Noah Brody, Noah Fensterheim, Gideon Miller, and Allen Sears Ida Crown Jewish Academy Skokie. IL

**Abstract:** Measurements were taken of the position angle (theta) and separation (rho) of the double star WDS 18028+3815. The measurements were made using images acquired by the 0.4 meter telescopes at the Las Cumbres Observatory's (LCOGT) McDonald Observatory and were taken with the aim of investigating the nature of the double star. The current position angle was found to be  $245.81^{\circ}$  +/- 0.22 and rho was found to be 11.39'' +/- 0.07. These newly collected measurements add more data to aid in determining the nature of the double star, but not enough to allow any definite conclusions to be drawn.

#### Introduction

Last observed 5 years ago and discovered in 1930, the double star WDS 18028+3815 ALI 867 is of unknown nature. Its spectral class is K2 (yellow-orange) and its absolute magnitude on the H-R diagram in Figure 1 suggests it is a subgiant or over luminous main-sequence star. The objectives of this research was to measure the separation and position angle between the primary star and one of its component stars and to use these measurements to aid in predicting whether this star is part of a binary system. The parallax values for the primary and secondary stars are 1.66 milliarcseconds (mas) and 3.12 milliarcseconds (mas), respectively. The proper motion in right ascension values for the primary and secondary stars are recorded to be -5.862 mas/year and -3.296 mas/year, respectively. The Proper motion in declination values for

the primary and secondary stars are recorded to be -3.891 mas/year and -5.86 mas/year, respectively. Although the stars may have non-constant magnitudes, the magnitude of the primary star has been measured to be 10.9, and the magnitude of the secondary star has been measured to be 12.8. The research team chose this system because of its uncertain nature. Additionally, this star is suitable to be measured by the 0.4 meter telescopes available to us: The separation is greater than five arcseconds, the difference in the magnitudes is small at 1.9, and the magnitude of each star is close to the magnitude range of 7-12. Adding a data point of position angle and separation is important for predicting their movements in the future, determining their orbital paths, and discovering whether the stars are gravitationally bound to one another. Orbital information is necessary in order to calculate the mass of the stars.



Astrometric Measurements of Double Star WDS 18028+3815

Figure 1: A Hertzsprung-Russell diagram of stars; our star is the marked point

#### **Equipment and Methods**

Telescopes from Las Cumbres Observatory (Brown et al. 2013) were used to acquire images of the stars. Images were taken with the 0.4 meter robotic telescope at McDonald Observatory (September 10, 2020). These telescopes are modified Meade telescopes with SBIG STL6303 cameras. In order to select a star that the 0.4-meter telescope in the LCOGT network could observe, certain criteria were used. The criteria for why this star was chosen include: a right ascension between 17:59:59 and 24:00:00, a declination between -90 and 90, a delta magnitude of three, and a minimum separation of five arc seconds. Once the star was selected, 10 images at 3.28 second exposure times were taken with the LCOGT telescopes at McDonald Observatory using the clear filter. Once images were received in

a reduced format, produced by LCOGT, the images were uploaded into AstroImageJ (Collins, 2018) for data analysis. The radius of the object aperture was set to 12, and the inner and outer radius background annuli were 40 and 60 respectively. The delta magnitude, separation, and position angle were collected for each of the ten images. One image from AstroImageJ is shown below in Figure 2. Historical data of the system was requested from Dr. Brian Mason of the US Naval Observatory (2019). The historical data and the current observations were put into the Plot Tool, made by Richard Harshaw (2020), to put the data into a Cartesian coordinate system with the primary star at the origin, and accounting for the Earth's precession. This allowed for analysis of the current data in context with the historical data.



Figure 2: Image of WDS 18028+3815in AstroImageJ.

### Results

Table 1 contains the separation, position angle, delta magnitude, and the Julian date of the observations. The bottom three rows show mean, standard deviation and standard error of the mean for the data. All 10 exposures were 3.28 seconds.

	Arc Length (arcseconds)	PA (Degrees)	Delt Mag	Julian Date	
1	11.48	245.73	2.41	59131.0591959	
2	11.45	246.21	2.42	59131.0593350	
3	11.46	245.84	2.43	59131.0596016	
4	11.43	245.95	2.42	59131.0594825	
5	11.46	245.87	2.44	59131.0597406	
6	11.27	245.34	2.34	59131.0585236	
7	11.31	245.69	2.33	59131.0586627	
8	11.36	245.82	2.37	59131.0588018	
9	11.31	245.65	245.65 2.37 5913		
10	11.37	245.97	2.35	5 59131.0590684	
Mean	11.39	245.807	2.388	8 N/A	
Standard Deviation	0.0718	0.2184	0.0384	N/A	
Standard Error of the Mean	0.0217	0.0659	0.0116	N/A	

 Table 1: The Separation, Position Angle, Delta Magnitude, and the Julian Date and the mean, standard deviation and standard

 error of the mean for WDS 18028+3815.

Figure 3 below is a graph of the data collected in context with the historical data all plotted on a Cartesian coordinate system. The current observation is the highlighted point.



Figure 3: Current position (highlighted) in context with the historical data.

Table 2 contains the historical data along with the current data point. The X, Y coordinates are the coordinates for the graph in Figure 3. New theta is the Position Angle accounting for the Earth's precession. The "Made By" column shows who made the observation. Finally, the "Type of Observation" column shows what kind of camera, telescope, or method was used to take the images of the star. The explanation of the methods used on this star can be found in Table 3.

Year	PA (deg)	Sep (arcsec)	X-coordinate (arcsec)	Y-coordinate (arcsec)	Aperture	New Theta	Made By	Type of Obs.
1930.67	250.8	12.41	-11.71953	-4.08124	-0.00247	250.79753	WFC1998	Pa
1991.25	247.99	11.34	-10.51409	-4.24804	-0.00237	247.99763	Fal1999	Hh
1998.40	246.9	11.49	-10.56856	-4.50795	-0.00236	246.89764	TMA2003	E2
2002.59	247.0	11.53	-10.61324	-4.50513	-0.00235	246.99765	UC_2013	Eu
2012.398	246.33	11.52	-10.55067	-4.62491	00233	246.32767	UR_2015	Er
2013.463	246.58	11.49	-10.54322	-4.56691	00233	246.57767	UR_2015	Er
2013.507	246.55	11.50	-10.55000	-4.57641	00233	246.54767	Mug2017	С
2014.429	246.54	11.47	-10.52168	-4.56631	00233	246.53767	UR_2015	Er
2015.0	245.411	12.07	-10.97524	-5.02240	00233	245.40867	Kpp2018	Hg
2015.341	246.08	11.54	-10.54867	-4.67902	00233	246.07767	UR_2015	Er
2020.75	245.807	11.39	-10.38943	-4.66775	00232	245.80468	ARS_2020	С

Table 2: Data for Figure 3

Table 3 provides the explanation of the abbreviations in "Type of Observation" column of Table 2. More specifically, it explains the method used by each astronomer or spacecraft for each entry in the historical data.

Abbreviation	Explanation
С	CCD or other two-dimensional electronic imaging
E2/ E2m	2MASS (Two Micron All-Sky Survey)
Er	USNO URAT
Eu/Eu3/Eu 4	UCAC3 or UCAC4
Hg	Gaia
Hh / Thp	Hipparcos (satellite)
Pa / G	Photographic, with astrograph

 Table 3: Explanation of "type of observation" Column in Table 2

Figure 4 is a graph of position angle with reference to the earth's precession, versus year of the observation. The current data is the orange point. This graph shows that the current data fits well with the historical data and continues the trend. It also shows the position angle is changing over time and one star is moving relative to the other.



Figure 4: Graph of position angle vs year. The current observation is highlighted in orange.

Figure 5 is a graph of separation versus year. The current data is the orange point. This graph once again shows that the

current data seems to line up with the historical data.





Figure 5: Graph of separation vs year. The current observation is marked in orange.

#### Discussion

The data collected follow the trends in the historical data. The graphs relating the year with the theta and rho have the newly collected data point very near the line of best fit. In addition, in the diagram comparing the theta and rho of the second star relative to the first, the new data point again seems to be in line with others. This consistency with previous data adds validity to both the newly collected data and the historical data and also suggests that the star is continuing to follow the path that it has been following. The collected data also helps to figure out a more precise path of the star. There is still not yet enough data to determine whether the path is that of an orbiting star or a star that is part of a co-moving pair. There is much deviation between the primary and secondary magnitudes and therefore also in the delta magnitudes of the stars in this system. Stelle Doppie recorded a primary magnitude of 10.9, a secondary magnitude of 12.8, and a delta of 1.9. Gaia data recorded a primary magnitude of 9.8, a secondary magnitude of 12.3, and a delta magnitude of 2.5. Finally, we recorded a delta magnitude of 2.38. While neither star in the system is in the AAVSO

database (American Association of Variable Star Observers), there is a possibility that both stars in the system are variable stars, stars which change brightness over time. Further study could provide insight on whether they are variable stars.

The proper motion values of stars tell about the speed and direction stars are moving across space. Proper motion is described using its components of direction, right ascension and declination. Declination motion describes the velocity the stars are moving in the north/south directions and right ascension motion describes the velocity a star is moving in the east/west direction. The proper motion right ascension values for the primary and secondary stars are recorded to be -5.862 mas/year and -3.296 mas/year, respectively. The Proper motion declination values for the primary and secondary stars are recorded to be -3.891 mas/year and -5.86 mas/year, respectively. Both proper motion values for right ascension and declination are similar among these two stars. However, although both are not moving at exactly the same speed, because their motions are similar, they are probably a co-moving pair.

As of now, more data and observations would be needed to confirm whether the system is a binary star system or

just an optical double. In the separation versus year graph, there seems to be an arc occurring, however, the LCOGT 0.4 meter telescopes can only measure within 5 arcseconds and the whole arc is within .2

# Conclusion

The position angle and separation of the primary and secondary stars of the double star WDS 18028+3815 seem to have shifted slightly since 1930. The mean position angle taken in 2020 is 245.881° +/- 0.22 degrees, which is slightly smaller than it had been typically recorded. Similarly, the arc length taken in 2020 is 11.39'' +/- 0.07, slightly lower than it has been typically recorded.

# Acknowledgements

We are greatly indebted to all those who have helped us study the nature of the potential double star WDS 18028+3815. Specifically, much thanks is due to Rachel Freed, who helped us every step of the process, for running the ARS program, for her help with choosing a star and analyzing it, and her help with the writing of the proposal and paper. We are also much indebted to Dr. Brian Mason of the U.S. Naval Observatory for providing our team with historical information regarding WDS 18028+3815, Richard Harshaw for his help with the tools to analyze the potential double star, Michael Fitzgerald for his help with processing the images, all the editors of the

## References

Brown, T. M., Baliber, N., Bianco, F. B.,Bowman, M., Burleson, B., Conway, P.,... & Willis, M. (2013). Las CumbresObservatory global telescope

arcseconds. Therefore, the arc is probably noise, and if more observations were taken over time the arc should flatten out and the data should continue on the linear trend line.

Since 1930, there seems to be a trend of both the arc length and the position angle decreasing, so it is probable that there is some movement of and between the stars. They have similar proper motion values suggesting they may be a common proper motion pair. It is unclear from the data over the past 90 years whether it is a true binary system, and more data over several more decades would be needed to determine this.

STAR textbook, and the team at LCOGT whose telescopes we used. We acknowledge with thanks to the variable star observations from the *AAVSO International Database* contributed by observers worldwide and used in this research.

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/c onsortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

network. Publications of the Astronomical Society of the Pacific, 125(931), 1031. Collins, K. A., Kielkopf, J. F., Stassun, K. G., and Hessman, F. V., (2018) AstroImageJ: image processing and photometric extraction for ultra-precise

astronomical light curves. The Astronomical Journal, 153(2):77 Harshaw, Richard W. (2020) "plot tool 3.19" Excel File <u>http://www.jdso.org/volume16/number4/</u> <u>Harshaw\_supplement\_files/Plot\_Tool\_31</u> <u>9.xlsx</u> Mason, B. (2019) The Washington Double Star Catalog, Astronomy Department, U.S. Naval Observatory
(2019-09-05) "Stelle Doppie." Stelle Doppie Double Star Database. <u>https://www.stelledoppie.it/</u>