Astrometric Measurements of WDS 04155+0611

Emma Smith[1], Antoni Rodriguez[2], Pat Boyce[3], Grady Boyce[4]
1. High Tech High, San Diego, CA; ejsdragon@gmail.com
2. High Tech High, San Diego, CA
3. Boyce Research Initiatives and Educational Foundation
4. Boyce Research Initiatives and Educational Foundation

Abstract

We used images taken from the Las Cumbres Observatory (LCO) to measure WDS 04155+0611. The 5-star system has A, B, C, D, and E components. The goal of this project was to determine whether conclusions could be drawn on the nature of the gravitational connection between these stars. With the data collected, we looked at the gravitational nature through the use of parallax, a conversion to relative distance, and finally application of the Harshaw statistic to analyze the nature. We found that only the A and B stars in this system are possibly gravitationally connected.

1. Introduction

The purpose of this project was to observe a system of five stars and determine which pairs may be gravitationally bound. Last measured in 2015, WDS 04155+0611 (Figure 1) has received a total of 44 observations since its discovery in 1782. The system includes pairs STTA 45 AB, H 6 98 AC, H 6 98 CD, STU 18 CE, with additional measurements and calculations done on the D and E components, identified as BD+05 617 and AG+06 438, respectively. The system is listed with spectral classes of G0IV, G8V, M5, K0, and G0, respectively, and is in Taurus.

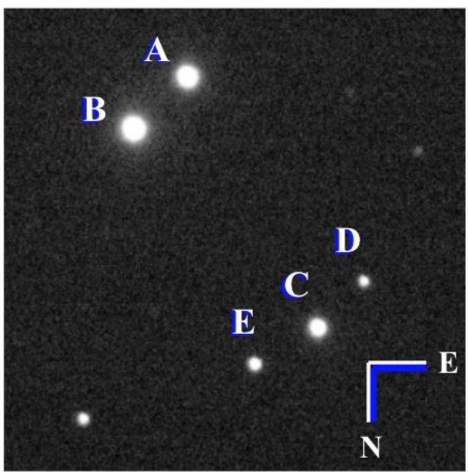

Figure 1: WDS 04155+0611 taken using the LCO 0.4-meter telescope with a SBIG STL-6303 camera in the G filter on 2021.23.

2. Equipment and Methods

The images for WDS 04155+0611 were taken through the LCO system at Siding Spring, Australia. The telescope is at an elevation of 1,165 meters and is a 0.4-meter telescope with a SBIG STL-6303 camera.

There were 9 filter options with a camera pixel scale of 0.571"/pixel (bin 1x1), and a field of view of 29'x19'.

A total of 79 photos were taken on 2021.23 through the W and G filters, Table 1. Many of the photos were discarded because they had little contrast between the stars and their surroundings, making the stars too small to measure. Additionally, all of the images were taken on the same night due to the fact that the systems altitude fell below observatory limits immediately thereafter. Selected photos were calibrated, and plate solved, through the Our Solar Siblings Pipeline (Fitzgerald 2018). AstroImageJ was used to measure θ and ρ 24 times in the best 7 images.

WDS 04155+0611 on 2021.23					
	AB	**AC**	**CD**	**CE**	**DE**
G Filter	3	3	2	2	3
W Filter	2	2	3	2	2

Table 1: Filters used when measuring each star system in 2021.23.

3. Data

Results were recorded and organized in a Microsoft Excel spreadsheet for calculations of the means, standard deviations, and mean errors of the θ and ρ values. Table 2 represents the quintuplet system's current data based on 24 measurements taken in AstroImageJ.

WDS 04155+0611 Current Position Angle (θ) and Separation (ρ) (2021.23)						
Pair	**θ Mean**	**St. Dev.**	**St. Err**	**ρ Mean**	**St. Dev.**	**St. Err**
STTA 48 AB	316.022°	0.322	0.104	64.634″	0.218	0.048
H 6 98 AC	63.468°	0.036	0.001	243.893″	0.435	0.189
H 6 98 CD	55.704°	0.211	0.209	134.290″	0.457	0.045
STU 18 CE	149.644°	0.271	0.074	62.639″	0.216	0.048
BD+05 617 + AG+06 438 (DE)	322.379°	0.106	0.011	117.183″	0.242	0.058

Table 2: Represents current θ and ρ measurements measured in 2021.23, accounting for pairs STTA 45 AB, H 6 98 AC, H 6 98 CD, and STU 18 CE, as well as stars BD+05 617 and AG+06 438 representing the D and E components. ρ is measured in arcseconds.

The AB and CD measurements show little difference when compared to the measurements in (Zhixin, 2016) Table 3 from 2015.23. The AC and CE data, however, show greater differences.

	Sep.	St. Dev.	St. Err.	P.A.	St. Dev.	St. Err.
STTA 45 AB	64.30”	0.44”	0.073”	315.58°	0.73°	0.122°
H 6 98 AC	233.01”	0.86”	0.143”	48.09°	0.05°	0.008°
H 6 98 CD	55.82”	0.18”	0.031”	314.55°	0.16°	0.026°
STU 18 CE	61.91”	0.14”	0.024”	149.28°	0.21°	0.035°

Table 3: The θ and ρ measurements taken on 2015.23, 6.00 epochs before 2021.23.

4. Discussion

Based purely on the parallax data provided by Gaia (Table 4), it is apparent that the C, D, and E stars are quite distant radially. Because of this, measurement of the closest possible lateral distance was not pursued. However, we will measure the closest lateral distance of the A and B stars, given that their parallaxes differ only by ~ 0.0071 mas.

WDS 04155+0611 Parallax Data		
Star	**Parallax**	**Error**
A	45.3005	0.0279
B	45.3076	0.0236
C	1.48	0.0347
D	13.1444	0.0647
E	3.5724	0.0199

Table 4: Parallax values of each star as provided by Gaia.

Assuming that the parallax measurements of two stars are close, the equation D = $63241 * X \frac{d}{206265}$ can be used to find the closest distance that the stars can be to each other. We can use this for the A and B stars of this system. After converting parallax values to light years, we find that the A and B stars have a midpoint distance of about ~ 71.95 light years away from Earth, with possible errors of 0.05 light years. We also know that both stars are about 64.634’’ apart, we can input those values into the equation $D = 63241 * \frac{64.634*71.95}{206265}$ to find that the A and B stars are ~ 1426 AU apart. That distance makes it likely that these stars are physical doubles.

The Harshaw Statistic method is a way of determining the probability that two stars are gravitationally bound based on proper motion alone. After reviewing how similar the proper motions of two stars are, Harshaw provides an equation that results in a number from 0 to 1. The closer the ratio is to 0 - indicating little difference in proper motion - the more likely it is that there is a gravitational connection between the two stars. For the A and B stars in WDS 04155+0611, the ratio is 0.030, suggesting a high likelihood of gravitational connection. The AC, CD, CE, and DE components have values of 0.79, 0.938, 0.736, and 0.855, respectively, each too high to be physical doubles. The proper motions of each star is visualized in Figure 2.

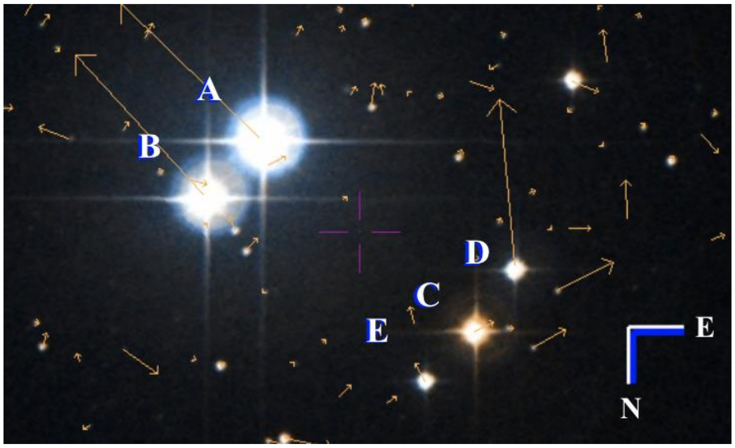

Figure 2: Aladin 10 image of WDS 04155+0611 depicting the Gaia proper motion measurements as arrow vectors.

As depicted in Table 5, the radial velocities are also very similar, with the two varying by 0.72. This is unlike the C, D, and E stars, which have much different radial velocities.

Radial Velocity of WDS 04155+0611		
	Radial Velocity	Error
A	-7.214	0.147
B	-7.934	0.155
C	50.64	0.29
D	32.52	0.43
E	-39.54	0.55

Table 5: Radial velocities of each star, as provided by Gaia.

5. Conclusions

Our evidence suggests that the A and B stars in WDS 04155+0611 are likely gravitationally bound, due to their similar parallax, proper motion, and radial velocity measurements. Alongside that, the pair's theta and rho values are also consistent with previous observations. However, we found that the C, D and E stars are not gravitationally connected to any of the stars in the system. This is proven by their dissimilar parallax measurements, high Harshaw statistic, and varying radial velocities, which all would make it very unlikely that there is any connection between those stars.

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This work makes use of observations from the LCOGT network

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