Analysis of Quadruple Star System WDS 00013+0742 DU 4AB

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Abstract

The stars in the quadruple system WDS 00013+0742 DU4 were analyzed to assess the probability that each star is physically related to the others. The analysis was performed using ten 20-second exposure images that were taken on 2021.0164 using a Las Cumbres Observatory 0.4m robotic telescope and measured in AstroImageJ. An additional star, not listed as part of the system, was measured, because it is similar to the A and B stars in both position and magnitude. However, since only the A and B stars exhibit similar parallax and common proper motion, the other stars are unlikely to be physically related. The position angle and separation of DU4 AB are measured here to be 264.187±0.2433º and 15.22±0.06164″, respectively.

Introduction

Figure 1 shows the location of DU4 in the sky as shown in Stellarium.

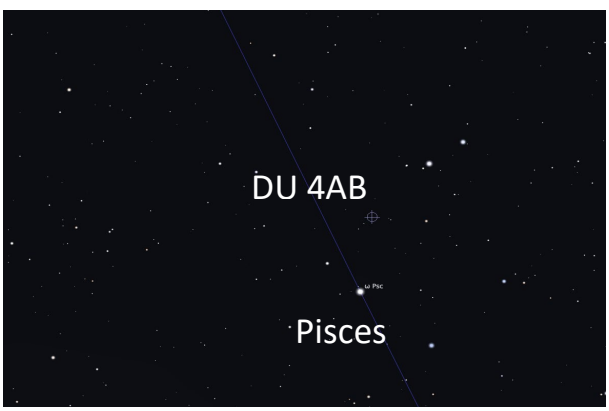

Figure 1: Location of quadruple system DU4 from Stellarium.

The parallaxes and proper motions (PM) of the stars in the DU4 system from Gaia Early Data Release 3 (EDR3) are shown in Table 1. The stars in this system are referenced by letter as they are presented in the Washington Double Star Catalog, with the exception of star "E." The E star has not been previously measured against this system, but appears near stars A and B, with a similar magnitude. Figure 2 shows all stars, labeled, in AstroImageJ. The figure was generated from a composite image that was stacked using the fits-align Python module to bring out the dim stars.

Star	Distance (pc)	Magnitude (G-band)	RA	Dec	PM RA (mas/yr)	PM Dec (mas/yr)
A	143.70 ± 0.357	9.34	00:01:20.06	07:42:05.89	-35.293 ± 0.018	-71.273 ± 0.011
B	143.69 ± 0.468	10.46	00:01:19.04	07:42:04.32	-34.154 ± 0.025	-71.049 ± 0.017
C	929.11 ± 14.071	13.24	00:01:18.44	07:44:51.19	-3.077 ± 0.017	-4.874 ± 0.011
D	750.36 ± 24.548	13.84	00:01:18.96	07:44:57.24	-5.105 ± 0.047	-3.238 ± 0.03
E	117.06 ± 2.239	10.03	00:01:26.71	07:41:43.31	16.086 ± 0.164	-32.589 ± 0.122

Table 1: Distance, magnitude, right ascension, declination, and proper motion of each star in quadruple system DU4AB, plus an additional nearby star, labeled "E." Data taken from Gaia EDR3.

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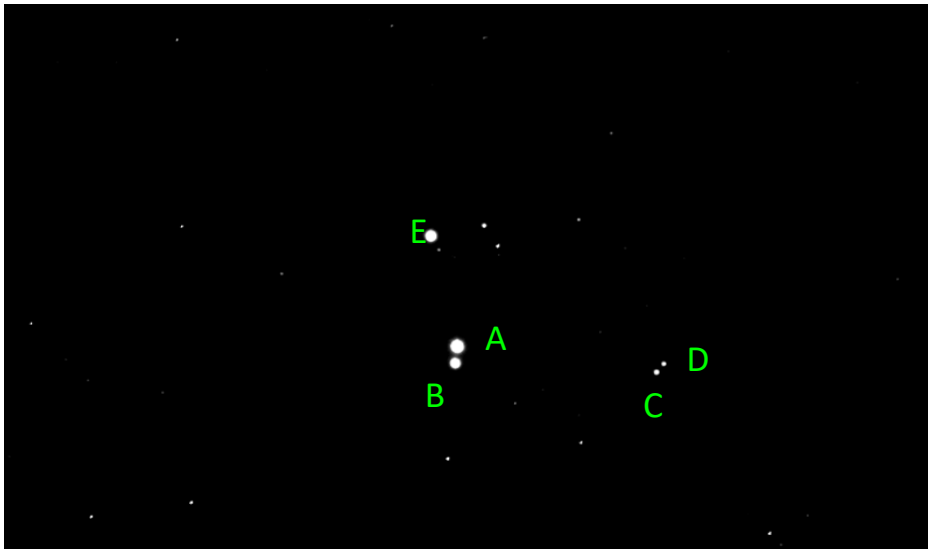

Figure 2: Positions of stars in the DU4 system in AstroImageJ, using a stacked composite image.

Table 2 shows the rPM for each combination. This is the ratio of the magnitude of the difference vectors of the stars' PM vectors divided by the magnitude of the longer star's PM vector (Harshaw, 2016). Given that the rPM of combination AB is < 0.2, the stars have common proper motion. All other doubles within the system are likely optical due to large rPM and due to their differences in parallax. Only one comparison was done for star "E" since it was not officially listed as part of the system, and parallax differences confirmed that it could not be.

Combination	rPM
AB	0.015
AC	0.928
CD	0.917
AD	0.936
BD	0.936
BC	0.927
AE	0.809

Table 2: Derived rPM values for stars in the DU 4 system.

Instruments Used

The images measured for this study were taken by 0.4 meter diameter robotic telescopes from Las Cumbres Observatory (LCO) Global Telescope network. The cameras used in LCO's 0.4 meter telescopes are SBIG STL-6303s, with a 29.2' by 19.5' field of view, and a pixel scale of 0.571″/pixel. The images were taken at the Haleakala observatory in Hawaii.

Measurements

The position angle and separation of the double stars in DU4 AB were measured in ten images using AstroImageJ. The exposure time was 20-seconds and a PanSTARRS-w filter was used. The measurements in these ten images were averaged into a single point, as shown in Table 3. Figure 3 shows an example measurement for stars A and B in AstroImageJ, with aperture radius of 4 pixels.

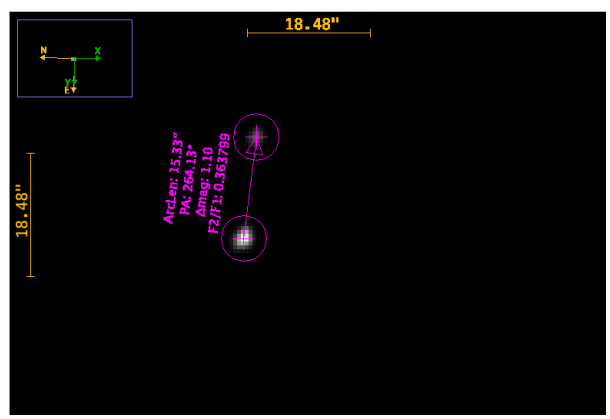

Figure 3: Example measurement of the position angle and separation of DU4AB in AstroImageJ.

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Image Number	PA (º)	Sep (″)
1	264.21	15.19
2	264.03	15.23
3	264.08	15.23
4	264.2	15.21
5	264.21	15.22
6	264.13	15.26
7	264.26	15.23
8	264.22	15.22
9	264.26	15.19
10	264.27	15.22
Average and Standard Error	264.187 ± 0.243	15.220 ± 0.062
Gaia EDR3 Measurement	264.104	15.208

Table 3: Measured Position Angle and Separation for ten images of stars A and B in DU4AB.

Masses of the Stars

The mass and luminosity were derived from Absolute Gaia magnitude according to the method in Dugan et. al, 2021. Mass was calculated from the absolute magnitude of each star, which was found using apparent magnitude and parallax (Dugan et. al, 2021; See Table 4).

Past Measurements

One piece of evidence for whether the stars are gravitationally bound is a plot of the historical measurements of the system over time. Curvature over time is indicative of a gravitationally bound system, while a plot that shows significant scatter over time is evidence of a system that is not gravitationally bound, or that some measurements have high uncertainty. Figure 4 shows our measurement of stars A and B in red compared to historical observations. Darker, more purple points are older while lighter, redder points are more recent. The bright red point is the measurement reported here, and the green point is the Gaia EDR3 measurement.

Star	Absolute Gaia Magnitude (Gmag)	Luminosity (Solar Units)	Mass (Solar Masses)
A	3.550 ± 0.0028	2.978 ± 0.0076	1.314 ± 0.0008
B	4.672 ± 0.0028	1.060 ± 0.0027	1.014 ± 0.0006
C	3.403 ± 0.0028	3.411 ± 0.0087	1.358 ± 0.0009
D	4.467 ± 0.0028	1.280 ± 0.0033	1.063 ± 0.0007
E	4.641 ± 0.0028	1.048 ± 0.0027	1.011 ± 0.0006

Table 4: Absolute Gaia Magnitude, Luminosity, and estimated mass, derived from Gaia EDR3 Data according to the method in Dugan et. al, 2021.

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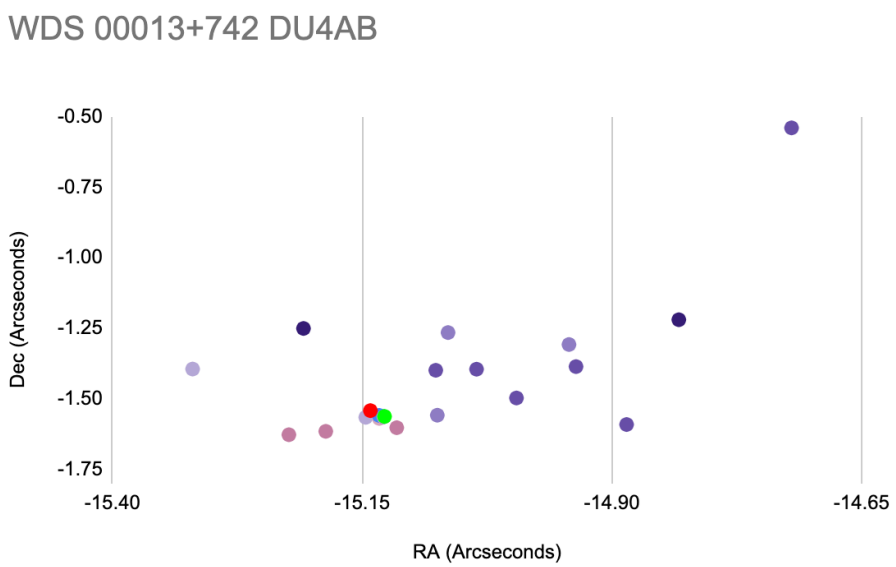

Figure 4: Plotting the RA and Dec of the secondary star, B in quadruple system DU4AB, comparing historical data to the most current observation (red) and Gaia EDR3 (green).

Currently, DU4 AB does not have a solved orbit. The lack of a clear trend in the data as a function of time does not suggest that the system is gravitationally bound unless it is a long period binary, though the rPM values do suggest some sort of physical relationship.

Conclusion

The data suggest that the DU 4 A and B stars exhibit common proper motion, and could be a long period gravitational binary near the sun (143pc away) while C and D are background stars due to having a farther distance and very small proper motion. Star E, while near A and B visually, is 26pc farther away than AB with different proper motion.

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This work makes use of observations taken by the 0.4m telescope of Las Cumbres Observatory Global Telescope Network located in Haleakala, and the fits-align module maintained by Edward Gomez of the LCO Education Division.

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