An Astrometric Measurement of 10420-3638 LDS314 and Analysis using GAIA Data. Evidence for a Binary Star System

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Abstract

The components of WDS 10420-3638 LDS314 show common proper motion and are included in the Luyten Double Star Catalogue. The nature of 10420-3638 LDS314 was further investigated using a current astrometric measure and GAIA data. WDS 10420-3638 LDS314 was imaged using the Las Cumbres Observatory (LCO) Global Network of Telescopes. Calibrated images were obtained and analysed using the software AstroImageJ to determine separation, position angle and delta magnitude. Using GAIA DR3 data and apparent separation reported in this paper, mean, minimum and maximum physical distance separation was estimated. Using GAIA DR3 data the angle (v) between each of the components space velocity vectors in 3-dimensional space and Buchheim distance probability estimation were calculated. Binding energy ($E_{binding}$), system escape velocity and relative 3-dimensional space velocity were also calculated. The analysis provides strong evidence that the components of WDS 10420-3638 LDS314 form a binary star system.

1. Introduction

The Luyten Double Star Catalogue (LDS) is a list of double stars culled from William Jacob Luyten's Palomar Survey publications. The Luyten Double Star Catalogue may be accessed at https://vizier.cds.unistra.fr/viz-bin/VizieR?-source=I/130

WDS 10420-3638 LDS314 was first measured in 1913.34 when the position angle was 303.4° and the separation was 17.05″ (Urban et al, 1998). The last measure was in 2021.17 when the position angle was 303.1° and the separation was 17.18″ (Thurman, 2021). The GAIA DR3 G-band magnitude of the primary is 9.44 and the magnitude of the secondary is 10.62. The spectral class of the primary is M0Vk and M2+V for the secondary (SIMBAD https://simbad.cds.unistra.fr/simbad/).

Selected GAIA DR3 data for 10420-3638 LDS314 is shown in Table 1 (Prusti et. al. 2016; Vallenari et. al. 2023). From the GAIA DR3 archive, the Renormalised Unit Weight Error (RUWE) for the primary is 1.067 and 1.075 for the secondary, both of which are consistent with a single star model for each star.

Table 1. Selected data on 10420-3638 LDS314 from GAIA DR3.

WDS Identifier 10420-3638 LDS314	Parallax ± 1σ mAS	Total proper motion ± 1σ mAS/yr	pmra ± 1σ mAS/yr	pmdec ± 1σ mAS/yr	Radial velocity ± 1σ km/sec	Apparent Gaia G-band magnitude
A Component Gaia source id: 5443051537858529792	56.3104 ± 0.0160	116.871 ± 0.015	-93.496 ± 0.013	70.123 ± 0.017	30.9 ± 0.1	9.44
B Component Gaia source id: 5443051537858529920	56.3140 ± 0.0171	118.779 ± 0.017	-96.878 ± 0.015	68.724 ± 0.017	31.7 ± 0.1	10.62

The distances from the Sun to the primary and secondary with 1σ parallax uncertainties were calculated using GAIA DR3 data, Figure 1.

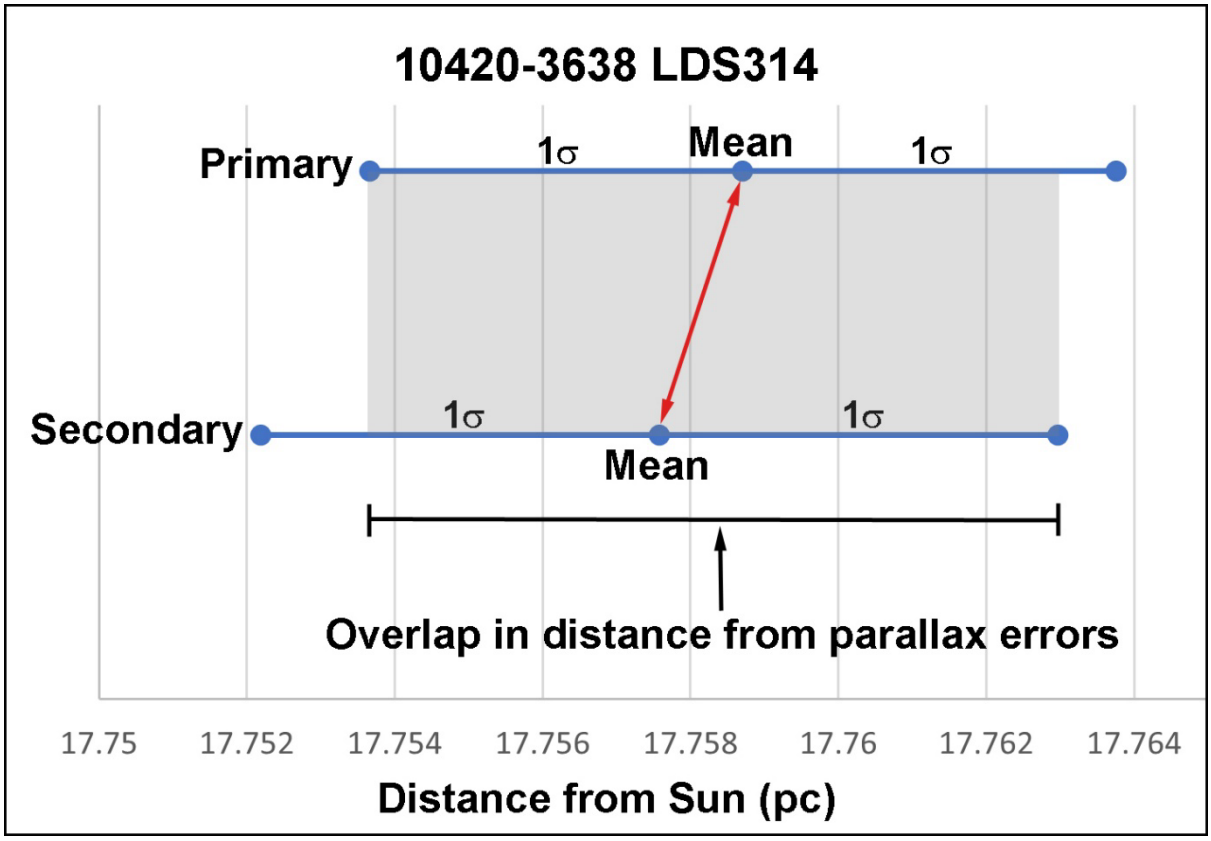

Figure 1: GAIA DR3 distances of the components of 10420-3638 LDS314 from the Sun including 1σ parallax errors. The distances from the Sun to the primary and secondary with 1σ parallax uncertainties show overlap. The red arrow is the mean physical distance separation of the primary and secondary (D) at the mean GAIA distance from the Sun.

2. Methods

Using the Las Cumbres Observatory Global Telescope Network, 10420-3638 LDS314 was imaged on May 16, 2025 (Decimal Date: 2025.371; JD UTC: 2460812.477) at Cerro Tololo Inter-American Observatory with a PlaneWave DeltaRho 350 telescope and QHY600 CMOS camera system. The camera format was 9576 x 6388 pixels, 3.76 micron pixels size. Field of view 1.9 degrees x 1.2 degrees readout mode full-frame, 30'x30' in readout mode central30x30. Pixel size (1x1 binning, arcsec) ~0.74"/pixel, default binning 1 x 1, read noise (e-) ~ 3 to 3.5 e- and gain (e-/ADU) 0.7 e-/ADU.

Twenty images were taken. The images were recorded through a Bessel-V Filter and the exposure time for each image was 10 seconds. The air mass was 1.0. The calibrated images were individually inspected for quality and all were chosen for analysis. The images were analysed using AstroImageJ with apertures set at 6 pixels (object aperture), 10 pixels (inner radius of background annulus) and 14 pixels (outer radius of background annulus), Figure 2, and mean, standard deviation and standard error of the mean were determined for theta, rho and delta magnitude, Table 2.

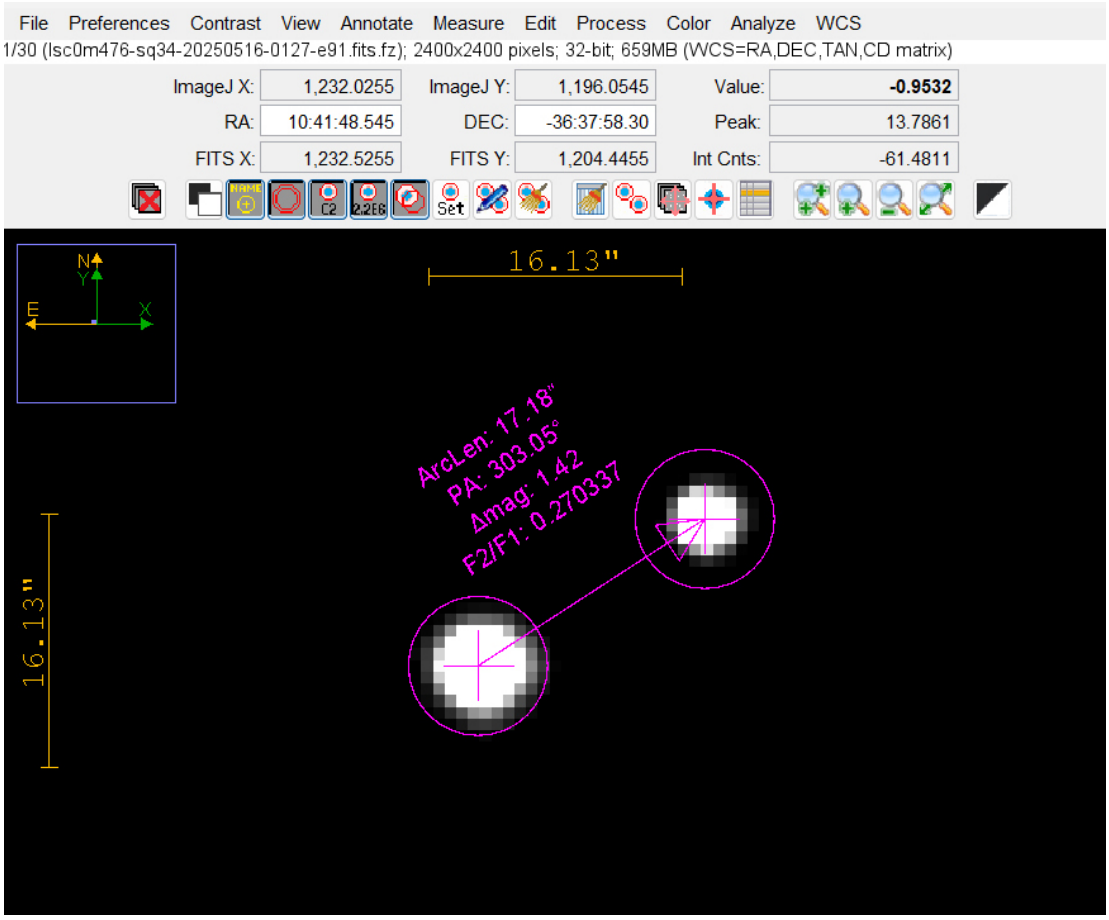

Figure 2: A representative image of 10420-3638 LDS314 analysed using AstroImageJ showing separation, position angle and delta magnitude.

To calculate *D*, the mean physical separation distance of the components in pc, the cosine rule was used:

$$D = \sqrt{[D_A^2 + D_B^2 - 2D_A D_B \cos(\rho/3{,}600)]} \quad (1)$$

Where *D* is the mean separation distance of the two stars in pc; D_A is the mean distance from the Sun to the primary in pc, obtained from parallax measures; D_B is the mean distance from the Sun to the secondary in pc, and ρ is apparent separation in arcseconds (″) reported in this paper, Table 3.

The minimum and maximum distance separation (Fig. 1), was calculated using the data in Table 1, measure of apparent separation reported in this paper and Equation (1), Table 3.

The angle (ν) between each of the components space velocity vectors in 3-dimensions was calculated using the method of Nugent (Nugent, 2025), Table 3. Angles < 15° are designated as Common Space Motion pairs, values > 15° and < 30° are designated as Similar Space Motion pairs and values > 30° are designated as Different Space Motion pairs.

The Buchheim's distance probability calculation involves calculating the probability that two stars are within one light-year of each other, using parallax and parallax error data from GAIA DR3. The core of the calculation uses the standard error of the mean of the probability distribution function of the distance difference between the two stars. Using this method (Sethi et al, 2024), the probability that the components of 10420-3638 LDS314 are within one light year of each other in the radial direction was calculated, Table 3.

Luminosity and stellar mass values for the primary and secondary of 10420-3638 LDS314 was not available from GAIA DR3 FLAME. The mass of the primary and secondary were calculated using the distance (derived from mean GAIA DR3 parallax) and the apparent magnitude (Nugent, 2025).

Firstly, the absolute magnitude (M) was calculated using the following formula

$$M = m + 5 - 5log_{10}(D) \quad (2)$$

Where m is the apparent Gaia G-band magnitude of the star and D is the distance between the star and the Sun (1/parallax), measured in parsecs.

Then the bolometric magnitude (Mbol) was calculated by adding the bolometric correction (BC) to the absolute magnitude (M) using the formula

$$Mbol = M + BC \quad (3)$$

The Teff (stellar effective temperature) of the primary and secondary from GAIA DR2 are 4,041K and 3,815K respectively. Bolometric corrections can be found here: https://github.com/emamajek/SpectralType/blob/master/EEM_dwarf_UBVIJHK_colors_Teff.txt

With Mbol and the following mass-luminosity relationship, the mass of the primary and secondary was calculated

$$Mass = 10^{(0.48-0.105Mbol)} \quad (4)$$

The mass of the primary was estimated to be ~ 0.57$M_\odot$ and the mass of the secondary was estimated to be ~0.43$M_\odot$.

Binding energy ($E_{binding}$), Table 4, was calculated using the following formula (Letchford et al, 2022):

$$E_{binding} = \frac{1}{2}\left(\frac{m_A m_B}{m_A + m_B}\right) v^2 - \frac{G m_A m_B}{D} \quad (5)$$

Where, $E_{binding}$ is in $M_\odot(km\ s^{-1})^2$; m_A and m_B are the masses of the primary and secondary in solar masses ($M_\odot$); v is the galactic space speed difference between the two stars in km s^{-1}; D is their physical separation in parsec (pc); and G is the gravitational constant (4.30091×10^{-3} $pc(km\ s^{-1})^2/M_\odot$).

The system escape velocity and relative 3-dimensional space velocity were calculated using the method of Bonifacio (Bonifacio et al, 2020), Table 4. The system escape velocity was calculated using the mean physical distance separation (D).

3. Data

The results of the analysis of the 20 images by AstroImageJ are given in Table 2.

Table 2. Theta, rho & delta magnitude determined for 10420-3638 LDS314 using AstroImageJ.

WDS 10420-3638 LDS314				
Epoch	**Measurement**	**Theta (degrees)**	**Rho (arcseconds)**	**Delta Magnitude (Bessel-V filter)**
DD: 2025.371 JD: 2460812.477	Mean	303.0	17.18	1.44
	Standard Deviation	0.05	0.022	0.01

Last measurement (2021.17)	Standard Error of the Mean	0.01 303.1	0.005 17.18	0.002 1.06

Table 3. Mean physical distance separation (*D*), minimum distance separation, maximum distance separation, angle (ν) between each of the components space velocity vectors in 3-dimensional space and Buchheim distance probability for 10420-3638 LDS314.

WDS IDENTIFIER	**Mean physical distance separation (*D*) between primary and secondary** **AU**	**Minimum distance separation** **AU**	**Maximum distance separation** **AU**	**Angle (ν) between each of the components space velocity vectors in 3-Dimensional space** **degrees**	**Buchheim distance probability calculation** **%**
10420-3638 LDS314	385	305	2407	0.48	100

Table 4. Binding energy ($E_{binding}$), system escape velocity and relative 3D space velocity values for 10420-3638 LDS314.

WDS Identifier	**Binding energy ($E_{binding}$)** **$M_\odot(km\ s^{-1})^2$**	**System escape velocity using mean physical distance separation (D)** **km/s**	**Relative 3-Dimensional space velocity** **km/s**
10420-3638 LDS314	–0.47	1.6	0.8

4. Discussion

Letchford et al, 2022 proposed conservative criteria for "confirmed" binary double stars of (a) $E_{binding}$ <+1 (ideally $E_{binding}$ should be <0 however, because of the expected large uncertainties in the calculated $E_{binding}$, Letchford et al included pairs with $E_{binding}$ <+1), (b) a physical separation (*D*) such that $D - 1\sigma < 1$ pc, and (c) pairs which displayed common proper motion.

WDS 10420-3638 LDS314 has an $E_{binding}$ value of $-0.47 M_\odot(km\ s^{-1})^2$. The mean physical distance separation of the components of WDS 10420-3638 LDS314 is 385AU. The primary and secondary have a 97.9% chance of a separation of 2,500AU or less. Luyten's observations indicate the components of WDS 10420-3638 LDS314 show common proper motion. Moreover, the angle (ν) between each of the components space velocity vectors in 3-dimensional space is 0.48 degrees indicating the pair show common space motion. 10420-3638 LDS314 fulfils the criteria of Letchford et al, consistent with a binary star system. In addition, the system escape velocity is greater than the relative 3D space velocity consistent with a bound system.

5. Conclusion

An updated astrometric measurement of WDS 10420-3638 LDS314 is provided. The above analysis provides strong evidence that the components of WDS 10420-3638 LDS314 form a binary star system.

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