An Astrometric Measurement of WDS 20515-6543 HJ 5221 and Analysis using GAIA Data. A Co-Moving Optical Double

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Abstract

WDS 20515-6543 HJ 5221 is a double star in the Constellation of Pavo. The nature of HJ 5221 was further investigated using a current astrometric measure and GAIA DR3 data. HJ 5221 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, minimum, mean and maximum physical distance separation was estimated. In addition, the angle between each of the components space velocity vectors in 3-dimensional space (Nugent metric), binding energy (E_{binding}), system escape velocity and relative 3-dimensional space velocity were calculated. Analysis shows that the components of WDS 20515-6543 HJ 5221 show features of an optical double in which the components are co-moving.

1. Introduction

HJ 5221 AB was first measured in 1835.55 when the position angle was reported as 124.3° and the separation 12″ (Herschel 1847). The last measure was in 2016 when the position angle was 44.02° and the separation was 10.27144″ (El-Badry 2021).

Selected GAIA DR3 data for HJ 5221 is shown in Table 1 (Prusti et. al. 2016; Vallenari et. al. 2023). The Renormalised Unit Weight Error (RUWE) for the primary is 0.824 and 0.917 for the secondary indicating good single star models.

Table 1: Selected data on HJ 5221 from GAIA DR3. Stellar luminosity and mass values come for GAIA DR3 FLAME.

WDS Identifier 20515-6543 HJ 5221	**Parallax ± 1σ mas**	**Total proper motion mas/yr**	**pmra ± 1σ mas/yr**	**pmdec ± 1σ mas/yr**	**Radial velocity ± 1σ km/sec**	**Luminosity SolLum**	**Mass $M_\odot$**
A Component Gaia source id: 6425425663576589184	3.3221 ± 0.0111	8.660	-8.642 ± 0.008	-0.548 ± 0.012	-10.004 ± 0.16	N/A	N/A
B Component Gaia source id: 6425425663576588672	3.3208 ± 0.0124	8.721	-8.718 ± 0.009	-0.207 ± 0.013	-9.04 ± 0.24	4.28	1.4

The distance from the Sun to the A and B components of HJ 5221 with 1σ parallax uncertainties are shown in Figure 1. The distances from the Sun to the primary and secondary show overlap.

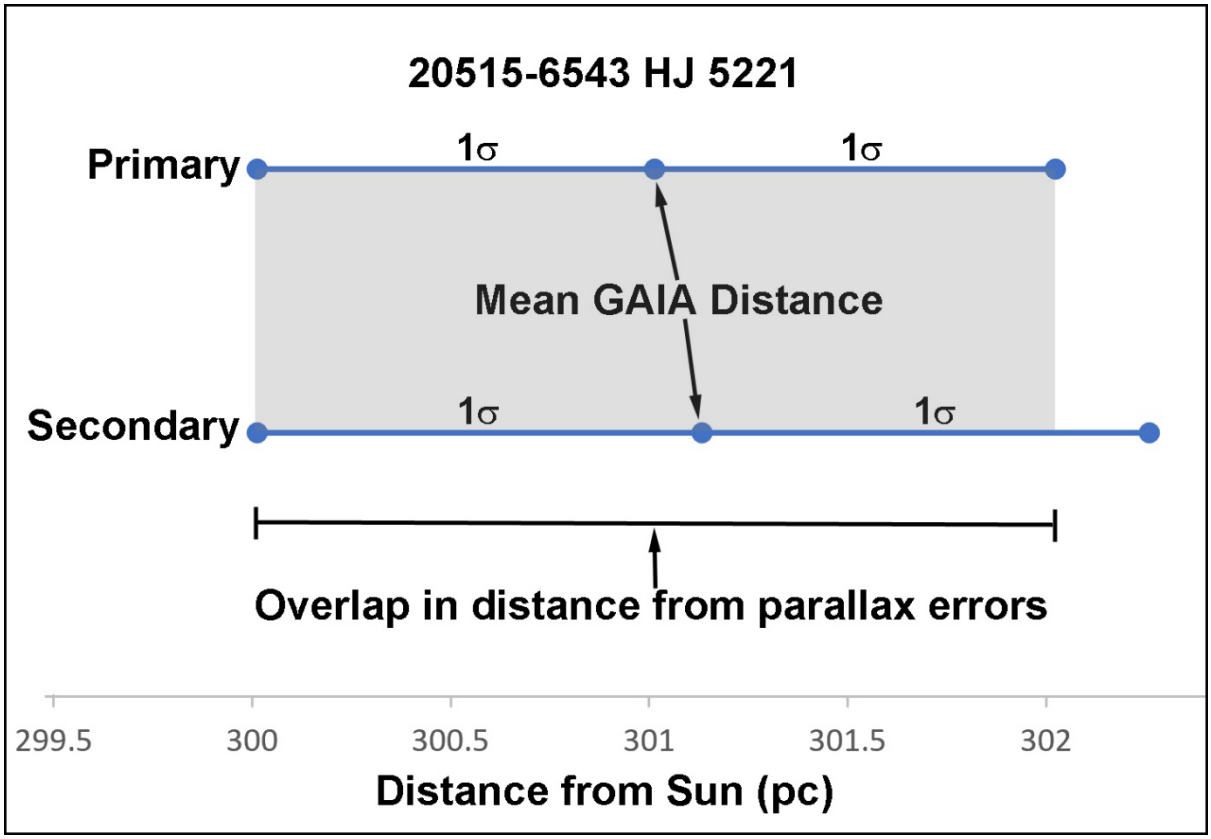

Figure 1: GAIA DR3 distances of the components of HJ 5221 from the Sun including 1σ parallax errors

2. Methods

Using the Las Cumbres Observatory Global Network of Telescopes, HJ 5221 AB was imaged on May 3, 2025 (Decimal Date: 2025.336; JD UTC: 2460798.803) at Cerro Tololo Inter-American Observatory with a Planewave Delta Rho 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 1.5. The calibrated images were individually inspected for quality and all were subsequently chosen for analysis. The images were analysed using AstroImageJ with apertures set at 6 pixels (object aperture), 8 pixels (inner radius of background annulus) and 9 pixels (outer radius of background annulus), Figure 2 and mean value, standard deviation and standard error of the mean determined for theta, rho and delta magnitude, Table 2.

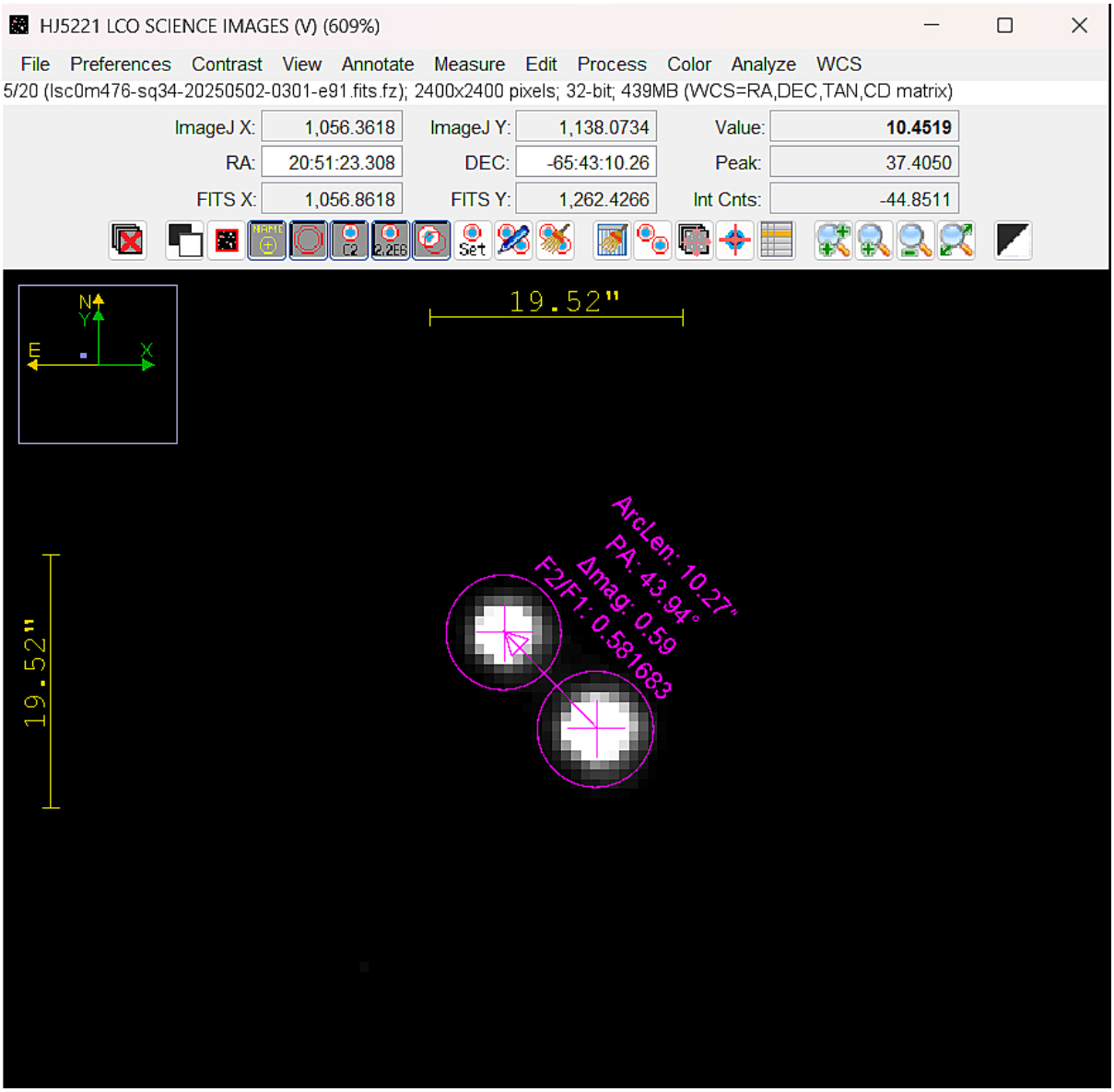

Figure 2: A representative image of HJ 5221 analysed using AstroImageJ showing separation, position angle and delta magnitude

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 with 1σ uncertainty was calculated using the data in Table 1, measure of apparent separation reported in this paper and Equation (1), Table 3.

The angle between each of the components space velocity vectors in 3-dimensions (Nugent metric) 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 space velocity of the A component and space velocity of the B component were calculated using the method of Nugent (Nugent, 2025). The relative 3-dimensional space velocity and system escape velocity were calculated using the method of Bonifacio (Bonifacio et al, 2020), Table 3.

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

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

Where, $E_{binding}$ is in $M_\odot(\text{km s}^{-1})^2$; 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$(\text{km s}^{-1})^2/M_\odot$). The mass of the B component from GAIA DR3 FLAME is 1.4 $M_\odot$. The luminosity and mass of the A component was not available with GAIA DR3 FLAME. Using the GAIA DR2 luminosity of 7.58 SolLum for the A component and Duric equations (Duric 2004, Letchford et al 2022), the mass of the A component was estimated as ~1.7 $M_\odot$.

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 HJ 5221 using AstroImageJ.

WDS 20515-6543 HJ 5221				
Epoch (Mean)	**Measurement**	**Theta (degrees)**	**Rho (arcseconds)**	**Delta Magnitude (Bessel-V filter)**
DD: 2025.336 JD: 2460798.803	Mean	44.0	10.27	0.60
	Standard Deviation	0.12	0.021	0.01
	Standard Error of the Mean	0.03	0.005	0.002
Last measurement (2016)		44.0	10.27	0.67

The mean physical distance separation of the A and B components of HJ 5221 is 0.12 pc which equates to ~24,752 AU.

The binding energy of HJ 5221 using the mean physical distance separation is +0.3 $M_\odot(\text{km s}^{-1})^2$.

Table 3. Primary space velocity, secondary space velocity, angle between the space velocity vectors (Nugent metric), relative space velocity, system escape velocity, mean physical distance separation, minimum distance separation and maximum distance separation for HJ 5221.

WDS Identifier	Primary space velocity (km/s)	Secondary space velocity (km/s)	Angle between the space velocity vectors (degrees)	Relative space velocity (km/s)	System escape velocity (km/s)	Mean Separation (AU)	Minimum Separation (AU)	Maximum Separation (AU)
11024+1631 HJ 5221	15.9	15.4	3.5	1.1	0.5	24,752	3,081	463,882

4. Discussion

The angle between each of the components of HJ5221 space velocity vectors in 3-dimensional space is 3.5 degrees indicating the pair show common space motion. The mean physical distance separation is 24,752 AU, the minimum separation distance is 3,081 AU and the maximum separation distance is 463,882 AU. The approximate upper bound for physical 3D separation of a binary systems is 2,500 AU (Nugent, 2026). In addition, the system escape velocity is less than the relative space velocity and the binding energy is positive (+0.3 $M_{\odot}(km\ s^{-1})^2$). These features indicate that HJ 5221 is an optical double star in which the components are co-moving.

5. Conclusion

An updated astrometric measurement of WDS 20515-6543 HJ 5221 is provided. Analysis using GAIA data shows that the components of WDS 20515-6543 HJ 5221 show features of an optical double in which the components are co-moving.

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