Astrometric measurements for double stars not found in the WDS

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Abstract: While in pursuit of a suitable target to study, two previously unrecorded visual binary star systems were discovered and observed. One of these binary stars is most likely an optical double, whereas the other binary has strong supporting evidence to be a true binary system. A minimal orbital period is calculated for this system.

Introduction

In seeking out neglected double-stars of an uncertain nature, images were taken of the binary system WDS 1108-6140 using the Las Cumbres Observatory (LCO) network. Upon analyzing the system, we found that the stars were too close together to take accurate measurements with AstroImageJ. Almost by accident, two nearby pairs of stars piqued our interest as they were visually close to their companion star, and had similar magnitudes within each pair.

We checked the data in Stelle Doppie and Aladin, and found that these stars are in close proximity to each other in terms of parallax. Determined to study these pairs, we scoured Stelle Doppie to find the star coordinates and historical data only to find that no star with these coordinates had been reported. Searching the Washington Double Star (WDS) catalogue resulted in a similar conclusion: these stars have not yet been observed as potential double star systems.

This research observes the position angle (θ) and separation (ρ) between these pairs of stars and will endeavor to calculate minimal orbital periods should data indicate they may be physical binaries and not optical doubles. Following are the primary stars' coordinates, GAIA DR2 IDs, and the way we will reference them in this paper:

Double 1
RA 11:06:30.6 DEC -46:10:28.97
GAIA DR2 ID: 5386565914691315968

Double 2
RA 11:06:34.7 DEC -46:11:55.3
GAIA DR2 ID: 5386565120119495296

Equipment and Methods

We gathered new CCD images from the LCO 0.4-meter telescope located at the Siding Spring Observatory in Australia, using an SBIG 6303 camera with a clear filter. The pairs are located close together in the sky, and so we were able to take ten, 30 second exposures (centered on Double 2) to capture both binaries. From these images we measured the position angle and separation for each pair using AstroImageJ. Examples of these images are shown in Figures 1 and 2.

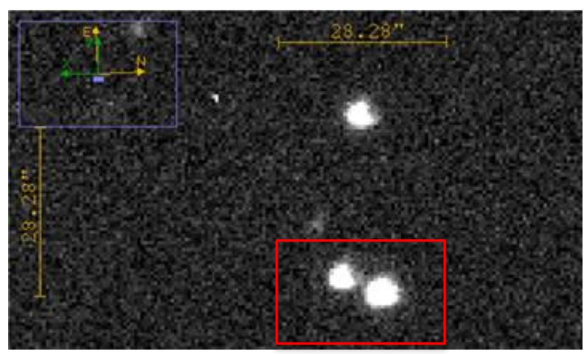

Figure 1. Image of Double 1 taken from the Siding Spring Observatory on May 28 2020, boxed in red .

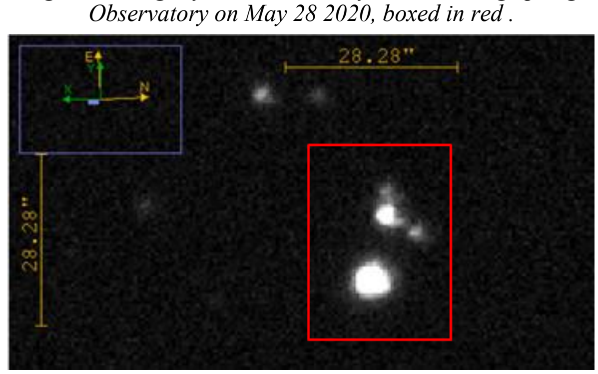

Figure 2. Image of Double 2 taken from the Siding Spring Observatory on May 28, 2020, boxed in red

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Results

The following data was collected using AstroimageJ.

The position angle and separation of each double was measured multiple times on each image to assure consistency and the individual measurements are shown in Table 1.

	Double 1		Double 2	
Image number	**θ (deg)**	**ρ (arcsec)**	**θ (deg)**	**ρ (arcsec)**
1	154.78	7.04	72.57	11.1
2	155.44	6.98	72.84	11.04
3	155.17	6.97	72.45	11.09
4	155.21	6.96	72.6	11.09
5	154.45	7.00	72.78	11.05
6	154.92	6.97	72.69	11.13
7	154.66	7.02	72.68	11.02
8	154.95	6.98	72.72	11.09
9	155.25	7.05	72.65	11.06
10	154.93	6.98	72.72	11.11
Mean	154.98	7.00	72.67	11.08
Std. Dev.	0.30	0.031	0.11	0.034
Std. Err. of Mean	0.09	0.01	0.03	0.01

Table 1. Set of data collected by measuring the Position Angle and Separation through AstroImageJ.

In addition to collecting these data we also reviewed the available GAIA data to draw additional conclusions concerning the nature of the stars in question. The data is contained in Tables 3 and 4. The spectral type indicated in the tables was estimated from plotting the luminosity and surface temperatures on an HR Diagram. We also computed the position angle and the separation based on the GAIA data, shown in Table 2, to assure our measurements are accurate.

Double 1		Double 2	
θ (deg)	ρ (arcsec)	θ (deg)	ρ (arcsec)
154.87	7.04	72.61	11.19

Table 2. θ and ρ based on data from GAIA.

Analysis

Based on the GAIA data it seems unlikely that Double 2 is a physical binary system, and the method we will be using to calculate star mass will not work on this system due to them being off of the main sequence. Further study with more precise measurements could add more evidence in regard to this hypothesis, though such measurements will likely be taken with a new mission.

The GAIA data for Double 1 does not rule out the possibility of it being a true binary system since the stars have similar parallaxes and proper motions. Hence, the following calculations will be for Double 1 only.

To calculate a minimum orbital period for the potential system we make use of the following properties: the distance between the two stars in AU's, and the masses of each star.

The distance is calculated through simple geometry. First, we use the parallax angle in arcseconds to calculate the distance (D) to our primary star:

$$D_P[pc] = \frac{1\ AU}{2.053 \times 10^{-3}\ ''}$$

This gives us 487.1 parsecs as our value for further calculations. Now using the separation angle in radians and the distance to the primary we can calculate the distance between the two.

$$D_S[pc] = D\ tan(\rho)$$

$$D_s = (487.1pc)\ tan(3.39 \times 10^{-5}\text{rads})$$

This would put the separation between the two stars at a distance of 0.0165 ± .00017 parsecs or 3400 ± 36 AU.

The next step will be to calculate the masses. We will be using the mass luminosity relationships from

$$log\ L / L_{\odot} = 4.841(log\ M / M_{\odot}) - 0.026$$

$$M = M_{\odot} 10^{\frac{log\ (L/L_{\odot}) + 0.026}{4.841}}$$

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Using this formula and luminosity data from GAIA the

Primary Star	Secondary Star
$M_P = M_{\odot} 10^{\frac{log(0.353)+0.026}{4.841}}$	$M_S = M_{\odot} 10^{\frac{log(0.195)+0.026}{4.841}}$
$M_P = 0.816 M_{\odot}$	$M_s = 0.722 M_{\odot}$

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GAIA Source ID	5386565914691315968	5386565914691315712
Reference epoch (yr)	2015.5	2015.5
Right ascension (deg)	166.63 ± 0.02	166.63 ± 0.02
Declination (deg)	-46.17 ± 0.02	-46.18 ± 0.02
Parallax (mas)	2.053 ± 0.022	2.015 ± 0.030
Proper motion: right ascension (mas/yr)	-20.745 ± 0.035	-20.87 ± 0.47
Proper motion: declination (mas/yr)	5.050 ± 0.034	5.011 ± 0.045
Effective temperature (K)	4920 ± 80	4790 ± 120
Lum (solLum)	0.353±0.010	0.195±0.008
Spectral Type (estimated)	K1 V	K4 V

Table 3. GAIA data for the primary and secondary stars in Double 1.

GAIA Source ID	538656512119495296	538656515877768800
Reference epoch (yr)	2015.5	2015.5
Right ascension (deg)	166.64 ± 0.02	166.65 ± 0.017
Declination (deg)	-46.20 ± 0.02	-46.20 ± 0.02
Parallax (mas)	0.284 ± 0.030	0.236 ± 0.026
Proper motion: right ascension (mas/yr)	-4.841 ± 0.047	-7.074 ± 0.038
Proper motion: declination (mas/yr)	3.200 ± 0.043	1.348 ± 0.036
Effective temperature (K)	4450 ±210	4680 ± 200
Lum (solLum)	88.57±15.90	26.29±7.25
Spectral Type (estimated)	B8 III	A0 III

Table 4. GAIA data for the primary and secondary stars in Double 2.

Now that we know the masses of the two stars in solar masses and the distance between them in astronomical units, we can calculate the minimal orbital period using Kepler's Third Law:

$$P^2(yrs) = \frac{a^3(AU)}{(M_P + M_S)}$$

$$P(yrs) = \sqrt{\frac{(3406AU)^3}{(0.816M_\odot + 0.722M_\odot)}}$$

$$P \approx 160{,}000\ yr$$

Should this be a physical binary the above would be the minimum orbital period which assumes the stars are at their maximum separation.

Conclusion

In this study we have located two possible binary systems and measured each system's position angle and separation. Upon dissection of the available GAIA data, we have determined that Double 2 is most likely an optical double, though one that still warrants research. We have also shed light on what may be a physical binary based on current GAIA data and our measurements. We have also calculated a minimum orbital period in order to give some idea of time frames for future significant measurements.

Future studies of these stars should go towards collecting data for orbital parameters in the case of Double 1 and confirming the nature of Double 2.

Acknowledgements

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This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

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