CCD and GAIA Observations Indicate That WDS 02222+2437 Is Not Gravitationally Bound

Hamza Samha, Jonathan Ginouves, Taime Clark, Savana LeBaron, Jasmine Tapia, Micah Jackson, and Cameron Pace

Southern Utah University
Cedar City, Utah

Abstract: The Double Star system WDS 02222+2437 was observed using the Great Basin Observatory (GBO) telescope. The images were separated and position angle measured using AstroImageJ. Compared to past observations, it was found that the separation in arcseconds decreased marginally while the position angle of the two stars decreased significantly. Our measurements along with proper motion and parallax data from the Gaia database, demonstrate that the two stars are an optical double, not a binary system.

Introduction

A double star is defined as any two stars which appear close to one another when viewed through a telescope. Without a sufficient number of observations, it is impossible to determine whether the double star is an optical double (a pair of stars that only appear to be close together) or a binary system (two stars gravitationally bound to one another). Binary stars are useful because the masses of the stars can be determined by observing the orbital motions of the system, and the mass can be used to determine the evolutionary path of the star. Spectral analysis can also be used to estimate stellar mass, but is not as accurate as determining the mass from the stars' orbit.

For the first time, SUU Success Academy, an early college high school hosted by Southern Utah University (SUU) assembled a student research team for the astronomy research seminar. We used the robotic telescope at Great Basin Observatory (GBO), as seen in Figures 1 and 2, to carry out our observations (Anselmo, 2018). The system observed by our team was WDS 0222+2437 (see Figure 3), and was selected from the Washington Double Star catalog (WDS). This system was selected because it was observable from the telescope's latitude, and the difference between the magnitudes of the primary and secondary star was not excessive. In addition, the primary and secondary components were well resolved by the telescope. In order to maximize the value of our observations, we ensured that the system we selected had not been observed in at least 10 years. The primary star has a magnitude of 12.46 and the secondary star has a magnitude 14.3.

Figure 1. The telescope control software uses the weather station (visible on top of the control room) to determine whether or not it is safe to open the dome. The dome and control room were both painted to match the desert landscape and not detract from the appearance of the park.

Methods

The methods used were based on those in *Small Telescope Astronomical Research Handbook* (Genet 2016). The telescope used, a PlaneWave 0.7m CDK 700, is located at the Great Basin Observatory at Great Basin National Park, Nevada. The GBO is equipped

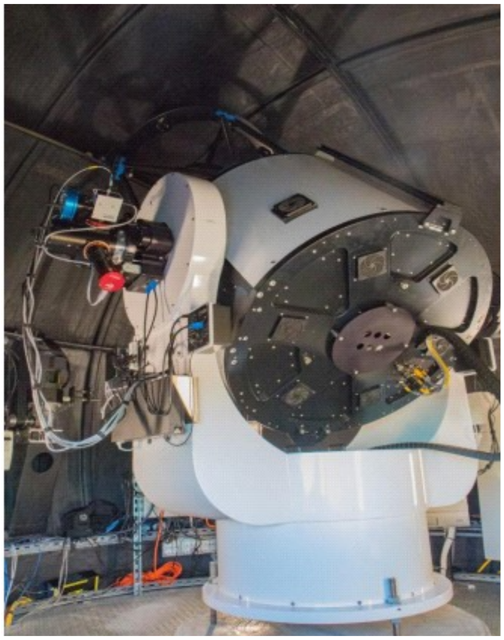

Figure 2: This is the PlaneWave 0.7 m CDK 700 telescope. The spectroscope and planetary camera are mounted at the left Nasmyth port, while the imager and filter wheel are housed at the right Nasmyth port.

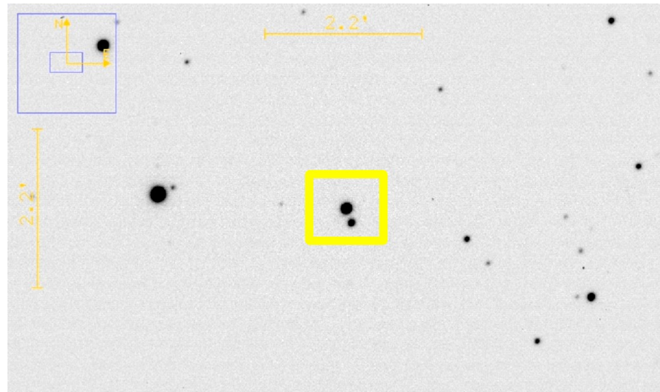

Figure 3: Finder chart for WDS 02222+2437. In this image, north is up, east is right, and the plate scale is 0.4 arcsec/pixel.

with an SBIG STX-16803 CCD camera, and is paired with the telescope which results in a plate scale of 0.4 arcsec per pixel. The telescope has a focal ratio of f/6.5, and the attached camera provides a field view of 27X27 arcminutes (Anselmo, 2018). The telescope is equipped with 16 filters, LRGB, Ha, OIII, SII, BVRI, griz, and a diffraction grating; all of our images were taken using the V filter. We restricted the exposure time to 3 minutes, for a greater amount of time could result in overexposure, which would render the images unuseable. The CCD was in the linear response domain. The images were taken on February 9th, 2018. Once the pictures were taken, we used the AstroImageJ (Collins et al. 2017) program to apply dark, flat, and bias calibrations to each of the images. After the images had been calibrated, the images were plate solved using Astronomy.net. After being plate solved, AstroImageJ was once again used to make the measurements of separation (ρ) and position angle (θ), using centroid apertures to ensure we were measuring from the centers of the stars.

Results

Our measurements for the system are given in Table 1, as well as the mean, standard deviation, and standard error. We have measured the average separation (ρ) to be 12.35" ± 0.002" and the average position angle (θ) as 160.16° ± 0.014°.

Discussion

There are 4 data entries for WDS 0222+2437 in the Washington Double Star Catalog. The first measurement was taken in 1899, followed by another almost a century later in 1997 (Tessier, 1933). Measurements were also recorded in 2000 and 2001, and finally in 2018, when our data was collected, as seen in Table 2 (2MASS, 2003; Hartkopf, 2013; Mason, 2018). Over this span of 120 years, the separation between the two stars, measured in arcseconds, decreased from 15" to 12.3". The position angle between the two stars decreased from 167.3° to 161° between 1899 and 1997, and has gradually decreased since, dropping from 161° to our measurement of 160.16°.

The trend of our observation and past observations is shown in Figure 4. The figure displays the historical

Table 1: Measurement data obtained from our twenty-five images. Average separation (ρ), average position angle (θ), and standard deviation and error are shown.

WDS No.	ID	Date	Observations		ρ [Arcsec]	θ [Degrees]
02222+2437	POU 180	2018.11	25	Mean	12.35"	160.16°
				Std. Dev.	0.011"	0.068°
				Std. Error	0.002"	0.014°

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Table 2. Historic measurement data for POU 180, courtesy of Brian Mason (Mason, 2018). The data has shown that the separation has changed by about 3", while the position angle has changed by about 7°, both over a 100 year period.

Epoch	ρ [Arcsec]	θ [Degrees]
1899.93	15	167.3
1997.85	12.8	161
2000.985	12.711	161.3
2001.577	12.726	160.9
2018.11	12.35	160.16

trends of Component B (blue circles) and our measurement (red triangle) in relation to Component A (yellow circle). The time gap in the observational measurements does not clear resolve the path of the star over the past 119 years; however, the data does indicate the B component is traveling roughly in a straight line. This seems to indicate that the stars are not gravitationally bound.

To further examine the relationship between these stars, we searched the Gaia database (Gaia Collaboration et al. 2016, 2018) for this system and found parallax and proper motion measurements for both components. These measurements are shown in Table 3. The measurements for Component A are shown in the first row while the measurements for Component B are shown in the second row. This table shows that the two components are actually quite far apart (~2,000 ly). Additionally, the proper motions are quite different, which further illustrates that these stars are an optical double, and not gravitationally bound.

Conclusion

This undergraduate research project performed at Southern Utah University indicated that WDS 0222+2437 is an optical double, not a gravitationally bound star. Based on the proper motion of WDS 0222+2437 it is predicted that the stars will move apart with the passage of time. All of this was concluded based on the measurements which are in concordance with the WDS catalog.

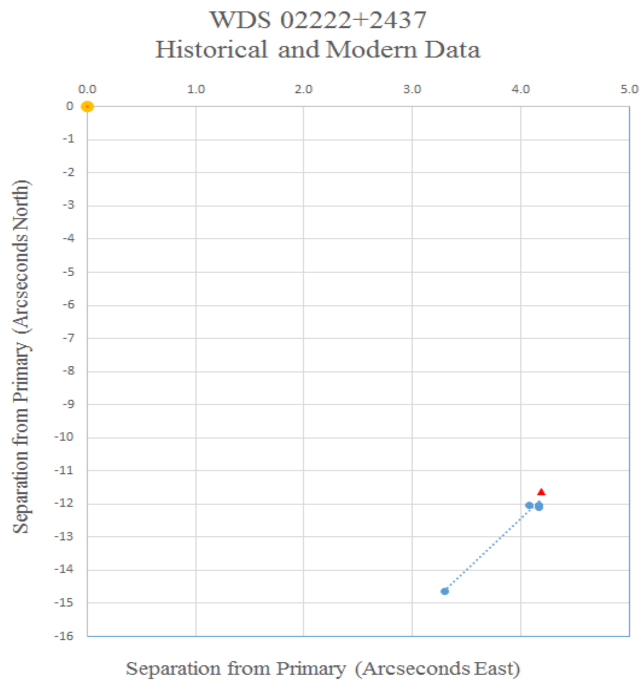

Figure 4: This figure displays the historical measurements of Component B (blue circles), our measurement (red triangle), along with a trend line showing the movement of the star over time. Component A is located at the origin (yellow circle). The first measurement, which is shown at the bottom left of the trend line, was taken in 1899. Our data is in agreement with the historical measurements.

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This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data

Table 3: Data obtained from ESA's Gaia astronomy satellite (Gaia Collaboration et al. 2018), which describes the movement and location of POU 180. This given data was used to help determine if these are gravitationally bound, specifically the parallax.

Components	Right Ascension [degree]	Declination [degree]	Parallax [milliarcsec]	Proper Motion RA [milliarcsec /year]	Proper Motion DE [milliarcsec /year]
A	35.55461778	24.6232385	0.711802998	3.676259036	1.784559247
B	35.55334081	24.62648409	1.364860433	2.228916274	-20.53233837

Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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