CCD Measurements of WDS 19203+0056 Physical Double

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Abstract

We report the results of an astrometric observation of the physical double star system WDS 19203+0056, also named BAL1202. The observations were carried out during March and May of 2021, utilising multi-site Las Cumbres Observatory's (LCO) 0.4 m telescopes. The research team used SBIGSTL-6303 CCD cameras to obtain 157 data points of the target, which were calibrated and analysed using the AstroImageJ software package. The analysed data indicated that the double star system WDS 19203+0056 has a Position Angle of 19.65°, a separation of 8.22″ and a Delta Magnitude of 0.38. The calculations denoted Standard Error Means of 0.0073 ° for position angle, 0.042″ for separation and 0.002 for delta magnitude. The calculated results tally with the previous observations confirming the unchanged physical parameters of the double star system. The research was conducted entirely online as part of an educational collaboration with the support of experts around the world.

1.Introduction

Ever since telescopes were initially used to study the stars, it was discovered that not all stars are single points of light. When viewed from Earth, certain stars appear to have two or more stars; this is referred to as double or multiple star systems. One challenge in the study of double stars is distinguishing between optical and physical doubles. The optical doubles appear adjacent from the vantage point of Earth whilst physical doubles are gravitationally associated pairs (Hidayat, B.Kopal and Rahe, 1984). The study of physical double stars, also named binary stars, is an essential aspect of stellar astronomy that allows direct calculation of absolute dimensions of the component stars: masses, radii, and effective temperatures (Docobo, J.A.Elipe and McAlister, 1997).

Directly resolvable binary stars are referred to as visual binaries (Heintz, 1978). The binary stars can also be discovered indirectly via spectroscopy (spectroscopic binaries), astrometry, and photometry (Chaubey, 1984). Visual binaries have orbital durations ranging from several centuries to millennia (Izmailov, 2019), which results in ubiquitous or inaccurately interpolated orbits (Kiyaeva, Romanenko and Zhuchkov, 2017). In such instances, a comparison of persistently observed historical data and recent observations is utilised to validate the orbital parameters (Quist, 2000). A multitude of catalogues comprising a temporal change in astrometric locations of double stars is publicly available for comparing the data. The Second Naval Observatory CCD Astrograph Catalog (Zacharias *et al.*, 2004) and Washington Double Star Catalog (WDS) are such catalogues with data of proper motion of double stars (Mason *et al.*, 2001). In addition, all previous observation data of a particular target can be requested from US Naval Observatory.

The study of double stars encompasses all the fundamental aspects of astronomy research. Hence, double star research has been used for astronomy education (Argyle, Swan and James, 2019). Therefore, this research was conducted as educational research with a team of undergraduates and graduate students at the Department of

Physics University of Ruhuna, Sri Lanka, utilising the Las Cumbres Observatory (LCO) 0.4m global telescope network. During the research astrometric observation of a physical double star system WDS 19203+0056 (BAL1202) was studied. The observations were carried out during March and May of 2021, utilising multi-site Las Cumbres Observatory's 0.4 m telescopes. The research team used SBIGSTL-6303 CCD cameras to obtain 157 data points of the target. The data was calibrated and analysed using the AstroImageJ software package and compared with the historical data.

2.Target selection

The LCO global telescope network is comprised of telescopes with apertures 0.4m, 0.8m, 1m, and 2m, located in professional observation locations. We had five hours of telescope time in 0.4 m telescopes. The 0.4 m telescopes are Cassegrain focus optical designs with C-ring equatorial mounts, utilising Meade RCX f/8 optics. Each telescope is equipped with an SBIG STX6303 optical imager with 30x20 arcmin field of view (Pickles *et al.*, 2014).

In selecting a target, the optical limitations of the telescope and the zenithal distance of the target at the time of observation were considered preliminary. Initially, various constellations that are visible during the observing period were selected using the Stellarium software. To reduce air mass, all of the selected Constellations were chosen around the Zenith point. Objects located near the moon were neglected, considering that moonlight will saturate the sensor, which may result in inadequate data. A double star database called Stelle Doppie was utilised to find a possible target from the selected constellations. Initially, primary & secondary magnitudes, delta magnitudes, and separation were set on Stelle Doppie, and the selected constellations were inserted into the system. Results were listed as possible targets for observation. The resulting list of double stars was further narrow downed by considering the criteria delta magnitude, separation, parallax, last observation and number of observations. A double star system should be at least 5 arc seconds apart and equal in brightness to be observable and resolved in the telescope and the CCD sensor.

The parameter delta magnitude was selected to be less than 3; if the delta magnitude is greater than 2, the double star requires greater separation to be detected in the telescope (more than 10 arc-seconds). Otherwise, the brightness of the primary star will overwhelm the secondary star. After the sorting process, the selected double stars were re-listed. The list was arranged according to the number of observations. The selected target details were rechecked with the GAIA database. The parallax of the selected targets was checked to see if they were similar; otherwise, the target had a lower chance of being a double star.

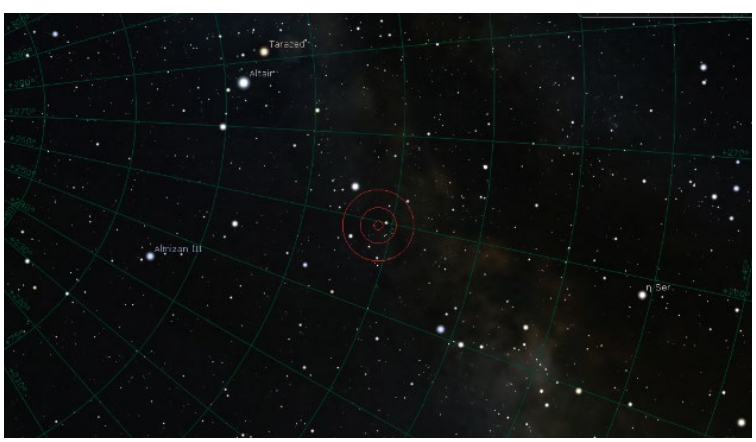
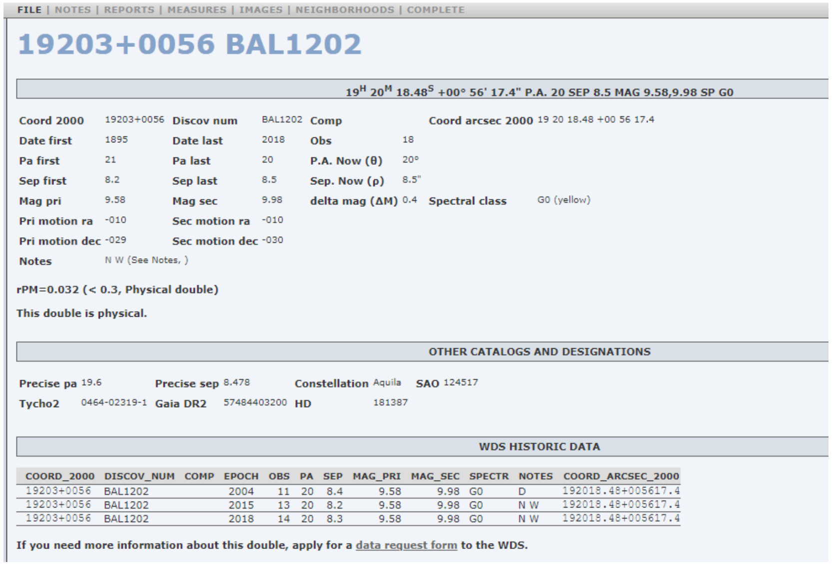


Figure 1: The target WDS 19203+00563483 in the Stellarium software



FILE | NOTES | REPORTS | MEASURES | IMAGES | NEIGHBORHOODS | COMPLETE

19203+0056 BAL1202

19H 20M 18.48S +00° 56' 17.4" P.A. 20 SEP 8.5 MAG 9.58,9.98 SP G0

Coord 2000	19203+0056	Discov num	BAL1202	Comp		Coord arcsec 2000	19 20 18.48 +00 56 17.4
Date first	1895	Date last	2018	Obs	18		
Pa first	21	Pa last	20	P.A. Now (θ)	20°		
Sep first	8.2	Sep last	8.5	Sep. Now (ρ)	8.5"		
Mag pri	9.58	Mag sec	9.98	delta mag (ΔM)	0.4	Spectral class	G0 (yellow)
Pri motion ra	-010	Sec motion ra	-010				
Pri motion dec	-029	Sec motion dec	-030				
Notes	N W (See Notes,)						

rPM=0.032 (< 0.3, Physical double)

This double is physical.

OTHER CATALOGS AND DESIGNATIONS

Precise pa	19.6	Precise sep	8.478	Constellation	Aquila	SAO	124517
Tycho2	0464-02319-1	Gaia DR2	57484403200	HD	181387		

WDS HISTORIC DATA

COORD_2000	DISCOV_NUM	COMP	EPOCH	OBS	PA	SEP	MAG_PRI	MAG_SEC	SPECTR	NOTES	COORD_ARCSEC_2000
19203+0056	BAL1202		2004	11	20	8.4	9.58	9.98	G0	D	192018.48+005617.4
19203+0056	BAL1202		2015	13	20	8.2	9.58	9.98	G0	N W	192018.48+005617.4
19203+0056	BAL1202		2018	14	20	8.3	9.58	9.98	G0	N W	192018.48+005617.4

If you need more information about this double, apply for a data request form to the WDS.

Figure 2: The data of the object from the Stella Doppie database

The double star WDS 19203+00563483 which is located in the constellation Aquila (Figure 1), was finalised as the target. The WDS 19203+00563483, also named BAL1202 was initially observed in 1895. The initial observation recorded a position angle of 20.7°, separation of 8.2″. The system is a G0 spectral class with a primary magnitude of 9.58 and a secondary of 9.98. The object was last observed in 2018; therefore, we expected to update astrometric data and compare it with the historical data.

3.Observations

The observation request was made through the LCO interface. Initially, the target name was entered by using its designation name in the WDS. Next, the telescope exposure settings were set. There were no bright objects near the target. Red Filters were selected because red light goes through the atmosphere better, green and blue lights scatter more than red so the stars can appear sharp in red.

The Right Ascension (RA) and Declination (Dec) were extracted from the WDS. The RA and DEC were added manually with the target name. The 0.4 m telescope network was selected, which allows remote access to more than 14 observatories and telescopes around the globe.

The selected target was observed in May 2021. Five sec to 20 sec exposure times were taken because the selected target magnitude is close to around 9.5 to 10. Observations were submitted on May 01 and May 03, 2021. The images were returned on May 03, 2021. One hundred fifty six images (observations) were taken.

4.Analysis of Results

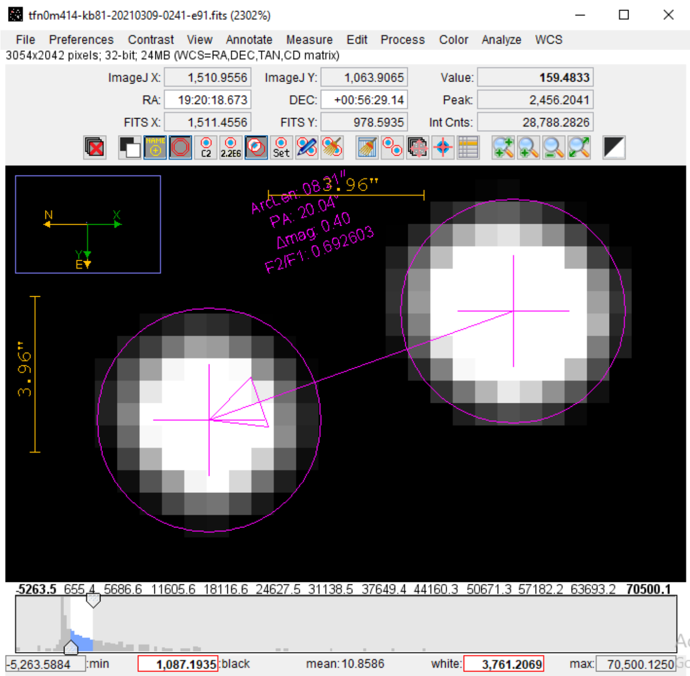


Figure 3: Observed data loaded in the AstroimageJ software

The acquired images were already platesolved and comprised of FITs headers. Figure 3 indicates the loaded image in AstroImageJ software. Initially the brightness is adjusted to -1,890.9913 pixels in black and 4,993.1401 pixels in white. The target has to be located in the middle of the image. However, the LCO portal has the advantage of using robotic telescopes that are usually focused on the target itself. We verified the RA coordinate to be 19:20:18.453 and the DEC coordinate to be +00:56:13:25 in the AIJ software with the comparison of Stella Doppie RA of 19:20:18.48 and DEC of +00:56:17.4 which led to more accurate target identification. Aperture photometry settings were selected with 5 pixels of object aperture radius and 8 pixels for both inner radii of background annulus and outer radius of background annulus. A linear state aperture setting was done throughout the process setting the target aperture radius within the object aperture and the background of the target within the inner and outer background aperture radius. Separation of 8.19 pixels, PA of 19.85 degrees, delta magnitude of 0.34 was measured and visible on the image that helped to calculate the average values of PA and separation to be 19.6 degrees and 8.22 pixels, respectively. The above steps were preceded in *images. The acquired data is comprised of a FITs header and plate solved. Figure 3 indicates the loaded image of the target in AstroImageJ. Separation and position angle for each exposure time was measured using a photometry aperture of 8 pixels. The analysis was done three times independently. Only 3 of the 37 images showed any difference at all in position angle and/or separation, and where variability existed, it was a maximum of 0.06" separation and 0.4 PA. This inconsistency did not affect our results to a significant extent.

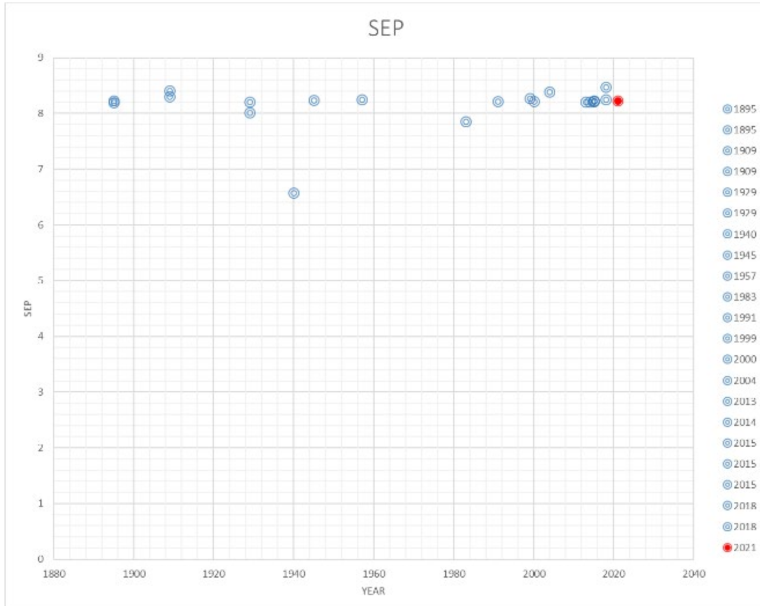


Figure 4: Separation Vs Year

The difference in the position angle measurement was statistically significant, but the difference was small: between 0.078 and 0.32" for the AURT minus Yerkes measurement with a 95% confidence interval. Exposure time did not have a statistically significant effect on the values obtained for position angle. For the separation values, there was a statistically significant difference between the 10 second and 30 second images from the exposure time that did not affect the value of the separation measurement. Figures 4 and 5 summarise these measurements.

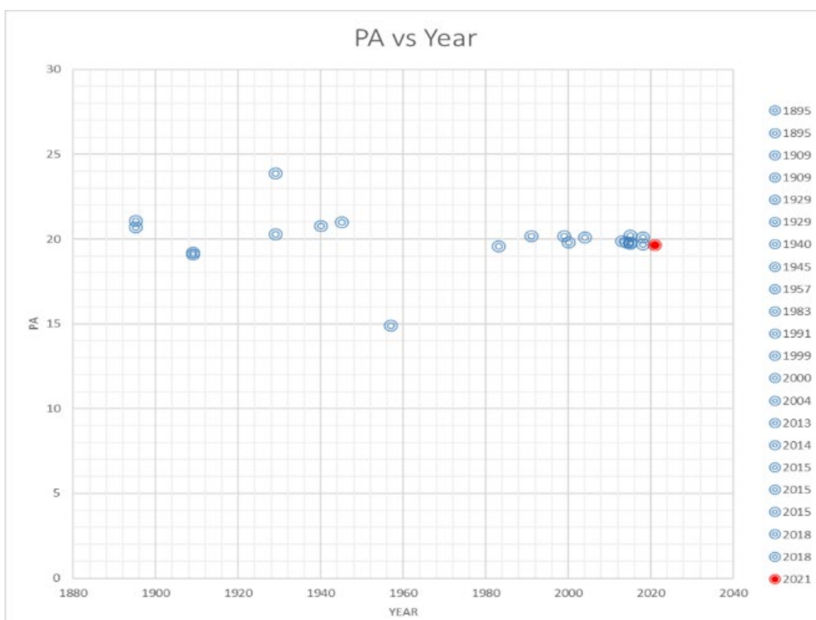


Figure 5: Position angle vs Year

5.Conclusion

The current measurements of the position angle and separation of WDS 19203+00563483 are 19.65° and 8.22″, respectively. A linear trend in the observations made over the course of the past 125 years corroborates the classification of this system as a physical double.

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References

Argyle, B., Swan, M. and James, A. (2019) 'Observing Double Stars', in *An Anthology of Visual Double Stars*, pp. 3–6. doi: 10.1017/9781316823163.003.

Chaubey, U. S. (1984) 'Evolutionary processes in close binary stars', *Astrophysics and Space Science*, pp. 385–389. doi: 10.1007/BF00653753.

Docobo, J.A.Elipe, A. and McAlister, H. (1997) *Visual Double Stars: Formation, Dynamics and Evolutionary Tracks*, *Astrophysics and Space Science Library0067-0057*. Edited by J. A. Docobo, A. Elipe, and H. McAlister. Dordrecht: Springer Netherlands (Astrophysics and Space Science Library). doi: 10.1007/978-94-009-1477-3.

Heintz, W. D. (1978) 'The Orbital Elements of a Visual Binary', in *Double Stars*, pp. 31–34. doi: 10.1007/978-94-009-9836-0_13.

Hidayat, B.Kopal, Z. and Rahe, J. H. (1984) *Double Stars, Physical Properties and Generic Relations*. 1st edn. Edited by B. Hidayat, Z. Kopal, and J. Rahe. Dordrecht: Springer Netherlands. doi: 10.1007/978-94-009-6372-6.

Izmailov, I. S. (2019) 'The Orbits of 451 Wide Visual Double Stars', *Astronomy Letters*, 45(1), pp. 30–38. doi: 10.1134/S106377371901002X.

Kiyaeva, O. V., Romanenko, L. G. and Zhuchkov, R. Y. (2017) 'New orbits of wide visual double stars', *Astronomy Letters*, 43(5), pp. 316–331. doi: 10.1134/S1063773717040041.

Mason, B. D., Wycoff, G. L., Hartkopf, W. I., Douglass, G. G. and Worley, C. E. (2001) 'The 2001 US Naval Observatory Double Star CD-ROM. I. The Washington Double Star Catalog', *The Astronomical Journal*, 122(6), pp. 3466–3471. doi: 10.1086/323920.

Pickles, A., Hjelstrom, A., Boroson, T., Burleson, B., Conway, P., De Vera, J., Elphick, M., Haworth, B., Rosing, W., Saunders, E., Thomas, D., White, G., Willis, M. and Walker, Z. (2014) 'LCOGT network observatory operations', *Observatory Operations: Strategies, Processes, and Systems V*, 9149, p. 914912. doi: 10.1117/12.2055215.

Quist, C. F. (2000) 'Studies of double and multiple stars using space astrometry', *Ph.D. Thesis*, p. 2.

Available at: http://adsabs.harvard.edu/abs/2000PhDT.........2Q.

Zacharias, N., Urban, S. E., Zacharias, M. I., Wycoff, G. L., Hall, D. M., Monet, D. G. and Rafferty, T. J. (2004) 'The Second US Naval Observatory CCD Astrograph Catalog (UCAC2)', *The Astronomical Journal*, 127(5), pp. 3043–3059. doi: 10.1086/386353.