Astrometric Measurements of Double-Star WDS 20437+3243(AB)

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Abstract: .Separation and position angle measurements were made for the double star WDS 20437+3243(AB) using two instruments and two methods for extracting data. The results were comparable for both instruments and methods. Separation was 7.50 arc seconds and the position angle was 123.6 degrees. These results were compared to the historical data and in conjunction with our data we can only say that the nature of these double stars remains “uncertain”.

Introduction

This work was undertaken as part of the Astronomy Research Seminar which provides practical experience in astronomical research and an understanding of the nature of scientific research. The goal of the program is to expose high school and undergraduate college students to research projects early in their education (Genet). The study of double stars with small telescopes is within the reach of students given the time they can devote to such a project and availability of equipment. At the same time their work provides an additional source of valuable data for the scientific community. The authors intend to offer this opportunity as courses available to undergraduates at their respective institutions. In addition the Jack C Davis Observatory will offer training in performing double star astrometry to interested members of the Western Nevada Astronomical Society (WNAS). By taking part in the fall 2019 Astronomy Research Seminar (ARS) Western US, offered by Rachel Freed at Sonoma State University, the authors are gaining skills in double star astrometry, associated data analysis, and insight into the learner experience in double star research. The future offerings at these institutions will provide research experience for a variety of learners and help to grow the community of double star researchers.

This paper describes the measurement of separation and position angle made for the double star WDS 20437+3243(AB) in the constellation Cygnus using two different instruments, one at the Jack C Davis Observatory (JCDO) and the other from the Las Cumbres Observatory (LCO) network. The results were compared using multiple images and measurements from each. An additional experiment was done in which the JCDO images were stacked using two different methods. A single measurement from each of the stacked images was made for comparison.

Equipment and Methods

This target was selected as a “neglected” double from the Washington Double Star Catalog that was downloaded into an Excel worksheet. The criteria used to select this double star was that the magnitude of the primary star should be between 7 and 11 with separation between 5 and 9 arc seconds and delta magnitude less than 3 so that the measurements could be made with the 0.4 meter telescopes available to us. It should also be visible in the night sky in October when measurements were made which limited RA between 18 and 8 hours. To qualify as ‘neglected’ we further limited our choice to between 4 and 10 measurements with the most recent no later than 2008. Ideally we also looked for measurements that spanned many years so that adding ours might tip the scales one way or the other in determining whether it is a gravitationally bound bina-

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Figure 1. JDCO Telescope, a) Takahashi c400 and b) authors Tom Herring and Omar Garza at the controls.

ry. The first measurement for the selected star was in 1929 (Espin) and the most recent was in 2002. As a result of our secondary goal for the JCDO we further limited candidates to the northern hemisphere and reduced the RA range. The selected star was easily seen from this site in Carson City, NV, given the clear skies experienced there in October 2019.

CCD images were acquired by multiple 0.4 meter telescopes from the Las Cumbres Observatory (LCO) network. These are modified Meade telescopes with custom equatorial mounts and high-quality SBIG STL-6303 cameras. All hardware and control software is identical. Complementary measurements were also taken at the Jack C Davis Observatory (JCDO) with a 0.4 meter Takahashi c400 Cassegrain telescope (focal length 5600 mm) and an SBIG STL1001 camera. See Figure 1. This system is equipped with The SkyX Planetarium software, a Paramount ME equatorial mount (both by Software Bisque for scope control), and Maxim DL 6 (for camera control).

LCO settings and image processing:

Ten images were acquired at exposure times of 1, 2 and 4 seconds from the LCO network. All were taken with a clear or air filter and processed by the LCO data pipeline called BANZAI. The best of these were 2 second exposures taken at the Teide Observatory on Tenerife in the Canary Islands and 4 second exposures taken at the McDonald Observatory in Texas. The latter 4 second exposures had SNRs greater than 40 dB and were therefore used to extract astrometric data with AstroImageJ (AIJ).

JCDO settings and image processing:

Twenty images were acquired using a 4 second exposure time at the JCDO after some experimenting and inputs from the LCO results. A clear filter was used. Corresponding dark, flat and bias images were taken for image processing and calibration with Maxim DL 6. The images were then plate solved for astrometric data extraction with AstroImageJ. The images were also stacked with Maxim DL 6 using an average algorithm and a median algorithm from which the same data was extracted using AstroImageJ.

Results

The collected images were analyzed with AstroImageJ to determine the separation (Sep) in arc seconds and the position angle (PA) measured from North towards East in degrees. These results are summarized in Tables 1 and 2. Table 3 shows the results for stacking images.

The images in Figures 2 and 3 are from AstroImageJ for the LCO and JCDO. Each is a single reduced image from which astrometric measurements were made. Figures 4 and 5 are images for the stacked JCDO images using the average and median method, respectively. These were then used to make a single measurement for each method as summarized in Table 3. Figure 6 is a wider field of view centered on the target system from the LCO images. By comparison, Figure 7 is an image from Stelladoppie.it.

We compared our measurements with historical WDS data which is summarized in Table 4. GAIA DR2 data from 2015 was used to calculate the separation and position angle (Gaia Collaboration et al 2016 and 2018b) on that date. Our measurements are included at the end of the table. This data is plotted in Figure 8a and 8b relative to the primary star (A). Each data

LCO Results	Average	StdDev	# samples	Std Err
Sep (as)	7.55	0.018	10	0.006
PA (deg)	123.9	0.2	10	0.06

Table 1. Summary of astrometric data extracted from LCO images.

JCDO Results	Average	StdDev	# samples	Std Err
Sep (as)	7.44	0.14	20	0.03
PA (deg)	123.4	0.75	20	0.17

Table 2. Summary of astrometric data extracted from JCDO images.

JCDO Stacked Results	By Averaging	By Median
Sep (as)	7.4	7.4
PA (deg)	123.2	123.1

Table 3. Summary of astrometric data using stacked JCDO images.

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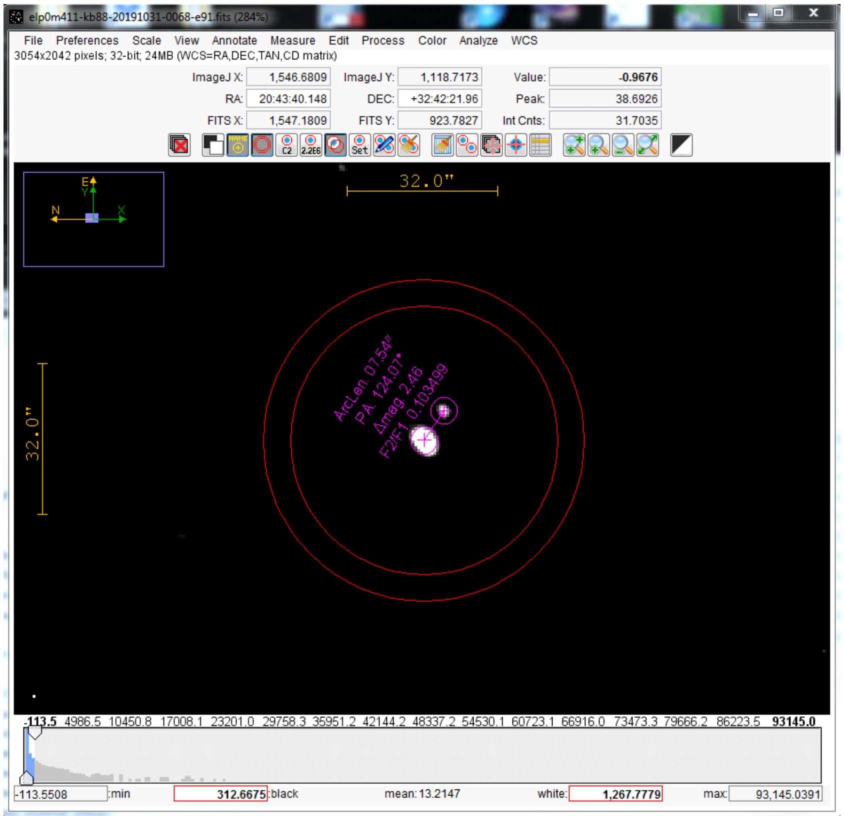

Figure 2. Single reduced image from the LCO data set.

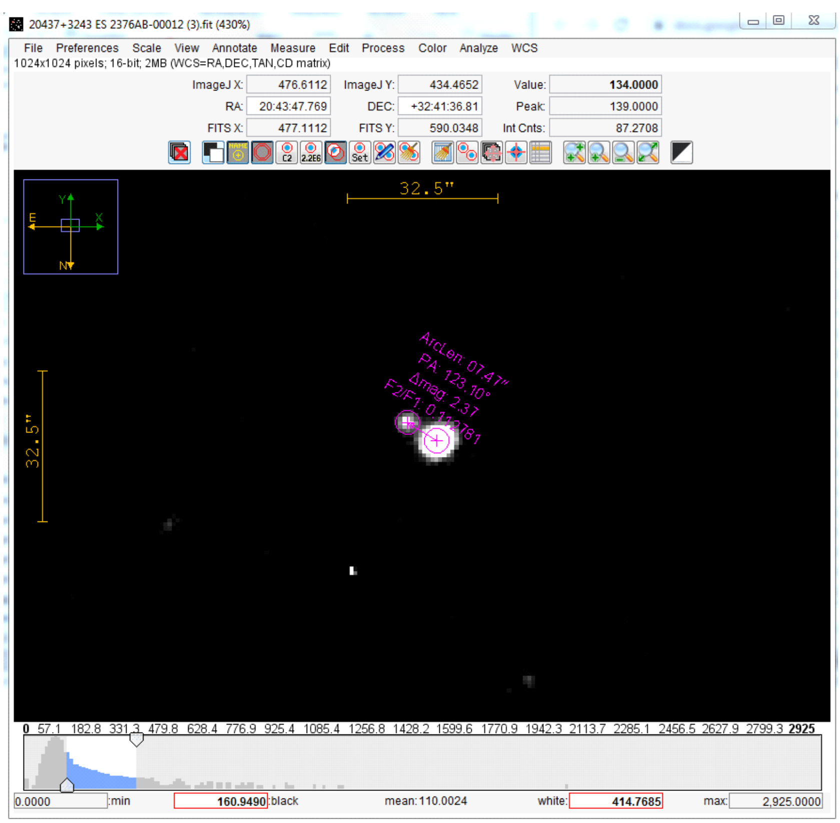

Figure 3. Single reduced image from the JCDO data set.

Astrometric Measurements of Double-Star WDS 20437+3243(AB)

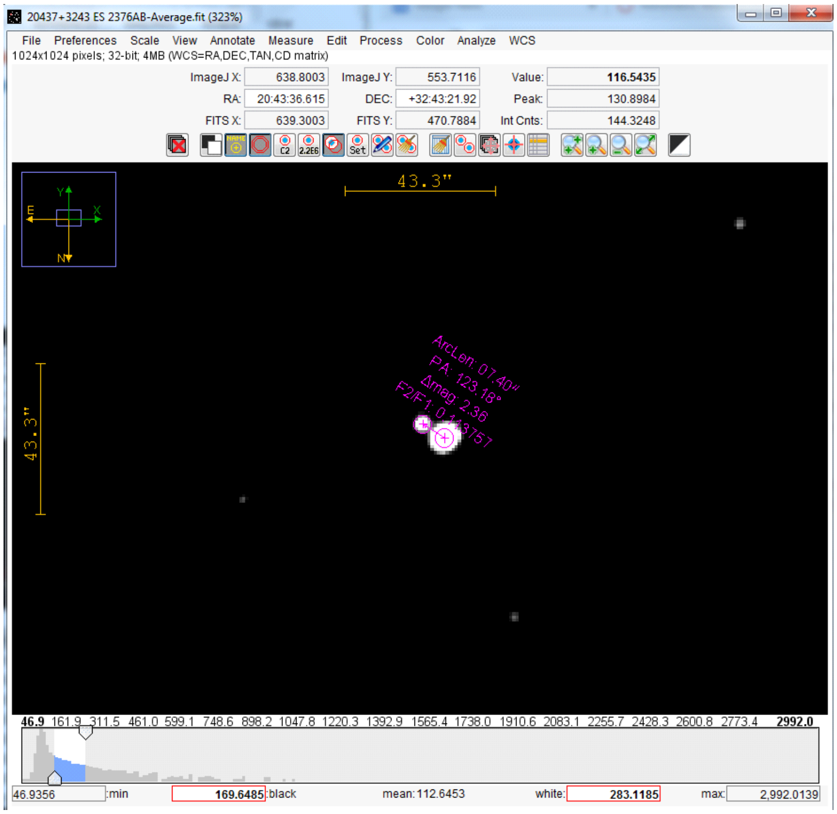

Figure 4. Stacked image using the averaging method from the JCDO data set.

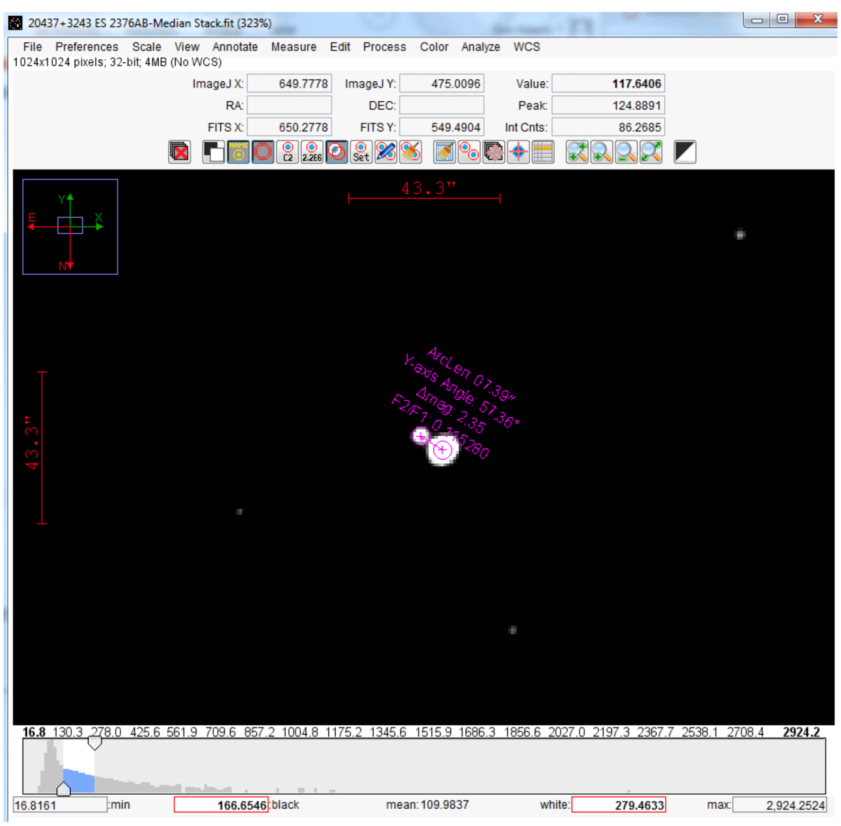

Figure 5. Stacked image using the median method from the JCDO data set.

Astrometric Measurements of Double-Star WDS 20437+3243(AB)

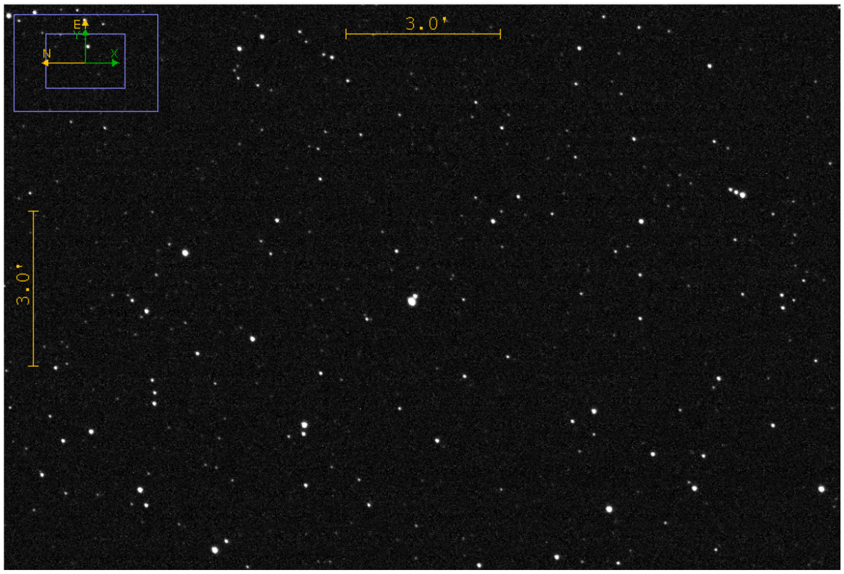

Figure 6. Wider view from an LCO image. WDS 20437+3243 is at the center.

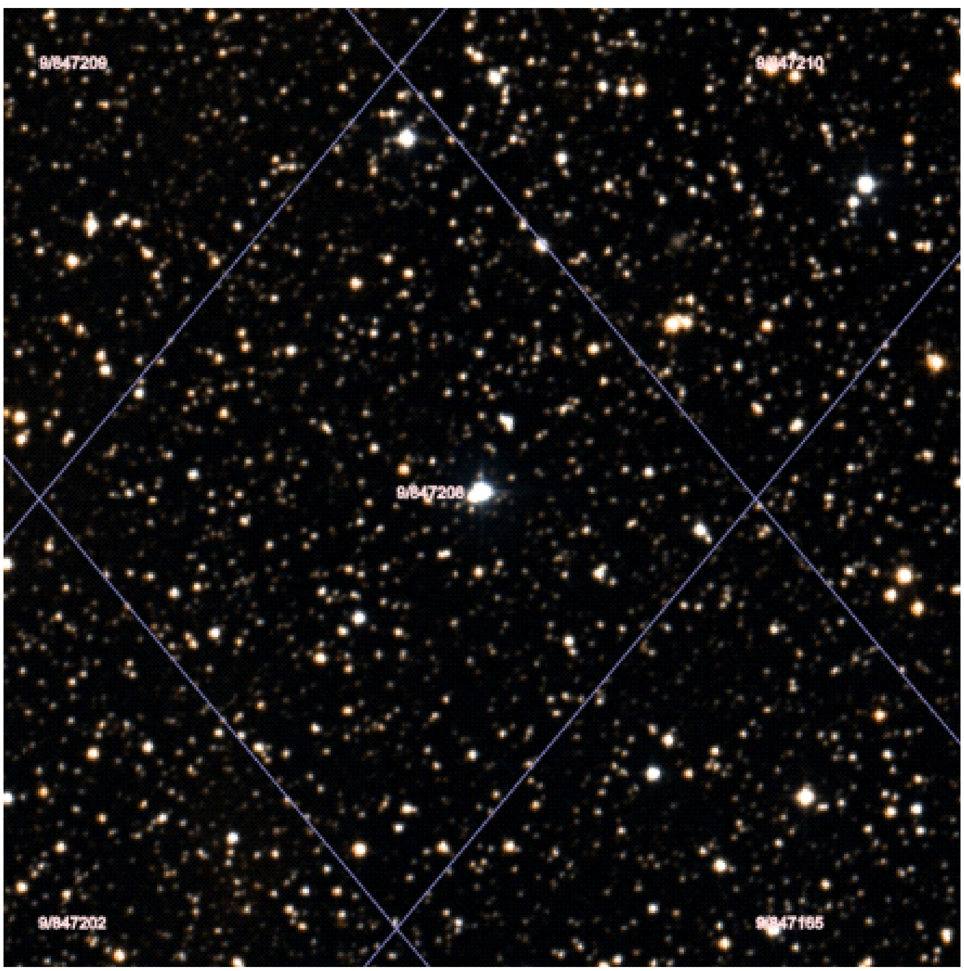

Figure 7. WDS 20437+3243 ES 2376AB : Aladin DSS image @ 20h 43m 44.64s +32° 42' 35.4", FOV = 12.05'. Image from Stelladoppie.it.

Astrometric Measurements of Double-Star WDS 20437+3243(AB)

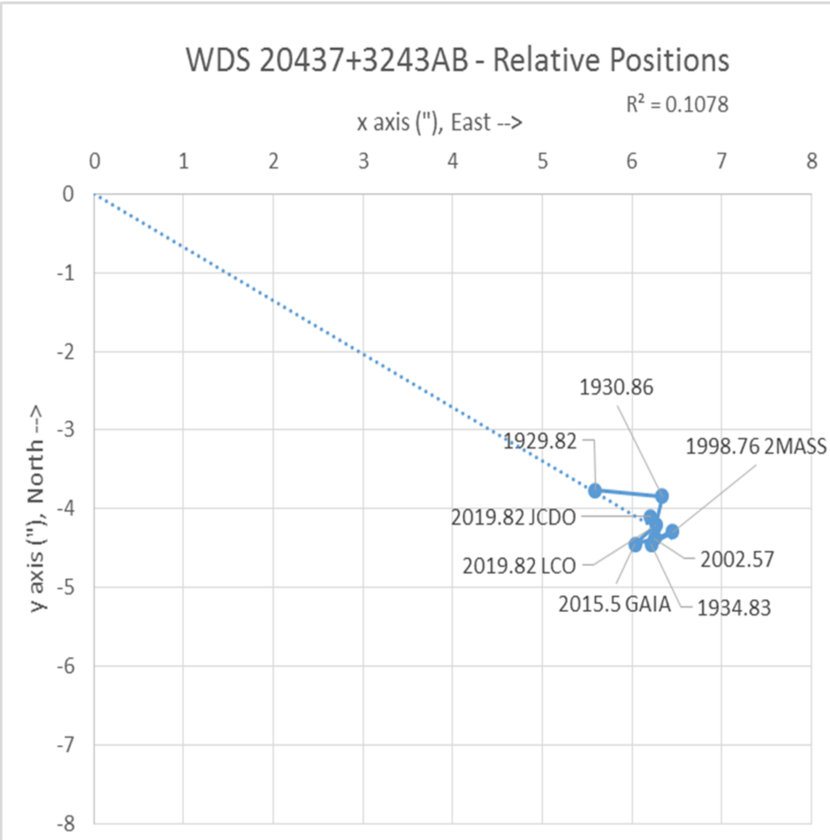

Figure 8a. Plot of historical data with our most recent measurement. The dotted line is a regression on the data including the primary star at the origin.

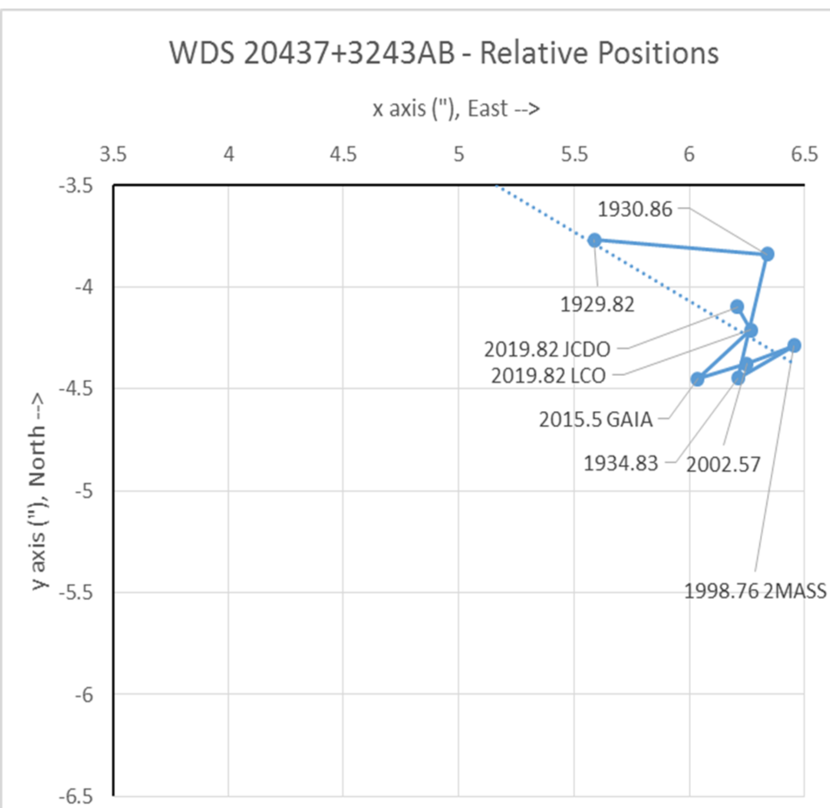

Figure 8b. Plot of historical data with expanded scales that more clearly show the range and sequence of measurements over 90 years.

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Date	PA	Sep	aperature	# Obs. Disc. Code
1929.82	124	6.74	0.6	2 Es_1930
1930.86	121.2	7.41	0.3	1 WFC1998
1934.83	125.6	7.64	0.3	1 WFC1998
1998.76	123.6	7.75	1.3	1 TMA2003
2002.57	125.0	7.63	0.2	5 UC_2013b Eu
2015.50	**126.4**	**7.50**		**GAIA DR2**
2019.82	**123.89**	**7.55**	**0.4**	**LCO**
2019.82	**123.42**	**7.44**	**0.4**	**JCDO**

Table 4. Historical data from the WDS catalog. The 2015 entry is calculated using GAIA DR2 data. The last two entries are our measurements from Tables 1 and 2.

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point is labeled since there are only eight. A linear regression line is shown that includes the primary star at the origin. This should be the major axis of an elliptical orbit if these stars are gravitationally bound. Note that there is no estimated orbit for this system in the 6th Orbit Catalog.

Discussion

Our most recent data appears to show no relative motion between the AB stars in this double system. In fact one could argue that the scatter in the measurements reflects measurement error. However, Richard Harshaw recently did a survey of the WDS catalog were he combined it with GAIA DR2 (Harshaw 2018) using 'physicality' metrics he defined. He defined 'physicality' as "the likelihood that a given pair is traveling together through space, may have a common origin, and may, in fact, be in orbit around a common center of gravity." From the worksheet he created this system is classified Y or 'definitely physical'. See Table 5 for an excerpt from that table. Our independent calculations using the GAIA DR2 data indicate the distance to the AB components is 664 ± 17 and 661 ± 14 parsecs. Since the distances overlap considerably, and if we assume they are really at the same distance, then with an angular separation of 7.5 arc seconds this gives a separation of 4980 - 5110 AU. The observed GAIA effective temperatures and luminosities place both stars on the main sequence of the H-R diagram. Using the mass-luminosity relationship for main sequence stars the estimated masses are roughly 2.1 and 1.3 solar masses. Using Kepler's Third Law these masses give an orbital period of roughly 192,000 - 200,000 years. It is odd they are traveling through space at about the same distance, and with about the same proper motion. Since the AB components of the system are separated by less than the 200,000 AU criteria suggested by Knapp (Knapp 2018 and a recent JDSO submission) this is further evidence it is probably physical. However, the small masses and large orbital period make confirmation difficult given measurements over just 90 years. It is no wonder the data look like random measurement error. It may be possible to use our data and future measurements, in the distant future, to resolve the status of this enigmatic system.

It is possible that we are viewing this double star system on edge such that the semi-major axis is small. If the secondary star is near a focus/vertex of the ellipse (apastron) the observed data would be bunched up as we have observed. In this case it may take much more than 90 years before an orbit is revealed, especially if the orbital period is almost 200,000 years.

We successfully made measurements of the AB components of this system. While doing our research we learned there is a third star in it, AaAb, with much smaller separation reported at as little as 1.3 arc seconds. The images from both the LCO network and at JCDO reveal this star as elongation of the primary A component but could not be resolved. It is possible this could affect the accuracy of AB component measurements since the centroid of the A star is less certain and could even be moving.

Similar results were obtained with the JCDO and LCO network instruments but the variation in JCDO measurements is larger as reflected in the standard deviations. It is likely this difference is a result of differences in the size and number of imager pixels for the

Key	WDSName	Discoverer	Gaia Sep	Gaia PA	Dist PROB	Avg PM Vect	PM Prob	Binary Prob	Net Weight Gauge	Physical?
120479	20437+3243	COU 1633 Aa-Ab	1.93	239.22	0.7110	13.87	0.1413	0.8523		Y
120480	20437+3243	ES 2376 AB	7.50	126.42	0.7450	2.24	0.1500	0.8950		Y

Table 5. Excerpt from Harshaw's worksheet with entries for the WDS 20437+3243 system.

cameras used. Both telescopes had the same aperture, 0.4 meters. The camera at the LCO has 3072x2048 9 um square pixels whereas at the JCDO has 1024x1024 24 μm pixels. This results in spatial resolution of 0.571" and 0.884" respectively. The lower resolution of the JCDO camera will result in more sampling noise as observed. Nonetheless, the JCDO equipment is capable of doing this type of precise measurement for double star research. There is slightly better agreement between the PA measurements. The stacking method using the JCDO images also yielded similar results but does not allow for an estimate of variation. In this case stacking did not result in any gains of the quality of the measurements indicating that the usual practice of analyzing individual images is more enlightening for separation and position angle measurements.

Conclusion

This project has demonstrated to us that it is possible for motivated high school students, college undergraduate students, and interested amateur astronomers to successfully tackle this type of scientific research using available small telescopes. Equipment at the JCDO and the LCO network are capable of making double star measurements with separations down to about 5 arc seconds. Use of the LCO network opens this experience to the widest possible range of learners/contributors.

The methods and equipment used for these measurements provided consistent results. Differences in results can be explained by differences in the cameras.

It appears this double star system may be gravitationally bound but it is still not clear. There is very little relative movement over 90 years, yet we estimate a period of almost 200,000 years. This is the sixth measurement of the system. We added another measurement for 2015 based on the GAIA DR2 data. These are clustered around the more recent data in which instruments and methods have likely improved. Future measurements and analysis in the distant future could provide a more definitive answer. This system is worthy of future study.

Acknowledgements

This research made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. It also used data and tools at the StelleDoppie.it site created and maintained by Gianluca Sordiglioni. This site has very a capable sorting tool. Historical data was provided by Dr. Brian Mason at the U.S. Naval Observatory. This work also made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esaint/gaia), processed by the Gaia Data 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. We would also like to thank Rachel Freed at Sonoma State University for her guidance and work to organize the Astronomy Research Seminar. Finally we'd like to thank Richard Harshaw for providing suggestions to improve this paper.

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LCO data pipeline (BANZAI), https://lco.global/documentation/data/BANZAIpipeline/

AstroImageJ software, https://www.astro.louisville.edu/software/astroimagej/