Astrometric Measurements of 3 Binary Star Systems: WDS 00033+5332, WDS 05283+0358, and WDS 19557+3805

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Abstract

We have taken astrometric measurements of three star systems: WDS 00033+5332 A 1500 AB,C, WDS 05283+0358 HJ 2266, and WDS 19557+3805 DAM 1 AB. We used the Las Cumbres Observatory telescopes to take images of these star systems, and we then analyzed them using Afterglow Workbench. For WDS 00033+5332, we found the position angle to be 81.62° ± 0.45° and an angular separation of 9.01'' ± 0.04''. Based on our analysis, we were not able to determine whether the WDS 00033+5332 double is physical. For WDS 05283+0358, we found the position angle to be 37.58° ± 0.15° and an angular separation of 7.29'' ± 0.04''. It is already known that WDS 05283+0358 is a physical double, and our new data supports this claim. For WDS 19557+3805, we found the position angle to be 234.64° ± 0.63° and an angular separation of 6.89'' ± 0.10''. Our new data points suggest this system is gravitationally bound

1. Introduction

In this paper we found astrometric measurements of three binary star systems: WDS 00033+5332 A 1500 AB,C, WDS 05283+0358 HJ 2266, and WDS 19557+3805 DAM 1 AB. Our goal was to provide more current measurements on these star systems so we can better understand their orbits. None of these systems have been measured in the last seven years, so this new information will give us a better understanding of these star systems.

We utilized the Stelle Doppie database[1] to search the Washington Double Star (WDS) catalog (Mason et al. 2001) for star systems in which there was a significant change in the position angle and separation from the first measurement to the most recent. We also wanted to find a system that hadn't been measured since 2015 or earlier, so that we could provide information on a star that hadn't been studied in a while.

Since the discovery of WDS 00033+5332 A 1500 AB,C in 1917 (Aitken 1932), there have been a total of seven measurements. The primary star has a spectral class of A3. This star system is composed of three stars, however, since stars A and B are so close in space, they cannot be resolved by our observations. Thus, we treat the combination of these as a primary star of magnitude 9.29, and star C as the secondary star of magnitude 13.10. In 1917, the first recorded angular separation was 8.60 arcseconds and the position angle was 78.6°. The most recent measurements were in 2014, and the angular separation was 9.394 arcseconds and the position angle was 82.05° (Zacharias et al. 2015). The physical nature of this binary is not known.

WDS 05283+0358 HJ 2266 was discovered nearly 200 years ago in 1830 (Herschel 1833). Since then, 8 other measurements have been taken bringing the total number of measurements to 9. Using these measurements, it has been determined that this is a physical binary system based on the Common Proper Motion of the binary. The data in this collection is meant to provide data to support a more complete picture of the movement of the system.

[1] https://www.stelledoppie.it/

The binary system WDS 19557+3805 DAM 1 AB was first discovered in 1998 (Skrutskie et al. 2006). Since its discovery there have been 7 other measurements that have been made. This double is a part of a quintuple system, however the nature of this double is uncertain. The first recorded separation and position angle were 7.22 arcseconds and 232.7° respectively. The current measurements are 6.641 arcseconds and 236.62° (Zacharias et al. 2015).

2. Equipment and Methods

In order to get the images of our star systems, we used the Las Cumbres Observatory (LCO), which is a network of 25 telescopes at multiple sites around the world. These can be controlled remotely, and because of this, our images were taken at different locations. However, the images were all taken using the same instrument, a 0.4-m telescope, with an SBIG STL6303 camera to capture the images. The images for WDS 00033+5332 and WDS 19557+3805 were taken by a telescope at LCO's Haleakala site in Hawaii. The images for WDS 05283+0358 were taken in Cerro Tololo, an observatory in Chile. For all our images, we used a Bessel V filter.

To ensure that we used an optimal exposure length for our systems, we used test images so that if they were either undersaturated or oversaturated, we could adjust our exposure length to get better results. Some of the star systems had primary and secondary stars with similar magnitudes, so it was easier to choose an exposure. However, for the star systems with larger changes in magnitude between the stars, we had to be careful to choose an exposure that allowed us to accurately see the secondary star without oversaturating the primary star. For WDS 19557+3805, we used an exposure time of 3s, for WDS 00033+5332 we used a 2s exposure, and for WDS 05283+0358 we used an exposure of 4s. After submitting our test images and determining a good exposure to use, we requested 10 images of each star.

After, retrieving our calibrated images from the LCO database, we used Afterglow Workbench[2] to analyze our images. Specifically, we used Afterglow to measure the angular separation between our primary and secondary stars and the position angle of the stars. After recording the data, we calculated the mean, standard deviation, and standard error of the mean for each star system. We were also able to obtain historical data about the star systems by requesting data through Dr. Rachel Matson from the Washington Double Star Catalog (Mason et al. 2001).

3. Data

Data for each star was collected by the LCOGT 0.4 m telescopes SBIG 6303 CCD camera with a Bessell-V filter. The FITS were reduced by LCOGT using the BANZAI pipeline to calibrate the images. During processing many tasks were performed including bad-pixel masking, bias subtraction, dark subtraction, and flat field division. The data was then analyzed in Afterglow Workbench to find the separation and position angle data for each of the binary systems. An example of these measurements is given in Fig 1.

[2] https://afterglow.skynetjuniorscholars.org

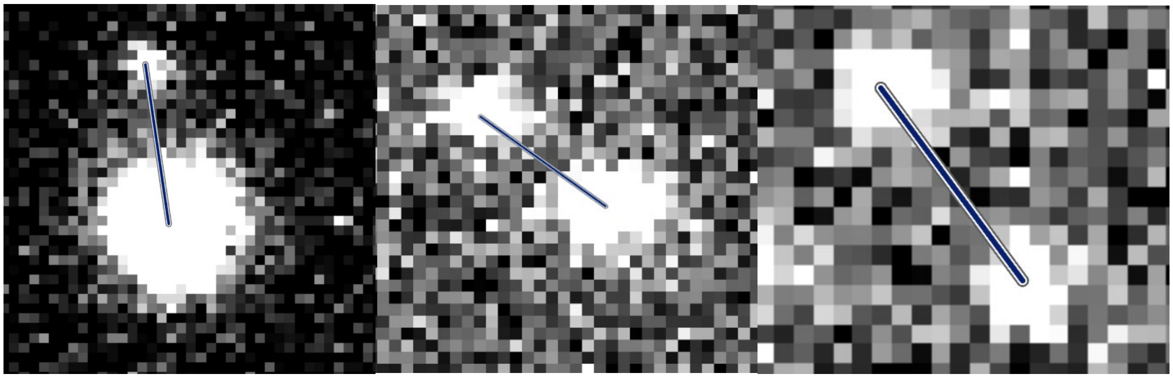

Figure 1. Example of a measurement image for WDS 00033+5332 A 1500 AB,C on the left, WDS 05283+0358 HJ 2266 in the middle and WDS 19557+3805 DAM 1 AB on the right.

Table 1. New Measurements for 3 Binary Star Systems

Binary System (WDS)	Observatory	Date of Observations	# of Images	Mean of PA(°)	Standard Deviation of PA	Standard Error of the Mean
00033+5332	Haleakala	2023.11.17	9	81.62	1.35	0.45
05283+0358	Cerra Tololo	2023.11.22	10	37.58	0.47	0.15
19557+3805	Haleakala	2023.11.22	10	234.64	1.14	0.63

Table 2. Separation for 3 Binary Star Systems

Binary System (WDS)	# of Images	Mean of Separation (arcsec)	Standard Deviation of Separation	Standard Error of the Mean
00033+5332	9	9.01	0.12	0.039
05283+0358	10	7.29	0.14	0.04
19557+3805	10	6.89	0.17	0.096

4. Discussion

The historical data for Table 2, WDS 00033+5332 A 1500 AB,C, Table 3, WDS 05283+0358 HJ 2266, and for Table 4, WDS 19557+3805 DAM 1 AB, was requested from the U.S. Naval Observatory and provided from the Washington Double Star Catalog (Mason et al. 2001). The historical data for Table 2 consists of 7 data points starting in 1917.68 and ending in 2014.752. The historical data for Table 3 consists of 9 data points starting in 1831.09 and ending in 2015.0. The historical data for Table 4 consists of 6 data points starting in 1998.39 and ending in 2015.41. Each table shows the position angle (PA) in degrees, the separation (Sep) in arcseconds and the measurement method used for each binary star system.

The historical data for position angle and separation in Table 2, Table 3, and Table 4 were converted into x-y coordinates so that the data could be plotted using the following equations:

$$x(RA) = \rho cos\theta$$
$$y(DEC) = \rho sin\theta$$

Where x is the right ascension and y is the declination, ρ is the angular separation and θ is the position angle. The date for each measurement is shown.

Table 3. Historical and Current Measurements of WDS 00033+5332 A 1500 AB,C

Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1917.68	78.6	8.60	1.70	8.43	Ma: Micrometer with refractor
1928.77	79.2	8.90	1.67	8.74	Ma: Micrometer with refractor
1998.85	81.4	9.34	1.26	8.34	E2: Two Micron All-Sky Survey
2003.591	81.6	9.250	1.351	9.151	Eu P: UCAC3
2012.797	82.16	9.307	1.281	9.303	Er: USNO URAT
2013.74	81.90	9.330	1.325	9.311	Er: USNO URAT
2014.752	82.05	9.351	1.300	9.303	Er: USNO URAT
2023.879	81.61	9.013	1.313	8.915	P: Photographic Technique

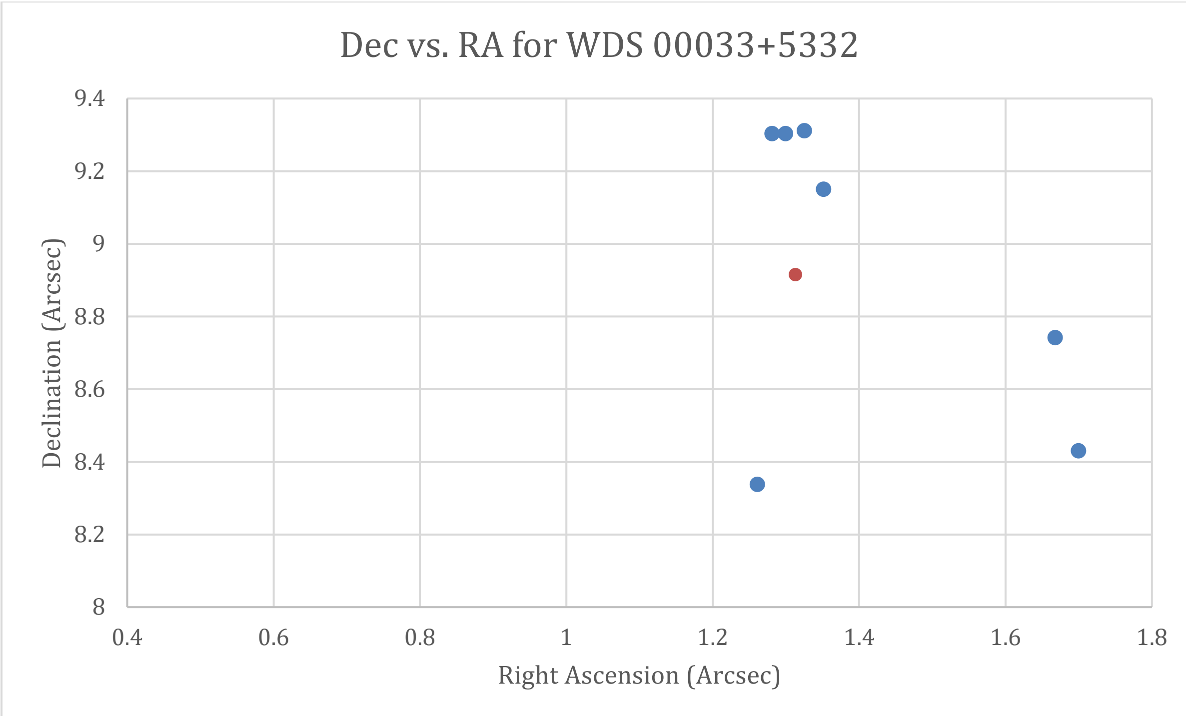

Figure 2. x(Right Ascension), and y(Declination) of the historical data (blue) and current data (orange)

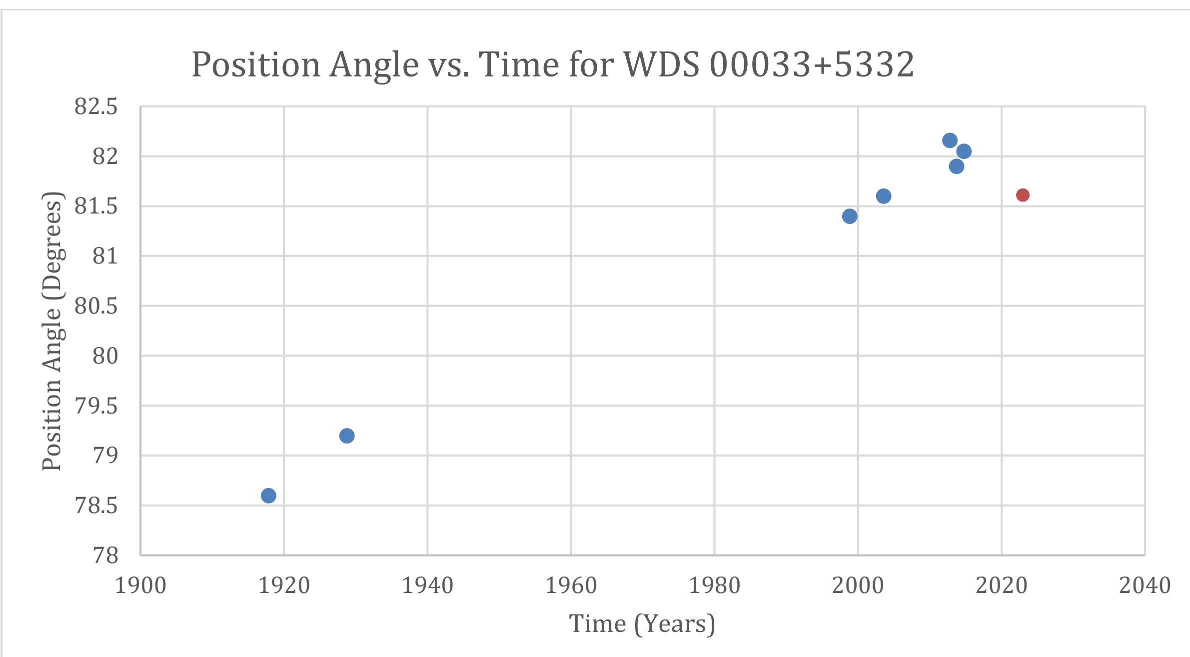

Figure 3. Position Angle vs. Time of the historical data (blue) and current data (orange)

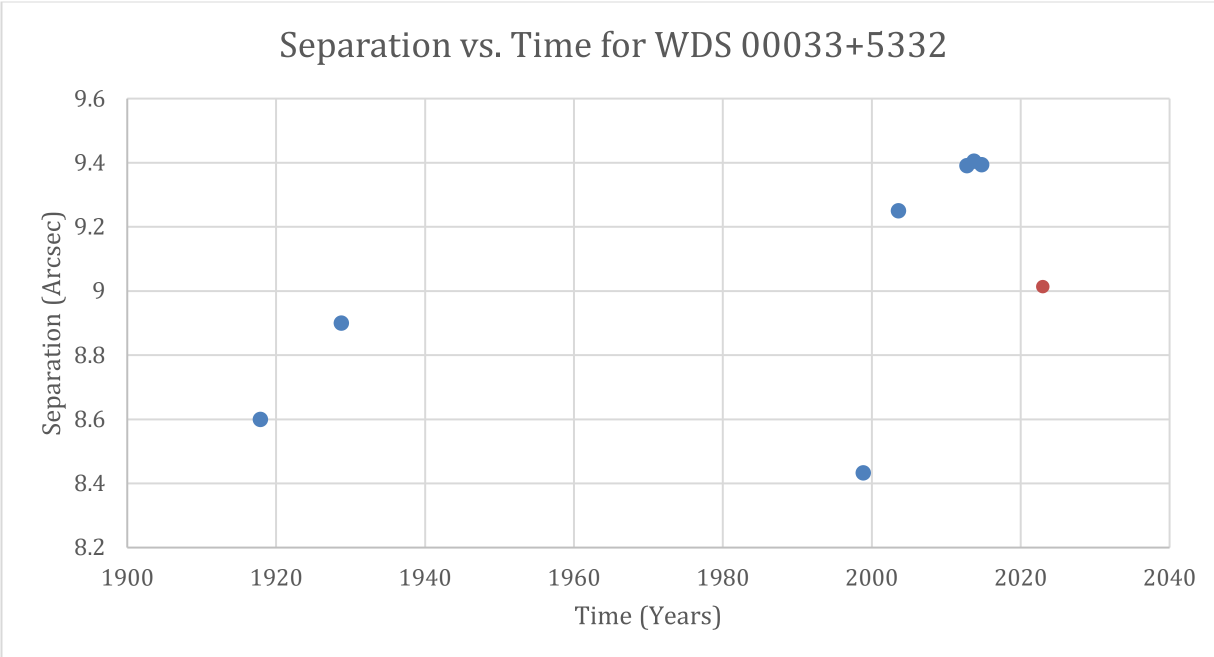

Figure 4. Separation vs. Time of the historical data (blue) and current data (orange)

For WDS 00033+5332, the position angle data (Figure 3) shows that the position angle has decreased from the 2015 measurement, after a steady increase from the first measurement in 1917. The separation data (Figure 4) shows that the separation seems to be increasing and decreasing with time. This cyclic variation could occur if the system was rotating in an ellipse, but such rotation is not consistent with the mostly steadily increasing position angle. If we decide the recent data points are more reliable than the pre-1930 data points, then the position angle traces out a clear arc with our new data point being the first along the return portion of the orbit. Similarly, if the 2MASS data point from 1998 is not considered due to its outlier status, the position angle would again trace out an orbit highly consistent with a physically bound pair. However, if we take all of the data equally, the decrease in both separation and position angle indicated by our new data point suggests the binary pair may be unphysical. Although this pair is likely unphysical, more observations on a longer timeline are needed to know for sure.

Table 4. Historical and Current Measurements of WDS 05283+0358 HJ 2266

Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1831.09	43.8	4.0	2.77	-2.89	Mb: micrometer with reflector
1910.14	41.8	7.987	5.32	-5.95	Pa: photographic, with astrograph
2000.06	38.5	7.49	4.66	-5.86	E2: Two Micron All-Sky Survey
2000.102	38.1	7.504	4.63	-5.91	Eu: UCAC
2001.05	37.6	7.59	4.63	-6.01	C: CCD or other two-dimensional electron imaging

2013.001	37.63	7.473	4.56	-5.92	Er: USNO URAT
2013.97	37.44	7.473	4.54	-5.93	Er: USNO URAT
2014.961	37.44	7.458	4.53	-5.92	Er: USNO URAT
2015.0	37.40	7.412	4.50	-5.89	Hg: Gaia
2023.89	37.58	7.2884	4.45	-5.77	P: Photographic Technique

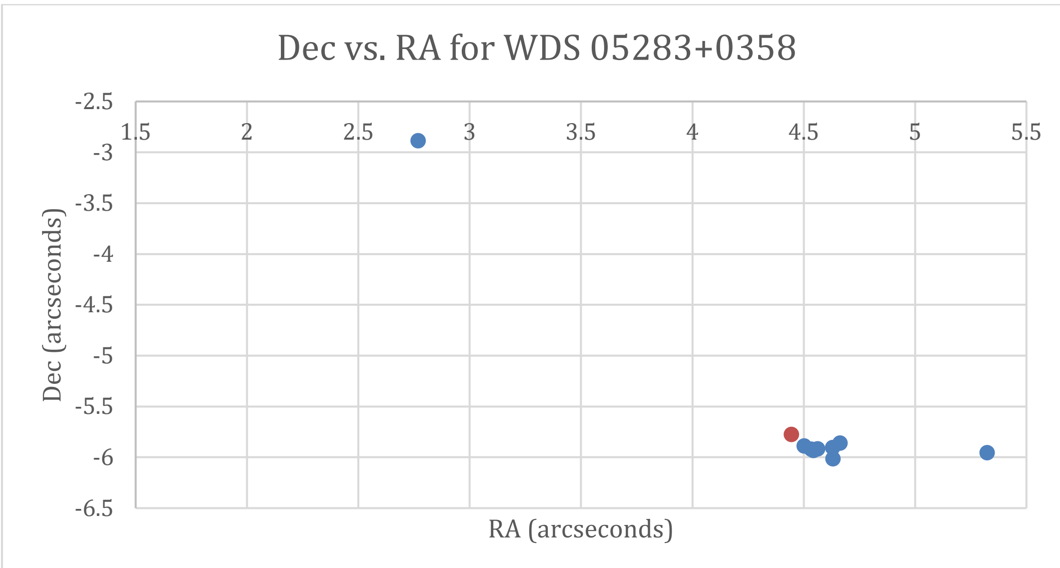

Figure 5. Declination versus right ascension of historical data in blue and new data in orange.

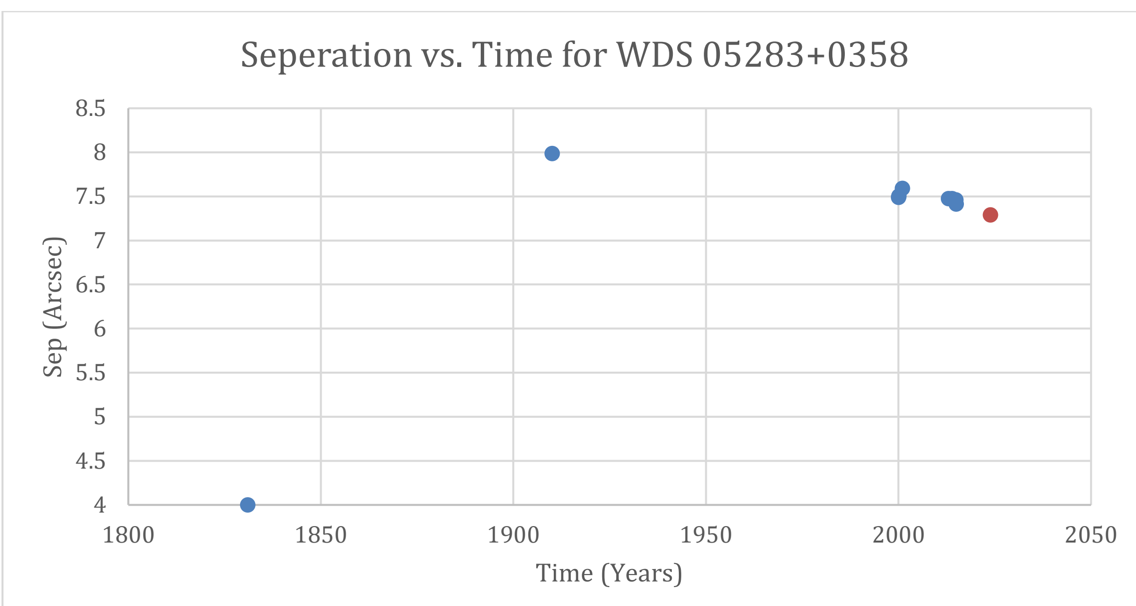

Figure 6. Separation vs. Time of the historical data (blue) and current data (orange).

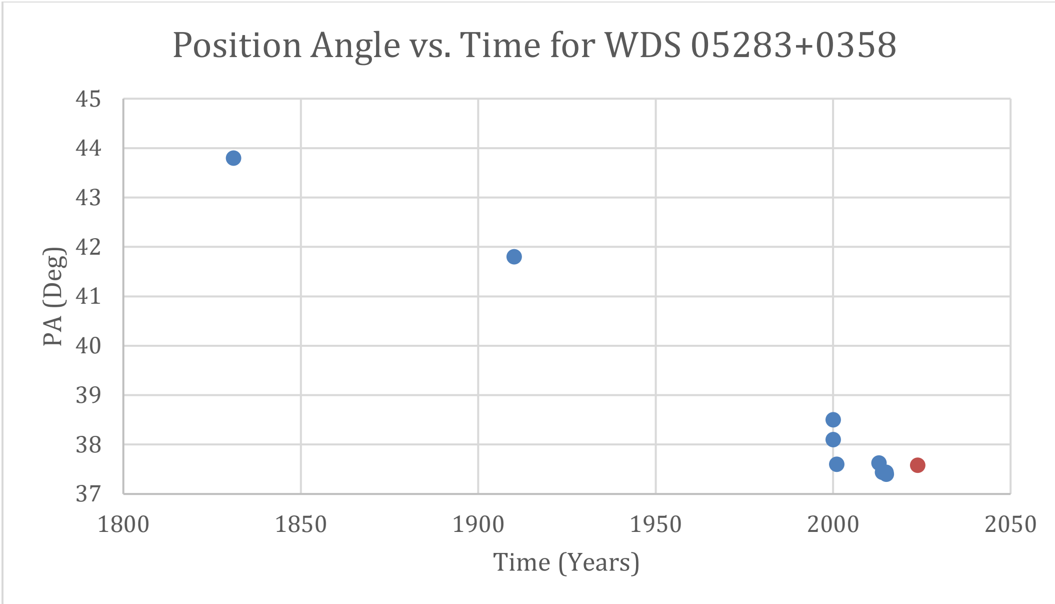

Figure 7. Position Angle vs. Time of the historical data (blue) and current data (orange).

WDS 05283+0358 is known as a physical binary thanks to the backlog of convincing historical data. The observations taken here agree with prior trends for the binary system indicating that the system is acting as expected of a physical double. The position data (Figure 5) indicates that the orbital pattern observed by the previous data points, especially those since 2000, has continued in a consistent manner. When examining the separation over time measurements (Figure 6) it appears that separation has increased since the early 1830s when the first measurement was taken but has come down since the early 1910s measurement. The new data point follows this downward trend which indicates that the binary is moving in an elliptical manner when viewed from Earth. The PA data (Figure 7) falls into the group of data points taken since 2000 that indicate a nearly linear relationship for the rotation of the star over time. None of these data points disagree with the expectation of a physical binary system and thus further support this classification. These new data points help further classify the orbital motion of the star for future study. They also prove the validity of our observation and analysis methods.

Table 5. Historical and Current Measurements of WDS 19557+3805 DAM 1 AB

Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1998.39	232.7	7.22	-4.38	-5.743	E2: Two Micron All-Sky Survey
2012.552	234.46	6.900	-4.011	-5.615	Er: USNO URAT
2013.519	234.54	6.886	-3.995	-5.609	Er: USNO URAT
2014.509	234.70	6.860	-3.964	-5.599	Er: USNO URAT
2015.0	234.765	6.860	-3.958	-5.603	Hg: Gaia

2015.410	234.70	6.881	-3.976	-5.616	Er: USNO URAT
2023.89	236.62	6.641	-3.654	-5.546	P: Photographic Technique

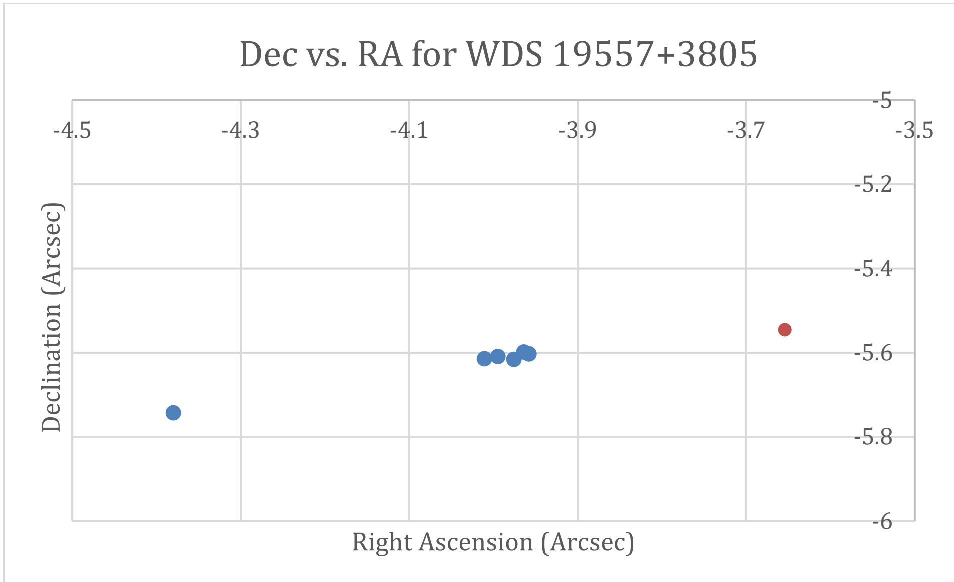

Figure 8. x(Right Ascension), and y(Declination) of the historical data (blue) and current data (orange)

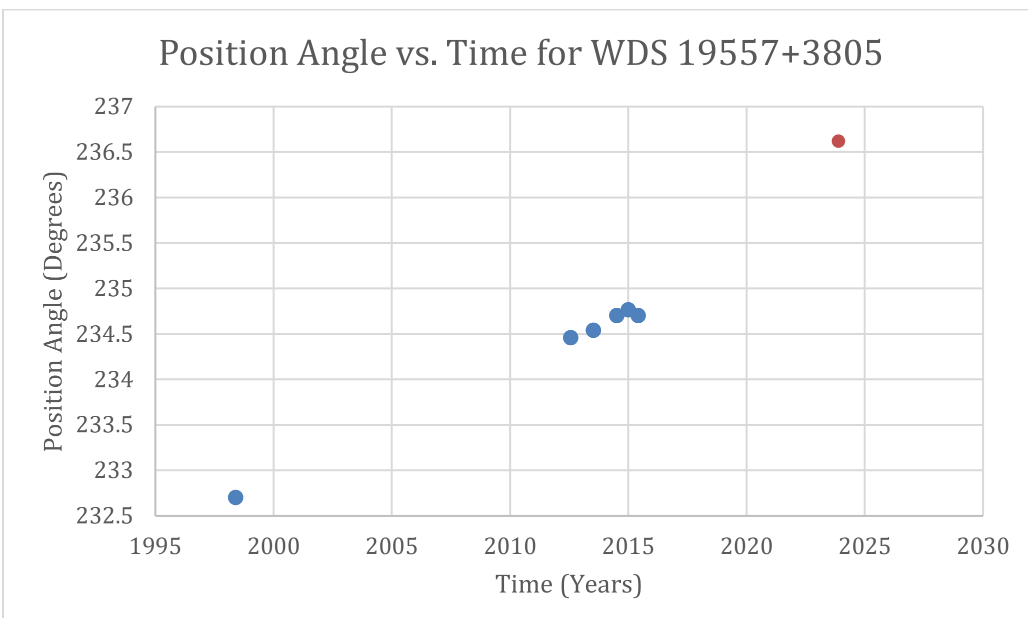

Figure 9. Position Angle vs. Time of the historical data (blue) and current data (orange)

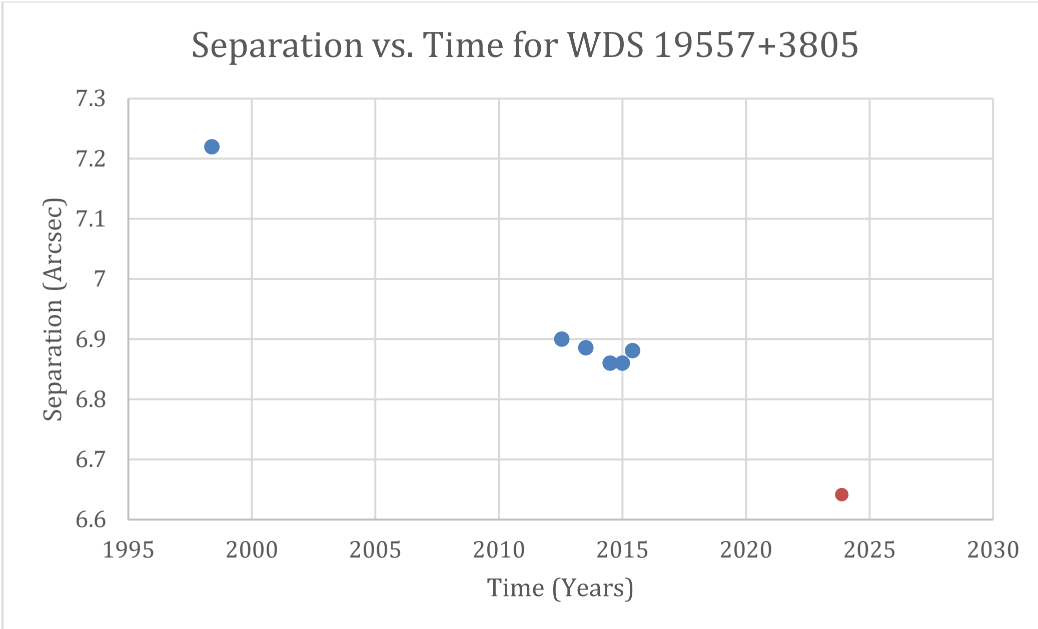

Figure 10. Separation vs. Time of the historical data (blue) and current data (orange)

WDS 19557+3805 appears to have a clear linear relationship when looking at both the position angle vs. time graph (Figure 9) and the separation vs. time graph (Figure 10). The position angle has been increasing steadily since the first measurement in 1998, and the data that we found continues this trend. The separation has been steadily decreasing since the first measurement when looking at the historical data, and the data point we found is consistent with this trend. Although it is currently uncertain if the system is gravitationally bound, our new observations strongly suggest that the system is physical because it seems as if these stars are indeed in an orbit.

Table 6. Parameters from Gaia Data Release 3

Binary System (WDS)	Star	Parallax (mas)	Distance (pc)	Proper Motion in RA (mas/year)	Proper Motion in Dec (mas/year)
00033+5332	Primary	-1.7318 ± 0.8620		-8.1322 ± 0.6100	5.3859 ± 0.6702
	Secondary	0.9505 ± 0.0112		5.8170 ± 0.0093	-4.5214 ± 0.0095
05283+0358	Primary	0.5861 ± 0.0192	1700	6.9393 ± 0.0209	-5.0661± 0.0147
19557+3805	Primary	0.1962 ± 0.0111		-2.9698 ± 0.0118	-4.6484 ± 0.0132
	Secondary	1.5471 ± 0.0136	633	3.7568 ± 0.0135	20.7847 ± 0.0164

In Table 6, we report the parallax and derived distance estimates for as many of our stars as are available in the Gaia Data Release 3 (Gaia Collaboration 2016b; 2023j). Parallax measurements can be used to rule out a physical double if the separation in distance is too large. However, incomplete Gaia data does not allow for this check for our three binary star systems. For WDS 00033+5332, Gaia gives a negative parallax for the primary star. Although negative parallaxes can be used statistically, they are not physical and thus cannot be easily interpreted for individual stars (Luri et al. 2018). A positive parallax is given for the secondary star, however, a distance isn't given for either star. Even with the parallax values for both stars, the distance can't be estimated due to incomplete photometry for the stars. As described by Luri et al. (2018), the determination of reliable distances requires more than simply inverting the parallax. For WDS05283+0358, parallax and distance estimates are only available for the primary star. For WDS 19557+3805, although parallax values are given for both stars, a distance is only estimated for the secondary due to incomplete photometry for the primary.

5. Conclusions

In this study, we were able to provide data points on the positions of three star systems: WDS 00033+5332 A 1500 AB,C, WDS 05283+0358 HJ 2266, and WDS 19557+3805 DAM 1 AB. By using the separation and position angle of each of these star systems and comparing them to historical data points, we were able to determine whether these systems are physical and gravitationally bound. We were not able to conclude whether WDS 00033+5332 is physical, so it will remain uncertain. WDS 05283+0358 is already known to be a physical double, and our new data point supports the idea that these stars are gravitationally bound. Our new data point strongly suggests that WDS 19557+3805 is physical.

Acknowledgements

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

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 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.

This research has also made use of data provided by Stelle Doppie: https://www.stelledoppie.it

The authors would like to thank the Las Cumbres Observatory for the use of their observatories in gathering our data.

The authors would like to thank Dr. Rachel Freed for her help in gaining a better understanding of star doubles and for helping us gain access to the Las Cumbres Observatory

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Biography

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