

Astrometric Measurements of Binary Star Systems WDS 19576+3454, WDS 06076+2457, and WDS 06043+2327

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Abstract

We used the Las Cumbres Observatory telescopes to take images of three star systems: WDS 19576+3454, WDS 06043+2327, and WDS 06076+2457, on April 3rd, April 8th, and April 4th, 2024 respectively. We analyzed their astronomical measurements using Afterglow Workbench. For WDS 19576+3454, the position angle was measured to be $265.2^\circ \pm 0.12^\circ$ with an angular separation of $7.38'' \pm 0.022''$. For WDS 06043+2327, the position angle was measured to be $298.5^\circ \pm 0.28^\circ$ with an angular separation of $9.83'' \pm 0.036''$. The new data show that both WDS 19576+3454 and WDS 06043+2327 are consistent with being physical binaries but the parallax distances from the GAIA data suggest the stars in these pairs are too far apart to be gravitationally bound. Thus we conclude these two pairs are likely optical doubles. For WDS 06076+2457, the position angle was measured to be $348.1^\circ \pm 0.10^\circ$ with an angular separation of $7.96'' \pm 0.023''$. The new data we observed, combined with available GAIA data, give evidence that WDS 06076+2457 may be a physical double.

1. Introduction

This paper presents astrometric measurements of 3 binary star systems: WDS 19576+3454, WDS 06043+2327, and WDS 06076+2457. Our research objective was to determine whether or not these systems are gravitationally bound. Measurements of these systems have not been taken for nine years - we hope that our work can fill this gap and provide greater insight into the orbits of the respective binary stars.

Using the Washington Double Star (WDS) catalog (Mason et al. 2001) through Stelle Doppie¹, we identified star systems in which position angle and separation differed significantly from the first to the most recent measurement. Our specific database search criteria included: a right ascension between 18 hours and 8 hours, a primary star magnitude between 9 and 11, an uncertain binary status, and a date of last observation before 2016. We also selected star systems with a 5-10 arcseconds separation between primary and secondary stars, and a difference in magnitude between the stars of each system that was less than 4.

WDS 19576+3454 was discovered in 1894 (Ellison, 1925). Since 1894, there have been a total of 17 observations with astrometric measurements. This system consists of two stars, the primary with a magnitude of 10.53 and the secondary with a magnitude of 10.70. The first recorded separation was 7.2 arcseconds and they found a position angle of 273° . The most recent observations, which were taken in

¹ <https://www.stelledoppie.it/>

2015, found a separation of 7.44 arcseconds and a position angle of 265.9° . It is currently uncertain whether this double is physical or not.

WDS 06043+2327 POU 885 was first discovered in 1926 (Pourteau, 1933). At that time, the position angle was recorded to be 306.5° and an angular separation of 9.8 arcseconds. Following this discovery, eight additional measurements have been made, with the most recent occurring in 2015 with Gaia. The position angle was shown to be steadily decreasing overtime, with a new measurement of 299.363° in 2015, whilst the angular separation appeared to be relatively stable except for a small jump in 1954 before returning back to stability. WDS 06043+2327 POU 885 has a spectral class of F8 (yellow-white) and the nature of this double is still uncertain.

The first recorded observation of WDS 06076+2457 was in 1909 (Pourteau, 1933). Since then, there have been nine additional observations with recorded measurements excluding our own, with all but one of these observations being recorded after the year 1998. Only one observation of this system has been made with Gaia (Gaia Collaboration et al. 2016b). Since its first observation, the separation and position angle of WDS 06076+2457 have both slightly increased over time. The name of this system, HD 251843, refers to the Henry Draper catalog (Moore, 1918), which catalogs stars visible from both hemispheres. The relative proper motion of this system is recorded at 0.33 arcseconds across the sky per year. WDS 06076+2457 is located in the constellation Gemini, and its spectral class is unknown. The nature of this double currently remains uncertain.

2. Equipment and Methods

To get images of our star systems, we used the Las Cumbres Observatory (LCO), which is a network of telescopes at various sites around the world. These can be controlled remotely, and so our images for our different star systems were taken at different locations. However, the images were all taken using the same type of instrument, a 0.4-m telescope, with an SCICAM QHY600 camera to capture the images. For all of our images, we used a Bessel V filter. The images for WDS 19576+3454 were taken by a telescope in Teide, which is in Spain. The images for WDS 06043+2327 and WDS 06076+2457 were taken in Haleakala, which is located in Hawaii.

In order to ensure an optimal exposure length for our systems, we submitted 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 that showed both stars and didn't oversaturate either of them. However, for the star systems with bigger changes in magnitude between the stars, we had to choose an exposure that didn't oversaturate the primary star but still allowed us to see the secondary star. For all of the stars, we ended up using an exposure time of 2s. After submitting our test images and determining that this was a good exposure to use, we requested 10 images of each star system.

After we retrieved our images from the LCO database, we used Afterglow Workbench² to analyze our images. We used Afterglow to measure the angular separation between our primary and secondary stars and the position angle of the stars. Examples of these measurements for each system are shown in Figure

² <https://afterglow.skynetjuniorscholars.org>

1. After obtaining this data, we found the mean, standard deviation, and standard error of the mean for the separation and position angle. We also obtained historical data about the star systems by requesting data from Dr. Rachel Matson at the Washington Double Star Catalog (Mason et al. 2001).

3. Data

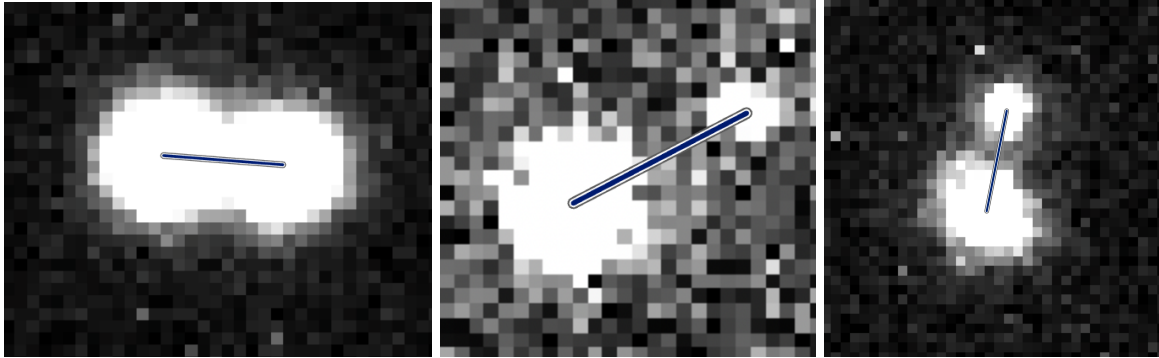


Figure 1. Example of a measurement image for WDS 19576+3454 on the left, WDS 06043+2327 in the middle, and WDS 06076+2457 on the right.

Table 1. Position Angle 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
19576+3454	Teide	April 5, 2024	10	265.2	0.38	0.12
06043+2327	Haleakala	April 8, 2024	11	298.5	0.92	0.28
06076+2457	Haleakala	April 3, 2024	11	348.1	0.34	0.10

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
19576+3454	10	7.38	0.07	0.022
06043+2327	11	9.83	0.12	0.036
06076+2457	11	7.96	0.08	0.023

4. Discussion

Historical data for Tables 3 (WDS 19576+3454), 4 (WDS 06043+2327), and 5 (WDS 06076+2457) was requested from the U.S. Naval Observatory via the Washington Double Star Catalog (Mason et al. 2001). Table 3 includes 17 measurements taken between 1894.59 and 2015.410. Table 4 includes 9 measurements taken between 1926.09 and 2015.0. Finally, Table 5 includes 10 measurements taken between 1909.12 and 2015.014. Each table also includes position angle (PA) in degrees, separation (Sep) in arcseconds, and the method used to measure each binary star system.

Historical data for position angle and separation was converted into x - y coordinates to allow the data to be plotted using the following equations:

$$\begin{aligned} x(RA) &= p \cos \theta \\ y(DEC) &= p \sin \theta \end{aligned}$$

Where x is right ascension, y is declination, p is angular separation and θ is position angle. We present these plots for WDS 19576+3454 in Figures 2, 3, and 4, for WDS 06043+2327 in Figures 5, 6, and 7, and for WDS 06076+2457 in Figures 8, 9, and 10.

Table 3. Historical and Current Measurements of WDS 19576+3454					
Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1894.59	273.4	7.230	0.429	-7.217	Pa: photographic, with astrograph
1894.6	271.8	8.28	0.260	-8.276	Pa: photographic, with astrograph
1895.56	272.2	9.428	0.362	-9.421	Pa: photographic, with astrograph
1924.80	270.3	7.41	0.039	-7.410	Mb: micrometer with reflector
1925.95	272.1	6.97	0.255	-6.966	Ma: micrometer with refractor
1928.63	271.3	7.28	0.165	-7.278	Ma: micrometer with refractor
1940.61	260.8	7.118	-1.138	-7.026	Pa: photographic, with astrograph
1941.64	270.7	7.550	0.092	-7.549	Pa: photographic, with astrograph

1971.768	268.1	7.47	-0.248	-7.466	Ma: micrometer with refractor
1998.36	267.6	7.34	-0.307	-7.334	E2: 2MASS (Two Micron All-Sky Survey)
2002.621	266.8	7.448	-0.416	-7.436	Eu: UCAC3
2006.6137	265.98	7.738	-0.542	-7.719	C: CCD or other two-dimensional electronic imaging
2012.57	266.15	7.426	-0.499	-7.409	Er: USNO URAT
2013.505	265.95	7.442	-0.526	-7.423	Er: USNO URAT
2014.565	265.98	7.457	-0.523	-7.439	Er: USNO URAT
2015.0	265.907	7.447	-0.532	-7.428	Hg: Gaia
2015.410	265.98	7.440	-0.522	-7.422	Er: USNO URAT
2024.258	265.22	7.380	-0.614	-7.355	P: Photographic Technique

Table 4. Historical and Current Measurements for WDS 06043+2327

Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1926.09	306.5	9.8	5.829	-7.878	Pa: photographic, with astrograph
1954.894	305.7	11.91	6.950	-9.672	Pa: photographic, with astrograph
1998.88	300.2	10.12	5.091	-8.746	E2: 2MASS (Two Micron All-Sky Survey)
2001.012	300.1	9.968	4.999	-8.624	Eu: UCAC3
2010.5	300.6	9.80	4.989	-8.435	Hw: WISE (Wide-field Infrared Survey Explorer) satellite (IR imaging)
2013.026	299.50	9.952	4.901	-8.662	Er: USNO URAT

2014.043	299.41	9.948	4.885	-8.666	Er: USNO URAT
2014.979	299.36	9.921	4.864	-8.647	Er: USNO URAT
2015.0	299.363	9.926	4.867	-8.651	Hg: Gaia
2024.270	298.496	9.830	4.567	-8.412	P: Photographic Technique

Table 5. Historical and Current Measurements for WDS 06076+2457

Date	PA (deg)	Sep (arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Source
1909.12	345.5	7.759	7.512	-1.943	Pa: photographic, with astrograph
1926.09	342.9	7.8	7.455	-2.294	Pa: photographic, with astrograph
1998.02	348.1	7.91	7.740	-1.631	E2: 2MASS (Two Micron All-Sky Survey)
2001.032	348.2	7.945	7.777	-1.625	Eu: UCAC3
2004.074	347.9	7.934	7.758	-1.663	Eu: UCAC3
2010.5	346.9	7.95	7.743	-1.802	Hw: WISE (Wide-field Infrared Survey Explorer) satellite (IR imaging)
2013.023	347.99	7.957	7.783	-1.656	Er: USNO URAT
2014.066	348.00	7.961	7.787	-1.655	Er: USNO URAT
2015.0	348.029	7.963	7.790	-1.652	Hg: Gaia
2015.014	348.01	7.947	7.774	-1.651	Er: USNO URAT
2024.257	348.08	7.96	7.788	-1.644	P: Photographic Technique

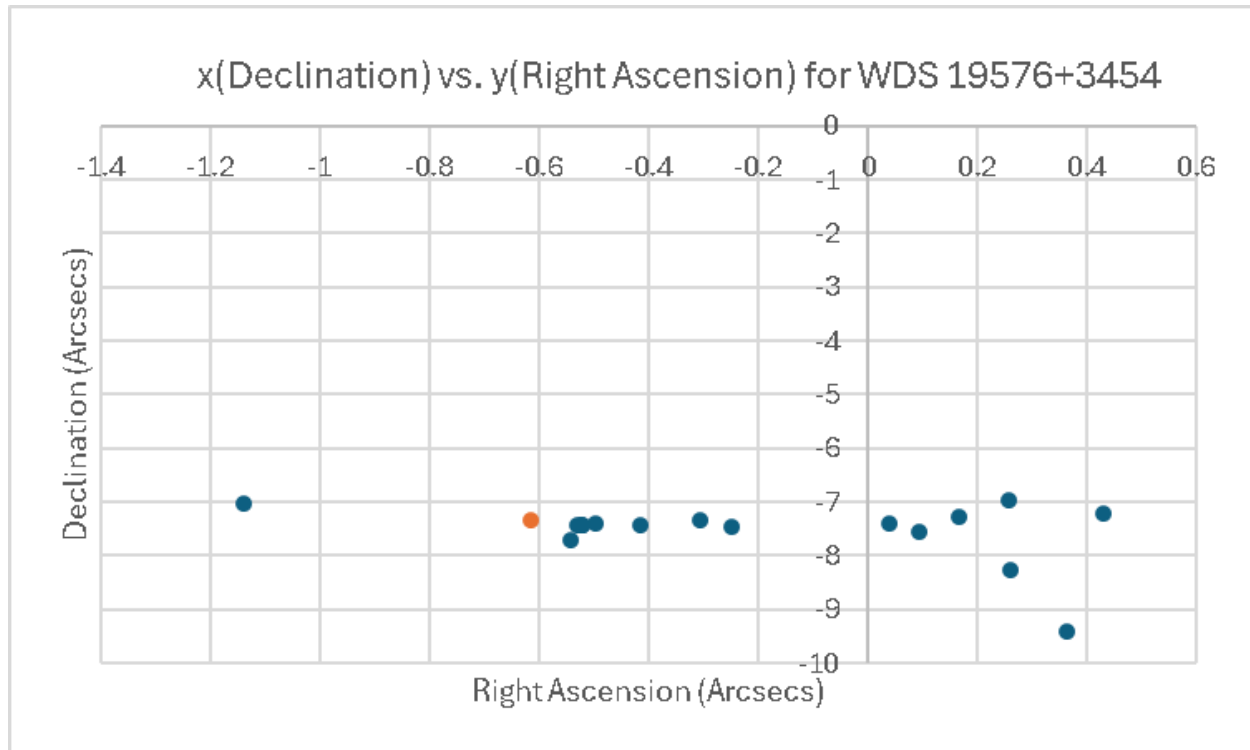


Figure 2. x (Right Ascension), and y (Declination) of the historical data (blue) and current data (orange)

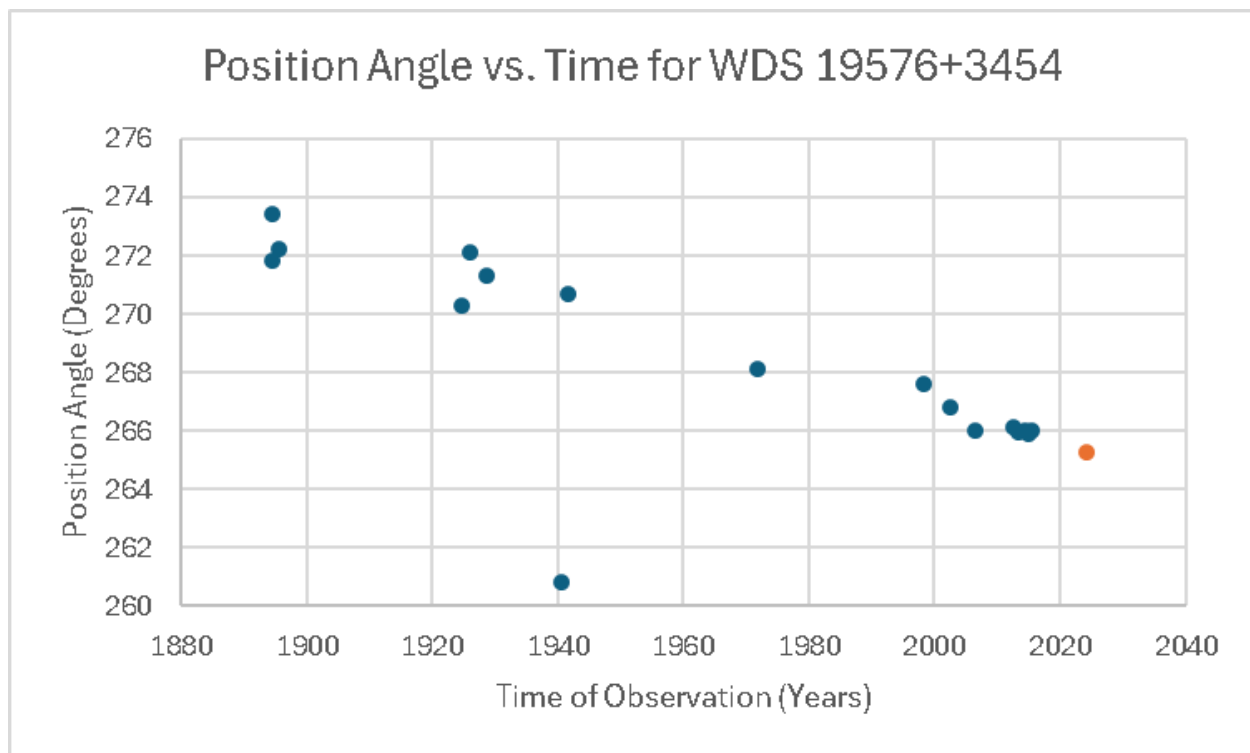


Figure 3. Position Angle vs. Time of the historical data (blue) and current data (orange)

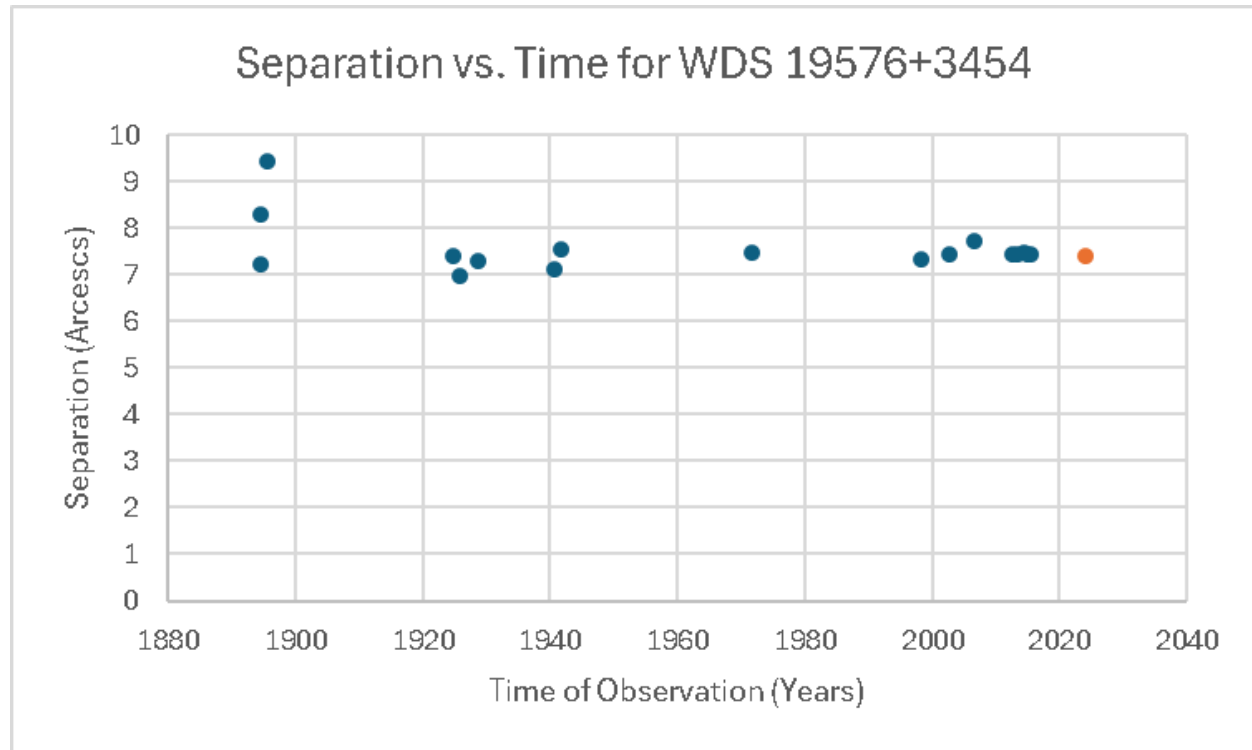


Figure 4. Separation vs. Time of the historical data (blue) and current data (orange)

In Figure 2, WDS 19576+3454 appears to be moving clockwise in an elliptical orbit from our viewpoint, suggesting that the system is physical. There also appears to be an outlier in the data, since the data point taken in 1940 has a significantly lower position angle and a much lower right ascension than any of the other points, making it the outlier in Figure 2 and Figure 3. If we ignore this data point, the position angle consistently decreases from the first measurement in 1894. Figure 4 provides a little bit less insight, since the separation remains steady over the course of the measurements. However, since the data we have only shows a change of less than ten degrees for the position angle, we don't expect a noticeable change in the separation. Although it is currently uncertain if this star is gravitationally bound or not, these data suggests that these stars could be gravitationally bound.

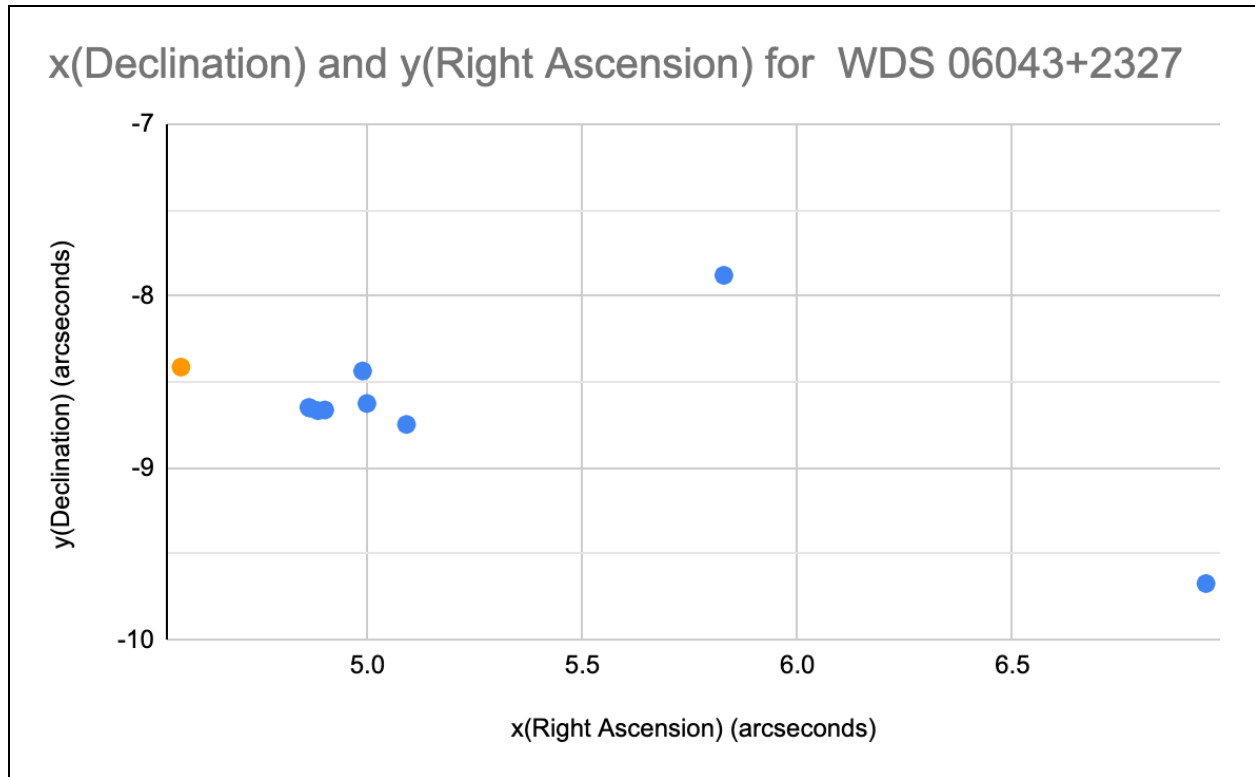


Figure 5. x(Right Ascension), and y(Declination) of the historical data (blue) and current data (orange)

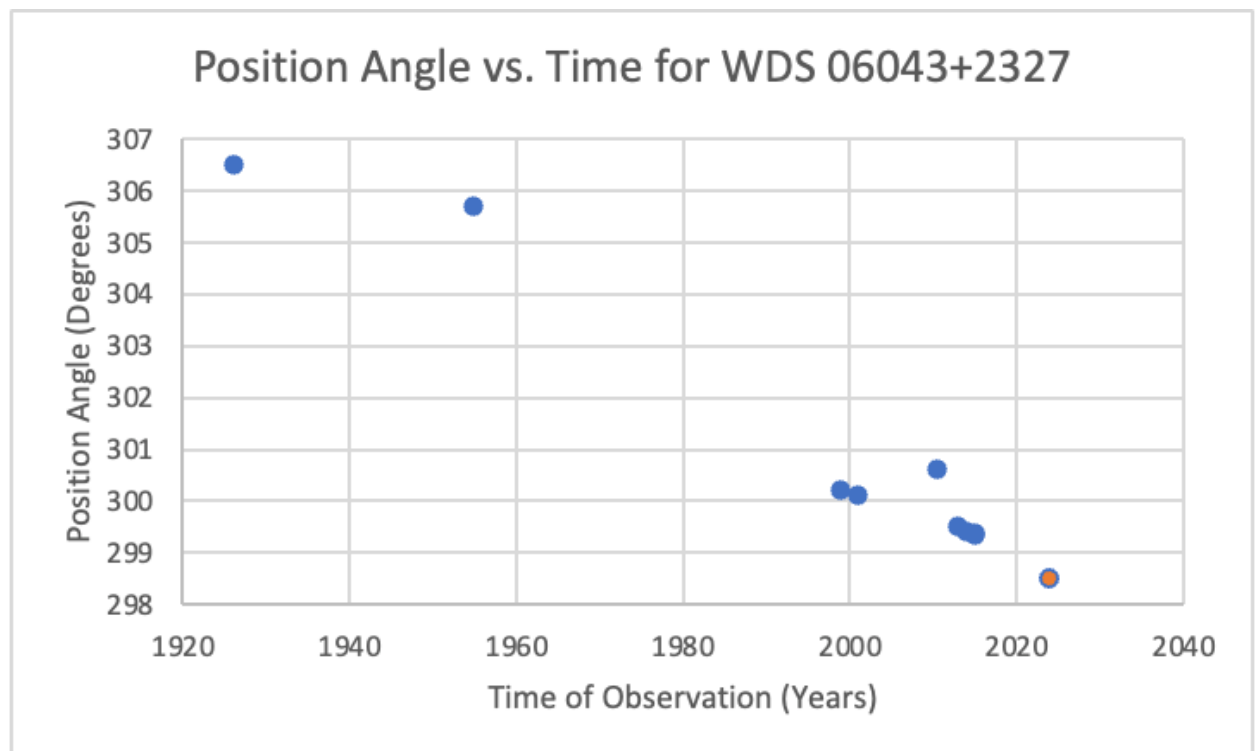


Figure 6. Position Angle vs. Time of the historical data (blue) and current data (orange)

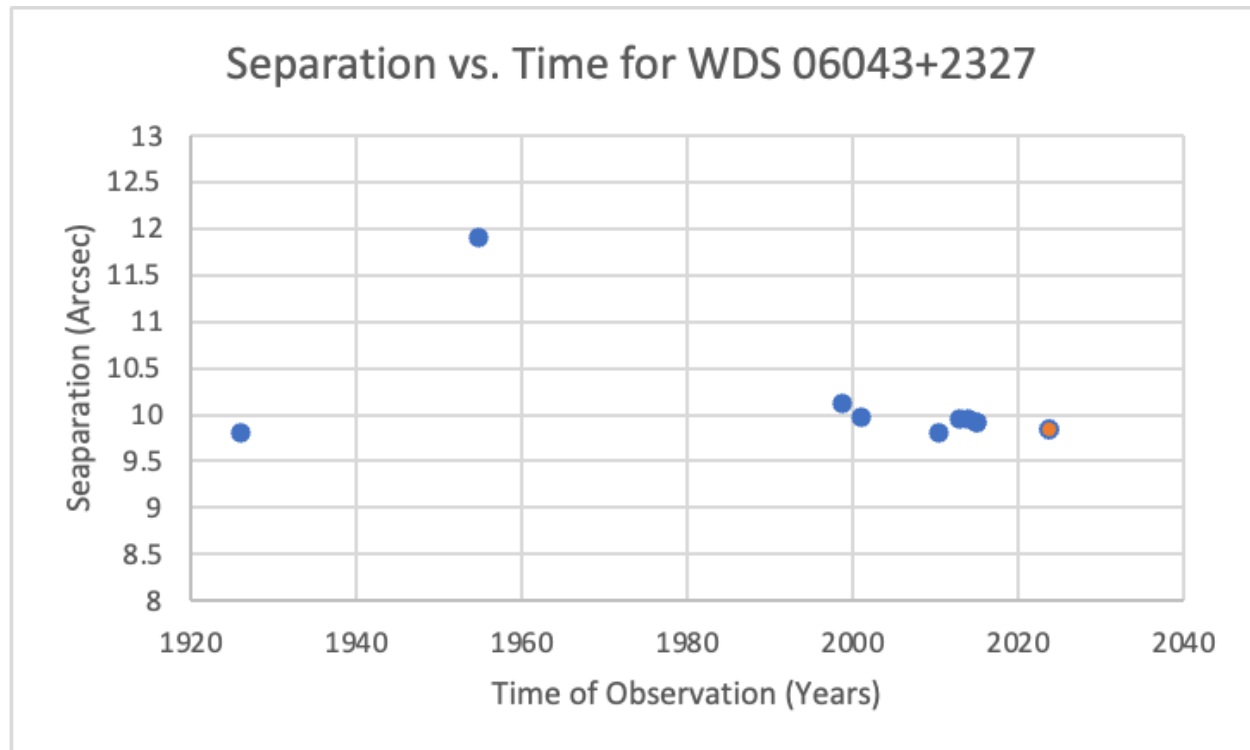


Figure 7. Separation vs. Time of the historical data (blue) and current data (orange)

WDS 06043+2327 appears to have a linear relationship based on the position angle vs. time graph (Figure 6), which has been steadily decreasing since the initial measurement in 1926. The new measurement in 2024 suggests a continuation of this relationship. The separation (Figure 7) has remained relatively stable since the first measurement, with a slight increase in 1954. Because the separation has remained relatively consistent, whilst the position angle has steadily decreased, this suggests that we are looking at WDS 06043+2327 more directly or face on. Although this double is currently classified as uncertain, the new observation from 2024 suggests that this system could be a physical double as the position angle has remained in a stable downward trend.

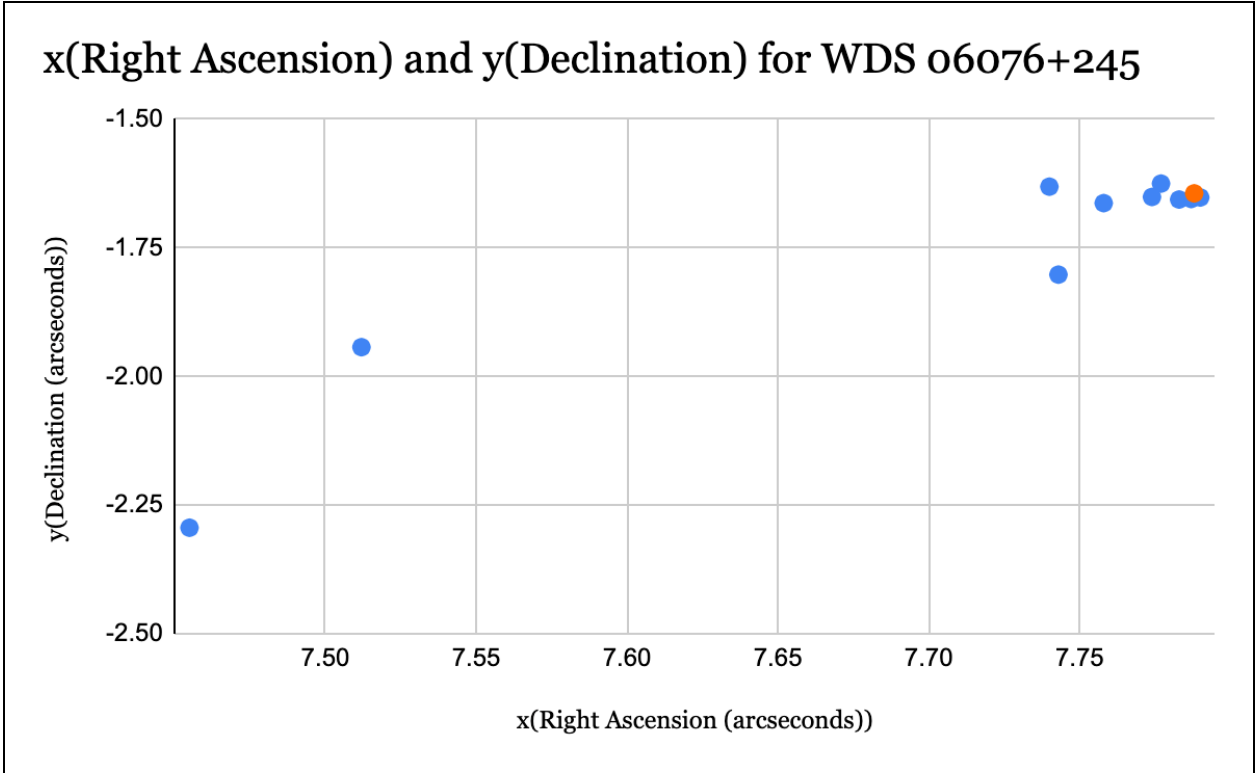


Figure 8. x(Right Ascension), and y(Declination) of the historical data (blue) and current data (orange)

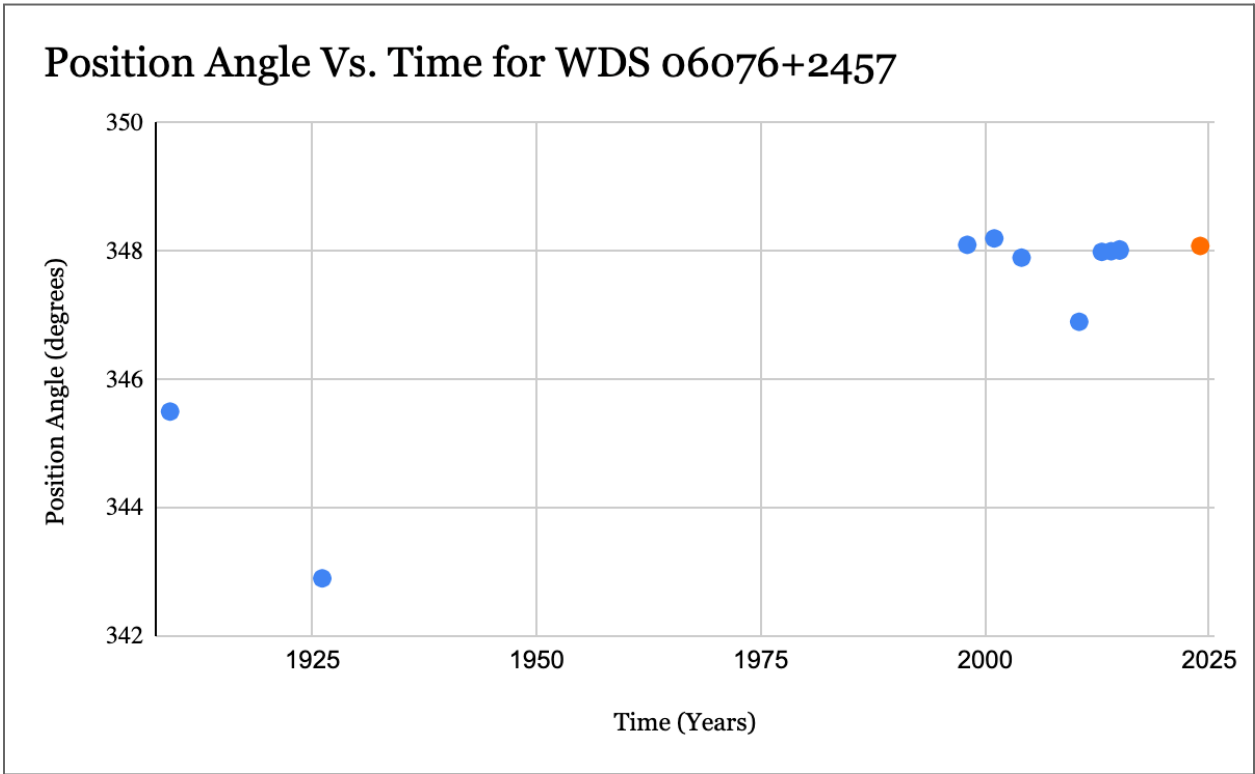


Figure 9. Position Angle vs. Time of the historical data (blue) and the current data (orange)

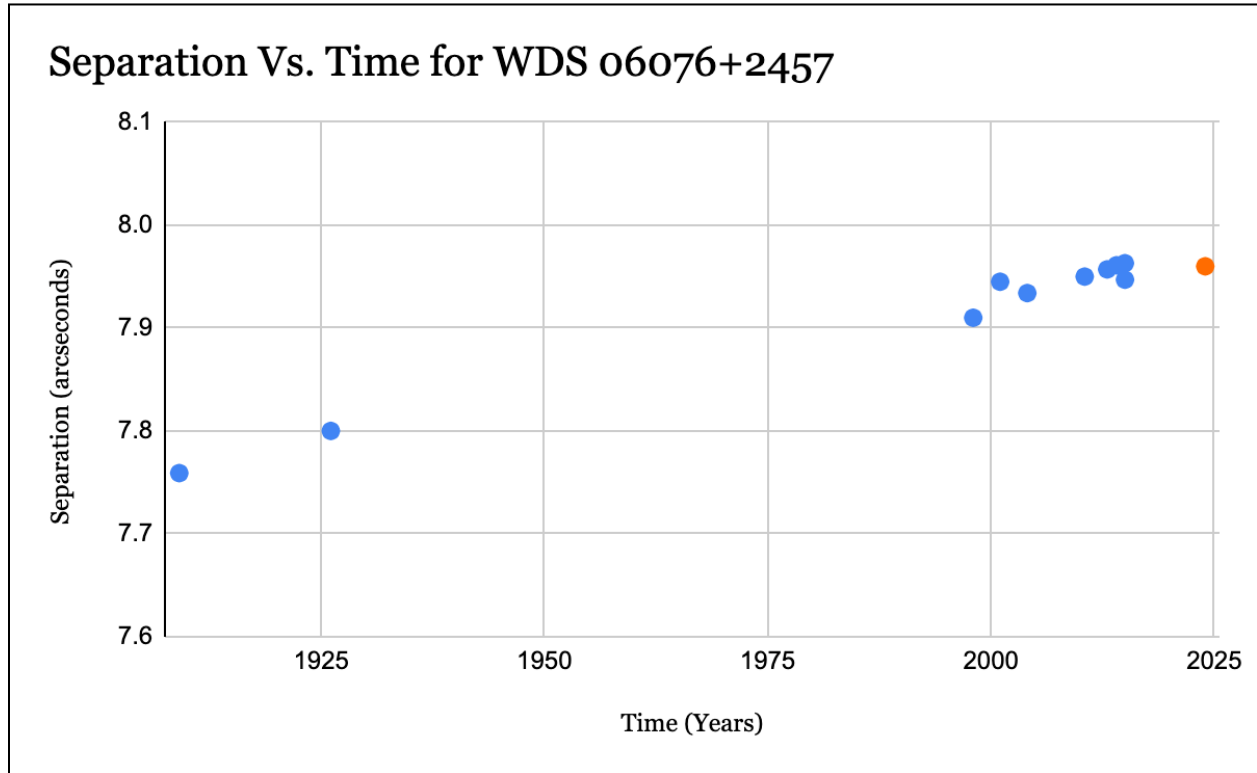


Figure 10. Separation vs. Time of the historical data (blue) and current data (orange)

The separation over time data for WDS 06076+2457 in Figure 10 has remained relatively stable, with a continuing trend of slight increase. These data collected from our observations remain consistent with the historical trend. The same can be said of the declination and right ascension (Figure 8), with two outliers that come from the observations in 1909 and 1926. The position angle (Figure 9) has also remained relatively constant over recent observations, with few fluctuations over time. There appears to be an outlier in the Figure 9 data from 1926, with a lower position angle than other observations, but not by a very significant amount. This position angle has not been observed since, indicating that this outlier might be due to observational error. The relatively stable separation angle over time between the two stars of this system suggests that this could be a physical double. However, further observations and data are necessary to determine the true nature of WDS 06076+2457.

Table 6. Parameters from Gaia Data Release 3

Binary System (WDS)	Star	Parallax (mas)	Parallax Distance (pc)	GSP-Phot Distance (pc)	Proper Motion in RA (mas/year)	Proper Motion in Dec (mas/year)
19576+3454	Primary	$1.9813 \pm$	504.7 ± 5.4	549	$-1.9031 \pm$	$-0.5592 \pm$

		0.0212			0.0214	0.0265
	Secondary	1.0071 ± 0.0189	993.0 ± 18.6	1187	3.5242 ± 0.0189	-9.1192 ± 0.0231
06043+2327	Primary	1.9648 ± 0.0150	509.0 ± 3.9	496	-7.5968 ± 0.0163	9.9047 ± 0.0109
	Secondary	0.9061 ± 0.0321	1103.6 ± 39.1	996	-1.5316 ± 0.0351	-6.8375 ± 0.0235
06076+2457	Primary	1.8051 ± 0.0202	554.0 ± 6.1	520	3.2544 ± 0.0211	-1.9718 ± 0.0161
	Secondary	1.7904 ± 0.0479	558.5 ± 14.5	467	4.0469 ± 0.0490	-3.7600 ± 0.0374

To place our results in further context with available data, we gather parallax and proper motion from the second and third GAIA data releases (Gaia Collaboration 2016b; 2023j). We also calculated the distance from the parallax angle given in GAIA using the equation:

$$D = \frac{1}{p}$$

where P is the parallax angle in arcseconds and d is the distance from Earth in parsecs. The parallax measurements and GSP-Phot distances can be used to rule out a physical double if the separation in distance is too large. For the WDS 19576+3454 and WDS 06043+2327 systems, both the parallax distance and GSP-Phot distances reveal that the primary and secondary stars are hundreds of parsecs away from each other. Most known physical binaries are closer than 1,000 AU with few being separated by more than 3,000 AU (Harshaw 2018). The maximum separations found in the GAIA catalog are around 10,000 AU. Given the large separations for WDS 19576+3454 and WDS 06043+2327, the GAIA data suggests, in contrast to the orbital parameters we compute above, that these pairs are too far away to be physical.

For WDS 06076+2457, the parallax and associated parallax distance between the primary and secondary stars are consistent within the stated uncertainties. This agreement suggests that the stars are much closer to one another than indicated by the GSP-Phot distance. Because of the uncertainties in the parallax angle, the parallax distance between the two stars also results in uncertainties. The uncertainty in our measurements indicates the possibility for the two stars to be close enough to be gravitationally bound. In addition, using the proper motions in right ascension and declination in Table 6, the combined proper motions for the primary and secondary stars in this system are within 30% of each other. These data strengthen the conclusion that the star system is physically bound. Given that this 30% difference is on the higher end of known physical doubles, there would need to be additional measurements to better determine either the parallax distance between the two stars or the proper motion to more confidently classify it as a physically bound system.

5. Conclusions

In this study, we provide astrometric measurements of three star systems: WDS 19576+3454, WDS 06043+2327, and WDS 06076+2457. By looking at the separation and position angle of the stars and comparing this to historical data points, we made the best estimates possible of whether or not the systems are gravitationally bound given the available data. For WDS 19576+3454, the orbital parameters suggest that the system is gravitationally bound, but the GAIA data suggests that the stars are too far apart to be physical. Because of this, we need more data to classify the star system as physical. For WDS 06043+2327, the orbital parameters suggest that this system is gravitationally bound as the position angle has remained in a stable downward trend. However, the GAIA data suggests that the stars are too far apart to be physical. As such, more data is needed to further classify this star system as physical. The stability over time of WDS 06076+2457's orbital parameters suggest that the binary system is gravitationally bound. The GAIA data further indicates that the stars could be close enough to each other to be physical. This data strongly suggests the physical nature of the system, but additional data and observations are needed to confirm this conclusion.

Acknowledgements

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Biography

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