

20306+1349: An Orbital Mystery

Bradley Brungardt 

Colorado State University, Ft. Collins, CO

John Major , Elias Faughn , Paul McCudden , Zaida Weems, Kassiopeia Wehlitz 
Colorado Mountain College, Steamboat Springs, CO, bradley.brungardt@colostate.edu

Abstract

Using data collected from the historic 60" telescope at the Mount Wilson Observatory in June of 2023 and 2024, the position angle and separation of the multiple system WDS 20306+1349 were calculated using Speckle Tool Box and compared with previous measurements. The AB system's mean position angle on 2024.482 was found to be 328.9° and the mean separation was 0.15". The two previously published orbits differ significantly from one another, and the authors' most recent observations of WDS 20306+1349 supports the Docobo 2021 orbit.

1. Introduction

Speckle interferometry on small telescopes has become a useful tool in the hands of amateur and student researchers for measuring position angles and separations for close (sub-arcsecond) binaries and refining their orbits (Faughn, 2023). A group of students from Colorado Mountain College, along with a number of amateur astronomers, have been making annual trips to Mount Wilson Observatory to use the historic 60" and 100" telescopes there for the same purpose, extending the process to larger aperture scopes. A three-day session in June 2023 yielded data on 53 known binaries, while a follow-up trip in June 2024 revisited some of the previously observed binaries and added data on 87 more.

Of the seven known binaries observed in 2023 and 2024, WDS 20306+1749 (HDS 2932) invites review. It was first cataloged by Henry Draper as HD195397 and its binary nature was first measured by Hipparcos in 1991. The pair has 11 published observations (see Table 1), 10 of which used speckle techniques. Because there are two published orbits in the USNO (Tok 2019 and Doc 2021), both Grade 4, it has an estimated period of either 95 or 31.65 years. Both orbits are featured in the 6th Orbit Catalog. The pair's Δmag is 0.62, and this has resulted in ambiguity about the primary and secondary stars in their measurements. The two stars have a combined spectral class of F8, and lie approximately 350 light years (Prusti, 2016) distant in the constellation Delphinus (See Table 2).

Table 1. USNO historical data for WDS20306+1349AB

Date	ρ (")	θ ($^\circ$)	Observer and Date of Observation
1991.25	0.144	325*	Hipparcos 1991.25
1997.7227	0.167	329.6*	Mason, B.D. 1997.7227
2004.8246	0.070	356.5*	Balega, I.I. 2004.8246

2007.3211	0.0339	212.6	Horch, E.P. 2007.3211
2007.8182	0.0423	238.8	Horch, E.P. 2007.8182
2008.4597	0.0386	258.8	Horch, E.P. 2008.4597
2015.4957	0.1011	309.2	Tokovinin, A. 2015.4957
2016.4898	0.122	309.4	Orlov, V.G. 2016.4898
2017.5991	0.1368	316.0	Tokovinin, A. 2017.5991
2018.3990	0.1461	317.4	Tokovinin, A. 2018.3990
2019.5394	0.1574	319.3	Tokovinin, A. 2019.5394

Table 2. WDS 20306+1349 Characteristics (2019 data from Stelle Doppie)

θ (°)	ρ (")	Grade	Date First Observed	Total # of Observations	# of Speckle Observations	Period (yrs)	Distance (ly)	Spectral Class	Pri mag	Sec mag
319.3	0.157	4	1991.25	11	10	95	356	F8	8.6	9.2

As noted, the two published USNO orbits for 20306+1349 differ significantly (see Figure 1). Both orbits are plotted together, using the commercial software Desmos, in Figure 2 to underscore the differences. Orbital parameters for the two published orbits are listed in Table 3.

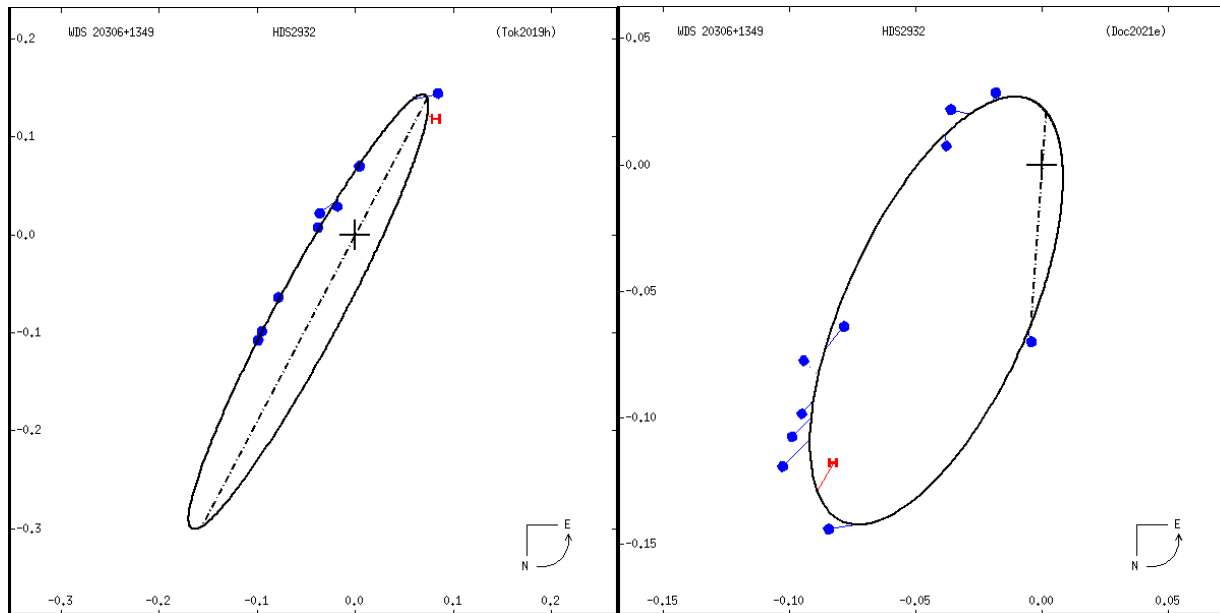


Figure 1: Published Orbits of 20306+1349 from USNO Catalog. Left is Tok2019; right is Doc2021

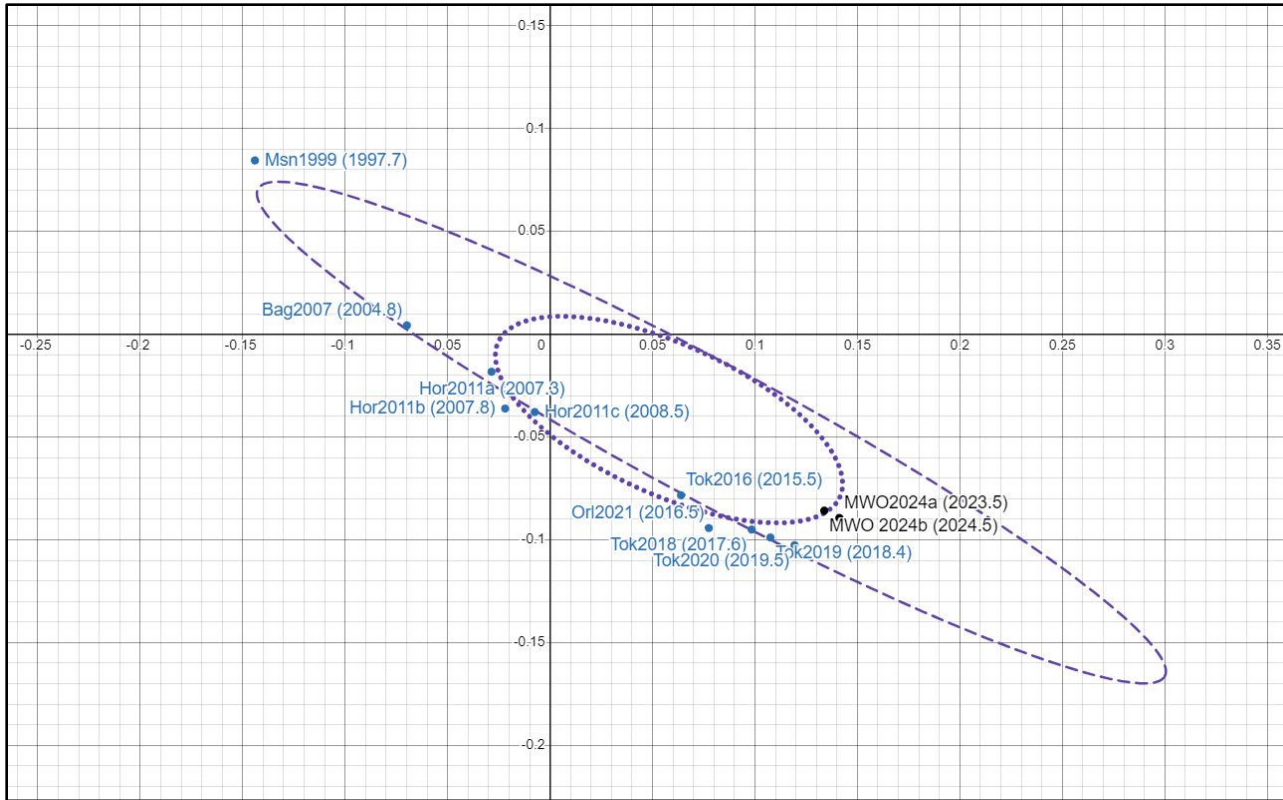


Figure 2: Published Orbits of 20306+1349 from USNO. Dotted is Doc2021; dashed is Tok2019. This paper’s observations are labeled as MWO. North is to the right.

Table 3: USNO published orbital parameters

Orbital element	Doc2021	Tok2019
Period (yr)	31.65	95
Semimajor axis (arcsec)	0.121	0.254
angle of inclination (°)	63.7	82
Node (°)	175.9	152.2
Time of periastron	2006.25	1991.3
eccentricity	0.859	0.392
Ω (°)	305.6	337.3

For the Tok2019 orbit, Tokovinin decided that the first three observations, Hipparcos1991.3, Msn1997.7, and Bag2004.8 (identified with * in Table 1) all had a 180° reflection error, presumably due to an assumed

ambiguity between the primary and secondary. He incorporated the adjusted measurements, which are depicted in Figure 3 with green circles, into his calculated orbit.

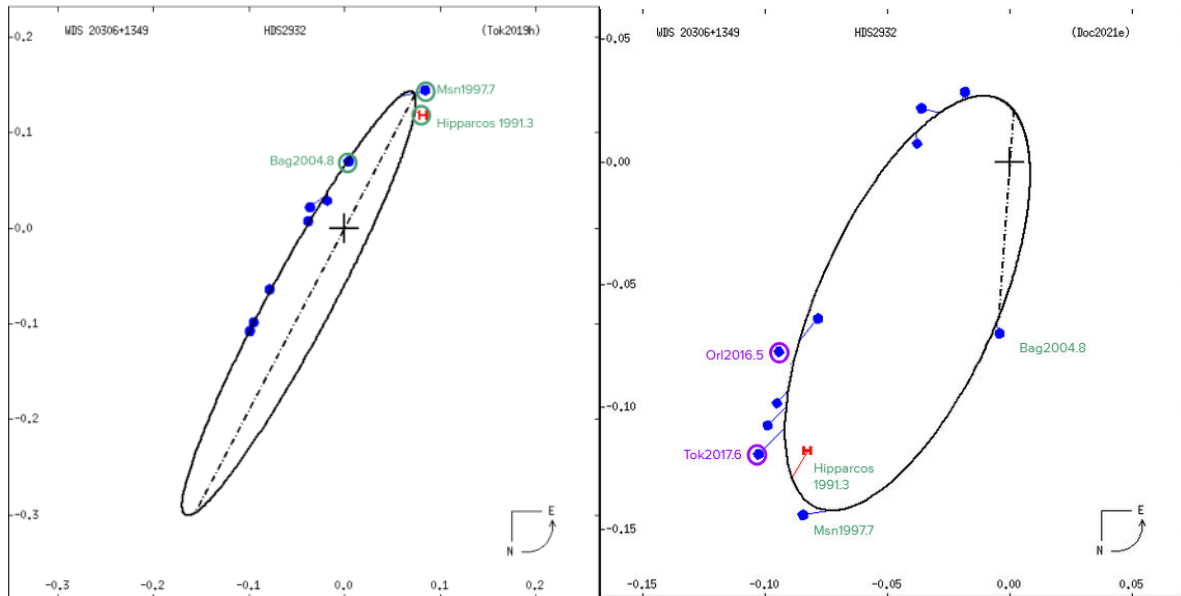


Figure 3: Both the Tokovinin (left) and Docobo (right) orbits with 180° adjustments to three observations

By contrast, Docobo included the original observation values in his orbit. Docobo also included two new observations (Tok2017.6 and Ori12016.5 – shown with purple circles in Figure 4). This results in two very different orbital plots. Our goal was to distinguish between these two published orbits or perhaps hint at a new one.

2. Equipment and Methods

Data on 20306+1349 was taken on 2023.488 (June 25, 2023), 2023.492 (June 28, 2023) and 2024.482 (June 25, 2024) using the historic 60 inch telescope at the Mount Wilson Observatory. For all data the telescope was equipped at the bent Cassegrain focus with a ZWO ASI 6200MM Pro camera, fitted with an Astronomik ProPlanet 642 BP 2850002585 (IR) filter with a midpoint transmission at 750 nm. Each image of the target and a nearby reference star consisted of one five-second exposure and 1000 twenty or thirty millisecond exposure images for the target, and 300 twenty or thirty ms exposures of the reference star. HD 193723 was used as a reference star in 2023, and HD 194914 was used as a reference star in 2024.

One 20-second image of the periphery of M13 was taken each night for a plate solution, which was then used to calibrate Speckle Toolbox (STB) (Rowe, 2017) for that night's results. The stars and their reference stars were then reduced using STB with an ROI pixel size of 128. The reduction of 20306+1349 from STB, using the 2023.492 data and the 2024.482 data are shown in Figure 4.

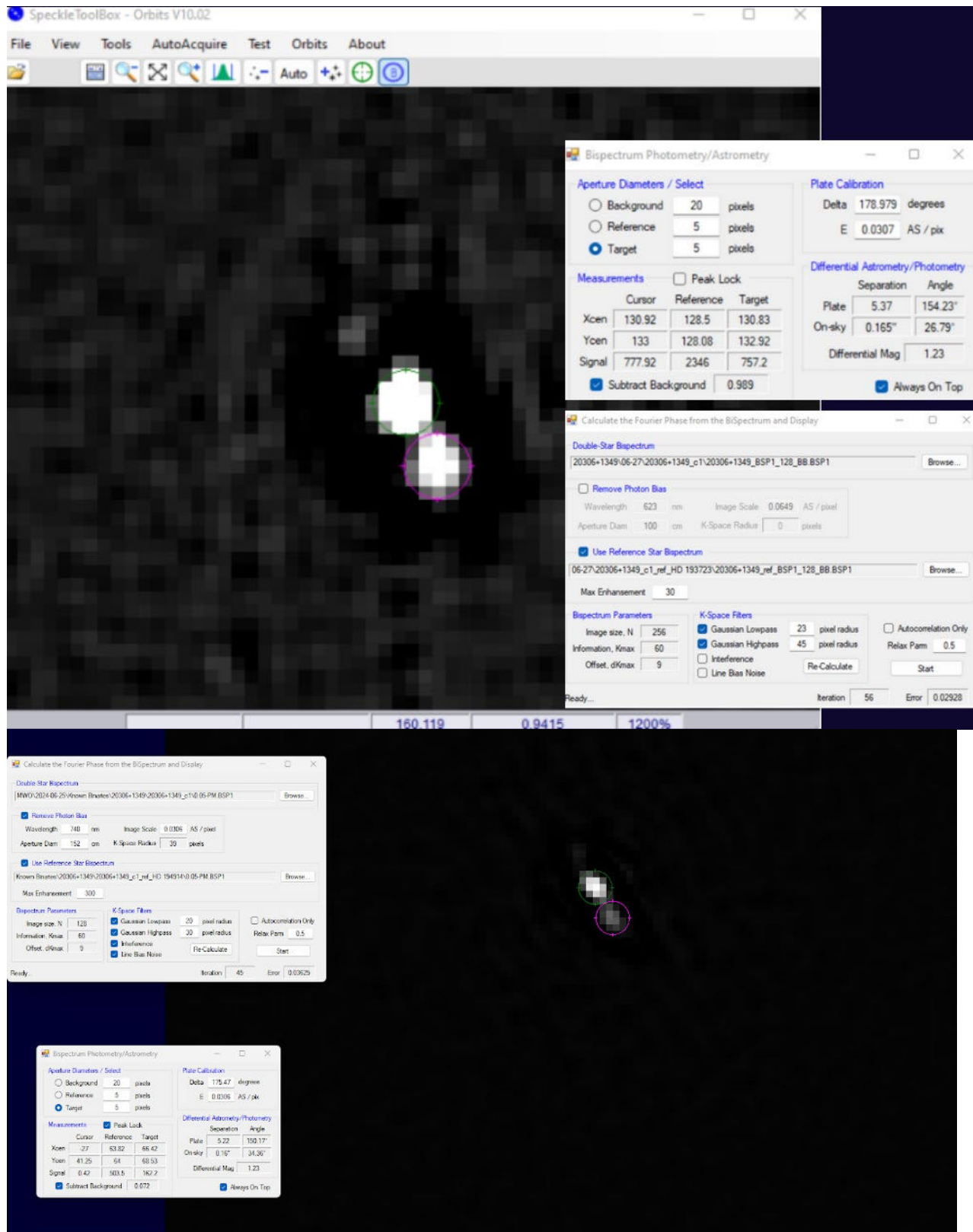


Figure 4: Bispectrum Images from Speckle Toolbox of WDS 20306+1349 in 2023 and 2024, showing the star pair, the display parameters screen, and the photometry/astrometry measurements screen

3. Data

Table 4 displays the measured mean ρ and mean θ from 2023 and 2024. Each author used STB to measure the ρ and θ of their star pairs five times using a 128-pixel image. Mean ρ and mean θ represent the average of all of those measurements. Those observed on two consecutive nights underwent this process twice, and Table 4 shows the average of all ten measurements in that case. It is important to note that 180° must be subtracted from each measured θ to account for the reflection of the image due to mirrors within the telescope. This has been accounted for in Table 4.

Table 4 - Reduced Data

Observation date	# of Nights Observed	mean ρ (")	Standard Deviation of ρ	mean θ ($^\circ$)	Standard Deviation of θ
2023.49	2	0.166	0.00299	330.068	2.23729
2024.48	1	0.15	0.01	328.9	2.1

4. Discussion

STB's new Orbits routine was used to optimize the orbit of 20306+1349AB using only speckle data and the 2023 and 2024 MWO data points. The results were imported into the commercial software Desmos, converting orbital parameters to x,y coordinates (Genet, 2024) and then plotted. The results are shown in Figure 5, with parameters of the newly optimized orbit calculated by STB, and the two published orbits collected in Table 5. All speckle observations were weighted equally. In these plots, North is to the right and East up for each, and the units are arcseconds. The newly optimized orbit is shown as a dotted line.

Table 5 - Orbital parameters for 20306+1349AB from two published orbits and an optimized orbit that includes MWO data

Orbital element	Doc2021	Tok2019	STB2024
Period (yr)	31.65	95	29
Semimajor axis (arcsec)	0.121	0.254	0.139
angle of inclination ($^\circ$)	63.7	82	70
Node ($^\circ$)	175.9	152.2	173
Time of periastron	2006.25	1991.3	2005.9
eccentricity	0.859	0.392	0.87
Longitude of periapsis - Ω ($^\circ$)	305.6	337.3	300

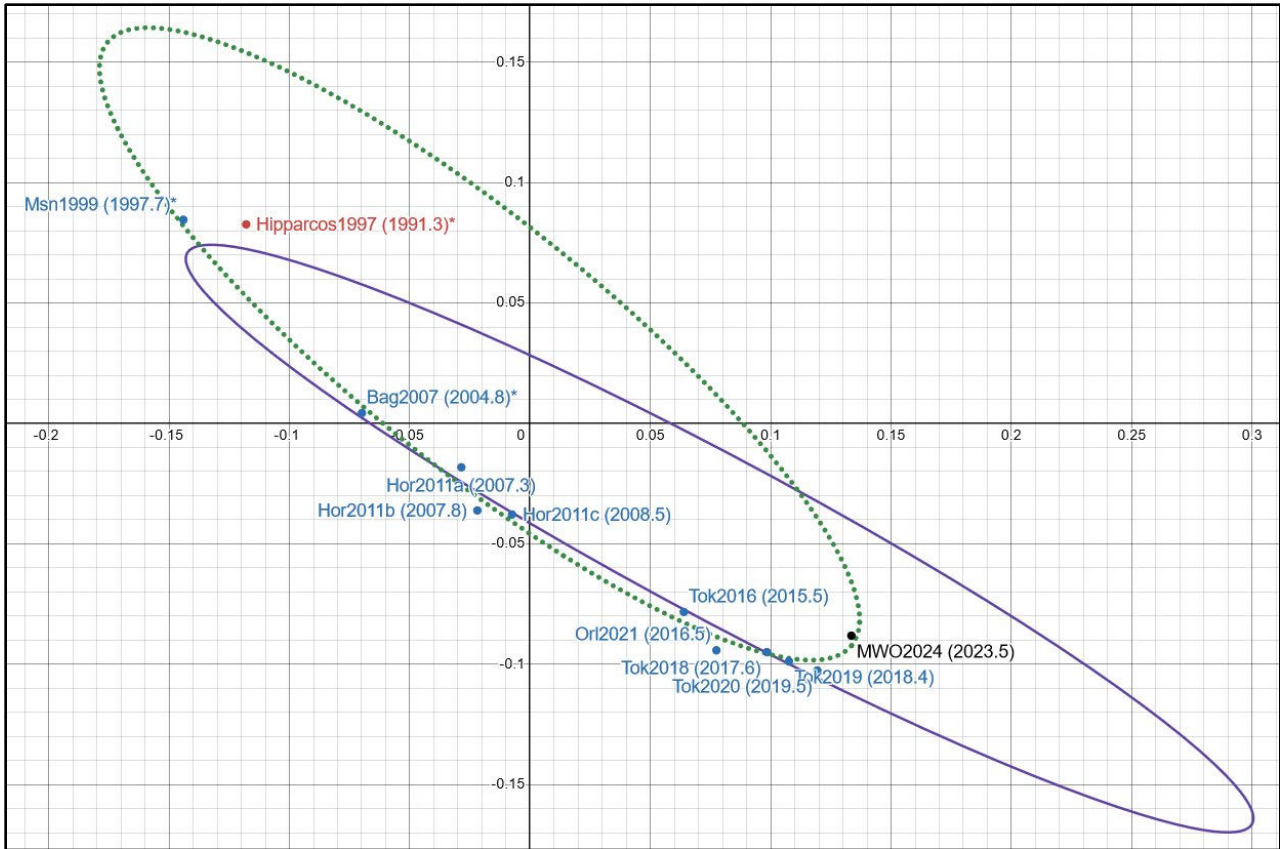


Figure 5: Original published orbit from USNO (Tok2019). Solid ellipse represents original orbit with all observations available before 2019. Observations with * were flipped 180° by Tokovinin. Optimized orbit with all available data in 2024 is indicated by the dotted orbital ellipse. Current measurement labeled “MWO 2024” Scale in arcseconds. Origin indicates primary star. Plotted in Desmos.

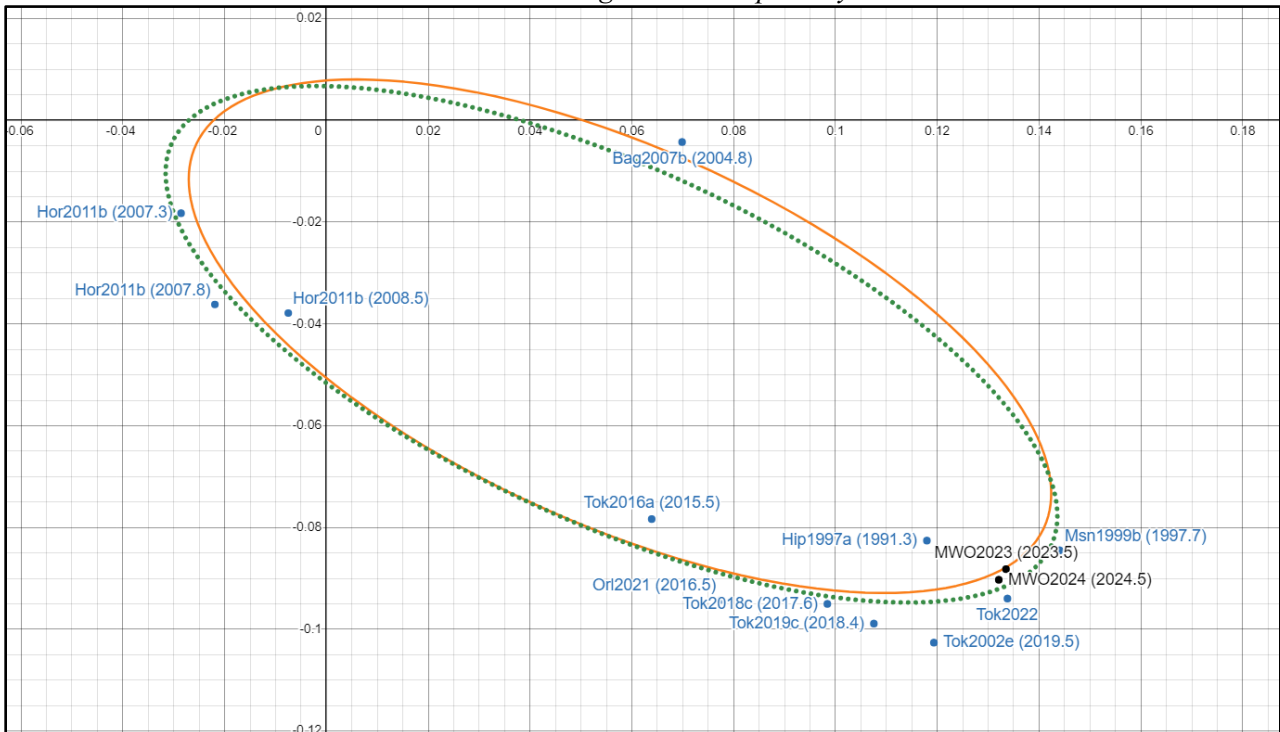


Figure 6: Original published orbit from USNO (Doc2021) represented by solid line plotted with optimized orbit using Speckle Tool Box Orbits routine represented by dotted line which includes subsequent Mt. Wilson Observations. Current measurement labeled “MWO2024” Scale in arcseconds. Origin indicates primary star. Plotted in Desmos.

The WRMSD (weighted root-mean square deviation, in mAS) goes from 24 to 8 for the Tok2019 orbit and from 10 to 7 for the Doc orbit when the authors’ observations and an additional recent Tokovinin observation are included. The STB Orbits calculation of the period at 29 years agrees closely with Docobo’s result.

5. Conclusion

STB Orbits and our data support the validity of the Docobo published orbit for 20306+1349 and not the Tokovinin published orbit. Deciding which observations should have their position angles quadrant flipped is not always clear, as was confirmed by Tokovinin (personal communication, August 26, 2024). The published USNO data, combined with more recent observations and the ones discussed in this paper support the listed values and Docobo’s published orbit.

The use of open-source software like STB alongside observations made with large aperture amateur and historical instruments allows researchers to make accurate measurements and to evaluate the previously calculated orbits. STB’s Orbits Routine offers the ability to include or exclude types of observations, weight them differently, and generate optimized orbits. Desmos is an intuitive and easily accessible tool to use for modeling orbits using values determined by the STB Orbits Routine, and has the advantage of being familiar to many high school and community college researchers. This combination of tools and methods allows researchers to economically and substantively contribute to double star measurements.

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

This work used the SIMBAD service operated by Centre des Données Stellaires (Strasbourg, France), bibliographic references from the Astrophysics Data System maintained by SAO/NASA

This research made use of the Stelle Doppie database, maintained by Gianluca Sordiglioni.

The authors are grateful to Colorado Mountain College for supporting student travel and research and funding telescope time at MWO

Thanks to Rachel Freed and the Institute for Student Astronomical Research for funding instrument time at MWO, and to Tom Menighini and MWO staff.

Thanks to Dave Rowe for Speckle Tool Box 10.04 and his development of the Orbits routine.

References

- Docobo, J. A. & Campo, P. International Astronomical Union Commission G1 (Binary and Multiple Star Systems) Double Stars Information Circular No. 205. Oct. 2021
<https://www.usc.gal/astro/circulares/cir205.pdf>
- Faughn, E., Major, J., McCudden, P. (2023) Speckle Astrometry of WDS 18181-0120 *The Journal of Double Star Observations*, Volume 19, Number 4, October 1, 2023.
- Genet, R., McCudden, P., Ellis, M. (2024) Desmos Graphical Analysis of Binary Stars — A Tutorial with HU 481 (WDS 16212+2259) Example. *The Journal of Double Star Observations*, 20(2), p. 264-274
- Harshaw, R., Rowe, D., & Genet, R. (2017) The Speckle Toolbox: A Powerful Data Reduction Tool for CCD Astrometry. *The Journal of Double Star Observations*, Volume 13, Number 1, January 1, 2017
- Labeyrie A. (1970) Attainment of Diffraction Limited Resolution in Large Telescopes by Fourier Analysing Speckle Patterns in Star Images. *Astron. & Astrophys.* 6, 85-87.
<https://adsabs.harvard.edu/pdf/1970A%26A.....6...85L>
- McCudden, P., Genet, R., Willie, E., Dugan, L., Risin, S. (2022) Known Binaries Excel Spreadsheet. *The Journal of Double Star Observations*, Volume 18, Number 4, October 1, 2022.
- Prusti, T., de Bruijne, J.H.J., et al. (2016) *The Gaia mission*. *A&A* 595, pp. A1.
- Scardia M., Jean-Louis Prieur, L. Pansecchi, Josefina Ling, R. Argyle, et al. (2021). Orbital elements of double stars: BU 453 AB, A 819 AB, STT 406, BU 367 AB. 2021, pp. *Circulaire* N° 205. hal-03741127
- Söderhjelm, Setaffan. Visual binary orbits and masses post Hipparcos. *Astronomy and Astrophysics*, v. 341, p. 121-140 (1999) <https://articles.adsabs.harvard.edu/pdf/1999A%26A...341..121>
- Tokovinin, A. International Astronomical Union Commission G1 (Binary and Multiple Star Systems) Double Stars Information Circular No. 199. Oct. 2019.
<https://www.usc.gal/astro/circulares/cir199.pdf>