Calibration Binaries Observed at the SOR

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ABSTRACT

In reviewing observations of binary stars taken with adaptive optics on the 3.5 m Starfire Optical Range telescope over the past two years, a quarter of these calibration binaries, taken from two Excel Spreadsheets offered at the 2011 AMOS conference, were found to be off orbit. In order to understand such a high number of discrepant position angles and separations, all previous observations in the Washington Double Star Catalogue for a sample of five binaries were obtained from the Naval Observatory. Adding our observations to these yields new orbits for all. We have detected both components of γ Gem for the first time, and we have shown that 7 Cam is an optical pair, not physically bound.

1. Background

At the AMOS Conference last year I offered two Excel Spreadsheets of binary stars for use in calibrating image scales and orientations, one a personally selected list of mostly brighter binaries that appear to be particularly reliable, and the other the complete list of all binaries that have orbits. The latter is the Sixth Catalog of Orbits of Visual Binaries from the Washington Double Star (WDS) Catalog (*http://ad.usno.navy.mil/wds*) maintained by the United States Naval Observatory. Over 23 nights between 2010 June 18 and 2012 April 6, during the course of many other experiments, 174 observations of 62 binaries from these two lists were obtained with Adaptive Optics (AO) on the 3.5 m telescope at the Starfire Optical Range (SOR), where all observations were made at an effective broadband wavelength of 0.78 μm, or through a narrow band Hα filter at 0.66 μm with the same Andor camera. Each binary was measured by fitting the pair as Lorentzians, since this function best describes the AO point spread function (Drummond 1998 ; Drummond et al. 1998). For close pairs, both components were forced to have the same shape in the fit, the isoplanatic assumption.

After comparing measurements to the predictions from the two lists, Fig 1 shows the scale obtained from 140 measurements of 47 binaries, and Fig 2 shows a histogram of the differences between the observed and predicted position angles for these same binaries. Not shown are 15 of the 62 binaries that were deemed to be less than calibration material because they are off orbit, where the criteria for exclusion was being off by $0.1''$or 10% of the predicted separation. Of the 15 non-accepted binaries, 8 are from my Calibration Bright Binaries and 7 are from the Calibration All Binaries spreadsheet. Of the 47 good binaries, 36 are among the Bright Binaries and 11 are from the Sixth Orbit Catalog.

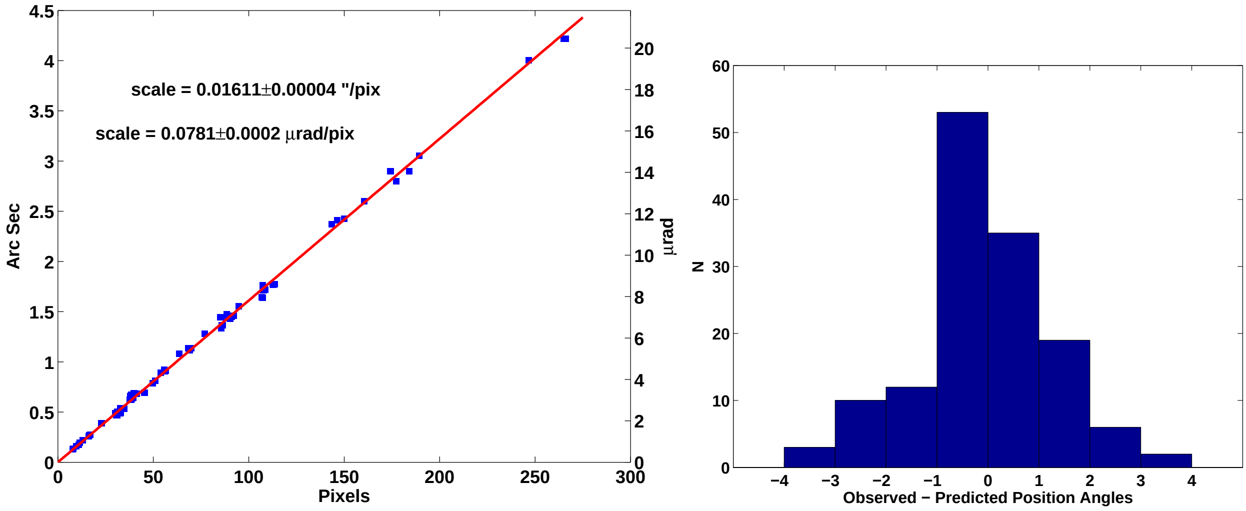


Fig. 1.— Left: Image scale obtained from 140 observations of 62 binaries. Right: Histogram of position angle residuals from 140 observations of 62 binaries.

2. Resolution

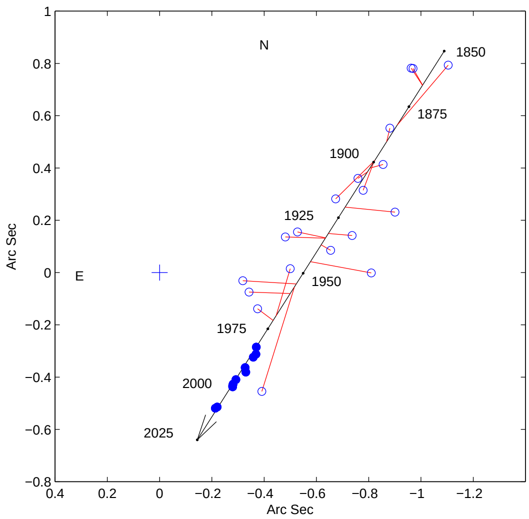
In an attempt to understand so many discrepancies among so-called calibration binaries, the Naval Observatory was queried for their data base of observations for five of the fifteen cases of off-orbit binaries. In each case, by adding observations (including ours) unavailable to the last orbit calculator, I find a new orbit that dissolves the apparent discrepancy. In most cases, modern CCD, speckle interferometry, or especially adaptive optics observations provide the latest and best data points.

Table 1 gives the position angles and separations obtained at the SOR for these five binaries, Table 2 gives the old and new orbits, and Figs 1-5 show old and new orbits calculated here after including all data. In all of the figures, points, which are the B components, are connected to their predicted positions on the orbit. Open circles are from visual measurements and filled circles are CCD, speckle interferometry, or AO measurements. Points marked as an X or connected to the orbit with a dotted line were not available or not used in the orbit calculation. The plus marks the A component and the dashed line through it is the line of apsides. Times along the orbit are shown as smaller dots. Units are seconds of arc.

Table 1. SOR Observations of Five Discordant Binaries

WDS	Date	PA(°)	Sep(″)	ΔMag	Filter†	obs	nights
04573+5345	2010.65	203.2±0.2	0.560±0.018	3.15±0.03	R	1	1
	2011.77	202.3±0.2	0.561±0.017	3.12±0.04	Hα	1	1
05413+1632	2010.91	244.4±0.3	0.210±0.002	1.52±0.02	R	1	1
	2011.15	248.5±0.3	0.216±0.001	1.79?±0.01	R	1	1
06377+1624	2012.26	259.3±0.4	0.378±0.002	3.06±0.03	Hα	1	1
08592+4803 AB	2012.26	95.9±0.4	1.925±0.001	6.95±0.04	Hα	2	2
AC	2012.26	81.6±0.3	2.398±0.001	7.00±0.10	Hα	2	2
BC	2012.26	39.6±0.3	0.716±0.001	0.05±0.03	Hα	2	2
10281+4847	2012.26	22.0±0.1	3.975±0.015	4.31±0.04	Hα	4	3

†$\lambda_R = 0.78\mu$m ; $\Delta\lambda_R = 0.10\mu$m
$\lambda_{H\alpha} = 0.656\mu$m ; $\Delta\lambda_{H\alpha} = 0.004\mu$m



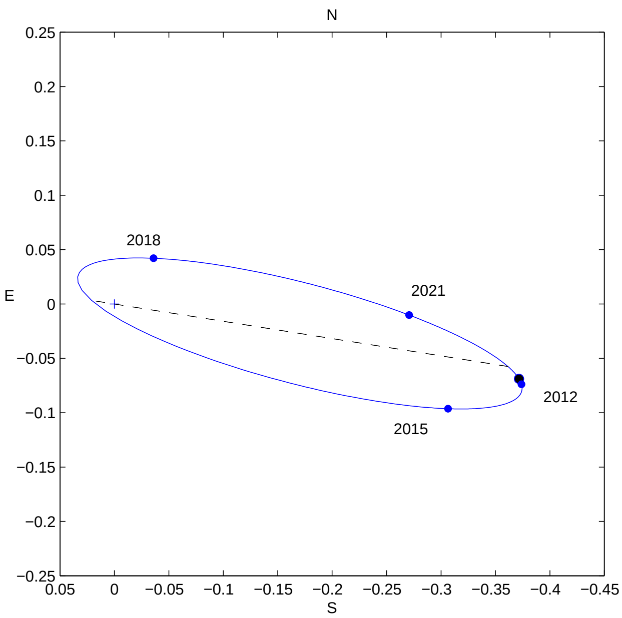


Fig. 2.— Left: WDS 04573+5345 = HIP 23040 = HR 1568 = 7 Cam AB. Rectilinear motion of 7 Cam. Pre-1979 observations listed the fainter companion as A, but afterwards, more appropriately as B. Straightening out the ambiguities clearly shows that the two stars are not physically related, but are an optical pair.

Fig. 3.— Right: WDS 06377+1624 = HIP 31681 = HR 2421 = 24 γ Gem. Adding our detection of both components to the astrometric and spectroscopic orbital elements sets the scale for both, and we derive the mass of the two as 3.0 $M_\odot$ and 1.2 $M_\odot$ (Drummond 2012, in prep).

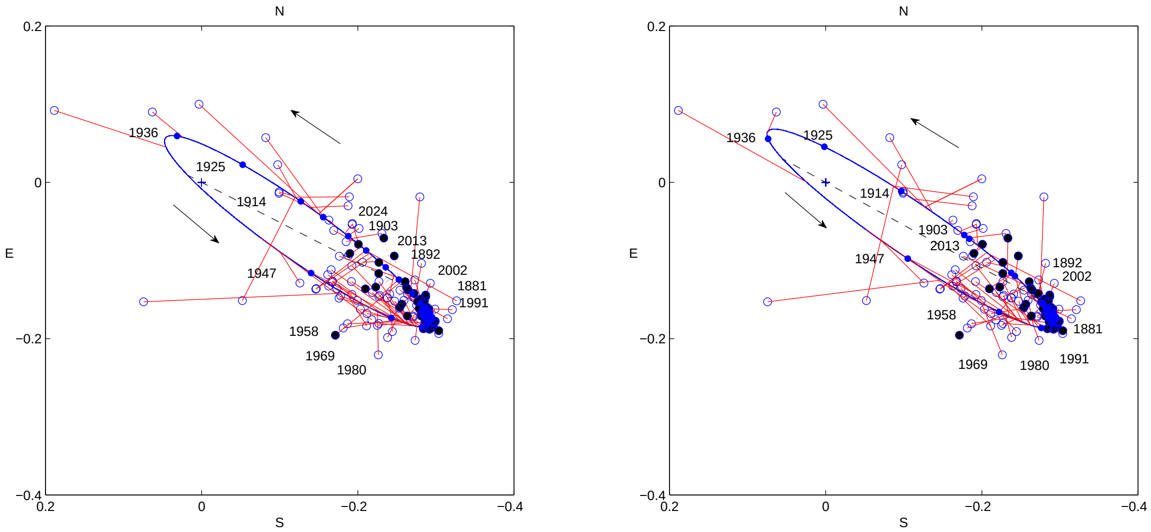


Fig. 4.— WDS 05413+1632 = HIP 26777 = HR 1946 = 126 Tau. Left: Old orbit. Old visual positions produce lots of scatter. Right: New orbit. Component B is now well past apastron. Scatter in the data base magnitude differences implies that one or both stars may be variable in brightness.

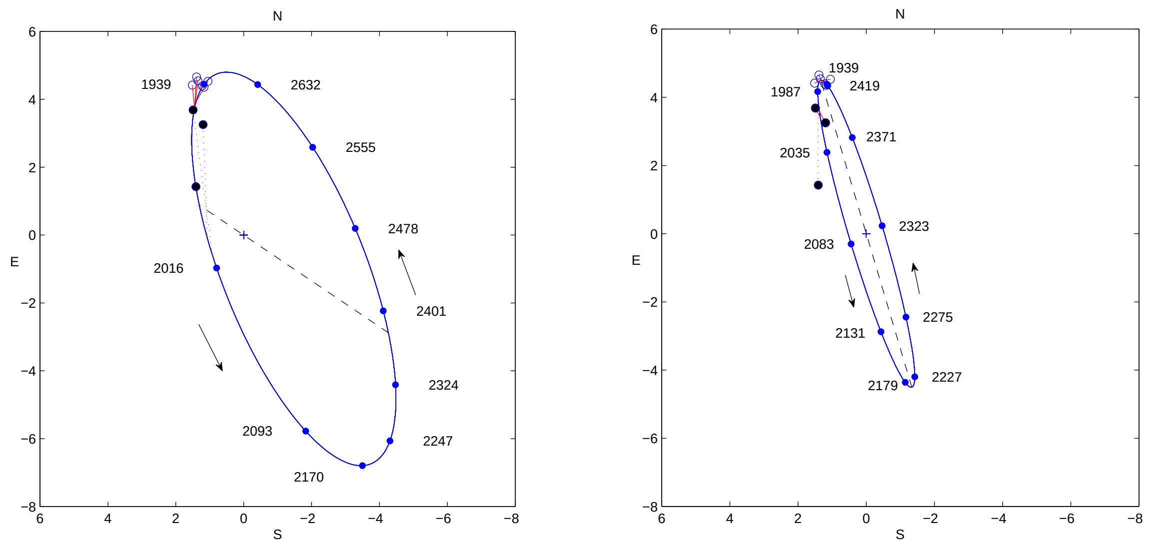


Fig. 5.— WDS 10281+4847 = HIP 51248 = HR 4098 AB. Left: Old orbit calculated before the last two measurements. Right: New orbit. Our measurement conflicts with the previous position, but both suggest that the antepenultimate measurement was in error. A new orbit is calculated, but both should be considered premature since so little of the orbital arc has been covered.

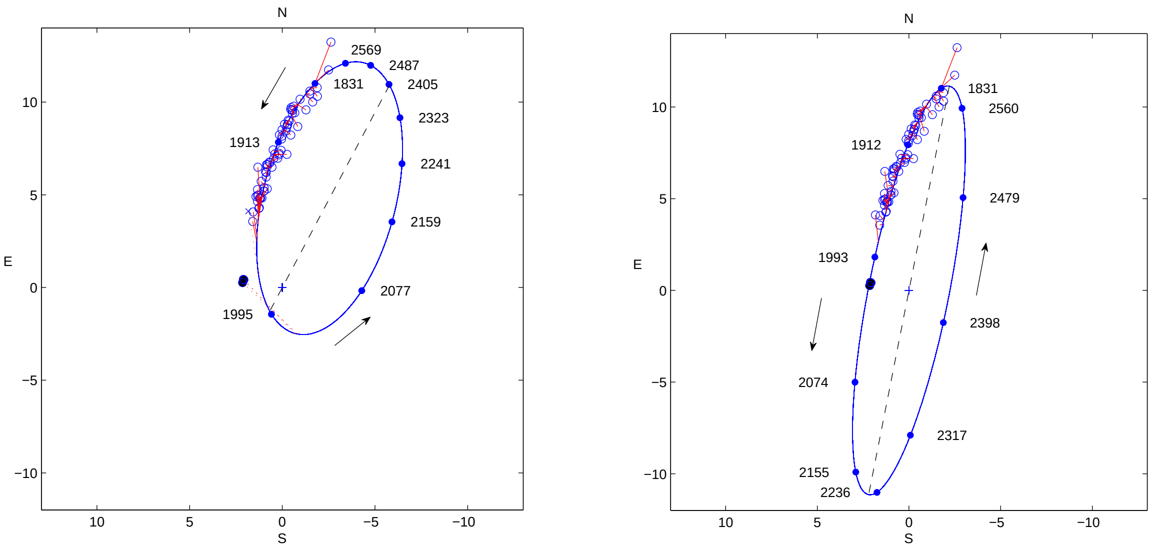


Fig. 6.— WDS 08592+4803 = HIP 44127 = HR 3569 = 9 ι UMa A-BC. Left: Old orbit of A around the photocenter (barycenter) of BC. Right: New orbit.

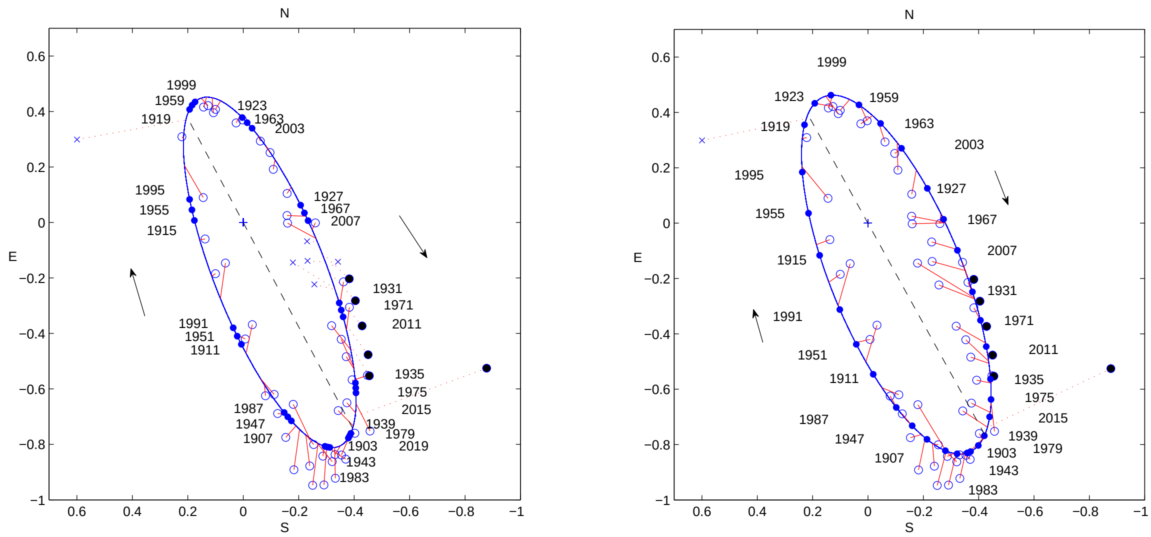


Fig. 7.— WDS 08592+4803 = HIP 44127 = HR 3569 = 9 ι UMa BC. Left: Old orbit. Right: New orbit. There is not a significant difference between the two orbits, but there may be evidence for sub-orbital motion indicating a third component.

Table 2. Old and New Orbits

WDS	a(″)	Node(°)	i(°)	Per (yrs)	T0	e	ω(°)	Reference
04573+5345								
Old	0.78	338.2	137.9	284.0	1986.0	0.74	30.2	Baize 1979
New[†]								
05413+1632								
Old	0.316±0.133	48.4±3.0	81.8±4.0	114.88±2.00	1941.25±6.00	0.869±0.092	61.1±16.0	Docobo & Ling 1999
New	0.245±0.014	53.2±0.8	80.5±1.1	111.02±1.37	1938.13±1.64	0.661±0.036	40.9±5.8	this paper
06377+1624								
A	0.0787±0.0023	243.6±2.6	106.7±1.7	12.634	1979.34	0.89	312.6	Jancart et al. 2005
AB	0.2732						132.6	this paper
08592+4803								
A-BC Old	9.092	184.8	57.8	817.91	2402.86	0.79	129.7	Hopmann 1973
New	11.3 ±0.2	169.0±0.5	78.9±0.3	803 ±25	2209.6 ±6.3	0	0	this paper
BC Old	0.68±0.01	21.0	108 ±1	39.69±0.53	1918.58±0.66	0.32±0.02	338.3	Eggen 1967
New	0.70±0.02	21.5±2.1	110.9±1.1	38.82±0.11	1919.49±0.45	0.32±0.01	339.9±3.7	this paper
10281+4847								
Old	7.08	18.94	72.01	765	1997	0.53	67.74	Hale 1994
New	4.70±0.10	16.5 ±1.1	83.7 ±2.8	482±101	1959.7±8.9	0	0	this paper

[†]Rectilinear motion B wrt A: $N('') = 0.430(\pm0.028) - 0.0087(\pm0.0004)(T - 1900)$; $E('') = -0.816(\pm0.027) + .0055(\pm0.0004)(T - 1900)$

3. Conclusions

Buoyed by the finding that the first five discrepant calibration binaries examined were merely in need of an orbit update, the remaining ten discordant binaries will be similarly analyzed. By the AMOS Conference next year I hope to offer revised spreadsheets.

Acknowledgements

The keepers of the Washington Double Star Library should be recognized for their important work: Brian D. Mason, Gary L. Wycoff, and William I. Hartkopf. Much more data and information is available at the WDS, and the keepers there are more than willing to provide assistance for interested users. For the current round, Brian Mason provided the data for the five binaries reported here.

My thanks go out to the able observing crews at the SOR for obtaining measurements of the binaries reported here, led by Test Directors Ryan Givens, Karl Schwenn, Jillian Conrad, Tod Laurvick, and Odell Reynolds.

4. References

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