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SPECKLE INTERFEROMETRY AT THE USNO FLAGSTAFF STATION: OBSERVATIONS OBTAINED IN 2003–2004 AND 17 NEW ORBITS

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ABSTRACT

Results are presented for 353 speckle interferometric observations of double stars, obtained in 2003 and 2004 at the USNO Flagstaff Station using the 1.55 m Kaj Strand Astrometric Reflector. Separations range from 0″.12 to 7″.42, with a median of 0″.42. These two observing runs concentrated on systems in need of improved orbital elements, and new solutions have been determined for 17 systems as a result.

Key words: binaries: general – binaries: visual – techniques: interferometric

Online-only material: color figure, machine-readable tables

1. INTRODUCTION

Although principally used with the historic 26 inch Clark refractor in Washington, DC, the USNO speckle camera has on occasion been transported to other instruments, including the KPNO and CTIO 4 m, the Mount Wilson 2.5 m, and the McDonald Observatory 2.1 m, to observe stars at declinations and/or separation regimes not accessible to the Clark (see Mason et al. 1999b, 2001, 2008, in preparation). In 2003 December and again in 2004 March, the camera was shipped to Arizona and mounted on the 1.55 m (61 inch) Kaj Strand Astrometric Reflector at the USNO Flagstaff Station. Our purpose was to test the feasibility of using this instrument, with its factor of ∼2.3 resolution improvement over the 26 inch, for observing closer visual pairs. In order to take advantage of this increased resolution we prepared an observing list of visual binaries from the Washington Double Star Catalog[2] (WDS) and Fourth Interferometric Catalog[3] which were too close to easily resolve in Washington. In addition, the Sixth Catalog of Visual Orbits[4] was examined for systems where a single new observation might be sufficient to significantly improve upon published orbital elements.

For this latter target selection, we started with the complete list of ∼1800 pairs in the Orbit Catalog, then successively narrowed the list to appropriate ranges in right ascension (R.A.) and declination (decl.), primary and secondary magnitudes, and separation. Pairs already having high-quality orbits were then removed (except for those chosen for scale calibration). Figures were then created for the remaining several hundred pairs, including all data from the current version of the WDS database; additional symbols indicated the predicted secondary location at the time of these observing runs. Visual inspection of these figures by W.I.H. and B.D.M. allowed us to select those pairs whose data were significantly "running off" the current orbit, or where a new measure would fall within a region of poor phase coverage.

2. CALIBRATION AND RESULTS

Both of these two five-night runs were successful, with no time lost to either weather or equipment problems. A total of 922 observations were obtained, with data reduced at the telescope in real time, using the directed vector autocorrelation (DVA) reduction technique described by Mason et al. (2001).

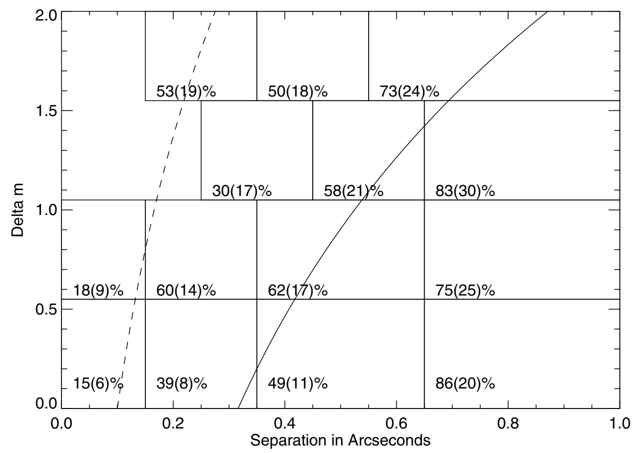

Figure 1. Success rates for different bins in Δm–ρ space for the 2003–2004 USNO 61 inch speckle data. Membership in the bins is based on the WDS Δm value and the last measured separation. Formal errors to these success rates, based on Poisson statistics, are given in parenthesis. Placement in these bins makes no allowance for doubles whose separations may have radically changed from the last published value, whose Δm is radically different than given in the WDS, or indeed for unconfirmed doubles which may in fact be single stars. The curved lines indicate the "measure of difficulty" relationship of Öpik (1924), as modified by Heintz (1978). The Δm–ρ combinations to the right of the solid line are considered completely known, those to the left of the dashed line completely unknown.

Absolute calibration of scale and camera orientation may be obtained at some telescopes (such as the Mount Wilson 2.5 m or the KPNO 4 m) through the use of a slit mask placed well in front of the primary mirror. This option is not available at other sites, however, so we had to rely on observations of well-observed binaries instead. During these two NOFS runs, we obtained 58 observations of 20 binaries with well-characterized orbits for this purpose. A weighted least-squares fit was made to transform between the (x, y) centroid positions of peaks in the calibration DVAs and the corresponding (ρ, θ) values predicted at the time of observation by the stars' orbits.

The rms O–C residuals for these calibration observations are 0°.70 in position angle and 0.0157 in relative separation or scale $(\delta\rho/\rho)$. We take these values, then, to represent the

[1] Retired.
[2] http://ad.usno.navy.mil/wds/wds.html.
[3] http://ad.usno.navy.mil/wds/int4.html.
[4] http://ad.usno.navy.mil/wds/orb6.html.

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Table 1
Speckle Interferometric Measurements of Double Stars without Orbits

WDS designation α, δ (2000)	Discoverer designation		Epoch 2000.+	θ (°)	ρ (″)	n	Note
00358+4901	STT	15	3.9515	321.2	0.210	1	
00366+5609	A	914	3.9515	25.7	0.451	1	
01029+5148	BU	1161	3.9515	14.1	0.325	1	
01198−0031	STF	113 A-BC	3.9598	17.8	1.636	1	
01493+4754	STF	162 Aa-B	3.9517	201.0	1.892	1	
02068+0354	HDS	281	3.9490	155.2 :	0.284 :	1	C
02270+1952	A	2328	3.9517	78.4	0.388	1	
02367+2908	COU	460	3.9517	92.5	0.144	1	
02473+1717	A	2222 CD	3.9600	106.0	0.453	1	
02483+1727	COU	672	3.9600	203.2	0.296	1	

Notes.
C: confirming observation.
L: linear elements determined; see Rectilinear Elements Catalog:
http://ad.usno.navy.mil/wds/lin1.html.
O–C residuals for this pair are −0°2 and 0″089.
(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

Table 2
Speckle Interferometric Measurements and Residuals of Systems with Orbits

WDS designation α, δ (2000)	Discoverer designation		Epoch 2000.+	θ (°)	ρ (″)	n	$O–C$ (°)	$O–C$ (″)	Reference	Notes
00134+2659	STT	2 AB	3.9487	166.2	0.375	2	4.6	0.019	Olević & Jovanović (2001)	
00134+2659	STT	2 AB					1.1	−0.004	Table 3	
00487+1841	BU	495	3.9597	277.9	0.203	1	−0.2	0.006	Scardia et al. (2000)	
00504+5038	BU	232 AB	3.9515	249.1	0.877	1	−2.9	0.073	Starikova (1985)	
00593−0040	A	1902	3.9597	203.5	0.342	1	0.3	−0.002	Docobo & Ling (2000)	
00596−0111	A	1903 AB	3.9598	4.2	0.386	1	3.5	−0.016	Mason et al. (1999a)	
01014+1155	BU	867	3.9597	357.9	0.603	1	2.1	0.032	Cvetković & Novaković (2006)	
01014+1155	BU	867					0.6	0.003	Table 3	
01036+6341	MLR	87	3.9517	45.1	0.248	1	−0.8	−0.058	Seymour et al. (2002)	
01036+6341	MLR	87					−3.7	0.041	Olević (2002a)	

Notes.
⋆: system used in characterizing errors.
1: position angle of this measure flipped by 180° for this orbit.
2: this is the nearby pair GJ 234.
3: this is the nearby pair G 250-209.
4: this is the nearby pair GJ 473.
(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

approximate precision of all the measures. Systems used for calibration are flagged in the tables of results described below.

The above-mentioned values are, of course, a convolution of internal error and imprecision in the orbital elements used for calibration. To determine the size of the internal error, 22 systems were observed on multiple occasions during the same run (anywhere from 2 to 5 times, with similar numbers of multiple observations during each of the two runs). The rms scatter in θ and $\delta\rho/\rho$ from these multiple observations was 0°14 and 0.0079, considerably smaller than the calibration residuals and suggesting that both position angle and scale errors are dominated by uncertainties in the orbital elements of the calibration pairs. This was as expected, as the overall errors were somewhat larger than those typically obtained at telescopes with absolute calibration capabilities.

After removal of poor measures and averaging of multiple observations, a total of 353 mean measures were obtained; results are given in Tables 1 and 2. Figure 1 illustrates our "success rate" during these two runs, as a function of angular separation and magnitude difference. Due to the relatively small numbers of observations in each Δm–ρ bin, formal errors to these success rates are high. However, results are about as one might expect. Success rates are low for pairs near the resolution limit of the telescope, but increase rapidly with separation. The number of binaries with small separation and large magnitude difference is too small (due to selection effects) to yield any statistics. Similarly, the number of pairs over the entire separation range with $\Delta m > 2$ mag is too small to illustrate the expected decrease in success rate at larger magnitude differences; little difference is seen over the plotted range.

Table 1 presents the results (211 measures in 195 means) for 191 pairs without published orbital elements. Columns 1 and 2 give the WDS designation (based on epoch-2000 coordinates)

Table 3
New Orbital Elements

WDS (figure number)	Discoverer designation		P (yr)	a ($''$)	i (°)	Ω (°)	T_0 (yr)	e	ω (°)
00134+2659	STT	2 AB	421.98	0.641	124.1	193.0	1969.97	0.720	286.1
(2a)			±7.92	±0.003	±0.9	±0.7	±0.28	±0.004	±0.6
01014+1155	BU	867	232.04	0.813	98.9	354.2	2012.72	0.230	2.9
(2b)			±18.15	±0.009	±1.0	±0.4	±9.12	±0.010	±20.4
01437+0934	BU	509	259.68	0.946	117.2	220.1	1980.56	0.314	85.1
(2c)			±5.80	±0.021	±0.6	±0.8	±1.26	±0.006	±3.6
01499+8053	STT	34	195.89	0.715	79.8	113.1	2025.36	0.620	263.5
(2d)			±4.13	±0.013	±0.8	±0.8	±1.31	±0.037	±1.1
03261+1229	A	829	111.38	0.417	120.6	260.1	1985.10	0.743	77.2
(2e)			±3.93	±0.012	±2.0	±2.4	±0.79	±0.018	±1.9
03362+4220	A	1535	145.05	0.531	48.1	156.8	1940.32	0.372	8.5
(2f)			±8.72	±0.010	±4.0	±3.6	±2.85	±0.034	±11.7
03489+6445	STT	62	178.15	0.382	52.3	158.6	1944.47	0.124	47.1
(2g)			±12.22	±0.008	±3.6	±3.2	±8.14	±0.058	±19.6
04091+2839	HO	326	158.18	0.643	72.7	147.6	1880.92	0.857	271.6
(2h)			±15.79	±0.036	±1.7	±4.9	±4.54	±0.051	±0.9
05247+6323	STF	677	361.89	1.464	130.6	95.1	2039.47	0.197	9.4
(2i)			±26.93	±0.030	±2.3	±1.1	±10.93	±0.007	±15.8
06345−1114	HO	234	542.84	0.942	61.7	221.2	2456.65	0.518	354.1
(2j)			±113.59	±0.063	±4.1	±1.1	±121.09	±0.024	±16.3
06478+0020	STT	157	307.83	0.593	132.2	154.4	1984.66	0.221	296.5
(2k)			±22.25	±0.026	±1.3	±4.6	±7.84	±0.021	±18.2
11520+4805	HU	731	207.77	1.179	96.6	118.7	1900.83	0.705	301.1
(2l)			±38.24	±0.046	±1.0	±1.9	±2.00	±0.033	±7.8
14295+3612	HU	1268	172.93	0.251	145.4	148.9	1975.69	0.599	28.4
(2m)			±18.10	±0.024	±11.0	±11.6	±2.85	±0.045	±14.3
15396+7959	STF	1989	171.62	0.464	135.2	123.4	1904.15	0.961	274.0
(2n)			±8.68	±0.083	±10.5	±32.6	±2.89	±0.014	±22.4
15542+1659	A	2080	382.99	0.369	62.9	294.0	2285.17	0.157	40.7
(2o)			±292.64	±0.137	±4.5	±12.3	±443.01	±0.083	±217.2
16366+6948	BU	953 AB	220.78	0.415	113.1	144.2	1899.73	0.444	264.1
(2p)			±72.76	±0.113	±5.9	±5.4	±7.11	±0.064	±30.2
22302+2228	HU	388	546.35	0.508	29.0	197.6	1934.49	0.842	74.3
(2q)			±89.34	±0.068	±6.7	±11.3	±1.02	±0.020	±12.2

and discoverer designation for each pair. Columns 3–5 give the date of observation (in fractional Besselian year), position angle θ (in degrees), and separation ρ (in arcseconds). Colons following θ and ρ indicate measures of lower quality (due to such factors as close separation, large Δm, faint primary and/or secondary, large zenith distance, or poor seeing or transparency). The final two columns indicate the number of observations included in each mean measure and a flag for any notes. The most common flag ("C") indicates a measure which confirms a new binary star discovery; 31 systems are confirmed by these measures, including 12 binaries discovered by *Hipparcos*/*Tycho*, 10 discovered micrometrically by Paul Couteau, and two first measured at the KPNO 4 m as part of a duplicity survey of G dwarfs (B. D. Mason et al., 2008, in preparation).

Table 2 presents the results (209 measures in 158 means) for 150 pairs with published orbital elements. Here the first six columns are identical to those in the previous table, while Columns 7 and 8 give O–C orbit residuals in θ and ρ to the orbit referenced in Column 9. Flags for notes are given in Column 10. Occasionally, the Sixth Catalog lists more than one possible orbital solution for a pair. In these cases, residuals

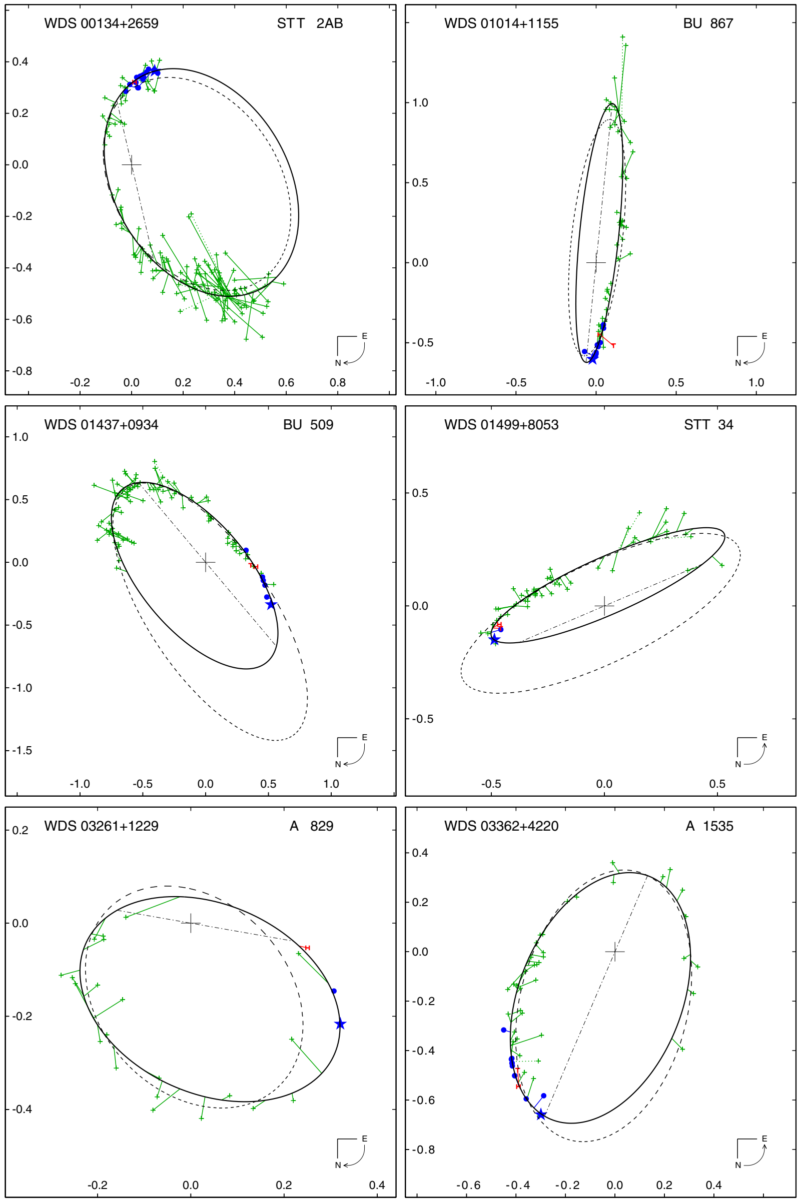

Figure 2. New orbits for the systems listed in Table 3, together with the most recent published elements for these systems and all published data in the WDS database. See the text for a description of symbols used in this figure.

(A color version of this figure is available in the online journal)

to the second orbit are listed on a separate line, with blanks in the remaining columns. Residuals to new orbital solutions (discussed below) are treated in a similar manner.

3. NEW ORBITS

Following final data reductions, new orbital solutions were attempted for all systems in Table 2 where recent measures showed considerable residuals from published elements. The "grid search" method used for these calculations is described by Mason et al. (1999a), with the weighting system for individual observations described by Hartkopf et al. (2001). A total of 17 systems yielded new solutions which were deemed sufficiently improved for publication. Elements for these systems are given in Table 3, where Columns 1 and 2 give the WDS and discoverer designations and Columns 3–9 list the seven Campbell elements: P (period, in years), a (semi-major axis, in arcseconds), i (inclination, in degrees), Ω (longitude of node, equinox 2000, in degrees), T_0 (epoch of periastron passage, in fractional Besselian year), e (eccentricity), and ω (longitude of periastron, in degrees). Formal errors are listed below each element.

As a comparison between earlier and new orbits, weighted rms residuals in ρ and θ for all orbits are given in Table 4. Separate means are calculated for visual (micrometry, photography) and high-resolution (speckle, adaptive optics, *Hipparcos* and *Tycho*) data. Also included is a rough grade for each orbit (where 1 = "definitive" and 5 = "indeterminate"), as described by Hartkopf et al. (2001) and based on similar grading schemes used in the orbit catalog of Worley & Heintz (1983) and its predecessors.

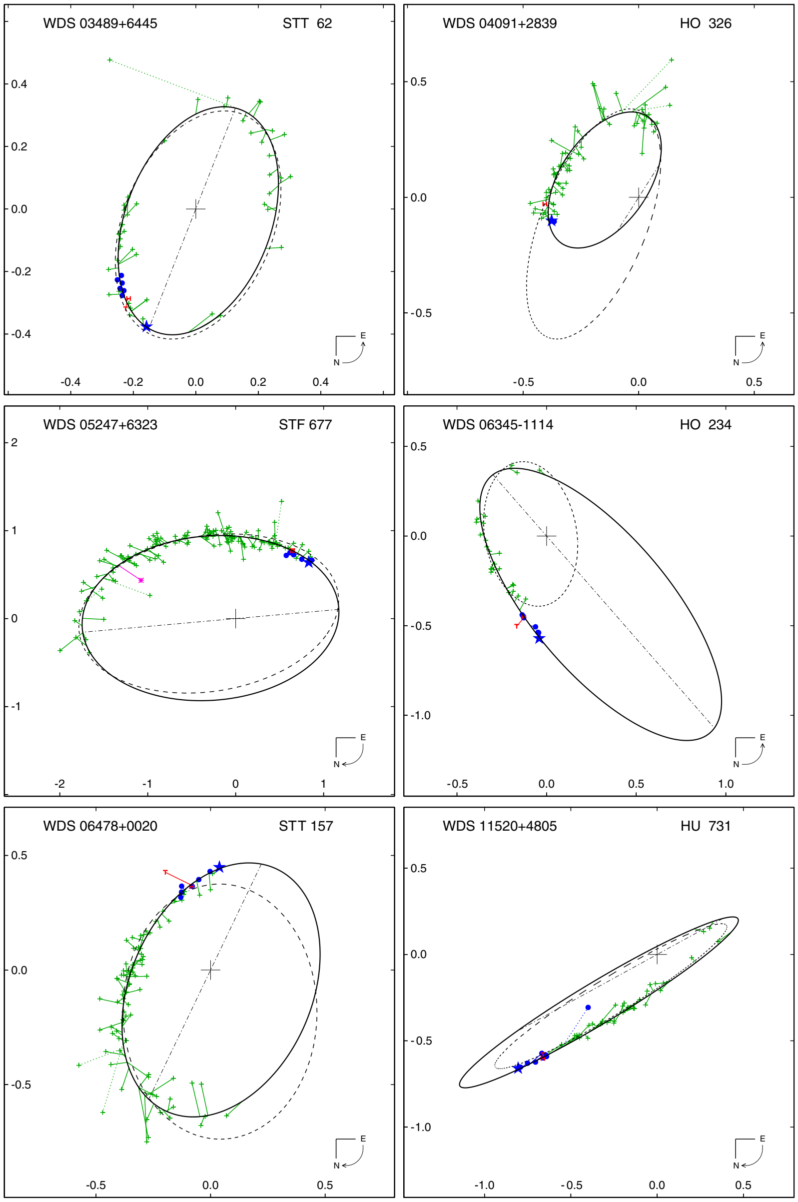

Figure 2. (Continued)

Figure 2 shows the new orbital solutions, plotted with all published data in the WDS database. In each of these figures, micrometric observations are indicated by plus signs, interferometric measures by filled circles or (for the new USNO measures) larger filled stars, *Hipparcos* and *Tycho* measures by the letters "H" or "T." "*O*–*C*" lines connect each measure to its predicted position along the new orbit (shown as a thick solid line). A dot-dashed line indicates the line of nodes, and a curved arrow in the lower right corner of each figure indicates the direction of orbital motion. Finally, the previous published orbit is shown as a dashed ellipse; references to each of the published orbits are given in the final column of Table 2.

Table 5 gives ephemerides for each orbit over the years 2008.0 through 2016.0, in 2 year increments. Columns 1 and 2 are the same identifiers as in the previous table, while columns 3 & 4, 5 & 6, etc., through 13 & 14 give predicted values of θ and ρ, respectively, for the years 2008.0, 2010.0, etc., through 2016.0.

Notes to individual systems follow. In each case, spectral types of primaries are taken from SIMBAD, while those of secondaries are estimated based on the primary spectral type and the magnitude difference between the components, using the tables of Allen (2001).

WDS 00134+2659. The large scatter in early micrometer measures, coupled with incomplete phase coverage, has led to a wide variety of solutions for this pair over the past half century; periods have ranged from about 200 years to over 930 years (Scardia 1980, 2000b). Interferometric measures are increasingly "running off" the most recently published orbit (Olević & Jovanović 2001). The new orbit appears to fit the newer data fairly well; still the orbit must be considered preliminary, given the lack of good coverage. The primary is a

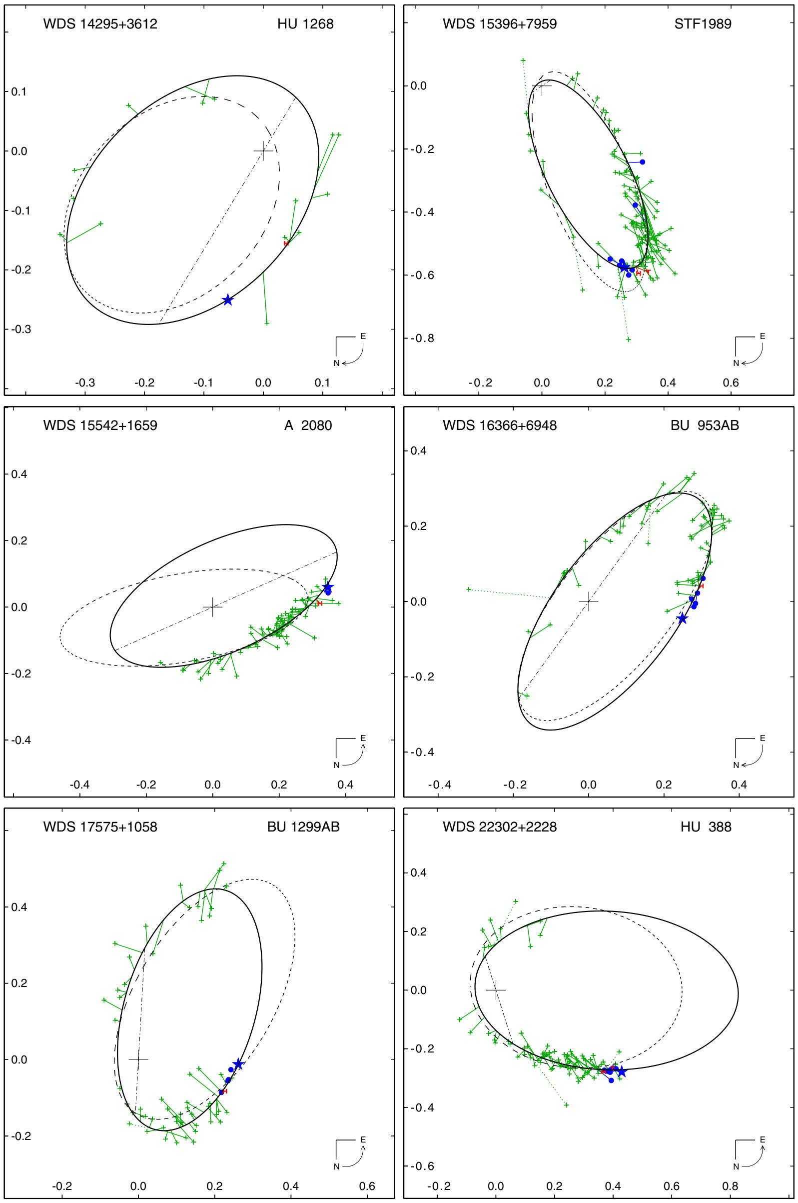

Figure 2. (Continued)

G0III; based on the magnitude difference between the pair the B component could be about A5V (corresponding mass sum 3.0 $M_\odot$) or K4III (mass sum 2.2 $M_\odot$). Given a *Hipparcos* parallax of 8.08 mas, the Olević & Jovanović orbit yields a mass sum of 2.5 $M_\odot$, while ours increases that to 2.8 $M_\odot$; neither spectral type for the secondary can be ruled out.

This close pair is part of a triple system. The C component has remained at a fixed distance of about 18″ from AB for over 160 years; proper motions are roughly similar but small, and the optical/physical nature of this wide pair is unknown, although Le Beau (1990) considers it physical.

WDS 01014+1155. The recent orbit by Cvetković & Novaković (2006) fits the published data reasonably well, but this orbit, with a slightly larger semi-major axis and ∼20° difference in ω, appears to better define the orbit at the two ends of the line of nodes. The 2.7 $M_\odot$ mass sum resulting from the Cvetković & Novaković orbit seems a closer match for an F5 + early-G pair than the 3.8 $M_\odot$ predicted by our elements. In any event, a better solution should be possible in perhaps a decade, after the stars reach maximum separation and begin to close in.

WDS 01437+0934. The most recent measures yield an orbit nearly 30% smaller in semi-major axis and some 150 years shorter in period than predicted by Heintz (1988). The predicted mass sums (1.4 and 1.3 $M_\odot$ for Heintz' and our orbit, respectively) are each a little smaller than would be expected for a K0 + K2 pair.

WDS 01499+8053. Systems such as this typically lend themselves to two possible orbit solutions: either long-period/low-eccentricity or short-period/high-eccentricity (with quadrant flips for some of the measures). Heintz (1962, 1997) favored long-period (∼400 yr) solutions, while Baize (1959, 1986) preferred short-period (∼170 yr) ones. Our solution is of the short-P/high-e variety, but with a considerably different geometry than determined by Baize. It is plotted in

Table 4
Weighted RMS Residuals to Orbits

WDS	Discoverer designation		Visual $\bar{\sigma}_\rho$ (arcsec)	Visual $\bar{\sigma}_\theta$ (°)	Interferometric $\bar{\sigma}_\rho$ (arcsec)	Interferometric $\bar{\sigma}_\theta$ (°)	Orbit grade	Orbit reference
00134+2659	STT	2 AB	0.020	2.67	0.067	3.68	3	Olević & Jovanović (2001)
			0.005	0.87	0.063	3.89	3	This paper
01014+1155	BU	867	0.016	1.15	0.111	4.65	4	Cveković & Novaković (2006)
			0.005	0.64	0.092	3.44	4	This paper
01437+0934	BU	509	0.024	1.46	0.069	4.20	4	Heintz (1988)
			0.009	0.87	0.070	3.99	4	This paper
01499+8053	STT	34	0.008	0.35	0.044	3.17	4	Baize (1986)
			0.092	1.02	0.049	3.79	5	Heintz (1997)
			0.008	0.26	0.042	3.69	3	This paper
03261+1229	A	829	0.104	7.25	0.030	7.06	4	Olević & Jovanović (2001)
			0.008	0.76	0.041	9.00	4	This paper
03362+4220	A	1535	0.017	3.58	0.041	3.43	5	Morel (1970)
			0.009	1.24	0.041	3.00	3	This paper
03489+6445	STT	62	0.012	1.27	0.032	3.60	3	Heintz (1973b)
			0.007	0.69	0.027	3.92	2	This paper
04091+2839	HO	326	0.065	1.77	0.043	4.00	5	Heintz (1997)
			0.014	1.81	0.043	3.90	4	This paper
05247+6323	STF	677	0.081	2.11	0.094	2.27	4	Heintz (1996b)
			0.036	1.71	0.088	2.37	4	This paper
06345−1114	HO	234	0.106	3.88	0.029	2.01	5	Heintz (1979)
			0.007	0.69	0.034	1.71	4	Romero (2007)
			0.005	0.65	0.029	2.18	4	This paper
06478+0020	STT	157	0.031	3.59	0.056	3.94	4	Heintz (1973a)
			0.011	0.82	0.050	3.95	3	This paper
11520+4805	HU	731	0.127	1.11	0.047	3.63	5	Ling (1992)
			0.021	0.21	0.069	5.33	4	This paper
14295+3612	HU	1268	0.115	32.11	0.072	27.25	5	Erceg (1975)
			0.004	1.80	0.038	14.01	4	This paper
15396+7959	STF	1989	0.074	0.64	0.064	3.59	3	Scardia (2003)
			0.013	0.80	0.059	3.77	3	This paper
15542+1659	A	2080	0.075	4.81	0.034	5.24	4	Heintz (1998)
			0.006	1.76	0.031	5.52	4	This paper
16366+6948	BU	953 AB	0.018	3.54	0.037	3.50	3	Scardia et al. (2002)
			0.007	3.49	0.037	3.62	3	This paper
22302+2228	HU	388	0.017	1.64	0.033	4.90	4	Cvetković & Olević (2005)
			0.007	0.50	0.034	3.54	4	This paper

Figure 2(d) with the later orbit by Heintz, as this orbit required no quadrant flips for the data. All these orbits give mass sums much higher than expected for a pair of early-A dwarfs, so something (spectral type, parallax, orbital elements) is still amiss.

WDS 03261+1229. This pair has completed just over one revolution since its discovery by Aitken (1904) a century ago. Although measures are fairly well distributed, the micrometry data for this close binary have too much scatter to define the orbit very well. Spectral types are G0 and K0, with an estimated mass sum of 1.8 $M_\odot$, nicely bracketed by the values predicted by the orbits of Olević & Jovanović (1.3 $M_\odot$) and us (2.3 $M_\odot$).

WDS 03362+4220. The northwest quadrant of this orbit is nicely defined by the interferometric data so far, but another 50 years' worth of data will be required before a full revolution is covered and the north/northeast portion of the orbit delineated. Spectral types are G5 and K0, giving a mass sum of about 1.7 $M_\odot$. Our predicted mass sum of 3.2 $M_\odot$ is slightly closer than that of Morel (3.4 $M_\odot$); it is unsure whether parallax or orbital elements is the source of this discrepancy.

WDS 03489+6445. The Heintz (1973b) orbit defined this pair quite well and has required only minor adjustment after 30+ years. Both orbits give reasonable mass sums for a pair of mid-F dwarfs.

WDS 04091+2839. This is another case of recent data showing a significant runoff from their predicted locations. This solution predicted a period only about half the solution by Heintz (1997). Both components appear to be of approximate spectral type F8V, with an expected mass sum of about 2.4 $M_\odot$. The Heintz orbit yields a too-small value of 1.3 $M_\odot$, while our orbit yields an overestimate of 3.6 $M_\odot$ (these values assume a parallax based on apparent magnitude and spectral type; the *Hipparcos* parallax for this pair yields masses about four times greater).

WDS 05247+6323. Some 175 years after its discovery by Struve (1837), this pair has yet to complete half a revolution. Given this, no prediction of masses is of any value; this solution should predict the relative motion of the pair pretty well for the next decade or two, however.

WDS 06345−1114. Heintz' (1979) solution ($P = 161.5$ yr) was published just as speckle interferometry was beginning to make a significant impact in the field of double star astrometry. Although his orbit gave a good fit to the measures available at that time, data obtained in recent years have deviated significantly from his prediction. Romero's (2007) orbit was published while this paper was in preparation. With a period of 382 yr, his orbit falls between the Heintz orbit and ours; it appears to fit the available data essentially as well as ours,

Table 5
Orbital Ephemerides

WDS designation	Discoverer designation		2008.0 θ	2008.0 ρ	2010.0 θ	2010.0 ρ	2012.0 θ	2012.0 ρ	2014.0 θ	2014.0 ρ	2016.0 θ	2016.0 ρ
00134+2659	STT	2 AB	161.4	0.392	159.7	0.397	158.0	0.403	156.3	0.408	154.7	0.413
01014+1155	BU	867	355.7	0.621	354.9	0.625	354.1	0.626	353.3	0.623	352.5	0.616
01437+0934	BU	509	52.9	0.701	50.8	0.732	48.8	0.760	47.0	0.786	45.4	0.809
01499+8053	STT	34	289.3	0.486	290.5	0.468	291.7	0.443	293.1	0.411	294.8	0.371
03261+1229	A	829	49.9	0.411	47.7	0.417	45.5	0.422	43.4	0.426	41.3	0.428
03362+4220	A	1535	338.5	0.726	340.2	0.726	341.8	0.725	343.5	0.722	345.1	0.718
03489+6445	STT	62	342.0	0.413	344.1	0.414	346.2	0.413	348.3	0.411	350.5	0.408
04091+2839	HO	326	290.5	0.403	292.3	0.403	294.1	0.401	295.9	0.399	297.7	0.396
05247+6323	STF	677	120.9	1.103	118.7	1.115	116.5	1.126	114.4	1.136	112.3	1.145
06345−1114	HO	234	358.4	0.597	359.8	0.613	1.0	0.629	2.2	0.645	3.3	0.661
06478+0020	STT	157	168.9	0.467	166.5	0.476	164.1	0.484	161.9	0.492	159.7	0.498
11520+4805	HU	731	308.9	1.095	308.6	1.118	308.3	1.140	308.0	1.162	307.7	1.182
14295+3612	HU	1268	342.5	0.276	340.3	0.287	338.3	0.296	336.4	0.306	334.6	0.314
15396+7959	STF	1989	23.8	0.631	23.4	0.627	22.9	0.623	22.5	0.618	22.0	0.613
15542+1659	A	2080	103.1	0.363	103.9	0.368	104.8	0.373	105.6	0.377	106.4	0.381
16366+6948	BU	953 AB	72.6	0.246	69.2	0.242	65.8	0.239	62.3	0.237	58.8	0.235
22302+2228	HU	388	58.7	0.522	59.3	0.529	59.9	0.537	60.4	0.544	61.0	0.551

although our most recent point suggests the orbit may not yet have begun to curve inward as Romero has predicted. Whichever orbit proves more accurate for the moment (all of us predict mass sums smaller than would be expected for a pair of F0 dwarfs), a couple more centuries' worth will be needed before this pair can be well defined!

WDS 06478+0020. Although designated as an Otto Struve discovery, this pair appears to have been first resolved by Mädler (1856) a year prior to Struve's first measurement in 1847 (Struve 1878). The designation is perhaps still appropriate, however, as Mädler's observation is quite discrepant. The stars have completed only half a revolution since these gentlemen first made their observations. The components are both early-A stars, with an expected mass sum of 4.9 $M_\odot$. The mass sums predicted by the orbits (6.5 $M_\odot$ for Heintz, 7.3 $M_\odot$ by us) are both too high.

WDS 11520+4805. The predicted period and semi-major axis of this pair continue to increase, from just over 100 years and 0″.4 (van den Bos 1959) to 195 years and 1″.1 (Ling 1986, 1992) and now 208 years and 1″.2. Most of the interferometric data fit the new orbit quite well, except for one early speckle measure by Bonneau et al. (1986). The stars are early-K dwarfs, with predicted mass sum 1.5 $M_\odot$. Both our orbit and that of Ling predict mass sums about three times larger.

WDS 14295+3612. The number of observations for this pair has more than doubled since the very preliminary solution by Erceg (1975). Our predicted mass sum (3.3 $M_\odot$) is much closer to the 2.7 $M_\odot$ expected for a pair of mid-F dwarfs than the 15 $M_\odot$ predicted by the earlier solution. However, coverage is still very sparse.

WDS 15396+7959. There is still a great deal of scatter in these data, which now cover one full revolution since the pair's discovery in 1832 (Struve 1837). Both the Scardia (2003) orbit and ours predict mass sums 2–3 times the expected value for an F2 + G0 pair (7.2 and 5.5 $M_\odot$, respectively, assuming the *Hipparcos* parallax); however, using a parallax based on apparent magnitude and spectral type, both yield masses that are far too low (0.4 and 0.3 $M_\odot$).

WDS 15542+1659. Although the orbit gives a reasonable fit to the data, the formal elemental errors are extremely large due to incomplete phase coverage. Both the Heintz (1988) orbit and ours yield unrealistically low mass sums, assuming either *Hipparcos* or spectroscopic parallax.

WDS 16366+6948. Only minor adjustment was needed to the Scardia et al. (2002) solution, due to increased runoff by the most recent interferometric data; the period increased by about 7%, *a* by 2%. This close pair constitutes two components of a system of at least six stars; the D component is similar in magnitude to AB and is also comprised of a subarcsecond pair. The position of D relative to AB has remained fixed at about 2′.5 and the same angle for 150 years; proper motions appear to be essentially the same, but it is unknown whether these two pairs can be considered to comprise a true common proper motion system. Both the C and E components are also very wide; the proper motion of E is rather different, while that of C is unknown.

WDS 22302+2228. Recent data appear to predict a much longer period and larger semi-major axis than the values calculated by Cvetković & Olević (2005). Our period is nearly 50% larger; determination of the true period (and any analysis of masses) must wait several decades, however.

4. CONCLUSIONS

We have presented an initial set of 353 speckle observations obtained at the Strand 61 inch reflector, as well as 17 improved orbital solutions based in part on some of these new data. The Strand telescope appears to be well suited to these types of observations, allowing us to resolve pairs a factor of 2 closer in separation than possible with the Clark 26 inch in Washington. While the Clark still maintains significant advantages as a local telescope dedicated solely to speckle work, the Flagstaff facility remains an attractive option for occasional observations of neglected closer binaries.

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