The Astronomical Journal, 127:539–548, 2004 January

SPECKLE INTERFEROMETRY AT THE US NAVAL OBSERVATORY. IX.

Brian D. Mason, William I. Hartkopf, Gary L. Wycoff, Dan Pascu, Sean E. Urban, David M. Hall, Greg S. Hennessy, Theodore J. Rafferty, Laura Flagg,[1] Dean Kang,[1] Paul Ries,[1] and Ellis Holdenried[2]
US Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC 20392-5420; bdm@usno.navy.mil
Received 2003 August 22; accepted 2003 September 24

ABSTRACT

The results of 3056 speckle interferometric observations of double stars, made with the 26 inch (66 cm) refractor of the US Naval Observatory, are presented. Each speckle interferometric observation of a system represents a combination of over a thousand short-exposure images. These observations are averaged into 1675 mean relative positions and range in separation from 0."19 to 45."21, with a median separation of 2."99. This is the ninth in a series of papers presenting measures obtained with this system and covers the period 2002 January 1 through 2002 December 29. Included in these data are 28 older measures whose positions were previously deemed possibly aberrant but are no longer classified this way following a confirming observation. Nine of these systems have new orbital elements, which are presented here as well.

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

On-line material: machine-readable table

1. INTRODUCTION

From 2002 January 1 through 2002 December 29, the 26 inch (66 cm) refractor of the US Naval Observatory was used on 138 of 308 scheduled nights (45%). The remaining nights were lost to marginal weather conditions. Not all nights were scheduled, as a consequence of either instrumental difficulties or the camera's being removed for other observing projects or runs. Further details describing the techniques and methodology of speckle interferometry are contained in the earlier papers in this series and references therein (most recently, Mason et al. 2002).

Individual nightly totals varied substantially (from two to 85 objects per night); these nights together yielded 3887 observations and 3056 resolutions. After removing marginal observations, calibration data, and tests, a total of 1757 measures remained (grouped into 1647 mean positions). Included in these are 197 confirmations of binaries with only one previous observation. While some of these are relatively recent discoveries of the *Hipparcos* or Tycho instruments (ESA 1997), some have remained unconfirmed for quite a while, including a discovery of John Herschel's from 1820! Also included in these data are 28 observations with the same USNO speckle camera system from earlier years (one from 2000 and 27 from 2001). These measures were not published, as they were significantly different from previous observations or orbital predictions; however, their positions have now been confirmed with new measures obtained in 2002. Some of these discrepancies reflect the prematurity of earlier orbit calculations; for nine of these systems we were able to obtain new elements that, although still premature, allow for better ephemerides to be published.

2. INSTRUMENTATION, OBSERVING LISTS, AND POSITIONS

The observing list was constructed using the same methodology discussed in Mason et al. (2002). Absolute calibration is determined by the use of a slit mask placed at the objective end of the telescope. Observation of a single star through this mask produces interference fringes that can then be used to determine spatial and angular calibration independently of any errors associated with using even "definitive" binaries.

3. RESULTS

While speckle interferometry has made significant progress in the discovery of new companions, or the first resolution of companions detected by other techniques, the pairs are frequently quite closely separated, often under 100 mas. Given the modest aperture of the telescope, it is certainly not ideal for the discovery of close companions, although it has confirmed the duplicity of many close binaries first detected from space. Table 1 presents those binaries that are resolved for the first time. These systems were usually found while searching for another pair or as an additional component to a known pair. Column (1) gives the coordinates of the primary of the pair. Column (2) is the discoverer designation, the WSI (Washington Speckle Interferometry) number. Columns (3) and (4) give the estimated magnitudes of the pair, while column (5) gives notes indicating the circumstance of the discovery. The mean double star positions (T, θ, and ρ) of these systems (all were observed two or more times) are given in Table 2.

Table 2 presents the mean relative positions of the members of 1481 systems having no orbital determination. The first two columns identify the system by providing the epoch 2000 coordinates and discoverer designation. The next three columns give the epoch of observation (expressed as fractional Besselian year), the position angle (in degrees), and the separation (in seconds of arc). Note that the position angle has not been corrected for precession and is thus based on the equinox for the epoch of observation. Objects whose measures are of lower quality are indicated by colons following the position angle and separation. These low-quality observations may be due to one or more of the following parameters: close separation, large Δm, one or both components too faint, a large zenith distance, and poor seeing or transparency. They are included primarily because of either the confirming nature

[1] Science and Engineering Apprenticeship Program (SEAP) intern.
[2] Retired.

TABLE 1
New WSI Pairs

Coordinates α, δ (2000) (1)	Discoverer Designation (2)	Mag_a (est.) (3)	Mag_b (est.) (4)	Note (5)
00 26 34.5, +30 10 42...........	WSI 19	10.3	11.0	1
04 07 48.0, +62 20 17...........	WSI 20 FQ	12.2	13.2	2
05 30 49.9, +39 13 32...........	WSI 21 AC	9.6	. . .	3
19 24 53.9, +21 26 29...........	WSI 22	10.3	10.5	4
21 24 42.9, +36 30 30...........	WSI 23 AC	11.0	12.2	5
21 51 22.7, +19 15 59...........	WSI 24	10.6	10.9	6

Notes.—(1) Serendipitously found while searching for COU 652. (2) New pair found while examining the complex system STF 484/485. The AQ and EQ pairings were also measured and are in Table 2. (3) New component to ES 2094; the precise coordinates are not certain but should be confirmed in 2003. The tertiary magnitude is unknown. (4) Serendipitously found while searching for STF 2515. (5) New component to ES 2126. (6) Serendipitously found while searching for STF 2834.

of the observation or the number of years since the last measured position. The sixth column indicates the number of observations contained in the mean, while the seventh flags any notes. While the sixth column reflects the number of measures, each measure comes from the combination of over 1000 short-exposure images, from which a single measure is obtained in autocorrelation space. The most common note indicators are either "C," indicating a confirming observation, or a number (N) indicating the number of years since the system was last measured. This is only given for systems with $N \geq 50$ yr. One hundred ninety-seven systems are here confirmed. Since priority is given both to unconfirmed systems and to systems not observed recently, the time since last observation can be surprisingly large; for the systems in Table 2, the average time since the last observation is 20 years. Fifteen have not been observed in 100 years or more, and HJ 467 was first resolved by John Herschel in 1820 (Herschel 1828, 1829). Of those confirmed, 92 are relatively recent: four from *Hipparcos* (ESA 1997), 85 from Tycho (Høg et al. 2000a, 2000b; Mason et al. 2000; Fabricius et al. 2002), and three discovered with the USNO speckle system last year (Mason et al. 2001a). Of the 1481 measures in Table 2 (i.e., systems without orbits), the median separation is 3.″16. Of these, most fall within a typical isoplanatic patch ($\rho < 4.''0$). However, 232 systems have separations between 4″ and 10″, 107 systems are between 10″ and 20″, 70 systems are between 20″ and 40″, and four systems have separations greater than 40″. All of these wider systems are outside a typical r_0 window within which interferometry would be expected to perform reliably. Indeed, in many of these cases the camera is functioning more as a fast-readout ICCD imager than a classical speckle interferometer. These wider (and therefore less optimal) systems were observed for typically three reasons: (1) to investigate the calibration parameters and repeatability of results outside the r_0 window; (2) to gather data on rectilinear systems that are currently under investigation (Hartkopf et al. 2004); and (3) finally, bright stars were observed, which are most useful for navigation purposes.

As a historical aside, several systems discovered with the USNO 26 inch in Washington were reobserved on the anniversary of their discovery. Careful perusal of all of the SKI doubles in the Washington Double Star Catalog will show that these new systems were first measured by a variety of observers: E. A. Boeger, Stimson Brown, H. L. Rice, and M. Fredrickson. However, all of them were first resolved with the 9 inch transit circle in the Washington zones by A. N. Skinner and subsequently added to the 26 inch and 12 inch observing lists (see Brown 1911; Fredrickson 1911). L. R. Wylie, in a study of proper motion, inferred a close double with a period less than 100 years. This pair was resolved first by H. Burton and then later by Wylie as well (Burton et al. 1947). It was decided to give it a WNO (Washington Naval Observatory) code to indicate the collaborative effort. Other systems resolved first by Worley (1972) and Josties et al. (1974) on the USNO 26 inch telescope are here resolved as well.

The system at 04078+6220, listed in Table 2, is rather complex. It has had numerous identification errors due to various difficulties. We have made an attempt to reconcile the

TABLE 2
Speckle Interferometric Measurements of Double Stars

WDS Designation α, δ (2000)	Discoverer Designation	Epoch (2000+)	θ (deg)	ρ (arcsec)	n	Notes
00012+1357	WNO 12	2.701	204.2	11.47	1	1
00026+6606	STF 3053 AB	2.747	70.5	14.95	1	
00029+2844	MLB 509	2.712	325.1	3.28	1	
00029+4715	A 800	2.712	291.3	1.65	1	
00039+2759	HJ 1929 AB-C	2.962	287.7	5.15	4	

Notes.—(C) Confirming observation. (L) Linear elements determined (see Hartkopf et al. 2004). (1) This pair, first resolved with the 26 inch on 1974 August 11 (Josties et al. 1974), was confirmed on this date in 2002. (N = 50–181) Number of years since last measure. Table 2 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content.

TABLE 3

Speckle Interferometric Measurements and Residuals to Systems with Orbits

WDS Designation α, δ (2000) (1)	Discoverer Designation (2)	Epoch (2000+) (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	$O-C$ (deg) (7)	$O-C$ (arcsec) (8)	Reference (9)	Notes (10)
00014+3937	HLD 60	2.924	170.2	1.27	1	−2.6	0.06	Heintz 1963	
00057+4549	STT 547 AB	2.559	182.9	6.02	1	−0.3	0.05	Popović & Pavlović 1996	*
00063+5826	STF 3062	2.690	333.9	1.49	1	0.8	−0.03	Söderhjelm 1999	
00093+7943	STF 2	1.759	20.1	0.71	2	1.8	−0.09	Heintz 1997	1
		2.690	18.7	0.78	3	0.6	−0.03	Heintz 1997	
00210+6740	HJ 1018	1.759	87.3	1.55	1	−0.3	−0.19	Söderhjelm 1999	1
		2.963	88.6	1.54	1	1.0	−0.21	Söderhjelm 1999	
00214+6700	STT 6 AB	2.856	158.8	0.58	1	5.0	−0.02	Olević & Jovanović 2001	
00318+5431	STT 12	1.778	195.9	0.35	2	1.0	−0.10	Heintz 1995	1
		2.690	199.1	0.36	1	1.6	−0.08	Heintz 1995	
00424+0410	STT 18 AB	2.788	203.7	1.90	1	−1.4	−0.01	Hartkopf & Mason 2001b	
00504+5038	BU 232 AB	2.925	247.6	0.84	1	−3.8	0.04	Starikova 1985	
00550+2338	STF 73 AB	2.690	312.8	0.92	3	−0.2	−0.02	Docobo & Costa 1990b	
00568+6022	BU 1099 AB	2.690	356.2	0.29	1	2.5	−0.01	Cole et al. 1992	
01030+4723	STT 21	2.834	173.7	1.15	2	−1.8	0.09	Heintz 1966	
01512+2439	HO 311	2.854	169.7	0.30	1	0.7	0.02	Hartkopf, McAlister, & Franz 1989	
01559+0151	STF 186	2.760	60.4	0.91	4	−4.6	−0.03	de Freitas Mourão 1977	
02020+0246	STF 202 AB	2.914	270.7	1.76	5	1.1	−0.05	Scardia 1983	*
02140+4729	STF 228	2.951	284.4	0.90	4	−0.7	−0.07	Söderhjelm 1999	
02257+6133	STF 257	2.963	70.9	0.36	1	6.2	−0.06	Zaera 1985	
02291+6724	STF 262 Aa-B	1.846	230.3	2.78	1	−0.4	0.21	Heintz 1996a	1
		2.996	230.5	2.81	1	0.0	0.23	Heintz 1996a	
02407+2637	STT 43	2.963	355.8	0.71	1	4.1	−0.01	Scardia et al. 2001a	
02475+1922	STF 305 AB	2.925	308.2	3.62	1	1.3	−0.09	Rabe 1961	
03054+2515	STF 346 AB	2.835	255.1	0.36	1	0.6	−0.05	Heintz 1981b	
03122+3713	STF 360	1.844	126.6	2.77	1	0.7	−0.01	See Table 5	L, 2
		2.962	126.0	2.78	2	0.1	−0.01	See Table 5	
03127+7133	STT 50 AB	2.963	155.1	1.05	1	0.3	0.05	Scardia et al. 2001b	
03140+0044	STF 367	2.963	136.0	1.13	1	3.3	0.02	Heintz 1963	
03344+2428	STF 412 AB	2.835	355.7	0.65	3	−0.2	−0.05	Scardia et al. 2002a	
03350+6002	STF 400 AB	2.887	265.8	1.43	1	−0.4	−0.01	Seymour & Mason 2000a	
03368+0035	STF 422	2.897	270.1	6.68	3	−0.1	0.00	Hopmann 1964	*
04100+8042	STF 460	1.844	133.6	0.77	1	−2.7	0.15	Baize 1958	1
		2.887	133.7	0.72	3	−4.2	0.10	Baize 1958	
04159+3142	STT 77 AB	2.925	282.8	0.62	1	−5.4	0.01	Starikova 1985	
04227+1503	STT 82 AB	1.860	342.2	1.29	2	−0.1	−0.00	See Table 5	3
		2.925	342.0	1.26	1	0.6	−0.03	See Table 5	
04233+1123	STF 535	2.152	279.0	1.11	1	0.9	−0.01	Hartkopf & Mason 2000	*
04367+1930	STF 567	2.152	341.6	2.08	1	0.9	0.04	Seymour et al. 2002	
04422+3731	STF 577	1.989	356.3	0.74	1	1.4	−0.05	See Table 5	3
		2.136	355.6	0.77	1	0.9	−0.01	See Table 5	
04433+5931	A 1013	2.906	283.7	0.32	2	−3.7	−0.01	Docobo & Costa 1990a	
05005+0506	STT 93	2.152	244.3	1.40	1	−0.5	0.01	Seymour & Mason 1999	*
05055+1948	STT 95	2.136	299.6	0.91	1	0.4	−0.04	Jasinta 1996	
05079+0830	STT 98	2.136	316.4	0.73	2	0.4	−0.08	Baize 1969	
05135+0158	STT 517 AB	2.152	238.4	0.61	1	−1.1	−0.01	Mason, Douglass, & Hartkopf 1999	
05255−0033	A 848	2.136	170.1	0.27	1	−14.1	0.02	Baize 1981	
05308+0557	STF 728	2.082	45.3	1.13	2	−0.5	−0.06	Seymour & Hartkopf 1999	
05364+2200	STF 742	2.136	272.8	4.02	1	−1.1	−0.08	Hopmann 1973	
06344+1445	STF 932	2.153	307.2	1.66	1	2.8	−0.02	Hopmann 1960	
06555+3010	STF 981	2.153	308.8	1.24	1	5.8	0.00	Hopmann 1971	
07012+1146	STT 163 AB	2.153	103.0	0.25	1	0.7	0.07	Zulević 1996	
07294−1500	STF 1104 AB	1.285	24.8	1.88	1	−2.2	0.04	See Table 5	3
		2.166	27.1	1.87	2	−0.6	0.04	See Table 5	
07346+3153	STF 1110 AB	2.207	63.4	3.99	2	0.6	−0.05	Docobo & Costa 1985	
08061−0047	A 1971	2.153	9.6	0.81	1	3.5	−0.08	Olević et al. 1993	
08095+3213	STF 1187 Aa-B	1.241	22.9	3.00	2	0.3	0.10	Olević & Jovanović 2001	1
		2.175	23.5	3.02	1	1.0	0.12	Olević & Jovanović 2001	
08122+1739	STF 1196 AB	2.251	72.1	0.87	3	2.0	−0.01	Söderhjelm 1999	
	STF 1196 AB-C	2.519	72.8	5.91	2	1.1	0.01	Heintz 1996a	*
09179+2834	STF 3121 AB	2.167	199.8	0.78	2	2.2	−0.01	Söderhjelm 1999	
09210+3811	STF 1338 AB	2.167	289.3	1.01	3	−1.4	−0.01	Scardia et al. 2002b	
09525−0806	AC 5 AB	2.292	58.8	0.53	3	0.8	−0.08	Heintz 1982	
10131+2725	STT 213	2.260	124.2	1.02	3	4.2	0.02	Heintz 1962	

WDS Designation α, δ (2000) (1)	Discoverer Designation (2)	Epoch (2000+) (3)	θ (deg) (4)	ρ (arcsec) (5)	*n* (6)	*O*−*C* (deg) (7)	*O*−*C* (arcsec) (8)	Reference (9)	Notes (10)
10192+2034	STF 1423	1.287	346.2	0.71	3	−1.5	−0.19	See Table 5	3
		2.234	342.0	0.70	5	−4.5	−0.20	See Table 5	
10292+1009	STT 220	2.270	95.0	0.57	3	−11.8	0.07	Seymour et al. 2002	
10480+4107	STT 229	2.284	268.4	0.68	2	−0.9	−0.02	Alzner 1998b	
11182+3132..........	STF 1523 AB	2.242	261.4	1.77	4	−0.3	−0.05	Mason et al. 1995	*
11308+4117..........	STT 234	2.314	163.4	0.47	1	1.4	−0.03	Docobo & Ling 2001	
11363+2747	STF 1555 AB	1.236	148.4	0.69	1	2.0	−0.15	Costa & Docobo 1983	L, 1
		2.164	147.7	0.69	1	1.2	−0.16	Costa & Docobo 1983	
11390+4109	STT 237	2.167	245.0	1.95	2	−0.9	−0.02	Seymour et al. 2002	
12108+3953	STF 1606	2.224	171.2	0.34	1	−0.7	−0.02	Mason et al. 1999	
12244+2535	STF 1639 AB	1.228	325.8	1.58	1	1.3	−0.14	Olević & Popović 2000	1
		2.191	325.5	1.60	1	1.1	−0.12	Olević & Popović 2000	
12272+2701	STF 1643	1.228	7.1	2.71	1	−0.3	0.05	See Table 5	L, 2
		2.191	7.7	2.71	1	0.3	0.05	See Table 5	
12291+3123	STT 251	2.303	57.4	0.64	4	−1.1	−0.03	Baize 1957	
12306+0943	STF 1647	2.140	245.0	1.32	2	−2.8	0.04	Hopmann 1970	*
12417−0127	STF 1670 AB	2.252	244.6	1.02	3	−0.7	−0.02	Söderhjelm 1999	
13235+2914	HO 260	1.310	82.6	1.49	1	0.7	0.02	See Table 5	3
		2.292	83.7	1.46	2	1.4	−0.02	See Table 5	
13237−0043	A 2489	1.354	192.7	0.81	6	0.6	−0.02	See Table 5	3
		2.292	192.3	0.82	3	0.3	−0.02	See Table 5	
13328+1649	VYS 6	2.318	45.9	2.89	2	−0.2	−0.08	Heintz 1990	
13329+3454	STT 269 AB	2.292	215.2	0.28	1	−2.5	0.02	Heintz 1997	
13343−0019	STF 1757 AB	2.252	127.4	1.90	1	−0.1	−0.08	Heintz 1988	
13347−1313	BU 932 AB	2.292	58.8	0.38	1	0.4	−0.02	Starikova 1980	
13461+0507	STF 1781	2.366	181.2	0.78	4	3.6	0.00	Heintz 1986a	
13491+2659	STF 1785	2.252	174.4	3.29	1	−0.5	0.01	Heintz 1988	
13550−0804	STF 1788 AB	1.285	98.4	3.62	1	0.5	0.11	Hopmann 1970	1
		2.252	98.2	3.61	1	0.2	0.10	Hopmann 1970	
13577+5200	A 1614	2.292	123.7	1.32	2	−1.8	−0.08	Heintz 2001	
14024+4620	SWI 1	2.292	23.6	3.74	1	−0.6	0.08	Seymour et al. 2002	
14131+5520	STF 1820	2.252	118.1	2.66	1	−0.1	0.08	Kiyaeva, Tokovinin, & Kalinichenko 1998	*
14153+0308	STF 1819	2.363	193.6	0.88	4	−1.7	0.00	Houser 1987	
14203+4830	STF 1834	2.252	102.1	1.51	1	−1.1	0.02	Seymour & Mason 2000b	
14323+2641	A 570	2.387	109.2	0.23	2	−5.0	0.02	Heintz 1991	
14411+1344	STF 1865 AB	2.345	299.0	0.70	2	0.1	−0.05	Wierzbinski 1956	
14455+4223	STT 285 AB	2.463	101.0	0.43	2	−0.2	−0.03	Couteau 1973	
14463+0939	STF 1879 AB	2.494	84.8	1.71	5	−0.7	0.01	Mason et al. 1999	
14464−0723	STF 1876 AB	2.372	109.2	1.29	2	0.7	0.01	Seymour et al. 2002	
14515+4456	STT 287	1.359	355.8	0.77	1	2.1	−0.10	Heintz 1997	1
		2.388	354.4	0.81	1	0.2	−0.05	Heintz 1997	
14534+1542	STT 288	2.345	164.5	1.16	2	−0.4	−0.02	Heintz 1998	
15160−0454	STF 3091 AB	2.372	229.5	0.57	3	2.7	−0.01	Mason & Hartkopf 1999	
15183+2650	STF 1932 Aa-B	2.372	260.3	1.57	2	−0.1	−0.04	Heintz 1965	
15232+3017	STF 1937 AB	2.372	80.7	0.57	3	−1.3	−0.02	Mason et al. 1999	
15245+3723	STF 1938 BC	2.372	7.9	2.26	1	0.0	0.02	Söderhjelm 1999	
15348+1032	STF 1954 AB	1.326	173.3	3.99	1	−0.5	−0.02	See Table 5	3
		2.455	173.7	4.02	2	0.1	0.02	See Table 5	
15360+3948	STT 298 AB	2.388	163.2	0.67	1	−0.8	−0.01	Söderhjelm 1999	
15559−0210	STF 1985	2.551	352.4	5.99	4	−0.7	−0.24	Hopmann 1973	
16044−1122.........	STF 1998 AB	2.435	327.2	0.49	2	−1.9	−0.06	Söderhjelm 1999	
16137+4638	A 1642	2.499	184.1	0.67	6	−0.1	−0.01	Hartkopf & Mason 2001b	
16147+3352	STF 2032 AB	2.540	236.2	7.00	4	−0.1	−0.06	Scardia 1979	*
16160+0721	STF 2026	2.386	18.7	3.31	1	−0.5	0.02	Heintz 1963	*
16289+1825	STF 2052 AB	2.386	122.9	2.04	2	−0.3	0.01	Söderhjelm 1999	
16309+0159	STF 2055 AB	2.389	29.9	1.38	1	−1.1	−0.07	Heintz & Strom 1993	
16511+0924	STF 2106	2.407	173.8	0.66	2	−0.3	−0.04	Scardia et al. 2001b	
16564+6502	STF 2118 AB	1.343	67.2	1.08	1	−0.7	−0.08	Scardia et al. 2002c	1
		2.407	67.5	1.06	2	−0.3	−0.10	Scardia et al. 2002c	
17053+5428	STF 2130 AB	2.372	16.3	2.26	1	1.4	0.02	Heintz 1981a	*
17066+0039	BU 823 AB	2.482	153.1	0.96	3	−2.6	0.03	Hartkopf & Mason 2000	
17104−1544	BU 1118 AB	2.443	240.5	0.53	1	0.1	−0.04	Docobo & Ling 1997	
17240+3835	HU 1179	2.509	271.5	0.25	1	−2.7	0.01	Hartkopf 2000	
17386+5546	STF 2199	2.443	57.2	1.99	1	1.0	0.08	Popović & Pavlović 1995	*
17400−0038	BU 631	2.542	97.4	0.23	5	6.3	−0.01	Heintz 1996c	

TABLE 3—*Continued*

WDS Designation α, δ (2000) (1)	Discoverer Designation (2)	Epoch (2000+) (3)	θ (deg) (4)	ρ (arcsec) (5)	*n* (6)	*O*−*C* (deg) (7)	*O*−*C* (arcsec) (8)	Reference (9)	Notes (10)
17457+1743	STF 2205	1.417	354.4	1.17	2	2.8	−0.10	Popović & Pavlović 1995	1
		2.491	354.5	1.17	2	2.1	−0.09	Popović & Pavlović 1995	
17471+1742	STF 2215	2.509	256.8	0.51	1	−1.0	−0.06	Popović & Pavlović 1995	
17571+0004	STF 2244	2.509	97.1	0.54	1	−1.1	0.02	Heintz 1997	
18055+0230	STF 2272 AB	2.423	142.2	4.34	3	−0.8	0.02	Pourbaix 2000	*, 4
		2.498	142.0	4.30	7	−0.8	−0.04	Pourbaix 2000	
		2.599	141.9	4.35	11	−0.7	−0.01	Pourbaix 2000	
		2.716	142.5	4.39	1	0.1	0.00	Pourbaix 2000	
18097+5024	HU 674	2.528	218.6	0.71	2	0.4	0.04	Seymour et al. 2002	
18101+1629	STF 2289	2.408	219.5	1.22	2	2.0	−0.02	Hopmann 1964	
18146+0011	STF 2294	2.509	93.0	1.26	2	−0.4	0.08	Luyten 1934	
18250−0135	AC 11	2.408	355.8	0.85	1	0.8	−0.01	Heintz 1995	
18339+5221	A 1377 AB	2.574	112.4	0.22	1	−7.3	−0.03	Scardia 1984	
18355+2336	STT 359	2.460	6.6	0.66	3	1.1	−0.05	Symms 1964	
18359+1659	STT 358 AB	2.408	153.9	1.66	2	0.7	0.08	Heintz 1995	
18374+7741	STT 363	2.581	337.8	0.36	3	−9.2	−0.03	Alzner 1998b	
18413+3018	STF 2367 AB	2.550	80.7	0.32	3	3.5	−0.02	Pourbaix 2000	
18428+5938	STF 2398 AB	2.389	174.2	12.38	1	−0.3	−0.03	Heintz 1987	*
18443+3940	STF 2383 Cc-D	2.400	81.6	2.31	2	0.2	−0.04	Docobo & Costa 1984	*
18575+5814	STF 2438	2.580	359.9	0.83	2	0.4	−0.01	Hartkopf & Mason 2001a	
19062+3026	STF 2454 AB	2.564	287.5	1.34	4	−0.1	0.03	Starikova 1982	
19110−0726.........	A 95	2.672	43.3	0.29	2	−4.5	0.03	Heintz 1996b	
19121+4951	STF 2486 AB	2.589	206.0	7.40	5	−0.1	−0.07	Hale 1994	*
19143+1904	STF 2484	1.417	240.8	2.20	1	2.8	−0.10	Hopmann 1973	1
		2.575	238.7	2.12	2	0.5	−0.18	Hopmann 1973	
19216+5223	BU 1129	2.607	351.6	0.26	2	6.6	−0.01	Baize 1984	
19266+2719	STF 2525	2.682	290.1	2.07	11	−0.5	0.03	Heintz 1984a	*
19282−1209	SCJ 22	2.594	264.1	0.77	1	−5.4	−0.01	Heintz 1988	
19456+3337	STF 2576 AB	2.463	162.7	2.75	1	−0.1	0.00	Söderhjelm 1999	
19487+3519	STT 387	1.764	137.5	0.52	2	−3.8	−0.12	Heintz 1996c	1
		2.558	135.9	0.56	2	−4.3	−0.08	Heintz 1996c	
19520−1021	BU 148 AB	1.731	230.3	0.68	2	12.4	0.19	Popović 1983	1
		2.602	236.0	0.64	3	19.5	0.15	Popović 1983	
20014+1045	STF 2613	1.706	355.0	3.77	1	3.2	−0.42	Hopmann 1973	1
		2.558	354.2	3.68	2	2.3	−0.51	Hopmann 1973	
20289−1749	SHJ 323 AB	2.644	193.6	1.34	4	1.1	−0.07	Heintz 1986b	
20375+1436	BU 151 AB	2.531	352.3	0.54	1	0.7	−0.05	Alzner 1998b	
20462+1554	STF 2725	2.564	10.6	6.04	3	−0.3	−0.05	Hopmann 1973	*
20467+1607	STF 2727	2.682	265.7	9.15	13	0.0	−0.07	Hale 1994	*
20514−0538	STF 2729 AB	2.602	21.4	0.90	3	−0.2	0.04	Heintz 1998	
20519+0544	A 613	2.673	327.8	0.68	1	0.4	0.01	Seymour et al. 2002	
21031+0132	STF 2744 AB	2.561	117.2	1.25	5	5.2	0.02	Popović 1969	
						0.9	0.20	Hopmann 1960	
21080+0509	STT 527	2.613	123.1	0.29	1	7.9	−0.04	Popović & Pavlović 1995	
21289+1105	STF 2799 AB	2.558	263.1	1.80	2	2.0	0.08	Popović 1987	
21555+1053	BU 75 AB	2.575	18.5	0.80	3	0.4	−0.05	Heintz 1996c	
22086+5917	STF 2872 BC	2.575	299.2	0.80	1	−0.1	−0.02	Seymour et al. 2002	
22241−0450	BU 172 AB	2.689	56.3	0.33	1	4.9	−0.01	Heintz 1996c	
22266−1645	SHJ 345 AB	2.558	12.1	1.51	2	−0.5	−0.06	Hale 1994	*
22280+5742	KR 60 AB	2.528	82.8	2.79	1	−0.2	−0.02	Heintz 1986b	4
		2.806	80.6	2.73	2	−0.9	−0.05	Heintz 1986b	
		2.889	80.5	2.78	1	−0.6	0.01	Heintz 1986b	
22288−0001	STF 2909	2.531	183.6	1.97	1	2.0	−0.03	Heintz 1984c	
22400+0113	A 2099	2.889	160.0	0.69	1	−2.7	−0.02	Docobo & Ling 1997	
22514+2623	HO 482 AB	2.769	25.8	0.48	1	6.0	0.01	Starikova 1982	
22557+1547	HU 987	2.750	79.7	1.02	2	−1.5	0.06	Heintz 1984b	
23088+1058	A 1238 AB	2.700	139.5	0.31	1	2.5	0.00	Scardia et al. 2001b	
23340+3120	BU 720	2.608	95.2	0.52	1	−2.9	−0.01	Starikova 1982	
23431+1150	A 1242	1.731	335.5	0.96	1	−2.2	0.22	Zulević 1977	1
		2.750	335.2	0.93	1	−3.1	0.19	Zulević 1977	
23487+6453	STT 507 AB	2.690	316.0	0.71	3	3.2	−0.02	Zulević 1977	
23595+3343	STF 3050 AB	2.668	330.8	2.08	12	0.8	0.06	Starikova 1977	*

NOTES.—(*) System used in characterizing errors. (L) Linear elements determined (see Hartkopf et al. 2004). (1) This measure was inconsistent with previous measures and so was not included in Mason et al. 2001a. However, available data are deemed insufficient for a new orbital calculation at this time. (2) This measure was inconsistent with previous measures and so was not included in Mason et al. 2001a. The new orbit is listed in Table 5, ephemerides based on these elements are listed in Table 6, and the orbit is illustrated in Fig. 1. However, linear elements may prove to be a more accurate representation of the motion of this pair. (3) This measure was inconsistent with previous measures and so was not included in Mason et al. 2001a. The new orbit is listed in Table 5, ephemerides based on these elements are listed in Table 6, and the orbit is illustrated in Fig. 1 or Fig. 2. (4) This system was expected to show significant motion over the calendar year, so multiple observations have been obtained.

TABLE 4
BINARIES NOT FOUND

Coordinate α, δ (2000)	Discoverer Designation	Observation Date	Published		Magnitude	
			P.A. (θ)	Separation (ρ)	Primary	Secondary
01556+0335	BAL 2096	1910	24	2.6	9.0	10.8
04576+0344	BAL 2132	1910	290	2.9	10.2	11.1
05330+2646	TDS 3233	1991	0	2.4	11.3	11.7
06149−1956	TDS 3662	1991	131	2.0	10.5	12.5
06580−0802	TDS 4331	1991	68	1.4	10.4	11.4
06593−0822	TDS 310	1991	66	1.3	10.5	11.6
07022−0817	TDS 4403	1991	102	2.6	10.8	12.4
07241−0825	TDS 4769	1991	175	2.4	10.2	11.4
07304+1352	STF 1102 AD	1983	131	1.0	8.5	8.5
08161−1959.........	TDS 5661	1991	66	1.8	10.9	11.7
08274−1523	TDS 5836	1991	163	1.6	10.3	12.3
08460+2725	BRT 152	1899	31	3.5	11.2	11.6
09564+1040	STF 1396 AC	1895	276	3.8	8.6	10.9
12490+7207	TDS 676	1991	337	2.0	10.6	12.3
13039+3724	TDS 8673	1991	253	1.3	10.4	12.2
14007+7057	TDS 9069	1991	18	2.7	11.5	12.3
14158+0421	BAL 2860	1910	208	2.3	11.0	11.4
14237−0657	BRT 453	1910	140	2.7	9.6	9.6
14312−1959	ARA 698	1917	289	3.9	8.9	10.6
14497+1710	TDS 9317	1991	141	2.3	11.0	12.0
14560−0422	BRT 456	1893	181	2.9	9.6	10.1
15421−0741	TDS 9595	1991	270	2.1	10.7	12.0
15580+0143	BAL 1909	1990	224	3.5	11.2	11.7
16255+2050	TDS 9890	1991	204	2.4	10.5	12.5
16450+1128	BRT 3316	1911	109	3.3	10.6	10.8
16452+6406	TDT 68	1991	201	1.5	10.8	12.1
16570+6835	TDS 845	1991	131	1.6	10.6	12.0
17078+0256	HEI 861	1992	75	2.3	10.5	11.5
17125+2341	POU 3261	1892	222	3.5	11.1	11.6
17191+5341	FUR 1 AB	1910	153	3.9	8.0	10.5
	FUR 1 BC	1910	144	1.8	10.5	11.0
17230+0157	J 3211	1947	149	3.4	11.0	12.0
17320+0249	BU 1538 DE	1903	166	2.6	11.5	11.5
17429+2019	COU 29	1963	195	2.3	11.5	11.5
18334+3727	ES 2481	1931	155	3.5	10.5	11.0
18449+1606	HEI 173	1980	309	3.2	11.0	11.2
19410+0925	TDT 1630	1991	16	2.5	11.1	11.1
19423+2104	TDT 1657	1991	226	2.4	9.9	12.2
19542+1605	J 3029	1944	175	3.0	10.6	10.6
19552+1154	OL 93	1921	160	1.5	9.8	11.2
20129+2238	J 2305	1942	190	3.0	9.7	10.2
20257+2258	BRT 2474	1892	103	3.3	11.4	11.8
20525−0438	TDS 1106	1991	252	1.4	9.9	11.5
21017−0552	TDS 1111	1991	51	1.3	10.5	11.7
21271+2305	POU 5372	1891	96	3.3	9.7	11.1
21321+2605	TDT 3013	1991	240	2.1	10.6	11.4
22045−1239	BRT 2789	1901	61	3.9	10.8	11.1
22124+3833	TDT 3403	1991	58	1.9	10.9	12.0
22266+0858	TDT 3525	1991	232	1.4	10.7	12.4
22302+4058	ES 1696 BC	1917	141	2.3	11.3	11.7
22323+5228	TDT 3576	1991	113	1.5	10.9	12.0
22425+3230	TDT 3665	1991	5	2.6	10.7	12.2
22506−0655	TDT 3744	1991	87	2.5	10.9	11.7
23228+3943	TDT 4008	1991	252	2.0	11.4	12.3

various difficulties and provide a more consistent nomenclature for the many components. The diagram provided by Lewis (1906) in his catalog of the Struve pairs seemed a good first step but was hampered by the quadrant error of the pair he designated Ca. This quadrant error was repeated in the ADS (Aitken & Doolittle 1932), IDS (Jeffers & van den Bos 1963), and earlier editions of the WDS (most recently, Mason et al. 2001b). In the ADS (where this pair is listed as No. 2984, although No. 2989 is part of this system, too) the errors multiplied. The pair Holmes AF (WDS designation HLM 3 AF) is apparently the same as STF 485 Ac. Inspection of scanned images of this region of the sky have allowed the Hertzsprung

TABLE 5

New Orbital Elements

WDS Designation α, δ (2000)	Discoverer Designation	P (yr)	a (arcsec)	i (deg)	Ω (deg)	T_0 (yr)	e	ω (deg)	Grade[a]
03122+3713	STF 360	871	3.66	98	111	1454	0.71	105	5
04227+1503	STT 82 AB	241	1.16	135	194	1891	0.26	49	3
04422+3731	STF 577	329	1.28	138	161	2024	0.65	259	4
07294−1500	STF 1104 AB	686	3.59	59	221	2038	0.68	246	5
10192+2034	STF 1423	258	1.01	145	251	2039	0.49	19	4
12272+2701	STF 1643	1628	3.72	123	156	2050	0.09	145	4
13235+2914	HO 260	1189	3.93	71	307	1889	0.83	327	4
13237−0043	A 2489	499	1.35	95	183	1905	0.80	142	5
15348+1032	STF 1954 AB	1038	3.83	111	171	2290	0.16	110	4

[a] For an explanation of orbit grading, see Hartkopf et al. 2001.

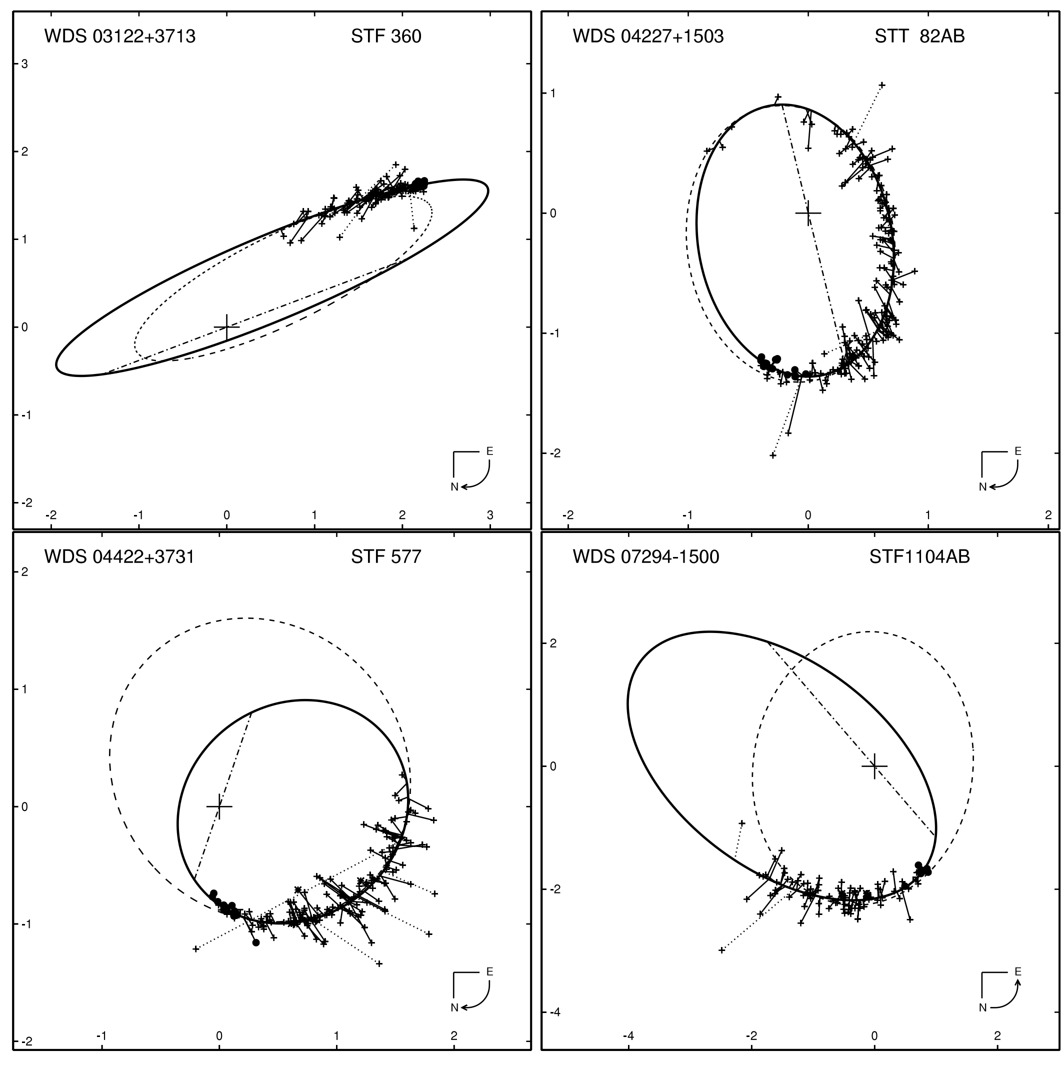

Fig. 1.—Relative visual orbits for WDS 03122+3713, 04227+1503, 04422+3731, and 07294−1500; the x and y scales are in arcseconds. The solid curves represent the newly determined orbital elements, while the dashed curves represent previously published orbital elements. The previous calculations are cited in Hopmann (1965; 03122+3713), Heintz (1969; 04227+1503), Heintz (1998; 04422+3731), and Olević & Jovanović (2001; 07294−1500). The dot-dashed lines indicate the line of nodes. Interferometric measures are shown as filled circles, and visual measures as small plus signs. Measures from the ESA *Hipparcos* or Tycho instrument are indicated by an "H" or "T," respectively. All measures are connected to their predicted positions on the new orbit by "$O-C$" lines, where dotted $O-C$ lines indicate measures given zero weight in the final solution. The direction of motion is indicated on the northeast orientation in the lower right of each plot.

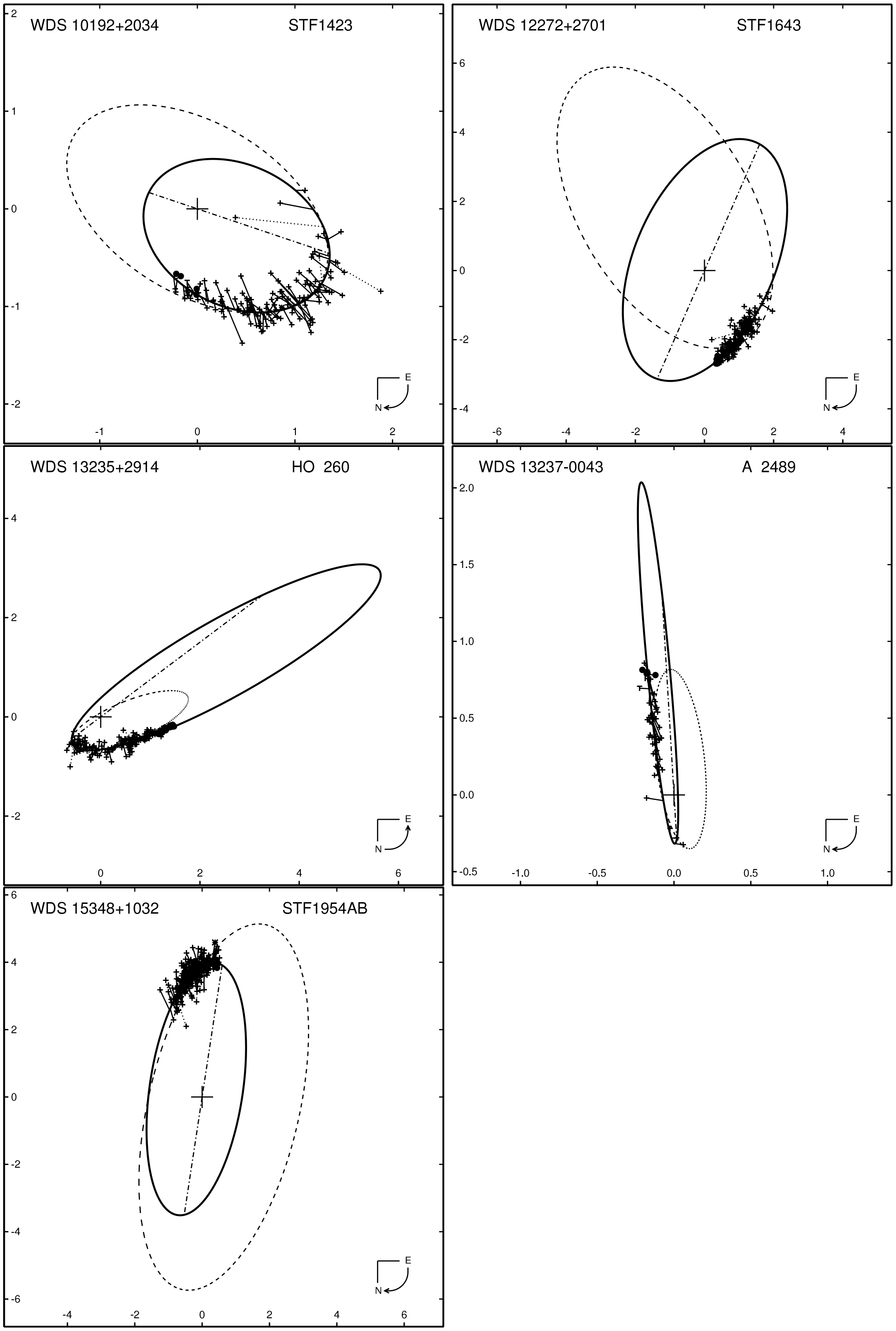

FIG. 2.—Same as as Fig. 1, but for WDS 10192+2034, 12272+2701, 13235+2914, 13237−0043, and 15348+1032. The previous calculations are cited in Heintz (1997; 10192+2034), Hopmann (1964; 12272+2701), Ambruster (1978; 13235+2914), Alzner (1998a; 13237−0043), and Hopmann (1973; 15348+1032).

TABLE 6
EPHEMERIDES FOR BINARIES WITH NEW ORBITAL ELEMENTS

WDS Designation α, δ (2000)	DISCOVERER DESIGNATION	2003 θ (deg)	2003 ρ (arcsec)	2005 θ (deg)	2005 ρ (arcsec)	2007 θ (deg)	2007 ρ (arcsec)	2009 θ (deg)	2009 ρ (arcsec)	2011 θ (deg)	2011 ρ (arcsec)
03122+3713	STF 360	125.9	2.783	125.7	2.797	125.6	2.811	125.5	2.825	125.3	2.839
04227+1503	STT 82 AB	341.3	1.286	339.6	1.274	337.9	1.262	336.2	1.249	334.4	1.235
04422+3731	STF 577	353.2	0.770	349.6	0.736	345.7	0.699	341.3	0.660	336.3	0.617
07294−1500	STF 1104 AB	28.6	1.805	30.2	1.772	31.8	1.736	33.6	1.697	35.4	1.654
10192+2034	STF 1423	339.7	0.802	335.9	0.715	331.8	0.695	327.5	0.677	322.9	0.659
12272+2701	STF 1643	7.0	2.668	6.5	2.681	6.1	2.695	5.6	2.708	5.2	2.721
13235+2914	HO 260	82.6	1.497	83.3	1.530	84.0	1.563	84.7	1.596	85.3	1.629
13237−0043	A 2489	191.9	0.844	191.8	0.866	191.6	0.888	191.4	0.910	191.3	0.932
15348+1032	STF 1954 AB	173.6	4.005	173.4	4.002	173.2	3.999	173.0	3.995	172.7	3.991

pairs (HZG 2), whose components are given within quotation marks in the ADS, to be identified. Of the HZG pairs, the "CD" pairing is the same as STF 484 AC and the "CE" pairing is the same as STF 484 AB. The ADS note to the "AJ" pairing of HZG 2 is a typo. The correct position angle is 77°, which corresponds to the AD (now AO) pair. In the midst of the investigation of this complex system, a new pair, WSI 20 FQ, which does not appear to have been previously measured, was resolved. This pair is listed in Tables 1 and 2.

Thirty-five of the systems in Table 2 have an "L" code in the notes column. These are pairs for which linear elements have been determined. A complete analysis of all linear systems is currently in preparation (Hartkopf et al. 2004). While some of these systems may indeed be orbit systems (with extremely long periods, observations of highly eccentric orbits made near apastron, or both), they are likely optical doubles.

Table 3 presents the mean relative positions for 190 double star systems with published orbital determinations. The first six columns are identical to the corresponding columns of Table 2. Columns (7) and (8) give $O-C$ orbit residuals (in θ and ρ) to the orbit referenced in column (9). These and other systems having notes are designated in column (10). The objects in Table 3 tend to be closer pairs than those in Table 2, with a median separation of 1″.05. Wider orbit systems were also observed, but only a few ($N = 15$) had separations greater than 4″.0.

As mentioned in § 2, absolute calibration is determined by means of a slit mask placed in front of the primary. Since absolute calibration is done in this manner, binaries with well-characterized motion can be used to approximate errors. Binaries on the calibration orbit list[3] were again selected. Many of those resolvable are too close to the resolution limit of the 26 inch telescope to be of adequate value. Further, two of the wider systems are beginning to show evidence that their motion is not suitable for calibration. Of the remaining measures ($N = 25$), mean errors are 0°.6 in position angle and 1.0% in separation. Three of the systems in Table 3 are also suitable for linear-element calculation. It is likely that these may prove to have smaller errors associated with them. However, nearly all of these will fall outside the typical r_0 window. Further investigation of these systems is certainly advisable. Some of these systems have new elements determined, which are described below.

Table 4 presents systems that were observed but not detected. In some cases, a binary that is not resolved may be detected by asymmetries in the autocorrelation. This usually occurs when the Δm is large and ρ is small. Given the most recent observational data, it was expected that these pairs should have been resolved; however, they were not. Possible reasons include orbital or differential proper motion making the binary too close or too wide to resolve, a larger than expected Δm, incorrect pointing, and misprints or errors in the original reporting paper. It is hoped that reporting these will encourage other double star astronomers to either provide corrections to USNO or to verify the lack of detection. While many are quite old and their lack of detection may be due to unknown proper-motion drift, some are recent and so should not show significant differential motion. In addition to the 85 TDS and TDT pairs from Tycho that were confirmed in Table 2, 27 were not detected and thus are presented in Table 4.

Finally, Table 5 presents the new, calculated orbits. All were determined with the method described in Seymour et al. (2002) using the observation-weighting rules of Hartkopf, Mason, & Worley (2001). Most of these systems, with the possibly exception of STT 82, are of the "Is this orbit really necessary?" type. Indeed, were there not earlier calculations it would probably be advisable to wait. However, all of these are beginning to show systematic runoff, which resulted in their earlier USNO speckle measures being unpublished. The orbital elements listed in Table 5 and illustrated in Figures 1 and 2 are, while better than the previously published orbit, probably not terribly reliable over the course of a complete orbit. However, the ephemerides in Table 6 should be quite adequate for the next decade. Indeed, it might be said that the greatest use of the elements from Table 5 is for the position determination for dates not given in Table 6. Using the orbit-grading precepts of Hartkopf et al. (2001), the grades of the new calculations are provided in Table 5 as well. All but one of these would be classified subjectively as preliminary or indeterminate. Nevertheless, the average orbit grade improvement is over half a grade. Relative visual orbits of each system are plotted in Figures 1 and 2, with the x- and y-axes indicating the scale in arcseconds. The solid curves represent the newly determined orbital elements of Table 5, while the dashed curves represent the previously published orbit cited in the figure legend.

We would like to acknowledge Ken Johnston for his continued support of the double star program. The Astrometry Department instrument shop, John Pohlman, Gary Wieder, John Bowles, David Smith, and Tie Siemers, continue to perform excellent work in the nursing and maintenance of the 26 inch telescope. We gratefully acknowledge this support.

[3] See http://ad.usno.navy.mil/wds/orb6/orb6c.html.

REFERENCES

Aitken, R. G., & Doolittle, E. 1932, New General Catalogue of Double Stars within 121° of the North Pole (Carnegie Inst. Washington Publ. 417) (Washington: Carnegie Inst.)
Alzner, A. 1998a, A&AS, 132, 237
———. 1998b, A&AS, 132, 253
Ambruster, C. 1978, PASP, 90, 219
Baize, P. 1957, J. Obs., 40, 197
———. 1958, J. Obs., 41, 163
———. 1969, Circ. d'Inf., No. 48
———. 1981, A&AS, 44, 199
———. 1984, A&AS, 56, 103
Brown, S. J. 1911, Publ. US Nav. Obs., 6, A117
Burnham, S. W. 1906, A General Catalogue of Double Stars within 121° of the North Pole (Washington: Carnegie Inst.)
Burton, H. E., Lyons, U. S., Raynsford, G. M., Wylie, L. R., Browne, W. M., & Smith, J. L. 1947, Observations of Double Stars Made with the 26-Inch Equatorial of the U.S. Naval Observatory (Publ. US Nav. Obs., 2d Ser., 15, Part 4) (Washington: GPO)
Cole, W. A., Fekel, F. C., Hartkopf, W. I., McAlister, H. A., & Tomkin, J. 1992, AJ, 103, 1357
Costa, J. M., & Docobo, J. A. 1983, Circ. d'Inf., No. 89
Couteau, P. 1973, A&AS, 12, 127
de Freitas Mourão, R. R. F. 1977, Astron. Nachr., 298, 227
Docobo, J. A., & Costa, J. M. 1984, Circ. d'Inf., No. 92
———. 1985, Circ. d'Inf., No. 96
———. 1990a, Circ. d'Inf., No. 111
———. 1990b, PASP, 102, 1400
Docobo, J. A., & Ling, J. F. 1997, Circ. d'Inf., No. 133
———. 2001, Circ. d'Inf., No. 145
ESA. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200) (Noordwijk: ESA)
Fabricius, C., Høg, E., Makarov, V. V., Mason, B. D., Wycoff, G. L., & Urban, S. E. 2002, A&A, 384, 180
Fredrickson, M. 1911, Publ. US Nav. Obs., 6, A117
Hale, A. 1994, AJ, 107, 306
Hartkopf, W. I. 2000, Circ. d'Inf., No. 141
Hartkopf, W. I., Kang, D., Urban, S. E., Mason, B. D., & Wycoff, G. L. 2004, in preparation
Hartkopf, W. I., & Mason, B. D. 2000, Circ. d'Inf., No. 142
———. 2001a, Circ. d'Inf., No. 143
———. 2001b, Circ. d'Inf., No. 145
Hartkopf, W. I., Mason, B. D., & Worley, C. E. 2001, AJ, 122, 3472
Hartkopf, W. I., McAlister, H. A., & Franz, O. G. 1989, AJ, 98, 1014
Heintz, W. D. 1962, Veröff. Sternw. München, 5, 135
———. 1963, Veröff. Sternw. München, 5, 247
———. 1965, Veröff. Sternw. München, 7, 7
———. 1966, Veröff. Sternw. München, 7, 19
———. 1969, A&A, 2, 169
———. 1981a, PASP, 93, 90
———. 1981b, ApJS, 45, 559
———. 1982, A&AS, 47, 569
———. 1984a, A&AS, 56, 5
———. 1984b, AJ, 89, 1063
———. 1984c, ApJ, 284, 806
———. 1986a, A&AS, 64, 1
———. 1986b, A&AS, 65, 411
———. 1987, PASP, 99, 1084
———. 1988, A&AS, 72, 543
———. 1990, AJ, 99, 420
———. 1991, A&AS, 90, 311
———. 1995, ApJS, 99, 693
———. 1996a, AJ, 111, 408
———. 1996b, AJ, 111, 412
———. 1996c, ApJS, 105, 475
———. 1997, ApJS, 111, 335
———. 1998, ApJS, 117, 587
———. 2001, Circ. d'Inf., No. 143
Heintz, W. D., & Strom, C. 1993, PASP, 105, 293
Herschel, J. F. W. 1828, MmRAS, 3, 47
Herschel, J. F. W. 1829, MmRAS, 3, 177
Høg, E., et al. 2000a, A&A, 357, 367
———. 2000b, A&A, 355, L27
Hopmann, J. 1960, Mitt. Univ.-Sternw. Wien, 10, 155
———. 1964, Ann. Univ.-Sternw. Wien, 26, No. 1
———. 1965, Mitt. Univ.-Sternw. Wien, 12, 201
———. 1970, Astron. Mitt. Wien, No. 5
———. 1971, Astron. Mitt. Wien, No. 7
———. 1973, Astron. Mitt. Wien, No. 13
Houser, J. L. 1987, PASP, 99, 509
Jasinta, D. M. D. 1996, A&AS, 118, 381
Jeffers, H. M., & van den Bos, W. H. 1963, Index Catalogue of Visual Double Stars, 1961.0 (Publ. Lick Obs. 21) (Mt. Hamilton: Lick Obs.)
Josties, F. J., Dahn, C. D., Kallarakal, V. V., Miranian, M., Douglass, G. G., Christy, J. W., Behall, A. L., & Harrington, R. S. 1974, Publ. US Nav. Obs., 22, Part 6
Kiyaeva, O. V., Tokovinin, A. A., & Kalinichenko, O. A. 1998, AZh Pisma, 24, 868 (English transl. Soviet Astron. Lett., 24, 753)
Lewis, T. 1906, MmRAS, 56, 107
Luyten, W. J. 1934, AJ, 43, 105
Mason, B. D., Douglass, G. G., & Hartkopf, W. I. 1999, AJ, 117, 1023
Mason, B. D., & Hartkopf, W. I. 1999, Circ. d'Inf., No. 138
Mason, B. D., et al. 2002, AJ, 124, 2254
———. 2001a, AJ, 122, 1586
Mason, B. D., McAlister, H. A., Hartkopf, W. I., & Shara, M. M. 1995, AJ, 109, 332
Mason, B. D., Wycoff, G. L., Hartkopf, W. I., Douglass, G. G., & Worley, C. E. 2001b, AJ, 122, 3466
Mason, B. D., Wycoff, G. L., Urban, S. E., Hartkopf, W. I., Holdenried, E. R., & Makarov, V. V. 2000, AJ, 120, 3244
Olević, D., & Popović, G. M. 2000, Circ. d'Inf., No. 141
Olević, D., Popović, G. M., Zulević, D. J., & Ćatović, Z. 1993, Bull. Obs. Astron. Belgrade, No. 148, 49
Olević, D., & Jovanović, P. 2001, Serbian Astron. J., 163, 5
Popović, G. M. 1969, Bull. Obs. Astron. Belgrade, No. 27, 33
———. 1983, Circ. d'Inf., No. 91
———. 1987, Bull. Obs. Astron. Belgrade, No. 137, 82
Popović, G. M., & Pavlović, R. 1995, Bull. Astron. Belgrade, No. 151, 45
———. 1996, Bull. Astron. Belgrade, No. 153, 57
Pourbaix, D. 2000, A&AS, 145, 215
Rabe, W. 1961, Vëroff. Sternw. München, 6, 113
Scardia, M. 1979, Astron. Nachr., 300, 307
———. 1983, Astron. Nachr., 304, 257
———. 1984, Circ. d'Inf., No. 93
Scardia, M., Prieur, J.-L., Koechlin, L., & Aristidi, E. 2001a, Astron. Nachr., 322, 161
———. 2001b, Circ. d'Inf., No. 145
———. 2002a, Circ. d'Inf., No. 146
———. 2002b, Circ. d'Inf., No. 147
———. 2002c, Circ. d'Inf., No. 148
Seymour, D. M., & Hartkopf, W. I. 1999, Circ. d'Inf., No. 139
Seymour, D. M., & Mason, B. D. 1999, Circ. d'Inf., No. 139
———. 2000a, Circ. d'Inf., No. 140
———. 2000b, Circ. d'Inf., No. 141
Seymour, D. M., Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2002, AJ, 123, 1023
Söderhjelm, S. 1999, A&A, 341, 121
Starikova, G. A. 1977, Soobshch. Gos. Astron. Inst. Shternberga, No. 199, 12
———. 1980, AZh Pisma, 6, 239 (English transl. Soviet Astron. Lett., 6, 130)
———. 1982, AZh Pisma, 8, 306 (English transl. Soviet Astron. Lett., 8, 166)
———. 1985, Tr. Gos. Astron. Inst. Shternberga, 57, 243
Symms, L. S. T. 1964, Circ. d'Inf., No. 33
Wierzbinski, S. 1956, Acta Astron., 6, 82
Worley, C. E. 1972, Micrometer Measures of 1,056 Double Stars (Publ. US Nav. Obs., 2d Ser., 22, Part 4) (Washington: GPO)
Zaera, J. A. 1985, Circ. d'Inf., No. 96
Zulević, D. J. 1977, Circ. d'Inf., No. 72
———. 1996, Bull. Astron. Belgrade, No. 153, 79