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SPECKLE OBSERVATIONS OF BINARY STARS WITH THE WIYN TELESCOPE. II. RELATIVE ASTROMETRY MEASURES DURING 1998–2000¹

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ABSTRACT

Five hundred twelve relative astrometry measures are presented for 253 double stars, including 53 double stars discovered by *Hipparcos*. In 15 cases, relative astrometry is reported for the first time for newly confirmed pairs. In addition, 20 high-quality nondetections of companions are reported for stars suspected of being nonsingle by *Hipparcos*. Observations were taken using a fast-readout CCD camera system at the WIYN 3.5 m telescope at Kitt Peak, Arizona. In comparing these measures with ephemeris predictions for binary stars with very well known orbits, we find that the measurement precision is better than 3 mas in separation and 1° in position angle per individual observation. Measurement precision and detection capabilities are fully discussed, and confirmed orbital motion is reported in four cases of the *Hipparcos* double star discoveries.

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

1. INTRODUCTION

Binary stars continue to be an important tool in stellar astronomy because of the fact that they represent the only way currently accepted for determinations of stellar masses other than that of the Sun. Up to the present time, however, few masses precise enough to provide detailed comparisons with stellar structure and evolution models have been forthcoming. Indeed, even the basic empirical relationship between mass and luminosity remains poorly determined, particularly in the important mass range of 1.0 to 0.2 $M_{\odot}$ (Henry & McCarthy 1993; Henry et al. 1999). Most of the stars contributing to this portion of the empirical mass-luminosity relation (MLR) are classic visual and speckle binaries. Often, the main limiting factor in the determination of masses is not the orbital information but rather the system parallax, which sets the absolute scale of the visual orbit.

The publication of the *Hipparcos* Catalogue (ESA 1997) has been a major step forward in the determination of the distances to nearby stars. With parallax uncertainties in the range of 1 to 2 mas, these values are more precise than ground-based parallax results by a factor of 2 to 5 in most cases. Nonetheless, even after revising the MLR with post-

Hipparcos distances (Martin et al. 1998; Söderhjelm 1999), the leading source of uncertainty in most cases remains the parallax. Looking toward the future, three major space astrometry missions have been planned for the next decade: the *Space Interferometry Mission*, the European Galactic Census Project (*GAIA*), and the *Full-Sky Astrometric Mapping Explorer*. (As of this writing, the future of *FAME* appears uncertain.) Because of the improved sensitivities of these systems, it is likely that parallax uncertainties of most nearby stars will be no more than 50 μ as after the completion of these projects. This is, finally, small enough that the distance measure will not overwhelm other sources of uncertainty in the overall error budget for the masses of many important stars on the lower MLR.

Because of the expected improvements in the distances to stars within a few hundred parsecs of the Sun over the next decade, reducing uncertainties in orbital parameters and magnitude differences in order to take the highest possible benefit from improved distances is of substantial importance. In addition, *Hipparcos* discovered over 3400 previously undetected double stars and flagged thousands of others as “suspected nonsingle” stars (i.e., those with an “S” flag in column H61 of the *Hipparcos* Catalogue entry). The nearest of these objects are potentially important as future MLR stars, if gravitational motion can be confirmed and the orbital parameters determined with sufficient precision. We therefore began a long-term program of speckle observations from the WIYN 3.5 m telescope in 1997. One of the main goals of the program is to provide high-quality relative astrometry measures of stars of potential importance to the MLR, both of previously known binaries and of the *Hipparcos* discoveries. In addition, we seek to observe

¹ The WIYN Observatory is a joint facility of the University of Wisconsin–Madison, Indiana University, Yale University, and the National Optical Astronomy Observatory.

² Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

the *Hipparcos* suspected nonsingle stars, in order to resolve any potential pairs lying just below the detection threshold of the satellite.

The first paper in this series (Horch et al. 1999, hereafter Paper I) presented measures obtained at WIYN with both a multianode microchannel array (MAMA) detector system and a fast-readout CCD during 1997. In this paper, we present results obtained during the period 1998 to 2000. In this time interval, only the CCD system was used. Only relative astrometry is presented here; an analysis of the relative photometry of these speckle measures is underway and will be reported in a future publication in this series. Recent work at two small telescopes has indicated that photometric information is retained in the CCD-based speckle technique (Horch, Ninkov, & Franz 2001), and if confirmed in WIYN data, this would provide a basis for determining luminosities and colors of the components of binary star systems in the course of normal speckle observations. Also, in this paper we focus only on known binaries and the *Hipparcos* suspected and discovered doubles. WIYN results of a survey project of F and G dwarfs carried out over the same time period in collaboration with the US Naval Observatory (USNO) will be discussed elsewhere.

2. OBSERVATIONS AND DATA REDUCTION

The observational technique is described fully in Paper I. With the CCD, we typically take 700 to 1000, 50 ms frames of a target object, where for all observations discussed here the speckle-strip method of Horch, Ninkov, & Slawson (1997) is employed. The CCD chip has been the same since the inception of the program; it is a front-illuminated Kodak device with 2038×2048 pixel format and read noise of approximately $10 e^-$. The observational program has been streamlined as much as possible to maximize the number of observations recorded per night. In particular, we have reduced the number of point-source calibration observations per night, choosing one point source for a small group (typically two to four) of binaries within a few degrees of one another on the sky. With the help of C. Corson at WIYN, we have also achieved a slewing capability from the speckle camera control computer, although the telescope operator continues to carefully monitor telescope movements and has override authority at all times. Seeing conditions at WIYN are very good for a continental site, and the majority of results described in the next section were obtained in subarcsecond conditions.

During the period from 1998 to 2000, speckle time on the telescope has been shared with multiobject spectrograph (Hydra) observations at WIYN. The Hydra instrument requires between 30 and 45 minutes to configure the fibers for a field observation, and during this time speckle data can be taken without problem at a rate of approximately one object every 2 minutes. Without a second instrument on the opposite Nasmyth port, the instrument setup time would be unused in the course of normal Hydra observations. Because of the short exposure time of speckle observations, meaningful science data can be taken with virtually 100% efficiency with the dual use of speckle and Hydra.

The data reduction method continues to be a weighted least-squares fit to the object spatial frequency power spectrum, appropriately deconvolved by the point-source calibrator power spectrum. The 180° ambiguity in the position angle determination inherent in the power spectrum analy-

sis is resolved with a basic reconstructed image computed using two orthogonal near-axis subplanes of the object bispectrum.

The speckle optics package developed at Stanford University by J. Morgan and J. G. Timothy has been used for all observations here. This system magnifies the image to the appropriate scale for speckle observations, contains narrow bandpass filters necessary for good speckle contrast, and uses Risley prisms for atmospheric dispersion compensation. As noted in Paper I, the lenses within the system generate a measurable amount of optical field angle distortion (OFAD; a change in the pixel scale as a function of position relative to the optical axis), which in turn affects the astrometry if not properly corrected. By mounting a slit mask to the tertiary baffle support structure of the telescope, we measure the pixel scale using the standard technique of observing the fringe spacing that results when one observes a bright unresolved star through the mask. We also account for the color of the target star in the calculation of the expected fringe spacing, as described in Paper I. However, in order to characterize the OFAD, we place the fringe pattern at various locations in the field of view, thereby taking several measures of the local pixel scale over the entire field once per run. In addition, we have also monitored the position of the optical axis on each run, as judged from flat-field images. On the large CCD chip that we use, there is considerable vignetting, and we consider the center of that pattern to be coincident with the optical axis. By accounting for these slight shifts in the location of the optical center and then measuring the pixel scale from mask observations as a function of distance from the optical center, we obtain the plot shown in Figure 1. The curve drawn is the average best-fit quadratic to the pixel scale as a function of distance from the optical axis. We have included in this plot only results from the five runs in which the distortion was characterized most fully; there was no compelling evidence of a change in the OFAD over the course of the observations discussed here. As in Paper I, the camera continues to exhibit classic barrel distortion in the f/16 arrangement used for most CCD observations, although the amount determined here is

FIG. 1.—Pixel scale measures as a function of distance from the optical axis, as judged from slit-mask observations. A different symbol is used for each run: open circles, data points from 1998 December; plus signs, 1999 January; asterisks, 1999 November; diamonds, 2000 August; filled circles, 2000 October. The solid curve is the average of the best quadratic least-squares fit to each run.

TABLE 1
PIXEL SCALE AND POSITION ANGLE OFFSET VALUES

Run	Magnification	Aperture Ratio	Pixel Binning	Optical Axis Location ^a	Pixel Scale ^b (mas pixel ⁻¹)	Position Angle Offset (deg)
1998 Dec.....	Low	f/16	1 × 1	(153, 1044)	32.672 ± 0.035	-0.29 ± 0.36
1999 Jan.....	Low	f/16	1 × 1	(91, 1082)	32.672 ± 0.035	-0.61 ± 1.00
1999 Apr.....	Low	f/16	1 × 1	(118, 1075)	32.672 ± 0.035	-0.52 ± 0.28
1999 Jul.....	Low	f/16	1 × 1	(124, 987)	32.672 ± 0.035	-1.05 ± 0.46
1999 Jul.....	2.5×	f/44	2 × 2	...	22.927 ± 0.071	-1.05 ± 0.46
1999 Aug.....	Low	f/16	1 × 1	(160, 1036)	32.672 ± 0.035	-0.07 ± 0.58
1999 Nov.....	Low	f/16	1 × 1	(139, 1031)	32.672 ± 0.035	-0.64 ± 0.78
2000 Feb.....	Low	f/16	1 × 1	(120, 1017)	32.672 ± 0.035	-0.44 ± 0.28
2000 Jul.....	Low	f/16	1 × 1	(136, 1057)	32.672 ± 0.035	-0.52 ± 0.28
2000 Aug.....	Low	f/16	1 × 1	(221, 1067)	32.672 ± 0.035	-0.52 ± 0.28
2000 Oct.....	Low	f/16	1 × 1	(135, 1050)	32.672 ± 0.035	-0.52 ± 0.28

^a In detector pixels from the corner of the chip containing the charge preamplifier.

^b At the optical axis.

slightly larger than in Paper I. The 2.5× lens used in Paper I with MAMA observations (f/44) was used here for some observations during July of 1999; in this case, the CCD pixels were binned 2 × 2 prior to readout. No significant distortion was observed, though only five mask observations were taken in this configuration and the locations of the fringe patterns in each case were not spaced far enough apart to fully characterize the OFAD over the entire field. However, nearly all star observations were taken in the same region of the chip as the mask observations. Therefore, for the f/16 observations, position angles and separations were corrected for OFAD as described above, using the updated characterization in Figure 1, while no correction was made for OFAD in the case of f/44 observations.

The orientation relative to the celestial coordinate system is determined primarily using short (1–2 s) exposures of single stars in which the telescope is offset in a certain direction between exposures. During two runs (1999 January and November), images of the Trapezium (θ^1 Orionis) were taken. Using the astrometry in the literature (van Altena et al. 1988), both scale and orientation determinations can be made, although the scale result is merely checked for consistency against the fundamental determination made with slit-mask observations, since mask observations are of much higher precision. However, the position angle offset measure for the two runs was taken to be the average of the Trapezium and telescope offset image results. Table 1 lists the final values for the pixel scale and detector offset angles relative to the celestial coordinate system. The position angle offsets varied from run to run, with extreme values of -2.6 ± 0.3 to $+0.1 \pm 0.3$. This may be due to a combination of small offsets in the zero point of the instrument rotator at the Nasmyth port from run to run and small changes in the position of the camera relative to the rotator. The latter is possible because of mounting-plate holes that are oversized relative to the screws holding the CCD camera to the speckle optics package.

3. RESULTS

3.1. Measures

Table 2 contains the main body of astrometric results from the data set. The columns give (1) the Aitken double

star catalog (ADS) number or, if none, the Bright Star Catalogue (HR) number or, if none, the Durchmusterung (BD, CP, or CD) number; (2) the discoverer designation; (3) the HD number; (4) the *Hipparcos* Catalogue number; (5) the right ascension and declination in 2000 coordinates, which is the same as the identification number in the Washington Double Star Catalog (WDS; Hartkopf & Mason 2001a; Mason, Wycoff, & Hartkopf 2002),³ for all objects that have WDS entries; (6) the observation date in fraction of the Besselian year; (7) the observed position angle (θ), in degrees, with north through east defining the positive sense of θ ; (8) the observed separation (ρ) in arcseconds; (9) the center wavelength of the filter used to make the observation, in nanometers; and (10) the full width at half-maximum of the filter passband, also in nanometers. The position angles have not been corrected for precession and are appropriate for the epoch of observation shown. Position angles and separations are shown without uncertainty estimates, but a reasonable uncertainty estimate for any measure shown may be obtained by combining the measurement precision given in the next subsection with the uncertainty in the scale and detector orientation given in Table 1 in quadrature using standard error formulae. Fifteen objects have no previous astrometry in the literature and are given discoverer designations of Yale-RIT (YR) 4 through 18 here. These objects are discussed further in § 4.

3.2. Measurement Precision

We investigate the measurement precision of the data in Table 2 in two ways. First, following Paper I, we have selected from Table 2 the list of objects that already have orbital determinations of high quality in the literature. As a basic criterion, the objects with orbits determined with the inclusion of highly weighted speckle data of the CHARA and USNO speckle interferometry programs were selected (Hartkopf, McAlister, & Franz 1989; Hartkopf, Mason, & McAlister 1996; Mason 1997; Mason, Douglass, & Hartkopf 1999). Three exceptions to this are the recent orbit for γ Virginis (STF 1670) from Girard et al. (2000) and recent unpublished orbits of MCA 47 and BU 151 AB

³ See <http://ad.usno.navy.mil/wds/wds.html>.

TABLE 2
DOUBLE STAR SPECKLE MEASURES

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
ADS 17175.....	BU 733 AB	224930	171	00022+2705	1999.0091	172.3	0.708	648	41
					1999.0091	172.3	0.707	648	41
					2000.7673	193.5	0.715	648	41
					2000.7674	194.2	0.708	503	40
BD +36°1	A 1501	292	634	00077+3711	1999.0145	237.7	0.996	648	41
					1999.0145	237.7	0.994	648	41
BD +34°3	HDS 17	375	689	00085+3456	1999.0145	251.0	0.134	648	41
					1999.8854	62.2	0.140	701	12 ^b
					1999.8854	62.6	0.138	503	40 ^b
					2000.7591	54.1	0.137	648	41 ^b
ADS 148	BU 1026 Aa-B	761	981	00121+5337	2000.7591	300.6	0.293	648	41
BD -12°63.....	YR 4	2237	2066	00261-1123	1999.8854	214.1	0.392	648	41
					2000.7674	211.4	0.409	648	41
BD -8°65	A 431	2333	2143	00271-0753	1999.8854	199.8	0.239	648	41
BD -17°61.....	YR 1 Aa	2394	2190	00277-1625	1999.0092	359.3	0.161	648	41 ^c
HR 108	B 1909	2475	2237	00283-2020	1999.5660	156.2	0.088	648	41
ADS 434	STT 12	2772	2505	00318+5431	2000.7591	196.9	0.380	648	41
					2000.7591	196.5	0.382	503	40
BD -13°89.....	HDS 71	2893	2532	00321-1218	1999.8855	352.3	0.252	648	41
					2000.7591	348.1	0.261	648	41
ADS 490	HO 212 AB	3196	2762	00352-0336	1999.8855	297.9	0.229	648	41
					2000.7591	339.2	0.094	648	41 ^a
BD +42°170.....	HDS 102	...	3669	00469+4339	1999.5686	148.1	0.191	648	41
					1999.8882	328.0	0.180	648	41 ^c
BD +43°159.....	HDS 109	4712	3857	00495+4404	1999.5686	64.0	0.241	648	41
					1999.8882	63.0	0.239	648	41
					2000.6171	60.7	0.224	503	40
					2000.7619	59.9	0.226	503	40
					2000.7620	59.8	0.225	503	40
BD +77°29.....	YR 5	4741	4041	00518+7837	2000.7646	47.3	0.269	648	41 ^a
ADS 755	STF 73 AB	5286	4288	00550+2338	2000.7674	309.8	0.899	648	41
					2000.7674	309.4	0.887	503	40
BD +39°210.....	A 1511	5314	4331	00554+4023	1999.0173	40.2	1.245	648	41
BD +24°163.....	HDS 134	6009	4809	01017+2518	1999.8882	52.5	0.089	648	41
					2000.7674	65.5	0.107	503	40 ^a
HR 310	YR 6 Aa	6456	5131	01057+2128	1999.0146	288.9	0.075	648	41 ^a
					1999.8882	296.2	0.095	648	41
					2000.6145	299.0	0.117	648	41 ^a
					2000.7674	300.2	0.113	648	41 ^a
					2000.7674	298.4	0.113	503	40 ^a
ADS 918	A 1516 AB	6586	5249	01072+3839	1999.5686	233.1	0.096	648	41 ^{a,d}
ADS 940	STT 515	6811	5434	01095+4715	1999.0173	126.5	0.502	648	41
					1999.0174	126.4	0.501	701	12
					1999.0174	126.4	0.504	551	10
					1999.5686	125.8	0.498	648	41
					1999.8882	126.1	0.499	701	12
					1999.8882	126.0	0.499	648	41
					1999.8882	126.0	0.500	551	10
					2000.6145	125.5	0.504	648	41
					2000.6145	125.5	0.504	648	41
BD +67°98.....	HDS 155	6840	5531	01108+6747	1999.6342	2.6	0.125	601	42 ^a
					2000.7646	193.3	0.102	648	41 ^a
BD +50°238.....	HDS 160	7169	5674	01129+5136	1998.9245	41.9	0.222	648	41
					2000.7646	223.8	0.207	503	40 ^b
BD +17°176.....	HDS 169	7640	5952	01166+1831	1999.5686	254.8	0.646	648	41
					1999.8882	254.1	0.649	648	41
ADS 1105	STF 115 AB	8272	6486	01234+5809	1998.9245	176.5	0.159	648	41
					2000.7646	170.8	0.183	503	40 ^a
ADS 1123	BU 1163	8556	6564	01243-0655	1999.0119	212.1	0.360	648	41 ^e
					1999.8882	210.9	0.342	551	10 ^e
					2000.7648	210.6	0.322	648	41 ^e
BD +48°436.....	HU 525	8785	...	01275+4915	1999.0174	320.9	1.159	648	41
					1999.0174	320.8	1.160	648	41
ADS 1158	BU 1164 AB	8875	6815	01277+0521	1999.8883	142.4	0.185	551	10
BD +7°214.....	YR 7	8956	6873	01285+0758	1999.0092	61.1	0.421	648	41
					1999.8911	58.2	0.439	648	41
					2000.6145	63.4	0.406	503	40

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
ADS 1183	A 1910 AB	9071	6966	01297+2250	2000.7648	58.2	0.435	648	41
					1998.9245	217.2	0.122	648	41
					2000.6145	209.7	0.134	503	40
BD +14°231.....	BU 506	9270	7097	01315+1521	1999.5687	53.0	0.630	648	41
					2000.6173	54.0	0.628	503	40
CD −30°529	DAW 31 AB	9770	7372	01350−2955	1999.8855	345.9	0.180	701	12 ^a
HR 466	KUI 7	10009	7580	01376−0924	1999.8882	149.0	0.274	551	10 ^c
					2000.7648	148.7	0.266	648	41 ^e
BD +47°466.....	HDS 215	9901	7589	01377+4825	1998.9245	208.2	0.555	648	41
					2000.6200	212.3	0.587	503	40
ADS 1473	HO 311	11284	8622	01512+2439	1999.8829	166.4	0.261	648	41 ^c
					2000.7593	169.4	0.282	503	40 ^c
BD +17°276.....	COU 2557	11326	8689	01518+1817	1999.0119	255.7	1.190	853	39
					1999.0119	255.6	1.191	853	39
BD +59°376.....	HDS 269	12112	9403	02008+5958	1999.8912	263.5	0.325	648	41
BD +15°292.....	BU 515	12315	9434	02012+1634	1999.0146	269.6	0.658	853	39
					1999.0146	269.1	0.674	648	41
					1999.0147	269.0	0.670	853	39
BD +70°153.....	BU 513 AB	12111	9480	02020+7054	1999.8856	261.7	0.805	648	41
					2000.7622	265.1	0.802	503	40
CD −24°867	HDS 272	12515	9497	02022−2402	2000.7676	180.6	0.535	648	41 ^{c?}
ADS 1613	A 1813 AB-C	12376	9500	02022+3643	1999.8856	207.6	1.494	648	41
ADS 1613	A 1813 AB	12376	9500	02022+3643	1999.8856	194.2	0.139	648	41 ^{b,e}
ADS 1630	STT 38 BC	12534	9640	02039+4220	1999.8856	104.7	0.467	648	41
ADS 1709	STF 228	13594	10403	02140+4729	1999.8856	282.6	0.994	648	41
					2000.7621	283.3	0.995	648	41
					2000.7621	283.4	0.993	503	40
BD +24°329.....	COU 79	13872	10535	02157+2503	1998.9245	336.5	0.099	648	41 ^{a,d}
					1999.6398	326.9	0.093	648	41 ^{a,d}
					1999.8829	319.3	0.099	648	41 ^{a,d}
					1999.8829	319.9	0.097	701	12 ^{a,d}
					2000.6146	308.0	0.098	503	40 ^{a,d}
					2000.7649	306.7	0.099	648	41 ^{a,d}
ADS 1729	A 2013	13959	10552	02159+0638	1999.8830	269.7	0.367	648	41 ^c
BD +3°313.....	YR 8	14031	10596	02164+0437	1999.8830	330.8	0.091	648	41 ^a
ADS 1747	A 206 AB	14016	10661	02172+3729	1998.9246	142.7	0.445	648	41
BD +32°433.....	BU 876 AB	14800	11178	02239+3330	1999.0093	240.9	1.197	648	41
BD +29°406.....	HDS 314	14874	11253	02249+3039	1998.9246	285.8	0.347	648	41
BD +33°429.....	HDS 318	15013	11352	02262+3428	1998.9246	205.8	0.124	648	41 ^c
					1999.8856	50.1	0.092	648	41 ^a
					2000.7622	103.7	0.062	648	41 ^a
ADS 1865	A 2329	15285	11452	02278+0426	1999.8830	124.3	0.515	648	41
BD +8°390.....	HDS 331	...	11793	02322+0901	1999.0120	336.5	0.620	853	39
					2000.7649	335.8	0.640	648	41
HR 763	MCA 7	16234	12153	02366+1227	1999.0120	136.4	0.074	648	41 ^{c?}
BD +11°366.....	A 2335	...	12291	02383+1146	1999.0120	319.2	1.421	648	41
HR 781	FIN 312	16620	12390	02396−1152	1999.0147	121.8	0.079	648	41 ^b
					2000.7622	346.3	0.117	503	40 ^b
ADS 2028	A 1928	16619	12421	02399+0009	1999.8830	232.7	0.207	648	41 ^c
BD −15°477.....	HDS 351	16826	12554	02415−1506	1999.0148	195.2	0.095	648	41 ^{b?}
ADS 2200	BU 524 AB	17904	13490	02537+3820	1999.8885	4.0	0.166	551	10
BD +18°382.....	YR 9	...	13855	02584+1914	1999.0120	246.9	0.641	648	41
					1999.8830	245.5	0.647	648	41
					2000.7649	246.0	0.644	648	41
BD +22°425.....	HDS 389	18940	14230	03035+2304	2000.7650	357.3	0.123	648	41 ^a
BD +10°432.....	HEI 449	20779	15633	03213+1038	1999.0121	24.8	0.085	648	41
BD +20°551.....	HDS 423	20893	15737	03228+2045	1999.0120	290.6	0.470	551	10
					1999.0120	290.7	0.465	648	41
					1999.8831	291.5	0.462	648	41
BD +34°645.....	HDS 430	21183	16025	03264+3520	1999.6399	222.8	0.291	503	40
					2000.7623	226.2	0.290	648	41
					2000.7677	227.2	0.291	648	41
HR 1038	HDS 433	21364	16083	03272+0944	1999.0121	342.6	0.447	648	41
					2000.7595	351.8	0.378	503	40
BD +49°945.....	BU 1179	21428	16244	03294+4931	1999.0174	146.5	0.676	648	41
HR 1100	HDS 456	22470	16803	03363−1728	2000.7650	96.7	0.134	648	41 ^a
BD +13°576.....	YR 10	...	16991	03385+1336	2000.7650	87.7	0.370	648	41
BD +7°537.....	STT 61	23110	17348	03428+0754	1999.0121	127.4	1.416	648	41

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
BD +72°187.....	HDS 476	22811	17580	03460+7302	1999.8912	5.5	0.866	648	41
BD +51°777.....	HU 546	23524	17782	03484+5202	1999.8831	68.4	0.393	648	41
HR 1158	CAR 1	23523	17891	03496+6318	1999.0175	12.3	0.072	853	39 ^a
					1999.8885	39.1	0.093	503	40 ^a
					2000.6174	60.3	0.100	648	41
					2000.7595	63.2	0.103	648	41 ^a
					2000.7676	64.0	0.104	503	40 ^a
ADS 2799	STT 65	23985	17954	03503+2535	1999.8831	29.8	0.151	701	12 ^c
					1999.8831	30.1	0.151	648	41 ^c
BD −8°751.....	HDS 492	24634	18293	03547−0755	2000.7595	170.3	0.836	648	41
ADS 2980	A 1710	25693	19159	04064+4325	1999.8831	138.9	0.603	701	12 ^c
BD −10°839.....	HDS 521	26040	19206	04070−1000	1999.8831	138.8	0.601	648	41 ^c
					1999.0122	28.0	0.179	648	41 ^a
					2000.7595	13.5	0.224	648	41
BD +29°676.....	YR 11	26397	19572	04116+2950	2000.7623	95.1	0.471	648	41
BD +23°635.....	CHR 14	284163	19591	04119+2338	2000.7678	180.1	0.280	648	41
ADS 3064	A 1938	26690	19719	04136+0743	1999.0094	161.8	0.096	648	41 ^{d,e}
					2000.7650	271.9	0.080	503	40 ^{a,d}
ADS 3072	BU 547 AB	26722	19740	04139+0916	2000.7650	342.0	1.267	503	40
					2000.7650	342.0	1.269	503	40
BD +37°909.....	HDS 552	27214	20176	04195+3800	1999.8913	99.8	0.097	648	41
ADS 3135	STT 79	27383	20215	04199+1631	1999.6290	306.1	0.318	648	41
					1999.6290	306.0	0.312	648	41
					1999.8859	308.5	0.349	701	12
					2000.7678	313.5	0.357	648	41
					2000.7678	313.1	0.357	503	40
ADS 3159	BU 744 AB	27710	20347	04215−2544	1999.8885	21.1	0.267	648	41
ADS 3182	HU 304	27820	20522	04239+0928	1999.8859	354.0	0.163	648	41 ^a
					2000.7678	178.0	0.175	648	41 ^b
					2000.7678	177.8	0.162	503	40 ^b
					1998.9274	150.4	0.733	648	41
BD +50°986.....	COU 2459	27673	20586	04245+5051	2000.7651	147.6	0.771	503	40
HR 1391	FIN 342 Aa	27991	20661	04256+1556	1999.0095	99.2	0.096	648	41 ^{a,d}
ADS 3248	HU 1080	28363	20916	04290+1610	1999.8913	88.0	0.080	648	41 ^a
ADS 3264	STF 554	28485	20995	04301+1538	2000.7678	18.2	1.592	503	40
					2000.7678	17.8	1.620	648	41
BD +14°721.....	CHR 17	285931	21280	04340+1510	2000.7679	230.1	0.158	648	41 ^c
BD +38°912.....	HU 1082	276666	21352	04349+3908	1999.8913	138.3	0.558	648	41
HR 1481	KUI 18	29503	21594	04382−1418	1999.8886	352.0	1.022	648	41
					2000.1412	352.2	1.020	503	40
BD −12°955.....	HDS 599	29573	21644	04389−1207	1999.8886	325.2	0.212	648	41
					2000.1413	326.4	0.208	503	40
ADS 3358	BU 1295 AB	29316	21730	04400+5328	1998.9274	165.0	0.279	648	41
					1999.8859	162.1	0.283	701	12
					2000.7651	161.2	0.285	503	40
ADS 3358	STF 566 AB-C	29316	21730	04400+5328	1998.9274	195.6	0.775	648	41
					1999.8859	192.7	0.775	701	12
					2000.7651	191.9	0.781	503	40
ADS 3389	A 1014	29599	21941	04430+5712	1999.8859	355.5	0.343	648	41
ADS 3475	BU 883 AB	30810	22550	04512+1104	1999.8914	79.5	0.230	701	12 ^a
					1999.8914	259.4	0.229	648	41 ^c
					1999.8914	81.6	0.231	551	10 ^a
					2000.7679	271.2	0.212	648	41 ^c
ADS 3483	BU 552 AB	30869	22607	04518+1339	1999.8914	224.2	0.510	701	12
					1999.8914	224.4	0.510	648	41
					1999.8914	224.3	0.515	551	10
					2000.7679	229.0	0.523	648	41
BD +75°193.....	MLR 465	30097	22703	04529+7543	1999.0175	208.2	0.886	648	41
BD +13°738.....	YR 12	31399	22942	04562+1358	2000.7679	160.6	0.501	648	41
ADS 3536	D 5 AB	31278	23040	04573+5345	1999.8860	213.4	0.511	701	12
					1999.8860	213.4	0.511	648	41
					2000.7651	212.9	0.515	648	41
					2000.7651	212.6	0.519	503	40
ADS 3608	A 1844 AB	32092	23395	05017+2640	1999.8888	194.5	0.181	648	41
					1999.8888	194.0	0.180	551	10
BD +26°785.....	HDS 666	240622	23772	05066+2630	1999.8888	202.6	0.198	648	41 ^{c?}
BD +13°803.....	HEI 105	32851	23789	05067+1405	2000.7679	114.5	1.047	648	41
BD +40°1253.....	HDS 701	34557	24902	05202+4105	2000.1413	59.5	0.295	648	41

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
BD +18° 864.....	A 2433 CD	36072	25747	05298+1825	1999.0176	253.8	1.430	648	41
ADS 4229	BU 1240 AB	37269	26536	05386+3030	1999.8888	344.8	0.185	648	41
					1999.8888	344.4	0.187	551	10
					1999.8888	344.9	0.188	551	10
ADS 4241	BU 1032 AB	37468	26549	05387−0236	1999.0151	114.9	0.254	648	41
					1999.8833	112.9	0.252	701	12
					2000.1413	112.1	0.257	503	40
					2000.7625	111.6	0.244	648	41
					2000.7625	107.0	0.244	503	40
					2000.7652	111.1	0.254	648	41
					2000.7652	110.7	0.255	503	40
					2000.7679	111.8	0.257	648	41
					2000.7679	110.6	0.256	503	40
ADS 4299	A 494 AB	38089	26926	05429−0648	1999.8833	64.0	0.072	648	41 ^c
ADS 4396	A 2657	38769	27410	05482+0137	1999.8833	201.9	0.197	648	41 ^a
BD −2° 1395.....	HDS 787	39438	27758	05525−0217	1999.0151	186.1	0.102	648	41 ^{b?}
BD −4° 1291.....	HDS 797	39927	28019	05556−0447	1999.0178	280.0	0.369	853	39
					1999.8833	277.3	0.364	648	41
					2000.7652	278.5	0.364	648	41
					2000.7679	278.0	0.367	648	41
ADS 4617	A 2715 AB	40932	28614	06024+0939	1999.0152	14.9	0.203	701	12
					1999.0152	13.3	0.196	648	41
					1999.0152	14.8	0.200	551	10
					1999.8915	12.5	0.145	701	12
					1999.8915	11.3	0.154	648	41
					1999.8915	11.7	0.150	551	10
					2000.7653	359.4	0.081	853	39
HR 2142	HDS 826	41335	28744	06042−0643	1999.0178	270.8	0.585	853	39
HR 2186	RST 3442	42443	29234	06098−2246	1999.8888	274.8	0.168	648	41 ^{a,d}
ADS 4866	A 668	43362	29705	06154−0902	1999.8888	312.6	0.160	648	41
HR 2236	RST 5225	43358	29746	06159+0110	1999.8833	125.2	0.150	648	41
ADS 4890	FIN 331 Aa	43525	29850	06171+0957	1998.9251	287.7	0.099	701	12 ^{a,d}
					2000.1454	128.1	0.096	648	41 ^{b,d}
ADS 4929	STF 888 AB-C	43885	30091	06200+2826	1999.8834	260.4	2.763	648	41
					1999.8834	260.8	2.786	551	10
ADS 4929	BU 895 AB	43885	30091	06200+2826	1999.8834	326.7	0.266	648	41 ^b
					1999.8834	325.6	0.268	551	10 ^b
GJ 234.....	B 2601	...	30920	06293−0248	1999.8833	269.7	0.453	853	39
					1999.8833	269.6	0.450	853	39
BD +7° 1327.....	A 2817	46055	31089	06314+0749	1999.8861	207.0	0.227	648	41
HR 2425	MCA 27	47152	31737	06384+2859	1999.8834	116.3	0.241	551	10
					1999.8834	116.0	0.240	648	41
BD +8° 1487.....	HDS 940	49015	32475	06467+0822	1998.9251	206.2	0.386	780	31
					1999.8861	211.1	0.409	648	41
HR 2541	COU 1877	50037	33064	06532+3826	2000.1456	187.1	0.316	648	41
					2000.7680	190.0	0.304	503	40
ADS 5586	STT 159 AB	50522	33449	06573+5825	1998.9251	221.8	0.405	780	31
ADS 5871	STF 1037 AB	55130	34860	07128+2713	1999.8835	313.9	1.151	701	12
					1999.8835	313.8	1.147	648	41
BD +44° 1604.....	HDS 1006	...	35100	07155+4428	1999.0153	65.5	0.571	780	31
ADS 5949	A 2855	56361	35221	07168+0059	1999.8835	229.7	0.402	648	41
BD +48° 1538.....	KUI 30 AB	58661	36348	07289+4811	1999.0153	94.3	1.118	780	31
					1999.0153	94.3	1.119	780	31
ADS 6185	STT 175 AB	60318	36896	07351+3058	1999.8835	144.0	0.122	648	41
BD +50° 1460.....	COU 2607	61931	37701	07441+5026	1999.0153	162.2	0.930	780	31
ADS 6354	HU 1247	62522	38052	07480+6018	1998.9251	143.0	0.185	780	31 ^c
					1999.0154	141.3	0.182	780	31 ^c
					1999.3214	319.3	0.184	701	12 ^a
ADS 6420	BU 101	64096	38382	07518−1354	1998.9252	319.4	0.278	780	31 ^e
					1999.8861	327.8	0.235	701	12 ^{d,e}
					1999.8861	327.5	0.233	648	41 ^{d,e}
HR 3072	FIN 325	64235	38474	07528−0526	1999.8835	145.3	0.165	701	12 ^c
ADS 6554	BU 581 AB	66509	39495	08044+1217	1999.8836	70.1	0.201	648	41
ADS 6650	STF 1196 AB	68255−57	40167	08122+1739	1999.8836	85.6	0.825	648	41
HR 3228	BU 1243 AB	68703	40342	08142+1741	1999.0126	330.2	1.649	648	41
ADS 6811	A 1746 BC	71153	41389	08267+2432	1999.3214	219.3	0.130	648	41 ^{a,d}
ADS 6828	A 551 AB	71663	41564	08285−0231	1999.0127	61.7	0.173	648	41 ^c
					1999.8836	62.0	0.170	701	12 ^c

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
CD $-32^{\circ}5465$	FIN 335	72954	42075	08345 -3236	1999.8836	62.0	0.172	551	10 ^c
BD $+67^{\circ}552$	YR 13	...	42220	08364 $+6718$	1999.8918	86.2	0.144	648	41 ^c
					1999.0180	34.9	0.554	853	39
					1999.0180	35.4	0.550	853	39
BD $-8^{\circ}2434$	HDS 1242	73399	42345	08380 -0844	1998.9253	293.8	0.291	648	41
BD $+20^{\circ}2150$	CHR 156 Dd	73598	42497	08399 $+1933$	1999.0127	291.9	0.951	648	41
ADS 6993	SP 1 AB	74874	43109	08468 $+0625$	1999.8837	202.4	0.268	701	12 ^{d,e}
					2000.1416	205.3	0.264	648	41 ^{d,e}
HR 3579	KUI 37 AB	76943	44248	09006 $+4147$	1998.9252	58.1	0.547	780	31 ^e
					1999.8891	45.0	0.620	648	41 ^e
					2000.1417	42.2	0.644	648	41 ^e
HR 3586	HDS 1311	77093	44331	09017 $+3943$	1998.9252	22.5	0.546	780	31
HR 3650	FIN 347 Aa	79096	45170	09123 $+1500$	1999.8918	336.7	0.138	648	41 ^c
ADS 7284	STF 3121 AB	79969	45617	09179 $+2834$	1999.8864	14.9	0.720	648	41
					1999.8864	194.7	0.720	551	10 ^c
BD $+46^{\circ}1500$	HDS 1353	81105	46199	09252 $+4606$	1999.0182	142.2	0.243	853	39 ^{c?}
					1999.8891	144.8	0.274	648	41 ^{c?}
ADS 7545	STT 208	85235	48402	09521 $+5404$	1999.8891	259.1	0.255	701	12
					1999.8891	258.9	0.256	648	41
					1999.8891	259.0	0.256	551	10
ADS 7555	AC 5 AB	85558	48437	09525 -0806	1999.8864	61.8	0.581	648	41
ADS 7651	KUI 48 AB	87822	49658	10083 $+3136$	1999.0156	351.1	0.201	648	41 ^{c,d,e}
BD $+50^{\circ}1721$	YR 14	88046	49825	10103 $+4930$	1998.9253	218.7	0.311	648	41
					1999.0128	218.7	0.307	648	41
					1999.0157	218.8	0.314	648	41
					1999.8892	219.2	0.321	648	41
					2000.1461	221.1	0.316	503	40 ^a
ADS 7674	HU 874	88355	49929	10116 $+1321$	1999.0101	286.7	0.211	648	41
ADS 7780	HU 879	90537	51233	10279 $+3642$	1999.3215	45.0	0.121	701	12
					1999.3215	46.0	0.117	648	41 ^a
					1999.3215	45.5	0.116	551	10 ^a
BD $+12^{\circ}2217$	HDS 1507	90823	51360	10294 $+1211$	1999.0102	309.0	0.093	648	41
ADS 7915	HO 532 Aa-B	...	52600	10454 $+3831$	1999.0128	254.1	0.659	853	39
					1999.0128	254.1	0.661	853	39
					1999.0129	253.7	0.656	853	39
BD $+18^{\circ}2430$	HDS 1568	95175	53731	10596 $+1800$	2000.1460	275.8	0.184	648	41
BD $+37^{\circ}2145$	HDS 1574	95485	53903	11017 $+3641$	1999.0129	353.3	0.370	853	39
					2000.1405	353.6	0.364	503	40
ADS 8035	BU 1077	95689	54061	11037 $+6145$	1999.8892	185.7	0.368	701	12
ADS 8048	A 676 BC	96064	54155	11047 -0413	1999.8864	263.7	0.311	648	41
BD $+14^{\circ}2382$	HDS 1622	99088	55661	11243 $+1354$	2000.1460	38.2	0.847	648	41
BD $+56^{\circ}1521$	A 1355	99620	55972	11282 $+5540$	1999.0158	358.3	1.399	648	41
ADS 8197	STT 235 AB	100203	56290	11323 $+6105$	1999.8865	341.9	0.619	701	12
BD $+15^{\circ}2348$	HDS 1641	100509	56427	11341 $+1453$	1999.0158	273.8	0.571	648	41
BD $+12^{\circ}2388$	HDS 1672	102988	57821	11514 $+1148$	1999.0158	192.2	0.354	648	41
ADS 8630	STF 1670 AB	110379-80	61941	12417 -0127	1999.3217	264.0	1.589	648	41
BD $+24^{\circ}2505$	COU 396	...	...	12526 $+2342$	1999.0185	311.2	0.884	648	41
ADS 8939	STT 269 AB	117902	66089	13329 $+3454$	1999.3218	214.1	0.214	648	41 ^b
ADS 9617	STF 1937 AB	137107-8	75312	15232 $+3017$	1999.3219	59.8	0.772	551	10 ^e
					2000.1466	65.1	0.727	503	40 ^e
HR 5747	JEF 1	137909	75695	15278 $+2906$	1999.3219	310.0	0.180	551	10 ^{b,e}
					2000.1466	105.4	0.092	503	40
ADS 9716	STT 298 AB	139341	76382	15360 $+3948$	1999.5681	150.2	0.426	648	41
ADS 9744	HU 580 AB	140159	76852	15416 $+1940$	1999.5681	236.3	0.129	648	41 ^b
ADS 9757	STF 1967	140436	76952	15427 $+2618$	1999.3220	115.3	0.713	648	41 ^c
					1999.3220	115.3	0.719	551	10 ^e
					2000.1466	114.9	0.699	503	40 ^e
					2000.5561	114.9	0.719	648	41 ^e
HR 6117	BU 625 AB	148112	80463	16254 $+1402$	2000.5562	277.9	0.811	648	41
					2000.5562	276.7	0.813	648	41
ADS 10157.....	STF 2084	150680	81693	16413 $+3136$	1999.5651	20.0	0.784	648	41
ADS 10425.....	STT 327	156389	84300	17141 $+5608$	1999.5624	324.9	0.435	648	41
HR 6436	HDS 2446	156729	84606	17177 $+3717$	2000.5563	142.1	0.925	648	41
HR 6469	MCA 47	157482	84949	17217 $+3958$	1999.5681	160.4	0.109	648	41 ^{a,d,e}
					1999.5681	164.0	0.115	551	10 ^{a,d,e}
					2000.5563	175.6	0.101	648	41 ^{a,d,e}
ADS 11060.....	STT 341 AB	165590	88637	18058 $+2127$	1999.8906	86.1	0.201	648	41
ADS 11077.....	AC 15 AB	165908	8875	18070 $+3034$	1999.5682	244.1	0.401	648	41 ^c

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
					1999.8878	250.4	0.441	701	12 ^c
					1999.8878	250.5	0.445	551	10 ^c
ADS 11149.....	B 2545 AB	166988	89156	18118+3327	1999.5681	208.6	0.074	648	41 ^a
ADS 11149.....	HO 82 AB-C	166988	89156	18118+3327	1999.5681	218.3	0.738	648	41
ADS 11520.....	A 88 AB	172088	91394	18384-0312	1999.5625	319.7	0.131	648	41 ^{a,d,e}
ADS 11950.....	HDO 150 AB	176687	93506	19026-2953	2000.7585	201.1	0.168	648	41
BD +33°3339.....	COU 1462	...	94056	19089+3404	2000.7667	237.5	0.148	648	41
					2000.7667	237.5	0.147	648	41 ^a
ADS 12145.....	SE 2 BC	179484	94252	19111+3847	1999.5654	77.5	0.448	648	41
ADS 12540.....	MCA 55 Aa	183912	95947	19307+2758	2000.7614	127.3	0.429	648	41
BD +58°1929.....	MCA 56	184467	95995	19311+5835	2000.6166	271.9	0.099	648	41 ^a
					2000.7640	253.8	0.111	503	40 ^a
HR 7499	KUI 94	186307	96907	19420+4015	2000.7667	170.3	0.313	648	41
ADS 12973.....	AGC 11 AB	187362	97496	19490+1909	1999.6390	144.1	0.147	601	42
					2000.6167	133.2	0.111	503	40 ^a
					2000.7640	130.8	0.107	503	40 ^a
BD +40°3908.....	COU 2530	226195	97706	19514+4044	2000.6167	180.5	0.212	648	41 ^b
					2000.7668	1.3	0.210	648	41 ^a
ADS 13125.....	HO 581	188753	98001	19550+4152	1999.8824	88.4	0.371	648	41
ADS 13104.....	STF 2597	188405	98038	19553-0644	1999.5626	104.2	0.427	503	40
					1999.8878	103.8	0.435	648	41
					2000.7668	103.8	0.453	503	40
					2000.7668	104.2	0.454	648	41
HR 7640	YR 15	189395	98325	19586+3059	1999.5626	35.1	0.183	551	10 ^a
HR 7637	HO 276	189340	98416	19598-0957	1999.5626	96.4	0.228	503	40
					1999.8879	108.4	0.236	648	41
					1999.8879	109.1	0.235	701	12
					2000.7668	129.0	0.216	503	40
ADS 13461.....	STT 400	191854	99376	20102+4357	1999.8824	344.4	0.497	648	41
ADS 13723.....	STT 406	193701	100241	20198+4522	1999.8824	108.3	0.459	648	41
					1999.8824	108.3	0.462	551	10
ADS 13728.....	A 1427 AB	193702	100268	20203+3924	2000.7587	119.7	0.302	853	39
BD +33°3930.....	COU 1962	...	101227	20311+3333	2000.7641	124.3	0.119	503	40 ^b
BD +10°4330.....	YR 16	196201	101597	20354+1121	2000.6195	215.5	0.528	648	41
BD +75°752.....	HEI 7	197433	101750	20374+7536	1999.8825	187.1	0.364	648	41
					1999.8825	186.9	0.366	648	41
ADS 14073.....	BU 151 AB	196524	101769	20375+1436	1999.6394	340.5	0.490	701	12 ^e
					1999.6394	340.3	0.498	648	41 ^e
					1999.6394	340.4	0.487	551	10 ^e
					2000.6168	343.8	0.530	701	12 ^e
					2000.6168	343.8	0.532	648	41 ^e
					2000.6168	343.7	0.531	551	10 ^e
					2000.7615	344.6	0.540	648	41 ^e
					2000.7615	344.2	0.535	503	40 ^e
					2000.7671	344.9	0.531	648	41 ^e
					2000.7671	344.8	0.528	503	40 ^e
ADS 14121.....	WCK 2 Aa	196867	101958	20396+1555	1999.6394	98.5	0.105	701	12 ^a
					1999.6394	93.1	0.104	648	41 ^a
					1999.6394	94.3	0.098	551	10 ^a
					2000.6195	39.4	0.081	648	41 ^a
BD +15°4227.....	HDS 2947	197039	102029	20406+1539	1999.6394	126.0	0.077	648	41 ^a
					2000.6168	117.9	0.115	648	41 ^a
					2000.7615	118.7	0.121	648	41 ^a
					2000.7670	117.7	0.124	503	40
ADS 14412.....	A 751	199306	103130	20537+5918	1999.8879	92.6	0.164	648	41
BD +40°4389.....	HDS 2995	200325	103749	21014+4037	2000.7641	279.9	0.259	503	40
BD +7°4621.....	HDS 3004	200746	104075	21051+0757	2000.7671	140.1	0.127	648	41
ADS 14761.....	HU 767	202128	104771	21135+1559	1999.5657	145.6	0.215	648	41 ^a
					2000.6195	328.3	0.225	648	41 ^b
					2000.7615	148.6	0.223	503	40 ^a
					2000.7671	149.0	0.221	648	41 ^a
ADS 14773.....	STT 535 AB	202275	104858	21145+1000	1999.5656	219.6	0.119	551	10 ^{b,e}
					1999.5656	219.2	0.121	551	10 ^{b,e}
					1999.5657	39.2	0.118	648	41 ^e
					1999.5657	39.3	0.118	648	41 ^e
					1999.5657	38.6	0.118	503	40 ^{a,e}
					1999.5657	38.4	0.119	503	40 ^{a,e}
					1999.8851	32.0	0.192	648	41 ^e

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
ADS 14787.....	AGC 13 AB	202444	104887	21148+3803	2000.6195	26.1	0.306	648	41 ^{d,e}
					2000.7671	26.1	0.311	648	41 ^{a,d,e}
					2000.7671	25.6	0.319	503	40 ^{d,e}
					1999.5683	306.4	0.797	648	41
					1999.5683	306.3	0.794	551	10
					1999.8824	305.1	0.792	551	10
ADS 14839.....	BU 163 AB	202908	105200	21186+1134	2000.7641	299.7	0.782	648	41
					2000.7641	299.6	0.785	503	40
					1999.8851	260.8	0.556	648	41 ^e
					2000.7671	260.9	0.583	648	41 ^e
					2000.7671	260.1	0.581	503	40 ^e
					1999.8851	279.7	0.162	648	41 ^c
ADS 14893.....	A 617	203345	105431	21214+1020	1999.8851	279.7	0.162	648	41 ^c
BD +47°3446.....	COU 2441	205073	106262	21314+4821	1998.9243	296.4	0.200	648	41
BD +23°4334.....	HDS 3065	205142	106394	21330+2408	1999.8879	295.5	0.210	503	40
					1999.6391	246.1	0.536	648	41
BD +47°3472.....	YR 3	...	...	21339+4833	1998.9243	212.0	0.238	648	41
					1999.5628	213.7	0.216	648	41
					1999.5685	211.3	0.243	648	41
					2000.7641	212.7	0.252	648	41
					2000.7642	212.9	0.248	648	41
					1999.8852	273.4	0.530	648	41
ADS 15176.....	BU 1212 AB	206058	106942	21395−0003	1999.8852	273.4	0.530	648	41
HR 8300	KUI 108	206644	107162	21424+4105	1999.5628	237.6	0.096	648	41 ^a
ADS 15267.....	HO 166	206792	107288	21439+2751	2000.6197	211.5	0.099	648	41 ^a
					2000.7644	207.8	0.098	503	40 ^a
					1999.5628	31.4	0.229	648	41 ^a
					2000.7644	307.7	1.868	648	41
					2000.7644	307.2	1.829	503	40
					1999.8852	105.0	0.231	648	41
ADS 15270.....	STF 2822 AB	206826−27	107310	21441+2845	2000.7644	307.7	1.868	648	41
ADS 15281.....	BU 989 AB	206901	107354	21446+2539	2000.7644	307.2	1.829	503	40
					1999.8852	105.0	0.231	648	41
HR 8344	COU 14	207652	107788	21501+1717	2000.6196	96.2	0.175	648	41
					2000.6196	252.1	0.311	503	40
BD +45°3750.....	COU 2138	...	108536	21593+4606	2000.7672	253.1	0.307	503	40
					2000.7672	252.5	0.306	648	41
					2000.7644	16.2	0.185	503	40 ^{c?}
					1999.5629	243.9	0.060	648	41 ^a
					1999.8852	352.1	0.090	648	41 ^a
					2000.7644	333.1	0.097	503	40 ^a
HR 8462	HDS 3152	210705	109624	22124−1412	2000.7672	261.6	0.536	648	41
ADS 15758.....	MCA 70 Ab	211073	109754	22139+3943	1998.9269	17.2	0.385	648	41
					1998.9269	15.5	0.392	551	10
					1999.8880	17.6	0.380	701	12
					1999.8880	17.0	0.376	648	41
					1999.8880	17.1	0.376	551	10
					2000.6169	15.9	0.384	551	10
					2000.7616	17.7	0.373	503	40
					2000.7672	73.5	0.309	648	41
					1999.8852	95.2	3.030	648	41
					1999.8852	95.2	3.034	648	41
ADS 15972.....	KR 60 AB	239960	110893	22280+5742	2000.7589	118.6	0.358	503	40
ADS 15988.....	STF 2912	213235	111062	22300+0426	2000.7589	118.2	0.360	648	41
					1999.5685	338.2	0.299	648	41 ^a
ADS 16046.....	HU 1320	213776	111303	22329+4923	1999.5685	338.2	0.299	648	41 ^a
BD +37°4611.....	COU 1343	213786	111335	22334+3808	1998.9269	147.8	0.666	648	41
BD +60°2414.....	HDS 3204	214165	111469	22350+6050	2000.7672	298.8	0.205	648	41
ADS 16098.....	A 1470	214222	111528	22357+5312	1999.8852	105.9	0.182	648	41
BD +38°4818.....	HDS 3211	...	111685	22375+3923	1998.9269	0.7	0.235	853	39
					1998.9269	0.5	0.231	853	39
					1998.9269	0.8	0.245	853	39
					2000.6170	29.7	0.300	648	41
					1998.9269	150.7	0.153	648	41 ^e
					1999.5685	149.1	0.169	648	41 ^e
ADS 16138.....	HO 295	214608	111805	22388+4419	2000.7617	151.9	0.211	503	40 ^{a,e}
ADS 16173.....	HO 296 AB	214850	111974	22409+1433	1999.6395	32.0	0.337	503	40 ^e
ADS 16417.....	STT 536 AB	217166	113445	22586+0921	2000.7589	22.5	0.288	503	40
					1999.5657	346.5	0.280	648	41
					2000.7589	346.8	0.283	648	41
					2000.7589	345.9	0.280	503	40 ^a
HR 8762	WRH 37 Aa-B	217675	113726	23019+4220	1999.5658	314.1	0.081	648	41 ^a
BD +57°2676.....	HDS 3285	217944	113852	23034+5834	2000.6171	286.6	0.075	648	41
					1998.9270	117.0	0.375	648	41

TABLE 2—*Continued*

Name	Discoverer Designation	HD	HIP	WDS α, δ (J2000.0)	Date	θ (deg)	ρ (arcsec)	λ (nm)	$\Delta\lambda$ (nm)
ADS 16497.....	A 417 AB	218060	113996	23052–0742	1999.8852	117.5	0.374	648	41
					1999.6396	349.5	0.189	601	42 ^{b,d,e}
					2000.7645	181.4	0.194	648	41 ^{a,d,e}
BD +8°5011.....	HDS 3302	218793	114444	23107+0947	1998.9243	325.4	0.376	648	41
					1999.5658	326.2	0.382	648	41
BD +15°4809.....	HEI 88	220077	115279	23209+1643	1998.9243	268.9	0.141	648	41
					1999.8907	281.8	0.123	648	41
BD +40°5078.....	COU 1845	220834	115723	23267+4103	1998.9270	356.5	0.828	648	41
					1999.5658	355.5	0.824	648	41
					1999.8827	356.5	0.832	503	40
BD +44°4419.....	YR 17	220821	115715	23267+4520	1998.9270	192.5	0.414	648	41
					1999.0091	192.5	0.418	648	41
					1999.0173	192.2	0.421	648	41
					1999.5658	193.2	0.415	648	41
					2000.6171	194.8	0.412	648	41
					2000.7590	195.7	0.428	648	41
ADS 16800.....	BU 1266 AB	221264	116017	23304+3050	1999.5659	206.3	0.150	648	41 ^c
BD +42°4700.....	HDS 3356	221613	116259	23334+4251	2000.6171	119.6	0.153	648	41
					2000.7590	114.7	0.154	648	41
BD +48°4109.....	COU 2674	222104	116578	23375+4922	1999.5685	19.7	0.356	648	41
					1999.8827	19.7	0.368	503	40 ^a
					2000.6171	19.5	0.359	503	40
					2000.7590	19.6	0.369	648	41
BD –1°4469.....	YR 18	222342	116756	23397–0044	2000.7645	271.5	0.343	648	41 ^a
BD +45°4301.....	MLR 4	222516	116849	23411+4613	1998.9270	221.9	0.120	648	41 ^{a,d}
					1999.0091	221.9	0.121	648	41 ^{a,d}
					1999.6341	229.6	0.130	601	42 ^{a,d}
					1999.8827	235.0	0.132	503	40 ^{a,d}
					2000.6171	241.9	0.136	503	40 ^{a,d}
					2000.7590	244.2	0.142	648	41 ^{a,d}
BD +35°5086.....	HDS 3373	222858	117094	23443+3620	1998.9271	254.3	0.553	780	31
					1999.5659	252.6	0.563	648	41
					1999.8909	253.2	0.562	648	41
ADS 17052.....	A 2700	223688	117666	23518–0637	2000.7645	236.1	0.209	648	41 ^a
HR 9041	FIN 359	223825	117761	23529–0309	1999.5659	265.8	0.087	648	41 ^b
					2000.7645	258.8	0.092	648	41 ^b
ADS 17111.....	A 2100	224315	118054	23568+0444	2000.7645	283.5	0.246	648	41

^a Quadrant ambiguous, but consistent with previous measures in the Fourth Catalog of Interferometric Measurements.

^b Quadrant ambiguous, but inconsistent with previous measures in the Fourth Catalog of Interferometric Measurements.

^{b?} Quadrant ambiguous, but possibly inconsistent with the few previous measures in the Fourth Catalog of Interferometric Measurements.

^c Quadrant unambiguous, but inconsistent with previous measures in the Fourth Catalog of Interferometric Measurements.

^{c?} Quadrant unambiguous, but possibly inconsistent with the few previous measures in the Fourth Catalog of Interferometric Measurements.

^d Measure appears in Fig. 4a.

^e Measure appears in Fig. 4b. If the quadrant here is inconsistent with previous measures, it has been flipped before being plotting in the figure.

(W. I. Hartkopf 2001, private communication). Most of these orbits also give uncertainties for the seven orbital parameters; we have used these to calculate the uncertainty in the observed parameters (ρ, θ) at our epochs of observation through standard propagation of errors.

Figure 2a shows observed-minus-ephemeris separation residuals for the subset of measures mentioned above. Figure 2b shows the same for the position angle residuals. Both indicate that there are no strong systematic offsets for our data versus orbital ephemerides over a wide range of expected separations. However, given the separation data, it is possible that a slight negative offset to the residuals exists. We have investigated this by studying objects with separations greater than $1''$ and comparing our measures with the work of previous observers. For example, seven objects in Table 2 have separations larger than $1''$ and have published orbital parameters listed in the Sixth Catalog of Orbits of

Visual Binary Stars (Hartkopf & Mason 2001b).⁴ For these seven objects, 12 measures appear in Table 2. In comparing with the orbital ephemeris predictions in each case, there is no evidence of a strong separation or position angle offset. Results of the study are shown in the first part of Table 3, under the orbit type of “large separation.” Figure 3 shows plots of four such examples using all data currently available in the Fourth Catalog of Interferometric Measurements of Binary Stars (Hartkopf et al. 2002).⁵ On balance, after studying these and other examples, we see no strong evidence for a significant systematic underestimate in separation.

The rightmost column in Table 3 gives the rms, that is, standard, deviation from the average residual, with upper

⁴ See <http://ad.usno.navy.mil/wds/orb6.html>.

⁵ See <http://ad.usno.navy.mil/wds/int4.html>.

FIG. 2a

FIG. 2b

FIG. 2.—(a) Separation residuals for objects in Table 2 that have speckle orbits; (b) position angle residuals for the same sample. The error bars plotted are the ephemeris uncertainties for the epoch of observation derived from the uncertainties in the orbital parameters. The gray region to the left marks the region below the diffraction limit of the telescope.

and lower error bar estimates. These error bars are derived from a Monte Carlo calculation, since the standard deviation is biased for small samples and the usual formula for the uncertainty in the standard deviation [$\sigma/(2N)^{1/2}$, where N is the number of trials] is likewise inaccurate. A standard χ^2 analysis would yield error bars that enclose 68.3% of the distribution of variance (typically 34.15% on one side of the average variance, and 34.15% on the other, though that choice is not unique). To obtain the error bars in standard deviation, one merely takes the square root of the values at the top and bottom of the variance error bar. An alternate approach, which we have taken here, is to work directly with the standard deviations. By selecting random Gaussian deviates of the given sample size ($N = 12$ in the case of the large-separation orbit comparison) many times (i.e., many trials of 12), we first estimate and correct for the bias in the small sample standard deviation that is caused by a poor estimate of the sample mean inherent in small-sample statistics. Then we search for the smallest possible interval in standard deviation that encloses 68.3% of the trials, regardless of where the average standard deviation falls within that interval. This procedure causes the data point to slide up in standard deviation after bias correction and then causes the error bar to slide down relative to the point after interval minimization as a result of the shape of the standard deviation histogram. Although this technique is somewhat different from the standard approach, we feel that it more accurately estimates both the average standard deviation of the process and the best estimate of the uncertainty in the standard deviation.

Figures 4a and 4b show similar residual plots for what we judge to be the highest-quality orbits from the above sample. Specifically, this “high grade” sample for Figure 4a is composed of observations in which the ephemeris prediction has uncertainty of less than 2 mas in separation, while the sample for Figure 4b is composed of observations for which the ephemeris prediction has uncertainty of less than 1° in position angle. The separation sample does not span the full range of separations represented in Table 2 but, because of the higher quality of the ephemeris predictions, is probably a better representation of the observational scatter in the separation coordinate. Table 3 contains numerical results from the high-grade ρ and θ samples, noted in the first column as “speckle” orbits. These indicate that the standard deviation of the separation residuals is less than 3 mas. The average residual for the sample is -0.56 ± 0.49 mas, a slight negative result. Although it is not statistically significant, a similar slight negative result was also obtained in Paper I. Likewise, for the standard deviation of the position angle residuals, we obtain a value of just under 1° . These standard deviation figures will contain not only our measurement uncertainty, but also the ephemeris uncertainty, and therefore are upper limits to the CCD speckle system measurement uncertainty. In order to obtain the rms deviations and error bars shown for the speckle orbits, we have used the same Monte Carlo method described above, although the larger sample sizes (34 and 57, respectively) yield results that are very close to those of the standard formulae.

TABLE 3
SUMMARY OF RESIDUALS AND ORBIT COMPARISONS

Orbit Type	Orbit Requirement	Number of Observations	Average Residual (obs. – eph.)	rms Deviation from Avg. Res.
Large separation	$\rho_{\text{obs}} > 1''$	12	-0.26 ± 0.52	$1.76^{+0.34}_{-0.41}$ deg
	$\rho_{\text{obs}} > 1''$	12	$+1.7 \pm 37.7$ mas	127^{+25}_{-29} mas
Speckle.....	$\delta\theta_{\text{eph}} < 1.0^\circ$	57	-0.01 ± 0.12	$0.91^{+0.08}_{-0.09}$ deg
	$\delta\rho_{\text{eph}} < 2.0$ mas	34	-0.56 ± 0.49 mas	$2.84^{+0.30}_{-0.39}$ mas

FIG. 3a

FIG. 3b

FIG. 3c

FIG. 3d

FIG. 3.—Typical examples of large-separation results from Table 2. (a) A 1813 AB-C; the orbit is that of Heintz (1973). (b) KR 60; the orbit is that of Heintz (1986). (c) STF 1037; the orbit is that of Mason et al. (1999). (d) STF 1670; the orbit is that of Girard et al. (2000). The crosses mark the origin, filled circles represent measures in Table 2, and the small plus signs are previous measures from the Fourth Catalog of Interferometric Measurements. Line segments are drawn from the ephemeris prediction for the position and the epoch of observation to the observed location. The results presented here show no obvious systematic differences when compared with previous interferometric observations.

Our second method of investigating the measurement precision is to study cases in which we have at least three measures for an object in Table 2 that are taken at or very near the same time, that is, typically within minutes of one another. Unlike the previous method, because such repeated observations generally involve similar seeing conditions and detector parameters, the scatter in such measures is presumably composed mostly of random error in the reduction and measurement technique and, therefore, repre-

sents lower limits on the overall measurement uncertainty. Nonetheless, if the standard deviation of the values is computed in each case, these results can be plotted as a function of various parameters. Again, the Monte Carlo method was used to estimate the uncertainties in σ_ρ and σ_θ , where the sample sizes range from $N = 3$ to $N = 6$ in this case. In Figures 5a and 5b, we plot the separation and position angle standard deviations, respectively, as a function of average system separation. Dashed curves are plotted in each case:

FIG. 4a

FIG. 4b

FIG. 4.—(a) Separation residuals for the subset of objects in Fig. 2a having ephemeris uncertainty in separation at the epoch of observation of less than 2 mas. (b) Position angle residuals for the subset of the objects in Fig. 2b having ephemeris uncertainty in position angle of less than 1° . As in Fig. 2, the error bars shown are the uncertainties in the coordinate derived from the published orbital parameters, and the gray region to the left marks the region below the diffraction limit of the telescope.

in Figure 5a, a dashed line is drawn at 2.84 mas, the value obtained from the speckle orbit ephemeris study; in Figure 5b, the curve drawn is $\sigma_\theta(\rho) = 0.16272/\rho$ (deg), which one expects given a linear measurement precision of 2.84 mas. No error bars are plotted in the horizontal coordinate; their size is typically smaller than the width of the plot symbol. The curves appear to be in reasonable agreement with the data, from which it may be suggested that the standard deviations obtained in the speckle orbit study are dominated by our own measurement precision. In Figure 6, the separation standard deviations are plotted as a function of magnitude difference, with the system magnitude encoded in the shade of the plot symbol. If the high point to the left is ignored because of its magnitude ($V = 9.4$), the curve shows a possible trend toward higher scatter at larger Δm 's.

In Figure 7, we show a plot of the magnitude difference versus total system V magnitude for all objects in Table 2. The large majority of objects have values for both param-

eters listed in the *Hipparcos* Catalogue; in such cases, we have plotted the point $(V, \Delta H_\rho)$. In cases where the object does not have one of the values listed in the *Hipparcos* Catalogue or was not a *Hipparcos* object, we have used total V magnitudes from the WDS or the Bright Star Catalogue (Hoffleit & Jaschek 1982) or, in the case of magnitude differences, if no other value exists we have used the preliminary magnitude difference estimate from our speckle observations. The separation of the system (taken from Table 2) is encoded in the shade of the plot point, with large separations receiving lighter shades and a separation at the diffraction limit of the telescope receiving black. The figure can be used as a lower limit to the overall detection capabilities of the system in good observing conditions. It indicates that systems with total apparent magnitudes of at least 10 can generally be resolved and measured and that systems with magnitude differences of at least 4.5 can be measured even at separations considerably below $1''$.

FIG. 5a

FIG. 5b

FIG. 5.—(a) Standard deviations of separation for objects in Table 2 having at least three observations taken at the same or nearly the same epoch. The dashed line marks the value of 2.84 mas, the standard deviation of residuals from the speckle orbit study. (b) Standard deviations of position angle for objects in Table 2 meeting the same criterion. The dashed curve marks the function $0.16272/\rho$ (deg), the value expected for a linear measurement uncertainty of 2.84 mas.

FIG. 6.—Standard deviations of separation for objects in Table 2 having at least three observations taken at or near the same epoch. The data are plotted as a function of the *Hipparcos* magnitude difference, with the shade of the plot symbol indicating the system magnitude. Black is *V* magnitude 3.5, and white is magnitude 7.0 and fainter.

4. DOUBLE AND SUSPECTED NONSINGLE STARS FROM *HIPPARCOS*

For the 53 *Hipparcos* discoveries that appear in Table 2, many show a significant change in position angle, separation, or both from the discovery epoch to the measures presented here. These are objects that should be regularly observed in the coming years, first, to determine whether the motion is orbital in nature and, second, to obtain the orbital parameters. Table 4 presents the fastest-moving objects, namely, those having moved more than 100° in position angle or 100 mas in separation between the *Hipparcos* measure and the latest measure in Table 2. The columns give (1) the WDS number; (2) the *Hipparcos* double star number; (3) the *Hipparcos* Catalogue number; (4) the system apparent *V* magnitude; (5) the system parallax in milliarcseconds; (6) the composite spectral type of the pair; (7) the change in position angle from 1991.25 to the latest measure in Table 2, in degrees; and (8) the change in separation from

1991.25 to the latest measure in Table 2 in milliarcseconds. Data listed in columns (3) through (6) are drawn from the *Hipparcos* Catalogue.

Four objects have already shown obvious orbital motion. These are HDS 17, HDS 318, CAR 1, and HDS 521. (We include CAR 1 in this context since its first observation epoch, namely, that of *Hipparcos*, predates the 1995 discovery observation of Carillet et al. 1996.) A number of others have shown probable orbital motion, including many mentioned in the previous paragraph, but we prefer to continue observing these stars until definitive statements can be made. The observation histories are plotted for the four obviously bound systems in Figure 8, along with a contour plot of a reconstructed image made from one of our recent observations. Three of the four objects have evidently already completed more than half an orbit since the *Hipparcos* discovery epoch. The reconstructed images are made via the technique of bispectral analysis in the Fourier plane. The initial guess for the phase of the object's Fourier transform was chosen to be that of a binary star with the brighter star located at the center of the image plane and a magnitude difference, separation, and position angle given by our power-spectrum analysis. In successive iterations, the phase map was then allowed to vary to best fit the data. While these reconstructed images are not unique solutions (they would not satisfy the criterion of maximum entropy, for example), they are consistent with the data. Furthermore, the images are not truly diffraction limited. In order to ensure high-quality image reconstructions, we have used a Gaussian low-pass filter in the frequency domain prior to inverse-transforming the image. The effective beam size used here (except as noted in the figure legend) has FWHM of 63 mas. Further information regarding these stars are given in Table 5, where the column headings are identical to those of Table 4.

Thirteen objects noted in the *Hipparcos* Catalogue as suspected nonsingles are present in Table 2, and as far as we are aware, the values here are the first published relative astrometry of the components. A 14th object, HIP 5131, was noted as a double in the Catalogue, but no relative astrometry was given. We have also presented, we believe for the

FIG. 7a

FIG. 7b

FIG. 7.—(a) Magnitude difference vs. system *V* magnitude (as it appears in the *Hipparcos* Catalogue) for all objects in Table 2 except new discoveries. The shade inside the plot symbol is an indication of the separation of the system; white is used for all systems with separation greater than $1''$, and as the separation decreases below $1''$, the shade deepens. Black represents a system at the diffraction limit of the telescope. (b) A similar plot for the 15 new discoveries listed in Table 2 and discussed in § 4.

FIG. 8a

FIG. 8b

FIG. 8c

FIG. 8d

FIG. 8.—Relative astrometry histories for four binaries that have earliest relative astrometry from the *Hipparcos* Catalogue and now show clear orbital motion. The cross marks the origin and the common point for all observations for the brighter star, while the filled circles indicate observed positions of the secondary over time. An indication of the observer and the year has been given next to each point; “H91” indicates the *Hipparcos* observation, “Wxx” indicates a WIYN observation and the year in all plots. Overlaid in each case is a contour plot of the reconstructed image made from one of our recent speckle observations. In all cases, solid contours have been drawn at 0.1, 0.3, 0.7, and 0.9 of the maximum, a dotted contour has been drawn at -0.02 of the maximum, and a dashed contour at 0.5 of the maximum. (a) HDS 17; here “M99.8” is the observation of Mason et al. (2001), and the position angles of the three observations in Table 2 that have quadrants inconsistent with other observers (table note b) have been flipped for plotting purposes here. (b) HDS 318. The position angle of the observation in Table 2 that has quadrant inconsistent with other observations (table note c) has been flipped for plotting purposes. (c) CAR 1; here “C95” is the 1995 observation of Carillet et al. (1996), “A97” is the 1997 observation of Aristidi et al. (1999), and “S98.65” is the 1998 observation of Scardia et al. (2000). (d) HDS 521; in this case an extra contour has been drawn at 0.2 of the maximum, and the reconstructed beam size is approximately 86 mas.

first time, evidence of a faint companion to HR 7640, which until now has escaped detection, even by *Hipparcos*. Because of the employment of the strip method, there is a small chance that a wide component falling outside the strip but on the CCD active area could be aliased to a smaller separation in our data. In all cases, we have checked for the existence of wide companions potentially on the chip in the

WDS and the SIMBAD database, and none were indicated. It is therefore unlikely that any of these stars have been confused with known stars in the vicinity of the primary. As noted above, these objects have been given the designation “YR” in Table 2. A plot of magnitude difference versus total magnitude for the sample is shown in Figure 7b. Eighteen objects listed as suspected nonsingles in the *Hipparcos*

TABLE 4
Hipparcos DOUBLE STARS SHOWING SUBSTANTIAL MOTION IN POSITION ANGLE OR SEPARATION

WDS	HDS	HIP	Total V	π (mas)	Spectrum	$\Delta\theta$ (deg)	$\Delta\rho$ (mas)
00321–1218 ...	HDS 71	2532	8.27	13.78	G1 V	–35	+113
00495+4404 ...	HDS 109	3857	7.78	14.85	G0	–25	–116
01017+2518 ...	HDS 134	4809	6.71	13.94	G8 IV	–122	–11
01129+5136 ...	HDS 160	5674	7.30	12.94	A5	–124	–5
02022–2402 ...	HDS 272	9497	7.87	15.71	F6 V	+153	–37
02249+3039 ...	HDS 314	11253	8.16	16.88	G0 V	–40	+108
02415–1506 ...	HDS 351	12554	7.27	13.59	F7 V	+190	–35
03272+0944 ...	HDS 433	16083	3.73	14.68	B9 V	+37	–250
04195+3800 ...	HDS 552	20176	7.17	13.35	F0	–209	–41
05066+2630 ...	HDS 666	23772	8.91	12.00	G0	+191	–36
05525–0217 ...	HDS 787	27758	7.26	18.40	F5	–169	+5
09252+4606 ...	HDS 1353	46199	9.09	38.90	K0	–159	+16
11243+1354 ...	HDS 1622	55661	8.34	15.30	K0	+0	–102
21014+4037 ...	HDS 2995	103749	7.14	19.29	F5	–29	–251
21051+0757 ...	HDS 3004	104075	7.97	22.57	G5	–169	–283
21330+2408 ...	HDS 3065	106394	8.54	26.18	K0	–3	–110
22161–0705 ...	HDS 3158	109951	8.72	15.04	G5	–259	+129
22375+3923 ...	HDS 3211	111685	9.41	52.94	M2	–35	+156
23334+4251 ...	HDS 3356	116259	7.14	30.24	G0	–226	–41

TABLE 5
Hipparcos DOUBLE STARS SHOWING ORBITAL MOTION

WDS	HDS	HIP	Total V	π (mas)	Spectrum	$\Delta\theta$ (deg)	$\Delta\rho$ (mas)
00085+3456 ...	HDS 17	689	7.41	12.72	F8	–124	+36
02262+3428 ...	HDS 318	11352	8.00	23.19	G5	+287	–71
03496+6318 ...	CAR 1	17891	5.82	12.72	A5 V	+343	+1
04070–1000 ...	HDS 521	19206	6.88	24.00	G0	–273	+46

TABLE 6
Hipparcos SUSPECTED NONSINGLE STARS THAT SHOW NO EVIDENCE OF DUPLICITY IN WIYN OBSERVATIONS

HIP	V Magnitude	Parallax (mas)	Date	λ (nm)	$\Delta\lambda$ (nm)
10652	9.06	14.43	1999.8830	648	41
14135	2.54	14.82	1999.0148	648	41
14354	3.32	10.03	1999.8885	551	10
16467	8.56	18.58	2000.7677	648	41
17022 ^a	6.73	23.61	1999.0175	648	41
18174	7.47	12.75	2000.7650	648	41
19301	7.70	33.43	1998.9274	648	41
20171	5.50	12.20	2000.1453	503	40
			2000.7678	648	41
33129	8.38	8.63	1999.0124	648	41
			1999.0152	648	41
44390	4.74	11.35	1999.0180	648	41
50801	3.06	13.11	1998.9253	648	41
53064	5.57	12.39	1999.0157	648	41
99498	7.75	15.06	2000.7587	853	39
109303	6.11	23.79	2000.7644	503	40
110538	4.42	19.21	2000.7672	648	41
115716	8.71	14.08	2000.7645	648	41
117403	9.14	14.51	2000.7673	648	41
117915	7.51	23.62	2000.7673	648	41

^a Also noted as a stochastic solution double star in the *Hipparcos* Catalogue.

Catalogue but which did not show any signs of duplicity in our observations are listed in Table 6.

5. CONCLUSIONS

Relative astrometry measures have been presented for 253 double stars, including 53 stars found to be double by the *Hipparcos* satellite. Because of multiple observations, the data set consists of over 500 independent measures. The measurement precision of the CCD-based speckle system appears to be $2.84^{+0.30}_{-0.39}$ mas in separation and $0.91^{+0.08}_{-0.09}$ deg in position angle, which are slightly lower values than those in Paper I under good observing conditions with the CCD system. Systems of total magnitude of as faint as 10 and with magnitude differences of up to 5 can be measured in good conditions, with occasional results beyond these limits during outstanding conditions.

Fourteen stars listed as suspected nonsingles in the *Hipparcos* Catalogue have been resolved at WIYN for the first time, and HR 7640 was found to have a faint companion at a separation of under $0''.2$. Eighteen *Hipparcos* suspected nonsingles observed under excellent conditions were not found to have companions to the limits of detection of the speckle system at WIYN. The measures presented here, in combination with our previous results and the *Hipparcos* discovery measures, allow for the conclusive determination that four systems are in fact gravitationally bound and that, in particular, HDS 318

and CAR 1 have orbital periods in the range of 10 to 15 yr. A number of other *Hipparcos* discoveries have changed significantly in position angle, separation, or both since the *Hipparcos* discovery epoch and should be observed routinely in the coming years to determine whether the motion is orbital in nature.

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