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Speckle observations of double and multiple stars at Pic du Midi: Measurements during 1995 and 1997 and new orbits^{★,★★,★★★}

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Abstract. We present speckle observations of 48 double and multiple stars observed with the 2-meter “Télescope Bernard Lyot” (TBL) in December 1995, January 1997 and June 1997. Angular separations, absolute position angles and relative photometry result from these observations. New orbital elements have been recalculated for 8 double stars.

Key words: techniques: interferometric — binaries: close

1. Introduction

This paper presents the results of double and multiple star speckle observations performed with the 2 m Télescope Bernard Lyot of the Pic du Midi observatory (France). Instrumentation and data analysis were partly described in a previous paper (Aristidi et al. 1997b). During the run of June 1997, we tested a real time system described in Sect. 2. Five stars could also be observed using the PAPA photon-counting detector (Papaliolios et al. 1982, 1985).

Double stars measured here are either long-period binaries for which the last observation is old, or stars previously observed by us and for which the companion's posi-

tion was measured far from the predicted value (Aristidi et al. 1997b). Some stars were also selected because their orbit parameters are very uncertain. Two of these double stars were recently discovered as double: MOAI 1 (SAO 12917) observed in December 1995 (Carbillet et al. 1996, 1998b), and ν Cyg discovered by Hipparcos (The Hipparcos Catalogue, 1997). Multiple stars were selected from the Multiple Star Catalogue (Tokovinin 1997). All of them present a lack of measurement: unknown orbits, unknown spectral classes of the components, companion suspected from other observational techniques (spectroscopy). These stars were selected together with A.A. Tokovinin.

2. Observations

Data were recorded during three observing runs in December 1995, January 1997 and June 1997 at the TBL. We had quite poor weather conditions with very short coherence times of a few milliseconds only and a FWHM seeing often larger than 2 arcsec. A total of 33 double stars and 15 multiple stars was observed; details are given in Table 1. The focal instrumentation is the speckle camera of the Aperture Synthesis group of Observatoire Midi-Pyrénées (OMP). For the major part of the nights it was coupled with the ICCD detector of Nice University. This instrumentation is described in Aristidi et al. (1997b) and Prieur et al. (1998). During the runs in January 1995 and January 1997, the images were recorded on video tape for further processing. In June they were also sent to a PC hosting a Matrox Genesis digitizer board equipped with a digital signal processor (C80) which enables near real-time processing. As an example the power spectrum for

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★ Based on observations made with 2 m Télescope Bernard Lyot, Pic du Midi, France.

★★ Tables 3 to 10 are only available in electronic form only via the CDS at ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/Abstract.html>

★★★ Figures 3 and 4 are only available in electronic form via <http://edpsciences.com>

Table 1. Table of measurements. λ denotes the wavelength and $\Delta\lambda$ the bandwidth. The column labelled Mult. gives the number of stars in the system (multiplicity). The column labelled Obj. give the name of the measured components of the multiple star. Predicted values of ρ and θ are computed from the latest available orbits. For orbits prior to 1982 (followed by a \star), orbital elements were found in the catalogue of Worley & Heintz, 1983. For ϵ Hya the angular separation ABxC was computed from AB, AC and Δm_{AB} as the distance between C and the photocenter of AB. The columns labelled $\Delta\rho$ and $\Delta\theta$ give the residuals in ρ and θ

WDS id. or other	Discover id.	Mult.	Reference star	Epoch	$\lambda/\Delta\lambda$ (nm)	Expos. (ms)	Obj.	Latest orbit	ρ (")	ρ_{cal} (")	$\Delta\rho$ (")	θ (°)	θ_{cal} (°)	$\Delta\theta$ (°)	Δm
SAO 12917	Moai 1	2	SAO 12929	1997.071	530/57	8			0.08 ± 0.01	—	—	209 ± 1	—	—	—
02537+3820	BU 524	3	none	1995.931	644/70	16	AB	Heintz, 1980	0.08 ± 0.01	0.04	0.04	194 ± 1	185	9	—
02537+3820	BU 524	3	none	1995.931	644/70	16	AB	Our orbit	0.08 ± 0.01	0.05	0.03	194 ± 1	189	5	—
04041+3931	STF 483	2	HD 25022	1997.070	530/57	10	AB	Couteau, 1990	1.20 ± 0.01	1.112	0.09	64.6 ± 0.2	62.7	1.9	—
06221+5922	STF 881	3	SAO 25731	1997.074	530/57	10	AB		0.750 ± 0.008	—	—	139.5 ± 0.2	—	—	1.4 ± 0.1
06462+5927	STF 948	3	SAO 13973	1995.930	644/70	16	AB	Popovic, 1995b	1.79 ± 0.02	1.69	0.1	75.3 ± 0.2	72.2	3.1	—
06474+1812	STT 156	2	SAO 95996	1997.071	447/47	16			—	—	—	—	—	—	—
06575+0253	A 2681	2	SAO 114523	1997.074	530/57	8		Baize, 1992	0.318 ± 0.003	0.383	-0.065	217.6 ± 0.2	219.4	-1.8	1.09 ± 0.15
06575+0253	A 2681	2	SAO 114523	1997.074	530/57	8		Heintz, 1974*	0.363 ± 0.004	0.247	0.116	139.4 ± 0.2	115.3	19.6	0.9 ± 0.2
07148-1529	BU 575	3	SAO 152663	1997.071	530/57	8	AB	Our orbit	0.551 ± 0.005	0.346	0.17	102.3 ± 0.2	316.584	177.2	0.8 ± 0.3
07277+2127	BD+21 1602	4	64 Gem	1997.074	530/57	8	AB	Mourao, 1962*	0.078 ± 0.002	0.727	-0.176	102.3 ± 0.2	283.3	-181	—
07346+3153	STF 1110	6	β Gem	1997.074	530/57	8	AB		—	—	—	361 ± 1	—	—	1.0 ± 0.2
08468+0625	STF 1273	5	HR 3418	1997.071	530/57	5	AB	Docobo, 1985	3.58 ± 0.04	—	-0.03	69.3 ± 0.2	—	—	1.3 ± 0.1
09008+4148	KUI 37	2	none	1995.930	644/70	16	AB	Heintz, 1988	—	—	-0.04	—	—	—	—
09245+1808	A 2477	2	SAO 98554	1997.074	530/57	7	AB		0.264 ± 0.003	0.273	-0.009	173.9 ± 0.2	174.5	-0.6	0.9 ± 0.2
09245+1808	A 2477	2	SAO 98554	1997.074	530/57	7	AC	Hartkopf 1989	2.79 ± 0.03	—	—	294.0 ± 0.2	—	—	1.9 ± 0.2
09412+0954	H 76	3	SAO 98955	1997.071	530/57	5	ABxC	Heintz, 1996	2.84 ± 0.03	2.87	-0.03	295.3 ± 0.2	295.7	-0.4	—
10017+1724	XY Leo	4	SAO 98976	1997.074	530/57	16		Hartkopf, 1989	0.373 ± 0.003	0.377	0.004	129 ± 1	131.0	2	—
10131+2725	STT 213	2	SAO 81273	1997.074	530/57	16		Zulevic, 1967*	0.407 ± 0.004	0.350	0.057	348.1 ± 0.2	356.9	-8.8	—
10397+0851	STT 224	2	SAO 118431	1997.071	530/57	16		Our orbit	—	0.407	0.009	—	347.8	0.3	—
11037+6145	BU 1077	4	β UMa	1997.074	530/57	1	AB		0.59 ± 0.01	—	—	267.9 ± 0.2	—	—	1.6 ± 0.2
11037+6145	BU 1077	4	β UMa	1997.074	530/57	1	AB		-not detected-	—	—	—	—	—	—
11137+2008	STF 1517	2	SAO 81770	1997.074	530/57	5	Ac		1.03 ± 0.01	0.971	0.059	125.9 ± 0.2	121.5	4.4	—
11486+1417	BU 603	2	SAO 99973	1997.074	530/57	15		Heintz, 1962*	0.530 ± 0.005	0.581	-0.051	158.3 ± 0.2	—	-2.2	—
11551+4629	A 1777	5	SAO 43839	1997.074	530/57	7	AB	Heintz, 1984	0.470 ± 0.005	0.416	0.054	226.2 ± 0.2	223.9	2.3	1.5 ± 0.2
11551+4629	A 1777	5	SAO 43839	1997.074	530/57	7	AB	Our orbit	0.533 ± 0.005	—	—	321.4 ± 0.2	—	—	—
11551+4629	A 1777	5	SAO 43839	1997.074	530/57	7	AB	Heintz, 1963*	1.01 ± 0.01	1.129	-0.128	343.1 ± 0.2	337.3	5.8	1.8 ± 0.1
11551+4629	A 1777	5	SAO 43839	1997.074	530/57	7	AB	Baize, 1991	0.121 ± 0.005	0.109	0.012	276 ± 1	308	-32	1.9 ± 0.1
11551+4629	A 1777	5	SAO 43839	1997.074	530/57	7	AB	Our orbit	0.121 ± 0.005	0.111	0.010	—	275	1	—
11551+4629	STF 1639	2	SAO 82456	1997.074	530/57	8	C		3.79 ± 0.03	—	—	222.3 ± 0.2	—	—	—
12244+2535	STF 1639	2	SAO 82456	1997.074	530/57	8	D		-not detected-	—	—	—	—	—	—
HD 114519	RS CVn	3	SAO 63388	1997.074	644/70	16		Aller, 1951*	1.68 ± 0.01	1.641	0.04	325.6 ± 0.2	323.9	1.7	—
13112+3050	A 1359	4	Weis 22389	1997.071	644/70	16			-not detected-	—	—	—	—	—	—
14323+2641	A 570	2	HD 130870	1997.468	644/70	10		Van den Bos, 1949*	0.257 ± 0.003	—	—	145 ± 1	—	—	—
14323+2641	A 570	2	HD 130870	1997.468	644/70	10			0.222 ± 0.01	0.219	0.003	161.2 ± 1	164.7	-3.5	—

Table 1. Table of measurements (continued). For observations made with the PAPA detector, a † has been added in superscript to the exposure time (usually 2 ms). (*) ν Cyg was in fact discovered as double and then not used as reference star in the processing of BU 151

WDS id. or other	Discover id.	Mult.	Reference star	Epoch	$\lambda/\Delta\lambda$ (nm)	Expos. (ms)	Obj.	Latest orbit	ρ (")	ρ_{cal} (")	$\Delta\rho$ (")	θ (°)	θ_{cal} (°)	$\Delta\theta$ (°)	Δm
14489+0557	STF 1883	2	HD 134169	1997.468	644/70	16		Starikova, 1982	0.773 ± 0.002	0.839	-0.066	283.2 ± 0.2	283.2	0.0	
14534+1542	ST† 288	2	none	1997.481	530/57	16		Zulevic, 1990	1.23 ± 0.01	1.23	0.000	167 ± 0.2	166.3	0.7	0.84 ± 0.06
15073+1827	A 2385	2	HD 137510	1997.468	644/70	12		Eggen, 1946*	-not detected-	0.101	—	—	215.2	—	
15273+0942	A 1120	2	none	1997.481	530/57	16		Muller, 1955*	0.180 ± 0.002	0.217	-0.037	318 ± 1	323	-5	
15390+2545	COU 612	2	HD 137510	1997.468	644/70	16		Baize, 1993 Our orbit	0.256 ± 0.007	0.161	0.095	208.3 ± 0.8	199.3	9.0	
15390+2545		2	HD 137510	1997.468	644/70	16		Baize, 1993 Our orbit	0.241	0.15	0.015	207.4	207.4	0.9	
16518+2840	STF 2107	3	HD 152896	1997.468	644/70	5	AB	Scardia, 1984a	1.425 ± 0.01	1.344	0.081	95.3 ± 0.6	97.2	-1.9	
17240+3835	HU 1179	2	HD 156632	1997.468	644/70	16		Baize, 1988	0.213 ± 0.004	0.183	0.030	275.4 ± 0.2	276.9	-1.5	
17490+3704	COU 1145	2	HD 156632	1997.468	644/70	16		Hartkopf et al., 1996	0.124 ± 0.008	0.126	-0.02	89 ± 1	92	3	
17542+1108	FIN 381	2	HD 164615	1997.468	644/70	10		Baize, 1990	-not detected-	0.066	—	—	184.6	—	
18096+0400	STF 2281	2	HD 166073	1997.468	644/70	12		Heintz, 1984	0.490 ± 0.005	0.510	-0.020	300.5	299.2	1.3	
18386+1632	HO 87	2	HD 172151	1997.468	644/70	16		Baize, 1987	0.338 ± 0.007	0.306	0.032	67 ± 1	59.5	7.5	
18558+0327	A 2192	2	HD 174966	1997.468	644/70	16		Docobo, 1988	0.226 ± 0.002	0.226	0.000	62.8 ± 1	64.2	-1.4	
18558+0327	A 2192	2	HD 174966	1997.471	644/70	2†		Docobo, 1988	0.238 ± 0.01	0.226	0.012	62.2 ± 1	64.2	-2.0	
19039+2642	A 2992	2	HD 176871	1997.471	644/70	—		Popovic, 1995a	0.231 ± 0.01	0.377	-0.146	253.5	258.9	-5.4	
19180+2012	COU 321	2	HD 181751	1997.468	644/70	16		Baize, 1991b Our orbit	0.093 ± 0.001	0.149	-0.056	135.8 ± 1	97.3	38.5	
19394+2215	STF 2556	2	none	1997.471	644/70	2†		Baize, 1991b Our orbit	0.104 ± 0.01	0.148	-0.045	138.6 ± 3	315.2	179.4	
19394+2215		2	none	1997.471	644/70	2†		Baize, 1991b Our orbit	0.149 ± 0.01	0.149	-0.045	138.6 ± 3	97.3	41.3	
19487+3519	ST† 387	2	HD 181751	1997.468	644/70	16		Baize, 1972*	0.362 ± 0.003	0.381	-0.019	10.6 ± 0.2	14.9	-4.3	
20375+1436	BU 151	2	HD 187795	1997.468	644/70	16		Our orbit	0.635 ± 0.006	0.357	-0.005	144.5 ± 0.4	8.8	1.8	
20375+1436		2	HD 187795	1997.468	644/70	16		Baize, 1961*	0.635 ± 0.006	0.553	0.082	144.5 ± 0.4	138.6	5.9	0.8 ± 0.2
20474+3629	ST† 413	3	ν Cyg*	1997.561	447/47	2		Hartkopf, 1989	0.373 ± 0.004	0.364	0.009	327.4 ± 0.2	325.9	1.5	1.0 ± 0.2
20474+3629		3	ν Cyg	1997.561	530/57	2		Hartkopf, 1989	0.373 ± 0.004	0.364	0.009	327.4 ± 0.2	325.9	1.5	1.0 ± 0.1
20474+3629		3	ν Cyg	1997.561	743/69	1		Hartkopf, 1989	0.373 ± 0.004	0.364	0.009	327.4 ± 0.2	325.9	1.5	1.0 ± 0.1
20474+3629		3	ν Cyg	1997.561	855/74	4		Hartkopf, 1989	0.373 ± 0.004	0.364	0.009	327.4 ± 0.2	325.9	1.5	1.1 ± 0.1
20550+2805	BU 367	2	none	1997.471	644/70	2†		Baize, 1983	0.873 ± 0.003	0.925	-0.052	9.9 ± 0.3	9.1	0.8	
HD 199629	ν Cyg	2	none	1997.471	644/70	16		Baize, 1991c	-not detected-	0.055	—	—	78.9	—	0.8 ± 0.1
HD 199629		2	none	1997.471	644/70	16		Baize, 1991c	-not detected-	0.050	—	—	92.87	—	1.0 ± 0.2
21080+0509	ST† 527	2	none	1997.468	644/70	10		Heintz, 1962*	0.452 ± 0.01	0.442	0.010	131.6 ± 1	133.9	-2.3	
21355+2427	HU 371	2	HD 200030	1997.471	644/70	2†		-not detected-	0.108 ± 0.01	—	—	247 ± 3	—	—	
21426+4103	BU 688	2	none	1997.468	644/70	16		-not detected-	—	—	—	—	—	—	0.8 ± 0.1
22431+4710	ST† 476	3	HD 214946	1997.471	644/70	2†	AB	Popovic, 1995a	0.115 ± 0.008	—	—	235.8 ± 0.5	—	—	1.0 ± 0.2
22431+4710		3	HD 214946	1997.471	644/70	2†	BC	Baize, 1961*	0.288 ± 0.007	0.294	-0.006	123.1 ± 0.5	119.6	3.5	1.00 ± 0.07
22431+4710		3	HD 214946	1997.471	644/70	2†		Baize, 1961*	0.296 ± 0.006	0.304	-0.008	306.7 ± 0.3	310.4	-3.7	
22431+4710		3	HD 214946	1997.471	644/70	2†		Baize, 1981	0.397 ± 0.004	0.426	-0.029	201.8 ± 0.5	203.0	-1.2	
22431+4710		3	HD 214946	1997.471	644/70	2†		Starikova, 1984	0.428	0.031	-0.031	202.9	202.9	-1.1	
22431+4710		3	HD 214946	1997.471	644/70	2†		Starikova, 1984	0.509 ± 0.01	—	—	122.8 ± 2	—	—	
22431+4710		3	HD 214946	1997.471	644/70	2†		Starikova, 1984	0.056 ± 0.006	—	—	44.0 ± 4	—	—	

a 128×128 image size is computed at a rate of about 20 frames per second. The use of a reference star for usual calibration of the telescope+atmosphere transfer function was sometimes avoided by computing the cross-correlation between time-separated images and subtracting it from the autocorrelation (Worden et al. 1977). Though at a lower speed (9 frames/s) the system is also programmed to compute the cross correlation between the images and their square in order to find the absolute position angles of binaries (Aristidi et al. 1997a). This system does not include yet the classification of images according to the seeing that is used in the data processing as described in Aristidi et al. (1997b). Bright stars ($m_V \lesssim 6$) were re-processed from the video tape for magnitude difference determination using probability imaging (Carbillet et al. 1998a). This provides also the absolute position angle (PA) and is useful to confirm the PA computed by the cross-correlation technique (Aristidi et al. 1997a).

Problem of saturation is taken into account the following way: before recording frames, the video digitizer displays saturated pixels, allowing the observer to adjust the gain and the offset of the detector to reduce the saturation. Moreover, at processing time (probability imaging), pixels at the maximum intensity level are rejected from the calculation of the magnitude difference.

The PAPA camera was used during part of these observations but because of technical testing and bad weather conditions it could only lead to measurements on the night of 23/06/97. It is actually a new version of the original camera described in Papaliolios et al. (1982, 1985). Modifications have been jointly implemented by P. Nisenson (Harvard Center for Astrophysics), D. Gezari (NASA) and L. Koechlin (OMP) in the last five years. The current version has a new binary mask setup and a refurbished image intensifier. A problem in the regulation of the high voltage power supply caused a strong geometric distortion and a variation of the overall scale which imposed quasi permanent scale calibrations during the night. A small “hole” at the center of the autocorrelation function was also noticed, due to a lack of detectivity of the electronics after each photo-event detection. A whole reduction procedure had to be set up in order to correct for these defects:

- Each star image was corrected with the distortion and scaling coefficients interpolated from the two images of the calibrating grid which were taken immediately before and after the star observation.
- To remove the hole at the center of the autocorrelation, each photo-event was correlated with the photo-events of a “gliding” time window located at 1 msec after the arrival time of the photo-event. The very poor atmospheric conditions did not allow us to use a time window larger than 2 msec (as the typical coherence time was less than 3 msec).

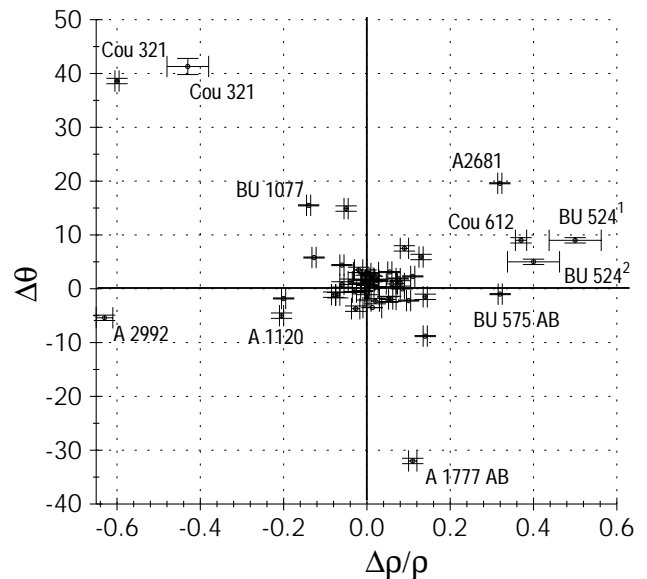


Fig. 1. Two dimensional plot of the residuals in position angle ($\Delta\theta$) and on the relative residuals in separation ($\Delta\rho/\rho$). For couples with known orbit, each measurement corresponds to a point in the graph. Error bars in ρ and θ have been drawn to scale. For points with large residuals, corresponding star names are given (in the case of BU 524, ¹ refers to the orbit of 1980 while ² refers to our orbit)

3. Results and discussion

The measurements are presented in Table 1. For multiple systems with at least 3 components, the name of each measured couple is given. Ephemeris are computed for double and/or multiple stars with known orbits. Figure 1 displays the residuals in ρ and θ as a cloud of points with error bars in the $(\Delta\rho/\rho, \Delta\theta)$ plane. This cloud of points centered on (0,0) validates the data reduction and calibration procedure. We also notice a few cases of abnormally large differences between our measurements and the expected values from the previously determined orbits. This is the case for example of Cou 321 ($\Delta\theta \simeq 40^\circ$) or A 2992 ($\frac{\Delta\rho}{\rho} \simeq 60\%$). Corresponding points are labelled with star names in Fig. 1. In order to check whether the problem comes from a poor observation or a bad orbit, we looked for other published data (Hartkopf 1998) and plotted residuals as a function of time. This was done for nine stars (BU 524, A 2681, BU 575, A 2477, BU 1077, A 1777, Cou 612, Cou 321, and STF 2556). Examination of these curves led us to recalculate new orbital elements for all these stars but BU 575.

The following comments can be made for some individual stars:

- **Moai 1** was discovered as double in December 1995 (Carbillet et al. 1996). An error occurred with the published values of the position angle, the correct values being: date = 1995.947, $\rho = 0'.110 \pm 0'.003$, $\theta = 167 \pm 1^\circ$ (Carbillet et al. 1998b).

- **BU 524** was observed near periastron, close to the limiting resolution of the telescope ($0''.066$ mas at $\lambda = 644$ nm).
- **A 1777** is a quintuple star. AB, AC and AD are expected to be resolved by a 2 m telescope. The couple AC did not fit in our field of view (separation $\simeq 60''$), so we did not measure it. We searched for companions close to star D but nothing was detected (for a separation $\geq 0''.05$ and a magnitude difference < 5).
- **STF 1517** is a double star with a very uncertain orbit (Hopmann 1970), computed period is about 4050 yr. This orbit cannot be used for ephemeris computation.
- ν **Cyg** was initially observed as a reference star and discovered double. The first observation (1997.468) being very poor, it has been reobserved in 1997.471 for confirmation and in 1997.561 for three colors relative photometry. Its duplicity was discovered by Hipparcos (The Hipparcos Catalogue, 1997).
- **BU 575** has a very uncertain orbit. A possible confusion between stars A and B (small magnitude difference) causes an uncertainty of 180° .
- **XY Leo** is mentioned as a quadruple star in Tokovinin (1997). Spectroscopic observations have revealed that this system is composed of two close pairs (denoted as Aab and Bab), one being a contact binary. The expected separation between the pairs deduced from spectrophotometric measurements is $AB \simeq 0''.15$ (Barden 1987). To our knowledge, it has never been resolved by visible speckle interferometry. We also did not detect this companion.

4. Orbit calculation

The orbits were computed using the method of Kowalsky (1873) and Hellerich (1925). The error bars calculation is described in Scardia (1983) for errors on the orbital elements, and in Scardia (1984b) for errors on the sum of masses of the stars.

The orbital elements are presented below for each couple. WDS identification (equinox 2000) (Mason 1998) is given for each star together with discover name and ADS catalog number. Orbits are plotted in Fig. 3 and Fig. 4. History of all measurements for each star are presented at the end of the paper. We computed eight orbits. Two of them may be considered as reliable (BU 524 and A 1777); a mass estimation and detailed discussion is given below. The six others are premature and the orbital elements are summarised in Table 3.

- **WDS 02537+3820 – BU 524 – ADS 2200 AB:** This close double star (separation $\simeq 0''.1$) with $\Delta m \simeq 1$ is a difficult object for visual observations. This explains the large residuals on the orbit plot. 160 measurements have been published since 1878, 129 have been retained for the orbit computation. On the plot of the new orbit one can see the lack of data near the periastron where

the predicted separation is under $0''.1$. In such a case this star is a good target dedicated for speckle interferometry techniques as demonstrated by the three points near periastron (two values comes from the CHARA, the third is ours). According to our orbit, the next periastron will occur in October 2027.

Orbital elements			
Ω ($^\circ$) (2000.0)	28.87	\pm	1.4
ω ($^\circ$)	266.78	\pm	0.6
i ($^\circ$)	115.8	\pm	1.9
P (yr)	31.572	\pm	0.50
T (yr)	1964.651	\pm	0.055
e	0.8067	\pm	0.017
a	$0''.253$	\pm	0.022
Astrophysical Information			
mag	5.34 – 6.35	Sp	F4 IV
Hipparcos parallax	$0''.01387$	\pm	$0''.00086$
Semi-major axis (AU)	18.2	\pm	2.7
Sum of masses (\mathcal{M}_\odot)	6.09	\pm	2.75

Dynamic parallax (Couteau 1978) could not be computed since star A is not a main-sequence star (spectral class F4IV). This does not agree with published masses of stars A and B estimated from their spectral classes (Tokovinin 1997): $\mathcal{M}_A = 1.38 \mathcal{M}_\odot$ and $\mathcal{M}_B = 1.15 \mathcal{M}_\odot$. If we suppose that the spectral class F4IV for the primary is well estimated, it might be possible that this system contains other stars to be discovered.

Van den Bos (1938) calculated two sets of orbital elements, a short period one ($P = 31.6$ yr) and a long period one ($P = 63.1$ yr), the second being justified by quadrant uncertainties and the fact that the observed separation was always greater than $0''.1$, whereas the short-period orbit predicted a very close periastron of about $0''.002$. We then computed a long period orbit with the following orbital elements: $T = 1988.066$, $P = 62.851$ yr, $e = 0.0286$, $a = 0''.211$, $\Omega = 129.79^\circ$, $\omega = 51.47^\circ$, $i = 133.73^\circ$. Residuals in separation and in position angle are plotted in Fig. 2 as a function of time. As can be shown on this figure and on the orbit plot, this long period orbit does not fit the observations close to the periastron when the star velocities are high (especially the last speckle measurements). From an astrophysical point of view, the total mass of the system given by this orbit is too small ($0.89 \mathcal{M}_\odot$). This long period orbit is then to be rejected.

Ephemeris					
Date	ρ ($''$)	θ ($^\circ$)	Date	ρ ($''$)	θ ($^\circ$)
1999.000	.165	7.6	2004.000	.206	341.9
2000.000	.181	1.3	2005.000	.207	337.5
2001.000	.192	356.0	2006.000	.208	333.2
2002.000	.199	351.0	2007.000	.207	328.8
2003.000	.203	346.4	2008.000	.206	324.4

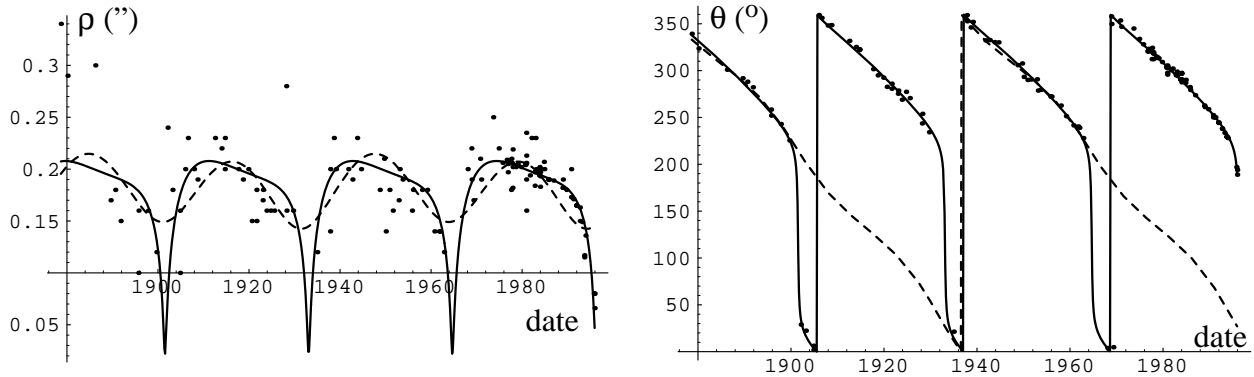


Fig. 2. Separation and angular positions versus date of the couple BU 524 AB. Measurements are represented by the points. The last measurements are interferometric ones. The solid line is the predicted position from our short-period orbit, dashed line is the solution given by our long-period one (see text)

– **WDS 11551+4629 – A 1777 – ADS 8347 AB:** Our orbit does well fit recent interferometric observations near periastron which present very small residuals. This is another example of the valuable contribution of speckle techniques. The star A is a spectroscopic binary of separation 0.222 mas (Tokovinin 1997). The star B seems (up to now) single. There are 2 more stars in the quintuple system whose separations are (Tokovinin 1997): $AB \times C \simeq 4''$ and $ABC \times D \simeq 63''$.

Orbital elements			
Ω ($^\circ$) (2000.0)	169.7	\pm	4.6
ω ($^\circ$)	26.9	\pm	2.1
i ($^\circ$)	39.7	\pm	1.9
P (yr)	136.538	\pm	8.4
T (yr)	1987.943	\pm	0.41
e	0.531	\pm	0.014
a	0''.225	\pm	0.018
Astrophysical Information			
mag	6.5 – 9.0	Sp	A3 V
Dynamic parallax	0''.0048		
Hipparcos parallax	0''.00407	\pm	0''.00124
Semi-major axis (AU)	55.3	\pm	21.2
Sum of masses (M_\odot)	9.1	\pm	11.6

Due to large error bars of semi-major axis a and period P , the total mass is very uncertain. For information we found in Tokovinin (1997):

- $M_{Ab} = 1.9 M_\odot$
- $M_{Aa} = 1.8 M_\odot$
- $M_B = 1.5 M_\odot$

giving a total mass $M_A + M_B = 5.2 M_\odot$ which agrees with our dynamic parallax.

Ephemeris					
Date	ρ (")	θ ($^\circ$)	Date	ρ (")	θ ($^\circ$)
1999.000	.124	287.1	2004.000	.164	308.6
2000.000	.132	292.4	2005.000	.171	311.7
2001.000	.140	297.2	2006.000	.179	314.6
2002.000	.148	301.42	2007.000	.187	317.1
2003.000	.156	305.2	2008.000	.194	319.5

– **Other orbits** Orbital elements for the stars A 2681, A 2477, BU 1077, COU 612, COU 321 and STF 2556 are given in Table 3. These orbits are premature and may be considered as equally tentative as previous ones. Some are based upon a few number of data (17 measurements for A 2681, 20 for Cou 321), some have very small magnitude difference causing quadrant errors. These orbits have to be improved by further observations.

5. Conclusion

These observations have shown that the association of the speckle camera of Observatoire Midi-Pyrénées, the ICCD detector of Université de Nice – Sophia Antipolis, and the reduction procedure we have been developing in the last few years is well adapted to binaries study. Despite poor atmospheric conditions, we have obtained a promising list of measurements and started to reach a productive stage in the field of binary stars. In the future we plan to make systematic observations of close double stars resolved by the TBL with unknown, old or uncertain orbits (grade 3 or more in the catalogue Heintz-Worley, Worley & Heintz 1983). We plan also to observe binaries with close periastron for which observations near the periastron are missing or uncertain. Complementary observations with the speckle camera will also be done with *BVR* imaging to measure the color indices (we could even obtain the spectra in some favorable cases) of the individual stars for which masses have been determined, in order to derive their spectral class.

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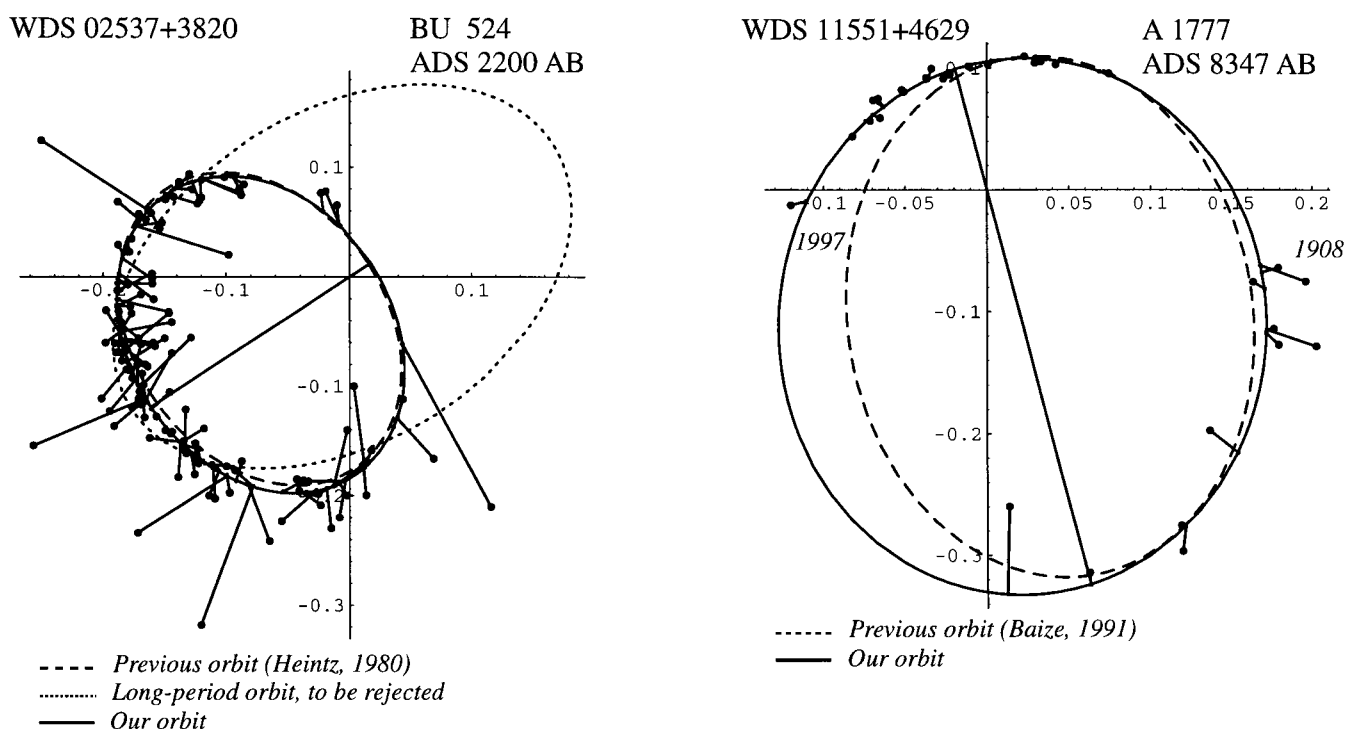


Fig. 3. Orbit of BU 524AB and A 1777. Our orbit is plotted in solid line on the graph, previous orbits in dashed line. For BU 524AB the long-period solution is plotted as well (see text). As usual North is down and East is right. Line of apsides of the new orbit is drawn in solid line. Measurements are plotted as points connected to their predicted value (“O–C” lines). Points corresponding the first and last measurement are labelled such as “1971” and “1997”

Table 3. Orbital elements for the 6 stars A 2681 (WDS 06575+0253), A 2477 (WDS 09245+1808), BU 1077 (WDS 11037+6145), Cou 612 (WDS 15390+2545), Cou 321 (WDS 19180+2012) and STF 2556 (WDS 19394+2215)

WDS	Ω ($^\circ$)	ω ($^\circ$)	i ($^\circ$)	P (yr)	T (yr)	e	a ($''$)
06575+0253	102.6	330.1	136.8	196.96	1946.157	0.884	0.247
09245+1808	9.8	99.1	46.6	196.67	1854.649	0.298	0.381
11037+6145	65.3 ± 16.5	276.2 ± 19.9	144.1 ± 22.5	44.637 ± 0.16	1955.541 ± 2.1	0.490 ± 0.13	0.660 ± 0.040
15390+2545	120.4	132.9	143.7	80.306	2054.944	0.394	0.248
19180+2012	126.0	80.0	114.0	152.3	2134.1	0.400	0.203
19394+2215	44.5	356.0	140.9	622.4	1970.310	0.476	0.678

astronomical database operated at CDS, Strasbourg, France, and of the CHARA (Georgia State University, Atlanta, Georgia, U.S.A.) 3rd catalogue of interferometric measurements of binary stars.

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