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Binary star speckle measurements during 1989–1993 from the SAO 6 m and 1 m telescopes in Zelenchuk*

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Abstract. — We have continued to survey visual and interferometric binary stars with significant orbital motion by means of speckle method at the telescopes of the Special Astrophysical Observatory (SAO) in Zelenchuk. Here we present the lists of 267 speckle observations made with the 6 m and the 1 m telescopes in the period May 1989–November 1993.

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

1. Introduction

The first list of binary speckle measurements from the 6 meter BTA (Bolshoi Azimuth Telescope) of the SAO was published in 1990 (Balega et al.). It contains a total of 533 observations of 247 stars made between 1981 and 1988. Part of our sample, collected before 1987, was listed by McAlister & Hartkopf (1988) in the Second Catalog of Interferometric Measurements of Binary Stars. In the recent years, only the Georgia State University Center for High Angular Resolution Astronomy continues the regular efforts to collect high-resolution data for bright pairs in the range of angular separations 30 milliarcseconds (mas) – 1 arcsecond, thus providing new points to fill in the still existing 1–10 years periods gap in binary orbits. See, for example, McAlister et al. (1993) for the description of the program. We believe it worthwhile to support these efforts with speckle observations at other large telescopes in order to avoid possible systematic errors and selection effects of the speckle data bank. The final goal of the programme is the determination of binary masses and luminosities through a detailed analysis of their orbital motion. Only long-term observing programs can substantially contribute to this study.

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*Tables 1 and 2 are also available in electronic form: see the Editorial in A&AS 1994, Vol. 103, No. 1

2. Speckle interferometer architecture

A digital speckle intereferometer was designed in 1983 for the prime focus of the BTA to fully exploit the high-angular resolution capabilities of the giant mirror. The general concept of a concave diffraction grating monochromator, first proposed by G.Courtes (1962) for solar imaging, is used in the optical layout. Bandpasses from 4 to 50 nm can be selected in the whole colour range 400–800 nm for speckle imaging. The instrument is devided into the following sub-systems:

1. A field viewing and guiding unit with $1.5' \times 1.5'$ field coverage.
2. A mechanical shutter providing exposures in the range 1–20 ms for speckles freezing.
3. A cylindrical wheel enclosing 4 microscope objectives required to adjust the detector's pixel size (30 μm) to the speckle size in the prime focus (2 μm). The microscope objectives with magnifications 3.7, 8, 20, and 40, provide the following scales in the detector's photocathode plane: 65, 30, 12, and 6 mas pixel^{-1}.
4. A holographic concave diffraction grating with the possibility of spectral bandpass selection by using a set of masks (2000 grooves mm^{-1}, 300 mm radius of the sphere, 20×20 mm ruled area, 55% efficiency).
5. A set of prisms for atmospheric dispersion compensation in the range of zenith distances $0 - 60°$.
6. A set of neutral density filters needed for bright star observations.

7. The detector is a 24 mm single microchannel plate image intensifier fiber-optically coupled to a SIT television tube. A 256×256 pixel image format is used with read-out frame rate 50 Hz. The detector can be used both in analogue and photon-counting image mode, depending on the image brightness.

We have estimated the overall efficiency of the instrumental chain, including the atmosphere, the telescope, the speckle intereferometer optics, and the detector, at 0.4%. This is the mean value avaraged over the blaze function of the grating. The low sensitivity due to short exposures and narrow-bandpass limitations restricts the applicability of interferometry to bright sources: the typical limiting magnitude is 14–15 for binary star observations under 1.5″ seeing, 1 hour total exposure time, and SNR of 5–10 for the central peak in the speckle images autocorrelation function (ACF). The maximum detectable brightness difference for a resolved binary is 3–3.5 magnitudes. It should be noted that atmospheric seeing degradation is the dominant noise source in speckle interferometry.

Installed in the cassegrain focus of the 1 m Zeiss telescope the speckle interferometer provides a scale of 22 mas pixel^{-1} when the 20× microscope objective is used. Therefore, with the 256×256 pixel detector the upper limit to angular separation at the 1 m telescope was about 5″. Under good seeing conditions reliable detection was possible to a magnitude limit of 10.

Currently, two different observing modes are provided. In one the instrument is operated using an online hard-wired digital vector correlator, producing in real time a two-dimensional autocorrelation function (ACF) of speckle images. In another mode the list of photon coordinates is stored on magnetic tape for later optimum treatment of speckle data, including a variety of image reconstruction algorithms.

3. Results of observations

Here we present two samples of binary speckle measurements from the 6 m BTA telescope and the 1 m Zeiss–1000 telescope of the SAO. The first data sample was obtained at the BTA during a few runs between 1989.4 and 1993.8. Altogether 118 observations were collected with this telescope for 95 stars. From these, 15 stars remained unresolved (marked as UR) for a few possible reasons: a) small angular separation – less than 30 mas for the BTA at 600 nm, b) large brightness difference – 3 magnitudes or more, c) too poor atmospheric seeing. The measured angular separations ρ in this sample range from 27 mas for BD +55°2347 to 602 mas for Wolf 424. The results are summarized in Table 1 which gives the star identification (catalogue number and the name), the coordinates for equinox 2000.0, the epoch of the observation as a fraction of the Basselian year, the measured position angle θ in degrees and the separation ρ in arcseconds. In case of +19°0662 and +38°1250, colons following θ and ρ values indicate uncertain secondary detection.

The majority of the measurements given below were made using the hard-wired vector auto-correlator. A few fainter pairs, such as Wolf 424, were observed in photon-by-photon acquisition mode with computer image restoration made afterwards by means of bispectrum algorithms.

For the BTA observations, the typical accuracy of a secondary peak measurement is 3 mas along both the x and y cartesian coordinates of the ACFs. Under 40× magnification this corresponds approximately to 1/2 of the detector's pixel size, or 1/10 of the speckle peak size. It means that the mean error of θ measurements is 1° for 200 mas separations, and up to 5° for close pairs at the Rayleigh resolution limit. The position angle calibration of the speckle interferometer was always made by means of vertical and horizontal trailing of a reduced star image across the detector's field.

The Z–1000 list, given in Table 2, includes 149 measurements of 116 objects observed in 1992.2–1993.7. Eighteen stars were not resolved in these series. The measured angular separation in the sample vary from 78 mas for Kui 23 AB, which is exactly two times smaller than the Rayleigh limit for the 1 m telescope at 600 nm, to 1530 mas for ADS 2185 AB,C. Typical accuracies for the Z–1000 measurements are 8 mas in ρ and 3° in θ.

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Table 1. Binary star speckle measurements from the 6 m telescope

Catalog no.	Name	Coord.2000	Date 1900.0+	θ°	ρ''
HR 9097	CHARA 121	00034+6339	93.7649	35.6	0.188
ADS 51	Hu 1201 AB	00055+3406	93.8442	310.0	0.164
ADS 238	A 1803 AB	00173+0852	93.8442	124.6	0.179
+51°0107	Cou 2351	00367+5149	93.8388	68.2	0.240
ADS 746	STT 20 AB	00546+1912	93.7650	200.0	0.490
ADS 784	Bu 1099 AB	00568+6022	93.8387	339.7	0.280
+36°0159	Cou 1054	00575+3738	93.8414	216.7	0.120
ADS 873	Ho 213	01039+3528	93.8415	104.5	0.298
			93.8442	105.0	0.301
ADS 887	CHARA 142 Aa	01070+3014	93.8415	UR	
ADS 1123	Bu 1163	01243−0655	89.8045	243.5	0.103
HR 466	Kui 7	01376−0924	93.8415	150.6	0.279
+34°0379	Cou 1067	02090+3541	93.7651	22.7	0.176
HR 719	Kui 8	02280+0158	89.8072	36.6	0.512
+31°0434	Wor 2	02287+3215	89.8075	281.4	0.290
+40°0568	Cou 1511	02415+4053	93.7652	161.1	0.122
+50°0607	Cou 2356	02418+5056	93.7654	156.3	0.226
			93.8418	154.2	0.229
ADS 2546	Cou 260	03280+2028	93.8389	23.1	0.238
HR 1048	66 Ari	03284+2248	93.7652	UR	
			93.8362	UR	
+57°0730	CHARA 117	03337+5752	93.7654	58.3	0.137
HR 1180	CHARA 125	03492+2408	93.7654	UR	
			93.8363	UR	
ADS 2965	McA 13 Aa	04044+2406	93.8418	UR	
+19°0662	CHARA 13 Aa	04063+1952	89.8077	37.7	0.068
			93.8419	353.0:	0.056:
HR 1331	McA 14 Aa	04185+2135	89.8078	347.1	0.114
			93.7655	199.1	0.127
ADS 3317	CHARA 18 Aa	04357+1010	89.8078	138.7	0.210
+14°0770	CHARA 20	04506+1505	93.8420	127.8	0.090
ADS 3501	CHARA 127 Aa	04536+2522	93.8420	140.5	0.174
+22°0818	STT 97	05056+2304	89.8160	153.5	0.373
			93.8390	150.5	0.372
+43°1251	Cou 2365	05210+4408	93.8393	199.6	0.298
+42°1292	Cou 2367	05282+4253	93.7655	325.1	0.412
ADS 4265	Bu 1007	05411+1632	89.8052	243.3	0.321
+38°1250	McA 21	05415+3811	93.7655	56.4:	0.119:
ADS 4617	A 2715 AB	06024+0939	93.8392	201.2	0.382
ADS 4890	Fin 331 Aa	06171+0957	89.8160	109.2	0.101
ADS 6089	McA 30 Aa	07277+2127	93.8396	170.6	0.061
+23°1346	CHARA 23	06255+2327	89.8080	155.6	0.120
ADS 6119	McA 31 Aa	07298+2755	93.8394	194.8	0.054
ADS 6993	SP AB	08468+0625	93.8396	140.0	0.244
HR 3635	CHARA 131	09098+1134	93.3512	UR	
HR 3650	Fin 347 Aa	09123+1459	93.3513	1.0	0.052
ADS 7231	A 1977	09124+2652	93.3514	133.1	0.156
+37°2177	Cou 1260	11221+3705	93.3487	14.5	0.335
ADS 8197	STT 235	11324+6105	93.3486	300.4	0.591
Wolf 424	Gliese 473	12332+0901	93.3514	135.8	0.602
+09°2696	Fin 380	12572+0818	90.2080	156.9	0.183
			93.3487	156.3	0.212
+61°1335	Mlr 154	13052+6052	93.3488	UR	
			93.3516	UR	
ADS 8863	A 2166	13202+1747	90.2081	357.9	0.132
+31°2500	Wor 24	13320+3109	90.2082	70.3	0.304
ADS 8987	Bu 612	13396+1044	89.4074	226.5	0.278
			90.2079	235.2	0.262
			93.3489	258.4	0.166
			93.3515	258.0	0.169
+31°2596	Cou 606	14138+3100	90.2082	112.6	0.175
+27°2367	Dan	14205+2634	93.3489	187.0	0.029
ADS 9301	A 570	14323+2641	90.2081	221.6	0.189
ADS 9504	A 689	15071−0217	93.3490	329.0	0.066
ADS 9505	A 2385	15073+1827	93.3491	UR	
ADS 9544	Gliese 580 A	15139−0120	93.3491	UR	
+84°0348	Mlr 347	15254+8431	93.3491	176.8	0.170
			93.3517	177.0	0.172
HR 5747	β CrB	15278+2906	89.3969	115.8	0.105
+26°2712	Cou 612	15390+2545	89.4075	238.8	0.208
			90.2084	236.7	0.203
ADS 9744	Hu 580 AB	15416+1941	90.2084	250.5	0.209
+35°2844	Cou 985	16384+3514	89.8150	124.6	0.138
−08°4352	Kui 75	16554−0820	89.4076	143.8	0.240
ADS 10360	Hu 1176 AB	17081+3555	89.8122	29.1	0.066
			93.3519	125.7	0.119
+04°3562	Kui 84	17584+0427	93.3520	351.4	0.260
+50°2501	Cou 2390	17598+5039	93.3493	99.7	0.150
+42°2995	Cou 1786	18043+4205	93.3493	221.6	0.110
+33°3339	Cou 1462	19089+3404	89.8150	30.0	0.249
+58°1929	McA 56	19312+5835	89.8041	92.2	0.100
			89.8096	88.2	0.102
			93.8438	91.3	0.102
ADS 12808	STT 380 AB	19426+1149	89.8041	79.1	0.440
ADS 12973	AGC 11 AB	19489+1908	93.7645	159.9	0.238
			93.8382	159.5	0.238
			93.8410	159.2	0.239
ADS 13499	STF 2652	20090+6205	93.8438	215.2	0.309
ADS 14296	McA 63 Aa	20474+3629	89.8124	24.5	0.052
+55°2347		20140+5557	93.8438	89.7	0.027
+33°3930	Cou 1962	20311+3332	93.8410	292.3	0.242
+39°4290	Cou 2421	20432+4026	93.8411	102.2	0.333
+40°4297	Cou 2423	20444+4103	93.8411	178.7	0.263
+43°3720	Cou 2425	20473+4345	93.8411	55.0	0.216
+41°3980	Cou 2433	21040+4225	93.8411	45.3	0.376
ADS 14749	McA 67 Aa	21118+6000	93.8439	9.0	0.049
ADS 14773	STT 535 AB	21145+1001	89.8070	25.7	0.327
ADS 14859	Ho 286	21194+3815	93.8385	UR	
ADS 14864	STF 2790 Aa	21192+5837	93.7645	120.5	0.113
			93.8439	119.8	0.109
HR 8238	β Cep Aa	21288+7034	93.8439	UR	
ADS 15281	Bu 989 AB	21446+2539	89.8069	74.4	0.084
			93.8440	243.9	0.110
ADS 15600	McA 69 Aa	22037+6437	93.8412	101.3	0.068
+81°0767	Mlr 257	22062+8240	93.7648	261.5	0.188
			93.8412	262.5	0.187
+17°4708	CHARA 119	22115+1806	89.8070	130.6	0.211
			93.8440	UR	
HR 8581	CHARA 111	22313−0633	93.8386	UR	
ADS 16072	Hu 983	22339+6550	93.8412	265.2	0.057
ADS 16138	Ho 295	22387+4418	93.8441	343.5	0.099
ADS 16214	Hu 91 BC	22431+4709	93.8414	45.3	0.066
HR 8762	McA 77 Aa	23019+4219	93.8441	340.0	0.165
+44°4388	Cou 2246	23215+4534	93.8413	79.7	0.261
ADS 16904	A 643	23392+4543	93.8413	154.1	0.214
ADS 16904	CHARA 149 Aa	23392+4543	93.8413	323.6	0.040
+57°2787	CHARA 120 Aa	23434+5804	93.8413	104.6	0.069
ADS 17151	A 1498	23594+5441	93.7648	85.9	0.385

Table 2. Binary star speckle measurements from the 1 m telescope

Catalog no.	Name	Coord.2000	Date 1990.0+	θ°	ρ''
ADS 147	Bu 255	00119+2825	3.7621	73	0.530
ADS 382	A 1504 AB	00287+3718	3.7594	41	0.570
ADS 449	McA 1 Aa	00323+0657	2.6776	UR	
ADS 490	Ho 212 AB	00352−0336	2.6777	293	0.222
ADS 493	STT 15	00358+4901	2.6777	318	0.201
			3.7595	320	0.211
ADS 504	A 914	00366+5608	2.6778	32	0.452
ADS 684	Bu 232 AB	00504+5038	2.6777	244	0.880
ADS 732	A 2307	00532+0406	2.6777	52	0.284
			3.7622	47	0.282
ADS 828	Bu 867	01014+1155	3.7596	3	0.500
ADS 859	Bu 1161	01029+5148	3.7596	10	0.351
ADS 871	Hu 517	01037+5026	3.7595	27	0.586
ADS 873	Ho 213	01039+3528	3.7596	106	0.280
ADS 940	STT 515	01093+4715	2.6778	132	0.474
			3.7595	130	0.514
			3.7622	131	0.507
ADS 1105	STF 115 AB	01233+5808	2.6778	UR	
+08°0316	McA 4	02026+0905	3.7597	146	0.200
ADS 1630	STT 38 BC	02039+4220	3.7598	107	0.545
+34°0379	Cou 1067	02090+3541	2.6778	28	0.182
HR 657	Cou 79	02157+2503	2.6779	42	0.190
ADS 1729	A 2013	02158+0638	2.6779	104	0.437
ADS 1865	A 2329	02277+0426	2.6779	98	0.432
HR 719	Kui 8	02280+0158	2.6779	35	0.516
ADS 1992	A 1278	02383+4604	2.6779	148	0.137
ADS 2185	A 2906 AB	02529+5300	2.6779	128	0.184
ADS 2185	STF 314 AB,C	02529+5300	2.6779	311	1.530
ADS 2200	Bu 524 AB	02537+3820	2.6780	238	0.163
+24°0562	CHARA 124	03470+2431	3.7598	UR	

Table 2. continued

Catalog no.	Name	Coord.2000	Date 1990.0+	$\theta°$	ρ''
HR 1180	CHARA 125	03492+2408	3.7598	UR	
ADS 2799	STT 65	03504+2536	3.7598	220	0.145
HD 27836	vB 50	04242+1446	3.7600	UR	
HR 1411	McA 15	04286+1557	3.7599	348	0.204
ADS 3248	Hu 1080	04290+1610	3.7600	255	0.338
+22°0818	STT 97	05056+2304	3.7600	151	0.372
ADS 4324	A 496	05449+2620	3.7628	5	0.298
ADS 4392	STT 118 AB	05484+2052	3.7628	UR	
ADS 4617	A 2715 AB	06024+0939	3.7601	199	0.400
HR 2134	Kui 23 AB	06041+2316	2.2225	223	0.168
			3.7600	298	0.078
ADS 4768	Bu 1058	06105+2300	3.7600	226	0.224
+23°1346	CHARA 23	06255+2327	2.2225	UR	
HR 2886	McA 32	07336+1550	2.2197	UR	
ADS 6185	STT 175 AB	07352+3058	2.2142	332	0.183
			2.2202	332	0.180
			2.2226	332	0.179
ADS 6313	A 2534 AB,C	07431+0012	2.2198	228	0.850
ADS 6354	Hu 1247	07479+6019	2.2146	UR	
ADS 6378	WRH 15 AB	07486+2309	2.2142	44	0.260
			2.2198	44	0.275
ADS 6405	A 2880	07508+0317	2.2143	UR	
+24°1805	Cou 929	07561+2342	2.2143	183	0.175
			2.2198	179	0.195
			2.2226	182	0.197
HR 3269	Fin 346	08199+0357	2.2198	64	0.265
ADS 6796	Hu 856	08253+3723	2.2199	273	0.240
ADS 6993	SP AB	08468+0625	2.2143	111	0.159
			2.2198	111	0.159
ADS 7039	A 2473	08507+1800	2.2199	54	0.293
ADS 7054	A 1584	08531+5458	2.2146	51	0.352
ADS 7284	STF 3121	09180+2835	2.2200	322	0.199
HR 3794	Fin 349	09326+0151	2.2200	34	0.130
ADS 7457	A 1765	09379+4554	2.2200	132	0.148
HR 3889	Kui 44	09498+2111	2.2200	208	0.185
ADS 7545	STT 208	09521+5404	2.2146	213	0.198
			2.2200	211	0.192
HR 3973	CHARA 30	10068+0537	2.2201	UR	
ADS 7674	Hu 874	10117+1321	2.2145	286	0.188
+20°2486	Cou 292	10269+1931	2.2145	45	0.245
ADS 7775	STT 217	10270+1713	2.2145	147	0.596
ADS 7780	Hu 879	10279+3643	2.2144	250	0.178
ADS 8092	A 1353	11136+5525	2.1272	219	0.503
ADS 8189	STT 234	11308+4117	2.1272	150	0.406
ADS 8197	STT 235	11324+6105	2.1272	297	0.560
ADS 8535	STT 249 AB	12238+5410	2.2148	257	0.408
ADS 8540	STT 250	12244+4306	2.2147	349	0.323
HR 4789	WRH	12348+2238	2.1273	1	0.197
			2.2148	359	0.194
			2.2174	359	0.195
			2.2202	359	0.195
ADS 8804	STF 1728 AB	13100+1731	2.1273	12	0.521
			2.2118	14	0.498
ADS 8987	Bu 612 AB	13396+1044	2.1273	243	0.235
			2.2119	240	0.222
			2.2175	242	0.218
			2.2202	242	0.218
ADS 9264	A 2069	14268+1625	2.1274	234	0.232
ADS 9301	A 570	14323+2641	2.2120	210	0.230
			2.2176	209	0.215
ADS 9329	STF 1863	14381+5135	2.2203	63	0.639
ADS 9392	STF 1883	14489+0557	2.1275	283	0.636
			2.2120	283	0.617
			2.2176	285	0.625
HR 5654	Cou 189	15121+1858	2.2177	142	0.472
HR 5747	β CrB	15278+2906	2.2121	UR	
			2.2178	UR	
ADS 9688	A 1634 AB	15318+4053	2.2122	UR	
			2.2204	UR	
ADS 9744	Hu 580 AB	15416+1941	2.2122	246	0.224
			2.2204	246	0.224
ADS 9758	Bu 619	15431+1340	2.2178	7	0.688
ADS 9794	A 1127	15474+5929	2.2203	293	0.299
ADS 9970	STF 2028	16129+3912	2.2179	156	0.155
ADS 10052	STF 2054 AB	16238+6141	2.2203	351	1.011
ADS 10189	Hu 664	16437+5132	2.2204	304	0.457
ADS 10360	Hu 1176 AB	17081+3555	2.2179	UR	
+19°3336	Cou 499	17313+1901	2.2179	53	0.172
+37°2949	Cou 1145	17490+3704	2.6824	122	0.148
ADS 11060	STT 341 AB	18059+2126	2.6825	92	0.429
ADS 11479	STT 359	18355+2336	2.6771	10	0.670
HR 7486	Kui 93	19412+1349	2.6771	314	0.163
			3.7618	312	0.206
HR 7499	Kui 94	19419+4015	3.7618	UR	
ADS 12808	STT 380 AB	19426+1149	2.6772	76	0.444
			3.7618	77	0.449
ADS 12962	STF 2583 AB	19487+1148	2.6772	105	1.332
ADS 12973	AGC 11 AB	19489+1908	2.6772	167	0.227
			3.7589	160	0.230
			3.7617	162	0.227
+09°4369	CHARA 118	20011+0931	3.7590	UR	
+39°4074	Cou 2415	20118+3936	3.7618	151	0.338
+35°4115	Cou 2130 Aa	20262+3547	2.6773	63	0.179
+33°3930	Cou 1962	20311+3332	3.7591	290	0.205
ADS 13946	CHARA 99 Aa	20312+1116	2.6772	131	0.320
ADS 14073	Bu 151 AB	20375+1436	2.6780	223	0.219
+04°4510	Kui 99	20396+0458	2.6773	130	0.878
+39°4290	Cou 2421	20432+4026	3.7591	102	0.295
HR 8038	Kui 102	21002+0731	3.7619	31	0.358
+28°4003	Cou 1332	21091+2922	2.6828	24	0.198
ADS 15115	Hu 371	21354+2427	2.6821	304	0.299
HR 8300	Kui 108	21425+4106	2.6829	343	0.174
+42°4203	Cou 1979	21462+4253	2.6774	231	0.230
HR 8344	Cou 14	21502+1718	2.6774	219	0.212
+22°4563	Cou 136	22100+2308	2.6801	42	0.515
HR 8629	Kui 114	22408−0333	2.6775	128	0.331
ADS 16345	Bu 382 AB	22537+4445	2.6774	218	0.965
HR 8762	McA 77 AB	23019+4219	2.6775	347	0.180
			2.6776	346	0.178
ADS 16467	Bu 1147 AB	23026+4245	2.6829	348	0.352
			3.7620	349	0.381
ADS 16518	Bu 180 AB	23072+6049	2.6802	142	0.555
ADS 16530	Hu 994	23078+6338	2.6802	314	0.195
ADS 16731	STT 495	23241+5732	2.6803	120	0.291
ADS 16836	Bu 720	23340+3120	2.6830	272	0.510
			3.7594	269	0.517
ADS 16877	STT 500 AB	23375+4426	2.6830	1	0.452
			3.7594	3	0.478
ADS 17151	A 1498	23594+5441	2.6803	82	0.402