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Binary star speckle measurements at Calar Alto. I.

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Abstract. We present the first results of our speckle interferometric measurements of binary stars made with the ICCD speckle camera using the 1.52-m telescope of the Observatorio Astronomico Nacional at Calar Alto (Spain) in September, 1999. The data contain 123 observations of 83 systems. The measured angular separations range from $0\farcs153$ to $6\farcs727$. We have used there new speckle measurements to improve the orbital elements for the binaries COU 247 and BU 524 AB.

Key words. binaries: visual – interferometry

1. Introduction

At the present time, although the orbits for more than 1000 visual binaries are available, the study of orbital motion of visual and interferometric pairs remains an important astronomical discipline. Visual binaries are the key source of information about stellar masses and distances, while for the lower part of the main sequence they define practically our understanding of stellar physical properties. However, visual measurements of binaries with a filar micrometer are rarely performed today. In comparison with digital speckle interferometric methods, micrometric data show, in general, lower precision. They are also often associated with significant errors, which is especially true for small angular separations, $\sim 0\farcs1$.

By means of speckle interferometry, the Rayleigh resolution limit of 70 mas (0.07 arcsec) for a 1.5-m telescope can be routinely achieved. That is high enough to study the relative motion of the components of the most well known visual binary stars, in order to define the parameters of their orbits. Only for very close visual pairs are the larger apertures needed, but the lack of the observing time at large telescopes is the reason for rare and unsystematic binary star observations.

Therefore, high quality speckle measurements, even with moderate size telescopes, can be an important source of data about the relative motion of the components in multiple star systems (Douglass et al. 1997). For these purposes a speckle interferometer with a photon-counting intensified CCD detector was developed in the Astronomical Observatory Ramon Maria Aller of the University of Santiago de Compostela, in cooperation with the Special Astrophysical Observatory (SAO) of the Russian Academy of Sciences. The new instrument has been used for speckle observations of binary stars using the 1.52-m telescope at Calar Alto, in 1999. Below, we provide a brief description of the instrument and report on the first interferometric data obtained. Orbits of visual binaries Cou 247 and Bu 524 were improved using the new measurements.

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2. Brief description of the speckle camera

The scheme of the instrument is essentially the same as for other speckle cameras in use today at several large telescopes. The main module contains a pair of interchangeable microscope objectives with magnifications 8× and 20×, which are necessary to sample the size of individual speckles (about 4 μ at 500 nm at the f/8 Cassegrain focus of the 1.52-m telescope) to a detector's pixel, with a size of 13.4 μ. The corresponding scale on the detector is 0.028 or 0.011 arcsec per pixel with total fields of view of 5.6 and 14.3 arcsec square. We normally use a 20× microscope objective; the 8× one is intended only for pointing at weak stars. In front of the microscope objective is the Uniblitz remote-controlled electronic shutter, which provides the exposure value in the range 5 to 40 ms. The shutter is synchronized with the CCD detector readout. An additional mirror, which can be installed in the beam in front of the shutter, sends light to the TV guidance camera for centering of an object in the field of view. A combination of narrow-pass band interference filters and neutral density filters is used for wavelength selection. Data are routinely obtained through the 520/24-nm filter; however, a filter wheel assembly also includes 600/50-nm and 660/40-nm filters. A set of 4 zero mean deviation prisms, mounted on a rotation stage, is used for atmospheric dispersion compensation at different zenith angles. Each prism is

designed to compensate for the atmospheric effect within a prescribed interval of zenith angle, while for the 20° radius from the zenith, the clear aperture is selected. The detector system consists of a PCO Computer Optics (Germany) Sensicam CCD camera with $1280(H) \times 1024(V)$ pixels of 6.7×6.7 μm, optically coupled by means of a pair of f/1.5 transfer lenses to a 3-stage electrostatically focused image intensifier. The input 24-mm photocathode of the intensifier has an S-25 spectral response with a peak sensitivity of 12% at 510 nm, and about 2% sensitivity is still available at 800 nm. For faster readout we use the sampling of speckle images to 512×512 pixels. The dynamic range of the system is limited by the 12-bit digitization. Single photoelectron events are recorded by the system with a signal-to-noise ratio of about 30. Shorter exposures and narrower filters are utilized when bright stars are studied in an analogue readout mode. The data are transferred via optical fibers to a computer system and then onto Exabyte tapes. The system is capable of acquiring and storing 12-bit digitized data at a speed of 5 images per second.

3. Observations and data reduction

The speckle camera has been primarily used for observations of binary stars at the Cassegrain focus of the 1.52-m telescope of the Observatorio Astronomico Nacional at Calar Alto, Spain. 83 pairs were observed between September 15 and 24, 1999, under a moderate seeing of $1''$ to $3''$. For each binary, a typical observing procedure involved the accumulation of 1000 to 3000 short exposure images on Exabyte tapes.

Calibration of our speckle data was accomplished only by observing wide binaries with very long orbital periods. A list of 10 pairs observed for calibration purpose on the 6-m telescope of SAO was used to define the orientation of the CCD with respect to the vertical. In addition, the detector orientation was checked by using star trails in right ascension with the magnification 8×. We could not use other calibration procedures because the telescope was not equipped with a slit mask and its focal length was not known to sufficient accuracy. The resulting value of the camera orientation error is less than 0.2°.

Processing of speckle data is made in three steps. Firstly, for each speckle frame we make a flat-field photometric correction and geometric correction of field distortions caused by the image intensifier. Then, we compute the mean power spectrum of an object following the standard Labeyrie procedure (1970). The average power spectrum is corrected for the photon noise bias. At the final stage, we compute a set of radial cross-sections through the power spectrum up to the diffraction cut-off frequency of the telescope and fit this with the model of a binary star spectrum to find the distance and position angle. From position measurements for pairs with at least 3 observations, we have found that the mean standard deviation in separation is 10 mas, while the error in position angle is 1°. With the present detector, we could observe binaries with a secondary as faint as 10.5 magnitude. However, we expect that with an improved image intensifier and by using the cooling of the photocathode, the limiting magnitude will be near 13.

Table 1. Orbital elements for COU 247 and BU 524 AB

Star	COU 247	BU 524 AB
Author(s)	Blanco J.	Docobo–Vasyuk
P(years)	280.00^y	$31.528^y \pm 0.072^y$
T	1990.21	1996.526 ± 0.014
e	0.426	0.753 ± 0.005
a	$0.846''$	$0.221'' \pm 0.003''$
i	124.9°	$121.0° \pm 0.6°$
Ω	21.3°	$25.4° \pm 0.6°$
ω	47.1°	$265.0° \pm 0.6°$
Σ masses	2.9 $M_\odot$	4.1 $M_\odot \pm 0.4$ $M_\odot$

Results of the measurements are given in Cols. (1) to (6) of Table 2. The first three columns list the Washington Double Star Catalogue coordinate (Worley & Douglass 1996), the name of the star or its catalogue number in common use and the discoverer designation. The fourth column gives the epoch of the observation in fractional Besselian year. The fifth and sixth columns contain the measured position angle θ in degrees and angular separation ρ in arcseconds. The note "UR" denotes the cases when the binary was not resolved. This might indicate too close a companion (less than 70 mas), too large a magnitude difference (more than 3 magnitudes), very bad seeing, or any combination of these factors. Finally, the note "R" means the use of the red 660/40-nm filter.

4. New orbits

Using the measurements presented in this paper, the orbits of the systems COU 247 (WDS 00095+1907) and BU 524 AB (WDS 02537+3820) were revised, as announced previously in the IAU Commission 26 Information Circular Nos. 140 and 141, respectively.

All available micrometric and speckle measurements, together with the analytical method of Docobo (1985), were used to compute the orbits shown in Figs. 1 and 2. Speckle data are indicated by dots, while O–C lines connect measures to their predicted locations on the orbit. For COU 247, visual measures are also included in the figure.

The solid line connects the primary component, indicated by the cross, with the periastron position. In Table 1 the individual orbital parameters are given for each star: line 1 – star identification; line 2 – orbit author(s); lines 3 to 9 – new orbital elements; line 10 – total mass of the system obtained by combining new a and P values with the Hipparcos parallax (ESA 1997). Because the COU 247 orbit may be evaluated only as preliminary, no errors for the individual elements are given in the table.

COU 247

The binarity of this star ($V = 7.96$, sp.type G3V) was discovered by P. Couteau in 1967. Jasinta (1996)

Table 2. Speckle measurements on the 1.52-m telescope (also available at the CDS via anonymous ftp `cdsarc.u-strasbg.fr (130.79.128.5)` or via `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/366/868`)

Coord. 2000	Name/Catalog no.	Discoverer designation	Epoch 1999.0+	θ (°)	ρ (″)	Note
00062+5826	ADS 61 AB	STF 3062	0.7259	327.8	1.492	
00095+1907	+18 0003	COU 247	0.7118	308.7	0.301	
00214+6700	ADS 293 AB	STT 6	0.7232	154.2	0.622	
00318+5431	ADS 434 AB	STT 12	0.7231	196.6	0.382	
00516+2237	ADS 701 AB	A 1808	0.7119			UR
			0.7230	197.5	0.165	
00546+1911	ADS 746 AB	STT 20	0.7229	194.7	0.526	
			0.7229	194.3	0.519	
			0.7254	194.2	0.516	
			0.7254	194.1	0.523	
			0.7280	194.2	0.518	
00550+2338	ADS 755 AB	STF 73	0.7256	308.2	0.884	
00568+6022	ADS 784 AB	BU 1099	0.7285	348.6	0.290	
00583+2124	ADS 805 AB	BU 302	0.7119	186.4	0.355	
00594-0040	ADS 819 AB	A 1902	0.7230	199.1	0.346	
01030+4723	ADS 862 AB	STT 21	0.7232			UR
			0.7259	175.2	1.148	
01040+3528	ADS 873 AB	HO 213	0.7116	109.7	0.301	
			0.7116	109.9	0.290	R
			0.7116	109.3	0.301	
			0.7119	108.8	0.302	
			0.7120	110.3	0.303	R
			0.7228			UR
			0.7257	109.2	0.310	
01049+3649	ADS 883 AB	A 1515	0.7094	297.0	0.229	
01148+6056	ADS 999 AB	BU 1100	0.7286			UR
01178+4901	ADS 1040 AB	STF 102	0.7230	276.2	0.482	
			0.7285	275.6	0.480	
01213+1132	ADS 1097 AB	BU 4	0.7121	111.8	0.550	
01234+5809	ADS 1105 AB	STF 115	0.7259	177.6	0.166	
			0.7285	176.7	0.166	
01337-1213	ADS 1223 AB	HWE 4	0.7230			UR
01376-0924	−10 0343	KUI 7	0.7228	149.0	0.288	
			0.7258	148.9	0.282	
01443+5732	ADS 1359 AB	BU 870	0.7286	347.2	0.726	
01551+2847	ADS 1522 AB	STF 183	0.7095	155.0	0.331	
01559+0151	ADS 1538 AB	STF 186	0.7121	62.4	1.037	
			0.7258	62.4	1.033	
01570+3101	ADS 1548 AB	A 819	0.7229			UR
02039+4220	ADS 1630 BC	STT 38	0.7258	105.1	0.477	
02140+4729	ADS 1709 AB	STF 228	0.7096	282.5	1.007	
02231+7021	+69 0144	MLR 377	0.7286	145.3	0.659	
02257+6133	ADS 1833 AB	STF 257	0.7286	64.9	0.390	
02280+0158	+01 0431	KUI 8	0.7228	36.5	0.520	
			0.7258	37.2	0.516	
02290+6724	ADS 1860 AB	STF 262	0.7287	230.5	2.772	
02407+2637	ADS 2034 AB	STT 43	0.7095	354.9	0.736	
02537+3820	ADS 2200 AB	STF 318	0.7095	5.9	0.156	
			0.7095	5.3	0.159	
			0.7121	5.6	0.162	
02586+2408	ADS 2246 AB	BU 1173	0.7121	97.1	0.235	
02589+2137	ADS 2253 AB	BU 525	0.7095	277.2	0.544	
03054+2515	ADS 2336 AB	STF 346	0.7123	71.4	0.347	
			0.7258	71.5	0.352	
03096+0512	ADS 2373 AB	A 2030	0.7124			UR

Table 2. continued

Coord. 2000	Name/Catalog no.	Discoverer designation	Epoch 1999.0+	θ (°)	ρ (″)	Note
03280+2028	ADS 2546 Aa	COU 260	0.7231	24.9	0.245	
			0.7231	24.2	0.252	
			0.7288	24.9	0.247	
03280+2028	ADS 2546 AB	COU 260	0.7230	163.8	6.727	
03284+6015	ADS 2538 AB	A 980	0.7124	353.1	0.349	
			0.7124	351.8	0.344	
03503+2535	ADS 2799	STT 65	0.7123	211.9	0.156	
			0.7261	210.8	0.155	
04263+3443	ADS 3211 AB	HU 609	0.7260	328.7	0.220	
04512+1104	ADS 3475 AB	BU 883	0.7234	77.4	0.236	
			0.7260	78.4	0.237	
			0.7260	79.1	0.228	
05056+2304	+22 0818	STT 97	0.7234	150.9	0.362	R
			0.7260	150.5	0.359	
			0.7260	149.9	0.357	R
17146+1423	ADS 10418 AB	STF 2140	0.7277	104.9	4.844	
17239-0050	ADS 10598 AB	STF 2173	0.7277	318.6	0.537	
			0.7251			UR
17563+0259	ADS 10899 AB	A 2189	0.7251			UR
17575+1058	ADS 10916 AB	BU 1299	0.7251	83.8	0.244	
17584+0428	+04 3562	KUI 84	0.7250	85.0	0.231	
			0.7250	84.3	0.227	R
18031-0811	ADS 11005 AB	STF 2262	0.7277	282.4	1.724	
18055+0230	ADS 11046 AB	STF 2272	0.7277	149.2	3.685	
18339+5221	ADS 11468 AB	A 1377	0.7277	116.4	0.261	
18355+2336	ADS 11479 AB	STT 359	0.7278	7.6	0.711	
18386+1632	ADS 11530 AB	HO 87	0.7251	72.1	0.365	
18594-1250	−13 5172	KUI 89	0.7114			UR
19110-0726	ADS 12126 AB	A 95	0.7278	49.5	0.263	
19159+2727	ADS 12239 AB	STT 371	0.7250	160.3	0.888	
			0.7252	160.1	0.885	
			0.7252	160.2	0.890	R
			0.7277	160.1	0.895	R
			0.7277	159.0	0.883	
			0.7278	160.0	0.880	
			0.7280	160.2	0.883	
19210+1909	ADS 12336	STF 2504	0.7278	348.3	0.238	
19459+5049	ADS 13135	HU 687	0.7252			UR
19487+1504	ADS 12961	A 1658	0.7252	144.0	0.211	
19487+3519	ADS 12972 AB	STT 387	0.7279	141.4	0.618	
19490+1909	ADS 12973 AB	AGC 11	0.7278	141.0	0.153	
20203+3924	ADS 13728 AB	A 1427	0.7279	118.7	0.310	
20375+1436	ADS 14073 AB	BU 151	0.7279	340.5	0.498	
20396+0458	+04 4510	KUI 99	0.7115	126.9	0.315	
			0.7115	126.5	0.324	
20537+5918	ADS 14412 AB	A 751	0.7279			UR
21001+0731	+06 4718	KUI 102	0.7279	11.9	0.346	
21208+3227	ADS 14889 AB	STT 437	0.7280	22.5	2.348	
21441+2845	ADS 15270 AB	STF 2822	0.7255	307.3	1.915	
21501+1717	+16 4612	COU 14	0.7256	246.5	0.338	
21597+4907	ADS 15530 AB	HU 774	0.7280	347.7	0.192	
22241-0450	ADS 15902 AB	BU 172	0.7116	63.1	0.288	
22288-0001	ADS 15971 AB	STF 2909	0.7255	188.2	1.919	
22302+2228	ADS 15992 AB	HU 388	0.7255	236.8	0.490	
22307+1758	+17 4759	COU 234	0.7256			UR

Table 2. continued

Coord. 2000	Name/Catalog no.	Discoverer designation	Epoch 1999.0+	θ (°)	ρ (″)	Note
22402+3732	ADS 16164 AB	HO 188	0.7280	215.7	0.372	
23114+3813	ADS 16576 AB	HO 197	0.7282	302.4	0.288	
23126+0241	ADS 16591 AB	A 2298	0.7282	296.9	0.235	
23176+1818	ADS 16650 AB	HU 400	0.7120	101.6	0.343	
23340+3120	ADS 16836 AB	BU 720	0.7282	94.2	0.550	
			0.7255	94.4	0.546	
23393+4543	ADS 16904 AB	A 643	0.7282	150.2	0.239	
23440+2922	ADS 16957 AB	AGC 14	0.7117	87.7	0.837	
			0.7120	88.0	0.827	
23475+4650	ADS 17006 AB	BU 995	0.7118	246.1	0.768	
23561+2520	ADS 17105 AB	A 426	0.7117	301.7	0.394	
			0.7117	304.2	0.385	
23595+5441	ADS 17151 AB	A 1498	0.7283	88.1	0.378	

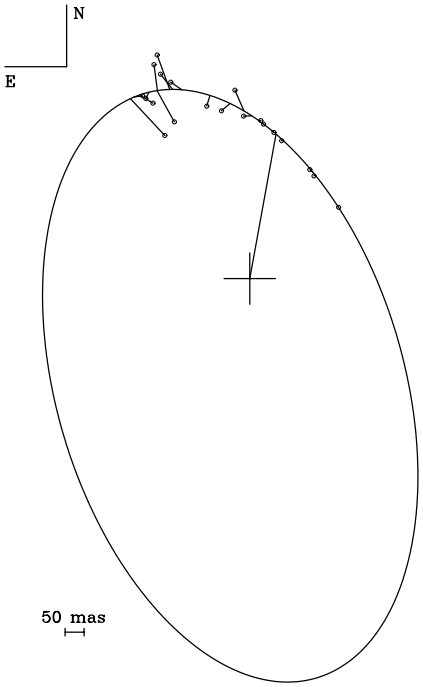

Fig. 1. Preliminary orbit for COU 247

calculated the orbit with a period of 60.52 years. However, new speckle measurements indicate a longer period. Although the binary has completed only about 80° of orbital motion, the new orbital solution gives the dynamical parallax (15 mas), which is in agreement with the Hipparcos parallax value (13.8 mas).

BU 524 AB

Due to its short period, this bright binary star ($V = 5.36$, sp. type F4IV) has completed several revolutions since the discovery of its binary nature by S. W. Burnham in 1878. Nevertheless, the last orbit, calculated for the system by Aristidi et al. (1999), does not fit well with recent speckle measurements. We tried to adjust the orbital parameters to the latest speckle data, and with these improvements, the orbit seems to be almost definitive.

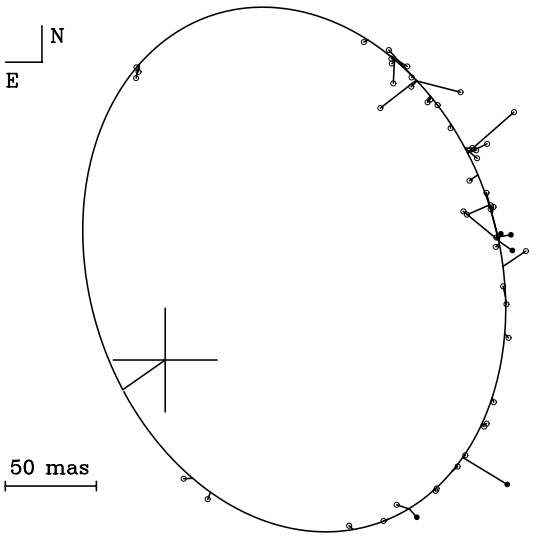

Fig. 2. New visual orbit for BU 524 AB

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