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SPECKLE INTERFEROMETRY AT THE OBSERVATORIO ASTRONÓMICO NACIONAL. I

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RESUMEN

Presentamos los resultados de mediciones mediante interferometría de motas de algunas estrellas binarias, llevadas a cabo en noviembre de 2008 en el telescopio de 1 m del Observatorio Astronómico Nacional en Tonantzintla (Puebla, México). Los datos consisten de 175 ángulos de posición y separaciones medidas para 163 sistemas. Las separaciones medidas están comprendidas entre $0.15''$ y $4.00''$. La magnitud máxima de las componentes más brillantes es igual a 9.32. El error medio en la medición de las separaciones es de $0.03''$, y en los ángulos de posición, de 1 grado. La mayor parte de los ángulos de posición tienen la usual ambigüedad de 180 grados, y algunos de ellos se corrigieron comparándolos con observaciones hechas por otros autores.

ABSTRACT

We present the results of speckle interferometric measurements of binary stars performed in November, 2008 with the 1 m telescope at the Observatorio Astronómico Nacional of Tonanzintla (Puebla, Mexico). The data include 175 position angle and separations measured for 163 systems. The measured angular separations range from $0.15''$ to $4.00''$. The maximum magnitude of the brighter components is equal to 9.32. The mean error in the separation measurement is $0.03''$ and in the position angle is 1°. The majority of position angles were determined with the usual 180° ambiguity, and some of them were corrected by comparison with observations performed by other observers.

Key Words: stars: binaries: visual — stars: fundamental parameters — techniques: interferometric — techniques: high angular resolution

1. INTRODUCTION

A binary star system is a pair of stars which are gravitationally bound. The study of the orbital motion around their centre of mass is the only direct method for the calculation of stellar mass, and presently there are many objects which can be investigated with this method. For example, the Washington Double Star Catalog (WDS) includes the notes for more than 84000 components of binary systems (Mason et al. 2001). However, only around 2000 orbits have been calculated up to now (Hartkopf & Mason 2003; Cvetković & Novaković 2006). Some of the stars in the WDS catalog are optical doubles; however, most of them are members of binary or multiple systems, so it is important to study their behavior. The wide binary systems ($\rho > 1''$) can be observed by amateur astronomers, but close binary systems ($\rho < 1''$) are difficult. Very close binary systems cannot be resolved into two separate stars without using special methods. Results of amateur observations are published en Journal of Double Star Observations (`http://www.jdso.org`). The speckle interferometry (SI) technique (Labeyrie 1970) allows the measurement of close binary systems. This technique recovers the information about relative positions of components in binary and in multiple stars systems with diffraction-limited accuracy.

In a previous paper (Orlov et al. 2007) we have described the usage of SI technique at Observato-

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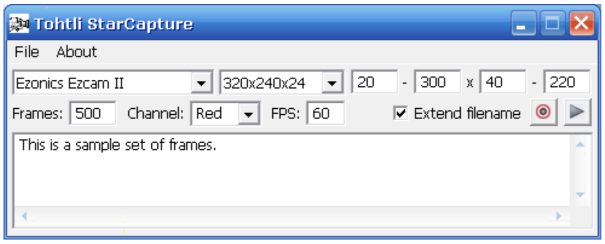

Fig. 1. The Graphic Interface of the Tohtli StarCapture program.

rio Astronómico Nacional (OAN). The OAN is a facility of the Instituto de Astronomía de la Universidad Nacional Autónoma de México (IA-UNAM). There are two astronomical sites where the four telescopes are mounted: one site is located at San Pedro Mártir (OAN-SPM), Baja California, Mexico, and the second one at Tonantzintla (OAN-T), near Puebla, Mexico. The 1 m telescope located at Tonantzintla can be effectively used for speckle interferometric measurements of binary stars to the Rayleigh resolution limit $R = 1.22\lambda/D$.

With this paper we start publishing results of SI observations of binary stars at the telescopes of OAN. In this paper we present result of observations which were carried out in November 2008 at OAN-T. For this observation we prepared an observing list of visual binaries from the WDS Catalog (Worley & Douglass 1997).

2. BRIEF DESCRIPTION OF THE EQUIPMENT

Speckle images were taken with an old Hamamatsu ICCD. The image intensifier of this ICCD does not allow us to take frames with resolutions higher than 25 lines per mm, so frame sizes of 352×240 px were chosen. The microscope objective provides a scale of $0.024 \times 0.026''$/px on the detector, with a total field of view of 8.448×6.24 arcsec. The very wide band filter centered at the V band ($\approx$ 550nm) was placed in front of the microscope objective. We developed the special software named Tohtli StarCapture for saving speckle images on the hard disc. Tohtli StarCapture is a video capture software for Windows. It does not require any installation; however it needs DirectX 8 or higher to be installed. It offers the following features:

- Capturing frames from any WDM / DirectX-enabled video device, such as PCI and PC-Card grabbers, TV tuner cards, FireWire cameras, USB/USB2 cameras, and DV (digital video) devices.
- Selecting any video mode exposed by the device.
- Selecting a region from the input video to be captured, so the resulting file will be smaller.
- Saving the frame set to a file without losing any precision using a RAW RGB format.
- Including a Unicode comment in the file.

Figure 1 shows the Graphic Interface of the Tohtli StarCapture program. It is free, and it is available upon request.

3. OBSERVATIONS AND RESULTS

The observations were performed at the 1 m telescope under moderate seeing that we estimated to be between 3 to 4 arcsec. For each binary star, a typical observing procedure involved the accumulation of one set of 999 short exposure images on a hard disk. One short exposure image consists of a two-dimensional 352×240 array of 8-bit numbers. The volume of one set of frames on the hard disk is only 80.5 MB.

The data were processed by the standard speckle algorithm which permits the derivation of binary-star parameters.

The calibration results show that the measured value of the camera orientation error is less than 1° and the scale error less than 1.5%. We must note that the accuracy obtained for the 1 m telescope depends on the separation between stars and on the effective focal length of system. The speckle data processing is made in three classical steps. The first step is the computation of the mean power spectrum (PS) of an object following the standard Labeyrie procedure (Labeyrie 1970). The second step is the Winer filtration of the PS which is applied to remove atmospheric distortions. The third step is the calculation of the autocorrelation function (ACF). As a final step, we compute the distance between stars and the position angle. The position of the component is calculated as the weighted center of the ACF in some area around the maximum value. Table 1 presents the main body of performed measures. Columns 1 and 2 give the identification number in the WDS (Worley & Douglass 1997) and discoverer designation. The third column gives the epoch of the observation in fractional Besselian year. The fourth and fifth columns contain the measured position angle θ in degrees and the angular separation ρ in arcseconds.

TABLE 1

SPECKLE MEASUREMENTS ON THE 1 M TELESCOPE

WDS ($\alpha, \delta J2000.0$)	Disc.	Date	P.A. (deg)	Sep. (arcsec)	WDS ($\alpha, \delta J2000.0$)	Disc.	Date	P.A. (deg)	Sep. (arcsec)
00028+0208	BU 281	2008.8875	162.7	1.57	02594 + 0639	STF 334	2008.8878	309.1	1.16
00047+3416	STF3056	2008.8492	139.7	0.77	03005 + 1800	STT 49	2008.8878	49.6	2.27
00073+0742	HDS 13	2008.8875	323.3	0.39	03051 + 1047	TDS2438	2008.8878	115.2	0.54
00089+0042	HDS 18	2008.8875	151.5	0.25	03096 + 0512	A 2030	2008.8878	12.7	0.27
00095+1907	COU 247	2008.8875	256.2	0.31	03140 + 0044	STF 367	2008.8878	134.1	1.23
00118+2825	BU 255	2008.8493	69.0	0.47	03160 − 0555	BU 84	2008.8878	8.5	0.99
00134+2659	STT 2	2008.8493	163.0	0.41	03177 + 3838	STT 53	2008.8497	242.6	0.67
00174+0853	A 1803	2008.8875	235.4	3.98	03184 − 0056	AC 2	2008.8878	260.0	1.25
00206+1219	BU 1015	2008.8875	103.8	0.49	03206 + 1911	STF 377	2008.8878	111.1	1.16
00209+1059	BU 1093	2008.8875	118.2	0.77	03213 + 1038	HEI 449	2008.8878	66.5	0.23
00266−0003	HDS 61	2008.8875	275.9	0.43	03284 − 0434	BU 1180	2008.8878	24.4	0.37
00352−0336	HO 212	2008.8876	207.4	0.15	03286 + 2904	STF 395	2008.8879	91.0	1.84
00424+0410	STT 18	2008.8876	209.4	1.97	03307 − 0416	STF 408	2008.8878	322.9	1.18
00470−0115	BU 494	2008.8876	161.1	1.29	03312 + 1947	STF 403	2008.8879	173.1	2.32
00487+1841	BU 495	2008.8876	257.0	0.26	03318 + 0749	A 1931	2008.8878	50.0	0.85
00516+2237	A 1808	2008.8494	199.7	0.19	03344 + 2428	STF 412	2008.8497	354.5	0.73
00521+1036	STF 67	2008.8876	350.7	2.28	03344 + 2428	STF 412	2008.8879	354.5	0.74
00546+1911	STT 20	2008.8876	183.9	0.57	03356 + 3141	BU 533	2008.8879	222.4	1.07
00550+2338	STF 73	2008.8494	321.9	1.04	03362 + 4220	A 1535	2008.8879	340.2	0.75
00554+3040	BU 500	2008.8494	122.6	0.48	03372 + 0121	A 2419	2008.8879	100.8	0.82
00583+2124	BU 302	2008.8494	206.6	0.30	03426 + 0838	HDS 472	2008.8879	245.1	0.54
00593−0040	A 1902	2008.8876	208.9	0.36	03443 + 3217	BU 535	2008.8879	23.7	1.04
01005+1841	HDS 132	2008.8876	135.0	0.41	03463 + 2411	BU 536	2008.8879	179.7	1.00
01007+0929	STF 82	2008.8876	305.4	1.86	03489 + 1143	A 831	2008.8879	46.2	0.26
01014+1155	BU 867	2008.8876	355.0	0.66	03493 − 0127	RST4760	2008.8879	286.0	0.81
01040+3528	HO 213	2008.8494	115.9	0.28	03520 + 0632	KUI 15	2008.8879	207.5	0.78
01063−0016	HDS 141	2008.8876	14.8	0.26	03521 + 4048	STT 66	2008.8879	145.0	1.03
01097+2348	BU 303	2008.8494	293.0	0.62	03565 + 0734	A 1935	2008.8879	4.8	0.56
01196−0520	A 313	2008.8876	324.7	0.23	03590 + 0947	HU 27	2008.8879	329.7	0.40
01213+1132	BU 4	2008.8876	109.9	0.59	04064 + 4325	A 1710	2008.8879	313.4	0.63
01291+1026	HDS 195	2008.8877	185.4	0.19	04069 + 3327	STT 71	2008.8497	230.3	0.76
01315+1521	BU 506	2008.8877	61.8	0.61	04081 + 3407	COU1082	2008.8879	57.4	0.31
01360+0739	STF 138	2008.8877	59.6	1.74	04081 + 3407	COU1082	2008.8497	56.4	0.32
01393+1638	BU 5	2008.8877	284.1	0.55	04089 + 2911	BU 1232	2008.8879	353.5	0.32
01512+2439	HO 311	2008.8495	173.5	0.34	04091 + 2839	HO 326	2008.888	290.1	0.41
01532+1526	BU 260	2008.8877	260.0	1.14	04117 + 3133	COU 880	2008.888	42.6	0.77
01559+0151	STF 186	2008.8877	247.3	0.87	04124 + 2334	COU 703	2008.888	98.0	1.09
02020+0246	STF 202	2008.8877	268.9	1.86	04140 + 4235	A 1711	2008.888	80.7	0.69
02026+0905	MCA 4	2008.8877	152.3	0.18	04159 + 3142	STT 77	2008.8497	294.6	0.56
02052−0058	BU 516	2008.8877	316.6	0.69	04159 + 3142	STT 77	2008.888	294.1	0.56
02070−0413	HDS 283	2008.8877	269.5	0.92	04170 + 1941	HO 328	2008.888	1.6	0.48
02214+0853	BU 8	2008.8877	224.7	1.53	04182 + 2248	STF 520	2008.8497	78.1	0.60
02280+0158	KUI 8	2008.8877	38.8	0.51	04182 + 2248	STF 520	2008.888	78.3	0.60
02296+0934	BU 518	2008.8877	143.2	1.50	04263 + 3443	HU 609	2008.8497	305.4	0.18
02409+0452	STT 45	2008.8878	264.3	0.84	04316 + 3739	BU 789	2008.8881	322.8	0.94
02460−0457	BU 83	2008.8878	16.6	0.94	04348 + 2242	STF 562	2008.8881	284.9	1.89
02477+0142	A 2411	2008.8878	284.9	0.32	04357 + 3944	HU 1084	2008.8498	75.9	0.24
02513+0142	VOU 36	2008.8878	12.2	0.32	04366 + 1946	STT 86	2008.8498	0.9	0.48
02572+0153	A 2413	2008.8878	157.2	0.54	04385 + 2656	STF 572	2008.8498	190.2	4.25
02586+2408	BU 1173	2008.8496	99.7	0.21	04422 + 3731	STF 577	2008.8498	344.0	0.76
02589+2137	BU 525	2008.8496	271.9	0.55	04422 + 3731	STF 577	2008.8881	344.2	0.76

TABLE 1 (CONTINUED)

WDS ($\alpha, \delta J2000.0$)	Disc.	Date	P.A. (deg)	Sep. (arcsec)	WDS ($\alpha, \delta J2000.0$)	Disc.	Date	P.A. (deg)	Sep. (arcsec)
$04529+3548$	HU 819	2008.8881	277.3	0.46	$06097+2914$	A 54	2008.8882	333.6	0.57
$05017+2050$	HU 445	2008.8498	133.8	0.39	$06117+2846$	A 55	2008.8882	260.5	0.42
$05017+2640$	A 1844	2008.8881	349.3	0.30	$06200+2826$	BU 895	2008.85	158.9	0.24
$05044+2139$	COU 154	2008.8881	301.4	0.20	$06211+3619$	A 1954	2008.8882	109.3	0.68
$05044+2139$	COU 154	2008.8498	302.3	0.21	$06256+2227$	STT 139	2008.8882	256.7	0.72
$05044+2938$	A 1024	2008.8881	333.8	0.78	$06290+2013$	BU 1192	2008.8882	320.9	0.25
$05055+1948$	STT 95	2008.8498	298.1	0.95	$06317+2823$	BU 1021	2008.8882	76.7	0.73
$05055+1948$	STT 95	2008.8881	298.1	0.96	$06357+2816$	A 506	2008.8882	39.5	0.21
$05056+2304$	STT 97	2008.8498	153.3	0.34	$06396+2816$	STT 152	2008.85	36.1	0.87
$05056+2304$	STT 97	2008.8881	149.3	0.35	$07486+2308$	WRH 15	2008.8501	33.0	0.26
$05060+3556$	HDS 664	2008.8498	33.1	0.23	$07560+2342$	COU 929	2008.8501	196.6	0.27
$05064+4002$	HU 1095	2008.8881	36.7	0.35	$22288-0001$	STF2909	2008.8873	170.7	2.11
$05072+2224$	COU 155	2008.8881	330.6	0.23	$22295-0012$	BU 76	2008.8873	8.4	1.64
$05072+2224$	COU 155	2008.8498	335.6	0.26	$22352+1437$	HU 982	2008.8874	219.0	0.58
$05081+2416$	HDS 674	2008.8881	202.5	0.37	$22385+0218$	HO 479	2008.8874	63.3	0.38
$05103+3718$	STF 644	2008.8881	222.3	1.64	$22400+0113$	A 2099	2008.8874	164.1	0.79
$05131+2424$	COU 468	2008.8882	39.3	0.63	$22409+1433$	HO 296	2008.8874	77.9	0.38
$05140+3655$	POP 140	2008.8498	166.5	0.31	$22552-0459$	BU 178	2008.8874	323.4	0.66
$05219+3934$	COU2037	2008.8498	145.7	0.39	$22579+1337$	HU 989	2008.8874	72.6	0.35
$05270+2737$	HO 226	2008.8498	90.3	0.70	$22586+0921$	STT 536	2008.8874	166.6	0.33
$05297+3523$	HU 217	2008.8498	253.9	0.62	$22592+1144$	STT 483	2008.8874	359.0	0.47
$05351+3056$	BU 1267	2008.8498	174.4	0.40	$23078+1240$	BU 1025	2008.8874	327.1	0.83
$05386+3030$	BU 1240	2008.8498	328.9	0.16	$23088+1058$	A 1238	2008.8874	118.4	0.31
$05399+3757$	STT 112	2008.8498	49.8	0.89	$23141-0238$	BU 714	2008.8874	107.0	0.35
$05449+2621$	A 496	2008.8499	5.8	0.29	$23176+1818$	HU 400	2008.8874	84.1	0.34
$05460+2119$	STF 787	2008.8499	57.2	0.72	$23176-0131$	BU 79	2008.8874	13.2	1.65
$05499+3147$	STF 796	2008.8499	63.0	3.74	$23189+0524$	BU 80	2008.8875	229.3	0.52
$05522+3834$	STF 799	2008.85	162.3	0.77	$23309+0929$	STT 497	2008.8875	217.2	1.42
$05558+3656$	STT 122	2008.8882	88.9	0.37	$23311+1847$	STF3020	2008.8875	100.7	2.26
$05558+3656$	STT 122	2008.85	87.8	0.38	$23322+0705$	HU 298	2008.8875	53.3	0.16
$05580+2437$	COU 905	2008.85	206.5	0.23	$23324+1724$	STF3023	2008.8875	281.4	1.79
$05580+2437$	COU 905	2008.8882	204.0	0.24	$23407-0023$	STF3030	2008.8875	223.0	2.46
$06046+4535$	A 1729	2008.8882	72.8	0.73	$23460+0016$	STF3036	2008.8875	222.5	2.64
$06078+4240$	STT 130	2008.8882	202.1	0.42	$23544+0228$	STF3045	2008.8875	272.2	1.74
$06097+2307$	BU 1241	2008.85	346.9	0.60	$23568+0444$	A 2100	2008.8875	267.1	0.36
$06097+2307$	BU 1241	2008.8882	247.4	0.61	$23587-0333$	BU 730	2008.8875	322.6	0.78

4. CONCLUSION

A program of speckle observations has been initiated at OAN telescopes, with the goal of obtaining data on the double stars. This study has been started with well-known binaries from WDS catalogue. One hundred seventy five position angle and separation measures for one hundred sixty three binaries have been presented, a subset of which has been used to determine the measurement precision. We only present here the cases when the binary was clearly resolved. The results for binaries which demand a more detailed analysis will be reported in subsequent publications.

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