CCD MEASUREMENTS OF DOUBLE AND MULTIPLE STARS AT NAO ROZHEN. III

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SUMMARY: Using the 2-m telescope of the Bulgarian National Astronomical Observatory at Rozhen, observations of 55 multiple stars were carried out during one night, December 16/17. 2006. This is the third series of CCD measurements of double and multiple stars carried out at Rozhen. In the paper we present the results for the position angle and separation for 49 multiple stars (67 pairs) which could be measured.

Key words. binaries: visual

INTRODUCTION

The first series of observations of double and multiple stars performed by the Belgrade team at the Bulgarian NAO Rozhen with a CCD camera attached to the 2-m telescope took place in the middle of October 2004. The results were published in Pavlović et al. (2005). The second series took place in the end of October 2005. The results were published in Cvetković et al. (2006).

The third series comprising observations of 55 multiple stars took place on December 16/17, 2006. The telescope is of the Ritchey-Chretien-Coude type with the focal length of 16 m. The frames were obtained by using the CCD camera VersArray:1300B. The chip dimensions are 1300×1300 pixels, the pixel size is 20×20 micrometers. The angle corresponding to one pixel is 0.258 arcsec. For each star pair ten frames were obtained (five frames with each of the two filters, B and V).

The observational team at the NAO Rozhen that obtained the frames for the measurements consisted of Z. Cvetković and R. Pavlović from Belgrade Astronomical Observatory and A. Strigachev from the Institute of Astronomy of Bulgarian Academy of Sciences.

RESULTS

The position angle and separation were measured (Table 1) for 49 double or multiple stars (67 pairs), whereas in the case of the other seven ones the star images were not visually separated and the measurements could not be carried out. The reasons are the proximity of the components and the limiting capabilities of the CCD camera. For multiple system WDS 00057+4549, the CCD frame given in Fig. 1, the position angle and separation were measured for six pairs: AB, AC, AD, AE, AP i AQ.

The frames were measured by using the programme AIP4WIN (version 1.4.21).

A total of 67 pairs was measured where for seven of them the orbits had been previously calculated and the orbital elements were given in the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf

Table 1. CCD Measurements of Double and Multiple Stars.[1]

WDS	Disc.	Mult.	HIP	Epoch 2006+	$\theta[°]$	$\rho\ ['']$	Notes
00057+4549	STT 547	AB	473	0.9574	184.66	5.997	O
00057+4549	STT 547	AC	473	0.9574	261.47	107.276	
00057+4549	STT 547	AD	473	0.9574	226.85	103.903	
00057+4549	STT 547	AE	473	0.9574	351.59	54.842	
00057+4549	Pop 217	AP	473	0.9574	349.58	10.216	N
00057+4549	Pop 217	AQ	473	0.9574	129.95	20.026	N
00057+4549	Pop 217	AX	473	0.9574	222.39	11.794	
00059+1805	STF 3060	AB	495	0.9574	133.75	3.356	
00059+1805	STF 3060	AC	495	0.9574	271.05	66.120	N
00085+4002	ES 1601			0.9574	52.81	8.114	
00126+5455	STI 1297			0.9574	32.64	12.330	
00131+3521	BU 864			0.9575	140.97	2.121	
00152+2722	J 868			0.9575	229.47	5.749	
00159+5233	ES 865	AB		0.9575	100.73	3.704	N
00159+5233	ES 865	AC		0.9575	69.17	11.820	
00159+5233	ES 865	BC		0.9575	56.38	8.887	
00175+0019	STF 23	AB	1397	0.9576	218.69	9.161	N
00175+0019	STF 23	AC	1397	0.9576	274.99	98.050	
00221+4822	J 2384			0.9577	87.39	4.193	
00235+3301	ES 313			0.9576	24.15	4.218	
00237+0357	PLQ 5			0.9576	272.95	5.815	
00239+5531	STI 1340			0.9577	13.13	13.655	
00248+1925	BRT 2296			0.9576	9.89	2.826	N
00251+1824	HJ 621			0.9576	3.11	4.973	
00260+7750	HJ 1965	AB		0.9578	60.54	9.004	
00260+7750	HJ 1965	AC		0.9578	289.76	18.309	
00261+4411	BU 489	AB	2059	0.9577	139.33	4.676	
00261+4411	FOX 107	AC	2059	0.9577	196.77	102.547	
00261+4411	TOB 10	AD	2059	0.9577	147.34	160.442	
00309+2135	J 634			0.9576	249.87	2.363	
00321+6715	VYS 2	Aa-B	2552	0.9578	174.62	3.881	O
00424+0410	A 3107	AC	3326	0.9579	274.96	45.753	
00458+5459	ARG 2	AB	3589	0.9577	63.40	2.275	N
00458+5459	ARG 2	AC	3589	0.9577	67.94	16.334	
00458+5459	WAL 9	AD	3589	0.9577	93.57	41.661	
00458+5459	ES 43	BC	3589	0.9577	68.92	13.895	
01130+3911	MLB 1026			0.9580	253.54	3.731	
01137+0735	STF 100	AB	5737	0.9580	62.99	22.498	
01393+5257	STF 139	AB		0.9578	39.38	9.171	
01393+5257	STF 139	AC		0.9578	84.55	112.911	
04509+3448	HJ 350			0.9580	129.15	5.052	
05098+4240	BU 751	AB		0.9581	242.86	4.231	
05098+4240	BU 751	AC		0.9581	114.06	11.471	
05134+1832	J 1043			0.9580	332.00	1.757	
05221+4047	ES 61			0.9581	177.24	2.357	
05295+2855	A 488			0.9581	266.91	2.773	

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[1]Table 1a contains the individual results of the measurements for each author, the errors and the number of measurements. It is too large to be published here. The complete Table 1a can be found at `http://saj.matf.bg.ac.yu/174/pdf/tab1a.pdf`

Table 1. Continued

WDS	Disc.	Mult.	HIP	Epoch 2006+	$\theta[°]$	$\rho\,['']$	Notes
06443+4414	ES 1383			0.9582	335.56	2.300	
07023+1030	J 21			0.9582	274.99	3.020	
07106+1543	J 703			0.9583	294.00	9.730	N
07111+2452	POU 2525			0.9583	193.63	2.735	
07142+0533	J 2039			0.9583	201.72	1.896	
07153+0754	J 42			0.9583	109.30	1.455	
07476+0122	J 418			0.9584	136.15	1.978	N
08190+4927	HU 1124	AB	40744	0.9584	37.34	5.539	
08507+0752	VDK 3		43422	0.9584	159.57	1.377	O
09002+1550	ALD 115		44197	0.9584	268.35	1.660	
09057+2354	POU 3026			0.9584	310.59	3.141	
09357+3549	HU 1128		47080	0.9585	60.53	5.620	O
09365+2820	ES 428			0.9585	202.80	13.166	
09368+5755	ES 1783	BC	47174	0.9585	16.58	1.545	
09413+6214	STI 693			0.9585	219.44	4.363	
10015+6843	STF 1398		49121	0.9585	105.14	3.551	N
10099+5420	MLB 126			0.9586	250.34	4.769	
10110+7508	KUI 47		49868	0.9586	119.06	1.530	O
10281+4847	KUI 50		51248	0.9586	20.18	3.466	O
10334+0705	A 2767		51671	0.9587	51.23	5.124	N
10596+2527	AG 342			0.9587	112.03	5.183	O

Table 2. Notes

WDS	Mult.	Notes
00057+4549	AB	Residual (O-C) from orbit Pop1996b (Popović and Pavlović 1996): (Cve) $-0°\!.5$, $+0''\!.04$; (Pal) $-0°\!.3$, $-0''\!.04$; (Nov) $-0°\!.4$, $+0''\!.04$; (Pop) $-0°\!.5$, $+0''\!.04$; Residual (O-C) from orbit Kiy2001 (Kiyaeva et al. 2001): (Cve) $-0°\!.2$, $-0''\!.06$; (Pal) $+0°\!.0$, $-0''\!.06$; (Nov) $+0°\!.0$, $-0''\!.06$; (Pop) $-0°\!.2$, $-0''\!.06$;
00057+4549	AP	Nov: estimated magnitude difference $m_A - m_P = 3.3$
00057+4549	AQ	Nov: estimated magnitude difference $m_A - m_Q = 7.4$
00059+1805	AC	given in the Catalog of Rectilinear Elements (Hartkopf et al. 2006)
00159+5233	AB	given in the Catalog of Rectilinear Elements
00175+0019	AB	given in the Catalog of Rectilinear Elements
00248+1925		Cve: since $m_A = m_B$, the value of θ can be higher by 180°
00321+6715	Aa-B	Residual (O-C) from orbit Doc2005 (Docobo et al. 2006): (Cve) $-0°\!.9$, $-0''\!.15$; (Pal) $-0°\!.9$, $-0''\!.09$; (Nov) $-0°\!.8$, $-0''\!.04$; (Pop) $-1°\!.2$, $-0''\!.13$;
00458+5459	AB	given in the Catalog of Rectilinear Elements
07106+1543		Cve: since $m_A = m_B$, the value of θ can be lower by 180°
07476+0122		Cve: since $m_A = m_B$, the value of θ can be higher by 180°
08507+0752		Residual (O-C) from orbit WSI2006b (Mason et al. 2006a): (Cve) $-0°\!.1$, $-0''\!.18$; (Pal) $-2°\!.8$, $+0''\!.03$; (Nov) $-2°\!.4$, $-0''\!.09$; (Pop) $+0°\!.5$, $-0''\!.08$;
09357+3549		Residual (O-C) from orbit Hei1988d (Heintz 1988): (Cve) $+9°\!.8$, $-0''\!.30$; (Pal) $+9°\!.4$, $-0''\!.73$; (Pop) $+9°\!.1$, $-0''\!.27$;
10015+6843		given in the Catalog of Rectilinear Elements
10110+7508		Residual (O-C) from orbit Hei1994a (Heintz 1994): (Cve) $-1°\!.9$, $-0''\!.26$; (Pal) $-2°\!.0$, $-0''\!.06$; (Nov) $-2°\!.6$, $-0''\!.20$; (Pop) $-3°\!.7$, $-0''\!.34$;
10281+4847		Residual (O-C) from orbit Hle1994 (Hale 1994): (Cve) $-74°\!.4$, $+2''\!.26$; (Pal) $-75°\!.3$, $+2''\!.26$; (Pal) $-74°\!.5$, $+2''\!.54$; (Pop) $-74°\!.0$, $+2''\!.50$;
10334+0705		given in the Catalog of Rectilinear Elements
10596+2527		Residual (O-C) from orbit Kis1997 (Kisselev et al. 1997): (Cve) $+0°\!.0$, $-0''\!.10$; (Pal) $+0°\!.2$, $-0''\!.09$; (Nov) $+0°\!.2$, $-0''\!.10$; (Pop) $+0°\!.2$, $-0''\!.09$;

and Mason 2006). In these cases the measurements are compared with the ephemerides. The residuals $(O - C)$ are computed using the orbits: Pop1996b (Popović and Pavlović 1996) and Kiy2001 (Kiyaeva et al. 2001) for the pair WDS 00057+4549 = STT 547 AB, Doc2006g (Docobo et al. 2006) for the pair WDS 00321+6715 = VYS 2 Aa-B, WSI2006b (Mason et al. 2006a) for the pair WDS 08507+0752 = VDK 3, Hei1988d (Heintz 1988) for the pair WDS 09357+3549 = HU 1128, Hei1994a (Heintz 1994) for the pair WDS 10110+7508 = KUI 47, Hle1994 (Hale 1994) for the pair WDS 10281+4847 = KUI 50 and Kis1997 (Kisselev et al. 1997) for the pair WDS 10596+2527 = AG 342. For five pairs the residuals are small, whereas in the case of WDS 10281+4847 the deviations from the orbit given in the Sixth Catalog of Orbits of Visual Binary Stars are unexpectedly large. The reason is probably the uncertain orbit. Its grade is 5 = indeterminate. In the case of orbit WDS 09357+3549 the residuals are also significant (grade also 5). All the residuals are given in Table 2.
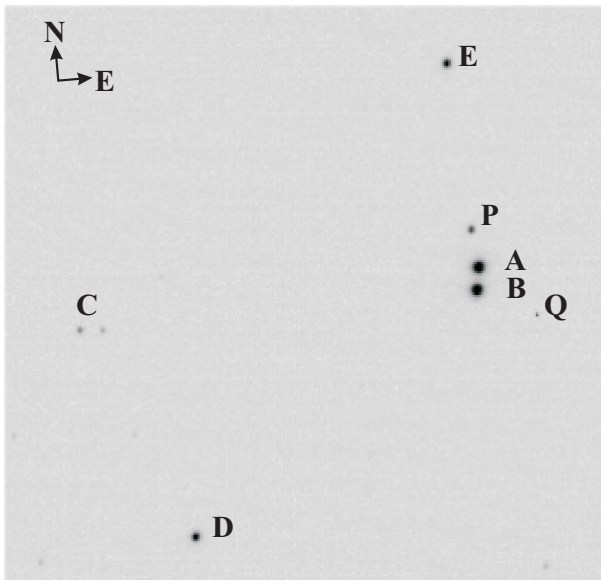

Fig. 1. *CCD frame of multiple star* WDS 00057+4549.

The results are given in Tables 1 and 1a, the notes in Table 2. In Table 1a the individual results of the measurements of position angle and separation for each analyzed case are given, and the corresponding mean values in Table 1. The designations used: WDS - identification in WDS Catalogue (Mason et al. 2006b); Disc. - double-star name after the discoverer; Mult. - designation for pair components; HIP - identification in Hipparcos Catalogue (ESA 1997); Epoch - observational epoch; θ [°] (σ_θ) - position angle in degrees (error of the position angle); ρ [″] (σ_ρ) - separation in seconds of arc (error of the separation); n - number of measurements;

Auth. - measurement author's name, Z. Cvetković (Cve), R. Pavlović (Pal), B. Novaković (Nov) and G.M. Popović (Pop); Notes - means that in Table 2 there is a comment (N), or the pair has an orbit (O).

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CCD МЕРЕЊА ДВОЈНИХ И ВИШЕСТРУКИХ ЗВЕЗДА НА НАО РОЖЕН. III

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У току ноћи 16./17. децембра 2006. године снимљено је 55 вишеструких система CCD камером на 2-метарском телескопу бугарске Националне Астрономске Опсерваторије на Рожену. Ово је трећа серија CCD мерења двојних и вишеструких звезда обављених на Рожену. За епоху посматрања дате су измерене вредности позиционог угла и растојања за укупно 67 парова у 49 вишеструких система које је било могуће измерити.