CCD measurements of double and multiple stars at Rozhen NAO

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Abstract. In this paper we present observations of double and multiple stars by using the 2-m telescope of the Bulgarian National Astronomical Observatory at Rozhen in the period from 2004 to 2011. The results of these measurements, i.e. position angles and angular separations, were used for calculation of the orbital or the linear elements. Two new and three recalculated orbits of binaries were obtained. Also, new linear solutions for three pairs are given.
Key words: visual double stars, CCD frames, orbits, linear solutions

Introduction

Binary stars have been studied for decades for the purpose of accurate determination of stellar masses, verification of the evolutionary models and star formation theories. Washington Double Star Catalog (WDS)[3] contains data for more than 100000 star pairs, but only for a small fraction of them (about 1%) there are orbital solutions in the Sixth Catalog of Orbits of Visual Binary Stars [4]. Because of this, as many as possible new observations of double stars should be performed.

With a CCD camera it is difficult to resolve too close pairs (separation less than 1.5 arcsec). Close pairs are observed by using various observational techniques of high angular resolution (speckle interferometry, lunar occultations, adaptive optics, eyepiece interferometry, Hipparcos, etc.). Sufficiently wide pairs have longer orbital periods. Many of them have not been observed enough (short orbital arc covered by observations). On the other hand, many measurements show a linear trend and it is necessary to collect observations over a long period of time to get the answer whether it is a physical or an optical pair.

1 Observations at Rozhen NAO

The Belgrade team has performed six series of observations of double and multiple stars at the Rozhen NAO in the period from 2004 to 2011. The first series of observations of double and multiple stars performed with a CCD camera attached to the 2-m telescope took place in the middle of October 2004. The telescope is of the Ritchey-Chretien-Coude type with the focal length of 16 m. The frames were obtained by using the Photometrics AT200 CCD camera. The chip dimensions are 1024x1024 pixels, the pixel size is

[3] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/WDS
[4] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6

24x24 micrometers. The angle corresponding to one pixel is 0.31 arcsec. The results have been published in Pavlović et al. (2005).

The other five series were obtained: in the end of October 2005 (second series); on December 16/17, 2006 (third series); on July 20/21, 2009 (fourth series); on September 7-10, 2010 (fifth series) and from March 29 to April 01 (sixth series). In the last five series the frames were obtained by using the CCD camera VersArray:1300B. The chip dimensions are 1300x1300 pixels, the pixel size is 20x20 micrometers. The angle corresponding to one pixel is 0.258 arcsec.

A total of 365 pairs was measured (from the first five series of observations) and the results were published in Pavlović et al. (2005) and Cvetković et al. (2006, 2007, 2010, 2011). The measurements of binaries whose frames were obtained on March, 2011 will be prepared for publishing.

The frames were measured by using the programme AIP4WIN (version 1.4.21 for the first four series and version 2.3.1 for later series). Initially, the observations were performed within the Balkan cooperation project with the support by UNESCO-ROSTE for the regional collaboration and after that as the collaboration between Bulgarian and Serbian astronomers. During the first three series of observations at Rozhen, the Bulgarian colleague Dr. Anton Strigachev was with the members of Belgrade team, while during the other three series, from the Bulgarian side, Svetlana Boeva was with the Belgrade astronomers.

2 New orbits and new linear solutions

Using the measurements obtained from the CCD observations at NAO Rozhen we have calculated the first orbits and masses for two binaries. The orbit of WDS 00152+2722 = J 868 (see Fig.1) was calculated by Novaković and was published (Novaković 2007). The orbit of WDS 07106+1543 = J 703 (see Fig.2) was calculated by Cvetković and was published (Cvetković 2007, Cvetković & Ninković 2008). Besides, the recalculated orbits for three binaries: WDS 03342+4837 = BU 787 AB, WDS 21289+1105 = STF 2799 AB and WDS 22234+3228 = WOR 11 were obtained. Also, three linear solutions were calculated for the first time for WDS 00251+1824 = HJ 621, WDS 03342+4837 = BU 787 AB and WDS 23581+2840 = HJ 995 (Cvetković et al. 2011).

These orbits and the linear solutions have been included in the Sixth Catalog of Orbits of Visual Binary Stars and in the Catalog of Rectilinear Elements [5].

Some binaries in our sample have orbits published previously. In these cases our measurements are compared to the ephemerides. For three binaries WDS 03342+4837 = BU 787 AB, WDS 21289+1105 = STF 2799 AB and WDS 22234+3228 = WOR 11 the residuals are large for recent measurements and the recalculated orbits are obtained (see Fig3 and Fig5 - left). The solid curves represent the newly determined orbits, while the dashed curves represent the previously published orbits.

[5] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1

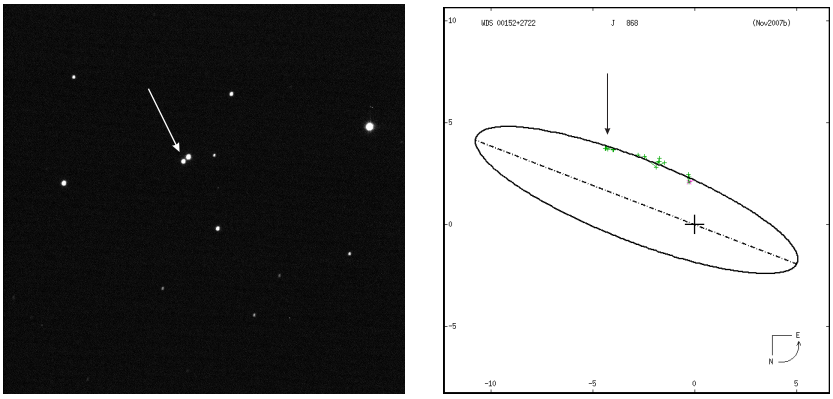

Fig. 1. CCD frame of double star WDS 00152+2722 = J 868 was obtained with the 2-m RCC telescope of the Rozhen NAO on 17.12.2006 (left) and its first orbit was calculated by an astronomer from the Belgrade Observatory (Novaković 2007). Our measurement was included for determination of orbital elements. The arrows indicate our measurement (right).

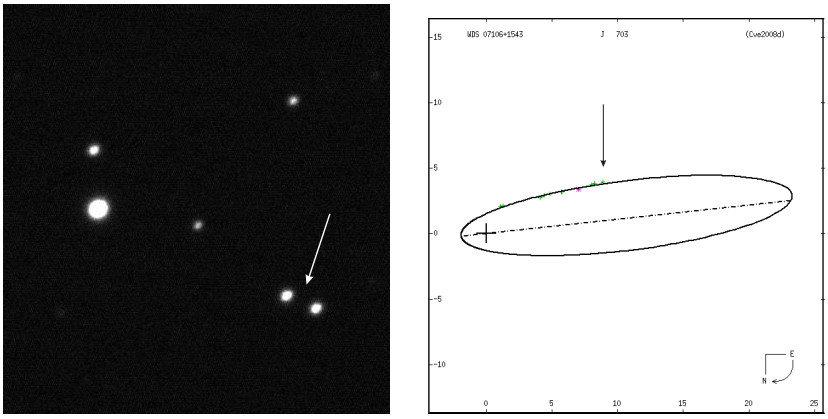

Fig. 2. CCD frame of double star WDS 07106+1543 = J 703 was obtained with the 2-m RCC telescope of the Rozhen NAO on 17.12.2006 (left) and its first orbit was calculated by an astronomer from the Belgrade Observatory (Cvetković 2008). Our measurement was included for determination of orbital elements. The arrows indicate our measurement (right).

The measurements of pairs: WDS 00251+1824 = HJ 621, WDS 03342+4837 = BU 787 AB and WDS 23581+2840 = HJ 995 show a linear trend and we calculated their first linear solutions (Cvetković et al. 2011). Their linear fits are illustrated in Fig.4 and Fig.5 (right). The arrow at the lower right corner indicates the direction of relative motion of the secondary; the dashed per-

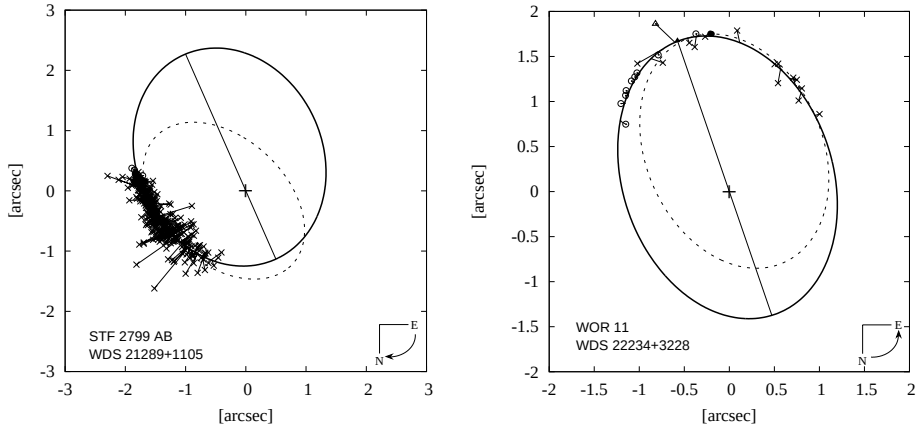

Fig. 3. Recalculated orbits for binaries WDS 21289+1105 = STF 2799 AB (left) and WDS 22234+3228 = WOR 11 (right).

pendicular line from the linear fit to the origin indicates the closest relative separation.

In two tables we present the orbital elements for three binaries (Table1) and the linear solutions for three pairs (Table2) given in Cvetković et al. (2011).

Table 1. Orbital elements

Name WDS	ADS HIP	$P[yr]$ σ_P	T σ_T	$a['']$ σ_a	e σ_e	$i[^o]$ σ_i	$\Omega[^o]$ σ_Ω	$\omega[^o]$ σ_ω	Last obs.
BU 787 AB	2609	655.8	2264.9	4.99	0.261	70.0	130.5	291.6	2010.6900
03342+4837	16649	±27.3	±13.5	±1.78	±0.093	±2.7	±0.9	±10.9	
STF 2799 AB	15007	1140.0	2880.1	1.86	0.335	151.6	23.8	357.8	2010.6874
21289+1105	106053	±5.0	±0.9	±0.14	±0.040	±2.9	±6.1	±9.4	
WOR 11	-	130.2	2049.1	1.61	0.101	43.3	19.0	343.9	2010.6871
22234+3228	110526	±1.1	±0.6	±0.06	±0.017	±0.8	±1.2	±3.9	

One pair, BU 787 AB, has both a linear fit and an orbital solution. For this pair until now there are 17 measurements and they cover a short orbital arc (less than 70 degrees). The residuals are large for recent measurements and we recalculated its orbit (Fig.4 - left). The solid curve represents our orbit, while the dashed curve represents the previously published orbit. Also,

Table 2. Linear elements

Name WDS	ADS HIP	$X_0[''] $ σ_{X_0}	$Y_0[''] $ σ_{Y_0}	$X_A[''] $ σ_{X_A}	$Y_A[''] $ σ_{Y_A}	T_0 σ_{T_0}	$\rho_0[''] $ σ_{ρ_0}	$\theta_0[^o] $ σ_{θ_0}	Last obs.
HJ 621	337	−2.32299	−2.08322	0.04978	−0.05550	1955.128	3.120	311.89	2010.6844
00251+1824	-	±0.06281	±0.04264	±0.00070	±0.00068	±0.206	±0.018	±0.57	
BU 787 AB	2609	−1.74409	1.46790	−0.02086	−0.02478	1878.073	2.258	229.91	2010.6900
03342+4837	16649	±0.07578	±0.02503	±0.00114	±0.00126	±1.879	±0.032	±1.39	
HJ 995	17130	3.71589	−1.59343	0.04285	0.09992	1948.823	4.043	66.79	2010.6900
23581+2840	-	±0.04285	±0.02830	±0.00098	±0.00139	±0.551	±0.035	±0.46	

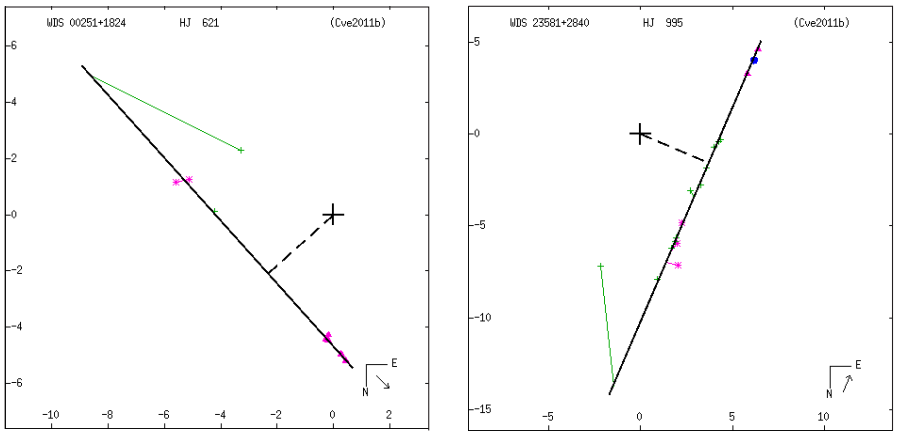

Fig. 4. Linear solutions for binaries WDS 00251+1824 = HJ 621 (left) and WDS 23581+2840 = HJ 995 (right).

the measurements show a linear trend and we are the first who calculated the linear solution for this pair (Fig.4 - right).

Conclusion

By using the 2-m telescope of the Bulgarian National Astronomical Observatory at Rozhen we have observed wide pairs that have long orbital periods. Most of them cannot be measured by using a modern speckle interferometric technique.

These measurements of visual double and multiple stars enabled us to calculate two orbits and three linear solutions for the first time and to recalculate three orbits.

For BU 787 AB, which has both a linear fit and an orbital solution, we found that it is most likely an optical pair rather than a physical one (see Cvetković et al. 2011).

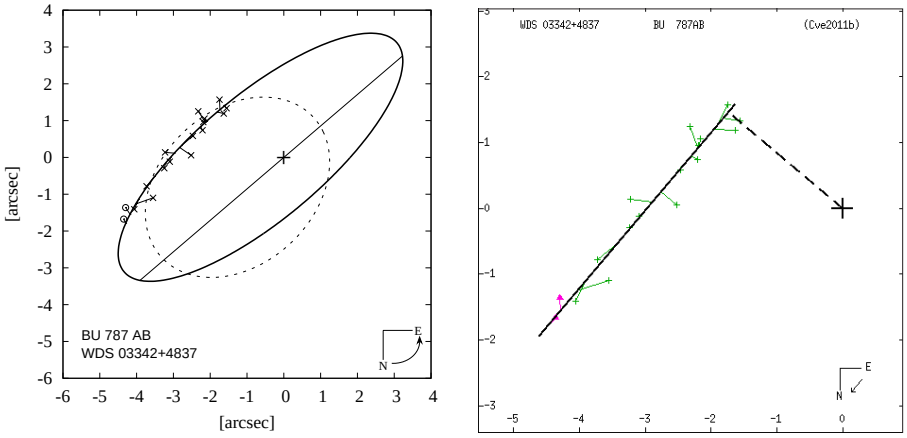

Fig. 5. Recalculated orbits (left) and linear solution (right) for pair WDS 03342+4837 = BU 787 AB.

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