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MEASUREMENTS OF VISUAL DOUBLE STARS BETWEEN 2011–2014

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Abstract. In the period from 2011 to 2014 we observed visual double and multiple stars at AS Vidojevica (ASV) and NAO Rozhen (NAOR) and measured the relative coordinates. Frames were taken by using three CCD cameras: SBIG ST-10ME and Apogee Alta U42 attached on the 60 cm telescope at ASV and VersArray 1300B attached on the 2 m telescope at NAOR. Analysing the relative coordinates of the same pairs obtained by using these two telescopes we detected a systematic difference in the separations. The reason of this is disagreement between the telescope focal length and that declared by the producer. We determined more correct focal lengths for both telescopes based on our measurements. Also, we give orbits, linear solutions and other parameters of visual double stars obtained in this period.

1. INTRODUCTION

The first observations of celestial bodies from the Astronomical Station on the mountain of Vidojevica (ASV) took place during the summer of 2011. More details can be found in Stojanović et al. (2012). Series of observations of double and multiple stars at the ASV have been made with a CCD camera attached to the 60-cm telescope. For these series we used either SBIG ST-10ME or Apogee Alta U42 CCD cameras. We obtained 10 frames per star: 5 in the Cousins/Bessel B filter and 5 in the Cousins/Bessel V filter. Series of observations of double and multiple stars at the Bulgarian National Astronomical Observatory at Rozhen (NAOR) have been made with the CCD camera VersArray 1300B attached to the 2 m telescope. For each double or multiple star, 10 frames were obtained: 5 in the Johnson B filter and 5 in the Johnson V filter. The basic characteristics of used cameras, including the field-of-view size, are given in Pavlović et al (2013).

In the period from 2011 to 2014 the Belgrade team has performed 15 series of observations of double and multiple stars at ASV and NAOR. In Table 1 we listed observational period and number of double or multiple stars of all 15 series for which we have taken frames.

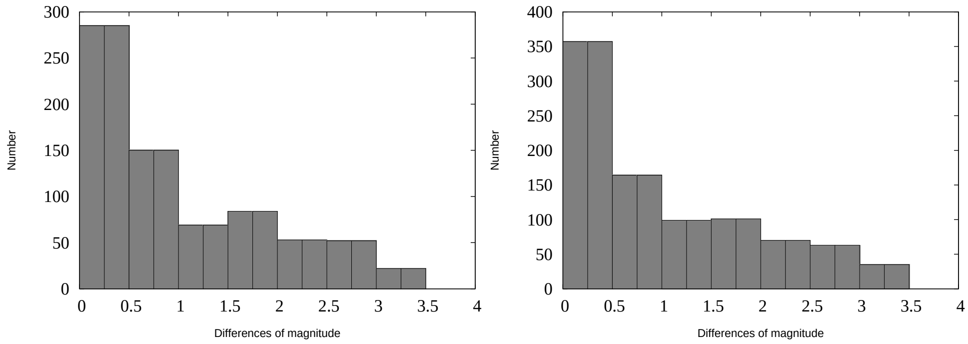

Figure 1: Distribution of the catalog magnitude differences between the components of a pair taken from WDS at ASV (left) and NAOR (right).

The histogram in Figure 1 presents the distribution of the catalog magnitude differences between the components of pairs, taken from the Washington Double Star Catalog, WDS[1] for double stars observed at both ASV and NAOR. The most of the observed pairs for both stations have differences in magnitude lower than 1 mag. In Figure 2 we present the distribution of angular separations of the components up to 20 arcsec. Our observational program of double and multiple stars contains mainly pairs with angular separations less than 10 arcsec and that is easily noted in Figure 2.

ASV			**N**AOR	
Year	Period	Number of double or multiple stars	Period	Number of double or multiple stars
2011	October 10/11 November 2–4	58 379	October 27/28	179
2012	April 22/23 June 21–24	16 101	April 24–26 November 8–10	174 100
2013	March 4–5 July 2–3, 12–15 September 11/12	43 190 10	April 14–16 October 7–10	88 190
2014	February 8/9 April 1–3	10 30	March 24–27	19

Table 1: The observational sessions of the Belgrade team at ASV and NAOR.

2. RESULTS

In this paragraph, we present the results which we obtained using our measurements at both ASV and NAOR in the period 2011-2014.

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

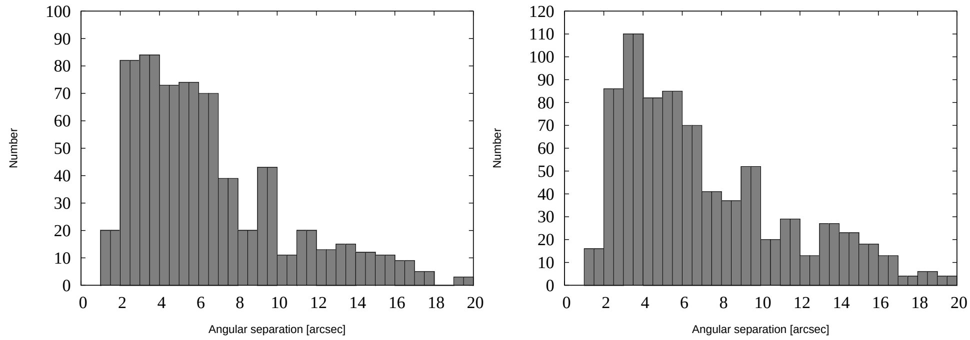

Figure 2: Distribution of the angular separations of the components taken at ASV (left) and NAOR (right).

2. 1. PRECISE FOCAL LENGTH OF THE TELESCOPES

During the autumn of 2011, we observed the same objects at both NAOR and ASV. We noticed that the measured separations ($\rho_{\rm NAOR}, \rho_{\rm ASV}$) differ for the same pairs of stars and the differences increase with increasing angular separation. Therefore, we measured the angular separations between the images of stars visible in our CCD frames. The results for measured separations for a selected sample of stars and their corresponding separation differences, $\Delta\rho = \rho_{\rm NAOR} - \rho_{\rm ASV}$ show a linear dependence and it can be given by the following equation: $\Delta\rho = 0.0019 + 0.0137\rho$.

The separation depends on the angle corresponding to one pixel, i.e., the focal length of the telescope. The result of determining the focal length of the 60 cm telescope at the ASV more precisely is given in Cvetković et al. (2012a), and for the 2m NAOR telescope in Cvetković et al. (2013). The differences are relatively small: of the order of 1.4%. For pairs of stars with angular separations smaller than 10.., the differences are approximately equal to measurement errors. Therefore small deviations in separations resulting from inaccurate telescope focal length could not be noted previously.

2. 2. DETERMINING THE NATURE OF SYSTEM ADS 48

Using only our CCD observations we analyzed a multiple system ADS 48. Its number in WDS is 00057+4549. Our aim is to establish which of the seven components are gravitationally bound, i.e. have an orbital motion around the mass center, and which of them are mutually very distant in space so that only their projections are close in the field of view. We used the measuring results from our CCD frames obtained between 1994 and 2011. The first CCD frames of ADS 48 multiple system at our disposal were obtained in 1994 (Popović and Pavlović, 1997). We also used frames of this system obtained at NAOR in the period 2004-2011 and ASV in 2011. The selected CCD frames are overlapped and presented in Figure 3. The detailed analysis of the system ADS 48 is given in the paper Cvetković et al. (2012b). The conclusions combined with the criteria based on celestial mechanics lead us to the following: i) only stars A and B are gravitationally bound; ii) one very distant component has common proper motion with A and B, but is not bound to them; iii) all other components

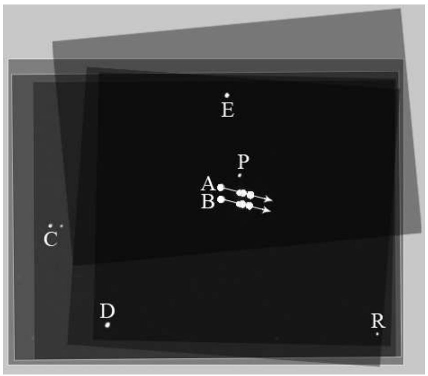

Figure 3: CCD frames of the multiple system ADS 48 obtained between 1994 and 2011 are overlapped in order to have at the same position images of the components (C, D, E, P, and R) for which the configuration is invariable. The motion of pair AB in the view field is clearly seen; the direction and sense are indicated by the arrow.

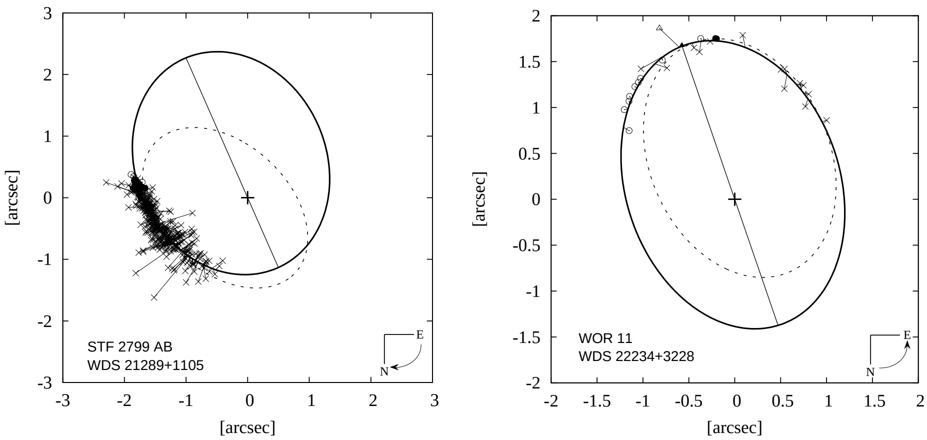

Figure 4: The recalculated orbits of two binaries STF 2799AB and WOR 11.

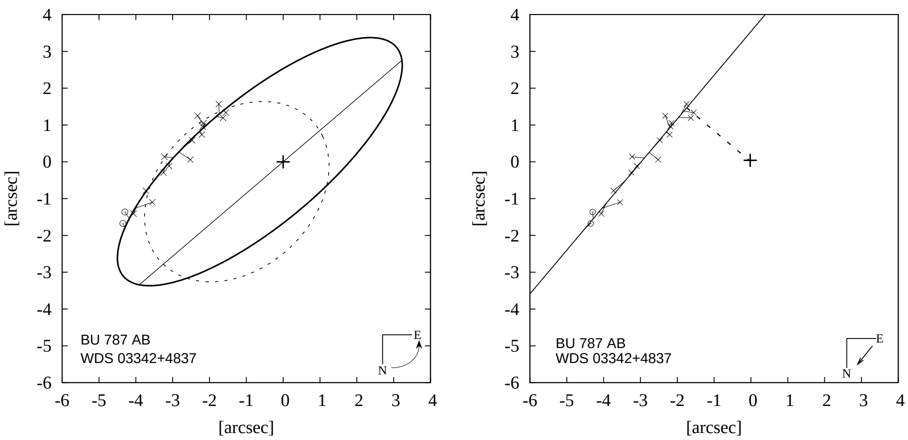

Figure 5: The recalculated orbit and linear solution of pair BU 787AB.

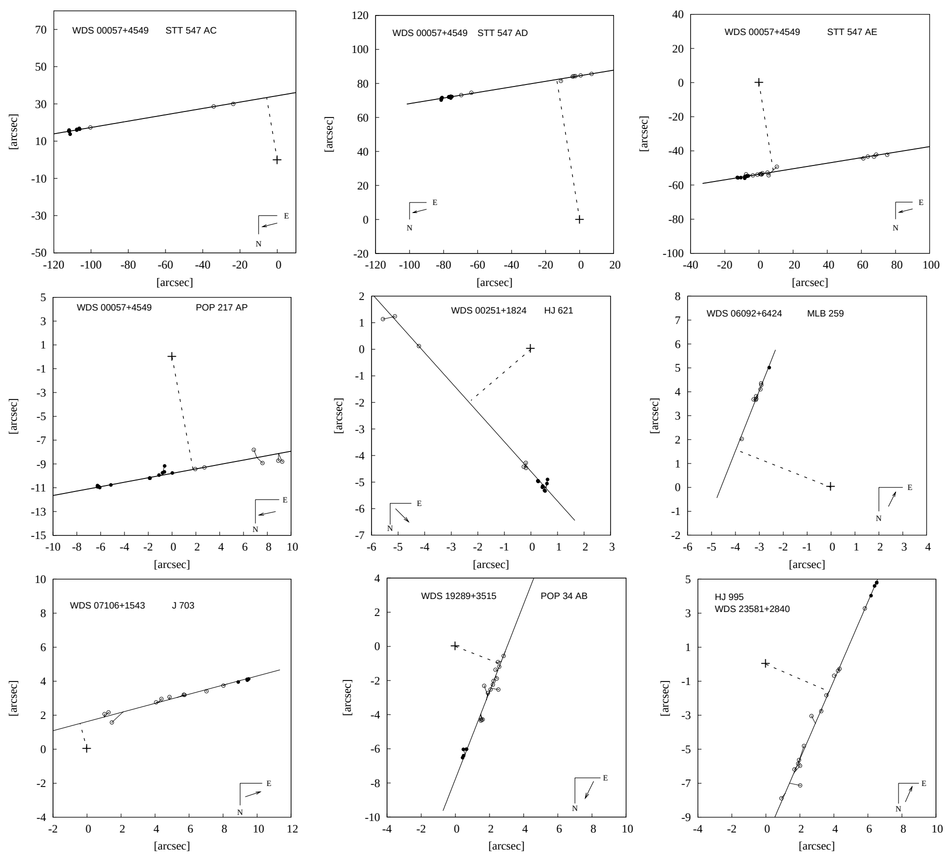

Figure 6: Linear fits for ten pairs: the arrow in the lower right corner indicates the direction of relative motion of the secondary; the dashed perpendicular line from the linear fit to the origin indicates the closest relative separation.

form optical pairs with AB.

2. 3. RECALCULATED ORBITS

Using the measurements obtained from the CCD observations at ASV and NAOR Cvetković has recalculated the orbits and masses for three binaries: WDS 03342+4837 = BU 787AB, WDS 2128+1105 = STF 2799AB and WDS 22234+3228 = WOR 11. The orbits, illustrated in Figure 4, were published in (Cvetković et al. 2011). The solid curves represent the newly determined orbits, while the dashed curves represent the previously published orbits. One pair, BU 787AB, has both orbital and linear solutions presented in Figure 5.

2. 4. LINEAR SOLUTIONS

We calculated the first linear solutions for ten pairs for which the measurements show a linear trend: WDS 00057+4549 = STT 547 AC, WDS 00057+4549 = STT

547 AD, WDS 00057+4549 = STT 547 AE, WDS 00057+4549 = POP 217 AP, WDS 00251+1824 = HJ 621, WDS 03342+4837 = BU 787 AB, WDS 06092+6424 = MLB 259, WDS 07106+1543 = J 703, WDS 19289+3515 = POP 34 AC and WDS 23581+2840 = HJ 995. For calculation we used the measuring results from our CCD frames obtained at NAOR and ASV. The linear solutions for pairs STT 547 AC, STT 547 AD, STT 547 AE, POP 217 AP and MLB 259 have been previously published in (Pavlović at al. 2013). The linear solutions for pairs HJ 621, BU 787 AB and HJ 995 have been previously published in (Cvetković at al. 2011). For the other two pairs J 703 and POP 34 AC, the linear solutions have been published in (Cvetković 2014).

In Figure 6 linear fits for ten pairs are presented. In the lower right (or left) corner the arrow indicates the sense of the motion for the secondaries with respect to the primary (brighter star). The linear solutions for these pairs have been determined from a set of measurements also including our ones from the frames obtained at NAOR and/or ASV. Our measurements are indicated by filled circles in Figure 6.

Moreover, we applied existing criteria for establishing the nature of these double stars (Cvetković et al. 2015). The criteria are mostly based on some fundamental properties, such as the energy-conservation law, Kepler's third law, etc, which should be obeyed by bound pairs. Our analysis shows that all eleven double stars are most likely not gravitationally bound, i.e. they are optical pairs.

3. CONSLUSION

In the period 2011-2014, we made 9 series of CCD observations of double or multiple stars with the 0.6 m telescope at ASV and 6 series with 2 m telescope at NAOR. We determined more precise focal lengths for both telescopes. Using only our CCD observations we analyzed a multiple system ADS 48 and we applied existing criteria for establishing the nature of this system. We obtained that only stars A and B are gravitationally bound and all other components form optical pairs with them. Also, we have used our measurements to recalculate three orbits and to calculate linear solutions of ten double stars for the first time. Our analysis shows that these ten double stars are most likely optical pairs.

Acknowledgments

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