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FIRST VISUAL MEASUREMENTS OF DOUBLE STARS AT VIDOJEVICA

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Abstract. On the basis of the first frames obtained by using CCD cameras SBIG ST-10ME and Apogee Alta U42 attached to the 60 cm telescope at Vidojevica, we report the measurements of double and multiple stars and the parameters of the limiting capabilities of the telescope and weather conditions. We also present the results for the position angle, angular separation and residuals for 10 star pairs with published orbital elements or linear solutions. The first linear fits are presented for 2 star pairs of the multiple system ADS 48.

1. INTRODUCTION

During the summer 2011 the first observations of visual double stars from the new Astronomical Station on the mountain of Vidojevica (ASV) took place. The geographic coordinates, measured by GPS, of the Station are: east longitude $21^\circ\ 33'\ 20''.4$, north latitude $43^\circ\ 08'\ 24''.6$ and altitude above sea level 1150 m. The telescope situated at this location is a Cassegrain reflector with the primary mirror of 60 cm diameter and 6 m focal length.

We carried out two series of CCD observations of visual double or multiple stars at ASV. The first series was obtained on June 18/19 when for imaging a SBIG ST-10ME CCD camera was used (15 double stars). The second series was obtained on August 19/20 when an Apogee Alta U42 CCD camera was used (20 double stars). For each star pair five frames were obtained. Our aim was to find out how close double stars one can resolve with this telescope and the cameras, i.e. to establish the minimum separation between the components still resolvable on the CCD frames. This depends on the apparent magnitudes of the pair components (m_A and m_B) and on their magnitude difference ($\Delta m = m_A - m_B$). Besides, there are other factors which affect the resolving of components: telescope resolving power, capabilities of cameras and seeing.

Telescope diffracting limited resolving power is about $0''.23$. For the CCD camera SBIG ST-10ME, the chip size is 1.485×1.026 cm. The chip dimensions are 2148×1472 pixels, the pixel size is 6.8×6.8 micrometers. The field of view is 8.51×5.88 arcminutes and the pixel size is 0.23 arcseconds. For the CCD camera Apogee Alta U42, the chip size is 2.76×2.76 cm. The chip dimensions are 2048×2048 pixels, the pixel size is 13.5×13.5 micrometers. The field of view is 15.81×15.81 arcminutes and the pixel size is 0.46 arcseconds.

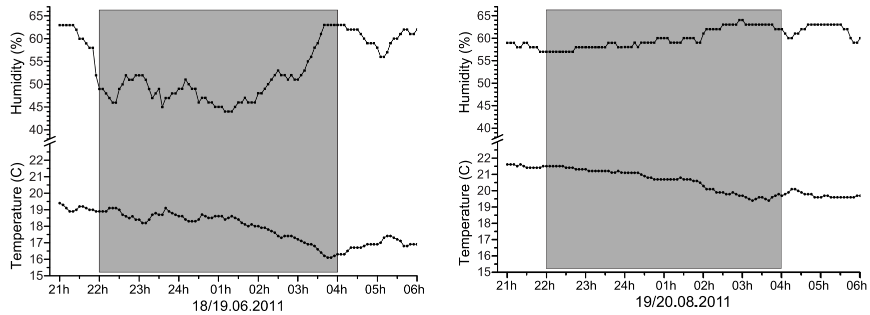

Figure 1: Temperature and humidity variations during the two nights in 2011, June 18/19 and August 19/20. The shaded area corresponds to the time interval within which the observations of visual double stars were carried out.

In Fig. 1 the temperature and humidity during the two observation nights are presented. The shaded area corresponds to the time interval within which the observations of visual double stars were carried out. The temperature and humidity in June were lower and with somewhat larger variations than in August. Due to the seeing perturbed stellar image the FWHM mean value in June was about 1″.5 and about 1″.3 in August.

2. STAR SELECTION

For observations at ASV we selected both faint and bright pairs (different magnitudes) and also pairs with magnitude differences and pair separations within wide intervals.

In our sample of 35 observed visual double stars the magnitudes of the primary m_A (the brighter component of a pair) cover an interval from 6.47 to 12.90, whereas those of the secondary m_B (fainter component) are within 7.33 to 13.30. The pair magnitude differences Δm are within 0.0 to 3.43. In Fig. 2 (left) the frequency of the pairs versus magnitude difference is presented. For 19 pairs, the magnitude difference is between 0 and 0.5. The frequency of the pairs versus separation is presented in Fig. 2 (right). The separations, angular distances between the components, are within 1″.30 to 17″.10. For six pairs the separation exceeds 6″, for the remaining ones the separation interval lies between 1″.3 and 6″.0. In the case of double stars with separations less than 2″.5 we selected those with magnitude differences $\Delta m < 1.0$.

In Fig. 3 selected CCD frames of visual double stars taken at ASV are presented. In the upper row there are those obtained with the ST-10ME camera on June 18/19 2011, in the lower one those obtained with Apogee Alta U42 on August 19/20 2011. The selection of CCD frames followed the requirement already mentioned above. For each pair in its CCD frame the magnitudes and separation are given.

The frames were measured by using AIP4WIN (version 2.3.1). The position angle and separation were measured for 31 double stars. In the case of the remaining four pairs with separations less than 1″.5, the star images were not separated and the measurements could not be carried out. The reasons are the proximity of the components and the limiting capabilities of the CCD cameras and seeing.

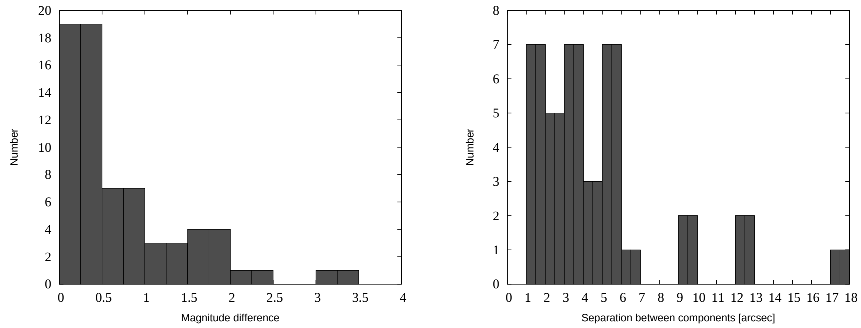

Figure 2: Frequency of the pairs versus: magnitude difference (left); separation (right).

Out of 35 double or multiple stars observed at ASV for six ones the orbital elements have been calculated (announced), whereas in the case of four ones a linear solution has been obtained (Table 1.) In Table 1 the relative positions for these pairs with the published (announced) orbital or linear solutions are given. The designations used: WDS - identification in the Washington Double Star Catalog[1] by its coordinates for the epoch 2000.0 in Column 1; Discoverer designation - double-star name after the discoverer with designation for pair components in Column 2; Column 3 gives the epoch of observation; ρ - separation in Column 4; θ - position angle in Columns 5; Columns 6 and 7 give O-C residuals (in θ and ρ) to the determination referenced in Column 8. The reference is to either a published orbit or a determination in the Catalog of Rectilinear Elements[2] indicated by the letter L. All residuals are small which indicates that the results of our observations are good and that the orbital or linear solutions fit well also the recent measurements.

3. MULTIPLE SYSTEM ADS 48

Among the observed systems there is WDS 00057+4549 = ADS 48 (a multiple system). Over long or short time intervals the observations of its six pairs have been collected. The closest pair was discovered by O. Struve in 1876 and its designation is STT 547AB after him. In the late XIX and early XX centuries Struve discovered other four components. The relative coordinates for the STT 547 pairs AC, AD, AE and AF have been measured from that time. The sixth component P was discovered by G. Popović in 1994 and measurements for the pair designated as POP 217AP are available. The complete measurements for this system were obtained from the Washington Database due to the courtesy of Dr B. Mason to whom we owe our very sincere gratitude. Till now the orbit for the closest pair AB has been calculated. In the Sixth Catalog of Orbits of Visual Binary Stars[3] one can find two orbital solutions for it: Popović & Pavlović (1996) and Kiyaeva et al.(2001). For two other pairs - AC (Friedman et al. 2011) and AE (Hartkopf & Mason 2011) linear solutions have

[1]http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/WDS
[2]http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1
[3]http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6

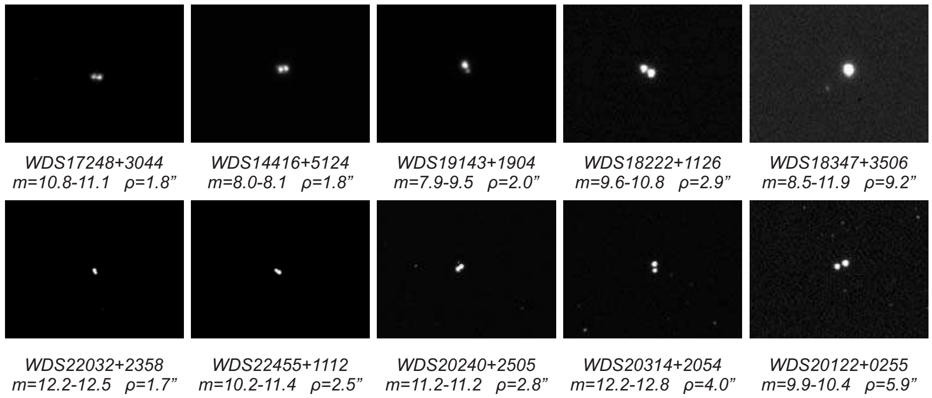

Figure 3: CCD frames of visual double stars obtained at ASV: the upper row contains frames obtained with ST-10ME on June 18/19, 2011; the lower row contains frames obtained with Apogee Alta U42 on August 19/20, 2011.

Table 1: Residuals of our CCD measurements from orbital or linear solutions. Reference: Kiy01=Kiyaeva et al. 2001, Pop96=Popović & Pavlović 1996, Nov07=Novaković 2007, Man04=Mante 2004, Hop73=Hopmann 1973, Doc10=Docobo & Ling 2010, Hei84=Heintz 1984.

WDS design. α, δ (2000)	Discoverer designation	Epoch 2000.+	ρ ($''$)	θ ($^\circ$)	$(O-C)_\rho$ ($''$)	$(O-C)_\theta$ ($^\circ$)	Reference
00057+4549	STT 547AB	11.64	6.06	186.4	0.03	–0.3	Kiy01
					0.13	–0.7	Pop96
00057+4549	STT 547AC	11.64	112.64	261.9	1.38	–0.2	L
00057+4549	STT 547AE	11.64	56.93	347.2	0.49	–0.5	L
00152+2722	J 868	11.64	5.99	229.9	0.03	1.0	Nov07
17248+3044	BU 1250	11.47	1.84	117.0	–0.05	–0.7	Man04
18222+1126	STF2311AB	11.47	2.87	92.1	–0.08	1.6	L
19143+1904	STF2484	11.47	2.01	239.3	–0.26	0.2	Hop73
20346+2914	J 565AB	11.64	6.15	48.7	0.06	–0.5	L
22455+1112	BU 711AB	11.64	2.42	349.8	–0.15	–0.8	Doc10
23317+1956	WIR 1AB	11.64	5.36	81.8	–0.14	–0.5	Hei84

been determined and one can find them in the Catalog of Rectilinear Elements. Most likely these pairs are optical (they are not bound), but a more reliable confirmation can be obtained only from observations covering a long time interval.

From the CCD frames obtained by astronomers of the Astronomical Observatory of Belgrade (AOB) at the NAO Rozhen in 2004, 2006 and 2010 and at ASV in 2011 a relative motion of the P component with respect to the A one has been noticed. Based on the measurements, also including the one of the frames obtained at ASV in August 2011, we have obtained (Cvetković 2011) the first linear fit for the AP pair (Fig. 4). Our measurement is indicated by a filled circle and it lies on the fitted line, being a confirmation of the good results obtained with the ASV 60 cm telescope. It is interesting that for the P component, discovered at AOB, the first trajectory (linear) has been calculated by the astronomer from AOB. For trajectory

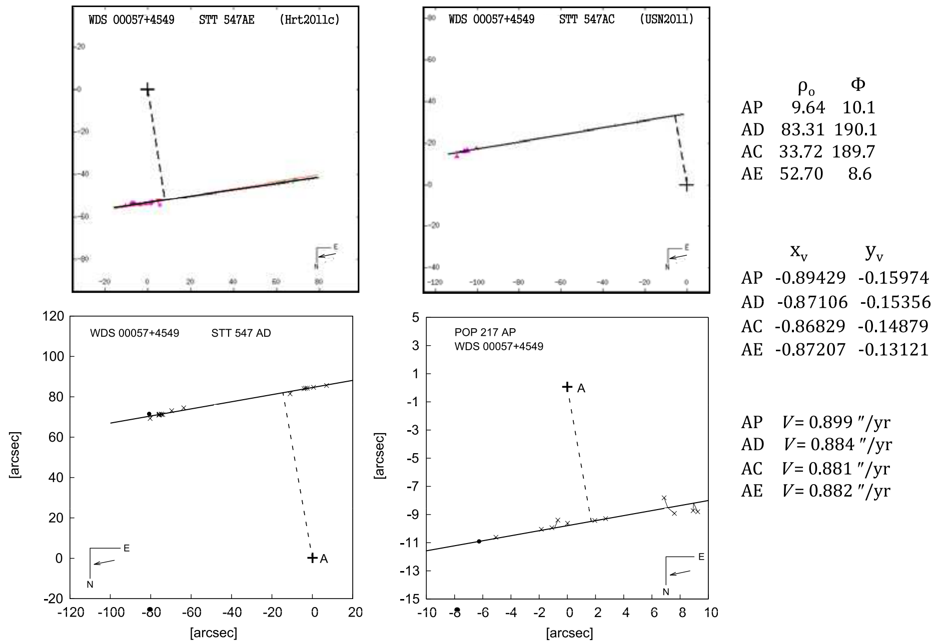

Figure 4: Linear fits for four pairs: STT 547AE, STT 547AC, STT 547AD and POP 217AP.

calculated in addition to the earlier measurements, those obtained at ASV were also used. A linear solution has been obtained for pair AD (Cvetković 2011) from a set of measurements also including the one obtained at ASV. It is indicated by a filled circle in Fig. 4.

A careful inspection of the frames concerning multiple system ADS 48 indicates that the configuration of its components D, E, F and P remains constant. Because of this we have measured the separations between the components for the pairs - DE, DF, DP and EF; they do not change with time, i.e. their mutual separations are almost constant (Table 2). The separation between the components of the pair AD has been also measured. It increases with time (Table 2). This means that the component A is moving (i.e. pair AB). These measurements and the obtained linear solutions indicate that the components C,D,E,F and P are not gravitationally bound to A and B. The AB pair is the only orbital one in this multiple system.

In Fig. 4 four linear fits concerning the pairs AC, AE, AD and AP are presented. In the right lower angle the arrow indicates the sense of the motion for the secondaries C,E,D and P with respect to the primary A. Obviously, all secondaries move in almost parallel directions and in the same sense (angle Φ) which confirms the motion of A, i.e. of the AB mass centre in space (with respect to other stars).

In addition to the linear fits (Fig. 4 right) the linear elements are also given. To us of interest are x_v and y_v - the components of the velocity of the secondary with respect to the primary. The values are almost the same for all four pairs (small differences

Table 2: Separations between the components for the pairs DE, DF, EF, DP and DA of ADS 48.

Pairs of ADS 48	2004	2006	2010	2011
DE	142.″29	142.″50	142.″46	142.″44
DF	148.39	148.36	148.42	148.40
EF	155.23	155.07	155.02	155.08
DP	109.55	109.81	109.80	109.75
DA	**102.63**	**103.92**	**106.09**	**106.64**

are due to the differences in angles and separations). The velocities V (″/yr) are also given. The agreement between these values is evident.

4. CONCLUSION

On the basis of the first series of CCD observations of double or multiple stars performed at ASV we can conclude the following:

1) out of 35 double stars 31 ones were measured successfully;

2) the components were successfully resolved, i.e. separations greater than 1.″5 were measured; pairs having smaller separations were not measured due to: the telescope resolving power (0.″23), capabilities of the cameras and seeing (about 1.″5);

3) for the first time, with data from ASV, two linear solutions were obtained;

4) the residuals from existing elements are small, a good confirmation of the quality of our measurements.

Acknowledgments

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