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ORBITS OF FOUR DOUBLE STARS

B. Novaković and N. Todorović

Astronomical Observatory, Volgina 7, 11160 Belgrade 74, Serbia and Montenegro

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SUMMARY: We present orbits of four double stars. Orbits of stars WDS 23516+4205 = ADS 17050 and WDS 18239+5848 = ADS 11336 were calculated for the first time. Orbits of double stars WDS 02022+3643 = ADS 1613 and WDS 18443+3940 = ADS 11635 were revised. We have also determined their masses, dynamical parallaxes and ephemerides.

Key words. binaries: visual

1. INTRODUCTION

The orbits of four double stars are presented here, together with dynamical parallaxes, stellar masses and ephemerides. The orbits of the stars WDS 02022+3643 and WDS 18443+3940 were revised and the orbits of stars WDS 18239+5848 and WDS 23516+4205 were calculated for the first time. All four new orbits have previously been published in the IAU Commission 26 Circular (Novaković and Todorović 2005). The orbits were calculated by using different methods and also in some cases these methods were combined, in order to find the best result.

2. METHODS

The problem of computing orbital elements of a binary from a set of observed positions is especially difficult in the case when observations cover a short arc. Whether a set of measurements suffices to determine orbit depends on the amount, consistency and distribution of the data. In cases with period of several centuries, or even more, the measurements define a limited ellipse arc, and orbits calculated in these cases are preliminary. Among the four double stars, presented in this work, three of them have a very short arc covered by the measurements, except for the star WDS 02022+3643. Hence, orbits of these three double stars are preliminary. The orbital elements were determined by using the following methods: Kovalski-Olević (Olević and Cvetković 2004, Pourbaix 1994) and the seven-dimensional grid search method. The grid search method was used in order to minimize the function D defined on:

$$D = [\sum_i w_i((x_o - x_c)_i^2 + (y_o - y_c)_i^2)]/\sum_i w_i. \quad (1)$$

In this formula, w_i denotes the weight of the i^{th} observation, x_o,y_o denotes the observed positions and x_c,y_c denotes the calculated positions of the companion. All weights were assigned to the appropriate observations using the observation-weighting rules of Hartkopf (Hartkopf et al. 1989, Hartkopf et al. 2001). The absolute magnitudes and dynamical parallaxes were calculated by using Angelov (1993) method. The calculated dynamical parallaxes were compared with the trigonometric parallaxes published in the Hipparcos and Tycho Catalogues (ESA 1997). Visual magnitudes and spectral types, presented in Table 2, were taken from WDS catalogue (Mason et al. 2003).

3. RESULTS AND DISCUSSIONS

Table 1 gives the corresponding numerical values for the orbital elements (equinox J2000) in the following order: P - period, T - time of periastron passage, a - semi major axis, e - eccentricity, i - inclination, Ω - longitude of the node, ω - longitude of the periastron. The orbits are presented in Figs. 1-4 The solid curves represent the newly determined orbital elements, while the dashed curves (Fig. 1 and Fig. 3) represent previously published orbital elements. The solid lines indicate the line of nodes. All measurements (filed circles) are connected to their predicted positions on the new orbit by "O-C" lines. The arrows indicate direction of the motion.

Table 2 gives the astrophysical quantities for both components: visual magnitudes, spectral types, absolute magnitudes, masses and, in the last two columns, the calculated dynamical parallax and the Hipparcos trigonometric parallax.

Table 3 gives predicted ephemerides for these systems for the period 2006-2010.

Finally, Table 4 contains the observational data and their residuals. Asterisks (*) mark measurements for which the quadrant was changed. Double asterisks (**) indicate the measurements not used in the final orbit calculation.

WDS 02022+3643. A triple system discovered by R. Aitken (1908) with the 12-inch refractor at the Lick Observatory. Prior to this work the orbit has been calculated by Heintz (1973), but it exhibits significant deviations from the separation obtained according the most recent observations. Our elements enable a somewhat better fit, but according to our calculations the dynamical parallax is equal to $0\farcs0338$. This value is in a poor agreement with the Hipparcos value of $0\farcs0163$ and, in our opinion, this difference arises due to the fact that the component C lies off the main sequence. The new orbit shows a significant difference only in eccentricity, the other orbital elements do not differ much from the previous orbit.

WDS 18239+5848. This multiple star was discovered by W. Struve (1833.20). Up to the present day 106 observations of the pair AB have been made. Almost 200 years of observation cover a very short arc (26°) that indicates a very long orbiting period. In this case, it is possible to find several orbits, which fit well the observational data, hence the orbit for this binary star, at this moment, should be classified as preliminary. The orbital elements were calculated by using the Kovalski-Olević method. The resulting dynamical parallax shows a good agreement with the Hipparcos value.

WDS 18443+3940. This multiple star was discovered by W. Struve in 1831.44, and up to the present day 539 observations of the pair AB have been made. Prior to this work, the orbit has been calculated by Güntzel-Lingner (1956) and recently, the newly calculated orbit was published by Mason (Mason et al. 2004). The orbit calculated by Güntzel-Lingner was preliminary because a very short arc was covered by the observations at that time. The second orbit, obtained by Mason et al., is very similar to ours with $P = 1725.0$ yr and $a = 4\farcs17$, but significantly different in orbital eccentricity ($e = 0.243$ Mason et al. and $e = 0.636$ this work). Both orbits fit well the observational data and new observations are needed to resolve this difference in eccentricity.

WDS 23516+4205. Since 1848.43 when it was discovered by O. Struve, 64 observations of this binary star have been made. These observations also cover a short arc (71°) but without gaps. Except the observations from 1843.90 (Maedler, J.H.), 1848.43 (Struve, O.), 1873.12 (Dembowski, E.), 1888.33 (Engelmann, R.), 1951.72 (Dommanget, J.) and 1982.6813 (Lefevre, J.R.A.) which were ignored in our final calculations because of their large residuals in the preliminary results, both visual and interferometric data are fitted well with the new orbit. The orbital elements, of this star, were calculated by using Pourbaix method for initial solution and then the grid search method was applied.

Table 1. Orbital elements.

Name WDS	P[yr]	T	a[″]	e	i[°]	Ω[°]	ω[°]
A 1813 AB-C	310.51	2210.24	1.790	0.636	113.2	168.5	135.5
02022+3643	±7.25	±1.43	±0.204	±0.108	±2.80	±1.99	±11.09
STF 2323 AB	3962.50	5671.40	6.621	0.553	107.7	179.9	128.0
18239+5848	±209.26	±12.08	±0.325	±0.006	±0.12	±0.10	±2.18
STF 2382 AB	1804.41	2091.43	4.742	0.691	121.2	162.1	255.5
18443+3940	±11.56	±10.25	±0.270	±0.007	±0.18	±0.23	±0.52
STT 510 AB	1522.90	1824.50	0.792	0.0685	117.2	96.4	85.3
23516+4205	±44.93	±49.08	±0.098	±0.025	±2.20	±2.64	±12.86

Table 2. Dynamical elements.

Name WDS	$m_A - m_B$	Sp.	M_A	M_B	$\mathcal{M}_A\odot$	$\mathcal{M}_B\odot$	$\pi_{\rm dyn}$[mas]	$\pi_{\rm HIP}$[mas]
A 1813 AB-C 02022+3643	8.29 - 11.19	-	5.93	8.83	0.94	0.60	33.80	16.29 ± 1.62
STF 2323 AB 18239+5848	5.06 - 8.07	A1V	1.31	4.32	2.12	1.18	17.77	17.31 ± 0.48
STF 2382 AB 18443+3940	5.01 - 6.10	A4V - F1V	1.63	2.72	1.96	1.56	21.05	20.10 ± 0.76
STT 510 AB 23516+4205	8.43 - 7.86	A6V	1.19	0.62	2.18	2.54	3.57	4.22 ± 2.22

Table 3. Ephemerides.

		2006		2007		2008		2009		2010	
WDS Designation α, δ (2000)	Discoverer Designation	θ [○]	ρ [″]	θ [○]	ρ [″]	θ [○]	ρ [″]	θ [○]	ρ [″]	θ [○]	ρ [″]
02022+3643.....	A 1813 AB-C	204.7	1.595	204.3	1.611	203.8	1.627	203.4	1.643	203.0	1.659
18239+5848.....	STF 2323 AB	348.9	3.750	348.8	3.749	348.7	3.749	348.6	3.749	348.6	3.748
18443+3940.....	STF 2382 AB	348.8	2.384	348.5	2.372	348.2	2.360	347.9	2.348	347.5	2.336
23516+4205.....	STT 510 AB	301.8	0.579	301.6	0.581	301.4	0.583	301.2	0.585	301.0	0.586

Table 4. Observations and residuals.[1]

WDS 02022+3643 = A 1813						
t	θ_t [○]	ϱ [″]	n	Obs	$\Delta\theta$[○]	$\Delta\varrho$[″]
1908.8100	338.9	0.70	3	A 1908c	-5.4	-0.067
1918.6600	324.8	0.85	1	A 1929a	-2.2	0.044
1919.6800	325.6	0.75	2	A 1929a	0.4	-0.052
1921.6600	322.2	0.83	1	A 1929a	0.5	0.037
1930.7500	308.6	0.67	1	A 1933d	4.4	-0.068
1932.8000	297.5	0.68	2	A 1933d	-2.4	-0.047
1933.7600	291.2	0.78	1	Kui1961b	-6.6	0.057
1934.8400	290.1	0.68	1	A 1937b	-5.4	-0.038
1947.6800	266.0	0.61	1	Jef9999	-1.0	-0.118
1958.6600	259.2	0.85	2	B 1960b	13.0	0.023
1961.0100	248.1	0.64	3	Cou1962a	5.7	-0.217
1968.7420	235.2	0.77	1	Cou1972e	3.3	-0.199
1971.8600	229.5	1.01	4	Hei1975a	1.2	-0.008
1972.8870	231.5	1.16	3	Wor1978	4.3	0.125
1976.9200	227.5	1.00	3	Hei1978b	4.2	-0.102
1991.2500	216.0	1.421	1	HIP1997a	3.6	0.074
1991.5000	215.7	1.43	1	TYC2002	3.4	0.078
1999.8856	207.6	1.494	1	Hor2002a	0.0	0.000
2001.7860	206.1	1.39	1	Mor2002	-0.6	-0.136

[1]This Table is too big to be published here. The whole Table can be found at `http://saj.matf.bg.ac.yu/172/pdf/tab4.pdf`

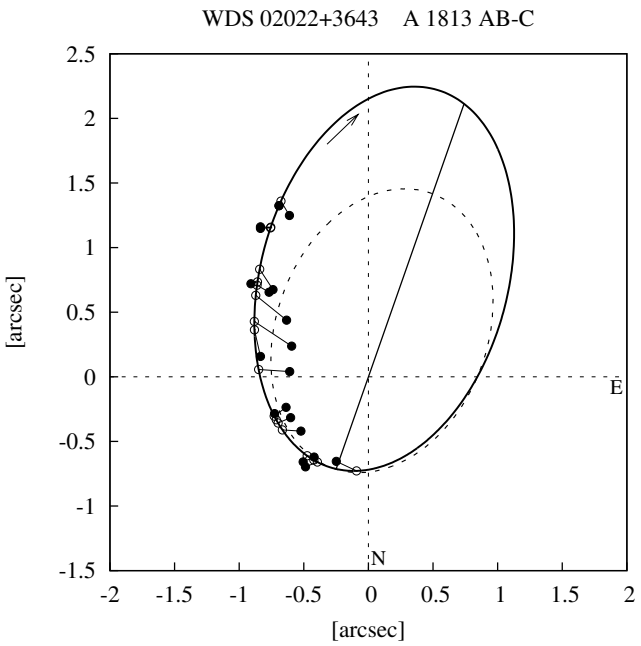

Fig. 1. *Orbit of A 1813.*

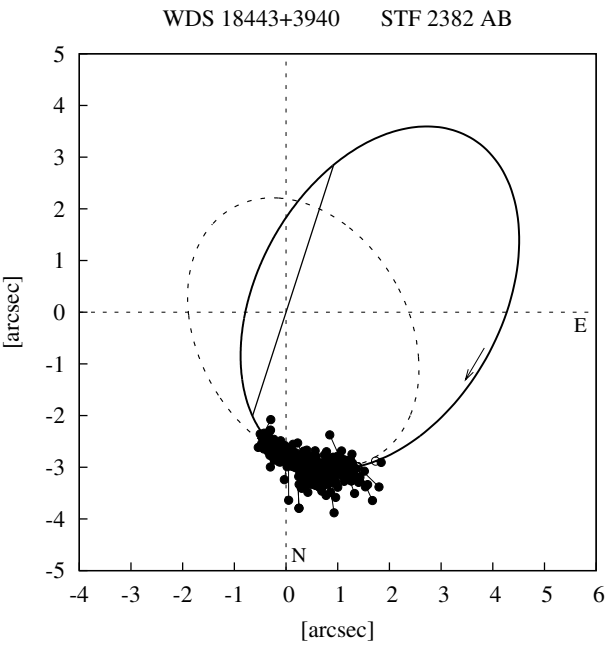

Fig. 3. *Orbit of STF 2382.*

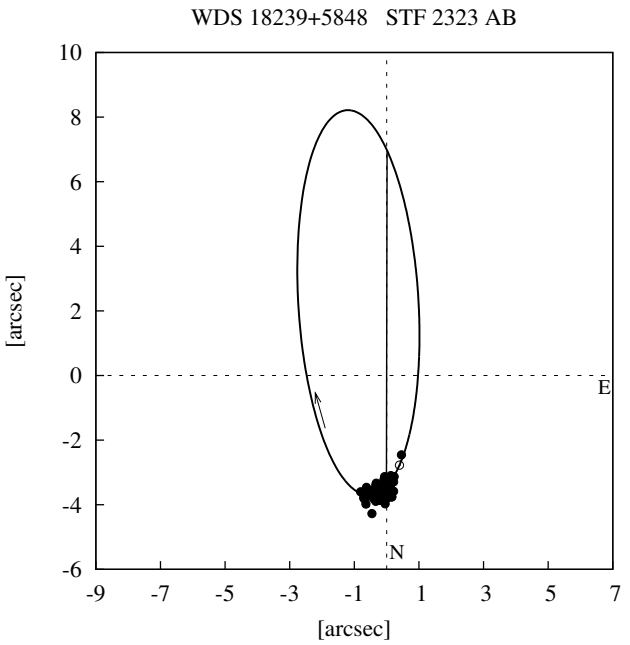

Fig. 2. *Orbit of STF 2323.*

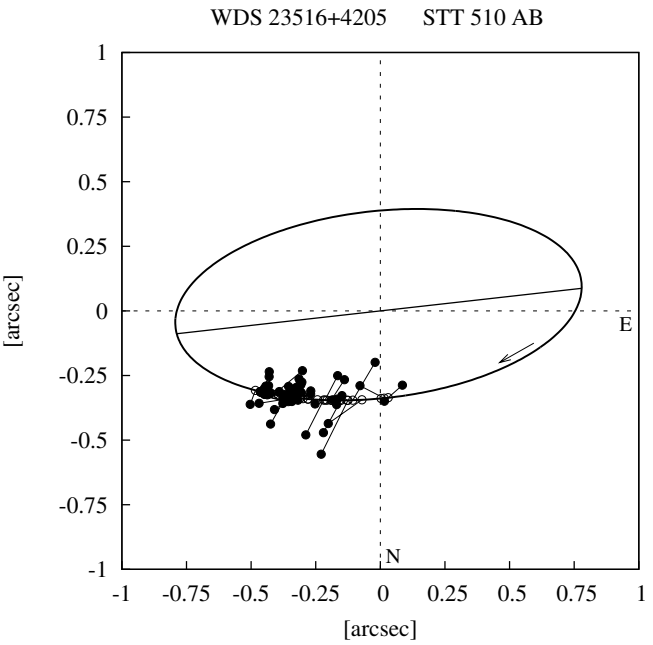

Fig. 4. *Orbit of STT 510.*

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ОРБИТЕ ЧЕТИРИ ДВОЈНЕ ЗВЕЗДЕ

B. Novaković and N. Todorović

Astronomical Observatory, Volgina 7, 11160 Belgrade 74, Serbia and Montenegro

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Оригинални научни рад

Представљени су орбитални елементи четири двојне звезде. Орбитални елементи за двојне звезде WDS 23516+4205 и WDS 18239+5848 одређени су први пут, док су код звезда WDS 02022+3643 и WDS 18443+3940 орбитални елементи поново одређивани. За све звезде дате су и њихове масе, динамичке паралаксе и ефемериде.