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VSX J075328.9+722424: A NEW SDB+M DWARF VARIABLE?

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VSX J075328.9+722424 (2MASS J07532886+7224246, FBS 0747+725) was identified as a blue object in the First Byurakan Survey of Northern blue stellar objects (Mickaelian, 2008). Based on low-dispersion spectra the object appeared to be a white dwarf of B1a spectral type.

The photometric observations of B. Stromar, K. Vardijan, and G. Srdoc implied that it is probably a new sdB+M dwarf eclipsing binary[1]. The extensive observations of G. Srdoc by a 30 cm telescope (Meade LX200 located at N $45.^\circ 38$, E $14.^\circ 40$) equipped with an SBIG ST-7XME CCD camera and the V filter clearly show a strong reflection effect amounting to about $0.^{\rm m}15$, deep primary and shallow secondary minima indicating a large difference between temperature of the components (Fig. 1). The orbital period of the system, $P \sim 5$ hours, and short duration of the minima precludes the primary component to be a main sequence star (see Połubek et al., 2007). The egress and ingress durations to the primary eclipse are longer than in the case the primary component would be a WD (this is confirmed by the fractional radius of the primary found by the light-curve analysis).

Fitting high-order symmetric trigonometric polynomials ($a_0 + \sum a_n \cos 2\pi n\varphi$, where φ is the orbital phase) to the discovery photometry led to the following preliminary ephemeris for the primary minimum:

$$\mathrm{MinI} = \mathrm{BJD\ (TDB)} 2\,455\,868.74969(7) + 0.^{\rm d}2082535(6) \times E. \qquad (1)$$

The orbital period of the system is the second longest (after AA Dor) among the previously known sdB+M dwarf eclipsing binaries. Out of 13 known sdB + M eclipsing binaries (Barlow et al., 2013) the system shows deepest primary eclipses.

Follow-up observations of the object were obtained at several observatories in the framework of the *Dwarf* campaign (see Pribulla et al., 2012): 60 cm Cassegrain telescope

[1]see http://www.aavso.org/vsx/index.php?view=detail.top&oid=270274

Table 1: Preliminary light curve solution of VSX J075328.9+722424. r_1 and r_2 are dimensionless volume mean fractional radii of the components (with respect to the major axis of the system). The mass ratio was fixed to $q = m_2/m_1 = 0.55$.

Parameter		rms
i [deg]	88.215	0.048
r_1	0.1314	0.004
r_2	0.1774	0.0002
T_1 [K]	26200	–
T_2 [K]	3500	300
l_3(V)	0.0702	0.0004
l_3(R)	0.1113	0.0004

at the Stará Lesná Observatory (Slovak Academy of Sciences), 1.2 m Oskar-Lühning telescope of the Hamburger Sternwarte, 1.2 m telescope of the Michael Adrian Observatory at Trebur, and 2 m Zeiss telescope of the Rozhen Observatory. Exposure times were 60-120 seconds with the exception of the Rozhen Observatory measurements (30 seconds).

We used the high-precision Rozhen VR photometric data to derive preliminary system parameters. The CCD frames were reduced by standard IDL procedures (adapted from DAOPHOT) using seven comparison stars. The resulting light curves clearly show total eclipses in the system. The photometric elements were determined using program *PHOEBE* (Prša & Zwitter, 2005). For this aim we fixed: (a) the primary temperature to $T_1 = 26200$ K assuming its B1 spectral type (Mickaelian, 2008) and calibration of Popper (1980); (b) the gravity darkening coefficients to $g_1 = 1.00$, and $g_2 = 0.32$; (c) the bolometric albedo of the primary to $A_1 = 1.00$. The limb-darkening coefficients were adopted from the tables of van Hamme (1993). The mass ratio can reliably be determined from photometry only in the case of the totally eclipsing contact binaries and with lower precision in the case of semi-detached eclipsing systems (Terrell & Wilson, 2005). For known sdB+M binaries the mass ratio ranges between 0.145 and 0.340 (see Table 5 of Barlow et al., 2013). Thus we fixed it to several values between 0.1 and 1.0 with a step of 0.05 and ran the optimisation process from different starting parameters. As expected, the resulting quality of the fit depends only slightly on the mass ratio and it is formally best for $q = 0.55$ (see Fig. 2). In order to reproduce the VR light curves we were forced to set $A_2 = 1.00$ for the secondary component and to enable non-zero third light. The resulting parameters are given in Table 1. The relative radius of the primary component implies that it is a hot subdwarf star that contributes above 95% to the binary brightness in the visual wavelength range. The secondary component seems to be a cold K0-5 dwarf.

As suggested by an anonymous referee, we allowed bolometric albedos larger than unity to avoid non-zero third-light solutions. Because *PHOEBE* does not support $A > 1$, Binary Maker 3.0[2] was used. The quality of the resulting solution with $A_2 = 1.3$ is, however, inferior to the solution with $A_2 = 1.0$, and $l_3 > 0$.

The best fits to the VR observations (Fig. 3) were used to determine the times of minima (the fit to the V data was used as a template for the observations without a filter). The timing information is derived from the whole light curve (see Pribulla et al., 2012), i.e. there is one "minimum" even if the data cover several minima during the night. On the other hand, not all nightly light curves enabled us to determine a minimum. The weighted linear regression of the all available times of minima (Table 2) resulted in the

[2] http://www.binarymaker.com/

Table 2: Times of minimum light of VSX J075328.9+722424. Observatory abbreviations: VI - Viskovo, G1 - G1 pavilion of the Stará Lesná Observatory, RZ - Rozhen Observatory, TR - Michael Adrian Observatory, Trebur, HS - Hamburger Sternwarte

BJD (TDB)	σ	Epoch	Filter	Obs.	Exposure [sec]
2455805.649883	0.000062	−2741	V	VI	60
2455811.688940	0.000034	−2712	V	VI	60
2455814.812994	0.000086	−2697	V	VI	60
2455866.875644	0.000034	−2447	V	VI	60
2455875.830313	0.000048	−2404	V	VI	60
2455879.787107	0.000050	−2385	V	VI	60
2455880.828491	0.000042	−2380	V	VI	60
2455881.869827	0.000029	−2375	V	VI	60
2455882.702641	0.000036	−2371	V	VI	60
2455883.744146	0.000041	−2366	V	VI	60
2455884.577043	0.000031	−2362	V	VI	60
2455885.826512	0.000036	−2356	V	VI	60
2455886.659502	0.000038	−2352	V	VI	60
2456354.602198	0.000027	−105	-	G1	60
2456356.476378	0.000013	−96	V	RZ	30
2456357.517650	0.000013	−91	R	RZ	30
2456365.639405	0.000029	−52	-	TR	60
2456384.382176	0.000080	38	V	HS	90
2456397.293716	0.000044	100	-	G1	60
2456398.334954	0.000036	105	-	G1	60
2456429.364556	0.000043	254	-	G1	60

ephemeris:

$$\mathrm{MinI} = \mathrm{BJD\ (TDB)}2\,456\,376.46857(2) + 0\overset{\mathrm{d}}{.}208252121(16) \times E. \qquad (2)$$

It is well known that sdB stars often show non-radial pulsations (see e.g. 2M1938+4603, Østensen et al., 2010; NY Vir, Kilkenny et al., 1998). Hence, we performed a period analysis of the residuals from the best fits to the Rozhen photometry. The standard deviation of the light curve residuals from the best fits are $0\overset{\mathrm{m}}{.}008$ for the V passband and $0\overset{\mathrm{m}}{.}01$ for the R passband, which sets an upper limit for the pulsation amplitude. Unlike the case of NY Vir (Kilkenny et al., 1998), where the pulsations with semiamplitudes $0\overset{\mathrm{m}}{.}005$ (141 seconds) and $0\overset{\mathrm{m}}{.}01$ (184 seconds) are clearly visible, visual inspection of VSX J075328.9+722424 light curve does not reveal any periodic variability. The Fourier power spectra for the V and R passbands residuals are shown in Fig. 4. The power spectra differ for the V and R passband residuals and do not show any significant frequencies. The detection of the pulsations obviously requires observations of higher cadence and precision.

VSX J075328.9+722424 definitely deserves medium or high-resolution spectroscopy to find the spectroscopic orbit of the primary and to reliably estimate the absolute parameters of the components. The spectroscopy would also solve the issue of third light which might come from (i) an additional source (quite likely in the case of close binary stars, see Pribulla & Rucinski, 2006) or (ii) result from inadequate modelling of the reflection effect. For this $V = 16\overset{\mathrm{m}}{.}5$ short-period eclipsing binary an 8 m-class telescope is required.

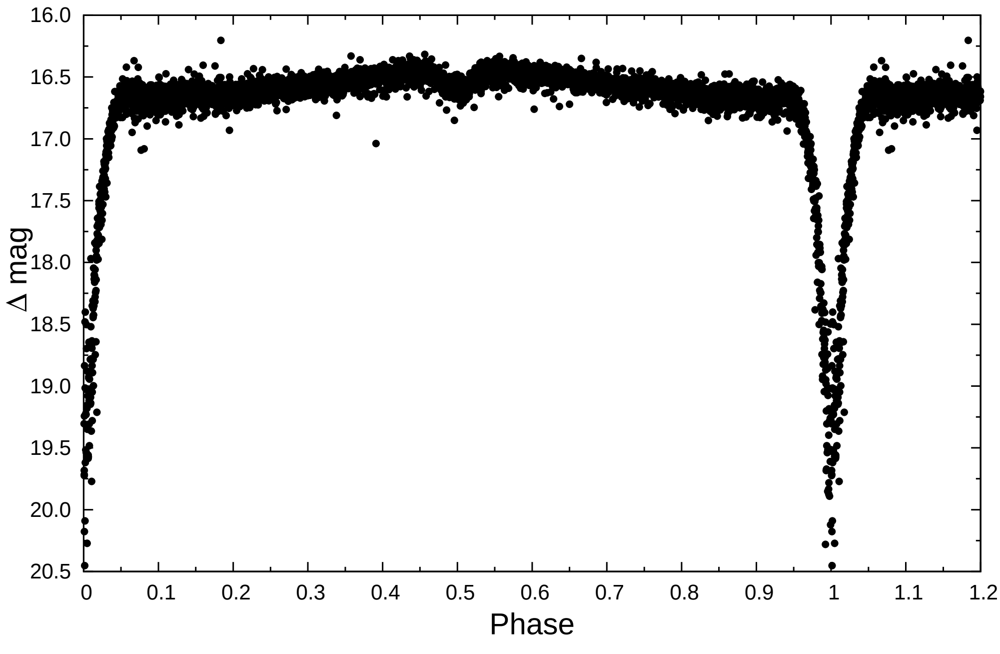

Figure 1. V light curve of VSX J075328.9+722424 obtained with 30 cm Schmidt-Cassegrain telescope at Viskovo, Croatia. The data were phased with ephemeris (1).

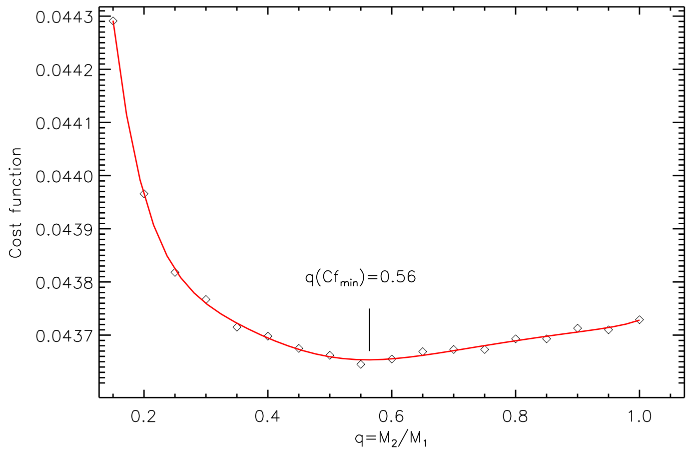

Figure 2. Goodness of the fit as the function of mass ratio

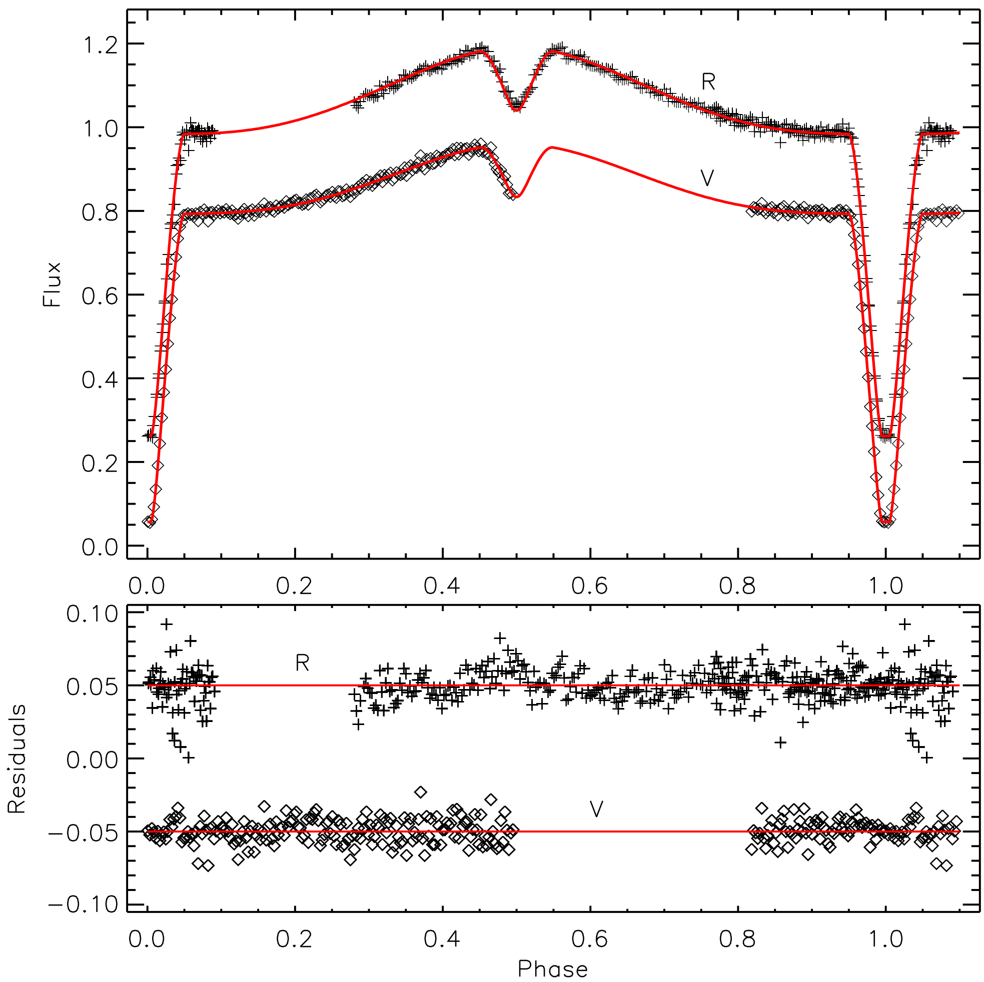

Figure 3. Rozhen VR photometric data and their fits corresponding to the parameters from Table 1.

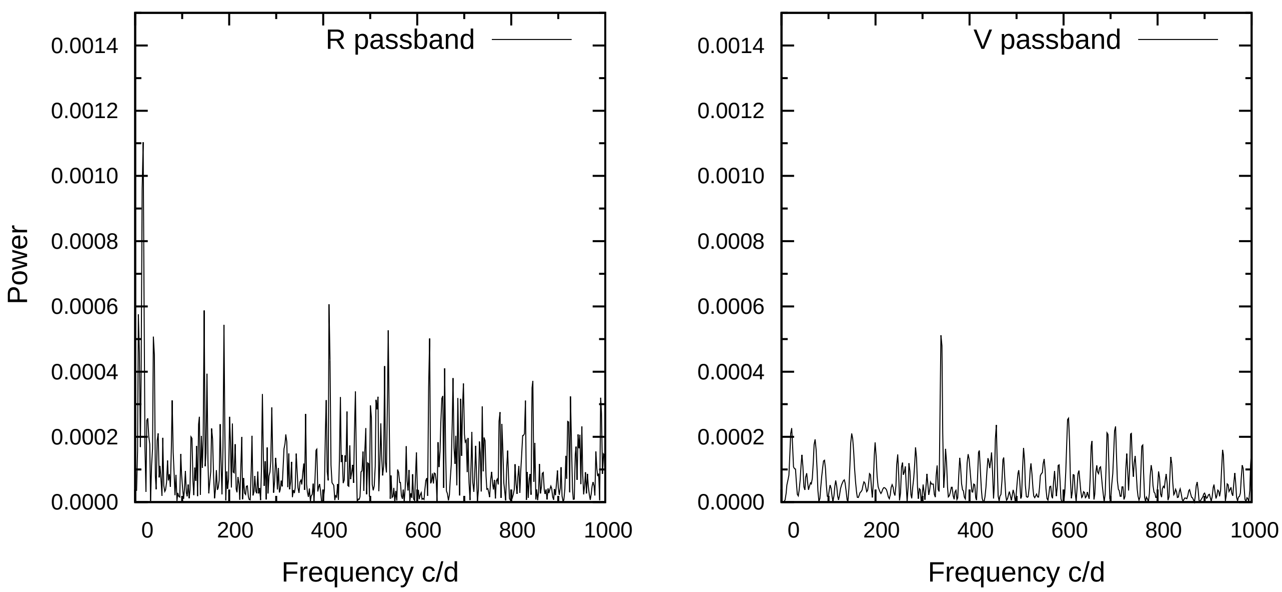

Figure 4. Power spectrum of the light-curve residual with respect to the best fit (Table 2) for the V and R passband data

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