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CzeV753 – A NEW ECLIPSING BINARY OF EW TYPE NEAR V1949 Cyg

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Abstract: Analysis of a new variable star CzeV753 in Cygnus is presented. It was discovered during observation of an RR Lyrae star V1949 Cyg in 2015. Based on the shape of the light curve and its characteristics (period of 0.387162 d, amplitude of 0.313 mag), the new variable star is an eclipsing binary of W Ursae Majoris type. According to the *B*-*V* = 0.344 mag from literature the CzeV753 is probably an F-type star.

1 Introduction

The pulsating star V1949 Cyg was one of the targets in the observation campaign of the Czech RR Lyrae Observational Project (Skarka et al., 2013, Groebel, 2015, priv. com.). In the measured field of view (FOV) we found a new short-period variable star. We registered it in the CzeV catalogue[1] (Brát, 2006) under the name CzeV753 (= UCAC4 704-063817 = USNO-B1.0 1406-0317839 = 2MASS J19283744 +50399530 at RA $19^h28^m37.44^s$, DEC $+50^\circ39'52.9''$, J2000) and in the International Variable Star Index[2] (Watson et al., 2006) under AUID 000-BLV-449. According to the UCAC4 catalogue (Zacharias et al., 2012, 2013) the star has brightness in *B* = 14.988(7) mag and *V* = 14.644(1) mag, which corresponds to *B*-*V* = 0.344(7) mag and implies the F spectral type.

2 Photometric Observation

The private observatory South-Moravian-Observatory[3] (SMO, N 49.28171°, E 16.45352°, altitude 243 m), where observations were performed, is running under full remote control and is located near Brno, Czech Republic. The main instrument is a 0.3 m (12") *f*/4.7 Newtonian telescope equipped with CCD camera G2-1600 made by Moravian Instruments Inc.[4] containing a Kodak chip KAF1602 (1536×1024 px, pixel size 9 μm) with Johnson-Cousins *BVRcIc* filters. The FOV is 33.7′×22.5′ and the angular resolution of the images is 2.63″/px used for 2x2 binning.

The field with V1949 Cyg and CzeV753 was measured with exposures of 60 s in *Ic*, 90 s in *V*, and 45 resp. 120 s in *C*– clear. The data with a time span of 94 days covers 71.5 hours of observation time (Tab. 1). They are available on-line as a supporting material.

[1] http://var2.astro.cz/czev.php
[2] https://www.aavso.org/vsx/
[3] http://south-moravian-observatory.jimdo.com/
[4] http://www.gxccd.com/

Table 1: Observation log of CzeV753 in 2015.

Date	HJD	Observation time [h]	*V*	*Ic*	*C*
21 Jul 2015	2457225	4.8	55	-	65
26 Jul 2015	2457230	3.9	63	65	74
06 Aug 2015	2457241	7.0	109	110	110
08 Aug 2015	2457243	7.2	121	121	121
10 Aug 2015	2457245	7.0	124	122	122
26 Aug 2015	2457261	7.7	108	108	108
01 Sep 2015	2457267	3.0	51	51	51
12 Sep 2015	2457278	7.8	81	81	81
20 Sep 2015	2457286	8.0	101	101	101
01 Oct 2015	2457297	7.0	120	120	120
23 Oct 2015	2457319	8.0	112	112	112
	Σ	71.4	1045	991	1065

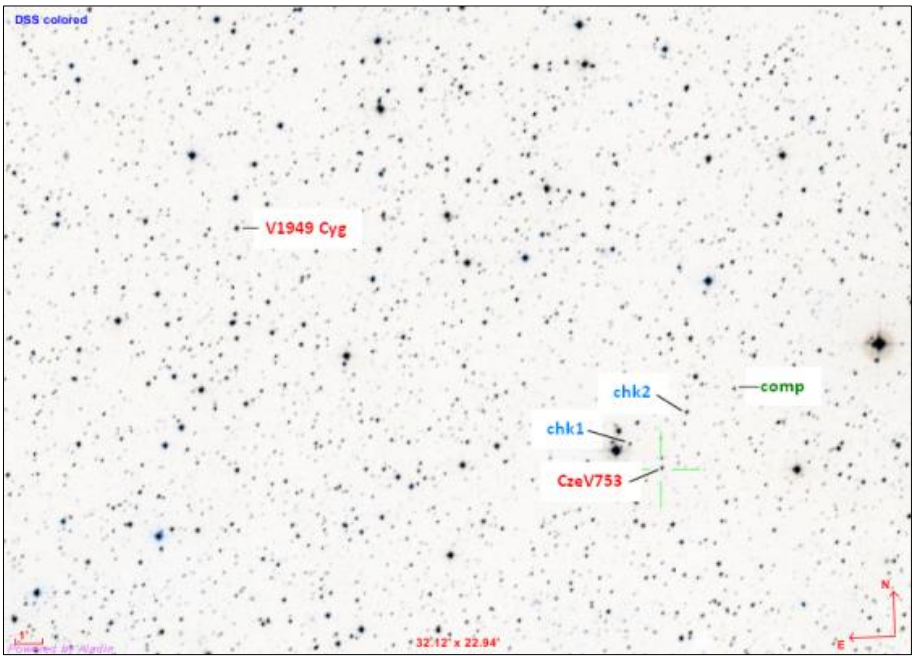

Figure 1: FOV (32.12'×22.94') for V1949 Cyg with CzeV753, comparison and check stars.

All images were dark-frame and flat-field corrected using SIPS (Scientific Image Processing Software)[5] Vers. 2.4.3 from Moravian Instruments Inc. The processing of the differential photometric data was carried out in C-MUNIPACK[6] Vers. 2.0.21 (Motl, 2009). The star UCAC4 704-063802 was used as comparison star, UCAC4 704-063830 and UCAC4 704-063782 were used as check stars (see Fig. 1 and Tab. 2).

[5] http://www.gxccd.com
[6] http://sourceforge.net/projects/c-munipack/

After that, the instrumental data were transformed into standard Johnson-Cousins *BVRcIc* photometric system using PERL-script "con2stand.pl"[7] (Brát, 2009). The transformation coefficients were derived from measurements of standard stars (Landolt, 2013), see "A Suitable Selection of Landolt Standard Stars" (FOV 1.1, 2.1, 3.1)[8].

Table 2: Cross identification of CzeV753 and basic parameters of comparison and check stars, given in UCAC4 catalogue, RA and DEC in J2000.

Star	ID	RA [^{h} ^{m} ^{s}]	DEC [° ' "]	*B* [mag]	*V* [mag]
CzeV753	UCAC4 704-063817	19 28 37.437	+50 39 52.91	14.988(7)	14.644(1)
COMP	UCAC4 704-063802	19 28 31.952	+50 41 49.58	14.972(4)	14.529(1)
CHK-1	UCAC4 704-063830	19 28 44.898	+50 40 43.83	-	-
CHK-2	UCAC4 704-063782	19 28 21.174	+50 42 41.02	-	-

3 Data Analysis

During our observations we sometimes recorded two brightness dips with a barely apparent difference in amplitudes and a period of approximately 0.188 d (Fig. 2) in individual nights. The amplitude of about 0.3 mag and almost symmetrical shape of the light curve (start and end of brightness depression cannot be determined) lead to the hypothesis, that the star is most probably an eclipsing binary of W Ursae Majoris (EW) type. We used trigonometric polynomial of degree 2. The period of CzeV753 should be approximately at the double value 2*0.188 ≈ 0.376 d which is confirmed by periodic analysis.

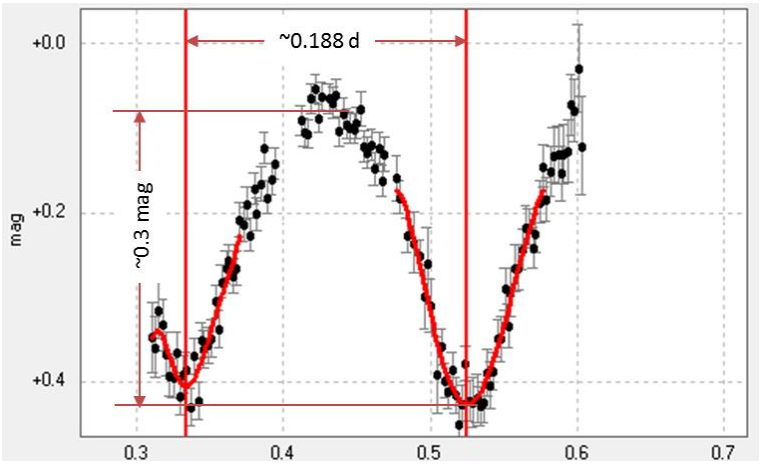

Figure 2: Example of an observation night at HJD 2457245+ (August 10th, 2015) showing both primary and secondary minima.

[7] http://var2.astro.cz/download
[8] http://south-moravian-observatory.jimdo.com/calibration-photometric-system/a-suitable-selection-of-landolt-stars/

To determine the period more accurate, we used PerSea Version 2.6 (2007). The algorithm is based on Fast and Statistically Optimal Period Search in Uneven Samples by A. Schwarzenberg-Czerny (1996). The data set in filter *C* is the most numerous and has the highest quality (the lowest noise), therefore it was used for the period analysis. The periodogram in Fig. 3 contains the highest peak at P = 0.387162(49) d.

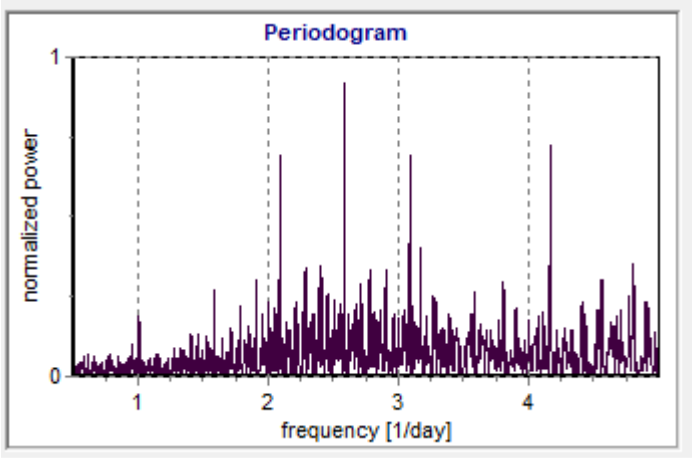

Figure 3: Periodogram with the most probably period.

The times of minima (T_{min}) were determined with the on-line fitting tool for filter *I*c, *V* and *C*, (Brát, Mikulášek, & Pejcha, 2012). The tool calculates the uncertainties using bootstrap method (Bradley, 1979). The values are shown in Tab. 3. The zero epoch E_0 for T_{min} was selected with E_0 = 2457245.3328(+11/-16) marked with * (see column "Type" in table 3).

Table 3: Determined T_{min} (HJD – 2400000) for filter *C, I, V*.

Type	*C -band*		*I - band*		*V - band*	
P	57319.2762	+0,0070/-0,0044	57319.2777	+0.0058/-0.0069	57319.2784	+0.0048/-0.0092
S	57297.4026	+0,0025/-0,002	57297.4053	+0.0038/-0.0056	57297.4028	+0.0030/-0.0026
P	57286.3694	+0,0013/-0,0012	57286.3682	+0.0022/-0.0022	57286.3681	+0.0025/-0.0024
S	57278.4331	+0,0008/-0,0009	57278.4340	+0.0038/-0.0034	57278.4325	+0.0031/-0.0038
S	57261.3997	+0,0026/-0,0014			57261.3983	+0.0051/-0.0032
P	57261.5921	+0,0015/-0,0012	57261.5934	+0.0039/-0.0053	57261.5908	+0.0026/-0.0022
S	57256.3674	+0,0029/-0,0017				
P*	57245.3328	+0,0011/-0,0016	57245.5272	+0.0031/-0.0032		
S	57245.5264	+0,0011/-0,0012				
P	57243.3967	+0,0012/-0,0012	57243.3964	+0.0031/-0.0036	57243.3970	+0.0022/-0.0020
P	57241.4621	+0,0014/-0,0017	57241.4620	+0.0044/-0.0029	57241.4621	+0.0014/-0.0017
S	57230.4227	+0,0017/-0,0033			57230.4224	+0.0055/-0.0196
S	57225.3942	+0,0022/-0,0023			57225.3958	+0.0029/-0.0044

* zero epoch

For the verification of the period, we created an $O - C$ diagram for filter C, see Fig. 4. Except for one outlier, a linearly decreasing trend is apparent. This indicated us that the received period by PerSea obviously needs to be refined. We subtracted the linear trend1[9] to improve the period and the zero epoch to a final ephemeris

$$T_{\min} = 2457245.3328(+11/-16) + 0.387138(7)\ \mathrm{d} \cdot E, \qquad (1)$$

where $T_{\min}$ is expressed in heliocentric Julian date (HJD). The final $O - C$ diagram with the refined period $P = 0.387138(7)$ d is present in Fig. 5. For an easy comparison we include previous values of period and zero epoch (determined using PerSea and on-line fitting tool) and more reliable values from *O-C* analysis in Tab. 4.

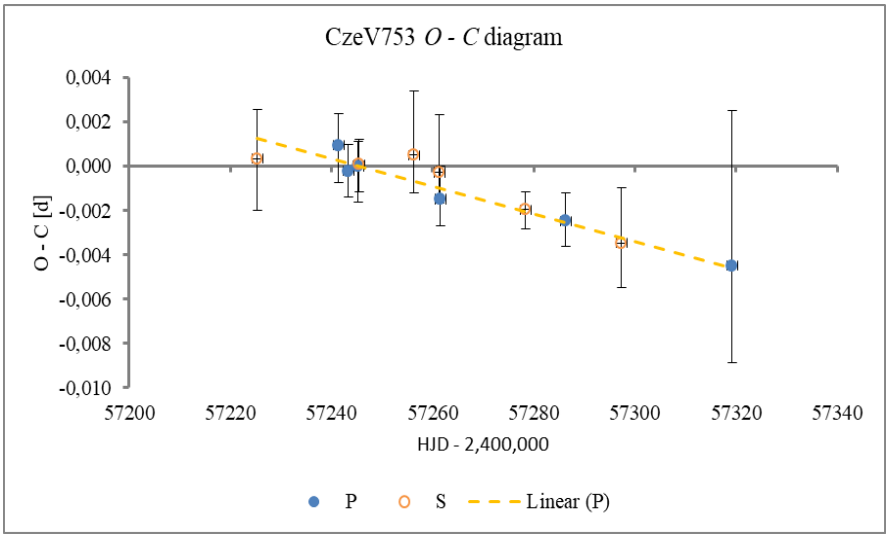

Figure 4: *O - C* diagram for star CzeV753 constructed using *C*-band minima times and the period estimated by PerSea.

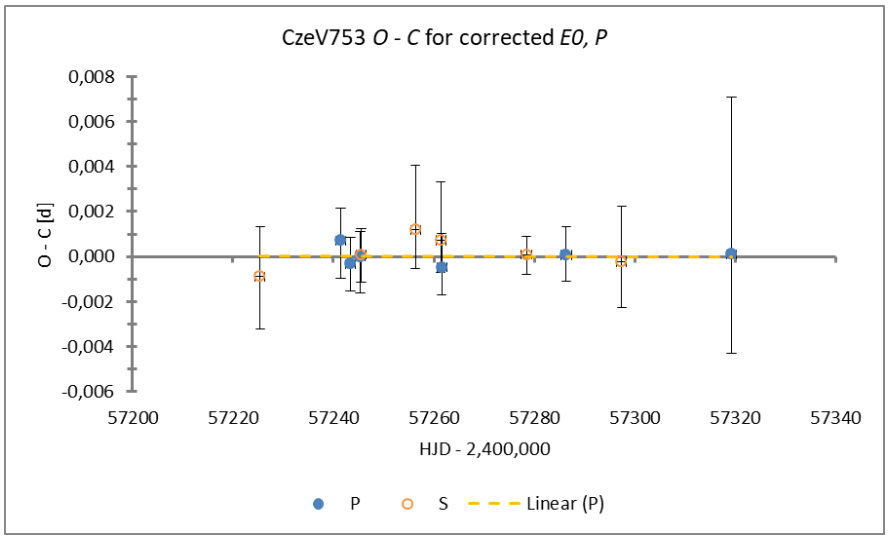

Figure 5: O - C diagram for star CzeV753 constructed with C-band minima times and final ephemeris (Eq. 1).

[9] Fit was performed without errors taken into account.

Table 4: Comparison of the results from PerSea and from *O* – *C* analysis.

	E_0 [HJD]	P [d]
PerSea (Fig. 4)	2457245.3328(+11/-16)	0.387162(49)
O-C diagram (Fig. 5)	2457245.3328(10)	0.387138(7)
difference	0	-0.000024

The brightness for the comparison star UCAC4 704-063802 is given for *BVr*-bands in UCAC4 catalogue. Because we measured the stars only in *V*, *I*c and *C* filters and UCAC4 does not provide the *I* magnitude, we investigated the brightness and the amplitude of CzeV753 only in *V*-band with standard Johnson-Cousins photometric system. To determine the mean, the maximum and the minimum brightness in *V*-band we used the software CurveExpert Professional Vers. 2.3.0 (Hyams, 2010)[11] employing a polynomial fit of the phased light curve. The program automatically shows the best found synthetic curve and calculates the uncertainties from the scatter of the residuals.

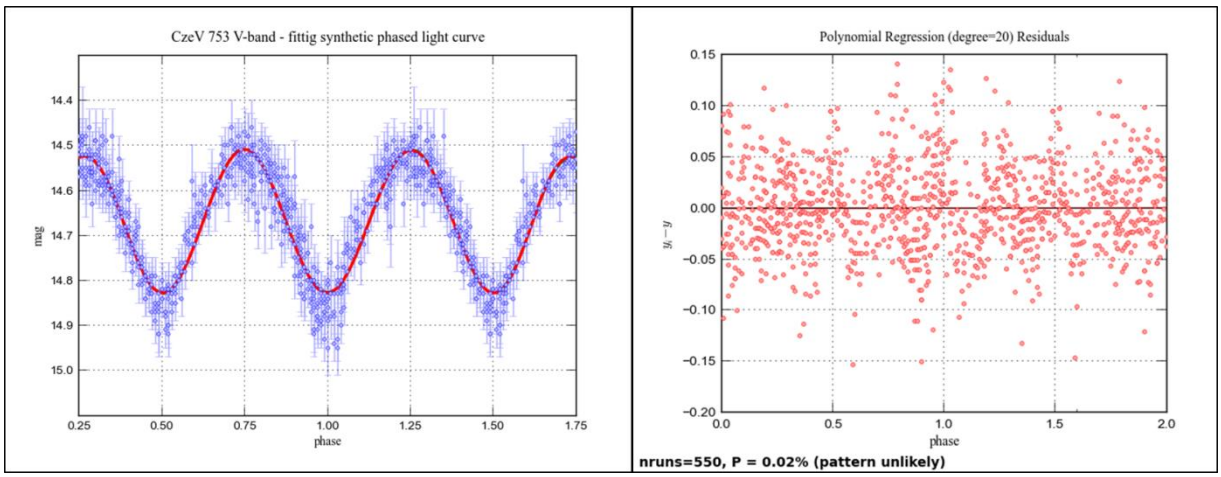

Figure 6: Observed and synthetic light curve of CzeV753 in *V*-band phased with the orbital period (left) and residuum (right).

The brightness of CzeV753 was found to be 14.721(41) mag (mean value), 14.575(41) mag (in maximum), 14.888(41) mag in the primary and 14.887(41) in the secondary minimum. With a tiny difference of 0,001 mag, the primary and secondary minimum is almost equal. The amplitude of the brightness depression is 0.313(58) mag.

4 Results and Conclusions

We present preliminary analysis of the new variable star CzeV753 identified in our photometric measurements from 2015. The shape of the light curve, the amplitude of 0.313 mag, the period of 0.387138 d and (acc. to the literature) the colour index of B-V = 0.344 mag (spectral F- type) implies that CzeV753 is, based on GCVS phenomenological classification (Samus et al., 2011), an EW type eclipsing binary. All determined photometric parameters are summarized in Tab. 5.

Table 5: Main characteristics of CzeV753 with magnitudes in *V*-band.

Name	Type	Period [d]	Zero epoch	Max [mag]	Min I [mag]	Min II [mag]
CzeV753	EW	0.387138 ±0.000007	2457245.3328 (+11/-16)	14.575 ±0.041	14.888 ±0.041	14.887 ±0.041

We determined the mean brightness in V as 14.721(41) mag which is in agreement with the value 14.644(1) from UCAC4 catalogue.

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