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A NEW ALGOL-TYPE ECLIPSING BINARY NEAR V 335 Cam

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Abstract: The new variable star CzeV336 Cam = GSC 4328-2164 = HD 26525 has been discovered near V 335 Cam by means of CCD photometry. Based on shape of the light curve it is an Algol-type eclipsing binary. Six timings of primary and secondary minima were obtained. The phase light curves in BV(RI)c bands for this star are presented and the ephemerides, color indexes and magnitudes in the standard system were computed. We have also registered this star in VSX (Variable Star Index, AAVSO).

1. Introduction

The new variable star CzeV336 Cam = GSC 4328-2164 = HD 26525 = USNO-B1.0 1578-0095608 has been found in the field of V 335 Cam eclipsing binary during CCD photometric session 5th December 2011 at Observatory and Planetarium of Johann Palisa (Ostrava, Czech republic). The new relatively bright variable star is located at R.A. = 04h 16m 35.98s , DEC = +67° 50' 19.3" , based on USNO-B1.0 catalog. We have discovered the variability of GSC 4328-2164 using the software package *C-Munipack* (Motl, 2007) by analyzing the dependence of the standard deviation of the brightness estimated for a given star on its mean brightness – the function "Find variables". We have preliminary registered our new variable star in the Czech Variable star catalog (CzeV336 Cam) and in VSX catalog operated by AAVSO.

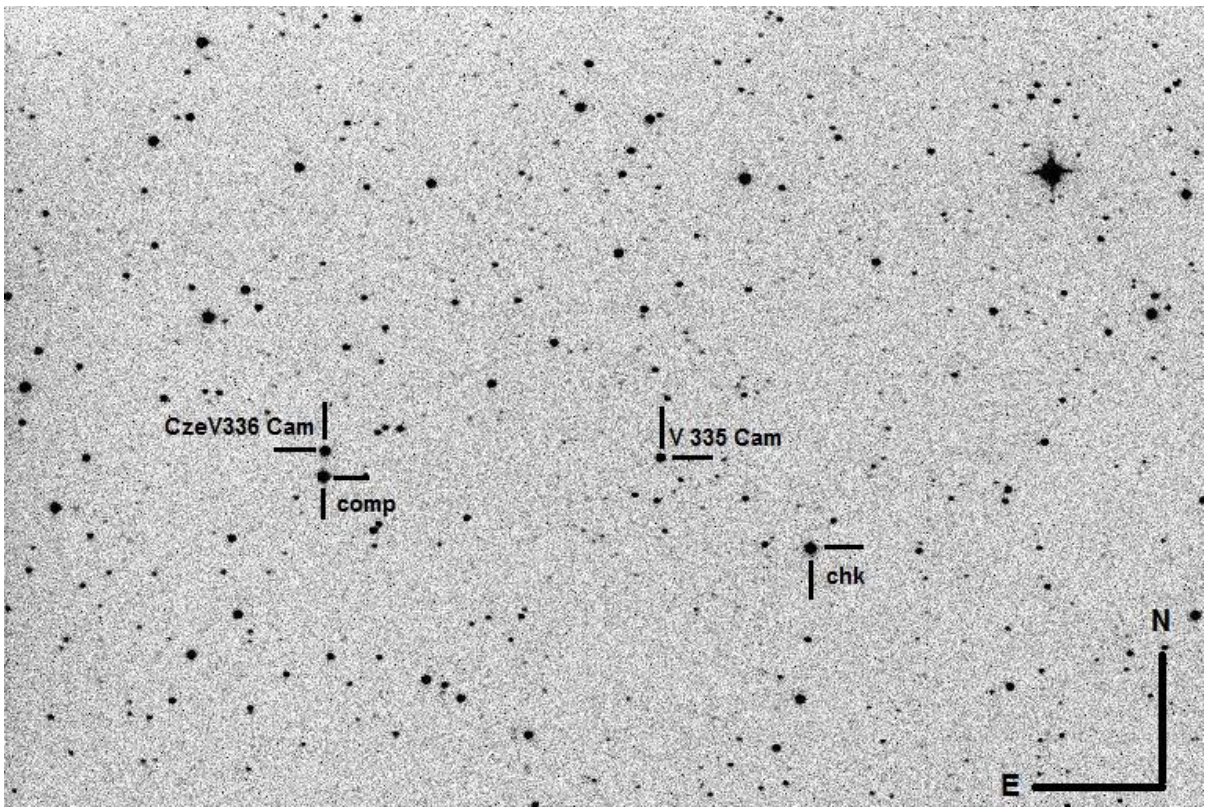

Figure 1. Chart of the vicinity of V 335 Cam, new variable CzeV336 Cam = GSC 4328-2164 and both comparison stars *comp* and *chk* are marked. The field of view is 39.4'x26.3'.

In this paper, we present the basic elements of new variable star (initial epoch and period), 6 timing of minima, the phase light curves in BV(RI)c bands and (B-V) color indexes, corrected of galactic interstellar reddening.

2. Instrumentation, photometric sessions and methodology

All observation have been obtained using a 200 mm f/6 Newton telescope of Observatory and Planetarium of Johann Palisa and SBIG-ST8XME CCD camera with a camera sensor area of 1530x1020 square pixels (pixel linear dimension is 9 μm). This configuration results in a field of view (FOV) of 39.4'x26.3' (1.545 arcsec/px). The CCD was configured in a 2x2 binning mode resulting in angular resolution of 3.09 arcsec/px. Photometric B, V, Rc and Ic band filters were used.

We observed CzeV336 Cam during 13 nights from 5th December 2011 to 30th July 2012. We have obtained a total of 5981 CCD frames of the new variable CzeV336 Cam, after deletions of bad measurements its 4617 data points. All of these data have been used for following analysis. The summary of observing nights, number of frames and photometric filters used are listed in Table 1. All frames have been reduced using software package C-Munipack. All frames have been calibrated by dark frame and flat-field corrections. Differential aperture photometry has been also performed in C-Munipack. Comparison stars *comp* GSC 4328-1782 and *chk* GSC 4328-2207 (see Table 2) have been chosen for the similar magnitudes and (B-V) color indexes like CzeV336 Cam. During our observations, the standard deviation of *comp-chk* differential magnitudes are ranging from 0.004 to 0.02 in the B band, 0.004 – 0.03 in the V band, 0.003 – 0.02 in the Rc band and 0.005 – 0.02 in the Ic band.

Dates of the observations (yyyy-mm-dd)	Time (UT)	N of images	t_{exp} (s)	Filters used
2011-12-05	17:58-20:14	149	40/30/30	V/Rc/Ic
2011-12-07	22:10-01:42	144	30	Rc
2011-12-10	19:58-05:21	708	30/30	V/Rc
2011-12-18	19:35-05:13	748	30/30	V/Rc
2011-12-22	20:21-04:13	526	50/40/30/30	B/V/Rc/Ic
2012-01-29	17:50-03:47	596	50/40/30/30	B/V/Rc/Ic
2012-01-30	16:47-02:56	601	60/50/40/40	B/V/Rc/Ic
2012-02-02	17:53-23:49	291	60/50/40/40	B/V/Rc/Ic
2012-03-16	20:26-23:15	184	60/50/40/40	B/V/Rc/Ic
2012-03-18	18:00-18:49	50	80/60/50/50	B/V/Rc/Ic
2012-03-19	17:58-22:54	259	80/60/50/50	B/V/Rc/Ic
2012-07-22	22:15-00:23	186	50/40/30/20	B/V/Rc/Ic
2012-07-30	22:13-01:54	175	80/60/50/50	B/V/Rc/Ic

Table 1. Summary of the observations: Date, time interval of photometric sessions, number of images applied for analysis and exposure time of each filter.

Several data sets have been transformed to standard Johnson-Cousins BV(RI)c photometric system from instrumental differential magnitudes to derive magnitude of variable star in maximum and both minima. We have used B and V magnitudes of *comp* star from APASS: AAVSO Photometric All-Sky Survey (Henden A.A. et al., 2009) to transform differential magnitudes to absolute magnitudes. The Rc and Ic magnitudes of *comp* star have been calculated by following relations (Warner, 2007):

$$Rc = J + 0.1045 + 2.5105 \cdot (J-K) - 1.7849 \cdot (J-K)^2 + 1.123 \cdot (J-K)^3$$
$$Ic = J + 0.0724 + 1.2816 \cdot (J-K) - 0.4866 \cdot (J-K)^2 + 0.2963 \cdot (J-K)^3$$

where J and K are magnitudes and (J-K) is a color index of *comp* star from 2MASS catalog. Values of (J-K) in previous equations were limited to a range of -0.1 to 1.0 (Warner, 2007) but (J-K) color index of *comp* star is 0.066 mag. Final magnitudes of comparison stars in Johnson-Cousins photometric system are listed in Table 2. The Rc and Ic magnitudes have been calculated only for *comp* star because *chk* star has not been used for transformation CzeV336 Cam to absolute magnitude.

Comparison	Catalogue ID	RA (hh:mm:ss.s	DE (±dd:mm:ss.s)	B	V	Rc	Ic
comp	GSC 4328-1782 USNO-B1.0 1578-0095620 UCAC4 790-011656	04:16:36.3	+67:49:29.9	10.101	9.857	9.679 ± 0.040	9.571 ± 0.030
chk	GSC 4328-2207 USNO-B1.0 1577-0094778 UCAC4 789-011437	04:13:50.7	+67:47:20.8	10.221	9.868	-	-

Table 2. Comparison stars used for differential photometry: Catalogue name, position and brightness in the B, V, Rc and Ic bands.

3. Data analysis and result

The times of minima in all of photometric filters have been determined using the polynomial fit algorithm in the *Peranso 2.5* (Vanmunster, 2007) software. The polynomials of third to fifth degree were used. The final times of minima (listed in Table 3) have been computed as weighted averages of each filter values. The error values are given as weighted standard deviations. 3 primary minima (I) and 3 secondary minima (II) were observed during December 2011 – July 2012 (see Table 3). First primary minimum is marked as Initial Epoch.

EPOCH	HJD	Error	Type
0	2455906.5610	0.0001	I
4.5	2455914.5950	0.0010	II
28	2455956.5372	0.0006	I
28.5	2455957.4302	0.0018	II
126	2456131.4544	0.0004	I
130.5	2456139.4862	0.0019	II

Table 3. Timing and type of minima of CzeV336 Cam.

To determine the approximate values of the period, the software *PerSea 2.6* (Maciejewski, 2007) and *Peranso 2.5* were used. The period has been determined from periodogram analysis using the ANOVA algorithm (Schwarzenberg-Czerny, 1996) implemented in *Peranso 2.5*. The periodogram is shown on the Figure 2. Dominant periods in the ANOVA-periodogram range around the half of the real period; the visual inspection of the phase curves revealed that the dominant periods are false.

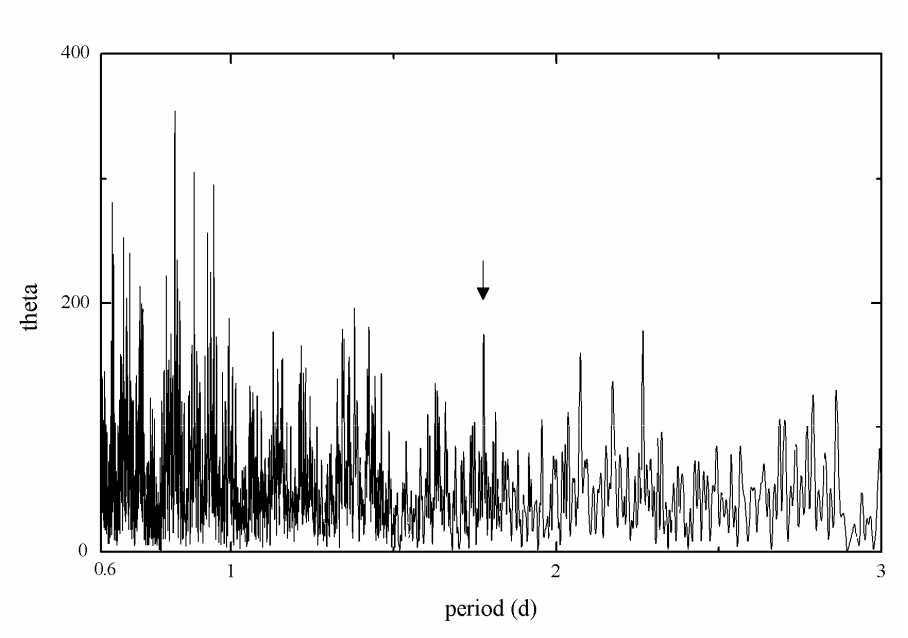

Figure 2. Periodogram of CzeV336 Cam, given by ANOVA period analysis.

We have used the ephemerides from *PerSea 2.6* analysis to create of O-C diagram for all primary and secondary minima. This O-C diagram has been used to refine the period by weighted linear regression using *Stagraphics Plus 3.0* software. The following ephemerides have been determined:

$$HJD_{MinI} = 2455906.5610 + 1.784868\times E$$
$$\pm 0.0001 \pm 0.000003$$

The O-C diagram for all primary and secondary minima, constructed with final ephemerides, is plotted in Fig. 3 with corresponding error bars.

We have used the polynomial fit algorithm implemented in *MCV v1.65* (Andronov & Baklanov, 2004) to estimate the magnitudes of both Cze336 Cam minima. The polynomials of fourth and fifth degree were used. We have computed the weighed mean of out of eclipse data to estimate the mean magnitudes of CzeV336 Cam maxima. The error values are given as standard deviations combined with error of calculate Rc and Ic magnitudes of *comp* star. Maximum and minima magnitudes of CzeV336 Cam in standard Johnson-Cousins BV(RI)c photometric system are listed in Table 4.

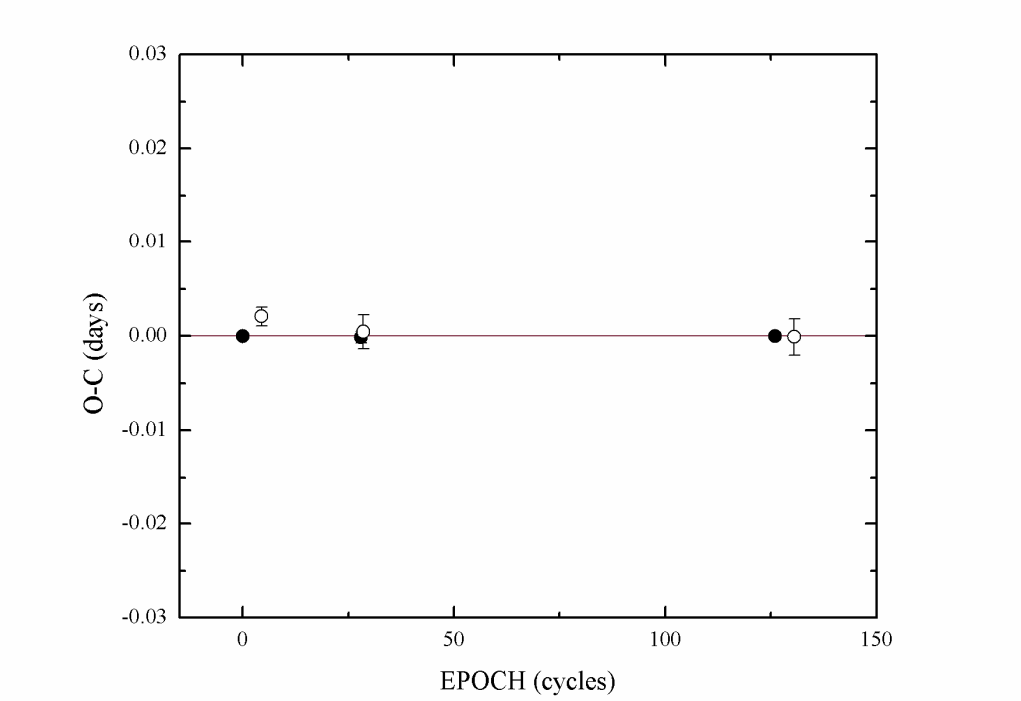

Figure 3. The O-C diagram for all observed primary and secondary minima.

	Max	Min I	Min II
B	10.780±0.008	11.012±0.009	10.839±0.009
V	10.426±0.008	10.649±0.009	10.499±0.007
Rc	10.181±0.041	10.395±0.040	10.262±0.040
Ic	10.001±0.031	10.212±0.031	10.098±0.031

Table 4. Maximum and both minima magnitudes of CzeV336 Cam.

The color indexes out of eclipse and in both minima are: $(B\text{-}V)_{Max}$= 0.354 ± 0.011, $(B\text{-}V)_{I}$ = 0.363 ± 0.018, $(B\text{-}V)_{II}$ = 0.340 ± 0.012. We have used the method described in (Arenou et al., 1992) to correct these values for the effect of interstellar reddening. This method describes extinction as a function of galactic coordinates and distance. Galactic coordinates of CzeV336 Cam are b = +12.260°, l = 140.462°. That is close to dusty Galactic plane and that is the reason why coefficient A_V is relatively large. We have adopted distance from (Pickles et al., 2010) as 590 pc and calculated interstellar extinction as A_V = 1.35 ± 0.51. Final values of corrected color indexes $(B\text{-}V)_0$, are given by following quadratic equation (Arenou et al., 1992):

$$0.24\cdot(B-V)_0^{\,2}+(3.30-0.20\cdot(B-V))\cdot(B-V)_0-3.30\cdot(B-V)-0.04\cdot(B-V)^2+A_V=0$$

And they are: $(B\text{-}V)_{Max\ 0}$ = -0.06 ± 0.17, $(B\text{-}V)_{I\ 0}$ = -0.05 ± 0.19 and $(B\text{-}V)_{II\ 0}$ = -0.07 ± 0.18. There are phase curves for BV(RI)c band, presented in standard absolute magnitudes, in the Fig. 4. Because there are no full eclipses, we have not derived stellar temperatures of both companions directly from $(B\text{-}V)_{I\ 0}$ and $(B\text{-}V)_{II\ 0}$ color indexes. Additionaly, small differences between corrected color indexes and big uncertainties did not allow us to derive temperatures of both stars not even roughly.

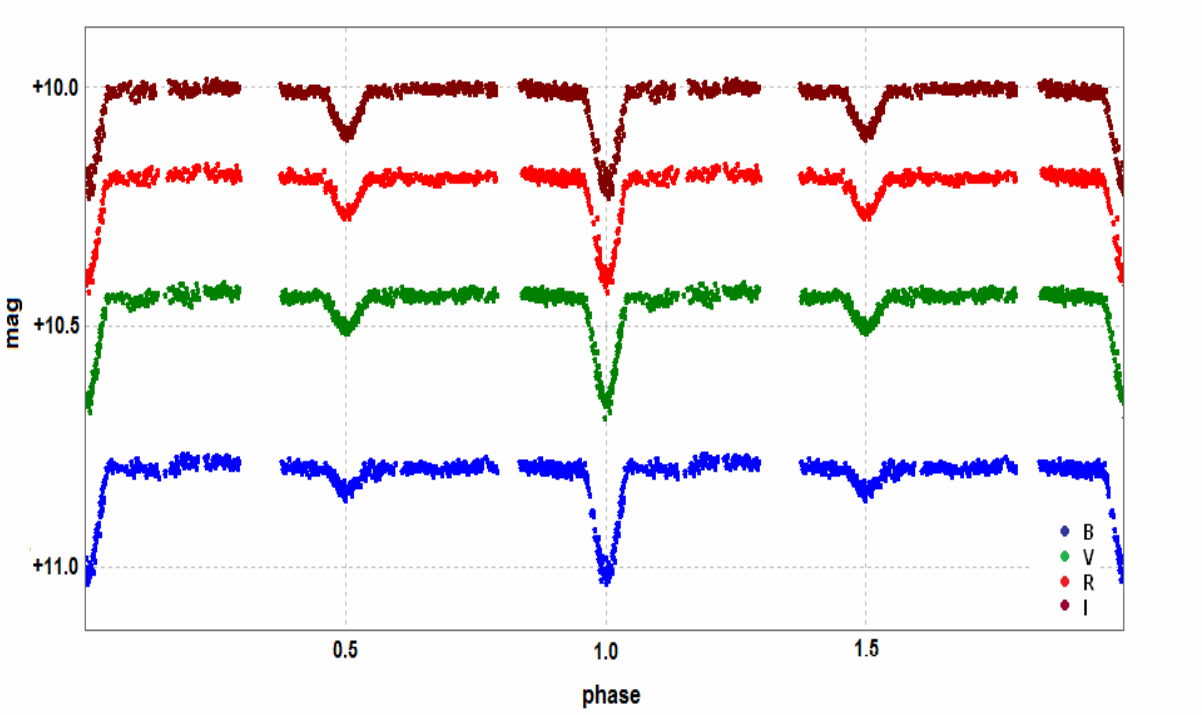

Figure 4. Phase curves for CzeV336 Cam in BV(RI)c band filters.

Based on the phased curve, we have derived eclipse duration (D/P parameter) as 0.083. The shape of light curve (see Fig. 4) and the period $1^d.784868$ implies that CzeV336 Cam is an Algol-type eclipsing binary based on GCVS phenomenological classification (Samus et al., 2011). The $(B\text{-}V)_0$ color indexes and low light variations out of eclipses indicate that is a detached system with two unevolved main-sequence stars (Sterken and Jaschek, 1996). All photometric parameters are summarized in Table 5.

Name	Type	Period (d)	Initial Epoch (HJD)	Max V mag	Min I V mag	Min II V mag
CzeV336 Cam	EA	1.784868 ± 0.000003	2455906.5610 ± 0.0001	10.426 ± 0.008	10.649 ± 0.009	10.499 ± 0.007

Table 5. Main characteristics of discovered star required for the GCVS. The magnitudes are in V-band.

4. Acknowledgments

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