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THE FIRST LIGHT CURVE ANALYSIS OF TWO OVERCONTACT BINARIES: EY Cas AND NO Vul

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Precise photometric observations of the two neglected and faint eclipsing binaries were carried out. All CCD measurements were obtained by the 65-cm telescope at the Ondřejov observatory, using Apogee AP-7 and Moravian Instruments† G-2 3200 ME CCD camera, only R filter was used. The observations were carried out from 2003 to 2007. New times of minima were also derived using the Kwee-van Woerden (1956) method, 4 and 3 for EY Cas and NO Vul, respectively (see Table 1.).

Table 1. New times of minima. Epochs and $O-C$ values correspond to the linear ephemeris. N denotes the number of points, from which the minimum was computed.

Star	HJD	Error (d)	Epoch	$O-C$ (d)	N
EY Cas	2453394.2190	0.0003	−0.5	0.0022	48
EY Cas	2453579.5457	0.0004	384.0	0.0030	46
EY Cas	2454000.3222	0.0001	1257.0	0.0006	77
EY Cas	2454027.5536	0.0001	1313.5	−0.0005	85
NO Vul	2453657.2381	0.0003	19718.5	0.0003	29
NO Vul	2453934.3847	0.0003	20466.0	−0.0001	41
NO Vul	2454364.2876	0.0002	21625.5	0.0007	106

EY Cas (= GSC 03660-00401, R.A.=$00^h03^m23^s$, Decl.=$+57°44'54''$, J2000.0, V_{max} = 13.9 mag) is a W UMa-type eclipsing binary system, with orbital period of about 0.48 days. The photometric variability of the star was discovered by C. Hoffmeister in 1936. Distance, spectral type as well as physical parameters of the components are known only with a low confidence level.

The PHOEBE programme (see e.g. Prša & Zwitter, 2005), based on the Wilson-Devinney algorithm (Wilson & Devinney, 1971), was used. The temperature of the secondary component was fixed at the value T_2 = 6700 K, according to the spectral type of F2 + F1.5 assumed by Svechnikov & Kuznetsova (1990). The results of the fit are presented in Table 2 and the light-curve with the theoretical fit is plotted in Fig. 1. The 3-D model of the system is in Fig. 2. Nevertheless, further observations are needed, spectroscopy in particular, to reveal the spectral types of the components and their respective masses.

†see http://ccd.mii.cz/

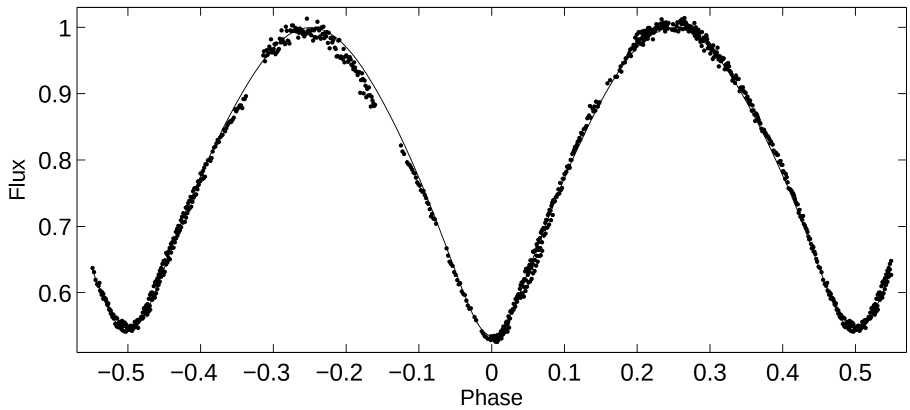

Figure 1. The R light curve of EY Cas, the solid curve stands for the model fit (with the parameters from Table 2), while the points represent the observed data.

One can see some distortion of the light curve near phase −0.15 and larger scatter near its maxima, which could be caused by the presence of spots, or by possible O'Connell effect. But these hypotheses could be confirmed only by another, more detailed analysis.

The period analysis of EY Cas was performed using 31 times of minima (listed in `5812-t1.txt`, available through the IBVS website), the first one is from 1935. Four new minima were observed, see Table 1. The linear light elements suitable for the observations are the following

$$\begin{aligned} \mathrm{HJD\ Min\,I} = 24\,53394.4578 \;&+\; 0\overset{d}{.}48199184 \cdot \mathrm{E}. \\ \pm 0.0009 \;&\pm\; 0\overset{d}{.}00000023 \end{aligned} \qquad (1)$$

From a numerical point of view, there is a problem with fitting the temperature. The final fit remains nearly the same for a very wide range of values (6200 K $< T_1 <$ 8300 K). In principle, the temperature could not be derived only on the basis of observations in one filter. The mass ratio q is also hardly derivable only from the photometry.

Table 2. The physical parameters of EY Cas and NO Vul.[†]

Parameter	EY Cas Value	NO Vul Value
i [deg]	77.61 ± 0.35	80.90 ± 0.32
$q_{ph} = M_2/M_1$	0.79 ± 0.10	0.71 ± 0.10
r_1/r_2	1.09	1.15
T_1/T_2	1.05	1.13
L_1/L_2	1.17 ± 0.11	1.78 ± 0.16
Ω	3.11 ± 0.20	3.08 ± 0.18
f	0.655	0.429

[†] T_i, r_i, and L_i denote the temperature, relative radius and luminosity for primary and secondary, respectively. f stands for the fill-out factor and Ω for the modified Kopal potential. The temperatures T_2 were fixed, see the text. The "Overcontact binary" mode was used for computing and the eccentricity was set to 0 (circular orbit). The limb-darkening coefficients were interpolated from van Hamme's tables (see van Hamme, 1993). The values of gravity brightening and bolometric albedo coefficients were set at their suggested values for convective atmospheres (see Lucy, 1968), i.e. $G_1 = G_2 = 0.32$, $A_1 = A_2 = 0.5$. Also the synchronous rotation was assumed for each star ($F_1 = F_2 = 1.0$). No third light was assumed: $l_3 = 0$.

The basic physical parameters (e.g. the individual masses) of the stars could not be derived only from the photometry. Therefore, detailed spectroscopic analysis is needed. Nevertheless, the results from the light-curve fit are in agreement with other analyses of similar overcontact systems. The high degree of the overcontactness $f = 0.66$ is comparable with other similar systems, such as GR Vir ($f = 0.78$, see Qian & Yang, 2004), or IK Per ($f = 0.60$, see Zhu et al., 2005).

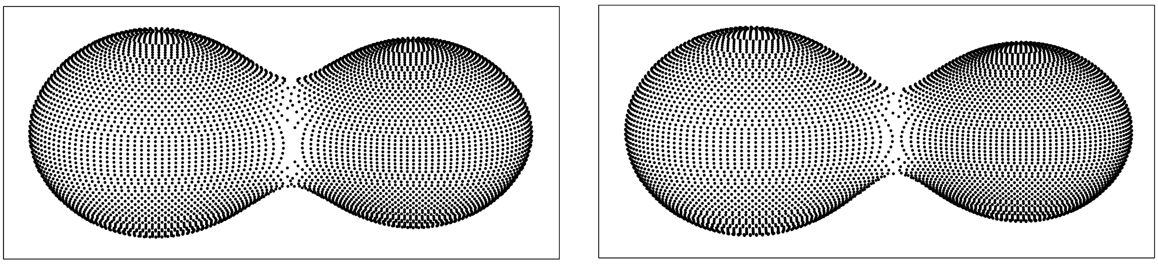

Figure 2. The 3-D plots of EY Cas (left) and NO Vul (right) at the phase 0.25, primary is on the left.

NO Vul (R.A. = $19^{\rm h}34^{\rm m}38^{\rm s}$, Decl.=$+20°37'14''$, $V_{max} = 12.83$ mag) is an eclipsing binary of W UMa type. The orbital period of NO Vul is about 0.37 days and the depth of the primary minimum is about 0.7 mag in R filter. Its photometric variability was discovered by Kalv & Leis (1973). However, the basic physical parameters of the system have not been derived so far. There is only one analysis of the period variations by Qian & Ma (2001).

The light curve was also analyzed by the PHOEBE code, the same fixed values were adopted as in the case of EY Cas. The light curve with its solution is plotted in Fig. 3 and the parameters are given in Table 1. From the spectral types F8 + F8.5 derived by Svechnikov & Kuznetsova (1990), we assumed the temperature $T_2 = 6100$ K (see e.g. Harmanec, 1988).

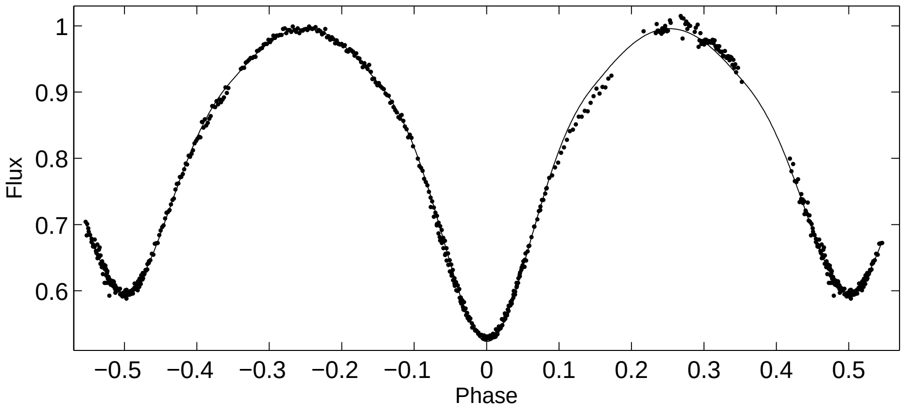

Figure 3. The R light curve of NO Vul, parameters of the fit are in Table 1.

Period analysis was done, using 108 times of minima, listed in `5812-t2.txt` (available through the IBVS website). A few new times of minima were observed given in Table 1. The $O-C$ diagram is plotted in Fig. 4, where the solid line represents the linear ephemeris, suitable for future observations,

$$\begin{array}{rcl} \mathrm{HJD\ Min\,I} = 24\,46346.3049 & + & 0\overset{\rm d}{.}37076516 \cdot \mathrm{E}. \\ \pm 0.0015 & \pm & 0\overset{\rm d}{.}00000018 \end{array} \qquad (2)$$

The previous period analysis (Qian & Ma, 2001), indicated quadratic term in the ephemeris, which describes the times of minima since 2001 (see the dash-dotted line in Fig. 4). Nevertheless, the recent times of minima deviate from this fit. Much better explanation of the period variation could be done using a light-time effect (see e.g. Mayer, 1990), this fit is plotted as a dashed line in Fig. 4. The period of such variation is about 64 years, with the semiamplitude of about 0.016 days and an eccentricity of 0.41. A predicted third body could have a minimum mass of about 0.36 $M_\odot$, corresponding to spectral type about M2 (according to Harmanec, 1988), and the contribution of the third light is only about 1%, which is undetectable in the present analysis. Further minimum observations in the upcoming years could prove or reject this hypothesis.

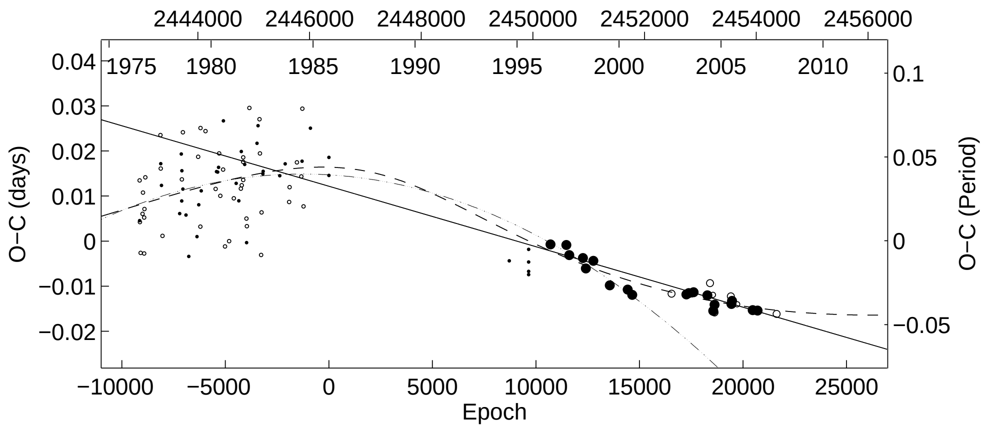

Figure 4. The $O-C$ diagram of NO Vul, the dots denote the primaries, the circles the secondaries, small ones for visual and bigger ones for the CCD and photoelectric measurements, respectively. For the explanation of the lines, see the text.

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