PHOTOMETRICAL STUDY OF CLOSE BINARY SYSTEM V841 Cyg

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ABSTRACT. We present the results of research of scantily explored close binary system V841 Cyg with possible period variations. It was attributed as β Lyr and as near contact binary star. We obtained light curve of the star in July 2013 in V-band. Both eclipses are partial, the depths of primary and secondary minima are $0^m.53$ and $0^m.20$. Light curve has feature near primary minimum: practically horizontal parts in phases $\pm(0.1 - 0.16)$. We found new time minima: $HJD_I = 2456504.48122$, $HJD_{II} = 2456493.44562$.

We obtained new parameters of binary system using Binary Maker 3 package. The system contains from A6 V+G5 V stars with mass ratio about 0.49. The components have temperatures $T_{effI} = 8550°$, $T_{effI} = 5500°$ and estimated masses $M_I = 1.85$, $M_{II} = 0.90$; they fill own Roshe lobes on 95% and 92% correspondingly and both components are deformed. The distance between components is about $5R_\odot$, the distance between component surfaces is about $1.4R_\odot$. We confirm the V841 Cyg classification as is NCB system, with not significant mass transfer.

Key words: Stars: eclipsing: close binary stars: individual: V841 Cyg.

1. Introduction

Close binary systems with period variations are test for evolution scenarios of these objects. Period variations in binary systems are explained either due to change of large axis in the system, either due to change of mass of system or due to both these factors. Unfortunately the number of well-studied eclipsing binaries is a small fraction of the total number listed in the last edition of the General Catalogue of Variable Stars (Samus at al., 2012).

In 2000 Kreiner et al. collected 1140 eclipsing binaries with period variations according to the next criteria: 1) at least 10 minima had been timed; 2) these minima spanned at least 2,500 cycles; 3) the 2,500 cycles represented no fewer than 40 years. The list of these eclipsing binaries was published as "An Atlas of $O - C$ Diagrams Of Eclipsing Binary Stars", Atlas hereinafter (Kreiner et al., 2000). We selected in the Atlas about 150 binary systems with the two-bit of the known time minima for the "Programm of Observations of Insufficiently Explored Eclipsing Binaries with Period Variations", which was initiated in Kalinenkov Astronomical Observatory (AOK) of Nikolaev National University in 2004. The results of investigation of Programm binaries such as CU Peg, V609 Aql and BM UMa were published (Panko et al., 2006, Turner at al.,2008, Virnina et al., 2010).

We present the study results of the next Programm star. The binary system V841 Cyg ($RA_{2000} = 19^h22^m18^s.4$, $DEC_{2000} = +28°41'08''$, $V = 11^m.1$) according to GCVS database (Samus et al., 2012) was described as variable by Wachmann (1963). The times minima according Kreiner et al. (2000), were determined in two sets of observations: 26 photographic time minima were found by Wachmann from 1948 to 1960 and 2 photoelectric ones by Agerer in 1993 and 1997. The depths of primary and secondary minima in V-band were noted as $0^m.2$ and $0^m.1$. Positions of time minima on the $O - C$ diagram of the star in the Atlas are random.

Brancewicz & Dworak (1980) included V841 Cyg into their "A catalogue of parameters for eclipsing binaries" and determined the parameters of the system, including the type of variability as β Lyr and specter as A5. In 1994 V841 Cyg was included in a List of Near Contact Binaries (NCB), a new subclass of close binary systems defined by Shaw (1994). NCB systems have periods of less than a day, exhibit the effects of tidal interaction, and have facing surfaces less than 0.1 orbital radius apart, but are not in contact. Such systems may be the evolutionary precursors to the A-type W UMa systems, and are probably in the early stages of mass transfer.

We initiated a new study of V841 Cyg system in order to obtain and to analyze light curve, as well as to find additional times of light minima for the in-

Table 1: The reference stars for V841 Cyg frame.

N	RA_{J2000}	Dec_{J2000}	TASS 4	V	SD
1	$19^h22^m17^s.70$	$+28°42'13''.8$	1788884	$12^m.658$	$0^m.154$
2	19 22 12.06	+28 41 20.0	3488546	12.973	0.091
3	19 22 06.97	+28 40 06.0	1788858	10.268	0.163
4	19 22 11.78	+28 39 13.4	1788868	13.021	0.202
5	19 21 51.40	+28 40 03.8	1788805	11.434	0.095

tent being to clarify the nature of its period variability.

2. Observations

The observational data were obtained using the 70-cm telescope ZTS-702 of AOK, equipped with a SBIG ST-7 camera in an instrumental photometric system closely approximating the standard V-band. The focal length of the telescope is 2.804 m and CCD-frame corresponds to $5' \times 8'$ sky area. V841 Cyg was observed on 8 nights in July 2013. Frames were taken with 30 *sec* exposure time, S/N ratio for variable was in limits $17 - 20$. The standard reduction included dark signal and flat field correction was executed for all 719 frames. Barycentric Julian Dates (HJD) were calculated using Eastman et al. (2010) code.

We used TASS Mark IV photometric catalog, version 2 (Droege et al., 2007) for reference stars search. The positions of variable and reference stars are shown in Fig. 1; information from TASS Mark IV is placed in the Table 1. Note the 3^{rd} star in V 841 frame (TASS Mark IV 1788858) was not reference one. It is semi-regular pulsating star V840 Cyg according GCVS (Samus et al., 2012). Its brightness diminished by $0^m.16$ from JD 2456493.46 to JD 2456513.38.

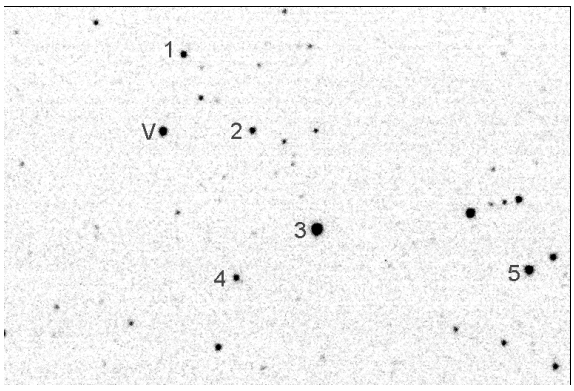

Figure 1: The reference stars in V 841 Cyg frame.

The reduction of the CCD frames was carried out using the MUNIPACK software (Motl, 2003-2012). The method of aperture photometry was used. The MUNIPACK software allows to determine the difference in magnitudes between comparison, control and variable stars. We assumed equal air mass for all stars in our small frames. The background has been estimated from neighboring pixels. The SD for individual relative magnitudes was not worse $0^m.040$.

The season light curve of V841 Cyg for 2 periods is shown in Fig. 2a by open circles. The magnitudes as $m_{var} - m_c$ were phased using an existing ephemeris (Kreiner et al., 2000), namely:

$$HJD_I = 2434629.425 + 0.76113618 \cdot E \qquad (1)$$

where E is the number of elapsed cycles.

The light curve allows as to determine the depths of primary and secondary minima, the new minima times and to reconstruction of the system.

3. Light curve analyze

The depths of minima on our phase curve are different from Kreiner et al.(2000) data - it is clearly seen in the Fig. 2a. We supposed the difference is connected with the some feature near the primary minimum of V841 Cyg. The part of light curve near the primary minimum is detailed in lower panel of Fig. 2. Our light curve with error bars is placed in Fig. 2b, the individual light curve in absolutely magnitudes, obtained by Ogmen (2009), is shown in Fig. 2c. Our light curve has practically horizontal parts in phases $\pm(0.1-0.16)$. Ogmen data are in agreement with our results. It is possible, the understated value of depths connected with comparison of this part of light curve, not with maximal value of flux. The difference is about $0^m.12$.

From analyze of V841 Cyg light curve we obtained $\Delta m_I = 0^m.53$, $\Delta m_{II} = 0^m.20$ and new time minima $HJD_I = 2456504.48122$, $HJD_{II} = 2456493.44562$.

We modelled the light curve for V841 Cyg using Binary Maker 3 along with reasonable estimates for the properties of the two components. The spectral class A5 and mass ratio 0.74 according to paper Brancewicz & Dworak (1980) was used as first approach. An initial effective temperature for the primary was established according its spectral class as $8700K$. The spectral type and temperature of the fainter star in V841 Cyg

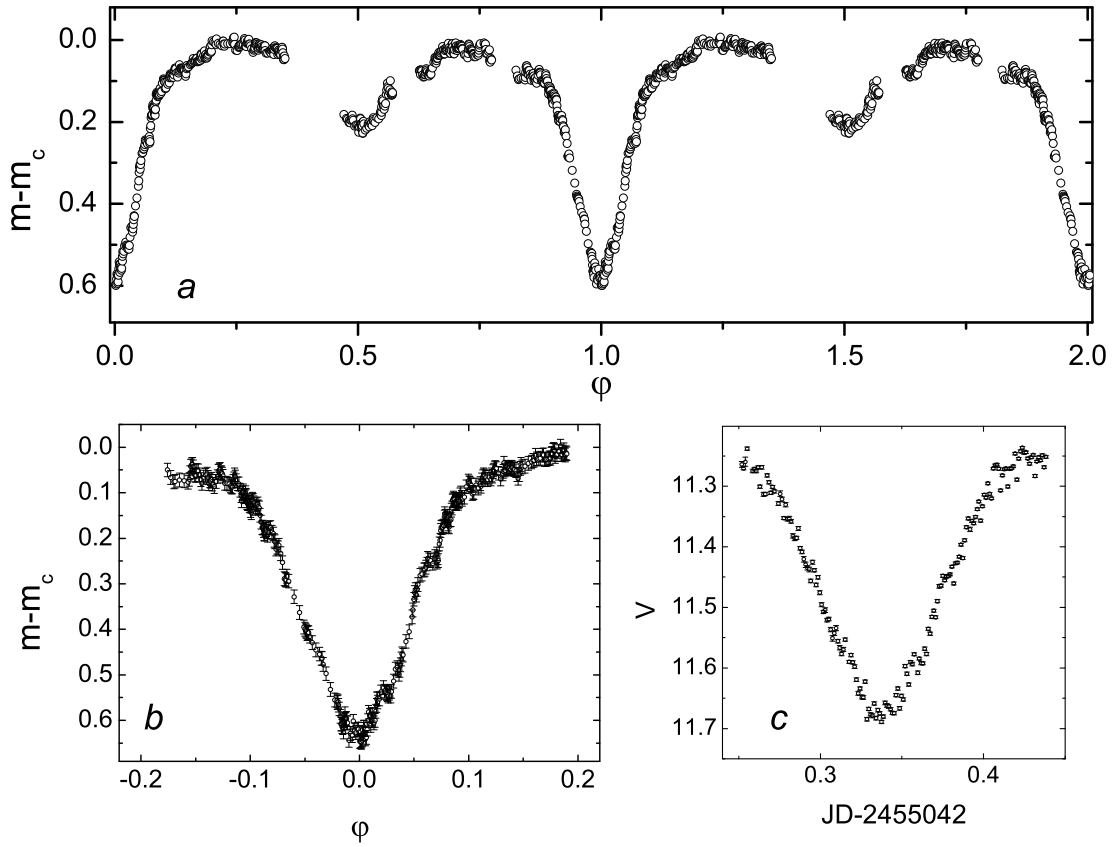

Figure 2: The light curve of V841 Cyg (a) and features of magnitudes variations in primary eclipse according our measurements (b) and Ogmen (2009) observations (c). Error bars for magnitudes are shown on lower panel.

system can be established through analysis of the light curve.

The final solution was chosen in model girds calculated with steps: 0.01 in mass ratio and Ω-potentials, $50K$ in temperature and 0.25° in inclination. The best solution implies $T_{effI} = 8550K$ and $T_{effII} = 5500K$, the temperatures corresponding to A6 and G5 spectral classes. The linear limb darkening coefficients were assumed according to van Hamme (1993) as 0.598 for primary and 0.851 for secondary taking into consideration the final temperatures. A mass of $M_I = 1.85M_\odot$ was adopted for the primary from its main-sequence spectral type, and the eclipse solution yielded a reasonably well-defined mass ratio of $M_{II}/M_I = 0.49$. The resulting implied secondary mass of $M_{II} = 0.90M_\odot$ is, in fact, the value expected for a $G4 - G6$ dwarf, apparently confirming the eclipse solution. The mass ratio for eclipsing systems is difficult to establish without radial velocity information, so, our solution we can assume as estimated.

The Ω-potentials estimated as 3.02 and 3.12 determine the fillout parameter f. Binary Maker 3 used the parameter f defined following Lucy & Wilson (1979):

$$f = \frac{\Omega_{inner}}{\Omega} - 1 \qquad (2)$$

were Ω_{inner} is inner critical surface potential and Ω is surface potential of the component.

The fillout parameter represents the percentage that the surface potential of the binary component lies outside the inner critical surface. It is positive for component bigger its Roche lobe. In case V841 Cyg we found $f_I = -0.05$, $f_{II} = -0.08$. So, the system is NCB, however the mass transfer in the system is not significant.

Using the period and mass sum we calculated the major semiaxis of system: 0.023 *a.u.* or $5.0R_\odot$. Ω-

potentials determined by Binary Maker 3 correspond to component radii 0.43 and 0.28 of the major semiaxis. So, we obtained the acceptable radii of stars as $2.1R_\odot$ and $1.4R_\odot$. The radii note to Main Sequence stars.

The light curve solution for the system is illustrated in Fig. 3, the system reconstruction on phase 0.25 in Fig. 4. Both eclipses are partial and inclination of system is 77.5°. Both primary and secondary are deformed by mutual gravity.

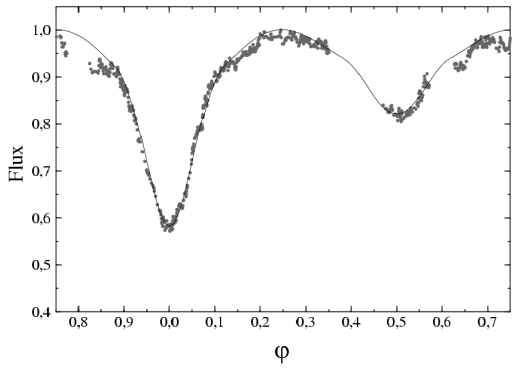

Figure 3: The light curve solution for V841 Cyg. Observational data are marked as gray dots, our final solution curve is black line.

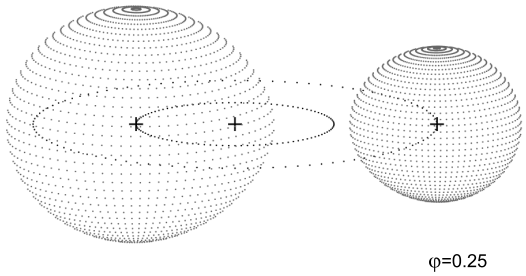

Figure 4: The view of reconstructed V841 Cyg system in phase 0.25.

According "All-sky spectrally matched Tycho 2" catalogue (Pickles & Depagne, 2010) V841 Cyg is F5 V star with weak metal lines, and its magnitude V=$11^m.534 \pm 0^m.098$. We did not find the satisfactory solution for light curve with beginning temperature of primary star corresponded to F5 V spectrum. Our light curve solution for parameters of V841 Cyg is different of Brancewicdz & Dworak (1980)catalogue, mainly for secondary component. Binary Maker 3 for their parameters constructed synthetic light curve, which is noticeably different from observed one.

4. $O-C$ variations.

Project B.R.N.O. of Brno Observatory (Czech Astronomical Society) was crated in traditional for the Observatory field: observing eclipsing binaries. The part the project named "$O-C$ Gateway" (administrator A. Paschke) collects the time minima for considerable quantity of eclipsing systems in the B.R.N.O. database, particularly it contains 45 records for V841 Cyg. The variable was attributed in the database as EB/KE (β-Lyrae contact system) with comment "deprecated".

The B.R.N.O. database used modified ephemeris:

$$HJD_I = 2434629.43 + 0.76113617 \cdot E \qquad (3)$$

where E is the number of elapsed cycles.

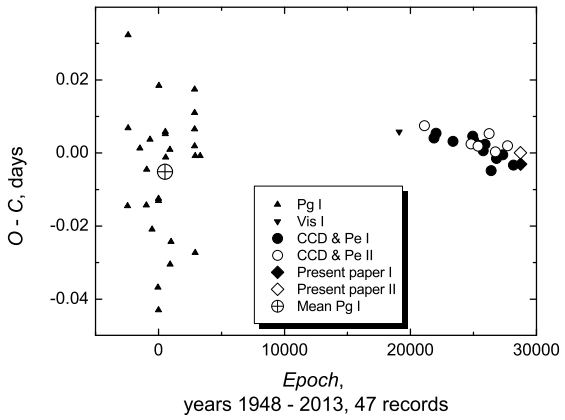

Figure 5: $O-C$ diagram for V841 Cyg. Mean value for photographic minima is noted additionally.

We calculated the $O-C$ values for out time minima using B.R.N.O. database modified ephemeris and compared the results with "$O-C$ Gateway" data. Common $O-C$ diagram is shows in Fig. 5. On left part of Fig. 5 only photographic data present. The scattering of these $O-C$ variations too big in comparison with photoelectric and CCD observations, which were beginning in 1993 year. The possible trend of $O-C$ values for all time minima can't be analyzed with sufficient accuracy. Mean value of photographic time minima excludes line trend and note to possible period decrease corresponding to mass transfer form primary to secondary. We assumed the absence of intensive mass transfer according our V841 Cyg system parameters. Possible trend in $O-C$ variations during two last decades are small and confirm our solution.

5. Conclusion.

From analyze of light curve, obtained in AOK (Nikolaev), we obtained the parameters of the eclipsing binary system V841 Cyg. It contains form A6 V+G5 V stars with mass ratio about 0.49. The components have estimated masses $M_I = 1.85$, $M_{II} = 0.90$ and temperatures $T_{effI} = 8550°$, $T_{effI} = 5500°$; they fill own Roshe lobes on 95% and 92% correspondingly and both components are deformed. The distance between components is about $5R_\odot$, the distance between component surfaces is about $1.4R_\odot$.

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