Photometric Analysis of the Eclipsing Binary: DE Canis Venatici (RX J1326.9+4532)

Ümit Deniz Göker[1], Günay Taş[2]

[1] Ege University Science Faculty, Astronomy and Space Sciences Department, 35100, Bornova, Izmir
udenizg@gmail.com

[2] Ege University Science Faculty, Astronomy and Space Sciences Department, 35100, Bornova, Izmir
tas@astronomy.sci.ege.edu.tr

Abstract: White dwarfs and red dwarfs represent two different evolutionary stages of low-mass stars. In our Galaxy, the low-mass stars form the most numerous group of objects. For members of binary systems among them, one can derive their physical parameters like mass and radius. In addition, they include valuable information about the mass distribution of our galaxy. Different evolutionary phases of the binary stars consisting of white dwarfs and red dwarfs are very important for astronomy because they allow us to test the theories of stellar evolution. In this study, a literature survey about the structure and evolution of these systems is done and theoretical and observational results for DE CVn are presented. After obtaining new light curves, we derived the geometrical and physical parameters of the eclipsing binary DE CVn consisting of a white dwarf and a red dwarf. We also discuss the problems of both DE CVn and related systems. DE CVn was observed with 3 different telescopes and 2 different receivers through the Johnson B, V, R filters in 2002-2003. Since the clearest variations were seen in the B filter, the B light curve was analysed using the Wilson-Devinney method with Mode 2 designed to solve detached binaries. The mass ratio q=1.1 was found. The visual magnitude of the white dwarf is 13.04 mag. in 0.0 phase and the orbital period of the system is 0.364077 days. The DE CVn system consists of a DA-DB white dwarf (He-WDs) and a M1-M2 red dwarf according to our solution. The system conforms to the classical cataclysmic-variable definitions, but the P-M and P-R relation of cataclysmic variables which results from the light curve differs from that obtained from Patterson's P-T relation (1984). The latter indicates a different spectral class for the red dwarf. It is not well known whether the second companion of the system is in post-evolution phase or is not conformed to standard ZAMS M-R relation.

Keywords: White Dwarfs – Red Dwarfs – Eclipsing Binary Stars - DE CVn

1. Introduction

DE CVn was firstly found in a survey by Beers et al. (1994) and the photometric observations of this star were made by Robb and Greimel (1997), Holmes and Samus (2001) and Kato (2002). In our study, DE CVn was observed with 3 different telescopes and 2 different receivers through the Johnson B, V, R filters in 2002-2003 and light and color curves were found. In addition to this, the first analysis results of the light curve was shown.

2. Observations

DE CVn was observed for a total of 13 nights in 2002-2003. Between these observation intervals a 48-cm Cassegrain telescope equipped with a HSTCP for 9 nights and a 30-cm Schmidt-Cassegrain telescope equipped with SSP-5 photometer for one night at Ege University Observatory, and a 40-cm Schmidt-Cassegrain telescope equipped with SSP-5 photometer for 3 nights at Çanakkale Onsekiz Mart University Observatory were used. We obtained 865, 2665 and 1343 observational points for B, V and R filters respectively. The magnitudes of the comparison and check star were taken at SIMBAD database, and the properties of these stars are shown in Table 1.

Table 1. The properties of comparison and check stars.

Star	GSC no.	V (mag)	Spectral type
DE CVn	GSC 3460-780	12.80	?
Comparison	GSC 3460-961	10.04	G0
Check	GSC 3031-728	10.54	F9

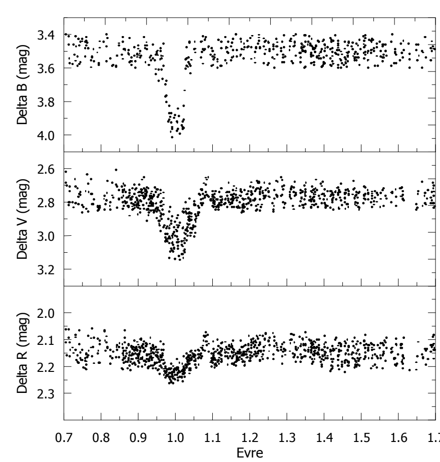

Figure 1. The observed light curves of DE CVn in 2003.

The observed B, V and R light curves of DE CVn in 2003 are shown in Figure 1. In 2002, because of insufficient observation nights which included all filters, we only presented (B-V, V-R) color curves in Figure 2 which were taken in 2003.

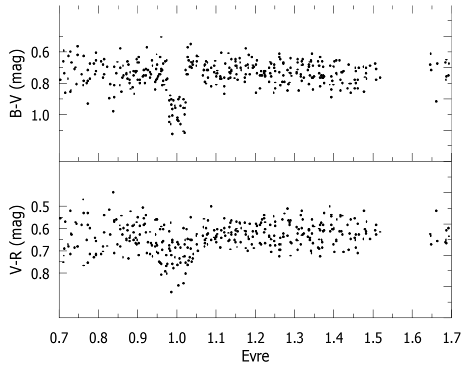

Figure 2. The B-V and V-R color curves of DE CVn in 2003.

The depths of eclipse in B, V and R filters are $0^m.45$, $0^m.28$ and $0^m.09$, respectively. The total duration of the primary minimum is $0^d.0229 = 33^{min}$. The duration of primary minimum is $\sim 21^{min}$ and the ingress and egress take $\sim 6^{min}$. The depth of primary minimum is not changing between two observational seasons, but the level of the light curve is changed. During the eclipse, we could clearly find the ingress of the primary minimum five times and added minimum times which were taken from literature in our analysis, we found out the O-C variation. O-C (I) results were calculated from the light curves which were taken from Robb and Greimel. Whether or not we use the minimum times of Robb and Greimel (1997) the period correction will change (Figure 3).

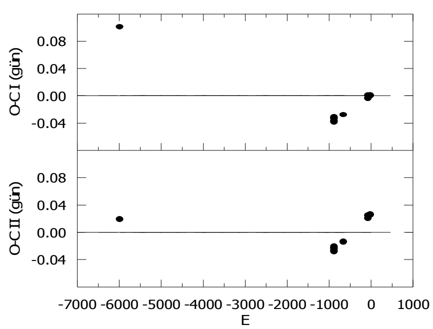

Figure 3. The O-C variation of DE CVn. O-C (I) (up level) and O-C (II) (down level).

We corrected the light elements T0 and P by using ***a Least-Squares Method*** and determined the new light elements:

HJD (Min I) = 24 52727.3585 (86) + 0^d.364077 (5) x E

3. The First Results of Light Curve Analysis

Since the clearest variations were seen in the B filter, the B (2003 datas) light curve was analysed using the Wilson-Devinney method. Adopted and adjusted paremeters are shown in Table 2.

Table 2. Adopted and adjusted paremeters by using W-D code.

Parameter	Result	Error
q (=M2/M1)	1.1	
X_1	0.0	
X_2	0.719	
A_1	1	
A_2	0.5	
G_1	1	
G_2	0.32	
T_2 (K)	3900	
T_1 (K)	8066	1151
Ω_1	52.400	13.288
Ω_2	5.119	0.093
L_1	3.691	0.132
L_2	8.981	
i (º)	78.05	0.53
r_1 (side=back=point=pole)	0.019	0.005
r_2 (side)	0.266	0.006
r_2 (back)	0.273	0.007
r_2 (point)	0.276	0.007
r_2 (pole)	0.262	0.006
Σ (res)^2	0.014	

The observed and theorical light curve of DE CVn is shown in Figure 4. The mass of the white dwarf 0.36 $M_{\odot}$ was found and because of this result, our system was composed of a helium white dwarf (Politano, 1996). While the fractional luminosity of the white dwarf is 29 %, the red dwarf is 71 % for B color. Because of this, the luminosity of the white dwarf 0.023 $L_{\odot}$ was found. All these orbital parameters are shown in Table 3.

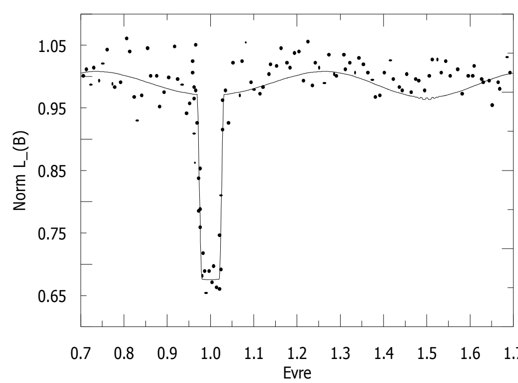

Figure 4. The observed and theorical light curve obtained by using the W-D code for B color (2003 datas) of DE CVn.

Table 3. The orbital parameters of DE CVn

Parameter	White Dwarf	Red Dwarf
Spectral Type	DA – DB	M1-M2 V
Mass ($M_{\odot}$)	0.36	0.40
Radius ($R_{\odot}$)	0.037	0.52
Temperature (K)	8066	3900
Luminosity ($L_{\odot}$)	0.023	0.056
Log g	6.84	4.61
M_V (mag)	8.89	7.92
m_V (mag)	14.01	13.04
a ($R_{\odot}$)	1.957	
Distance (pc)	106	
Inclination (°)	78	

4. Discussion

By using the P-M and P-R relation of CVs (Warner 1995, Patterson 1984, Ritter 1986) to the DE CVn, the mass and the radius of the second component as 1.05 $M_{\odot}$ and 1.01 $R_{\odot}$ were found, and also from the P-T relation, the temperature of the second component were found to be 5543 K. These results indicate a different spectral class which results from the light curve for the RD. We applied our observational results to the mass-spectral type relation which was given from Kolb and Baraffe (2000) and we found that ***an evolved, low $\dot{M}$ sequence*** (initial central hydrogen content X_c=4x10^{-4}, initial donor mass M_2=1.2 $M_{\odot}$, $\dot{M}$ =1.5x10^{-9} $M_{\odot}y^{-1}$) can be suitable for our CV donor (Figure 5). This result was also applied in the orbital period-spectral type diagram (Figure 6) which was given by Kolb and Baraffe (2000). The line which was transmitted to the spectral type in figure 6 cuts the theoretical curve in two point as 0.17 $M_{\odot}$ and 0.33 $M_{\odot}$.

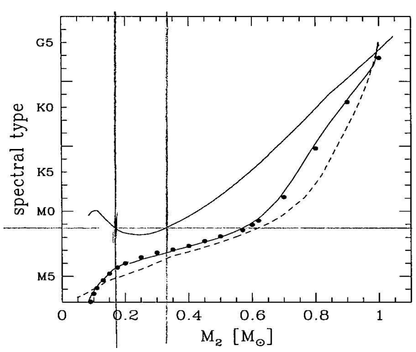

Figure 5. Spectral type versus secondary mass with assumptions for the evolved sequence (low $\dot{M}$, X_c=4x10^{-4}) and the unevolved high $\dot{M}$ sequence (10^{-7} $M_{\odot}y^{-1}$). Dots denote ZAMS models.

By using the relation taken from Ritter (1986); the mass ratio (q) of the system as 0.46 and 1.04, and the white dwarf mass as 0.37 $M_{\odot}$ and 0.32 $M_{\odot}$, respectively was calculated for these red dwarf masses. The best result was found for the white dwarf mass 0.32 $M_{\odot}$ and these masses resemble the light curve results by using W-D code.

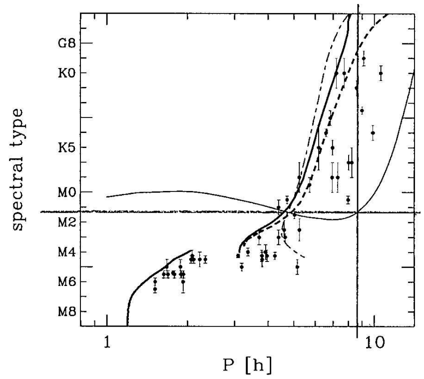

Figure 6. Spectral type versus orbital period for CV secondaries with various evolutionary sequences. Data taken from Beuermann et al. (1998). Thick solid: standart sequence; thin solid: evolved low $\dot{M}$ sequence (X_c=4x10^{-4}); short/long dashes: unevolved sequence ($\dot{M}$ =10^{-8} $M_{\odot}y^{-1}$); thick dashes: evolved high $\dot{M}$ sequence (X_c=4x10^{-4}).

5. Conclusions

Further efforts to calibrate the empirical ZAMS, especially for low-mass stars (< 0.4 $M_{\odot}$) were recommended by Patterson (1984). The system conforms to the classical CV definitions, but the P-M and P-R relation of CVs which results from the light curve differs from that obtained from Patterson's P-T relation (1984). Both the mass values which were calculated from the light curve (0.40 $M_{\odot}$) and from theoretical curve (0.17 $M_{\odot}$ and 0.33 $M_{\odot}$) is near or smaller than the limit value. The latter indicates a different spectral class for the red dwarf. It is not well known whether the second companion of the system is in post-evolution phase or is not conformed to standard ZAMS M-R relation.

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