Photometric study of the short-period contact binary CW Canis Minoris

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Abstract. We present the new BV light curves of the short-period contact binary CW Canis Minoris. The (O-C) diagram was fitted with times of minima for a new linear ephemeris which the period of the contact binary is found to be 0.313152 (±0.000053) days. The orbital period of the eclipsing binary is found to show a long-term increase at a rate of 3.34 (±0.50) × 10^{-7} days per year. The light curves were analyzed by the Wilson-Devinney code which has a mass ratio of 0.710 (±0.003) and a degree of contact about 0.013 (±0.989) %. The geometric structures of CW CMi are obtained with the components exactly filling its limited lobe.

1. Introduction

Researching topics associated with binary star systems provide us with a higher understanding of the origin and end of stars. The late-type systems of contact binaries are eclipsing binary variable star, it is called also W Ursae Majoris (W UMa) type. CW CMi or GSC 4832-0400 (α = 07h 50m 45s.49 and δ = -0° 0′ 11″.39) is a short-period of eclipsing binary systems. This star was found to be a variable star as EW-type of variability by Kwee and Van Woerden (1956) [1]. Benitez and Vargus (2000) rediscovered it to be an eclipsing binary of W UMa-type [2]. This system is a near-contact binary given by Pribulla et al. (2003) [3]. However, Avvakumova and Malkov (2014) reported the evolutionary status of eclipsing binary of CW CMi that it is a contact W UMa type of W-subtype (with Membership probability = 50 per cent) or A-subtype (with Membership probability = 45 per cent) [4].

This paper presents the observations and data reduction procedures in section 2. Section 3 an analysis of the period changes and (O-C) diagram of CW CMi. The photometric solutions are described in section 4. In section 5, we discuss our results and get to the conclusion.

2. Observations and data reduction

We carried out the new photometric observations of CW CMi on 9, 12 and 13 January 2019 using the 0.7-m reflecting telescope (CDK700) at the Regional Observatory for the Public Nakhon Ratchasima in Nakhon Ratchasima, Thailand. The telescope was equipped with a 4096 × 4096 pixel FLI Proline 16803 CCD camera and it includes Johnson BV filters. The exposure time for B and V filters were 90s and 30s, respectively. The data reduction and differential magnitude measurements were made with Siril 0.9.10 software. The stars TYC 4832-2073-1 (α = 07h 51m 12′.15 and δ = -0° 0′ 31″.94) and TYC 4832-
266-1 (α = 07h 51m 06s.23 and δ = - 0° 07′ 26″.94) were used as comparison and check stars, respectively. The BV light Curves of CW CMi plotted in figure 1.

![Figure 1. The BV light curves of CW CMi take on three night.](image1)

![Figure 2. The (O-C) diagram of CW CMi represents the linear and the polynomial fitting.](image2)

3. **Period analysis and (O-C) diagram**

The data of 16 times of minima were calculated from several researchers [1-2, 5-9]. Equation (1), shows that the linear ephemeris of CW CMi was initially phased [1]:

\[
\text{Min. } I = HJD2451242.23011(\pm0.00067) + 0^d.31315(\pm0.00001) \times E
\]

where \( E \) is the epoch number. The (O-C) residuals for all the times of minima light according to the linear and quadratic ephemeris were calculated, which are plotted in figure 2. We used the least squares method that the new linear ephemeris of CW CMi was revised in equation (2):

\[
\text{Min. } I = HJD2458496.98283(\pm0.00049) + 0^d.313152(\pm0.000053) \times E.
\]

Figure 2 showed a parabola curve to fit the formula of a long-term increase tendency. The following quadratic ephemeris of CW CMi was amended:

\[
\text{Min. } I = HJD2451242.25600(\pm0.00017) + 0^d.313152(\pm0.000036) \times E + 1^d.430(\pm1.004) \times 10^{-10} \times E^2.
\]

The quadratic term in equation (3) found that a continuous increase in period of CW CMi at a rate of \( \frac{dP}{dt} = +3.34 \ (\pm0.5) \times 10^{-7} \ \text{days/year}.\)

4. **Photometric solutions**

The BV light curves of CW CMi were analyzed with Wilson Devinney (WD) code by PHOEBE 0.32 software. The effective temperature of the primary component (\( T_1 \)) was fixed at 5610 K that the calibration reported by Hog et al. (2000) with the color index B-V (11.88 - 11.14 = 0.74) of CW CMi [10]. The gravity darkening coefficients were set at values of \( g_1 = g_2 = 0.32 \) [11] while, the bolometric albedo coefficients as \( A_1 = A_2 = 0.5 \) [12]. The logarithmic limb-darkening coefficients interpolate with van Hamme table [13]. A \( q \)-search method was used to get the mass ratio (\( q = M_2/M_1 \)) values of an initial input parameter. In figure 3, the \( q \) value ranged from 0.1 to 3.0 with step 0.1 shows that the best value is around 0.71. The double contact (Mode 6) of unspotted model was computed for CW CMi. The parameters of the temperature of secondary component (\( T_2 \)), the orbital inclination (\( i \)), the surface potentials (\( \Omega_1 = \Omega_2 \)) and the relative luminosity of primary component (\( L_1/(L_1+L_2) \)) were adjusted.
Figure 3. The relations of the mass ratio and the residuals show values around the minimum.

Figure 4. The BV light curves for CW CMi are fitted with unspotted model.

The following figure 4 showed the best fit of BV light curve between the observation and theoretical light curve model for CW CMi, which the light curve presents the O’Connell effect at Maximum asymmetry around the phase 0.25 (Max. I) [14]. Table 1 lists the obtained parameters of CW CMi. The geometrical structure of CW CMi by Nightfall 1.92 software is shown in figure 5.

Table 1. The physical parameters are estimated for CW CMi.

| Parameters       | Value | Error      |
|------------------|-------|------------|
| $T_1$ (K)        | 5610  | Fixed     |
| $T_2$ (K)        | 4830  | ±22        |
| $q=M_2/M_1$      | 0.71  | ±0.003     |
| $i$ (°)          | 74.85 | ±0.224     |
| $L_1/(L_1+L_2)(B)$ | 0.8248 | ±0.0029 |
| $L_1/(L_1+L_2)(V)$ | 0.7907 | ±0.0031 |
| $\Omega_1=\Omega_2$ | 2.9894 | ±0.0137 |
| $\Omega_{in}$    | 2.989444 | -         |
| $\Omega_{out}$   | 2.659126 | -         |
| $f$ (%)          | 0.013 | ±0.989    |
| $r_1$ (pole)     | 0.4048 | ±0.0124   |
| $r_1$ (side)     | 0.4289 | ±0.0160   |
| $r_1$ (back)     | 0.4574 | ±0.0216   |
| $r_2$ (pole)     | 0.3087 | ±0.0212   |
| $r_2$ (side)     | 0.3225 | ±0.0248   |
| $r_2$ (back)     | 0.3548 | ±0.0351   |
| $X_1=X_2$        | 0.29  | ±0.159    |
| $g_1=g_2$        | 0.32  | Fixed     |
| $A_1=A_2$        | 0.5   | Fixed     |
| $\Sigma(O-C)^2$ | 0.0028 | -         |

5. Discussion and Conclusions

This paper has presented a new CCD photometric study in BV filters for the short-period contact binary CW Canis Minoris. The observation light curves were analyzed using PHOEBE software based on the Wilson-Devinney code. The new linear and quadratic ephemeris were derived from thirteen times of
minima from literature together with our three times of minima by using the (O-C) residual. We have calculated the long-term orbital period increase with a rate of \( \frac{dp}{dt} = 3.34 \pm 0.5 \times 10^{-7} \) days/year. Photometric solutions of contact binary CW CMi were obtained by using WD code. The 3D shape of the geometric structures and the potential lines of CW CMi shown the fill-out configuration have been revealed that each component of contact binary system fills exactly its critical Roche lobe with fill-out factors \( f = 0.013 \pm 0.989 \) %. is shown in figure 6.

\[
\frac{dp}{dt} = 3.34 \pm 0.5 \times 10^{-7} \text{ days/year.}
\]

**Figure 5.** Geometric structures of CW CMi display at phases 0.00, 0.25, 0.50 and 0.75.

**Figure 6.** The potential outlines of CW CMi reveal over contact configuration at phase 0.25.

From the orbital and physical parameters of CW CMi system, it is found that the primary component is the massive one. Also, the temperature of the primary component is hotter than the secondary component with temperature difference \( \Delta T = 780 \) K and could be classified as A-subtype of W UMa eclipsing binary. The effective temperature of each component is denoted by spectral types G6 and K3 for the primary and the secondary component, respectively. The best fit for the BV light curves of CW CMi yields a mass ratio \( q = 0.71 \pm 0.003 \). The spotted model in the primary or the secondary component is required to contact binary CW CMi to follow up and treat the maximum asymmetry.

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