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Investigating the OB associations in CMa using eclipsing binary systems: Preliminary results on LV CMa

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Abstract. In this study, an eclipsing binary of a short orbital period ($P = 1\overset{\mathrm{d}}{.}1834857$) LV CMa ($V = 8\overset{\mathrm{m}}{.}7$) is selected as a candidate member of an association in the direction of CMa OB1/R1 region. Light curves in $UBVR_cI_c$ photometric bands were obtained and low-resolution ($R \sim 5500$) spectra were collected. Preliminary results show that the system is a detached binary containing at least one B spectral type star. It seems that LV CMa has no connection with the nearby OB associations or stellar clusters.

Key words: eclipsing binaries – associations

1. Introduction

There have been some opposing views about determining the physical boundaries, ages and distances of young stellar groups in the CMa constellation (for details, see Gregorio-Hetem, 2008). In a brief summary, it would be appropriate to mention that CMa consists of three stellar associations (SAs): two of them are located at the same position with a distance of 1.15 kpc from the Sun, hence named together as CMa OB1/R1. Another one, known as CMa OB2 (Kopylov, 1958), is centered at 740 pc away from the Sun. The predicted ages are 3 Myr and 100 Myr for CMa OB1/R1 and OB2, respectively (Clariá, 1974 a; Clariá, 1974 b; Eggen, 1981). A couple of studies on early-type eclipsing binaries (EBs) in CMa revealed the existence of differences between the ages of members and nearby SAs.

For example, in the case of FM CMa, a well-known member of OB1/R1, the photometric distance and age of the system is found to be 980 ±130 pc and 30 ±10 Myr (Zejda *et al.*, 2018), which is in agreement with the values of CMa OB1/R1. Also, another early-type binary LT CMa was investigated by Bakış *et al.* (2010) and they found that the distance to LT CMa is 535 ±45 pc and its age is 35 ±5 Myr, meaning that it is closer than FM CMa, but has a similar age. We see a picture that early-type stars with the similar age are located around the CMa OB1/R1 association. So, our main motivation in this research is to investigate how star forming regions evolve with respect to the distance through the SAs in the vicinity of CMa by examining early-type EBs, which are likely to be members.

Despite the fact that determining precise boundaries of SAs and, consequently, their radii is a difficult task, discoveries of new members located in the outer frontiers of SAs may lead us to review our knowledge about star forming scenarios. In this aim, we have selected LV CMa (HD 53931), which is a relatively bright ($V = 8^{\mathrm{m}}\!.7$), early-type (B9.5V) EB with a short orbital period ($P = 1^{\mathrm{d}}\!.1834857$). According to the GAIA parallax (Gaia Collaboration *et al.*, 2016) of LV CMa, it is located at a distance of 510 ± 18 pc from the Sun, revealing that it has a similar distance as LT CMa and also their lines of sight in the sky are close to each other. This encouraged us to question the possibility of a dynamical relationship of LV CMa with other early-type stars around.

2. Observations

Photometric observations were carried out between 2016 and 2017 in a total of six nights. The data were collected with AUT25, a 25 cm Ritchey-Chrétien type of telescope which is equipped with a back-illuminated CCD camera and $UBVR_cI_c$ photometric filters. Bias, dark subtraction and flat field correction were applied to the raw data. Subsequently, aperture photometry was performed with the aperture chosen to be three times the *FWHM* of the stellar profile. The orbital period was calculated with the up-to-date ephemerides provided by Kreiner (2004) to form light curves (LCs). Also, a new time of the secondary minimum was extracted from our observations. An example LC can be found in Fig. 1.

Spectroscopic observations were carried out in 2016 with the low-resolution ($R \sim 5500$) Faint Object Spectrograph and Camera (TFOSC) installed at the Cassegrain focus of the 1.5 m RTT150 telescope of TUBITAK National Observatory of Turkey. TFOSC covers a wavelength range between 3300 Å and 12000 Å in 11 spectral orders. An example spectral region of LV CMa, which was observed at orbital phase near the primary minimum, is shown in Fig. 1.

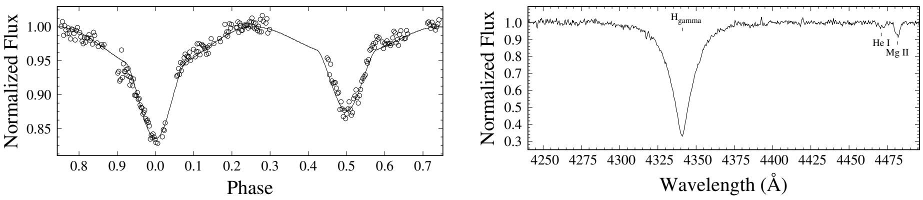

Figure 1. The best fitting model for a V-band light curve (left) and the observed spectrum of LV CMa around H_γ, He I and Mg II lines (right).

Table 1. Light curve solutions for LV CMa.

Parameter	Primary	Secondary
i (°)	68.1 ± 0.4	
e	0	
ω (°)	0	
q	0.80 ± 0.05	
$T_{\rm eff}$ (K)	9300	8200 ± 95
Ω	3.97 ± 0.04	4.30 ± 0.08
$L/L_{\rm total}$	0.64 ± 0.02	0.36 ± 0.02
$r_{\rm mean}$	0.322 ± 0.004	0.253 ± 0.007
$d_{\rm parallax}$ (pc)	510 ± 18	

3. Analysis

To begin with, we analyzed the LC of LV CMa using the Wilson-Devinney (WD) code (version 2015) with Mod 2, which was provided for detached binaries. The V-band LC was used to check if reliable convergence of free parameters can be reached using different input parameters. Unfortunately we weren't able to determine the mass ratio (q) of the system from radial velocity curves due to unevenly distributed data over the orbital revolution, so we used a q-search method. For each q value assigned as a fixed-parameter, a convergent solution was obtained and sum of squared deviations (χ^2) from the model was calculated. The value with minimum χ^2 is adopted as the mass ratio of LV CMa. By setting q, $T_{\rm eff,1}$ (adopted from GAIA DR2), P, $T_{\rm o}$, $A_{1,2}$, $g_{1,2}$, and $F_{1,2}$ (under a radiative atmospheres assumption) as fixed parameters (linear limb darkening coefficients are adopted from van Hamme, 1993) we modeled the LC (see Fig. 1). Our best fitting model parameters are given in Tab. 1. The uncertainities given in the table are calculated by the WD code. The parallax of LV CMa is also adopted from GAIA DR2 (Gaia Collaboration *et al.*, 2018), as we decided it would be convenient to use it instead of the photometric distance which can be vulnerable to effects of interstellar medium.

4. Preliminary Results

By investigating the low-resolution spectrum of LV CMa, we confirm that at least one of the components in the system is a B-spectral type star, as the spectrum at the primary minimum includes He I lines (see Fig. 1). Although the secondary star is in the front as the conjunction occurs, this weak He I line seen in the spectrum could be from the primary star's spectrum since the inclination of the orbit is as low as 68 degrees, where $\sim$60 per cent of light of the primary is still visible by the observer. A collection of the spectra covering the whole orbital cycle would help us to characterize the components in the system. For now, we keep the temperature of the primary components as given in the GAIA catalogue.

The spectrum at the primary minimum also tells us about the approximate center of mass velocity of the system, which is ~ -21 km/s. This velocity, when combined with the proper motion and distance of the system, would give us information about the space velocity components of LV CMa as $U = 20$ km/s, $V = 3$ km/s and $W = -11$ km/s. These velocity components correspond to neither space velocity components of CMa OB1 ($U = -40.3$ km/s, $V = -4.6$ km/s and $W = -21.3$ km/s) nor those of LT CMa ($U = -25.2$ km/s, $V = -7.3$ km/s and $W = -12.5$ km/s).

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