Stars and their variability observed from space
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PARAMETERS OF DETACHED O- AND B-TYPE ECLIPSING BINARIES IN THE LMC

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Abstract.
Detached eclipsing double-lined spectroscopic binaries (SB2) offer a unique opportunity to measure directly, and accurately, stellar parameters like masses, luminosities and radii of the component stars. Such accurate parameters are very important for constraining evolutionary models, especially of early-type stars for which such knowledge is lacking. SB2 eclipsing binaries are also very good distance indicators, and are being used successfully to measure distances in the Galaxy and beyond. Here we present our solution for two O and B-type massive detached SB2 systems in the Large Magellanic Cloud (LMC). The masses of the components of these binaries are about 20 M⊙ and 14 M⊙, respectively, and were determined with an accuracy of 1%. We compared our solution with different evolutionary models and found that the one with higher overshooting agrees better with our results.

Keywords: Eclipsing binaries, early-type stars, Large Magellanic Cloud

1 Observational Data

The two systems that we analyzed, OGLE-LMC-ECL-22270 (hereafter BLMC-01) and OGLE-LMC-ECL-06782 (hereafter BLMC-02), are located close to the centre of the LMC. They have not been analyzed previously, and nothing was known about their physical properties except for a very rough spectral type for BLMC-01 (Muraveva et al. 2014; Evans et al. 2015).

For the purpose of the current analysis we collected photometric data available in the literature, mostly from the OGLE project (Udalski et al. 2008) but also fr om the MACHO and EROS projects.

We also acquired high-resolution optical spectra using the UVES spectrograph (VLT, Paranal Observatory, Chile) and MIKE spectrograph (Magellan telescope, Las Campanas Observatory, Chile).

2 Analysis and results

The radial velocities (RV) of the components (see Fig. 1) were obtained using the Broadening Function technique (Rucinski 1999) implemented in the `RaveSpan` code (Pilecki et al. 2017). Spectra of standards similar to those of our system were used as templates. During these processes, rotational velocities (v_{rot} sin$i$) were also measured.

A preliminary light-curve solution was obtained using the `JKTEBOP` (Southworth et al. 2007) modelling tool, scanning the parameter space through a wide range of parameters. This solution was subsequently employed as a starting point for more sophisticated modelling of both RV and light-curves using the `Wilson-Devinney` code (Wilson & Devinney 1971) with the `Phoebe GUI` (Prša & Zwitter 2005). We modeled all the photometric bands simultaneously (IVK in the case of BLMC-01 and IVR for BLMC-02). The best-fitting orbital solutions are presented in Fig. 1; the light-curve solutions for all the bands used are shown in Fig. 2.

We then calculated the physical properties of the components; they have been published in Table 4 of Taormina et al. (2019).

The reddening was estimated using both the reddening map from Haschke et al. (2011), and directly to the object from the analysis of interstellar sodium lines. For BLMC-01 we found a reddening of $E(B-V)$=0.193, and $E(B-V)$=0.082 for BLMC-02. BLMC-01 is located in 30 Doradus region, so greater reddening is expected there.

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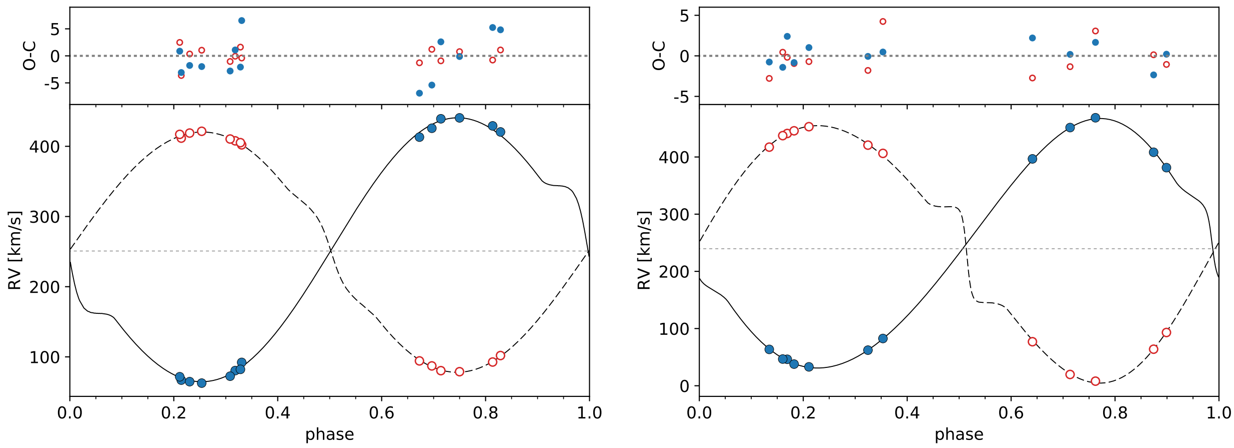

Fig. 1. Orbital solution from the `WD` code (lines) and the RV measurements (circles) from `Ravespan` for BLMC-01 (left) and BLMC-02 (right). Residuals are shown in the upper panels.

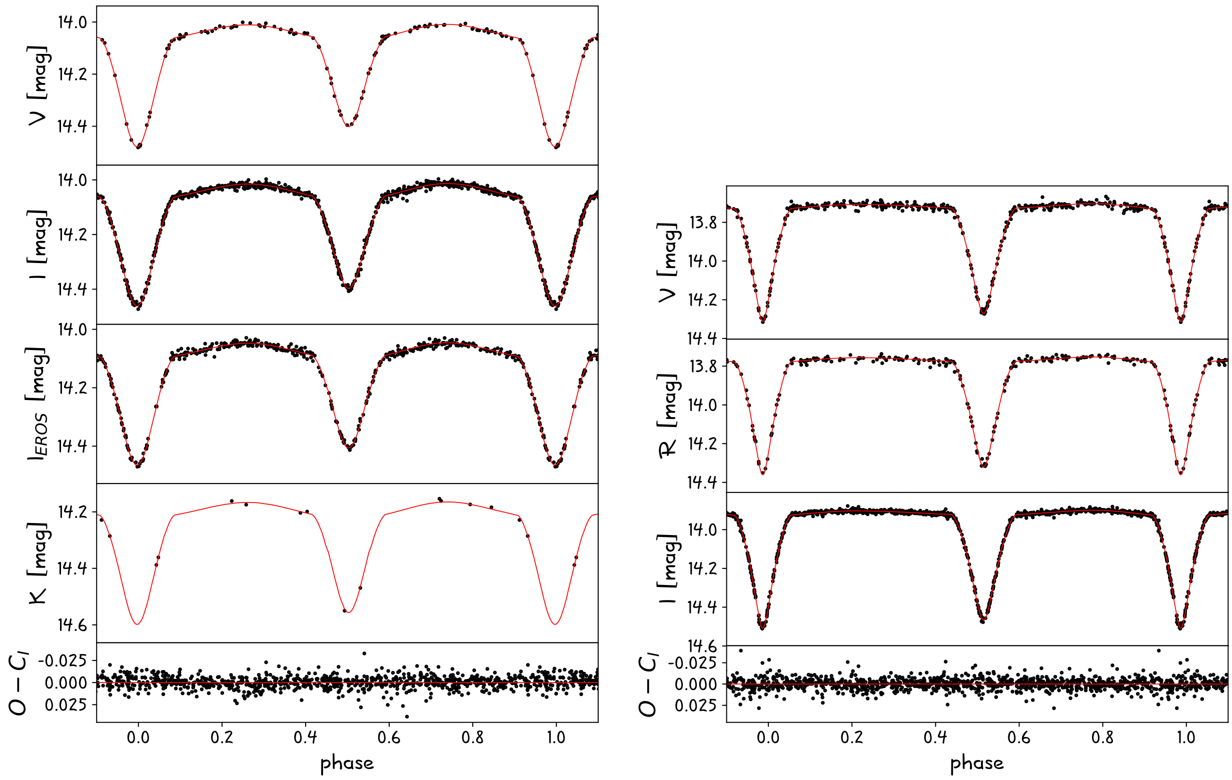

Fig. 2. Light-curves for BLMC-01 (left) and BLMC-02 (right). Data (points) and the model (red line) are plotted. The bottom panels show the I-band residual light-curves.

3 Evolutionary status

The evolution of early-type stars is not well understood, and discrepancies are often found between the observations and models. We used our results for BLMC-01 to test two different sets of evolutionary tracks, calculated for different sets of parameters.

In the left panel of Fig. 3 we compare our measurements with the tracks of Choi et al. (2016). We used a set of models for the LMC metallicity and masses from 13 to 16 M⊙, and also two interpolated tracks for the masses of the components of BLMC-01. These models were calculated with overshooting $\alpha = 0.2$.

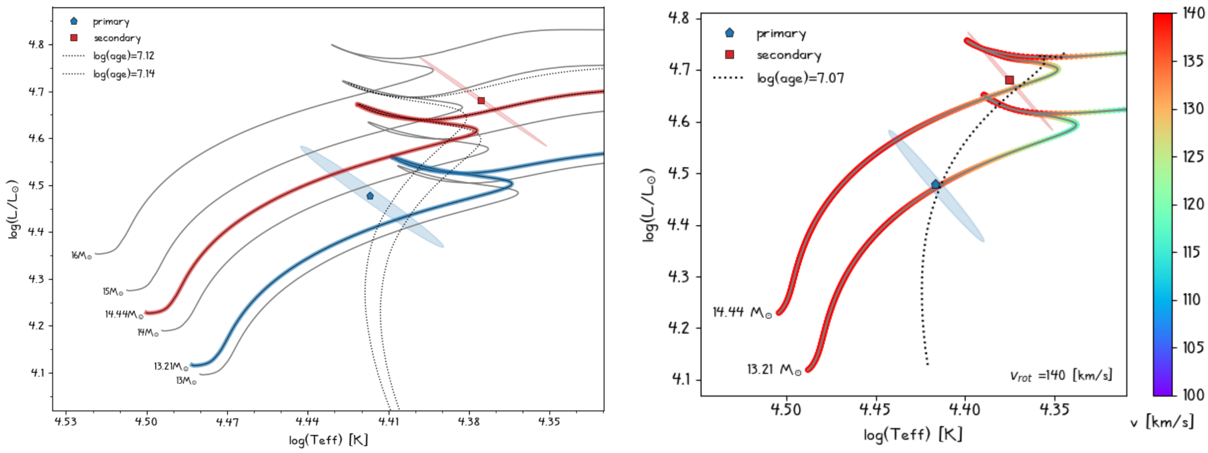

Fig. 3. H–R diagram showing the positions of the components of BLMC-01, on a grid of evolutionary tracks of Choi et al. (2016) (**left**) and evolutionary models from Brott et al. (2011) (**right**). All tracks start at the zero-age main sequence. Error ellipses are shown for the components.

In the right panel of Fig. 3 we show the evolutionary tracks of Brott et al. (2011). This grid covers a wide range of surface rotation velocities and masses. The overshooting used in these models is higher (α=0.335). We chose models with the LMC metallicity and an initial velocity of $\sim$ 140 km/s, consistent with measured current rotational velocities. We note that for different initial velocities the consistency with our results is lower.

As one can see, models of Brott et al. (2011) are more consistent with the results and predict both components to be on the main sequence, which is more probable than the results from Choi et al. (2016). Furthermore, although the uncertainty of the temperature determinations is large, the ratio of the two temperatures is very well constrained so both models should appear at the same distance from the tracks, which is not the case for the models of Choi et al. (2016).

From this comparison we conclude that models with higher overshooting describe our measurements better. The rotation has a lower, but also significant, effect on the results.

For more details regarding the results and analysis of the systems presented here, please refer to Taormina et al. (2019).

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