Estimating mass-loss rate in low-mass, evolved eclipsing binaries

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We use PARSEC isochrones to determine evolutionary stages of low-mass eclipsing binaries in the Galactic Bulge. For each system, we look for an isochrone that best fits both components in the parameter space of temperature, luminosity, and mass. Without mass loss, models predict almost equal masses of the stars at the stages after the main sequence. A moderate rate of mass loss must be included in the evolution to reproduce the position of components in the mass-temperature and mass-luminosity diagrams. The larger the mass ratio of the system, the higher the mass-loss rate is needed.

1 Introduction

When a star is evolving across the red giant branch, it loses its mass due to winds which can be described by Reimers formula (Reimers, 1975):

$$\dot{M}_{\rm R} = 4 \times 10^{-13} \eta \frac{LR}{M}, \tag{1}$$

where η is a free parameter and L, R, and M are luminosity, radius, and mass. Asteroseismic observations (Miglio et al., 2012) of G-K giants from old globular clusters constrain their mass-loss efficiency in the broad range of $0.1 \leq \eta \leq 0.3$.

In the case of low-mass, post-main sequence stars it turns out that the efficiency of mass-loss significantly changes the shape of isochrones in the mass-luminosity and the mass-temperature dimension. This in turn affects the determination of age.

We fit PARSEC isochrones (Bressan et al., 2012) to two low-mass eclipsing binaries in the Galactic Bulge – OGLE-BLG-305487 and OGLE-BLG-116218. We use χ^2 minimisation with effective temperature, radius, and mass (from Suchomska et al., in preparation) as observables to find the best age and metallicity from our grid. We repeat this process for different values of η.

2 Results

For each system we present our best isochrone on a Hertzsprung–Russell diagram (Figs. 1 and 3) and two mass diagrams (Figs. 2 and 4) which show the dependence of effective temperature and luminosity on stellar mass. The isochrones on the mass diagrams form three distinct branches: Red Giant Branch (RGB) ascend, descend after helium ignition in the core and the Asymptotic Giant Branch (AGB) ascend, from right to left.

The primary component is marked with a blue square and the secondary with a red circle. Filled symbols correspond to best matching points on isochrones, while

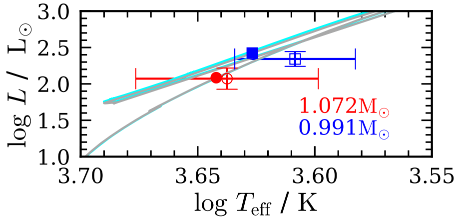

Fig. 1: Best solution for OGLE-BLG-305487 with metallicity [Fe/H] = −0.3, age log$t$ = 9.8651 and χ^2 = 3.2.

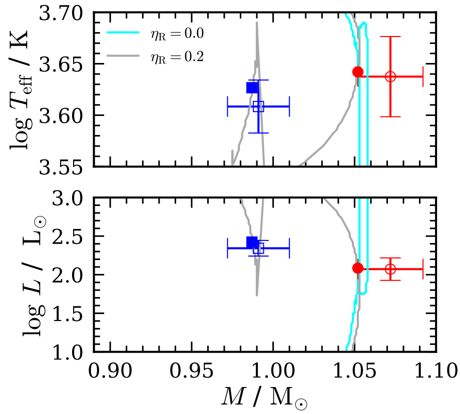

Fig. 2: The same as Fig. 1 but as a function of mass.

open symbols represent observational values. In both cases, a non-zero mass loss is necessary to fit the mass of both stars on a single isochrone.

OGLE-BLG-305487. For this system we achieved three solutions of similar quality with ages 7.32 – 10 Gyr and with the metallicity within 1-σ from the spectroscopic value. The primary (blue) component is at the stage of core helium burning, while the secondary (red) is on the RGB. Here we present the solution with the lowest χ^2.

In Fig. 2 it is visible that the isochrone with no mass-loss (cyan line) is not able to fit both stars simultaneously. A value of $\eta = 0.2$ (grey line) is sufficient to find a good solution.

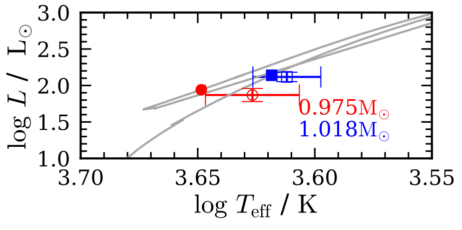

Fig. 3: Best solution for OGLE-BLG-112216 with metallicity [Fe/H] = 0.0, age log$t$ = 10.003 and χ^2 = 4.42.

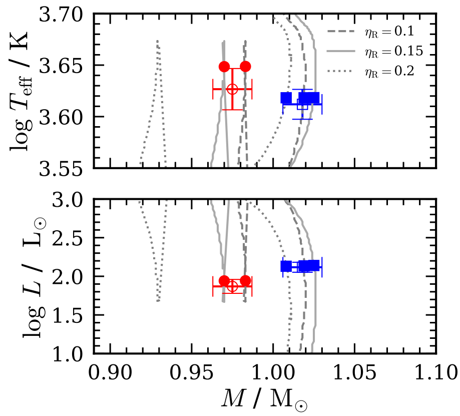

Fig. 4: The same as Fig. 3, but as a function of mass. Additionally, two isochrones with different mass-loss efficiencies are shown.

OGLE-BLG-116218. The only good solution, with age ∼ 10 Gyr, is found for a metallicity that is 2-σ away from the spectroscopic value. The primary star is ascending the RGB and the secondary is burning helium in the core. When the metallicity is kept within 1-σ error, the isochrones predict that the stars should be $\sim 500\,\mathrm{K}$ hotter. From Fig. 4 one may constrain mass-loss rate for the system, namely $\eta \leq 0.15$.

3 Conclusions

As Fig. 4 illustrates, the mass-loss efficiency affects the shape of the isochrones. The larger the mass-loss rate, the wider the shape of the isochrone (mass separation for different evolutionary stages) and the larger the mass ratio of the components that may be fitted with a single isochrone. Conversely, for evolved, post-MS, low-mass giants in eclipsing binary systems, the larger the mass ratio, the higher the mass-loss rate is required to fit the system to a single isochrone.

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