Volume Title
ASP Conference Series, Vol. **Volume Number**
Author

Formation of the Long-Period Eccentric Binary IP Eri

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Abstract. We present a formation channel that is able to reproduce the observational properties of the K0 + He white dwarf binary IP Eri, in particular its high eccentricity ($e \approx 0.25$). Our scheme invokes a tidally-enhanced wind loss mechanism on the red giant branch that can counteract the circularising effect of tides, thereby preserving or even increasing the eccentricity.

1. Introduction

IP Eri is a long period ($P_{\rm orb} \approx 1100$ d), significantly eccentric binary system, consisting of a Helium white dwarf (He-WD) and a K0IV companion situated at the base of the first red giant branch (RGB, Merle et al. 2014). The He-WD formed by the ejection of the progenitor's envelope as it ascended the RGB. However, the high eccentricity cannot be accounted for by canonical formation channels. Using our state-of-the-art binary evolution code BINSTAR (Siess et al. 2013, 2014), we investigate an alternative scenario which invokes a tidally-enhanced wind-loss mechanism.

2. The Companion Reinforced Attrition Process (CRAP)

Tout & Eggleton (1988) suggested that tidal interactions are responsible for stellar wind-loss enhancement, proposing a mass loss rate given by

$$\dot{M}_{\rm wind} = \dot{M}_{\rm Riemers}\left[1 + B_{\rm wind} \times \min\left(\frac{R_1}{R_{\rm L1}}, \frac{1}{2^6}\right)\right], \quad (1)$$

where $\dot{M}_{\rm Riemers}$ is the Riemers mass loss rate, R_1 and $R_{\rm L}$ are the giant's stellar and Roche lobe radius respectively, and a parameter $B_{\rm wind} \approx 10^4$.

Changes in the eccentricity, e, via tidal interactions of the ith star ($\dot{e}_{{\rm tide}i}$) are calculated using the formalism described by Zahn (2008), while the contribution from systemic wind losses, $\dot{e}_{\rm wind}$, is (see, e.g. Soker 2000)

$$\dot{e}_{\rm wind} = \frac{|\dot{M}_{1,\rm wind} + \dot{M}_{2,\rm wind}|}{M_1 + M_2}(e + \cos\nu). \quad (2)$$

Here, M_i is the ith star's mass, $\dot{M}_{i,\rm wind}$ is the wind loss rate from the ith star and ν is the true anomaly. The total rate of change of e is therefore

$$\dot{e} = \dot{e}_{\rm tide,1} + \dot{e}_{\rm tide,2} + \dot{e}_{\rm wind}. \quad (3)$$

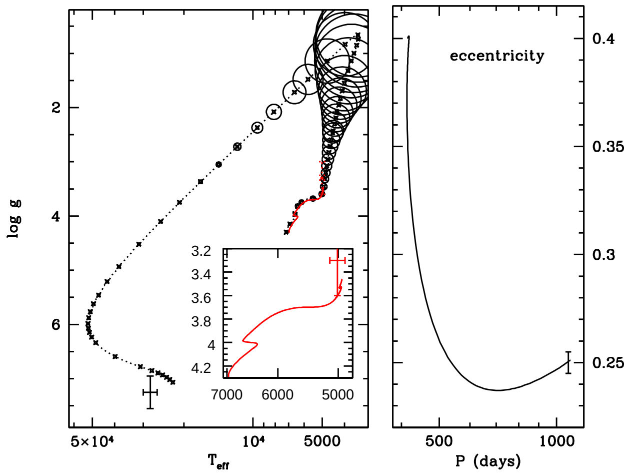

Figure 1. Evolution of different parameters for the model calculation (see text) that best reproduces the observed values of IP Eri: the left panel indicates the gravity ($\log g$) vs. $T_{\rm eff}$ (the WD is shown as the black cross, and the K0 star by the red cross, including the inset). The circle sizes are proportional to the radius of the mass-losing star. The right panel shows the eccentricity versus orbital period, where the vertical bar indicates the location of IP Eri.

3. Results

Using a binary model consisting of a primary and a secondary star with initial masses 1.5+1.45 $M_\odot$, we obtain a remarkable agreement with the observed stellar parameters (Fig. 1, left panel). Additionally, the observed location of IP Eri on the e-$P_{\rm orb}$ plane (right panel) can be fitted very well, taking an initial period and eccentricity of 415 d and $e = 0.4$, respectively, with a strong wind enhancement factor $B_{\rm wind} = 3.6 \times 10^4$.

Winds always act to increase the eccentricity (Eq. 2). If the mass loss rate is sufficiently enhanced via the CRAP, then we have $\dot{e}_{\rm wind} > |\dot{e}_{\rm tide,1} + \dot{e}_{\rm tide,2}|$, i.e. winds counteract the circularising impact of tides, and the eccentricity globally increases. Thus, CRAP is a promising mechanism to generate significant eccentricities observed in post-AGB stars or Ba stars.

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