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Mass-loss rate in EHB binary progenitors

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This study was undertaken to continue our research of assumed binary progenitors of Extreme Horizontal Branch stars (EHBs). We assumed that the progenitor system fills in its critical Roche lobe near the tip of the RGB. Here we discuss a simple power-law relation between the mass-loss rate and the Roche lobe radius.

Keywords: Binaries: close; Stars: horizontal-branch: evolution

1 Introduction

It is currently accepted that EHBs form due to mass loss on the RGB when the degenerate helium core loses almost all hydrogen convective envelope close to the RGB tip but the core goes on to ignite helium and may appear as sdB star. Most of EHBs seem to be components of binary systems with orbital periods $P_{\rm orb} \sim 0^{\rm d}.12$–$27^{\rm d}$ in pair with a MS low mass companion (Maxted *et al.* 2001; Morales-Rueda *et al.* 2003). In our previous works (Pustynski & Pustylnik 2006, 2007) we developed a model of an EHB as a binary system where the donor loses mass after having filled in its Roche lobe during the nuclear evolution phase. We computed period change caused by mass loss, mass interchange and additional angular moment loss $K = d(\log J)/dt$ due to matter corotation at the Alfven radius:

$$\frac{\dot{P}}{P} = -2\frac{\dot{M}}{M} + 3\frac{\dot{M}_1\,(M_2 - M_1)}{M_1 M_2} + 3K,$$

where M_1, M_2 are correspondingly the masses of the donor and the accretor, $M = M_1 + M_2$ is the total mass of the system (Tout & Hall 1991). Mass loss rate is linked to the Roche lobe overflow extent $\Delta R = R_1 - R_{\rm L}$ as $dM/dt = (M_1/t_{\rm HD})(\Delta R/R_{\rm L})^3$, $t_{\rm HD}$ being the hydrodynamic timescale and $R_{\rm L}$ being the radius of the Roche lobe. Mass accretion rate is set by the value of mass transfer effectiveness parameter dM_1/dM_2. The results of our modeling are published in Pustynski & Pustylnik (2006, 2007).

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2 Mass-loss rate empirical dependence on the radius of the Roche lobe

We found out a simple empirical formula for the mass-loss rate as function of the Roche lobe radius. It was discovered that in a wide range of parameters the following analytical expression takes place:

$$\dot{M}_1 = C R_{\rm L}^b. \tag{1}$$

The factor C depends on the system's parameters, the value of the exponent is $b \approx -2.8$. Under certain conditions this relation may appear *twice* during the orbital evolution. When the donor fills in its Roche lobe and the mass transfer starts, the Roche lobe initially reacts to the mass-loss by expansion. At this phase the relation (1) holds. Orbital evolution stops if the period becomes very shot. However, if the semimajor is long enough, the evolution continues. At this stage the accretor already has gained a considerable portion of the mass, the mass-ratio has increased, and the following mass transfer leads to progressive contraction of the $R_{\rm L}$. The law (1) also holds here, but with higher value of the factor C.

3 Applicability limits

The empirical expression (1) holds in a wide range of the system's parameters. However, certain limits for its fulfillment exist. The initial mass of the accreting star is limited to $M_2 \sim 1.5 M_{\rm sol}$. The donor's mass is also important. Larger M_1 enables Roche lobe overflow at the stage of its nuclear evolution even in unsuitable conditions (for instance, no angular momentum loss due corotation). The duration of the phase at which the relation (1) holds also depends on the effectiveness of the mass transfer. The higher fraction of the donor's mass is accreted by the secondary, the more effectively the orbit shrinks and the more stable and lengthy is the mass transfer. Larger Alfven corotation radii also benefit to effective shrinkage of the orbit. Larger initial separations benefit to fulfillment of the law (1), too.

4 Conclusions

The empirical law (1) for the mass-loss rate in assumed binary precursors of EHBs was found. The law holds in the orbital shrinkage phase induced by mass transfer. The initial mass of the accretor should not exceed $\sim 1.5 M_{\rm sol}$. Larger initial mass rates M_1/M_2, larger Alfven radii and larger fractions of accreted mass favor the fulfillment of (1). This law holds for a wide range of the mass-loss rates, $10^{-6} - 10^{-2} M_{\rm sol}$/yr. Under certain conditions, the fulfillment of (1) may be twofold: the binary follows this trend once on the stage of the R_L expansion, and thereafter, with a higher C, during the $R_{\rm L}$ contraction. *sse.f* code (Hurley *et al.* 2000) and the set of models (Schaller *et al.* 1992) was used to compute nuclear evolution tracks of the donor.

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