Applying Wind Roche-Lobe Overflow in Binary Evolution Using MESA and POSYDON

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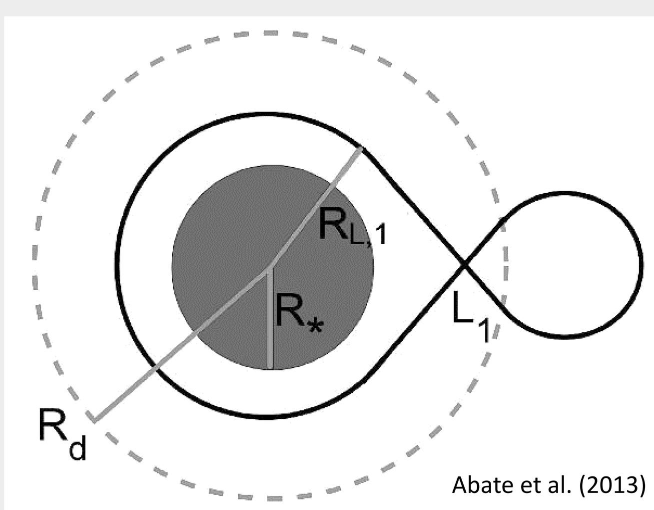
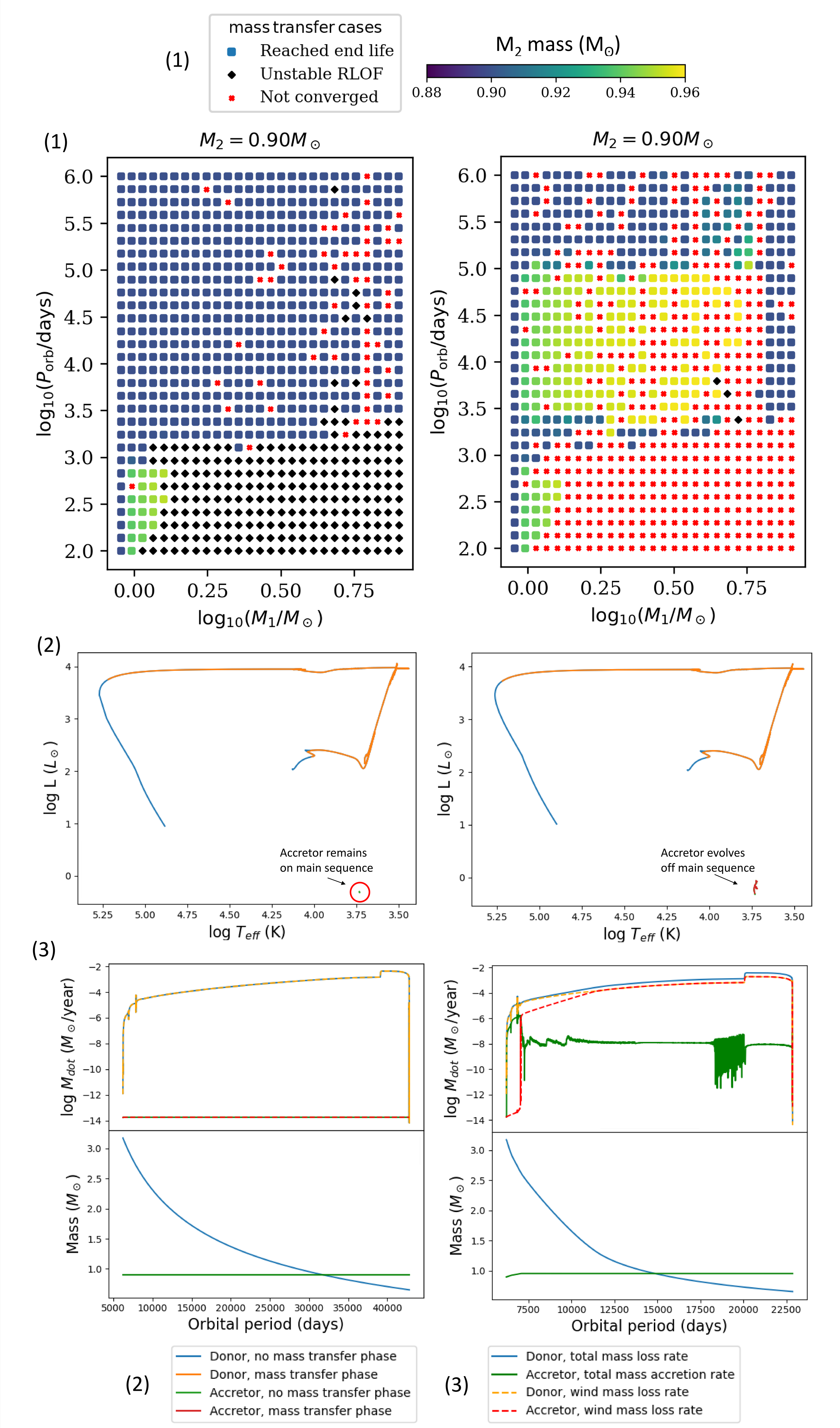
Introduction

Wind Roche-Lobe Overflow (WRLOF) is a mechanism of mass transfer in a binary system in which the stellar wind of the donor star is contained within the wind acceleration zone radius R_d. When $R_d \geq R_{L,1}$, the wind becomes focused in the direction of the secondary star, and mass is accreted onto the secondary star through the inner Lagrangian point where the Roche lobes of the two stars meet. This occurs in the case of slow and dense winds, which are characteristic of asymptotic giant branch (AGB) star. Abate et al. (2013) showed that WRLOF can account for the discrepancy between the observed population of carbon-enhanced metal-poor (CEMP) stars and the predictions of standard stellar models.



Methods

We follow the analysis by using Modules for Experiments in Stellar Astrophysics (MESA) and POpulation SYnthesis with Detailed binary-evolution simulatiONs (POSYDON) to evolve a 30x10x30 grid of binary systems. MESA performs 1-dimensional simulations to evolve two stars of specified mass and metallicity in a binary system with a given initial orbital period. POSYDON is used to evolve a grid of MESA binaries. We used a grid with M_1 = [0.7, 8.0] $M_{\odot}$, M_2 = [0.1, 0.9] $M_{\odot}$, and $P_{orbital}$ = [10^2, 10^6] days, solar metallicity and assumed a circular orbit. We first calculate R_d, then model the WRLOF accretion efficiency, the ratio between mass accreted and mass lost from the system, β_{acc}.



$$R_{\rm d} = \frac{1}{2} R_* \left(\frac{T_{\rm eff}}{T_{\rm cond}} \right)^{2.5}$$

$$\beta_{\rm acc} = \min \left\{ \frac{25}{9} q^2 \left[c_1 x^2 + c_2 x + c_3 \right], \beta_{\rm acc,max} \right\}$$

We follow the methods of Abate et al. (2013) to use $c_1 = -0.284$, $c_2 = 0.918$, and $c_3 = -0.234$ and implement a dependency on the mass ratio $q = M_2/M_1$ and set a limit on β_{acc} where $\beta_{acc,max}$ = 0.5 according to calculations. The ratio of the wind accretion zone radius to Roche lobe radius is $x = R_d/R_{L,1}$.

Results

We found that when WRLOF was used (right), the final mass of the accretor increased by approximately 0.02-0.06 $M_{\odot}$ in the region $M_1 < 5.6\ M_{\odot}$ and $1500 < P_{orbital} < 10^5$ days. Using a standard binary model (left), the mass of the accretor remained constant except in the region where regular Roche lobe overflow has occurred in both grids. The plots show the HR diagram and the mass accretion rate and mass as a function of the orbital period in days for a binary with initial $M_1 = 3.2\ M_{\odot}$, $M_2 = 0.9\ M_{\odot}$, and $P_{orbital}$ = 6200 days. The accretor is shown to gain mass, begin to have strong stellar winds, and start evolving off the main sequence.

Future Work

We have shown that the application of WRLOF has an effect on the evolution of the accretor star. To apply this analysis to potential progenitors of CEMP stars, we will repeat the grids with lower metallicity (0.01 $Z_{\odot}$). We will also allow the donor star to gain mass from the accretor's wind. We will also consider the effect of WRLOF on parameters other than M_2, such as orbital period and spin.

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