Massive Stars Near and Far
Proceedings IAU Symposium No. 361, 2024
J. Mackey, J. S. Vink, & N. St-Louis, eds.
doi:10.1017/S1743921322002708

Contact Tracing of Massive Binary Stars

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Abstract. Stellar mergers produce more massive, rejuvenated (strongly magnetic) stars, with potentially peculiar properties, and can be detected as luminous red novae. Using a grid of detailed 1D binary evolution models, we aim to determine which binary systems are likely to merge and at what evolutionary stage. This will tell us more about the merger products, and might help us understand some of the trends found in observed single- and multiple-star populations.

Keywords. binaries: general, binaries: evolution

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1. Introduction

A significant fraction of massive stars live in binaries (Sana et al. 2012; De Marco & Izzard 2017). When binary components merge as "living" stars they can be observed as luminous red novae (Nandez et al. 2014) and produce more massive, rejuvenated (magnetic) stars (Schneider et al. 2019). Knowing which binaries are likely to merge might provide explanations for some open question regarding multiple main sequences (Wang et al. 2022) and over-massive main sequence (MS) stars in stellar clusters (Schneider et al. 2016). Furthermore, around 10% of early-type massive stars are expected to be merger products (de Mink et al. 2014) and a quarter of massive O-type stars is expected to merge during their lifetime (Sana et al. 2012). The actual merger event between two stars is usually preceded by a contact phase, where both stars overfill their respective Roche lobes and form a "peanut" shaped star. Whether such configurations always lead to an actual merger is a question on its own.

We aim to constrain the progenitor parameter space of stellar mergers, characterise their structure at the point of contact, and describe the mechanisms leading to contact/merging. To this end we compute a grid of ~ 6000 detailed binary evolution models using the stellar structure and evolution code `MESA` (Paxton et al. 2019, and references therein). In this grid, component masses range from 0.5 to $20\,\mathrm{M}_\odot$, initial mass ratios $q_\mathrm{i} = M_2/M_1$ from 0.1 to 0.97 , and initial separations a_i from $\sim 1\,\mathrm{R}_\odot$ to $\sim 10^4\,\mathrm{R}_\odot$.

2. Results & Conclusions

In our binary grid, we find a variety of contact/common envelope (CE) configurations that might eventually lead to stellar mergers. Specifically at an initial primary mass of $20\,\mathrm{M}_\odot$, shown in Fig. 1, we see MS contact phases for all initial mass ratios, and a large region of the parameter space at $q_\mathrm{i} > 0.5$ in which stripped stars, that avoid contact, are produced. Furthermore, for this primary mass, case C mass transfer seems to be stable, which is most likely related to strong wind mass loss during the red supergiant phase.

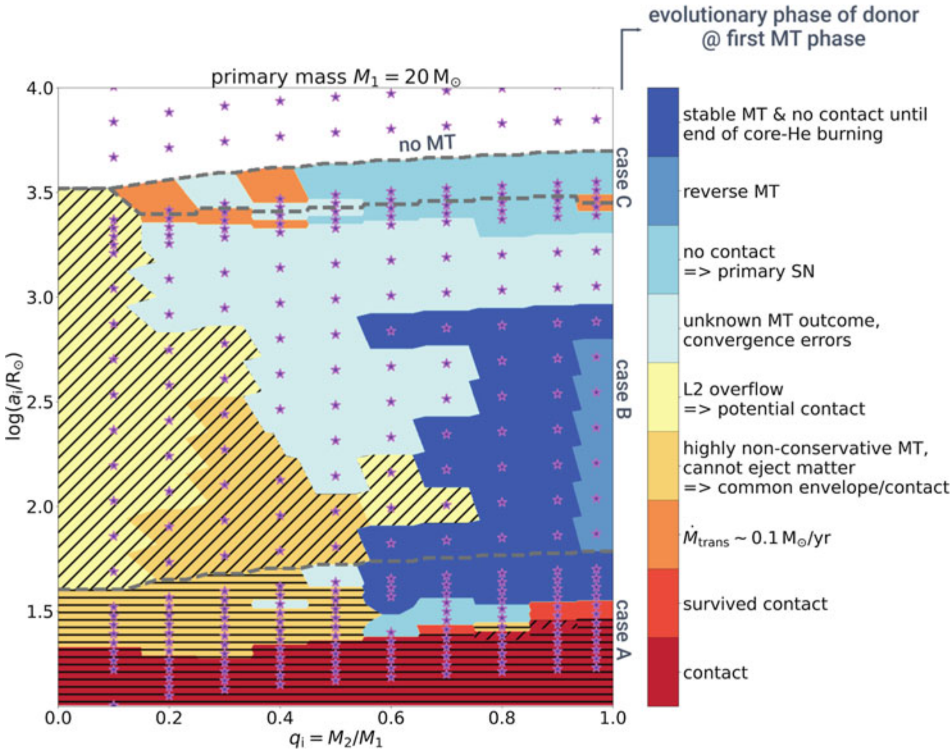

Figure 1. Overview of binary models with initial primary masses of $20\,M_\odot$. Each purple star corresponds to a model. Colours in between models are determined by their nearest neighbour. The evolutionary stages refer to the following; case A: main sequence star, case B: star before core-He exhaustion, and case C: star after core-He exhaustion. Horizontal and diagonal hatching indicate case A + case A and case B + case A contact/common envelope phases respectively.

Lastly, for twin systems ($q_i = 0.97$) with a post-MS primary star, a phase of reverse mass transfer from the secondary occurs, since at mass ratios close to 1, the latter is able to catch up with the primary in terms of evolutionary stage.

Based on the properties of the stars at contact and/or the mechanisms that lead to contact, we can now make predictions for which systems will likely merge. Furthermore we will be able to compare this over a range of initial primary masses.

Lastly, the scope of this grid is not limited to contact tracing alone and can be used to study for example X-ray binaries and Be-type stars.

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