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ABSTRACT

Common phases of mass transfer in stellar binaries are case A (during the donor's main sequence) and case B (after the donor's main sequence but before helium core depletion). For most masses, radii significantly grow after the main sequence, making case B more common. However, very massive stars ($\gtrsim 30\,M_{\odot}$) may undergo significant expansion already during the main sequence increasing the probability of case A mass transfer, but this depends on uncertain stellar physics. For observationally-informed convective boundary mixing, case A mass transfer dominates for donor masses $\gtrsim 75\,M_{\odot}$. This is not the case without convective boundary mixing or with the values assumed in rapid binary population synthesis. Therfore, case A mass transfer may be more dominant than commonly assumed, with potential impact on rates of Wolf-Rayet+O-type binaries, X-ray binaries, and gravitational wave progenitors.

1. MASS TRANSFER BETWEEN VERY MASSIVE STARS

Binary stars with a sufficiently small orbital separation undergo a mass transfer phase in which one donor star transfers mass to an accretor star. As the stellar main sequence progresses, the donor star's radius expands until it exceeds its Roche Lobe, allowing for the surface to become gravitationally bound to the accretor, which triggers a mass transfer phase. For very massive stars ($> 30M_{\odot}$), this occurs in two cases. Case A mass transfer occurs while the donor star is in the main sequence, while case B mass transfer occurs while the donor star is burning helium in its core [?]. In both cases, the accretor gains the mass lost by the donor until the masses are equal **[no, typically until m2=1.1*(m2 before RLOF), see ?]**, or the mass gainer cannot accrete due to increased rotational velocity caused by angular momentum conservation. The increase in total mass of the accretor, typically a main sequence star during RLOF, causes by the virial theorem an increase in its central temperature and thus in the extent of core-convection resulting in access to more nuclear fuel and elongation of the lifespan of the star (**?** but see also **?**) and potentially modifying its internal structure and future evolution (**?????**, e.g.,).

In nature, case B mass transfer is observed more often than case A mass transer –CITE–. This result is expected from theory; stars in most mass ranges expand most prominently post-main sequence in the Hertzsprung gap (**?**). However, very massive stars undergo a drastic expansion in radius during their main sequence. (e.g., **?**). This increases the relative abundance of instances of case A mass transfer (**?**), which has significant implications on the evolution of X-ray binary systems and gravitational wave progenitors.

[probably already from the "introduction" we need to say why we care, why would readers care? binary interactions are crucial to the formation of GW sources, and in particular for BBH stable mass transfer may dominate ??]

The relative proportion of case A mass transfer in comparison to case B mass transfer scales with mass of the donor star. This is expected, as larger stars see greater rates of radial expansion during the main sequence. This has a significant side effect for stars with($\gtrsim 75M_{\odot}$), case A mass transfer is expected to explain in all possible mass transfer processes. For stars of lesser mass, the thermal expansion of the star at the end of the main sequence expands the star beyond its maximum radius during the main sequence. However, for stars in this mass range, the radius expands drastically during the main sequence, such that the maximum radius during the main sequence and helium core burning phase are similar.

[maybe here you need to explain a bit what we do in this research note before jumping in the results!] ■ **[Describe the models you run (which input physics, which code) with and without overshooting, and the pols+98 models (just reference)]** ■

In order to demonstrate the change in ratio between instances of case A and case B mass transfer, we mod-

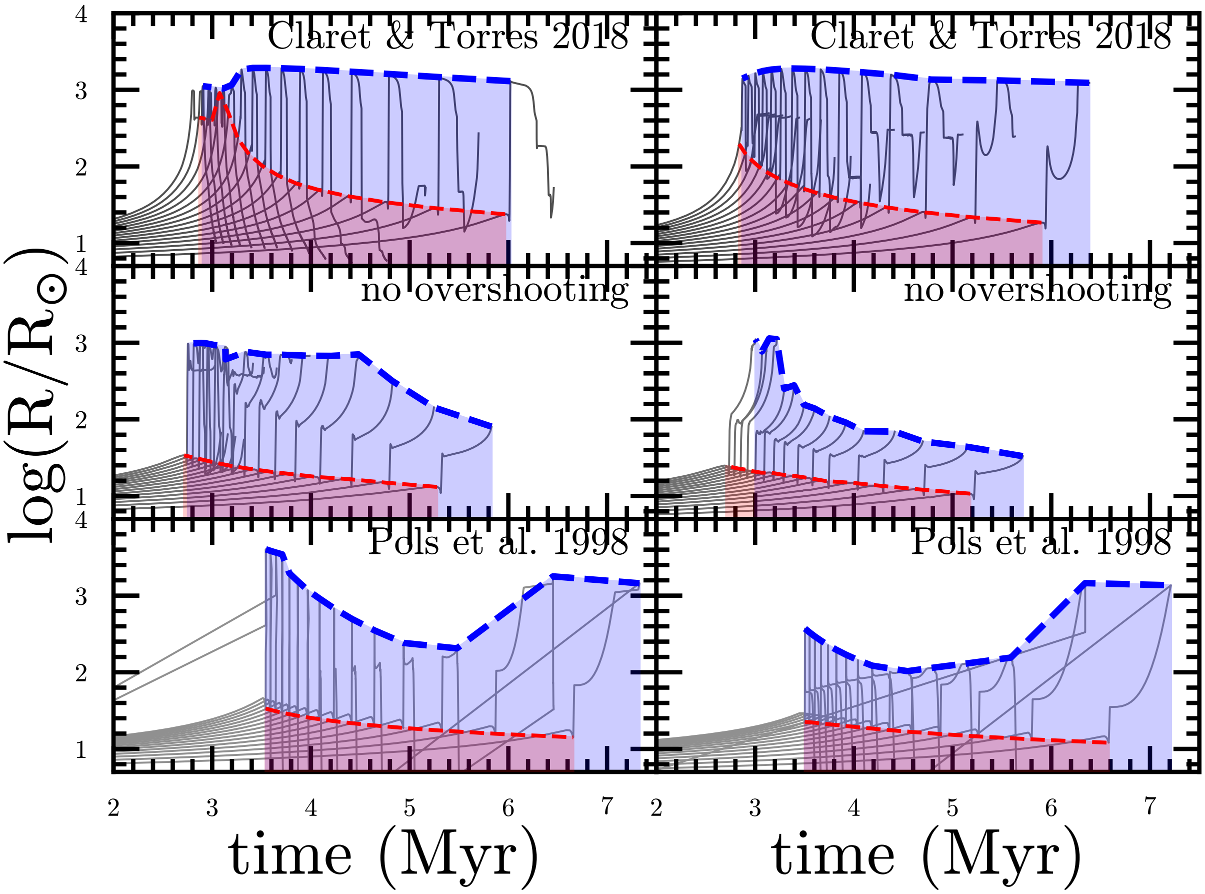

Figure 1. Each panel contain 15 stellar models spanning from a 30 $M_\odot$ star on the right to a 100 $M_\odot$ with intervals of width 5 $M_\odot$. The top panels plot models that feature broad convective boundary mixing, the middle panels plot models that do not feature overshooting, and the bottom panels plot models generated from COMPAS using data from **?**. The left panels have a metallicity $Z = 0.001$ and the right panels have a metallicity $Z = 0.0001$

elled 60 stars while varying mass ($30 - 100M_\odot$; of $5M_\odot$ intervals), metallicity ($Z = 0.001, 0.001$) and model of boundary mixing. The top panels of FIGURE are determined from the exponential boundary mixing model from **?** fit to the expected values from the step boundary mixing model from **?**. This is configured in **?**. This "broad convective boundary mixing" model is compared to a model that does not consider boundary mixing. Both models were instructed to end before the carbon burning phase could commence.

In addition, 30 models generated using the rapid population synthesis code COMPAS using models generated from data gathered in **?** are plotted in the bottom panels of FIGURE. These models match the metallicities of the stellar evolution models in the other panels. These models include data until core collapse.

Stellar radius is strongly dependent on many parameters. This research note specifically consideres different regimes of convective boundary mixing

Convective boundary mixing has a strong effect on stellar radius **??**, which determines Roche lobe overflow. The vast differences in the ratio of expected abundances of case A and case B mass transfer are consequentially expected. The broad convective boundary mixing models limit case B mass transfer for stars of mass ($\gtrsim 75M_\odot$) . In contrast, omitting convective boundary mixing allows case B mass transfer to occur at a significant scale in all mass regimes such that $M < 100_\odot$. HOW TO CITE Brott's paper suggests broad convective boundary mixing models currently provide the best approximation for observed characteristics of massive stars. As a result, many rapid population synthesis softwares and other stellar mass transfer models may underestimate the abundance of case A mass transfer procedures.

Binary interactions are crucial to the formation of X-ray binaries and gravitational waves sources. in particular for BBH stable mass transfer may dominate **??**