

## Rotational properties and stellar wind mass-loss rate in very massive close binary systems - possible progenitors of gravitational wave sources?

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In this study, we model very massive close binary systems at solar metallicity using the MESA (Modules for Experiments in Stellar Astrophysics) numerical code. We examine systems with initial orbital periods ranging from 3 to 10 days, tracking the evolution of both stellar components, with masses above 100 solar masses, from the Zero-Age Main Sequence (ZAMS) to the formation of their carbon-oxygen (CO) cores. Our simulations indicate that extreme stellar wind mass loss dominates the evolution, preventing mass transfer between the stars. Furthermore, tidal synchronization with the binary orbit causes fast rotation of stellar components and additionally enhances this mass loss.

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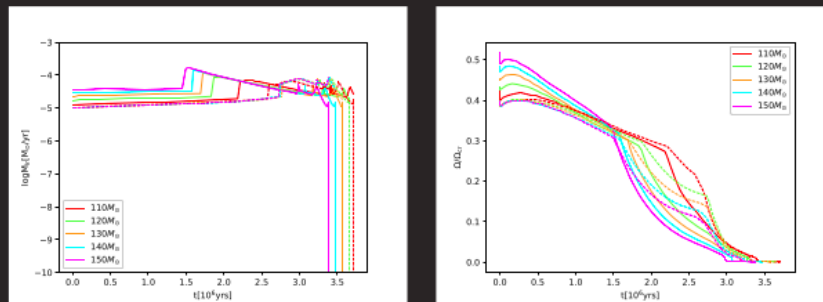


Figure 1:

Left panel: Stellar wind mass-loss rate for primary (solid line) and secondary stars (dashed line) as a function of time in very massive binary systems. Initial masses are between 110 Ms and 190 Ms for the primary and fixed at 100 Ms for secondary stars. The initial orbital period is 3 days. A step towards higher values of mass loss is due to the transition to the Wolf-Rayet stellar wind.

Right panel: Ratio of angular velocity to critical angular velocity as a function of time for the same selection of very massive binary systems.

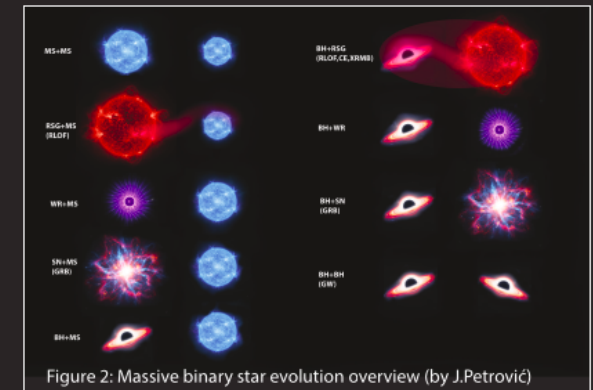


Figure 2: Massive binary star evolution overview (by J.Petrović)

We present binary evolution models with solar metallicity, component masses from 100 to 190 solar masses and the initial orbital period between 3 and 10 days. The evolution is calculated until carbon-oxygen core formation in both stars. Shellular rotation was implemented according to Meynet & Maeder (1997). Stellar wind mass loss was included according to Vink et al. (2001) and Nugis and Lamers (2000). The rotationally induced mass loss is included as proposed in Langer (1998).

Due to the synchronization of stellar rotation with the orbital period, all stars exhibit fast rotation at the Zero-Age Main Sequence (ZAMS). This rotational velocity decreases throughout their evolution as the stars undergo severe mass depletion from very high stellar wind rates. Because there is no mass transfer from the primary to the secondary stars, the secondary stars do not experience accretion-driven spin-up. The most massive stars start with the highest rotational velocities, but they also lose angular momentum the fastest. The surface rotational velocities of the presented systems at the ZAMS are in the range between 250 km/s and 340 km/s for primary stars, while the secondary stars maintain a surface rotational velocity of approximately 240 km/s across all systems.

**As a consequence of this intense mass loss, increasing the initial stellar mass does not yield significantly more massive remnants; instead, all resulting black holes (BHs) fall within a narrow mass range of 7 to 14 solar masses. Furthermore, the significant orbital widening caused by this mass loss ensures that none of the resulting double BH systems will merge within a Hubble time. Rather than serving as progenitors for gravitational-wave sources indicated by the Virgo-LIGO-KAGRA observatories, these massive binaries ultimately evolve into wide black hole binaries.**

### Literature:

Paxton B., et al., 2011, ApJS, 192, 3; 2013, ApJS, 208, 4; ApJS, 220, 15; ApJS, 234, 34  
Petrovic J., 2022, SerAJ, 205, 45  
Vink J. S., de Koter A., Lamers H. J. G. L. M., 2001, A&A, 369, 574  
Nugis T., Lamers H. J. G. L. M., 2000, A&A, 360, 227  
Meynet, G., Maeder, A., 1997, A&A, 321, 465  
Langer, N., 1998, A&A, 329, 521

