

Influence of binary mass-transfer on pre-supernova stellar structures

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Key physics governing supernova (SN) explosions

There are two key ingredients that determine how stars explode (or not)

1. Supernova explosion physics:

- Iron core collapse? Electron capture supernova?
- Neutrino driven explosion: location of gain radius, fallback, ...
- Other type of explosion? Engine? ...

2. Supernova progenitor evolution:

- Convective (core/shell) under-/overshooting
- Stellar wind mass loss (→ metallicity dependent)
- **Binary mass transfer**
- Other mixing processes, rotation, magnetic fields, ...
→ Determine pre-SN evolution

Next, we discuss how binary mass transfer and particularly envelope stripping affect pre-SN stellar structures and hence SN explosion properties

Binary stars – why do we have to care about them?

Sana et al. 2012: >70% of all SNe from O stars affected by past binary mass transfer

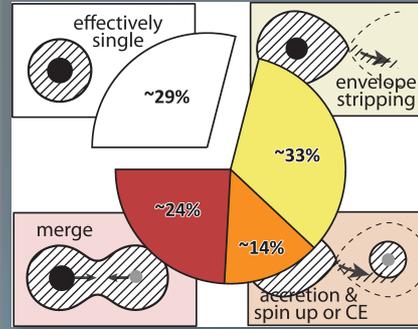


Figure courtesy of Selma de Mink

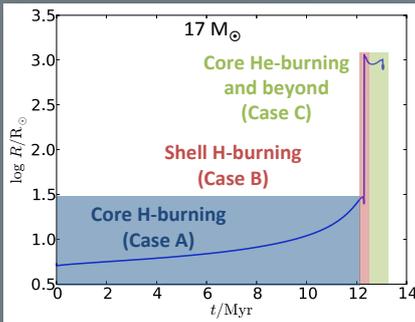
Here: envelope stripping



Highly relevant for (first) neutron stars (NSs) and black holes (BHs) in compact binaries
→ All such progenitors stripped off their envelope
→ E.g. impacts NS and BH mass distributions

Envelope stripping

Consequences of envelope stripping for evolution of stars depend on **when** mass is lost:

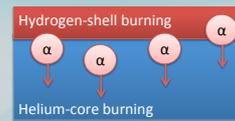


- Case C:** Core structure mostly established but no hydrogen envelope
- Case B:** Stars evolve without hydrogen envelope
- Case A:** Transform star into lower mass equivalent (if star adjusts to new mass)

In all cases: Large consequences for supernova lightcurves
→ SN from, e.g., Wolf-Rayet progenitor leading to Type Ib/c and IIb supernovae

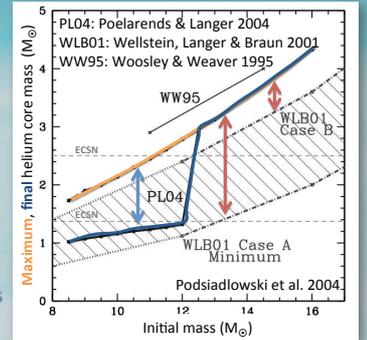
Envelope stripping

1. No hydrogen-shell burning that adds helium to layers beneath



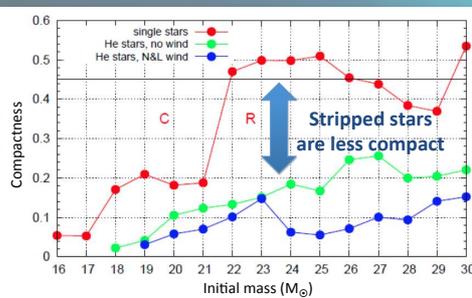
2. No 2nd dredge-up in AGB stars that can otherwise reduce helium core masses (e.g. Iben 1974)

3. ¹²C(α, γ)¹⁶O destroys carbon during core helium burning, lowering final C/O ratio → No H shell: more C and larger C/O ratio, affecting strength of subsequent carbon and other burning phases (e.g. Timmes et al. 1996, Brown et al. 1996/2001, Fryer et al. 2001, Podsiadlowski et al. 2004, ...)

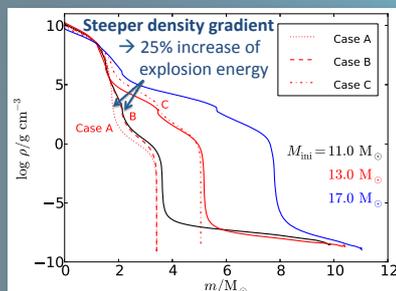
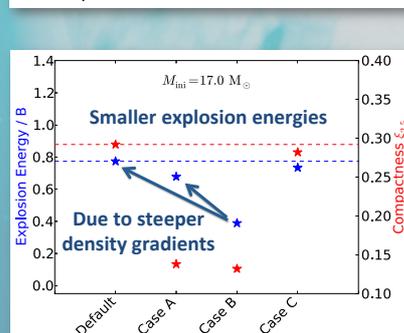
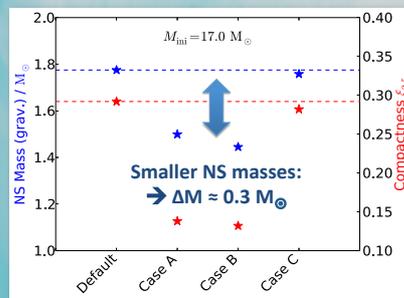


What are the consequences of envelope stripping?

We couple our stellar models to the parametric SN approach of Müller et al. 2016 to explore the consequence of envelope stripping for SN properties such as the compact remnant masses, explosion energies etc.



Petermann, Langer and Podsiadlowski (priv. comm.)



Summary

More than 70% of all supernovae from products of binary mass transfer

About 1/3 of all massive stars are stripped-off their envelopes

→ Affects stellar cores and thereby supernova properties (and of course also stellar envelopes and hence SN lightcurves)
→ Outcome depends on when star loses its envelope

Generally, envelope stripping results in:

- Less compact cores → easier to explode
- Steeper density gradients
- Smaller NS masses
- Smaller explosion energies

References

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