Binary progenitor models of type IIb supernovae

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Massive stars that lose their hydrogen-rich envelope down to a few tenths of a solar mass explode as extended type IIb supernovae, an intriguing subtype that links the hydrogen-rich type II supernovae with the hydrogen-poor type Ib and Ic. The progenitors may be very massive single stars that lose their envelope due to their stellar wind, but mass stripping due to interaction with a companion star in a binary system is currently considered to be the dominant formation channel.

Anticipating the upcoming automated transient surveys, we computed an extensive grid of binary models with the Eggleton binary evolution code. We identify the limited range of initial orbital periods and mass ratios required to produce type IIb binary progenitors. The rate we predict from our standard models, which assume conservative mass transfer, is about six times smaller than the current rate indicated by observations. It is larger but still comparable to the rate expected from massive single stars. We evaluate extensively the effect of various assumptions such as the adopted accretion efficiency, the binary fraction and distributions for the initial binary parameters. To recover the observed rate we must generously allow for uncertainties and consider low accretion efficiencies in combination with limited angular momentum loss from the system.

Motivated by the claims of detection and non-detection of companions for a few IIb supernovae, we investigate the properties of the secondary star at the moment of explosion. We identify three cases: (1) the companion is predicted to appear as a hot O star in about 90% of the cases, as a result of mass accretion during its main sequence evolution, (2) the companion becomes an over-luminous B star in about 3% of the cases, if mass accretion occurred while crossing the Hertzsprung gap or (3) in systems with very similar initial masses the companion will appear as a K supergiant. The second case, which applies to the well-studied case of SN 1993J and possibly to SN 2001ig, is the least common case and requires that the companion very efficiently accretes the transferred material -- in contrast to what is required to recover the overall IIb rate. We note that relative rates quoted above depend on the assumed efficiency of semi-convective mixing: for inefficient semi-convection the presence of blue supergiant companions is expected to be more common, occurring in up to about 40% of the cases.

Our study demonstrates that type IIb supernovae have the potential to teach us about the physics of binary interaction and about stellar processes such as internal mixing and possibly stellar-wind mass loss. The fast increasing number of type IIb detections from automated surveys may lead to more solid constraints on these model uncertainties in the near future.

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