Massive star evolution in close binaries:conditions for homogeneous chemical evolution

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We investigate the impact of tidal interactions, before any mass transfer, on various properties of the stellar models. We study the conditions for obtaining homogeneous evolution triggered by tidal interactions, and for avoiding any Roche lobe overflow during the Main-Sequence phase. By homogeneous evolution, we mean stars evolving with a nearly uniform chemical composition from the center to the surface. We consider the case of rotating stars computed with a strong coupling mediated by an interior magnetic field. Models with initial masses between 15 and 60 M$_\odot$, for metallicities between 0.002 and 0.014, with initial rotation equal to 30\% and 66\% the critical rotation on the ZAMS are computed for single stars and for stars in close binary systems. Close binary systems with initial orbital periods equal to 1.4, 1.6 and 1.8 days and a mass ratio equal to 3/2 are considered. In models without any tidal interaction (single stars and wide binaries), homogeneous evolution in solid body rotating models is obtained when two conditions are realized: the initial rotation must be high enough, the loss of angular momentum by stellar winds should be modest. This last point favors metal-poor fast rotating stars. In models with tidal interactions, homogeneous evolution is obtained when rotation imposed by synchronization is high enough (typically a time-averaged surface velocities during the Main-Sequence phase above 250 km s^{-1}), whatever the mass losses. We give plots indicating for which masses of the primary and for which initial periods, the conditions for the homogenous evolution and for the avoidance of the Roche lobe overflow are met, this for different initial metallicities and rotations. In close binaries, mixing is stronger at higher than at lower metallicities. Homogeneous evolution is thus favored at higher metallicities. Roche lobe overflow avoidance is favored at lower metallicities due to the fact that stars with less metals remain more compact. We study also the impact of different processes for the angular momentum transport on the surface abundances and velocities in single and close binaries. In models where strong internal coupling is assumed, strong surface enrichments are always associated to high surface velocities in binary or single star models. In contrast, models computed with mild coupling may produce strong surface enrichments associated to low surface velocities. This observable difference can be used to probe different models for the transport of the angular momentum in stars. Homogeneous evolution is more easily obtained in models (with or without tidal interactions) with solid body rotation. Close binary models may be of interest for explaining homogeneous massive stars, fast rotating Wolf-Rayet stars, and progenitors of long soft gamma ray bursts, even at high metallicities.

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