Exploring massive stars advanced evolution: The impact of new nuclear reactions rates

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Nuclear reactions involving ^{12}C and ^{16}O are key to compute the energy production and chemical evolution of massive stars during their advanced burning phases. These reactions shape the stellar structure, the evolution up to the pre-supernova stage and, ultimately the nature of the compact remnant.

We explored the impact of new nuclear reaction rates from both experimental and theoretical studies for $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$, $^{12}\mathrm{C} +^{12} \mathrm{C}$, $^{12}\mathrm{C} +^{16} \mathrm{O}$ and $^{16}\mathrm{O} +^{16} \mathrm{O}$ reactions along the advanced evolution of massive stars, and we investigate the consequences for the stellar fate. Using the stellar evolution code GENEC, we computed non-rotating and rotating models of massive stars for three masses at solar metallicity. We find that the variation in nuclear rates modify the $^{12}\mathrm{C}/^{16}\mathrm{O}$ ratio at He-exhaustion, the C-, Ne-, and O-burning lifetimes, the ignition conditions, and the chemical structure. These changes, in turn, influence the compactness and type of remnant formed at the end of stellar life, highly sensitive to the amount of ^{12}C and CO core mass.

Our results highlight that access to new and accurate determinations of reaction rates can significantly affect key aspects of massive stars evolution, from stellar burning lifetimes to nucleosynthesis and stellar fate. These effects accumulate over time and must be accounted for to improve predictions of stellar evolution and supernova progenitor properties (Dumont et al. submitted). Finally, we discuss how the impact of different approaches used to describe rotation (and the resulting angular momentum and chemical transports) in our models may affect these outcomes and how their cumulative effect along evolution can further shape the evolutionary outcomes of massive stars (Dumont et al. in prep.).