The effect of $^{12}C + ^{12}C$ rate uncertainties on the evolution and nucleosynthesis of massive stars

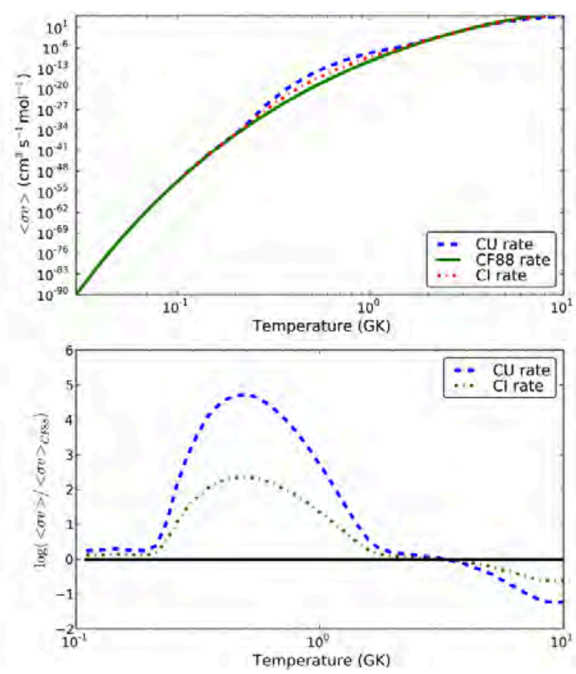

Fig 1 - Top panel: Maxwellian-averaged cross-sections for $^{12}C + ^{12}C$ rates used in this study. The three rates are the Caughlan & Fowler (1988) 'standard' rate (ST), an upper limit rate (CU) and an intermediate rate (CI). The CI rate is a geometric mean of the ST and CU rates. Bottom panel: The Maxwellian-averaged cross-sections relative to the ST rate.

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Over the last forty years, the $^{12}C + ^{12}C$ fusion reaction has been the subject of considerable experimental efforts to constrain uncertainties at temperatures relevant for stellar nucleosynthesis. Recent studies have indicated that the reaction rate may be higher than that currently used in stellar models. In order to investigate the effect of an enhanced carbon burning rate on massive star structure and nucleosynthesis, new stellar evolution models and their yields are presented exploring the impact of three different $^{12}C + ^{12}C$ reaction rates. Non-rotating stellar models considering five different initial masses, 15, 20, 25, 32 and 60$M_\odot$, at solar metallicity, were generated using the Geneva Stellar Evolution Code (GENEC) and were later post-processed with the NuGrid Multi-zone Post-Processing Network tool (MPPNP). A dynamic nuclear reaction network of ~1100 isotopes was used to track the s-process nucleosynthesis. An enhanced $^{12}C + ^{12}C$ reaction rate causes core carbon burning to be ignited more promptly and at lower temperature. This reduces the neutrino losses, which increases the core carbon burning lifetime.

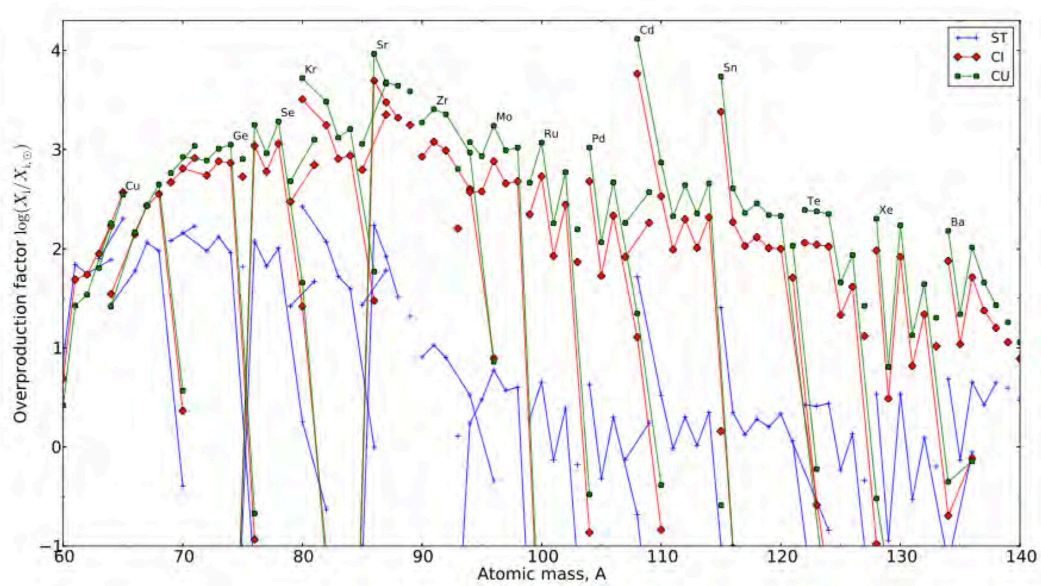

Fig. 2 - Central overproduction factors for most stable isotopes at the end of central carbon burning for the 15$M_\odot$ models. The plot shows a significant increase in nucleosynthesis of isotopes between $60 < A < 140$ in the CI and CU models, which is beyond the Sr-Y-Zr peak at an atomic mass ≈ 90.