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Carbon Burning in Massive Stars

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Carbon burning marks the ignition of the third nuclear fuel supply after H- and He-burning in the evolution of massive stars. Since the stellar core temperature is strongly correlated with the stellar mass, a minimum mass is required for carbon ignition. This critical mass limit, common referred to as M_{up}, depends on the reaction rate of the carbon fusion reactions. This parameter determines the upper limit for carbon-oxygen white dwarf progenitors and the lower limit for core collapse supernovae. Consequently, the expected number of CO and ONeMg white dwarfs in a given stellar population and, thus, the rate of type Ia supernovae as well as the number of type II supernova events depend on the carbon fusion reaction rates.
Current estimates of these reaction rates at astrophysical energies rely on extrapolations from higher energy data. Low energy studies of $^{12}C+^{12}C$ reactions have focused either on charged particle or on γ-ray spectroscopy. Charged particle spectroscopy has the advantage that the total fusion cross section can in principle be measured, while γ-ray spectroscopy (and γ-particle coincidences) cannot account for direct transitions to the ground state of the residual nucleus. However, the condition of being a total cross section measurement is not fulfilled in practice in the case of the particle spectroscopy due to finite energy resolution and low-energy detection limits.
Recently, the Trojan Horse Method (THM) has been exploited to determine the $^{12}C+^{12}C$ cross section over the entire energy range of the Gamow window. Comparison of these results with information from newly published experiments reveal tension between THM data and direct experiments.
The current status of the carbon fusion cross section and its implication as well as prospects for underground measurements of the carbon fusion reactions will be discussed.

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