Uncertainties in the 12C+12C reaction rate and their impact on the composition of ultra-massive WDs

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Ultra-massive white dwarfs (WDs) are expected to harbor oxygen-neon (ONe) or carbon-oxygen (CO) cores. Isolated ONe WDs are expected to be formed by progenitor stars with initial masses $7\,M_{\odot} \lesssim M_{\rm ZAMS} \lesssim 10\,M_{\odot}$. Stars in this mass range reach temperatures high enough to ignite C under degenerate conditions after the end of He-core burning. After the end of C-burning, the stars evolve into the so-called super AGB (SAGB) phase, ending their lives either as ultra-massive WDs or electron-capture supernovae. The exact proportions of O and Ne found in the core at the end of the SAGB phase will determine the cooling times and pulsational properties of these WDs. In this way, uncertainties affecting the nuclear reaction rates that are operative during the C burning phase are expected to have a measurable impact on the distribution of ^{16}O, ^{20}Ne, ^{23}Na, and ^{24}Mg, and consequently, on the evolution of the WD.

Here we present a study of the impact of uncertainties in the $^{12}\mathrm{C}(^{12}\mathrm{C},\alpha)^{20}\mathrm{Ne}$ and $^{12}\mathrm{C}(^{12}\mathrm{C},p)^{23}\mathrm{Na}$ nuclear reaction rates on the chemical structure of intermediate- to high-mass progenitors at the end of the C-burning phase. Using the stellar evolution code Modules for Experiments in Stellar Astrophysics (`MESA`) we computed evolutionary sequences for stars with initial masses from 7.25 to $8.25\,M_{\odot}$, from the ZAMS to the SAGB phase, adopting different prescriptions for the $^{12}\mathrm{C}+^{12}\mathrm{C}$ burning rates. Specifically, we adopted the recently reported reaction rates for carbon burning (Monpribat et al. 2022) and compared them with the results derived using the standard rates from Caughlan & Fowler (1988). We found that adopting lower reaction rates for the $^{12}\mathrm{C}+^{12}\mathrm{C}$ burning delays C-ignition by at most 2000 yrs, and that the latter takes place in a position farther from the center. We present the complete chemical profiles for selected models at the end of the C-burning phase. Our results shows that differences in the ^{20}Ne central abundances remain modest, below 13%.