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Stellar Modelling for Nuclear Astrophysics: Constraining the astrophysical origin of the p-nuclei

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The production of the proton-rich stable isotopes beyond iron that we observe today in the solar system is still uncertain. Core collapse supernovae (ccSNe) and thermonuclear supernovae (SNe Ia) exploding within the single-degenerate scenario have been proposed to be a potential source for these isotopes. Recent works performing Galactic Chemical Evolution (GCE) calculations, showed that explaining the inventory of the p-nuclides in the Solar System by the contribution from ccSNe alone is really challenging, thus requiring a complementary contribution from SNe Ia, assuming in this last case an s-process rich pre-explosive seeds distribution, built by neutron captures in the external layers of the progenitor white dwarf (WD), during the accretion phase. Presently there are no complete stellar models calculating these abundances, covering the WD mass range up to the Chandrasekhar mass. We calculate accretion models for five WDs with different initial masses using the stellar code MESA. We then focus on the nucleosynthesis calculating the full abundance distribution. In our models the dominant neutron source are the 22Ne(α,n)25Mg, which is activated at the bottom of the convective thermal pulse driven by the Helium flashes along the accretion phase, for WD masses lower than 1.26 solar masses, and the 13C(α,n)16O for WD masses equal or higher than 1.26 solar masses. We found neutron densities up to few 10^15 cm^-3 in the most massive WDs. In particular, we obtain a strong production by neutron captures up to the Pb region, showing how the classic assumption of a pre-existing s-process rich pre-explosive seeds distribution is actually justified. Using these results, we compute the resulting explosive nucleosynthesis of proton rich heavy stable isotopes using a multi-D SNe Ia model, and discuss the uncertainties affecting our results, focusing in particular on the list of the main nuclear reaction-rates which provide the dominant contribution to the production uncertainty, highlighting which of the identified key reactions are realistic candidates for improved measurement by future experiments.

Selected session

Nuclear Astrophysics

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