The ^{13}C neutron source for the s-process in AGB low-mass stars

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About half of all elements heavier than iron are produced during the asymptotic giant branch (AGB) phase of low-mass stars (LMSs, with $M < 3 - 4$ M$_\odot$) through the s-process, which involves a series of slow neutron captures and β-decays. The ^{13}C$(\alpha, n)^{16}$O is considered to be the main neutron source at about 8 keV in radiative conditions.

From a nuclear point of view it still remains matter of debate because of the contribution to the astrophysical factor, recently determined also using the Trojan Horse Method (THM), of a broad resonance located near the reaction threshold. For long time, this state was recognized as a sub-threshold resonance, but it is recently considered to be centred at positive energies; so, we had to calculate the asymptotic normalization coefficient (or ANC) of the same resonance in the case of unbound states. Moreover, direct measurements are affected by large systematic errors due to the spread in absolute normalization even at high energies. In this context, we have reversed the usual normalization procedure combining two indirect approaches, ANC and the THM, to unambiguously determine the absolute value of the ^{13}C$(\alpha, n)^{16}$O astrophysical factor. Implementing the recent and precise ANC calculation and the full width for the threshold resonance from literature into a modified R-matrix fit of THM experiment, it was possible to define an absolute and unique normalization for ^{13}C$(\alpha, n)^{16}$O data. Therefore, we calculated a very accurate reaction rate to be introduced into astrophysical models of s-process nucleosynthesis in LMSs during their AGB phase.

At the same time, on the modelling side, the mechanism for locally producing a sufficient amount of ^{13}C was so far treated as a free parameter. We present the first self-consistent physical, analytical, and exact model for the ^{13}C formation, based on magnetic buoyancy in a dynamo mechanism in both 2D and 3D. The strong magnetic fields ($10^4 - 10^6$ G) requested by this model have now been shown by the KEPLER mission to be typical of LMSs. The resulting pocket, having a flat distribution of ^{13}C and a little ^{14}N, is more extendedthan those so far assumed. It permits the reproduction of solar abundances in high-metallicity AGB stars and accounts for the ensuing chemical evolution of s-elements. Moreover, the so far unexplained s/(C/O) ratios in certain low-metallicity post-AGB stars together with the abundance, and isotope ratios of s-elements in presolar SiC grains are also explained.