$^{12}C(\alpha,\gamma)^{16}O$ thermonuclear reaction rate: Present status and perspectives

A. Lefebvre-Schuhl[1]
[1] Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (CSNSM), UMR8609, CNRS/IN2P3; Université Paris-Sud, F-91405 Orsay-Campus, France.

The radiative capture $^{12}C(\alpha,\gamma)^{16}O$ is one of the most important thermonuclear reactions in nonexplosive astrophysical sites. This reaction follows the production of ^{12}C by the $\alpha(2\alpha,\gamma)^{12}C$ triple-α process in stellar cores which have exhausted their hydrogen. The ratio of both reaction rates in helium burning determines directly the ratio of carbon and oxygen abundances at the end of helium burning. It has a strong impact on the abundances of the heavier elements, produced in later hydrostatic burning stages and on the final destiny of a massive star as a neutron star or a black hole.

In spite of its importance in nuclear astrophysics, the cross section of this reaction at stellar temperature is still uncertain. The Gamow peak is situated at 300 keV for helium burning temperatures ($T\approx2\times10^8$ K) and any measurement of the cross section at 300 keV is excluded, at least with today's experimental techniques because of its extremely low value of about 0.01 fb.

Up to now, only the European Recoil separator for Nuclear Astrophysics (ERNA) allowed to determine this cross section in the energy range $E_{cm} = 1.9 - 4.9\,\text{MeV}$, while numerous experimental efforts were devoted to precise the main contributions of this cross section, still limited around and above 1 MeV.

The theoretical extrapolation, to the Gamow peak energy range, of experimental values obtained at higher energies is particularly difficult due to the superposition of the various contributions still too uncertain or even just estimated: E1 and E2 radiative captures to the ^{16}O ground and excited states.

The present status of the $^{12}C(\alpha,\gamma)^{16}O$ cross section knowledge and its consequences on the reaction rate uncertainties will be presented with some perspective to reach the desired precision at stellar temperatures.