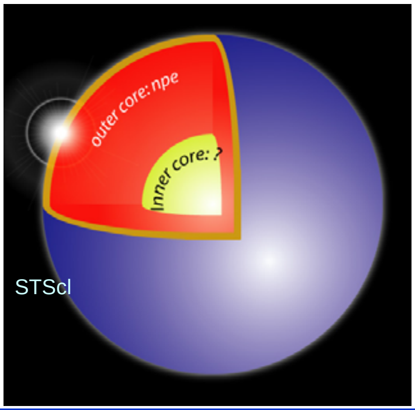
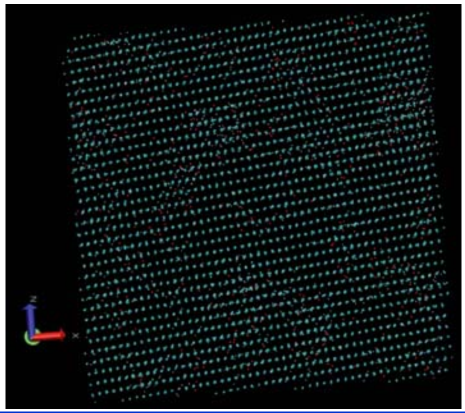
Fusion Reactions at the Limits of Stability



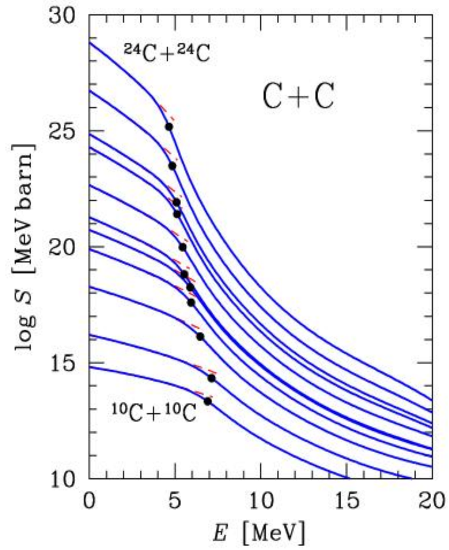


Nuclear reactions are at the heart of stellar structure, evolution and nucleosynthesis from main sequence, giants and super-giants to supernovae, white dwarfs and neutron stars. Depending on fuel, temperature, and density, stellar burning may involve many reactions of different nuclei, from light to heavy and stable to extremely neutron rich ones. The possibility of fusion reactions between low mass nuclei at low temperatures but extremely high densities occurs in the cores of white dwarfs and the crust of neutron stars. In white dwarf matter the $^{12}C+^{12}C$ fusion may trigger type I supernovae, in neutron star crusts fusion between very neutron rich nuclei may provide internal heating.

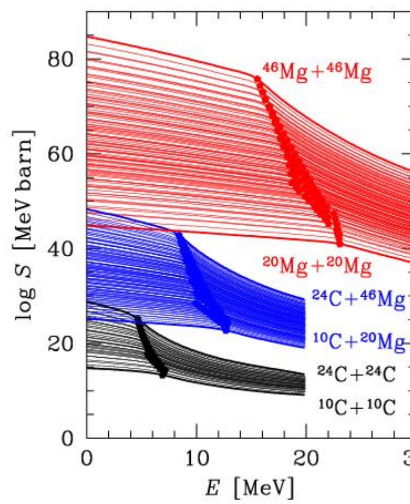
The reaction rates or S-factors of such fusion processes are extremely uncertain. Using the Sao Paulo potential [1] and the barrier penetration model we have calculated the S-factor for 946 fusion reactions involving stable and neutron rich C, O, Ne, and Mg isotopes for a range of center-of-mass energies, from 1MeV → 18-22 MeV. We have characterized the energy dependence of the S-factor by an accurate universal 9-parameter analytic expression. Tables of the 9 fit parameters have been produced. [2]

When used with the analytic expression the fit parameters can easily be converted into thermonuclear or pycnonuclear reaction rates to simulate various nuclear burning phenomena, which means they can be easily used for real time applications in computer codes.

[1] Gasques et al. Phys Rev C 76 45802 (2007)
[2] Beard et al. ADNDT (2009) in press



Analytic approximations of S(E) for C+C reactions involving different isotopes. The curves from bottom are (A1, A2) = {10,10}, {12,12}, {16,20}, {16,24}, {20,20}, {20,24} and {24.24} reactions. Filled dots correspond to the Coulomb barrier.



Analytic approximation of S(E) for 36 C+C reactions, 112 C+Mg reactions, and 105 Mg+Mg reactions.

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