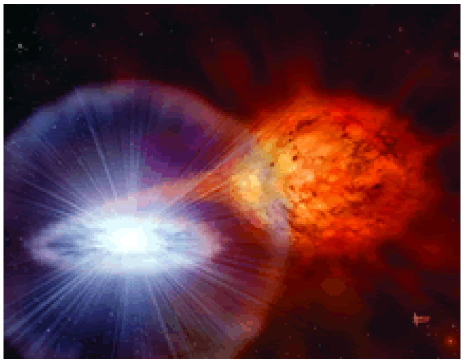
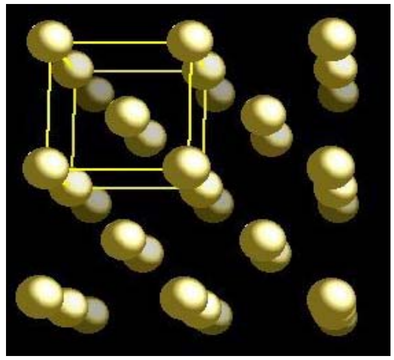
Pycnonuclear Burning



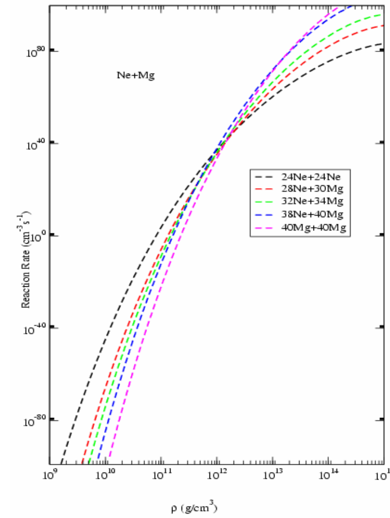


Pycnonuclear reactions occur in high density matter when nuclei are frozen in lattice structures. Such matter characterizes the cores of white dwarfs, and the crusts of accreting neutron stars. While pycnonuclear reactions in white dwarf matter are dominated by ^{12}C and ^{16}O induced fusion processes, pycnonuclear reactions in neutron star crust matter are dominated by fusion between very neutron rich carbon, oxygen, and neon isotopes at the limits of stability. In a post X-ray burst neutron star binary system ashes from the burst are forced deep into the crust by the weight of freshly accreted matter. With increasing density the remnant abundance distribution is changed by a host of electron capture reactions and neutron emissions, leading to the effective processing of the ashes into very neutron rich nuclei in the carbon to magnesium range. Near nuclear matter densities the nuclei are forced into a lattice, surrounded by a neutralizing degenerate electron gas. Though held in a solid lattice, reactions are still possible due to the reduction of Coulomb potential by screening and the overlap of nuclear wave functions between lattice sites. This type of reaction is highly density dependant, and unlike the more familiar thermonuclear counterpart, is not strictly temperature dependent.

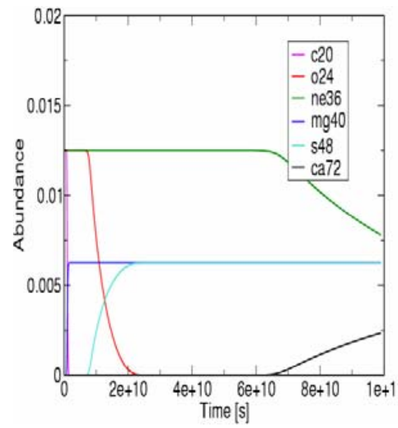
While previous work has focused on pycnonuclear fusion between identical particles, new formalism for calculating pycnonuclear reactions in a many component plasma has been developed at Notre Dame [1]. The pycnonuclear fusion becomes an important process for generation energy and changing the abundance structure in stellar matter at densities in excess of 1% of nuclear matter density. Network simulations of pycnonuclear burning have been performed for neutron crust matter and show indeed fusion reactions taking place on a timescale of years. The code is presently developed for including a full network electron capture reactions [2], this will allow us to follow the entire nucleosynthesis development in accreting neutron star binary systems from the thermonuclear runaway in the neutron star atmosphere to steady pycnonuclear burning deep in the neutron star crust.

This work was supported by the Joint Institute for Nuclear Astrophysics under NSF Grant PHY0216783.

[1] D.G.Yakovlev L.R. Gasques A.V. Afanasjev M. Beard M. Wiescher, Phys. Rev. C 74 035803 (2006)
[2] S. Gupta, E.F. Brown, H.Schatz, P.Moller K.-L.Kratz arXiv:astro-ph/0609828 v2 (2006)



Pycnonuclear reaction rates as a function of density for a range of neutron rich nuclei. The reaction rate exhibits both a strong Z and density dependence.



Reaction network simulations for pycnonuclear burning between neutron rich carbon, oxygen, and neon isotopes building heavier isotopes. Lightest Z nuclei burn first as the deflective Coulomb barrier is the most easily overcome.

Researchers:

M. Beard [1], L. Gasques [1], H. Schatz [2], M. Wiescher [1], D.G.Yakovlev [3]

[1] University of Notre Dame,
[2] Michigan State University
[3] Ioffe Physical-Technical Institute, St. Petersburg, Russia