Professor Claudio O. Dorso
Departamento de Fisica, FCEN, Universided de Buenos Aires, Argentina

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Italian delicacies served in Neutron Stars Crust

A Neutron Star is the remnant of a supernova, resulting from the gravitational collapse of a massive star. Neutron stars have masses of about two solar masses with a 10 km radius. They are composed (roughly) by neutrons protons and electrons. The system is neutral and the proton fraction (x=Z/A) is $0.01\varrho_0<x<0.5\varrho_0$. Neutron Stars cool down via neutrino emission. They are the densest and smallest stars. We start our study of Neutron Stars Crusts using a Classical Molecular Dynamics model developed for heavy-ion reactions. We first show that the so called "pasta shapes" are readily obtained at low temperatures. We then show using a series of techniques borrowed from nuclear physics, condensed matter physics and cosmology that we can craft a method that can be used to characterize the shape of the pasta structures in a unequivocal way. We then focus on the properties of the corresponding Nuclear Matter system at low temperatures and sub-saturation densities and we show that the "Nuclear Pasta resembling structures that appear" are an unavoidable consequence of the Periodic boundary conditions and are independent of the size of the system. We then explore the effect of the size of the Debye screening length on the structural properties of the neutral system. We show that as the screening length increases a transition from "one-per-cell" pasta regime to a more appealing multiple pasta per simulation box, takes place. When we focus our attention on the morphological evolution of the system with temperature, we find that as we heat it up, starting from very low temperatures in which nuclear pasta is formed, a solid to liquid phase transition takes place "within the nuclear pasta", if the temperature is further raised, morphological changes take place. This allows us to calculate the temperature dependence of the neutrino opacity finding that even though, the morphology of the structure differ significantly from those of the traditional pasta, the neutrino opacity remains high. Finally we show the preliminary results regarding the process of Neutron Star matter expansion and fragmentation as a first step towards the analysis of Neutron Stars Mergers.

Claudio O. Dorso , Full Professor University of Buenos Aires. Main research CONICET.
Master Physics University of Buenos Aires, Argentina
PhD Physics University of Buenos Aires, Argentina
Post Doc Nuclear Theory Group-LBL-Berkeley
Caltech-Univ Nantes, LNS-Catania.
Expertise: Nuclear Astrophysics, Nuclear Physics, Social Systems, Complex systems