Nuclear liquid-gas phase transition in asymmetric matter: from nuclei to compact stars

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In the formation and evolution of compact stars, nuclear matter explores high thermal, mechanical and chemical excursions and is the site of intense neutrino emission. Neutrino transport as well as structural properties of this matter depend on the presence of inhomogeneous phases, often called “pasta” phases at low temperature. Those inhomogeneous phases are the result of Coulomb frustration of the Liquid-Gas phase transition. In stars, these transitions occur in a neutron rich matter. The understanding of the compact stars structure and of the associated neutrino transport and beta-equilibrium thus requires both i) the knowledge of the neutron-rich nuclear matter equation of state (EoS) and associated phase diagram and ii) the understanding of the Coulomb frustration which is a general thermodynamics issue.

The nuclear phase diagram is studied looking at hot nuclei often created using heavy ion collisions. The finiteness of the experimentally accessible systems imposes the extension of the phase transition concepts to finite systems while the strong asymmetry of stellar matter imposes the study of the role of the isospin degree of freedom.

In this paper we will review the recent progresses in

1. the extension of phase transition concepts to finite systems and its applications to nuclei
2. the understanding of the role of the isospin degree of freedom in the EoS and the associated phase diagram
3. the description of the Coulomb frustration both in nuclei and in compact-stars matter
4. the possible consequences for the neutrino propagation

We will present both realistic calculations using mean-field concepts to discuss nuclear systems and general statistical physics demonstration which we will illustrate on schematic model to present general results on phase transition and frustration. Experimental results from negative heat capacity and bimodality to isospin scalings as well as recent theoretical achievements will be reviewed.