Contribution ID: **54** Type: **not specified**

Clusterized nuclear matter in the (proto-)neutron star crust and the symmetry energy

Monday, 24 March 2014 15:30 (15 minutes)

Though generally agreed that the symmetry energy plays a dramatic role in determining the structure of neutron stars and the evolution of core-collapsing supernovae, little is known in what concerns its value away from normal nuclear matter density and, even more important, the correct definition of this quantity in the case of unhomogeneous matter. Indeed, nuclear matter traditionally addressed by mean-field models is uniform while clusters are known to exist in the dilute baryonic matter which constitutes the main component of compact objects outer shells. In the present work we investigate the meaning of symmetry energy in the case of clusterized systems and the sensitivity of the proto-neutron star composition and equation of state to the effective interaction. To this aim an improved Nuclear Statistical Equilibrium (NSE) model is developed, where the same effective interaction is consistently used to determine the clusters and unbound particles energy functionals in the self-consistent mean-field approximation. In the same framework, in-medium modifications to the cluster energies due to the presence of the nuclear gas are evaluated. We show that the excluded volume effect does not exhaust the in-medium effects and an extra isospin and density dependent energy shift has to be considered to consistently determine the composition of subsaturation stellar matter. The symmetry energy of diluted matter is seen to depend on the isovector properties of the effective interaction, but its behavior with density and its quantitative value are strongly modified by clusterization.

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Session Classification: Afternoon session - Parallel B