Clusters in Nuclear Matter

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We investigate nuclear matter at temperatures $T \leq 20$ MeV and densities below saturation, including the formation of light clusters up to the α particle. The novel feature of this work [1] is to include the formation of clusters as well as their dissolution due to medium effects in a systematic way using two many-body theories: a microscopic quantum statistical approach and a generalized relativistic mean-field model where nucleon and cluster properties are modified by medium effects. Both approaches reproduce the limiting cases of nuclear statistical equilibrium at low densities and cluster-free nuclear matter at high densities. The treatment of the cluster dissociation is based on the Mott effect due to Pauli blocking.

The effects of cluster formation on the liquid-gas phase transition and, in particular, on the density dependence of the symmetry energy are studied. It is demonstrated that the parabolic approximation for the asymmetry dependence of the nuclear equation of state breaks down at low temperatures and at subsaturation densities. Conventional theoretical mean-field calculations of the symmetry energy fail to give the correct low-temperature, low-density limit that is governed by correlations, in particular by the appearance of bound states. The quantum statistical approach predicts symmetry energies that are in very good agreement with experimental data extracted from heavy-ion collisions [2].

[1] S. Typel, G. Röpke, T. Klähn, D. Blaschke, and H.H. Wolter. Phys. Rev. C **81**, 015803 (2010).

[2] B. Natowitz, G. Röpke, S. Typel, D. Blaschke, A. Bonasera, K. Hagel, T. Klähn, S. Kowalski, L. Qin, S. Shlomo, R. Wada, and H.H. Wolter. arXiv:1001.1102 [nucl-th], accepted for publication in Phys. Rev. Lett.