Nuclear matter properties at finite temperatures from effective interactions

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To study if the commonly used nucleon-nucleon effective interactions, which are usually constructed from fitting the properties of cold nuclear matter and of finite nuclei, can properly describe nuclear matter at finite temperatures, we have used the improved isospin- and momentum-dependent interaction ImMDI-GF [1,2] and the recently constructed Skyrme interaction Skχm* [3] to evaluate the nucleon occupation probabilities, the equations of state, and the mean-field potentials in symmetric nuclear matter and pure neutron matter at finite temperatures using the Hartree-Fock approach [4]. These results have been compared with those from the microscopic self- consistent Green's function method [5] and the chiral effective many-body perturbation theory [6] using chiral nuclear forces [7]. We have found that differences start to appear more strongly at higher temperatures between results for nuclear matter properties from the two effective interactions and also between these two and those from the microscopic theories. The deviations seen in the nucleon occupation probabilities have been understood from the different momentum dependence in the single-nucleon potential obtained within these approaches, while the latter is strongly suppressed at high momenta in the microscopic calculations based on chiral forces compared to those from the effective interactions, especially for Skχm∗ that has a quadratic momentum dependence. These differences in the nucleon momentum distributions lead to deviations in the kinetic energy contribution and also partially in the potential energy contribution to the nuclear equation of state. The energies per nucleon for symmetric nuclear matter and pure neutron matter from these two effective interactions, shown in the left and right windows of Fig.1, respectively, are roughly consistent with those from the self-consistent Green's function approach, although the equation of state for symmetric nuclear matter from Skχm* remains softer at higher temperatures. Using the ImMDI-GF model in the Hartree-Fock calculation reproduces remarkably well the mean-field potential from the microscopic approaches at various temperatures for both symmetric nuclear matter and pure neutron matter. Our study thus shows that effective interactions with the correct momentum dependence in the mean-field potential, such as the one from the ImMDI-GF model, can properly describe the properties of hot dense nuclear matter and is thus suitable for use in transport models to extract the equation of state of cold nuclear matter, which is needed for describing the properties of neutron stars [8], from intermediate-energy heavy-ion collisions [9,10].

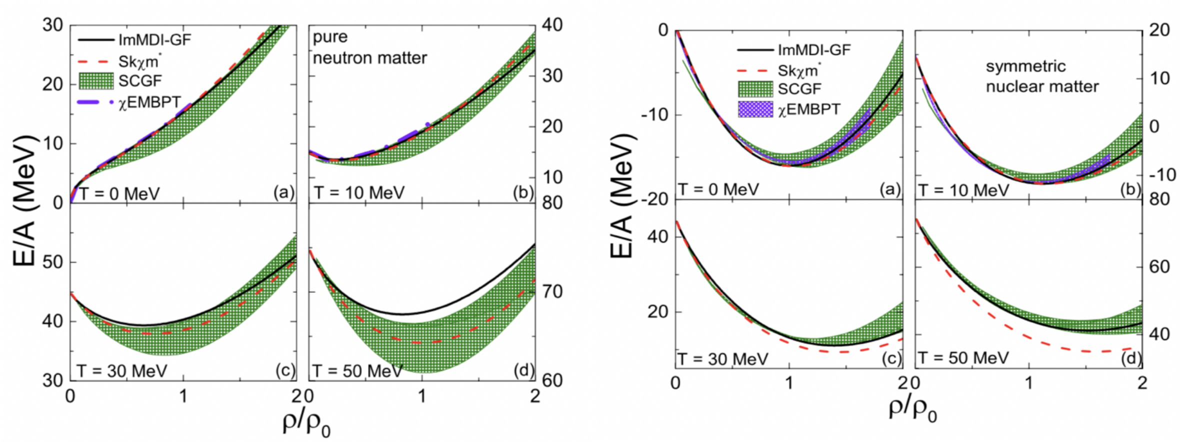

Fig. 1. Total energy per nucleon as a function of reduced nucleon density for symmetric nuclear matter (left window) and pure neutron matter (right window) at various temperatures from ImMDI-GF and Skχm∗ compared with results from the self self-consistent Green's function approach and from the chiral effective many-body perturbation theory using chiral nuclear forces.

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