Analyzing chiral condensate dependence on temperature and density

Determining the thermodynamic properties of the chiral condensate, the order parameter for chiral symmetry restoration, gives insight into whether there are phase transitions in dense astrophysical objects, such as young neutron stars. The chiral condensate is the scalar density of quarks in the ground state, and its presence violates chiral symmetry. Chiral effective field theory is used to study the behavior of the scalar quark condensate with changing temperature and density of neutron matter. Two-body and three-body chiral nuclear forces were employed to find the free energy and its dependence on the pion mass at lower temperatures. With increasing temperature (up to 100 MeV), the chiral condensate is strongly reduced, indicating a fast approach to chiral symmetry restoration. Chiral restoration seems to be hindered, however, at higher densities (around 0.2 fm^{-3}). The role of the different perturbative contributions and their change with temperature and density was extracted. Although the dominant contribution is the noninteracting term in the perturbation series expansion, nuclear interactions are important particularly at high densities where they delay chiral symmetry restoration.