# Variational method with an explicit energy functional for neutron matter at finite temperature taking into account the spin-orbit force

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A variational method with an explicit energy functional for cold neutron matter, taking into account the central, tensor, and spin-orbit components in the two-body nuclear force, is extended to hot neutron matter.

We have been studying a variational method for nuclear matter at zero temperature based on realistic two-body and three-body nuclear potentials. In this method, the energy per nucleon is explicitly expressed using various state-dependent two-body distribution functions, and the fully minimized energy is obtained by numerically solving the Euler-Lagrange equations for these distribution functions. An expression is derived for the kinetic energy that includes at least two-body cluster terms and the main component of three-body cluster terms. Furthermore, the necessary conditions on structure functions are automatically guaranteed by performing the variational procedure. Previously [1], we constructed an energy expression for neutron matter with the two-body nuclear potential composed of central, tensor, and spin-orbit components. The numerical results obtained using the AV8' potential [2] agree well with those obtained using the auxiliary field diffusion Monte Carlo method [3].

This variational method was extended to hot nuclear matter via the procedure proposed by Schmidt and Pandharipande [4]. In this method, the internal energy per nucleon is constructed as an extension of the energy expression at zero temperature by replacing the occupation probability of the single-nucleon state at zero temperature with the average occupation probability parameterized by the nucleon effective mass at a finite temperature. Furthermore, the entropy of nuclear matter is expressed using Landau's Fermi liquid theory, and the free energy per nucleon is minimized with respect to the two-body distribution functions and effective mass.

In another study [5], we constructed a free-energy expression for nuclear matter using the central and tensor components of the realistic two-body nuclear potential. The numerical results obtained using this variational method were reasonable.

In this study, we extend the energy expression for cold neutron matter with the AV8' potential, including the spin-orbit component, to hot neutron matter. Preliminary numerical calculations show reasonable free-energy behavior, although the numerical error is large. Therefore, in this presentation, we report more accurate thermodynamic quantities of hot neutron matter using our variational method.

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