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2nd-order superfluid Thomas-Fermi approximation and FAM-QRPA method for ultracold fermions

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The superfluid many-body systems can be described by Hartree-Fock-Bogoliubov equation. However, the HFB calculations is not feasible when systems have a large number of particles or quasi-continuum spectrum. In this case, the superfluid Thomas-Fermi approximation is very useful. Furthermore, the second-order superfluid Thomas-Fermi approximation has been derived. We know the 2nd-order Thomas-Fermi method without pairing has been applied a long time ago. The 2nd-order superfluid Thomas-Fermi method is very complex and has been applied to only a few examples. Based on the Green's function expansion method, we derived the 2nd-order superfluid Thomas-Fermi method with effective mass and spin-orbit potential so that it can be applied to general cases. The expressions have been examined in nuclei.
The collective modes of many particle systems are usually described by linear response approximation or hydrodynamic method. For cold atomic systems, there are strong experimental interests for measurements of multipole collective modes, which are related to equation of state and superfluidity. We have developed the FAM-QRPA code for describing collective modes of deformed nuclei and general superfluid systems. Compared with the conventional QRPA method, the FAM-QRPA is more efficient and can be applied to large deformed systems. In this cases, the detailed discrepancy between QRPA and hydrodynamic method for cold atomic systems in a trap have been studied to explore the finite-size effects.

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