Quantum phase-space methods for fermions

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Abstract: We present a phase-space method for fermionic systems, which enables simulations of the dynamics and thermal equilibrium states of many-body quantum systems from first principles. As examples, we calculate finite-temperature correlation functions.

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We report on a general phase-space method for first-principles quantum calculations of many-body systems of fermions. The technique can be used for both dynamical simulations (real time) and for calculations of equilibrium distributions (imaginary time). The method is based on a general Gaussian representation[1], which generalises earlier techniques successful in quantum optics[2].

Previous adaptations of the phase-space representations to fermions have relied on fermionic coherent-state expansions. Such expansions, which are defined in terms of anticommuting fermionic operators, require the use of anticommuting (Grassman) algebra[3], and thus do not lead to useful methods for numerical simulations. In contrast, our representation is based on a Gaussian-operator expansion, which is defined in terms of pairs of fermionic operators. Since such pairs commute with each other, the method enables a direct mapping from fermion operators to complex numbers. In particular, many-body operator equations can be mapped to nonlinear stochastic differential equations, which can be simulated numerically, without incurring the huge memory costs associated with number-state based matrix calculations. To demonstrate the method, we calculate finite-temperature correlation functions for some simple systems.

An analogous method can also be used for bosonic systems, and together these form a general class of methods which are naturally suited to problems of Bose-Fermi mixtures. As an illustration, we apply the method to a simple model of boson molecule formation from a degenerate Fermi gas.

References