Quantum kinetic equation and thermal conductivity tensor for neutral bosons

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Résumé

We systematically derive the quantum kinetic equation in full phase space for any quadratic Hamiltonian of bosonic fields, including in the absence of translational invariance. This enables the treatment of boundaries, inhomogeneous systems, and states with nontrivial textures, such as skyrmions in the context of magnetic bosons. We relate the evolution of the distribution of bosons in phase space to single-electron, band-diagonal physical quantities such as Berry curvature and energy magnetization by providing a procedure to "diagonalize" the Hamiltonian in phase space, using the formalism of the Moyal product. We obtain exact equations, which can be expanded order by order, for example, in the "smallness" of the spatial gradients, providing a "semiclassical" approximation. In turn, at first order, we recover the usual full Boltzmann equation and give a self-contained and exact derivation of the intrinsic thermal Hall effect of bosons. The formulation clarifies the contribution from "energy magnetization" in a natural manner, and does not require the inclusion of Luttinger's pseudogravitational field to obtain thermal transport quantities.

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