Quantum mechanics in phase-space and applications to quantum transport

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Abstract

The aim of this course is to introduce the phase-space formulation, or “Wigner formulation”, of quantum mechanics and to illustrate its applications to quantum transport. In the Wigner picture, the state of a quantum system is described by a pseudo-distribution in phase-space (Wigner function) which has many analogies (but obviously also important differences) with the Boltzmann distribution of classical kinetic theory. This similarity allows the formulation of quantum transport models and, using the mathematical techniques of classical kinetic theory, the consequent derivation of quantum fluid equations. A particularly interesting feature of the theory is that it leads very naturally to the semiclassical expansion of the equations, which means that "quantum corrections" to classical diffusion, hydrodynamics, etc., can be obtained. Furthermore, the formalism allows to describe fluids with additional discrete degrees of freedom, such as spin.

Outline

- Basic quantum mechanics of pure and mixed states.
- Wigner-Weyl correspondence and Moyal product.
- Wigner equation.
- Functional calculus in phase-space.
- Maximum entropy principle and Chapman-Enskog method.
- Derivation of quantum fluid equations and semiclassical expansion.
- Systems with spin-like degrees of freedom; graphene.