Advanced quantum mechanics

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The aim of the course is to present in depth the basic theoretical tools in quantum mechanics with a focus on degenerate N-body systems and open systems. The concepts discussed in the course will be illustrated in the tutorials by significant physical applications, often inspired by the current research especially in the field of cold atoms. The course is divided into three parts: a first part on the second quantization formalism, which includes the diagonalization of quadratic Hamiltonians and its application to the Bogoliubov theory for bosons and the BCS theory for fermions. A second part on approximation methods including the resolvent, the projectors method and the formal theory of scattering. A third part on open systems, with the Master equation and the Monte Carlo wave functions approach.

1. **Second quantization formalism an applications**

   (a) Indistinguishable particles
   (b) Second quantization formalism
   (c) Wick theorem
   (d) Bogoliubov method for bosons
   (e) BCS theory, Anderson's RPA approximation and excitation spectrum for fermions

2. **The resolvent and applications**

   (a) Perturbative calculation of the evolution operator
   (b) The resolvent of the hamiltonien
   (c) Projectors method
   (d) Formal scattering theory

(e) Phase dynamics of a BEC (bosons or paired fermions)

3. **Master Equation**

   (a) Derivation in the Born-Markov approximation

   (b) Comparaison with PGP formalism

   (c) Lindblad form

   (d) Monte Carlo wavefunctions

Bibliography

- M2 Lecture notes of Yvan Castin (2013) "Mécanique quantique, seconde quantification et résolvante" http://www.phys.ens.fr/ castin/cours.pdf

- Claude Cohen-Tannoudji, Bernard Diu, Franck Laloë "Quantum Mechanics - Volume 3 : fermions, bosons, photons, Correlations and Entanglement", Blackwell (2019).

- Claude-Cohen Tannoudji, Jacques Dupont-Roc, Gilbert Grynberg "Atom-Photon Interactions: Basic Process and Applications", WILEY (2008).