Master 2: *Physics of Complex Systems*

INTERNSHIP PROPOSAL

Laboratory name: LPTMS and LPS
CNRS identification code: UMR 8626 and UMR8502
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Internship location: Orsay (labs will be neighbor in January)
Thesis possibility after internship: YES

Title: **Pairing and topological phases in cold atoms with long-range interaction**

Correlated quantum systems in low dimensions show fascinating properties that distinguish them from their three dimensional counterparts as a consequence of the enhancement of quantum fluctuations. Interacting fermions and bosons in one-dimension (1D) can exhibit many exotic phases of matter. Although short-range interacting particles in 1D are rather well understood, much less is known for long-range interacting systems.
Seminal efforts are underway in the control of artificial quantum systems to simulate arbitrary model Hamiltonians which are now barely accessible to classical computation methods.
Ultra-cold dipolar or Rydberg atoms can realize Bose or Fermi gases with long-range interactions.

In this internship we would like to study 1D fermions interacting via a long-range potential. Taking only into account nearest and next-nearest interactions, it has been shown recently that two distinct liquid phases emerge among which a cluster quantum liquid phase where the essential granularity in the liquid is given not by individual atoms but rather by cluster of two atoms like in a superconducting paired phase [1]. These two liquid phases are separated by a quantum critical point with an emerging Ising degree of freedom [1]. Our goal is to characterize the topological properties of these phases [2] by relating them to well-tabulated 1D topological superconducting phases in condensed matter systems (see for example [3] for a pedagogical review of topological matter) like the ones appearing in the paradigmatic Kitaev model [4]. During the internship, we want to analyze models with interactions going beyond next-nearest interactions, and to explore whether other exotic phases and quantum critical points could take place in such system. In the longer run, we will study atoms with internal (pseudo-spin) degrees of freedom and also move toward 2D systems.

These issues will be addressed theoretically using a combination of analytical approaches (field theory and bosonization [5]) and numerical approaches (such as Matrix Product States techniques [6]).

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[5] T. Giamarchi, Quantum physics in one dimension (Oxford university press, 2004)
[6] U. Schollwöck, Annals of Physics 326, 96 (2011).

keywords: Cold atoms, many-body quantum physics, topological phases