Informal Workshop on

"Cold atoms and Quantum Simulations"

Monday 3 and Tuesday 4 December 2012

Venue: Department of Theoretical Physics and History of Science
UPV/EHU, Seminar room

Program

Monday, December 3

10:00 **Chiara Fort** (LENS, Florence)
Physics of 1D systems with ultracold atoms

11:00 **Gonzalo Muga** (UPV/EHU, Bilbao)
Shortcut to adiabaticity

12:00 **Giacomo Roati** (INO-CNR and LENS, Florence)
Simulating condensed matter systems with degenerate atomic gases

Tuesday, December 4

10:00 **Lucas Lamata** (UPV/EHU, Bilbao)
Quantum simulations with trapped ions

11:00 **Leonardo Fallani** (LENS, Florence)
Two-electron Quantum Gases

12:00 **Dmitri Sokolovski** (IKERBASQUE and UPV/EHU, Bilbao)
TBA

Duration of the talks: 45 + 15 (for discussions and coffee)

Abstracts

Physics of one-dimensional systems with ultracold atoms

Chiara Fort
Dipartimento di Fisica e Astronomia Università di Firenze and European Laboratory for Nonlinear Spectroscopy (LENS), via Nello Carrara 1, 50019 Sesto Fiorentino (FI) - Italy

Low dimensional systems present a rich physics as fascinating effects may arise due to the enhanced role of interactions and quantum fluctuations. Furthermore, for 1D systems some exactly solvable models are available.
In the last years the advancement in the realization and manipulation of ultra-cold atoms have allowed the investigation of fundamental properties of low dimensional systems with unprecedented control but several open questions still deserve investigation.
After an introduction on the general technique to produce and investigate quantum gases in low dimensions, we will report last results on the physics of one-dimensional interacting bosons obtained in our group at LENS and give the prospects.

Shortcuts to adiabaticity

Gonzalo Muga
Departamento de Quimica Física, UPV/EHU, Bilbao

I will present an overview of the concept of shortcuts to adiabaticity as well as applications in cold atom physics and beyond.

Simulating condensed matter systems with degenerate atomic gases

Giacomo Roati*
INO-CNR and LENS, University of Florence, via N. Carrara 1, 50019, Sesto Fiorentino, Italy

Nowadays ultracold atoms are considered ideal quantum simulators of strongly-correlated systems due to the unprecedented possibility of controlling all the relevant physical parameters, including the interactions between the particles and the shape and strength of the trapping potentials [1, 2]. In this seminar, I will present two paradigmatic examples in which ultracold gases are used to mimic the behavior of electrons in ordinary crystals. In a first kind of experiments we observe Bloch oscillations by trapping the degenerate atoms into an optical lattice aligned along gravity. We observe Bloch oscillations both using spin-polarized Fermi gases and ideal BEC [3, 4]. By measuring the Bloch period, we are able to estimate accurately the external force that drives the oscillatory dynamics. In this sense we realize a trapped atom-interferometer with large spatial resolution. The high sensitivity of our interferometer allows us to measure the effects of dipole-dipole interaction, typically hindered by the s-wave scattering contribution [5].

In a second kind of experiments, we study the effects of disorder on a BEC in which the interactions are controlled at will via a Feshbach resonance. The disorder is introduced into the system by means of a quasi-periodic lattice. We study two different regimes. First, the interactions between the particles are tuned to zero. This ”ideal” gas in the bichromatic lattice reproduces the Aubry-Andr´e hamiltonian [6], which shows a transition between extended and exponentially localized single- particle wavefunction, similar to the Anderson model [7]. We have directly observed the onset of localization by probing the momentum distribution and the absence of diffusion of the non- interacting condensate [8]. In a second experiment, we reintroduce some repulsive interactions into the sample [9]. In particular, we investigate the interplay between disorder and interactions. We observe the transition from incoherent Anderson localized states to fully coherent extended states. For large interactions the effect of the disorder is highly reduced and the system enters the BEC regime. The characterization of this superfluid to insulator transition (SIT) is particularly important. Infact, despite it is present in many different physical systems such as, for example, helium in porous media [10] and high T_C superconductors [11], its complete understanding is still missing.

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Quantum Simulations with Trapped Ions

Lucas Lamata
UPV/EHU Bilbao

We will review the research we have been developing at UPV/EHU Bilbao regarding quantum simulations in trapped ions. We will explain the possibility to simulate relativistic quantum mechanics in trapped ions, including the Dirac equation and Zitterbewegung [1,2], Klein's paradox [3,4], two interacting Dirac particles [5], and the Majorana equation [6]. Then, we will describe a scalable approach towards the simulation of quantum field theories in trapped ions [7], and also the realization of interacting fermion lattice models in an efficient manner [8]. Finally, we will propose an implementation of protected qubits in trapped ions by means of Majorana fermions [9], the quantum simulation of the Holstein model [10], and further developments in our group.

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Two-electron Quantum Gases

Leonardo Fallani
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We will present the new LENS experimental activity on quantum degenerate gases of two-electron atoms. Differently from the more commonly-used alkali atoms, atoms with two electrons are characterized by electronically-excited metastable states and ultra-narrow optical transitions. We will report on the recent production of ytterbium Bose-Einstein condensates and quantum degenerate Fermi gases, illustrating the possibilities that are offered by these systems for quantum simulation and quantum information experiments with ultracold two-electron atoms in optical lattices.

TBA

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