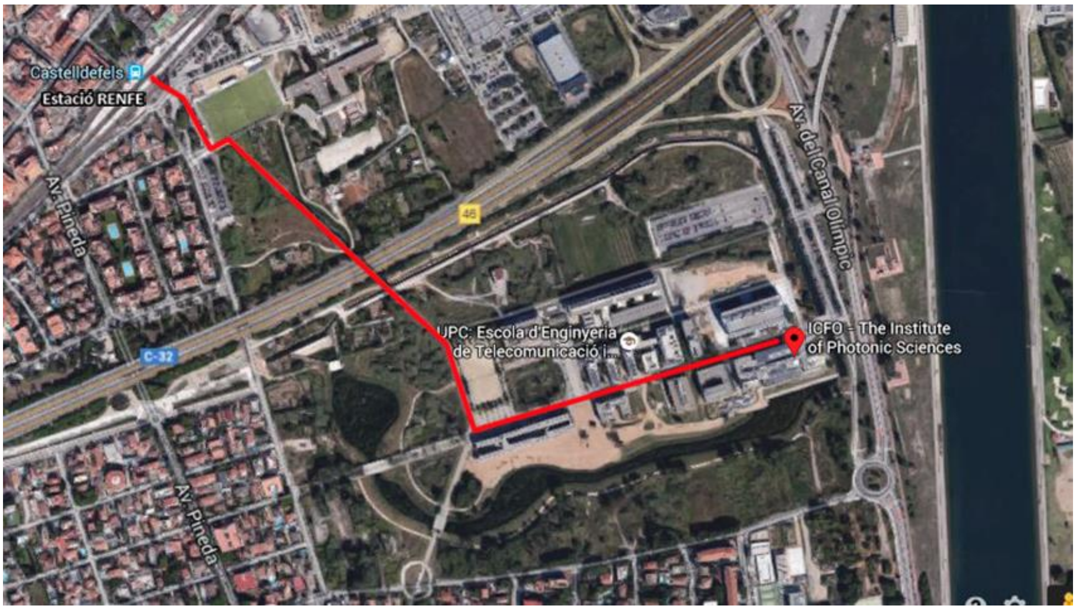
Half day meeting on cold atoms in the BCN region 2016

Date: February 5
Venue: Auditorium.
ICFO-The Institute of Photonic Sciences
Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona)



Two buses from Barcelona arriving at 9h00

Schedule:

09:30 - 10:05	Robert Moszynski, University of Warsaw *Ultracold chemistry and asymptotic physics with diatomic strontium molecules*
10:05 - 10:30	Antonio Muñoz Mateo, UB *Josephson vortices in spin-orbit coupled Bose-Einstein condensates*
10:30 - 10:55	James Douglas, ICFO *Cold atoms coupled to photonic crystals: a platform for tunable interactions and non-linear optics*
10:55 - 11:20	César Cabrera, ICFO *Dual Bose-Einstein condensation of ^{41}K and ^{39}K*
11:20 - 12:20	Posters
12:20 - 12:45	Guillem Ferré, UPC *Phase diagram of a quantum Coulomb wire*

12:45 - 13:10	Joan Polo, UAB *Geometrically induced complex tunnelings for ultracold atoms carrying orbital angular momentum*
13:10 - 13:35	David Raventós, ICFO *Controlled complexity and number partitioning in a quantum Mattis glass of trapped ions*
13:35 - 14:00	Simon Coop, ICFO *A double-well BEC with tuneable interactions: realisation, dynamics, and a parity-breaking quantum phase transition*
14:00	Lunch

Labtours after lunch for those interested.

Abstracts:

Ultracold chemistry and asymptotic physics with diatomic strontium molecules

Robert Moszynski
Quantum Chemistry Laboratory, Faculty of Chemistry, University of Warsaw, Poland

State-of-the-art ab initio methods of quantum chemistry have found numerous applications in many areas of atomic, molecular, condensed matter, and nuclear physics. During the last decade they have been applied with success to interpret precision experiments on two-body and many-body processes in atomic gases in the ultracold regime. In this talk I will present recent examples of successful applications of the ab initio methods to describe two-body processes in atomic optical lattices leading to the formation of unusual chemical bonds and to observations of exotic optical transitions in diatomic molecules. I will also discuss the studies of ultracold chemistry enabled by photodissociation of diatomic strontium molecules, including the phenomena of resonant and nonresonant barrier tunneling, matter wave interference of reaction products, and forbidden reaction pathways.

Josephson vortices in spin-orbit coupled Bose-Einstein condensates

Antonio Muñoz Mateo
Departament d'Estructura i Constituents de la Matèria, Universitat de Barcelona

We have analyzed the dynamics of planar solitons in two-component Bose-Einstein condensates with Rashba-Dresselhaus spin-orbit coupling by using the Gross-Pitaevskii equation. In particular, we have focused on Josephson vortex (JV) states, which are the analogues of Josephson fluxons in superconducting systems. JVs are current states made of solitons in each condensate component, and are coupled in such a way that the relative phase jumps an integer multiple of 2π. These configurations provide an excellent playground to observe the rich dynamics of planar solitons and vortex dipoles as has been previously done in scalar Bose-Einstein condensates through other states. We have found stable JVs in multidimensional systems within a regime of parameters typical of current experiments. Above an interaction threshold, and in oblate condensates, we have reported on how the JVs decay through the snake instability to produce vortex dipoles, which display an interesting dynamics guided by the spin-orbit coupling.

Cold atoms coupled to photonic crystals: a platform for tunable interactions and non-linear optics

James Douglas
Theoretical Quantum-Nano Photonics group, ICFO

Trapping cold atoms near a photonic crystal enables the formation of a novel quantum material where atomic spin degrees of freedom, motion and photons strongly couple over large distances. In this system, an atom trapped near the photonic crystal seeds a localized, tunable cavity mode around the atomic position. This effective cavity facilitates interactions with other atoms within the cavity length that are highly tunable and robust under realistic imperfections.

These long range atom-atom interactions can also lead to interactions between photons propagating through the cold atomic media. We show how these interactions can be designed to support molecular-like bound states of photons.

Dual Bose-Einstein condensation of ^{39}K and ^{41}K

César Cabrera
Ultracold Quantum Gases group, ICFO

Quantum mixtures are versatile systems for the study of a broad range of phenomena, including both few- and many-body physics. During my talk, I will introduce a new experimental setup designed to produce ultracold Bose-Bose or Bose-Fermi mixtures of potassium isotopes. In particular, I will focus on our latest results: the production of a ^{41}K Bose-Einstein condensate (BEC) by direct evaporative cooling, of a dual BEC of ^{39}K and ^{41}K by sympathetic cooling, and the very recent observation of the miscible-inmiscible quantum phase transition in the binary condensate mixture.

Due to the favorable Feshbach resonances of ^{39}K, our system is an ideal candidate for the controlled study of this phase transition. It should also enable the study of polaron physics in the strongly interacting regime, and the emergence of interactions between atoms of one species mediated by the other one.

Phase diagram of a quantum Coulomb wire

Guillem Ferré
Barcelona Quantum Monte Carlo group, Universitat Politècnica de Catalunya

The quantum phase diagram of a one-dimensional Coulomb wire is obtained using the path-integral Monte Carlo method. The exact knowledge of the nodal points of this system permits us to find the energy in an exact way, solving the sign problem which spoils fermionic calculations in higher dimensions. The results obtained allow for the determination of the stability domain, in terms of density and temperature, of the one-dimensional Wigner crystal. At low temperatures, the quantum wire reaches the quantum-degenerate regime, which is also described by the diffusion Monte Carlo method. Increasing the temperature, the system transforms to a classical Boltzmann gas, which we simulate using classical Monte Carlo. At large enough density, we identify a one-dimensional ideal Fermi gas which remains quantum up to higher temperatures than in two-and three-dimensional electron gases. The obtained phase diagram and the energetic and structural properties of this system are relevant to experiments with electrons in quantum wires and to Coulomb ions in one-dimensional confinement.

Geometrically induced complex tunnelings for ultracold atoms carrying orbital angular momentum

Joan Polo
Quantum and Atom Optics Group, Universitat Autòmoma de Barcelona

We investigate the dynamics of angular momentum states for a single ultracold atom trapped in two dimensional systems of sided coupled ring potentials. The symmetries of the system show that tunneling amplitudes between different ring states with variation of the winding number are complex. In particular, we demonstrate that in a triangular ring configuration the complex nature of the cross-couplings can be used to geometrically engineer spatial dark states to manipulate the transport of orbital angular momentum states via quantum interference.

Controlled complexity and number partitioning in a quantum Mattis glass of trapped ions

David Raventós
Quantum optics theory group, ICFO

Spin models with disorder, and spin glasses in particular, are paradigms of multidisciplinary science. They are most relevant for various fields of physics, reaching from condensed matter to high energy physics, but they also find several applications beyond the physical sciences. D-Wave computers, recently introduced on the market, are in fact quantum simulators that solve classical spin glass models using quantum annealing. It remains an open question whether the machine provides a speed-up advantage over the best classical algorithms. This triggers interest in alternative quantum systems designed to solve general spin models via quantum simulation. Indeed, exploiting quantum properties to outperform classical ways of information-processing is an outstanding goal of modern physics. A promising route is quantum simulation which aims at implementing relevant and computationally hard problems in controllable quantum systems. A noteworthy physical system for this goal are trapped ions. Here we consider trapped ions and demonstrate concretely that, with present day technology, a spin model of the Mattis type can be obtained that exhibits spin glass phases. Remarkably, our method produces the glassy behavior without the need of any disorder potential, just by controlling the detuning of the spin-phonon coupling. Applying a transverse field, the system can be used to benchmark quantum annealing strategies which aim at reaching the ground state of the spin glass starting from the paramagnetic phase. In the vicinity of a phonon resonance, the problem maps onto number partitioning, and instances which are difficult to address classically can be implemented.

A double-well BEC with tuneable interactions: realisation, dynamics, and a parity-breaking quantum phase transition

Simon Coop
Quantum Information with cold atoms and non-classical light group, ICFO

In this talk I'll discuss theory and recent experimental results from a ^{39}K BEC experiment at LENS in Florence, where we observe a parity-symmetry-breaking quantum phase transition. With complete control over all the experimental parameters, we fully characterise the transition and additionally observe a hysteresis effect that stabilises the system against external perturbations.

Posters:

1. Samuel Mugel, ICFO: *Topological bound states of a quantum walk with cold atoms*
2. Alejandro Turpin, UAB: *Dipolar potentials for Bose-Einstein condensates based on the conical refraction of light*
3. Aniello Lampo, ICFO. *Bose polarons as an Instance of quantum Brownian motion*
4. Pere Mujal, UB. *Quantum correlations in binary bosonic mixtures*
5. Georg Heinze, ICFO. *Controlled Rephasing of Single Collective Spin Excitations in a Cold Atomic Quantum Memory*
6. Julio Sanz, ICFO. *Observation of quantum degenerate mixtures of potassium*
7. Lukas Neumeier, ICFO. *Self induced back-action optical trapping in nanophotonic systems*
8. Joan Polo, UAB. *Transport of ultracold atoms between concentric traps via spatial adiabatic passage*
9. Antonio Muñoz, UB. *Coherent Quantum Phase Slip in two-component Bosonic Atomtronic Circuits*
10. Albert Gallemí, UB. *Multidimensional Josephson vortices in spin orbit coupled two-component Bose-Einstein condensates: snake instability and decay through vortex dipoles*
11. David Paredes, ICFO. *Storage enhanced nonlinearity in a cold Rydberg ensemble*
12. Emanuele Tirrito, ICFO. *Hybrid DMRG simulations*
13. Bruno Juliá Díaz, UB. *Macroscopic superpositions of Tonks Girardeau states and the Bose-Fermi mapping*
14. Pau Gómez, ICFO. *Coherent magnetometry with ferromagnetic superfluids*