Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Internship location: Laboratoire Charles Fabry

Thesis possibility after internship: YES
Funding: to be discussed

Light-cone-like dynamics in Strontium Bose–Einstein condensates

Statistical mechanics is one of the most powerful constructions of physics. It predicts that the equilibrium properties of any system composed of a large number of particles depend only on a handful of macroscopic parameters, no matter what the particles are and how they behave at the microscopic level. But the question of how many-body systems relax towards such equilibrium states remains largely unsolved. This problem is especially acute for quantum systems, which evolve in a much larger space than the classical space-time and obey non-local equations of motion.

Despite the formidable complexity of quantum dynamics, recent theoretical advances have put forward a very simple picture: the dynamics of quantum many-body systems would be essentially local, meaning that it would take a finite time for correlations between two distant regions of space to reach their equilibrium value, as happens in relativistic theory because of the limit imposed by the speed of light. This locality would be an emergent collective property, similar to spontaneous symmetry breaking, and have its origin in the propagation of quasiparticle excitations.

The fact is, however, that only few observations directly confirm this scenario. In particular, the role played by the dimensionality and the range of the interaction potential between the particles is largely unknown. This has motivated the construction of a new experiment in our group to investigate the relaxation dynamics of ultracold atomic gases in regimes well beyond the boundaries of our current knowledge. Our project started almost three years ago. The choice was made to use Strontium atoms for their versatile electronic spectrum. We have decided to equip our apparatus with advanced measurement and manipulation tools, such as a fluorescence microscope for imaging the gas with single-atom sensitivity and sub-micron resolution.

We are looking for a student to join our team of 3 people for a master internship, and then a PhD thesis. His/her first task will be to characterize the last stages of the experimental cycle using the newly built apparatus, namely the transport of atoms from the first vacuum chamber devoted to the magneto-optical trap to the second chamber devoted to the Bose-Einstein condensation and microscopy imaging. Our team is currently working on the second vacuum chamber and the optical setup surrounding it. Then, we will work on the microscopy imaging system, built around an aspheric lens placed inside the vacuum chamber, close to the atoms. The microscopy images will reveal the position of every single atom and enable the characterization of the quantum of the gas with unprecedented resolution!

The construction work should cover the duration of the master internship. The optimization and characterization of the last stages of the experimental cycle, including the microscopy imaging, should be achieved by the end of 2020. The rest of the thesis will be devoted to the experimental study of the relaxation dynamics of the Strontium gas after quantum quenches. A quench is a sudden change of one of the parameters controlling the state of the system, such as the strength of the interaction between particles. The gas that is initially at equilibrium close to the ground state is thus brought out of equilibrium. We will characterize how the system's state evolves with time in different settings by extracting multi-point correlation functions from the microscopy images. We will first seek an experimental signature of the locality of the dynamics in a two-dimensional geometry, which would manifest by the emergence of a "light cone" in a space-time diagram. Observing this phenomenon would be a premiere!

Condensed Matter Physics: YES	Soft Matter and Biological Physics: NO
Quantum Physics: YES	Theoretical Physics: NO