PhD thesis project

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Quantum magnetism of ultracold fermions in optical lattices

Themes: quantum degenerate gases, quantum simulation, magnetism
Methods and techniques: Laser-cooled ultracold atoms: lasers, optics, electronics, ultra-high vacuum

We offer a PhD project in the field of ultracold atoms. Our activity is devoted to the study of quantum magnetism, i.e., the collective behavior of ensembles of interacting spin-carrying particles. It relies on what is called today a **quantum simulator**: the realization of a complex and rich quantum system, with a tunability that enables the study of physical situations of broad interest. We produce quantum degenerate gases of fermionic strontium atoms, arranged in periodic potentials created by lasers. This many-body quantum system is then studied in a regime **emulating the antiferromagnetic Heisenberg Hamiltonian,** usually invoked to describe condensed matter systems, that we will now probe with the specific tools of atomic physics. Remarkably, we can realize situations analogous to those encountered by electrons (of spin ½) in crystalline materials, but also situations that strongly contrast with those, as a consequence of the spin 9/2 of our atomic species. In the long run, these systems appear promising to create novel magnetic phases, such as spin liquids, with connections with topological materials and exotic forms of superfluidity.

We are presently implementing protocols to **deterministically prepare low-energy spin textures**, using the strongly energy-selective lines of strontium (of use e.g. to optical atomic clocks). For the present PhD project, our aim is to **study the dynamics** of these spin textures when we vary effective external magnetic fields. The dynamical response of the sample will provide insight into the low-energy properties of Heisenberg antiferromagnets. In the context of our collaboration with the team of T. Roscilde, ENS Lyon, we are furthermore developing observables for **measuring the growth of correlations, and ultimately evidencing many-body entanglement.**

This research activity is a team effort on a complex experimental apparatus, rich with technologies of lasers, optics, electronics, ultra-high vacuum, high-sensitivity cameras, automated control. It will involve in autumn 2022, apart from the new PhD candidate, one PhD student (2nd-year), one CNRS research engineer, and two CNRS researchers. We operate this experiment in strong connection with two other experiments in our group: i) quantum magnetism with dipolar chromium atoms, ii) continuous superradiant lasing with strontium atoms; and with theory activities both in our group (P. Pedri) and at ENS Lyon (T. Roscilde).

Group webpage and recent publications : http://www-lpl.univ-paris13.fr/gqm/