ÉCOLE DOCTORALE GALILÉE
Université Sorbonne Paris Nord

Contrat doctoral – ED Galilée

Titre du sujet : Large Spins in 2D Optical Lattices

- Unité de recherche : Laboratoire de Physique des Lasers
- Discipline : Physique
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- Domaine de recherche : physique atomique expérimentale
- Mots clés : gaz quantique dipolaire – réseau optique – magnétisme quantique hors équilibre - intrication

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Magnetic atoms in optical lattices offer a relevant platform for studying quantum magnetism of dipolar interacting particles. It combines high filling factors, sufficiently strong dipole interactions (using short period lattices), and possible tuning of the relative strength of interactions and transport. These features open exciting possibilities that the GQM group at LPL has explored recently with large spins chromium atoms in 3D lattices: itinerant magnetism across the Superfluid-to-Mott quantum phase transition [1], and the quantum thermalization process [2].

We now aim at reaching the favorable 2-dimensional (2D) geometry for dipolar physics, where atoms are loaded in a square lattice within one single atomic sheet. For that, we have started rebuilding the core part of our experimental platform: we will improve optical access, and better control the magnetic environment close to the atoms. The PhD student will first work with permanent members of the group on the assembling of the new science chamber, the obtention of a Bose Einstein Condensate, and the realization of a dipolar planar system. He/she will then run the experiment to reach new scientific objectives.

We will first proceed to dynamical investigation of the underlying phase diagram of our spin system (see [3]). The initial state will be prepared into a coherent spin state with all spins orthogonal to the external magnetic field, B. This initial out-of-equilibrium state can be either a low energy state (i.e. close to the ground state) or a high energy state (i.e. very different from the ground state), depending on the Hamiltonian driving the system. Growth of macroscopic (respectively microscopic) fluctuations are expected after the quench in the former (latter) case. The Hamiltonian can be controlled through the orientation of B compared to the atomic plane, or by the addition of a quadratic term [2,3] through the tensorial light shift created by a (not too) far detuned laser.

Our second objective will be to further tackle the topic of thermalization of long-range interacting systems by reaching entanglement certification, a key feature in the context of the development of quantum technologies. Indeed, in the quantum thermalization scenario an isolated system acquires a local thermal character as it becomes globally entangled. Recently, scalable spin squeezing has been predicted for our target 2D experimental system [3], which opens the door for the measurement of entanglement witnesses based on spin squeezing like inequalities. For that we will try to improve the performances of the Dynamical Decoupling (DD) techniques we have recently developed [4], in order to measure all components of the collective spin at the quantum level.

These studies will be performed in close collaboration with the theoretical groups of Ana Maria Rey (Jila, Boulder), and T. Roscilde (ENS Lyon).

[1] T. Lauprêtre et al, Phys. Rev. Lett. 136, 103401 (2026)
[2] Y. A. Alaoui et al, Phys. Rev. Lett. 133, 203401 (2024)
[3] Y. Triffa et al, Phys. Rev. Lett. 133, 083601 (2024)
[4] T. Lauprêtre et al, Phys. Rev. A. 113, 033306 (2026)