Spin mixtures of a strongly magnetic quantum gas

Internship + PhD thesis – Laboratoire Kastler Brossel, ENS-PSL, Collège de France, Paris

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Context. Dysprosium is one of the most magnetic atoms in the periodic table ($\mu \simeq 10\,\mu_B$). In an ultracold Dy gas, long-range and anisotropic dipolar interactions give rise to new states of matter such as quantum droplets (Fig. 1) and supersolids. So far, these experiments have used atoms in a single spin state because of dipolar relaxation, an inelastic process in which two colliding atoms in different states convert their internal energy difference into kinetic energy, leading to the loss of both atoms. Using spin-dependent light shifts, our team can now stabilize mixtures of two Zeeman states of ^{162}Dy [1] and has recently produced the first long-lived mixtures of the opposite states $|-8\rangle$ and $|+8\rangle$, whose magnetic moments are exactly antiparallel. Theory predicts that such a mixture organizes into alternating magnetic domains, held together by the dipolar attraction between neighbouring domains of opposite magnetization, much as the electrostatic attraction between positive and negative ions holds a crystal of salt together [2]. This crystal would be self-bound: no external lattice fixes its period. The key input to this physics, the interaction between atoms in different Zeeman states, is still largely unknown, and dysprosium collisions are notoriously complex: they involve hundreds of Feshbach resonances, in which we recently showed that regular and chaotic dynamics coexist [3].

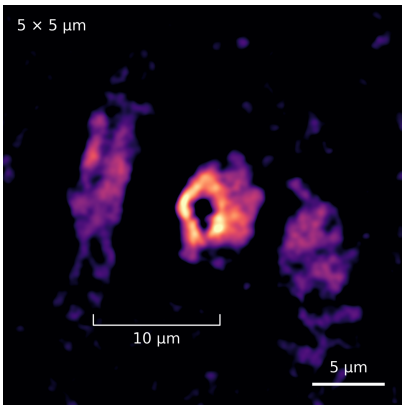


Figure 1: Absorption image of dysprosium droplets after a short time of flight, recently acquired in our quantum gas experiment (false colours; effective pixel size $0.12\,\mu$m).

In parallel, we are preparing to add a second atomic species, ^{41}K, to the experiment. Potassium interacts differently with the two spin states of Dy: it should preferentially occupy one type of magnetic domain and act back on the crystal. This coupling can be reversed simply by flipping the potassium spin with a radio-frequency pulse. Beyond spin mixtures, the Dy–K system will open up other directions, such as the stabilization of Efimov trimers.

Project. The student will join the experimental team and work on:

- optical tools for spin-dependent imaging;
- the cooling stages needed to produce a potassium quantum gas;
- the determination of the scattering length between atoms in $|-8\rangle$ and $|+8\rangle$.

Profile. We are looking for a student with a background in quantum mechanics and optics and a taste for experimental work. Programming experience (Python, Julia or Mathematica) is an asset. The internship offers hands-on training in lasers, optics, electronics and data analysis, in close contact with our theory collaborators.

[1] M. Lecomte *et al.*, Phys. Rev. Lett. **134**, 013402 (2025).

[2] M. Arazo *et al.*, Phys. Rev. Research **5**, 043038 (2023).

[3] J. Veschambre *et al.*, arXiv:2606.28233 (2026).