

Internship / PhD Position

Quantum simulation with a hybrid Rydberg atom platform

Laboratory: Laboratoire Kastler Brossel

Location: Collège de France, Paris

Website: www.lkb.fr/rydbergatoms

Supervisors:

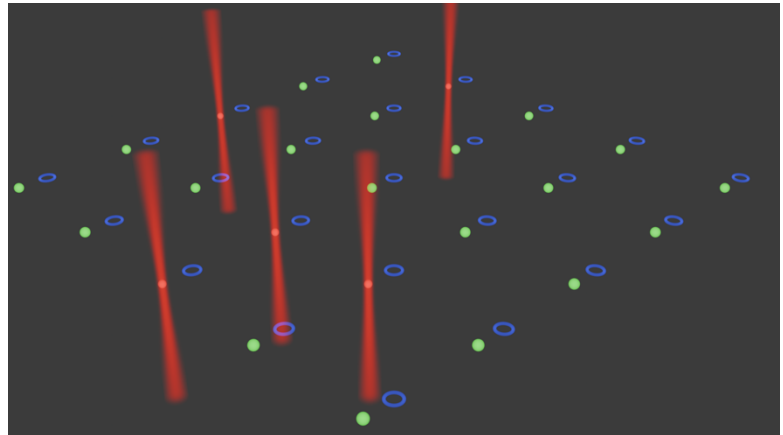
Clément Sayrin (clement.sayrin@lkb.ens.fr), Michel Brune (michel.brune@lkb.ens.fr)

Thesis possibility after internship: YES

Funding: NO

Scientific context:

Rydberg atoms, i.e., atoms excited to high-principal-quantum-number levels, are particularly well suited to the **quantum simulation** of condensed matter systems [1]. They can be prepared from arrays of single atoms, laser-trapped in optical tweezers, and their strong dipole-dipole interactions (in the MHz range, even at a few microns) enable the observation of quantum phase transitions and of quenched dynamics. However, the lifetime of Rydberg levels currently limits the simulation time to a few microseconds only.



Hybrid array of circular Rydberg atoms (torus) and ancilla atoms (red and green spheres). Optical manipulation of the ancillae is used to detect and manipulate the quantum state of the circular atoms.

In Laboratoire Kastler Brossel, we have developed a novel **hybrid platform** where spin $1/2$ s are encoded into **circular Rydberg atoms**, i.e., Rydberg atoms with maximal angular momentum. The latter have a 100-times longer lifetime than usually employed Rydberg atoms. Their use would bring quantum simulations to unprecedented regimes, with the simulation of **long-term dynamics**. We trap the circular Rydberg atoms in optical bottle beams [2], and we locally manipulate and detect them by coupling them to an array of **ancilla atoms** transiently excited to a regular low-angular momentum Rydberg level.

We have demonstrated the quantum non-demolition measurement of the circular Rydberg atoms with the ancillae, as well as a spatially-resolved manipulation of their quantum states [3]. Recently, we have used this hybrid platform to observe the spin-exchange interaction between two circular Rydberg atoms over more than $60\mu\text{s}$ [4], improving the state of the art by an order of magnitude.

This work opens the route towards the simulation of complex phenomena, including the observation of long-term dynamics of interacting spin $1/2$ s, or the interaction of larger ($>1/2$) spins. This would significantly enrich the scope of Rydberg-based quantum simulators.

Internship:

Our experiments are performed in a UHV chamber operated at room-temperature. To fully benefit from the long lifetimes of the circular Rydberg atoms, we need to transfer the existing setup to a cryogenic environment. The intern will actively participate to the development of the cryogenic platform, which should be operational at the beginning of the internship. The intern will participate to the implementation of existing atom manipulation into the new cryogenic setup. In particular, he/she will participate to the adaptation of the optics, microwave and radiofrequency setups to the cryogenic platform. His or her work will, thus, constitute, a decisive contribution to our quantum simulations project.

PhD Thesis:

The end of the internship and the first months of the PhD work will be devoted to the operation of the new cryostat and its optimization. We will benefit from the enhanced lifetimes of the Rydberg levels to improve the performances of the existing room-temperature setup. During the PhD work, **the proposed quantum simulator will then be operated**. Quantum simulation of **spin-1/2 Hamiltonians** will first be performed, with the observation of **long-term dynamics**, out of the reach of existing simulators. We will then focus on the simulation of the interaction between **spin 1s or larger**. We will in particular use the ancillae to tune the interaction between the circular Rydberg atoms, using techniques developed in on-going collaborations with theoretical teams [5].

References:

- [1] [T. L. Nguyen *et al.*, PRX **8**, 011032 \(2018\)](#)
- [2] [B. Ravon *et al.*, PRL **131**, 093401 \(2023\)](#)
- [3] [Y. Machu *et al.*, PRX **16**, 021040\(2026\)](#)
- [4] [A. Durán-Hernández *et al.*, arXiv :2609.37766 \(2026\)](#)
- [5] [T. Botzung *et al.*, PRR **8**, L022019 \(2026\)](#)