

INTERNSHIP PROPOSAL

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Internship location: Collège de France, 1 place Marcelin Berthelot, 75005 Paris
Thesis possibility after internship: YES
Funding: YES (not yet secured, application for a doctoral school fellowship)

Quantum simulation with circular Rydberg states of strontium

Context: Rydberg atom arrays are powerful platforms for the quantum simulation of spin models. Ground-state atoms trapped in optical tweezers are arranged in an arbitrary geometry before being transferred into low-angular momentum Rydberg states using laser pulses. However, the duration of the simulation is currently limited by the relatively short lifetime of laser-accessible Rydberg states. Circular Rydberg states, i.e. Rydberg states with maximum angular momentum, have an extremely long radiative lifetime, and open the way to studying quantum dynamics on much longer timescales [1]. In our group, we are building a quantum simulator based on circular states of strontium. Strontium is a two-valence-electron atom, and its ionic core remains optically active when one of the valence electrons is excited to a circular Rydberg state. The ionic-core transitions can be driven without autoionizing the atoms [2], which enables laser slowing of atoms directly in the Rydberg state [3] as well as optical manipulation of the Rydberg state via its electrostatic interactions with the ionic core [4]. In the experiment, we prepare individual strontium ground-state atoms in optical tweezer arrays inside a cryostat and excite them to circular Rydberg states. The circular atoms are trapped in the same tweezers as the ground-state atoms using the polarizability of the ionic core. Thanks to the suppressed blackbody radiation in our cryogenic environment, we have demonstrated a circular state lifetime of about 2 ms, roughly 40 times longer than that of laser-excited Rydberg states [5]. We are currently studying the interactions between pairs of circular Rydberg atoms.

PhD Project: The purpose of the PhD is to pursue our ongoing effort toward building a strontium circular state quantum simulator. The long lifetime of the circular state, combined with the ability to trap the atom with very low power thanks to the polarizability of the ionic core, opens the way to performing quantum simulation over very long timescales with a large number of atoms, even in a cryogenic environment. In the coming years, we plan to develop innovative methods to prepare defect-free 2D arrays of circular atoms that will give access to a rich landscape of spin models, including frustrated systems that can host exotic, highly entangled ground states. This will open the way to the preparation and study of quantum spin liquids. Circular states of strontium also offer interesting prospects in quantum optics. The interaction between the Rydberg electron and its ionic core opens a way to directly couple Rydberg atoms to optical photons.

Master Project: We have recently purchased a new closed-cycle cryostat. During the master's internship, the student will focus on building a new laser system to prepare Rydberg atoms in this setup.

- [1] T. L. Nguyen et al., Towards quantum simulation with circular Rydberg atoms, [Phys. Rev. X 8, 011032](#) (2018)
[2] R. C. Teixeira et al., Preparation of long-lived, non-autoionizing circular Rydberg states of strontium, [Phys. Rev. Lett. 125, 263001](#) (2020)
[3] L. Lachaud et al., Slowing down a coherent superposition of circular Rydberg states of strontium, [Phys. Rev. Lett. 133, 123202](#) (2024)
[4] A. Muni et al., Optical coherent manipulation of alkaline-earth circular Rydberg states, [Nat. Phys. 18, 502-505](#) (2022)
[5] B. Muraz et al., Measuring the $\text{Sr}^+ 5s1/2$ Landé g-factor using singlet-triplet oscillations in a circular Rydberg state of strontium, [arXiv:2608.26784](#) (2026)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES

Soft Matter and Biological Physics: NO

Quantum Physics: YES

Theoretical Physics: YES