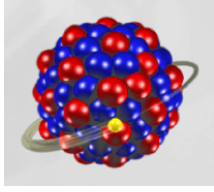
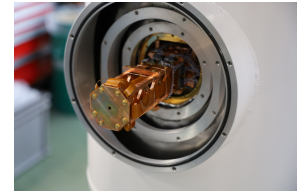


## **Internship PROPOSAL**



### **Fundamental tests through precision spectroscopy of exotic atoms with quantum sensors**



High-precision studies of the quantum structure of atomic systems allow to probe many important fundamental physics questions, from quantum electrodynamics to astrophysics, to tests of the standard model and studies of nuclei. Our group is pioneering a new domain of atomic spectroscopy by applying quantum sensing x-ray detectors to study exotic atoms. An exotic atom is formed when a heavier, negatively-charged particle like a muon ( $\mu^-$ ) or an antiproton replaces the electron on the atomic orbitals. Due to their larger mass, these particles lie much closer to the nucleus (e.g.  $\sim 207$  times closer for the  $\mu^-$ ), and thus allow to probe many properties of matter otherwise inaccessible including the details of nuclear charge radii and strong-field quantum electrodynamics [1].

A new experimental program called QUARTET (QUAntum inteRacTions with Exotic aToms) [2] begins in 2023 at the Paul Scherrer Institute (Switzerland) to use, for the first time, magnetic x-ray microcalorimeter detectors to study the quantum structure of muonic atoms. QUARTET will perform spectroscopy of the  $2p-1s$  transition in light muonic atoms (Li, B, Be) to improve our knowledge of the nuclear charge radius by factors of 3-10, meanwhile demonstrating the compatibility of these new quantum sensing detectors and exotic beams for future QED tests and beyond standard model searches.

The student will work on first data analysis from the QUARTET campaign, to extract and analyze the x-ray spectrum from muonic boron. The student will also have the opportunity to participate in development of a new ERC-funded project for spectroscopy of antiprotonic atoms using similar methods at CERN.

The internship may be continued into a PhD.

[1] N. Paul, G. Bian, T. Azuma, S. Okada, and P. Indelicato, Phys. Rev. Lett. **126**, 173001 (2021).

[2] B. Ohayon et al, <https://arxiv.org/abs/2310.03846>

**Laboratory: Laboratoire Kastler Brossel** (UMR 8552), Jussieu, Paris

**Internship director: Nancy Paul**

**E-mail:** [nancy.paul@lkb.upmc.fr](mailto:nancy.paul@lkb.upmc.fr)

**Web page:** <https://www.inp.cnrs.fr/fr/personne/nancy-paul>

**Twitter:** @MmeAtomic

