

**Title: Quantum interference measurement of the free fall of antihydrogen**

**Scientific project:**

The GBAR experiment (*Gravitational Behavior of Antihydrogen at Rest*) is currently installed in CERN. It aims at measuring the free fall acceleration  $\bar{g}$  of antihydrogen atoms in the Earth's gravitational field with accuracy at the % level [1]. Existing gravitational experiments on antihydrogen are so imprecise that even the sign of  $\bar{g}$  is not known today [2].

Low-energy atoms surface experience quantum reflection from the attractive Casimir-Polder potential above a matter plate, with a probability depending on the material properties [3]. The atom can then be trapped in quantum levitation states [4] whose spacing depends on the free fall acceleration  $\bar{g}$ . Measurements of quantum interferences between those quantum gravitational states could lead to a determination of  $\bar{g}$  with an accuracy improved by around three orders of magnitude with respect to the current objective of GBAR [5].

The internship and PhD project will explore problems of interest in this context~: new ways to improve the lifetimes of antiatoms in quantum levitation states, best strategies regarding the preparation and the dynamics of the interfering wave packet, analysis of the estimation of the parameter  $\bar{g}$ , integration of the quantum method in the GBAR data analysis...

[1] P. Pérez *et al*, *Hyperfine Interactions* **233** (2015) 21.

[2] The ALPHA Collaboration, *Nature Communications* **4** (2013) 1785.

[3] P.-P. Crépin *et al*, *Europhysics Letters* **119** (2017) 33001.

[4] P.-P. Crépin *et al*, *Physical Review A* **95** (2017) 032501.

[5] P.-P. Crépin *et al*, *Physical Review A* **99** (2019) 042119.

**Methods and techniques:**

The calculation of Casimir interactions is based on the methods of quantum optics. The quantum reflection is calculated by solving the Schrödinger equation for the atomic matter waves. The project corresponds to theoretical work in Laboratoire Kastler Brossel, in the vicinity of experiments performed in international collaborations, in particular GBAR. It implies analytical calculations as well as numerical simulations.

**Supervisors:**

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