Title: Quantum levitation states of hydrogen on a liquid helium surface

Scientific project:

Quantum reflection is a generic phenomenon for matter waves in a rapidly varying potential. It has been observed in particular for atoms experiencing an attractive Casimir-Polder potential in the vicinity of a solid surface. It is an important question in the GBAR experiment (*Gravitational Behaviour of Antihydrogen at Rest*) which aims at measuring the free fall acceleration of neutral antihydrogen atoms in the terrestrial gravitational field [1].

When antimatter touches a material plate, it annihilates, which leads to a particularly simple boundary condition for the problem of quantum reflection of antimatter on matter. On the other hand, an atom can interact with a material surface in a more complicated way. We study a liquid helium surface which shows very high quantum reflection probabilities [2]. It is known that an hydrogen atom can be adsorbed on a liquid helium surface through the exchange of kinetic energy to the ripplons, the quantum excitations of the liquid helium surface. This leads to brand new short-range phenomena which have to be incorporated in the theoretical description of quantum reflection.

In this context, the proposed internship and PhD project aims at studying hydrogen atoms trapped in quantum levitation states due to the combined effect of gravity and quantum reflection above a liquid helium surface. An important point will be to describe the short-range physics between the hydrogen atom and the liquid surface and discuss consequences on quantum levitation. Another aim will be to investigate the possibility of high precision measurements on the hydrogen atom trapped in quantum levitation states [3-4].

[1] P. Pérez and Y. Sacquin, *Class. Quantum Grav.* **29** (2012) 184008.
[2] P.-P. Crépin *et al*, *Europhysics Letters* **119** (2017) 33001.
[3] S. Vasiliev *et al*, *Hyperfine Interactions* **240** (2019) 14.
[4] P.-P. Crépin *et al*, *Physical Review A* **99** (2019) 042119.

Methods and techniques:
The scattering approach used to calculate 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 close vicinity of experiments performed in international collaborations. It implies analytical calculations as well as numerical simulations.

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