Ultra-cold matter waves in microgravity for atom interferometry

Our research group is devoted to the production of ultra-cold quantum gases in microgravity. The main goal is to achieve atom interferometers with large scale factor to push the sensitivity until the fundamental limits of these systems. Our experiment plays a key role in the roadmap aiming to launch an atom accelerometer in Space, which is the goal of the CARIOQA project funded by the program Horizon Europe.

The ICE project aims to develop a matter wave interferometer operating in microgravity. The development of a portable experiment adapted to the airbus 0g led to the world's first demonstration of the use of atomic inertial sensor onboard and in microgravity. Ultimately, we will carry out an initial comparison of atomic accelerometers with two different atomic species (potassium and rubidium) at 10 pm/s2, allowing to test the universality of free fall (equivalence principle). In parallel with the onboard experiments, a micro-gravity simulator installed in the laboratory allows to put the experiment chamber and the measurement instruments (200 kg) in weightlessness during 500 ms, and in a highly repetitive way leading to one hour of microgravity per day.

One of the objectives consists in testing the equivalence principle with ultra-cold Rubidium and Potassium atoms. The development of this new generation of sensors is based on ultra-cold bi-species degenerated gas. Our strategy involves using atom cooling technics developed in the laboratories to achieve the coldest double species Rubidium-Potassium source with a compact device compliant with onboard applications. Studies will be led to get the most collimated atom sources possible to limit the velocity dispersion hence, to limit the contrast loss for long interrogation times. More specifically, our work is dedicated to all optical techniques where the atoms are trapped in a far detuned laser beam. This solution has the advantage of a better control of the environment of the ultracold gas but is less mature than on-chip magnetic traps and thus requires further investigation.

After optimizing the Rubidium ultra cold atomic source and perform a state-of-the-art atom interferometer in microgravity, the Ph. D student will implement a new detection scheme to reach the quantum projection noise limit. Then the student will adapt the techniques for Potassium. Fast productions of Bose Einstein Condensates combining gray molasses cooling and painting potentials will be implemented. Interestingly, Potassium is also particularly suitable for Feshbach resonances to control the interactions, which is a predominant effect for atom interferometry using ultracold atoms. The production of ultra-cold atom sources and atom interferometry in microgravity will be an important benchmark for the future Space missions.

The work will take place at LP2N within Institut d'Optique d'Aquitaine. The candidate will be asked an advanced expertise in the following fields: quantum physics and ultra-cold gases, laser, electronics, and signal processing.

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