ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

ed560.stepup@u-paris.fr

**Titre du sujet :** **SEARCHING FOR PRIMORDIAL GRAVITATIONAL WAVES WITH QUBIC: High Precision Calibration using Interferometry**

Directeur (trice) : **TORCHINSKY Stephen, IRHC, satorchi@apc.in2p3.fr**
Co-directeur (trice) / Co-encadrant(e) : **HAMILTON Jean-Christophe, DR, hamilton@apc.in2p3.fr**
Equipe d'accueil : **APC, Equipe de Cosmologie - UMR7164**

Financement : **Contrat doctoral avec ou sans mission d'enseignement**

**Développement du sujet :** (Maximum 2 pages)

The quest for B-mode polarization of the Cosmic Microwave Background is the primary challenge in Observational Cosmology and is pursued by a worldwide effort. Measurement of B-mode polarization in the CMB will be clear evidence of primordial gravitational waves which are theoretically expected to be produced during inflation at about $10^{-35}$ seconds after the Planck epoch. Their presence would be a non-trivial result concerning quantum gravity because tensor modes would mean the metric must be quantized. The B-mode measurement is perhaps the most difficult cosmological challenge because the expected signal is very small. It requires high sensitivity and negligible instrument systematic effects with wide frequency coverage to separate the primordial signal from foreground emissions.

QUBIC (QU Bolometric Interferometer for Cosmology: http://qubic.org.ar) is a novel instrument that brings together the advantages of bolometers with their high sensitivity and interferometers with their exquisite control of instrument systematic effects. QUBIC is similar to a radio interferometer but uses optics to perform the signal combining, rather than digital electronics. This results in an extremely wideband interferometer which can take advantage of the radio aperture synthesis technique called "Self Calibration". QUBIC has a number of differences from a radio interferometer making the implementation of self-calibration a complex task. A primary goal of the thesis project is the implementation of this method, including taking measurements with a calibration source installed on-site, as well as with astrophysical sources.

QUBIC will also be used to characterize a high-precision polarized calibration source which is being developed by our collaborators at LPENS and is planned for deployment in space. The project, called COSMOCAL, is an orbital calibration source to be used by a number of B-mode experiments around the world currently in development, or already taking data.

The QUBIC Observatory was inaugurated in Nov. 2022 on its observing site at 5000m a.s.l. in the province of Salta in Argentina. The Technological Demonstrator is installed at the site and is currently undergoing commissioning. Observations are expected to start in 2025.

The Ph.D. student will participate in the following topics, and is expected to travel to Argentina for measurement campaigns:

- Modeling instrumental systematics in the QUBIC software in order to achieve a realistic numerical description of the acquisition model.

- Implementation of the self-calibration method, including development and implementation of the algorithm, and measurements with QUBIC to test and refine the method.

- Characterization of the COSMOCAL polarized millimetre-wave source.

- Use of astrophysical sources for calibration. This could include cosmic rays to be used to measure bolometer time constants. The student will also work on astronomical observations of the Moon and the Galactic Plane, and will help implement and verify the map making pipeline for QUBIC.

The student will work within the QUBIC-APC team at APC, with the rest of the collaboration in France, Italy, Ireland, and Argentina.