M2 Internship: *Onset of dissipation in three-dimensional superconductors*

Introduction: The Josephson effect describes the flow of superconducting charge carriers across thin barriers. It has played a pre-eminent role in the application of superconducting devices, notably for designing quantum circuits, and radiation emitters and detectors. According to the Josephson relations, dissipation in superconductors is related to the time-variation of the phase of the wavefunction. This physics is usually studied in the case of superconducting weak links in microbridges and nanowires, when a voltage develops across a thin barrier having a length (L) shorter than the coherence length (ξ). It results in the flow of normal carriers simultaneously with the tunnelling of Cooper pairs, which produces a charge current having both dissipative and non-dissipative components. This is theoretically modelled by a resistively-shunted Josephson junction. Although this kind of effect is typically observed in low-dimensional systems (for which at least one dimension is comparable to or smaller than ξ, typically of the order of tens of nanometres), there are some specific situations where it may arise in large systems ($L >> \xi$) as well. One particular case is that of phase slip lines in wide superconducting films, for which all the dimensions exceed the superconducting coherence length. Current-voltage characteristics display step-like structures, resulting from oscillations of both the amplitude and phase of the wavefunction. Several aspects of this phenomenon in 3D specimens are still awaiting in-depth investigations. If we can understand these issues in greater detail, it may become possible to design devices that display Josephson-effect-like behaviour without requiring the complex microfabrication processes associated with low-dimensional samples.

Objectives: In this project, our aim is to experimentally study current-voltage relations and the fluctuations of these quantities in the phase slip regime of three-dimensional (3D) superconducting systems.
The experiments will focus on the following aspects:
- determining the properties of dissipative carriers in the non-equilibrium state,
- investigating possible correlations of these properties with the supercurrent component,
- statistical study of conductance fluctuations in these dissipative states.

Research team and working environment: The internship work will be carried out in the team 'Astroparticles Solid-State Detectors' (ASSD), in the pôle 'Astroparticules, Astrophysique et Cosmologie' (A2C) at IJCLAB in Orsay. The experiments will involve the use of cryogenic and clean room facilities at IJCLAB (Bat. 104 and 108). Some measurements requiring the use of a magnetic field will be carried out at the 'Plateforme de Mesures Physiques' of Université Paris-Saclay located at the Laboratoire de physique des Solides (Bat. 510).

Contact person: Shamashis Sengupta (email: shamashis.sengupta@ijclab.in2p3.fr)
Deadline: 20 January 2026