Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: YES
Funding already obtained for a PhD: NO If YES, which type of funding:

Dynamics of a quantum magnetic impurity in a superconductor

Magnetism and superconductivity are potentially two competing phases of matter. However, their interplay can lead to new exotic phases of matter such as topological superconductivity, a state of matter able to harbor Majorana fermions, long-sought particles which are their own antiparticles. As topological superconductivity seems not so frequent in nature, one strategy consists of engineering it based on building arrays of magnetic impurities (Fe, Co, Mn,…) on a superconducting substrate [1]. The interaction between a single impurity and the superconductor leads to intra-gap localized and almost polarized bound states [2]. Controlling and functionalizing these quantum bound states is a route actively followed for topological superconductivity but also to realize qubits [3].

Most of the theoretical descriptions of the magnetic impurities rely on a classical spin model which simply describes the excitation spectrum but however artificially breaks time-reversal symmetry and fails to reproduce correctly the ground state degeneracy. Despite a lot of experimental and theoretical works that have been devoted to the interplay between magnetism and superconductivity, the dynamics of these bound states have hardly been studied. Since external driving is important for experimental probing of the dynamics, as well as a tool for manipulating the topological phase of the system, the non-equilibrium theory would be highly valuable.

In this internship, we propose to study the dynamics of a simple model of a **quantum** spin impurity interacting with a superconducting substrate in the zero-band limit [4] and subject to a time-dependent magnetic field. This proposal is part of a collaboration we have with experimentalists on the Saclay Plateau studying atomic-scale spin dynamics.

[1] L. Schneider et al., Nature Physics 17, 943 (2021); *ibid* Nature Nano. 17, 384(2022).
[2] A. V. Balatsky, I. Vekhter, and J.-X. Zhu, Rev. Mod. Phys. **78**, 373 (2006).
[3] A. Mishra, P. Simon, T. Hyart, and M. Trif, Yu-Shiba-Rusinov qubit, Phys. Rev. X Quantum **2**, 040347 (2021).
[4] K. Franke and F. von Oppen, Phys. Rev. B 103, 205424 (2021).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	YES