Master 2: *International Centre for Fundamental Physics*

<u>INTERNSHIP PROPOSAL</u>

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Internship location: Orsay
Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Study of the interplay between superconductivity and quantum magnetism: a new route toward topological superconductivity?

The study magnetically ordered states has always been a central problem in condensed matter physics. Dilute magnetic impurities immersed in a conductor (a metal or a semiconductor) are known to favor a magnetically ordered state depending on the impurity concentration and the exchange interaction between the magnetic impurities and the conduction electrons (the so-called Kondo interaction) [1]. One may wonder what happens when we replace the metal by a superconductor because magnetism and superconductivity are potentially two competing phases of matter. In other words, which phases can arise from the coupling of a lattice of quantum magnetic impurities with an already superconducting electron gas ?
To this purpose we will work within the framework of Dynamical Mean Field Theory (DMFT) [2], which is a state-of-art many-body method capable of treating the strongly-correlated Kondo interaction on a lattice which cannot be solved by standard techniques. DMFT becomes exact, in the limit of large lattice coordination. It is considered an excellent approximation for systems with strong local interactions, and therefore it is perfectly adapted to our problem. The strategy will therefore be to follow the model used in [1] by including a superconducting pairing potential. In some limiting cases it will be possible to obtain analytical results. An issue of interest is to find under which circumstances such interplay between magnetism and superconductivity could favor new topological superconducting phases of matter which are actively studied theoretically and experimentally (see [3] for example).
For some special electronic filling factors, it is more favorable for interacting electrons to be in an insulating phase, called a Mott insulator. This phase is well captured by DMFT. In presence of proximity induced superconductivity, a competition then may occurs between a Mott insulator and a superconducting phase, both presenting a spectral gap. We plan to analyze the phase diagram of such system applying DMFT on a simple model. This study could be also completed by considering the one-dimensional case, where low-energy analytical approaches based on field theory are available [4].

[1] A. Chattopadhyay, S. Das Sarma, and A. J. Millis, Phys. Rev. Lett. 87, 227202 (2001)
[2] A. Georges, G. Kotliar, W. Krauth and M. Rozenberg, Rev. Mod. Phys. 68, 1 (1996).
[3] X.-L. Qi and S.-C Zhang, Rev. Mod. Phys. 83, 1057 (2011).
[4] T. Giamarchi, Quantum physics in one dimension, Cambridge University Press.

Profile: Condensed matter theory, superconductivity, magnetism, many-body physics, topology,

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

Condensed Matter Physics:	YES	Macroscopic Physics and complexity:	NO
Quantum Physics:	YES	Theoretical Physics:	YES