Master 2

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR 8502
Internship director'surname: MESAROS Andrej / SIMON Pascal
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Internship location: Orsay
Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Title: **Study of quantum bound states in Dirac materials**

The graphene revolution in utilizing atomic layers is today lead by the transition metal dichalcogenide (TMD) materials, which show signatures of various quantum topological electron states, either insulating, superconducting, or semiconducting. A key question is how to exploit these states to build unconventional quantum quasiparticles, such as Majorana bound states in superconductors, whose braiding would enable quantum computation, or such as fractionalized bound states in insulators, which may participate in qubits or form exotic collective states.

Recently it was shown that the electric charge around defects in graphene reveals the Dirac-electron band structure [1]. We have shown that defects may produce fractionalized bound states in topological insulators [2], as well as Majorana bound states in superconductors with spin-orbit coupling [3]. In contrast to graphene, TMDs have strong spin-orbit coupling that leads to topological insulator and exotic superconducting states, but although various kinds of impurities and lattice defects in TMDs were recognized as important for overall charge effects and magnetism, their quantum bound states are not understood in detail.

During this internship, the student will characterize the local charge and spin dynamics of various impurities and lattice defects in models of TMD insulators. Quantum bound states will be studied using analytical calculations in low-energy Dirac-like theories, complemented with numerical lattice model calculations. If time allows, we will consider superconducting TMDs, and the impact of both band structure and superconducting pairing on the bound states, in self-consistent calculations. Based on collaboration with experiments on the Saclay Plateau studying atomic-scale spin dynamics, there is a possibility to expand the work onto topological endstates of chains of impurities.

[1] Dutreix, C., *et al. Nature* **574,** 219–222 (2019).
[2] Juričić, V., Mesaros A., *et al.* Phys. Rev. Lett. **108**, 106403 (2012).
[3] Ménard, G.C., Mesaros, A., *et al. Nat Commun* **10,** 2587 (2019).

Profile: Condensed matter theory, superconductivity, magnetism, quantum transport.

Please, indicate which specialities seem to be more adapted to the subject:

Condensed Matter Physics: YES Quantum Physics: YES
Theoretical Physics: YES