Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

(One page maximum)

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

Dynamics and correlations of magnetic impurities on a superconductor

Hybrid magnet-superconducting systems (i.e. arrays of magnetic impurities on a superconducting substrate) have attracted widespread interest for their high potential in topological quantum computation. Nano-fabrication techniques combined with local probe microscopies have recently revealed the emergence of zero-energy modes on ferromagnetic chains [1,2] and ferromagnetic nano-islands on s-wave superconductors [3,4]. The next main challenge is to control these (alleged Majorana) modes, and understanding their coherence and entanglement properties.

The building block of the hybrid systems is the single magnetic impurity, whose spin can be screened by electrons with opposite spin that hop on and off the impurity (Kondo effect). For partial spin screening, the magnetic impurity acts as a pair-breaking potential leading to Bogoliubov excitations with electron-hole parity named Yu-Shiba-Rusinov (YSR) states. Although the time-averaged properties of these in-gap states (spatial extent, orbital dependence, spin polarization…) are well understood from scanning probe studies, little is known about the dynamics of transport into them. This is because typical scanning probes have a limited bandwidth, and therefore cannot access time dependent processes.

In this project, we will use our recently developed finite frequency scanning tunnelling microscope [5, 6] to quantify the correlations and charge of the tunneling processes into YSR states. Secondly, we will extend the YSR studies to more complicated systems in order to shed the light on the emergence of Majorana Fermions. For that, we will build up defect-free magnetic chains, magnetic islands or any other combination of well-defined-geometric structures, such as T-shape structures for quantum computing, by atom manipulation techniques.

As a master student, you will first become familiar with the scanning tunnelling microscopy (STM) setup, characterise the atomically sharp tip and calibrate the finite frequency circuitry through shot-noise measurements on standard metals such as platinum. Afterwards, you will investigate the properties of magnetic impurities on superconductors grown in-situ under ultra-high vacuum (UHV) conditions by conventional and shot-noise STM measurements.

[1] S. Nadj-Perge et al., Science 346, 6209 (2014)
[2] H. Kim et al., Science Adv. 4, eaar5251 (2018)
[3] G. Menard et al., Nat. Comm. 8, 2040 (2017)
[4] A. Palacio-Morales et al., Science Adv. 5, aav6600 (2019)
[5] F. Massee, Rev. Sci. Instrum. 89, 093708 (2018)
[6] F. Massee et al., Nat. Comm. 10, 544 (2019)

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: NO