INTERNSHIP PROPOSAL

(One page maximum)

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https://w3.insp.upmc.fr/recherche-2/equipes-de-recherche/spectroscopie-des-nouveaux-etats-quantiques/
Internship location: Jussieu campus

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

Magnetism and superconductivity in hybrid magnetic/superconductor van der Waals heterostructures

Keywords: Scanning tunnelling microscopy (STM), spin polarized STM, Van der waals, low dimensional magnetism, topological superconductivity

Scientific description:

Van der Waals (vdW) materials are emerging as exceptionally versatile building blocks for a wide range of applications, including spintronics, superconductivity, nanoelectronics, and optics. They also hold great promise as tunable quantum simulators. The recent surge of interest in vdW materials began with the discovery of graphene, and new breakthroughs continue to appear each year. Among the most exciting developments is the discovery of intrinsic ferromagnetism in monolayer 2D crystals, which opens tremendous opportunities for exploring novel quantum phenomena.

In particular, the family of chromium trihalides - $CrCl_3$, $CrBr_3$, and CrI_3 (collectively denoted as CrX_3, X = I, Br, Cl) - represents one of the most promising classes of vdW magnetic monolayer materials. Their integration into vdW heterostructures is expected to yield a rich variety of exotic effects. For example, combining a magnetic insulator such as a chromium trihalide with a transition metal dichalcogenide (TMD) may give rise to new and exciting physics, including the emergence of topological superconductivity, as recently suggested in $CrBr_3/NbSe_2$ heterostructures [1]. In this system, pronounced edge states have been observed at the boundaries of $CrBr_3$ islands deposited on $NbSe_2$, which were initially interpreted as dispersive Majorana edge modes, signatures of an induced topological superconducting phase. However, more recent measurements seem to indicate a non-topological origin of these edge states [2].

Even if $CrBr_3/NbSe_2$ is finally topologically trivial, the stacking of magnetic insulators and superconducting vdW materials remains highly appealing, owing to its exceptional compatibility with nanoelectronic device architectures. In this internship, we aim to further pursue this strategy. Specifically, we will investigate the growth of several magnetic insulators ($FeCl_2$, $NiBr_2$, $CrCl_2$, VCl_3) on $NbSe_2$, targeting the formation of either two-dimensional islands or one-dimensional nanoribbons. Spin-polarized scanning tunneling microscopy (SP-STM) will be employed to probe their magnetic ground states, and low-temperature scanning tunneling spectroscopy (STS) will be performed to search for potential signatures of topological superconductivity in these heterostructures.

[1] S. Kezilebieke *et. al.*, Nature **588**, 424 (2020)

[2] Y. Li et al., Nature Communications **15**, 10121 (2024)

Techniques/methods in use: Low temperature STM, Spin polarized STM, molecular beam epitaxy.
Applicant skills: Background in solid physics state, enthusiasms, motivation, taste for experimental physics.

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:	NO	Theoretical Physics:	NO