INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Institut des NanoSciences de Paris (INSP)
CNRS identification code: UMR7588
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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:

Tuning magnetism in van der Waals magnet using moiré pattern

Keywords: Magnetism, Superconductivity, Van der Waals heterostuctures, skyrmions, spin polarized scanning tunnelling microscopy, moiré, molecular beam epitaxy, surface science.

Scientific description:

Van der Waals materials are emerging as extremely versatile building blocks in many applications such as spintronics, superconductivity, nanoelectronics, optics, and may serve as tunable quantum simulators. These materials appear as extremely attractive for exploring new exotic physics due to their ability to be stacked with an infinite number of combinations that lead to unexpected physical properties. The recent discovery of ferromagnetic order down to the monolayer limit in van der Waals materials confers new opportunities to engineer hybrid quantum materials [1,2]. The family of chromium trihalide, $CrCl_3$, $CrBr_3$ and CrI_3 (CrX_3, X = I, Br, Cl) is one of the most promising classes of two-dimensional magnetic materials [1, 3]. Their integration in a van der Waals heterostructure may form moiré patterns which are expected to lead to a wealth of exotic effects such as non-colinear magnetism. Indeed, we know from recent experimental and theoretical works [4, 5, 6] that the moiré potential give rise to a periodic modulation of the magnetic interaction between the neighboring atoms which can lead to the emergence of exotic non-collinear spin texture such as spin spiral, vortex or skyrmion lattices.

The SNEQ team has the expertise to prepare by molecular beam epitaxy of CrX_3 ultra-thin film [7]. During the internship we will investigate moiré pattern in such Van der Waals magnets coupled to metallic and superconducting substrate. Using the atomically resolved spin polarized scanning tunneling microscope, we will study the magnetic ground of the heterostructures and investigate how the moiré pattern influence this magnetic ground state.

[1] B. Huang *et al.*, *Nature* **546**, 270-273 (2017).
[2] C. Gong *et al.*, *Nature* **546**, 265-269 (2017).
[3] D. Soriano, M. I. Katsnelson, J. Fernández-Rossier, *Nano Letters* **20**, 6225-6234 (2020).
[4] H. Xie *et al.*, *Nature Physics* **19**, 1150-1155 (2023).
[5] Y. Xu *et al.*, *Nature Nanotechnology* **17**, 143-147 (2022).
[6] A. O. Fumega, J. L. Lado, *2D Materials* **10**, 025026 (2023).
[7] E. Gambari, S. Meyer *et al.*, Advanced Functional Materials, 2407438 (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