INTERNSHIP PROPOSAL

(One page maximum)

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Internship location: INSP

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Tuning magnetism in van der Waals magnet using moiré pattern

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

Van der Waals materials are emerging as extremely versatile building blocks in many fields 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 leads to unexpected physical properties. The recent discovery of ferromagnetism down to the monolayer limit in van der Waals materials confers new opportunities to engineer magnetic 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 van der Waals heterostructure may give rises to the formation of 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 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 CrX_3 ultra-thin film by molecular beam epitaxy [7]. During the internship, we will investigate moiré patterns in such Van der Waals magnets coupled to metallic and superconducting substrates. Using atomically resolved spin polarized scanning tunneling microscopy, we will probe the magnetic ground of the heterostructures and investigate how the moiré patterns influence the magnetic ground state.

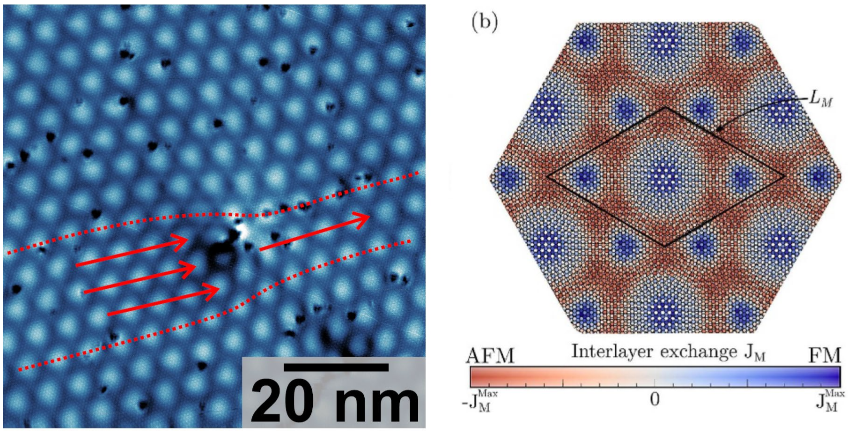

Figure: *Left – Moiré pattern we have observed in a monolayer of CrCl3 deposited on Au(111) substrate. Right – Periodic modulation of the Heisenberg exchange interaction due to a moiré pattern in a chromium trihalide [6]*

[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

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	NO	Theoretical Physics:	NO