Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: **Matériaux et Phénomènes Quantiques – MPQ**
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Thesis possibility after internship: YES
Funding: NO

Duality in the Hofstadter spectrum

The Hofstadter model [1] describes electrons moving on a crystalline 2D lattice in the presence of a perpendicular magnetic field. The interplay between the lattice periodicity and the magnetic flux leads to a fractal energy spectrum known as the Hofstadter butterfly, with energy gaps characterized by integer Chern numbers. This model provides a fundamental link between lattice physics and topological phenomena such as the integer quantum Hall effect. Recent advances in moiré superlattices, such as twisted bilayer graphene and transition metal dichalcogenides, have made the Hofstadter spectrum experimentally accessible [2], offering a rich platform to study topological bands, Chern physics, and fractal quantum phenomena.

The goal of this internship is to investigate the duality of the Hofstadter model in moiré crystalline lattices. Unlike the original model, the moiré crystal is described using a continuous model rather than a tight-binding Hamiltonian [3-5]. Interestingly, the model appears to exhibit a duality whereby the high-flux spectrum can be mapped onto an effective tight-binding model, corresponding to the original Hofstadter model. The project will focus on understanding this duality and how it shapes the Chern number hierarchy.

[1] D. R. Hofstadter, Phys. Rev. B 14, 2239 (1976)
[2] C. R. Dean, L. Wang, P. Maher, … J. Hone, P. Kim, Nature 497, 598 (2013)
[3] R. Bistritzer, A. H. MacDonald, Phys. Rev. B 84, 035440 (2011)
[4] K. Hejazi, C. Liu, L. Balents, Phys. Rev. B 100, 035115 (2019)
[5] K. Kolář, K. Yang, F. von Oppen, C. Mora, PRB 110, 115114 (2024)

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: YES