Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: **Matériaux et Phénomènes Quantiques – MPQ**
CNRS identification code: **UMR7162**
Internship director: **Christophe Mora**
e-mail: christophe.mora@u-paris.fr
phone number **: 01 57 27 62 44**
Web page: http://www.phys.ens.fr/~mora/
Internship location: MPQ, Bâtiment Condorcet, Université Paris Cité, Paris 13e

Thesis possibility after internship: YES
Funding: NO

Layer skyrmions in topological bands and anomalous Hall crystal

Recent breakthrough experiments [1-3] have identified fractional Chern insulator phases in two-dimensional platforms. Despite the absence of an external magnetic field, these phases break time-reversal symmetry and exhibit strong similarities to the celebrated fractional quantum Hall effect. They suggest a broad analogy between topological flat bands (which have no kinetic energy) and Landau levels [4]. For a specific class of experimentally relevant bands, known as ideal bands, a mapping has even been established between these bands and conventional Landau levels. This mapping is generally linked [5] to an orbital winding of the band, called a skyrmion, in analogy with non-trivial spin texture in magnetic systems.

The aim of this internship is to investigate the formation of orbital skyrmions in topological flat bands. By solving continuum models with superlattice (moiré) potentials, the robustness of the topological orbital skyrmions will be studied for generic bands beyond the ideal case. One objective is to explore how the Landau level duality between real-space and momentum topology extends to genuinely topological bands. Additionally, electrons interactions may stabilize a Wigner crystalline structure [6] with topological properties. Using a Hartree-Fock approach, the orbital skyrmion texture of this symmetry-broken state will be then investigated. Typical examples will include models of twisted bilayer graphene, twisted transition metal dichalcogenides, and rhombohedral multilayer graphene.

[1] Cai, Anderson, Wang, Xiao, Yao, Xu et al., Nature 2023
[2] Kang, Shen, Shan, Mak et al., Nature 2024
[3] Lu, Han, Yao, Fu, Long et al., Nature 2023
[4] Wang, Zheng, Millis, Cano, PRR 2021
[5] Guerci, Wang, Mora, arXiv:2408.12652
[6] Dong, Wang, Vishwanath, Parker, PRL 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