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

Fractional Chern insulator and quantum geometry

Recent breakthrough experiments [1–3] have revealed the existence of fractional Chern insulator (FCI) phases in two-dimensional systems. Remarkably, these phases arise without an external magnetic field, yet they break time-reversal symmetry and closely resemble the celebrated fractional quantum Hall effect. This discovery highlights a deep analogy between topological flat bands—characterized by quenched kinetic energy—and Landau levels [4]. In certain regimes, one can even establish a direct mapping between them, identifying the real-space Berry curvature as an effective (fictitious) magnetic field [5]. A central open question remains: under what conditions does a given band structure favor the formation of a fractional Chern insulator?

The goal of this internship is to explore fractional Chern insulator states in a model *without* intrinsic band topology. Until recently—before the identification of a counterexample [6]—it was widely believed that nontrivial band topology was a prerequisite for the emergence of FCIs. By focusing on a model where the relevant band displays rich quantum geometry and significant Berry curvature but a *trivially quantized* Chern number, this work will investigate the possible emergence of a fractional Chern state at filling 1/3. The study will analyze the respective roles of quantum geometry and real-space Berry curvature in stabilizing the fractional Chern phase.

[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, Phys. Rev. B **112**, L041108 (2025)
[6] Lin, Lu, Yang, Zhai, Yao, arXiv:2505.09009

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