INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique et Modélisation des Milieux Condensés
CNRS identification code: UMR 5493

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Thesis possibility after internship: YES
Potential funding: EDPHYS Grenoble, Quant-EDU, QuantAlps

Exploring Spin-Orbit Coupling in Quantum Hall Systems

The quantum Hall effect (QHE) has long been a key area of research in condensed matter physics, exemplifying the role of topology in quantum mechanics. In QHE systems, the Hall conductance becomes quantized with significant applications in quantum metrology. The fractional quantum Hall effect, which arises due to electron-electron interactions, leads to the creation of exotic quasi-particles with fractional charge and statistics that are neither fermionic nor bosonic.

Recent experimental progress [1] has unveiled numerous fractional Hall plateaus, particularly in bilayer systems like graphene or double quantum wells. These bilayer structures introduce new complexities [2] due to strong interlayer interactions. Spin-orbit coupling can also be present – or engineered – in these materials. The spin-orbit coupling complicates the traditional picture of spin being a good quantum number and alters the nature of the QHE states [3]. Near Landau level crossings, these effects are further amplified, leading to rich and intricate physics [4] that demands theoretical attention.

This internship project will focus on the effects of spin-orbit coupling on integer QHE systems. It will begin by analyzing how spin-orbit coupling modifies the wavefunctions and edge states of non-interacting electrons in a single Landau level in the presence of trapping potentials. The second phase will consider Landau level crossings effects in bilayer structures and address electron interactions through a mean-field Hartree-Fock approach.

Combining both analytical and numerical work, this research will contribute to a better understanding of topological phases. Long-term (PhD) goals include extending this analysis to study transport and disorder effects, light-matter coupling to a QED cavity, or a more precise numerical treatments of interactions to study fractional phases.

[1] K. Huang et al, Phys. Rev. X 12, 031019 (2022)
[2] E. McCann et al, Rep. Prog. Phys. 76 056503 (2013)
[3] Y. Xing et al., Phys. Rev. B 77, 114346 (2008)
[4] P. Nataf et al., Phys. Rev. Lett. 123, 207402 (2019)

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