Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR8502
Internship director'surname: Corentin MORICE and Mark-Oliver GOERBIG
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Internship location: LPS Orsay

Thesis possibility after internship: YES
Funding already obtained for a PhD: NO

Topology and geometry in correlated matter

Topological band theory has become a central aspect of the field of condensed matter physics. Topological invariants have been extensively studied both in analytical models and using ab-initio calculations, leading to the classification of a large variety of new phases of matter, including crystalline and higher-order topological phases, and to the prediction of such phases in some 30% of known materials. Quantum geometry, and in particular its best-known component, the Berry curvature, is now understood to be crucial for understanding electronic transport, its most striking manifestation being quantum Hall effects.

Despite these recent developments, the theoretical framework commonly used for understanding topological states remains based on Bloch wave-functions. Because of this, it is not suitable to take many-body effects, such as the influence of electronic correlations, or of temperature, into account. This limits our understanding of the physics of real topological materials, and our ability to predict or replicate experimental results.

This internship aims to deepen our understanding of the interplay between many-body physics and topological quantities by studying how topology and geometry enter in many-body Green's functions. The intern will be able to choose whether they would like to pursue an analytical approach, and ab-initio approach, or both.

In the analytical approach, we will study the analytical structure of Green's functions in simple interacting systems where the self-energy can be calculated. There, we will seek signatures of topology in the energy and momentum dependence of zeros of the Green's function. We will also generalise the notion of quantum geometry, which is so far defined using derivatives of Bloch wave-functions in reciprocal space. By using derivatives of Green's functions instead, we will define a new geometric tensor, and connect it to topological and transport properties.

In the ab-initio approach, the student will use many-body perturbation theory, and in particular the GW approximation, in a more recent form named quasiparticle self-consistent GW (QSGW). This technique allows the calculation of quasiparticle wave functions, as well as of the self-energy, both of which include the influence of correlations. We will calculate the differences in geometry between non-interacting wave-functions and quasiparticle wave functions and how they impact topology. We will also study the frequency dependence of the self-energy to grasp how it connects to topological invariants, which is inherently frequency-independent.

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