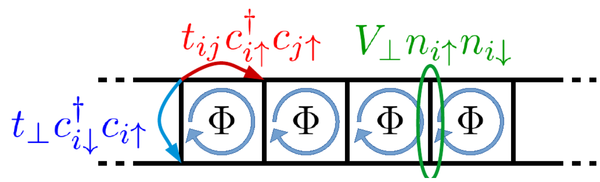
Stage M2: fractional topological insulators in quasi-1D Hubbard models

Soon after the discovery of the quantum Hall effect, i.e. the quantization of the transverse Hall conductance at integer values times e^2/h, people realized that certain rational values were also observed, with a well defined hierarchy of insulating states. Even though the understanding of the integer quantum Hall effect is (relatively) simple, leading to a topological explanation for the robustness of the quantization, the fractional quantum Hall effect is much more complicated since the interactions play a crucial role. Many effective theories have been proposed providing not only a clear qualitative understanding of the underlying topological properties, but also a fair agreement with the experiments. Unfortunately, from a numerical point of view, the difficulties of the problems are such that quantitative results only exist for very small system sizes, extremely far away from the thermodynamic limit.

On the other hand, simpler quasi-1D systems such as ladders with a magnetic flux (see figure), leads to simpler numerical and theoretical approaches to compute both static and dynamic properties. Recently, it has been emphasized that the ground states of interacting bosons or fermions in such a geometry can exhibit (topological) properties similar to the fractional quantum Hall ones. As such, these systems are considered as precursors of the genuine 2D fractional topological insulators. Still, for these quasi-1D system, one needs to address the low energy excitations on top of the ground states, allowing us to compute the transport properties which are of experimental interest.



The main goal of the project is therefore to figure out the properties of fermions in a ladder geometry, in the presence of a magnetic field, as functions of the microscopic parameters (filling, transverse hopping amplitude, interaction strength, magnetic flux), using two complementary methods, an analytic one (bosonisation) and a numerical one (density matrix renormalization group). At first, in order to learn the different methods, the student will determine the ground state properties, in particular recovering fractional quantum Hall like states. In a second step, she/he will address the transport properties looking for unambiguous experimental signatures. For instance, we could consider the electronic transport across a normal metal- quantum Hall junction.

The project could be extended to a PhD project.

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