Artificial gauge fields with ultracold atoms in optical lattices

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Ultracold atoms in optical lattices are powerful experimental platforms to study a variety of phenomena ranging from condensed-matter to statistical physics. Recently, a promising new direction was opened by the successful realization of two paradigmatic topological condensed matter models, i.e. the Hofstadter and the Haldane model. Topological states of matter exhibit unique conductivity properties, which are particularly robust against perturbations. One of the most prominent examples is the integer quantum Hall effect, where a two-dimensional electron gas under extreme conditions exhibits a quantized conductivity.

Investigating related phenomena with charge-neutral atoms required the development of novel experimental techniques to mimic the behavior of charged particles in magnetic fields. I will introduce some of the most common methods based on periodic driving of the system's parameters, which lead to the successful generation of artificial magnetic fields in optical lattices and direct observations of the associated non-trivial topological properties.

The simulation of complete gauge theories requires additional ingredients that mimic the interaction between the atoms and the internal degrees of freedom of the gauge field. The challenge consists in implementing dynamical gauge fields that interact with the atoms in a suitable way that respects the symmetry of the gauge theory. Here, I will present recent results, where we have used a combination of periodic modulation and strong interactions to realize a Z_2 lattice gauge theory in a double well using a mixture of ultracold bosonic atoms.