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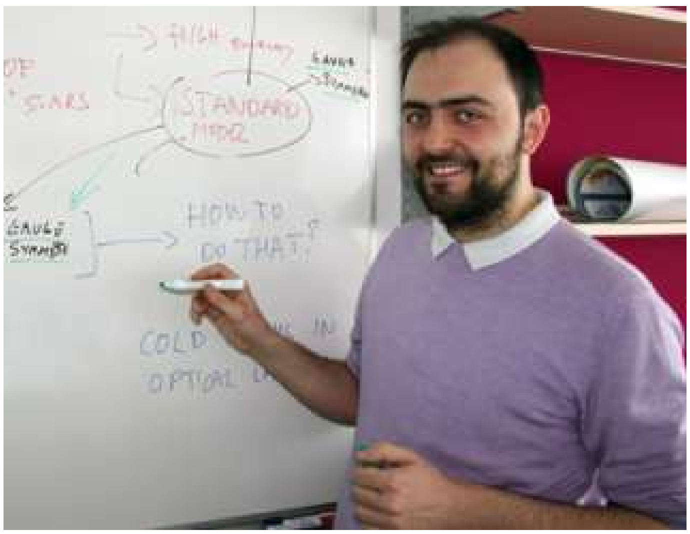

Researchers in Florence and Innsbruck have simulated a physical phenomenon in an atomic quantum gas that can also be observed at the edge of some condensed matter systems: chiral currents. The scientists have published the experiment, which will open new doors for the study of exotic states in condensed matter, in the journal *Science*.

Condensed matter physics remains a field of study with many puzzles to solve. New studies have become possible due to advances in experimental quantum physics. In particular, ultracold atoms in optical lattices and an environment that is fully tunable and controllable represent an ideal system for studying the physics of condensed matter problems. One of these phenomena can be observed in connection with the quantum Hall effect: When certain materials are subjected to a strong magnetic field, the electrons cannot move in a singular circular direction at the edges anymore but repeatedly bounce against the edge, where they are reflected. This corresponds to skipping trajectories. As a macroscopic consequence so called chiral currents, which move in the opposite direction at the opposite edges, can be observed at the boundaries of such two-dimensional materials.

"You could compare it to a river where the fish swim towards the right on one bank and towards the left on the other bank," explains theoretical physicist Marcello Dalmonte from the Institute for Theoretical Physics at the University of Innsbruck and a member of Peter Zoller's research group at the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences.

Hopping atoms

Already ten years ago, Peter Zoller's research team proposed a way to simulate chiral currents with neutral atoms. This idea combined with the synthetic dimension approach, put forward by the Barcelona group at ICFO, was picked up and implemented by physicists at the European Laboratory for Nonlinear Spectroscopy (LENS) in Florence collaborating with theoretical physicists in Innsbruck. In their experiment, the scientists confined an ultracold gas of ytterbium atoms in an optical lattice generated by laser beams. As it is difficult to reproduce the structure of two-dimensional condensed matter systems, the physicists use a new approach: They used a one-dimensional chain of atoms and produced the second dimension synthetically. The dynamics along the synthetic dimension are generated by laser-induced hopping between two or three internal spin states. "From a theoretical perspective this hopping into different internal spin states represents the same concept as the geometrical hopping of electrons at the edges of a condensed matter system," explains Marcello Dalmonte.

Together with Marie Rider and Peter Zoller, Marcello Dalmonte laid the theoretical groundwork for the experiment and suggested how to observe this phenomenon. The observations published in *Science* show that the particles move mostly to the right at one edge and to the left on the other edge. "This behavior is very similar to chiral currents known in condensed matter physics," says Dalmonte. This simulation of exotic effects opens up new ways for the researchers to study other new physical phenomena, for example, in connection with quantum Hall effects, the study of anyons in atomic systems. These exotic quasi particles are suggested to being suitable as the main building block for topological quantum computers.

More information: Observation of chiral edge states with neutral fermions in synthetic Hall ribbons. *Science*, 2015; 349 (6255): 1510 DOI: 10.1126/science.aaa8736

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