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Experimental realisation of topological pumping in a synthetic Hall cylinder

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Topological invariants are both interesting and promising tools in various fields of physics, such as quantum computation, due to their robustness against external perturbations. For instance a well-known consequence of topology is the emergence of a discretised conductivity in two-dimensional electron gases in the presence of an external magnetic field, known as the integer quantum Hall effect. The extension, developed by Laughlin, to a cylinder geometry associates the threading of a quantum of magnetic flux inside the hole of the cylinder to a quantised particle transport along the infinite dimension. The quantisation of the response is protected by the topology of the system, which is characterised by a non-trivial Chern number equal to one, and does not depend on the flux variations, nor experimental imperfections.

We report on the realisation of a Laughlin pump experiment using ultracold samples of atomic dysprosium. The large total angular momentum J = 8 of dysprosium atoms in their electronic ground state constitutes a synthetic dimension, which can be probed using time-of-flight imaging with a magnetic gradient. By inducing cyclic optical Raman transitions between the Zeeman sublevels of the electronic ground state, the angular momentum of the atoms effectively acts as a discretised dimension with periodic boundary conditions. We first probe the structure of the effective Hamiltonian, notably the flatness of its ground band and Bloch oscillations associated to an adiabatic flow along the synthetic dimension. We then show experimental evidence of topological pumping with the quantisation of transport along the real dimension as quanta of magnetic flux are adiabatically threaded through the cylinder.