Realizing a chiral BF theory in an optically dressed Bose-Einstein condensate

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Ultracold atoms constitute a versatile testbed for exploring the behaviour of quantum matter subjected to electric and magnetic fields. While most experiments consider classical gauge fields that act as a simple static background for the atoms, gauge fields appearing in nature are instead quantum dynamical entities that are influenced by the spatial configuration and motion of matter, and that fulfil local symmetry constraints. In my talk, I will discuss our recent realization of a chiral BF theory: a gauge theory that was initially proposed as a model for linear anyons, and which corresponds to a one-dimensional reduction of the Chern-Simons theory effectively describing fractional quantum Hall systems. By using the local symmetry constraint, we encode the gauge field in terms of the matter. The result is a system with chiral interactions, which we engineer by synthesizing optically dressed atomic states with a momentum-dependent scattering length. When this dependence is linear, matter behaves as if minimally coupled to a density-dependent vector potential. Theoretically, we show that the system then realizes the chiral BF Hamiltonian at the quantum level. Experimentally, we observe its two main features: the formation of chiral bright solitons - self-bound states of the matter field that only exist when propagating in one direction – and the back-action of matter into the gauge field. Our results establish chiral interactions as a novel resource for quantum simulation experiments with ultracold atoms and pave the way towards implementing topological gauge theories in higher dimensions.