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Realizing the entanglement Hamiltonian of a topological quantum Hall system

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A quantum Hall system is characterized by non-trivial topological order of its underlying quantum states. While topological order cannot be accessed using local measurements, it leads to specific signatures in the structure of entanglement upon spatial partition, characterized by the entanglement spectrum. According to the Li-Haldane conjecture, the entanglement spectrum corresponds to a chiral gapless mode, mimicking the excitation spectrum of a topological edge mode.

We investigate this behavior by reconstructing experimentally the entanglement Hamiltonian of an atomic quantum Hall system. We use the large spin J = 8 of dysprosium atoms to encode a synthetic dimension, which we couple to the atomic motion using two-photon optical transitions. We engineer a quantum Hall system with a position-dependent effective mass along the synthetic dimension, such that the two spin sectors of projection states m <= 0 and m > 0 are decoupled. Combining this tool with linear and quadratic Zeeman fields, we perform a variational study of the entanglement Hamiltonian, and measure a dispersive ground band consistent with a chiral gapless virtual edge. This approach could be generalized to a wide range of many-body systems, allowing one to access complex entanglement properties.

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