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Quantum Hall physics in a quantum Foucault pendulum

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When charged particles are placed in a magnetic field, the single-particle energy states form discrete, highly-degenerate Landau levels. Since all states within a Landau level have the same energy, the behaviour of the system is completely determined by the interparticle interactions and strongly-correlated behaviour such as the fractional quantum Hall effect occurs. Here, we present recent experiments from MIT on the microscopy of a rapidly-rotating Bose-Einstein condensate, in which the Coriolis force felt by a massive particle in a rotating frame plays the role of the Lorentz force felt by a charged particle in a magnetic field. In a magnetic field the X and Y coordinates of a particle do not commute, leading to a Heisenberg uncertainty relation between spatial coordinates. We exploit the ability to squeeze non-commuting variables to dynamically create a Bose-Einstein condensate occupying a single Landau gauge wavefunction, and investigate its purely interaction-driven dynamics in the lowest Landau level. We reveal a spontaneous crystallization of the fluid, driven by the interplay of interactions and the magnetic field; increasing the cloud density smoothly connects this quantum behavior to a classical Kelvin-Helmholtz-type hydrodynamic instability, driven by the sheared superfluid flow profile arising from the vector potential. Finally, we project a sharp optical boundary onto our system and demonstrate controllable injection of its associated chiral edge states, quantifying their speed, excitation energy, and dependence upon wall structure.

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