PHYSICAL MATHEMATICS SEMINAR

Quantum Hall physics in the quantum Foucault pendulum

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ABSTRACT:

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. In contrast to transport measurements in condensed matter systems which probe the behaviour of the entire sample, ultracold atomic quantum gases afford the ability to manipulate and observe the dynamics of single wavefunctions subject to a magnetic field, offering a complementary, microscopic insight into the individual building blocks of quantum Hall systems.

However, atomic quantum gases are electrically neutral, meaning one must engineer ‘synthetic’ magnetic fields for the atoms. Here, we present recent experiments from MIT on high-resolution microscopy of a 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. Remarkably, 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 directly observe the zero-point motion of atoms which sets a fundamental limit on their position. In a second experiment, we investigate the purely interaction-driven behaviour of a Bose-Einstein condensate living entirely in the lowest Landau level, where all single-particle states are degenerate. We reveal a spontaneous crystallisation of the fluid, driven purely by the interplay of interactions and the magnetic field. Increasing the cloud density smoothly connects this behaviour to a quantum version of the Kelvin-Helmholtz hydrodynamic instability, driven by the sheared internal flow profile intrinsic to a rapidly rotating condensate.

TUESDAY, NOVEMBER 9, 2021
2:30 PM – 3:30 PM
Building 2, Room 449

MIT Covid policies must be adhered to:

- **remember to keep your mask on while inside buildings**
- **eating food is not allowed within lecture rooms**

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