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Currents and Phases in Quantum Rings.

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Emergent phenomena in quantum systems often exhibit magnetic signatures. In this talk, I will describe how to use the current in a ring to access fundamental and topological properties of quantum states of charge-carrying particles. Applying a magnetic flux through a ring creates a phase gradient, in response to which a current flows, creating magnetic fields that we measure with a scanning SQUID microscope. I will take you on a tour of currents and phases in common and exotic quantum materials. Gold rings are normal metals with finite resistance down to the lowest measured temperatures. Remarkably, they nevertheless carry currents that flow forever (called persistent currents), whose sign and magnitude are a test of quantum theories of disordered metals. Aluminum rings superconduct at low temperatures, and are an ideal model system to study superconducting fluctuations. The strong agreement of theory and experiment in conventional metals and superconductors sets the stage to study superconducting rings interrupted by a single Josephson junction. This geometry allows us to measure a fundamental and informative property of the junction, called the current-phase relation. In junctions made of topological materials, the current could theoretically be 4pi-periodic rather than 2pi-periodic as a function of the phase winding in the ring. I will report on progress towards this smoking-gun signature for Majorana modes.