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Emergent Phenomena in Quantum Materials

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Electrons are seemingly simple particles with charge e and spin . But, when they live in materials whose composition, structure, and even dimensionality can be carefully designed, they display various complex, emergent states of matter. These states have tremendous potential to be useful as well as interesting, but they can be theoretically difficult to describe and predict. After an introduction to ways of thinking about strongly correlated quantum materials, I will describe how imaging local magnetic fields with a scanning Superconducting QUantum Interference Device allows us to non-invasively watch the electrons on mesoscopic length scales. I will give several examples of the ways in which the magnetic flux quantum (h/e or h/2e in metals and superconductors respectively) can play a special role in diagnosing the state of quantum materials ranging from normal metals to topological insulators to proposed chiral superconductors.