Department of Physics Colloquium

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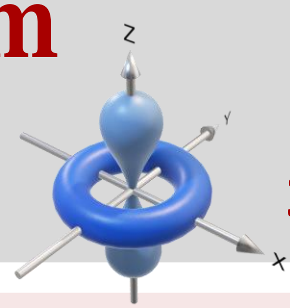

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Using vortices to explore unconventional superconductivity

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Topological properties of materials are of fundamental as well as practical importance. Of particular interest are unconventional superconductors that break time-reversal symmetry, for which the superconducting state is protected topologically and vortices can host Majorana fermions with potential use in quantum computing. However, in striking contrast to the unconventional A phase of superfluid 3He where chiral symmetry was directly observed, identification of broken time-reversal symmetry of the superconducting order parameter, a key component of chiral symmetry, has presented a challenge in bulk materials.

In this talk I will present our recent studies of the topological superconductor UPt_3. This material exhibits three distinct superconducting phases, labelled A, B and C, providing a strong indication that it breaks additional symmetries of the normal state beyond gauge symmetry. Here, the presence of a weak symmetry-breaking field (SBF) – for example, weak in-plane anti-ferromagnetism or strain – lifts the degeneracy of different order parameter symmetries and leads to multiple superconducting phases.

In a type-II superconductor, such as UPt_3, vortices are nucleated when it is subjected to an applied magnetic field. The vortices introduce singularities in the order parameter, with properties that depend sensitively on the superconducting state in the host material. Using small-angle neutron scattering to image the vortex lattice, we demonstrate that the vortices in UPt_3 possess an internal degree of freedom in the superconducting B phase, providing direct evidence for bulk broken time-reversal symmetry. Furthermore, we show how certain features of the vortex lattice phase diagram can be directly attributed to the SBF.

Time permitting, I will also discuss how UPt_3 presents a novel avenue for vortex matter studies by allowing the introduction of localized and reversible quenched disorder. The disordering is due to local heating events, caused by neutron induced fission of ^{235}U, which leaves an increasing fraction of the sample in a quenched vortex glass state. While the system does not spontaneously re-order, it is possible to re-anneal the vortex lattice by the application of a small-amplitude field oscillation once the local heating has been dissipated.

This colloquium will be held in-person, at SERC 116 unless announced otherwise.