Physics & Astronomy Colloquium – Spring 2019

Tuesday, Jan 29th at 3:30 pm in SC 234

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New routes to topologically nontrivial states on the surface of HfNiSn single crystals and at superconducting interfaces.

Quantum materials have the potential to revolutionize modern electronics, where protected quantum states could push limits set by disorder in even the purest "classical" semiconductors like silicon, and improve device performance at ever decreasing length scales. They also hold the promise of using quantum states for storing and transporting information, quantum computing and quantum cryptography.

In some materials, it is only at interfaces that their true quantum nature becomes apparent, and surface or edge states arise as a consequence of the geometric properties – or topology - of electronic wavefunctions. Over the past decade, such topological systems have garnered immense interest as potential new functional materials: as their surface or edge states are protected by global geometric properties and symmetries of the material, they could allow for lossless charge transport or the transmission of quantum information over macroscopic length scales. However, we are only beginning to experimentally identify topological materials, like $Bi_{1-x}Sb_x$ alloys, Bi_2Se_3 and Bi_2Te_3, as well as a few half-Heusler compounds like YPtBi. Current predictions indicate that up to one quarter of all known solids may indeed be topologically nontrivial, highlighting the enormous potential for future discoveries and applications based on topological materials.

In this talk I will discuss a potentially new route to topological boundary states, similar to the edge states in quantum Hall effect systems, found on the surface of the half - Heusler compound HfNiSn. These states appear to originate from strong electronic correlations, and they form even in the absence of external magnetic fields. I will show how even simple transport experiments can reveal valuable information on these states, demonstrating low-dimensional confinement and timereversal symmetry breaking, as well as nonlinear I(V) characteristics indicating electronic interactions. Oscillations in the magnetoresistance suggest quantum interference with coherence lengths up to 1μm. Such long coherence lengths are unexpected even in relatively high quality crystals, and suggest topological protection of the current carrying states. Encouraged by these initial discoveries, I want to develop a tool kit of transport measurements to facilitate the discovery of topological states and understand their origin in HfNiSn and related materials.

Considering technological applications, the combination of quantum Hall edges or similar chiral one-dimensional states and superconductors is particularly attractive, as such junctions are expected to host the elusive Majorana fermions that seem a promising choice for future qubits, and the chiral nature of quantum Hall edge states could enable braiding operations between them, providing a possible platform for topological quantum computing. Our first tests of metal deposition on HfNiSn single crystals show promising results, where proximity to superconducting tin or niobium leads to conductance steps close to the quantized value of ~ 0.5 e^2/h expected for Majorana fermions. We further observe a clear disruption of quantum interference patterns at the superconducting transition, and magnetoresistance features associated with the critical field that can be traced up to approximately 80 K. These results not only provide further evidence for topologically nontrivial states on the HfNiSn surface, they also suggest that superconducting states could be stabilized along the interface. Future research on this material system could therefore lead to significant advances in quantum information technology, from topologically protected quantum computing to improving superconducting qubits.

Refreshments at 3:00 pm in SC 103