Exchange and collective behavior of magnetic impurities in a disordered helical metal

Héctor Ochoa

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We study the exchange interaction and the subsequent collective behavior of magnetic impurities embedded in a disordered two-dimensional helical metal. The exchange coupling follows a statistical distribution whose moments are calculated to the lowest order in $(p_F \ell)^{-1}$, where p_F is the Fermi momentum of itinerant electrons and ℓ is the mean free path. We find that (i) the first moment of the distribution decays exponentially, and (ii) the variance of the interaction is long range, however, it becomes independent of the orientation of the localized magnetic moments due to the locking between spin and momentum of the electrons that mediate the interaction. As a consequence, long-range magnetic order tends to be suppressed, and a spin glass phase emerges. The formalism is applied to the surface states of a three-dimensional topological insulator. The lack of a net magnetic moment in the glassy phase and the full randomization of spin polarization at distances larger than ℓ excludes a spectral gap for surface states. Hence, nonmagnetic disorder may explain the dispersion in results for photoemission experiments in magnetically doped topological insulators.

Nanosized helical magnetic domains in strongly frustrated Fe3PO4O3

Kate A. Ross, Mitchell Bordelon, Greg Terho, James R. Neilson arXiv:1509.07846

Fe3PO4O3 forms a non-centrosymmetric lattice structure (space group R3m) comprising triangular motifs of Fe^{3+} coupled by strong antiferromagnetic interactions (|\Theta_{CW}| > 900 K). Neutron diffraction from polycrystalline samples shows that strong frustration eventually gives way to an ordered helical incommensurate structure below T_N = 163 K, with the helical axis in the hexagonal ab plane and a modulation length of ~ 100 \AA. The magnetic structure consists of an unusual needle-like correlation volume that extends past 900 \AA along the hexagonal c-axis but is limited to ~ 70 \AA in the ab plane, despite the three-dimensional nature of the magnetic sublattice topology. The small in-plane correlation length, which persists to at least T = T_N/40, indicates a robust blocking of long-range order of the helical magnetic structure, and therefore stable domain walls, or other defect spin textures, must be abundant in Fe3PO4O3. Temperature dependent neutron powder diffraction reveals small negative thermal expansion below T_N. No change in lattice symmetry is observed on cooling through T_N, as revealed by high resolution synchrotron X-ray diffraction. The previously reported reduced moment of the Fe^{3+} ions (S=5/2), mu ~ 4.2 mu_B, is confirmed here through magnetization studies of a magnetically diluted solid solution series of compounds, Fe(3-x)GaxPO4O3, and is consistent with the refined magnetic moment from neutron diffraction 4.14(2) mu_B. We attribute the reduced moment to a modified spin density distribution arising from ligand charge transfer in this insulating oxide.

Theory of Andreev Bound States in S-F-S Junctions and S-F Proximity Devices

Matthias Eschrig arXiv:1509.07818

Andreev bound states are an expression of quantum coherence between particles and holes in hybrid structures composed of superconducting and non-superconducting metallic parts. Their spectrum carries important information on the nature of the pairing, and determines the current in Josephson devices. Here I give a short review on Andreev bound states in systems involving superconductors and ferromagnets with strong spin-polarization. I show how the processes of spin-dependent scattering phase shifts and of triplet rotation influence Andreev point contact spectra, and provide a general framework for non-local Andreev phenomena in such structures in terms of coherence functions. Finally, I demonstrate how the concept of coherence functions cross-links wave-function and Green-function based theories, by showing that coherence functions fulfilling the equations of motion for quasiclassical Green functions can be used to derive a set of generalised Andreev equations.

Observation of surface states derived from topological Fermi arcs in the Weyl semimetal NbP

Ilya Belopolski, Su-Yang Xu, Daniel Sanchez, Guoqing Chang, Cheng Guo, Madhab Neupane, Hao Zheng, Chi-Cheng Lee, Shin-Ming Huang, Guang Bian, Nasser Alidoust, Tay-Rong Chang, BaoKai Wang, Xiao Zhang, Arun Bansil, Horng-Tay Jeng, Hsin Lin, Shuang Jia, M. Zahid Hasan arXiv:1509.07465

The recent experimental discovery of a Weyl semimetal in TaAs provides the first observation of a Weyl fermion in nature and demonstrates a novel type of anomalous surface state band structure, consisting of Fermi arcs. So far, work has focused on Weyl semimetals with strong spin-orbit coupling (SOC). However, Weyl semimetals with weak SOC may allow tunable spin-splitting for device applications and may exhibit a crossover to a spinless topological phase, such as a Dirac line semimetal in the case of spinless TaAs. NbP, isostructural to TaAs, may realize the first Weyl semimetal in the limit of weak SOC. Here we study the surface states of NbP by angle-resolved photoemission spectroscopy (ARPES) and we find that we *cannot* show Fermi arcs based on our experimental data alone. We present an *ab initio* calculation of the surface states of NbP and we find that the Weyl points are too close and the Fermi level is too low to show Fermi arcs either by (1) directly measuring an arc or (2) counting chiralities of edge modes on a closed path. Nonetheless, the excellent agreement between our experimental data and numerical calculations suggests that NbP is a Weyl semimetal, consistent with TaAs, and that we observe trivial surface states which evolve continuously from the topological Fermi arcs above the Fermi level. Based on these results, we propose a slightly different criterion for a Fermi arc which, unlike (1) and (2) above, does not require us to resolve Weyl points or the spin splitting of surface states. We propose that raising the Fermi level by >20 meV would make it possible to observe a Fermi arc using this criterion in NbP. Our work offers insight into Weyl semimetals with weak spin-orbit coupling, as well as the crossover from the spinful topological Weyl semimetal to the spinless topological Dirac line semimetal.

Self-Organized Topological Superconductivity in a Yu-Shiba-Rusinov Chain

M. Schecter, K. Flensberg, M. H. Christensen, B. M. Andersen, J. Paaske arXiv:1509.07399

We study the magnetic order of a spin chain embedded in an $s-$wave superconductor. The spin-spin interaction mediated by the exchange with the superconducting host renders ferromagnetism of the chain unstable to the formation of a magnetic spiral whose wavevector is a strong function of the local exchange coupling and spin lattice spacing. As the exchange coupling increases, the band of Yu-Shiba-Rusinov subgap states formed along the spin chain approaches the Fermi energy, leading to a resonant antiferromagnetic superconducting exchange interaction and a strong increase of the spiral wavevector. The spin-spin exchange description breaks down as the subgap band crosses the Fermi energy, wherein the spiral phase is instead stabilized by a spontaneous $p-$wave superconducting instability within the band. This leads to the existence of topological superconductivity and Majorana bound states in the Yu-Shiba-Rusinov chain formed by the spins. We provide the exact magnetic and topological phase boundary lines of a minimal model in the classical spin approximation and discuss its experimental viability.

Exact magnetic field control of nitrogen-vacancy center spin for realizing fast quantum logic gates

Wen-Qi Fang, Bang-Gui Liu arXiv:1509.07365

The negatively charged nitrogen-vacancy (NV) center spin in diamond can be used to realize quantum computation and to sense magnetic fields. Its spin triplet consists of three levels labeled with its spin z-components of +1, 0, and -1. Without external field, the +1 and -1 states are degenerate and higher than the 0 state due to the zero-field splitting. By taking the symmetrical and anti-symmetrical superpositions of the +1 and -1 states as our qubit basis, we obtain exact evolution operator of the NV center spin under time-dependent magnetic field by mapping the three-level system on time-dependent quantum two-level systems with exact analytical solutions. With our exact evolution operator of the NV center spin including three levels, we show that arbitrary qubits can be prepared from the starting 0 state and arbitrary rapid quantum logic gates of these qubits can be realized with magnetic fields. In addition, it is made clear that the typical quantum logic gates can be accomplished within a few nanoseconds and the fidelity can be very high because only magnetic field strength needs to be controlled in this approach. These results should be useful to realizing quantum computing with the NV center spin systems in diamond and exploring other effects and applications.