Mapping the topological phase diagram of multiband semiconductors with supercurrents

Pablo San-Jose, Elsa Prada, and Ramón Aguado, arXiv:1309.2239

We show that Josephson junctions made of multiband semiconductors with strong spin-orbit coupling carry a critical supercurrent I_c which contains information about the non-trivial topology of the system. In particular, we find that the emergence and annihilation of Majorana bound states in the junction is reflected in strong even-odd effects in I_c under specific conditions. This effect allows for a direct mapping between the critical supercurrent and the topological phase diagram of the junction, thus providing a dc measurement of the nontrivial topology, despite the absence of a 4π effect in the steady state.

Off-Diagonal Bethe Ansatz and Exact Solution of a Topological Spin Ring

Junpeng Cao, Wen-Li Yang, Kangjie Shi, and Yupeng Wang, Phys. Rev. Lett. **111**, 137201 (2013)

A general method is proposed for constructing the Bethe ansatz equations of integrable models without U(1) symmetry. As an example, the exact spectrum of the XXZ spin ring with a Möbius-like topological boundary condition is derived by constructing a modified T-Q relation based on the functional connection between the eigenvalues of the transfer matrix and the quantum determinant of the monodromy matrix. With the exact solution, the elementary excitations of the topological XX spin ring are discussed in detail. It is found that the excitation spectrum indeed shows a nontrivial topological nature.

Quantum phase transitions of a disordered antiferromagnetic topological insulator

P. Baireuther, J.M. Edge, I.C. Fulga, C.W.J. Beenakker, J. Tworzydlo arXiv:1309.5846

We study the effect of electrostatic disorder on the conductivity of a three-dimensional antiferromagnetic insulator (a stack of quantum anomalous Hall layers with staggered magnetization). The phase diagram contains regions where the increase of disorder first causes the appearance of surface conduction (via a topological phase transition), followed by the appearance of bulk conduction (via a metal-insulator transition). The conducting surface states are stabilized by an effective time-reversal symmetry that is broken locally by the disorder but restored on long length scales. A simple self-consistent Born approximation reliably locates the boundaries of this socalled "statistical" topological phase.

Imaging the Conductance of Integer and Fractional Quantum Hall Edge States

Nikola Pascher, Clemens Rossler, Thomas Ihn, Klaus Ensslin, Christian Reichl, and Werner Wegscheider, arXiv:1309.4918

We measure the conductance of a quantum point contact (QPC) while the biased tip of a scanning probe microscope induces a depleted region in the electron gas underneath. At finite magnetic field we find plateaus in the real-space maps of the conductance as a function of tip position at integer (ν = 1,2,3,4,6,8) and fractional (ν = 1/3, 2/3,5/3,4/5) values of transmission. They resemble theoretically predicted compressible and incompressible stripes of quantum Hall edge states. The scanning tip allows us to shift the constriction limiting the conductance in real space over distances of many microns. The resulting stripes of integer and fractional filling factors are rugged on the micron scale, i.e. on a scale much smaller than the zero-field elastic mean free path of the electrons. Our experiments demonstrate that microscopic inhomogeneities are relevant even in high-quality samples and lead to locally strongly fluctuating widths of incompressible regions even down to their complete suppression for certain tip positions. The macroscopic quantization of the Hall resistance measured experimentally in a non-local contact configuration survives in the presence of these inhomogeneities,and the relevant local energy scale for the $\nu = 2$ state turns out to be independent of tip position.

Anomalous Hall effect arising from noncollinear antiferromagnetism

Hua Chen, Qian Niu, A. H. MacDonald, arXiv:1309.4041

In most conductors current flow perpendicular to electric field direction (Hall current) can be explained in terms of the Lorentz forces present when charged particles flow in an external magnetic field. However, as established in the very early work of Edwin Hall, ferromagnetic conductors such as Fe, Co, and Ni have an anomalous Hall conductivity contribution that cannot be attributed to Lorentz forces and therefore survives in the absence of a magnetic field. Although the anomalous Hall effect is experimentally strong, it has stood alone among metallic transport effects for much of the last century because it lacked a usefully predictive, generally accepted theory. Progress over the past decade has explained why. It is now clear that the anomalous Hall effect in ferromagnets has contributions from both extrinsic scattering mechanisms similar to those that determine most transport coefficients, and from an intrinsic mechanism that is independent of scattering. The anomalous Hall effect is also observed in paramagnets, which have nonzero magnetization induced by an external magnetic field. Although no explicit relationship has been established, the anomalous Hall effect in a particular material is usually assumed to be proportional to its magnetization. In this work we point out that it is possible to have an anomalous Hall effect in a noncollinear antiferromagnet with zero net magnetization provided that certain common symmetries are absent, and predict that Mn3Ir, a technologically important antiferromagnetic material with noncollinear order that survives to very high temperatures, has a surprisingly large anomalous Hall effect comparable in size to those of the elemental transition metal ferromagnets.

Interaction Driven Zero-Field Quantum Hall Effect in Graphene

E. C. Marino, Leandro O. Nascimento, Van Sergio Alves, C. Morais Smith, arXiv:1309.5879

The interaction that naturally exists among electrons in graphene, namely the electromagnetic interaction, is often neglected or only partially considered in models describing transport. Here we compute the dc conductivity of graphene, using the so-called Pseudo Quantum Electrodynamics approach, which provides a *complete* description of the *full* electromagnetic interaction in spite of being strictly two-dimensional. We find that below a certain critical temperature, the longitudinal component vanishes, whereas a quantized *transverse* (Hall) component exists, which is identical to the one occurring in the Quantum Hall Effect. This occurs in the absence of magnetic fields or any explicit T-symmetry breaking term. Rather, the breakdown of time reversal symmetry occurs *dynamically* through vacuum fluctuations. A discrete set of electronic energy eigenstates that correspond to the conductivity plateaus and are analogous to the Landau levels is dynamically generated by the interaction as non-perturbative renormalizations of the free-electron poles in the electron propagator. Above the critical temperature the transverse (Hall) conductivity vanishes and for the longitudinal component, we obtain the usual "minimal" conductivity found in the literature plus corrections due to the interactions. We estimate the upper temperature threshold for observing this phenomenon to be of the order of 10 mK for suspended graphene in vacuum.

Diffusive transport in Weyl semimetals

Rudro R. Biswas, Shinsei Ryu, arXiv:1309.3278

Diffusion, a ubiquitous phenomenon in nature, is a consequence of particle number conservation and locality, in systems with sufficient damping. In this paper we consider diffusive processes in the bulk of Weyl semimetals, which are exotic quantum materials, recently of considerable interest. In order to do this, we first explicitly implement the analytical scheme by which disorder with anisotropic scattering amplitude is incorporated into the diagrammatic response-function formalism for calculating the 'diffuson'. The result thus obtained is consistent with transport coefficients evaluated from the Boltzmann transport equation or the renormalized uniform current vertex calculation, as it should be. We thus demonstrate that the computation of the diffusion coefficient should involve the transport lifetime, and not the quasiparticle lifetime. Using this method, we then calculate the density response function in Weyl semimetals and discover an unconventional diffusion process that is significantly slower than conventional diffusion. This gives rise to relaxation processes that exhibit stretched exponential decay, instead of the usual exponential diffusive relaxation. This result is then explained using a model of thermally excited quasiparticles diffusing with diffusion coefficients which are strongly dependent on their energies. We elucidate the roles of the various energy and time scales involved in this novel process and propose an experiment by which this process may be observed.

Quasiparticle interaction function in a 2D Fermi liquid near an antiferromagnetic critical point

Andrey V Chubukov, Peter Wolfle arXiv:1309.5228

We present the expression for the quasiparticle vertex function (proportional to the Landau interaction function) in a 2D Fermi liquid (FL) near an instability towards antiferromagnetism. This function is relevant in many ways in the context of metallic quantum criticality. Previous studies have found that near a quantum critical point, the system enters into a critical FL regime in which the fermionic self-energy is large near hot spots on the Fermi surface and has much stronger dependence on frequency than on momentum. We show that in this regime the conventional approach, developed for an ordinary (non-critical) FL, breaks down, and to properly calculate the vertex function one has to sum up an infinite series of terms which were explicitly excluded in the conventional treatment. We show that the total quasiparticle vertex function is larger than the conventional result – roughly, by an extra power of magnetic correlation length. However, the enhancement of quasiparticle vertex function is highly non-uniform and depends on the interplay between the momenta of the interacting particles. We show that the fully renormalized quasiparticle vertex function satisfies the Ward identity related to the conservation of the particle number. We exploit this Ward identity and the one induced by spin conservation to obtain the renormalization of the single particle response to changes of a chemical potential and a magnetic field. We show that the density of states and the "bare" charge susceptibility diverge at a QCP however the fully renormalized charge susceptibility remains finite. In the spin sector, we show that both the bare and the full susceptibilities remain finite, although renormalizations increase the tendency towards ferromagnetism.

Weak localization effects as evidence for bulk quantization in Bi_2Se_3 thin films, Phys. Rev. B **88**, 121103(R) (2013)

Li Zhang, Merav Dolev, Qi I. Yang, Robert H. Hammond, Bo Zhou, Alexander Palevski, Yulin Chen, and Aharon Kapitulnik

Strong spin-orbit coupling in topological insulators results in the ubiquitously observed weak antilocalization feature in their magnetoresistance. Here we present magnetoresistance measurements in ultrathin films of the topological insulator Bi2Se3 and show that in the two-dimensional quantum limit, in which the topological insulator bulk becomes quantized, an additional negative magnetoresistance feature appears. Detailed analysis associates this feature with weak localization of the quantized bulk channels, thus providing evidence for this quantization. Examination of the dephasing fields at different temperatures indicates different scattering mechanism in the bulk vs the surface states.

Transport signature of fractional Fermions in Rashba nanowires

Diego Rainis, Arijit Saha, Jelena Klinovaja, Luka Trifunovic, Daniel Loss, arXiv:1309.3738

Full counting statistics of electron transport in networks of Majorana bound states

Luzie Weithofer, Patrik Recher, and Thomas L. Schmidt, arXiv:1309.4126