Journal club

Two-dimensional p-wave superconducting states with magnetic moments on a conventional s-wave superconductor

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arXiv:1306.3686

Unconventional superconductivity induced by the magnetic moments in a conventional spin-singlet s-wave superconductor is theoretically studied. By choosing the spin directions of these moments, one can design the spinless pairing states appearing within the s-wave energy gap. For example, with the non-collinear spin configurations, both $p_x + p_y$-wave and $p_x + ip_y$-wave like states can be realized. The nodes of the energy gap and the zero energy flat band of Majorana edge states exist in the former one, while it is found that chiral Majorana channel along the edge of the sample and the zero energy Majorana bound state at the core of the vortex appear in the latter case.

Equivalent topological invariants for 1D Majorana wires in symmetry class D

Jan Carl Budich, Eddy Ardonne

arXiv:1306.4459

Topological superconductors in one spatial dimension exhibiting a single Majorana bound state at each end are distinguished from trivial gapped systems by a Z_2 topological invariant. Originally, this invariant was calculated by Kitaev in terms of the Pfaffian of the Majorana representation of the Hamiltonian: The sign of this Pfaffian divides the set of all gapped quadratic forms of Majorana fermions into two inequivalent classes. In the more familiar Bogoliubov de Gennes mean field description of superconductivity, an emergent particle hole symmetry gives rise to a quantized Zak-Berry phase the value of which is also a topological invariant. In this work, we explicitly show the equivalence of these two formulations by relating both of them to the phase winding of the transformation matrix that brings the Majorana representation matrix of the Hamiltonian into its Jordan normal form.

Edge Channel Transport in InAs/GaSb Topological Insulating Phase

Kyoichi Suzuki, Yuichi Harada, Koji Onomitsu, Koji Muraki

arXiv:1306.4234

Transport in InAs/GaSb heterostructures with different InAs layer thicknesses is studied using a six-terminal Hall bar geometry with a 2-μm edge channel length. For a sample with a 12-nm-thick InAs layer, non-local resistance measurements with various current/voltage contact confgurations reveal that the transport is dominated by edge channels with negligible bulk contribution. Systematic non-local measurements allow us to extract the resistance of individual edge channels, revealing sharp resistance fluctuations indicative of inelastic scattering. Our results show that the InAs/GaSb system can be tailored to have conducting edge channels while keeping a gap in the bulk region and provide a way of studying 2D topological insulators even when quantized transport is absent.

Evidence for A Two-dimensional Quantum Wigner Solid in Zero Magnetic Field

Jian Huang, L. N. Pfeiffer, K. W. West

arXiv:1306.4196

We report the first experimental observation of a characteristic nonlinear threshold behavior from dc dynamical response as an evidence for a Wigner crystallization in high-purity GaAs 2D hole systems in zero magnetic field. The system under increasing current drive exhibits voltage oscillations with negative differential resistance. They confirm the coexistence of a moving crystal along with striped edge states as observed for electrons on helium surfaces. However, the threshold is well below the typical classical levels due to a different pinning and depinning mechanism that is possibly related to a quantum process.

Ultrasensitive Detection of Majorana Fermions via Spin-based Optomechanics with Carbon Nanotubes

Hua-Jun Chen, Ka-Di Zhu

arXiv:1306.4102

We propose a novel optical method to detect the existence of Majorana fermions at the ends of the semiconductor nanowire via the coupling to an electron spin trapped on a carbon nanotube resonator under the control of a strong pump field and a weak probe field. The coupling strength of Majorana fermion to the spin in the carbon nanotube and the decay rate of the Majorana fermion can be easily measured from the probe absorption spectrum via manipulating the spin-mechanical coupling in the suspended carbon nanotube. The scheme proposed here will open a good perspective for its applications in all-optical controlled Majorana fermion-based quantum computation and quantum information processing.

Inter-valley scattering induced by Coulomb interaction and disorder in carbon-nanotube quantum dots

Andrea Secchi, Massimo Rontani

arXiv:1306.3502

We develop a theory of inter-valley Coulomb scattering in semiconducting carbon-nanotube quantum dots, taking into account the effects of curvature and chirality. Starting from the effective-mass description of single-particle states, we study the two-electron system by fully including Coulomb interaction, spin-orbit coupling, and short-range disorder. We find that the energy level splittings associated with inter-valley scattering may be comparable to those induced by spin-orbit interaction and are nearly independent of the chiral angle.

A symmetry-respecting topologically-ordered surface phase of 3d electron topological insulators

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arXiv:1306.3286

A 3d electron topological insulator (ETI) is a phase of matter protected by particle-number conservation and time-reversal symmetry. It was previously believed that the surface of an ETI must be gapless unless one of these symmetries is broken. A well-known symmetry-preserving, gapless surface termination of an ETI supports an odd number of Dirac cones. In this paper we deduce a symmetry-respecting, gapped surface termination of an ETI, which carries an intrinsic 2d topological order, Moore-Read x anti-semion. The Moore-Read sector supports non-Abelian charge 1/4 anyons, while the Abelian, anti-semion sector is electrically neutral. Time-reversal symmetry is implemented in this surface phase in a highly non-trivial way. Moreover, it is impossible to realize this phase strictly in 2d, simultaneously preserving its implementation of both the particle number and time-reversal symmetries. A 1d edge on the ETI surface between the topologically-ordered phase and the topologically trivial time-reversal-broken phase with a Hall conductivity $\sigma_H = 1/2$, carries a right-moving neutral Majorana mode, a right-moving bosonic charge mode and a left-moving bosonic neutral mode. The topologically-ordered phase is separated from the surface superconductor by a direct second order phase transition in the XY* universality class, which is driven by the condensation of a charge 1/2 boson, when approached from the topologically-ordered side, and proliferation of a flux 4π-vortex, when approached from the superconducting side. In addition, we prove that time-reversal invariant (interacting) electron insulators with no intrinsic topological order and electromagnetic response characterized by a θ-angle, $\theta = \pi$, do not exist if the electrons transform as Kramers singlets under time-reversal.

Symmetry Enforced Non-Abelian Topological Order at the Surface of a Topological Insulator

Xie Chen, Lukasz Fidkowski, Ashvin Vishwanathr

arXiv:1306.3250

The surfaces of three dimensional topological insulators (3D TIs) are generally described as Dirac metals, with a single Dirac cone. It was previously believed that a gapped surface implied breaking of either time reversal T or U(1) charge conservation symmetry. Here we discuss a novel possibility in the presence of interactions, a surface phase that preserves all symmetries but is nevertheless gapped and insulating. A requirement is that the surface develops topological order of a kind that cannot be realized in a purely 2D system with the same symmetries. We discuss two candidate surface states - both of which are non-Abelian Fractional Quantum Hall states which, when realized in 2D, have $\sigma_{xy} = 1/2$ and hence break T symmetry. However, by constructing an exactly soluble 3D lattice model, we show they can be realized as T symmetric surface states. Both the corresponding 3D phases are confined, have $\theta = \pi$ magnetoelectric response, and require electrons that are Kramers doublets. The first, the T-Pfaffian state, is the (Read-Moore) Pfaffian state with the neutral sector reversed, while the second, the Pfaffian-antisemion state is a product of the Pfaffian state with antisemion topological order. The latter can be connected to the superconducting TI surface state on breaking charge U(1) symmetry, while for the T-Pfaffian there is no simple way to do so. We discuss two physical scenarios for the T-Pfaffian, either (i) it is equivalent to the Pfaffian-antisemion theory and also describes the 3D TI surface OR (ii) it represents a new, interacting 3D TI.

Gapped Symmetry Preserving Surface-State for the Electron Topological Insulator

Chong Wang, Andrew C. Potter, T. Senthil

arXiv:1306.3223

It is well known that the 3D electronic topological insulator (TI) with charge-conservation and time-reversal symmetry cannot have a trivial insulating surface that preserves symmetry. It is often implicitly assumed that if the TI surface preserves both symmetries then it must be gapless. Here we show that it is possible for the TI surface to be both gapped and symmetry-preserving, at the expense of having surface-topological order. In contrast to analogous bosonic topological insulators, this symmetric surface topological order is intrinsically non-Abelian. We show that the surface-topological order provides a complete non-perturbative definition of the electron TI that transcends a free-particle band-structure picture, and could provide a useful perspective for studying strongly correlated topological Mott insulators.

Classification of interacting electronic topological insulators in three dimensions

Chong Wang, Andrew C. Potter, T. Senthil

arXiv:1306.3238

A Time-Reversal Invariant Topological Phase at the Surface of a 3D Topological Insulator

Parsa Bonderson, Chetan Nayak, Xiao-Liang Qi

arXiv:1306.3230