arXiv:1212.5879 [cond-mat.mes-hall]

Majorana Fermion Induced Non-local Current Correlations in Spin-orbit Coupled Superconducting Wires

Jie Liu, **Fu chun Zhang**, **K. T. Law**

Recent observation of zero bias conductance peaks in semiconductor wire/superconductor heterostructures has generated great interest, and it is in hot debate if the observation is associated with Majorana fermions (MFs). Here we study the local and crossed Andreev reflections in a junction of two normal leads and a sand- wiched superconductor-semiconductor wire with two spatially separated but strongly coupled MF end states. The conductance and the Fano factors of such a device are sharply distinguished from the topologically trivial case even in the presence of disorder, hence can be used to identify MFs unambiguously.

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arXiv:1301.2068 **Magnetic impurities on the surface of topological superconductor**

Ting-Pong Choy, K.T. Law, Tai-Kai Ng

We consider the effects of magnetic impurities on the surface of superconducting Cu doped $Bi_{2}Se_{3}$ in the odd parity pairing phase which support topologically protected Majorana fermions surface states with linear spectrum. We show that a single magnetic impurity on the surface may induce a pair of in-gap localized bound states. The energy of the in-gap state is extremely sensitive to the orientation of the magnetic impurity due to the so-called Ising properties of Majorana fermions. The magnetic impurity induced spin-texture, which can be measured using spin sensitive STM, is calculated. We also show that the RKKY interactions between magnetic impurities mediated via the Majorana fermions are always ferromagnetic and dense enough magnetic impurities will develop long-range magnetic order and break the time-reversal symmetry on the material surface eventually.

Charge Fractionalization in a Mesoscopic Ring **[Phys. Rev. Lett. 110, 026402 (2013)]**

Wade DeGottardi , Siddhartha Lal , and Smitha Vishveshwara

We study the fractionalization of an electron tunneling into a strongly interacting electronic one-dimensional ring. As a complement to transport measurements in quantum wires connected to leads, we propose noninvasive measures involving the magnetic field profile around the ring to probe this fractionalization. In particular, we show that the magnetic field squared produced by the electron and the power that it would induce in a detector exhibit anisotropic profiles that depend on the degree of fractionalization. We contrast true fractionalization with two other scenarios which could mimic it—quantum superposition and classical probabilistic electron insertion. We show that the proposed field-dependent measures and those of the persistent current can distinguish between these three scenarios.

Coulomb Drag in Graphene Near the Dirac Point **[Phys. Rev. Lett. 110, 026601 (2013)]**

M. Schütt, P. M. Ostrovsky, M. Titov, I. V. Gornyi, B. N. Narozhny and A. D. Mirlin

We study Coulomb drag in graphene near the Dirac point, focusing on the regime of interaction-dominated transport. We establish a novel, graphene-specific mechanism of Coulomb drag based on fast interlayer thermalization, inaccessible by standard perturbative approaches. Using the quantum kinetic equation framework, we derive a hydrodynamic description of transport in double-layer graphene in terms of electric and energy currents. In the clean limit the drag becomes temperature independent. In the presence of disorder the drag coefficient at the Dirac point remains nonzero due to higher-order scattering processes and interlayer disorder correlations. At low temperatures (diffusive regime) these contributions

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manifest themselves in the peak in the drag coefficient centered at the neutrality point with a magnitude that grows with lowering temperature.

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arXiv:1301.2833 **Bound States and Supercriticality in Graphene-Based Topological Insulators**
D. Kloepfer, A. De Martino, R. Egger

We study the bound state spectrum and the conditions for entering a supercritical regime in graphene with strong intrinsic and Rashba spin-orbit interactions within the topological insulator phase. Explicit results are provided for a disk-shaped potential well and for the Coulomb center problem

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arXiv:1301.3161 **Proposal for coherent coupling of Majorana and fluxonium qubits**
David Pekker, Chang-Yu Hou, Vladimir Manucharyan, Eugene Demler

We propose to use an ancilla fluxonium qubit to interact with a Majorana qubit hosted by a topological 1D wire. The coupling is obtained using the Majorana qubit controlled 4π Josephson effect to flux bias the fluxonium qubit. We demonstrate how this coupling can be used to sensitively identify topological superconductivity, to measure the state of the Majorana qubit, to construct 2-qubit operations, and to implement quantum memories with topological protection.

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arXiv:1301.3434 **Strongly correlated dynamics in multichannel quantum RC circuits**
Prasenjit Dutt, Thomas L. Schmidt, Christophe Mora, Karyn Le Hur

We examine dissipation effects in a multichannel quantum RC circuit, comprising a cavity or single-electron box capacitively coupled to a gate and connected to a reservoir lead via several conducting channels. Depending on the engineering details of the quantum RC circuit, the number of channels contributing to transport vary, as do the form of the interchannel couplings. For low-frequency AC transport, the charge-relaxation resistance (R_{q}) is a nontrivial function of the parameters of the system. However, in the vicinity of the charge degeneracy points and for weak tunneling, we find as a result of cross-mode mixing or channel asymmetry that R_q becomes universal for a metallic cavity at low temperatures, and equals the unit of quantum resistance. To prove this universality we map the system to an effective one-channel Kondo model, and construct an analogy with the Coulomb gas. Next, we probe the opposite regime of near-perfect transmission using a bosonization approach. Focussing on the two-channel case, we study the effect of backscattering at the lead-dot interface, more specifically, the role of an asymmetry in the backscattering amplitudes, and make a connection with the weak tunneling regime near the charge degeneracy points.

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arXiv:1301.3623 **Floquet poor man's Majorana fermions in double quantum dots**
Yantao Li, Yankui Wang, Fan Zhong

We consider a system consisting of two quantum dots connected by an s-wave superconductor in the presence of periodically varying electric or magnetic fields. The Floquet theory shows that there may be Floquet poor man's Majorana fermions (FPMMFs) in the high frequency region depending on the phase difference between the applied external fields to the two dots. Numerical results confirm this expectation and find in addition a lot of FPMMFs in the low frequency region. The FPMMFs survive for nonzero energy levels of the two dots and their interaction though the frequencies at which they emerge change and thus may be a promising candidate to be detected in experiments.

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arXiv:1301.3908 **Relaxation of Weakly Interacting Electrons in One Dimension**
Zoran Ristivojevic, K. A. Matveev

We consider the problem of relaxation in a one-dimensional system of interacting electrons. In the limit of weak interactions, we calculate the decay rate of a single-electron excitation, accounting for the nonlinear dispersion. The leading

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processes which determine the relaxation involve scattering of three particles. We elucidate how particular forms of Coulomb interaction, unscreened and screened, lead to different results for the decay rates and identify the dominant scattering processes responsible for relaxation of excitations of different energies. Interestingly, temperatures much smaller than the excitation energy strongly affect the rate. At higher temperatures the quasiparticle relaxes by exciting co-propagating electron-hole pairs, whereas at lowest temperatures the relaxation proceeds via excitations of both co-propagating and counter-propagating pairs.

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arXiv:1301.4400 **Phase-locked magnetoconductance oscillations as a probe of Majorana edge states**
M. Diez, I. C. Fulga, D. I. Pikulin, M. Wimmer, A. R. Akhmerov, C. W. J. Beenakker

We calculate the Andreev conductance of a superconducting ring interrupted by a flux-biased Josephson junction, searching for electrical signatures of circulating edge states. Two-dimensional pair potentials of spin-singlet d-wave and spin-triplet p-wave symmetry support, respectively, (chiral) Dirac modes and (chiral or helical) Majorana modes. These produce h/e-periodic magnetoconductance oscillations of amplitude \simeq (e^{2}/h)N^{-1/2}, measured via an N-mode point contact at the inner or outer perimeter of the grounded ring. For Dirac modes the oscillations in the two contacts are independent, while for an unpaired Majorana mode they are phase locked by a topological phase transition at the Josephson junction.

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arXiv:1301.4408 **Multiple Andreev reflection and critical current across a topological transition in superconducting nanowire junctions**
Pablo San-Jose, Jorge Cayao, Elsa Prada, Ramón Aguado

We study transport in biased Josephson junctions made of nanowires with strong spin-orbit coupling, as it transitions into a topological superconducting phase for increasing Zeeman field B. Despite the absence of a fractional steady-state ac Josephson current in the topological phase, the dissipative Multiple Andreev Reflection current I_dc at different junction transparencies is particularly revealing. It exhibits unique features related to topology, such as the gap inversion, the formation of Majorana bound states, and fermion-parity conservation. In contrast, and rather surprisingly, the critical current I_c does not vanish at the critical point where the superconducting gap vanishes, exhibiting a discontinuous dI_c/dB instead. These results demonstrate the feasibility to probe the formation of Majorana states without the need of phase sensitive or noise-related measurements.

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arXiv:1301.4433 **Transport signatures of Floquet Majorana fermions in driven topological superconductors**
Arijit Kundu, Babak Seradjeh

Topologically nontrivial steady bound states may arise when a topologically trivial system is driven periodically. In the superconducting state, these are equal mixtures of electrons and holes known as Floquet Majorana fermions. We consider the non-equilibrium transport through Floquet Majorana fermions and show, both analytically and numerically, that their presence is signaled by a quantized conductance sum rule over discrete values of lead bias differing by multiple absorption or emission energies at drive frequency. We also study the effects of disorder on this quantization and suggest that it could help identify the topological signatures of Floquet Majorana fermions.

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arXiv:1301.5182 **Josephson junction on one edge of a two dimensional topological insulator affected by magnetic impurity**
Shu-feng Zhang, Wei Zhu, Qing-feng Sun

Current-phase relation in a Josephson junction formed by putting two s-wave superconductors on the same edge of a two dimensional topological insulator is investigated. We consider the case that the junction length is finite and magnetic impurity exists. The similarity and difference with conventional Josephson junction is discussed. The current

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is calculated in the semiconductor picture. Both the 2π- and 4π-period current-phase relations ($I_{2\pi}(\phi), I_{4\pi}(\phi)$) are studied. There is a sharp jump at $\phi=\pi$ and $\phi=2\pi$ for $I_{2\pi}$ and $I_{4\pi}$ respectively in the clean junction. For $I_{2\pi}$, the sharp jump is robust against impurity strength and distribution. However for $I_{4\pi}$, the impurity makes the jump at $\phi=2\pi$ smooth. The critical (maximum) current of $I_{2\pi}$ is given and we find it will be increased by asymmetrical distribution of impurity.

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arXiv:1301.5639 **Z2 topological zero-energy modes in commensurate Aubry-André-Harper models**

Sriram Ganeshan, Kai Sun, S. Das Sarma

Aubry-Andr\'e (AA) model has been the subject of extensive theoretical research in the context of quantum localization. Recently, it is shown that one-dimensional quasicrystals described by the incommensurate Aubry-Andr\'e model has non-trivial topology. In this paper, we show that the commensurate off-diagonal Aubry-Andr\'e model is topologically nontrivial in the gapless regime and supports zero-energy edge modes with Z2 index. Unlike the incommensurate case, the nontrivial topology in the off-diagonal Aubry-Andr\'e model is attributed to the topological properties of the one-dimensional Majorana chain. We discuss the feasibility of experimental observability of our predicted Z2 topological phase.

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arXiv:1301.5822 **Fractional Fermions with Non-Abelian Statistics**

Jelena Klinovaja, Daniel Loss

We introduce a novel class of low-dimensional topological tight-binding models that allow for bound states that are fractionally charged fermions and exhibit non-Abelian braiding statistics. The proposed model consists of a double (single) ladder of spinless (spinful) fermions in the presence of magnetic fields. We study the system analytically in the continuum limit as well as numerically in the tight-binding representation. We find a topological phase transition with a topological gap that closes and reopens as a function of system parameters and chemical potential. The topological phase is of the type BDI and carries two degenerate mid-gap bound states that are localized at opposite ends of the ladders. We show numerically that these bound states are robust against a wide class of perturbations.

Generation of Pure Bulk Valley Current in Graphene [Phys. Rev. Lett. 110, 046601 (2013)]

Yongjin Jiang, ,Tony Low, Kai Chang, Mikhail I. Katsnelson, and Francisco Guinea

The generation of valley current is a fundamental goal in graphene valleytronics but no practical ways of its realization are known yet. We propose a workable scheme for the generation of bulk valley current in a graphene mechanical resonator through adiabatic cyclic deformations of the strains and a chemical potential in the suspended region. The accompanied strain gauge fields can break the spatial mirror symmetry of the problem within each of the two inequivalent valleys, leading to a finite valley current due to quantum pumping. An all-electrical measurement configuration is designed to detect the novel state with pure bulk valley currents.

Integer Quantum Hall Effect for Bosons [Phys. Rev. Lett. 110, 046801 (2013)]

T. Senthil and Michael Levin

A simple physical realization of an integer quantum Hall state of interacting two dimensional bosons is provided. This is an example of a symmetry-protected topological (SPT) phase which is a generalization of the concept of topological insulators to systems of interacting bosons or fermions. Universal physical properties of the boson integer quantum Hall state are described and shown to correspond with those expected from general classifications of SPT phases.
