Time-Reversal-Invariant Z4 Fractional Josephson Effect

Fan Zhang, C. L. Kane, arXiv:1404.1072

We study the Josephson junction mediated by the quantum spin Hall edge states and show that electron-electron interactions lead to a dissipationless fractional Josephson effect in the presence of time-reversal symmetry. Surprisingly, the periodicity is 8π, corresponding to a Josephson frequency $eV/2\hbar$. We estimate the magnitude of interaction induced many-body level splitting responsible for this effect and argue that it can be measured using tunneling spectroscopy. For strong interactions we show that the Josephson effect is associated with the weak tunneling of charge $e/2$ quasiparticles between the superconductors. Our theory describes a fourfold ground state degeneracy that is similar to that of coupled "fractional" Majorana modes, but is protected by time reversal symmetry.

An On-Demand Single-Electron Time-Bin Qubit Source

J. R. Ott, M. Moskalets, arXiv:1404.0185

We propose a source capable of on-demand emission of single electrons with a wave packet of controllable shape and phase. The source consists of a hybrid quantum system, relying on currently experimentally accessible components. We analyze in detail the emission of single electron time-bin qubits, which we characterize using the well known electronic Hong-Ou-Mandel (HOM) interferometry scheme. Specifically, we show that, by controlling the phase difference of two time-bin qubits, the Pauli peak, the electronic analogue of the well known optical HOM dip, can be continuously removed. The proposed source constitutes a promising approach for scalable solid-state architectures for quantum operations using electrons and possibly for an interface for photon to electron time-bin qubit conversion.

Screening Clouds and Majorana Fermions

Ian Affleck, Domenico Giuliano arXiv:1404.0047

Ken Wilson developed the Numerical Renormalization Group technique which greatly enhanced our understanding of the Kondo effect and other quantum impurity problems. Wilson's NRG also inspired Philippe Nozieres to propose the idea of a large "Kondo screening cloud". While much theoretical evidence has accumulated for this idea it has remained somewhat controversial and has not yet been confirmed experimentally. Recently a new possibility for observing an analogous crossover length scale has emerged, involving a Majorana fermion localized at the interface between a topological superconductor quantum wire and a normal wire. We give an overview of this topic both with and without interactions included in the normal wire.

Majorana and Condensed Matter Physics

Frank Wilczek, arXiv:1404.0637

Ettore Majorana contributed several ideas that have had significant, lasting impact in condensed matter physics, broadly construed. Here I will discuss, from a modern perspective, four important topics that have deep roots in Majorana's work: 1. Spin Response and Universal Connection; 2. Level Crossing and Generalized Laplace Transform; 3. Majorana Fermions, From Neutrinos to Electrons; 4. Majorinos and Emergent Symmetry.

Ground state cooling of a carbon nano-mechanical resonator by spin-polarized current

Pascal Stadler, Wolfgang Belzig, Gianluca Rastelli, arXiv:1404.0485

We study the non-equilibrium regime of a mechanical resonator at low temperature realized with a suspended carbon nanotube quantum dot contacted to two ferromagnets. Due to spin-orbit interaction and/or an external magnetic gradient, the spin on the dot couples directly to the flexural eigenmodes. Owing to this interaction, the nanomechanical motion induces spin-flips of the electrons passing through the nanotube. When a finite voltage is applied, a spin-polarized current causes either heating or active cooling of the mechanical modes, depending on the gate voltage. Optimal cooling is achieved at resonance transport realized when the energy splitting between two dot levels of opposite spin equals the resonator frequency. We show that weak interaction coupling strength and moderate polarization can achieve ground state cooling.

Superfluid-Bose glass transition in one dimension

Zoran Ristivojevic, Aleksandra Petkovic, Pierre Le Doussal, Thierry Giamarchi, arXiv:1404.0678

We consider a one-dimensional system of interacting bosons in a random potential. At zero temperature, it can be either in the superfluid or in the insulating phase. We study the transition at weak disorder and moderate interaction. Using a systematic approach, we derive the renormalization group equations at two loop order and discuss the phase diagram. We find the universal form of the correlation functions at the transitions and compute the logarithmic corrections to the main universal power-law behavior. In order to mimic large density fluctuations on a single site we study a simplified model of disordered two leg bosonic ladders with correlated disorder across the rung. Contrarily to the single chain case, the latter exhibits a superfluid-Bose glass transition where the exponents of the correlation functions at the transition do not take universal values.

Unconventional Superconductivity in Double Quantum Dots

Björn Sothmann, Stephan Weiss, Michele Governale, Jrgen König, arXiv:1404.0813

The formation of electron pairs is a prerequisite of superconductivity. The fermionic nature of electrons yields four classes of superconducting correlations with definite symmetry in spin, space and time. Here, we suggest double quantum dots coupled to conventional s-wave superconductors in the presence of inhomogeneous magnetic fields as a model system exhibiting unconventional pairing. Due to their small number of degrees of freedom, tunable by gate voltages, quantum-dot systems provide an ideal tool to gain fundamental insight in unconventional pairing. We propose two detection schemes for unconventional superconductivity, based on either Josephson or Andreev spectroscopy.

Thermoelectric efficiency of three-terminal quantum thermal machines

Francesco Mazza, Riccardo Bosisio, Giuliano Benenti, Vittorio Giovannetti, Rosario Fazio, Fabio Taddei, arXiv:1404.0924

The efficiency of a thermal engine working in linear response regime in a multi-terminals configuration is discussed. For the generic three-terminal case, we provide a general definition of local and non-local transport coefficients: electrical and thermal conductances, and thermoelectric powers. Within the Onsager formalism, we derive analytical expressions for the efficiency at maximum power, which can be written in terms of generalized figures of merit. Also, using two examples, we investigate numerically how a third terminal could improve the performance of a quantum system, and under which conditions non-local thermoelectric effects can be observed.

Phases of triangular lattice antiferromagnet near saturation

Oleg A. Starykh, Wen Jin, Andrey V. Chubukov, arXiv:1404.1046

We consider 2D Heisenberg antiferromagnets on a triangular lattice with spatially anisotropic interactions in a high magnetic field close to the saturation. We show that this system possess rich phase diagram in field/anisotropy plane due to competition between classical and quantum orders: an incommensurate non-coplanar spiral state, which is favored classically, and a commensurate co-planar state, which is stabilized by quantum fluctuations. We show that the transformation between these two states is highly non-trivial and involves two intermediate phases – the phase with co-planar incommensurate spin order and the one with non-coplanar double-Q spiral order. The transition between the two co-planar states is of commensurate- incommensurate type, not accompanied by softening of spin-wave excitations. We show that a different sequence of transitions holds in triangular antiferromagnets with exchange anisotropy, such as $Ba_3CoSb_2O_9$.

Short-range charge order reveals the role of disorder in the pseudogap state of high-Tc superconductors

T. Wu, H. Mayaffre, S. Krmer, M. Horvati, C. Berthier, W.N. Hardy, R. Liang, D.A. Bonn, M.-H Julien, arXiv:1404.1617

The main obstacle towards explaining superconductivity in copper-oxides resides in the mysterious nature of their pseudogap state. Most controversial is whether a genuine (static and long-ranged) ordered phase universally lies behind the diverse indications of symmetry breaking in this state. Here, using nuclear magnetic resonance in YBa2Cu3Oy, we identify a phenomenology that unifies existing results: while no static magnetic order is detected, charge order in the pseudogap state is static, though only short-ranged, it is accompanied by probable intra-unit-cell nematic order and its impacts on most transport and spectroscopic properties. However, we find that this universal phenomenology is insufficient to conclude on the intrinsic nature of the pseudogap state. Indeed, because charge order is found to be pinned by native defects even in such a clean cuprate, it is unknown whether it would be static and long-ranged or fluctuating and short-ranged in the absence of disorder. Recognising the impact of disorder thus appears to be key to elucidating whether any electronic order in the pseudogap state is intrinsically static or fluctuating.

A new superconductor derived from topological insulator heterostructure

Satoshi Sasaki, Kouji Segawa, Yoichi Ando, arXiv:1404.1707

Topological superconductors (TSCs) are of significant current interest because they offer promising platforms for finding Majorana fermions. Here we report a new superconductor synthesized by intercalating Cu into a naturally-formed topological insulator (TI) heterostructure consisting of Bi2Se3 TI units separated by nontopological PbSe units. For the first time in a TI-based superconductor, the specific-heat behavior of this material suggests the occurrence of unconventional superconductivity with gap nodes. The existence of gap nodes in a strongly spin-orbit coupled superconductor would give rise to spin-split Andreev bound states that are the hallmark of topological superconductivity. Hence, this new superconductor emerges as an intriguing candidate TSC.

Quantifying the Fermi paradox in the local Solar neighborhood

Daniel Cartin, arXiv:1404.0204

The Fermi paradox highlights the dichotomy between the lack of physical contact with other civilizations and the expectation that technological civilizations are assumed likely to evolve in many locations in the Milky Way galaxy, given the large number of planetary systems within this galaxy. Work by Landis and others has modeled this question in terms of percolation theory and cellular automata, using this method to parametrize our ignorance about possible other civilizations as a function of the probability of one system to colonize another, and the maximum number of systems reachable from each starting location (i.e. the degree in the network used for percolation). These models used a fixed lattice of sites to represent a stellar region, so the degree of all sites were identical. In this paper, the question is examined again, but instead of using a pre-determined lattice, the actual physical positions of all known star systems within 40 parsecs of the Solar System are used as percolation sites; in addition, the number of sites accessible for further colonization from a given system is determined by a choice of maximum distance such efforts can travel across. The resulting simulations show that extraterrestrial colonization efforts may reach the Solar System, but only for certain values of the maximum travel distance and probability of an occupied system further colonizing other systems. Indeed, large numbers of systems may be colonized with either vessels that lack insufficient travel distance to reach the Solar System or else have a colonization probability where they are statistically unlikely to reach us.