**Supersymmetry in the Majorana Cooper-pair box**

*Jascha Ulrich, İnanç Adagideli, Dirk Schuricht, and Fabian Hassler*, Phys. Rev. B 90, 075408 (2014)[Editors' Suggestion]

Over the years, supersymmetric quantum mechanics has evolved from a toy model of high energy physics to a field of its own. Although various examples of supersymmetric quantum mechanics have been found, systems that have a natural realization are scarce. Here, we show that the extension of the conventional Cooper-pair box by a $4\pi$-periodic Majorana-Josephson coupling realizes supersymmetry for certain values of the ratio between the conventional Josephson and the Majorana-Josephson coupling strength. The supersymmetry we find is a "hidden" minimally bosonized supersymmetry that provides a non-trivial generalization of the supersymmetry of the free particle and relies crucially on the presence of an anomalous Josephson junction in the system. We show that the resulting degeneracy of the energy levels can be probed directly in a tunneling experiment and discuss the various transport signatures. An observation of the predicted level degeneracy would provide clear evidence for the presence of the anomalous Josephson coupling.

**Emergent Space-time Supersymmetry at the Boundary of a Topological Phase**

*Tarun Grover, D. N. Sheng, and Ashvin Vishwanath*, Science **344**, 280 (2014)

In contrast to ordinary symmetries, supersymmetry interchanges bosons and fermions. Originally proposed as a symmetry of our universe, it still awaits experimental verification. Here we theoretically show that supersymmetry emerges naturally in topological superconductors, which are well-known condensed matter systems. Specifically, we argue that the quantum phase transitions at the boundary of topological superconductors in both two and three dimensions display supersymmetry when probed at long distances and times. Supersymmetry entails several experimental consequences for these systems, such as, exact relations between quantities measured in disparate experiments, and in some cases, exact knowledge of the universal critical exponents. The topological surface states themselves may be interpreted as arising from spontaneously broken supersymmetry, indicating a deep relation between topological phases and SUSY. We discuss prospects for experimental realization in films of superfluid $He_3$-B.

**Direct Observation of a Majorana Quasiparticle Heat Capacity in $^3$He**

*Y. M. Bunkov*, J. Low Temp. Phys. **175**, 385 (2014).

The Majorana fermion, which acts as its own antiparticle, was suggested by Majorana in 1937 (Nuovo Cimento 14:171). While no stable particle with Majorana properties has yet been observed, Majorana quasiparticles (QP) may exist at the boundaries of topological insulators. Here we report the preliminary results of direct observation of Majorana QPs by a precise measurements of superfluid $^3$He heat capacity. The bulk superfluid $^3$He heat capacity falls exponentially with cooling at the temperatures significantly below the energy gap. Owing to the zero energy gap mode the Majorana heat capacity falls in a power law. The Majorana heat capacity can be larger than bulk one at some temperature, which depends on surface to volume ratio of the experimental cell. Some times ago we developed the Dark matter particles detector (DMD) on a basis of superfluid $^3$He which is working at the frontier of extremely low temperatures (Winkelmann et al., Nucl. Instrum. Meth. A 559:384-386, 2006). Here we report the observation of zero gap mode of Majorana, follows from the new analyses of DMD heat capacity, published early. We have found a 10 % deviation from the bulk superfluid $^3$He heat capacity at the temperature of 135 $\mu$K. This deviation corresponds well to the theoretical value for Majorana heat capacity at such low temperature. (Note, there were no fitting parameters).

**Room-Temperature High-Frequency Transport of Dirac Fermions in Epitaxially Grown $Sb_2Te_3$ and $Bi_2Te_3$ Based Topological Insulators**

*P. Olbrich et al.*, Phys. Rev. Lett. **113**, 096601 (2014)

We report on the observation of photogalvanic effects in epitaxially grown $Sb_2Te_3$ and $Bi_2Te_3$ three-dimensional (3D) topological insulators (TI). We show that asymmetric scattering of Dirac fermions driven back and forth by the terahertz electric field results in a dc electric current. Because of the "symmetry filtration" the dc current is generated by the surface electrons only and provides an optoelectronic access to probe the electron transport in TI, surface domains orientation, and details of electron scattering in 3D TI even at room temperature.

**Ambegaokar-Eckern-Schön theory for a collective spin: geometric Langevin noise**

*Alexander Shnirman, Yuval Gefen, Arijit Saha, Igor S. Burmistrov, Mikhail N. Kiselev, Alexander Altland*, arXiv:1409.0150

The presence of geometric phases is known to affect the dynamics of the systems involved. Here we consider a quantum degree of freedom, moving in a dissipative environment, whose dynamics is described by a Langevin equation with quantum noise. We show that geometric phases enter the stochastic noise terms. Specifically, we consider small ferromagnetic particles (nano-magnets) or quantum dots close to Stoner instability, and investigate the dynamics of the total magnetization in the presence of tunneling coupling to the metallic leads. We generalize the Ambegaokar-Eckern-Schön (AES) effective action and the corresponding semiclassical equations of motion from the U(1) case of the charge degree of freedom to the SU(2) case of the magnetization. The Langevin forces (torques) in these equations are strongly influenced by the geometric phase. As a first but nontrivial application we predict low temperature quantum diffusion of the magnetization on the Bloch sphere, which is governed by the geometric phase. We propose a protocol for experimental observation of this phenomenon.

**Pairing in half-filled Landau level**

*Zhiqiang Wang, Ipsita Mandal, Suk Bum Chung, and Sudip Chakravarty*, arXiv:1408.6860

Pairing of composite fermions in half-filled Landau level state is reexamined by solving the BCS gap equation with full frequency dependent current-current interactions. Our results show that there can be a *continuous* transition from the Halperin-Lee-Read state to a chiral odd angular momentum

Cooper pair state for short-range contact interaction. This is at odds with the previously established conclusion of first order pairing transition, in which the low frequency effective interaction was assumed for the entire frequency range. We find that even if the low frequency effective interaction is repulsive, it is compensated by the high frequency regime, which is attractive. We construct the phase diagrams and show that $l = 1$ angular momentum channel is quite different from higher angular momenta $l \geq 3$. Remarkably, the full frequency dependent analysis applied to the bilayer Hall system with a total filling fraction $\nu = \frac{1}{2} + \frac{1}{2}$ is quantitatively changed from the previously established results but not qualitatively.

**Emergence of $p + ip$ superconductivity in 2D strongly correlated Dirac fermions**

*Zheng-Cheng Gu, Hong-Chen Jiang, and G. Baskaran*, arXiv:1408.6820

Searching for $p+ip$ superconducting(SC) state has become a fascinating subject in condensed matter physics, as a dream application awaiting in topological quantum computation. In this paper, we report a theoretical discovery of a $p + ip$ SC ground state (coexisting with ferromagnetic order) in honeycomb lattice Hubbard model with infinite repulsive interaction at low doping($\delta < 0.2$), by using both the state-of-art Grassmann tensor product state(GTPS) approach and a quantum field theory approach. Our discovery suggests a new mechanism for $p+ip$ SC state in generic strongly correlated systems and opens a new door towards experimental realization. The $p+ip$ SC state has an instability towards a potential non-Fermi liquid with a large but finite $U$. However, a small Zeeman field term stabilizes the $p+ip$ SC state. Relevant realistic materials are also proposed.

**Magnetization signatures of light-induced quantum Hall edge states**

*Jan P. Dahlhaus, Benjamin M. Fregoso, Joel E. Moore*, arXiv:1408.6811

Circularly polarised light opens a gap in the electronic Dirac spectrum of graphene and topological insulator surfaces, thereby inducing a quantum Hall like phase. We propose to detect the accompanying light-induced edge states and their current by the magnetic field they produce. The topological nature of the edge states is reflected in the mean orbital magnetization of the sample, which shows a universal linear dependence as a function of a generalized chemical potential - independent of the driving details and the properties of the material. The proposed protocol overcomes several typically encountered problems in the realization and measurement of Floquet phases, including the destructive effects of phonons and coupled electron baths and provides a way to occupy the induced edge states selectively. We estimate practical experimental parameters and conclude that the magnetization signature of the Floquet topological phase may be detectable with current techniques.

**Moving solitons in a one-dimensional fermionic superfluid - an exact solution**

*Dmitry K. Efimkin, and Victor Galitski*, arXiv:1408.6511 A fully analytical theory of a traveling soliton in a one-dimensional fermionic superfluid is developed within the framework of time-dependent self-consistent Bogoliubov-de Gennes equations, which are solved exactly. The soliton manifests itself in a kink-like profile of the superconducting order parameter and hosts a pair of Andreev bound states. They adjust to soliton's motion and play an important role in its stabilization. A phase jump across the soliton and its energy decrease with soliton's velocity and vanish at the critical velocity, corresponding to the Landau criterion, where the soliton starts emitting quasiparticles and becomes unstable. The "inertial" and "gravitational" masses of the soliton are calculated and the former is shown to be orders of magnitude larger than the latter. This results in slow oscillations of the soliton in a harmonic trap. These results may be related to recent experiments in cold fermion gases [T. Yefsah et al., Nature 499, 426, (2013)], which observed "heavy" soliton-like excitations in a paired fermion superfluid.

**Gapped Domain Walls, Gapped Boundaries and Topological Degeneracy** *Tian Lan, Juven Wang, and Xiao-Gang Wen*, arXiv:1408.6514, Gapped domain walls, as topological line defects between topologically ordered states in two spatial dimensions (2D), are examined. We provide simple criteria to determine the existence of gapped domain walls, which apply to both Abelian and non-Abelian topological orders. Our criteria also determine whether the edge modes of a 2D topological order must be gapless, due to "global gravitational anomalies". Furthermore, we introduce new mathematical objects, the tunneling matrix $\mathcal{W}$ whose entries are the fusion-space dimensions $\mathcal{W}_{ia}$, to label and completely classify different types of gapped domain walls. Mathematically, we propose a classification of bimodule categories between modular tensor categories. Since a gapped boundary is a gapped domain wall between a bulk topological order and vacuum (regarded as a trivial topological order), our result of gapped domain walls inclusively contains that of gapped boundaries. In addition, we derive a topological ground state degeneracy formula, on arbitrary orientable spatial 2-manifolds with gapped domain walls, including closed 2-manifolds as well as open 2-manifolds with gapped boundaries.

**Many body localization and delocalization in the two dimensional continuum** *Rahul Nandkishore*, arXiv:1408.6235, I discuss whether localization in the two dimensional continuum can be stable in the presence of short range interactions. I conclude that, for an impurity model of disorder, if the system is prepared below a critical temperature $T < T_c$, then perturbation theory about the localized phase converges almost everywhere. As a result, the system is at least asymptotically localized, and perhaps even truly many body localized, depending on how certain rare regions behave. Meanwhile, for $T > T_c$, perturbation theory fails to converge, which I interpret as interaction mediated delocalization. I calculate the boundary of the region of perturbative stability of localization in the interaction strength - temperature plane. I also discuss the behavior in a speckle disorder (relevant for cold atoms experiments) and conclude that perturbation theory about the non-interacting phase diverges for arbitrarily weak interactions with speckle disorder, suggesting that many body localization in the two dimensional continuum cannot survive away from the impurity limit.