David Pekker, Chang-Yu Hou, Doron L. Bergman, Sam Goldberg, İnanç Adagideli, Fabian Hassler
**Suppression of 2π phase-slip due to hidden zero modes in one dimensional topological superconductors**,
arXiv:1209.2161

We study phase slips in one-dimensional topological superconducting wires. These wires have been proposed as building blocks for topologically protected qubits in which the quantum information is distributed over the length of the device and thus is immune to local sources of decoherence. However, phase-slips are non-local events that can result in decoherence. Phase slips in topological superconductors are peculiar for the reason that they occur in multiples of $4\pi$ (instead of $2\pi$ in conventional superconductors). We re-establish this fact via a beautiful analogy to the particle physics concept of dynamic symmetry breaking by explicitly finding a "hidden" zero mode in the fermion spectrum computed in the background of a $2\pi$ phase-slip. Armed with the understanding of phase-slips in topological superconductors, we propose a simple experimental setup with which the predictions can be tested by monitoring tunneling rate of a superconducting flux quantum through a topological superconducting wire.

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V. V. Cheianov, I. L. Aleiner, and V. I. Fal'ko
**Gapped Bilayer Graphene: A Tunable Strongly Correlated Band Insulator**,
Phys. Rev. Lett. 109, 106801

We introduce the notion of the strongly correlated band insulator (SCI), where the lowest energy excitations are collective modes (excitons) rather than the single particles. We construct controllable 1/N expansion for SCI to describe their observable properties. A remarkable example of the SCI is bilayer graphene which is shown to be tunable between the SCI and usual weak coupling regime.

Rex Lundgren, Victor Chua, Gregory A. Fiete
**Entanglement Entropy and Spectra of the One-dimensional Kugel-Khomskii Model**,
arXiv:1209.1643

We study the quantum entanglement of the spin and orbital degrees of freedom in the one- dimensional Kugel-Khomskii model, which includes both gapless and gapped phases, using analytical techniques and exact diagonalization with up to 16 sites. We compute the entanglement entropy, and the entanglement spectra using a variety of partitions or "cuts" of the Hilbert space, including two distinct real-space cuts and a momentum-space cut. Our results show the Kugel-Khomski model possesses a number of new features not previously encountered in studies of the entanglement spectra. Notably, we find robust gaps in the entanglement spectra for both gapped and gapless phases with the orbital partition, and show these are not connected to each other. We observe the counting of the low-lying entanglement eigenvalues shows that the "virtual edge" picture which equates the low-energy Hamiltonian of a virtual edge, here one gapless leg of a two-leg ladder, to the "low-energy" entanglement Hamiltonian breaks down for this model, even though the equivalence has been shown to hold for similar cut in a large class of closely related models. In addition, we show that a momentum space cut in the gapless phase leads to qualitative differences in the entanglement spectrum when compared with the same cut in the gapless spin-1/2 Heisenberg spin chain. We emphasize the new information content in the entanglement spectra compared to the entanglement entropy, and using quantum entanglement present a refined phase diagram of the model. Using analytical arguments, exploiting various symmetries of the model, and applying arguments of adiabatic continuity from two exactly solvable points of the model, we are also able to prove several results regarding the structure of the low-lying entanglement eigenvalues.

H. Sickinger, A. Lipman, M. Weides, R. G. Mints, H. Kohlstedt, D. Koelle, R. Kleiner, E. Goldobin
**Experimental Evidence of a φ Josephson Junction,**
Phys. Rev. Lett. 109, 107002 (2012)

We demonstrate experimentally the existence of Josephson junctions having a doubly degenerate ground state with an average Josephson phase $\psi=\pm\varphi$. The value of $\varphi$ can be chosen by design in the interval $0<\varphi<\pi$. The junctions used in our experiments are fabricated as 0-$\pi$ Josephson junctions of moderate normalized length with asymmetric 0 and $\pi$ regions. We show that (a) these $\varphi$ Josephson junctions have two critical currents, corresponding to the escape of the phase $\psi$ from $-\varphi$ and $+\varphi$ states, (b) the phase $\psi$ can be set to a particular state by tuning an external magnetic field, or (c) by using a proper bias current sweep sequence. The experimental observations are in agreement with previous theoretical predictions.

Ashvin Vishwanath, T. Senthil
**Physics of three dimensional bosonic topological insulators: Surface Deconfined Criticality and Quantized Magnetoelectric Effect**,
arXiv:1209.3058

We discuss physical properties of `integer' topological phases of bosons in D=3+1 dimensions, protected by internal symmetries like time reversal and/or charge conservation. These phases invoke interactions in a fundamental way but do not possess topological order and are bosonic analogs of free fermion topological insulators and superconductors. Recently, the mathematical classification of such states was discussed in terms of cohomology theory . However, their physical properties remain mysterious. Here we develop a field theoretic description of several of these states and show that they possess unusual surface states, which, if gapped, must either break the underlying symmetry, or develop topological order. While this is the usual fate of the surface states, exotic gapless states can also be realized. For example, tuning parameters can naturally lead to a deconfined quantum critical point or, in other situations, a fully symmetric vortex metal phase. We discuss cases where the topological phases are characterized by quantized magnetoelectric response \theta, which, somewhat surprisingly, is an odd multiple of 2\pi. Two different theories of surface states are shown to capture these phenomena - the first is a nonlinear sigma model with a topological term. The second invokes vortices on the surface with fractional quantum numbers, that transform under a projective representation of the symmetry group. A bulk field theory consistent with these properties is identified, which is a multicomponent BF theory, supplemented, crucially, with a topological term. Bulk sigma model field theories of these phases are also provided. Topological phases that lie beyond the cohomology classification, characterized by the thermal analog of the quantized magnetoelectric effect, are also discussed.

V. H. Dao, D. Denisov, A. Buzdin, J. P. Brison
**On the theory of the vortex state in the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) phase,**
arXiv:1208.1839

We demonstrate that the vortex state in the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) phase may be very different depending on the field orientation relative to the crystalline axes. We calculate numerically the upper critical field near the tricritical point taking into account the modulation of the order parameter along the magnetic field as well as the higher Landau levels. For s-wave superconductors with the anisotropy described by an elliptical Fermi surface we propose a general scheme of the analysis of the angular dependence of upper critical field at all temperatures on the basis of the exact solution for the order parameter. Our results show that the transitions (with tilting magnetic field) between different types of mixed states may be a salient feature of the FFLO phase. Moreover we discuss the reasons for the first-order phase transition into the FFLO state in the case of CeCoIn5 compound.