CMT Journal club, 30.06.2015, Marcel Serina

1. **Tunable Spin-Qubit Coupling Mediated by a Multielectron Quantum Dot**

   V. Srinivasa, H. Xu, and J.M. Taylor; *PRL 114, 226803*

2. **Connecting Berezinskii-Kosterlitz-Thouless and BEC Phase Transitions by Tuning Interactions in a Trapped Gas**

   R. J. Fletcher, M. R. de-Saint-Vincent, J. Man, N. Navon, R. P. Smith, K. G.H. Viebahn, and Z. Hadzibabic; *PRL 114, 255302*

   We study the critical point for the emergence of coherence in a harmonically trapped two-dimensional Bose gas with tunable interactions. Over a wide range of interaction strengths we find excellent agreement with the classical-field predictions for the critical point of the Berezinskii-Kosterlitz-Thouless (BKT) superfluid transition. This allows us to quantitatively show, without any free parameters, that the interaction-driven BKT transition smoothly converges onto the purely quantum-statistical Bose-Einstein condensation transition in the limit of vanishing interactions.

3. **Realizing Majorana zero modes by proximity effect between topological insulators and d-wave high-temperature superconductors**

   Zi-Xiang Li, Cheung Chan, and Hong Yao; *PRB 91, 235143*

   We theoretically study the superconducting proximity effect between a topological insulator (TI) and a high-temperature d-wave superconductor (dSC). When the TI-dSC heterostructure violates 90 rotation and certain reflection symmetries, we show that a sizable s-wave pairing, coexisting with a d-wave one, emerges in the proximity-induced superconductivity in the TI's top surface states. Weak disorder further suppresses d-wave pairing (but not s-wave pairing) in the TI's surface states. More importantly, the pairing gap in the surface states is found to be nodeless and nearly isotropic when the Fermi pocket of surface states is relatively small. Our theoretical results qualitatively explain recent experimental evidences of a nearly-isotropic pairing gap on surface states of Bi2Se3 induced by proximity to high-Tc cuprate Bi2Ca2Cu2O8+. We also demonstrate convincing evidence of Majorana zero modes in a magnetic hc/2e vortex core which may be detectable in future experiments.

4. **Gapped Surface States in a Strong-Topological-Insulator Material**

   A.P. Weber, Q.D. Gibson, Huiwen Ji, A.N. Caruso, A.V. Fedorov, R.J. Cava, and T. Valla; *PRL 114, 256401*

   A three-dimensional strong-topological insulator or semimetal hosts topological surface states which are often said to be gapless so long as time-reversal symmetry is preserved. This narrative can be mistaken when surface state degeneracies occur away from time-reversal-invariant momenta. The mirror invariance of the system then becomes essential in protecting the existence of a surface Fermi surface. Here we show that such a case exists in the strong-topological-semimetal Bi4Se3. Angle-resolved photoemission spectroscopy and ab initio calculations reveal partial gapping of surface bands on the Bi2Se3 termination of Bi4Se3(111), where an 85 meV gap along K closes to zero toward the mirror-invariant M azimuth. The gap opening is attributed to an interband spin-orbit interaction that mixes states of opposite spin helicity.

5. **Topological Valley Currents in Gapped Dirac Materials**

   Yuri D. Lensky, Justin C.W. Song, Polnop Samutpraphoot, and Leonid S. Levitov; *PRL 114, 256601*

   Gapped 2D Dirac materials, in which inversion symmetry is broken by a gap-opening perturbation, feature a unique valley transport regime. Topological valley currents in such materials are dominated by bulk currents produced by electronic states just beneath the gap rather than by edge modes. The system ground state hosts dissipationless persistent valley currents existing even when topologically protected edge modes are absent. Valley currents induced by an external bias are characterized by a quantized half-integer valley Hall conductivity. The undergap currents dominate magnetization and the charge Hall effect in a light-induced valley-polarized state.

6. **Negative static permittivity and violation of Kramers-Kronig relations in quasi-two-dimensional crystals**

   Vladimir U. Nazarov; *arXiv:1506.07229*

   We investigate the wave-vector and frequency-dependent screening of the electric field in atomically thin (quasi-two-dimensional) crystals of graphene and hexagonal boron nitride. We find that, above a critical wave-vector qc, the static permittivity $\varepsilon(q > q_c, \omega = 0)$ becomes negative and the Kramers-Kronig relations do not hold for $\varepsilon(q > q_c, \omega)$. Thus, in quasi-two-dimensional crystals, we reveal a robust physical confirmation of a proposition put forward decades ago (Kirzhnits, 1976), allowing for the breakdown of Kramers-Kronig relations and negative values of the static permittivity. In the vicinity of the critical wavevector, we find a giant growth of the permittivity. We argue that these properties, being exceptional in the three-dimensional case, are common to quasi-two-dimensional crystals, while their discovery opens new pathways in the two-dimensional superconductivity.

7. **Robust Majorana conductance peaks for a superconducting lead**

   Yang Peng, Falko Pientka, Yuval Vinkler-Aviv, Leonid I. Glazman, Felix von Oppen; *arXiv:1506.06763*

   Experimental evidence for Majorana bound states largely relies on measurements of the tunneling conductance. While the conductance into a Majorana state is in principle quantized to $2e^2/h$, observation of this quantization has been elusive, presumably due to temperature broadening in the normal-metal lead. Here, we propose to use a superconducting lead instead, whose gap strongly suppresses thermal excitations. For a wide range of tunneling strengths and temperatures, a Majorana state is then signaled by symmetric conductance peaks at $eV = \pm\Delta$ with quantized height $G = (4 - \pi)2e^2/h$. For a superconducting scanning tunneling microscope tip, Majorana states appear as spatial conductance plateaus while the conductance varies with the local wavefunction for trivial Andreev bound states. We discuss effects of nonresonant (bulk) Andreev reflections and quasiparticle poisoning.

8. **Dirac electrons and domain walls: a realization in junctions of ferromagnets and topological insulators**

   Yago Ferreiros, F. J. Buijnsters, M. I. Katsnelson; *arXiv:1506.07668*

   We study a system of Dirac electrons with finite density of charge carriers coupled to an external electromagnetic field in two spatial dimensions, with a domain wall (DW) mass term. The interface between a thin-film ferromagnet and a three-dimensional topological insulator provides a condensed-matter realization of this model, when an out-of-plane domain wall magnetization is coupled to the TI surface states. We show how, for films with very weak intrinsic in-plane anisotropies, the torque generated by the edge electronic current flowing along the DW competes with an effective in-plane anisotropy energy, induced by quantum fluctuations of the chiral electrons bound to the wall, in a mission to drive the internal angle of the DW from a Bloch configuration towards a Néel configuration. Both the edge current and the induced anisotropy contribute to stabilize the internal angle, so that for weak intrinsic in-plane anisotropies DW motion is still possible without suffering from an extremely early Walker breakdown.

9. **Equilibration in closed quantum systems: Application to spin qubits**

   Daniel Hetterich, Moritz Fuchs, Björn Trauzettel; *arXiv:1506.07697*

   We study general properties of equilibration in a central spin model. The model is motivated by a single electron captured in a quantum dot. Evidently, the spin degree of freedom of the electron can be viewed as a qubit that is coupled – via the hyperfine interaction – to the quantum bath of nuclear spins. On the basis of the so-called distinguishability, we analytically derive general equilibration bounds with respect to observables. Furthermore, we relate the abstract concept of these equilibration bounds to the standard deviation of the fluctuations of the corresponding observable. Subsequently, we analyze an experimentally relevant model for an electron spin (in a carbon- or silicon-based quantum dot) coupled to a quantum bath of nuclear spins using exact diagonalization. Thereby, we are able to make concrete predictions for the experimental observability of the quantum equilibration procedure described above.

10. **Heat transport between antiferromagnetic insulators and normal metals**

    Arne Brataas, Hans Skarsvåg, Erlend G. Tveten, Eirik Løhaugen Fjærbu; *arXiv:1506.06705*

    Antiferromagnetic insulators can become active spintronics components by controlling and detecting their dynamics via spin currents in adjacent metals. This cross-talk occurs via spin-transfer and spin-pumping, phenomena that have been predicted to be as strong in antiferromagnets as in ferromagnets. Here, we demonstrate that a temperature gradient drives a significant heat flow from magnons in antiferromagnetic insulators to electrons in adjacent normal metals. The same coefficients as in the spin-transfer and spin-pumping processes also determine the thermal conductance. However, in contrast to ferromagnets, the heat is not transferred via a spin Seebeck effect which is absent in antiferromagnetic insulator-normal metal systems. Instead, the heat is transferred via a large staggered spin Seebeck effect.