Chez Pierre

Presents ...

Wednesday, May 17, 2017

12:00pm noon

MIT Room 4-331

Special Chez Pierre Seminar

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"From the parity anomaly to a Majorana fermion - realization of the ultrarelativistic physics in topological insulators"

A realization of the high energy ideas in the solid state physics lab, like the parity anomaly or Majorana fermions, is one of new directions of current research. Topological insulators are perfect materials to realize both of these phenomena.

Topological insulators (TIs) have a bulk energy gap that separates the highest occupied band from the lowest unoccupied band while gapless energy electronic states that are protected by time reversal symmetry live at the edge (2D TIs) or surface (3D TIs). When doped with the magnetic impurities the TIs show the quantum anomalous Hall effect i.e. a single circulating chiral mode at the boundary of 2D TI. Interestingly, in the odd space-time dimensions, one would expect that the formation of the quantum anomalous Hall effect is directly connected to the parity anomaly. We prove theoretically this relation and discuss the experimental consequences [1,2].

On the other hand, a topological insulator in the proximity to an s-wave superconductor is the prefect material to detect signatures of Majorana fermions. S-wave superconductor on the top of the surface states of 3D TI generates s-wave and p-wave pairing mixture in the surface state due to the spin-momentum locking [3]. We predict that in the Josephson junction setup, namely superconductor (S) /surface state of topological insulator/superconductor (S), existence of this p-wave component leads to novel features in transport like superconducting Klein tunneling i.e. the perfect transmission of hybridized Majorana states for normal incidence, the non-sinusoidal current phase relation [4] and unusual phase-dependent thermal conductance [5]. Further, we propose the experimental setups to observe signatures of Majorana fermions in the ac Josephson effect on TI hybrid structures [6] as well as in topological superconductors based on the hexagonal lattices [7].

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[3] Liang Fu and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008).
[4] G. Tkachov and E. M. Hankiewicz, Phys. Rev. B 88, 075401 (2013).
[5] B. Sothmann and E. M. Hankiewicz Phys. Rev. B 94, 081407(R) (2016).
[6] R. S. Deacon, J. Wiedenmann, E. Bocquillon, F. Domínguez, T. M. Klapwijk, P. Leubner, C. Brüne, E. M. Hankiewicz, S. Tarucha, K. Ishibashi, H. Buhmann, and L. W. Molenkamp, Phys. Rev. X 7, 021011 (2017).
[7] L. Elster, C. Platt, R. Thomale, W. Hanke, and E. M. Hankiewicz, Nature Comm. 6, 8232 (2015).