Topological Insulators: Disorder, Interaction and Quantum Criticality of Dirac Fermions

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Topological insulators represent an emergent research field attracting a lot of attention of experimentalists and theoreticians. These are bulk insulators with delocalized (topologically protected) states on their surface. In this talk, I will first review a full symmetry classification of topological insulators. I will then focus on 2D and 3D topological insulators (and on topologically protected metals on their boundaries) in systems with strong spin-orbit interaction ("symplectic symmetry class"). I will analyze the field theories of these systems in the presence of disorder. A non-trivial topological nature of these theories leads to topological protection of boundary states from Anderson localization. I will also discuss an analogy with graphene where the same topological protection is operative as long as the intervalley scattering can be neglected.

Further, I will analyze the effect of Coulomb interaction on transport in topological insulators. While the Coulomb interaction does not affect the topological protection, it leads to emergence of a novel quantum critical state with a conductivity ~e^2/h on the surface of a 3D topological insulator. Remarkably, this critical state emerges without any adjustable parameters. Such a ``self-organized quantum criticality'' is a novel concept in the field of interacting disordered systems. Finally, we predict a quantum spin-Hall transition between the normal and topological insulator phases in 2D that occurs via a similar (or identical) quantum critical point.