Project January – July 2019

[1] Higher Order Topological Insulators

Short Description:

Three-dimensional topological (crystalline) insulators are materials with an insulating bulk but conducting surface states that are topologically protected by time-reversal (or spatial) symmetries. In this project, we would like to extend our understanding of three-dimensional topological insulators to systems that host no gapless surface states but exhibit topologically protected gapless corner states carrying fractional charge, manifesting fractionalization at the boundary of the boundary. We intend to study recently developed minimal models for such systems for which the quadrupole and octupole moments are topologically quantized electromagnetic observables. We would also study to characterize these insulating phases by implementing proper topological invariants for them.

[2] Graphene: a tunable Floquet Topological Insulator

Short Description:

Graphene is the first relativistic condensed matter system synthesized experimentally from Graphite. The aim of this project would be to study the emergence of topological Floquet chiral edge states in graphene nanoribbon in presence of external irradiation in the form of Laser/circularly polarized light. The nature of these Floquet states has to be understood by both analytical and numerical calculations. We would also like to understand how graphene can be used for realizing nonequilibrium topological states with striking tunability: while the laser/light intensity can be used to control their velocity and decay length, changing the laser polarization switches their propagation direction.

[3] Josephson effect in a Weyl Superconductor

Short Description:

A Weyl semimetal, a semimetal in which conduction and valence bands have nondegenerate touching points, is a paradigm of gapless topological matter. In this project, first we would like to understand the intrinsic superconductivity in a doped Weyl semimetal. It can be shown that two distinct superconducting states are possible in a time reversal symmetry broken Weyl semimetal in principle: a zero-momentum pairing BCS state, with point nodes in the gap function, and a finite-momentum FFLO-like state, with a full nodeless gap. Finally, our aim would be to calculate the Josephson current for a “Weyl superconductor–normal-metal–superconductor” junction (SNS) taking into account the two pairing mechanisms inside the superconductors that have been proposed in the literature and mentioned above.

[4] Majorana Zero Modes (Topological Superconductivity) in helical Shiba Chains

Short Description:

In this project, at first we would like to understand the recent experiment, which suggests that topological superconductivity and Majorana end states can be realized in a chain of magnetic impurities on the surface of an **s**-wave superconductor. Then, our aim would be to investigate this scenario via a recently developed theoretical model Hamiltonian starting from the Shiba bound states induced by the individual magnetic impurities. We would like to understand the similarities and differences between this model Hamiltonian with the Kitaev model for one-dimensional spinless **p**-wave superconductors. Also using both analytical and numerical approaches we would like to explore the consequences of these differences for the phase diagram and the localization properties of the Majorana end states when the Shiba chain is in the topological superconducting phase.

[5] Transport signature of Exciton Condensate in an electron-hole bilayer in contact with a Superconductor

Short Description:

Semiconductors/semimetals could undergo, at sufficiently low temperatures, a phase transition into an insulating state described by electron-hole bound pairs. These pairs form a so-called exciton condensate (EC), as theoretically predicted a long time ago. In this project, our aim would be to investigate the transport properties of a junction consisting of an electron-hole bilayer in contact with normal and superconducting leads. We would like to explore how the sub gapped electronic transport through the junction is mainly governed by the interplay between two kinds of reflection processes at the interfaces: the standard Andreev reflection at the interface between the superconductor and the exciton condensate, and a coherent crossed reflection at the semimetal–exciton condensate interface that converts electrons from one layer into the other. We would like to find analytically/numerically the differential conductance of the junction. Some features of the conductance signal can be seen as a direct hallmark of the existence of the gapped excitonic state.