HL 101: Theoretical advances in interacting topological phases (organized by TT)

Topological insulators have attracted considerable attention recently. Today, the theoretical and experimental understanding of such systems has become comparably well. The continued high interest in this topic is caused by exciting proposals and concepts for new exotic physics based on the interplay of the non-trivial band topology and strong electron-electron interactions. Fractional Chern insulators, topological Mott insulators, topological Kondo insulators, and spin liquids are just a few examples. Some of these phases have already been claimed to be found in experiments.

The aim of this focus session is to give an overview of the most recent advances in this exciting and rapidly evolving field presented by leading experts in the field.

Organizer: Stephan Rachel (TU Dresden)

Time: Thursday 15:00–18:25 Location: HSZ 03

Invited Talk HL 101.1 Thu 15:00 HSZ 03
Fractional Topological Insulators — •Andrei Bernevig — Princeton University

Topological insulators are remarkable materials whose insulating "boring" bulk nonetheless gives rise to perfectly metallic edge or surface states not disturbed by disorder. In this talk, I will relay new phenomena beyond the recently discovered topological insulators with time-reversal symmetry. I will show that topological insulators exist with any point group symmetry, and, upon adding interactions, can transform in much more interesting systems. I will show that fractionally filling a band of a one-body topological insulator and then subjecting its electrons to repulsive interaction can create new states of matter non-existent in the continuum, whose quasiparticles exhibit non-abelian braiding. I will then show that a new description of these states in terms of matrix product forms can greatly enhance our capability to calculate their many-body properties.

Invited Talk HL 101.2 Thu 15:30 HSZ 03
Non-Fermi Liquid, Quantum Critical, and Topological States in Iridates — •Leon Balents — Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA, USA

The combination of band topology and strong correlations is an intriguing and largely open area for theory and experiment. I will discuss a theory of a "parent state" for both topological and quantum critical descendants. This state is suggested to describe one of the prototypical materials families in this area: the pyrochlore iridates.

Parts of this work were done in collaboration with Yong-Baek Kim, Eun-Gook Moon, Lucile Savary, and Cenke Xu

Topical Talk HL 101.3 Thu 16:00 HSZ 03
Collective Spin-Orbit Physics in $j = 1/2$ Mott Insulators — •Simon Trebst — Universität zu Köln

The greatly enhanced spin-orbit coupling in 5d transition metal oxides can lead to a novel class of Mott insulators in which the local moment is a $j = 1/2$ spin-orbit entangled momentum. The rich physics arising in these novel Mott insulators has been extensively probed in the context of the quasi two-dimensional compounds Sr_2IrO_4 (square lattice) with regard to superconducting instabilities and Na_2IrO_3 (honeycomb lattice) in context of possible spin liquid behavior. Here we report on our endeavor to understand the collective states of such spin-orbit entangled j=1/2 momenta when considering other lattice geometries, in particular the triangular lattice motivated by the recent synthesis of $Ba_3IrTi_2O_9$ and the three-dimensional hyperoctagon lattice in the context of β-Li_2IrO_3. For the triangular system we find that weak anisotropic Kitaev-like interactions stabilize a Z_2-vortex phase. For the hyperoctagon lattice (the premedial lattice of the hyperkagome lattice) we find that strong Kitaev-like couplings give rise to a gapless quantum spin liquid with a Majorana Fermi surface – a highly unusual spin liquid state, which is intimately connected to and protected by the lattice symmetries.

15 min. break.

Topical Talk HL 101.4 Thu 16:45 HSZ 03
Topological Kondo Insulators: An Example of Correlated Quantum Spin Hall States — •Fakher Assaad — Universität Würzburg

In the very same way as the heavy fermion paramagnetic state at $T = 0$ is adiabatically linked to a gas of free electrons, the topological Kondo insulator can be deformed to a quantum spin Hall insulator without going through a quantum phase transition. The interest however lies in the fact the quasi-particles forming this coherence state are dynamically created by correlation effects, and may be viewed as the Kondo screening clouds of the magnetic impurities. The minimal model to capture this piece of physics consists of odd parity localized f-states hybridizing with an even parity conduction band alongside strong spin-orbit coupling and time reversal symmetry. In this talk we will consider such a minimal model, and concentrate on the temperature dependence of various quantities from the mixed valence to local moment regimes [1-2] The quantities we consider include topological invariants as well as the single particle spectral function on slab topologies. We show that there is a single low energy scale, the coherence scale, below which one observes the emergence of the topological state.

This work has been carried out in collaboration with J. Werner.

[1] J. Werner and F. F. Assaad, Phys. Rev. B 88, 035113 (2013).
[2] J. Werner and F. F. Assaad, arXiv:1311.3668.

Topical Talk HL 101.5 Thu 17:15 HSZ 03
Fractional Chern Insulators in Strongly Correlated Multiorbital Systems — •Maria Daghofer, Stefanos Kourtis, Jörn W. F. Venderbos, and Jeroen van den Brink — IFW Dresden, Dresden, Germany

Interaction between itinerant carriers and localized spins on frustrated lattices can stabilize phases that are in many respects similar to a Landau level, with a non-coplanar spin background taking the role of the magnetic field. If the bands are nearly flat, longer-range Coulomb repulsion can then induce states that are like lattice-analogs of fractional Quantum-Hall (FQH) states, but do not require an external magnetic field. I will discuss a t_{2g}-orbital system on a triangular lattice that supports a spin-chiral magnetic ordering pattern with precisely the required topologically non-trivial and flat bands[1]. Exact-diagonalization methods reveal signatures of a FQH-like ground state. Moreover, we also find states that go beyond the physics of Landau levels: They show a combination of conventional (charge) and topological order and are related to the frustration of the underlying triangular lattice [2].

[1] J. W. F. Venderbos et al., PRL **108**, 126405 (2012)
[2] S. Kourtis and M. Daghofer, arXiv:1305.6948

HL 101.6 Thu 17:45 HSZ 03
Non-Abelian quasiparticles in strongly interacting helical liquids — •Thomas Schmidt, Christoph Orth, and Rakesh Tiwari — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

The interplay of strong Coulomb interactions with Rashba spin-orbit coupling can lead to the opening of a gap in the edge spectrum of a two-dimensional topological insulator, even if the system Hamiltonian is time-reversal invariant. We investigate the properties of such a strongly interacting helical system in proximity to an s-wave superconductor. We show that the interface between a region gapped out by the proximity effect and a region gapped out by strong interactions can host non-Abelian bound states, and determine their exchange statistics.

HL 101.7 Thu 18:05 HSZ 03
From fractionally charged solitons to Majorana bound states in a one-dimensional interacting model — •Frank Pollmann[1], Doru Sticlet[1,2], Luis Seabra[1,3], and Jerome Cayssol[1,2] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Ger-

many — [2]CNRS and University Bordeaux, Talence, France — [3]Technion, Haifa, Israel

We investigate the one-dimensional Creutz model in the presence of induced superconductivity and Hubbard type interactions. We show that zero-energy Majorana edge modes develop in the presence of superconducting pairing for a certain range of parameters. Additionally, the system hosts regular electronic zero-energy modes in a trivial superconducting phase. We study the effect of interactions using a combination of density matrix renormalization group (DRMG) methods and mean field theory. It is shown how local repulsive interactions expand the parameter range for which a topological Majorana phase is stabilized. In contrast, we find that interactions remove the zero-energy modes found in the trivial superconducting phase.