Interdisciplinary seminar

Topological and Analytical Aspects of Condensed Matter Physics

June 22, 2pm – June 23, 2pm
Forschungskolleg Humanwissenschaften
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12:30 pm: Lunch & Welcoming

Th, 2:00 pm

Felix von Oppen (FU Berlin)
Edge modes of the random-field Floquet quantum Ising model

Abstract: Motivated by a recent experiment on a superconducting quantum processor [Mi et al., Science 378, 785 (2022)], we study the stability of edge modes in the random-field Floquet quantum Ising model and its ramifications for temporal boundary spin-spin correlations. The edge modes induce pairings in the many-body Floquet spectrum with splittings exponentially close to zero (Majorana zero mode or MZM phase) or π (Majorana π phase or MPM phase). We find that random transverse fields induce a log-normal distribution of both types of splittings. In contrast, random longitudinal fields affect the zero and π splittings in drastically different ways. While the random longitudinal field rapidly lifts the zero pairings, it strengthens the π pairing, with concomitant differences in the boundary spin-spin correlations. We explain our result within a low-order Floquet perturbation theory. The strengthening of π pairings by random longitudinal fields may have applications in quantum information processing.

Th, 2:40 pm

Stefan Teufel (University of Tübingen)
Some results on bulk-edge correspondence for interacting fermion systems at positive temperature

We consider lattice fermions with short-range interactions and above a certain critical temperature. We show that in systems with edges the edge current is equal to the bulk orbital magnetisation density in the thermodynamic limit. The equality also holds for the derivatives of both sides with respect to the chemical potential, quantities related to the bulk Hall conductivity and the edge conductance, respectively. This form of bulk-edge correspondence is essentially a consequence of the homogeneity in the bulk and of the locality of the Gibbs state. This is based on joint work with Jonas Lampart, Massimo Moscolari and Tom Wessel.

Th, 3:20 pm

Ashley Cook (MPI-CPfS Dresden)
Quantum skyrmion Hall effect

Topological skyrmion phases of matter are recently-introduced topological phases of electronic systems in equilibrium, in which a system with more than one degree of freedom (e.g. spin and orbital degrees of freedom) realizes a topological state for a subset of the degrees of freedom (e.g. only spin). For topological skyrmion phases of spin, this topology is relevant even if spin is not conserved due to non-negligible atomic spin-orbit coupling, and is distinguished by a skyrmion forming in the spin texture over the Brillouin zone, distinct from a skyrmion forming in the texture of the projector onto occupied states over the Brillouin zone.
We present results on three band Bloch Hamiltonians realizing this non-trivial spin topology, and outline some bulk-boundary correspondence features, such as gapless edge states corresponding to zero net charge—but finite spin angular momentum—pumped across the bulk gap. Tracing out the orbital degree of freedom, we can identify this spin pumping with pumping of spin point charges, and local curvature of the k-space spin skyrmion with a Berry curvature of these spin point charges. That is, the spin pumping is identified with pumping of spin magnetic skyrmions, which reduce to point magnetic charges after tracing out the orbital degree of freedom.
We therefore identify topological skyrmion phases as lattice counterparts of quantized transport of quantum magnetic skyrmions, a quantum skyrmion Hall effect. This indicates that the theory of the quantum Hall effect must be generalized, by relaxing point charges in the theory to small skyrmions.

4 pm: Coffee break

Th, 4:30 pm

Hermann Schulz-Baldes (FAU Erlangen-Nuremberg)
The spectral localizer as new tool for topological materials

The talk gives a short overview of recent results on the spectral localizer and applications thereof.

Th, 5:10 pm

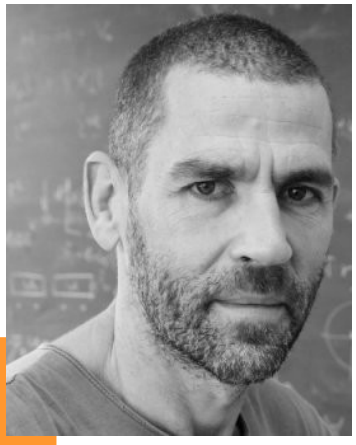
Michael Potthoff (University of Hamburg)
Interacting Chern Insulator in Infinite Spatial Dimensions

We study a generic model of a Chern insulator supplemented by a Hubbard interaction in arbitrary even dimension D and demonstrate that the model remains well-defined and nontrivial in the $D \to \infty$ limit. Dynamical mean-field theory is applicable and predicts a phase diagram with a continuum of topologically different phases separating a correlated Mott insulator from the trivial band insulator. We discuss various features, such as the elusive distinction between insulating and semi-metal states, which are unconventional already in the non-interacting case. Topological phases are characterized by a non-quantized Chern density replacing the Chern number as $D \to \infty$.

Fri, 9:00 am

Titus Neupert (University of Zurich)
Two-dimensional Shiba lattices as a possible platform for crystalline topological superconductivity

Localized or propagating Majorana boundary modes are the key feature of topological superconductors. They are rare in naturally-occurring compounds, but the tailored manipulation of quantum matter offers opportunities for their realization. Specifically, lattices of Yu-Shiba-Rusinov bound states – Shiba lattices – that arise when magnetic adatoms are placed on the surface of a conventional superconductor can be used to create topological bands within the superconducting gap of the substrate. I will present a experimental-theoretical study where scanning tunnelling microscopy is used to create and probe adatom lattices with single atom precision we reveal two signatures consistent with the realization of two types of mirror symmetry protected topological superconductors. The first has edge modes as well as higher-order corner states, and the second has symmetry-protected bulk nodal points. In principle, their topological character and boundary modes should be protected by the spatial symmetries of the adatom lattice. Our results highlight the potential of Shiba lattices as a platform to design the topology and sample geometry of 2D superconductors.



Fri, 9:40 am

Alexander Altland (University of Cologne)
Topological insulator surface state enigmas

About two decades after the discovery of topological band insulators, one would think that the basic physics of these materials is reasonably well understood. However, this isn't the case, at least not if the inevitable presence of static disorder is taken into account. Proposed solutions to the enigmatic behavior shown by the surface states of some three-dimensional topological insulators include the formation of globally quantum-critical phases, or the spontaneous breaking of antiunitary symmetries. In this talk, we will review the state of affairs and propose solutions to the most pressing (but not all) of these riddles.

10:20 am: Coffee break

Fri, 10:50 am

Gianluca Panati (Sapienza University of Rome)
Wannier-localizability as a tool to detect non-periodic Chern insulators

I will discuss the correspondence between localization properties of (generalized) Wannier bases and the Chern triviality of the space of occupied states, in gapped quantum systems.
In the periodic setting, the correspondence has been proved with an optimal localization threshold: if the system admits a Wannier basis with finite expectation value for the squared position operator, then it is Chern trivial, and vice versa.
I will report on recent progresses in the non-periodic setting, and discuss future perspectives and possible applications.

Fri, 11:30 am

Maria Hermanns (Stockholm University)
Topological phases at criticality

One standard assumption for classifying topological phases of matter is that the system has an (at least partial) energy gap. More precisely, the corresponding topological invariants become generically ill-defined when the system becomes gapless, i.e. at critical points. Nevertheless, it was observed that certain hallmarks of topological phases, in particular the presence of robust edge modes, survive at criticality. In this talk, we discuss two distinct ways of how to generalize topological invariants to systems without an energy gap, as well as their properties. We will also introduce a relation between critical hermitian and gapped non-hermitian phases, using the example of one-dimensional systems with chiral symmetry.

12:10 pm: Lunch & Farewell