Programme Topological Phases of Matter

time	Mon	Tue	time change	Wed
	26.07.2021	27.07.2021		28.07.2021
09:00-9:45	***Tasaki***	***Thiang***		***Kubota***
	Ogata index and Symmetry Protected Topological Phases in Quantum Spin Chains *I will review the notion of symmetry protected topological phases (SPT phase) in quantum spin chains, and discuss the topological index recently defined by Ogata. The Ogata index is an extension of the index by Pollmann, Turner, Berg and Oshikawa defined for matrix product states. I will describe how the index can be used to classify and characterize nontrivial SPT phases.*	***On the topological protection of spectral gaplessness*** *While topological invariants of gapped lattice models have received tremendous attention, gapless boundaries in continuum models are perhaps more consequential for physics. Crucially, extra topology can arise from the space of boundary conditions, leading to interesting spectral flow underlying gapless systems. I will discuss the topology of unbounded spectral flow, its higher and "Real" versions via gerbes, and its relation to coarse index theory. These techniques are applicable to a large range of real physical systems.*		***The bulk-dislocation correspondence: an operator-algebraic approach*** *A weak topological insulator in dimension 3 is known to have a topologically protected gapless mode along the screw dislocation. In this talk I present a formulation and proof of this fact with the language of C*-algebra K-theory. The proof is based on the coarse index theory of the helical surface.*
10:00-10:45	***Bourne***	***Gomi***		**Tauber**
	Localized/de-localized Wannier bases of aperiodic Schrödinger operators *Given a Schrödinger-type operator with a lattice-periodic potential and spectral gap, a Wannier basis is an orthonormal basis of a spectral subspace built from the lattice translates of a finite set of functions. The Bloch-Floquet transform guarantees the existence of such bases, but their regularity changes dramatically depending on whether the spectral subspace forms a trivial vector bundle over the Brillouin torus (momentum space) or not. In this talk, I will review these results and consider an extension to aperiodic Schrödinger operators using a framework based on operator algebras and Morita equivalence. In particular, this framework can be used to prove a weaker version of the Localization Dichotomy Conjecture raised by Marcelli et al. This is joint work with Bram Mesland.*	***Homological bulk-edge correspondence for Weyl semimetal*** *For topological insulators, the bulk-edge correspondence is a characterizing property, and has been established theoretically for various models. Typically, this correspondence is formulated as a coincidence of two invariants, called a bulk invariant and an edge invariant. The subject of my talk is a bulk-edge correspondence for Weyl semimetals. This will be formulated as a coincidence of two homology classes, based on an idea of Mathai and Thiang. A point of this 'homological' bulk-edge correspondence is that it explains the topology of Fermi arcs. I will also explain a model of Weyl semimetals for which the bulk-edge correspondence is established.*		**Topological indices for shallow-water waves** In this talk, I will apply tools from topological insulators to a fluid dynamics problem: the rotating shallow-water wave model with odd viscosity. The bulk-edge correspondence explains the presence of remarkably stable waves propagating towards the east along the equator and observed in some Earth oceanic layers. The odd viscous term is a small-scale regularization that provides a well defined Chern number for this continuous model where momentum space is unbounded. Equatorial waves then appear as interface modes between two hemispheres with a different topology. However, in presence of a sharp boundary there is a surprising mismatch in the bulk-edge correspondence: the number of edge modes depends on the boundary condition. I will explain the origin of such a mismatch using scattering theory and Levinson's theorem. This talk is based on a series of joint works with Pierre Delplace, Antoine Venaille, Gian Michele Graf and Hansueli Jud.
11:00-11:30	coffee	coffee		coffee
11:30-12:15	**Zirnbauer**	**Kapustin**		**Porta**
	Comments on the "AZ classification" Building on Dyson's Threefold Way, the scheme of the Tenfold Way of Altland-Zirnbauer classifies free-fermion Hamiltonians with symmetries. Originally conceived for disordered systems, the scheme has been found to have a bearing on the classification of topological phases of matter. In this talk, I will review the history of the Tenfold Way, with an emphasis on the distinction between "symmetry" and "structure".	**Zero-temperature Hall conductance as a topological invariant of gapped 2d lattice systems** I will describe how to assign a numerical invariant to a gapped ground state of an infinite U(1)-invariant lattice system in two dimensions. This invariant is locally computable, does not depend on the Hamiltonian of the system, and does not change under homotopies. The invariant turns out to be equal to the zero-temperature Hall conductance computed via the Kubo formula. The talk is based on a joint work with Nikita Sopenko.		**Anomaly non-renormalization in Weyl semimetals** Weyl semimetals are three-dimensional condensed matter systems characterized by a degenerate Fermi surface, consisting of a pair of 'Weyl nodes'. Correspondingly, in the infrared limit, these systems behave effectively as Weyl fermions in 3+1 dimensions. As predicted by Nielsen and Ninomiya in 1983, when exposed to electromagnetic fields these materials are expected to simulate the axial anomaly of QED, by giving rise to a net quasi-particle flow between Weyl nodes. We consider a class of interacting lattice models for Weyl semimetals and prove that the quadratic response of the quasi-particle flow is universal, and equal to the chiral triangle graph of QED. Universality is the counterpart of the Adler-Bardeen non-renormalization property of the axial anomaly for QED, in a condensed matter setting. Our proof relies on the rigorous Wick rotation for real-time transport coefficients, on constructive bounds for Euclidean ground state correlations, and on lattice Ward Identities. Joint work with A. Giuliani and V. Mastropietro.
12:30-13:30	Lunch	Lunch		Lunch
15:00-15:45	**Nachtergaele**	**Bachmann**	14:00-14:45	**Marcelli**
	The stability of gapped phases and automorphic equivalence Gapped ground state phases of infinite quantum many-body systems can be defined as classes of ground states equivalent under automorphisms of the algebra of local observables with good quasi-locality properties. We will review recent progress on the stability of such phases, in particular those that exhibit topological order.	**Two results on the quantum Hall effect** I will discuss two results pertaining to the quantum Hall effect for interacting systems. First of all, that linear response theory is exact in that the full response of the system to the driving force is given by the linear response coefficient; this is really a corollary of the adiabatic theorem. Second of all, that the quantum Hall conductance vanishes for Hamiltonians that are a sum of commuting terms; this shows in particular that commuting Hamiltonians cannot represent all topological phases.		**A new approach to transport coefficients in the quantum spin Hall effect** We investigate some foundational issues in the quantum theory of spin transport, in the general case when the unperturbed Hamiltonian operator does not commute with the spin operator in view of Rashba interactions. A gapped periodic one-particle Hamiltonian is perturbed by adding a constant electric field of small intensity and the linear response, with respect to the strength of the electric field, in terms of a spin current is computed. We derive a general formula for the spin conductivity that covers both the choice of the conventional and of the proper spin current operator. We study the independence of the spin conductivity from the choice of the fundamental cell, and we isolate a subclass of discrete periodic models (including the Kane-Mele model) where the conventional and the proper spin conductivity agree. As a consequence of the general theory, we obtain that whenever the spin is (almost) conserved, the spin conductivity is (approximately) equal to the spin-Chern number. The method relies on the characterization of a non-equilibrium almost-stationary state, which well approximates the physical state of the system. This seminar is based on joint work with G. Panati and S. Teufel.

time	Mon	Tue	time change	Wed
16:00-16:45	**Young**	**Doll**	15:00-15:45	**Stoiber**
	Gap stability of topologically ordered ground states in the infinite volume setting In this talk, we consider the spectral gap stability of gapped ground states of frustration-free quantum spin models. We will show that for models satisfying a local topological order condition, which captures that the finite volume ground states are effectively indistinguishable by local operators, the gap remains open in the presence of uniformly small short-ranged perturbations. In contrast to earlier results, we do not require a positive lower bound for a sequence of finite-volume Hamiltonians uniform in the system size. This result is proved by adapting the Bravyi-Hastings-Michalakis strategy for gap stability to the GNS representation of the infinite-system ground state. This talk is based on joint work with Bruno Nachtergaele and Robert Sims.	**Skew localizer for real index pairings** The object of this talk are index pairings of a projection and an unitary where both, the projection and the unitary fulfill Real symmetry relations. For a given combination of symmetries the integer-valued index of the pairing vanishes, but there may be a Z_2-index given by the dimension of the kernel, modulo 2. In this talk an interpretation of these Z_2-indices as spectral flows is given. The main aim is then to construct a finite dimensional real skew-adjoint matrix called the skew localizer for these pairings and to show that the Z_2-index can be computed as the sign of the Pfaffian of the skew localizer.		**Weak Chern numbers of semimetals and strongly disordered topological insulators** Non-interacting topological insulators that are covariant under translations may have topological invariants, called weak Chern numbers, that determine the occurence of directionally dependent surface states for certain cuttings of the lattice. Those Chern numbers are still well-defined but less understood for certain semimetals and strongly disordered weak topological insulators without a spectral gap. Both of those more general settings can still be analyzed in an operator-algebraic framework, however, a purely C*-algebraic approach appears to be unworkable. I will recall the definitions of weak Chern numbers and talk about recent results on the index theory, issues of stability and elements of bulk-boundary correspondence for systems without a spectral gap.
17:00-17:30	pause	pause	16:00-16:45	**Shapiro**
17:30-18:15	***Weinstein***	**Cedzich**		**Mobility-Gapped Time Reversal Invariant Topological Insulators in 2D** We study strongly-disordered time reversal invariant 2D topological insulators, where time reversal squares to -1. Such systems are known to have a Z_2 invariant in the spectral gap regime. We extend homotopy techniques to the mobility gap regime. Using this we prove stability w.r.t. the Fermi energy as well as the bulk-edge correspondence for such systems. Based on joint work with Jeff Schenker.
	Tight binding approximation of continuum 2D quantum materials We consider 2D quantum materials, modeled by a continuum Schroedinger operator whose potential is comprised of an array of identical potential wells centered on the vertices of a discrete subset, \Omega, of the plane. We study the low-lying spectrum in the regime of deep potential wells (strong binding). We present results on scaled resolvent norm convergence to a discrete (tight-binding) operator and, in the translation invariant case, corresponding results on the scaled convergence of low-lying Floquet-Bloch dispersion surfaces. Examples include the single electron model for bulk graphene (\Omega=honeycomb lattice), and a sharply terminated graphene half-space, interfaced with the vacuum along an arbitrary line-cut. We also apply our methods to the case of strong constant perpendicular magnetic fields, and to a proof of the equality of topological indices (for bulk and edge systems) of discrete (tight binding) and continuum (strongly bound) Hamiltonians. This lecture is based on joint work with C.L. Fefferman and J. Shapiro.	**The topological classification of quantum walks** In this talk I discuss the topological classification of one-dimensional quantum walks that are symmetric for the symmetries of the ten-fold way. The indices are constructed via finite-dimensional representations of the symmetry group. The classification does not depend on the underlying lattice and is stable under symmetry-preserving homotopies. However, in contrast to the continuous-time setting, this does not capture all relevant perturbations. Additional indices, defined in terms of the spatial structure, possess the desired stability and allow for a straightforward formulation of bulk-edge correspondence. Moreover, I will provide the proof idea of the completeness of the classification.		
18:30-19:15	**Pizzo**	***Carpentier***		
	Stability of gapped quantum lattice systems under small perturbations We consider a family of quantum lattice systems that has attracted much interest amongst people studying topological phases of matter. Their Hamiltonians are perturbations, by interactions of short range, of a Hamiltonian consisting of on-site terms and with a strictly positive energy gap above its ground-state energy. We prove stability of the spectral gap, uniformly in the size of the lattice. In our proof we use a novel method based on local Lie-Schwinger conjugations of the Hamiltonians associated with connected subsets of the lattice. We can treat fermions and bosons on the same footing, and our technique does not face a large field problem, even though bosons are involved. Furthermore the method can be extended to complex Hamiltonians obtained by considering complex values of the coupling constant. (Joint works with S. Del Vecchio, J. Fröhlich, and S. Rossi.)	***Non-orientable Mechanics*** *Over the last decade, topology sparked a new line of research in solid-sate physics, revolutionizing our understanding of electronic properties of matter. Today, the use of topology extends far beyond the specifics of solids and offers a single framework to understand optical, mechanical and electronic phenomena. In this seminar I will discuss a unique example of topological mechanics originating from non-orientability. First, I will consider the deformations of Möbius strips. I will establish that the elastic response of such non-orientable surfaces is non-additive, non-reciprocal and contingent on stress-history. Beyond the specifics of Möbius strips, I will show that non-orientability also emerges in the elastic response of frustrated metamaterials and protects them against homogeneous deformations. I will illustrate this property by showing that the deformation bundles of rings and tori assembled from counter-rotating units share the same non-orientability as the bending bundle of Möbius strips. This topological property allows to engineer structures that feature robust nodes and lines of vanishing deformations under the action of any homogeneous load, and leads to mechanical memory under point-like loads.*		
19:30-20:30	Dinner	Dinner		