TOPQM20 2020 - March 30 to April 03, 2020

Preliminary Program

Monday, Mar. 30

Nigel Cooper, "Symmetry-Protected Topology in Open Quantum Systems, Mo 9:45

Christof Weitenberg, "Topological effects in Floquet-engineered ultracold matter", Mo 11:00

Ultracold atoms in optical lattices constitute a versatile platform to study the fascinating phenomena of gauge fields and topological matter. Periodic driving can induce topological band structures with non-trivial Chern number of the effective Floquet Hamiltonian and paradigmatic models, such as the Haldane model on the honeycomb latticce, can be directly engineered. In this talk, I will report on our recent experiments, in which we realized new approaches for measuring the Chern number in this system and map out the Haldane phase diagram. This includes time-resolved Bloch-state tomography allowing for the observation of a dynamical linking number after a quench as well as the application of machine learning techniques to analyse experimental data. In the future, the combination of gauge fields with a quantum gas microscope will allow accessing new regimes such as fractional Chern insulators.

Hannah Price, "Exploring 4D Topological Phases of Matter in Synthetic Systems", Mo 11:45

Spatial dimensionality deeply affects the physical phenomena which can emerge in a system. Although our physical world has only three spatial dimensions, new topological phases of matter are predicted to emerge in four or more spatial dimensions. Now, this physics is becoming accessible thanks to advances in synthetic systems, including ultracold atoms, photonics and electric circuits. In this talk, I will review the basic concepts of 4D topological physics, and then report on recent developments towards simulating and exploring these effects in synthetic systems. These advances open the way towards exploring a wealth of topological matter in higher spatial dimensions. Ian Spielman, "Chaos in a Harper-Hofstadter system"

Ian Spielman, "Chaos in a Harper-Hofstadter system", Mo 14:00

The Harper-Hofstadter model describes particles in two-dimensional (2D) lattices subject to a uniform magnetic field. We experimentally assembled such a 2D lattice rolled into a long tube, just 3-sites around, thereby realizing periodic boundary conditions. These three sites were constructed from the synthetic dimension formed by the atoms' internal degrees of freedom. We inserted an additional longitudinal flux through the long axis of the cylinder, a process which has no analogy in a planar geometry. We observe both chaotic and regular dynamics: When the transverse flux is a simple rational number (2/3 in our experiments), the system's unitary evolution is exquisitely sensitive to the longitudinal flux and trajectories with different longitudinal fluxes diverge. Remarkably, away from simple rational fractions, paths do not diverge. We explain this transition equivalently in terms of a spatial self-averaging effect, interference between different matter-wave momentum states, and a momentum-space Aubry-Andre lattice.

Fabian Grusdt, "Partons and fractionalization in strongly correlated quantum matter", 14:45

Strong interactions can radically change the properties of correlated quantum systems and

their excitations: Quantum numbers can fractionalize and the excitations can be described by new emergent quasiparticles. These effects can be directly probed in state-of-the-art quantum gas microscopy experiments, or using more traditional spectroscopic tools such as ARPES. Here we discuss strongly correlated anti-ferromagnetic Mott insulators in two dimensions, hosting regimes where fractionalization is incomplete: Their constituents can be described by bound, or confined, partons. Specifically we discuss Z2 lattice gauge theories in arrays of coupled 1D chains, and the paradigmatic 2D t-J model. For the latter we show how one-hole ARPES spectra reveal the properties of constituting spinons in the 2D Heisenberg model. Our results provide a new microscopic perspective on the Fermi arcs observed in the pseudogap phase of cuprates.

Tuesday, Mar 31

Maia Vergniory, TBA, Tu 9:00

Matthias Punk, "Metals with topological order", Tu 9:45
Doping a Mott insulator with holes can lead to a variety of interesting, strongly correlated metallic states. In this talk I'm going to discuss the possibility that hole doped Mott insulators realize a metal with topological order. Such phases exhibit a variety of interesting properties, such as an anomalously low charge carrier concentration as well as a pseudogap in the electronic spectrum, which closely resembles the pseudogap phenomenology of underdoped high-Tc cuprate superconductors. Starting from a standard slave-boson representation of the t-J model I will show that metals with topological order arise quite naturally as potential ground state candidates.

Robert König, "Correcting coherent errors with surface codes", Tu 11:45
We study how well topological quantum codes can tolerate coherent noise caused by systematic unitary errors such as unwanted Z-rotations. Our main result is an efficient algorithm for simulating quantum error correction protocols based on the 2D surface code in the presence of coherent errors. The algorithm has runtime O(n^2), where n is the number of physical qubits. It allows us to simulate systems with more than one thousand qubits and obtain the first error threshold estimates for several toy models of coherent noise. Numerical results are reported for storage of logical states subject to Z-rotation errors and for logical state preparation with general SU(2) errors. We observe that for large code distances the effective logical-level noise is well-approximated by random Pauli errors even though the physical-level noise is coherent. Our algorithm works by mapping the surface code to a system of Majorana fermions.

Sergej Moroz, "Quantum phases of fermions coupled to Z2 gauge fields", Tu 14:00
I will present our recent study of a quantum many-body lattice system of one-dimensional fermions interacting with a dynamical Z2 gauge field. The gauge field mediates long-range attraction between fermions resulting in their confinement into bosonic dimers. At strong coupling we developed an exactly solvable effective theory of such dimers with emergent hard-core constraints. I will show that even at a generic coupling and fermion density, the model can be rewritten as a local spin 1/2 chain and forms a Luttinger liquid. In a finite chain we observed the doubling of the period of Friedel oscillations which paves the way towards experimental detection of confinement in this system. Finally, I will also discuss the possibility of a Mott phase at the commensurate filling 2/3, emergence of exact quantum scars and our current work on extension of this study to two spatial dimensions in pursuit of exotic p-wave superfluidity.

Norbert Schuch, TBA, Tu 14:45

Michael Knap, "Ergodicity-breaking arising from Hilbert space fragmentation in fractonic quantum matter", 16:00
Strong interactions and frustration often lead to dynamically constrained excitations of quantum matter. Examples include spin-ice compounds whose spin moments are aligned to fulfill a local ice rule, frustrated quantum magnets with dimerized excitations, and fracton phases with excitations that are only mobile in certain directions if at all. In this talk we show that the combination of charge and dipole conservation, a characteristic of fractonic quantum matter, leads to an extensive fragmentation of the Hilbert space, which in turn can lead to a breakdown of thermalization. We characterize such a Hilbert space fragmentation by

introducing `statistically localized integrals of motion' (SLIOM), whose eigenvalues label the connected components of the Hilbert space. SLIOMs are not spatially localized in the operator sense, but appear localized to sub-extensive regions in space when their expectation value is taken in typical states with a finite density of particles. Furthermore, we discuss that there exist perturbations which destroy these integrals of motion in the bulk of the system, while keeping them on the boundary. This results in statistically localized strong zero modes, leading to infinitely long-lived edge magnetizations along with a thermalizing bulk, constituting the first example of such strong edge modes in a non-integrable model. We also discuss that in a particular example, these edge modes lead to the appearance of topological string order in a certain subset of highly excited eigenstates. A variant of these models can be realized in Rydberg quantum simulators.

Thomas Schmidt, "Topological phases with parafermions", 16:45

Parafermionic bound states are generalizations of Majorana bound states which can exist in strongly correlated topological systems. In recent years, interest in these quasiparticles has been mounting thanks to their proposed applications in topological quantum computation. In the first part of the talk, I will discuss how Z4 parafermions can be realized in different experimental platforms. In particular, I will show how the edge states of two-dimensional topological insulators [1] as well as nanowires with Rashba spin-orbit coupling [2] can host parafermions, and discuss their respective experimental signatures. Moreover, I will present a one-dimensional fermionic lattice model featuring exact symmetry-protected parafermionic edge modes [3], which can be regarded as a generalization of the Kitaev chain model to the parafermion case. Using a combination of analytical and numerical techniques, I will discuss the different phases of this model. Moreover, I will discuss non-Abelian braiding of parafermions in one-dimensional systems. Such braiding can in principle be achieved by a series of nucleation and fusion processes of parafermion pairs, but this imposes constraints on adiabaticity. I will discuss these constraints and propose an optimized braiding protocol for parafermions in one-dimensional systems [4]. References:

[1] Phys. Rev. B 91, 081406(R) (2015)
[2] Phys. Rev. B 96, 165429 (2017)
[3] Phys. Rev. B 98, 201110(R) (2018)
[4] Phys. Rev. B 100, 205424 (2019)

Wednesday, Apr 1

Christian Pfleiderer, "Emergent electrodynamics of chiral magnets", We 9:00

Titus Neupert, "A real-space perspective on the topology of superconductors", We 9:45
In the tenfold way classification of topological matter, superconductors and insulators are treated on the same footing. However, the classification of topological insulators has since been substantially refined with the inclusion of topological crystalline systems, the methodology of topological quantum chemistry, and the discovery of higher-order topology. When extending these notions to topological superconductors, the underlying physical concepts such as "atomic limit" and "localization obstructions" have to be defined for the superconducting case. To this end, I will define topological superconductors from a position-space perspective. I will show that for a one-dimensional superconductor, the wave function of an individual Cooper pair decays exponentially with separation in the trivial phase and polynomially in the topological phase. This behavior is in accordance with the fact that, unlike insulators, superconductors can support strong topological phases in one dimension. I will further discuss a so-called Majorana polarization, which captures an irremovable and quantized separation of Majorana Wannier centers from the atomic positions. Finally, I will introduce the notion of an atomic limit for superconductors and, based on it, develop the classification of inversion-symmetry protected superconducting phases, including higher-order ones, based on symmetry indicators.

Claudia Felser, "Magnetic Weyl Semimetals! ", We 11:00
Topology a mathematical concept became recently a hot topic in condensed matter physics and materials science. One important criteria for the identification of the topological material is in the language of chemistry the inert pair effect of the s-electrons in heavy elements and the symmetry of the crystal structure [1]. Beside of Weyl and Dirac new fermions can be identified compounds via linear and quadratic 3-, 6- and 8- band crossings stabilized by space group symmetries [2]. In magnetic materials the Berry curvature and the classical AHE helps to identify interesting candidates. Magnetic Heusler compounds were already identified as Weyl semimetals such as Co2YZ [3,4], in Mn3Sn [5,6,7] and Co3Sn2S2 [8-10].
The Anomalous Hall angle helps to identify even materials in which a QAHE should be possible in thin films. First evidence for a QAH in Co3Sn2S2 will be discussed. Besides this k-space Berry curvature, Heusler compounds with non-collinear magnetic structures also possess real-space topological states in the form of magnetic antiskyrmions, which have not yet been observed in other materials [11].

[1] Bradlyn et al., Nature 547 298, (2017) arXiv:1703.02050
[2] Bradlyn, et al., Science 353, aaf5037A (2016).
[3] Kübler and Felser, Europhys. Lett. 114, 47005 (2016)
[4] Belopolski, et al., Science 365, 1278 (2019), arXiv:1712.09992
[5] Kübler and Felser, EPL 108 (2014) 67001 (2014)
[6] Nayak, et al., Science Advances 2 e1501870 (2016)
[7] Nakatsuji, Kiyohara and Higo, Nature 527 212 (2015)
[8] Liu, et al. Nature Physics 14, 1125 (2018)
[9] Liu, et al., Science 365, 1282 (2019)
[10] Morali, et al., Science 365, 1286 (2019) arXiv:1903.00509
[11] Nayak, et al., Nature 548, 561 (2017)

Ignacio Cirac, "Tensor Networks: Fundamental theorems and applications"
, We 11:45

Certain Quantum Many-body states can be efficiently described in terms of tensor networks. Those include Matrix Product States (MPS), Projected Entangled-Pair Etates (PEPS), or the Multi-scale Entanglement Renormalization Ansatz (MERA). Some of them play an important role
in quantum computing, error correction, or the description of topological order in condensed matter physics, and are widely used in computational physics. In this talk
I will briefly review one of the basic results in the theory of tensor networks and explain some of its applications in the classification of gapped phases in spin systems, the descritption of topological order or gauge symmetries in lattices, the characterization of quantum cellular automata,
or the state transformations in entanglement theory.
This basic result addresses the following question: if two different tensors generate
the same many-body state, how are they related to each other?

Thursday, Apr 2

Moty Heiblum, TB, Th 9:00

Xie Chen, "Fracton order: from quantum hard drive to foliated manifold", Th 9:45
One major open problem in quantum information theory is how to build a quantum hard drive, i.e. a quantum mechanical system that can store quantum information reliably for a very long time without active error correction. No completely satisfying solution to this problem has been found, but in the search for possibilities a whole new class of quantum many-body models have been discovered with exotic properties that have never been seen before. This new class of models, dubbed the "fracton" models, host point excitations that cannot move freely, have robust ground state degeneracy that increase with system size, and have unusually slow thermalization dynamics even in the absence of any disorder. In this talk, I will introduce some of the most important fracton models and present a systematic framework for characterizing their universal properties. By realizing the dependence of the model properties on the foliation structure of the underlying manifold, we are able to reveal the hidden equivalence relation between many seemingly different models and identify the direction of search for new nontrivial features.

Mitali Banerjee, "Quantization of heat flow in the fractional quantum Hall regime", Th 11:45
Topological states of matter are characterized by topological invariants, which are physical quantities whose values are quantized and do not depend on details of the measured system. Among them the electrical Hall conductance, which is expressed in units of e2/h, is easiest to probe. In the fractional quantum Hall effect regime, fractional quantized values of the electrical Hall conductance attest to topologically ordered states, which are states that carry quasi-particles with fractional charge and (expected) anyonic statistics. Another topological invariant, which is much harder to measure, is the thermal Hall conductance, KT, expressed in units of κ0T=(π2kB 2/3h)T. In 1D transport it does not depend on the particles charge, particles exchange statistics, and is even insensitive to the interaction strength among the particles. A fractional value of the quantized thermal Hall conductance shows that the probed state of matter is non-abelian. Quasiparticles in nonabelian states may be useful for topological quantum computation. In this talk, I will report our measurements of the thermal Hall conductance of the v=5/2 state to be fractional, implying non-abelian nature of the state.

Erez Berg, "Superconductivity in planar Josephson junctions", Th 14:00

Radu Coldea, "Neutron scattering studies of touching points in magnon bands", Th 14:45

Roni Ilan, TBA, Th 16:00

Lucile Savary, "Thermal transport in quantum magnets", Th 16:45

Friday, Apr 3

Ingrid Mertig, "Transversal transport coefficients and topological properties", Fr 9:00
Spintronics is an emerging field in which both charge and spin degrees of freedom of electrons are utilized for transport. Most of the spintronic effects—like giant and tunnel magnetoresistance—are based on spin- polarized currents which show up in magnetic materials; these are already widely used in information technology and in data storage devices. The next generation of spintronic effects is based on spin currents which occur in metals as well as in insulators, in particular in topologically nontrivial materials. Spin currents are a response to an external stimulus—for example electric field or temperature gradient—and they are always related to the spin-orbit interaction. They offer the possibility for future low energy consumption electronics. The talk will present a unified picture, based on topological properties, of a whole zoo of transversal transport coefficients: the trio of Hall, Nernst, and quantum Hall effects, all in their conventional, anomalous, and spin flavour. The formation of transversal charge and spin currents as response to longitudinal gradients is discussed. Microscopic insight into all phenomena is presented by means of a quantum mechanical analysis based on the Dirac equation in combination with a semi-classical description which can be very elegantly studied within the concept of Berry curvature.

Yizhi You, "Emergent Fractons in Correlated Matter", Fr 9:45

James Analytis, "Freezing of charge degrees of freedom across a quantum critical point in CeCoIn5", Fr 11:45