TT 101: Low-Dimensional Systems: Topological Order 2 (jointly with DS, HL, MA, O)

Time: Thursday 15:00–18:30 Location: H 3010

TT 101.1 Thu 15:00 H 3010

Topological entropy in the classical toric code model — •Johannes Helmes and Simon Trebst — Institut für Theoretische Physik, Universität zu Köln, Germany

For interacting quantum many-body systems the study of entanglement entropies is well established to analyze the fundamental nature of their ground states. In particular, the O(1) correction to the prevalent boundary-law can be used to identify topological order. However, not only in quantum systems, but also in classical systems we can track topological contributions to the classical entropy by employing an analogous approach.

We report results for the classical toric code model in a magnetic field which has a topologically protected zero field degeneracy. We show, how the classical entropy tracks the break-down of the classical topological order upon increasing the external field or temperature. In more technical terms, we apply the replica technique to calculate Renyi entropies from classical Monte Carlo simulations using a newly developed update scheme for efficient loop-gas sampling.

TT 101.2 Thu 15:15 H 3010

Symmetry fractionalization in SU(2n) antiferromagnetic Heisenberg chains — •Andreas Weichselbaum[1] and Thomas Quella[2] — [1]Ludwig Maximilians University, Munich, Germany — [2]University of Cologne, Germany

We explore generalizations of the Affleck-Kennedy-Lieb-Tasaki (AKLT, 1987) model for spin-1 antiferromagnetic Heisenberg chains to higher-rank SU(2n) symmetries. In particular we show that by proper tuning of higher order spin interactions there also exist exact low-dimensional matrix-product ground states with fractionalized edge states. These states are adiabatically connected to the ground state of the plain SU(2n) Heisenberg model. The parameter space is explored using state of the art density matrix renormalization group (DMRG), explicitly utilizing SU(N) symmetry up to N=6 based on the QSpace tensor library.

TT 101.3 Thu 15:30 H 3010

Protection of topological phases by quantum deformed symmetries — •Thomas Quella — Universität zu Köln, Institut für Theoretische Physik, Köln, Germany

We show that topological phases of quantum spin systems may enjoy protection even in the absence of ordinary group symmetries. The relevant mechanism is explained in full detail for the example of 1D spin chains with quantum group (q-deformed) symmetry $SO_q(3)$. We also sketch the generalization to quantum deformations of other continuous Lie groups such as those associated with $SU(N)$ or $SO(N)$. Our results provide a complete classification of quantum group symmetry protected topological phases for real values of q.

TT 101.4 Thu 15:45 H 3010

Topological phase transition in the quench dynamics of a Fermi gas — •Pei Wang — Department of Physics, Zhejiang University of Technology, Hangzhou 310023, China and Institute for Theoretical Physics, University of Goettingen, German

We study the quench dynamics of a one-dimensional ultracold Fermi gas with synthetic spin-orbit coupling. At equilibrium, the ground state of the system can undergo a topological phase transition and become a topological superfluid with Majorana edge states. As the interaction is quenched near the topological phase boundary, we identify an interesting dynamical phase transition of the quenched state in the long-time limit, characterized by an abrupt change of the pairing gap at a critical quenched interaction strength. We further demonstrate the topological nature of this dynamical phase transition from edge-state analysis of the quenched states. Our findings provide interesting clues for the understanding of topological phase transitions in dynamical processes, and can be useful for the dynamical detection of Majorana edge states in corresponding systems.

TT 101.5 Thu 16:00 H 3010

Diagnosing the statistics of excitations from the dynamical structure factor — •Siddhardh Morampudi[1], Ari Turner[2], and Frank Pollmann[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, Maryland

We show that the statistics of excitations in quantum spin liquids yield characteristic features in the dynamical structure factor. Quantum spin liquids are exotic phases of matter which fall beyond the traditional paradigm of symmetry breaking. Originally proposed by Anderson with regard to high temperature superconductivity, they are now widely believed to arise in frustrated spin systems such as the antiferromagnetic Heisenberg model on the kagome lattice. Recently, various theoretical methods to characterize spin liquids have been introduced, especially with regard to numerical simulations. In this work, we obtain results connecting the statistics of the excitations to features of the dynamical structure factor which can be obtained from neutron scattering. We furthermore demonstrate how the results can be used to distinguish different types of gapped spin liquids.

TT 101.6 Thu 16:15 H 3010

Dissipative Chern Insulators — •Jan Carl Budich[1,2], Peter Zoller[1,2], and Sebastian Diehl[3] — [1]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, 6020 Innsbruck, Austria — [3]Institute of Theoretical Physics, TU Dresden, D-01062 Dresden, Germany

Engineered dissipation can be employed to prepare interesting quantum many body states in a non-equilibrium fashion. The basic idea is to obtain the state of interest as the unique steady state of a quantum master equation, irrespective of the initial state. Due to a fundamental interference of topology and locality, the dissipative preparation of gapped topological phases with a non-vanishing Chern number has so far remained elusive. Here, we study the open quantum system dynamics of fermions on a two-dimensional lattice in the framework of a Lindblad master equation. In particular, we discover a novel mechanism to dissipatively prepare a topological steady state with non-zero Chern number by means of short-range system bath interaction. Quite remarkably, this gives rise to a stable topological phase in a non-equilibrium phase diagram. We demonstrate how our theoretical construction can be implemented in a microscopic model that is experimentally feasible with cold atoms in optical lattices.

TT 101.7 Thu 16:30 H 3010

Absence of an interaction driven Chern insulating phase on the honeycomb lattice — •Johannes Motruk, Adolfo G. Grushin, and Frank Pollmann — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Deutschland

Mean field calculations in the literature have suggested the existence of an interaction-induced Chern insulator (CI) phase in a tight-binding model of spinless fermions on a honeycomb lattice with nearest- and next-nearest-neighbor interactions. The CI phase is an example of a state that breaks time-reversal symmetry spontaneously and possesses a quantized Hall conductance. However, it has been proven elusive in exact diagonalization (ED) studies of this system. Since ED is limited to small system sizes, the fate of this phase in the thermodynamic limit still remains unclear. Using the infinite density matrix renormalization group (iDMRG) algorithm we reach system sizes exceeding those accessible in ED calculations while keeping track of quantum fluctuations neglected in mean field studies. We map out the phase diagram as a function of both nearest- and next-nearest-neighbor interaction strengths for an infinite cylinder geometry and find different charge-ordered phases but no sign of the interaction driven Chern insulator phase.

15 min. break.

TT 101.8 Thu 17:00 H 3010

Quasiparticle interference patterns from different impurities on the surface of pyrochlore iridates: signatures of the Weyl phase — •Fabian Lambert[1], Andreas Schnyder[2], Roderich Moessner[3], and Ilya Eremin[1] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany — [3]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

Weyl semi-metals exhibit topologically protected surface Fermi arcs, which pairwise connect projections of bulk band touchings in the surface Brillouin zone. The nontrival spin and orbital character of these topological surface states can be tested experimentally using quasiparticle interference (QPI) measurements. Here, we compute the QPI patterns for a Hubbard Hamiltonian on a pyrochlore lattice. For weak impurity potentials, the QPI patterns can be computed within the First Born approximation. To account for the antiferromangetic spin configuration of $R_2Ir_2O_7$, we treat the Hubbard interaction at the mean-field level. In the antiferromagnetic state the quadratic band touching of the model is split into eight linear band touchings, each of which carries a non-trivial Chern number, thereby realizing a Weyl phase with broken time- reversal symmetry. Using exact diagonalization, we compute the surface spectrum and quasiparticle interference patterns of this Weyl phase for various surface impurities. We show that the spin and orbital texture of the surface states can be inferred from the absence of certain backscattering processes and from the symmetries of the QPI features.

TT 101.9 Thu 17:15 H 3010

Interacting surface states of three-dimensional topological insulators — •Titus Neupert[1], Stephan Rachel[2], Ronny Thomale[3], and Martin Greiter[3] — [1]Princeton Center for Theoretical Science, Princeton University, Princeton, New Jersey 08544, USA — [2]Institute for Theoretical Physics, Technische Universitaet Dresden, 01171 Dresden, Germany — [3]Institute for Theoretical Physics, University of Wuerzburg, Am Hubland, D-97074 Wuerzburg, Germany

We numerically investigate the surface states of a strong topological insulator in the presence of strong electron-electron interactions. We choose a spherical topological insulator geometry to make the surface amenable to a finite size analysis. The single-particle problem maps to that of Landau orbitals on the sphere with a magnetic monopole at the center that has unit strength and opposite sign for electrons with opposite spin. Assuming density-density contact interactions, we find superconducting and anomalous (quantum) Hall phases for attractive and repulsive interactions, respectively, as well as chiral fermion and chiral Majorana fermion boundary modes between different phases. Our setup is preeminently adapted to the search for topologically ordered surface terminations that could be microscopically stabilized by tailored surface interaction profiles.

TT 101.10 Thu 17:30 H 3010

Resonant scattering in the topological Dirac semimetal Cd_3As_2 — Vladimir Gnezdilov[1,2], Azat Sharafeev[1], •Peter Lemmens[1], Raman Sankar[3], and Fangcheng Chou[3] — [1]IPKM, TU-BS, Braunschweig — [2]ILTPE NAS, Ukraine — [3]CCMS, National Taiwan Univ., Taipei, Taiwan

In the symmetry-broken topological Dirac semimetal with strong spin-orbit coupling, Cd_3As_2, a pronounced temperature evolution of quasielastic electronic Raman scattering and resonant effects are observed. These effects are then compared to observations in topological insulators, as Bi_2Se_3.

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TT 101.11 Thu 17:45 H 3010

Angle-resolved Photoemission Investigation of SmB_6 — •Peter Hlawenka[1], Oliver Rader[1], Konrad Siemensmeyer[1], Eugen Weschke[1], Andrei Varykhalov[1], Natalya Shitsevalova[2], Slavomir Gabani[3], Karol Flachbart[3], and Emile Rienks[1] — [1]Helmholtz-Zentrum Berlin — [2]Institute for Problems of Material Science, Kiev — [3]IEP, Slovak Academy of Science, Kosice

Recently the mixed valence compound SmB_6 has drawn great attention. Theoretically predicted surface states, which should result from a hybridisation of localised f-bands with conduction electrons and a band inversion, would make SmB_6 the first realisation of a so called topological Kondo insulator [1-2]. Conductivity and transport measurements, as well as spin-resolved photoemission spectroscopy seem to fortify the scenario of a topological nature of the conductive surface [3-5]. We investigate the surface electronic structure of SmB_6 by means of high resolution angle-resolved photoemission spectroscopy measurements below 1 K. We will present new insights into the surface states that determine the low temperature conductivity of this material.

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[2] Lu et al., PRL 110, 096401 (2013).
[3] Wolgast, PRB 88, 180405 (2013).
[4] Kim, Sci. Rep. 3, 3150 (3013).
[5] Xu et al., Nat. Com. 5, 4566 (2014).

TT 101.12 Thu 18:00 H 3010

Calculation of topological properties of strongly correlated electrons without inversion symmetry using Wannier charge centres. — •Robert Triebl and Markus Aichhorn — Institute of Theoretical Physics and Computational Physics, Graz University of Technology, Petersgasse 16, 8010 Graz, Austria

We study the topological properties of a role model for interacting Z_2 topological insulators, namely the Kane-Mele-Hubbard model including a staggered sublattice potential controlled by a parameter λ_ν, which breaks inversion symmetry. The applicability of a naïve mean field approach was analysed by comparing to a variational cluster approach, employing a two-site dynamical impurity approximation (DIA). The obtained Greens function determines the topological Hamiltonian, which maps the interacting system to an effective free-particle model with the same topological properties. Since inversion symmetry is lost, we calculate the Z_2 invariant for both Mean Field and topological Hamiltonian using Wannier charge centers. We conclude that a two-site DIA in combination with Wannier charge centers is an easy-to-implement and stable method to determine topological invariants for interacting systems. Comparing with mean field results we find that the direction of magnetisation is crucial for topological properties and hence an inherent mean field magnetisation may lead to incorrect results.

TT 101.13 Thu 18:15 H 3010

An analytical study of the entanglement spectrum of graphene bilayers — •Sonja Predin and John Sliemann — Institute for Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany

We present an analytical study of the entanglement spectrum of graphene bilayers. The entanglement spectrum has been proposed as a ground state property that exhibits characteristic energy excitations[1]. Futhermore, it was claimed that gapless systems possess the same number of Dirac cones as their entanglement spectrum [2]. In addition, it was suggested that the entanglement spectrum is a promising tool to characterize topological phases. In this work we will show that the energy spectrum of an gapless system and its entanglement spectrum can have a different topology. In particular, we will show that Lifshitz transitions change the topology of the energy spectrum of graphene bilayers in a different way than the topology of entanglement spectrum. The topology of the energy spectrum of graphene bilayers for small energies is changed by Lifshitz transitions by changing the connectivity by the appearance of the three additional Dirac cones around every Dirac point [3]. The entanglement spectrum, on the other hand, is changed by deforming a Dirac cone into a neck charaterized by vanishing eigenvalues of the entanglement Hamiltonian.

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[2] A. M. Turner, et al., Phys. Rev. B, 82, 241102R (2010)
[3] J. Cserti, et al., Phys. Rev. Lett. 99, 066802 (2007)