DS 10: Transport: Topological Phases (jointly with DS/MA/TT)

Time: Monday 15:00–18:00 Location: HSZ 304

DS 10.1 Mon 15:00 HSZ 304

Dynamical Buildup of a Quantized Hall Response from Non-Topological States — Ying Hu[1], Peter Zoller[1,2], and •Jan Carl Budich[3] — [1]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria — [2]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [3]Department of Physics, University of Gothenburg, SE 412 96 Gothenburg, Sweden

We consider a two-dimensional system initialized in a topologically trivial state before its Hamiltonian is ramped through a phase transition into a Chern insulator regime. This scenario is motivated by current experiments with ultracold atomic gases aimed at realizing time-dependent dynamics in topological insulators. Our main findings are twofold. First, considering coherent dynamics, the non-equilibrium Hall response is found to approach a topologically quantized time averaged value in the limit of slow but non-adiabatic parameter ramps, even though the Chern number of the state remains trivial. Second, adding dephasing, the destruction of quantum coherence is found to stabilize this Hall response, while the Chern number generically becomes undefined. We provide a geometric picture of this phenomenology in terms of the time-dependent Berry curvature.

DS 10.2 Mon 15:15 HSZ 304

Sign reversal of the quantized topological Hall effect in skyrmion crystals — •Börge Göbel[1], Alexander Mook[1], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

The topological Hall effect (THE) of electrons [1] is the hallmark of a skyrmion crystal phase [2]. It can be understood either by coupling of the electrons' spin to the local magnetic texture (Zeeman interaction) or by coupling of the electrons' charge to the emergent field generated by the texture (Peierls substitution).

Here, we study the THE on a triangular lattice, addressing band structure, Hall conductivity, and topological surface states. In this system, the THE is quantized and the transverse conductivity changes sign if the Fermi energy crosses a van Hove singularity. By mapping the THE to a quantum Hall effect (QHE) on a lattice [3], we assign this prominent feature to the cyclotron mass of electron orbits, that is, when constant-energy cuts of the band structure change from electron to hole pockets. Based on this picture, we derive an approximate rule which allows to determine the energy dependence of the topological Hall conductivity in *any* two-dimensional lattice.

[1] K. Hamamoto et al., Phys. Rev. B **92**, 115417 (2015)
[2] S. Mühlbauer et al., Science **323**, 915 (2009)
[3] Y. Hatsugai et al., Phys. Rev. B **74**, 205414 (2006)

DS 10.3 Mon 15:30 HSZ 304

Edge states and topology in finite-length single-wall carbon nanotubes — •Wataru Izumida[1,2], Rin Okuyama[3], Ai Yamakage[4,5], Mikio Eto[3], and Riichiro Saito[1] — [1]Department of Physics, Tohoku University, Sendai 980-8578, Japan — [2]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Faculty of Science and Technology, Keio University, Yokohama 223-8522, Japan — [4]Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan — [5]Institute for Advanced Research, Nagoya University, Nagoya 464-8601, Japan

Edge states in finite-length single-wall carbon nanotubes, which appear in the energy gap of the bulk states, are studied from the topological viewpoint [1,2]. An effective one-dimensional (1D) lattice model is introduced to analyze the quantum system with boundary. By analyzing the 1D lattice model, a bulk-edge correspondence, relationship between the number of edge states in the energy gap and the topological winding number defined in the corresponding bulk system, is given [1]. Manipulation of the edge states by magnetic field [3,4] is suggested in terms of the topological phase transition [2].

[1] W. Izumida, R. Okuyama, A. Yamakage, R. Saito, Phys. Rev. B 93, 195442 (2016).
[2] R. Okuyama, W. Izumida, M. Eto, arXiv:1610.05034.
[3] K. Sasaki, S. Murakami, R. Saito, Y. Kawazoe, Phys. Rev. B 71, 195401 (2005).
[4] M. Marganska, M. del Valle, S. H. Jhang, C. Strunk, M. Grifoni, Phys. Rev. B 83, 193407 (2011).

DS 10.4 Mon 15:45 HSZ 304

Topological invariants in carbon nanotubes with superconducting pairing — •Lars Milz[1], Magdalena Marganska[1], Wataru Izumida[1,2], and Milena Grifoni[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93 047 Regensburg, Germany — [2]Department of Physics, Tohoku University, Sendai 980-8578, Japan

The symmetries present in a gapped Hamiltonian system determine the types of topological invariants which can be defined for that system. Our case of interest here is a carbon nanotube, which in its normal state is known to possess a non-trivial integer topological invariant, the winding number. Its value determines the number of edge states. When a superconducting pairing is imposed on the nanotube, the symmetry class of the system changes and it is possible to define also a Z2 Pfaffian topological invariant, exploiting the particle-hole rather than the chiral symmetry. We explore the relationship between the two invariants and their influence on the energy spectrum and eigenstates, in particular the edge modes, of a finite carbon nanotube.

DS 10.5 Mon 16:00 HSZ 304

Renormalization group approach to topological phase transitions — •Wei Chen[1], Manfred Sigrist[1], and Andreas Schnyder[2] — [1]ETH Zurich, Zurich, Switzerland — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Have you thought about this: every time you tie your shoelaces, you are using a scaling procedure (the tying) to make the topology (the knot) more obvious? Akin to knot-tying, a renormalization group approach is proposed to judge topological phase transitions for systems that belong to any dimension and symmetry class, and whether the topological phase transition is driven by noninteracting parameters (hopping, chemical potential, etc) as in the usual topological insulators, or interacting parameters (Hubbard interaction, etc) as in fractional Chern insulators. The meaning of scale invariance at the critical point and the fixed point is shown to be related to the notion of correlation length, which was previously thought to be nonexistent for topological insulators.

[1] W. Chen, J. Phys. Condens. Matter 28, 055601 (2016)
[2] W. Chen, M. Sigrist, and A. P. Schnyder, J. Phys. Condens. Matter 28, 365501 (2016)

DS 10.6 Mon 16:15 HSZ 304

Fermionic topological quantum states as tensor networks — •Carolin Wille, Oliver Buerschaper, and Jens Eisert — Institut für theoretische Physik, Freie Universität Berlin

Tensor network states, and in particular projected entangled pair states, play an important role in the description of strongly correlated quantum lattice systems. They do not only serve as variational states in numerical simulation methods, but also provide a framework for classifying phases of quantum matter and capture notions of topological order in a stringent and rigorous language. The rapid development in this field for spin models and bosonic systems has not yet been mirrored by an analogous development for fermionic models. In this work, we introduce a tensor network formalism capable of capturing notions of topological order for quantum systems with fermionic components. At the heart of the formalism are axioms of fermionic matrix product operator injectivity, stable under concatenation. Building upon that, we formulate a Grassmann number tensor network ansatz for the ground state of fermionic twisted quantum double models. A specific focus is put on the paradigmatic example of the fermionic toric code. This work shows that the program of describing topologically ordered systems using tensor networks carries over to fermionic models.

15 min. break.

DS 10.7 Mon 16:45 HSZ 304

Finite-size scaling around a topological phase transition — •Tobias Gulden[1,2], Yuting Wang[2], and Alex Kamenev[2] — [1]Technion - Israel Institute of Technology — [2]University of Minnesota

The critical point of a phase transition is described by a conformal field theory, where perturbations away from criticality are known to give rise to universal scaling functions. We consider perturbations around a critical point which separates two distinct topological phases. For both energy and entropy we find the existence of scaling functions which depend on the sign of the perturbation, i.e. they discriminate between topological phases. Renyi entropy of the Kitaev model contains two distinct scaling functions which separate a well-known universal part and the topological contribution, while energy has one asymmetric scaling function. The latter is universal for all five Altland-Zirnbauer symmetry classes with non-trivial topology in one spatial dimension.

DS 10.8 Mon 17:00 HSZ 304

Fractionalization of charge and energy after electron injection in 1D helical systems — •Alessio Calzona[1,2,3], Matteo Acciai[1], Matteo Carrega[4], Fabio Cavaliere[1,3], and Maura Sassetti[1,3] — [1]University of Genova, Italy — [2]University of Luxembourg, Luxembourg — [3]SPIN-CNR, Genova, Italy — [4]NEST, Pisa, Italy

The possibility to inject a single electron into ballistic 1D conductors is at the basis of the new and fast developing field of electron quantum optics. In this respect, helical edge states of topological insulators can be used as electronic waveguides and would be an ideal playground [1,2].

Here we thus study and characterize the tunneling of a single electron from a mesoscopic capacitor into a couple of interacting helical edge channels [3]. The injection process leads to the creation of a pair of fractional excitations travelling in opposite directions. Their charge and energy profiles are analyzed. We also show that the energy partitioning between the two fractional excitations depends both on the interaction strength and on the injection parameters. Interestingly, this allows for a situation in which energy and charge mainly flow in opposite directions. In addition, such peculiar behavior of energy partitioning suggests that it can be also used as a tool to probe features of out-of-equilibrium systems [4].

[1] G. Fève et al., Science 316, 1169 (2007)
[2] D. Ferraro et al., PRB 89, 075407 (2014)
[3] A. Calzona et al., PRB 94, 035404 (2016)
[4] A. Calzona et al., arXiv:1610.04492

DS 10.9 Mon 17:15 HSZ 304

Solitons in one-dimensional lattices with a flat band — •Dario Bercioux[1,2], Omjyotu Dutta[1], and Enrique Rico[2,3] — [1]Donostia International Physics Center (DIPC), E-20018 San Sebastián, Spain — [2]IKERBASQUE, Basque Foundation for Science, Maria Diaz de Haro 3, 48013 Bilbao, Spain — [3]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, E-48080 Bilbao, Spain

We investigate the spectral properties of a quasi-one-dimensional lattices in two possible dimerization configurations [1]. Both configurations are characterized by the same lattice topology and the same spectra containing a flat band at zero energy. We find that, one of the dimerized configuration has similar symmetry to an one-dimensional chain proposed by Su-Schrieffer-Heeger [2] for studying solitons in conjugated polymers. Whereas, the other dimerized configuration only shows non-trivial topological properties in the presence of chiral-symmetry breaking adiabatic pumping.

[1] D. Bercioux, O. Dutta & E. Rico, arXiv:1609.06292.
[2] W. P. Su, J. R. Schrieffer, & A. J. Heeger Phys. Rev. Lett. **42**, 1698 (1979).

DS 10.10 Mon 17:30 HSZ 304

Local nature of Quantized Hall Effect — •Afif Siddiki — Mimar Sinan Fine Arts University, Physics Department, Sisli-Istanbul, Turkey 34380

Here, we investigate the electrostatic properties of two dimensional electron system (2DES) in the integer quantum Hall regime. As it is well known, the Landau quantization emerges from strong perpendicular magnetic fields. The (Landau) energy levels are broadened due to impurities, which we embedded their effects in density of states (DOS). As a simple model, DOS have two different forms: the Gaussian and semi-elliptic descriptions, i.e. the self consistent Born approximation (SCBA). Having in hand DOS, we obtain both the longitudinal and Hall (transversal) conductivities (σ_L, σ_H) utilizing Thomas-Fermi-Poisson approximation to calculate the charge density profile and Drude model to obtain transport coefficients. Since, the definition of capacitance is closely related with compressibility, (local) screening properties of 2DES is extremely important. Here we numerically simulate a translational invariant Hall bar subject to high magnetic fields which is perpendicular to the plane of the 2DES using realistic parameters extracted from the related experiments. Using the above mentioned approaches the local capacitances are calculated, numerically. Our findings are in perfect agreement with the related experiment which is based on a dynamic scanning capacitance microscopy technique.

DS 10.11 Mon 17:45 HSZ 304

Properties of non-abelian hierarchy states in the fractional quantum Hall effect — •Yoran Tournois and Maria Hermanns — Institute for Theoretical Physics, Cologne, Germany

The fractional quantum Hall effect is one of the paradigmatic examples of topological order in condensed matter physics. While the physics of the fractional quantum Hall effect is well understood in the lowest Landau level by means of the Haldane-Halperin hierarchy, a general method to describe the properties of quantum Hall liquids in the second Landau level is lacking. These are of particular interest, as it is believed that they may harbor exotic excitations - non-abelian anyons. In this talk, we consider a general class of model wave functions, which were recently proposed as a generalization of the Haldane-Halperin hierarchy. While these are conjectured to describe non-abelian quantum Hall liquids, many of their properties are not manifest and thus previously unknown. We determine their properties using a variety of methods. In particular, we derive the explicit conformal field theory description of the model wave functions, which reveals the non-abelian braiding statistics of the quasiparticles as well as the edge theory.