TT 83: Topology: Quantum Hall Systems

Time: Thursday 15:00–18:30 Location: HSZ/0105

TT 83.1 Thu 15:00 HSZ/0105

Many-body Euler topology — •Axel Fünfhaus[1], Titus Neupert[2], Thilo Kopp[3], and Roser Valentí[1] — [1]Goethe Uni Frankfurt, Frankfurt am Main, Germany — [2]University of Zurich, Zurich, Switzerland — [3]University of Augsburg, Augsburg, Germany

Chern insulators exhibit an anomalous nonzero Hall conductivity due to a spontaneous breaking of time-reversal symmetry. To identify nontrivial topology in their time-reversal symmetric many-body spectra, we identify many-body Euler numbers as a counterpart to many-body Chern numbers. Exemplarily, we perform calculations in a topological Hubbard model that can realize Chern and fractional Chern insulating phases. Furthermore, we lay out a classification scheme to realize different topological phases using symmetry indicators in analogy to topological band theory.

TT 83.2 Thu 15:15 HSZ/0105

Topological signatures in the electrostatics of Chern junctions — •Robin Durand[1,2], Pascal Simon[1], and Ion Garate[2] — [1]Laboratoire de Physique des Solides, Université Paris-Saclay, CNRS, Orsay 91405, France — [2]Département de physique, Institut quantique and Regroupement Québécois sur les Matériaux de Pointe, Université de Sherbrooke, Sherbrooke, Québec J1K 2R1, Canada

Electrostatic control in topological materials is a key challenge for next-generation electronic and quantum devices. We investigate how topological properties, especially Berry curvature and Chern number, reshape electrostatic equilibrium in Chern-insulator junctions under magnetic field. We show that Berry curvature corrections to the modified Landau quantization significantly modify both the built-in potential and the intrinsic chemical-potential profile at the junction.

Using a Landau-level framework combined with a semiclassical expansion, we derive an analytical expression revealing that the built-in potential becomes directly governed by spectral asymmetry, and therefore by the Chern number on each side. Large-scale tight-binding simulations of the half-BHZ model validate this prediction quantitatively.

Our results show that topological properties can directly influence electrostatic profiles in Chern junctions. By linking the built-in potential to spectral asymmetry and Chern number, we reveal how Berry curvature affects charge redistribution and electrostatic equilibrium at topological interfaces.

TT 83.3 Thu 15:30 HSZ/0105

Non-Hermitian topology of transport in the quantum Hall phases in graphene — •Raghav Chaturvedi[1,2], Ewelina M. Hankiewicz[2], Jeroen van den Brink[1], and Ion Cosma Fulga[1] — [1]Leibniz Institute for Solid State and Materials Research, IFW Dresden, Germany — [2]Institute for Theoretical Physics and Astrophysics, Julius-Maximilians-Universität Würzburg, Germany

Signatures of non-Hermitian topology can be realized in a conventional quantum Hall device connected to multiple current sources. These signatures manifest as robust current-voltage characteristics, dictated by the presence of a nontrivial, non-Hermitian topological invariant of the conductance matrix. Chiral edge states are believed to be responsible for this non-Hermitian response, similar to how they lead to a quantized Hall conductivity in the presence of a single current source. Here, we go beyond this paradigm, showing that multiterminal conductance matrices can exhibit non-Hermitian topological phase transitions that cannot be traced back to the presence and directionality of a boundary-localized chiral mode. By performing quantum transport simulations in the quantum Hall regime of graphene, we find that when the chemical potential is swept across the zeroth Landau level, unavoidable device imperfections cause the appearance of an additional non-Hermitian phase of the conductance matrix. This highlights graphene as an ideal platform for the study of non-Hermitian topological phase transitions, and is a first step towards exploring how the geometry of quantum devices can be harnessed to produce robust, topologically-protected transport characteristics.

TT 83.4 Thu 15:45 HSZ/0105

Superconducting Beam Splitting of Quantum Hall Edge States for HOM Interference — •Maxime Jamotte[1], Tom Menei[1], Alexander Zyuzin[2], Manohar Kumar[2], and Thomas L. Schmidt[1] — [1]University of Luxembourg, Luxembourg, Luxembourg — [2]Aalto University, Aalto, Finland

Electron interferometers have proven to be important tools for characterizing the exchange statistics of quantum Hall edge states. Moreover, it has recently become possible to proximitize quantum Hall edge states using superconductors. This opens a new avenue for interferometers based on the particle-hole degree of freedom. We propose a Hong-Ou-Mandel interferometer in which an s-wave type-II superconductor is located between two graphene systems in a magnetic field, with chiral edge states serving as the interferometer arms. Local and crossed Andreev processes hybridize electron and hole edge excitations, producing delocalized electron-hole pairs. Using a microscopic tight-binding Bogoliubov-de Gennes model, we simulate the injection of subgap electrons and compute anti-bunching probabilities and current cross-correlations, revealing how normal and Andreev processes shape the interferometric signatures of this new hybrid geometry.

TT 83.5 Thu 16:00 HSZ/0105

Plasma mapping for the Moore-Read state in ideal Chern bands — •Qi Hu[1], Saranyo Moitra[1], Inti Sodemann Villadiego[1], and Victor Gurarie[2] — [1]Institut für Theoretische Physik, Universität Leipzig, 04103 Leipzig, Germany — [2]Department of Physics, CB390, University of Colorado, Boulder, Colorado 80309, USA

We construct an improved short distance regularization of the plasma mapping for the Moore-Read fractional quantum Hall state and also extend it from Landau levels to Aharonov-Casher ideal Chern bands, which are relevant in moire materials. This allows us to map correlations of the Moore-Read wave-function onto those of a classical statistical plasma with two components which in addition are coupled to a non-uniform neutralizing background. We exploit this to understand not only the universal topological properties of the Moore-Read state but also other details of their correlation functions. We will discuss the possibility of a phase transition from the plasma into novel dielectric states that can occur when the effective magnetic field in the Chern band becomes increasingly non-uniform.

TT 83.6 Thu 16:15 HSZ/0105

Universal Transport Theory for Paired Fractional Quantum Hall States in the Quantum Point Contact Geometry — •Eslam Ahmed[1], Ryoi Ohashi[2], Yukio Tanaka[1], and Kentaro Nomura[2] — [1]Nagoya University, Nagoya, Japan — [2]Kyushu University, Fukuoka, Japan

Even-denominator fractional quantum Hall (FQH) states can be viewed as topological superconductors of composite fermions, supporting a charged chiral mode and $|C|$ neutral Majorana modes set by the Chern number C. Distinguishing the many competing paired phases remains an open problem. We develop a unified theory of transport through a quantum point contact (QPC) for arbitrary C by analyzing quasiparticle and electron tunneling within the edge CFT $SO(|C|)_1 \otimes U(1)$. Using an instanton expansion, we show that strong quasiparticle tunneling is dual to weak electron tunneling for all even-denominator states. This duality yields universal scaling dimensions and identifies a stable insulating fixed point. The resulting transport exponents provide experimentally accessible signatures capable of distinguishing different paired FQH states.

TT 83.7 Thu 16:30 HSZ/0105

Quantum Hall Effect without Chern Bands — •Benjamin Michen[1] and Jan Carl Budich[1,2] — [1]TU Dresden, 01062 Dresden, Germany — [2]MPIPKS, 01187 Dresden, Germany

The quantum Hall effect was originally observed in a two-dimensional electron gas forming Landau levels when exposed to a strong perpendicular magnetic field and was later generalized to Chern insulators without net magnetization. In this talk, further extending the realm of the quantum Hall effect, we report on the robust occurrence of an integer quantized transverse conductance at the onset of disorder in a microscopic lattice model, all bands of which are topologically trivial (zero Chern number). We attribute this phenomenon to the energetic separation of nonquantized Berry fluxes within those bands. Adding disorder then nudges the system into a quantum Hall phase from an extended critical regime obtained by placing the Fermi energy within a broad window inside a trivial band. This natural integer-rounding mechanism manifests as the mobility-gap-induced quantization of a nonuniversal Hall conductance. Our results are corroborated by numerical transport simulations and the analysis of two complementary topological markers.

15 min. break

TT 83.8 Thu 17:00 HSZ/0105

Hollow Topological Matter and Dual Fractional Quantum Hall Effect — •Ram Mummadavarapu and Roman-Pascal Riwar — Peter Gruenberg Institute, Theoretical Nanoelectronics, Forschungszentrum Juelich, D-52425 Juelich, Germany

The Integer Quantum Hall Effect (IQHE) at filling factor m and the Fractional Quantum Hall Effect (FQHE) at 1/m are commonly viewed as distinct phases of matter. We propose various chiral/non-chiral heterostructures that effectively pin m co-propagating IQHE edge states to a synchronised single mode. This setup thus realizes the Dual Fractional Quantum Hall Effect (DFQHE), a phase where fractionalization is reversed, that is, fundamental excitations retain integer electric charge but carry fractional magnetic flux. While the transconductance remains integer quantized, the edge correlations nonetheless exhibit anyonic power-law scaling. We show that this is a physical manifestation of Hollow Topological Matter: due to pinning, the edge no longer corresponds to the original physical bulk, but rather to a virtual bulk that may be bosonic or fermionic independent of the microscopic exchange statistics.

TT 83.9 Thu 17:15 HSZ/0105

Fractional Statistics in Anyon Colliders: A Keldysh-Instanton Approach — •Julian Kälber, Matthias Thamm, Felix Puster, and Bernd Rosenow — Universität Leipzig

The observation of fractional statistics in fractional quantum Hall (FQH) systems remains a central goal of modern condensed-matter physics. In recent collider-type experiments, dilute anyon beams are injected through quantum point contacts (QPCs) into unbiased edges, and signatures of anyonic exchange statistics are extracted from current cross-correlations. A quantitative description of these experiments, however, requires an accurate treatment of the QPCs, which act as dynamical tunnelling gates and introduce non-equilibrium effects that are not captured by simple Poissonian models.

In this work we develop an approximation scheme that incorporates the QPC dynamics within the Keldysh formalism. From the full action we derive an effective tunnelling action and obtain real-time instanton solutions of the free chiral-edge theory. The resulting non-equilibrium prefactor for tunnelling-operator correlation functions has the same structure as the Poissonian averaging employed in dilute-beam models, it reproduces the correct long-time asymptotics, and naturally generates oscillatory short-time features absent in previous treatments. Using this formalism we calculate a generalized Fano factor for a balanced anyon collider. The predicted values agree with theoretical expectations and with experimental measurements in the limit of small QPC transparencies, and remain consistent with experimental results at finite transparencies.

TT 83.10 Thu 17:30 HSZ/0105

From hidden order to skyrmions: Quantum Hall states in an extended Hofstadter-Fermi-Hubbard model — Fabian J. Pauw[1], Ulrich Schollwöck[1], Nathan Goldman[2,3], Sebastian Paeckel[1], and •Felix A. Palm[2] — [1]LMU Munich & MCQST, Munich, Germany — [2]Université Libre de Bruxelles, Brussels, Belgium — [3]Laboratoire Kastler Brossel, Collège de France, Paris, France

The interplay between topology and strong interactions gives rise to a variety of exotic quantum phases, including fractional quantum Hall (FQH) states and their lattice analogs - fractional Chern insulators (FCIs). Such topologically ordered states host fractionalized excitations, which for spinful systems are often accompanied by ferromagnetism and skyrmions. Here, we study an extended Hofstadter-Hubbard model of spinful fermions on a square lattice. Using DMRG simulations, we demonstrate the emergence of a spin-polarized 1/3-Laughlin-like FCI phase, characterized by a quantized many-body Chern number, a finite charge gap, and hidden off-diagonal long-range order. In contrast to systems at filling factor ν=1, we do not find skyrmionic excitations upon doping, thereby disentangling spin physics and topological order. The diagnostic toolbox presented in this work, based on local densities, correlation functions, and spin-resolved observables, is directly applicable in quantum gas microscopy experiments. Our results open new pathways for experimental exploration of FCIs with spin textures in both ultracold atom and electronic systems.

TT 83.11 Thu 17:45 HSZ/0105

The fate of the Laughlin state in ideal Chern bands — •Saranyo Moitra and Inti Sodemann Villadiego — Universität Leipzig, Leipzig, Germany

Ideal Chern bands are believed to be crucial to realizing the recently discovered fractional quantum Hall states at zero magnetic field. However, the nature of even the most archetypical Laughlin states and its competition with other phases remains poorly understood in this setting. We rigorously demonstrate that the Laughlin wave-function in ideal Chern bands is unstable to a novel gapless dielectric phase. Even the celebrated filling 1/3 state crystallizes into a correlated phase with continuously tunable power-law exponents, and quasiparticles with fractional charges varying smoothly below e/3. Remarkably, this state remains gapless without spontaneous symmetry breaking, exemplifying a form of beyond-Goldstone gaplessness. Our results bridge the physics of fractional quantum Hall and Coulomb gases, and we will discuss potential implications of this finding for moiré materials and its possible connections to critical states in other settings.

TT 83.12 Thu 18:00 HSZ/0105

Parafermions emerging from spin-polorized $\nu = 2/3$ fractional quantum Hall state — •Steffen Bollmann[1], Andreas Haller[2], Jukka I. Väyrynen[3], Thomas L. Schmidt[2], and Elio J. König[4] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]University of Luxembourg, Luxembourg — [3]Purdue University, West Lafayette, Indiana, USA — [4]University of Wisconsin*Madison, Madison, Wisconsin, USA

We study the theoretical realization of Z_3 parafermions in the spin-polarized $\nu = 2/3$ fractional quantum Hall (FQH) state, motivated by recent experimental advances in materials such as rhombohedral graphene or twisted $MoTe_2$. We discuss how parafermions can emerge in FQH-superconductor heterostructures, unlike earlier proposals that rely on spin-unpolarized systems. Disorder-induced backscattering of FQH edge states drives the system toward the Kane-Fisher-Polchinski fixed point, where the edge theory decouples into a charged mode carrying charge $2e/3$ and an electrically neutral mode. Inter-edge interactions in the neutral sector lead to a strong-coupling regime that gaps the neutral modes entirely. This reduction leaves an effective low-energy description governed by lattice parafermion modes.

TT 83.13 Thu 18:15 HSZ/0105

Quantized and nonquantized Hall response in topological Hatsugai-Kohmoto systems — •Thibaut Desort, Mark Oliver Goerbig, and Corentin Morice — Laboratoire de physique des solides, Université Paris-Saclay, Orsay, France

The Hall conductivity of insulators is well-known to be quantized, including in interacting systems [1]. The Hatsugai-Kohmoto (HK) interaction [2], a type of Hubbard model diagonal in reciprocal space, is now widely studied in the context of topology, owing to the fact that its eigenstates, eigenenergies and Green's functions can be computed exactly. Using the Kubo formula, it is possible to access the Hall conductivity which has, even in the presence of the HK interaction, been reported to be quantized because it coincides with a Chern number [3]. In this work, using Zeeman fields, we lift the many-body degeneracy induced by the Hatsugai-Kohmoto interaction in the topological Kane-Mele model. This selects specific states within the ground-state manifold that reveal a surprising non-quantized Hall response.

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[2] Y. Hatsugai, M. Kohmoto, J. Phys. Soc. Jap. 61, 2056 (1992)
[3] P. Mai, B. E. Feldman, P. W. Phillips, Phys. Rev. 5, 013162 (2023)