TT 53: Topology: Other Topics

Time: Friday 9:30–12:45 Location: H32

TT 53.1 Fri 9:30 H32

Quantum Geometric Tensor and Inertial Effects — •Maike Fahrensohn and Richard Matthias Geilhufe — Condensed Matter and Materials Theory Division, Department of Physics, Chalmers University of Technology, 41258 Göteborg, Sweden

The quantum geometric tensor (or Fubini-Study metric), defined on a parametrized quantum state manifold, encodes the full geometric structure of quantum space. The real part of the quantum geometric tensor, known as the quantum metric tensor, is a positive semidefinite Riemannian metric that measures the geometric distance between quantum states. This tensor has recently been shown to play a crucial role in the description of physical phenomena such as quantum transport, quantum noise, and optical conductivity. The antisymmetric part of the quantum geometric tensor, proportional to the Berry curvature, has been extensively studied and is central to the classification of topological insulators through their first Chern number.

While inertial effects have been well explored in classical mechanics, their role in quantum systems remains less understood. We build a connection between the quantum geometric tensor and inertial effects to bridge the geometric and topological properties of quantum systems to their physical response. This relationship may offer new insights into transport phenomena, stability, and collective dynamics in quantum systems.

TT 53.2 Fri 9:45 H32

Theory of Quantum Geometry in Unconventional Magnets — •Johannes Mitscherling, Jan Priessnitz, and Libor Smejkal — Max Plank Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Metals with altermagnetic spin-polarisation [1] and non-collinear spin textures [2] are emerging platforms exhibiting rich fundamental physics and spintronics applications. Remarkably, this class of materials intrinsically yields a complex interplay of at least two orbital degrees of freedom besides spin. It was recently noticed that such multiband Hamiltonians host previously overlooked geometric invariants beyond the quantum metric and Berry curvature, especially when more than two bands are involved, making altermagnetic and non-collinear magnetic systems promising candidates for novel quantum geometric responses [3]. In this talk, I will introduce a quantum geometric perspective adequate for multiband systems with both spin and orbital degrees of freedom, which helps us to determine and quantify the properties of the nontrivial Bloch states. With this systematic geometric characterization, I will elaborate on a pathway to identify the most promising observables, model parameter regimes, and tuning parameters, simplifying the search for experimental realizations.

[1] L. Smejkal, J. Sinova, T. Jungwirth, PRX 12, 031042 (2022).
[2] A. Birk Hellenes, T. Jungwirth, R. Jaeschke-Ubiergo, A. Chakraborty, J. Sinova, L. Smejkal, arXiv:2309.01607v3.
[3] A. Avdoshkin, J. Mitscherling, J. E. Moore, arXiv:2409.16358.

TT 53.3 Fri 10:00 H32

Topological Order in the Spectral Riemann Surfaces of Non-Hermitian Systems — •Anton Montag[1,2], Alexander Felski[1], and Flore Kiki Kunst[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We show topologically ordered states in the complex-valued spectra of non-Hermitian systems. These arise when the distinctive exceptional points in the energy Riemann surfaces of such models are annihilated after threading them across the boundary of the Brillouin zone. This process results in a non-trivially closed branch cut that can be identified with a Fermi arc. Building on an analogy to Kitaev's toric code, these cut lines form non-contractible loops, which parallel the defect lines of the toric-code ground states. Their presence or absence establishes topological order for fully non-degenerate non-Hermitian systems. Excitations above these ground-state analogs are characterized by the occurrence of additional exceptional points. We illustrate the characteristics of the topologically protected states in a non-Hermitian two-band model and provide an outlook toward experimental realizations in metasurfaces and single-photon interferometry.

TT 53.4 Fri 10:15 H32

Exceptional Points of Any Order in a Generalized Hatano-Nelson Model — •Julius T. Gohsrich[1,2], Jacob Fauman[1,2], and Flore K. Kunst[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

Exceptional points (EPs) are truly non-Hermitian (NH) degeneracies where matrices become defective. The order of such an EP is given by the number of coalescing eigenvectors. On the one hand, most work focuses on studying Nth-order EPs in ($N \leq 4$)-dimensional NH Bloch Hamiltonians. On the other hand, some works have remarked on the existence of EPs of orders scaling with systems size in models exhibiting the NH skin effect.

In this talk, I introduce a new type of EP and provide a recipe on how to realize EPs of arbitrary order not scaling with system size. Therefore, I introduce a generalized version of the paradigmatic Hatano-Nelson model with longer-range hoppings. The EPs existing in this system show remarkable physical features: Their associated eigenstates have support on a subset of sites and exhibit the NH skin effect, which can be tuned to localize on the opposite end of the chain compared to all remaining states. Furthermore, the EPs are robust against generic perturbations in the hopping strengths as well as against a specific form of on-site disorder.

TT 53.5 Fri 10:30 H32

Topological Properties of the Non-Reciprocal α-Diamond Chain — Carolina Martinez-Strasser[1] and •Dario Bercioux[1,2] — [1]Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastián, Spain — [2]Ikerbasque, Basque Foundation for Science, Plaza Euskadi 5 48009 Bilbao, Spain

This work explores the topological properties of a generalized non-Hermitian quasi-1D lattice, dubbed as the non-reciprocal α-diamond chain. The diamond chain is a tripartite lattice featuring three sites per unit cell, characterized by a flat band at zero energy associated with compact localized states, and topological edges edge states in the Hermitian and non-Hermitian regimes [1,2]. Building upon our previous investigations [2], we extend the analysis to a more general framework by introducing an α-parameter, quantifying the non-reciprocal hopping strength in the lower part of the diamond chain. Our generalization reveals a spectrum of non-Hermitian phenomena, including exceptional points of order 3 (EP3s) under specific parameter tuning. These EP3s, where three eigenvalues and their eigenvectors coalesce, offer valuable insights into the behavior of three-band non-Hermitian systems. The α-diamond chain thus serves as an effective 1D platform for exploring such phenomena, particularly in the presence of sublattice symmetries [3].

[1] Bercioux *et al.*, Ann. Phys. **529**, 1600262 (2017).
[2] Martinez-Strasser *et al.*, Adv.Quantum.Technol.**7**,2300225(2023).
[3] Montag and Kunst, Phys. Rev. Res. **6**, 023205 (2024).

TT 53.6 Fri 10:45 H32

Topological characterization of carbon nanotubes — •Udo Schwingenschlögl, Xiaoning Zang, and Nirpendra Singh — King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

Orbital angular momentum plays a central role in quantum mechanics, from the microscopic interaction between light and matter to the macroscopic behavior of superconductors and superfluids. We show that the topology of carbon nanotubes can be characterized by winding numbers related to the orbital angular momentum. The tight-binding Hamiltonian of any carbon nanotube with C_N symmetry can be represented by N tight-binding Hamiltonians of decoupled molecular chains, for which a pseudospin formulation, characterized by specific paths in a two-dimensional auxiliary space, is developed. The quantum phases are given by the N winding numbers of these paths. The paths rotate in the auxiliary space when a magnetic field of varying strength is applied along the carbon nanotube, which gives rise to quantum phase transitions.

15 min. break

TT 53.7 Fri 11:15 H32

Non-Hermitian Quantum Fractals and Inner Non-Hermitian Skin Effects — Changan Li[1], Junsong Sun[2], Huaming Guo[2], and •Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [2]School of Physics, Beihang University, Beijing, 100191, China

The first quantum fractal discovered in physics is the Hofstadter butterfly. It stems from large external magnetic fields. We discover instead a class of non-Hermitian quantum fractals (NHQFs) emerging in coupled Hatano-Nelson models on a tree lattice in the absence of any fields. Based on analytic solutions, we are able to rigorously identify the self-similar recursive structures in the energy spectrum and wave functions. We prove that the complex spectrum of NHQFs bears a resemblance to the Mandelbrot set in fractal theory. We further investigate the non-Hermitian Su-Schrieffer-Heeger (SSH) model on Bethe lattice, revealing a novel localization phenomenon coined inner non-Hermitian skin effect. Our findings open another avenue for investigating quantum fractals in non-Hermitian systems.

TT 53.8 Fri 11:30 H32

Non-Hermitian Dynamics Close to Exceptional Points — •Aisel Shiralieva, Grigorii Starkov, and Björn Trauzettel — University of Würzburg, Würzburg, Germany

Exceptional points (EPs), which are degeneracies occurring in both open classical and quantum systems, play a crucial role across numerous areas of physics. This work examines the behavior of dissipative systems with N levels, with a particular emphasis on non-Hermitian qubits and qutrits. These systems are of interest due to recent experimental studies involving a driven non-Hermitian superconducting qubit embedded within a three-level structure, where the ground state serves as an "effective bath". Although significant progress have been made in understanding EPs, the precise connection between their occurrences in non-Hermitian Hamiltonians and in the Lindblad formalism remains unclear, especially if quantum jumps are treated as perturbations. Our results reveal how EPs in these two frameworks relate to each other and illustrate how perturbations can either lift the degeneracy or eliminate the EPs entirely in the Lindblad formalism.

TT 53.9 Fri 11:45 H32

Polarization-Induced Topology in Quantum Emitter Chains — •Jonathan Sturm and Adriana Pálffy — Julius-Maximilians-Universität Würzburg

Synthetic quantum matter has become a field of strongly growing interest over the past decade due to its versatility, adaptibility, and applicability in areas like quantum simulation and others. One particulary suited platform for engineered quantum systems are arrays of quantum emitters, which can be optically excited and couple by the exchange of virtual photons [1].

We theoretically study a quantum emitter implementation of the Su-Schrieffer-Heeger model. Different from earlier studies [2], we show that for certain chain geometries the topological invariant depends on the polarization of the chain, allowing us to alter the topology without altering the lattice. Moreover, we demonstrate how this mechanism can be used for a topological pumping protocol enabling controlled transport of photons through the chain.

[1] M. Reitz *et al.*, PRX Quantum **3**, 010201 (2022).
[2] B. X. Wang and C. Y. Zhao, Phys. Rev. A **98**, 023808 (2018).

TT 53.10 Fri 12:00 H32

Topological Signatures and Induced Triplet Pairing in Proximitized Quantum Hall - Superconductor Heterostructures — •Yuriko Baba, Rafael Sánchez, Alfredo Levy Yeyati, and Pablo Burset — Department of Theoretical Condensed Matter Physics, Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain

In a quantum Hall (QH) state, the proximity to a superconductor (SC) leads to the formation of hybridized electron-hole states called chiral Andreev edge states (CAES). Although the strong magnetic fields required for the QH effect are detrimental to superconductivity, recent experiments have achieved QH-SC hybrid junctions based on InAs 2DEGs [1], graphene [2], and magnetic topological insulators [3]. In this work, we theoretically study the formation of CAES in QH-SC hybrid junctions on a 2DEG. Using numerical simulations in Kwant [4], we study the formation of spin-polarized triplet Cooper pairs induced by Rashba spin-orbit coupling and Zeeman splitting [5], which may be important in 2DEG devices. We also consider the effect of the geometry of nanodevices in planar junctions [6] and in a narrow-finger configuration. In these geometries, the coupling of CAES can induce a topological band inversion and trivial localized states, both of which show particular signatures in non-local electron transport.

[1] Hatefipour et al, Nano Lett. 22, 6173 (2022);
[2] Zhao et al., Nat. Phys. 16, 862 (2020);
[3] Uday et al., Nat. Phys. 20, 1589 (2024);
[4] Groth et al., NJP. 16, 063065 (2014);
[5] Arrachea et al., arXiv:2310.13729;
[6] David at al. PRB 107, 125416 (2023).

TT 53.11 Fri 12:15 H32

Optical Hopfion quantizes inverse Faraday effect — •Emma L. Minarelli and Matthias R. Geilhufe — Chalmers University of Technology, Department of Physics, 412 96 Göteborg, Sweden

Control and manipulation of quantum materials is of paramount significance, both for fundamental characterization and for quantum technologies. Among others, light-matter interaction has recently gained traction because both optical counterpart of solid-state phenomena and emergent effects can be investigated.

We extend this paradigm to 3D topological optical quasiparticle i.e. optical Hopfion (oHop) - a knotted structure presenting robust topological protection, resolution on ultrafast time-scales, localization on nanometer-scale - as novel source to probe and regulate properties and phases of matter.

We show a first instance of OHop-matter coupling: an oHop travelling through a non-magnetic material induces a net effective magnetization, that is now promoted to be topologically quantized in virtue of the linking number (Hopf index) classifying the oHop source. By relating the induced magnetization to the Hopf index, we identify the quantum inverse Faraday effect. This quantized optical response is obtained without constraints on the material but only by introducing topological light. We conclude with a demonstration for a specific material and we give predictions about its promising application in optical protocols for communication and storage of information.

TT 53.12 Fri 12:30 H32

Network Model for Magnetic Higher-Order Topological Phases — Hui Liu[1,2], Ali G. Moghaddam[3,4,5], •Daniel Varjas[1,2,6,7], and Ion Cosma Fulga[1] — [1]IFW Dresden, Dresden, Germany — [2]Stockholm University, Stockholm, Sweden — [3]Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan, Iran — [4]Research Center for Basic Sciences and Modern Technologies (RBST), Zanjan, Iran — [5]Tampere University, Tampere, Finland — [6]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [7]Budapest University of Technology and Economics, Budapest, Hungary

We propose a network-model realization of magnetic higher-order topological phases (HOTPs) in the presence of the combined space-time symmetry $C_4\mathcal{T}$ – the product of a fourfold rotation and time-reversal symmetry. We show that the system possesses two types of HOTPs. The first type, analogous to Floquet topology, generates a total of 8 corner modes at 0 or π eigenphase, while the second type, hidden behind a weak topological phase, yields a unique phase with 8 corner modes at $\pm\pi/2$ eigenphase (after gapping out the counterpropagating edge states), arising from the product of particle-hole and phase-rotation symmetry. By using a bulk $\mathbb{Z}_4$ topological index (Q), we found both HOTPs have $Q = 2$, whereas $Q = 0$ for the trivial and the conventional weak topological phase. Together with a $\mathbb{Z}_2$ topological index associated with the reflection matrix, we are able to fully distinguish all phases. Our work suggests that such phases may find their experimental realization in coupled-ring-resonator networks.