TT 51: Topological Semimetals II

Time: Wednesday 15:00–17:00 Location: H 3007

TT 51.1 Wed 15:00 H 3007

Singularity theory of Weyl-point creation and annihilation — •György Frank[1], Gergö Pintér[1], and András Pályi[1,2] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, M. egyetem rkp. 3., H-1111 Budapest, Hungary — [2]MTA-BME Quantum Dynamics and Correlations Research Group, M. egyetem rkp. 3., H-1111 Budapest, Hungary

Weyl points (WP) are robust spectral degeneracies, which can not be split by small perturbations, as they are protected by their non-zero topological charge. For larger perturbations, WPs can disappear via pairwise annihilation, where two oppositely charged WPs merge, and the resulting neutral degeneracy disappears. In this work [1], we reveal and analyze a fundamental connection of the WP mergers and singularity theory: phase boundary points of Weyl phase diagrams, i.e., control parameter values where Weyl point mergers happen, can be classified according to singularity classes of maps between manifolds of equal dimension. We demonstrate this connection on a Weyl–Josephson circuit where the merger of 4 WPs draw a swallowtail singularity, and in a random BdG Hamiltonian which reveal a rich pattern of fold lines and cusp points. Our results predict universal geometrical features of Weyl phase diagrams, and generalize naturally to creation and annihilation of Weyl points in electronic (phononic, magnonic, photonic, etc) band-structure models, where Weyl phase transitions can be triggered by control parameters such as mechanical strain.
[1] Gy. Frank, G. Pintér, A. Pályi, arXiv:2309.05506 (2023)

TT 51.2 Wed 15:15 H 3007

Quantum oscillations from interface Fermi arcs — Adam Yanis Chaou, •Vatsal Dwivedi, and Maxim Breitkreiz — Freie Universität Berlin

Fermi arcs — the characteristic boundary signatures of Weyl semimetals — generically also appear at a weakly coupled interface between two Weyl semimetals. We study the magnetotransport across such an interface in presence of a magnetic field normal to the interface, and describe signatures of these interface modes in the quantum oscillations. These oscillations stem from a momentum-space analog of Aharonov-Bohm interference of electrons moving along various branches of the interface Fermi arcs. The localization of the interface modes along the transport direction manifests in a strong field-angle anisotropy of the oscillations, which distinguishes them from conventional Shubnikov-de Haas oscillations and makes them identifiable even in complex quantum oscillation spectra.

TT 51.3 Wed 15:30 H 3007

Fermi-Arc Metals — •Maxim Breitkreiz, Tommy Li, and Piet Brouwer — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

Weyl-semimetal superstructures with spatially varying positions of Weyl nodes host a chiral-symmetry preserving Fermi-arc metal state, where the chirality is carried by three-dimensional flat bands instead of Weyl nodes, which can be understood as being built from Fermi arc-like states. In this talk I introduce this novel topological state and discuss some of its characteristic transport and interaction effects. In particular, I will show that a helical node-position variation supports an excitonic instability leading to a dynamical axion insulator.

TT 51.4 Wed 15:45 H 3007

Multiplicative topological semimetals — •Adipta Pal[1,2], Joe H. Winter[1,2,3], and Ashley M. Cook[1,2] — [1]Max Planck Intitute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany — [3]SUPA, School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY169SS, UK

Exhaustive study of topological semimetal phases of matter in equilibriated electonic systems and myriad extensions has built upon the foundations laid by earlier introduction and study of the Weyl semimetal, with broad applications in topologically-protected quantum computing, spintronics, and optical devices. We extend recent introduction of multiplicative topological phases to find previously-overlooked topological semimetal phases of electronic systems in equilibrium, with minimal symmetry-protection. We look into the multiplicative counterpart of the Weyl semimetal and find rich and distinctive bulk-boundary correspondence and response signatures that greatly expand understanding of consequences of topology in condensed matter settings, such as limits on Fermi arc connectivity and structure and transport signatures such as the chiral anomaly.

TT 51.5 Wed 16:00 H 3007

Stability of Weyl node merging processes under symmetry constraints — •Viktor Könye[1], Gabriele Naselli[1], György Frank[2], Gergö Pintér[2], Dániel Varjas[1], János Asbóth[2], András Pályi[2], and Cosma Fulga[1] — [1]IFW Dresden, Dresden, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary

Weyl semimetals are topological materials with topologically protected band crossing points called Weyl nodes, characterized by a linear low energy dispersion relation and chirality given by an integer Chern number. By continuously changing the system parameters the number of nodes can only change through charge conserving mergings or creations. When no symmetries are present in the system the most likely process is pairwise annihilation and creation. Pairwise annihilation can be forbidden by adding symmetry constraints and multi-node merging processes can be observed.

Motivated by the prediction of a three-node process in $MoTe_2$ we study merging processes in the presence of C_2T symmetry. We find that, when this symmetry is present, the most common merging process involves a three-node process. Additionally we propose a way to realize these merging processes in $SrSi_2$ and in bilayer graphene.

TT 51.6 Wed 16:15 H 3007

Weak $\mathbb{Z}_2$ Supertopology — •Kirill Parshukov[1], Moritz M. Hirschmann[1,2], and Andreas P. Schnyder[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany — [2]RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan

We study symmetry-enforced $\mathbb{Z}_2$ topology in non-magnetic centrosymmetric materials. We provide a classification of space groups whose symmetries enforce a nontrivial $\mathbb{Z}_2$ indicator for all bands, independent of material details. For the found space groups we list all 2D subplanes in the Brillouin zone (BZ) that host the non-trivial 2D indicator. In the presence of strong spin-orbit coupling, the enforced indicator leads to quantum spin Hall states in the 2D subplanes of the BZ. If the spin-orbit coupling is negligible, the indicator enforces quantized π Berry phases along special contours. The enforced π Berry phases correspond to an odd number of Dirac nodal lines piercing the topological planes. We discuss experimental consequences and list a number of example materials.

TT 51.7 Wed 16:30 H 3007

Fundamental laws of chiral band crossings — •Kirill Alpin[1], Moritz M. Hirschmann[1,2], Niclas Heinsdorf[1,3], Andreas Leonhardt[1], Wan Yee Yau[1,4], Xianxin Wu[1,5], and Andreas P. Schnyder[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany — [2]RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan — [3]Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver BC V6T 1Z4, Canada — [4]Institute for Theoretical Physics III, University of Stuttgart, D-70550 Stuttgart, Germany — [5]Institute for Theoretical Physics, Chinese Academy of Sciences, Beijing, China

We derive two fundamental laws of chiral band crossings: (i) a local constraint relating the Chern number to phase jumps of rotation eigenvalues and (ii) a global constraint determining the number of chiral crossings on rotation axes. Together with the fermion doubling theorem, these laws describe all conditions that a network of chiral band crossing must satisfy. We apply the fundamental laws to prove the existence of enforced double Weyl points, nodal planes, and generic Weyl points, among others. Combining the local constraint with explicit low-energy models, we determine the generic topological phase diagrams of all multifold crossings. Remarkably, we find a fourfold crossing with Chern number 5, which exceeds the previously conceived maximum Chern number of 4. We identify materials crystallizing in space group 198, such as B20 materials and BaAsPt, as suitable compounds with this Chern number 5 crossing.

TT 51.8 Wed 16:45 H 3007

Representation-enforced topology and signatures of quantum geometry in hexagonal nodal-plane materials — •Raymond Wiedmann[1], Moritz M. Hirschmann[1,2], Kirill Alpin[1], Niclas Heinsdorf[1,3], Wan Yee Yau[1,4], Andreas Leonhardt[1], Johannes Mitscherling[1,5], and Andreas P. Schnyder[1] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]RIKEN Center for Emergent Matter Science, Wako, Saitama, Japan — [3]Department of Physics and Astronomy & Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver BC, Canada — [4]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [5]Department of Physics, University of California, Berkeley, California, USA

Nodal planes can carry a topological charge, which has to be compensated by Weyl points of opposite charge in the Brillouin zone, due to the fermion doubling theorem. Depending on the symmetries and constraints of the system, this can allow for a very high Chern number of the nodal plane. We study under which circumstances the interplay of Wyckoff positions and orbital content leads to representation-enforced topological nodal planes in hexagonal systems, finding Chern numbers of up to $\nu = 16$. Since the anomalous Hall effect scales with the Chern number, one expects a strong response in conductivity measurements of such materials. Another effect that influences the conductivity is the quantum metric. We investigate the signatures of topological and trivial nodal planes in the electrical and optical conductivity caused by the non-trivial quantum geometry of the bands.