MA 25: Topological Semimetals - Theory (joint session TT/MA)

Time: Wednesday 9:30–12:30 Location: H22

MA 25.1 Wed 9:30 H22

Semiclassical transport theory in Weyl semimetals beyond the relaxation time approximation — •Tobias Meng — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

Transport is a frequently used tool to study the properties of topological semimetals. In Weyl semimetals, the negative magnetoresistance proportional to the square of the magnetic field is a famous example of such a transport property. However, experimental semimetals usually are multi band systems containing disorder. It is essential to further develop the description of transport in Weyl semimetals in order for theory to match the experimental progress. We report on some first steps towards this goal by extending the Boltzmann approach towards a more realistic description of disorder scattering, which in turn allows us to identify novel signatures of Berry phase physics in transport.

MA 25.2 Wed 9:45 H22

Topological crossings in magnetic space groups — •Darshan G. Joshi[1], Yang-hao Chan[2], and Andreas P. Schnyder[1] — [1]Max-Planck-Institute for Solid State Research, Stuttgart, Germany — [2]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, Taiwan

Non-symmorphic symmetry is known to enforce topological crossings in crystals. Using the elementary band irreducible representations nontrivial crossings in the form of hour-glass or accordian spectrum have been discovered in certain space groups. Here we extend such an analysis to a wider domain of magnetic space groups (MSGs). We show that the magnetic co-representations (coreps), which are derived from the non-magnetic irreducible representations, can be used to detect non-symmorphic symmetry enforced topological crossings in MSGs. We demonstrate this with two examples, where we find magnetic Weyl points and hour-glass dispersions. DFT band-structure calculation of corresponding magnetic materials confirms our findings. Furthermore, we compute the surface states and discuss other experimental consequences of the hourglass dispersion in magnetic materials.

MA 25.3 Wed 10:00 H22

Chiral anomaly in Weyl semimetals within a Fermi surface harmonics approach — •Annika Johansson[1,2], Jürgen Henk[2], and Ingrid Mertig[2,1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

In Weyl semimetals, external nonorthogonal magnetic and electric fields lead to nonconservation of the chiral charge, known as chiral anomaly [1-4]. This quantum phenomenon manifests itself in a negative longitudinal magnetoresistance. Using a Fermi surface harmonics approach [5] for solving the semiclassical Boltzmann equation, we calculate transport properties of type-I Weyl semimetals, including influences of chiral anomaly, Lorentz force as well as momentum-dependent scattering. Respecting a modified phase-space volume, we identify additional contributions to the chiral charge conductivity which can change the sign of the magnetoresistance in systems with broken inversion symmetry. Considering momentum-dependent scattering modifies the energy-dependence of the transport properties. On top of this, we show for TaAs that a misalignment of an applied magnetic field with the crystal axes can destroy the negative longitudinal magnetoresistance.

[1] S. Adler, Phys. Rev. **177**, 2426 (1969)
[2] J. S. Bell and R. Jackiw, Nuovo Cimento A **60**, 47 (1969)
[3] H. B. Nielsen and M. Ninomiya, Phys. Lett. B **130**, 389 (1983)
[4] D. T. Son and B. Z. Spivak, Phys. Rev. B **88**, 104412 (2013)
[5] P. B. Allen, Phys. Rev. B **13**, 1416 (1976)

MA 25.4 Wed 10:15 H22

Symmetry-Protected Nodal Phases in Non-Hermitian Systems — •Jan Carl Budich[1], Johan Carlström[2], Flore K Kunst[2], and Emil J Bergholtz[2] — [1]Institute of Theoretical Physics, TU Dresden, 01062 Dresden, Germany — [2]Department of Physics, Stockholm University, AlbaNova University Center, 106 91 Stockholm, Sweden

Non-Hermitian (NH) Hamiltonians have become an important asset for the effective description of various physical systems that are subject to dissipation. Motivated by recent experimental progress on realizing the NH counterparts of gapless phases such as Weyl semimetals, here we investigate how NH symmetries affect the occurrence of exceptional points (EPs), that generalize the notion of nodal points in the spectrum beyond the Hermitian realm. Remarkably, we find that the dimension of the manifold of EPs is generically increased by one as compared to the case without symmetry. This leads to nodal surfaces formed by EPs that are stable as long as a protecting symmetry is preserved, and that are connected by open Fermi volumes. We illustrate our findings with analytically solvable two-band lattice models in one and two spatial dimensions, and show how they are readily generalized to generic NH crystalline systems.

MA 25.5 Wed 10:30 H22

Evolution of surface states of the Luttinger semimetal under strain and inversion symmetry breaking: Dirac and Weyl semimetals — •Benedikt Mayer, Maxim Kharitonov, and Ewelina Hankiewicz — Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany

Luttinger semimetal, the quadratic-node semimetal for $j = 3/2$ electrons under full cubic symmetry, is the parent highest-symmetry minimal model for a variety of topological and/or strongly correlated materials, such as HgTe, α-Sn, and iridate compounds. Recently, Luttinger semimetal has been demonstrated to exhibit surface states of topological origin that can be attributed to approximate chiral symmetry. In the present work, we theoretically study the effect of the symmetry-lowering perturbations on these surface states within an analytical model. Under compressive strain lowering rotational symmetry, Luttinger semimetal becomes a Dirac semimetal with a pair of double-degenerate linear nodes. Breaking further inversion symmetry, the system turns into a Weyl semimetal, with each Dirac node split into four Weyl nodes. We analyze the corresponding evolution of the surface states, connecting the surface-state structures in the linear regime near the nodes and in the quadratic regime of the Luttinger semimetal away from the nodes. In particular, we demonstrate agreement of the Chern numbers with the chiralities of the surface states.

MA 25.6 Wed 10:45 H22

Photo-induced anomalous Hall effect in nodal-line semimetals — •Andreas Leonhardt and Andreas P. Schnyder — Max Planck Institute for Solid State Research

Spatial symmetries like reflection or PT-symmetry are able to protect band crossings along closed lines in the Brillouin zone at momenta left invariant by the symmetry. These nodal-lines carry a topological charge, characterized by a quantized Berry phase. This implies a divergent Berry curvature at these topological defects.

In semi-classical transport theory, a non-vanishing Berry curvature is associated with an anomalous velocity. In most cases however, the contributions from opposite points in the Brillouin zone cancel exactly, such that no anomalous Hall effect can be observed. Since circular polarized light couples differently to positive and negative momenta, the cancellation of anti-symmetric terms can be lifted, leading to a non-vanishing Hall current that changes direction with switching the polarization.

We describe the lattice model of a nodal-line semimetal driven by circular polarized light in the Floquet formalism. Coupling this system to leads with a potential difference allows us to calculate the Hall current in the Keldysh formalism. We investigate the relation of the photo-induced Hall conductivity to material characteristics and light amplitude and frequency and provide estimates for the required intensities and magnitude of the effect for some known nodal-line compounds.

15 min. break.

MA 25.7 Wed 11:15 H22

Tuning the anomalous Hall effect in topological magnets via the Berry curvature design — •Kaustuv Manna, Lukas Muechler, Ting Hui Kao, Rolf Stinshoff, Nitesh Kumar, Jürgen Kübler, Chandra Shekhar, Yan Sun, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

For a long time anomalous Hall effect (AHE) has been considered as one of the characteristic signature of finite spontaneous magnetization in a material. It was considered to scale with sample's magnetization. However, the recent realization of the connection between the intrinsic AHE and the Berry curvature predicts other possibilities. AHE is an excellent method to understand the effect of various topological states and the Berry phase on the physical properties of material. Depending on the details of the band structure, the Hall conductivity can take a colossal value or even zero, independent of the corresponding magnetization of the sample. As a case study, we illustrate the situation in the Heusler compounds where one can easily tune the band structure by engineering the crystal symmetry and composition. With experimental evidences, we demonstrate how the Hall conductivity can be tuned from 0 to 2000 Ω-1cm-1 without disturbing sample's magnetization. With the help of the theoretical band structure calculations and ARPES data, we discover the first topological magnet with giant anomalous Hall conductivity (˜ 1700 Ω-1cm-1) and an exceptionally high anomalous Hall angle up to 12% in a topological magnetic Heusler.

MA 25.8 Wed 11:30 H22

Disorder-driven exceptional lines and Fermi ribbons in tilted nodal-line semimetals — •Kristof Moors[1], Alexander A. Zyuzin[2,3], Alexander Yu. Zyuzin[3], Rakesh P. Tiwari[4], and Thomas L. Schmidt[1] — [1]University of Luxembourg, Luxembourg, Luxembourg — [2]Aalto University, Aalto, Finland — [3]Ioffe Physical-Technical Institute, St. Petersburg, Russia — [4]McGill University, Montréal, Québec

We consider the impact of disorder on the spectrum of three-dimensional nodal-line semimetals. We show that the combination of disorder and a tilted spectrum naturally leads to a non-Hermitian self-energy contribution that can split a nodal line into a pair of exceptional lines. These exceptional lines form the boundary of an open and orientable bulk Fermi ribbon in reciprocal space on which the energy gap vanishes. We find that the surface of such a disorder-induced bulk Fermi ribbon in general lies orthogonal to the direction of the tilt, which can be exploited to realize a bulk Fermi ribbon with nontrivial topology by means of a tilt vector that twists along a nodal loop. Our results put forward a new paradigm for the exploration of non-Hermitian topological phases of matter.

MA 25.9 Wed 11:45 H22

Hopf-link topological nodal-loop semimetals — •Feng Xiong[1,2] and Yao Zhou[2] — [1]Institute for Theoretical solid state physics, RWTH Aachen. — [2]National Laboratory of Solid State Microstructures, Department of Physics, Nanjing University, Nanjing 210093, China

We construct a generic two-band model which can describe topological semimetals with multiple closed nodal loops. All the existing multi-nodal-loop semimetals, including the nodal-net, nodal-chain, and Hopf-link states, can be examined within the same framework. Based on a two-nodal-loop model, the corresponding drumhead surface states for these topologically different bulk states are studied and compared with each other. The connection of our model with Hopf insulators is also discussed. Furthermore, to identify experimentally these topologically different semimetal states, especially to distinguish the Hopf-link from unlinked ones, we also investigate their Landau levels. It is found that the Hopf-link state can be characterized by the existence of a quadruply degenerate zero-energy Landau band, regardless of the direction of the magnetic field.

MA 25.10 Wed 12:00 H22

Access to Weyl point properties revealed by anomalous Nernst effect — •Steffen Sykora[1], Christoph Wuttke[1], Federico Caglieris[1], Bernd Büchner[1,2,3], and Christian Hess[1,3] — [1]IFW Dresden, 01069 Dresden, Germany — [2]Institute for Solid State Physics, TU Dresden, 01069 Dresden, Germany — [3]Center for Transport and Devices, TU Dresden, 01069 Dresden, Germany

In Weyl semimetals the Nernst coefficient is dominated by anomalous contributions to the thermal particle transport which originate from a specific property of the conduction electrons, the Berry curvature. Here we extend our recently developed theoretical approach of the anomalous Nernst effect to find explicit expressions for the temperature dependence of the thermal and electrical conductivity components. We apply these findings to fit experimental curves of recent Nernst effect measurements in a Weyl semimetal where it could be shown that signatures of Weyl physics are dominating the Nernst signal. From this analysis we determine fundamental properties of the Weyl points, such as their energy and distance in k-space.

MA 25.11 Wed 12:15 H22

Anomaly transport normally explained — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The anomalous term $\sim \vec{E}\vec{B}$ in the balance of the chiral density can be rewritten as quantum current in the classical balance of density. Therefore it does not violate classical conservation laws as it is claimed to be caused by quantum fluctuations. Moreover this term is derived from the quantum kinetic equations for systems with SU(2) structure within a completely conserving approach. Therefore the origin of this term is not a unique signal of symmetry-breaking terms in the field-theoretical Lagrangian. Regularization-free density and pseudospin currents are calculated in Graphene and Weyl-systems realized as the infinite-mass limit of electrons with quadratic dispersion and a proper spin-orbit coupling. The intraband and interband conductivities are discussed. The optical conductivity agrees well with the experimental values using screened impurity scattering and an effective Zeeman field. The universal value of Hall conductivity is shown to be modified due to the Zeeman field.

[1] arXiv:1809.01547, arXiv:1806.06214, Phys. Rev. B 94 (2016) 165415, Phys. Rev. B 92 (2015) 245425, errata: Phys. Rev. B93 (2016) 239904(E), Phys. Rev. B 92 (2015) 245426