TT 41: Topological Semimetals

Time: Wednesday 9:30–12:30 Location: HSZ/0103

TT 41.1 Wed 9:30 HSZ/0103

Pushing transport to the edge: Inducing superconductivity in WTe_2 — •Marieke Altena, Guido Wiersma, Jort Verbakel, Esra van 't Westende, Pantelis Bampoulis, Alexander Brinkman, and Chuan Li — MESA+ Institute for Nanotechnology, University of Twente, 7500 AE, Enschede, The Netherlands

WTe_2 is a type-II Weyl semimetal hosting higher-order topological states (HOTS) protected by crystal symmetries and characterized by quantum spin Hall-like spin-momentum locking. These states are of particular interest for quantum computing. Recent studies have reported anomalous edge-enhanced supercurrents in WTe_2-based Josephson junctions [1,2].

To reveal the topological nature and test the robustness of HOTS, we measured the electronic transport properties of thin, nanometer sized WTe_2 devices at low temperatures. Superconductivity was successfully induced into the WTe_2 flakes by using superconducting Nb-contacts. We observe a strong enhancement of the supercurrent at the edge of the WTe_2 flake by studying single junctions. Interestingly, the enhancement of the supercurrent at the edge is also observed at a step in the middle of the flake. The current-phase relation is also measured via superconducting quantum interference devices (SQUID), which provides the insight to its topological properties. The topological nature of these states is studied with RF Shapiro measurements and DC SQUID measurements.

[1] Choi et al., Nat. Mater. 19, 974 (2020).
[2] Endres et al., Nano Letters 23, 4654 (2023).

TT 41.2 Wed 9:45 HSZ/0103

Terahertz third-harmonic generation of lightwave-driven Weyl fermions far from equilibrium — •Patrick Pilch[1], Changqing Zhu[1], Sergey Kovalev[1,2], Renato M. A. Dantas[3,4], Amilcar Bedoya-Pinto[5,6], Stuart S. P. Parkin[5], and Zhe Wang[1] — [1]TU Dortmund University, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]University of Basel, Switzerland — [4]University of Minho, Portugal — [5]Max Planck Institute for Microstructure Physics, Halle, Germany — [6]University of Valencia, Spain

We report on time-resolved ultrafast terahertz third- harmonic generation spectroscopy of nonequilibrium dynamics of Weyl fermions in a nanometer thin film of the Weyl semimetal TaP [1]. Terahertz third-harmonic generation is observed at room temperature under the drive of a multicycle narrowband terahertz pulse with a peak field strength of down to tens of kV/cm. The observed terahertz third-harmonic generation exhibits a perturbative cubic power-law dependence on the terahertz drive. By varying the polarization of the drive pulse from linear to elliptical, we realize a sensitive tuning of the third harmonic yield. By carrying out theoretical analysis based on the Boltzmann transport theory, we can properly describe the experimental results and ascribe the observed THz nonlinearity to field-driven kinetics of the Weyl fermions.

[1] P. Pilch et al., *Nano Lett.* (2025), DOI: 10.1021/acs.nanolett.5c04143

TT 41.3 Wed 10:00 HSZ/0103

Quantum Geometric Origin of Intrinsic Nonlinear Hall effects — •Yannis Urich[1,2], Johannes Mitscherling[3], Laura Classen[1,2], and Andreas Schnyder[1] — [1]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]School of Natural Sciences, Technische Universität München, D-85748 Garching, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

We decompose the intrinsic second-order nonlinear Hall effect (NLHE) of a generic multiband system into quantum geometric contributions using a fully quantum-mechanical projector formalism. Expanding the nonlinear conductivity in powers of the quasiparticle lifetime τ, we recover the established Berry curvature dipole at order τ and clarify discrepancies in prior work concerning the (interband) quantum metric dipole (also called Berry curvature polarizability) at order τ^0. Our method further reveals an additional order-τ^0 term, determined by the *intraband* quantum metric dipole (intraQMD), which originates from virtual interband transitions captured only within the fully quantum-mechanical treatment. The intraQMD is generically nonzero in systems with broken time-reversal symmetry and can be identified independently by symmetry. We highlight candidate materials expected to exhibit a large intrinsic NLHE, including the topological antiferromagnet Yb_3Pt_4. Finally, we discuss the extension of this framework to higher-order nonlinear responses, which requires a structured understanding of higher-order quantum geometry beyond Berry curvature and quantum metric.

TT 41.4 Wed 10:15 HSZ/0103

Raman spectroscopic evidence for linearly dispersed nodes and magnetic ordering in the topological semimetal $V_{1/3}NbS_2$ — •Shreenanda Ghosh[1,2], Chris Lygouras[1], Zili Feng[3], Mingxuan Fu[3], Satoru Nakatsuji[1,3], and Natalia Drichko[1] — [1]Institute for Quantum Matter and William H. Miller III Department of Physics and Astronomy, Johns Hopkins University, Baltimore, USA — [2]Institute of Physics, University of Münster, Germany — [3]Department of Physics, University of Tokyo, Japan

We report polarization-resolved magnetic and electronic Raman scattering of the intercalated transition metal dichalcogenide $V_{1/3}NbS_2$, proposed as a Weyl semimetal [1,2]. The electronic scattering reveals a linear with frequency continuum of excitations, as the signature of electronic transitions within the proposed Weyl nodes in a 2D electronic structure [3]. Additionally, two-magnon excitations of V moments are observed near 15 meV in the magnetically ordered phase below 50 K[3], which are well reproduced by calculations using spin wave exchange parameters [4] and confirm the antiferromagnetic character of the order. These magnetic and electronic scattering, observed in the same spectra, provide independent spectroscopic evidence for a collinear antiferromagnetic Weyl semimetal state in $V_{1/3}NbS_2$.

[1] M. K. Ray et al., Nat Com 16, 3532 (2025).
[2] H. Wang et al., Phys. Rev. B 107, 134436 (2023).
[3] S. Ghosh et al., arXiv:2504.04590 (2025).
[4] K. Lu et al., Phys. Rev. Mat 4, 054416 (2020).

TT 41.5 Wed 10:30 HSZ/0103

Large tunability of the magnetism in the Dirac semimetal $EuMnBi_2$ under uniaxial pressure — •Caitlin I. O'Neil[1], Hilary M.L. Noad[1], Andrew P. Mackenzie[1], Hideaki Sakai[2], and Elena Gati[1,3] — [1]MPI-CPfS, Dresden — [2]Tohoku University, Japan — [3]Goethe University Frankfurt

Uniaxial pressure provides a controlled method for breaking lattice symmetries in crystals, and it has therefore become a powerful tool for tuning quantum materials. Although uniaxial-pressure techniques have been widely used in recent years to probe the coupling between correlated electrons and the lattice [1-2], their use to investigate the interplay between topological electrons, magnetism, and the lattice has been less common. We report on the discovery of a strong uniaxial pressure response in the magnetic Dirac semimetal $EuMnBi_2$. In this material, there are layers of localised Eu^{2+} moments alternating with Bi square nets that host Dirac fermions. By measuring the AC Young's modulus [3], we map out the phase diagram as a function of [1 0 0] uniaxial pressure and magnetic field, revealing a strong sensitivity of the Eu^{2+} magnetic order to strain, including the observation of multiple magnetic phases. We suggest that the pronounced tunability of the Eu^{2+} order arises from its coupling to a low-energy electronic structure that is sensitive to symmetry-breaking strains.

Work is supported by the DFG through TRR 288-422213477.

[1] Gati *et al.*, Sci. Adv. **2**, e1601646 (2016)
[2] Noad *et al.*, Science **382**, 447 (2023)
[3] O'Neil *et al.*, RSI **95**, 073909 (2024)

15 min. break

TT 41.6 Wed 11:00 HSZ/0103

Novel difference-frequency quantum oscillations in $MoSi_2$ — •Ivan Volkau[1], Nico Huber[2], Louw Feenstra[1], Andreas Bauer[1,4], Christian Pfleiderer[1,3,4], and Marc A. Wilde[1,4] — [1]Technical University of Munich (TUM) — [2]Cornell University — [3]MCQST, Munich — [4]TUM Zentrum für Quantum Engineering

Recently, we established temperature-stable quantum oscillations of the quasiparticle lifetime (QPLOs) in CoSi (space group $P2_13$) [1]. QPLOs may shed new light on scattering processes in materials, since they arise in transport properties at finite coupling between semi-

classical Onsager orbits. $MoSi_2$ (space group *I4/mmm*) exhibits a difference frequency in its SdH spectra, composed of distinct low- and high-temperature (LT and HT) components. The temperature stability and the absence in thermodynamic properties of the HT component is consistent with the theoretical framework of QPLOs [2]. Conversely, the LT component cannot be attributed to QPLOs, as it is observed in both SdH and dHvA measurements. Furthermore, its phase shift of approximately $0.75(10)\pi$ relative to the HT component is inconsistent with standard non-Onsager mechanisms, such as magnetic breakdown, magnetic interaction, or chemical potential oscillations [3]. In this work, we present a detailed study of quantum oscillations in $MoSi_2$, analyzing the interplay between these components to clarify the nature of the scattering mechanisms involved.

[1] Huber et al., Nature **621**, 276 (2023)
[2] Leeb et al., PRB **108**, 054202 (2023)
[3] Leeb et al., APR, Vl4, Is4 2400134 (2025)

TT 41.7 Wed 11:15 HSZ/0103

Probing the Fermi Surface of $NdAgSb_2$ through Large Linear Magnetoresistance and Quantum Oscillations — •Aarti Gautam[1], Haribrahma Singh[1], Prabuddha Kant Mishra[3], Rie. Y Umetsu[4], and Ashok Kumar Ganguli[1,2] — [1]Indian Institute of Technology Delhi, Hauz Khas New Delhi — [2]Indian Institute of Science Education and Research, Berhampur — [3]Institute of Low Temperature and Structure Research, Polish Academy of Sciences, ul. Okolna 2, 50-422 Wroclaw, Poland — [4]Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

We present a comprehensive study of the magnetic, transport, and magnetotransport properties of single-crystalline $NdAgSb_2$. The compound exhibits anisotropic magnetic behavior, with an antiferromagnetic ground state for fields applied in the ab plane and de Haas van Alphen oscillations observed along the c axis. Magnetotransport measurements reveal a large linear magnetoresistance (450 % at 2 K under 9 T), indicative of a clean-limit electronic structure with suppressed scattering. Notably, both de Haas van Alphen and Shubnikov de Haas quantum oscillations are observed simultaneously, enabling a detailed mapping of the Fermi surface. Analysis of the oscillation frequencies, effective masses, and Berry phases provides insight into the low-energy electronic states governed by the two-dimensional Sb square-net topology, highlighting $NdAgSb_2$ as a model system to explore the interplay of anisotropic magnetism, high-mobility carriers, and quantum oscillations in layered rare-earth pnictides.

TT 41.8 Wed 11:30 HSZ/0103

Topological Dirac Semimetal Carbon Nanoscroll — •Tzu-Ching Hsu[1], Jhih-Shih You[1], Hsiu-Chuan Hsu[2], and Ion Cosma Fulga[3] — [1]Department of Physics, National Taiwan Normal University, Taipei, Taiwan, — [2]Graduate Institute of Applied Physics, National Chengchi University, Taipei, Taiwan — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, Germany

Carbon nanoscrolls (CNS), rolled-up structures formed from single-layer graphene, have recently attracted significant attention owing to their distinctive geometry. In this work, we theoretically investigate the topological properties of a series of CNS under different axial magnetic fields and various edge alignment conditions, within the large-radius approximation. As a function of magnetic field strength and the number of turns in the scroll, these systems host topologically protected Dirac cones, which survive even when chiral symmetry is broken. Furthermore, the number of Dirac cones, their real-space probability density, and the magnetic flux at which they occur can be controlled deterministically, being dictated by the system's symmetries. Our results establish a foundation for further studies of the fundamental physics and potential applications of CNS and other two-dimensional materials with similar geometries.

TT 41.9 Wed 11:45 HSZ/0103

End spin formation in capped carbon nanotubes — •István Markó[1], Dominik Szombathy[1,2], Cătălin P. Moca[4,2], and Gergely Zaránd[1,3] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Nokia Bell Labs Budapest site, Hungary — [3]HUN-REN–BME Quantum Dynamics and Correlations, Budapest, Hungary — [4]University of Oradea, Oradea, Romania

Semiconducting open carbon nanotubes (CNTs) have been shown to exhibit topological bound states within the spectral gap [1], giving rise to spin formation at the ends of the nanotube [2]. However, the production of open-ended CNTs is difficult. Here, we investigate the electronic properties of capped topological CNTs using exact diagonalization and Chebyshev expansion methods to identify local resonances and bound states in the density of states at the end of long tubes [3]. While capping removes topological states, non-topological bound states and resonances localized on the pentagons appear, presumably related to Euler topology. We observe an abundance of local resonances and bound states, and about 20% of the investigated stable caps are predicted to produce end spins [4]. We identify a specific CNT of chirality (6,5) which produces well-defined end spins. This type of CNT can be produced with ultra-high purity (>95%) [5], and is an excellent candidate for a geometrically controlled spin qubit.

[1] W. Izumida, et al. Phys. Rev. B 93, 195442 (2016).
[2] C. P. Moca, et al. Phys. Rev. Lett. 125, 056401 (2020).
[3] A. Weiße, et al. Rev. Mod. Phys. 78, 275 (2006).
[4] I. Markó, et al. unpublished
[5] S. Shiina, et al. ACS Nano 18, 23979 (2024)

TT 41.10 Wed 12:00 HSZ/0103

Anomalous Fractional Chiral Currents in Step Edges of Weyl Semimetals — •Oskar Schweizer[1], Virginia Gali[1], Piet Brouwer[1], Gal Lemut[1], Adam Yanis Chaou[2], and Maxim Breitkreiz[1] — [1]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastián, Spain

Bulk-boundary correspondence predicts surface states in Weyl semimetals (WSM) only when the 3d bulk Weyl-node separation projects nontrivially onto a given 2d surface. However recent experiments report states on surfaces where no such protected modes are expected, localized instead to 1d step-edge defects. We study such WSM surfaces with step edges and find chiral currents bound to the steps, even though the surface itself hosts no protected modes. Remarkably, these currents can take fractional, non-integer values determined solely by the bulk Weyl-node separation.

TT 41.11 Wed 12:15 HSZ/0103

Correlated Hopf Insulators — •Konstantinos Ladovrechis[1] and Shouvik Sur[2] — [1]Ruhr Universität Bochum, Germany — [2]Rice University, USA

Hopf insulators represent an exceptional class of topological matter, unanticipated by the periodic table of topological invariants. These systems point to the existence of previously unexplored states of matter with unconventional topology. In this work, we take a step toward exploring this direction by investigating correlation-driven instabilities of Hopf insulators. Organizing our analysis around the topological quantum critical point that separates the Hopf insulating phase from a trivial insulator, we demonstrate the emergence of unconventional Weyl semimetallic and topological insulating states. Notably, upon doping, the Weyl semimetal supports non-reciprocal superconductivity and a Bogoliubov-Fermi surface, potentially providing a novel framework for realizing the superconducting diode effect. Finally, we highlight the interconnectedness of the effective descriptions of correlated Hopf insulators, two-dimensional quadratic band-touching semimetals, and Luttinger semimetals.