MA 19: Transport: Topological Semimetals 1 (jointly with DS, MA, HL, O)

Time: Tuesday 9:30–11:45 Location: HSZ 201

MA 19.1 Tue 9:30 HSZ 201

Electron-hole pairing of Fermi arc surface states in a Weyl semimetal bilayer — •Paolo Michetti and Carsten Timm — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

The topological nature of Weyl semimetals (WSMs) is corroborated by the presence of chiral surface states at the boundaries, connecting the bulk Fermi surface by Fermi arcs (FAs). We develop an analysis of the electron-hole pairing instability between the surface states of a bilayer structure realized by introducing a thin insulating spacer into a bulk WSM. We employ a minimal WSM model for the description of the surface states and a self-consistent mean-field treatment of the pairing interaction. We find that the system is unstable towards the formation of coherent electron-hole pairs, which leads to partial gapping of the FA dispersion curve and possibly to a superfluid dipolar exciton condensate, where dissipationless counter-propagating currents can be induced in the two layers. A signature of such condensate is the modifications of the peculiar quantum oscillations from surface FAs. We characterize the dependence of the single-particle energy gap and the critical temperature on the model parameters, where we emphasize in particular the linear scaling of these quantities with the separation between the Weyl points. A detrimental role is played by the curvature of the FA, although the phenomenon persists for moderately low curvature.

MA 19.2 Tue 9:45 HSZ 201

Universality and stability of the edge states of chiral nodal topological semimetals; Luttinger model for $j = \frac{3}{2}$ electrons as a 3D topological semimetal — •Maxim Kharitonov, Julian-Benedikt Mayer, and Ewelina Hankiewicz — Institute for Theoretical Physics and Astrophysics, Wuerzburg University

We theoretically demonstrate that the chiral structure of the nodes of nodal semimetals is responsible for the existence and universal local properties of the edge states in the vicinity of the nodes. We perform a general analysis of the edge states for an isolated node of a 2D semimetal, protected by *chiral symmetry* and characterized by the topological winding number N. We derive the asymptotic chiral-symmetric boundary conditions and find that there are $N+1$ universal classes of them. The class determines the numbers of flat-band edge states on either side off the node in the 1D edge spectrum and the winding number N gives the *total* number of edge states. We then show that the edge states of chiral nodal semimetals are *robust*: they persist in a finite-size *stability region* of parameters of chiral-asymmetric terms. This significantly extends the notion of 2D and 3D topological nodal semimetals. We demonstrate that the Luttinger model with a quadratic node for $j = \frac{3}{2}$ electrons is a 3D topological semimetal in this new sense and predict that α-Sn, HgTe, and possibly $Pr_2Ir_2O_7$, as well as many other semimetals described by it are topological and exhibit surface states.

MA 19.3 Tue 10:00 HSZ 201

Interband optical conductivity of the Dirac semimetal Cd_3As_2 — •D. Neubauer[1], J. P. Carbotte[2], A. A. Nateprov[3], A. Löhle[1], M. Dressel[1], and A. V. Pronin[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Department of Physics and Astronomy, McMaster University, Canada — [3]Institute of Applied Physics, Academy of Sciences of Moldova, Chisinau, Moldova

We measured the optical reflectivity of [001]-oriented n-doped Cd_3As_2 in a broad frequency range (50 – 22 000 cm^{-1}) for temperatures from 10 to 300 K. The optical conductivity, $\sigma(\omega) = \sigma_1(\omega) + i\sigma_2(\omega)$, is isotropic within the (001) plane; its real part follows a power law, $\sigma_1(\omega) \propto \omega^{1.65}$, in a large interval from 2000 to 8000 cm^{-1}. This behavior is caused by interband transitions between two bands, which are effectively described by a sublinear dispersion relation, $E(k) \propto |k|^{0.6}$. The momentum-averaged Fermi velocity of the carriers in these bands is energy dependent and ranges from 1.2×10^5 to 3×10^5 m/s, depending on the distance from the Dirac points. These values are in agreement with the published data on Cd_3As_2. We detect a gaplike feature in $\sigma_1(\omega)$ and associate it with the Fermi level positioned around 100 meV above the Dirac points. Finally, we compare our results with recent magneto-optical infrared data.

MA 19.4 Tue 10:15 HSZ 201

Angular-dependent magnetoresistance of 3D Dirac materials — •Henry Legg and Achim Rosch — Institute for Theoretical Physics University of Cologne Zülpicher Straße 77 D-50937 Köln Deutschland

The realisation of 3D Dirac and Weyl semi-metals has created a new playground for transport phenomena, such as the possibility to produce the chiral anomaly in a condensed matter setting. Many materials that realise a 3D Dirac dispersion are protected by crystal symmetry and therefore have multiple Dirac cones within their Brillouin zone; examples include Cd_2As_2, Na_3Bi, and $Pb_{1-x}Sn_xSe$.

In this work we show that the application of a parallel magnetic and electric field in a direction perpendicular to that connecting a pair of Dirac cones can lead to a large positive magnetoresistance. The magnetic field leaves only an effective one-dimensional dispersion parallel to the field, due to the formation of Landau levels perpendicular to the magnetic field. The result is a large inter-nodal scattering matrix between the two Dirac cones since the Dirac nodes are close in the dimensionally reduced system. Our results are compared to recent experiments on $Pb_{1-x}Sn_xSe$.

15 min. break.

MA 19.5 Tue 10:45 HSZ 201

Quantum oscillation and Dirac fermion in $BaZnBi_2$ system — •Kan Zhao and Philipp Gegenwart — Experimentalphysik VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86159 Augsburg, Germany

Dirac semimetals represent new quantum states of matter and have stimulated intensive studies. $AMnBi_2$(A = alkali earth/rare earth metal) is one of the established Dirac semimetals, with both antiferromagnetic order in $MnBi_4$ layer and Dirac fermion in Bi square net layer.

To investigate how the magnetism interacts with Dirac fermions, we synthesized single crystals of $SrZnBi_2$ and $BaZnBi_2$. Being isostructural to $SrMnBi_2$, $SrZnBi_2$ shows no quantum oscillation in resistivity and magnetic susceptibility up to 14 T. However, $BaZnBi_2$ shows clear multiple quantum oscillations down to 4 T in magnetic susceptibility. According to the temperature dependence of the oscillation amplitude after fast Fourier transformation (FFT), the effective electron mass is about 0.1me, comparable with that of $BaMnBi_2$. In the resistivity measurement up to 14 T at 2 K clear SdH oscillations with main oscillation frequency 168T are observed. The frequency follows a $1/|\cos(\theta)|$ dependence (θ is the angle between magnetic field and c axis), indicating a quasi 2D Fermi surface. Band-structure calculations by I. Mazin, indicate that $BaZnBi_2$ exhibits a unique structure feature and electronic structure, with a quasi Dirac band near the Fermi level. ARPES and high-field SdH measurements, to further characterize the Dirac fermions, are in progress.

MA 19.6 Tue 11:00 HSZ 201

Observation of Topological Surface States and Strong Electron/hole Imbalance in an Extreme Magnetoresistance Semimetal — •Niels Bernhard Michael Schröter[1], Juan Jiang[1,2,3,4], Shu-Chun Wu[5], Nitesh Kumar[5], Chandra Shekhar[5], Han Peng[1], Xiang Xu[6], Cheng Chen[1], Haifung Yang[7], Chan Hwang[4], Sung-Kwan Mo[3], Zhongkai Liu[2], Lexiang Yang[6], Claudia Felser[5], Binghai Yan[5], and Yulin Chen[1,2,6] — [1]University of Oxford, Oxford, UK — [2]ShanghaiTech University, Shanghai, P. R. China — [3]Advanced Light Source, Berkeley, USA — [4]Pohang Accelerator Laboratory, POSTECH, Pohang, Korea — [5]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [6]Tsinghua University, Beijing, P. R. China — [7]Chinese Academy of Sciences, Shanghai, P. R. China

The discovery of an extreme magnetoresistance (XMR) in the non-magnetic rare-earth monopnictides LaX (X = P, As, Sb, Bi), a recently proposed new topological semimetal family, has inspired intensive research on the correlation between the XMR and their electronic structures. In this work, using ARPES to investigate the three dimensional band structure of a lanthanum monopnictide, we unraveled its topologically non-trivial nature with the observation of multiple topological surface Dirac fermions, as supported by our ab-initio calculations. Furthermore, we observed substantial imbalance between the volumes of electron and hole pockets, which rules out the electron-hole compensation as the primary cause of the XMR, putting strong constraints on future theoretical investigations.

MA 19.7 Tue 11:15 HSZ 201

Topological metal with multiple Dirac cones and nodal line

— •Ashis Kumar Nandy[1], Alex Aperis[1], M. Mofazzel Hosen[2], Klauss Dimitri[2], Pablo Maldonado[1], Dariusz Kaczorowski[3], Tomasz Durakiewicz[4], Madhab Neupane[2], and Peter M. Oppeneer[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]Department of Physics, University of Central Florida, Orlando, Florida, USA — [3]Institute of Low Temp. & Structure Research, PAS, Wroclaw, Poland — [4]Condens. Matter and Magnet Science Group, LANL, Los Alamos, USA

The extended class of topological materials includes topological (semi) metals that support non-trivial topological surface states in the form of one-dimensional Dirac lines or Fermi-arcs connecting two Weyl points. Here we study a ternary compound using a combination of systematic theoretical calculations and detailed angle-resolved photoemission spectroscopy (ARPES) measurements. In contrast to other topological materials, our first-principles calculations suggest that the band inversion is $d-p$ type instead of the mostly observed $s-p$ type band inversion. We identify multiple Dirac fermionic states at various binding energies. A Dirac cone is computed at the Γ point about 0.5 eV above the chemical potential. Most importantly, at around 1 eV below the Fermi level our calculations reveal a surface nodal line-like feature passing through the time-reversal invariant point M. Our systematic study suggests a new family of materials for exploring the coexistence and competition of multiple fundamental fermionic quantum states.

MA 19.8 Tue 11:30 HSZ 201

***PT* Anomalous Transport in a Nodal Line Dirac Semimetal**

— •Wenbin Rui, Yuxin Zhao, and Andreas P. Schnyder — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

Recently PT invariant topological nodal line Dirac semimetals have attracted increasing attentions in quantum matter. Here we study the anomalous transport of the PT symmetric Dirac semimetals of (3+1) dimensions as responses to electromagnetic fields, for which the universal currents are originated from the parity anomaly in (2+1)-dimensional quantum field theory. Considering that the total sum of anomalous currents from soft modes spreading along the nodal loop vanishes, we design a feasible experiment to detect the effect, which is able to separate anomalous currents from distinct regions of the nodal loop.