TT 45: $PtBi_2$ and Weyl Superconductors

Time: Wednesday 11:30–13:15 Location: H 3010

TT 45.1 Wed 11:30 H 3010

Unconventional Nernst effect in Weyl semimetal $PtBi_2$ — •Federico Caglieris[1,2,6], Michele Ceccardi[1,6], Dmitriy Efremov[2], Grigory Shipunov[2], Saicharan Aswartham[2], Arthur Veyrat[2], Joseph Dufouleur[2], Christian Hess[2,4,5], Bernd Büchner[2,3,4], and Daniele Marré[1,6] — [1]CNR-SPIN, 16152 Genoa, Italy — [2]IFW Dresden, 01069 Dresden, Germany — [3]Institut für Festkörperphysik, TU Dresden, 01069 Dresden, Germany — [4]Center for Transport and Devices, TU Dresden, 01069 Dresden, Germany — [5]Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, 42097 Wuppertal, Germany — [6]University of Genoa, 16146 Genova, Italy

Trigonal $PtBi_2$ represents an exceptional playground for the exploration of topological materials. In fact, it is a Weyl semimetal with broken inversion symmetry and strong spin-orbit coupling, showing also superconductivity at low temperatures. The Nernst effect has been proven to be a powerful technique to investigate the fermiology of unconventional materials and in systems characterized by non-trivial topology, it often assumes distinctive anomalous features, as observed in various Weyl semimetals. In this work, we deeply investigate the evolution of the Nernst coeffcient in a sigle crystal of trigonal-$PtBi_2$ as a function of different parameters: temperature (T), magnetic field (B) and angle between the magnetic field direction and the c-axis of the sample. In particular, we found an unconvetional Nernst phenomenology, resulting from a combination of the peculiar Fermi surface of $PtBi_2$, its non-trivial topology and the incipient superconductivity.

TT 45.2 Wed 11:45 H 3010

Topology and superconductivity in trigonal-$PtBi_2$ — •Jiang Qu, Ankit Kumar, Arthur Veyrat, Louis Veyrat, Romain Giraud, Bernd Büchner, and Joseph Dufouleur — Leibniz-Institute for Solid State and Materials Research (IFW Dresden), Helmholtzstraße 20, 01069 Dresden, Germany and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

The layered type-I Weyl semimetal trigonal-$PtBi_2$ (t-$PtBi_2$) is a promising candidate for topological superconductors with broken inversion symmetry and strong spin-orbit coupling. In this talk, we first present methods developed to exfoliate t-$PtBi_2$ into thin layers with a modified mechanical exfoliation technique. We then focus on the result of the investigations of the low dimensional superconductivity in t-$PtBi_2$ exfoliated flakes by transport measurements [1]. Finally, we present a complete study of magnetoresistance above the superconducting transition for a magnetic field oriented in any direction, highlighting the highly untrivial properties of this material.
[1] A. Veyrat et al., Nano Lett. 23 (2023) 1229 and arxive:2101.01620

TT 45.3 Wed 12:00 H 3010

A puzzling superconducting weyl semimental: band structure and effective model of $PtBi_2$ — •Riccardo Vocaturo[1], Klaus Koepernic[1], Jorge Facio[2], Cosma Fulga[1], Oleg Janson[1], and Jeroen van den Brink[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Centro Atomico Bariloche, Instituto de Nanociencia y Nanotecnologia (CNEA-CONICET) and Instituto Balseiro, Av. Bustillo, 9500, Argentina

Weyl semi-metals are interesting phases of matter where topological crossings in the bulk band-structure dictates the presence of protected surface states, i.e. Fermi arcs. Recently, theoretical and experimental works have been suggesting a possible interplay between this features and the presence of superconductivity, both in the bulk and at the surface. In this study we focuses on Trigonal-$PtBi_2$, an inversion-breaking type-I Weyl semimetal, known for its intriguing superconducting properties and distinctive metallic phase. For instance, despite reports of high-Tc superconductivity on the surface and robust BKT transition in think flakes, bulk-$PtBi_2$ is found to be a sub-Kelvin superconductor, posing several theoretical question. In this work, we perform DFT calculations to analyze its electronic structure and surface states. Additionally, we propose a minimal tight-binding model able to reprocisde the number and distribution of Weyl points, preserving the all the crystal symmetries, which we believe to be very helpful in reducing the complexity of this system.

TT 45.4 Wed 12:15 H 3010

Surface superconductivity on time-reversal symmetric Weyl systems: a self-consistent approach — •Mattia Trama[1,2,3], Viktor Könye[3], Ion Cosma Fulga[3], and Jeroen van den Brink[3,4] — [1]Physics Department "E.R. Caianiello", Universitá degli Studi di Salerno, Fisciano, Italy — [2]INFN-Sezione di Napoli, Naples, Italy — [3]Institute for Theoretical Solid State Physics, IFW Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, Dresden, Germany — [4]Institute for Theoretical Physics, TU Dresden, Dresden, Germany

The recent discovery of the superconducting surface on the time-reversal symmetric Weyl semimetal PtBi2 has raised the question of the origin of such a phenomenon. Indeed, such a compound exhibits a critical temperature difference between the surface and the bulk of about an order of magnitude. Here we propose an explanation for this phenomenon using a time-reversal symmetric Weyl model for a finite system, invoking standard local s-wave singlet pairing as the superconducting coupling. Our self-consistent calculation predicts a different critical temperature for the surface and the bulk, leading to the possibility of superconductivity in only few layers of the material. We also predict a temperature dependence on the penetration of surface superconductivity, suggesting a competition between two order parameters.

TT 45.5 Wed 12:30 H 3010

Topological Fermi arcs in superconducting Weyl semimetal candidate t-$PtBi_2$ revealed by quasiparticle interference — •Sebastian Schimmel[1,2], Sven Hoffmann[1,2], Riccardo Vocaturo[2], Joaquin Puig[3], Grigoriy Shipunov[2], Oleg Janson[2], Saicharan Aswartham[2], Danny Baumann[2], Julia Besproswanny[1,2], Bernd Büchner[2], Jeroen van den Brink[2], Yanina Fasano[2,3], Jorge I. Facio[3], and Christian Hess[1,2] — [1]Bergische Univertsität Wuppertal, 42119 Wuppertal, Germany — [2]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [3]Centro Atómico Bariloche and Instituto Balseiro, CNEA,CONICET and Instituto de Nanociencia y Nanotecnología , 8400 San Carlos de Bariloche, Argentina

Trigonal $PtBi_2$ (t-$PtBi_2$) is promising candidate material for topological superconductivity. Ab-initio calculations predicted Weyl-nodes near the Fermi-level [1], and ARPES [2] as well as STM/STS [3] reveal signatures of surface superconductivity at $T > 5$ K – one order of magnitude higher T than the bulk Tc. Here we report on the Weyl nature of t-$PtBi_2$ experimentally addressed via quasiparticle interference investigations. The revealed scattering channels can be attributed to the predicted Fermi arcs – the hall mark surface features of a Weyl semimetal. Our findings thus experimentally corroborate the non-trivial topology of the surface electrons in t-$PtBi_2$.
[1] A. Veyrat et al., ACS Nano Lett. (2023)
[2] A. Kuibarov et al., arXiv:2305.02900 (2023)
[3] S. Schimmel et al., arXiv:2302.08968 (2023)

TT 45.6 Wed 12:45 H 3010

Axion electrodynamics of Weyl superconductors with broken time-reversal symmetry — •Flavio Nogueira[1], Vira Shyta[1], and Jeroen van den Brink[1,2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden — [2]Institute for Theoretical Physics and Würzburg-Dresden Cluster of Excellence ct.qmat

Weyl superconductors with broken time-reversal symmetry are effectively described by a Higgs axion electrodynamics, where the axion term is given by a magnetoelectric coupling yielding a planar Hall effect in the normal phase. This leads to significant changes in the electrodynamics of superconductors. Here we investigate how the application of an external magnetic field changes the nature of superconductivity both in absence and in the presence of vortices. In fact, due to the axion term, an electric field is generated, which in turn induces electric charge densities on the material surfaces, thus leading to interesting vortex dynamics on the surface. An interesting result following from our analysis is an axion-induced ac Josephson effect provided the sample is thin enough.

TT 45.7 Wed 13:00 H 3010

Chiral Meissner state in time-reversal invariant Weyl superconductors — •Vira Shyta[1], Jeroen van den Brink[1,2],

and Flavio S. Nogueira[1] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Institute for Theoretical Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, 01069 Dresden, Germany

Weyl semimetals have nodes in their electronic structure at which electrons attain a definite chirality. Due to the chiral anomaly, the non-conservation of charges with given chirality, the axion term appears in their effective electromagnetic action. We determine how this affects the properties of time-reversal invariant Weyl superconductors (SCs) in the London regime. For type II SCs the axion coupling generates magnetic B-fields transverse to vortices, which become unstable at a critical coupling so that a transition into type I SC ensues. In this regime an applied B-field not only decays inside the SC within the London penetration depth, but the axion coupling generates an additional perpendicular field. Consequently, when penetrating into the bulk the B-field starts to steadily rotate away from the applied field. At a critical coupling the screening of the magnetic field breaks down. The novel chiral SC state that emerges has a periodically divergent susceptibility that separates onsets of chiral Meissner regimes. Thus the axion leaves very crisp experimentally accessible signatures in Weyl SCs.