Oral Session A3 (Tuesday, February 13)

Chair: Surjeet Rajendran, Johns Hopkins University

Special Session Talk

16: 00 - 16 : 40

Maria A. H. Vozmediano

Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

Quantum field theory aspects of Dirac semimetals

After the synthesis of graphene (massless Dirac fermions in (2+1) dimensions), Weyl semimetals emerged as physical realization chiral particles in (3+1) dimensions. Although they can be seen as 3D graphene, a series of new phenomena arise from the fundamental differences between chiral fermions in two and three dimensions. Chiral imbalance in 3D implies a set of anomaly related transport phenomena first discussed in the context of high energy collisions (quark-gluon plasma). In particular, quantum anomalies - most prominently the chiral anomaly - have provided a novel theoretical frame for the understanding of new magneto transport features in Weyl semimetals. More recently thermal transport has taken the lead in relation with the gravitational anomaly [1,2]. In this talk I will describe some of the aspects of the cross-fertilization between condensed matter, particle physics and gravity. I will try to be pedagogical.

References

[1] "Thermal transport, geometry, and anomalies", M. N. Chernodub, Y. Ferreiros, A. G. Grushin, K. Landsteiner, M. A. H. Vozmediano", Physics Reports 977 (2022) 158.

[2] Generation of a Nernst current from the conformal anomaly in Dirac and Weyl semimetals, Maxim N. Chernodub, Alberto Cortijo, and M. A. H. Vozmediano, Phys. Rev. Lett. 120, 206601 (2018).

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Special Session Talk

16: 40 - 17 : 20

Naoki Yamamoto

Department of Physics, Keio University

Chiral transport in the universe

In many-body systems of relativistic chiral fermions, unusual transport phenomena emerge due to the spin-momentum locking and resulting nontrivial Berry curvature. These chiral transport phenomena may appear in various physical systems, such as Weyl/Dirac semimetals, quark-gluon plasmas in relativistic heavy-ion collisions, electroweak plasma in the early universe, and neutrino matter in core-collapse supernovae. In this talk, we discuss how these chiral transport phenomena are relevant in astrophysical and cosmological systems, especially in core-collapse supernovae [1,2].

References

[1] K. Kamada, N. Yamamoto, and D. L. Yang, Prog. Part. Nucl. Phys. 129, 104016 (2023)
[2] N. Yamamoto and D. L. Yang, Phys. Rev. Lett. 131, 012701 (2023)

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Contributed Oral

17: 20 - 17: 40

Chiral anomalies through laser-induced chiral gauge fields in disordered 3D Dirac semimetals

Hung-Hsuan Teh, Tokiro Numasawa, and Takashi Oka
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Inspired by a recent experiment that observed a significant photoexcited surface current in bismuth semimetal, we consider a Dirac semimetal subjected to a gradient chiral gauge field. The chiral gauge field, which can be generated for instance by circularly polarized light (CPL), is known to separate a Dirac fermion into a Weyl pair, leading to an appearance of Fermi arc states. Our study reveals that, due to the gradient, which can be achieved through the skin effect of the CPL on the semimental surface, one of the Fermi arc states leaks into the bulk, becoming a delocalized chiral Landau level state. We then introduce a homogeneous disorder and find that remarkably the chiral Landau level state exhibits greater robustness against scattering than the Fermi arc state, resulting in distinct lifetimes for two chiral states. Exploiting this asymmetry, we demonstrate an emergence of finite anomalous current, all without applications of external electric and magnetic fields. This discovery also serves as a realization of non-Hermitian topological quantum field theory within materials.

17: 40 - 18: 00

Emergent spin-momentum locking and triplet-mixed cooper pairs in a chiral organic superconductor

Takuro Sato[1, 2], and Hiroshi M. Yamamoto[1, 2, 3]

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Chirality is a novel source of several asymmetrical charge/spin transports such as electrical magnetochiral anisotropy (EMChA)[1] and chirality-induced spin selectivity (CISS)[2]. Especially, CISS gives a significant spin-rectification even at room temperature despite the negligible spin-orbit coupling (SOC) in organics, which distinguishes it from Edelstein effect that assumes large SOC from heavy elements. Both CISS and EMChA are distinct manifestations of chirality-induced spin/charge rectification effects and moreover share a similar parity-time symmetry, strongly suggesting the intimate relationship between them [Figs. 1(a, b)]. This issue, however, remains a fundamental open question.

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Here we experimentally address the issue by reporting a gigantic EMChA in a chiral organic superconductor, κ-(BEDT-TTF)2Cu(NCS)2, that exhibits a giant CISS effect as well [3]. Our study also reveals chiral superconducting diode effect and two-gap superfluid in the same device, suggesting a strong hedgehog-type spin-momentum locking and the triplet-mixed Cooper pairs as a common origin for both giant CISS and EMChA [Fig. 1(c)]. We anticipate that a similar strong spin-momentum locking in molecular orbitals can be also explored to rationalize high spin polarization in molecular CISS effect. The revealed triplet-mixed Cooper pair in chiral material may play roles in future developments of high critical field superconductors as well as novel types of quantum computers.

References

[1] G. L. J. A. Rikken, et al, Phys. Rev. Lett. 87, 236602 (2001).
[2] R. Naaman, and D. H. Waldeck, J. Phys. Chem. Lett. 3, 2178–2187 (2012).
[3] R. Nakajima, et al, Nature 613, 479–484 (2023).