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Dirac and Weyl Physics with Plasmons

Tuesday 2 December 2025 10:40 (30 minutes)

Over the past decade, the discovery of topological quantum matter—such as topological insulators, Weyl semimetals, and topological superconductors—has transformed condensed matter physics. Remarkably, many of these concepts are not confined to electrons in solids, but also apply to classical waves, from light and sound to water ripples and plasma oscillations.

In this talk, I will show how the collective oscillations of electrons—plasma waves, or *plasmons*—can emulate exotic Dirac and Weyl particles known from high-energy physics. In particular, the hydrodynamic equations for plasmons in a two-dimensional electron gas can be rewritten in a form that mirrors the relativistic Dirac equation for massive spin-1 particles. This perspective makes it possible to realize plasmonic counterparts of well-known phenomena such as Jackiw–Rebbi bound states and other topologically protected modes. I will also discuss how plasmons scatter from tiny micromagnets in ways strikingly similar to Dirac electrons interacting with magnetic impurities—unveiling new regimes of resonant and skew scattering.

Finally, I will extend these ideas to three-dimensional systems, where magnetoplasma waves exhibit striking parallels to the Weyl quasiparticles of electronic materials. This opens new possibilities for engineering and controlling exotic, trapped plasmonic states in solids.

Topological spin-plasma waves - D. K. Efimkin and M. Kargarian - Phys. Rev. B 104, 075413 (2021)

Equatorial magnetoplasma waves - C. Finnigan, M. Kargarian, and D. K. Efimkin - Phys. Rev. B 105, 205426 (2022)

Weyl excitations via helicon-phonon mixing in conducting materials - D. K. Efimkin, and S. Syzranov - Phys. Rev. B 108, L161411 (2023)

Giant resonant skew scattering of plasma waves in graphene off a micromagnet - C. Finnigan and D. K. Efimkin - Phys. Rev. B 110, L041406 (2024) [Editors' suggestion]

Anomalous skew scattering of plasma waves in a Dirac electron fluid - C. Finnigan and D.K. Efimkin - Phys. Rev. B 111, 165404 (2025)

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