Electronic Correlations and Nano-optics in Nodal Metals

Yinming Shao (Columbia University)

Dirac fermions with highly-dispersive linear bands are usually considered weakly correlated, due to relatively large bandwidths (W) compared to Coulomb interactions (U). With the discovery of nodal-line semimetals, the notion of Dirac point has been extended to lines and loops in the momentum space [1, 2]. The anisotropy associated with nodal-line structure gives rise to greatly reduced kinetic energy along the line. However, experimental evidence for anticipated enhanced correlations in nodal-line semimetals is sparse. Here we report on prominent correlation effects in a nodal-line semimetal compound ZrSiSe [3] through a combination of optical spectroscopy and density-functional-theory calculations. We observed two fundamental spectroscopic hallmarks of electronic correlations: strong reduction (1/3) of the free carrier Drude weight and of the Fermi velocity compared to predictions of density functional band theory. The observed correlation effects also have implications on various collective modes of the nodal-line semimetals at finite momentum. In particular, the anisotropic plasma frequencies in ZrSiSe supports hyperbolic plasmon polaritons inside a broad frequency range. The unique nodal-line structure and attendant Van Hove singularities suppress the interband loss to the level that enables propagating modes, which are directly imaged using our near-field microscope [4].

[1] L. M. Schoop et al, Nat. Commun. **7**, 11696 (2016)

[2] Y. Shao, Z. Sun et al, PNAS **116**, 1168 (2019)

[3] Y. Shao et al, Nat. Phys. **16**, 634 (2020)

[4] Y. Shao et al, “Infrared Plasmons Propagate through a Hyperbolic Nodal Metal”,

arXiv: 2206.01828 (2022)