Geometry-Enforced Topology in Amorphous Chiral Metals

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Beyond symmetry and topology, geometry has recently emerged as an additional knob for tuning the quantum properties of materials. One of the simplest manifestations of geometry is structural chirality, the notion that two 3D objects with the same symmetry can still be distinguished by their handedness. In structurally chiral crystals, there exists a profound link between lattice and wavefunction (topological) chirality, which gives rise to abundant chiral (Weyl) quasiparticles, extended Fermi-arc surface states [1], and enhanced photogalvanic effects. Despite numerous efforts, many aspects of strongly disordered Weyl semimetals remain puzzling, including whether they still carry quantized wavefunction topology that is bound by lattice fermion-doubling theorems [2], and hence exhibit topological surface Fermi arcs. In amorphous insulators with strong structural disorder, the average system symmetry [3] has been established as a tool for characterizing the bulk topology. In this work, we find that this approach overlooks a crucial additional ingredient: the average structural chirality. We find that in nonmagnetic amorphous metals, there exist generalizations of Kramers-Weyl, charge-two Weyl fermions, and spin-1 multifold, fermions that inherit their topological chirality from the system-averaged chirality of the position-space local lattice structure. We introduce an amorphous Wilson-loop numerical method to, for the first time, demonstrate the existence of Weyl fermions with quantized Berry curvature fluxes in fully disordered 3D metals. We further demonstrate the existence of vestigial surface Fermi arcs, which along with the chirality and spin textures of the bulk Weyl fermions, can be controlled via the average system chirality. Our work opens pathways to engineer geometry-enforced topological phenomena in non-crystalline materials and metamaterials.

References

[1] Niels B. M. Schröter et al, Science, 369 (2020). Observation and control of maximal Chern numbers in a chiral topological semimetal.
[2] H.B. Nielsen, M. Ninomiya, Nuclear Physics B, Volume 185, Issue 1 (1981). Absence of neutrinos on a lattice: (I). Proof by homotopy theory
[3] Yu-Liang Tao, Jiong-Hao Wang, Yong Xu, SciPost Phys, 15, 193 (2023). Average symmetry protected higher-order topological amorphous insulators.