INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Topological 3D multifold semimetals beyond Weyl/Dirac semimetals

It is now well established that in many topological semimetallic materials electrons can behave as ultrarelativistic chiral quantum particles, hence many elusive features of high-energy physics are now experimentally accessible through their distinct electronic thermodynamic and transport properties. The emblematic example is graphene which has two Fermi points nearby which the electrons behave as 2D pseudospin-1/2 massless ultrarelativistic chiral quantum particles. Their wavefunction carries a topological Berry phase, which has signatures in low- and high-magnetic field experiments. Beyond graphene and other 2D systems, during the last decade alloys were discovered which exhibit pairs of crossing points between multiple bands, giving rise to 3D massless ultrarelativistic chiral quantum particles that are analogs of Weyl and Dirac particles of high-energy physics. In such 3D pseudospin-S Weyl/Dirac semimetals, the electron wavefunction now carries a Berry curvature monopole that is at the origin of anomalous low field magnetotransport properties.

In a recent work we have predicted [1] that new kinds of massless ultrarelativistic quantum particle can exist, in which now the Berry curvature of the electron wavefunction is characterized by a multipole (dipole, quadrupole, octupole...). For the case of a Berry curvature dipole we have also predicted distinct magnetotransport as compared to those of pseudospin-S Dirac/Weyl semimetals. Furthermore, we have also shown that such “multifold dipole" semimetals naturally appear at the transition between two distinct topological Hopf- insulating phases that were recently studied [2].

The aim of this PhD project is to continue the exploration of this novel family of multifold semimetals associated to singular multipoles of Berry curvature, using analytical band-topological and numerical methods on tight-binding and continuum models. The first goal is to systematically construct models and explore their key features such as symmetries and topological properties. The next goal is to reveal the corresponding consequences in physical thermodynamic and transport measurements.

This project also envisions a challenging study of the topological insulating phases associated to these multifold semimetals, i.e., insulating phases obtained by opening an energy gap in various ways.Hence it will involve a study of stability of such semimetals to: (i) the breaking of symmetries and (ii) the electron-electron interactions.

[1] A.Graf and F.Piéchon, Phys.Rev.B 108,115105 (2023).
[2]A.Nelson,T.Neupert,A.Alexandradinata,and T.Bzdušek, Phys.Rev.B 106,075124(2022).

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES