Chiral symmetry breaking, axionic insulators, and inverse magnetic catalysis in topological semimetals

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Topological semimetals are topological condensed matter systems where gap is closed at a discrete set of points in the Brillouin zone. Around these nodal points, the low energy excitations follow the dynamics of the Weyl Hamiltonian, in a similar fashion that ultra-relativistic particles. These states are endowed with geometrical structures with topological significance, like the Chiral Magnetic Effect (CME) or the Chiral Anomaly. The recent interest in these properties is that they can be experimentally observed in transport and optical experiments.

Another prominent feature of some of these systems is that they become axion insulators under the effect of an external magnetic field. This mechanism, called *magnetic catalysis*, has been proposed in the context of Nuclear Physics, but observed in some materials, like $(TaSe_4)_2I$ or $TaTe_4$. This phase, where the chiral symmetry is dynamically broken, displays interesting properties, like an electric conductivity in the gapped phase, driven by the coupling between the Goldstone boson to the electromagnetic field through the chiral anomaly.

Also, in the context of Nuclear Physics, numerical simulations suggest that this mechanism of magnetic field-induced symmetry breaking pattern might be more complex than expected, and in some regimes the magnetic field might obstruct this symmetry breaking instead of inducing it. This is called the *inverse magnetic catalysis scenario*. The ground state and properties of this phase are not known.

The main objective of the present project is to theoretically analyze under which circumstances this inverse magnetic catalysis can be observed in condensed matter systems, and to study the transport and optical properties that can be observed to characterize such phase.

We search for students inclined to Condensed Matter Theory with knowledge in Quantum Field Theory, that will be extensively used in this project.

The advisor will be Dr Alberto Cortijo Fernández (alberto.cortijo@uam.es), a Ramón y Cajal fellow in the Departamento de Física de la Materia Condensada (C3). Alberto possesses experience in the physics of topological states of matter and he is currently carrying theoretical research in the topic of many-body physics in Weyl and Dirac semimetals.