INSTITUT DE PHYSIQUE ET CHIMIE DES MATERIAUX DE STRASBOURG
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Séminaire AXE 1 - Sciences et Matériaux Quantiques

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Unusual 2D superconductivity and topological signatures in the Weyl and nodal line semimetal trigonal-$PtBi_2$

Recently, topological phases of matter have attracted considerable attention due to their unique and robust properties. In particular, the possibility of finding or inducing superconductivity in a topological phase (known as topological superconductivity) has been an active area of research in recent years, for instance in quantum engineering where such a phase would be useful for quantum computing.

In this seminar, I will present a charge transport study of nanostructures of trigonal-$PtBi_2$, a non-centrosymmetric crystal with very strong spin-orbit coupling. In recent works [1-3], we evidenced the superconducting properties of this material and we predict it to be a Weyl- and nodal-line-semimetal. I will focus on two main results: the discovery of 2-dimensional superconductivity at sub-kelvin temperatures, and the discovery of an anomalous planar Hall effect (APHE) in the normal phase, robust up to room temperature.

While superconductivity has already been reported under pressure in t-$PtBi_2$ above 2 K [4, 5], we found that single crystals of t-$PtBi_2$ also display superconductivity at ambient pressure, with a critical temperature $T_c \sim 600$ mK [1]. When thinning down the crystals with mechanical exfoliation, the superconductivity becomes two-dimensional below $t \sim 70$ nm. Remarkably, even at such large thicknesses, nanostructures show clear Berezinskii–Kosterlitz–Thouless (BKT) transitions, a usually very fragile transition only evidenced yet in nearly-atomically thin superconducting films. This unusual feature might be related to the recent discovery in ARPES that the superconductivity occurs on the Fermi arcs, the topological surface states of Weyl semimetals.

At higher temperature (in the normal state), we discovered a large planar Hall effect [3] – the appearance under an external in-plane magnetic field of a transverse voltage dependent on the relative orientations of the electric (current) and magnetic fields – which is a signature of Weyl physics in non-magnetic materials [6, 7]. Additionally, we characterized an anomalous planar Hall response [8], which we attribute to a mechanism where topological nodal-lines – 1d band touchings in k-space, which we predict in t-$PtBi_2$ – get converted into Weyl nodes under even infinitesimal magnetic fields. Both effects, which are signatures of topological phases, are robust up to room temperature [2].

[1] A. Veyrat et al., Nano Letters (2023)
[2] A. Veyrat et al., under review (2024)
[3] A. Veyrat et al., under preparation (2024)
[4] J. Wang et al., Physical Review B (2021)
[5] D.L. Bashlakov et al., Low Temperature Physics (2022)
[6] A.A. Burkov et al., Physical Review B (2017)
[7] S. Nandy et al., Physical Review Letters (2017)
[8] R. Battilomo et al., Physical Review Research (2021)

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