Magnetically Confined Low-dimensional Quasiparticles in Quantum Matter

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Abstract: *Quasiparticles*, the collective excitations that emerge from the interactions of many particles, have captivated physicists for decades. Unlike the dozens of fundamental particles that are the building blocks of the known universe, quasiparticles are emergent and constantly advancing our understanding of materials. Novel quantum phenomena often emerge when new approaches to confine the underlying quasiparticles are developed. In this talk, I will highlight our recent work on low-dimensional quasiparticles realized by magnetic confinement. In the first example, I will explain how the complex momentum-space structures of Dirac nodal-lines can host exotic quasiparticles that are massless in one direction and massive in the perpendicular direction. These so-called semi-Dirac fermions ignited intense theoretical interest since their prediction more than 16 years ago, but remain undetected. Using magneto-optical spectroscopy, we demonstrate the defining feature of semi-Dirac fermions $-B^{2/3}$ scaling of Landau levels – in a prototypical nodal-line metal ZrSiS [1]. For the second example, I will report a previously unidentified type of optical excitation – a magnetic surface exciton – enabled by the antiferromagnetic spin correlations that confine excitons to the surface [2]. By quenching interlayer interactions, the antiferromagnetic order of CrSBr strictly confines the bound electron-hole pairs within the same layer, regardless of the total number of layers and without the need of external magnetic fields.

[1] Y. Shao et al., Semi-Dirac Fermions in a Topological Metal, Phys. Rev. X **14**, 041057 (2024).

[2] Y. Shao et al., Magnetically confined surface and bulk excitons in a layered antiferromagnet, Nat. Mater. **24**, 391 (2025).