

Magnetic topological phases in rare-earth monopnictides unveiled by ARPES

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Antiferromagnetic topological materials have emerged as a fertile platform for realizing novel quantum phenomena, including the quantum anomalous Hall effect and axion electrodynamics. A central prediction in this class of systems is that long-range magnetic order opens an energy gap at the Dirac point of the topological surface state. However, despite extensive experimental efforts, both the existence and magnitude of this Dirac gap have remained highly controversial. In prototypical systems such as MnBi_2Te_4 , angle-resolved photoemission spectroscopy (ARPES) has often reported either vanishing or strongly sample-dependent gaps, in apparent contradiction with theoretical expectations. This long-standing discrepancy has hindered a unified understanding of the interplay between magnetism and topology.

In this talk, I present a resolution to this long-standing problem based on our recent studies of lanthanide monopnictides, which provide an ideal platform owing to their low carrier density, strong spin-orbit coupling, and interplay between itinerant electrons and localized 4f moments. In particular, I show that NdBi hosts an intrinsic topological Dirac gap that emerges in the antiferromagnetic phase. Combining high-resolution laser-based ARPES with spin-resolved measurements, we achieve a clear separation of the topological surface state from bulk-derived Dirac-like features, overcoming a key limitation of previous studies. This enables the direct observation of a spin-polarized surface Dirac cone with an intrinsic energy gap of 17 ± 2 meV, in excellent agreement with density functional theory predictions [1].

Importantly, we demonstrate that previously reported large gaps originate from bulk band hybridization enhanced by antiferromagnetism, rather than from the intrinsic surface Dirac state, thereby reconciling conflicting experimental results. We further show that the Dirac gap is closely connected to surface magnetism. Temperature-dependent measurements reveal a pronounced reconstruction of the surface electronic structure below the Néel temperature: a magnetically induced surface state hybridizes with the topological surface state, producing a hybridization gap whose temperature dependence closely follows the magnetic order parameter.

Furthermore, controlled surface aging suppresses both the hybridization gap and the Dirac gap while leaving the overall surface-band dispersion well defined, establishing a direct connection between surface magnetism and the intrinsic Dirac gap. These results establish lanthanide monopnictides as a robust platform for exploring intrinsic magnetic topological states and provide a unified framework for understanding Dirac gap formation in correlated topological materials, bridging theory and experiment. The ability to access and control intrinsic Dirac gaps opens new avenues for topological spintronics and higher-temperature topological quantum phenomena.

[1] Y. Fukushima et al., *Nat. Commun.* (in press), doi:10.1038/s41467-026-77571-4.