Weyl quantum links and non-linear topological Hall effects: frontiers of topological magnetism in momentum & real space

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Quantum materials exhibit rich emergent properties, with unusual connections to mathematics and applications to next-generation technology[1-7]. In this talk, I first introduce our discovery of Weyl loops and topological drumhead surface states using ultraviolet ARPES in the ferromagnet Co_2MnGa[3]. Through systematic investigation by soft X-ray ARPES, we further find that the Weyl loops in Co_2MnGa are linked in momentum space[1]. I explicitly draw their link diagram and show a linking number of (2,2,2), in analogy with knot theory, providing a direct experimental measurement of a new kind of topological invariant in physics. I next introduce our observation of a non-linear topological Hall effect (THE) arising from emergent electrodynamics of current-driven skyrmions in Gd_2PdSi_3[2]. With increasing current, we observe a dynamic transition across the skyrmion pinned, creep and flow regimes. Surprisingly, we observe complete cancellation of the THE by the emergent electric field, which is intimately related to an emergent Galilean relativity in the flow regime. These exotic magnetic topological quantum properties in Co_2MnGa and Gd_2PdSi_3 motivate an exciting interdisciplinary conversation about new physics which may arise from coexisting momentum and real space topology.

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