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Weyl-Orbit Quantum Hall Effect in Cd_3As_2

Zhang, C., Yuan, X., Zhao, M.H., Leng, P.L. and Xiu, F.X. (Fudan Univ., Physics)

Introduction

Discovered decades ago, the quantum Hall effect remains one of the most active fields in condensed matter physics and is intimately connected with many ongoing research frontiers, such as topological phases, strong electron correlations, and quantum computing. The iconic quantized transport originates from the chiral edge states of the two-dimensional electron systems when subjected to a high magnetic field. Here, we report the evidence of a new type of quantum Hall effect in Cd_3As_2 nanostructures assisted by mixed-dimensional Weyl orbits (refer to Fig. 1 a-b for illustration). These Weyl orbits consist of Fermi arcs on the two-dimensional surfaces and one-dimensional chiral Landau levels along the magnetic field through the bulk, which results in a thickness-dependent quantum phase. Consequently, chiral states can even emerge in the bulk as a result of thickness variation.

Experimental

To measure the quantum phase shifts and search for the existence of chiral modes in the bulk, we have conducted transport experiments on wedge-shape Cd_3As_2 nanostructures with thickness variation across the samples. The experiments were performed at high field up to 34.5 T and low temperature down to 300 mk in Cell 12, DC field facility.

Results and Discussion

We find that the quantum Hall transports are strongly modulated by the sample's thickness (Fig. 1 c-d). The field-, thickness- and angle- dependences of the Landau levels agree with the modified Lifshitz-Onsager relation for the Weyl orbit. Samples with a real-space thickness variation cause the shifts in the quantum phase and the emergent chiral channels in the 3D bulk. Meanwhile, the thickness-dependent phase shift of the Weyl orbit is also measured directly and quantitatively in experiments.

Conclusions

In summary, we demonstrated in a 3D Dirac semimetal system a new type of QH effect based on the Weyl orbits, which is beyond the conventional scenario of stacking 2D QH planes observed before. The interplay between topological Weyl and Dirac semimetals and QH physics opens a new frontier in the research of topological phenomena and device applications with extra dimensions and tunability.

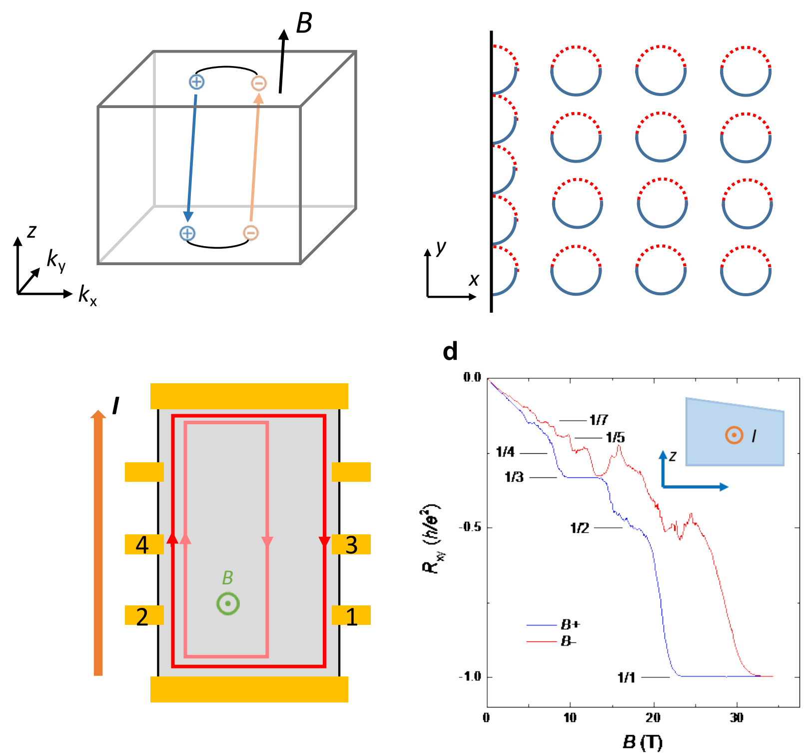

Fig.1 a, Illustration of the Weyl orbit under magnetic fields. The Weyl node pair in the bulk is connected by the two Fermi arcs on two surfaces. b, The Weyl orbit consisting of surface Fermi arcs and bulk chiral modes of a 3D Weyl semimetal slab in a magnetic field perpendicular to the slab. The solid blue and dashed red trajectories are on the top and bottom surfaces, respectively, and are connected through the chiral Landau levels in the bulk. c, A schematic sketch of the quantum Hall edge states for the wedge-shape sample with the gradient along y axis. d, The Hall resistance R_{xy} measured with the magnetic field along positive- and negative-z directions.

Acknowledgements

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References

[1] Zhang, C. *et al.*, Nature, in press (2018).