北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Seminar

Rethinking Parity Anomaly in Quantum Matter:
From a Misconception to the Discovery of the Half-Quantized Hall Effect

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Time: 1:30 pm, June 11, 2026 (Thursday)

时间：2026年6月11日（周四）下午1:30

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

The half quantized Hall effect is a newly identified macroscopic quantum phenomenon in two-dimensional ferromagnetic semimetals. Unlike the conventional integer and fractional quantum Hall effects, which occur in insulating phases, this effect appears in a metallic system with finite longitudinal conduction. As a result, the Hall resistance is not quantized; instead, it is the Hall conductance that exhibits half-integer quantization, while the longitudinal conductance remains finite.

The origin of this phenomenon can be traced back to the parity anomaly proposed in quantum field theory in the early 1980s. The original theoretical picture suggested that massive Dirac fermions could generate a half-integer quantized Hall conductance, an idea that was later introduced into condensed-matter physics. Following the discoveries of graphene and topological insulators, the parity anomaly attracted broad interest and played an important role in the theoretical development leading to the prediction and discovery of the quantum anomalous Hall effect. However, in 2021, my collaborators and I found that the accepted picture needed to be revised: it is a single massless Dirac cone, rather than massive Dirac fermions, that gives rise to the half-integer quantized Hall conductance. This reversal led us to reexamine the physical origin of the parity anomaly in condensed-matter systems. Over the past several years, we have shown that a system with a single massless Dirac cone exhibits three characteristic features: half-integer Hall conductance, a minimum longitudinal conductance, and a Hall current that decays algebraically from the boundary. These predictions have recently been confirmed experimentally in magnetic topological-insulator thin films, providing evidence that the parity anomaly is realized in massless, rather than massive, Dirac fermions.

In this talk, I will present the historical development of this topic, from its field-theoretical origin to its modern realization in quantum materials. I will discuss the key theoretical ideas, recent experimental progress, and the broader implications for topological phases and quantum transport. I will also reflect on how an initially incorrect theoretical picture can nevertheless stimulate important developments and eventually lead to the discovery of new physics.

References:

- S. Q. Shen, *Absence of parity anomaly in massive Dirac fermions on a lattice*, Phys. Rev. B 113, 155412 (2026)
- B. Wang, J. Hu, B. Fu, J. Li, Y. Kong, K. Z. Bai, S. Q. Shen and Di Xiao, *Parity anomalous semimetal with minimal conductivity induced by an in-plane magnetic field*, Phys. Rev. Lett. 136, 146602 (2026)
- B. Fu, J. Y. Zou, Z. A. Hu, H. W. Wang, and S. Q. Shen, *Quantum anomalous semimetals*, npj Quantum Materials **7**, 94 (2022).

About the speaker

Shun-Qing Shen is Chair Professor of Condensed Matter Physics in the Department of Physics at The University of Hong Kong. He is a theoretical condensed-matter physicist whose research focuses on topological insulators, quantum transport, and novel quantum states of matter. He has made important contributions to the understanding of topological phases and related transport phenomena, and is the author of the monograph *Topological Insulators* published by Springer in 2012.

Professor Shen received his B.Sc., M.Sc., and Ph.D. degrees from Fudan University in Shanghai. He was a postdoctoral researcher at the China Center of Advanced Science and Technology (CCAST) in Beijing, a Humboldt Fellow at the Max Planck Institute for the Physics of Complex Systems in Dresden, Germany, and a JSPS Fellow at the Tokyo Institute of Technology in Japan. He joined the Department of Physics at The University of Hong Kong in 1997.