Quantum Hall Effects in Graphite

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Our team has uncovered new physics in graphite by focusing on the quantum Hall effect (QHE) and high magnetic field phenomena. We discovered a novel 2.5-dimensional (2.5D) QHE that persists in thick graphite films and shows layer number parity dependence [1]. In thinner films, we observed exotic phenomena such as fractional 2.5D QHE, magnetic ordering, and spontaneous valley polarization. By combining van der Waals technology with crystallographic alignment, we discovered that changes in surface states drastically alter bulk states, leading to the 2.5D fractal QHE [2]. This demonstrates a new approach to controlling 3D materials using twistronics. Furthermore, controlling interlayer stacking in graphene layers allows the programming of quantum properties of graphite films. By tuning the stacking order, we fabricated rhombohedral graphite films and revealed strong electronic correlations [3, 4], offering an alternative approach to program layered crystals without moiré superlattices. These findings highlight the rich new physics in graphite, inspiring further exploration and potential applications.

[1] J. Yin, S. Slizovskiy, Y. Cao, *et al.*, *Nat. Phys.* **15**, 437 (2019).
[2] C. Mullan, S. Slizovskiy, J. Yin, *et al.*, *Nature* **620**, 756 (2023).
[3] Y. Yang, Y.-C. Zou, C.R. Woods, *et al.*, *Nano Letters* **19**, 8526 (2019).
[4] Y. Shi, S. Xu, Y. Yang, *et al.*, *Nature* **584**, 210 (2020).