

Geometrical response in moiré Fractional Chern Insulator

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Fractional Chern insulators (FCIs) are strongly correlated topological phases that realize fractional quantum Hall physics in lattice systems without an external magnetic field. Recent observations of fractional quantum Hall behavior in twisted bilayer MoTe₂ (tMoTe₂) have provided strong evidence for the realization of FCI states in moiré semiconductors [1]. Unlike conventional Landau levels, however, moiré Chern bands generally possess nonuniform quantum geometry, and how such geometric properties are reflected in the interacting many-body state remains an important open question.

In this work, we investigate how the Hall viscosity of an FCI evolves with experimentally tunable parameters in a realistic moiré model of tMoTe₂. Hall viscosity is a nondissipative stress response to an area-preserving shear deformation [2] and is known to characterize geometric properties of fractional quantum Hall wave functions in continuum systems [3]. This motivates us to examine whether Hall viscosity can provide complementary information about FCI states in moiré systems, where lattice effects and nonuniform quantum geometry play essential roles.

We study the $\nu = 1/3$ state of an interacting continuum model of tMoTe₂ using exact diagonalization [4] and calculate the many-body Hall viscosity by introducing an area-preserving geometric deformation into the Hamiltonian. By varying the twist angle and displacement field, we construct a phase diagram of the Hall viscosity and compare it with the many-body excitation gap, which is commonly used as an indicator of the robustness of an incompressible FCI state.

We find that the Hall viscosity varies strongly with twist angle and displacement field, and its phase-diagram structure closely follows that of the many-body excitation gap. This correlation reveals a close connection between the geometric response of the many-body wave function and the energetic stability of the FCI state. Our results demonstrate that Hall viscosity provides a geometric diagnostic of FCI stability in realistic moiré systems.

[1] J. Cai *et al.*, Nature **622**, 63 (2023).

[2] J. E. Avron, R. Seiler, and P. G. Zograf, Phys. Rev. Lett. **75**, 697 (1995).

[3] N. Read, Phys. Rev. B **79**, 045308 (2009).

[4] P. Sharma, Y. Peng, and D. N. Sheng, Phys. Rev. B **110**, 125142 (2024).