# Tunable Topological Phase Transitions in Rhombohedral Pentalayer Graphene

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In two-dimensional electron systems, a combination of non-trivial band topology and strong electronic interactions can give rise to correlated topological phases beyond the single-particle picture. Rhombohedral pentalayer graphene, with its concentrated Berry curvature and large density of states near the conduction band edge [1], is a promising candidate for realizing such phases. When the graphene is aligned to a layer of hexagonal boron nitride (hBN), a moiré superlattice develops at the interface due to the slight lattice mismatch and the system develops narrow moiré minibands. A recent experiment on this material platform demonstrated the fractional quantum anomalous Hall effect (FQAHE) [2], the long-sought zero-field analogue of the fractional quantum Hall effect first observed over four decades ago. The FQAHE appears in the moiré-distant case, when the conduction electrons are pushed away from the hBN interface. We explore this system in the moiré-proximal limit, where the superlattice potential is considerably stronger.

Here, we report a variety of correlated phases at fractional fillings of the first moiré miniband. In particular, we observe a close competition between generalized Wigner crystals, fractional Chern insulators, and symmetry-broken Chern insulators, states exhibiting both charge density wave order and non-trivial topology. At a particular displacement field, the fractional Chern insulator at $\nu = 1/3$ filling persists to nearly zero magnetic field, highlighting the favorable quantum geometry of the band. The phase diagram is highly sensitive to both displacement and magnetic fields, which modify the band dispersion and redistribute the electronic wavefunctions over the moiré Brillouin zone. Our quantum capacitance measurement enables precise displacement field control not possible with local probes and provides access to the electronic compressibility $\partial n/\partial \mu$, which we use to extract charge gaps for various correlated phases. Our work establishes the pentalayer graphene-hBN system in the moiré-proximal limit as a highly tunable platform for the study of topological phase transitions.

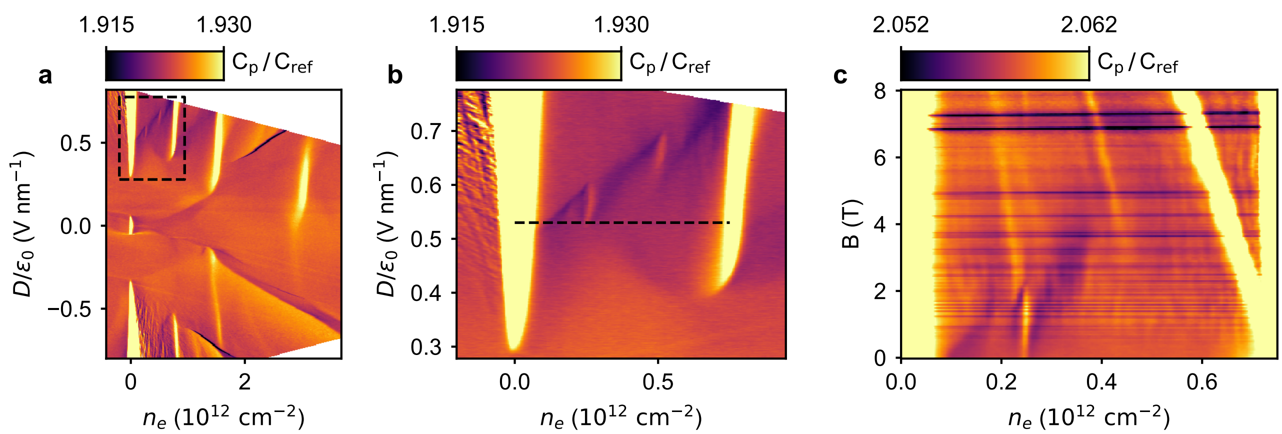


Fig. 1. **a)** Penetration capacitance of the rhombohedral pentalayer graphene superlattice as a function of electron density and displacement field. Bright features correspond to incompressible states. **b)** High-resolution map of the penetration capacitance between moiré miniband filling $\nu = 0$ and $\nu = 1$, within the dashed box in **a**. **c)** Magnetic field dependence of the compressibility along the dashed line in **b**.

References

[1] A. Kumar and R. Nandkishore, Physical Review B **87**, 241108 (2013)

[2] Z. Lu et al. Nature **626**, 759-764 (2024).