Moiré fractional Chern insulators from topological bosons and trivial fermions

Raul Perea-Causin
Hui Liu, Zhao Liu, Emil J. Bergholtz

Department of Physics, Stockholm University, AlbaNova University Center, Stockholm, Sweden

raul.perea.causin@fysik.su.se

Recent realizations of fermionic fractional Chern insulators (FCIs) and anomalous Hall crystals have established moiré systems as a powerful platform for exploring strongly-correlated topological phases [1-4].

Here, we predict the emergence of robust bosonic topological order arising from long-lived interlayer excitons consisting of holes in twisted bilayer WSe_2 and electrons in an additional $MoSe_2$ layer [5]; cf. Fig. 1. In particular, exact diagonalization reveals that realistic long-range interactions stabilize Laughlin and non-Abelian Moore–Read states at filling factors 1/2 and 1 of the exciton Chern band present in this system.

In parallel, we uncover (Laughlin-like) fermionic FCIs in topologically trivial bands of twisted multilayer graphene, where a strongly inhomogeneous quantum geometry drives topological order independent of band topology [6].

Together, these results highlight the extraordinarily rich landscape of moiré quantum matter, encompassing both bosonic and fermionic topological order shaped by quantum geometry.

References

[1] H. Park, et al., Nature, 622 (2023) 74
[2] F. Xu, et al., Phys. Rev. X, 13 (2023) 031037
[3] Y. Zeng, et al., Nature, 622 (2023) 69
[4] R. Su, Nature, 637 (2025) 1084
[5] R. Perea-Causin, H. Liu, E. J. Bergholtz, Phys. Rev. Res., 7 (2025) L042033
[6] H. Liu, R. Perea-Causin, Z. Liu, E. J. Bergholtz, preprint at arXiv:2510.1502

Figures

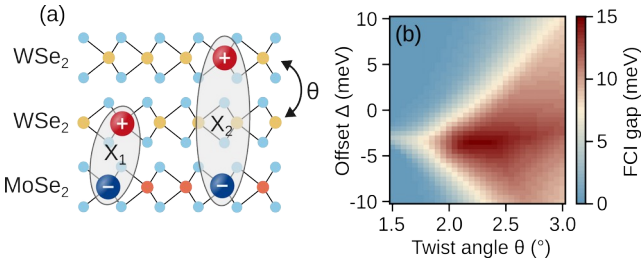

Figure 1: (a) Interlayer excitons in the $tWSe_2$-$MoSe_2$ structure. (b) Energy gap of the FCI (Laughlin) ground state vs. twist angle and offset between the X_1 and X_2 energies. The latter can be controlled by a vertical electric field.

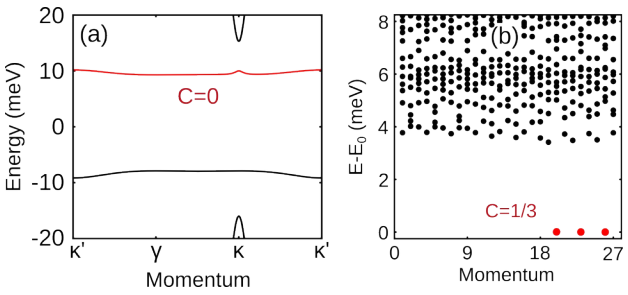

Figure 2: (a) Trivial band in a tuned theoretical model of twisted bilayer graphene. (b) Many-body energy spectrum obtained by exact diagonalization of the interacting 1/3 filled trivial band in a finite-size system. The threefold degenerate ground state with Chern number C=1/3 corresponds to a Laughlin state.