Discovering emergent correlated states and quantum phase transitions in a moiré superlattice

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Abstract:
New phase of matter usually emerges when a given symmetry breaks spontaneously, which can involve charge, spin, and valley degree of freedoms. By twisting graphene multilayer to form a moiré superlattice, it leads to moiré flat band where various correlated states are developed. Here, we observe valley polarized correlated insulator [1] at half fillings in twisted double bilayer graphene (TDBG), as shown schematically in Fig.1a, resulted from an isospin competition between spin and valley flavours. The valley polarized correlated insulators are found hosting anomalous quantum oscillations (QOs) [2] with a period of 1/B (Fig.1b), and the periodicity strongly displacement field dependent: the carrier density extracted from the 1/B periodicity decreases almost linearly with D from -0.7 to -1.1V/nm. In addition to the discoveries in the valley polarization, we have observed first order phase transitions and ferromagnetism [3] in the spin polarized correlated insulator in TDBG, and have also observed many other first-order phase transitions with hysteresis when valley degree of freedom competes in finite magnetic field. Our study suggests that TDBG is an excellent platform to discover exotic phases where correlation and topology are at play.

References

[1] Le Liu, Wei Yang*, et al., Isospin competitions and valley polarized correlated insulators in twisted double bilayer graphene, Nature Communications, 13, 3292 (2022).
[2] Le Liu, Wei Yang*, et al., Quantum oscillations in correlated insulators of a moiré superlattice. arXiv: 2205.10025(2022).
[3] Le Liu, Wei Yang*, et al., Observation of first-order phase transitions and ferromagnetism in twisted double bilayer graphene. To be submitted (2023).

Figures

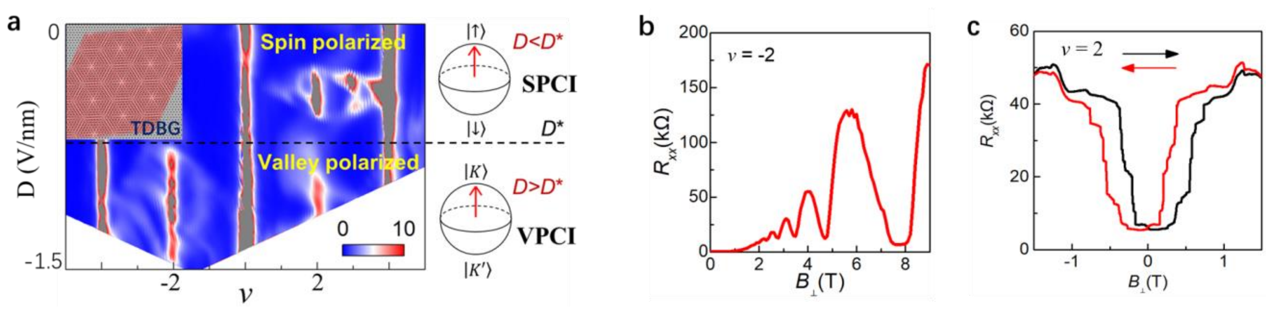

Figure 1: (**a**) A colour mapping of resistance as a function of moiré band filling (ν) and displacement field (D) in TDBG, and SPCI and VPCI denote spin polarized and valley polarized correlated insulator, respectively. (**b**) Unconventional quantum oscillations in the VPCI at ν=-2 (D>D*). (**c**) Evidences of the first-order phase transitions and ferromagnetism in the SPCI at ν=2 (D<D*).