Aharonov-Bohm oscillations on a network of trajectories joined by magnetic breakdown as a precursor of Brown-Zak fermions in twistronic graphenes

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Brown-Zak magnetic minibands for electrons are common for metals with a rational value of magnetic field flux, $\phi = \phi_0\, p/q$, piercing the unit cell of a crystal [1]. Here, we study how this ultra-quantum phenomenon, usually, attributed to strong magnetic fields emerges at low magnetic fields and moderate temperatures from the interplay between peculiar dynamics and interference of electrons at the fundamental Lifshitz transition (LT), realised using moire superlattice miniband in twistronic graphene. We show that precursors of Brown-Zak minibands appear in the form of Aharonov-Bohm oscillations of conductivity produced by electrons propagating along entwining paths with a kagom\'e network topology, Fig.1(left). We report the observation of coinciding features in the vicinity of LT of both in twisted tetralayer graphene and in highly aligned graphene - hexagonal boron nitride heterostructures. In particular, the maximal amplitude of conductance oscillations is located in the vicinity of LT, displacing from the LT by the amount growing linearly in the magnetic field Fig.1 (right). These findings are naturally explained by the topology of interfering paths.

References

[1] R. K. Kumar, X. Chen, G. Auton, A. Mishchenko, D. A. Bandurin, S. V. Morozov, Y. Cao, E. Khestanova, M. B. Shalom, A. Kretinin, et al., Science 357, 181 (2017).

Figures

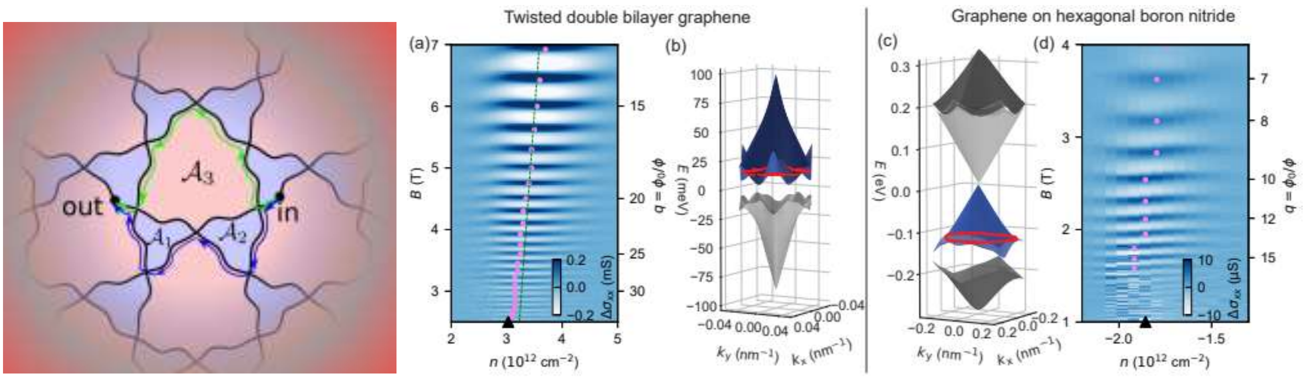

Figure 1: Left: At the LT, ballistic trajectories of electrons in a magnetic field form a kagome network. Green and blue lines in (b) exemplify the shortest paths responsible for quantum magneto-oscillations at the LT. Due to magnetic breakdown, electrons scatter at the intersections of chiral paths (linked to the saddle points in the band dispersion.
Right: The shift of the oscillations maxima in twisted double bilayer graphene (a,b) and graphene aligned to boron nitride (c,d). Pink dots are the maxima of the oscillations, bending away from LT. The green dashed line is a theoretical fit to this data. The LT density is indicated with the solid triangle.