Kagomé quantum oscillations in graphene superlattices

Sergey Slizovskiy,
Folkert K. de Vries, Petar Tomić, Aitor Garcia-Ruiz, Giulia Zheng, Peter Rickhaus, Thomas Ihn, Klaus Ensslin, Vladimir Fal'ko
National Graphene Institute,University of Manchester, UK and ETH, Zurich, Switzerland.
Sergey.Slizovskiy@manchester.ac.uk

Periodic systems feature the Hofstadter butterfly spectrum produced by Brown-Zak minibands of electrons formed when magnetic field flux through the lattice unit cell is commensurate with flux quantum and manifested by magneto-transport oscillations. Quantum oscillations, such as Shubnikov - de Haas effect and Aharonov-Bohm effect, are also characteristic for electronic systems with closed orbits in real space and reciprocal space. Here we show the intricate relation between these two phenomena by tracing quantum magneto-oscillations to Lifshitz transitions in graphene superlattices, where they persist even at relatively low fields and very much above liquid-helium temperatures. The oscillations originate from Aharonov--Bohm interference on cyclotron trajectories that form a kagomé-shaped network (Fig.1 left) characteristic for Lifshitz transitions. In contrast to Shubnikov - de Haas oscillations, the kagomé oscillations are robust against thermal smearing and they can be detected even when the Hofstadter butterfly spectrum is undermined by electron's scattering. We expect that kagomé quantum oscillations are generic to rotationally-symmetric two-dimensional crystals close to Lifshitz transitions. We report the observation of coinciding features in the vicinity of LT of both the twisted double graphene bilayer and in highly aligned graphene - hexagonal boron nitride heterostructures, Fig.1 (right). 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 [1]

References

[1] F. K de Vries, S. Slizovskiy, P. Tomić, R. Krishna Kumar, A. Garcia-Ruiz, G. Zheng, E. Portolés, L. A. Ponomarenko, A. K. Geim, K. Watanabe, T. Taniguchi, V. Fal'ko, K. Ensslin, Th. Ihn, P. Rickhaus, arXiv **2303.06403**, under review in Nat.Comm.

Figures

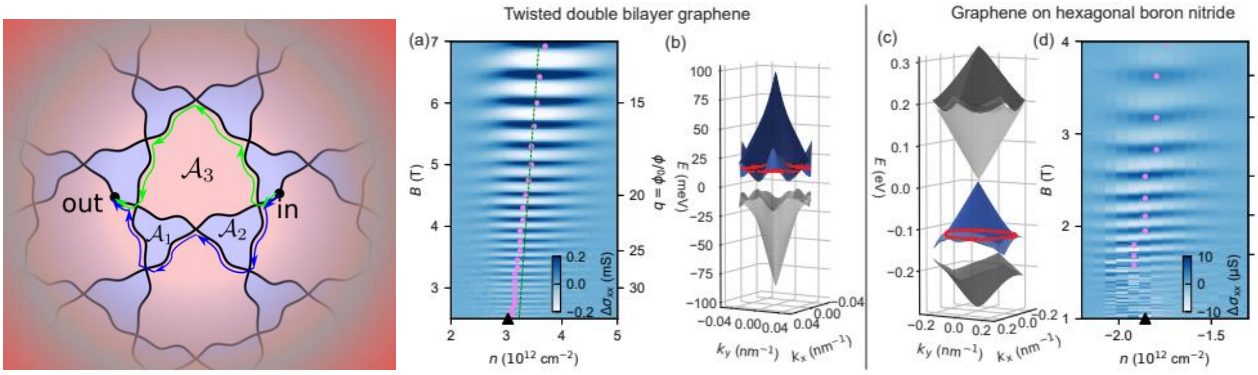

Figure 1: Left: At the LT, ballistic trajectories of electrons in a magnetic field form a kagomé network. Green and blue lines exemplify the shortest paths responsible for quantum magneto-oscillations at the LT. Due to magnetic breakdown, electrons scatter near the saddle points in the band dispersion.