Universal sequence of Chern insulators in superconducting magic angle graphene

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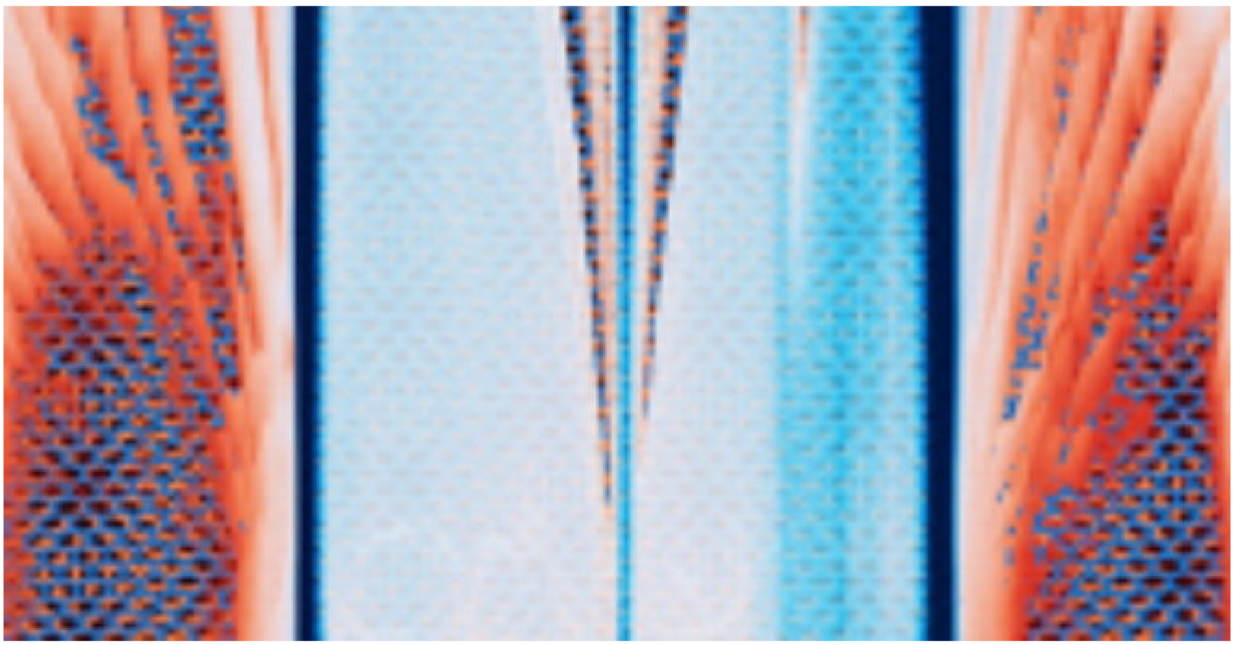

Energy spectrum of magic angle moire graphene in magnetic field, showing magic series of Chern insulators inside of the flatbands and landau level crossings in the dispersive bands. Credit: ICFO

Scientists from ICFO, Princeton and NIMS have discovered a full sequence of symmetry-broken Chern insulators that are induced by strong correlations in magic angle graphene. The study has been published in *Nature Physics*.

A Chern insulator is a 2D insulator that spontaneously breaks time-reversal symmetry and hosts conducting chiral edge states. The study of Chern insulators in the past decade has deepened the understanding of condensed matter and could lead to the development of low-power-consumption electronics. Magic angle twisted bilayer graphene (MATBG) has recently emerged as a rich platform to explore strong correlations, superconductivity and magnetism and band topology.

In a recent study published in *Nature Physics*, a team of scientists including ICFO researcher Ipsita Das, Xiaobo Lu (former postdoc at ICFO), led by ICFO Prof. Dmitri Efetov and colleagues from Princeton (Jonah Herzog-Arbeitman, Zhida Song and B. Andrei Bernevig) and the National Institute for Material Sciences (Kenji Watanabe and Takashi Taniguchi), has reported a full sequence of symmetry-broken Chern insulators within the flatbands of magic angle graphene.

In contrast with traditional Chern insulators, which are usually achieved in magnetized topological insulators, the newly discovered Chern insulators in magic angle graphene, which only consists of non-magnetic carbon atoms, originate from strong correlation induced symmetry breaking. In their experiment, they used magneto-transport technique to measure both longitudinal resistance and hall resistance. They managed to observe Chern insulators with a magic sequence of quantized Hall conductance C = ±1, ±2, ±3, ±4 which nucleate from integer fillings of the moire unit cell = ±3, ±2, ±1, 0 correspondingly. The magic sequence and correspondence of Chern numbers and filling factors suggest that these states are driven directly by electronic interactions which specifically break time-reversal symmetry in the system.

Furthermore, they studied quantum magneto oscillations in the as-yet unexplored higher energy dispersive bands of magic angle bilayer graphene. In a magnetic field, the energy spectrum shows a rich sequence of level crossings that directly come from the unique Rashba-like dispersion of the bands. Further analysis of the Landau-level crossings allowed the researchers to provide constraints on the parameters w0 and w1 of the Bistritzer-MacDonald MATBG Hamiltonian.

The study provides direct insights into the complex nature of symmetry breaking in MATBG and allows for quantitative tests of the proposed microscopic scenarios for its electronic phases. Ipsita Das, researcher at ICFO and first author of the study says, "We were quite stunned when we saw the richness of these new topological states for the first time."

Dr. Xiaobo Lu, former ICFO postdoc and coauthor of this study, says, "the observation of nontrivial topology in superconducting magic angle graphene is exciting. The integration of strong correlation, superconductivity and Chern insulating phases in magic angle bilayer graphene could lead to new research avenues in the future."

Prof. at ICFO Dmitri Efetov says, "Such achievements mark the next step in the understanding of the amazing properties of twisted bilayer graphene, adding now topology as one of its defining characteristics."

More information: Ipsita Das et al. Symmetry-broken Chern insulators and Rashba-like Landau-level crossings in magic-angle bilayer graphene, *Nature Physics* (2021). DOI: 10.1038/s41567-021-01186-3

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