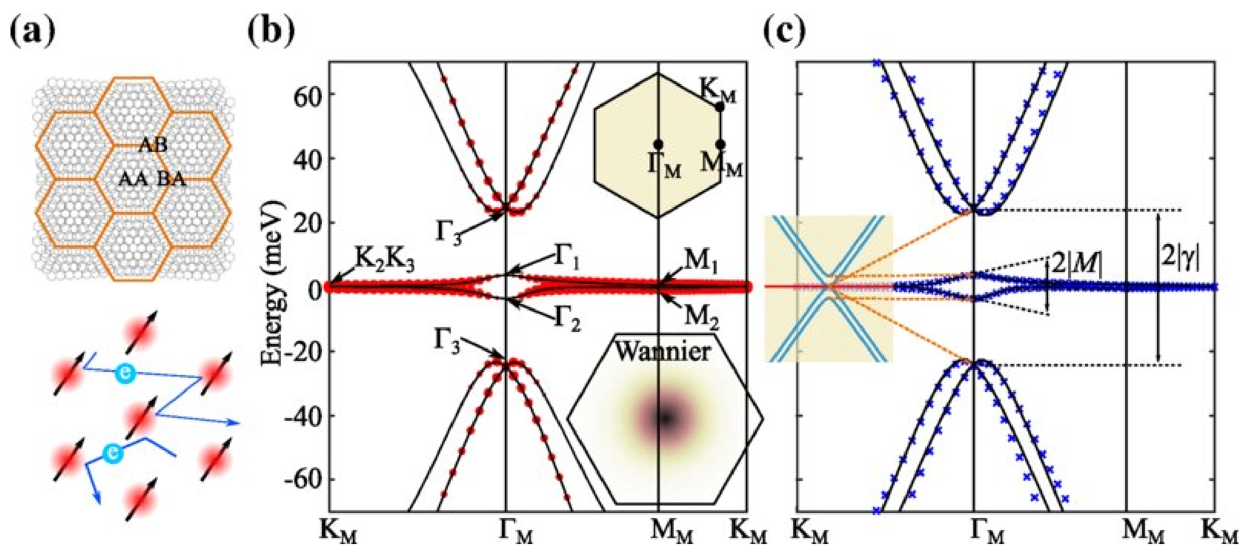
Twisted-graphene model exhibits complex electronic behavior

August 9 2022, by Bob Yirka



Topological heavy fermion model. (a) A sketch of the moiré unit cell of MATBG and its heavy fermion analog, where the local moments and itinerant electrons are formed by the effective *f* orbitals at the *AA* -stacking regions and topological conduction bands (c), respectively. (b) The band structure of the BM model at the magic angle $\theta=1.05°$, where the moiré BZ and high symmetry momenta are illustrated in the upper inset panel. The overlaps between the Bloch states and the trial WFs are represented by the red circles. The density profile of the constructed maximally localized WFs (*f* orbitals) is shown in the lower inset panel. (c) Bands given by the topological heavy fermion model (black lines) compared to the BM bands (blue crosses). The c (blue) and *f* bands (red) in the decoupled limit, where $\gamma=v'_\star=0$, are shown in the inset. Orange dashed lines indicate the evolution of energy levels as $f-c$ coupling is turned on. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.047601

A pair of researchers, one with Peking University, the other with Princeton University, has found that the parameters of twisted-graphene's excitation spectra correspond directly to attributes of the heavy fermion model. In their paper published in the journal *Physical Review Letters,* Zhi-Da Song and B. Andrei Bernevig describe building a model to show aspects of the Bistritzer-MacDonald model and then used it to demonstrate characteristics of twisted bilayer graphene. Aline Ramires with the Paul Scherrer Institute has published a News & Views piece in the journal *Nature* outlining the work by Bernevig and Song.

Graphene is a flat, 2D sheet of carbon and a subject of considerable research. One research effort four years ago involved placing one sheet of graphene on top of another and then twisting the top sheet. After much trial and error, those researchers found that twisting the top sheet a certain amount (1.05 degrees) led to the creation of a superconductor. That led them to refer to the twisted amount as a "magic angle."

Since that time, other researchers have been studying the attributes of twisted bilayer graphene aligned at its magic angle. In this new effort, the researchers studied its excitation spectra and found it corresponded to the parameters of the fermion model.

Prior work has shown that twisted bilayer graphene at just the right orientation takes on some unique properties—one set of electrons, for example, moves around, which accounts for its conductivity. But another set of electrons remain fixed. The two contradictory characteristics of the material allow scientists to push a sample between an insulator and a superconductor.

To better understand why this happens, Song and Bernevig created a model of the system and then used it to carry out exact calculations describing the behavior of the material. They found that they were able to describe the structure of twisted bilayer graphene as it compared to heavy fermion materials. More work showed that the parameters of the material corresponded directly to the parameters of the heavy fermion model. Heavy fermion materials are those that are found at the bottom of the periodic table.

More information: Zhi-Da Song et al, Magic-Angle Twisted Bilayer Graphene as a Topological Heavy Fermion Problem, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.047601

Aline Ramires, Twisted-graphene model draws inspiration from heavy elements, *Nature* (2022). DOI: 10.1038/d41586-022-02108-w