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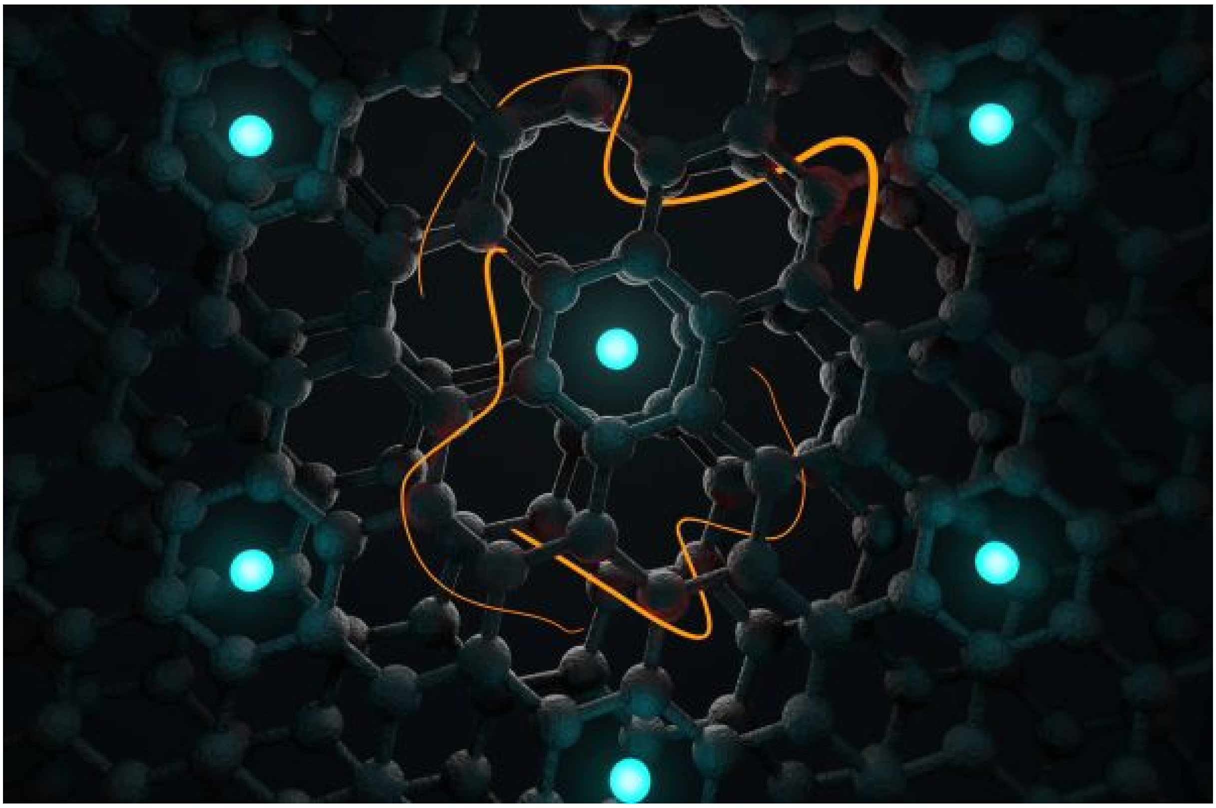

Magic-angle twisted bilayer graphene hosts two distinct electronic species

A team of researchers provides direct evidence of two electronic ?species' coexisting in magic-angle twisted bilayer graphene. The technique, based on thermoelectric measurements, provides insight into the strongly-correlated phases of this condensed matter platform.

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During the mid-20th century, the idea of a one-atom-thick layer of graphite was theorized. The term ï¿½grapheneï¿½ was introduced some years later, in 1986, by chemists Hanns-Pet r Boehm, Ralph Setton and Eberhard Stumpp. Once single graphene layers were successful y produced, scientists noticed their remarkable properties: they are flexible, light yet stron , excellent thermal and electrical conductors, and host a myriad of intriguing physic l phenomen . However, it turns out that two layers of graphene can create an even more fascinati g system. That became evident in March of 2018, when an international team led by Pab o Jarillo-Herrero from MIT reported the discovery of superconductivity after stacking two layers of graphene on top of each other with a twist angle of approximately 1.1 . At this very specific ?magic angle', the electronic properties change so dramatically that exotic physical phenomena - like the discovered superconductivity- emerge.

Despite the enormous research effort around magic-angle twisted bilayer graphene (MATBG), many open questions remain. One of them concerns its energy band structure. Normally, in a solid, electrons can move through a range of energy bands, and the curvature of these bands determines how fast the electrons can move-their effective mass. But in MATBG, some of the bands are nearly flat. What are the electrons in the flat bands like? How do they behave, and what are the consequences of such behaviors?

Now, ICFO researchers **Dr. Rafael Luque Merino**, **Dr. Jaime Diez-Merida** (now member of the STM on 2D Quantum Materials group at ICFO), **Andres Diez-Carlon**, **Dr. Paul Seifert**, led by the former ICFO Professor Dmitri K. Efetov, now Professor at Ludwig-Maximilians-Universitat and the Munich Center for Quantum Science and Technology (MCQST), together with other research institutions, have provided experimental evidence of the coexistence of two electronic ?species' in the flat bands of MATBG. ï¿½This had been hinted at experimental y before, but lacked direct evidence, which we have provided for the first time,ï¿½ shares Dr. Rafael Luque Merino, first author of the arti le. One of the species corresponds to itinerant electrons, similar to the ?usual' free electr ns. Such electrons can move across the material, carrying charge and heat. Due to their igh mobility, and low effective mass, they are sometimes referred to as ?light carriers'. The o her species resides in highly localized orbitals and interact very strongly between them, w ich causes a drastic reduction of their mobility. Consequently, these ?heavy carriers' do not contribute significantly to charge and heat transp

Researchers recorded an unusual thermoelectric response

The interplay between heavy and light carriers, which have very different properties, gave rise to an unusual thermoelectric response. To record it, the researchers used a focused laser beam to locally heat the electrons in the MATBG. By tuning the experimental setup appropriately, they managed to ?direct' the heat gradient that the hot electrons followed. As the electrons carry charge, this naturally generated a voltage, that is, a thermoelectric signal. ï¿½One might expect that the overall thermoelectric response coming from all the electro s would cancel out at specific fillings of the flat bands.ï¿½ said Rafael. ï¿½But that is n t the case. It turns out that, at those specific fillings, heavy carriers are incredibly localized nd do not contribute to the thermoelectric signal. This happens due to their localiz d and strongly-interacting natu

The proposed method, based on thermoelectric measurements, served as a powerful tool to probe the asymmetry in the properties of the flat-band electrons. Since the presence of strong interactions between electrons has long been acknowledged as the underlying cause of many correlated physics effects, **the technique could thus be applied to many other**

correlated phases that appear in twisted 2D materials.

Moreover, the team observed that the system behaved differently depending on the temperature. In particular, at low (cryogenic) temperatures, light carriers dominated the response. But, surprisingly, at higher temperatures, the roles were reversed. ï¿½We fou d that these results can be explained naturally in this scenario of two electronic specie , through the so-called Topological Heavy Fermion model for twisted bilayer graphene,ï¿½ sa s Dr. Luque Merino. Within this model, put forward by Andrei Bernevig and Zhi-Da Song, bo h the low- and high-temperature thermoelectricity could be understood quite elegantly. ï¿½ **After our discovery, I think more and more people will explore this ?heavy fermion' framework to model the properties of twisted graphene, hopefully shedding more light on these intriguing materials.ï¿½**

Reference:

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