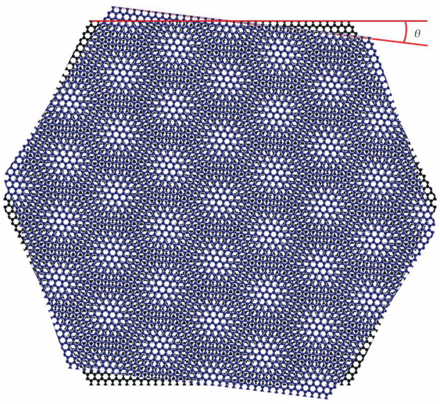
Master project: Interaction effects in twisted bilayer graphene

Background: Graphene is an artificial two-dimensional material made of a single sheet of carbon atoms that form a hexagonal lattice. Electrons moving in this lattice have many unusual properties: For example, they are described by the Dirac equation, which was originally invented for relativistic electrons (i.e., electrons moving close to the speed of light), a behaviour that is different from most metals or semiconductors. For the past decade, intensive efforts have been devoted to study the unusual properties of graphene structures and maybe even use them in technological devices.

A system of current interest are two graphene sheets stacked on top of each other. The lattice structure of theses two sheets may be twisted with respect to each other, and hence this setup is called "twisted bilayer graphene". Here, it turns out that interactions between the electrons are very important and give rise to a number of new thermodynamic phases like superconductivity. From a theoretical point of view, it is very challenging and interesting to describe such interacting systems.



Left: Sketch of two graphene sheets on top of each other. With a small twist angle between the sheets, a superstructure (called a Moiré lattice) becomes apparent. Right: The QR code links to a popular article on the subject by quantamagazine.org called "With a Simple Twist, a 'Magic' Material Is Now the Big Thing in Physics"

Project proposal: When interactions are taken into account, the graphene-relativistic electrons will behave collectively, and these collective excitations are often more closely related to experimental data and give important clues to the nature of thermodynamic phases. In this project, you will explore the exotic collective behaviour of electrons in twisted bilayer graphene. Possible projects are related, for example, to so-called plasmonic or nematic excitations. Please talk to us to find out more.

A basic knowledge of solid state physics and some thermodynamics is highly advantageous. Work on these projects will involve analytical calculations but will also require some numerical work, where the choice of programming language and platform is left to you.

The project is suitable for one or more students. Office space at Physics is expected to be available, but depending on future corona-virus restrictions we might have to work remotely.

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