Gourmet Physics - Berries and Cakes in Graphene Quantum Dots

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The quantization of energy due to quantum confinement, taking place when the particle's de Broglie wavelength becomes comparable to the system's length scale, is a striking manifestation of quantum coherence. Quantum dots (QD) offer an ideal platform for studying the interplay between quantum confinement, caused by spatial constraints or by large magnetic fields via cyclotron motion, and interaction effects. Recently, the ability to apply local nanometer scale gate potentials in graphene heterostructures has enabled the creation of QDs for Dirac particles. Graphene QDs are formed inside circular *p-n* junction [1,2], where one has detailed control of electron orbits by means of local gate potentials and magnetic fields. In this talk, I describe scanning tunneling spectroscopy measurements of the energy spectrum of graphene QDs as a function of energy, spatial position, and magnetic field. In zero field, the Dirac quasiparticles are confined by Klein scattering at large incident angle at the *p-n* junction boundary. The confined carriers give rise to an intricate eigenstate spectrum, characterized by radial and angular momentum quantum numbers, effectively creating a multi-electron artificial atom [1]. Applying a weak magnetic field results in a sudden and giant increase in energy for certain angular momentum states of the QD, creating a discontinuity in the energy spectrum as a function of magnetic field [2]. This behavior results from a π-Berry phase associated with the topological properties of Dirac fermions in graphene, which I show can be turned on and off with magnetic field. With increased applied magnetic field, the QD states are observed to condense into Landau levels, providing a direct spatial visualization of the transition from spatial to magnetic confinement in these artificial graphene atoms. We directly observe the development of a multi-tiered "wedding cake"-like structure of concentric rings of compressible/incompressible quantum Hall states, a signature of electron interactions in the system [3]. Addressing the compressible rings shows Coulomb blockade peaks in the conductance measurements. A characteristic feature of the Coulomb blockade in these systems is the presence of different families of charging lines, one for each Landau level, which intersect each other and experience avoided crossings. The avoidance pattern of these anticrossings is novel and reflects the interaction of electrons in different Landau level compressible rings, occupying different parts of the QD, and is tunable via the magnetic field and gate voltage.

REFERENCES:

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