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Strongly Correlated Electron Phenomena in Carbon Nanotubes

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In this talk I will discuss our recent results demonstrating strongly correlated electron behavior in ultra-clean carbon nanotube quantum dots. Specifically, we have observed one-dimensional (1D) Wigner crystal behavior of dilute holes in semiconducting nanotubes, finding three distinct regimes of spin and valley quantum number ordering as the charge density and axial magnetic field are varied. The boundaries between the regimes in density and magnetic field are well-described by the theory of Levitov and Tsvelik for a narrow-gap Luttinger liquid. In the second part of the talk I will present results showing that the electrons in nominally metallic nanotubes comprise a 1D Mott insulator. This indicates that carbon nanotubes are never truly metallic, in agreement with theoretical predictions that account for Umklapp scattering at half-filling due to electron-electron interactions. Using inelastic cotunneling spectroscopy, we also observe neutral electronic excitations within the gap, yielding an additional signature of the Mott insulating state. Our results demonstrate nanotubes' promise for studying a variety of tunable correlated electron phenomena in 1D.