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Symmetries and interaction effects in carbon nanotube quantum dots[1]

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By controlling the contact transparency within the same nanotube quantum dot, we observe the conductance evolving from the well- developed Coulomb blockade through the Kondo regime to the mixed valence regime. We work with high quality nanotubes, where energy subbands are doubly-degenerate, resulting in the SU(4) Kondo effect for one, two, and three electrons filling two degenerate orbitals. As the contacts are made more transparent, the sample enters the mixed valence regime, where different charge states within a pair of orbitals are hybridized. The hallmark of this regime in nanotube conductance is washing out of single-electron features at low temperature. In our measurement the level broadening is close to the charging energy and level spacing (both ≈ 10 meV). Nevertheless, the low temperature regime is established only at temperatures of the order or less than 0.5 meV. The same low energy scale is also apparent from the width of the zero-bias peak in the tunneling density of states.

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