

## Kondo temperatures in nanoscale quantum dots

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Electron correlation is manifested at low temperature as Kondo effects. Contrary to the fact that the resistivity rises upon lowering the temperature for the bulk Kondo system, quantum dots usually exhibit the zero-bias resonant tunnelling, known as the non-equilibrium Kondo effect. This has been observed in several experiments on various quantum dots, such as a single-electron-transistor, carbon nanotubes and molecular quantum dots.<sup>1</sup> It is known that the Kondo temperature for non-equilibrium quantum dot system increases when the electronic degrees of freedom increases, as reported in emergent SU(4) or two channel Kondo system.<sup>2</sup>

Here we present different kinds of quantum dot systems exhibiting the Kondo behavior by controlling the size of degeneracy under external electric or magnetic field. The non-crossing or one-crossing approximation for the electronic self-energy is used together with non-equilibrium Green's functions formalism for the electron transport.

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1. Goldhaber-Gordon, D. *et al.* *Kondo effect in a single-electron transistor*, Nature 391, 156-159 (1998).  
Cronenwett, S.M., Oosterkamp, T.H., Kouwenhoven, L.P. *A tunable Kondo effect in quantum dots* Science 281, 540-544 (1998).  
Nygard, J., Cobden, D.H., Lindelof, P.E. *Kondo physics in carbon nanotubes* Nature 408, 342-346 (2000).
  2. Jarillo-Herrero, P. *et al.* *Orbital Kondo effect in carbon nanotubes* Nature 434, 484-488 (2005).  
Potok, R.M. *et al.* *Observation of the two-channel Kondo effect* Nature 446, 167-171 (2007).