# Conductance Signatures of Kondo Interference and Quantum Criticality in Double Quantum Dots

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## Introduction

Semiconductor quantum dots offer unique opportunities for controlled investigation of quantum phase transitions (QPTs) within a single sample. We have previously proposed a system consisting of a smaller "dot 1" exhibiting Kondo physics and a larger "dot 2" that is effectively noninteracting and lies near a transmission resonance as a versatile experimental realization of a single magnetic impurity coupled to an electron bath having a structured density of states [1]. Here we focus on a particular configuration of these dots that gives rise to a pair of continuous QPTs between Kondo-screened and non-Kondo ground states. We show that these QPTs have robust signatures in the finite-temperature linear conductance [2].

## Model

Dots 1 and 2 are connected in parallel to left ($L$) and right ($R$) leads of half-bandwidth $D$, as shown schematically in the inset to Fig. 1(b). Dot $j$ is modeled as an Anderson impurity with energy $\varepsilon_j$, interaction $U_j$, and hybridization width $\Delta_j$. Dot 1 is tuned to have an odd number of electrons in a Coulomb blockade valley, so that it has an unpaired spin. Dot 2 is near resonance and can be considered noninteracting ($U_2 = 0$). For $|\omega| \ll D$, the Green's function for dot 1 is identical to that for a single quantum dot with an effective hybridization function $\Delta(\omega) = \frac{\Delta_1(\omega-\varepsilon_2)^2}{(\omega-\varepsilon_2)^2+\Delta_2^2}$, which vanishes quadratically at $\omega = \varepsilon_2$. The linear conductance can be calculated within the Landauer formalism using the numerical renormalization-group method.

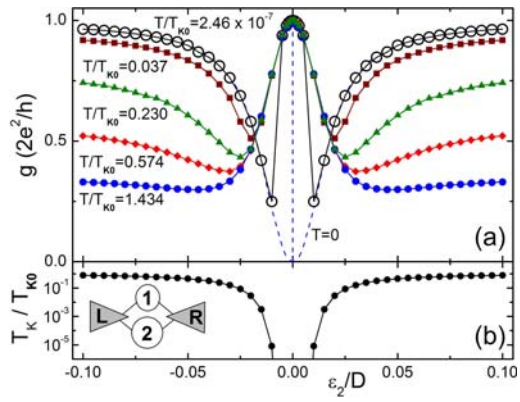


**Figure 2.** (a) Conductance $g$ vs dot-2 level energy $\varepsilon_2$ at six temperatures $T$. (b) For the case $\varepsilon_1 = -U_1/2$ shown, $T_K$ vanishes at $\varepsilon_2 = 0$, signaling suppression of the Kondo effect. $T_{K0} = 7 \times 10^{-4} D$ is the Kondo temperature of dot 1 in the absence of dot 2.

## Results

The zero in $\Delta(\omega)$ at can be positioned at the Fermi level ($\omega = 0$) by adjusting $\varepsilon_2$ via a plunger gate voltage on dot 2 to reach a peak in the conductance; see Fig. 1(a). Then, $\varepsilon_1$ can be tuned using a plunger gate on dot 1 to reach one of two continuous QPTs that separate Kondo phases from a local-moment phase in which Kondo screening of the dot-1 spin is completely suppressed. The location of each QPT is signaled by a near-unitary peak in the conductance defined by dips that become more prominent as the temperature increases, as illustrated in Fig. 2. The details of its evolution with temperature differentiate this conductance signature from similar features arising from interference effects unrelated to quantum criticality [2].

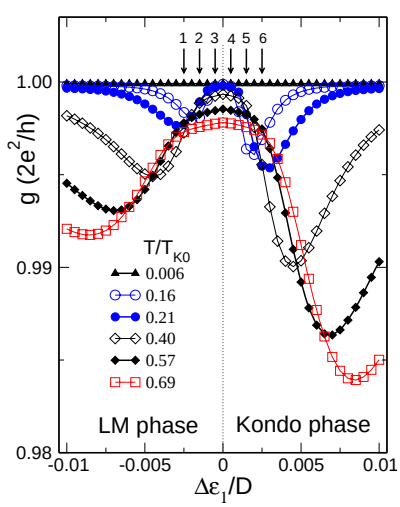


**Figure 1.** Conductance $g$ vs dot-1 level energy $\varepsilon_1$ near a QPT (located at $\Delta\varepsilon_1 = 0$). The peak marking the QPT becomes more prominent with increasing temperature $T$.

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## References

[1] Dias da Silva, L.G.G.V., *et al.*, Phys. Rev. Lett. **97**, 096603 (2006).
[2] Dias da Silva, L.G.G.V., *et al.*, Phys. Rev. B **78**, 153304 (2008).