Microscopic origin of the 0.7-anomaly in quantum point contacts

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Quantum point contacts, elementary building blocks of semiconductor-based quantum circuits, are narrow one-dimensional constrictions usually patterned in a two-dimensional electron system, e.g. by applying voltages to local gates. It is one of the paradigms of mesoscopic physics that the linear conductance of a point contact, when measured as function of its channel width, is quantized in units of $G_Q = 2e^2/h$. However, its conductance also exhibits an unexpected shoulder at $\simeq 0.7G_Q$, known as the "0.7-anomaly", whose origin is still subject to controversial discussions. Proposed theoretical explanations have evoked spontaneous spin polarization, ferromagnetic spin coupling, the formation of a quasi-bound state leading to the Kondo effect, Wigner crystallisation and various treatments of inelastic scattering. However, explicit calculations that fully reproduce the various experimental observations in the regime of the 0.7-anomaly, including the zero-bias peak that typically accompanies it, are still lacking. Here we offer a detailed microscopic explanation for both the 0.7-anomaly and the zero-bias peak: their common origin is a smeared van Hove singularity in the local density of states at the bottom of the lowest one-dimensional subband of the point contact, which causes an anomalous enhancement in the Hartree potential barrier, magnetic spin susceptibility and inelastic scattering rate. We present theoretical calculations and experimental results that show good qualitative agreement for the dependence of the conductance on gate voltage, magnetic field, temperature, source-drain voltage (including the zero-bias peak) and interaction strength. We also clarify how the low-energy scale governing the 0.7-anomaly depends on gate voltage and interactions. For low energies we predict and observe Fermi-liquid behavior similar to that known for the Kondo effect in quantum dots. At high energies, however, the similarities between 0.7-anomaly and Kondo effect cease.