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Transport Through A Critical Magnetic Quantum Dot Away From Equilibrium

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The last decades saw substantial progress in understanding the equilibrium phases and phase transitions of low-temperature quantum matter. These so-called quantum phase transitions host genuine quantum coherent phenomena that may display exotic properties and phase transitions whose universality classes differ from those of classical systems. However, certain systems —namely electronic transport setups —are inherently out of equilibrium, as they are coupled to different environments (leads) with distinct thermodynamic potentials. Such setups may host energy, charge and spin currents, and must be modeled as non-equilibrium open quantum systems. These bring novel paradigms for studying quantum matter and its phases transitions, with properties not possible under equilibrium conditions. Although these represent new opportunities for fundamental and technological advancements many challenges need yet to be addressed to understand these phases. Recent studies indicate that non-equilibrium conditions can significantly alter the properties of equilibrium stable phases, induce exotic phase transitions, cause heating, and generate novel phases of matter. A comprehensive body of work has addressed the so-called Markovian regime where the memory of the environment is much shorter than the typical system's time scales. In a transport setting this regime corresponds to a large bias or high temperature. The non-Markovian regime, which connects known equilibrium results to these extreme conditions, and is especially relevant for low temperature electronic systems at small bias, remains widely unexplored.

The current project aims to fill in some of these gaps by investigating non-equilibrium phase transitions in a voltage-biased magnetic quantum dot. This model is directly relevant to understanding the transport and magnetic properties of quantum spintronic devices in systems near criticality. Specifically, we aim to develop a theoretical framework in terms of the quantum dots' collective degrees of freedom as they undergo a quantum phase transition under an applied bias voltage.

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