Quantum simulation of the spin-boson model: Monitoring the bath

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The spin-boson model occupies a central position in condensed matter physics. It describes the interaction between a two-level system and a collection of harmonic oscillators or dissipative bath. It was originally developed as a general, fully quantum-mechanical, framework to account for the dissipation inherent to any quantum system [1]. This formalism was successfully applied to various physical systems weakly coupled to a bosonic bath (mesoscopic circuits, amorphous solids…). However only a few experiments [2,3] explored its more challenging limit -when the quantum system is strongly coupled to the many degrees of freedom of the bath - despite numerous theoretical predictions. In this regime the ground state of the whole system is non-trivial: the spin is highly entangled with the bath, forming a many-body system.

I will present a new architecture based on superconducting circuits to tackle this challenging problem. It offers two main advantages: first it allows to reach the ultra-strong coupling between the quantum system and its bath; second one can experimentally monitor the qubit and its bath at the same time, and thus reveal the many-body correlations which are building up when all the degrees of freedom become entangled.

Our approach consists in coupling a superconducting artificial atom (namely a transmon qubit) to a meta-material made of thousands of SQUIDs. The latter sustains many photonic modes and shows characteristic impedance close to the quantum of resistance. As a direct application, we use this circuit to explore quantum optics in the ultrastrong coupling regime, where new phenomena arise [4–7].

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