Quantum heat transport and heat rectification through a qubit

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Heat transport is a ubiquitous phenomenon in nature. When a mediated system coupled to hot and cold baths is reduced to the nanoscale, quantum effects play an important role in heat transport, known as quantum heat transport [1]. In particular, when the mediated quantum system is strongly coupled to heat baths, quantum many-body phenomena can emerge in quantum heat transport. Recently, thanks to technological advances in superconducting circuits, quantum heat transport has been observed in a transmon qubit, and can be controlled by an external magnetic flux through the SQUID loop, enabling tunable quantum heat devices [2].

A two-level system (TLS) is the most fundamental nonlinear quantum system. Despite its simplicity, heat transport through a TLS shows various transport processes near thermal equilibrium using the linear response theory [3]. Beyond the linear response regime, heat rectification can be observed when the coupling between the TLS and the heat baths is asymmetric (see Figure 1). Heat rectification in a TLS has been theoretically studied within perturbation theory with respect to the system-bath coupling [4]. Experimentally, heat rectification has been demonstrated in a similar but different setup, a superconducting resonator-qubit-resonator assembly [5]. However, quantum many-body effects in heat rectification at strong system-bath coupling remain underexplored.

In this poster, we investigate heat rectification through a TLS under nonequilibrium conditions. By comparing numerical results obtained using a tensor network approach [6] with analytical expressions, we identify signatures of quantum many-body effects in heat rectification. Our results provide a fundamental understanding of nonequilibrium heat transport and would be useful for developing quantum heat devices that utilize quantum many-body effects.

References

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Figures

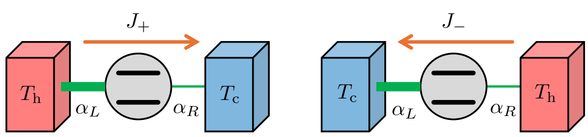

Figure 1: Quantum heat transport through a two-level system coupled to two heat baths at different temperatures. When the left bath is hot ($T_{\rm h}$) and the right bath is cold ($T_{\rm c}$), the heat current J_+ flows from left to right, while the heat current J_- flows from right to left when the temperatures are reversed. An asymmetric coupling ($\alpha_L \neq \alpha_R$) induces heat rectification ($J_+ \neq J_-$).