

# **A bath with a memory: Initial states in quantum thermodynamics**

Patrick Haughian, Edvin Idrisov, Massimiliano Esposito, and Thomas Schmidt

*University of Luxembourg, 162a, avenue de la Faiencerie, L-1511 Luxembourg, Luxembourg*

The Markov approximation is a common simplification for open quantum systems and involves neglecting memory effects in the thermal bath. Although this approximation is often justified for systems weakly coupled to a bath, a finite coupling strength makes a more careful study of bath memory effects necessary. To address this question, we examine the role of initial-state contributions for the driven resonant-level model, an exactly solvable prototypical model for quantum thermodynamics. By solving its equations of motion, we obtain an analytical expression for the work performed on the system given a general drive protocol and arbitrary coupling to a bath for different initial conditions. We establish that our definition of work coincides with the one introduced in stochastic thermodynamics. Moreover, we investigate how the memory of the initial state decays in local correlation functions and to what extent it survives in non-local correlation functions.