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Detailed balance and fluctuation relations in quantum thermodynamics

Quantum detailed balance conditions and quantum fluctuation relations are two important concepts in the dynamics of open quantum systems; both concern how such systems behave when they thermalize because of interaction with an environment. I show that for thermalizing

quantum dynamics the quantum detailed balance conditions yield validity of a quantum fluctuation relation (where only forward-time dynamics is considered). This implies that to have such a quantum fluctuation relation (which in turn enables a precise formulation of the second law of thermodynamics for quantum systems) it suffices to fulfill the quantum detailed balance conditions. I, however, argue that the converse is not necessarily true; there exit cases of thermalizing dynamics which feature the quantum fluctuation relation without satisfying detailed balance.