Minimum Action Principle for Entropy Production Rate of Far-From-Equilibrium Systems

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The Boltzmann distribution connects the energetics of an equilibrium system with its statistical properties, and it is desirable to have a similar principle for non-equilibrium systems. Here, we derive a variational principle for the entropy production rate (EPR) of far-from-equilibrium discrete state systems, relating it to the action for the transition probability measure of discrete state processes [1,2]. This principle leads to a tighter, non-quadratic formulation of the dissipation function, speed limits, the thermodynamic-kinetic uncertainty relation, the large deviation rate functional, and the fluctuation relation, all within a unified framework of the thermodynamic length [2]. Additionally, the optimal control of non-conservative transition affinities using the underlying geodesic structure is explored, and the corresponding slow-driving and finite-time optimal driving exact protocols are analytically computed [1,3]. We demonstrate that discontinuous endpoint jumps in optimal protocols are a generic, model-independent physical mechanism that reduces entropy production during finite-time driving of far-from-equilibrium systems [3].

References:

[1]A.T. Mohite and H. Riger, arXiv:2511.00967.
[2]A.T. Mohite and H. Riger, arXiv:2511.00970.
[3]A.T. Mohite and H. Riger, arXiv:2511.00974.