Abstract Submitted
for the MAR10 Meeting of
The American Physical Society

Thermodynamic length, Fisher information, and dissipation
DAVID SIVAK, GAVIN CROOKS, Physical Biosciences Division, Lawrence Berkeley National Laboratory — We explore thermodynamic length, defined as the root-mean squared fluctuations of the variables conjugate to the control parameters, as a non-equilibrium framework for understanding physical limits on the efficiency of non-equilibrium processes. Thermodynamic length equips thermodynamic state space with a Riemannian metric, and minimum thermodynamic length paths minimize the dissipation for slow, but finite time, transformations. Our reformulation of thermodynamic length analysis provides access to a non-equilibrium quantity (dissipation) through equilibrium properties (relaxation time and Fisher information). We derive analytic expressions for Fisher information (related to the derivative of thermodynamic length) in one-dimensional bistable energy landscapes, and find that it can vary by several orders of magnitude across a given landscape. Through simulation, we find that thermodynamic length analysis accurately predicts the instantaneous dissipation of far-from-equilibrium processes across the entire energy landscape. Finally, we derive the thermodynamic length framework as a special case of linear response theory.

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Date submitted: 17 Nov 2009 Electronic form version 1.4