THERMODYNAMIC INFERENCE: CYCLE AFFINITY, CROSS-CORRELATION ASYMMETRY AND BEYOND

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ABSTRACT

I will discuss the problem of *thermodynamic inference*, which aims to infer thermodynamic quantities from statistics of fluctuating systems. Most work in the field has focused on the inference of *entropy production*, a measure of thermodynamic dissipation that depends on microscopic kinetics. However, one may also consider a different — and complementary — problem of inferring *cycle affinity*, a measure of nonequilibrium driving strength that does not depend on microscopic parameters.

In this context, I will introduce our recent work [1] which derived a simple inequality for discrete-state Markovian systems. This inequality relates cycle affinity to *cross-correlation asymmetry*, the asymmetry of time-lagged cross-correlations between any pair of observables a and b in stationarity. Remarkably, our inequality can be understood as a thermodynamic version of the isoperimetric inequality, which relates the area and perimeter of regular polygons. As one illustration of our result, we prove a previously-conjectured bound on the coherence of noisy oscillations [2]. As another illustration, we derive a thermodynamic bound on directed information flow in a model of biochemical signal transduction [3]. This last example is illustrated below in Figure 1.

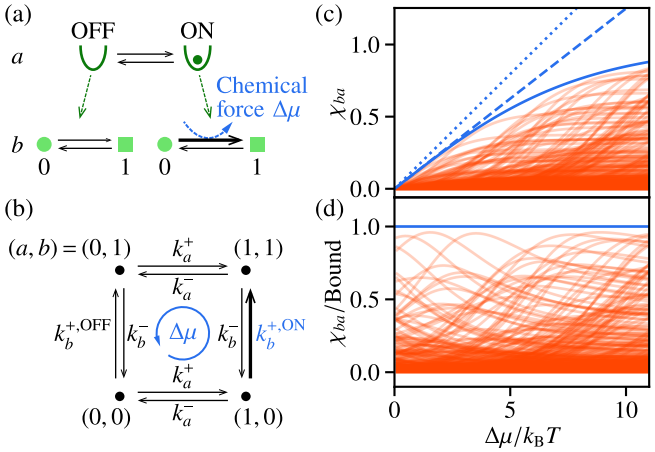

Figure 1: (a) Simple model of biological signal transduction from [3]. (b) Formulation as a Markov jump system with a nonequilibrium cycle. (c) Illustration of the bounds reported in Ref. [1]. Orange indicates (normalized) cross-correlation asymmetry χ_{ab} as a function of the cycle affinity $\Delta\mu$, which determines the rate of the transition $k_b^{+,\mathrm{ON}}$ (other kinetic rates set to random but fixed values). χ_{ba} is nonnegative for $\Delta\mu \geq 0$ in this model. Blue indicates three upper bounds on χ_{ab} in terms of cycle affinity [1]. (d) The ratio between χ_{ba} and the tightest bound $\tanh(\Delta\mu/8k_BT)$.

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