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Fluctuating Energetics in Long Range Interacting Systems

Long-range interacting systems are characterized by interaction potentials that decay slowly with the separation distance, e.g. with power-law dependencies. Such systems give rise to a plethora of intriguing physical phenomena such as ensemble in-equivalence, ergodicity breaking, synchronization, etc. The dynamics of long-range interacting systems in bounded domains can be quantitatively studied using tools from non-equilibrium statistical mechanics. However, little is known about the thermodynamics, and in particular, the energetics of long-range interacting systems in the presence of noise. Very recently, several fluctuation theorems from the emerging field of stochastic thermodynamics have been verified numerically in multi-particle systems with long-range interactions, using the mean field approximation. Such test opens the possibility of understanding notions like fluctuating fluxes of energy, matter of entropy in this class of systems. Moreover, an important question is how to achieve efficient conversion of heat from thermal fluctuations into useful work in the presence of long-range interactions.

We investigate the thermodynamics of stochastic models with long-range interactions using the framework of stochastic energetics. We perform a thorough numerical and analytical study of a simple one-dimensional model describing a dissipative forced pendulum. We study the transition in the stochastic energetics of the pendulum due to the presence of a separatrix in the motion between oscillation and rotations. These results are put in context with active biological oscillations.

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