Stochastic thermodynamics for noise-mixing environment

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Noise mixing refers to a phenomenon where a single degree of freedom is affected by multiple thermal noises simultaneously. This situation can easily be encountered experimentally, for example, when a Brownian particle is immersed in a liquid with a temperature gradient. When noise mixing occurs, the conventional stochastic thermodynamics approach does not reveal all thermodynamic constraints enforced by the second laws of thermodynamics; for example, the total entropy production is underestimated. In addition, setting up the stochastic equation for noise-mixing environment has been the focus of only limited discussion. In this presentation, we first discuss what is the proper form of the stochastic equation for noise-mixing environment. In the second part, we will introduce a new formulation of the stochastic thermodynamics in terms of noise realization. Using our formalism, we derive a hierarchy of fluctuation theorems when noise mixing occurs. These theorems and the associated second laws of thermodynamics put stricter bounds on the thermodynamics of Langevin systems. We apply our results to a stochastic machine in noise-mixing environments and demonstrate that our new bounds play a crucial role in determining the potential function and performance of the machine. \(^\dagger\).