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Generic properties of stochastic entropy production

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The laws of thermodynamics can be extended to mesoscopic systems for which energy changes are on the order of the thermal energy are relevant. Therefore, thermodynamic observables associated with mesoscopic degrees of freedom are stochastic. A key example of such thermodynamic observable is the stochastic entropy production in nonequilibrium processes. Little is known beyond fluctuation theorems about universal or model-independent statistics of entropy-production fluctuations.

Using Martingale theory we have discovered novel universal statistics of stochastic entropy production in nonequilibrium steady states such as: (i) The distribution of the negative record (which we call infimum) of entropy production (ii) the passage probabilities of entropy production; (iii) the stopping-time fluctuations of entropy production.

For nonequilibrium Langevin processes, we derive an Ito stochastic differential equation for entropy production. Introducing a random-time transformation, entropy production obeys a one-dimensional drift-diffusion equation, independent of the underlying physical model. This transformation allows to identify novel generic properties of entropy production. It also leads to an exact uncertainty equality relating the Fano factor of entropy production and the Fano factor of the random time.

Our results have interesting implications for stochastic processes that can be discussed in colloidal systems and active molecular processes. For example, we make predictions for the distribution of the maximum backtrack depth of RNA polymerases during RNA transcription in eukaryotes.

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