Detailed Balance Breaking and Housekeeping Entropy Production in Continuous Stochastic Dynamics

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We revisit the detailed balance (DB) condition and its breakage in the continuous stochastic dynamics in the presence of the odd-parity variable such as momentum. In this case, the housekeeping entropy production (EP) does not satisfy the fluctuation theorem (FT). We investigate how to construct a component of housekeeping EP, which represents the breakage of DB and satisfies the FT. We find that this can be achieved in an infinitely many ways characterized by a single parameter σ. For an arbitrary value of σ, one of the two parts contributing to the housekeeping EP satisfies the FT.

We show that for a range of σ values these EPs can be associated with the breakage of the detailed balance in the steady state, and can be regarded as continuous versions of the corresponding EP that has been obtained for discrete state variables. The other part of the housekeeping entropy does not satisfy the FT and is related to the parity asymmetry of the stationary state distribution. We discuss our results in connection with differences between continuous and discrete variable cases especially in the conditions for the detailed balance and the parity symmetry of the stationary state distribution.