Entropy production in run-and-tumble particles mapped to Brownian motion in an inhomogeneous temperature

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Run-and-tumble particle (RTP) dynamics, a paradigmatic model of active motion, offers a minimal setting in which nonequilibrium effects arise from the interplay between self-propulsion, external forces, and thermal fluctuations. In this talk, we present recent work on a mapping of RTP steady states onto overdamped Brownian motion in a spatially inhomogeneous temperature field, allowing thermodynamic concepts to be formulated within a thermodynamic framework based on an effective temperature field.

At the level of global entropy production, this mapping proves particularly useful in certain explicit examples. For RTP dynamics in a piecewise linear potential, the steady state assumes a double-exponential form that can be interpreted as an effective splitting of the system into two components with temperatures and , both different from the bath temperature [1]. This picture provides a natural description of the steady-state entropy exchange between the thermal bath and the effectively split system.

The main focus of the talk, however, is the more challenging problem of spatially resolved entropy production. Recently, we introduced an inverse-Clausius thermodynamic framework in which the effective temperature field is inferred directly from the steady-state density, without requiring explicit knowledge of the full position–velocity distribution [2]. Within this approach, local entropy fluxes and local entropy production rates can be reconstructed from steady-state observables directly accessible in simulations. The resulting description yields a physically transparent picture in which entropy production and entropy flux need not coincide spatially: entropy is generated and transported from hotter to colder regions through an emergent temperature landscape, while being continuously exchanged with the bath. Langevin dynamics simulations in a harmonic potential reveal that the approach is exact for the standard two-state RTP model and quantitatively accurate for multistate models.

References:

[1] R. K. Singh and O. Farago, Phys Rev. E 111, 064131 (2025).

[2] O Farago, arXiv:2509.08565, submitted.