Entropy augmentation in irreversible dynamics: A journey from epistemology to numerical simulation.

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Reconciling the axiomatic status of irreversibility in phenomenological thermodynamics with time-reversal symmetry in microscopic models is a challenge which has been recognized ever since kinetic theory acquired predictive power. Known approaches picturing irreversibility as *emerging* from microscopic dynamics either feature deliberate modifications of the microscopic dynamics (Stoßzahlansatz, coarse-graining) or postulate a map which assigns to each phase-space point $X(t)$ (microstate) a region $\Gamma(t)$ (macrostate), whose volume determines the (Boltzmann) entropy.

Both approaches reflect the important fact that is important but is sometimes overlooked: A thermodynamic system is a system under *incomplete* observation. Modifications of microdynamics are performed under the proviso that they remain undetectable within the scope of incomplete observation. Direct mappings from microstates X to macrostates Γ implicitly require that the macroscopic state cannot be further differentiated by any practical observation.

The EASE (entropy augmentation through subadditive excess) approach [1] constructs modifications of microdynamics from an information theoretic perspective which embraces the Boltzmann equation as a paradigmatic model, yet radically generalizes the idea of lost correlation information. Its key features are the following:

i) A physical system is partitioned into subsystems, whose size can be microscopic or macroscopic or anywhere in between.

ii) A memory time represents a delay period after which the detection of past correlations between subsystems is deemed infeasible.

While EASE propagation can be based on either classical or quantum Liouville equations, the quantum case has special features: Entanglement arising in an initially pure quantum state can be the seed of entropy augmentation. This allows EASE-based quantum jump methods describing self-equilibration.

[1] J. T. Stockburger, Eur. Phys. J. Spec. Top. (2025), doi:10.1140/epjs/s11734-025-01923-2