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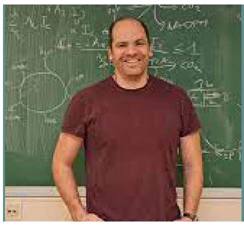

Prof. Massimiliano Esposito

University of Luxembourg

Towards a Nonequilibrium Thermodynamics of Complex Systems

Equilibrium thermodynamics emerges from equilibrium statistical mechanics as the most likely behavior of a system in the macroscopic limit. Over the last two decades, enormous progress has been made in formulating statistical mechanics for small systems operating far-from-equilibrium. The resulting theory is called stochastic thermodynamics. I will show that taking the macroscopic limit of stochastic thermodynamics enables to formulate a nonequilibrium thermodynamics of large systems typically described by nonlinear deterministic dynamics which can also capture macroscopic fluctuations around it [1]. This macroscopic stochastic thermodynamics gives rise to novel fundamental results (for instance, once can bound nonequilibrium steady state fluctuations using the entropy production along deterministic relaxation trajectories [2]) and enables to recover many classical phenomenological results in macroscopic irreversible thermodynamics within well controlled approximations. It also opens the way to study the energetics of many complex nonlinear phenomena in a broad range of systems such as chemical reaction networks (CRNs), nonlinear electrical circuits, and Potts models. For systems displaying a modular structure, one can go even further and formulate a thermodynamic circuit theory, which, similarly to electrical circuit theory, uses the analogue of current-voltage characteristics and Kirchhoff's laws. I will focus on CRNs [3] and illustrate these ideas in the context of metabolism [4].

[1] G. Falasco and M. Esposito, "Macroscopic stochastic thermodynamics", to appear.
[2] N. Freitas and M. Esposito, "Emergent second law for non-equilibrium steady states", Nature Communications 13, 5084 (2022).
[3] F. Avanzini, N. Freitas and M. Esposito, "Circuit Theory for Chemical Reaction Networks", arXiv:2210.08035.
[4] A. Wachtel, R. Rao and M. Esposito, "Free-Energy Transduction in Chemical Reaction Networks: From Enzymes to Metabolism", J. Chem. Phys. 157, 024109 (2022)

Tuesday 9 May 2023 at 4:00 P.M.

COFFEE AND TEA WILL BE SERVED AT 3:45 P.M IN FRONT OF THE SOLVAY ROOM

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