Anomalous relaxation in systems far from equilibrium

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In this talk I will present very recent theoretical and experimental results about the relaxation of systems subject to one or several quenched. In particular, I will show that during the transient evolutions, before reaching an equilibrium or stationary state and under some particular conditions, the studied systems show surprising and counterintuitive effects. Namely, the Mpemba effect [3, 2, 1], the Kovacs effect [4] and an asymmetry between equidistant and symmetric heating and cooling processes. The ME happens when two identical systems, but with different initial temperatures, are put instantly in contact with a heat bath at a colder-than-both temperature, and the system that is further from equilibrium reaches it faster than the system that is initially closer to equilibrium and the opposite, the Inverse Mpemba effect, the cooler heats up before the heater and the Kovacs effect can take place when a thermalization process is suddenly interrupted by a change of the bath temperature, leading to a nonmonotonic evolution of the energy of the system. Finally we will show that heating was predicted to be faster than cooling, which we experimentally confirmed using an optically trapped colloidal particle. More strikingly, we show with both experiments and theory that between any pair of temperatures, heating is not only faster than cooling but the respective processes in fact evolve along fundamentally distinct pathways, which we explain with a new theoretical framework we coin "thermal kinematics" [5].

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[1] JANUS, *The Mpemba effect in spin glasses is a persistent memory effect*, PNAS **116**,153501(2019).

[2] Lasanta, Antonio and Vega Reyes, Francisco and Prados, Antonio and Santos, Andrs, *When the Hotter Cools More Quickly: Mpemba Effect in Granular Fluids*, Phys. Rev. Lett.. **119**, 148001(2017).

[3] Carollo, Federico and Lasanta, Antonio and Lesanovsky, Igor, *Exponentially accelerated approach to stationarity in Markovian open quantum systems through the Mpemba effect* Phys. Rev. Lett.. **127**, 060401(2021).

[4] Militaru, Andrei and Lasanta, Antonio and Frimmer, Martin and Bonilla, Luis L and Novotny, Lukas and Rica, Ral A, *Kovacs memory effect with an optically levitated nanoparticle* Phys. Rev. Lett.. **127**, 130603(2021).

[5] Ibez, Miguel and Dieball, Cai and Lasanta, Antonio and Godec, Alja and Rica, Ral A, *Heating and Cooling are Fundamentally Asymmetric and Evolve Along Distinct Pathways*, arXiv preprint arXiv:2302.09061(2023).