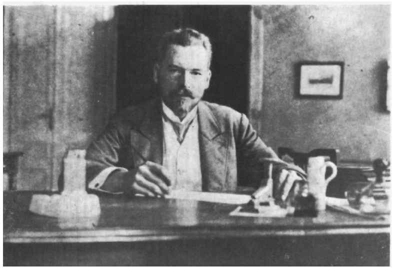

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Stochastic thermodynamics of anomalous diffusion generated by scaled and fractional Brownian motions

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We study stochastic thermodynamics for non-equilibrium systems that can exhibit anomalous diffusion with the main focus on deriving an integral fluctuation relation (IFR) for the total entropy production. The dynamics of those systems are described by (i) Markovian processes with a time-dependent diffusivity such as scaled Brownian motion and (ii) non-Markovian fractional Brownian motion. The former case is an immediate generalization of normal diffusion which is used here mainly, first, to generalize the definitions of the thermodynamic quantities such as heat, work and entropy production along a single trajectory and, second, to revisit the derivation of the IFR for the total entropy production by considering that the fluctuation-dissipation relation may or may not be valid. In the latter case, we investigate how the non-Markovian feature of the dynamics alters the conventional notion of stochastic thermodynamics by leading to a violation of the IFR for the total entropy production. We demonstrate that, such a violation can be circumvented by formally defining a temperature functional that fulfils a general form of fluctuation-dissipation relation. Using a perturbation method, we calculate the first two leading terms of the temperature functional. Our perturbative analysis also unravels that the origin of that violation can be tracked to a generalized form of a heat exchange between the system and the environment. We obtain an analytical expression for the generalized heat function and provide a physically meaningful interpretation by introducing the concepts of retarded force and retarded velocity that include the impact of the memory of the environment.

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