Anomalous Langevin dynamics, fluctuation-dissipation relations and fluctuation relations

Rainer Klages

Queen Mary University of London, School of Mathematical Sciences, London, UK

I will address the problem of how to model the earth's global surface temperature by means of what is called Langevin dynamics in nonequilibrium statistical physics. Such stochastic systems have been derived for the above geophysical problem starting from linearized energy-balance equations by adding a stochastic forcing, which mimicks the driving of the ocean-land heat content by the atmospheric weather system. I will first briefly review the basic concept of the Langevin equation for modeling Brownian motion. I will then discuss the role of fluctuation-dissipation relations in Langevin dynamics and in which sense they indicate an external driving of a system, or an internal energy balance between fluctuations and dissipation. This becomes especially important if Langevin dynamics is generalized by using (power law) memory kernels for the friction coefficient and/or the noise. Modeling such correlations makes the dynamics non-Markovian by typically leading to anomalous diffusion where the mean square displacement of an ensemble of particles grows nonlinearly for long times [1]. These models are explored in view of fluctuation relations generalizing the second law of thermodynamics to nonequilibrium systems [2]. I will show that for generalized Langevin dynamics satisfying fluctuation-dissipation relations the conventional form of fluctuation relations is preserved while breaking fluctuation-dissipation relations leads to violations of conventional fluctuation relations [3].

[1] R. Klages, G.Radons, I.M.Sokolov (Eds.), *Anomalous transport: foundations and applications.* Wiley-VCH, Weinheim (2008)

[2] R.Klages, W.Just, C.Jarzynski (Eds.), *Nonequilibrium Statistical Physics of Small Systems.* Wiley-VCH, Weinheim (2013)

[3] A.V.Chechkin, F.Lenz, R.Klages, J.Stat.Mech. L11001 (2012)