Out-of-equilibrium stochastic dynamics in power-law viscoelastic and non-Ohmic thermal environments

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When particles diffuse in viscoelastic and non-Ohmic thermal environments, the resulting effective Langevin description becomes non-Markovian, exhibiting memory kernels and colored noise. In many cases, such environments lack a single relaxation scale and instead exhibit a broad continuum of timescales. This naturally leads to the use of fractional operators and fractional Gaussian noises in effective descriptions because of their scale-free and fractal-like properties. In this talk, I will present recent results on the fractional Langevin equation for out-of-equilibrium systems. Two types of forces driving out-of-equilibrium dynamics are discussed: linear white noise and rotational self-propulsion. In the first case, the long-range memory effects drive the emergence of prethermal periodic time-ordered phases, such as time crystals and time glasses, which are robust against white noise. In the second, counterintuitive persistent properties arise from the viscoelastic rotational dynamics. Finally, a general path-integral formalism for non-Markovian fractional settings is discussed, and an analytical route to simplify the propagator for heterogeneous processes driven by fractional Gaussian noise is provided.

[1] D.S. Quevedo, R.C. Verstraten, C. Morais Smith, Phys. Rev. A 110 (2024) 052208

[2] D.S. Quevedo, M. Conte, M. Dijkstra, C. Morais Smith, arXiv:2512.20205v1 (2025)

[3] D.S. Quevedo, F.S. Abril-Bermúdez and C. Morais Smith, arXiv:2512.20205v1 (2026)