Long-lasting but transient anomalous diffusion

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The theory of Brownian motion has played a guiding role in the development of statistical physics. It provides a link between the microscopic dynamics and the observable macroscopic phenomena such as diffusion. The latter has been in the research spotlight already for over 100 years. One century after pioneering Einsteins work it remains both a fundamental open issue and a continuous source of developments for many areas of science. Normal and anomalous diffusion can be detected in diverse systems: both physical and biological, sociological and economical ones. We show that anomalous diffusion can be observed in simple, one dimensional classical systems assisted by thermal equilibrium noise of Gaussian nature, i.e. without the need to introduce heavy-tailed distributions nor disorder or many-body physics. We analyze a standard ac-driven Brownian ratchet (which has many real physical realizations like SQUID devices and cold atoms in optical lattices) and demonstrate that the mean square deviation of the Brownian particle coordinate evolves in three following stages: initially as superdiffusion, next as subdiffusion and finally as normal diffusion in the asymptotic long time limit. The lifetimes of superdiffusion and subdiffusion can last many many orders longer than characteristic times of the system, thus being comfortably detectable experimentally. These lifetimes turn out to be extraordinarily sensitive to the system parameters like temperature or the potential asymmetry. E.g small parameter changes of order 10^{-2} are accompanied by the giant increase of order 10^{3} in the superdiffusion lifetime. We explain the underlying mechanism standing behind the emergence of diffusion anomalies and control of their regimes which are related to ergodicity of the system and ultraslow relaxation of the particle velocity towards its non-equilibrium stationary state. The proposed setup for experimental verification of our findings provides a new and promising testing ground for investigating anomalies in diffusion phenomena.

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