Brownian motors in the micro-scale domain: Enhancement of efficiency by noise

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Transport occurring in the micro-scale domain is strongly influenced by fluctuations and random perturbations. The impact has seemed to be usually destructive, i.e. transport is weakened with respect to such quantifiers like averaged velocity or current. However, a constructive role of both equilibrium and non-equilibrium fluctuations has since been demonstrated for many situations with the occurrence of several intriguing, noise-assisted phenomena such as Brownian ratchets[1], stochastic resonance[2], molecular motors and machines[3], genetic and biochemical regulatory systems[4,5], intracellular transport[6], to mention only a few. Fluctuations and noise may enhance the average velocity, reverse the natural transport direction, or induce anomalous transport processes.

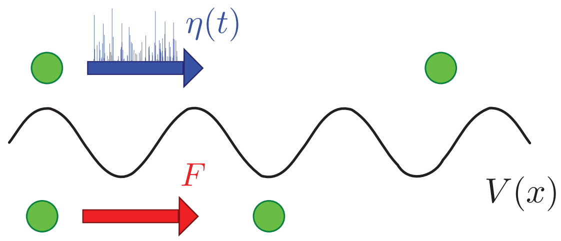

FIG. 1. Brownian motors moving in symmetric periodic structures in the presence of an unbiased harmonic force and driven by a static, biasing force F can be transported much faster and in a more effective way when F is replaced by noise $\eta(t)$ of equal average bias $\eta(t) = F$.

We study a noisy drive mechanism for efficiency enhancement of Brownian motors operating on the microscale domain. It was proven[7] that biased noise $\eta(t)$ can induce normal and anomalous transport processes[8] similar to those generated by a static force F acting on inertial Brownian particles in a *reflection-symmetric* periodic structure in the presence of *symmetric* unbiased time-periodic driving. Here, we show that within selected parameter regimes, noise $\eta(t)$ of the mean value $\eta(t) = F$ can be significantly more effective than the deterministic force F: the motor can move much faster, its velocity fluctuations are much smaller, and the motor efficiency increases several times[9]. These features hold true in both normal and absolute negative mobility regimes. We demonstrate this with detailed simulations by resource to generalized white Poissonian noise.

Our theoretical results can be tested and corroborated experimentally by use of a setup that consists of a resistively and capacitively shunted Josephson junction. The suggested strategy to replace F by $\eta(t)$ may provide a new operating principle in which micro- and nanomotors could be powered by biased noise.

Yet, a number of open questions of the studied system still remain to be answered. Prominent examples of such problems may include the following: Does the main conclusion of this work hold true also for other models of non-equilibrium perturbation? Is the inherent nonlinearity of the system necessary for the observation of this effect? Can this phenomenon be detected also in the limiting case of over-damped dynamics? Is our proposed strategy of the efficiency enhancement *universal* and may be realized both in classical and quantum systems?..

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