Anomalous transport in Josephson junction induced by non-equilibrium noise

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Absolute negative mobility (ANM) is a counterintuitive phenomenon: particles move in a direction opposite to a static bias force. It seems to be in contradiction to the Newton equation of motion, the second law of thermodynamics and observations of motion at a macroscopic scale. However, under non-equilibrium conditions, there is no fundamental principle which excludes ANM. What are essential ingredients for the occurrence of ANM? The minimal model can be formulated in terms of a one-dimensional Newton equation for a Brownian classical particle moving in a symmetric spatially periodic potential, driven by an unbiased harmonic force and biased by a static force F [1]. The ANM response in a symmetric priodic potential is so that an average particle velocity $\langle v(F) \rangle$ obeys the relation: $\langle v(F) \rangle = -\langle v(-F) \rangle$, which follows from the symmetry arguments. In particular, $\langle v(0) \rangle = 0$. So, for $F = 0$ there is no directed transport in the long-time regime. The non-zero static force F breaks the symmetry and therefore induces a directed motion of particles. In the lecture, we replace the static force F by a random force $\eta(t)$ of a time-independent non-zero mean value $\langle \eta(t) \rangle = \eta_0$ [2]. We assume that the particle is coupled to its environment (thermostat) of temperature T and thermal fluctuations $\xi(t)$ are included as well. As an example of the random force $\eta(t)$, we consider non-equilibrium Poissonian shot noise, which is composed of a random sequence of δ-shaped pulses with random amplitudes. We analyze the dependence of the long-time average velocity $\langle v \rangle$ on parameters of both random forces $\eta(t)$ and $\xi(t)$. We find a rich variety of anomalous transport regimes including the absolute negative mobility regime around zero biasing Poissonian noise, the emergence of a negative differential mobility and the occurrence of a negative nonlinear mobility (for values of bias η_0 far from zero). As a feasible physical system, we propound a setup consisting of a single resistively and capacitively shunted Josephson junction driven by both a time periodic current and a noisy current. In this case the phase difference between the macroscopic wave functions of the Cooper electrons in both sides of the junction translates to the Brownian particle coordinate and the voltage across the junction translates to the particle velocity. For such a system, the anomalous transport characteristics can be measured, thus putting our predictions to a reality check.

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