Fluctuation theorems and stochastic thermodynamics : applications to energy fluctuations in electric circuits and micro devices

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Thermal fluctuations play a very important role and cannot be neglected in small systems, such as electric circuits and micro-devices driven out of equilibrium by external forces. In these systems the work performed by the external forces and the dissipated heat fluctuate and stochastic thermodynamics imposes several constrains on their behavior. In this talk we will recall first the main concepts of stochastic thermodynamics using experimental measurements of work and heat in electric circuits and micro-devices. We will show that the probability distributions of the injected work and dissipated heat satisfy an asymptotic Fluctuation Theorem(FT) , which imposes strong constrains on the energy fluctuations. We will introduce the stochastic and total entropies which satisfy an FT for any time. We will apply these concepts to the experimental and theoretical study of the statistical properties of the energy exchanged between two electrical conductors, kept at different temperature by two different heat reservoirs, and coupled only by the electric thermal noise. Such a system is ruled by the same equations as two Brownian particles kept at different temperatures and coupled by an elastic force. We measure the heat flowing between the two reservoirs, the thermodynamic work done by one part of the system on the other, and we show that these quantities exhibit a long time fluctuation theorem. Furthermore, we evaluate the fluctuating entropy, which satisfies a conservation law. These experimental results are fully justified by the theoretically analysis. The other important point that we will describe is the case of the fluctuations of the work done by an external Gaussian random force on an atomic force microscopy cantilever. We finally discuss the open problems of the stochastic thermodynamics and useful perspectives, such as the efficiency of energy transformation in small devices and the connections with information.

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