The quest for the missing noise in a micro-mechanical system out of equilibrium

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Abstract

Equipartition principle plays a central role in the understanding of the physics of systems in equilibrium: the mean potential and kinetic energy of each degree of freedom equilibrates to kT/2, with k the Boltzmann constant and T the temperature. This equality is linked to the fluctuation-dissipation theorem (FDT): fluctuations of one observable are proportional to the temperature and dissipation in the response function associated to that observable. In non equilibrium situations however, such relations between fluctuations and response are not granted, and excess noise is usually expected to be observed with respect to an equilibrium state.

In this presentation, we show that the opposite phenomenon can also be experimentally observed: a system that fluctuates less than what would be expected from equilibrium ! Indeed, when we measure the thermal noise of the deflexion of a micro-cantilever subject to a strong stationary temperature gradient (and thus heat flow), fluctuations are much smaller that those expected from the system mean temperature.

We will first present the experimental system, an atomic force microscope (AFM) micro-cantilever in vacuum heated at its free extremity with a laser. We will show that this system is small enough to have discrete degrees of freedom but large enough to be in a non-equilibrium steady state (NESS). We will then estimate its temperature profile with the mechanical response of the system [1], and observe that equipartition theorem can not be applied for this NESS: the thermal noise of the system is roughly unchanged while its temperature rises by several hundred degrees ! We will explain how a generalized FDT taking into account the temperature field can account for these observations, if dissipation is not uniform. Further experimental evidences of the validity of this framework will conclude the presentation.

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