Temperature, susceptibility and transport in an experimental non-equilibrium steady-state

Jean-Christophe Géminard[1]

[1] *CNRS, ENS de Lyon, Laboratoire de Physique, Lyon, France*

ABSTRACT

Statistical mechanics, which uses probability theory to study the average behaviour of mechanical systems composed of many bodies, proved to be a fruitful extension of classical thermodynamics to describe the properties of equilibrium systems. In nature, however, out-of-equilibrium systems are widespread, which explains the efforts produced during the last decades to develop theoretical tools adapted to systems in which energy conservation, for instance, is not satisfied. Dissipative systems spontaneously tend to come to rest. However, non-equilibrium steady states (NESS) can be acchieved by continuously injecting energy in the system, in order to compensate the intrinsic dissipation.

We achieve a granular gas, the NESS, by shaking a collection of millimetric beads in a container. A blade, fastened to the shaft of a small DC-motor and immersed in the grains, behaves as a driven 1D Brownian rotator. Thanks to its electromechanical reversibility, the motor is used as both actuator and sensor, simultaneously.

On the one hand, we focus on potential definitions of the temperature of our system, first based on the Gallavotti-Cohen fluctuation theorem (asymmetry of the energy exchanges between rotator and the NESS), and second on the fluctuation-dissipation theorem (relation between the spontaneous fluctuations and the response to a weak perturbation). Both methods give nicely concordant results.

On the other hand, we duplicate the system, couple two granular gases by simply connecting the DC-motors to one another and report on the energy transport through the probes in contact. First, we show that the energy flux from one probe to another is, in temporal average, proportional to the temperature difference. Second, we observe that the instantaneous flux is highly intermittent and that fluctuations exhibit an asymmetry which increases with the temperature difference. This asymmetry, related to irreversibility, is correctly accounted for by a relation strongly evoking the Fluctuation Theorem.