Heating/cooling asymmetry with an optically trapped particle

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Microparticles can be individually manipulated by different trapping mechanisms, among which optical tweezers and Paul traps are the most extended approaches. Trapped particles are subject to Brownian motion due to collisions with water or gas molecules, depending on the dispersing medium. In this talk, we will discuss some of our recent works with trapped particles driven out of equilibrium.

For example, when a system is subjected to a temperature contrast that pushes it far away from equilibrium, a wide variety of anomalous phenomena such as the Mpemba [1, 2] and Kovacs [3, 4] effects have been reported and studied. In addition, relaxation processes that take place in opposite directions, i.e., heating and cooling, have also been found to exhibit this type of anomalies [5]. First, we will show, both theoretically and experimentally, that heating and cooling are inherently asymmetric and evolve along distinct pathways [6]. Specifically, we confirm that although departing from thermodynamically equidistant hot (T_h) and cold (T_c) temperatures with respect to an intermediate one (T_w, so that $T_c < T_w < T_h$), the heating process $T_c \rightarrow T_w$ is always faster than the process $T_h \rightarrow T_w$. Conversely, we also confirm that this asymmetry holds in the opposite scenario; that is, the heating process $T_w \rightarrow T_h$ is always faster than the cooling process $T_w \rightarrow T_c$. Most surprisingly, we demonstrate that, between a single pair of temperatures $T_1 < T_2$, heating ($T_1 \rightarrow T_2$) is always faster than the reciprocal cooling ($T_2 \rightarrow T_1$).

To explain these observations, we develop a new theoretical framework we call “thermal kinematics”, revealing that thermalization at the microscale is more intricated that originally thought.

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