WORK DISTRIBUTIONS OF A FORCED TRACER IN A DENSE COLLOIDAL BATH: EFFECT OF THE TRACER SIZE

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Thermal fluctuations in driven systems provoke microscopic deviations from the expected, macroscopic, behaviour dictated by the laws of Thermodynamics. This is well described by the Fluctuation Theorem in its several forms, and confirmed by experiments and simulations. In particular, in the case of a colloidal particle dragged by an external force, the work executed by the force follows a distribution due to the inherent random motion of the particle. This distribution extends to negative works, but in the limit of large forces or systems, where fluctuations become negligible, the distribution moves to larger values and narrows (recovering the thermodynamic limit).

In this work, we perform simulations with Langevin microscopic dynamics of a tracer colloidal particle dragged by a constant external force through a bath of colloidal particles (unaffected by the force), and the work distribution is studied as a function of the tracer size and external force. The density of the bath is large enough (volume fraction 50%) to hinder the free diffusion of the tracer notably. The ratio of the tracer radius to bath particle radius has been varied between 0.5 (small tracer) to 7 (large tracer, shown in the snapshot of Fig. 1). The effective friction coefficient measured by the tracer can be obtained from the average work, while the overall shape of the distribution depends on the bath thermal and density fluctuations.

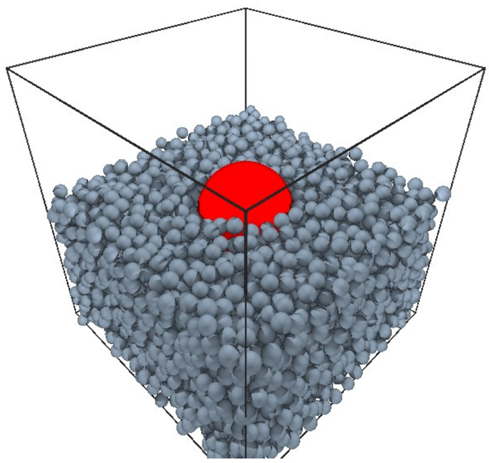

Figure 1: Snapshot of the system (tracer marked in red). The tracer has a radius seven times larger than bath particles, and the particles above it have been removed in the representation.

After careful examination of finite size effects, the results indicate that for small forces the friction coefficient grows with the tracer size faster than linearly, and the bath can be modeled as a Brinkman fluid. The work fluctuations deviate from Gaussian, expected for a purely Brownian particle, due to the complex dynamics of the bath. However, the deviations are stronger for tracers slightly smaller than the bath particles, while large tracers show only small deviations. For large forces, on the other hand, the friction coefficient decreases due to thinning of the colloidal bath induced by the external force.