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Effective time-dependent temperature in hot Brownian motion

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Hot Brownian motion is the diffusive dynamics of a colloidal particle maintained at constant higher temperature than the surrounding fluid [1, 2]. It is of practical relevance, e.g. for laser-heated suspended nanoparticles involved in several experimental applications ranging from particle trapping and tracking [3] to self-thermophoretic motion [4], but also of considerable theoretical interest since it can be thought as an archetypal example of systems in contact with a non-isothermal bath, thus intrinsically out-of-equilibrium. While the qualitative differences with isothermal Brownian motion, i.e. enhanced thermal fluctuations and lowered viscous friction, are easily anticipated, a complete formal description of the phenomenon was not available so far. Starting from the fluctuating hydrodynamic equations for the solvent, we obtain for the colloid's motion a generalized Langevin description that exhibits, as the most remarkable feature, a time-dependent temperature resulting from the scale separation between the dynamics of fluid and colloid. Moreover, we show that in the long-time limit different degrees of freedom, such as position and velocity, equilibrate to different effective temperatures, whose analytic expressions are verified through large-scale molecular dynamics simulations. This provides an excellent starting point for experimental tests and applications involving heated nanoparticles and paves the way for further theoretical investigations on colloidal systems in the presence of temperature inhomogeneities.

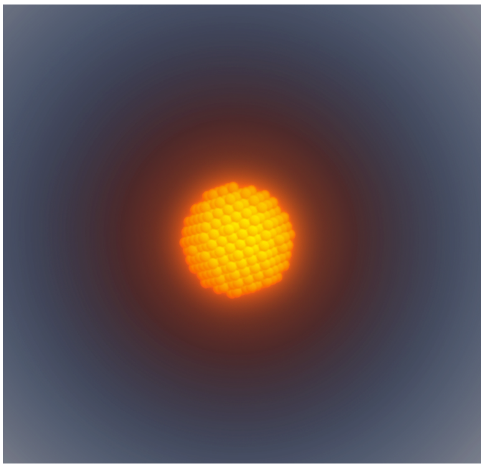

Figure 1: Artist's conception of a Brownian particle heated above the temperature of the embedding fluid.

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