Stokes's law in a bath of colloidal hard spheres

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Stokes's law provides the friction force experienced by a spherical particle inmersed in a Newtonian fluid. This force is proportional to the particle radius, external force, and solvent viscosity and a geometrical factor. Stokes's law is valid for small Peclet numbers, namely, small external forces. Within the Navier-Stokes description of the bath, different works have extended this law to the case of compressible fluids, or viscoelastic ones, but the same relation is obtained between the friction force and viscosity when a constant force is applied, in the stationary regime.

In this work, we present simulations of a fluid colloidal hard spheres where a large colloidal tracer has been introduced (see the snapshot in Fig. 1). All particles, including the intruder, undergo microscopic Langevin dynamics, and a small constant external force acts only onto the tracer. Its stationary (long-time) velocity is used to obtain the effective friction coefficient γ_{eff}. A finite size analysis must be performed, as the large size of the tracer induces strong finite size effects. It is found that the inverse friction coefficient depends linearly on the inverse simulation box size, as expected from theoretical arguments based on the Navier-Stokes equation, only for small sizes. Contrary to this prediction, for large systems the friction coefficient becomes independent on the system size.

The ratio of γ_{eff} to the solvent friction coefficient, included in the microscopic dynamics, grows for increasing size of the tracer and reaches a plateau for large sizes (tracer size to bath particle size above six), apparently reaching the limit where the bath is described as a continuous medium. The value of the friction coefficient, however, does not agree with the result from Stokes's law. The origin of the discrepancy is traced back to the dissipative character of the microscopic Langevin dynamics.

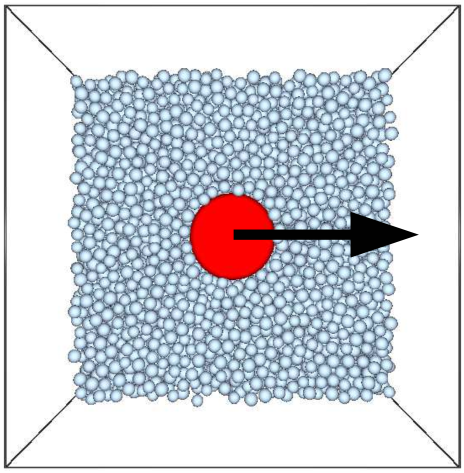

Fig. 1. Snapshot of the system with a large tracer (marked in red). The arrow indicates the external force. The particles in front of the tracer have been removed.