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Microscopic origin of drag force: A new mathematical and physical interpretation[1] CHANGHO KIM, GEORGE KARNIADAKIS, Brown Univ
— We present a new microscopic interpretation of the friction force on a Brownian particle of finite mass suspended in a fluid: it originates from the deviation of the system trajectory due to the movement of the particle. We perform a systematic theoretical investigation on the observation that compared with the frozen dynamics of the fluid where the Brownian particle is fixed, the movement of the Brownian particle perturbs the trajectory of the fluid particles and correspondingly the force on the Brownian particle. We show that as the mass M of the Brownian particle increases, the drag force becomes the ensemble average of the force deviation over the fluid configurations, whereas the thermal noise due to the fluctuation of the fluid becomes the force in the frozen dynamics. In addition, we obtain asymptotic expansions (with respect to M) of the friction force and thermal noise defined by the memory function and derive several expressions for single-particle Brownian motion near the Brownian limit. We perform a molecular dynamics simulation study on the Rayleigh model (i.e., a Brownian particle in an ideal gas), which provides a clear validation of the theory. We also observe the skewness in the force distributions and the bath-particle density on the simulation.

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