MAR12-2011-006863

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Brownian motion goes ballistic[1]

ERNST-LUDWIG FLORIN, University of Texas at Austin

It is the randomness that is considered the hallmark of Brownian motion, but already in Einstein's seminal 1905 paper on Brownian motion it is implied that this randomness must break down at short time scales when the inertia of the particle kicks in. As a result, the particle's trajectories should lose its randomness and become smooth. The characteristic time scale for this transition is given by the ratio of the particle's mass to its viscous drag coefficient. For a 1 μm glass particle in water and at room temperature, this timescale is on the order of 100 ns. Early calculations, however, neglected the inertia of the liquid surrounding the particle which induces a transition from random diffusive to non-diffusive Brownian motion already at much larger timescales. In this first non-diffusive regime, particles of the same size but with different densities still move at almost the same rate as a result of hydrodynamic correlations. To observe Brownian motion that is dominated by the inertia of the particle, i.e. ballistic motion, one has to observe the particle at significantly shorter time scales on the order of nanoseconds. Due to the lack of sufficiently fast and precise detectors, such experiments were so far not possible on individual particles. I will describe how we were able to observe the transition from hydrodynamically dominated Brownian motion to ballistic Brownian motion in a liquid. I will compare our data with current theories for Brownian motion on fast timescales that take into account the inertia of both the liquid and the particle. The newly gained ability to measure the fast Brownian motion of an individual particle paves the way for detailed studies of confined Brownian motion and Brownian motion in heterogeneous media.

[1] Einstein, A. Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen. Ann. Phys. 322, 549–560 (1905).

[2] Lukic, B., S. Jeney, C. Tischer, A. J. Kulik, L. Forro, and E.-L. Florin, 2005, Direct observation of nondiffusive motion of a Brownian particle, Physical Review Letters 95, 160601 (2005).

[3] Huang, R., Lukic, B., Jeney, S., and E.-L. Florin, Direct observation of ballistic Brownian motion on a single particle, arXiv:1003.1980v1 (2010).

[4] Huang, R., I. Chavez, K.M. Taute, B. Lukic, S. Jeney, M.G. Raizen, and E.-L. Florin, 2011, Direct observation of the full transition from ballistic to diffusive Brownian motion in a liquid, Nature Physics 7, 576–580 (2011).

[1]This research was supported by NSF grants PHY-0647144 and DBI-0552094