Brownian motion under the microscope

11 October 2005

An international group of researchers from the EPFL (Ecole Polytechnique Fédérale de Lausanne), the University of Texas at Austin and the European Molecular Biology Laboratory in Heidelberg, Germany have demonstrated that Brownian motion of a single particle behaves differently than Einstein postulated one century ago.

Their results, to be published online October 11 in *Physical Review Letters*, provide direct physical evidence that validates a corrected form of the standard theory describing Brownian motion. Their experiment tracked the Brownian fluctuations of a single particle at microsecond time scales and nanometer length scales, marking the first time that single micron-sized particles suspended in fluid have been measured with such high precision.

A hundred years ago, Einstein first quantified Brownian motion, showing that the irregular movement of particles suspended in a fluid was caused by the random thermal agitation of the molecules in the surrounding fluid.

Scientists have subsequently discovered that many fundamental processes in living cells are driven by Brownian motion. And because Brownian particles move randomly throughout their surroundings, they have great potential for use as probes at the nanoscale. Researchers can get detailed information about a particle's environment by analyzing its Brownian trajectory.

"It is hard to overemphasize the importance of thoroughly understanding Brownian motion as we continue to delve ever deeper into the world of the infinitesimally small, " comments EPFL's lead researcher Sylvia Jeney.

Researchers have known for some time that when a particle is much larger than the surrounding fluid molecules, it will not experience the completely random motion that Einstein predicted. As the particle gains momentum from colliding with surrounding particles, it will displace fluid in its immediate vicinity. This will alter the flow field, which will then act back on the particle due to fluid inertia. At this time scale the particle's own inertia will also come into play. But no direct experimental evidence at the single particle level was available to support and quantify these effects.

Using a technique called Photonic Force Microscopy, the research team has been able to provide this evidence. They constructed an optical trap for a single micron-sized particle and recorded its Brownian fluctuations at the microsecond time scale. "The new microscope allows us to measure the particle's position with extreme precision," notes University of Texas professor Ernst-Ludwig Florin, a member of the research group.

At this high resolution, they found that the time it takes for the particle to make the transition from ballistic motion to diffusive motion was longer than the classical theory predicted.

"This work ratchets our understanding of the phenomenon up a step, providing essential physical evidence for dynamical effects occurring at short time scales," says Jeney.

Their results validate the corrected form of the equation describing Brownian motion, and underline the fact that deviations from the standard theory become increasingly important at very small time scales.

As researchers develop sophisticated, high resolution experimentation techniques for probing the nanoworld, these dynamical details of Brownian motion will be increasingly important.

Dr. Jeney was awarded the SSOM prize at the August 2005 meeting of the Swiss Society for Optics and Microscopy for her work in photonic force microscopy, the technique used in this research.

On the web:
nanotubes.epfl.ch/index.php?m1=research&m2=to

pic3b

Source: Ecole Polytechnique Fédérale de
Lausanne

APA citation: Brownian motion under the microscope (2005, October 11) retrieved 3 December 2021 from https://phys.org/news/2005-10-brownian-motion-microscope.html