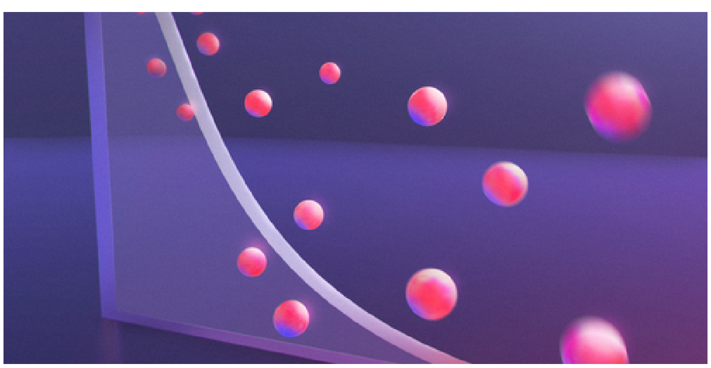
How Walls Change a Colloid's Diffusivity

An analytical model paired with precise experimental measurements explains the origin of the complex dynamics of a colloidal particle close to a flat surface.

By Agnese Curatolo

A particle diffusing in the bulk of a simple fluid moves according to a straightforward law: its mean square displacement increases linearly with time, and its position increments obey Gaussian statistics. In more realistic situations involving complex media and heterogeneous environments, the tail of the probability distribution for such a colloid's position has been predicted to follow an exponential pattern. Now Arthur Alexandre and colleagues at the University of Bordeaux and the École Normale Supérieure of Lyon, both in France, explore the mechanism behind this non-Gaussianity using an experimental, numerical, and analytical study of a colloid close to a flat surface [1].

The team considers a particle that can diffuse parallel or perpendicular to two confining walls. In the parallel direction, the particle's diffusion constant depends on its distance from both walls. Because this distance fluctuates, the diffusion constant also fluctuates, a behavior known as diffusing diffusivity.



Credit: D. Dean/University of Bordeaux

In order to quantify this behavior, the researchers draw an analogy with a well-known fluid-mechanical effect called Taylor dispersion, in which the diffusivity of a colloid is enhanced by a shear flow. This trick allows them to derive the expressions for the cumulants of the probability distribution function related to the mean square displacement (second cumulant) and the non-Gaussianity (fourth cumulant). They numerically and experimentally verify these predictions. The team hopes that the study will spur others to explore related systems and potentially uncover additional interesting properties of these particle systems.

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REFERENCES

1. A. Alexandre *et al.*, "Non-Gaussian diffusion near surfaces," Phys. Rev. Lett. 130, 077101 (2023).