Fluid & Bio Dynamics Seminar

MAX PLANCK INSTITUTE
FOR DYNAMICS AND
SELF-ORGANIZATION

Settling of particles in quiescent fluids and turbulent flows

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In spite of its apparent simplicity, the problem of spherical particles settling in a fluid hides a whole hierarchy of rich intricate phenomena, some of which are still shrouded in mystery. Notably, the interplay between inertia and gravity in the coupling of dense particles with a carrier turbulent background remains unclear. The question is by no means just rhetorical, as it impacts numerous real situations, such as the atmospheric dispersion of pollutants, dynamics of dust in proto-planetary accretion disks, transport of grains in geophysical flows and sprays in industrial processes to cite just a few examples. Unveiling the fundamental mechanisms of drifting particles in turbulence has become a crucial issue to improve our capacity to accurately model and predict such particle-laden flows. For instance, a question as simple as « Do particles settle faster, slower or at the same rate in a turbulent flow than in a quiescent fluid ? » has not found yet a clear and definite answer.

In this context we will present recent experiments exploring the coupling between finite size settling spherical particles and the surrounding fluid (either quiescent or turbulent). In the quiescent case, we explore and characterize (in a range of particle-to-fluid density ratios not investigated before) non-trivial settling regimes (oblique, ocsillating, planar, helicoidal, chaotic, etc.) in good agreement with existing numerical predictions. In the turbulent case, we propose a novel approach using magnetic particles to disentangle the role of inertial and gravitational mass on particle/turbulence interactions. Indeed, these interactions are controlled by at least 4 dimensionless parameters (and any combination of those) : (i) the Reynolds number which quantifies the intensity of turbulence, (ii) the particle-diameter-to-turbulent-dissipation-scale ratio (which quantifies particle finite size effects), (iii) the Stokes number (or particle to fluid density ratio) which quantifies inertial effects and (iv) the Rouse number (or settling parameter) which quantifies the strength of gravity compared to turbulence. These parameters are intrinsically entangled and almost impossible to vary independently from each other in classical experiments. By using magnetic particles in a well designed external field, we are able to tune the effective gravity experienced by the particles. The magnetic compensation of gravity is first validated in the quiescent case and then used in the turbulent case to vary the Rouse number independently from the Stokes number. Preliminary results on the impact on settling velocity and particle dynamics will be presented. In particular, we find that particle settling is either enhanced (in agreement with Wang & Maxey's preferential sweeping mechanism) or hindered (in agreement with Nielsen's loitering phenomenology) by turbulence depending on the Rouse number. Detailed experiments where the flow and the particles are simultaneously tracked allow to further scrutinize these sublte particle/turbulence couplings.

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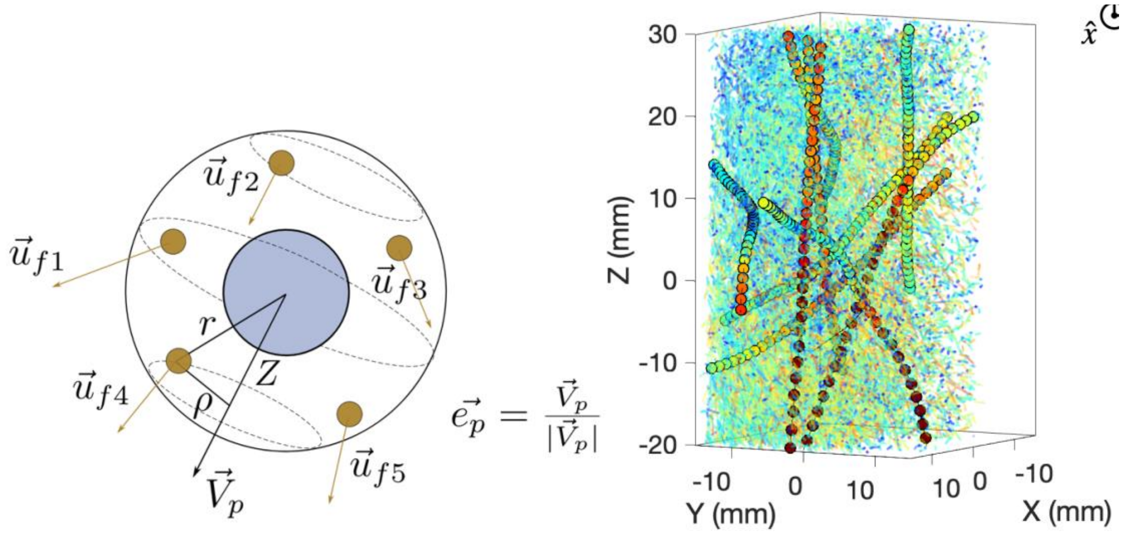

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MPI-DS, Seminar Room 0.79 and Zoom

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