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Acceletion statistics of heavy particles in turbulent flows

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Small impurities like dust or droplets suspended in an incompressible flow are finite-size particles whose density may differ from that of the fluid, and cannot thus be modelled as fluid tracers. The description of their motion must account for their finite response time, i.e. their inertia whence the name *inertial particles*. Remarkably such particles display strong spatial inhomogeneities even in incompressible flows, a phenomenon known as *preferential concentration*, whose statistical description is an open issue with many industrial and environmental applications. We mention the formation of rain droplets in warm clouds and spray combustion in Diesel engines. Inertial particles are also relevant to aerosols, pollen or chemicals dispersion in the atmosphere where diffusion by air turbulence may be overcome by preferential clustering.

Fundamental for developing models of particle motion and dispersion is a detailed knowledge of the particle acceleration statistics. We present here the results of direct numerical simulations of particle transport in homogeneous, isotropic, fully developed turbulence, up to resolution 512^3 ($R_\lambda \approx 185$). We focus on the acceleration statistics of particles much heavier than the carrier fluid as a function of both R_λ and St (being the Stokes number a nondimensional measure of particle inertia).

We show that: (i) The root-mean-squared acceleration $a_{\rm rms}$ sharply falls off from the fluid tracer value already at small Stokes numbers; (ii) At a given St the normalised acceleration $a_{\rm rms}/(\epsilon^3/\nu)^{1/4}$ increases with R_λ consistently with the trend observed for fluid tracers; (iii) The tails of the probability density function of the normalised acceleration $a/a_{\rm rms}$ decrease with St. The results are heuristically explained in terms of two concurrent mechanisms: preferential concentration that is very effective at $St \ll 1$, and filtering induced by the particle response time more effective at larger St.