LAGRANGIAN STUDIES IN TURBULENT FLOWS: FROM INERTIAL PARTICLES TO ACTIVE MATTER

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Particle-laden turbulent flows are widespread phenomena both in natural sciences and in industrial applications. We encounter particle seeded turbulence in the description of pollutant dispersion in the atmosphere, in cloud physics of rain formation, in marine biology for the description of ocean plankton colonies, in astrophysics for planet formation and finally in technological applications such as chemical and mechanical industrial processes aimed at controlling mixing, energy dissipation or sedimentation. The advancement of the understanding of statistical properties of particles in turbulent flows has a pivotal role in each of these areas and a great amount of work has been devoted to better understand them through experiments, numerical simulations and theoretical studies.

In this talk, I will first review recent findings on the properties of small inertial particles and bubbles in a flow. The focus will be on the properties of acceleration, a quantity that is closely linked to the hydrodynamic forces acting on the particles and that allows for the most direct comparison between numerical studies and experiments. In particular we will see to what extent a buoyant sub-Kolmogorov scale inertial particle can be considered a faithful proxy of fluid tracer acceleration, a feature that results from a non trivial interplay of the effect of gravity and turbulent fluctuations [1].

Due to the sinking/rising velocity induced by buoyancy, in some respect small particles and bubbles in turbulence can be assimilated to particles cruising in a flow. This provides a link with a second series of studies where self-propelled point-like probes drifting in a flow are considered [2]. Like a vessel in a flow, these particles are continuously deviated by their intended course as the result of local sweeping of the fluid. The recorded time-series of fluid velocity and of the intensity of a scalar concentration along these moving probes represents the simplest realisation of a transect measurement in a fluid environment. I will show how transect measurements display a non trivial combination of Lagrangian and Eulerian phenomenology and how a transition from one regime to the other occurs at increasing the propulsion velocity. The study of intermittent properties of transect measurements highlights, in a striking way, the opposite trends displayed by fluid velocity and scalar statistics. The model of drifting particles can also be extended to include the occurrence of particle reorientation by the surrounding fluid flow. In its simple realisation small axisymmetric particles are oriented by the instantaneous local fluid gradients at the particle position. However, even in this simple case the resulting tumbling dynamics in a turbulent flow is far from being trivial [2, 3] and this is even more complex when particle propulsion and orientation combines with each other.

Finally, I will present the results of a modelling study on the motility of zooplankton in turbulence [4]. This bio-inspired modelisation aims at taking into account the most relevant dynamical feature of planktonic copepods, whose peculiarity is to react to velocity gradients cues by a fast swimming behaviour, dubbed jump. I will examine how a jump escape reaction from high-intensity turbulence may lead to micro-organisms preferential accumulation, with possible ecological implications linked to the increase of inter-species contact rate [5].