Thesis proposal for a Doctoral position 2023-2026

Title	Transport and dispersion of a cluster of particles by a vortex structure
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<u>Research project description</u>:

In many configurations fluid flows interact with particles. Examples are plumes in stellar mantles, river flows on a sandy bottom, or the transport and dispersion of aerosols in the wake of aircraft. The particles, according to their characteristics (density, size), are considered as inertial or as passive tracers, leading to various interactions with the surrounding fluid flow. The particle volume fraction also plays a role on their individual or collective kinetics. Furthermore, the structure of the fluid flow can be complex due to the presence of vortex structures of different spatio-temporal scales and there is no univocal model to evaluate the relative weight of the different hydrodynamic forces acting on the particle (or particles) (see [1] for example).

As part of this thesis, we propose a numerical study (DNS using the OpenSource code Basilisk [2]) along with an experimental one of the interaction of particles in variable concentrations with a vortex ring (the experimental set-up is operational and has been used in several recent works [3-5]). Indeed, vortex rings (VR) are coherent vortical structures classically considered as the main order of many flows. In addition, VR are self-propagating structures which transport mass and momentum along their trajectory. They are therefore good candidates for agitation and dispersion.

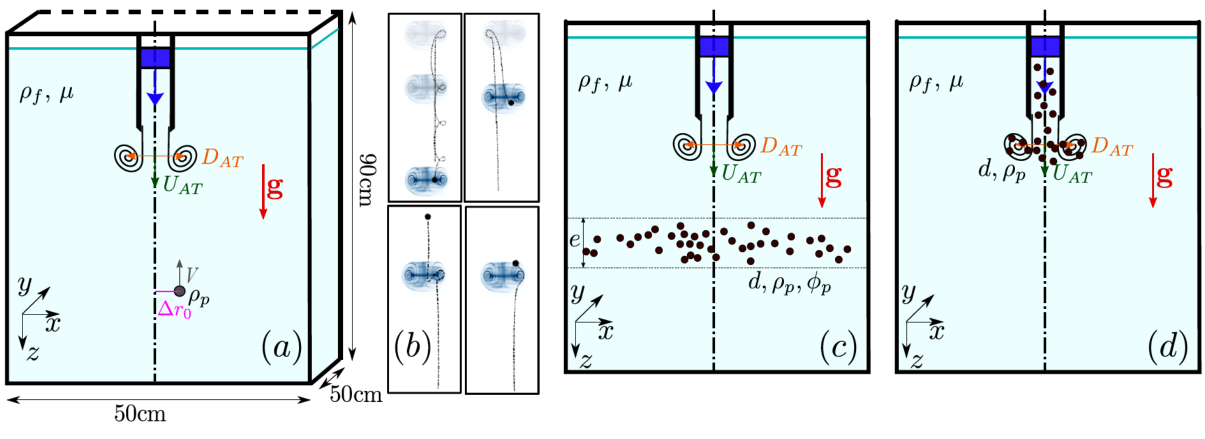

Figure 1: Schematics of the configurations aimed at (a) studying the physical mechanisms of interaction between a vortex ring and an isolated particle, and evaluating the transport and dispersion in (c) the case of a particle cloud traversed by a vortex ring and in (d) the case of a vortex ring initially loaded with particles. Figure (b) shows different types of particle-VR interactions observed by [5].

The thesis will then consist in three major scientific axis:

- A first step will consist in **evaluating, through a parametric study, the physical mechanisms involved in the isolated particle-VR interaction** (configuration of Figure 1(a)). The objective here will be to propose a modeling of the mechanisms leading to various particle trajectories (as illustrated in Figure 1(b)) for small particles relative to the VR diameter.

- In a second stage, the complexity of the flow will be increased as we will study the interaction between a VR and a cloud of particles whose volume fraction Φ_p will be gradually varied. The objective will be to **identify the criteria for the appearance of collective effects and to characterize them** (configuration of the Figure 1(c)).

- The third part will aim at **evaluating the global transport and dispersion budgets** for two different initial configurations: a VR passing through a particle cloud with variable volume fraction Φ_p and relative thickness e/D_{AT} (configuration of Figure 1(c)) and an initially particle-laden VR evolving in a homogeneous fluid (configuration of Figure 1(d)). We will then be interested in the amount of particles entrained and the radial and vertical reorganization of the particle concentrations.

[1] M.Maxey, J.Riley (1983) Phys. Fluids, 26(4) 883-889
[2] http ://basilisk.fr/
[3] J.Pinaud, J.Albagnac, P.Brancher (2020), PhD thesis
[4] J.Pinaud et al. (2021) Phys. Rev. Fluids 6, 104701
[5] N.Sasso, J.Albagnac, L.Lacaze, P.Brancher (2019), Master thesis