EULERIAN VS LAGRANGIAN IRREVERSIBILITY IN AN EXPERIMENTAL TURBULENT VON KARMAN FLOW

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In a viscous fluid, the energy dissipation is the signature of the breaking of the time-reversal symmetry $t \rightarrow -t$, $u \rightarrow -u$, where $u$ is the velocity. This symmetry of the Navier-Stokes equations is explicitly broken by viscosity. Yet, in the limit of large Reynolds numbers, when flow becomes turbulent, the non-dimensional energy dissipation per unit mass becomes independent of the viscosity, meaning that the time-reversal symmetry is spontaneously broken[1, 2, 3]. Natural open questions related to such observation are: what is the mechanism of this spontaneous symmetry breaking? Can we associate the resulting time irreversibility to dynamical processes occurring in the flow? Can we devise tools to locally measure this time irreversibility?

Figure 1. An example of Lagrangian trajectories obtained in a $45mm \times 40mm \times 6mm$ volume at the center of a von Karman flow at Reynolds $Re = 6000$. There are 19 time-step plotted for each trajectory. The trajectories are coded by intersecting spheres representing one particle position. Color represent velocity magnitude. On average, there are about 50 000 trajectories per time step.

In this talk, I try to answer these questions in a turbulent von Karman experiment. The flow is generated by two counter-rotating impellers fitted with blades. Thanks to a high resolution 4-D PTV technique, we obtain time-resolved Lagrangian and Eulerian velocity measurements, at a resolution of the order of the Kolmogorov scale (see Figure 1). I use these measurements to compare Eulerian and Lagrangian signatures of irreversibility, and link them with peculiar properties of the local velocity field or trajectories.

References