Investigation and multifractal description of a Lagrangian irreversibility indicator in a experimental Von Kármán turbulent flow

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Turbulence is a dissipative phenomenon subject to irreversible events. Indeed, the time-reversal symmetry is explicitly broken by viscosity, and it is spontaneously broken in the inviscid limit. This is the dissipative anomaly. Recently, Theodore D. Drivas [1] proved the equivalence of two local indicators of time-irreversibility: a) an Eulerian one, based on regularity properties of the velocity field [2] and local energy transfers ; b) a Lagrangian one, based on symmetry properties of the trajectories under time reversal [3]. Theodore D. Drivas, rigorously proved that under suitable limits, the Eulerian and Lagrangian indicators converge to the same quantity $\epsilon(x,t)$, the local energy dissipation. This result is crucial because it provides two different indicators that discriminate between regions where the fluid is or is not time-irreversible. By tracking in time and space such regions, one may then get hints of the physical processes responsible for the symmetry breaking. Furthermore, it provides a local Lagrangian description of dissipation and energy transfer which statistical dynamics across the scales could leverage interesting information on the space-time support of the anomalous dissipation, complementing the Eulerian approach of Chhabra et al. [4].

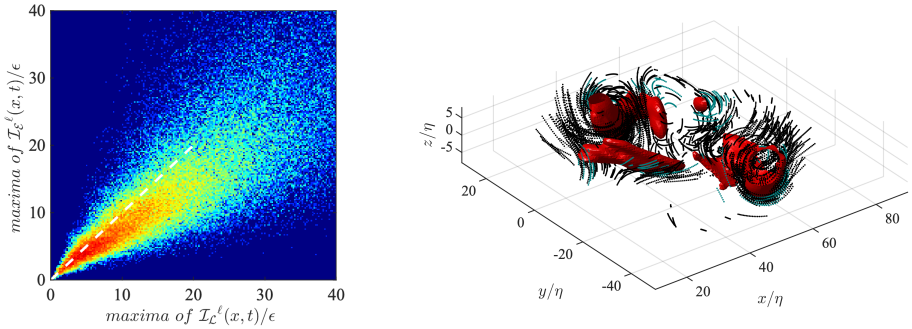

Figure 1: (Left) Joint PDF of Lagrangian and Eulerian maxima found at each snapshot. (Right) Eulerian and Lagrangian 3D visualization of Eulerian irreversiblity iso-surfaces (in red) and highly irreversible trajectories selected from the Lagrangian criterion in black (positive) and blue (negative).

In this talk, I will first test the equivalence of the two indicators in an experimental turbulent Von Kármán flow using high resolution 4D-PTV (Fig 1 left). I will then perform a joined Eulerian-Lagrangian exploration of the dynamics leading to time irreversibility, and find that it is linked with vortex interaction, suggesting a link between irreversibility and singularity (Fig 1 right). Finally, similar to Chhabra et al., we measure the singularity spectrum of the Lagrangian irreversibility indicator.

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