# Are vortex interactions the source of time-irreversibility and singularities in turbulent flows ?

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Turbulence is a dissipative phenomenon, thus subject to irreversible events. Indeed, the time-reversal symmetry is explicitly broken by viscosity, and yet it is spontaneously broken in the inviscid limit. We term this the dissipative anomaly. Recently, Theodore D. Drivas [1] formally proved the equivalence of two different local indicators of time-irreversibility: i) an Eulerian one, based on regularity properties of the velocity field [3] and local energy transfers ; ii) a Lagrangian one, based on symmetry properties of the trajectories under time reversal [2]. Theodore D. Drivas [1], 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 dynamically in time and space such regions, one may then get hints of the physical processes that are responsible for the symmetry breaking.

In this talk, I will first test the equivalence of the two indicators in an experimental turbulent Von Kármán flow at a resolution of the order of the Kolmogorov scale using a high resolution 4D-PTV technique. I will then use the equivalence to perform the first 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 (Figure 1).

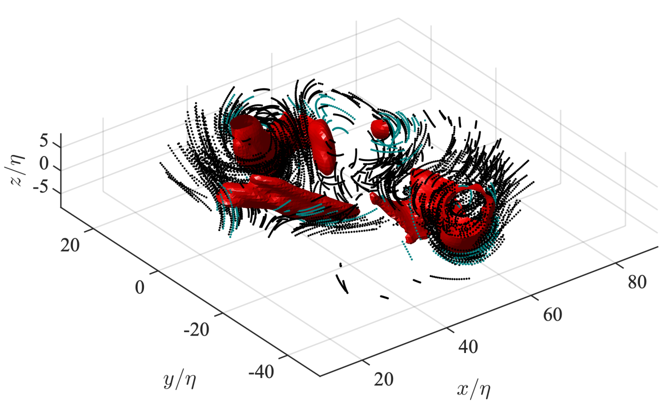


**Figure 1.** 3D visualization of Eulerian irreversiblity iso-surfaces (in red) and highly irreversible trajectories selected from the Lagrangian criterion in black (positive) and blue (negative).

## References

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3. Jean Duchon & Raoul Robert, Inertial energy dissipation for weak solutions of incompressible Euler and Navier-Stokes equations, *Nonlinearity*, **13**, 249–255 (2000).