Numerical and experimental direct observation of vortex reconnection in a turbulent swirling flow

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The energy budget for weak solutions of incompressible Navier-Stokes derived by Duchon and Robert[1] has been instrumental in studying local in space, scale and time energy transfers (denoted D_l^I where l is the probed scale) and dissipation (denoted D_l^ν) in turbulent flows. At scales smaller than the Kolmogorov scale η, a downscale (positive) transfer of energy can potentially identify the presence of singularities or quasisingularities within the flow. Dubrulle[2] examined the experimental datasets of the von Kármán flow and linked large values of D_l^I and D_l^ν with coherent structures having a shock-like (or front-like) and spiral-like geometry. Recently, Harikrishnan et al.[3] analysed numerical and experimental datasets of the von Kármán flow and showed that strong $|D_l^I|$ events, defined $|D_l^I| > \tau(q = 0.95)$ where τ is a threshold associated with a quantile q, can be seen at the plane of reconnecting vortices.

In this work, we will extend the analysis of Harikrishnan et al.[3] to study the links between vortex reconnection and energy transfer. To this end, a tracking technique with region-based correspondence capable of automatically identifying reconnecting pairs of vortices is developed. A change in the order of the components of enstrophy is used as an indicator for vortex reconnection as shown in Fig. 1. This technique is applied to numerical and experimental datasets of the von Kármán flow, the latter of which is performed on a much larger tank thereby allowing for the exploration of scales close and below η.

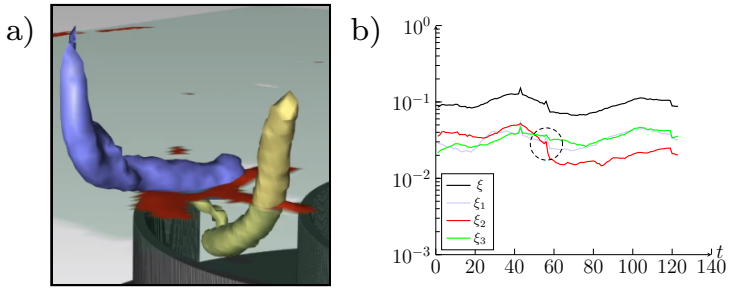

Figure 1. (a) Strong $|D_l^I|$ (red patch) can be seen at the plane of reconnection of the blue and yellow vortex structures (b) Enstrophy ξ and its components ξ_1, ξ_2, ξ_3 versus time t.

References

1. J. Duchon, R. Robert, *Nonlinearity*, **13**, 1 (2000).
2. B. Dubrulle, *J. Fluid Mech*, **867**, P1 (2019).
3. A. Harikrishnan et al., Tracking singularities: A journey through the scales. *Gallery of fluid motion*, (2022).