Enstrophy conditioned extreme-event statistics and their morphology

Benjamin Musci[1], Jean Le Bris[1], Adam Cheminet[1], Christophe Cuvier[2], Pierre Braganca[2], Cecile Wiertel-Gasquet[1], Berengere Dubrulle[1]

[1] SPHYNX Lab, CEA-Saclay, 91191 Gif-sur-Yvette
[2] LMFL, Centrale Lille, 59655 Villeneuve d'Ascq
benjamin.musci@cea.fr

A key problem in our understanding of turbulence is the existence of the so-called dissipative anomaly [1][3]. One possible explanation to this could be the existence of quasi-singularities (or extreme-events) in the flow, which are able to dissipate energy inertially, near or below the Kolmogrov scale [1]. Mathematicians also link the possible existence of these singularities in the equations of motion to the violent phenomenon of "spontaneous stochasticity." [1] However, to date, there is no experimental demonstration of this phenomenon, nor any proof of its link with singularities or quasi-singularities.

This work aims to help fill this void with state-of-the-art experimental results from the Giant-von-Karman (GvK) facility at CEA Paris-Saclay. [2]. The resulting data covers a range of Reynolds number (6,000-150,000) at resolved scales rarely reached in experimental flows (down to $\frac{1}{4}$ Kolmogorov). By performing 4D Particle Tracking Velocimetry at these very high spatial resolutions, the time-resolved velocity fields are used to better understand the occurrence of extreme events in turbulence, both statistically and instantaneously. The fine resolution achieved in this work is crucial for helping to better answer the elusive description of the smallest scales in turbulent flows.

We statistically investigate the amplification of vorticity gradients occurring during intermittent extreme events. By conditioning these statistics using enstrophy, we allow for a better understanding of the vortex stretching mechanisms specifically in those regions where intermittency occurs, and exclude quiescent regions. [4]. Additionally, we re-investigate the possible universality of the alignment of vorticity vector with the intermediate strain-rate eigenvector [5].

This work also investigates individual extreme-event morphologies to better understand amplification processes in such events. The identification of an event in time and space allows for the tracking of this event spatio-temporally. With this tracking, the changing alignment of the strain and vorticity vectors can be used to answer questions about extreme-event generation and enstrophy production.

References

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