A TOY FOR TURBULENCE

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Summary

The present research is aimed at understanding the subtle (and not yet fully understood) relationship between the complex nonlinear dynamics of fluid turbulence and Kolmogorov power-law scaling in wavenumber space. Time evolution is often overlooked in DNS of turbulent flows, hence investigation of a suitably simple Minimal Flow Unit (MFU) can help to understand the passage from a vortical-dominated stage to a turbulent stage having all the ingredients of turbulent flows. In particular, we aim at clarifying the physical phenomena associated with the formation of a finite-time singularity (FTS) in the Euler equations and of Kolmogorov's $k^{-5/3}$ scaling in the Navier-Stokes equations. For that purpose, high-resolution simulations of the Euler and Navier-Stokes equations are carried out and analyzed by means of state-of-the-art eduction techniques to isolate the contribution of tube-like and sheet-like structures. Equipping the MFU with passive scalars (relevant in turbulent combustion) further helps understanding why passive scalar spectra have a different behavior than the velocity field spectra close to the FTS, but they also attain a $k^{-5/3}$ power spectrum at subsequent times, in the presence of finite viscosity. By adding a passive vector (relevant in MHD flows), dynamical differences with respect to the vorticity field can also be established.

The MFU has been also used to investigate the possibility to destroy the coherence of wake vortices generate by airplanes during landing or take-off. Simulations of Lamb dipoles interacting with walls with solid obstacles of different shape or with walls with an array of small jets demonstrate that it is possible to reduce the energy content of the wake vortices. The practical results is to increase the airport capacity.