Energy transfer and vortex structures: Visualizing the incompressible turbulent energy cascade

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The transfer of kinetic energy from large to small scales is a hallmark of turbulent flows. Yet, a precise mechanistic description of this transfer, which is expected to occur via an energy cascade, is still missing. Several conceptually simple configurations with vortex tubes have been proposed as a testing ground to understand the energy cascade. Here, we focus on incompressible flows and compare the energy transfer occurring in a statistically steady homogeneous isotropic turbulent (HIT) flow with the generation of fine-scale motions in configurations involving vortex tubes. We start by filtering the velocity field in bands of wavenumbers distributed logarithmically, which allows us to study energy transfer in Fourier space and also visualize the energy cascade in real space. In the case of a statistically steady HIT flow at a moderate Reynolds number, our numerical results do not reveal any significant correlation between regions of intense energy transfers and vorticity or strain, filtered in corresponding wavenumber bands, nor any simple self-similar process. In comparison, in the transient turbulent flow obtained from the interaction between two antiparallel vortex tubes, we observe a qualitatively simpler organization of the intense structures, as well as of the energy transfer. The process leading to vortex reconnection via flattening of interacting vortex cores in two intense ribbons of vorticity, also appears as qualitatively different from the physics of HIT. Our results indicate that the specific properties of the transient flows affect the way energy is transferred, and may not be representative of HIT.

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