The intense vortices in non-equilibrium turbulence

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The intense vorticity structures (IVS)[1] are studied in unbalanced (non-equilibrium) turbulence using direct numerical simulations (DNS)[2], of homogeneous isotropic turbulence (HIT), with Reynolds number varying between $180 \leq Re_\lambda \leq 360$. The non-equilibrium is achieved by applying a temporal varying power input (forcing) into an initially statistically stationary simulation of HIT. In these DNS the non-dimensional dissipation obeys the power law, $C_\epsilon \sim Re_\lambda^{-1.2}$ (Fig. 1(a)), which is typical of non-equilibrium turbulence[3,4].

The analysis of the IVS uses the 'wormtracker' algorithm recently employed by the authors in steady conditions[5]. The radius of the IVS normalised with the instantaneous Kolmogorov scale exhibits a small perturbation when the unsteady conditions are applied (Fig. 1(b)), because the applied perturbation needs time to flow through the energy cascade towards the small scales, in contrast the tangential velocity of the IVS is affected immediately when the power input is varied (not shown). The results show that the statistics of the IVS that are solely governed by the local, small scale variables, are relatively insensitive to changes in the large scales of motion, and are essentially similar in classical and non-equilibrium turbulence. However, the statistics of the IVS involving non-local flow dynamics are strongly affected and differ significantly in equilibrium and non-equilibrium turbulence.

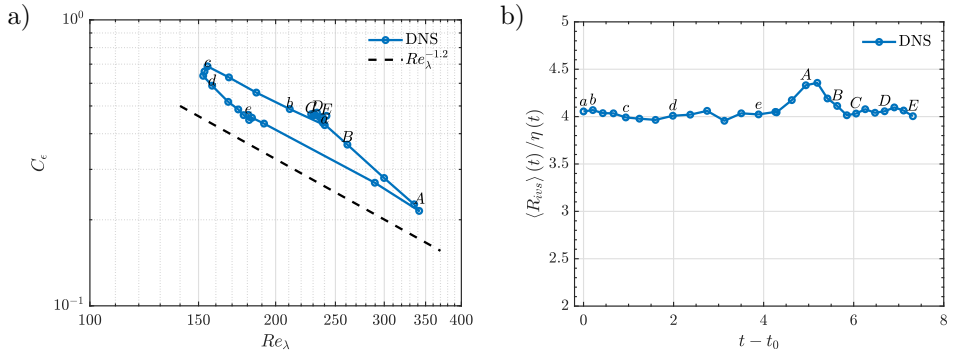

Figure 1: Results for one DNS of unbalanced HIT: (a) Non-dimensional dissipation C_ε as function of the turbulent Reynolds number Re_λ; (b) Mean radius of the IVS normalised by the instantaneous Kolmogorov length scale, $\langle R_{ivs} \rangle / \eta(t)$, as function of timel t.

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