DNS data analysis of the velocity-gradient tensor in high Reynolds number isotropic turbulence

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Scale dependence as well as Reynolds number dependence of the second and third invariants (Q and R) of the velocity-gradient tensor in homogeneous isotropic turbulence was studied using a series of direct numerical simulations (DNSs) of incompressible turbulence in a periodic box. The highest Taylor micro-scale Reynolds number attained by the DNSs with $k_{\max}\eta \sim 2$ is approximately 1100, where $k_{\max}$ is the maximum wavenumber and η is the Kolmogorov length scale.

The second and third invariants of coarse-grained velocity-gradient tensors obtained by a DNS of turbulence with $R_\lambda \sim 1100$ were investigated. It was observed that the shapes of the joint p.d.f.s of the second and third invariants are independent of the length scale for coarse-graining when the scale is in the inertial range. On the other hand, it was also observed that the larger the length scale for coarse-graining, the smaller the probability of intense deformation (figures omitted).

The analysis of joint p.d.f.s of the second and third invariants obtained by a series of the DNSs of turbulence shows that the probability of the occurrence of very strong deformation at small scales increases as the Reynolds number increases (see Figure 1). It could be also confirmed that the volume of the weak deformation zone increases as the Reynolds number increases.

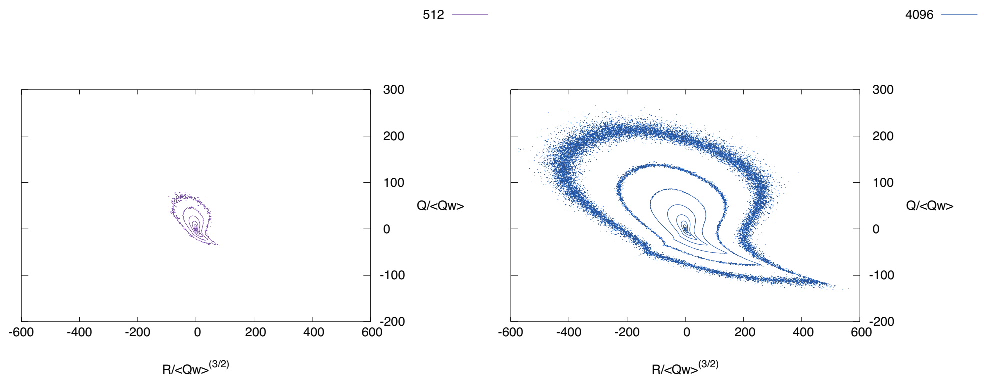

Figure 1: Joint p.d.f.s $P(R/\langle Q_w\rangle^{3/2}, Q/\langle Q_w\rangle)$ obtained by DNS data of turbulence at $R_\lambda = 173$(left) and at $R_\lambda = 730$(right). Here $\langle Q_w\rangle = \langle \omega^2\rangle/4$ and ω is the amplitude of vorticity. The contour levels are $\log_{10} P = -8, -7, \cdots$ in the left and $\log_{10} P = -10, -9, \cdots$ in the right.

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