Departure from the statistical equilibrium of large scales in three-dimensional hydrodynamic turbulence

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We study the statistically steady states of the forced dissipative three-dimensional homogeneous isotropic turbulence at scales larger than the forcing scale in real separation space. The probability density functions (PDFs) of longitudinal velocity difference at large separations are close to but deviate from Gaussian, measured by their non-zero odd parts. Under the assumption that forcing controls the large-scale dynamics, we propose a conjugate regime to Kolmogorov's inertial range, independent of the forcing scale, to capture the odd parts of PDFs. The analytical expressions of the third-order longitudinal structure functions derived from the Kármán-Howarth-Monin equation prove that the odd-part PDFs of velocity differences at large separations are non-zero and show that the odd-order longitudinal structure functions have a universal power-law decay as the separation tends to infinity regardless of the particular forcing form (Fig. 1), implying a strong coupling between large and small scales. Thus, dynamics of large scales depart from the *absolute equilibrium*, and we can partially recover small-scale information without explicitly resolving small-scale dynamics.

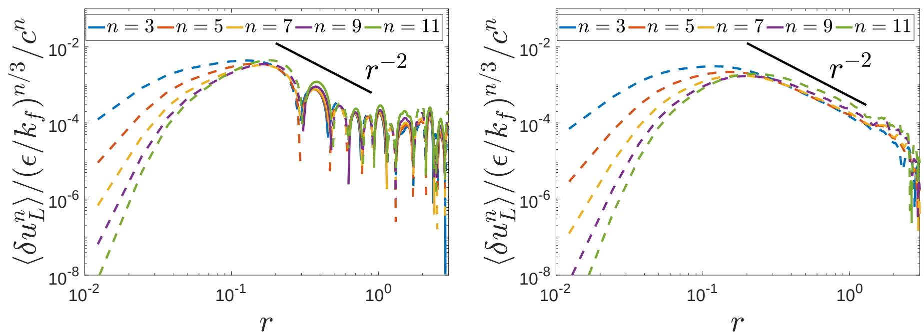

Figure 1: Normalized high-odd-order structure function $\langle \delta u_L^n \rangle / (\epsilon/k_f)^{n/3}/c^n$, with the spherical shell forcing (left, $c = 6.6$) and exponential forcing(right, $c = 7.0$), where δu_L, ϵ, k_f represent the longitudinal velocity difference, energy dissipation rate, and forcing wavenumber, respectively.

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