Elastic range scaling in polymeric turbulence at large Reynolds and Deborah numbers

Marco E. Rosti*, Prasad Perlekar† and Dhrubaditya Mitra‡

Turbulent flows containing modest amounts of long-chained polymers have remained an intriguing area of research since the discovery of turbulent drag reduction. Here, we perform direct numerical simulations of statistically stationary, homogeneous, and isotropic turbulent flows of dilute solutions of polymers at high Reynolds numbers and Deborah numbers[1].

We present evidence that there is a range of scales r over which the energy spectra and the structure functions show new scaling consistent with recent experimental results[2]. In particular, we find that for small wavenumbers k, the kinetic energy spectrum shows Kolmogorov–like behavior which crosses over at a larger k to a novel, elastic scaling regime, $E(k) \approx k^{-\xi}$, with $\xi \approx 2.3$.

We uncover the mechanism of the elastic scaling by studying the contribution of the polymers to the flux of kinetic energy through scales, and show that this elastic behaviour is non-monotonic in the Deborah number.

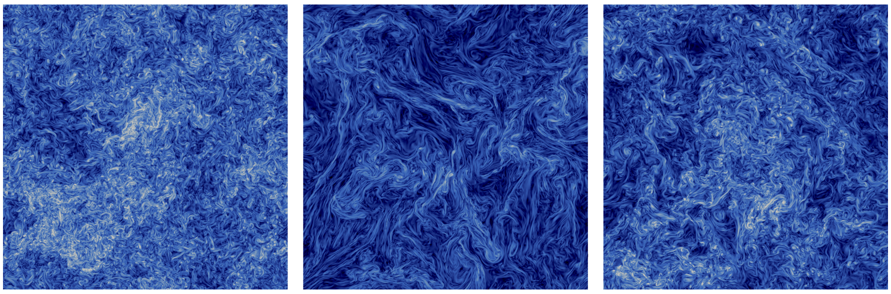

Figure 1: Instantaneous snapshots of the magnitude of the vorticity field for (A) Newtonian and viscoelastic fluids with (B) $De \approx 1$ and (C) $De \approx 25$. The color scale goes from 0 (blue) to the maximum (white).

*Complex Fluids and Flows Unit, Okinawa Institute of Science and Technology, Japan.
†TIFR Centre for Interdisciplinary Sciences, Tata Institute of Fundamental Research, India
‡Nordita, KTH Royal Institute of Technology and Stockholm University, Sweden.

[1]Rosti, Perlekar, Mitra. Science Advances, 2023.
[2]Zhang, Bodenschatz, Xu, Xi. Science Advances, 2021.