Emergent elastic inertial range from smooth velocity fields in low Re polymeric flows

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The addition of polymers to a Newtonian fluid is well known to modify the flow characteristics. The question of precisely how polymers modify the flow of a solvent fluid is still a puzzling one, both at high and low Re numbers. We address this question for low Re flows using the commonly adopted Oldroyd-B model of polymers. We show that dilute polymer solutions, at low Re numbers, exhibit an extended emergent universal scaling regime: the *elastic range*. This behaviour of low Re polymeric flows holds certain similarities to classical high Re, Newtonian turbulence whilst also breaking the analogies at other times. At low Re, even though the scale-by-scale non-linear energy transfer is absent, we still find the evidence of intermittency which manifests in the deviation of structure function scaling exponents from the diffusive prediction $\zeta_p = p$. The distributions of velocity increments, consequently, show strong non-Gaussian fluctuations. However, despite intermittency, the fluid velocity fields still remain smooth and show a universal k^{-4} scaling for the energy spectrum $E(k)$ in the elastic range. We conclude that polymeric flows, at low Re numbers, exhibit emergent universal, intermittent *elastic turbulent* states. However, purely elastic turbulence is distinct from classical, Newtonian turbulence in the fact that instabilities are driven by fluid-polymer interactions rather than the non-linear energy flux.

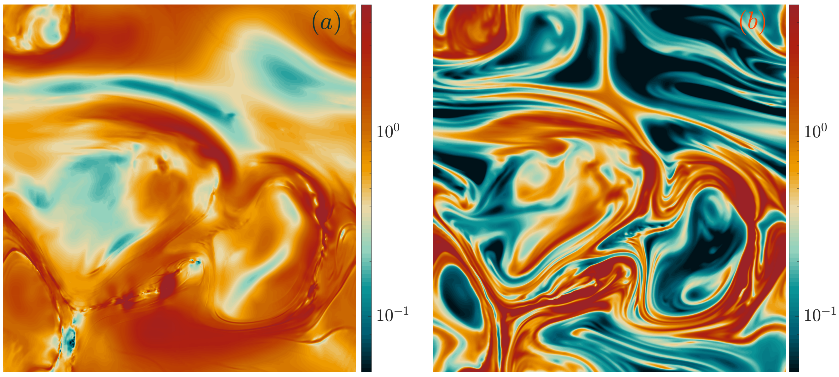

Figure 1: Two-dimensional snapshots of the three-dimensional fields of the normalised (a) fluid dissipation field $\epsilon_f/\langle\epsilon_f\rangle$ and (b) the corresponding polymer dissipation field, $\epsilon_p/\langle\epsilon_p\rangle$.

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