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From rolls to streaks and from waves to sheets: Unravelling the dynamics of viscoelastic turbulence

Summary:

Viscoelastic, wall-bounded turbulence is a visually striking departure from its Newtonian counterpart, and is accompanied by a significant reduction in skin friction. In this work the key coherent motions underpinning elasto-inertial chaos are identified in snapshots from Direct Numerical Simulations of a turbulent viscoelastic channel flow (see figure 1). Familiar coherent structures in the form of rolls and streaks are still present, but their properties are markedly changed in both strength and size. New phenomenology emerges as well, with elongated sheets of polymer stretch and associate vorticity becoming dominant. A pair of carefully designed canonical problems is used to explain the mechanics of these structures for the first time in terms of the vorticity and *polymer torque* — a new concept that greatly simplifies the analysis and lends physical interpretation to the influence of elasticity. New vorticity amplification mechanisms associated with the polymer torque are identified, and the importance of elastic wave propagation in the formation and evolution of the coherent structures is established. The analysis provides a comprehensive account of the flow dynamics sustaining the drag reduced state. In addition, the new understanding is leveraged to propose a novel mixing strategy for viscoelastic fluids, whereby surface roughness can be used to generate vorticity at locations far from the wall.