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Elastic and Binary-fluid Turbulence: An overview

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This talk will begin with a summary of what we know about elastic turbulence in fluids with polymer additives. It will then (a) elucidate the analogue of such turbulence in binary-fluid mixtures and (b) explore the relations of this turbulence with two-dimensional (2D) magnetohydrodynamic (MHD) turbulence. This talk will be based principally on work from our group on turbulence in fluids with polymer additives and in multi-phase flows [see, e.g., Refs. (1-4)] and it will build on the studies of Refs. (5-8) to explore relations with 2D MHD. We will use the paradigm of the turbulence-induced melting of a nonequilibrium vortex crystal [Ref. (9)] to examine elastic turbulence and its analogues in the systems mentioned above.

For example, for the case of elastic turbulence in a fluid with polymer additives, we will summarise the results of our direct numerical simulations (DNSs) of the forced, incompressible two-dimensional Navier-Stokes equation coupled with the FENE-P equations for the polymer-conformation tensor [Ref. (2)]: The forcing in this DNS is such that, without polymers and at low Reynolds numbers Re, the film attains a nonequilibrium steady state with a cellular flow that comprises a square lattice of vortices and antivortices. An increase in the Weissenberg number Wi, leads to nonequilibrium phase transitions, to spatially distorted, but temporally steady, crystals, then to crystals that oscillate in time (periodically, at low Wi, and quasiperiodically, as Wi is enhanced), until spatiotemporal chaos and elastic turbulence set in.

We will then examine the binary-fluid generalizations [Ref. (4)] of the melting of such cellular flows in fluids [Ref. (9)] and 2D MHD [Refs. (5-8)]. In particular, we will characterize (a) the emergent spatiotemporal chaos in low-Re binary-fluid mixtures, (b) their energy spectra, which exhibit broad power-law regimes, as in conventional fluid turbulence, and (c) mixing properties by using Lagrangian-tracer statistics (specifically, we will demonstrate that the mean-square-displacement (MSD) of tracer trajectories displays long-time diffusive behaviour).

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