Turbulence in 2D Spinodal Decompositions

P. H. Diamond[1] & X. Fan[1]

University of California, San Diego, USA
diamondph@gmail.com

We report on studies [1] of turbulence in 2D spinodal decompositions of symmetric binary mixtures. This study emphasizes a comparison and contrast of the physics of spinodal turbulence with that of 2D MHD turbulence. The basic equations and dissipationless invariants for these two systems have many similarities. Both cascades and spectral power laws are studied, as is transport of concentration and momentum. The equations for the two systems are analogous, with concentration difference Ψ corresponding to magnetic potential A, and the spinodal 'bubble' surface tension force acting as the counterpart of the $J \times B$ force in the fluid equation of motion. Most importantly, both systems are 'elastic fluids', which possess a degree of memory. In this regard, the analogue of the Alfven wave in MHD is a capillary wave produced by bubble surface tension. The competition of capillarity vs eddy straining defines the Hinze scale - at which the fluid elasticizes - an important mesoscale which joins the macroscale and the turbulent dissipation scale in defining the turbulent cascades. Finally, in the spinodal problem the dissipation of Ψ is nonlinear.

Studies of spinodal turbulence with relatively large Hinze scale (i.e. nearly elasticized) yield paradoxical but interesting results. The concentration fluctuation spectrum (analogous to $\langle A^2 \rangle_{\mathbf{k}}$) suggests an inverse cascade of $\langle \Psi^2 \rangle$, corresponding to the case in MHD. However, the kinetic energy spectrum scales as $\langle V^2 \rangle_{\mathbf{k}} \sim k^{-3}$, as in the forward enstrophy cascade range for a 2D fluid (not MHD)! The resolution of this dilemma is that capillarity acts only at bubble boundaries, which become less dense as bubbles coalesce. Thus, as bubble merger progresses, the fluid 'cares less and less' that bubbles are present, thus explaining the outcome for the spectrum. Ongoing studies are concerned with cases with smaller Hinze scale. Detailed comparisons with MHD are ongoing, both for power laws and for transport coefficents. We will discuss the evident possibility that spatial representations - i.e. tracking contours of bubble surfaces - may be a more useful way of representing the turbulence physics than the traditional power law spectrum. Finally, we will discuss the relation of this problem to turbulent polymer hydrodynamics, another elastic fluid, which is central to the classic problem of drag reduction.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, under Award Numbers : DE-FG02-04ER54738.

1. We thank L. Chacon, H. Li (LANL) for assistance with the computation.