Dual Cascade, "Blobby" Turbulence, and Target Pattern Formation in Elastic Systems: A New Look at Themes in Plasma Turbulence

P.H.Diamond, Xiang Fan: University of California, San Diego,USA
Luis Chacon: LANL,USA

Issues central to understanding plasma turbulence and transport include: 1) Dynamics of dual cascades in EM turbulence; 2) Understanding 'negative viscosity phenomena' and up-gradient transport in drift-ZF systems; 3) The physics of blobby turbulence (as in the SOL). Here, we present a study of a simple model – that of Cahn-Hilliard Navier-Stokes (CHNS) Turbulence – which sheds new light on these issues.

The CHNS equations describe the motion of binary fluid undergoing a second order phase transition and separation called spinodal decomposition. The CHNS system and 2D MHD are analogous , as they both contain a vorticity equation and a scalar concentration equation,with diffusion . The CHNS system differs from 2D MHD by the appearance of negative diffusivity, and a nonlinear dissipative flux. An analogue of the Alfven wave exists in the 2D CHNS system.

DNS shows that mean square concentration spectrum scales as k^-7/3 in the elastic range. This suggests an inverse cascade of concentration. However, the kinetic energy spectrum behaves as in the direct enstrophy cascade range for a 2D fluid (not MHD!). The resolution is that feedback of capillarity acts only at blob interfaces. Thus, as blob merger progresses, the packing fraction of interfaces decreases, thus explaining weakened surface tension feedback and the outcome for the energy spectrum.

Given the evident importance of isolated blob structures, we also examine the evolution of scalar concentration in a single eddy or blob in the Cahn-Hilliard system. This extends the classic problem of flux expulsion in 2D MHD. The simulation results show that target patterns form and evolve dynamically, albeit episodically . Target patterns are meta stable states, since band merger continues on a time scale exponentially long relative to the eddy turnover time. Band merger resembles step merger in drift-ZF staircases.

[1] Phys. Rev. Fluids 1, 054403.