Scalar dissipation fronts in high-Schmidt number mixing

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Passive scalar fields advected by turbulent flows develop regions of very strong gradients. Such regions are of interest because of their relation to dissipation, mixing, and chemical reactions. The upper left panel of Fig. 1 shows a two-dimensional cut of the instantaneous scalar dissipation rate (proportional to the gradient squared) obtained in a direct numerical simulation. The Schmidt number is 32, i.e., the Batchelor scale η_B of the passive scalar is about a sixth of the Kolmogorov scale η of the advecting fluid. The color coding runs logarithmically from 10^{-5} (blue) to 10^2 (red) in units of the mean scalar dissipation rate.[1]

Magnifications of the of the two framed regions are given in the lower panels. They show that many structures are much narrower than the mean scales η and η_B, which are indicated by the colored squares. Hence much higher resolutions for a proper numerical representation are required. The grid resolution is $N=1024$ in all three directions and also indicated by small grids in both panels.

In three dimensions, the high intensity regions of the scalar dissipation rate are concentrated in sheets. This is evident from the isosurfaces of the field at a level of 11 times the mean scalar dissipation value. This is shown in the upper right panel. Their geometric properties enter models that describe the small-scale intermittency of passive scalar turbulence or the intensity of chemical reactions in nonpremixed turbulent combustion.[2]

[1] J. Schumacher and K. R. Sreenivasan, Phys. Rev. Lett. **91**, 174501 (2003).
[2] J. Schumacher, K. R. Sreenivasan, and P. K. Yeung, J. Fluid Mech. **531**, 113 (2005).