131f Tendrils and Sheets: Topology of Injections in Steady Chaotic 3d Flow

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The topology of tracer areas in chaotic 2D laminar liquid flows has been studied extensively. The distributions of the thicknesses of striations within the chaotic domain have been correlated to the distributions of stretching rates. The focus is shifted from the well-studied topology of tracer areas in 2D unsteady flows to the topology of tracer volumes in 3D steady flow where little is known. In 3D systems, the existence of a neutral direction ensures that all instantaneous injections of fluid into the system will lead to ribbons with an expanding length, a contracting thickness, and a width unchanged by the flow. At short to intermediate time scales the neutral width can be of comparable size to the expanding length; thus, the orientation of these two directions can lead to vastly different topologies at these time scales. The neutral direction also becomes a factor in continuous injections because mass is injected along the same pathlines within the flow. As shown in this paper, the angle between the neutral direction and the stretching direction at each point leads to the mixture of 1D and 2D topologies called tendrils and sheets respectively. The implications are explored through a 3D convection-diffusion-reaction model, and the analysis technique is confirmed through simulations of a stirred tank. A neutral-stretching angle of 10º is found to be the barrier between the tendril and sheet topologies. Using this criterion, cumulative distribution functions of the neutral-stretching angle are used to predict the percentage of the stirred tank at different parameters that is governed by sheet topology versus tendril topology.