Spreading of a Localized Two-Dimensional Vorticity Patch

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The spreading of a localized patch of 2D turbulence is a fundamental problem with direct relevance to the radial spreading of turbulence in confinement devices. We study the relaxation of an isolated two-dimensional vorticity patch using high-resolution Dedalus simulations. We track the enstrophy-weighted radius, $R_{eff} \propto t^{\alpha}$, of the patch for a variety of initial conditions. The expansion is ***subdiffusive*** ($\alpha < ½$) — i.e. slower than ordinary diffusion ($\alpha = ½$) and far from ballistic ($\alpha = 1$). We interpret the exponent through two self-similarity frameworks — conserved per-length momentum invariants (the turbulent "spot," $\alpha = ¼$, vs "puff," $\alpha = ⅓$) and nonlinear, density-dependent ("porous-medium"/Barenblatt) diffusion with $D \propto \omega^m$ — and show that the scale of an applied zero-net-circulation stirring relative to the blob selects the regime. Small-scale forcing drives the spot ($\alpha \to ¼$), while initial-scale forcing preserves the puff ($\alpha \to ⅓$). We discuss the effective diffusivity's dependence on vorticity and the extension to drift-wave (Hasegawa–Mima/Wakatani) dynamics, where wave radiation competes with turbulent mixing. The implications for models of turbulence spreading in confinement devices are discussed.