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A Lagrangian fluctuation-dissipation relation for scalar turbulence THEODORE DRIVAS, GREGORY EYINK, The Johns Hopkins University — An exact relation is derived between the dissipation of scalar fluctuations and the variance of the scalar inputs (due to initial scalar values, scalar sources, and boundary fluxes) as those are sampled by stochastic Lagrangian trajectories. Previous work on the Kraichnan (1968) model of turbulent scalar advection has shown that anomalous scalar dissipation, non-vanishing in the limit of vanishing viscosity and diffusivity, is in that model due to Lagrangian spontaneous stochasticity, or non-determinism of the Lagrangian particle trajectories in the limit. We here extend this result to scalars advected by any incompressible velocity field. For fluid flows in domains without walls (e.g. periodic boxes) and for insulating/impermeable walls with zero scalar fluxes, we prove that anomalous scalar dissipation and spontaneous stochasticity are completely equivalent. For flows with imposed scalar values or non-vanishing scalar fluxes at the walls, spontaneous stochasticity still implies anomalous scalar dissipation but simple examples show that a distinct mechanism of non-vanishing dissipation can be thin scalar boundary layers near the walls. As an example, we consider turbulent Rayleigh-Benard convection. We here obtain an exact relation between steady-state thermal dissipation and the time for diffusive tracer particles released at the top or bottom wall to mix to their final uniform value near those walls. We show that an "ultimate regime" of turbulent convection as predicted by Kraichnan (1962) will occur at high Rayleigh numbers, unless this near-wall mixing time is asymptotically much longer than the large-scale circulation time.

Theodore Drivas
The Johns Hopkins University

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