Anomalous diffusion of tracer particles in fast cellular flows

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It is well known that a diffusive tracer particle in the presence of an array of strong opposing vortices (aka cellular flow) behaves like an effective Brownian motion on long time scales. On intermediate time scales, however, a robust anomalous diffusive behaviour was numerically observed by W. Young. This work studies this intermediate time behavior analytically. Our main result shows that on time scales shorter than the diffusive time scale, the limiting behaviour of trajectories that start close enough to cell boundaries is a fractional kinetic process: A Brownian motion time changed by the local time of an independent Brownian motion. Our proof uses the Freidlin-Wentzell framework, and the key step is to establish an analogous averaging principle on shorter time scales. As a consequence of our main theorem, we obtain a homogenization result for the associated advection-diffusion equation. We show that on intermediate time scales the effective equation is a fractional time PDE that arises in modelling anomalous diffusion.