Two-Particle Dispersion in Weakly Turbulent Thermal Convection – Supplementary Material

The video (file rbc.ra3074.pr1.dispersion.mp4) shows the process of particle dispersion in the Spiral Defect Chaos state of Rayleigh-Bénard convection. It shows a convection system at $Ra = 3074$, $Pr = 1$, with an aspect ratio of $\Gamma = 100$. The resolution of the simulation was $512 \times 512 \times 5$ modes in the spatial domain, with a time step of $dt = 0.005t_v$ (where $t_v \equiv d^2/\kappa$ is the vertical diffusion time). A total number of $10^5$ particles move with a diffusion coefficient of $D = 10^{-3}\kappa$. The video shows the full periodic domain, with three layers: The background image is a black/white image of the fluid temperature. Plotted over that is a map of probability density of a particle initialized at a certain location in the image center. Finally, four individual particles of the particle distribution are displayed as large, colored circles.

The black/white fluid temperature image is reminiscent of images created by the experimental technique of shadowgraphy, often used to visualize temperature in Rayleigh-Bénard experiments. However, our image differs from those visualizations in that we display the temperature at the midplane between lower and upper plate, rather than a measure for the refraction index gradients over the whole height of the cell, as shadowgraphy does. Therefore, hot, rising fluid has lighter color in our images (whereas a shadowgraph would display it darker). At its native frame rate, the video displays $12t_v$ per second, at an average fluid velocity of $U \approx 5.5d/t_v$. The convection rolls rotate several dozen times per second; the dynamics visible in the video is the long-term change of the convection pattern.

The colored density distribution in the second video layer can be interpreted either as a probability distribution for the location of a single particle, or as the distribution for many particles started from the same location. Both views are equally valid. The color scheme from low (blue) to high (red) density is normalized to the maximum density (with some backward temporal averaging), and cut off at very low values ($c = 10^{-6}d^{-2}$) to show the background layer. In the temporal evolution of the density distribution, dispersion enhancement normal to the rolls and within the nonstationary flows of spiral cores is visible.

We consider point particles, and the colored circles in the third layer represent the particle locations. The size of the circles is arbitrary. Most of the time, the particles just move back and forth with a small amplitude but high frequency. Note here that the time scale of vortex turnover is faster than the frame rate of the video. There are rare events in which a particle is transported over a large distance, which bears resemblances to the phenomenon of intermittency known from turbulent flows.