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Particle Dynamics in Turbulence

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The interaction between particles and turbulence features in many environmental and engineering problems, e.g., the formation of rain, the dispersion of particulate pollutants, and sedimentation in rivers and oceans. In addition, tracer particles are routinely used in scientific research to study the flow itself. Understanding the behavior of particles in turbulent flows is not only an important practical problem, but also an intriguing scientific challenge. Our group has developed a three-dimensional Lagrangian Particle Tracking (LPT) system. Using high speed CMOS cameras, the system is capable of following simultaneously hundreds of particles in a turbulent flow with Taylor microscale Reynolds number R_λ up to 10^3. The LPT measurements provide both single- and multi-particle statistics following Lagrangian trajectories, at temporal resolutions better than the Kolmogorov time scales of the turbulence. Using the LPT system, we investigated the Lagrangian properties of turbulence by tracking tracer particles seeded in the flow. In the study of turbulent relative dispersion, our measurement of the separation of pairs of fluid elements in turbulence demonstrated that only when the separation between a time scale related to the initial separation between the pair and the turbulence integral time scale is large enough, or equivalently, at very large Reynolds numbers, the long-believed Richardson's t^3 law may be observed. Furthermore, measurements of multiple particles in the flow showed the evolution of geometric structures in turbulence. Due to its ability to follow individual particles, the LPT system is an ideal tool to study the behavior of non-tracer particles in turbulence. The inertial particles have density different from the fluid, but size smaller than the Kolmogorov length scale of turbulence. On the other hand, neutrally buoyant particles with size larger than the Kolmogorov scale behave very differently from inertial particles. We will present results from both cases.