How to optimally concentrate particles in a turbulent flow

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Inertial particles suspended in a turbulent flow can become concentrated in regions of high strain and low vorticity. This process, called inertial concentration, is thought to be important in a number of applications, from droplet growth in clouds, to the sedimentation of particles from river outflows, to dust growth in protostellar disks. Often, a key question of interest is how densely packed the particles can become as a result of inertial concentration. The question can be studied numerically as an initial value problem for some given initial conditions, but in this project we will attempt to answer the more theoretical question of how large the particle over-densities can ever become.

To do so, we propose to model the particles as a continuum using two-fluid equations, in which a separate momentum equation is used to evolve the particle velocity field, coupled with the carrier fluid through a linear drag law. We will then use nonlinear adjoint looping techniques to determine, for a given model setup (to be selected), what initial conditions for the flow field lead to maximal particle concentration, and what that maximal concentration may be as a function of flow and system parameters. This will require first deriving the adjoint equations, then modifying our existing two-fluid code to solve the optimal problem; for this reason, this project requires both strong analytical skills and coding proficiency (ideally in Fortran, though anyone with a good knowledge of C or Python will pick it up quickly). Supercomputing access will be provided.