GÖTEBORGS UNIVERSITET

Inertial collisions in random flows

Kristian Gustafsson

Vetenskaplig avhandling för avläggande av filosofie doktorsexamen i fysik vid Göteborgs universitet. Avhandlingen försvaras vid ett seminarium fredagen den 3 juni 2011, kl 10.00 i Euler, Institutionen för matematiska vetenskaper, Chalmers Tvärgata 3, Göteborg. Avhandlingen försvaras på engelska.

Fakultetsopponent:
Professor Predrag Cvitanović
School of Physics, Georgia Institute of Technology
Atlanta, USA

Inertial collisions in random flows

Kristian Gustafsson
Department of Physics
University of Gothenburg
SE-412 96 Göteborg, Sweden

Abstract

In nature, suspensions of small particles in fluids are common. An important example are rain droplets suspended in turbulent clouds. Such clouds can start to rain very quickly and the reason for this is still not fully explained, but it is believed that the turbulent motion in the cloud plays an important role. This thesis gives an introduction to the model we use to describe inertial particles suspended in such systems and some results coming from this model.

We identify a general behavior of the particle motion which is asymptotically correct independent of how the fluid velocity is generated and on the equation of motion of the suspended particles. This asymptotic behavior can be matched to other limiting cases where the details of the system are important. This allows us to calculate an asymptotically correct distribution of particle separations and relative velocities in a form which is universally valid. The form of the distribution depends on the phase-space fractal dimension, which describes the degree upon which particles cluster in phase-space, and on d scales at which the asymptotes are matched, where d is the spatial dimension. If the fluid velocity gradients consist of white-noise, the phase-space fractal dimension and the single matching scale can be calculated analytically in one spatial dimension.

We introduce a new series expansion around deterministic particle trajectories. The expansion is done in terms of the magnitude of typical fluctuations of the fluid velocity at a fixed position. If typical fluctuations are small, we can calculate statistical quantities averaged along particle trajectories. In particular, we can calculate the degree of clustering for particles of general inertia in this limit.

Keywords: Collisions, nonlinear dynamical systems, particles and aerosols, random processes, suspensions, turbulent diffusion, turbulent flows