Clusters of heavy particles in two-dimensional Keplerian turbulence

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Protoplanetary disks are systems composed of gas and a small fraction of dust orbiting around young stars. Dust has to grow into planetesimals, ∼ km size objects that are the building blocks of planets. However, planetesimals formation is still one of the major open questions in planet formation theory. Solids can't grow up to asteroid size relying on sticking after pairwise collisions only, due to the fragmentation barrier and drift barrier [1]. A possibility to overcome this difficulty is to form dense particle clumps, with low velocity-dispersion, that can then collapse under self-gravity. Turbulence in disks is then critical for particle concentration and therefore for planetesimal formation. In this context, we need to understand the dynamics of particles in turbulent flows with Keplerian rotation and shear.

We perform 2D direct numerical simulations using the shearing box approach and a pseudo-spectral solver, varying the rotation frequency Ω and the solid stopping time t_s. We then use tools borrowed from the study of dynamical systems to characterize the dust dynamics in the flow. In particular, the Lyapunov dimension d_L is calculated for each run. This dimension gives an estimation of the fractal attractor dimension in the phase space [2]. The results obtained for different values of Ω and t_s are showed in Fig. 1. In the two snapshots we see that while the particles are expelled from the eddies and form fractal structures for low values of Ω, they tend to concentrate inside the anticyclones for higher rotation rates, eventually forming a pointwise cluster for $d_L = 0$. These are promising results for the formation of planetesimals.

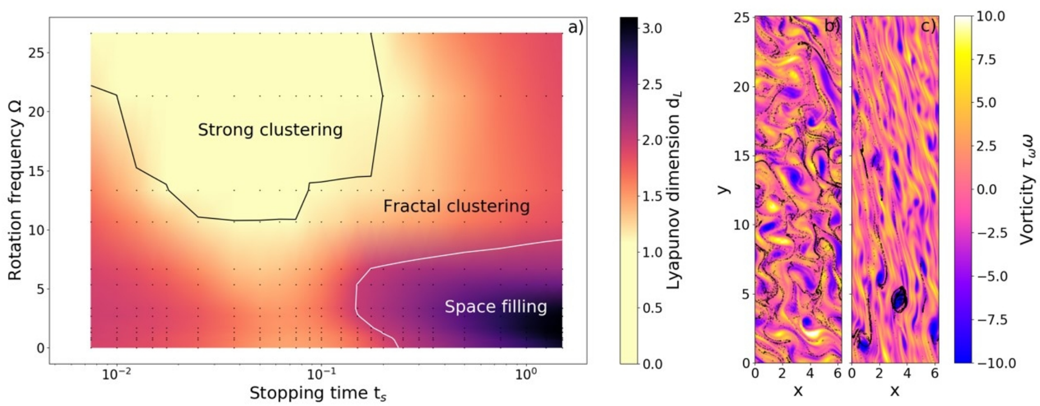

Figure 1. a) Phase diagram of Ω vs t_s. The black line is the contour level for $d_L = 1$, the white line for $d_L = 2$. b) Snapshot at t=200 for Ω=4/3 and t_s=0.1. c) Snapshot at t=200 for Ω=32/3 and t_s=0.1.

References

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