New approach to planetesimal formation: clusters of heavy particles in 2D Keplerian turbulence

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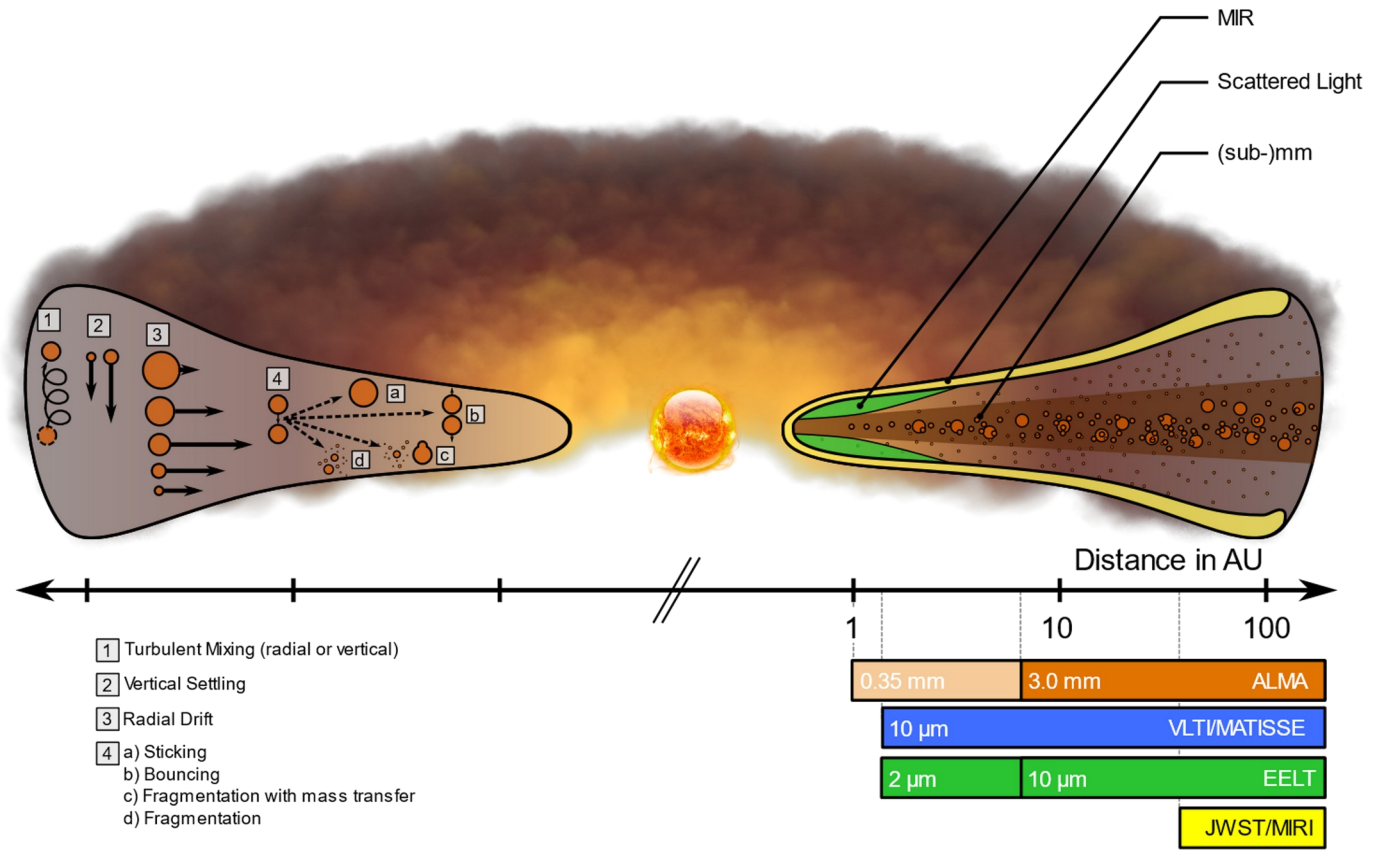
Introduction



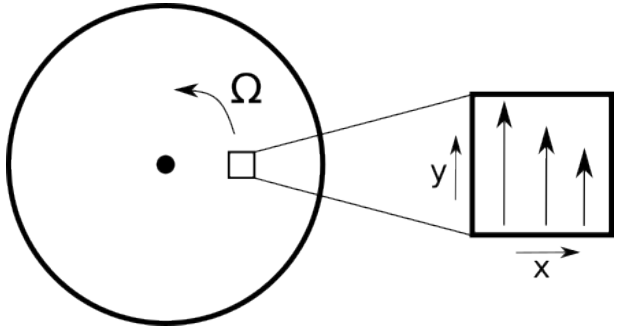
Credits: Testi et al., 2014

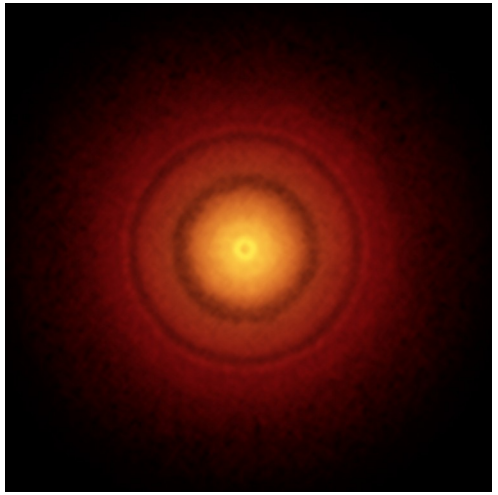
PROTOPLANETARY DISKS

- 99% gas and 1% dust
- Dust ~ µm-cm ⟶ Planetesimals ~ km
- Formation of planetesimals: open question
- Turbulence for particles concentration

Method

2D DIRECT NUMERICAL SIMULATIONS



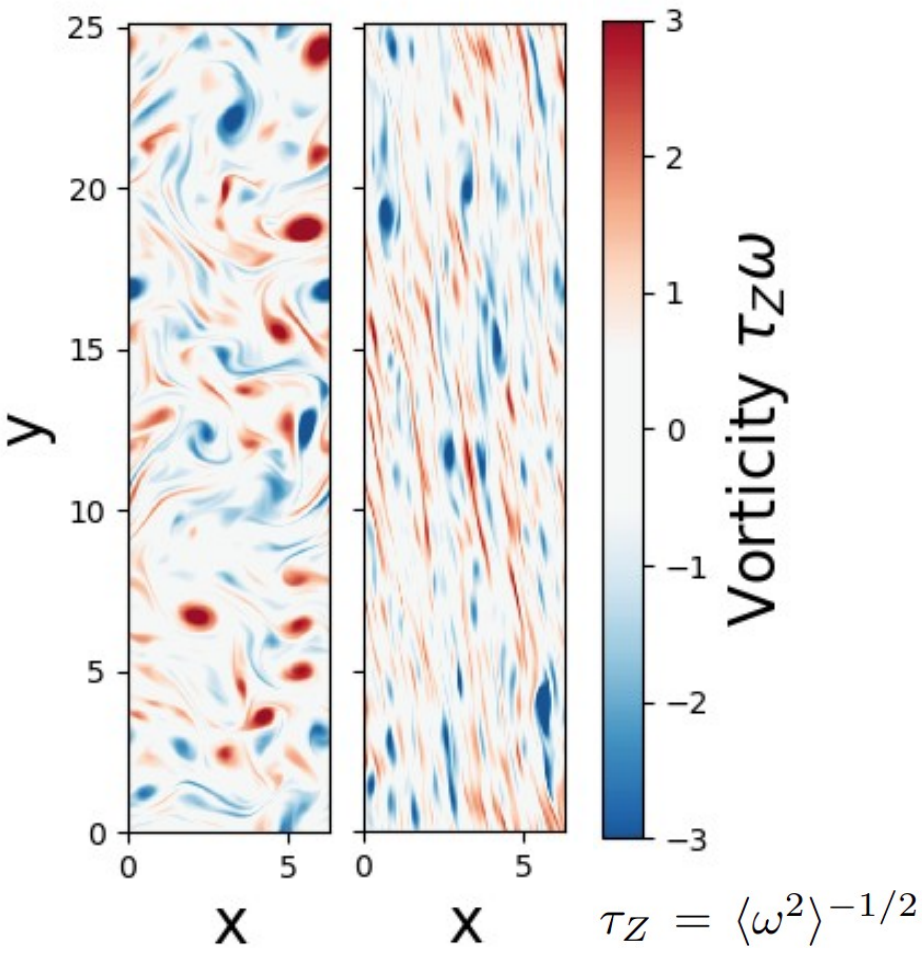


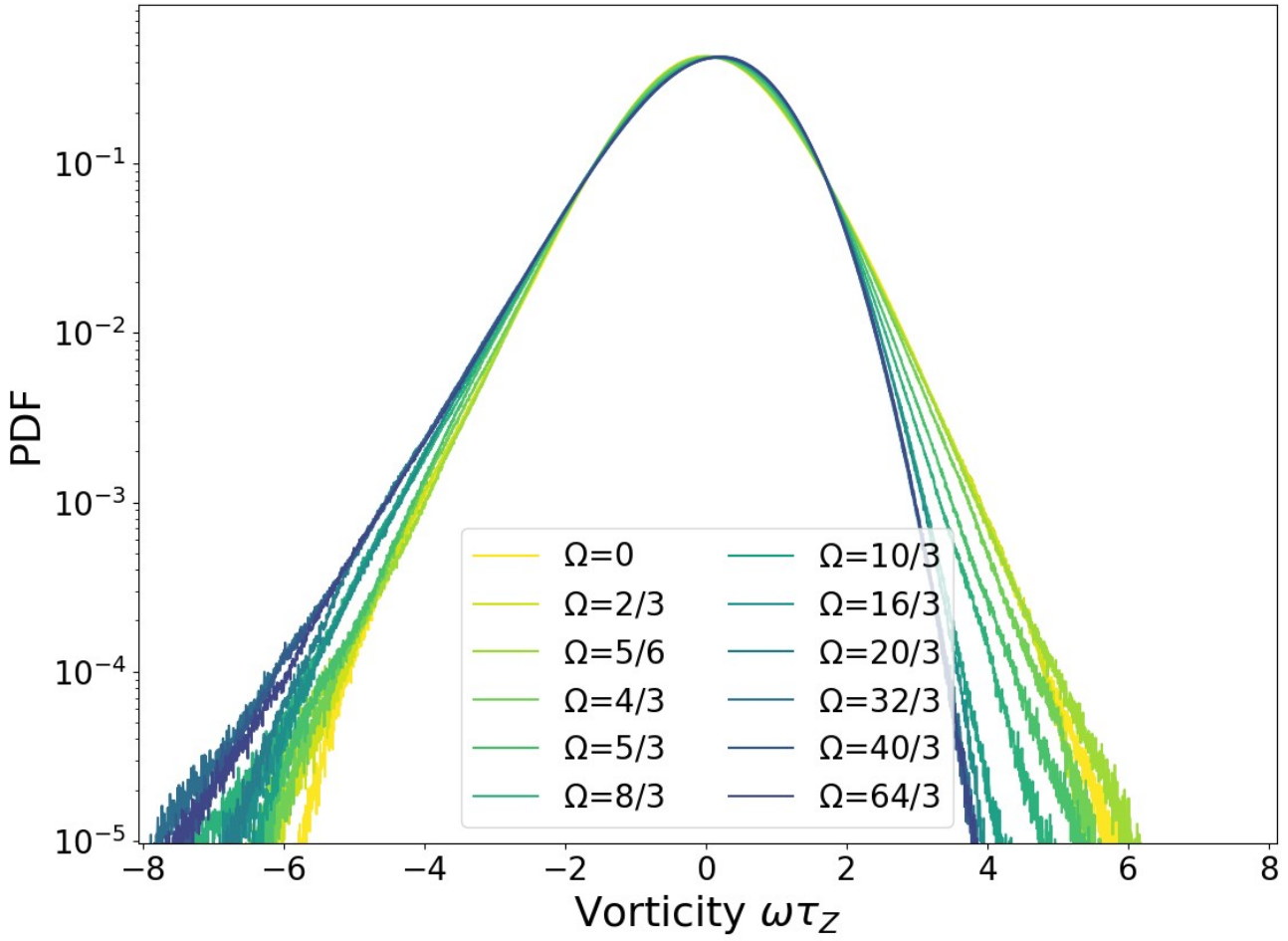
Credits: ALMA (ESO/NAOJ/NRAO)

- Shearing box approach
- Incompressible Navier–Stokes equation with stochastic forcing and linear friction
- Eulerian approach for the gas
- Lagrangian approach for the dust
- Pseudo-spectral solver
- Parameters: rotation frequency Ω and solid response time τ
- Tools borrowed from the study of dynamical systems

The flow

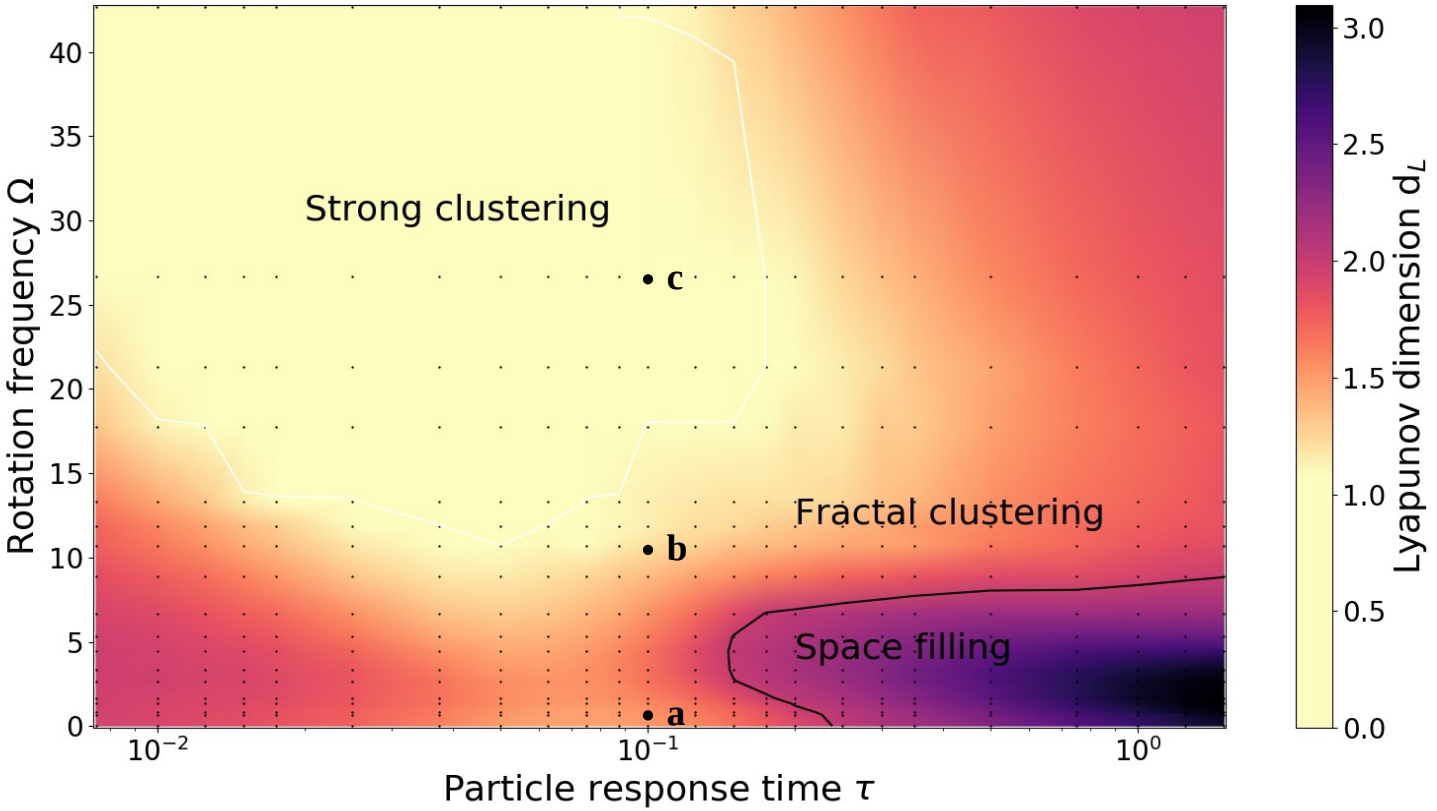
Ω=0 Ω=64/3

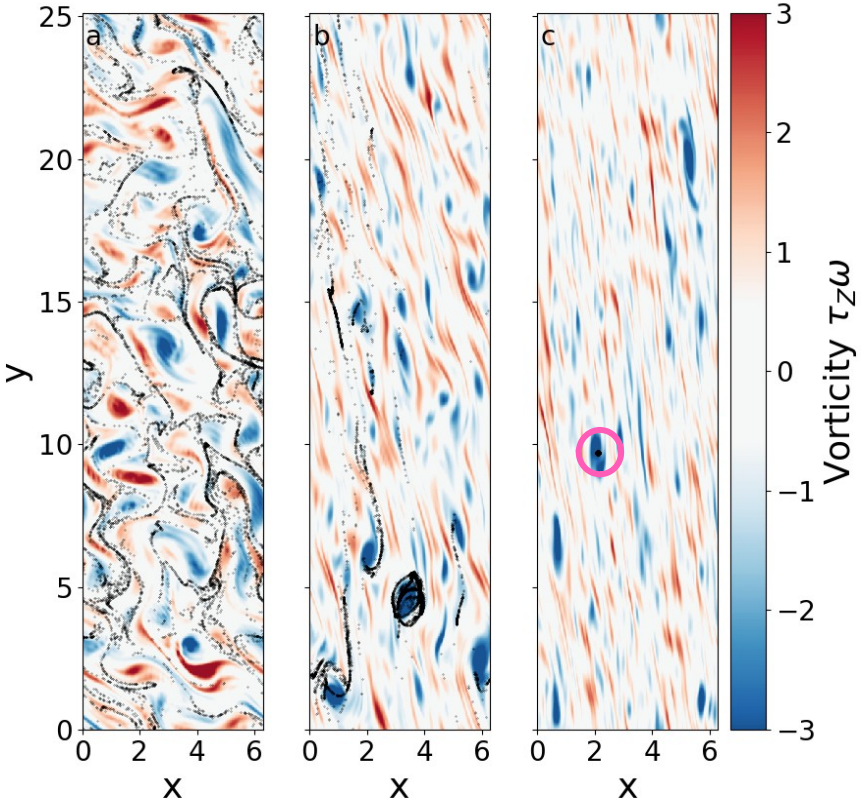




Fractal and strong clustering

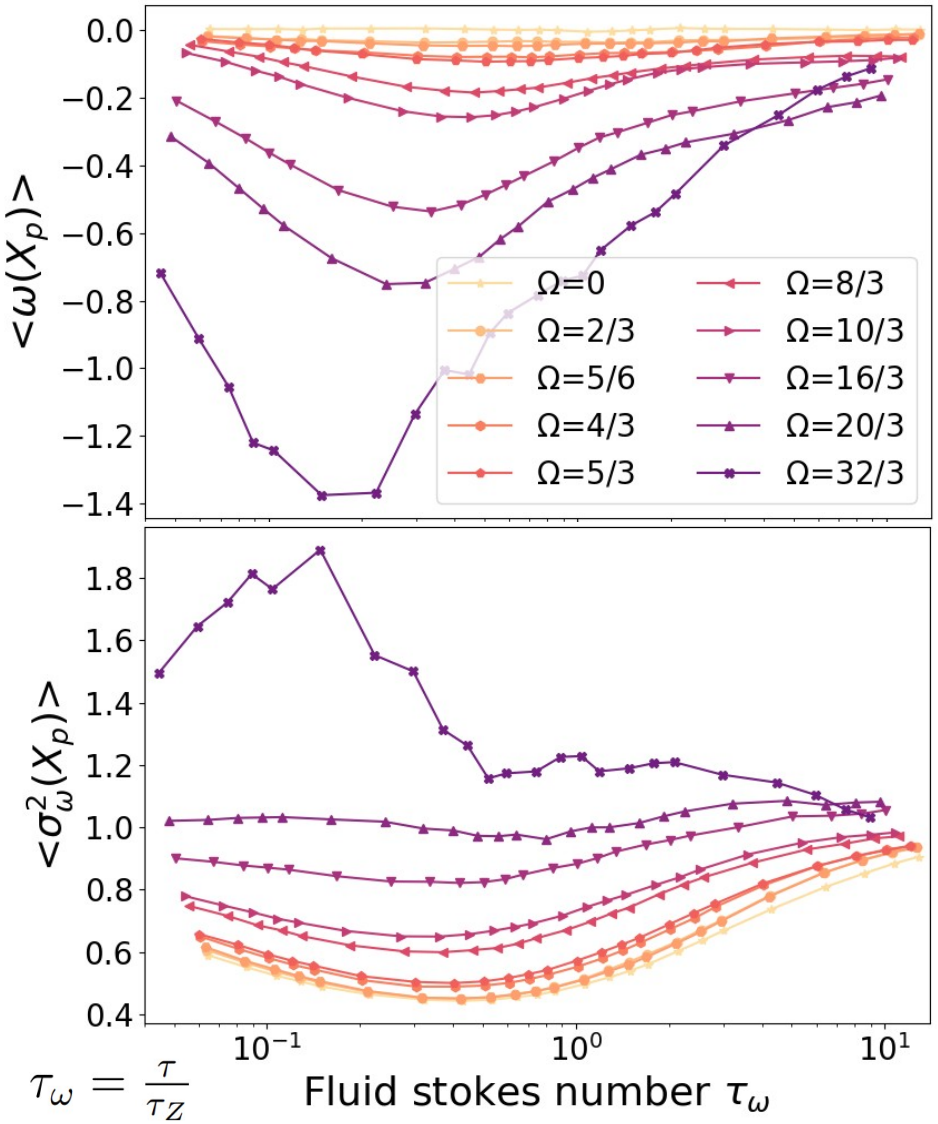
LYAPUNOV DIMENSION

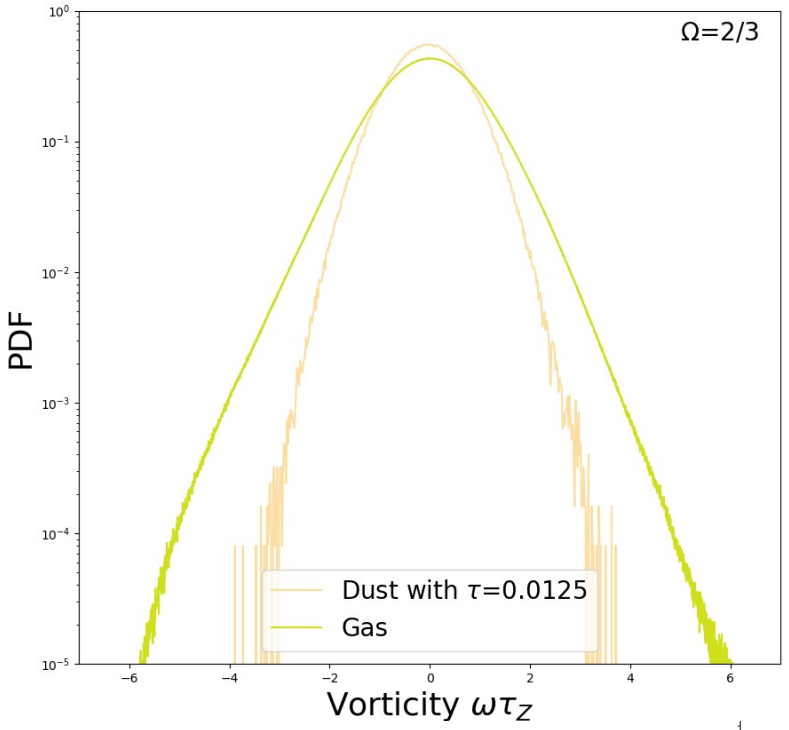


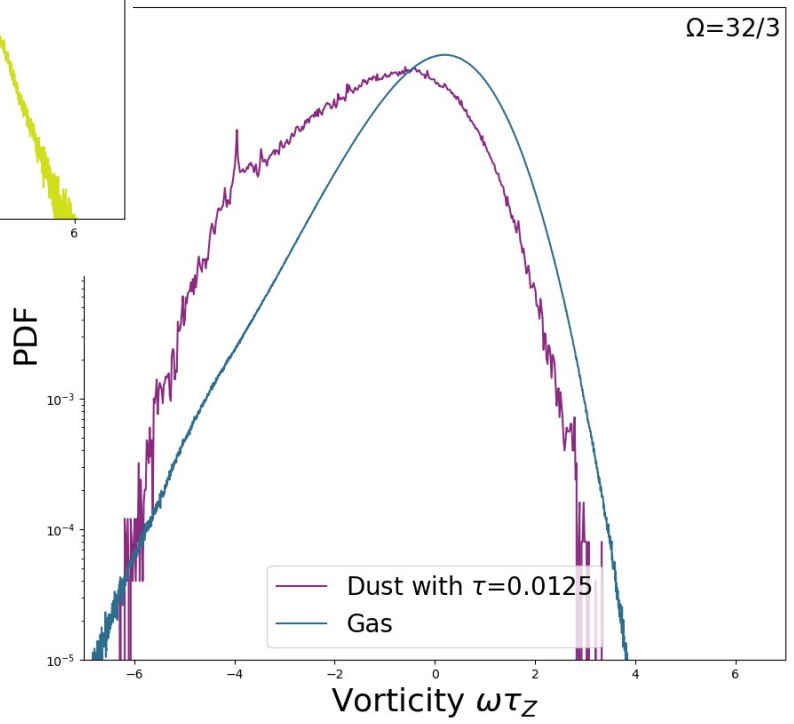


Fractal and strong clustering

VORTICITY AT PARTICLE POSITION

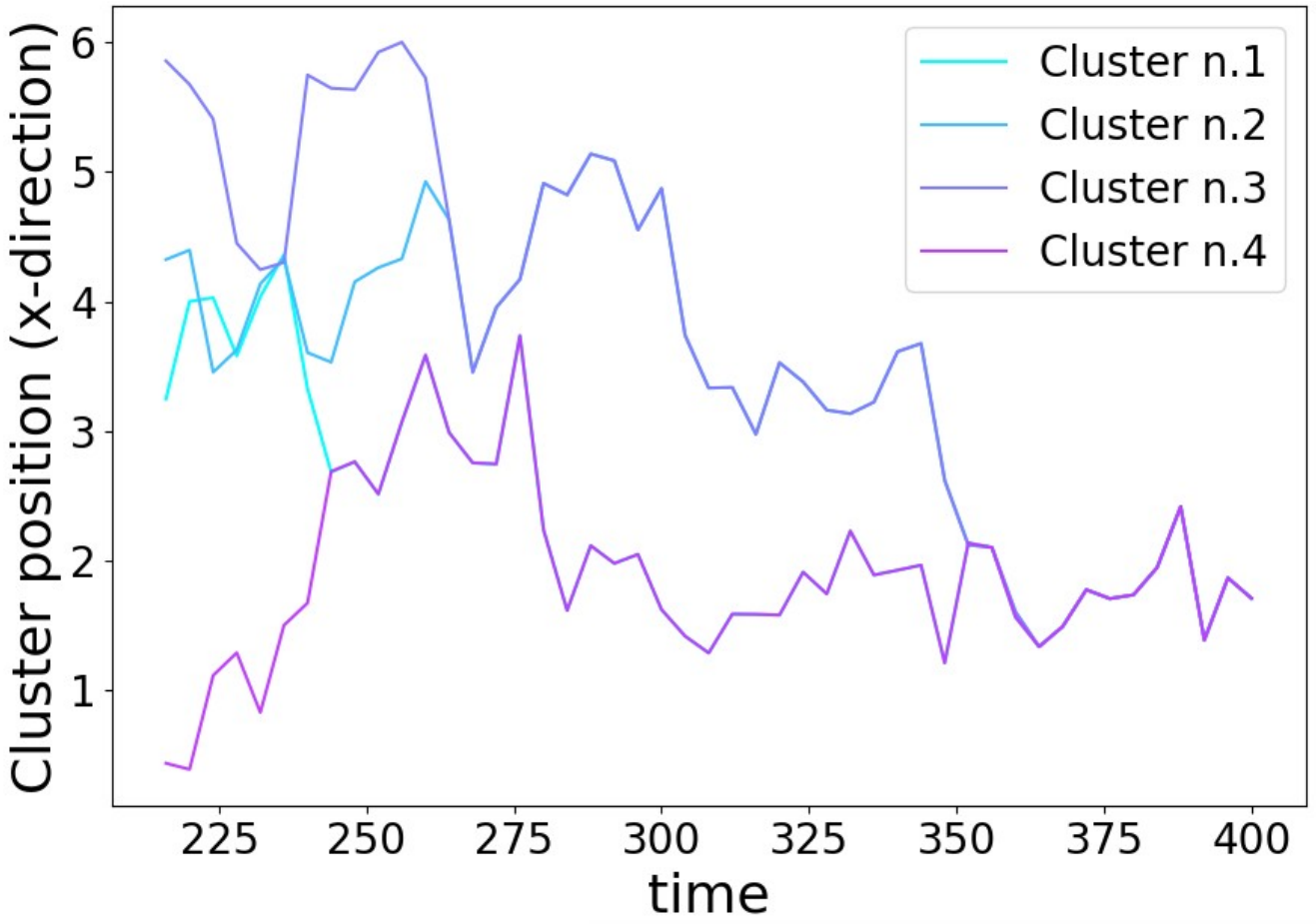


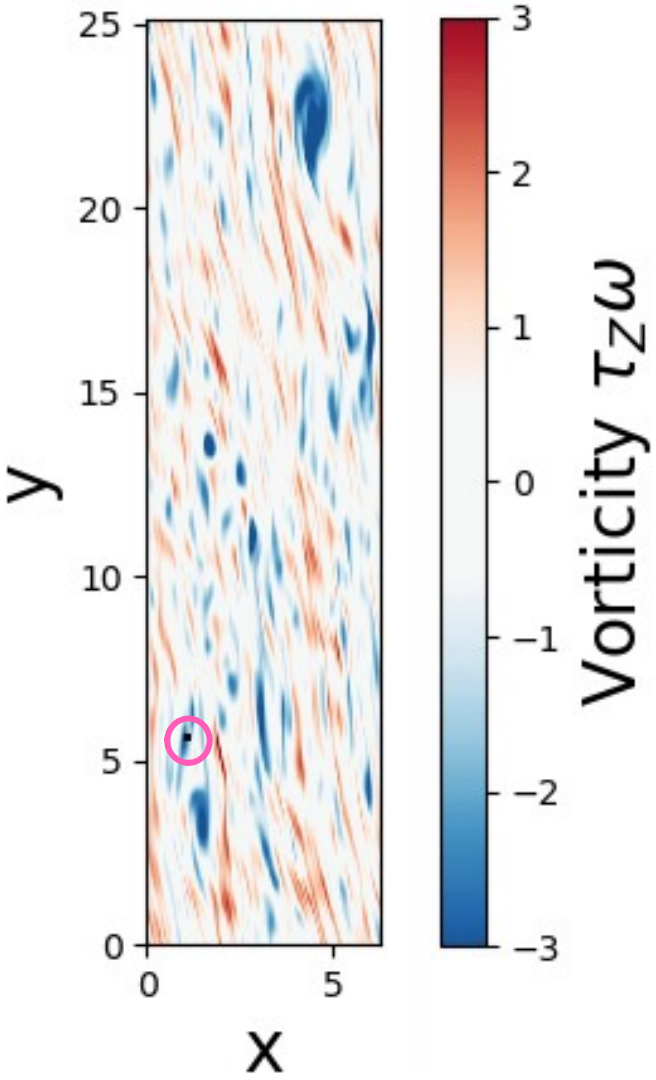




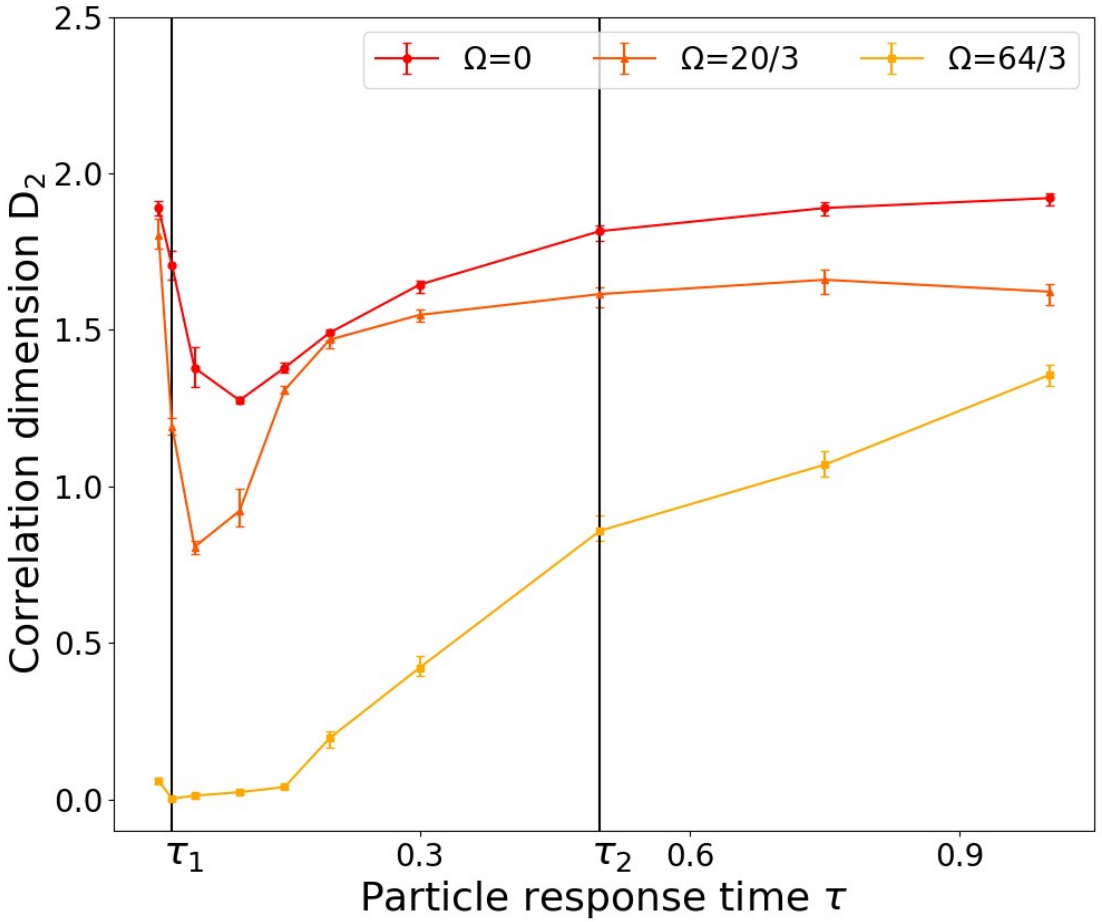
STRONG CLUSTERING

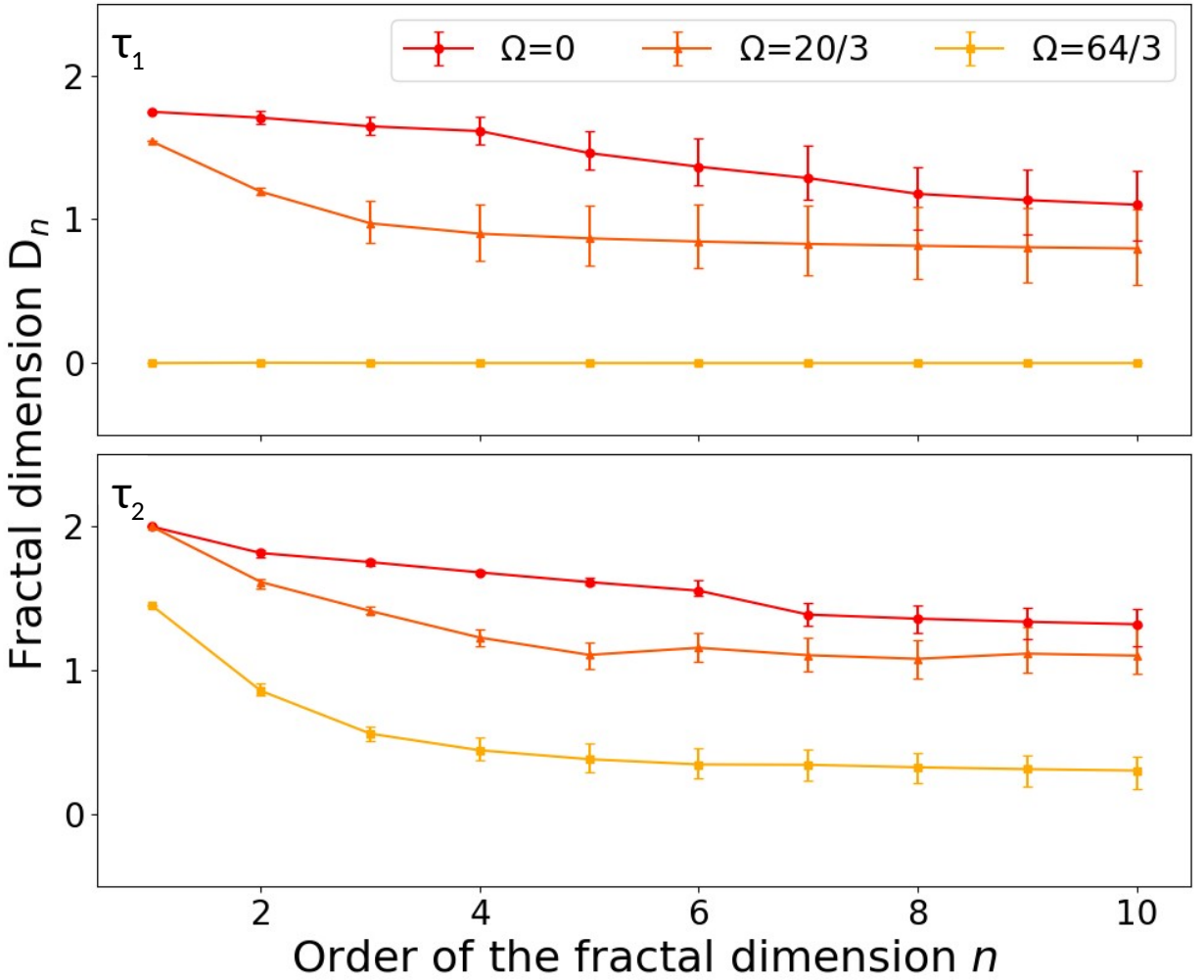
τ=0.05
Ω=64/3





FRACTAL DIMENSIONS $\langle m_r^n \rangle \sim r^{(n-1)D_n+2n}$





Conclusions

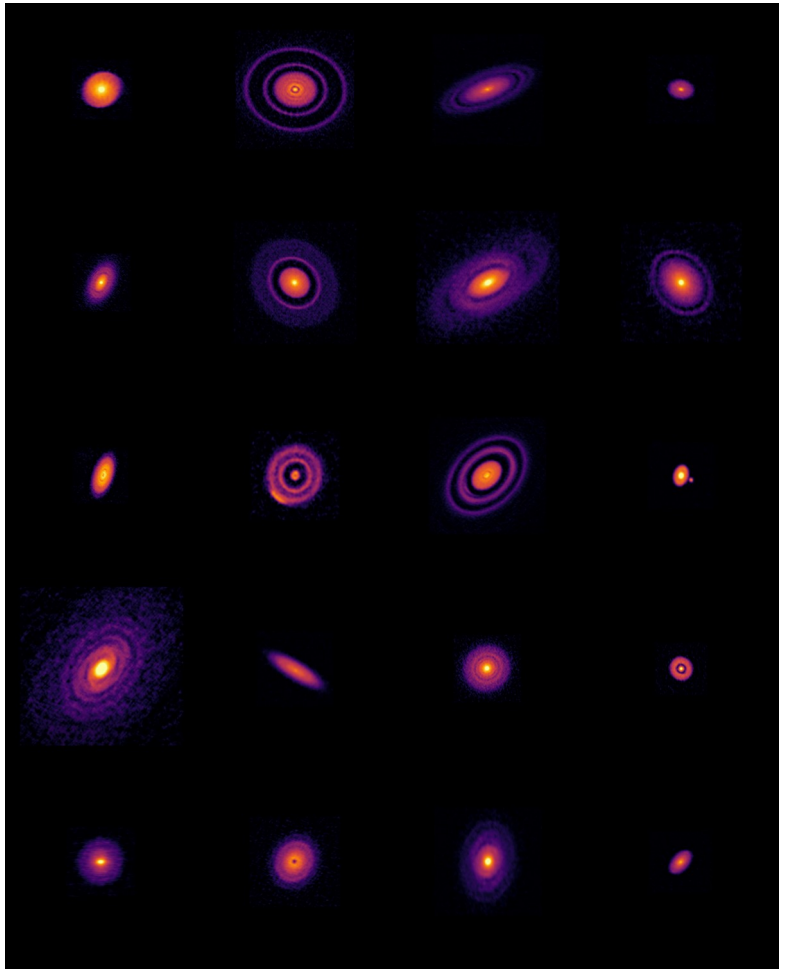
CONCLUSIONS

- Promising tools for the understanding of planetesimal formation: Lyapunov dimension, vorticity at particle position, Okubo Weiss parameter at particle position, fractal dimensions
- Dependency on rotation rate of dust clustering
- Formation of strong dust clumps

→ **Gerosa et al., in prep**

FUTURE PERSPECTIVES

- Drift between dust and gas
- Back-reaction from dust on gas (streaming instability?)
- Self-interaction between solids particles (e.g. collisions, gravity)
- From 2D to 3D
- Compressible fluid



Credits: ALMA (ESO/NAOJ/NRAO)

Thank you!