Dust Dynamics and Planetesimal Formation in MRI Turbulent Protoplanetary Disks

Ziyan Xu (Peking Univ.) & Xue-Ning Bai (Tsinghua Univ.)

ziyanx@pku.edu.cn

Does streaming instability still operate to concentrate dust in weakly MRI turbulent disks?

Can dust rings in MRI turbulent disks be precursors to planetesimal formation?

We conduct local 3D non-ideal MHD simulations with dust feedback (crucial for dust concentration by streaming instability) to study the interplay between weak MRI turbulence and dust dynamics, and the role of dust-gas interaction in dust rings.

▸ **In smooth disk, dust settles more when feedback included, clumps at a solid abundance of a few percents.**

▸ **With a gas pressure bump, dust clumps in the ring for near-solar global solid abundance, feedback makes rings narrower.**

3D Non-ideal MHD Simulations

- Local 3D non-ideal MHD simulations with ambipolar diffusion (AD), with pure hydro simulations for comparison.
- With particles marginally coupled to gas (Stokes number of 0.1).
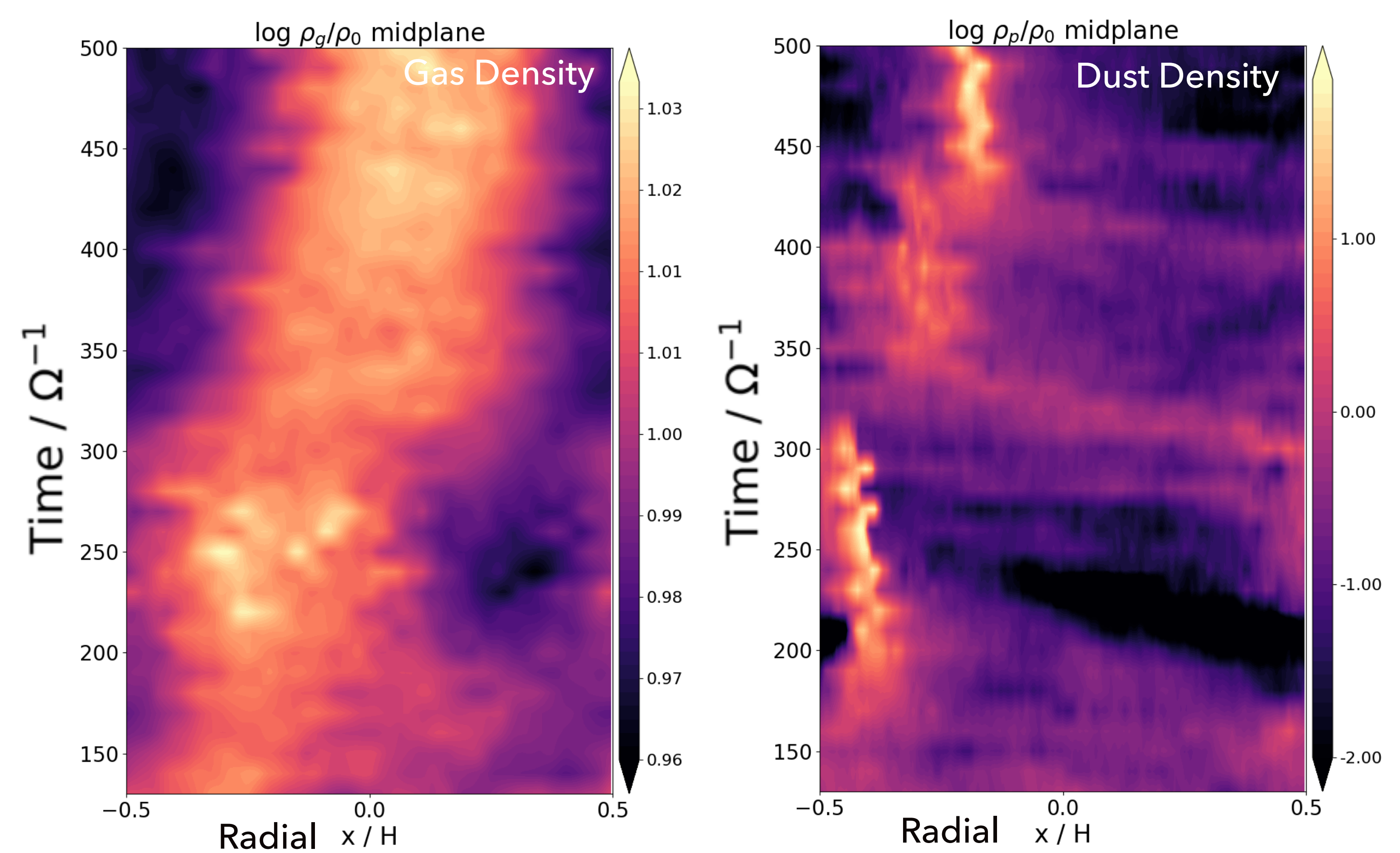- Solid abundance $Z = 0.005 \sim 0.04$, with & without feedback to gas.

▸ *Illustration of particle density distribution in the MRI turbulent simulation box, and the projections to box faces.*

dust
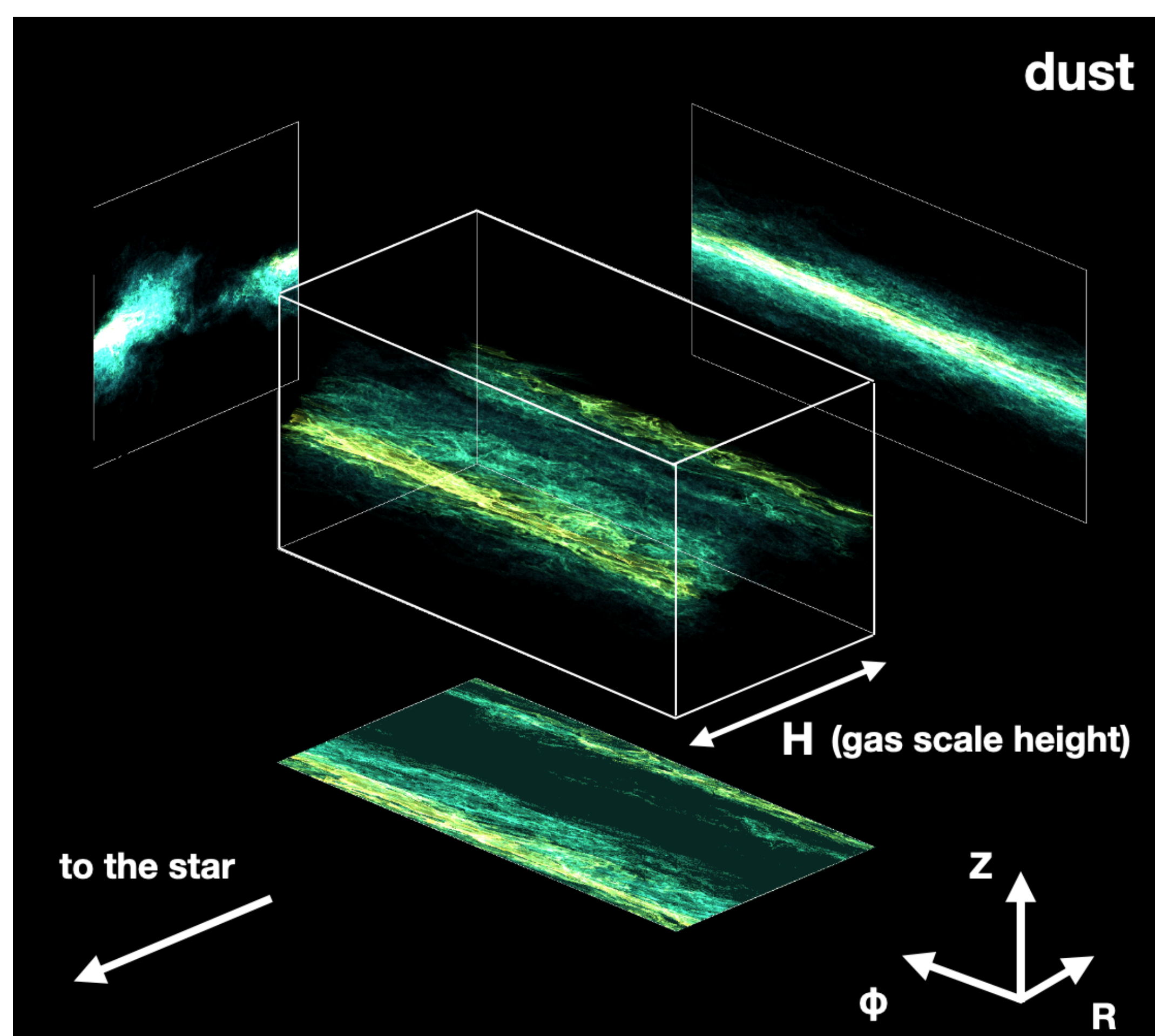
Boxsize:

Turbulent: H*2H*H

Hydro: 0.6H*1.2H*0.6H

Resolution:

Turbulent: 256 per H

Hydro: 800 per H

H (gas scale height)
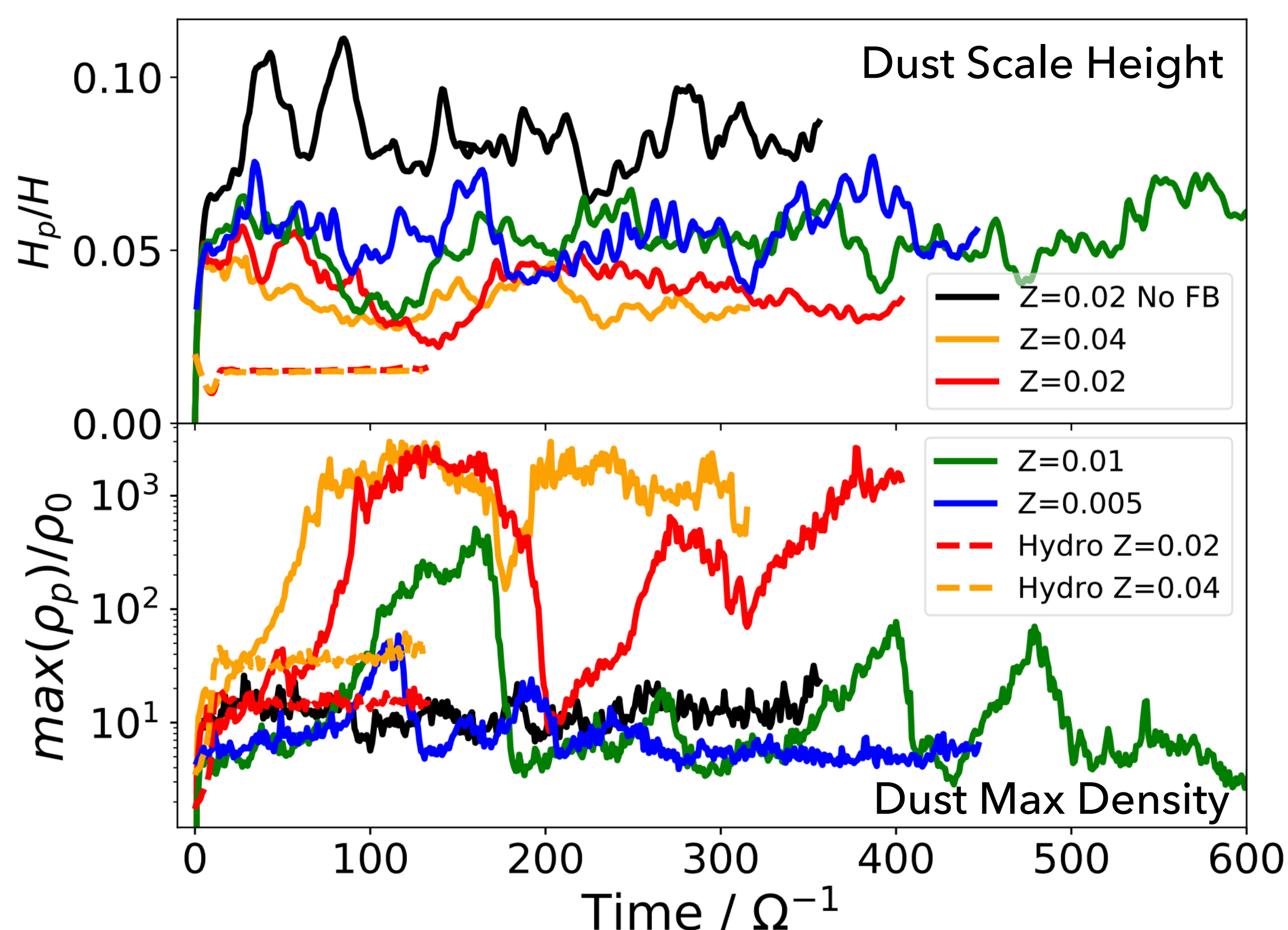
to the star

Clumping Related to Pressure Bumps

- Particle clumping related to the location of local pressure bump induced by magnetic zonal flow.

▸ *Further extend simulation box to 8H*16H*H, resolution up to 128/H.*

▸ **Introduce gas pressure bump** *(bump profile shown in blue curve).*
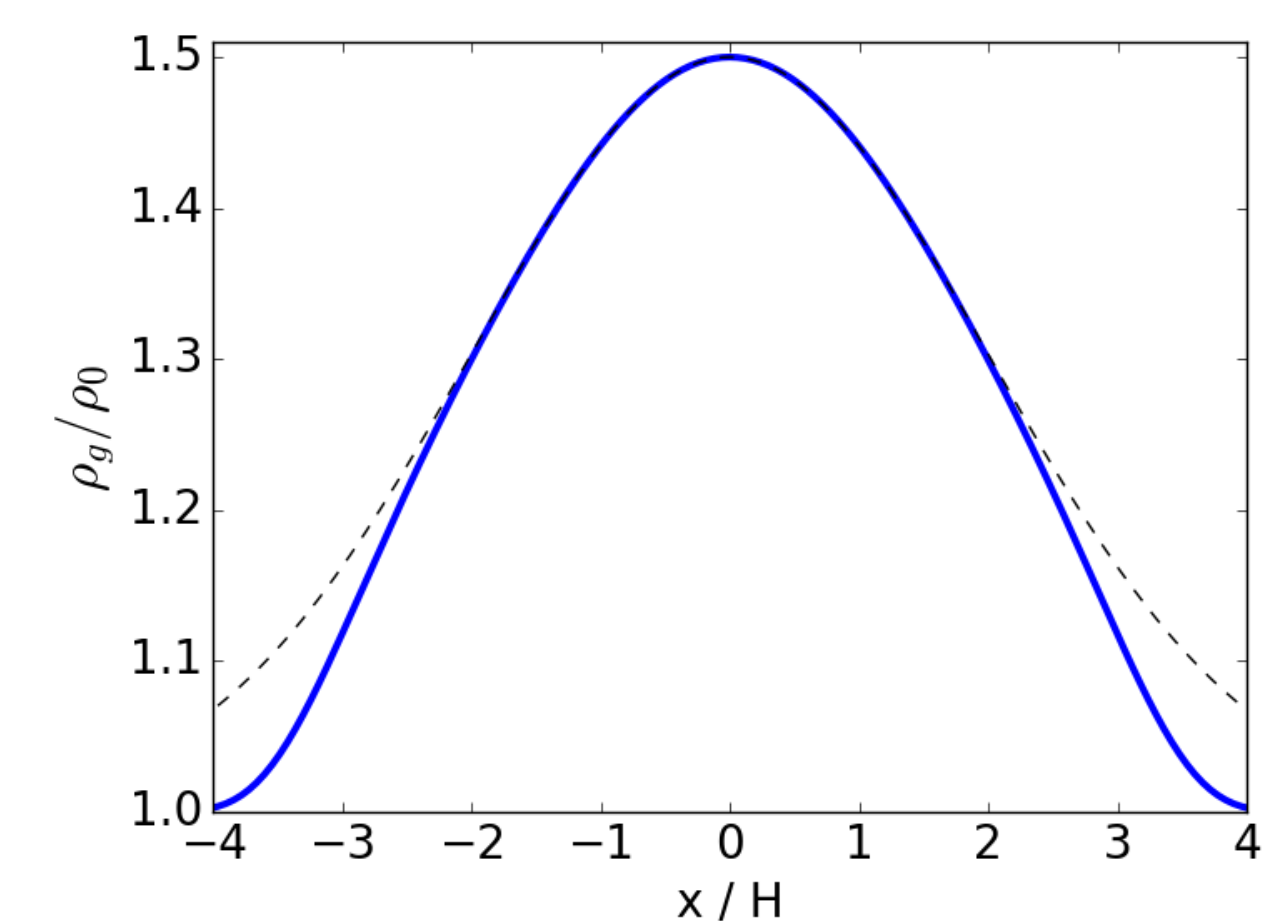
Dust Settling and Clumping

Dust Scale Height

- Z=0.02 No FB
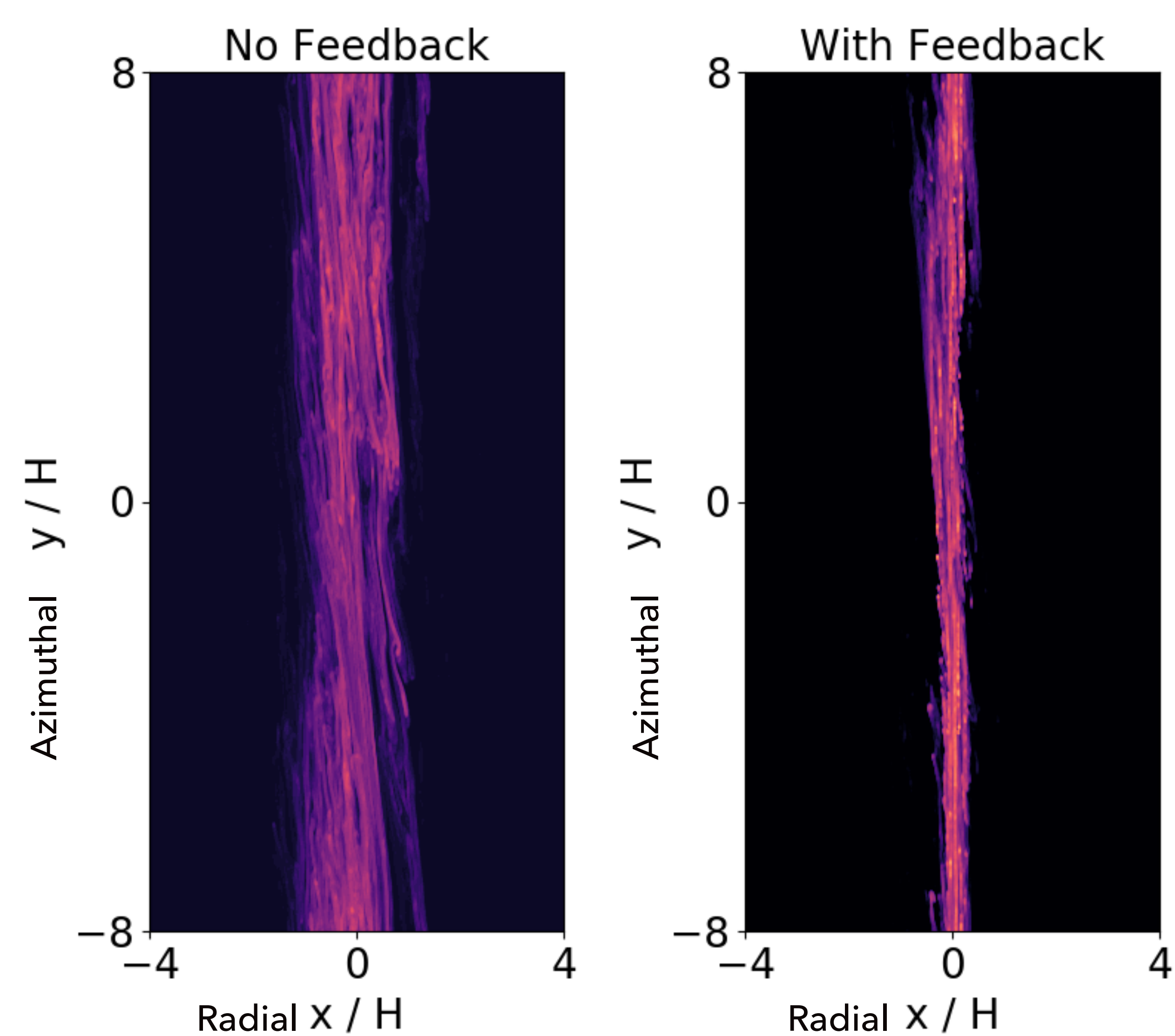- Z=0.04
- Z=0.02
- Z=0.01
- Z=0.005
- Hydro Z=0.02
- Hydro Z=0.04

Dust Max Density

- Particles in turbulent disks settle to thinner layer in the presence of feedback, but still thicker than that in the pure hydro case.
- Dust clumping triggered at solid abundance of $Z \geq 0.01$ in turbulent disks, but not in pure hydro case with even higher Z.

Dust Clumping in Rings

No Feedback   With Feedback

- Feedback promotes dust trapping by making the dust ring narrower.
- Dust clumping in the ring for near-solar global solid abundance.