Streaming instabilities in modern protoplanetary disks

Min-Kai Lin

September 2022

中央研究院 ASIAA

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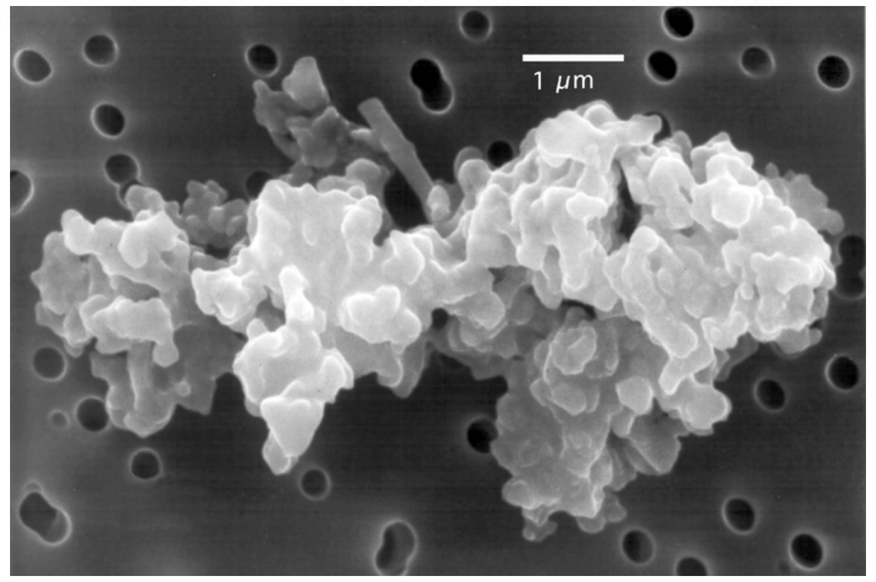
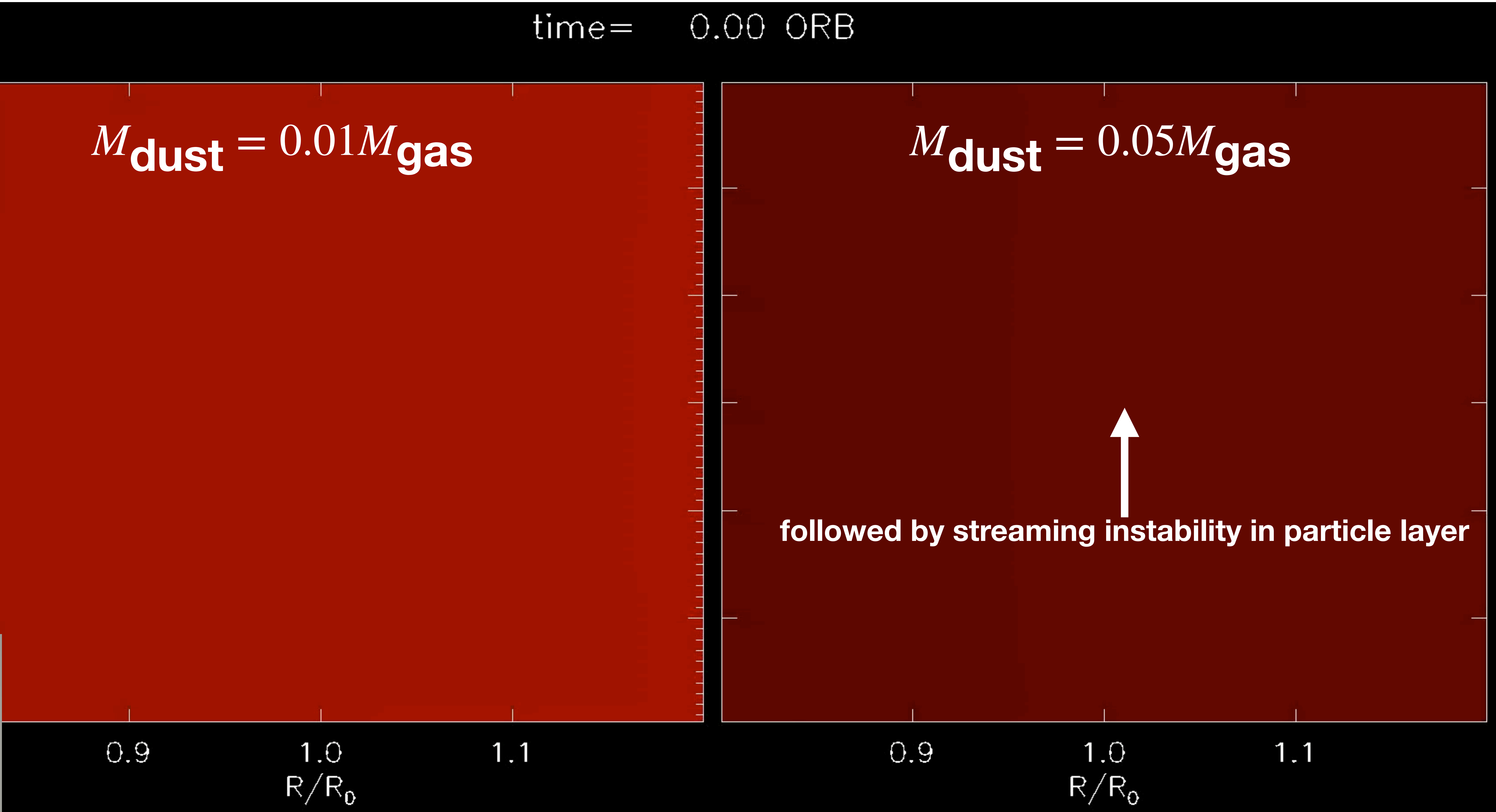
Planetesimal formation



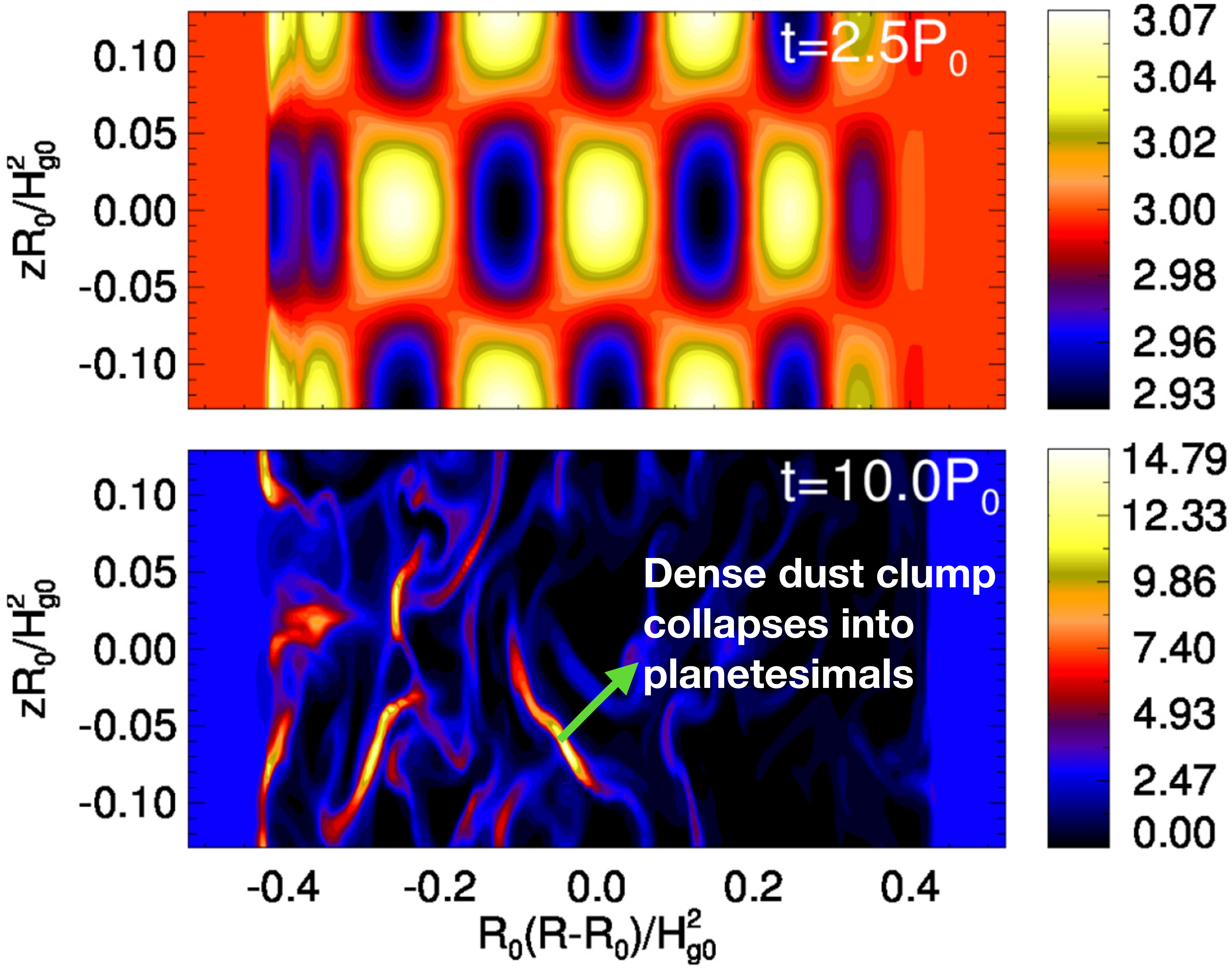
(Drazkowska et al., 2022, PPVII)

But first: dust settling



Lehmann & Lin (2022)

Planetesimal formation via the SI

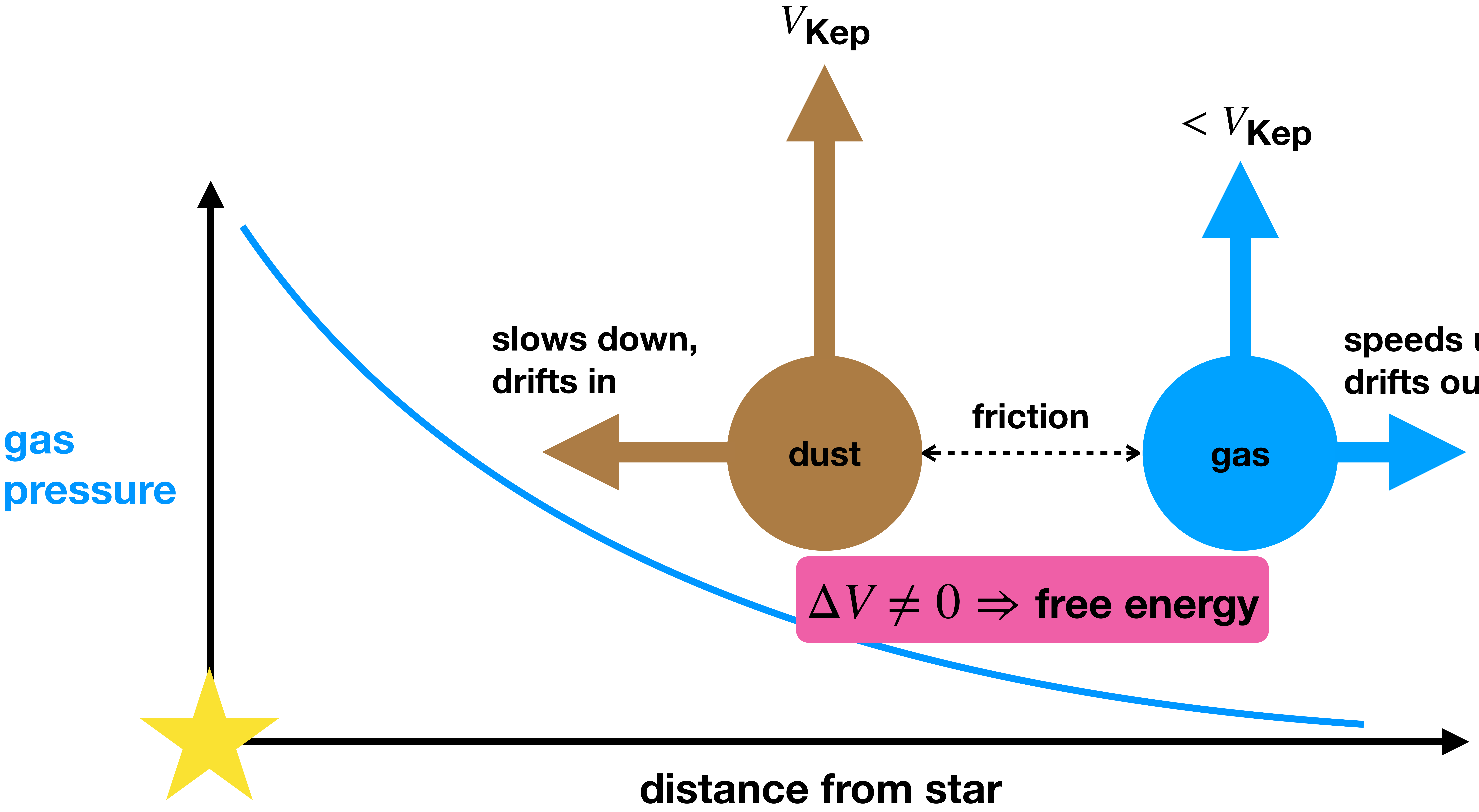


Chen & Lin (2018)
“Dust-free” simulations of the SI

second fluid

Lagrangian particles

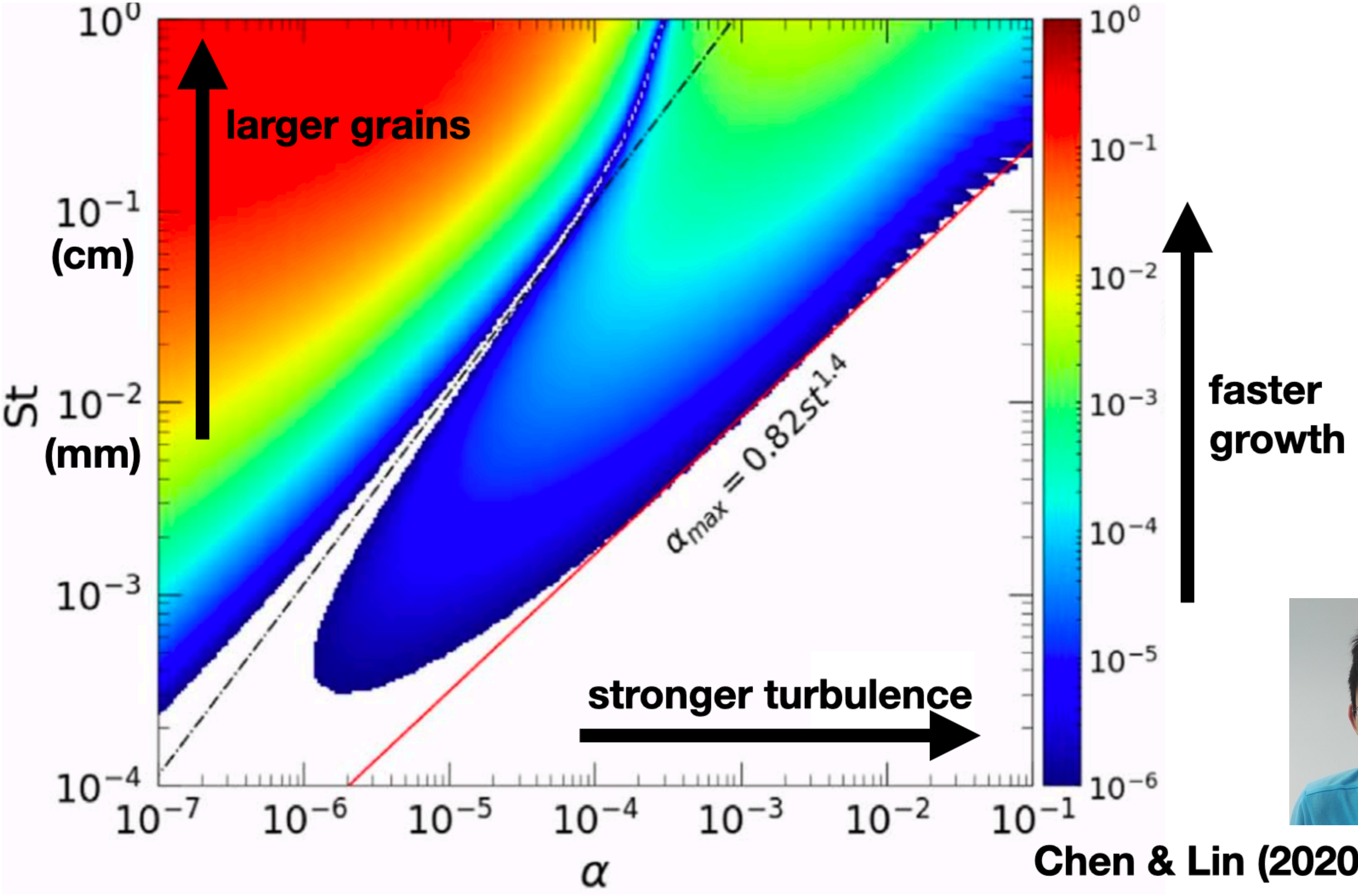
SI is powered by radial drift

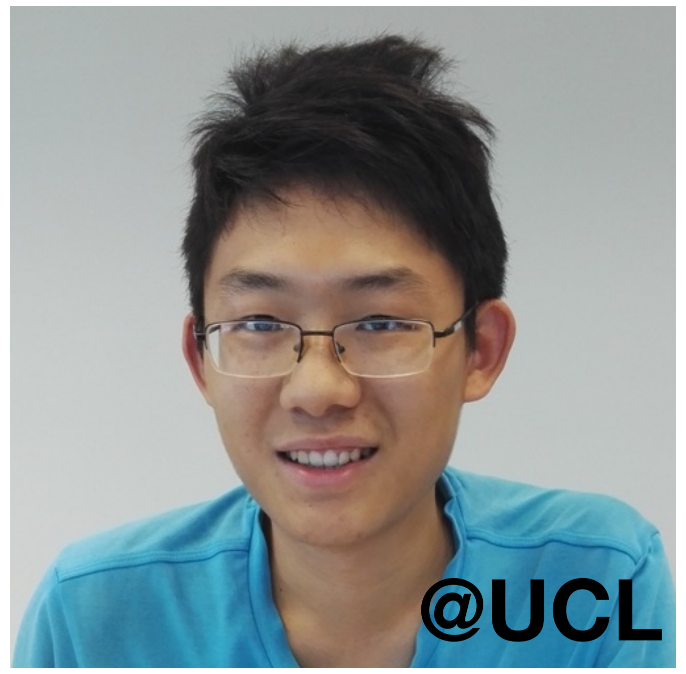


The ideal SI

- disk is non-turbulent → Chen & Lin (2020)
- disk has no vertical structure → Lin (2021)
- disk is unmagnetized → Lin & Hsu (2022), Hsu & Lin (2022)

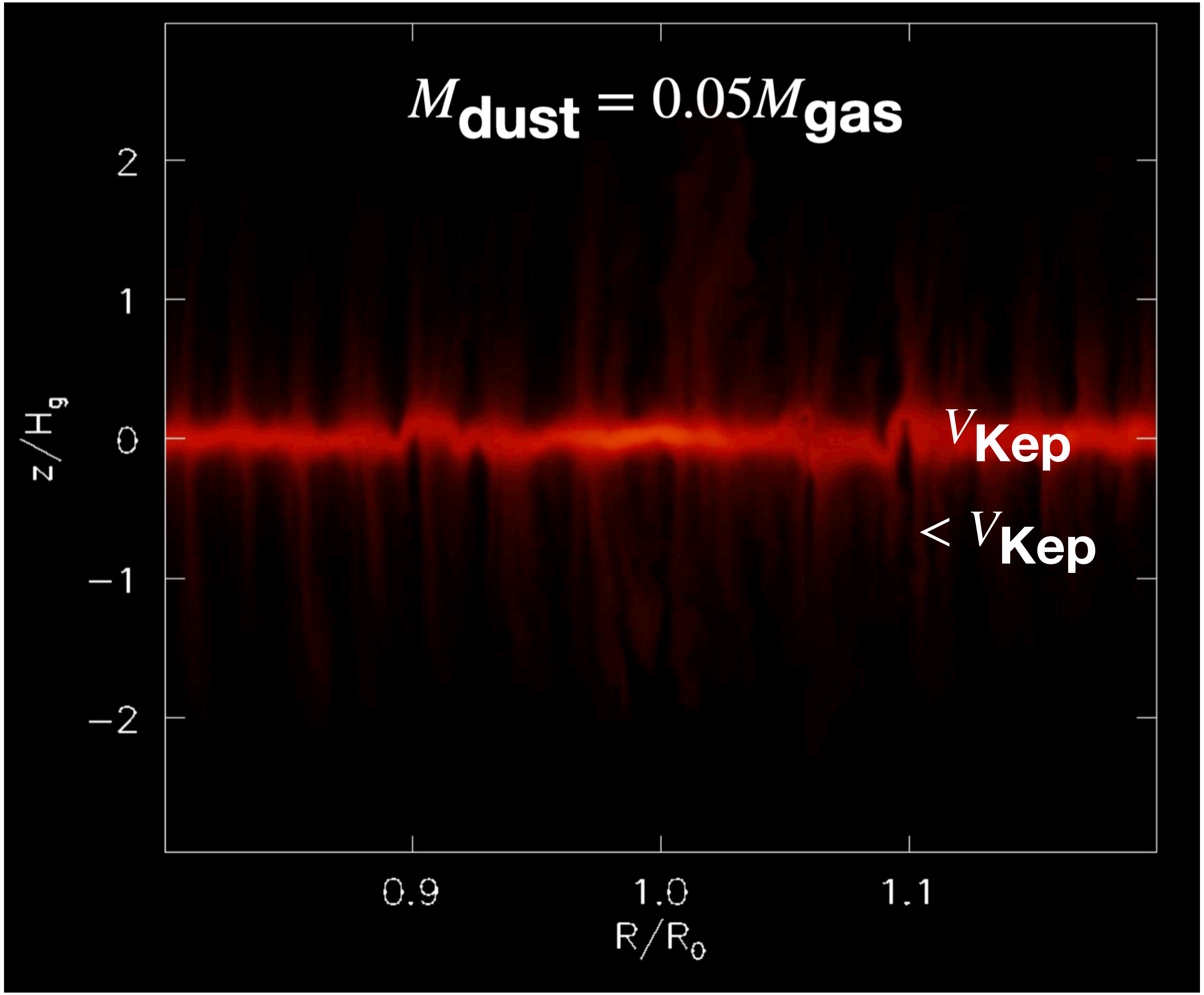
Streaming instability is easily killed by turbulent viscosity





Chen & Lin (2020)

Stratified dust layers

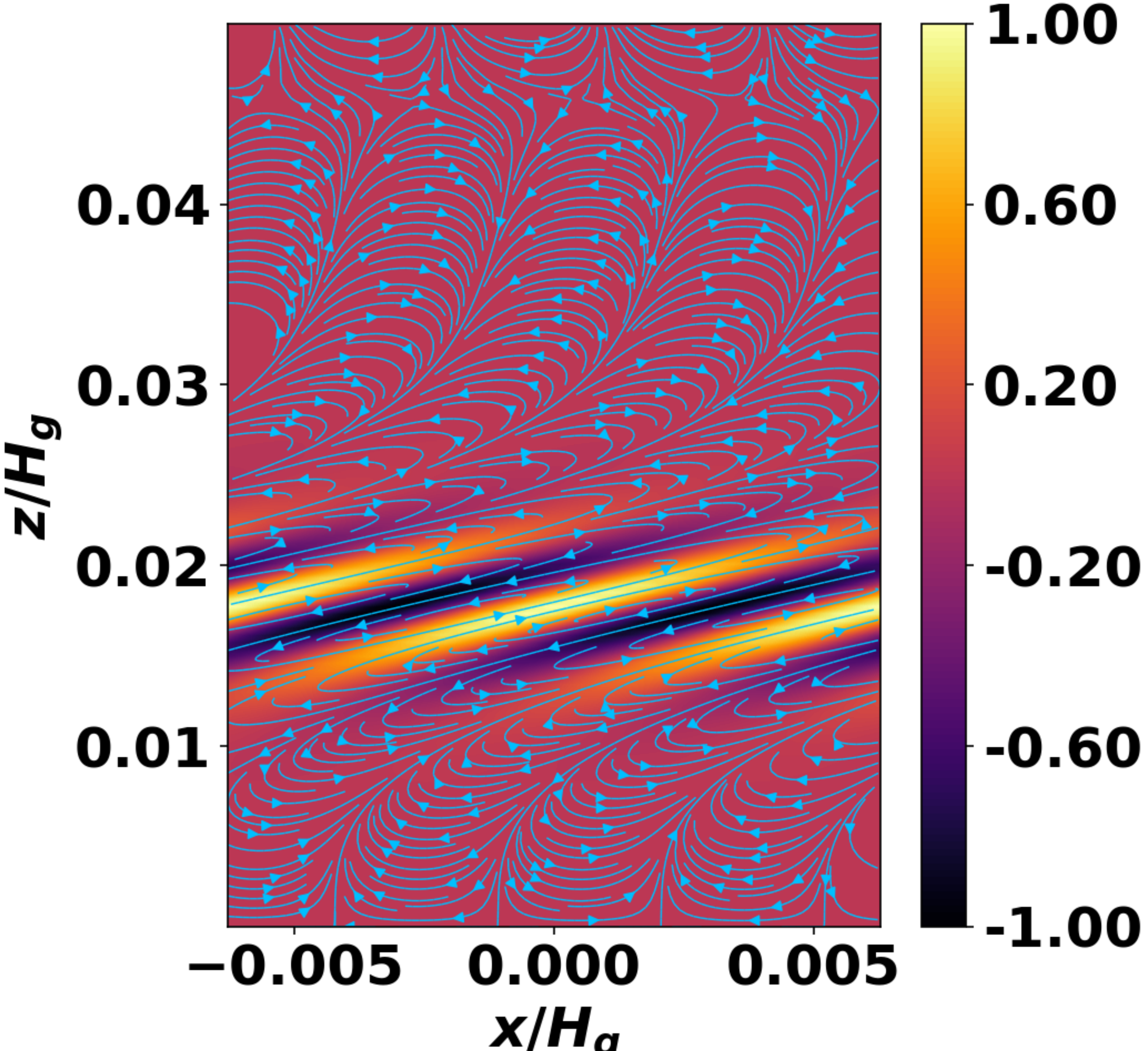


$$\frac{\partial \Omega}{\partial z} \neq 0$$

Lehmann & Lin (2022)

“Vertically shearing SI” in stratified disks

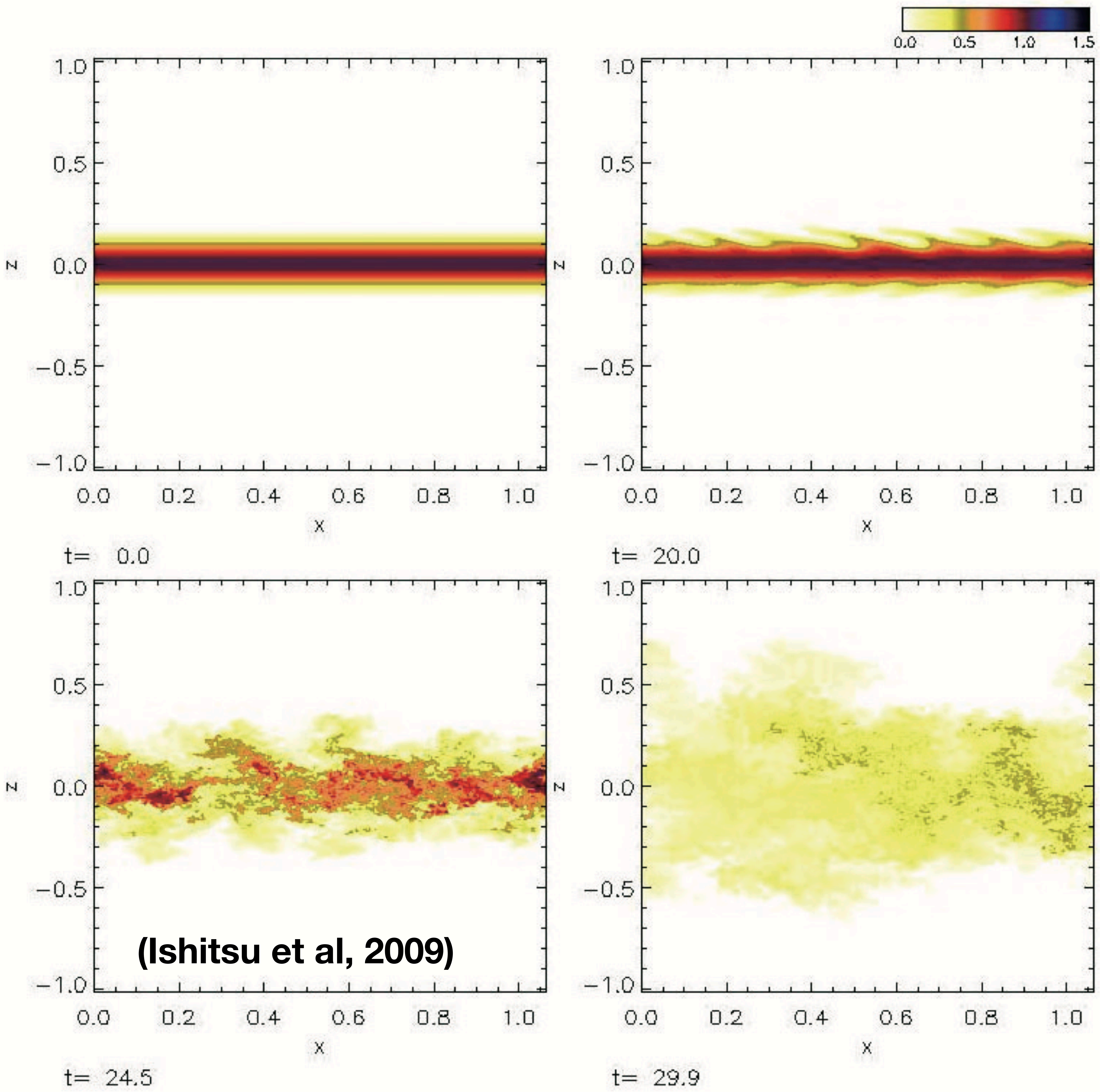
$s_{\mathbf{grow}} \sim \Omega$



$$\frac{\Delta\rho_{\mathrm{d}}}{\rho_{\mathrm{d}}}$$

Lin (2021)

Vertically shearing SIs grow fast but…

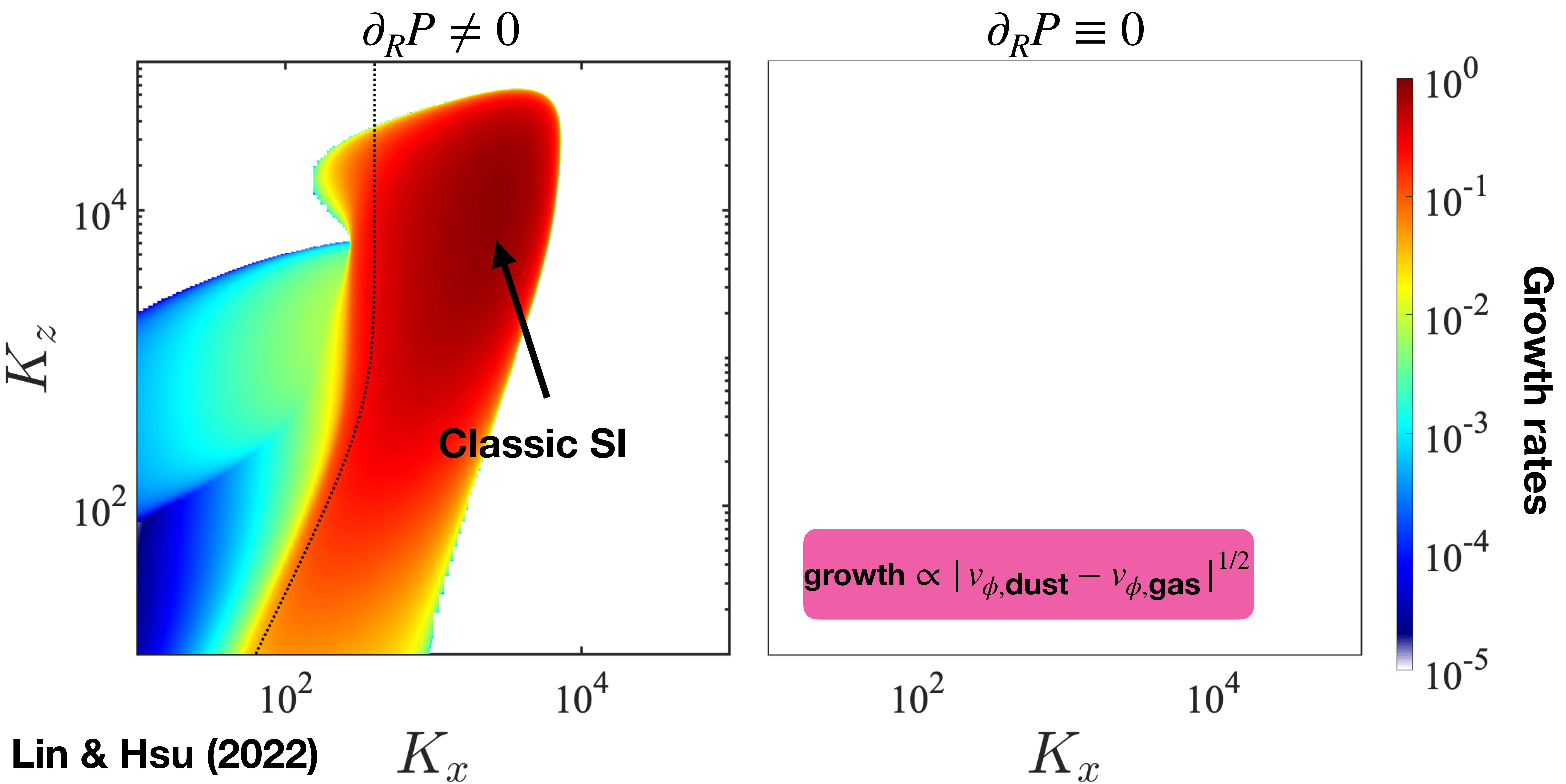


dust layer dispersed ☹️

Can modern disk models help?

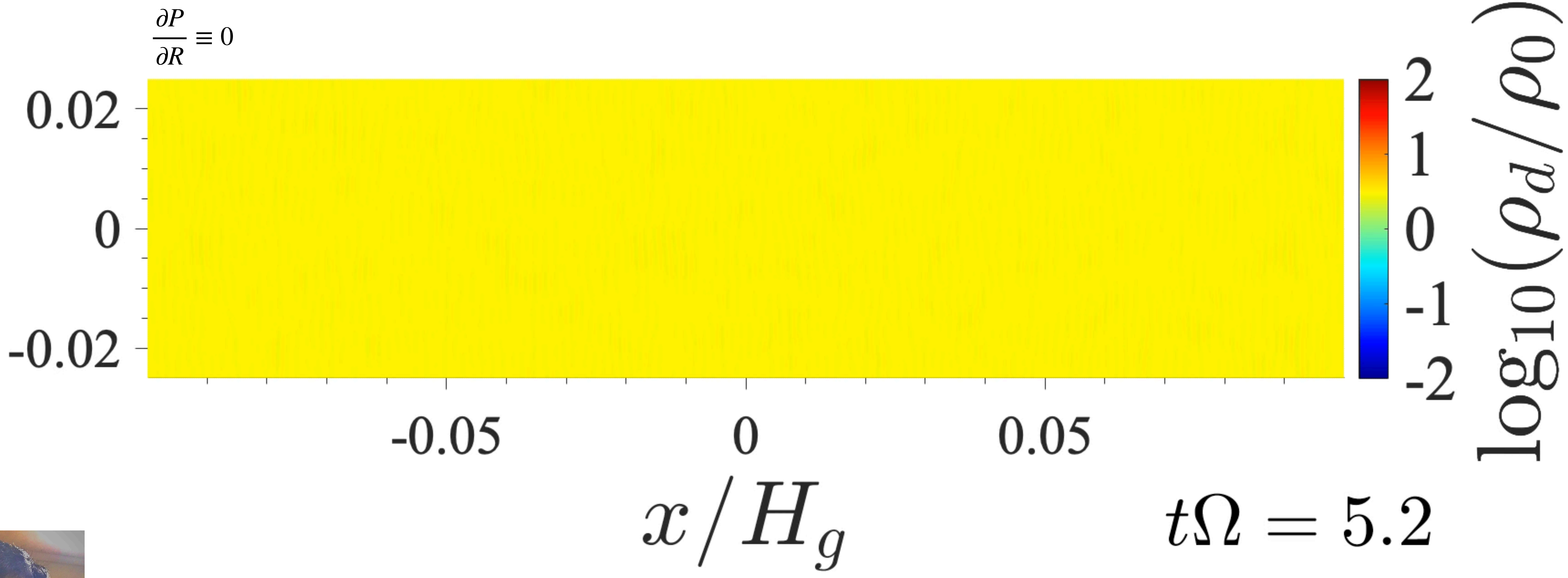
(e.g. Riols et al. 2020, Cui & Bai 2021)

Streaming instability without pressure gradients



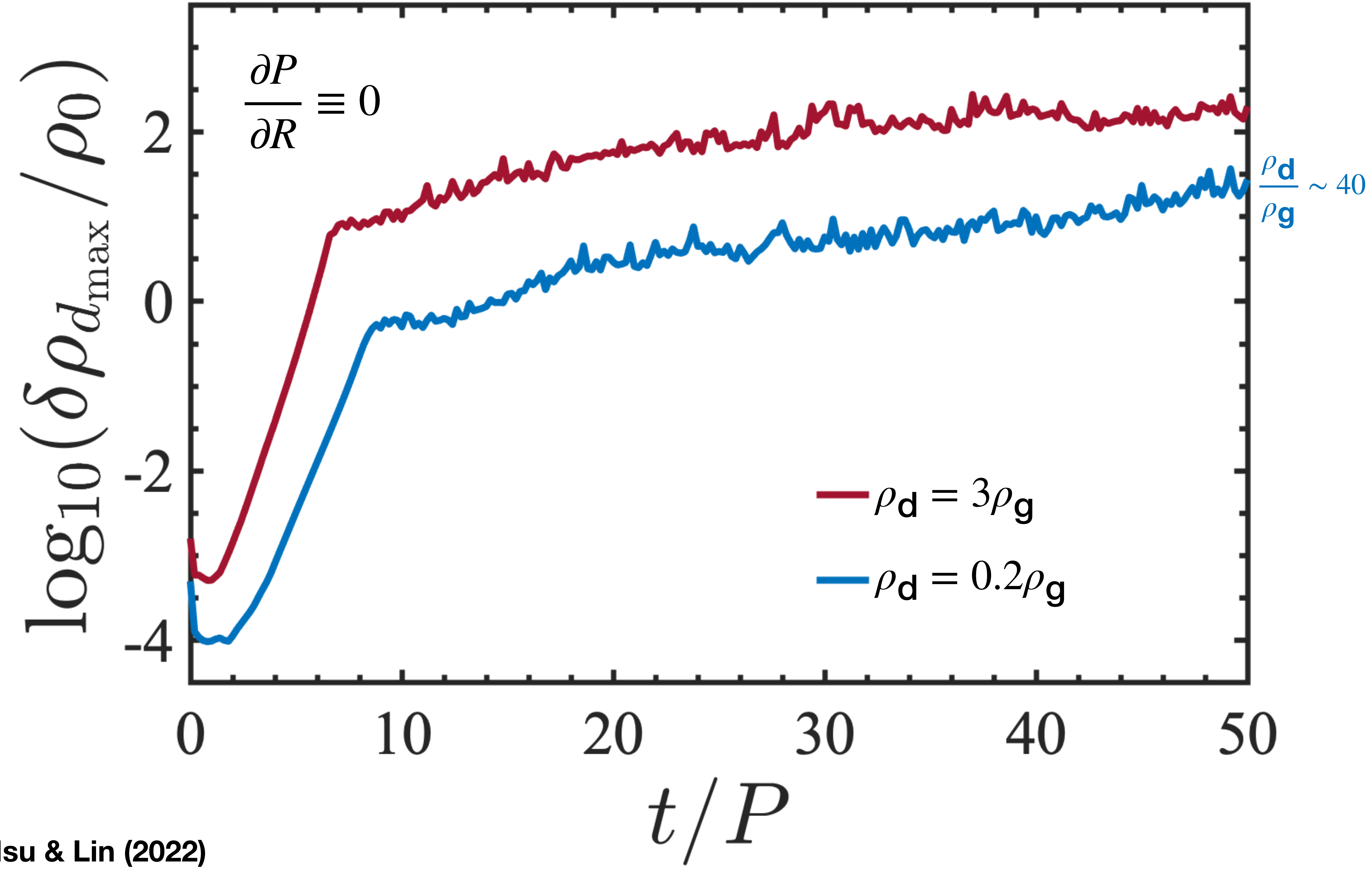
Lin & Hsu (2022)

Azimuthal drift streaming instability



Hsu & Lin (2022)

Dust concentrates even when $\rho_d < \rho_g$ initially



Hsu & Lin (2022)

Summary

- Dust settling opposed by turbulence 👎
- SI is easily stabilized by viscosity 👎
- Vertically shearing SI in stratified disks 👎
- Azimuthal drift SI in accreting disks 👍

Thank you

@linminkai