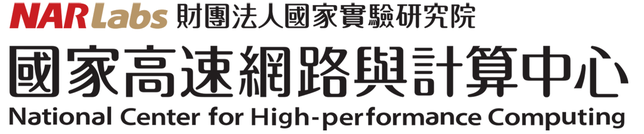
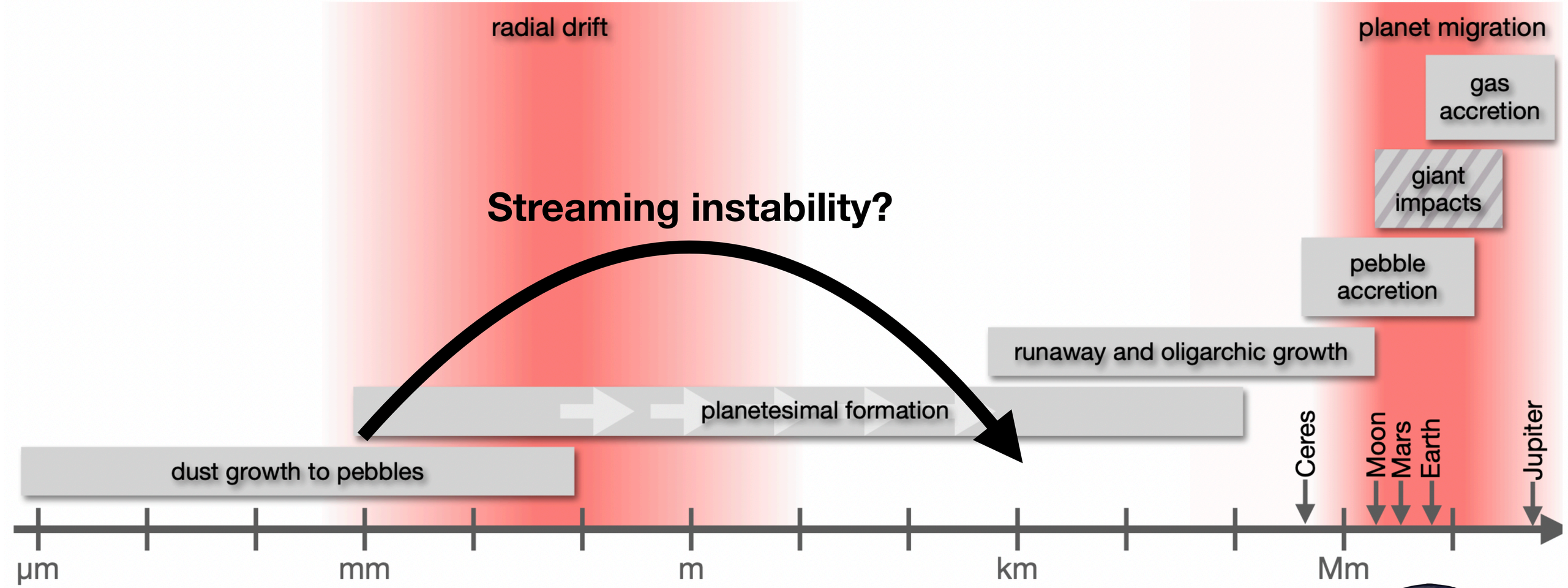
Streaming instabilities in modern protoplanetary disks

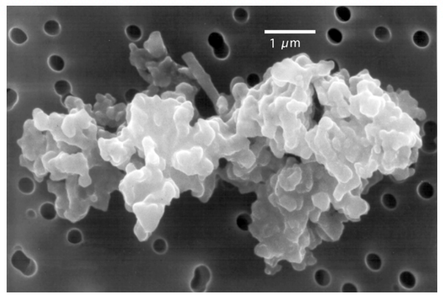
Min-Kai Lin

September 2022



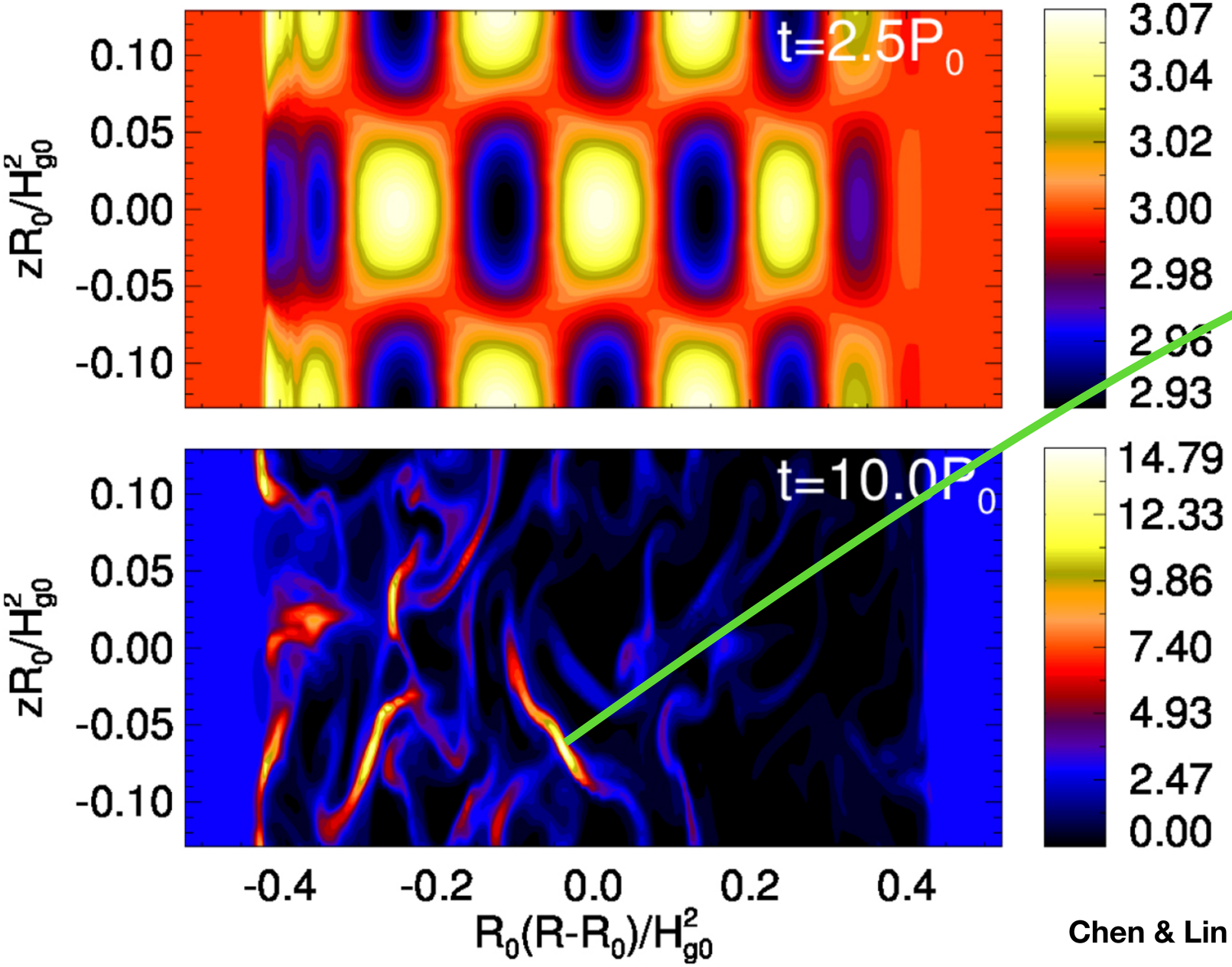
Conventional planet formation theory





(Drazkowska et al., 2022, PPVII)

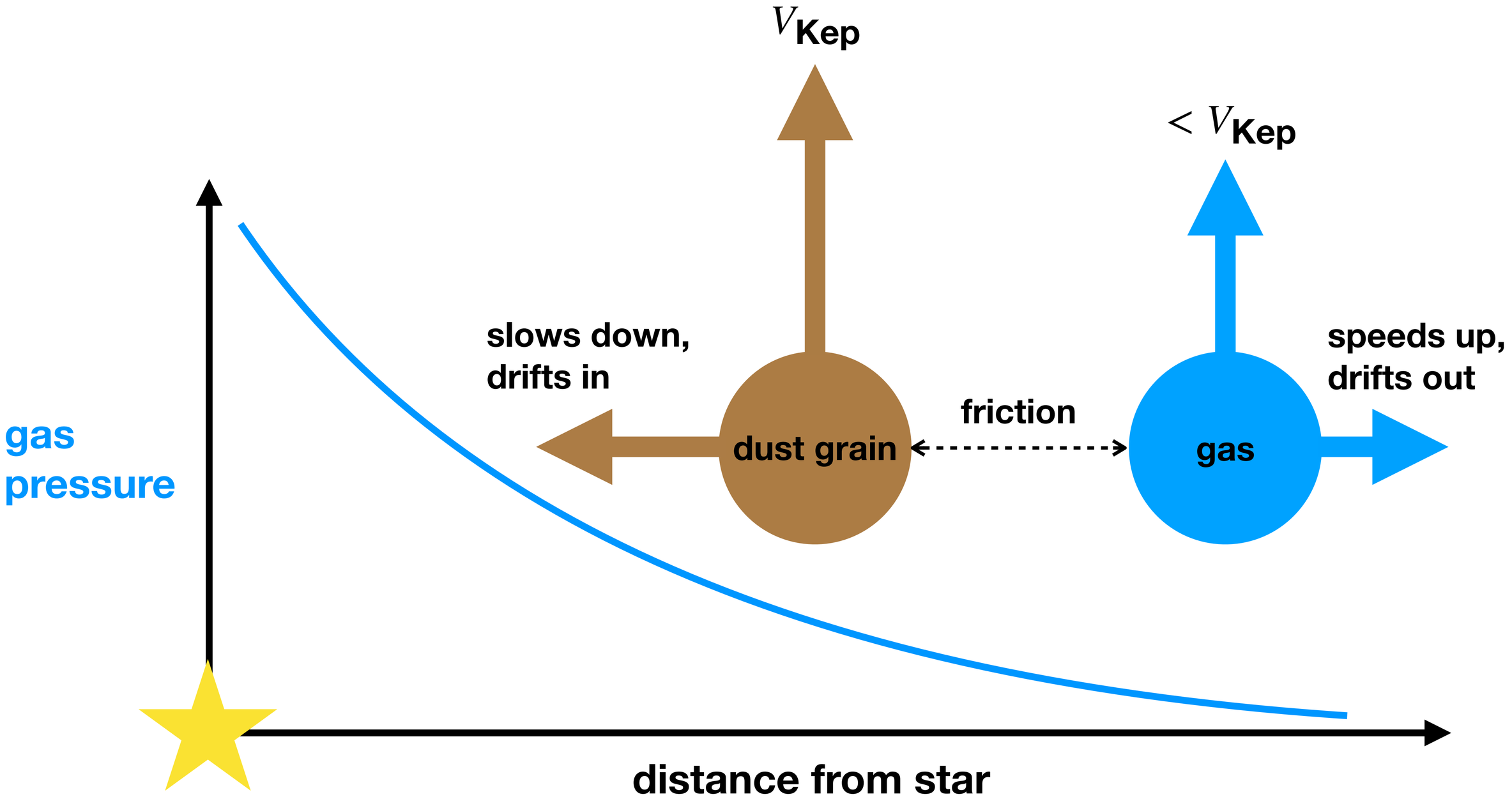
Planetesimal formation via the SI



Dense dust clump collapses into planetesimals

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

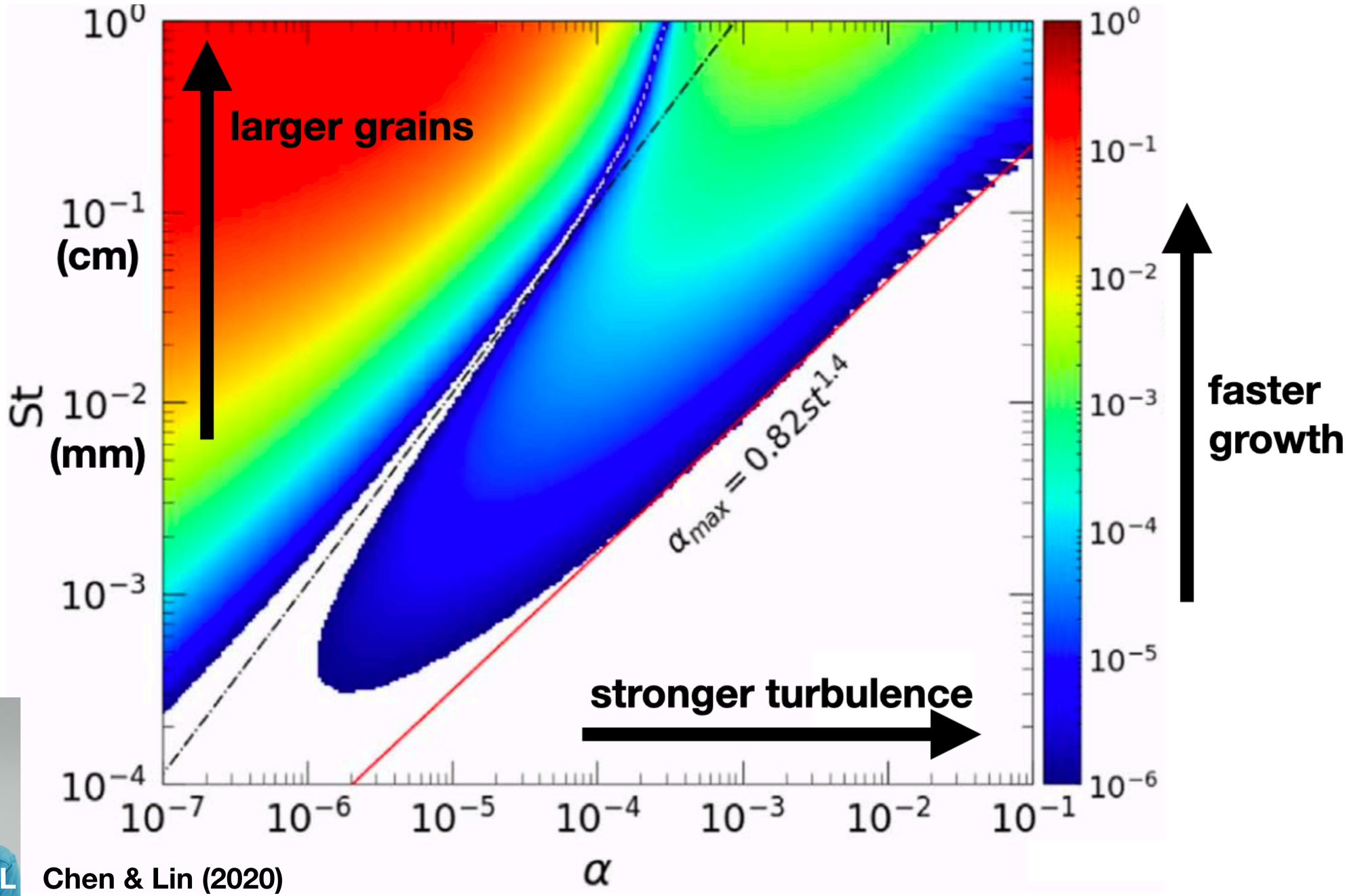
Radial drift powers the classical SI



The ideal SI

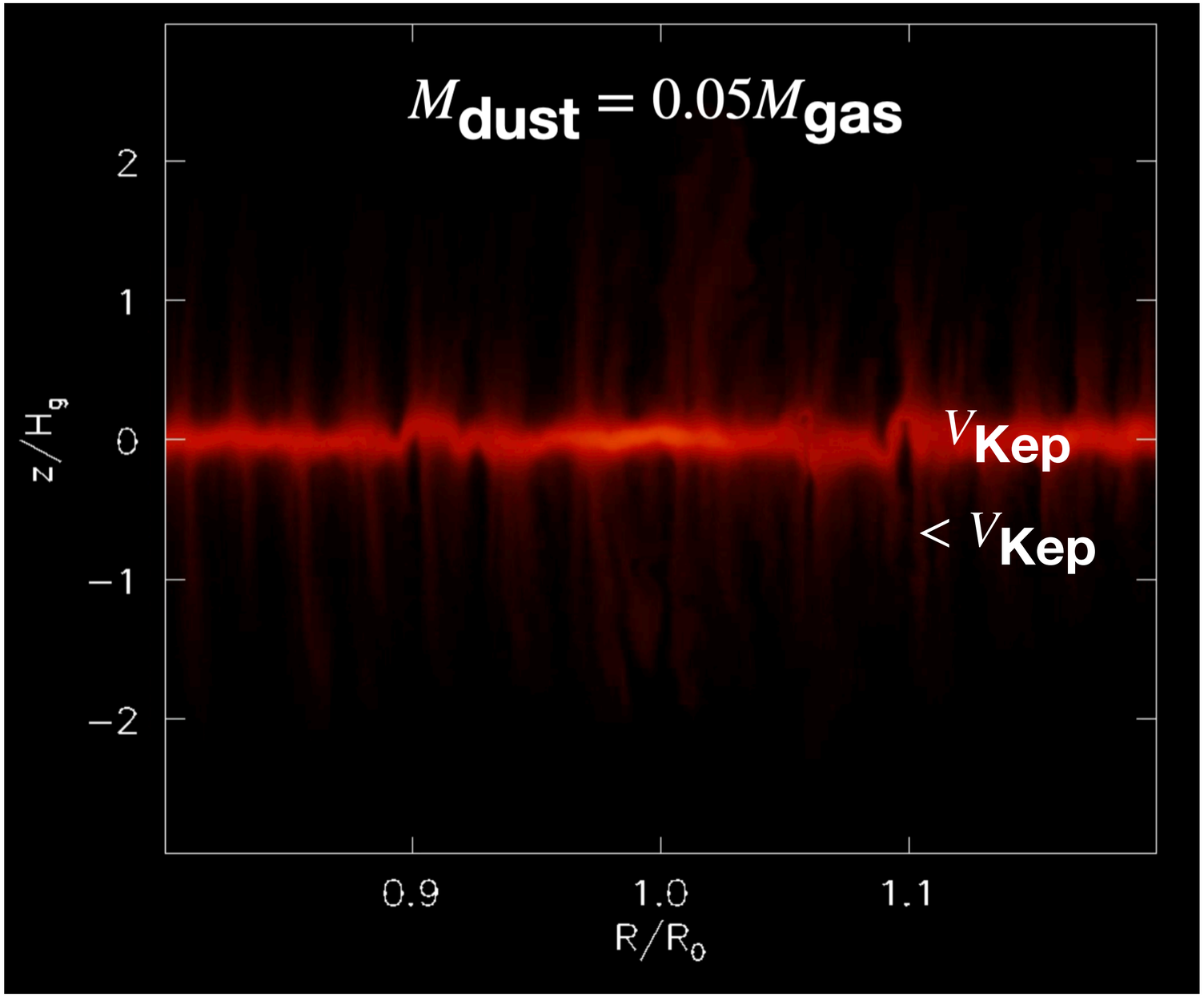
- disk is non-turbulent → Chen & Lin (2020)
- disk has no vertical structure → Lin (2021)
- disk is unmagnetized → Lin & Hsu (2022)
  Hsu & Lin (in press)

SI is easily killed by viscosity

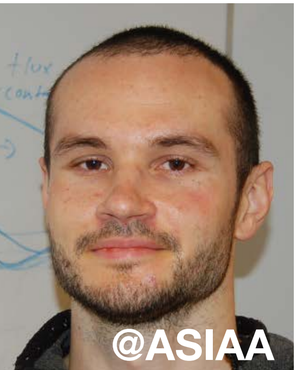


Chen & Lin (2020)

Stratified dust layers



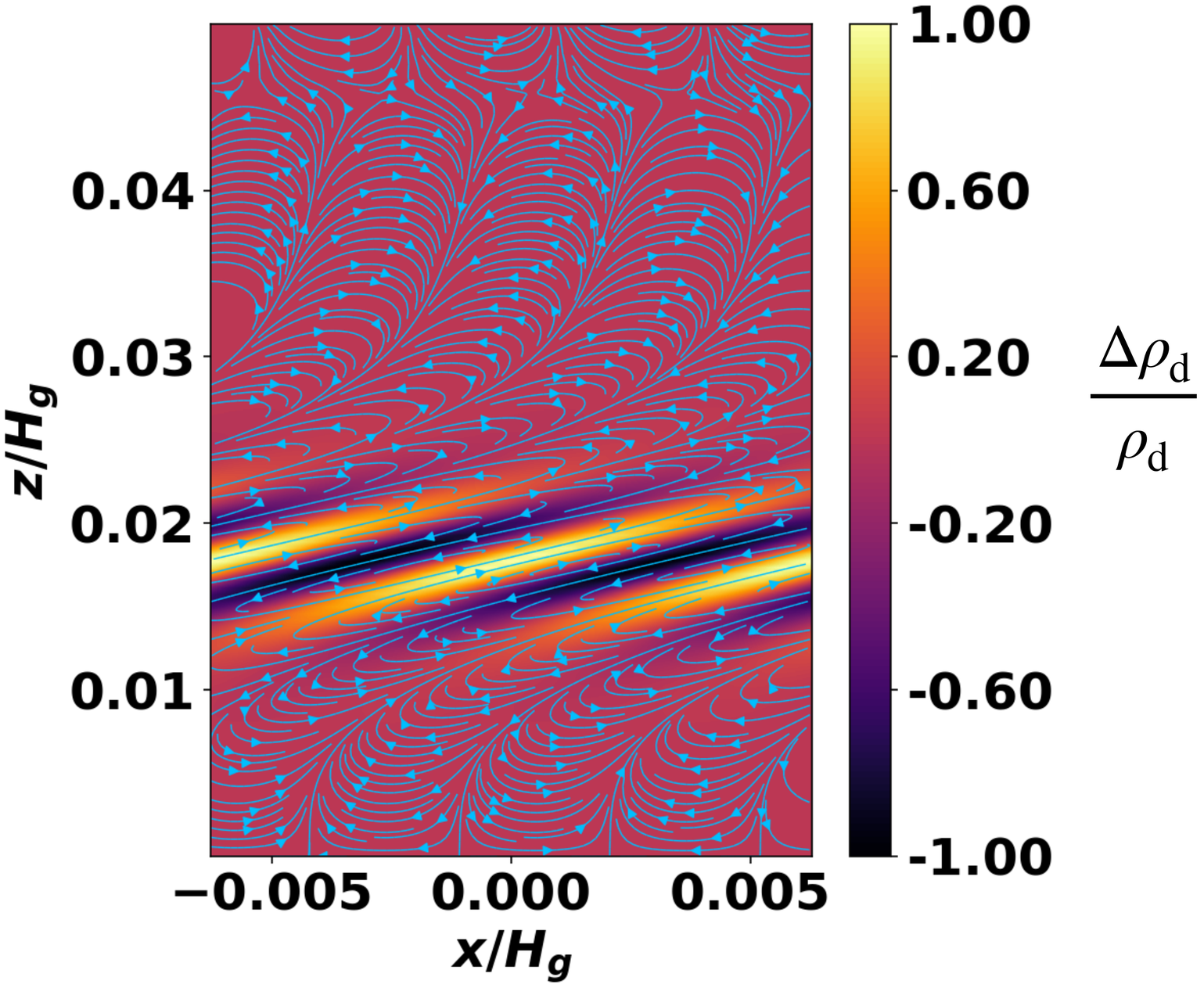
$$\frac{\partial \Omega}{\partial z} \neq 0$$



Lehmann & Lin (2022): Dust settling in VSI-turbulent disks

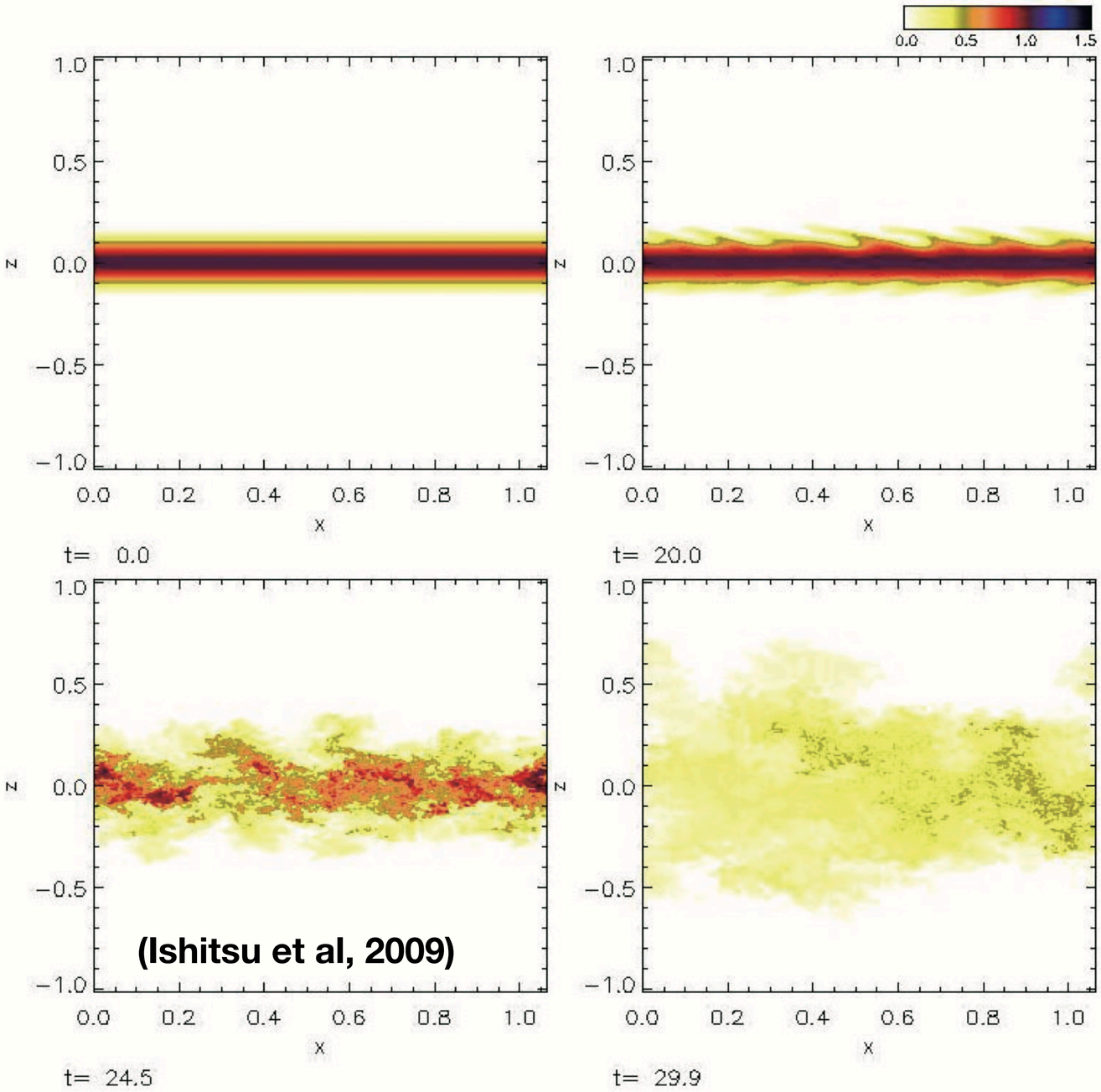
“Vertically shearing SI” in stratified disks

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



Lin (2021)

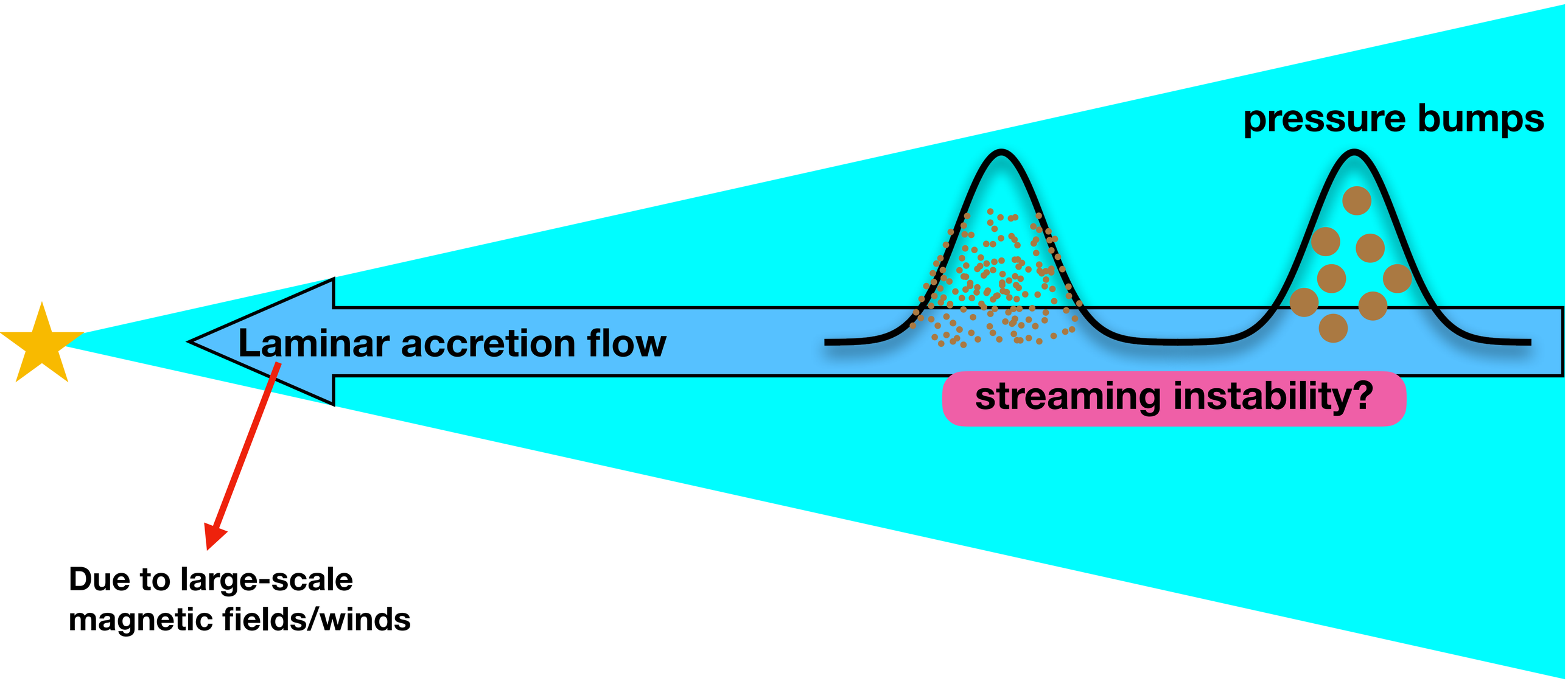
Vertically shearing SIs grow fast but…



dust layer dispersed

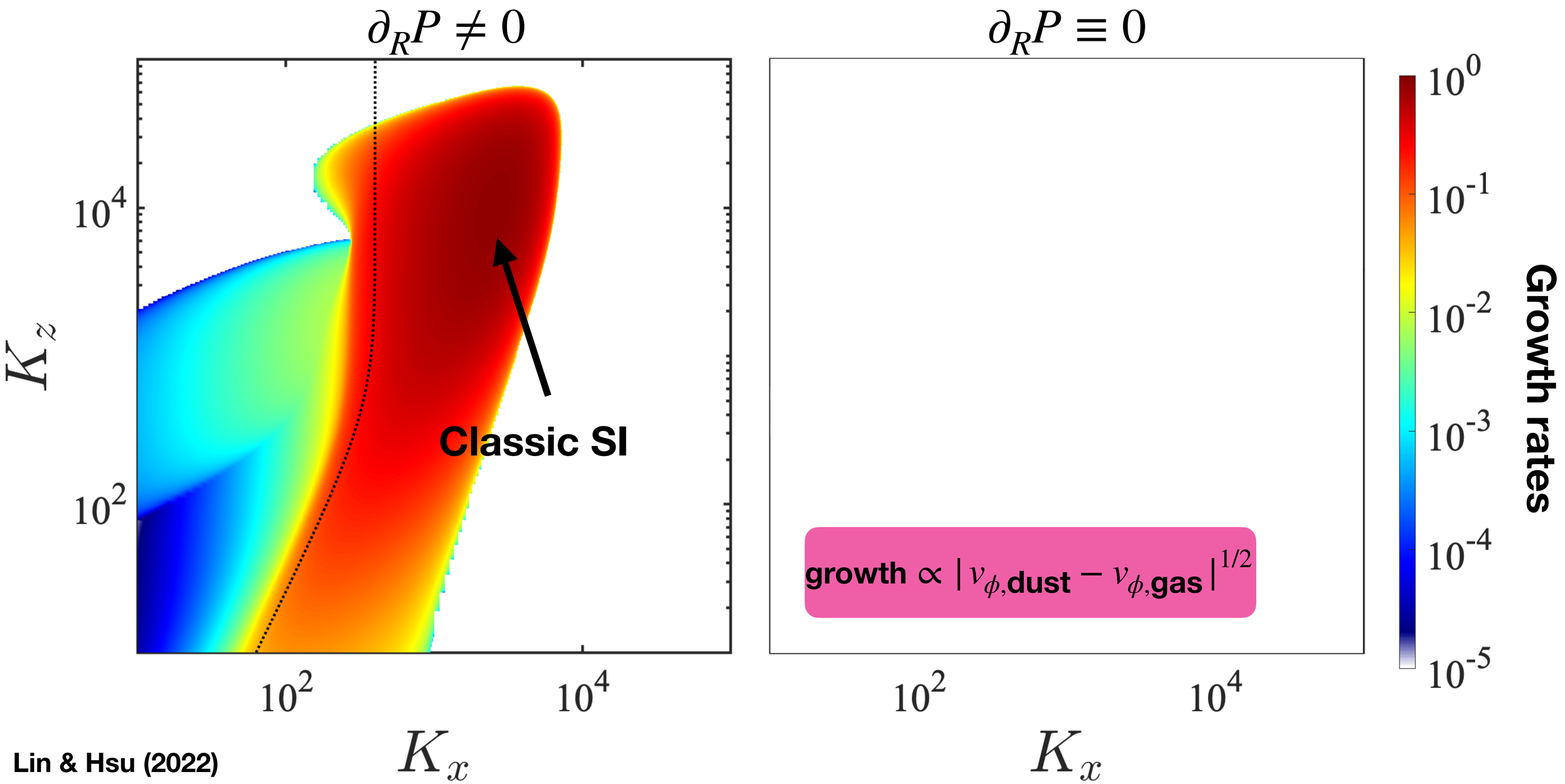
☹️

Can modern disk models help?



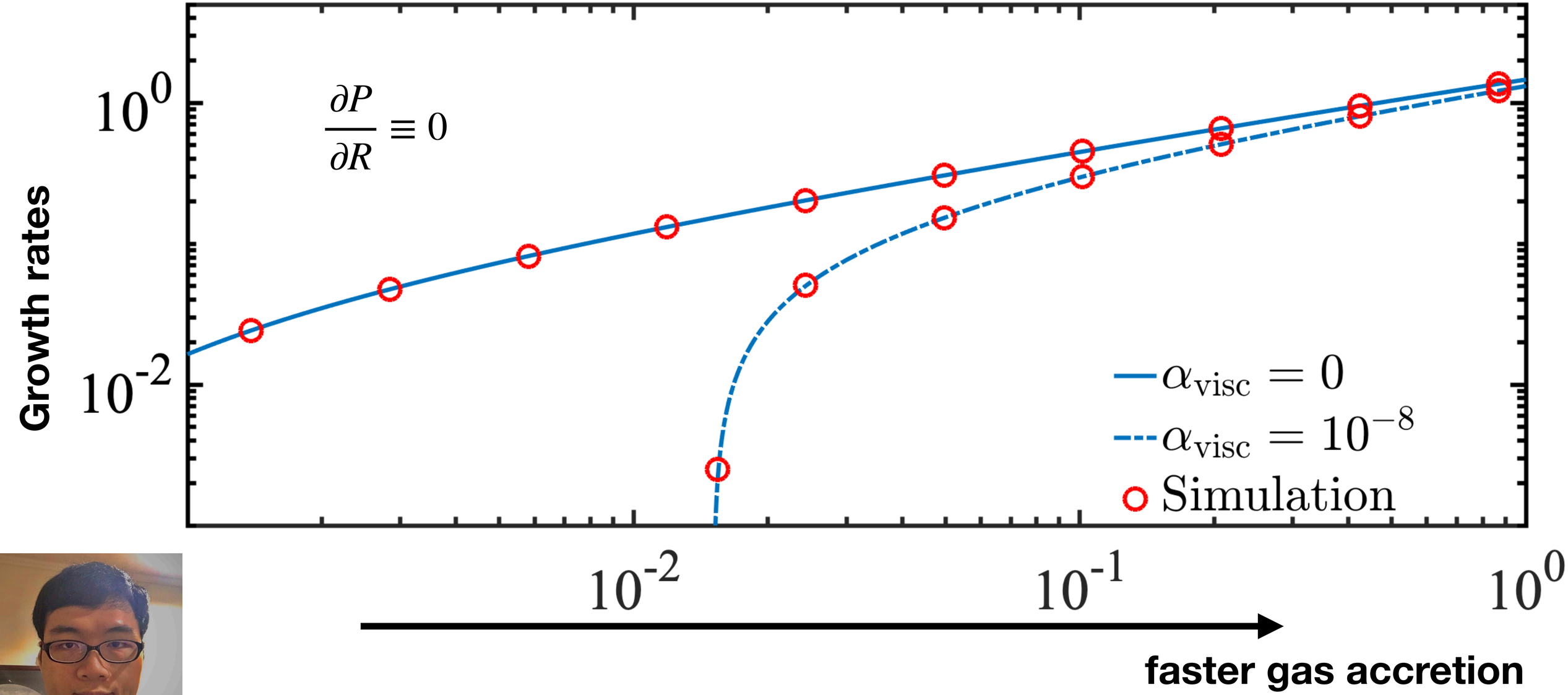
(e.g. Riols et al. 2020, Cui & Bai 2021)

SI without pressure gradients



Lin & Hsu (2022)

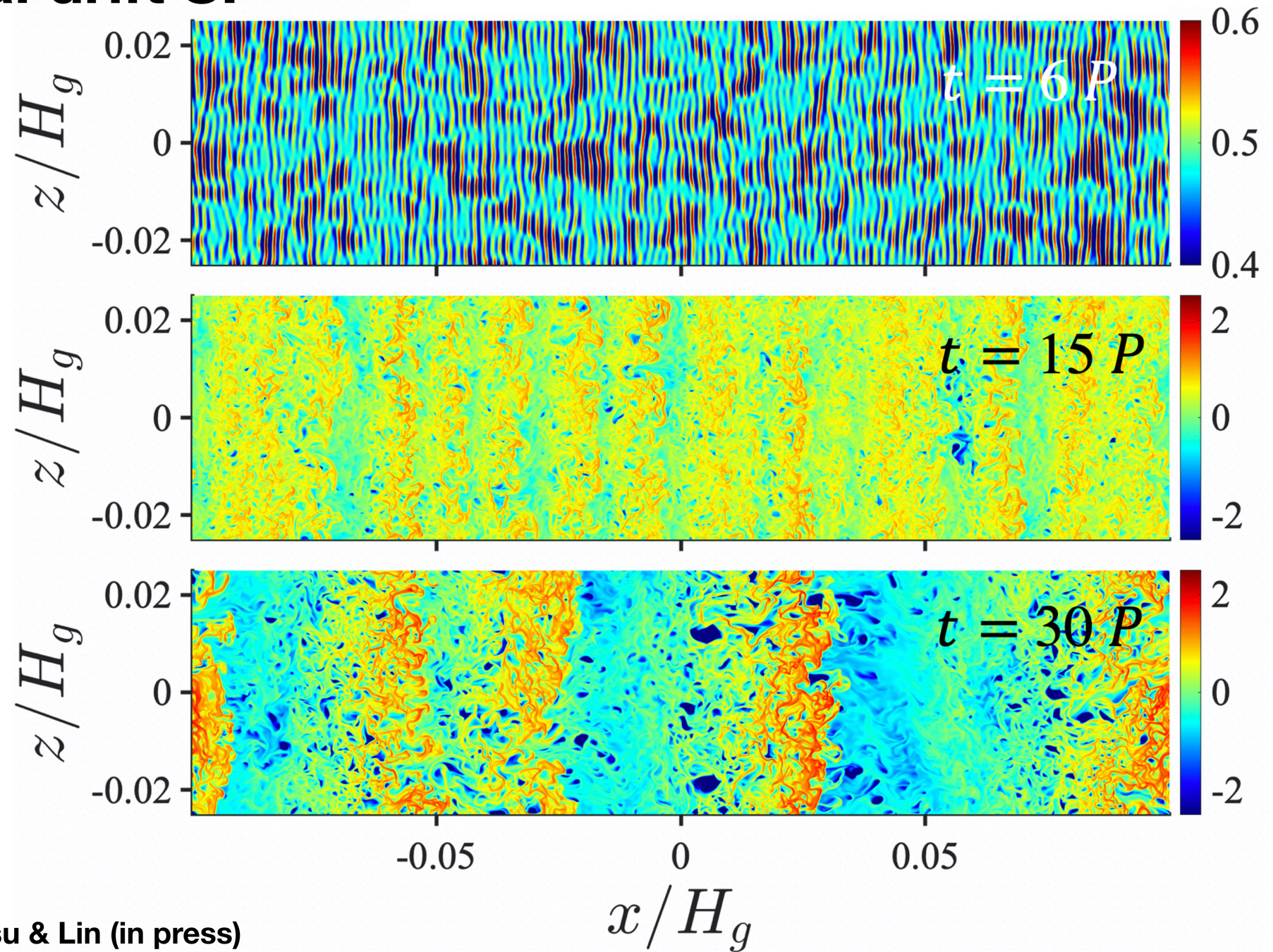
Verification by FARGO3D



Hsu & Lin (in press)

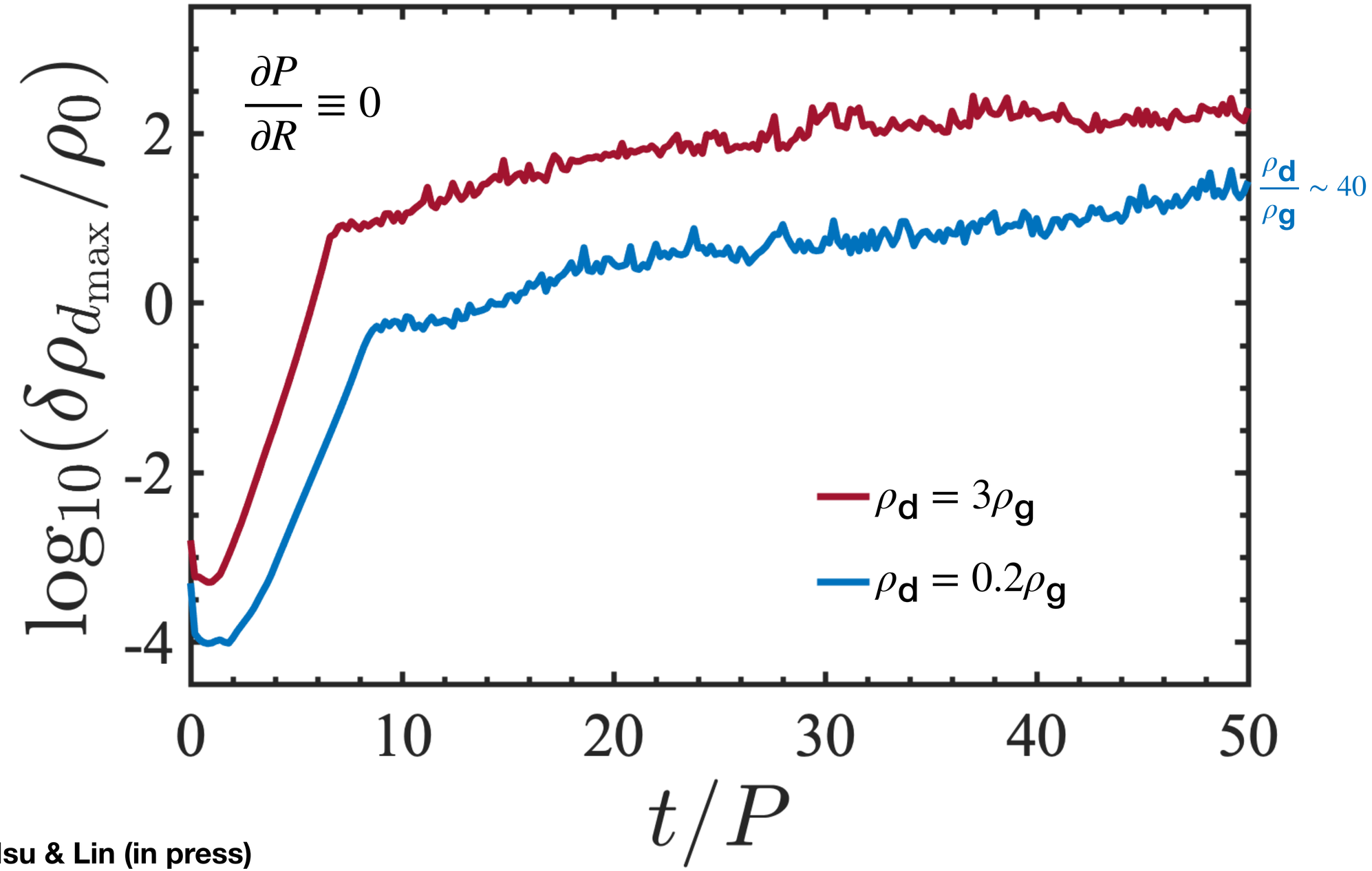
Azimuthal drift SI

$$\frac{\partial P}{\partial R} \equiv 0$$

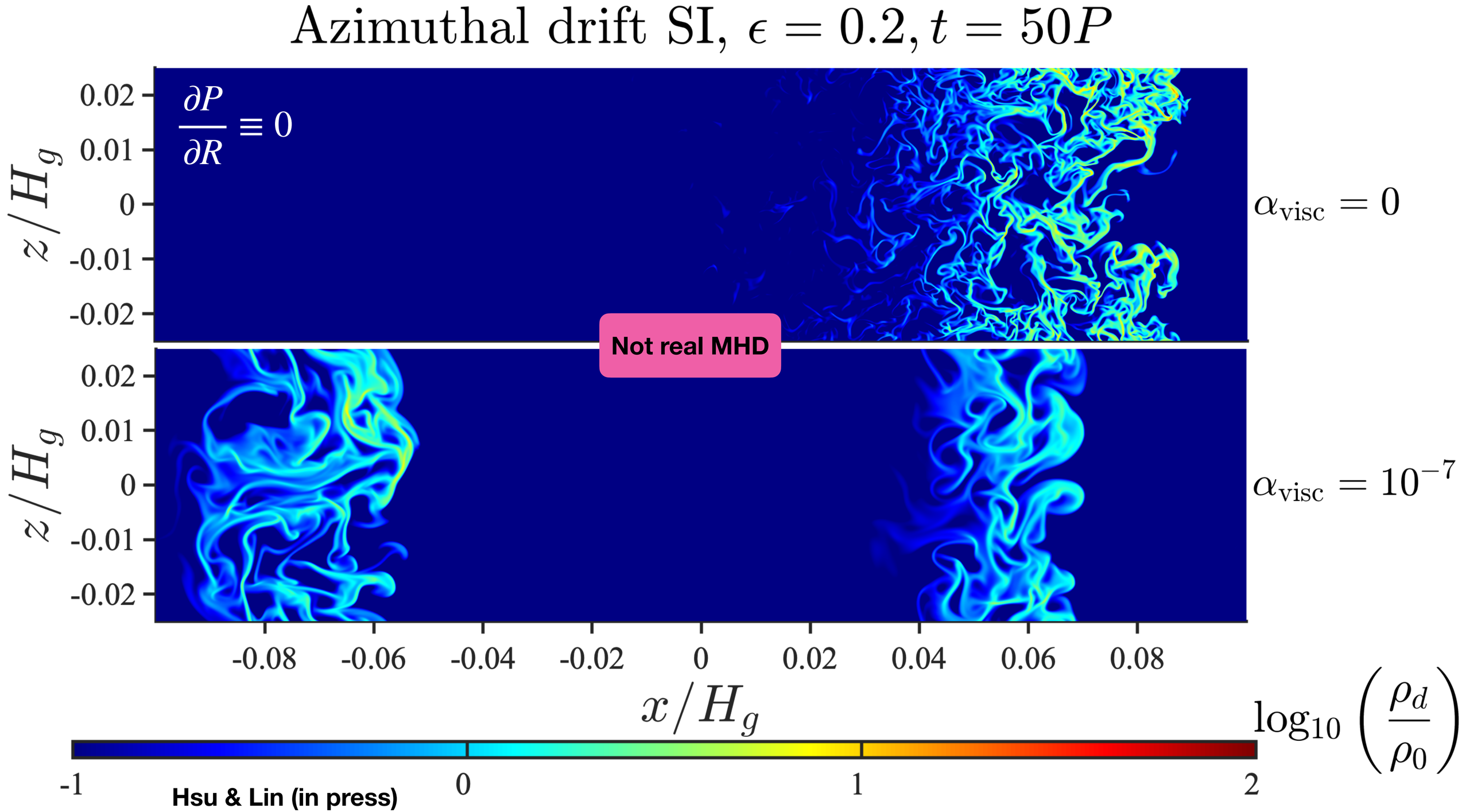


Hsu & Lin (in press)

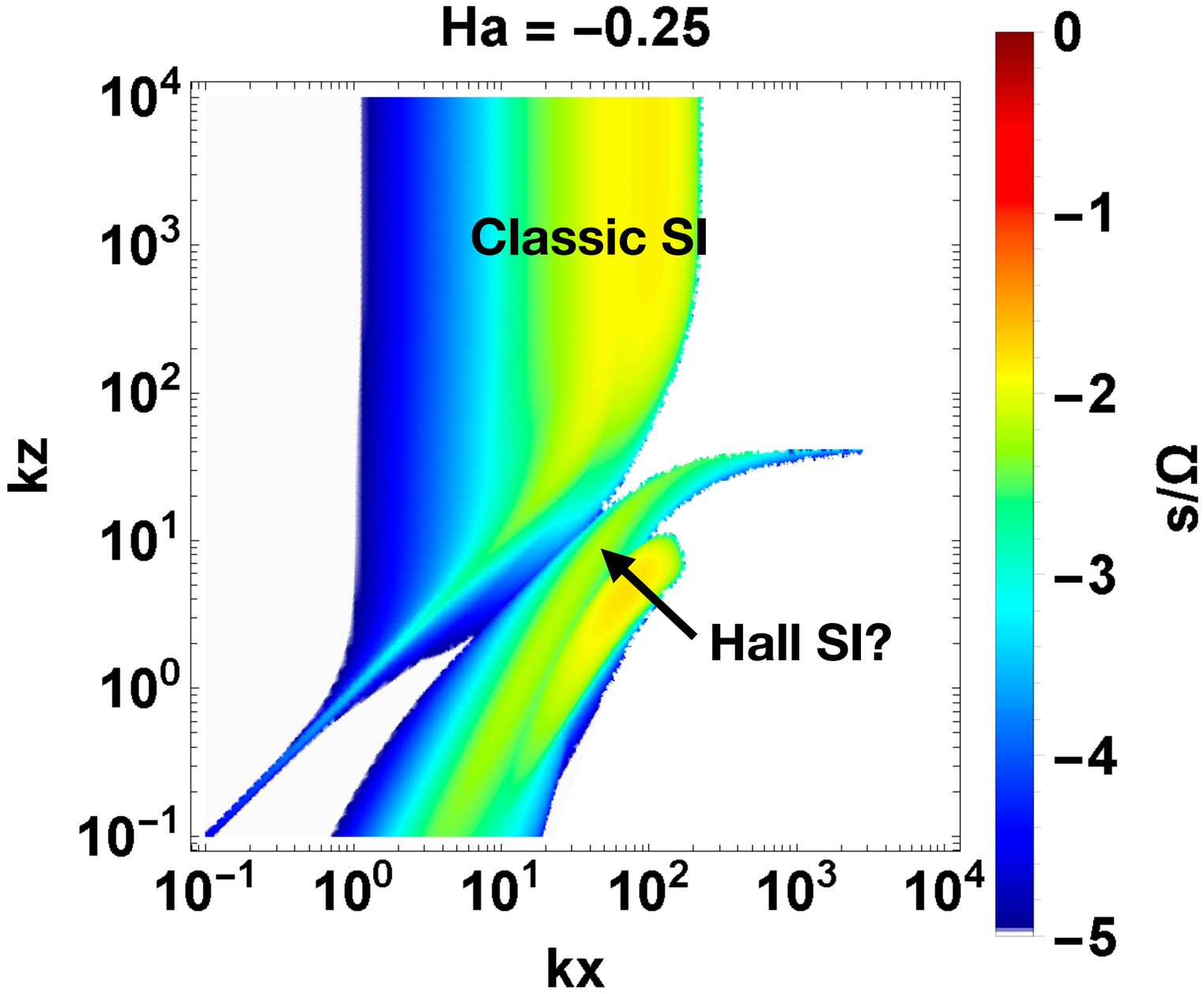
Dust concentrates even when $\rho_d < \rho_g$ initially



Hsu & Lin (in press)


Azimuthal drift SI, $\epsilon = 0.2, t = 50P$
$\frac{\partial P}{\partial R} \equiv 0$
$\alpha_{\rm visc} = 0$
$\alpha_{\rm visc} = 10^{-7}$
Not real MHD
z/H_g
x/H_g
0.02
0.01
0
-0.01
-0.02
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
$\log_{10}\left(\frac{\rho_d}{\rho_0}\right)$
-1
0
1
2
Hsu & Lin (in press)

SI + live, non-ideal MHD



Wu & Lin (in prep)

Summary

- **SI is easily killed by viscosity**
- **Vertically shearing SIs may disperse dust layers**
- **Azimuthal drift SI: works without pressure gradients, concentrates dust even at low metallicities**

Astrophysics > Earth and Planetary Astrophysics

arXiv:2209.06784 (astro-ph)

[Submitted on 14 Sep 2022]

Nonlinear evolution of streaming instabilities in accreting protoplanetary disks

Chun-Yen Hsu (ASIAA), Min-Kai Lin (ASIAA, NCTS Physics Division)

On arXiv today!

Thank you

@linminkai