

Dust settling in turbulent protoplanetary disks

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- Governmental research institute
- ~ 1000 Research Fellows (equiv. professors); ~ 1000 post-docs
- No teaching duties, but plenty of research students
- Additional grants available from the Ministry of Science and Technology

AS Institute of Astronomy and Astrophysics

The screenshot shows the homepage of the ASIAA website. At the top, there is a navigation bar with links to Academia Sinica, Research Brochure, ASIAA Login, and social media icons for Facebook and YouTube. Below the navigation bar is a search bar and a "Print Friendly" link. On the left side, there is a large image of three astronomical simulations: a yellow disk-like structure, a green and yellow ring-like structure, and a blue and green spiral galaxy. A "Theory" section is overlaid on the image, containing text about advanced research in theoretical astrophysics and a "Learn more" link. To the right of the main content area are four sidebar boxes: "CFHT Canada-France-Hawaii Telescope" (with an image of a telescope dome), "Theory Theoretical Astrophysics" (with an image of a colorful simulation), "ALMA Atacama Large Millimeter/ submillimeter Array" (with an image of a large dish antenna), and "CHARMS Coordinated Hydrodynamic and Astrophysical Research, Modeling, and Synthesis" (with an image of a red and blue simulation). Below the main content area is a horizontal menu bar with links to About ASIAA, People, Research, Project, Publication, Activity, News, Education/Outreach, Library, and Link. On the left side of the bottom section, there is a "What's New" section with two items: "(Research Award) Dr. Ke-Jung Chen has won the 2019 Young Scholar Innovation Award from the Foundation for the Advancement of Outstanding Scholarship." and "(Science Highlight) Beer On Space Hamburger around a Baby Star — Cheers to the first black hole image!". On the right side of the bottom section, there is a "Job Openings" section with an image of a resume.

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Sitemap 中文 Print Friendly

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About ASIAA People Research Project Publication Activity News Education/Outreach Library Link

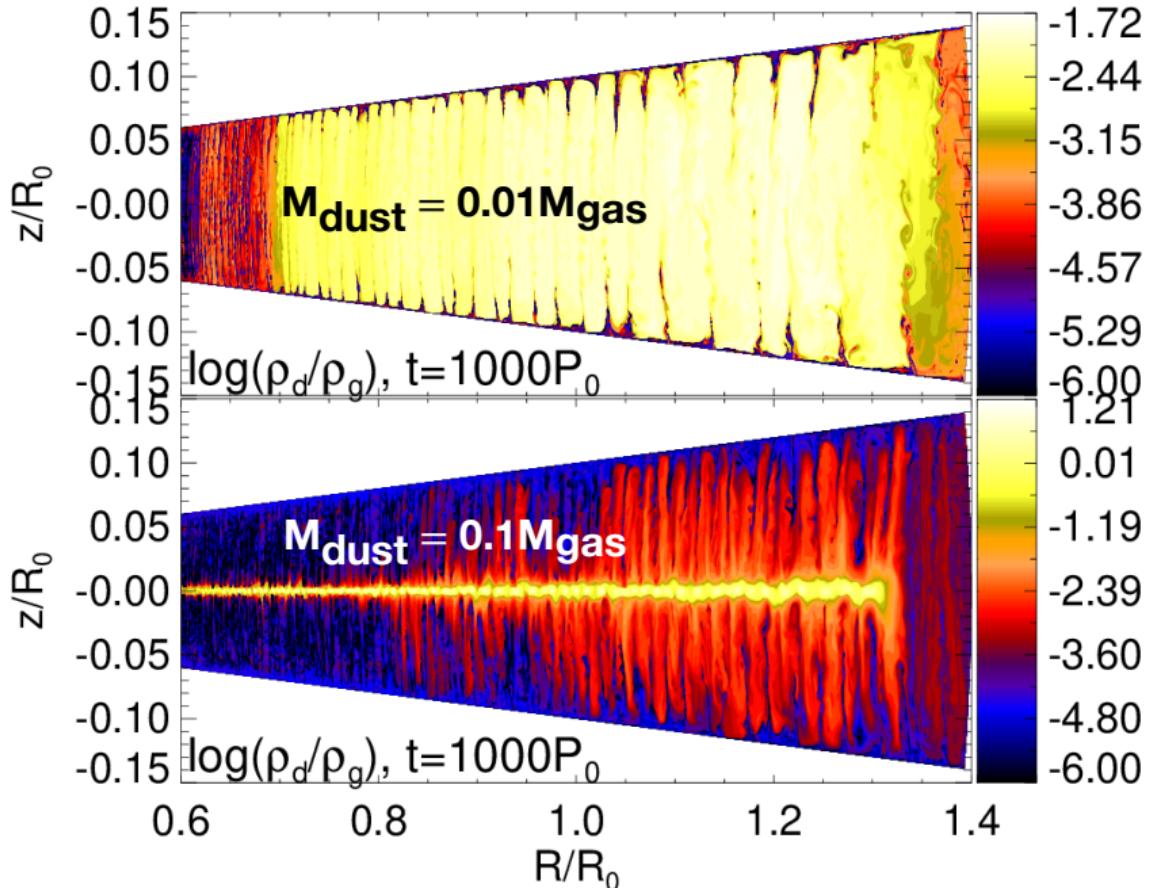
What's New

- (Research Award) Dr. Ke-Jung Chen has won the 2019 Young Scholar Innovation Award from the Foundation for the Advancement of Outstanding Scholarship.
- (Science Highlight) Beer On Space Hamburger around a Baby Star — Cheers to the first black hole image!

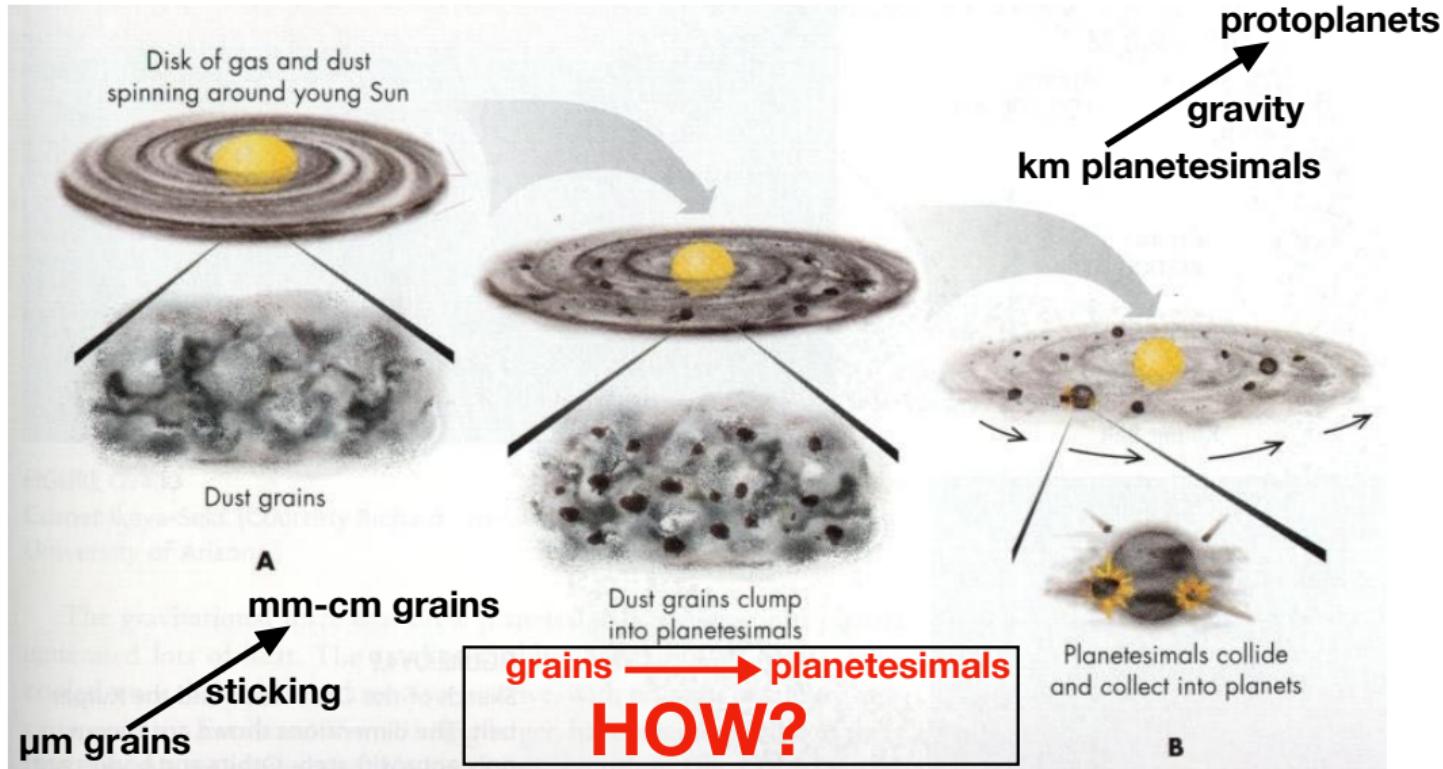
Job Openings

- Physical location in National Taiwan University; office in Hilo, Hawaii
- Total ~ 200 people
- International staff, English working environment

Long story short

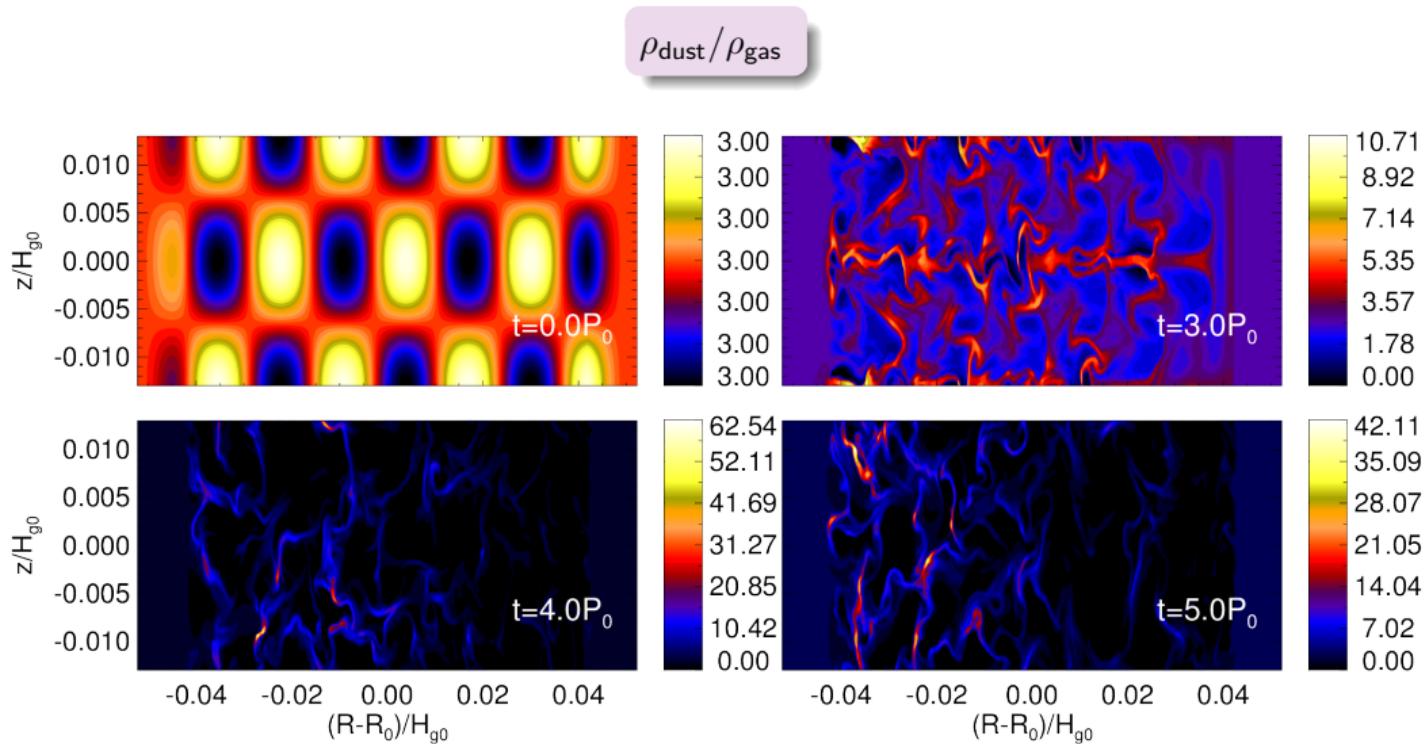


From dust to planets



- Streaming instability? (Youdin & Goodman, 2005)
- Secular gravitational instabilities (Youdin 2011; Takahashi & Inutsuka, 2014)

Streaming instability



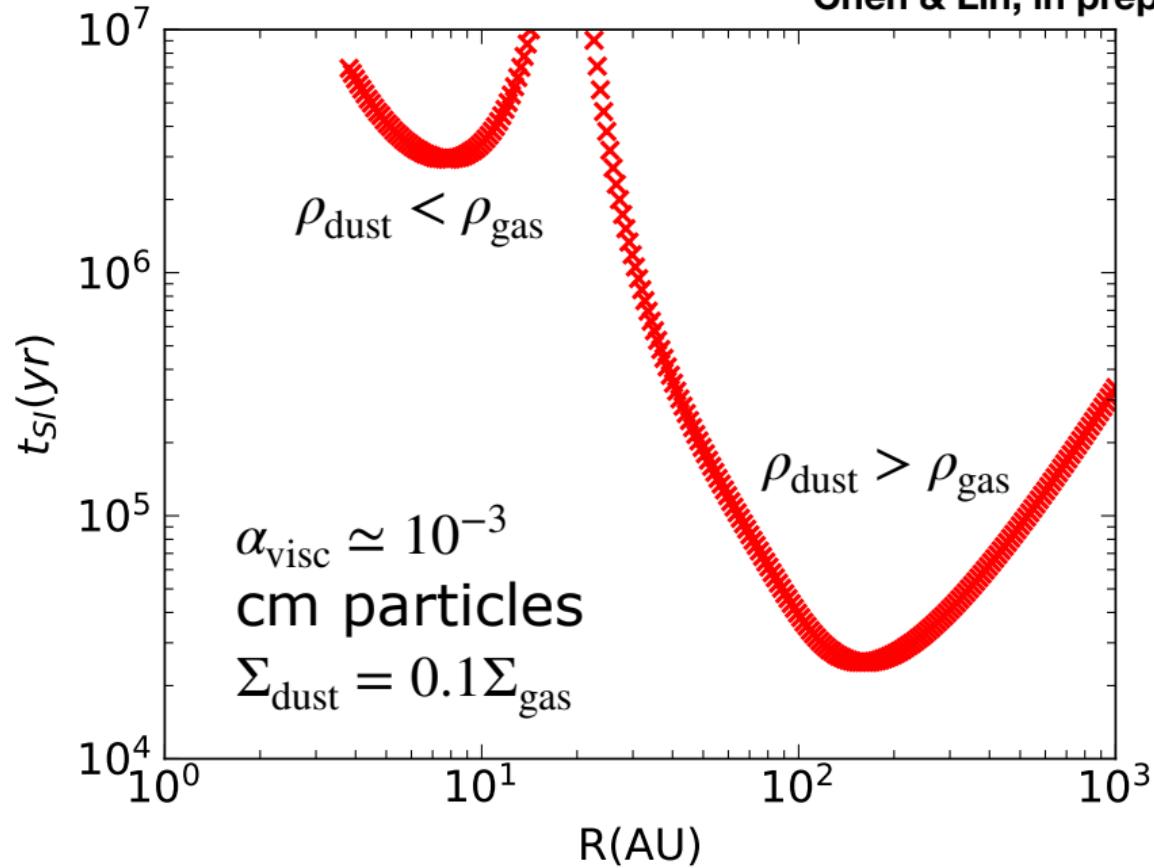
- One-fluid model of dusty gas (Lin & Youdin, 2017)
- PLUTO code

Streaming instability timescales in a MMSN-like disk

Chen & Lin, in prep.



Kan Chen,
Nanjing
→ Cambridge

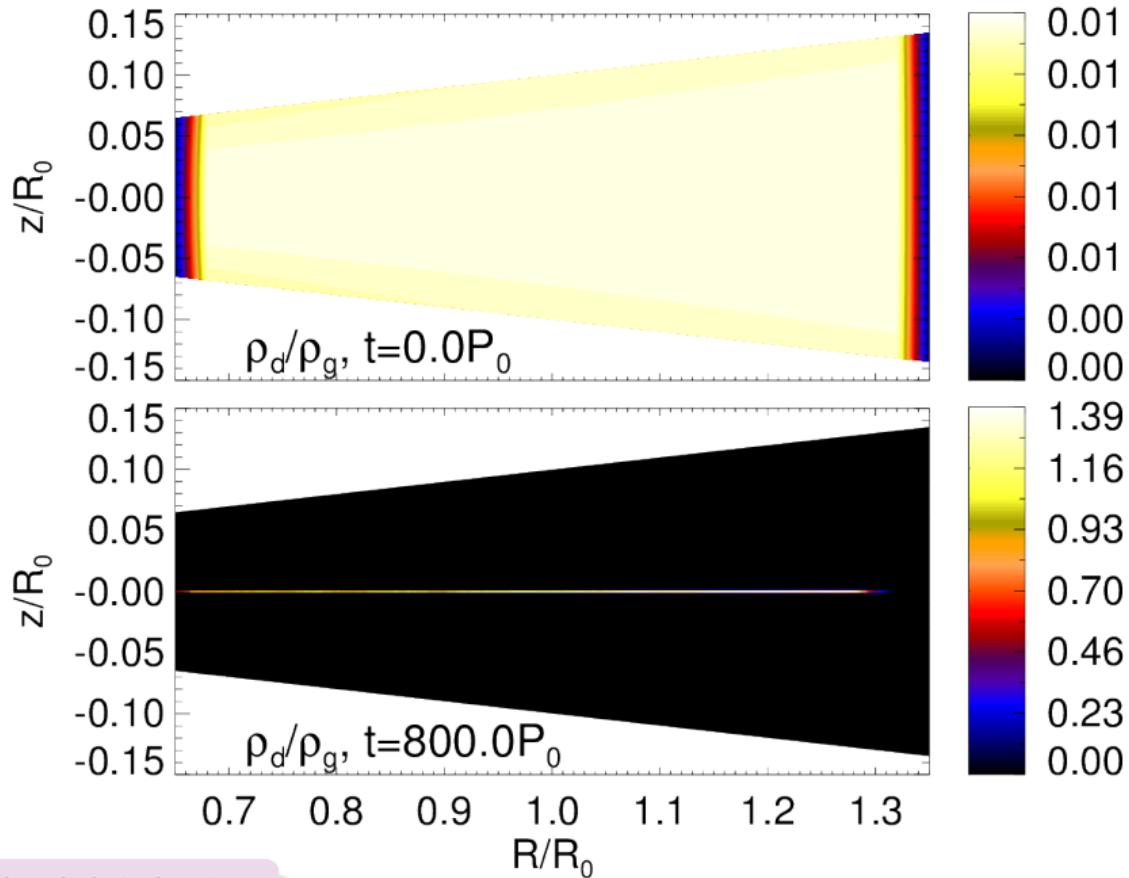


- SI is easily killed by viscosity

Rapid planetesimal formation require $\rho_{\text{dust}} \gtrsim \rho_{\text{gas}}$



Dust settling?

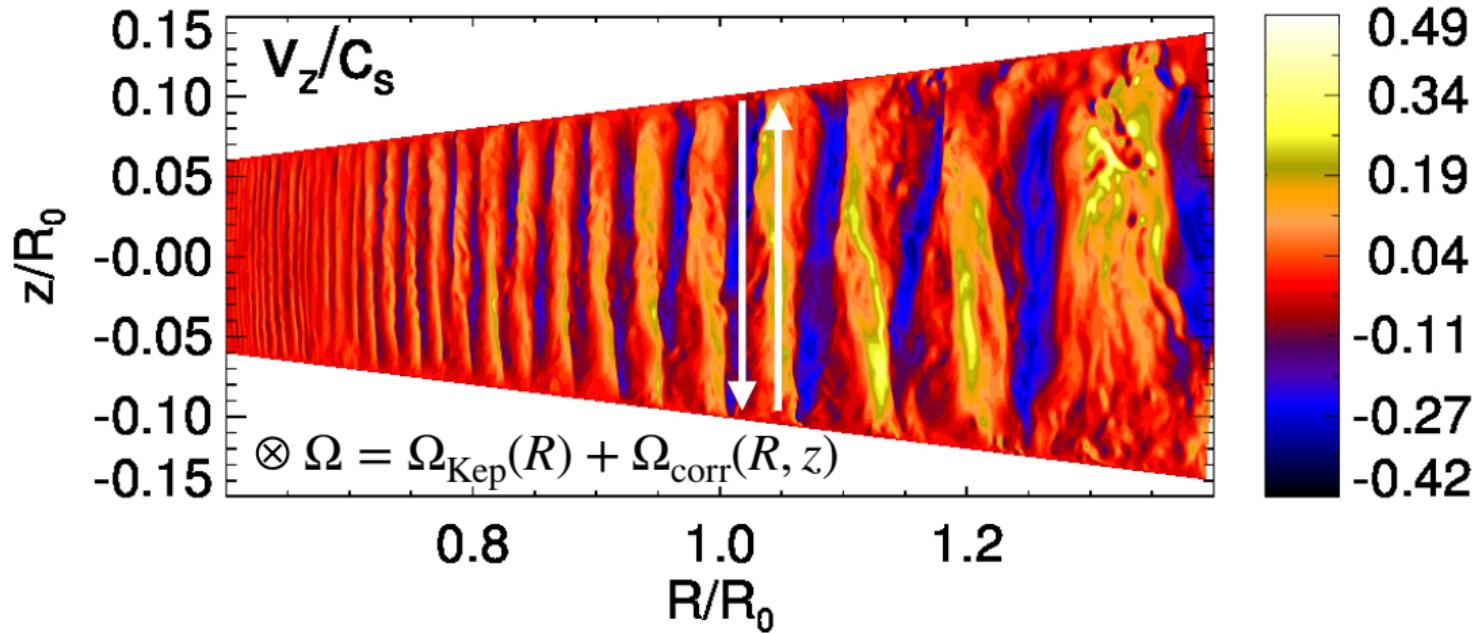


- Yes... if the disk is laminar

Hydrodynamic turbulence in protoplanetary disks

- Vertical shear instability (Nelson et al., 2013)

► $\frac{\partial \Omega}{\partial z} \neq 0 + \text{rapid cooling} \Rightarrow \text{unstable}$

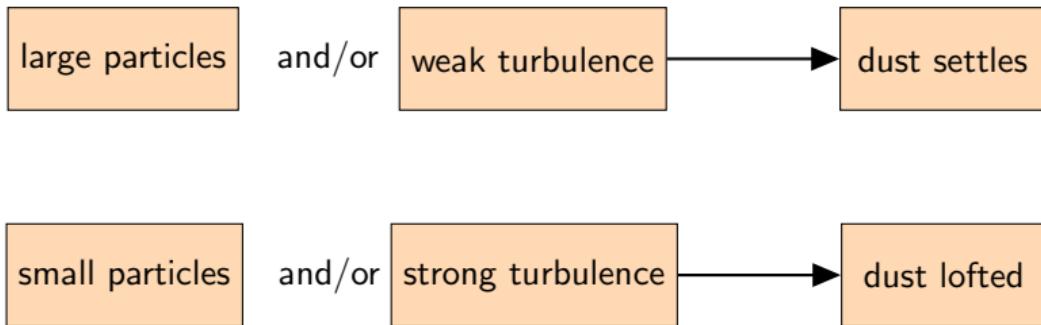


What happens to dust?

Lifting dust particles by the VSI

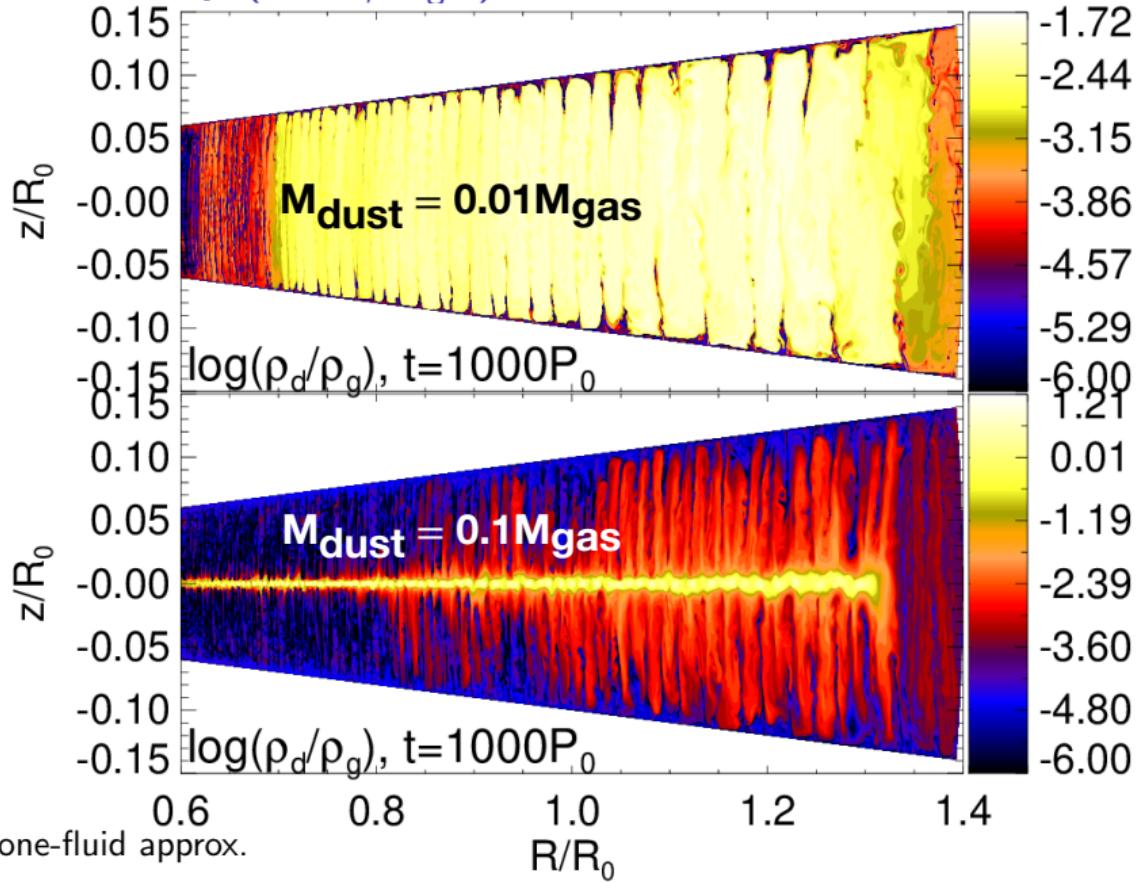
Lin (2019), one-fluid approximation

Classic picture: passive particles



- What about particle feedback and solid abundance?

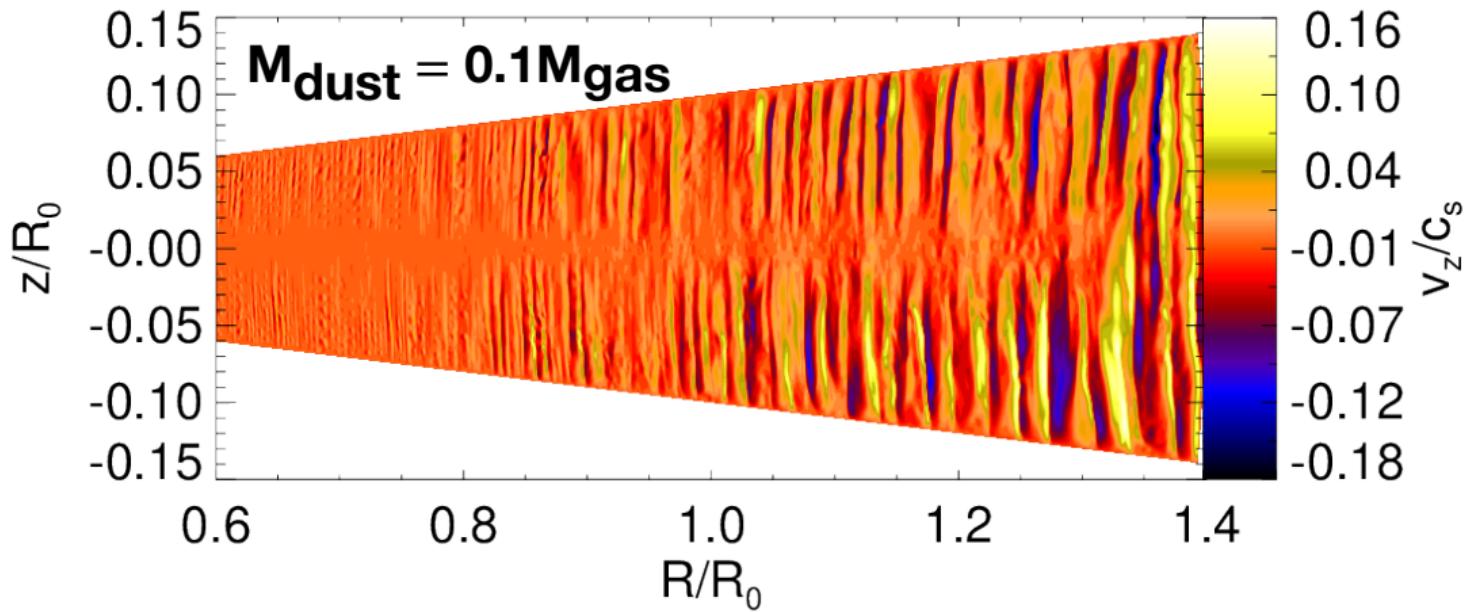
Effect of metallicity ($\Sigma_{\text{dust}}/\Sigma_{\text{gas}}$)



Lin (2019), one-fluid approx.

- Dust-loading \rightarrow buoyancy \rightarrow stabilizes VSI

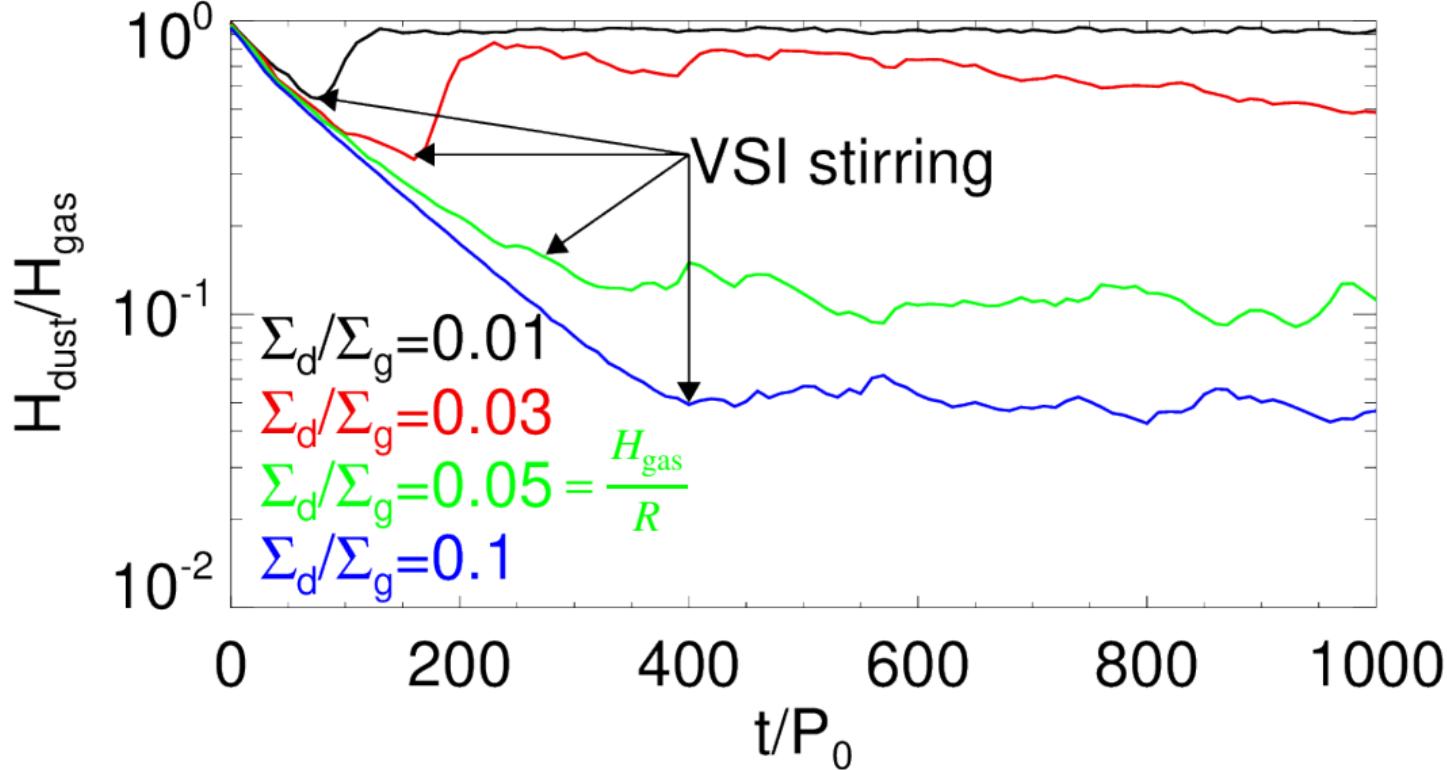
Effect of metallicity ($\Sigma_{\text{dust}}/\Sigma_{\text{gas}}$)



Lin (2019), one-fluid approx.

- Self-stabilized dust layer, similar to 'dead zones'

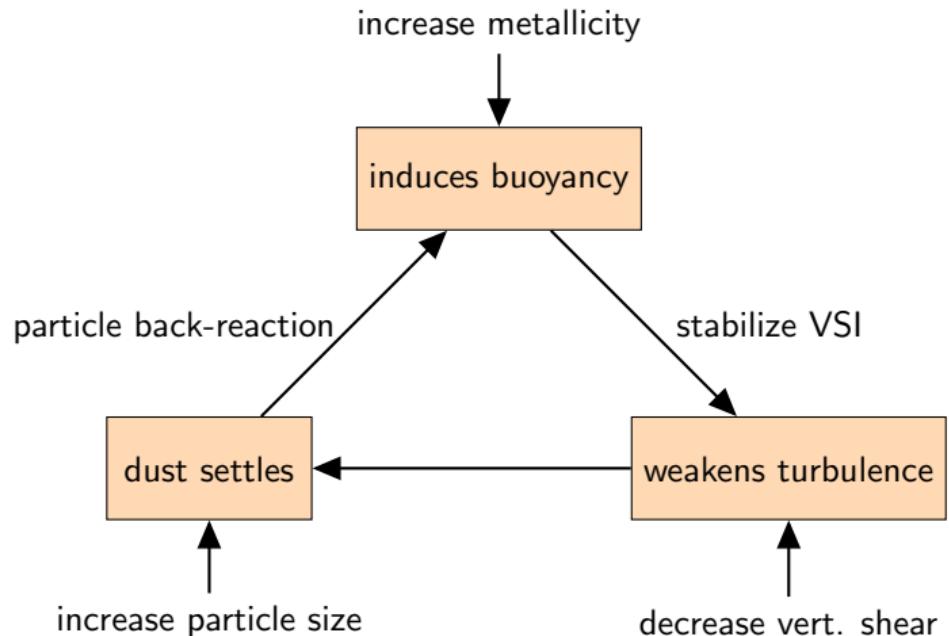
Effect of metallicity ($\Sigma_{\text{dust}}/\Sigma_{\text{gas}}$)



Lin (2019), one-fluid approx.

- More dust settles to thinner layers

Active dust settling in turbulent disks



- Settling via dust-loading: $\Sigma_{\text{dust}} \gtrsim (H_{\text{gas}}/R)\Sigma_{\text{gas}}$
- Dust rings should be thinner than dust gaps

Side note: dust-free model of dusty gas

**polytropic gas
with dust**



**pure gas
with cooling**

(for small particles)

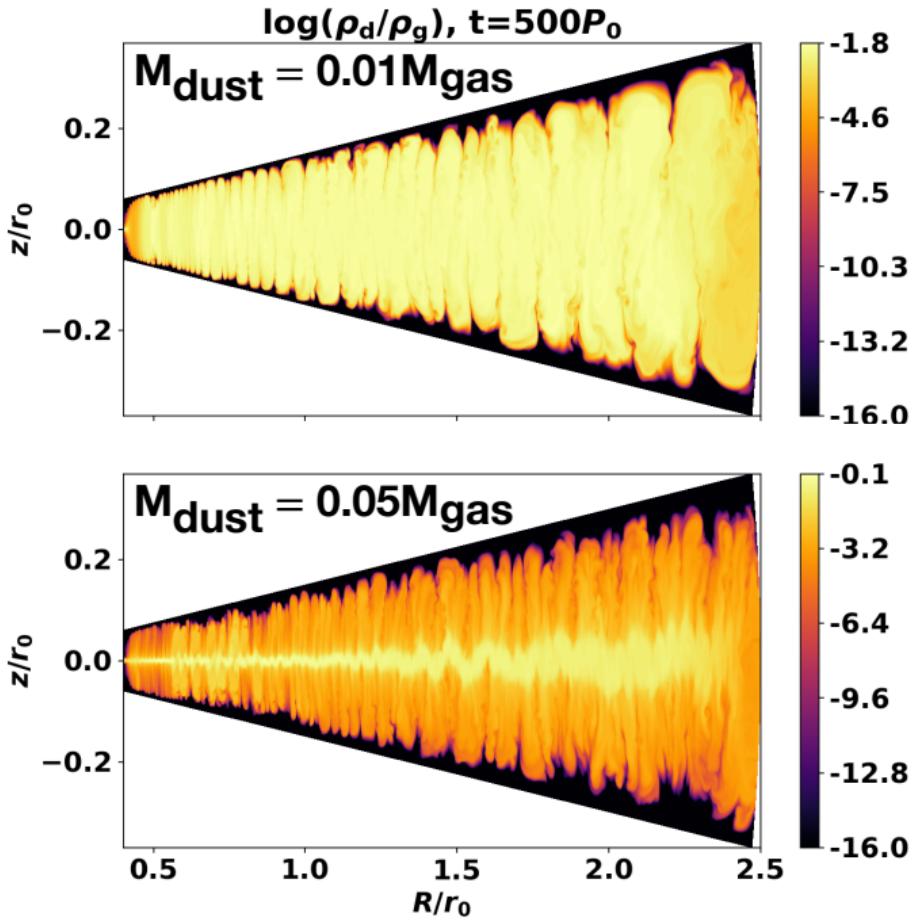
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0,$$

$$\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} = -\frac{1}{\rho} \nabla P - \nabla \Phi,$$

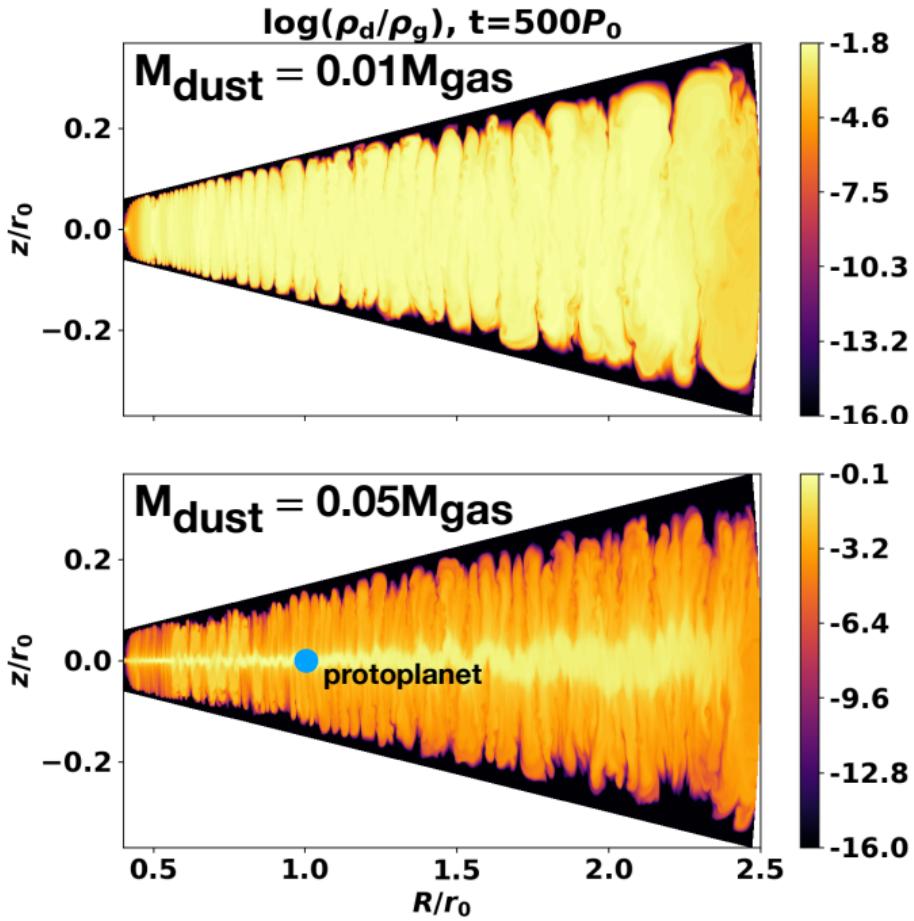
$$\frac{\partial P}{\partial t} + \mathbf{v} \cdot \nabla P = -\Gamma P \nabla \cdot \mathbf{v} + P \mathbf{v} \cdot \nabla \ln c_s^2 + \frac{\Gamma P}{\rho_{\text{gas}}} \nabla \cdot (f_{\text{dust}} t_{\text{stop}} \nabla P).$$

Lin & Youdin (2017); built upon Laibe & Price (2014), also Fromang & Papaloizou (2006)

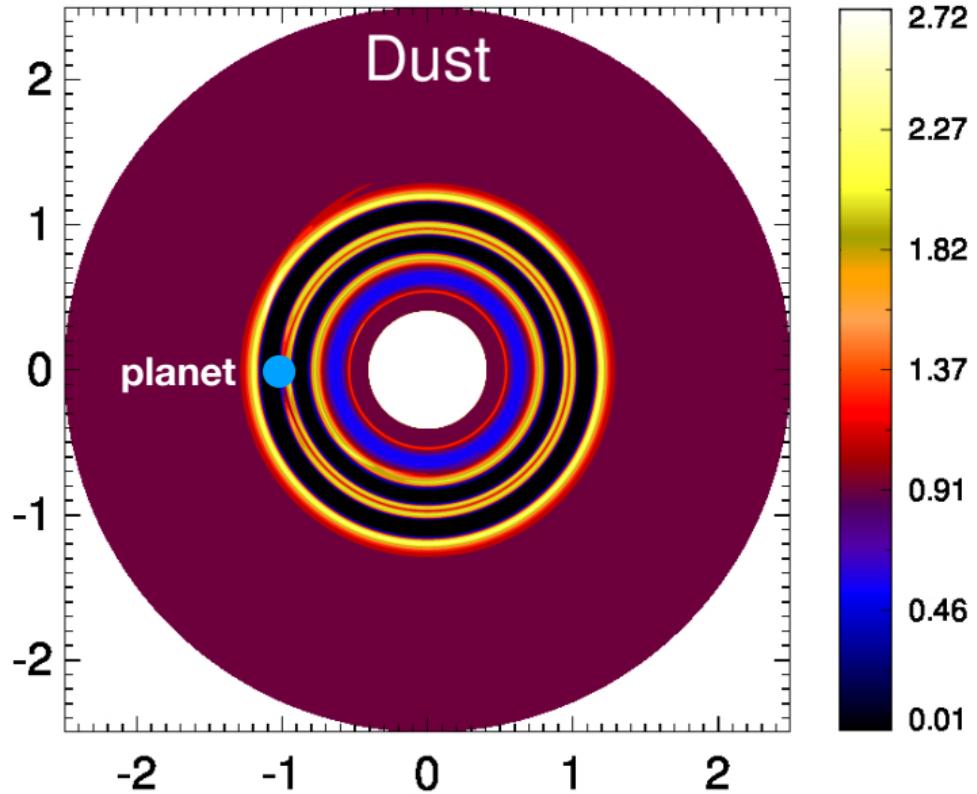
Full two-fluid treatment with FARGO3D



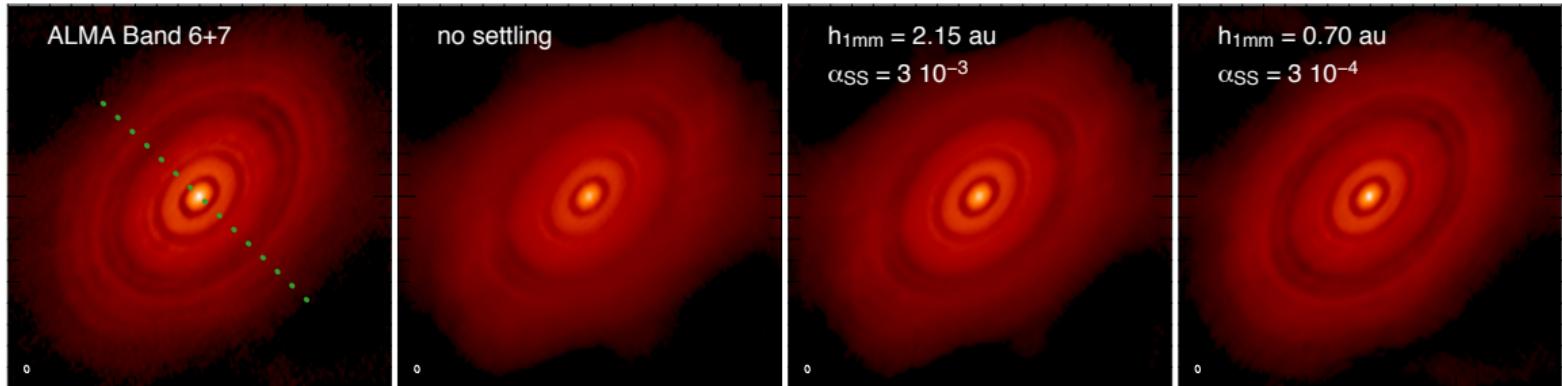
Full two-fluid treatment with FARGO3D



Dusty disk-planet interaction



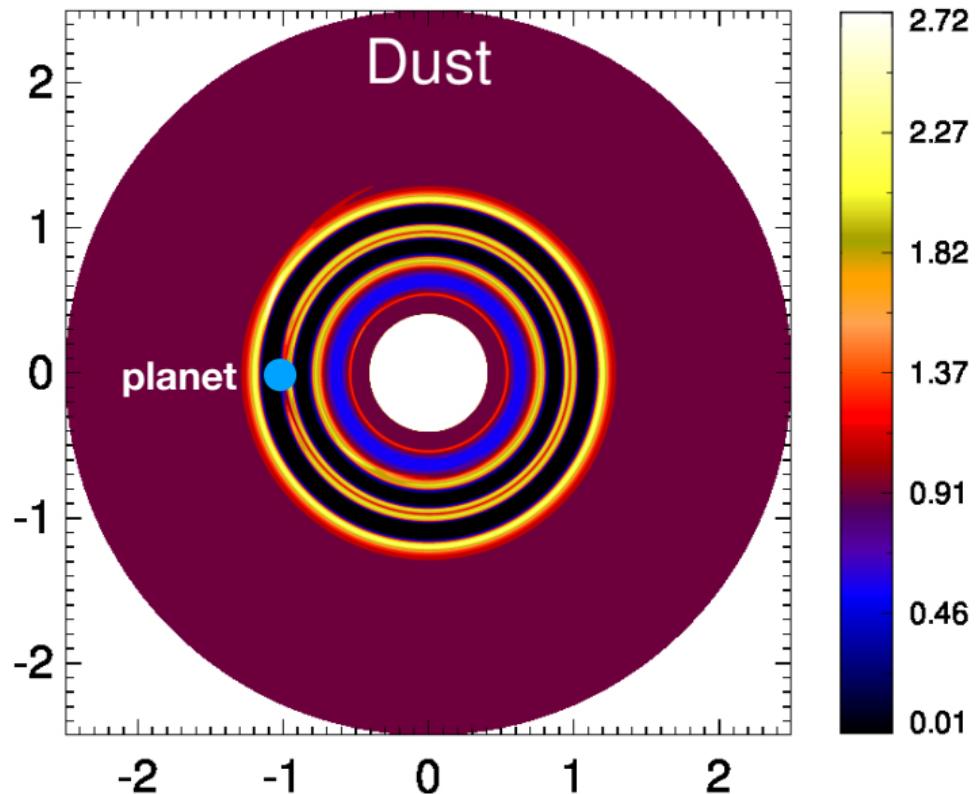
Dusty disk-planet interaction



(Pinte et al. 2016)

- Well-defined rings \Rightarrow settled dust
- Dust settling also implied by polarization observations (S. Ohashi)

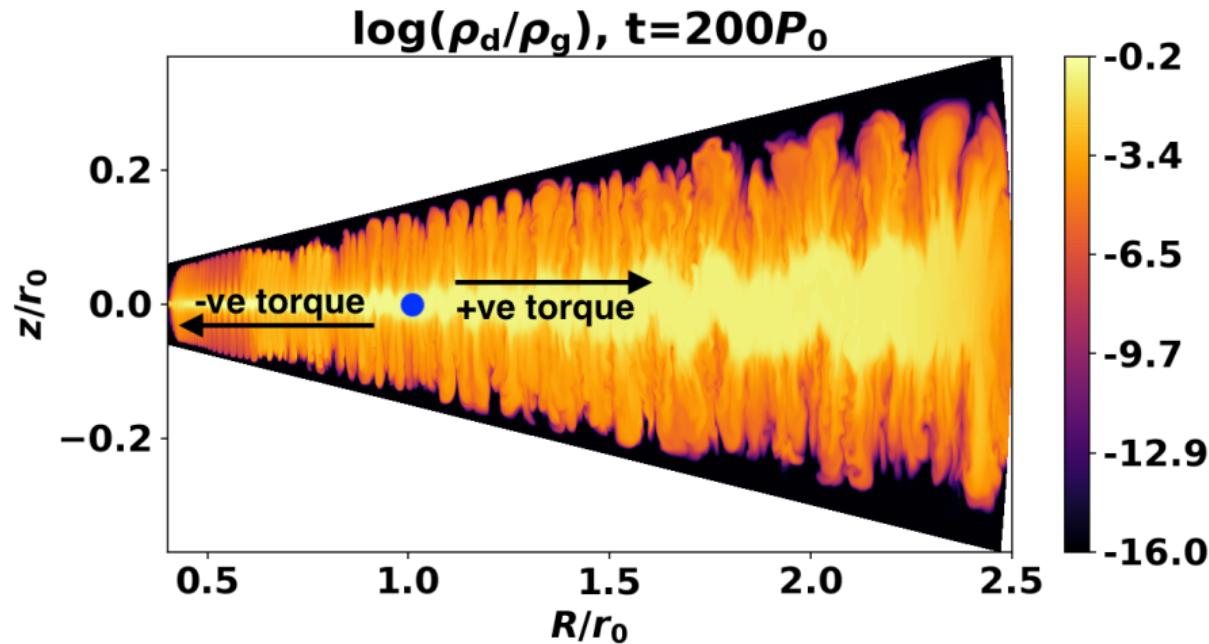
Dusty disk-planet interaction



Is dust settling compatible with gap opening?

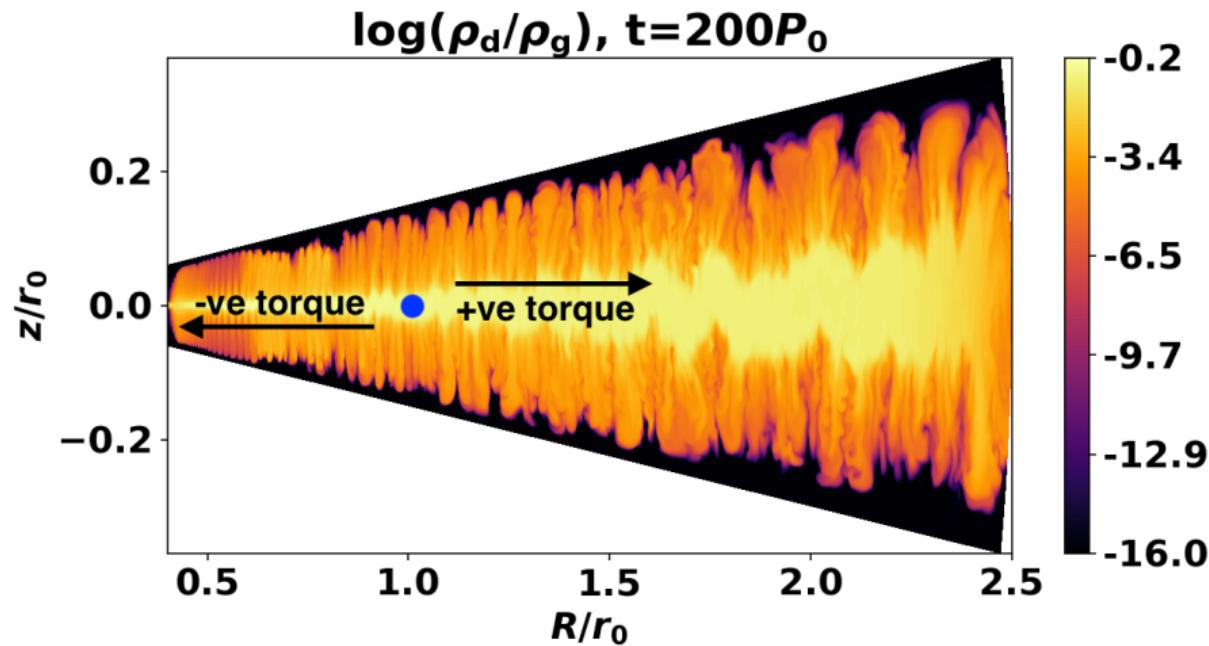
2019 ASIAA Summer Student Program

- Full 3D disk-planet simulations
(Jiaqing Bi & Robin Dong, UVic)



2019 ASIAA Summer Student Program

- Axisymmetric disk-planet simulations
(Simin Tong, Jilin → Leiden)



2019 ASIAA Summer Student Program

(Credit: Simin Tong)

An unsettling result...

Summary

Dust settling depends on solid abundance (Lin, 2019)

Some questions under investigation

- Dust settling v.s. disk-planet interaction
with Jiaqing Bi (UVic), Simin Tong (\rightarrow Leiden)
- Streaming instability v.s. physical disk conditions
with Kan Chen (\rightarrow Cambridge)
- ‘Streaming instability’ in razor-thin disks?
with Sayantan Audy (ASIAA)

Thank you



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