PLANET-INDUCED GAS AND DUST SUBSTRUCTURE FEEDBACKS ON DISK THERMAL STRUCTURE

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EANAM10

Background: gaps/rings affect temperature

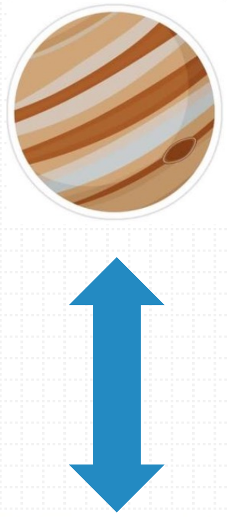
❖ Ariel mission -> exoplanetary atmosphere affected by disk gas composition, C/O ratio

- Disk chemical composition is set by disk temperature

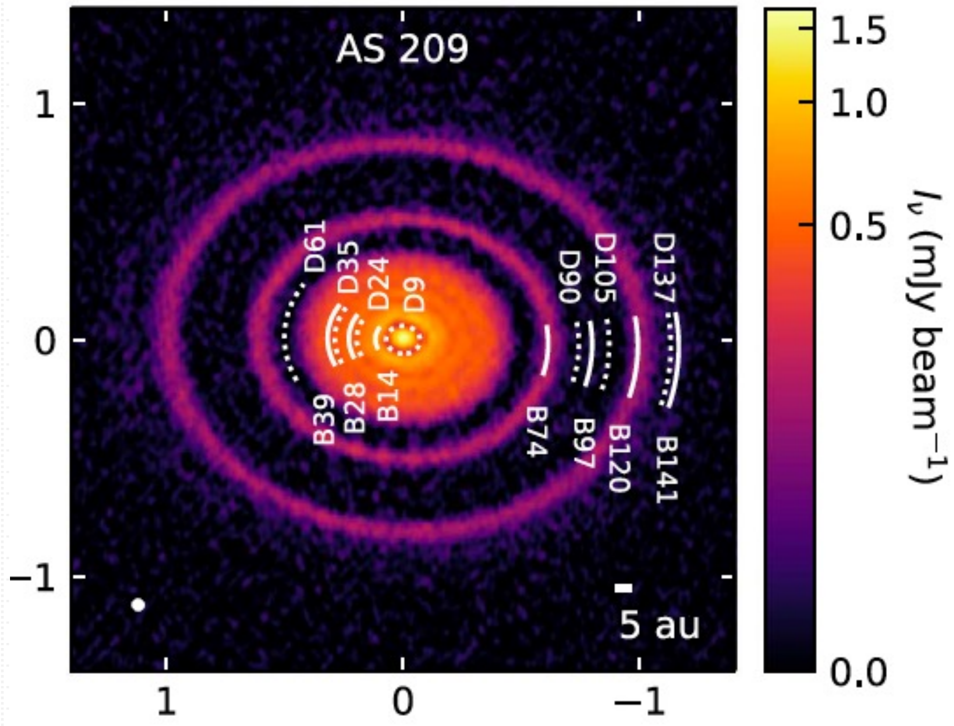
❖ Gaps are observed by ALMA observations

- Gaps suggest young planets

❖ Our goal: How planet gap opening feedback affects disk temperature and further changes icelines, C/O ratio …



Huang+2018



Background: previous work

❖ Previous paper Chen+ 2024

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Planet gap-opening feedback on disc thermal structure and composition

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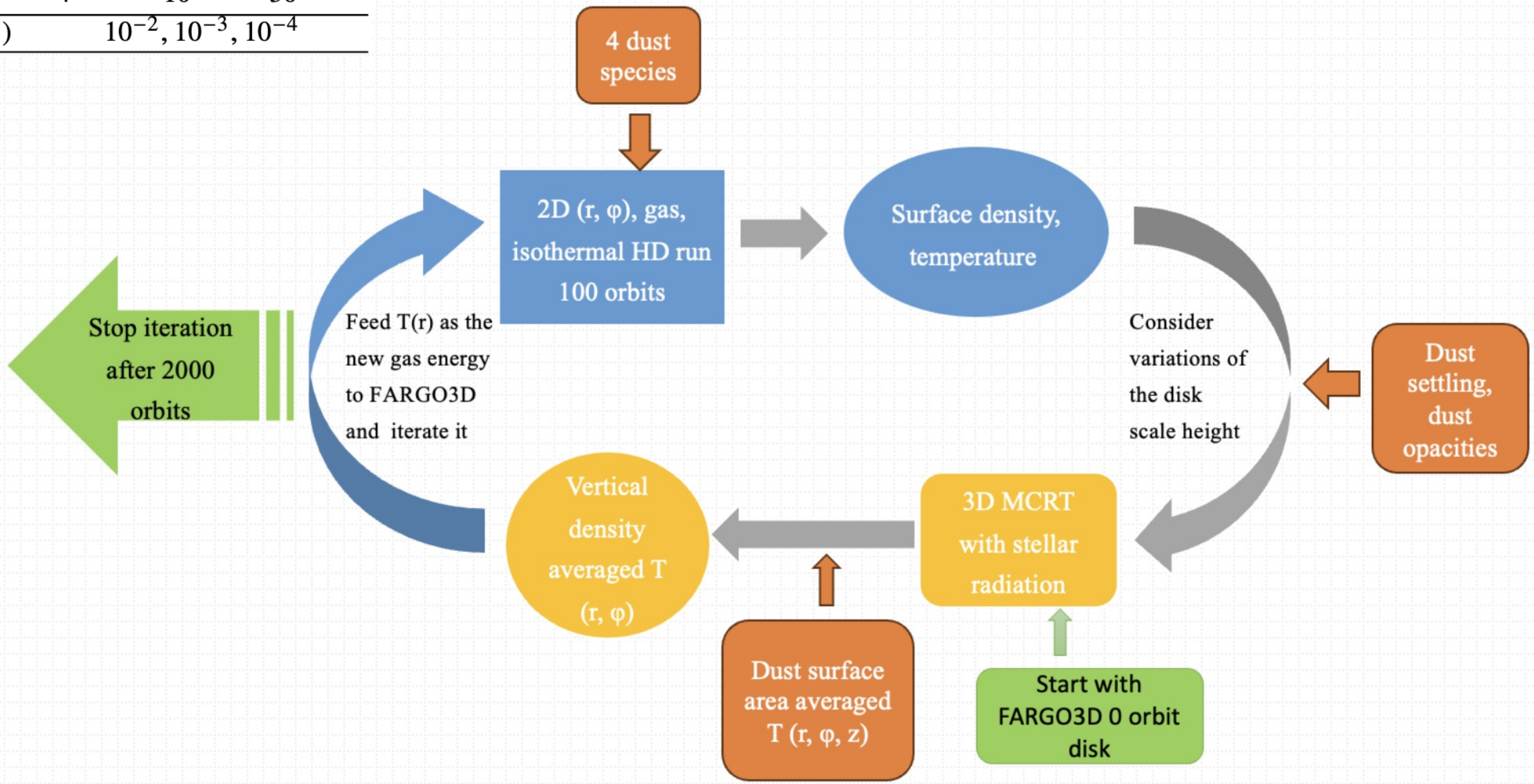
- ❖ Develop a new iterative HD+MCRT modeling
- ❖ Gaps induced by giant planets can significantly alter disk temperature
- ❖ Complicate locations and numbers of ice lines, as well as C/O ratio

- ❖ However, in this paper, we did not include dust though different species of dust distribution, opacity can affect disk temperature strongly. Also, we did not vary alpha viscosities.

Method: iterate HD + MCRT with multiple dusts

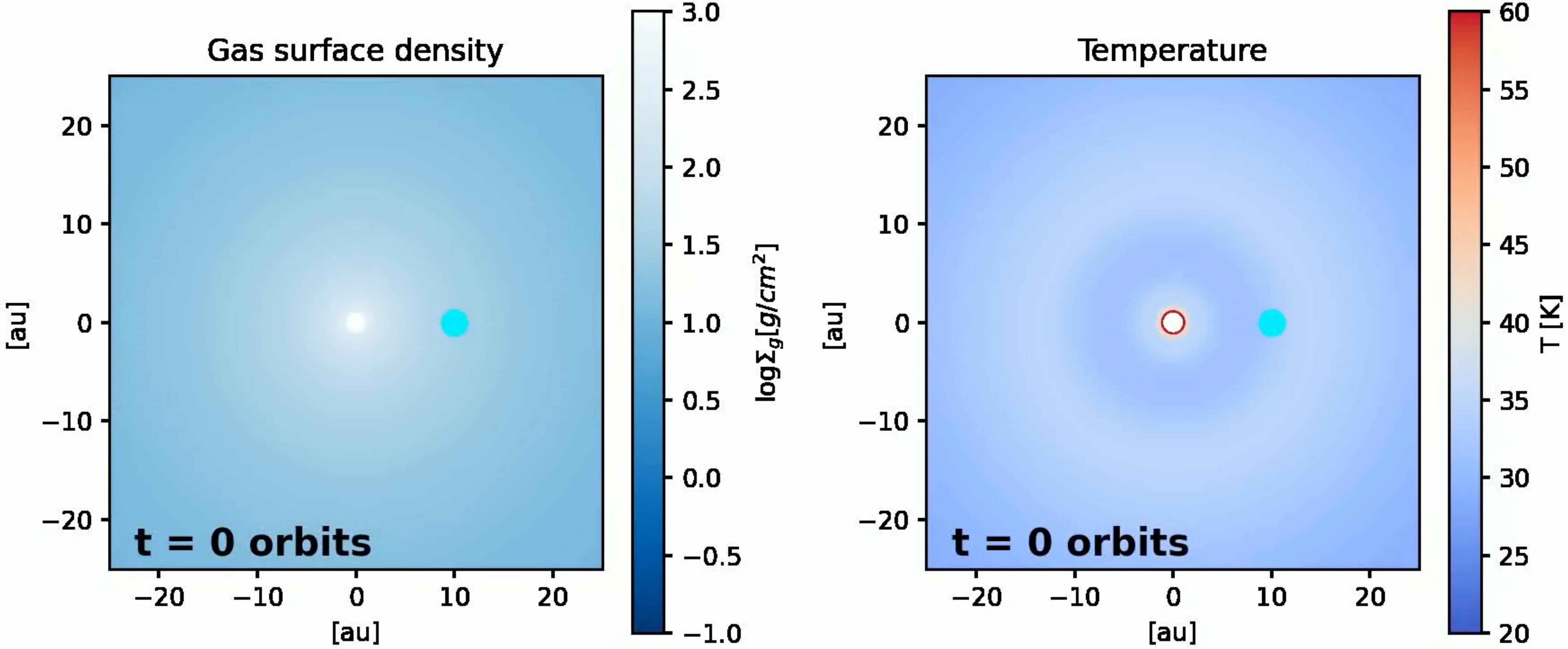
parameters	values		
M_p	$3M_J$, $100M_\oplus$, $10M_\oplus$		
$a_i [\mu m]$	0.1, 2.2, 46, 1000		
$r_0 = r_p$ [au]	4	10	30
α (for $100M_\oplus$)	10^{-2}, 10^{-3}, 10^{-4}		

❖ Codes: FARGO3D (Benítez-Llambay & Masset 2016) and RADMC3D (Dullemond+ 2012)



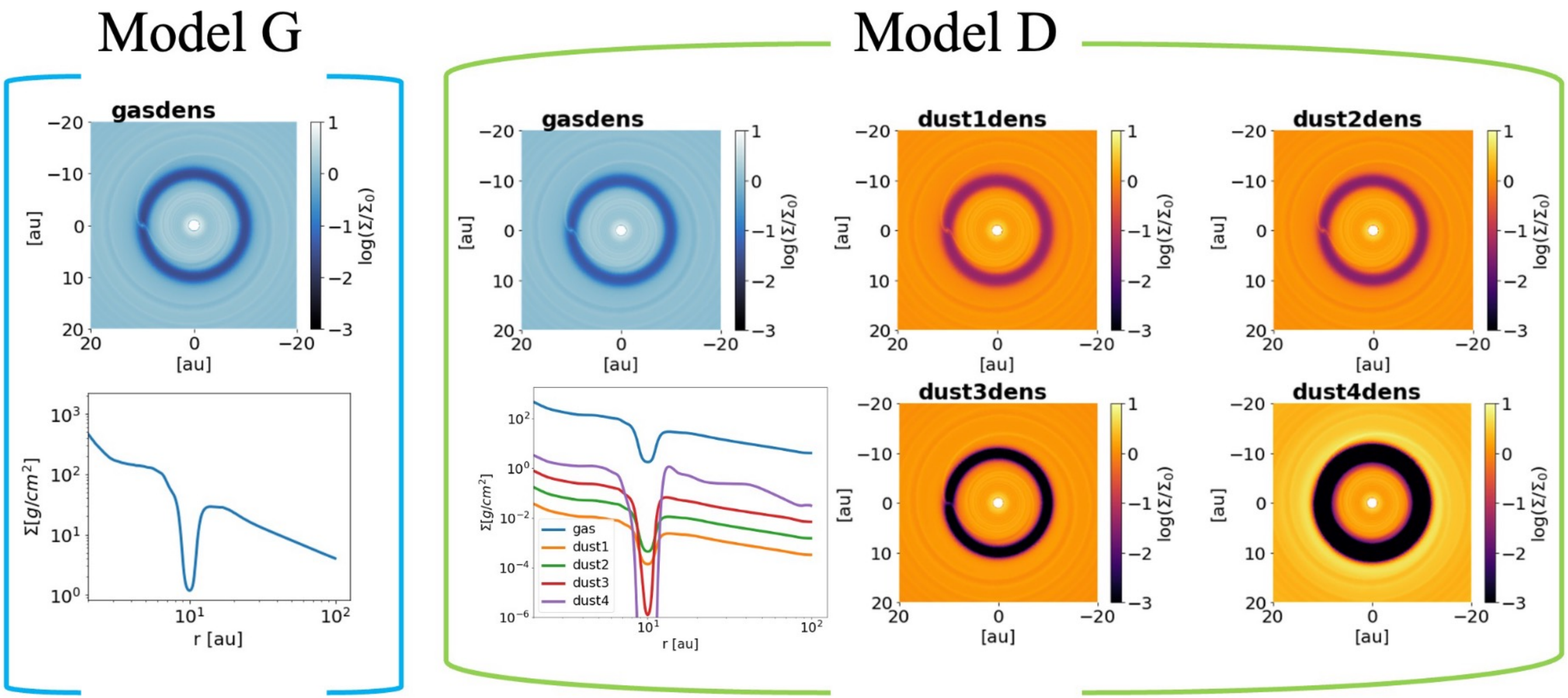
Method: example

❖ Planet and disk interactions



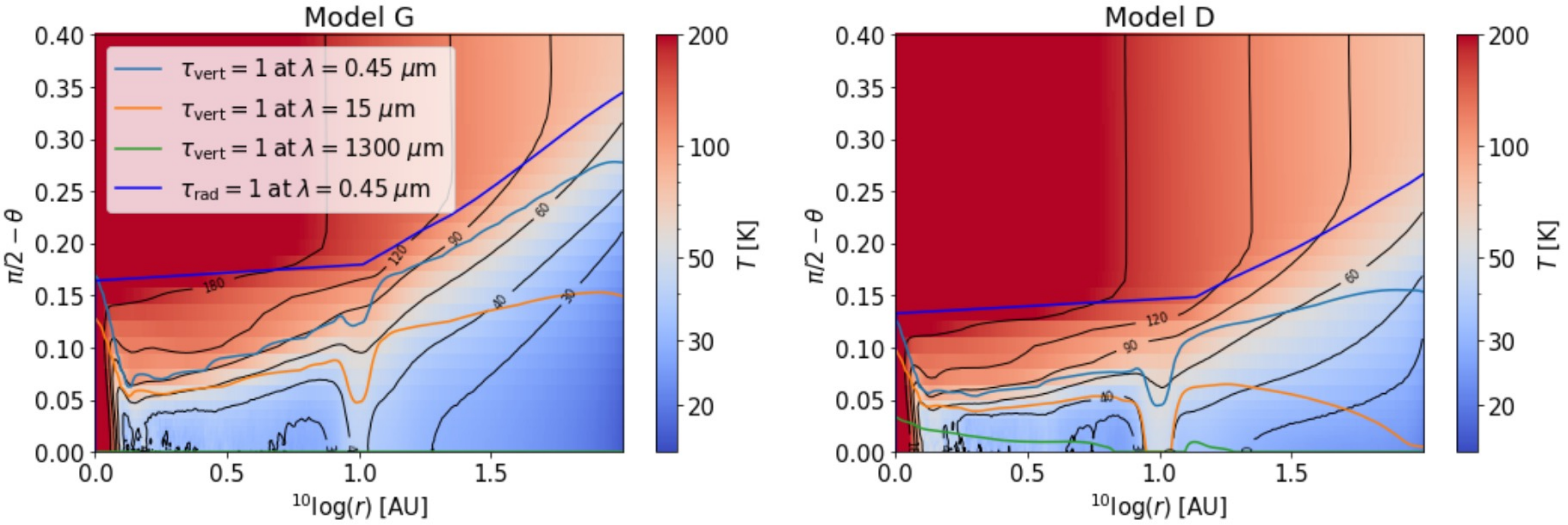
Results: density

- Surface density of $100M_\oplus$ @ 10au over 2000 orbits
- Gaps and rings of gas and four dust species, 0.1 micron ~ 1mm



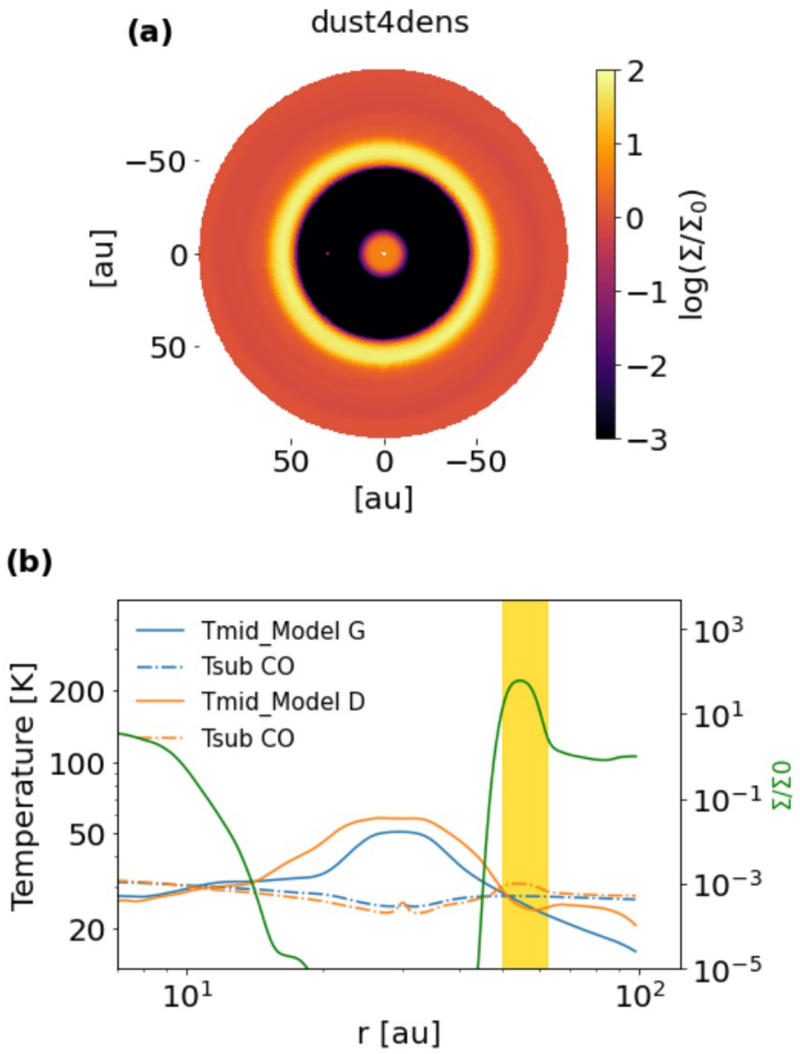
Results: temperature & Tau=1 surfaces

- T at gaps (induced by 100 $M_\oplus$ @ 10au over 2000 orbits) increases by several tens of Kelvin
- Vertical T cut of Model D is hotter in most of the disk regions
- T_{mid} is relatively similar

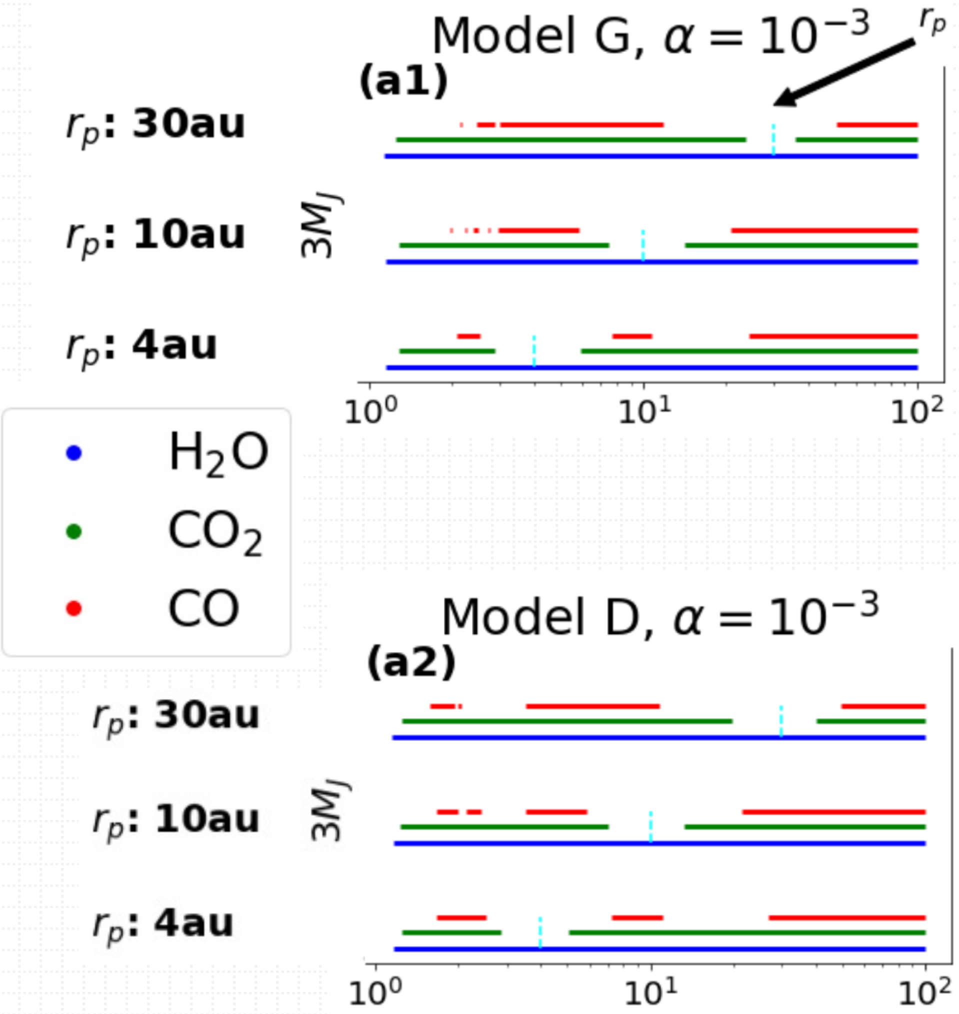


Results: ring temperature and ice distribution

❖ T at the dust ring decreases by a few K

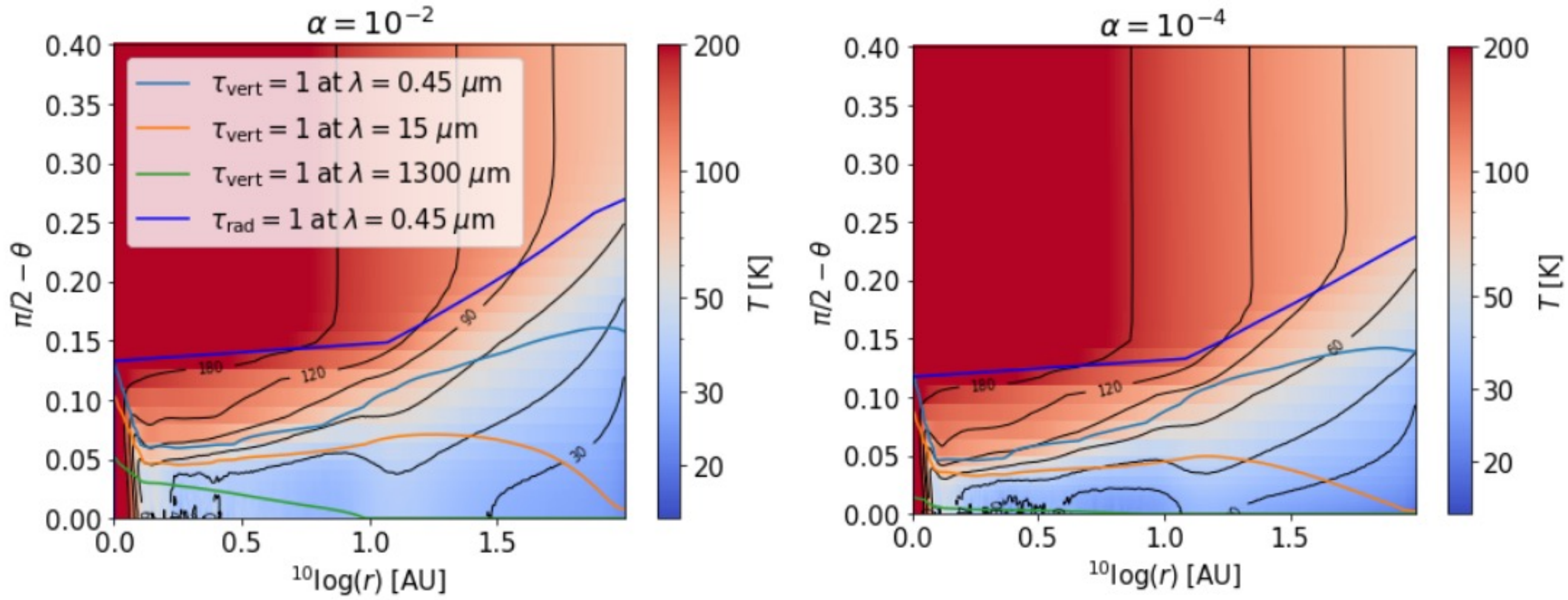


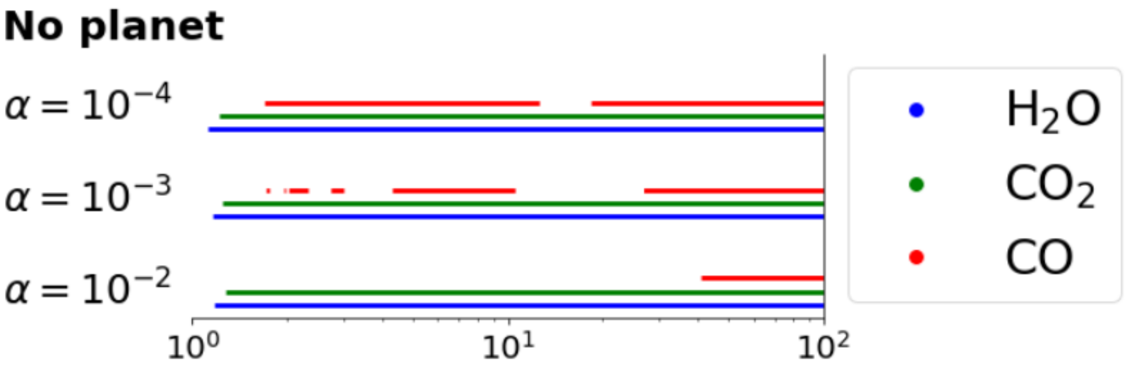
❖ Midplane ice distribution is similar



Results: dust mixing affected by viscosity in a smooth disk

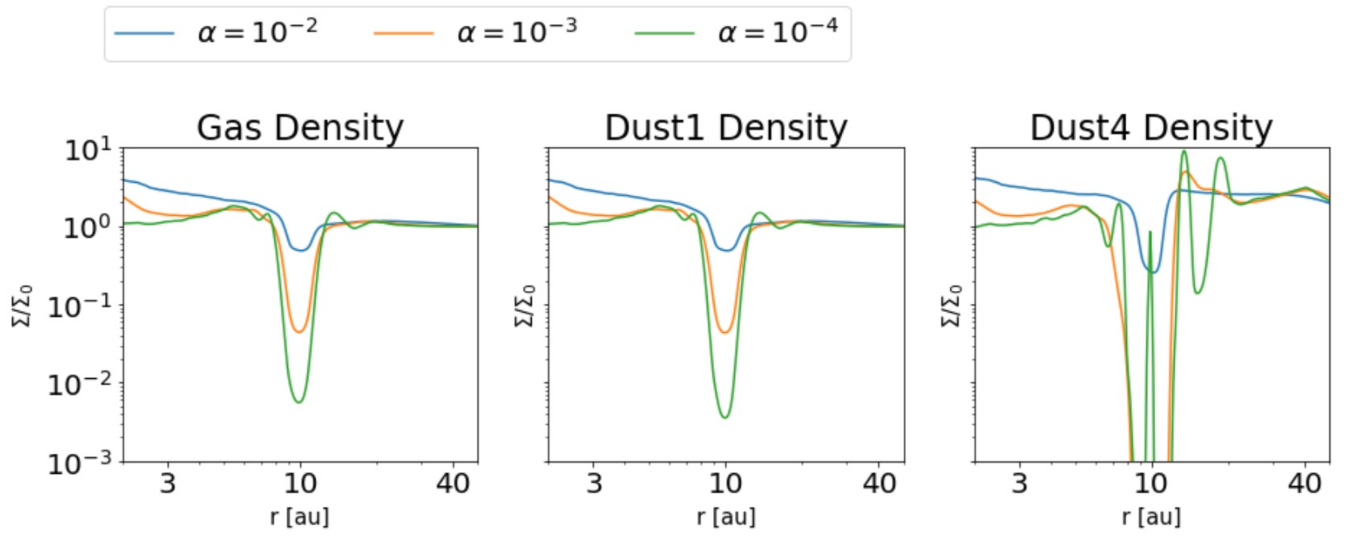
❖ Temperature and ice distribution of a non-planet disk with different viscosities



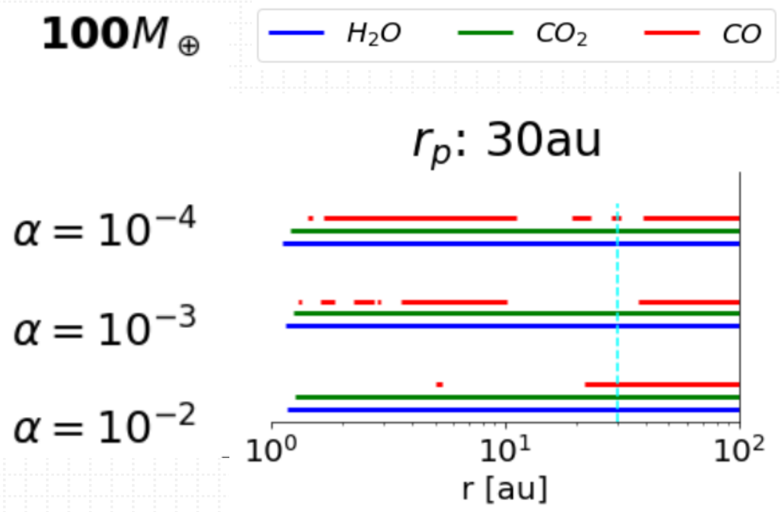


- Higher alpha, higher T_{mid}
- Note that we only include stellar radiation in MCRT, no viscous heating

Results: viscosity affect in a disk with planet gap-opening



- ❖ Surface density profiles in different viscosities
- ❖ Smaller alpha viscosity makes deeper gaps



- ❖ No simple correlation between viscosities and midplane ice line locations for a deep gap opening planet case

Summary

- ❖ We compare our new model, which includes gas and multiple dust components (Model D), with our previous gas-only model (Model G) in terms of disk density and temperature structure.
- ❖ We investigate how different turbulent viscosities affect Model D.

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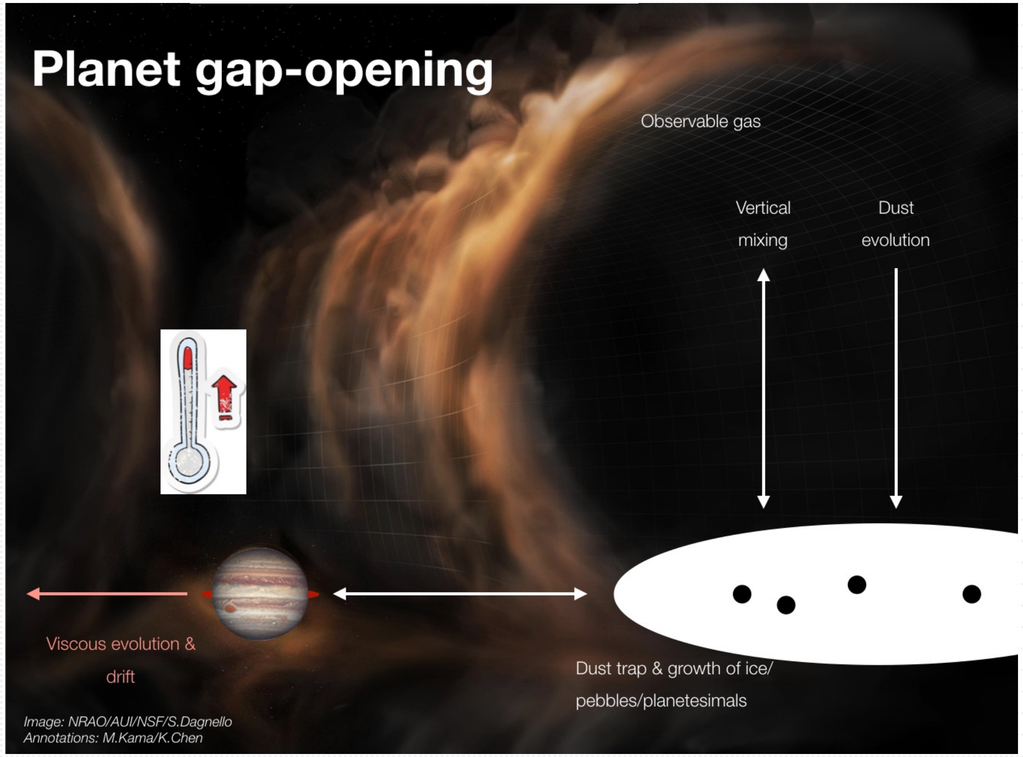
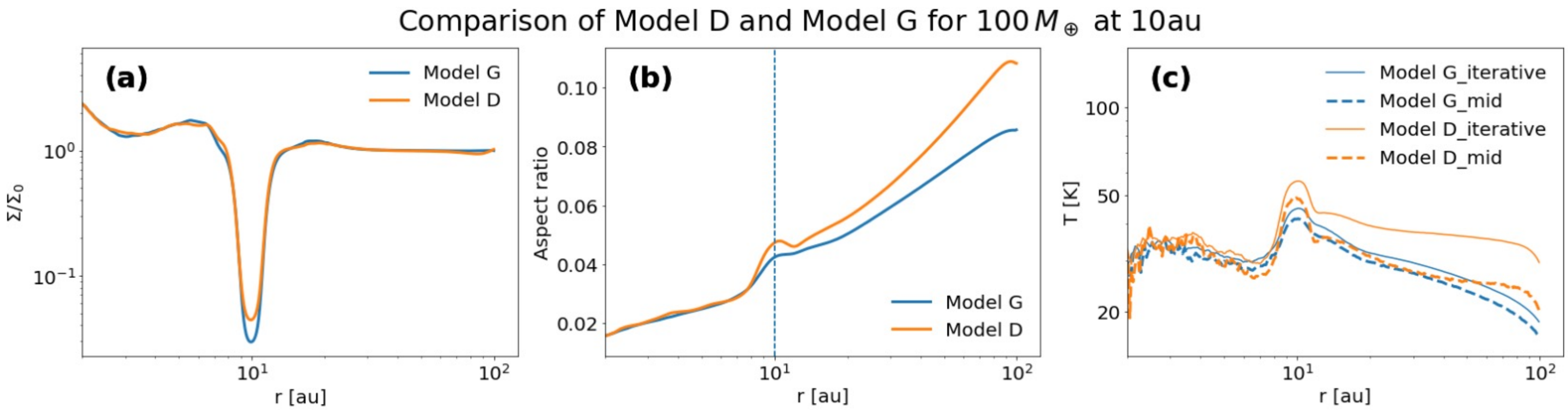
Implications

- ➢ Gas and dust gaps and rings induced by planets can alter disk temperature, especially a deep gap can enhance disk temperature by several tens of Kelvin.
- ➢ The midplane ice distribution is relatively similar between two models.
- ➢ No simple correlation between viscosity and gap temperature.
- ➢ CO ice sublimation due to hot gap may be detectable in intensity map with ALMA.



Back up


Comparison of Model D and Model G for 100 $M_\oplus$ at 10au
(a)
Model G
Model D
Σ/Σ_0
10^0
10^{-1}
10^1
10^2
r [au]
(b)
Aspect ratio
0.10
0.08
0.06
0.04
0.02
Model G
Model D
10^1
10^2
r [au]
(c)
Model G_iterative
Model G_mid
Model D_iterative
Model D_mid
T [K]
100
50
20
10^1
10^2
r [au]

Back up

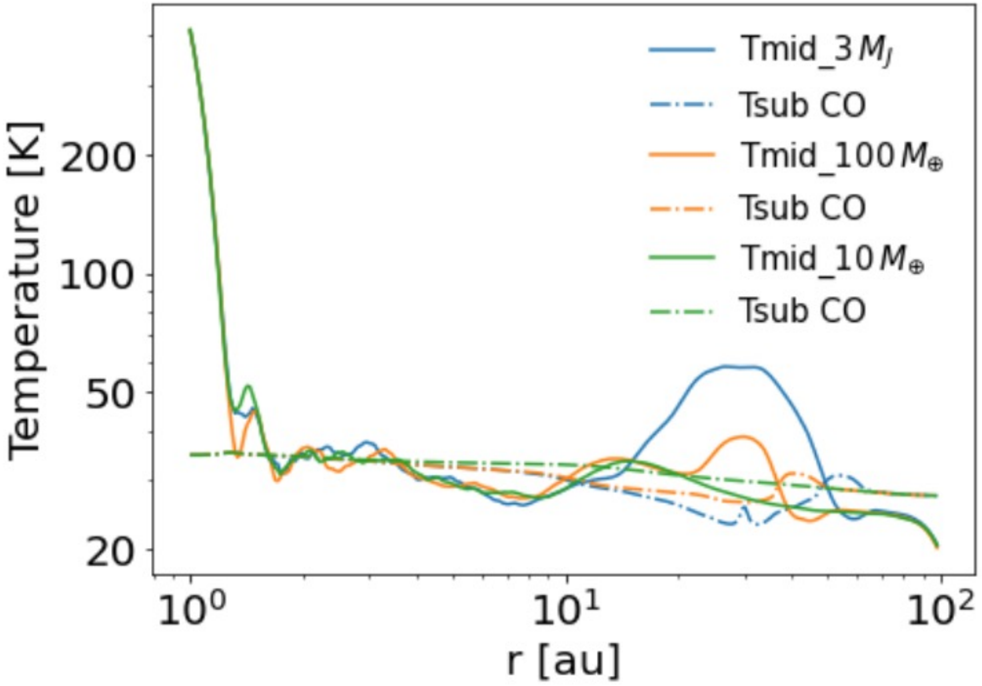
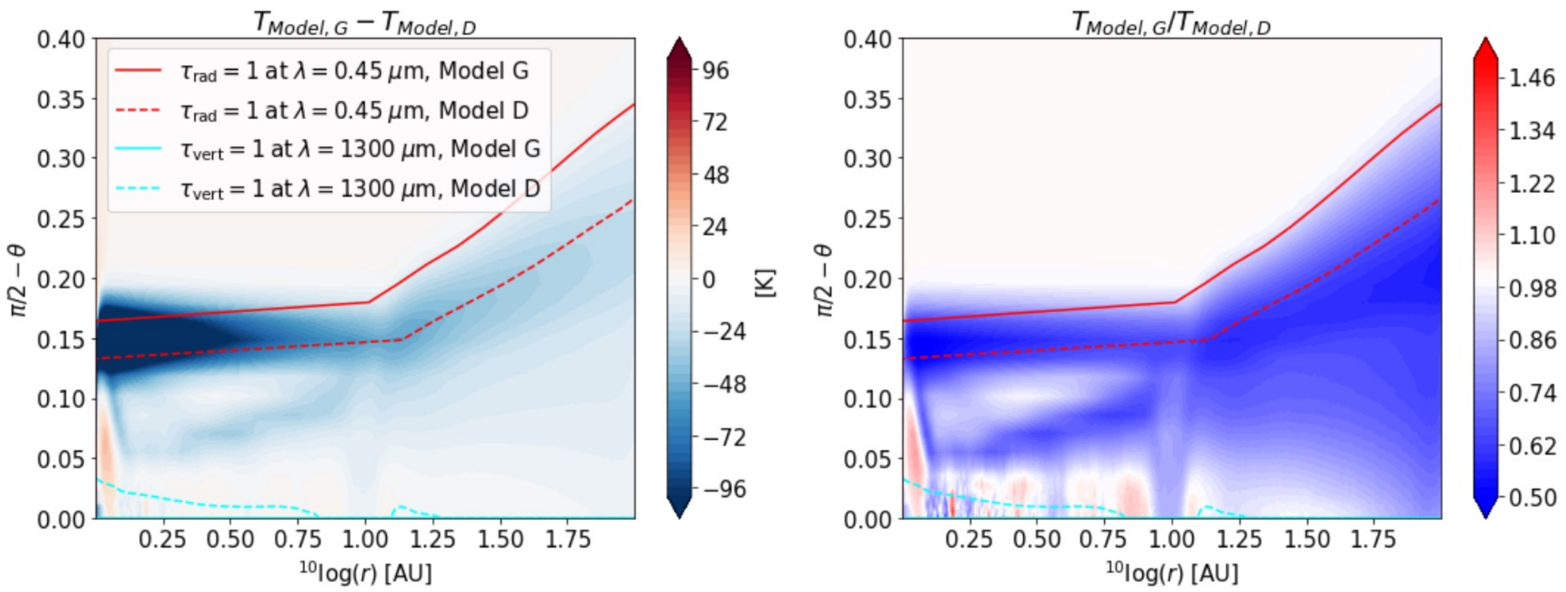


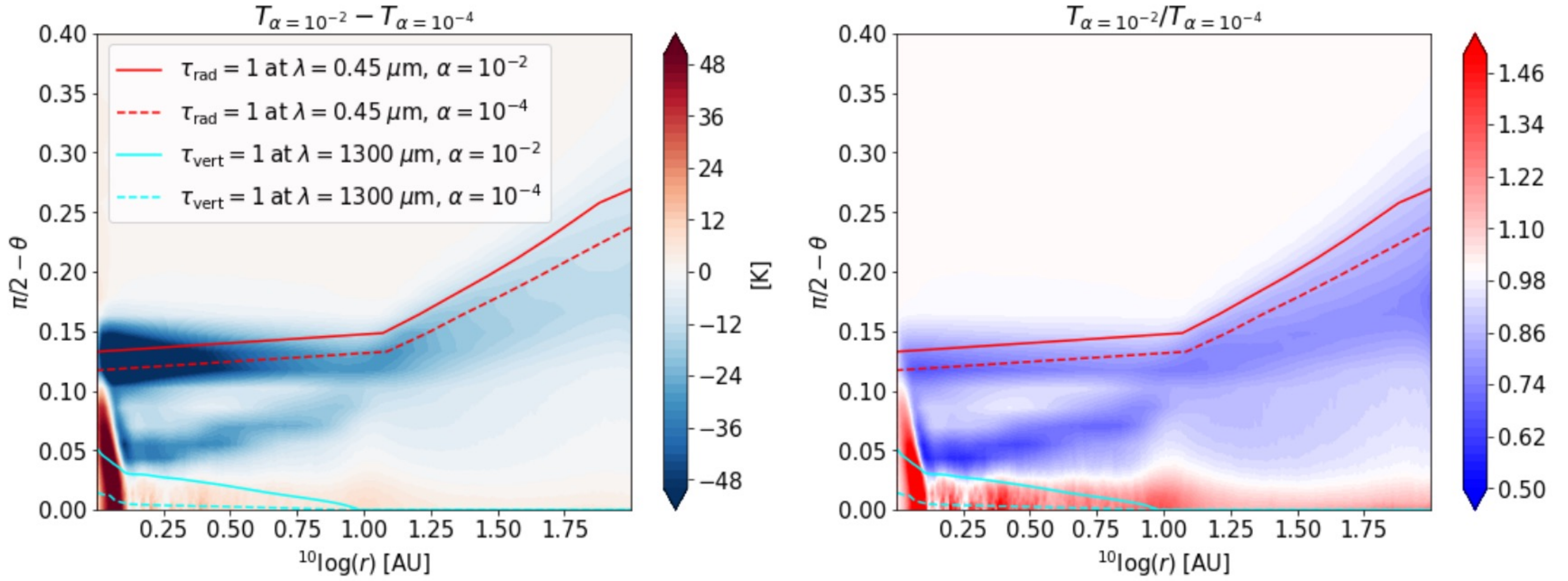
Figure 6. Miplane (solid) and sublimation (dashed) temperature profiles of differemt M_p at r_p = 30 au of Model D

Back up



$T_{Model,G} - T_{Model,D}$
$\tau_{rad} = 1$ at $\lambda = 0.45\ \mu m$, Model G
$\tau_{rad} = 1$ at $\lambda = 0.45\ \mu m$, Model D
$\tau_{vert} = 1$ at $\lambda = 1300\ \mu m$, Model G
$\tau_{vert} = 1$ at $\lambda = 1300\ \mu m$, Model D
$\pi/2 - \theta$
$^{10}\log(r)$ [AU]
[K]
96
72
48
24
0
−24
−48
−72
−96
$T_{Model,G}/T_{Model,D}$
1.46
1.34
1.22
1.10
0.98
0.86
0.74
0.62
0.50

Back up



$T_{\alpha=10^{-2}} - T_{\alpha=10^{-4}}$
$\tau_{rad} = 1$ at $\lambda = 0.45\ \mu m$, $\alpha = 10^{-2}$
$\tau_{rad} = 1$ at $\lambda = 0.45\ \mu m$, $\alpha = 10^{-4}$
$\tau_{vert} = 1$ at $\lambda = 1300\ \mu m$, $\alpha = 10^{-2}$
$\tau_{vert} = 1$ at $\lambda = 1300\ \mu m$, $\alpha = 10^{-4}$
$\pi/2 - \theta$
$^{10}\log(r)$ [AU]
[K]
$T_{\alpha=10^{-2}}/T_{\alpha=10^{-4}}$
$\pi/2 - \theta$
$^{10}\log(r)$ [AU]

Back up