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Inner Disk Chemistry and the Effects of Drifting Icy Grains: The Case of CO₂

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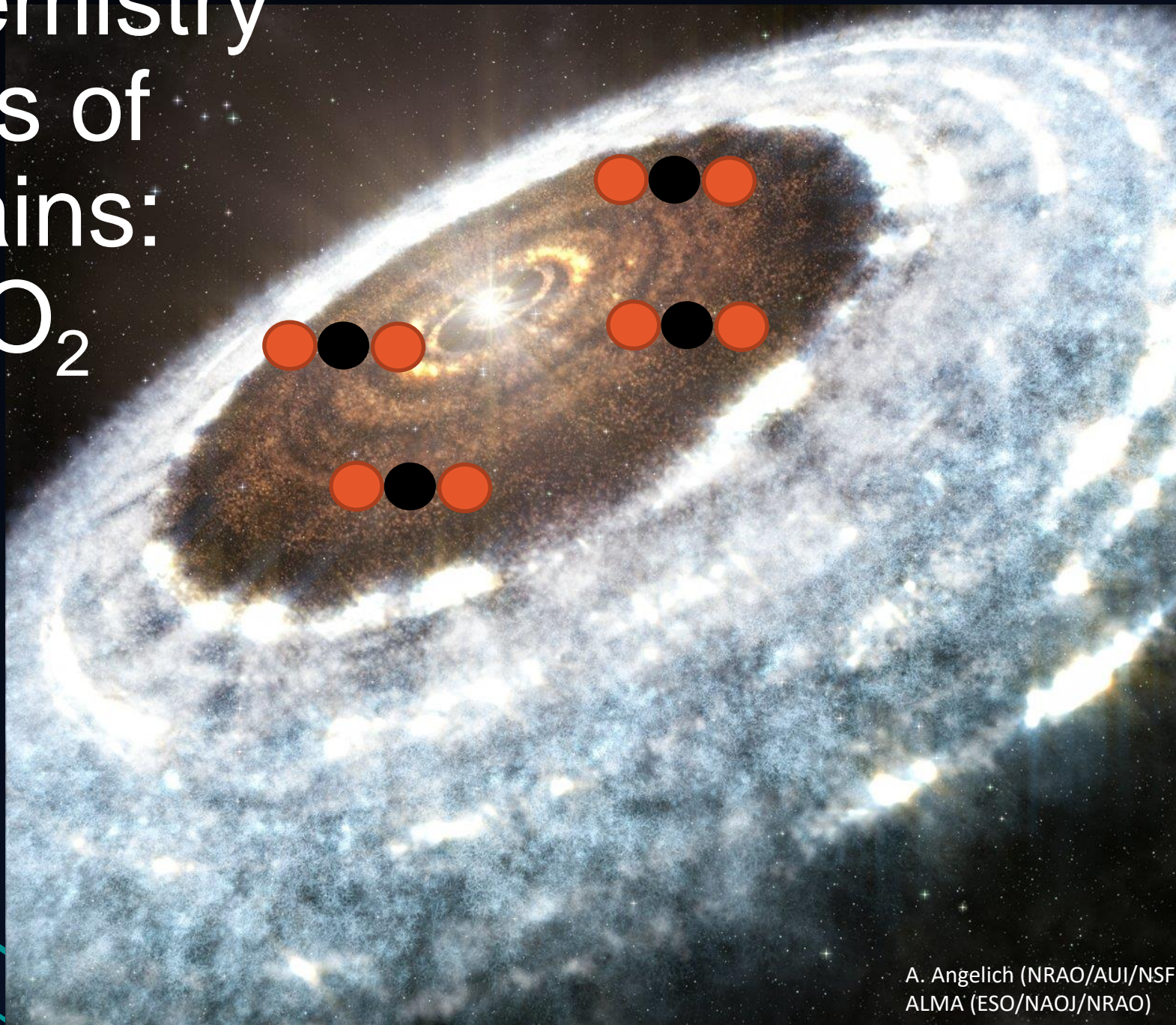
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Inner disk chemistry and the effects of drifting icy grains: the case of CO₂

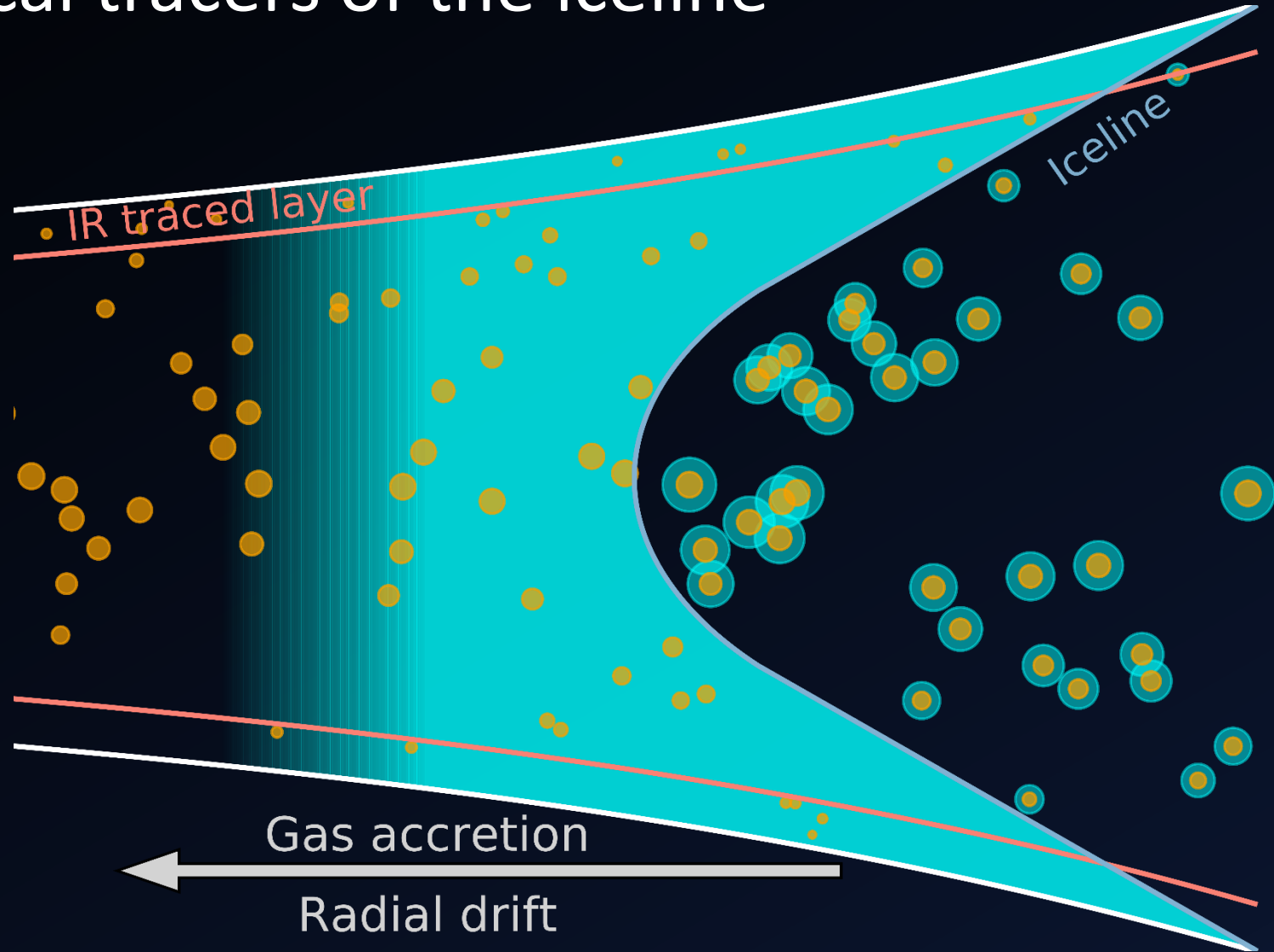
Arthur Bosman
PhD candidate
Leiden University
Bosman+ 2018 A&A, 611, 80



Radial transport of disk material

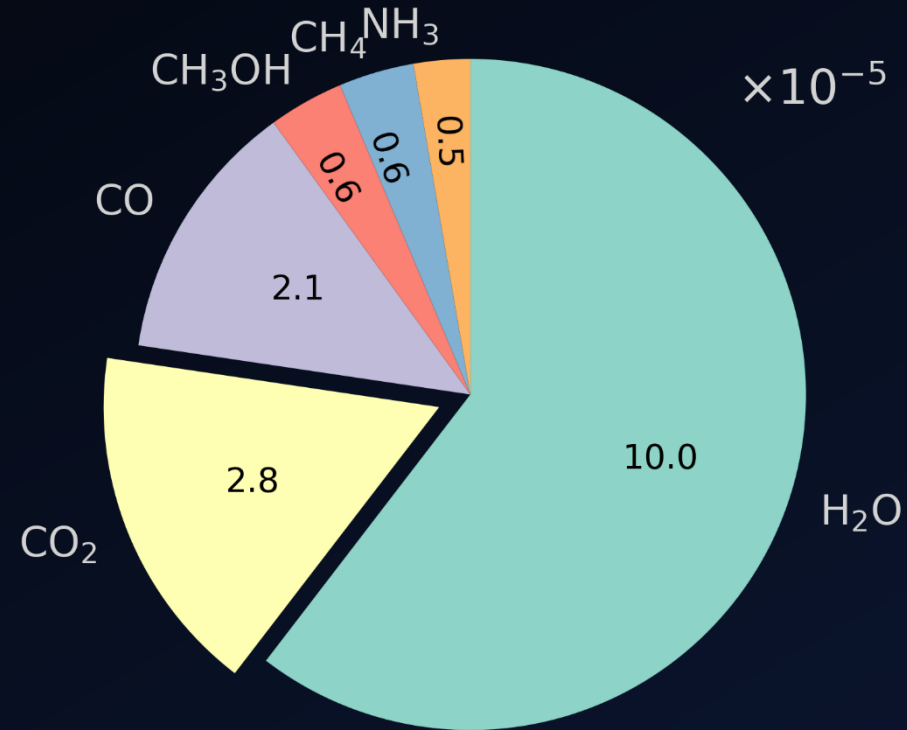
- Gas accretion transports gas and small dust inwards
 - Assumed here to happen along the midplane
- Radial drift of large grains
 - Fast transport, but how fast?
 - Through the disk midplane
 - Can assist in quickly building planets
- We need a tracer for midplane transport of material

Chemical tracers of the iceline



Abundant outer disk ices

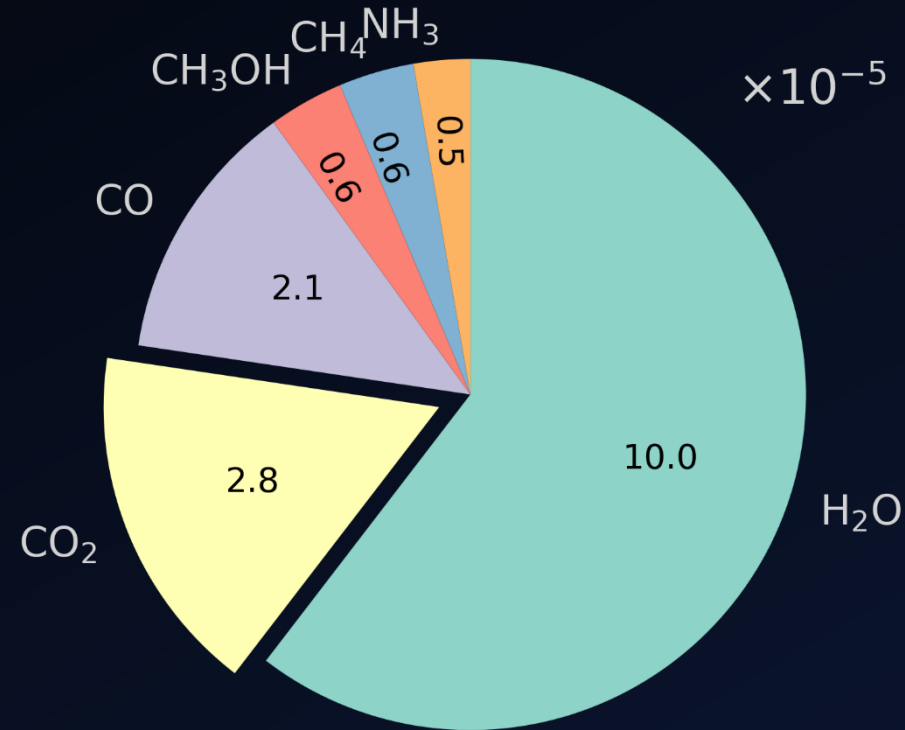
- H₂O and CO are abundant in the inner disk
 - small contrast



Outer disk ice
(Boogert+ 2015)

Abundant outer disk ices

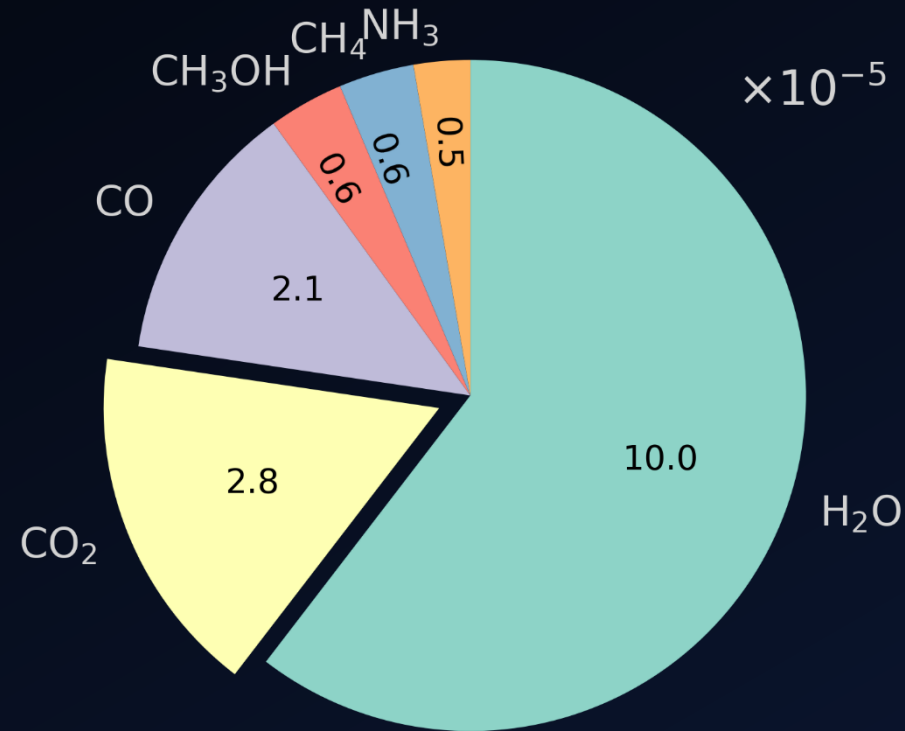
- H₂O and CO are abundant in the inner disk
 - small contrast
- CO₂ low abundance in the inner disk (<10⁻⁷)
 - More than two orders of contrast



Outer disk ice
(Boogert+ 2015)

Abundant outer disk ices

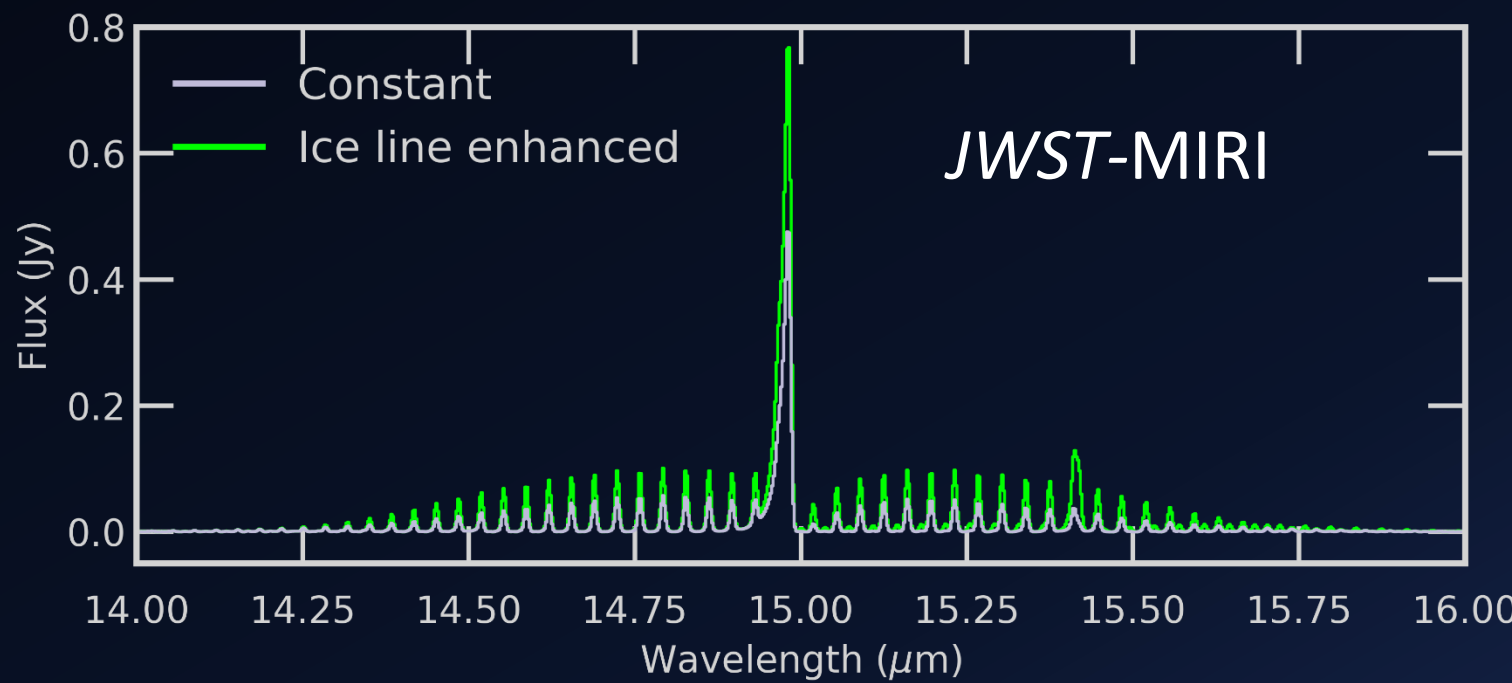
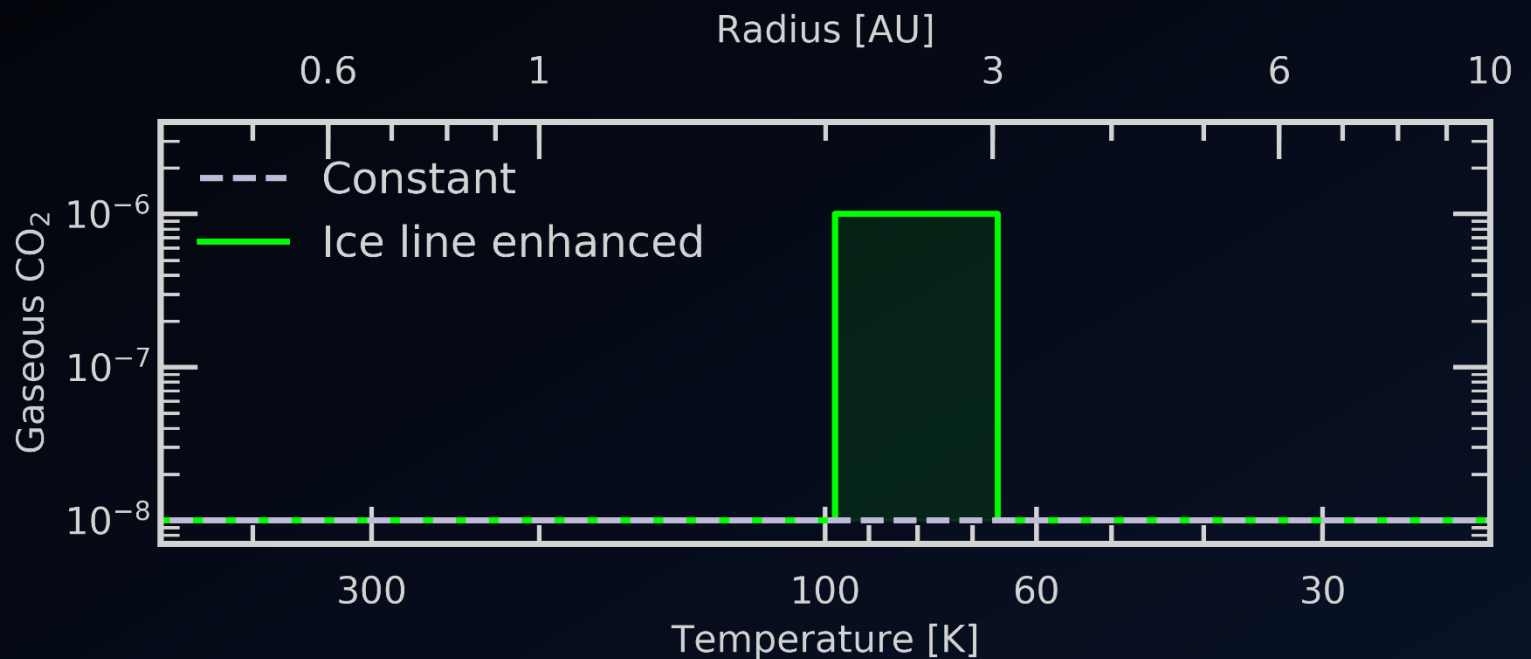
- H₂O and CO are abundant in the inner disk
 - small contrast
- CO₂ low abundance in the inner disk (<10⁻⁷)
 - More than two orders of contrast
- CH₃OH, CH₄ and NH₃ have no abundance estimate within their iceline
 - Future possibilities



Outer disk ice
(Boogert+ 2015)

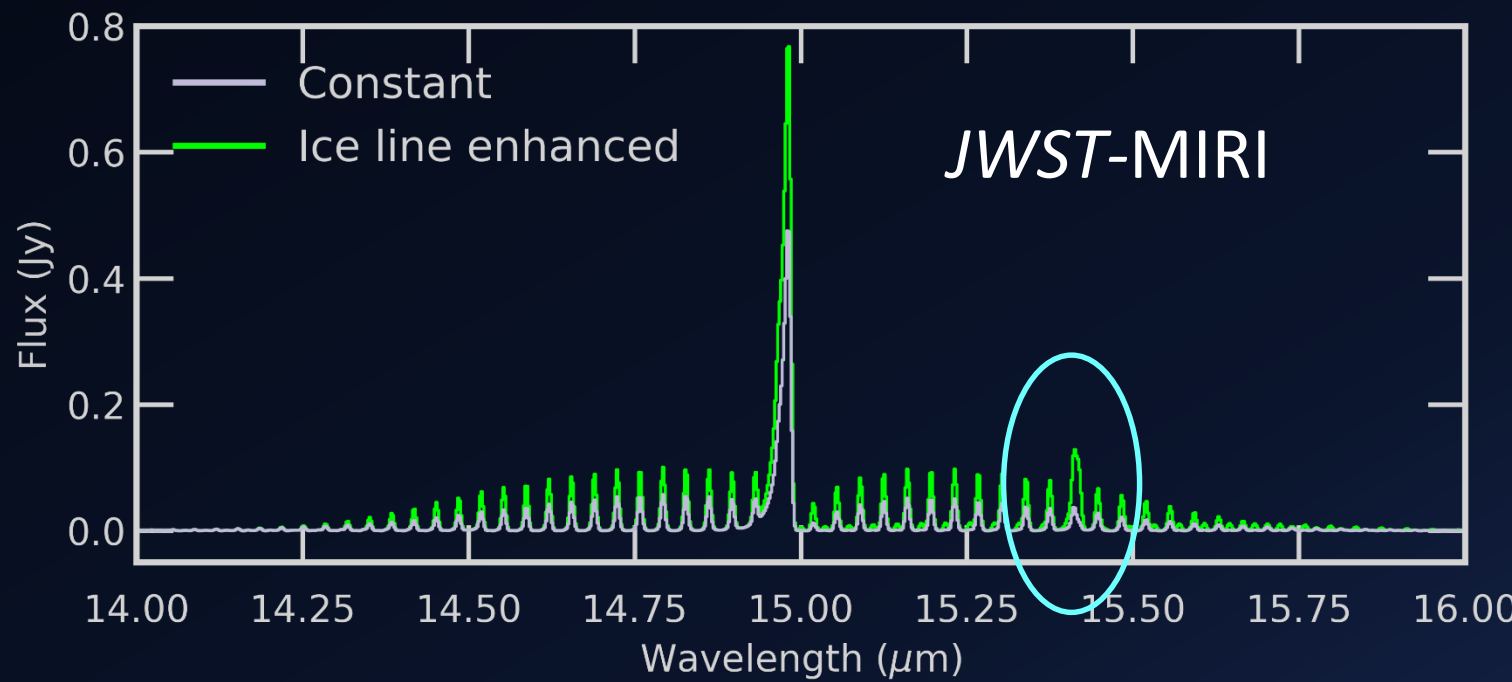
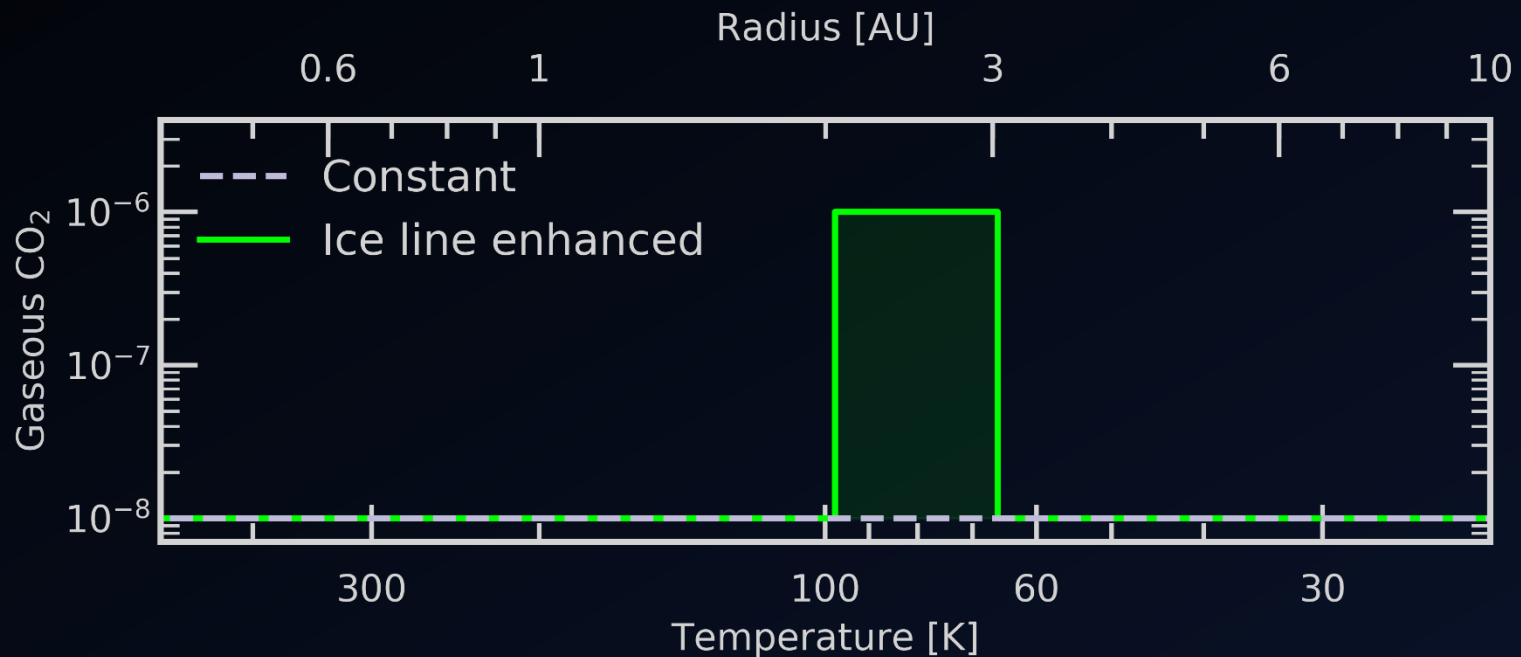
Toy model has
signature
observable
with *JWST*

Bosman et al. 2017



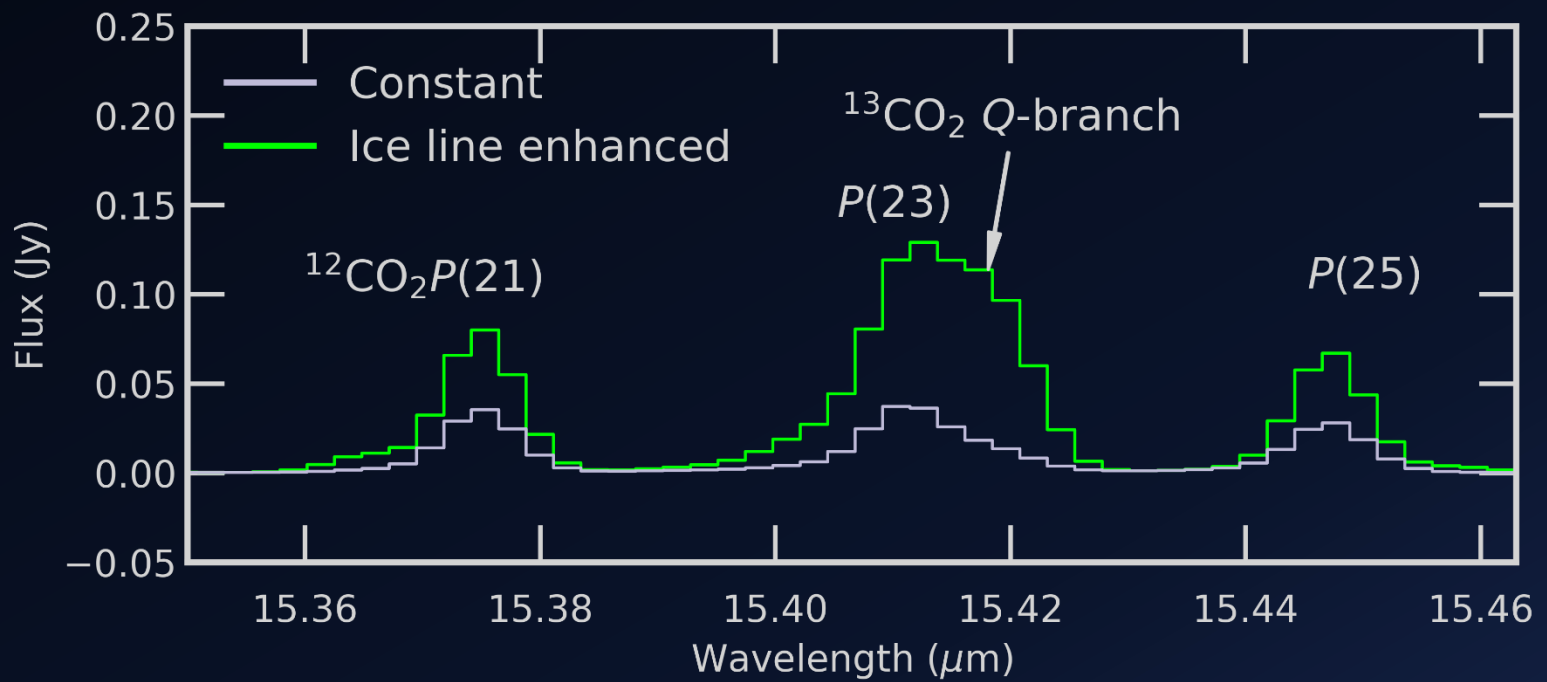
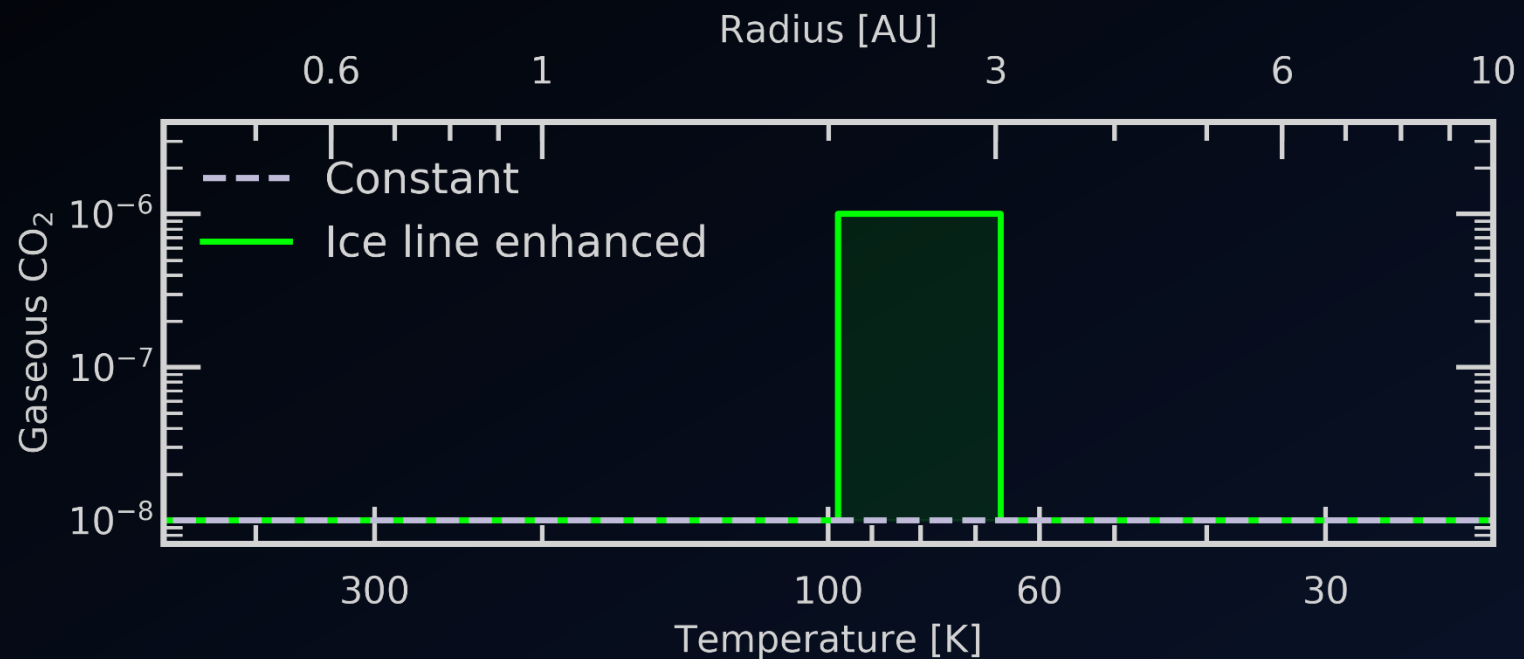
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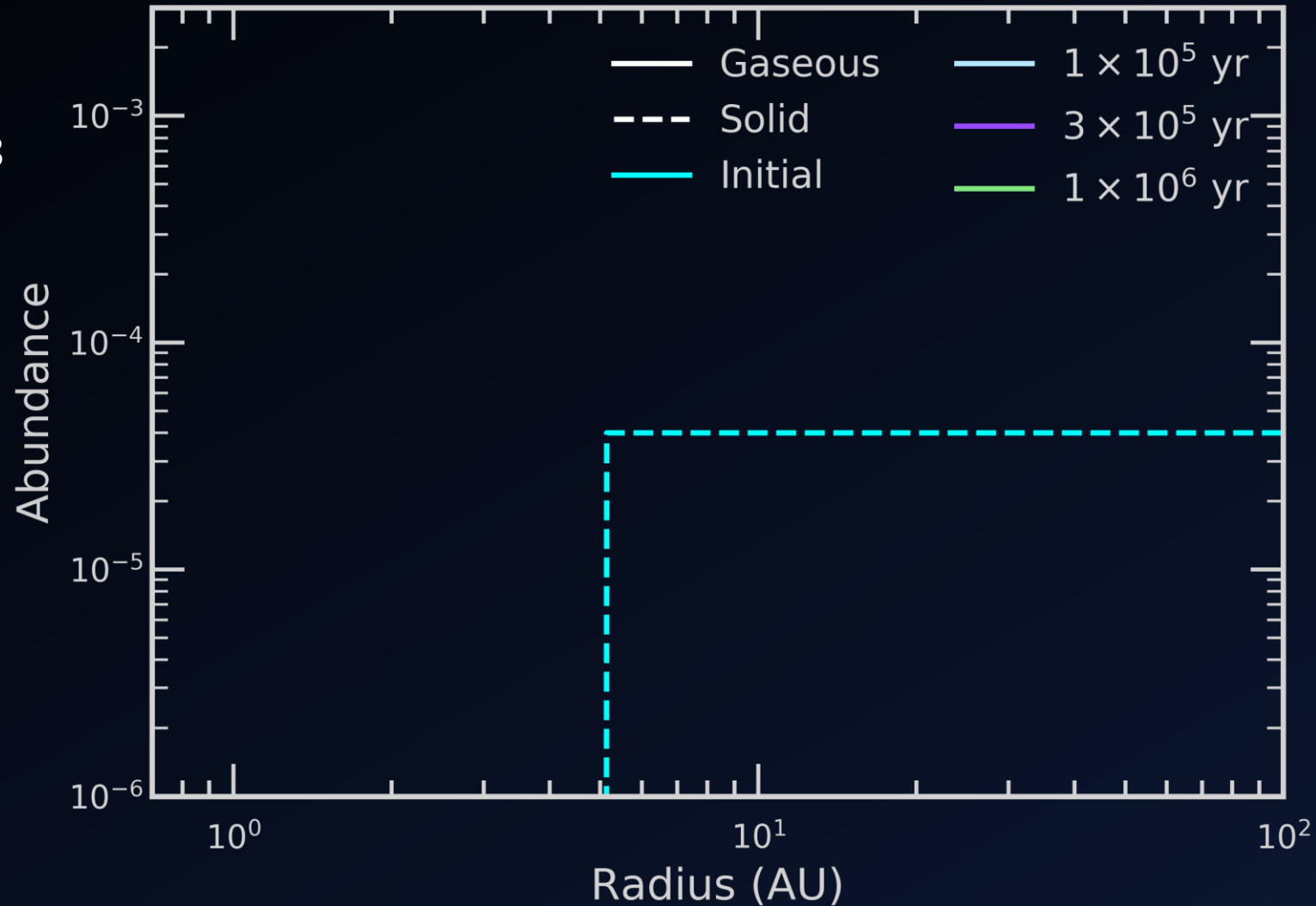


Modelling approach

- 1D viscous disk model
- Two population dust model (Birnstiel et al. 2012)
 - Grain growth
 - Fragmentation
 - Radial drift
- Two contaminant model
 - Diffusion and advection due to viscous accretion
 - CO₂
 - H₂O

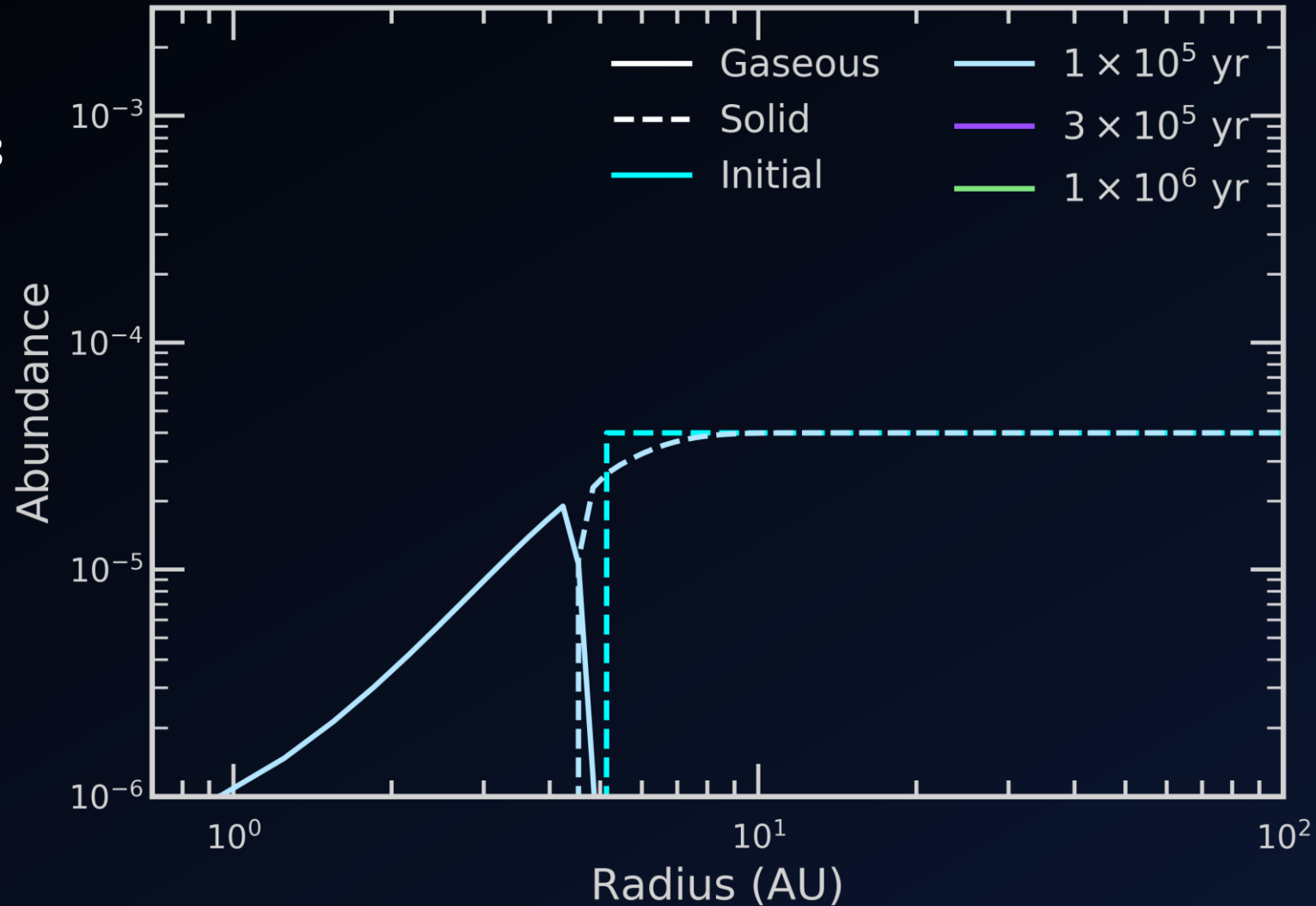
Results – without radial drift of pebbles

$$\alpha = 10^{-3}$$



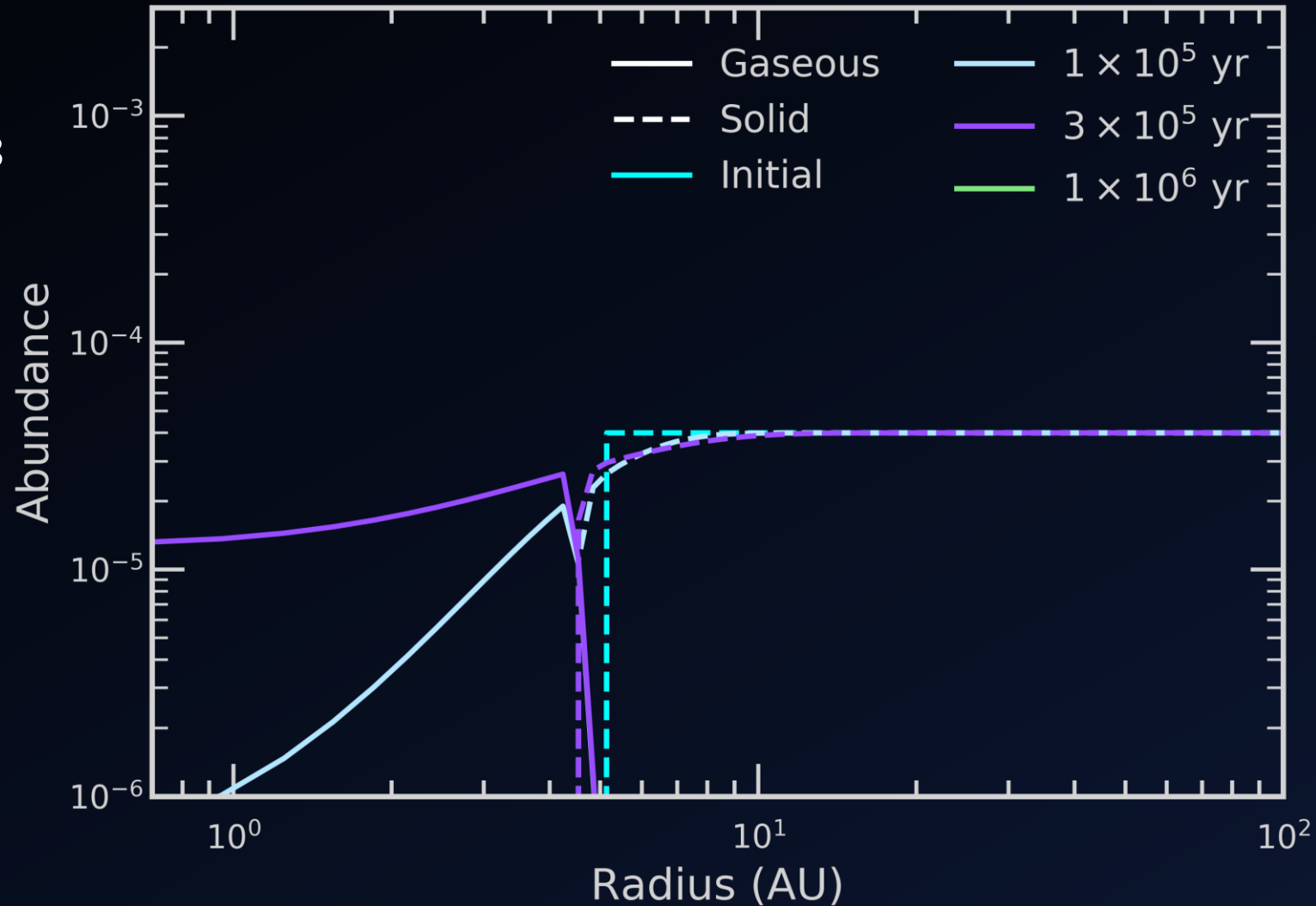
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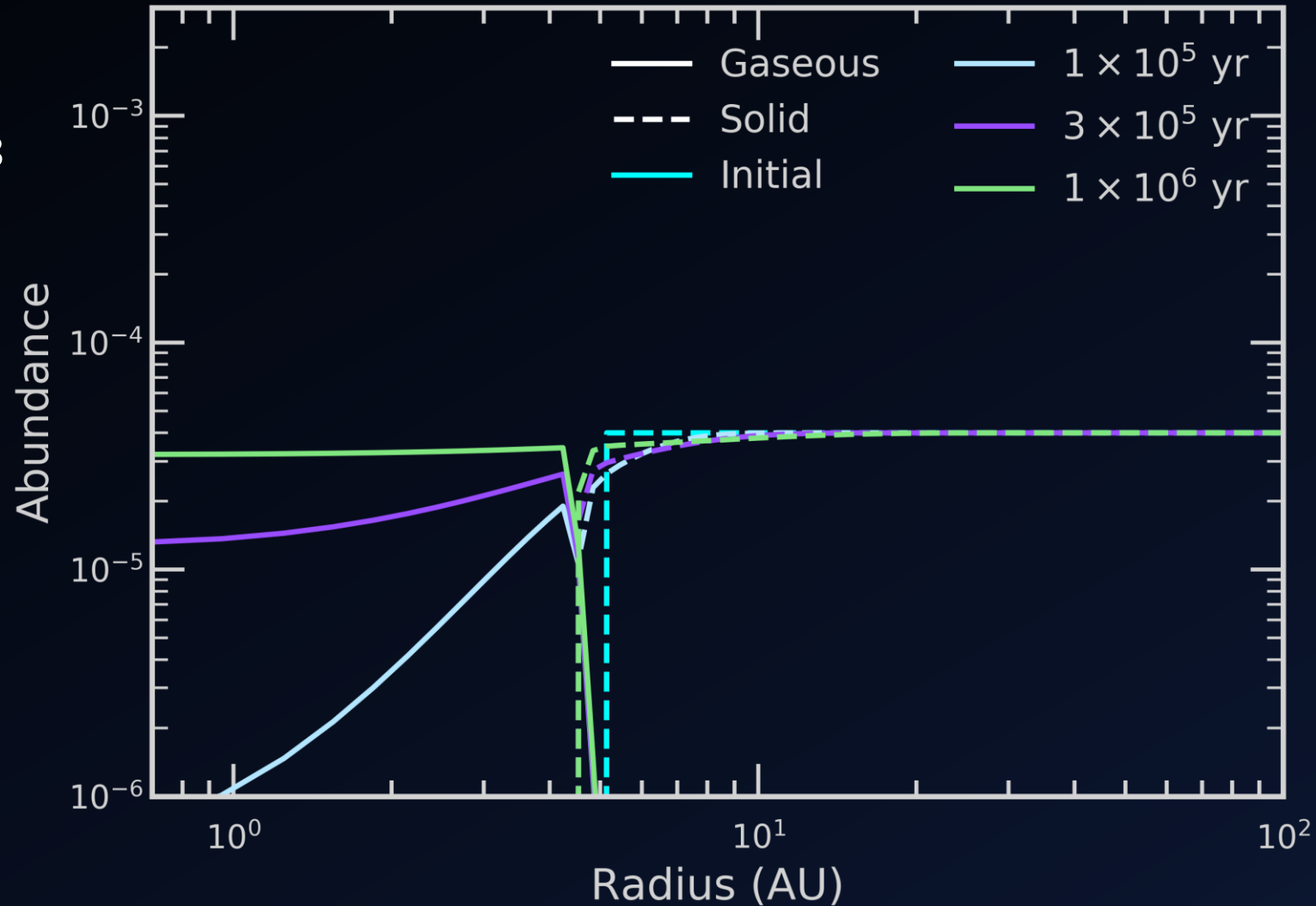
Results – without radial drift of pebbles

$$\alpha = 10^{-3}$$



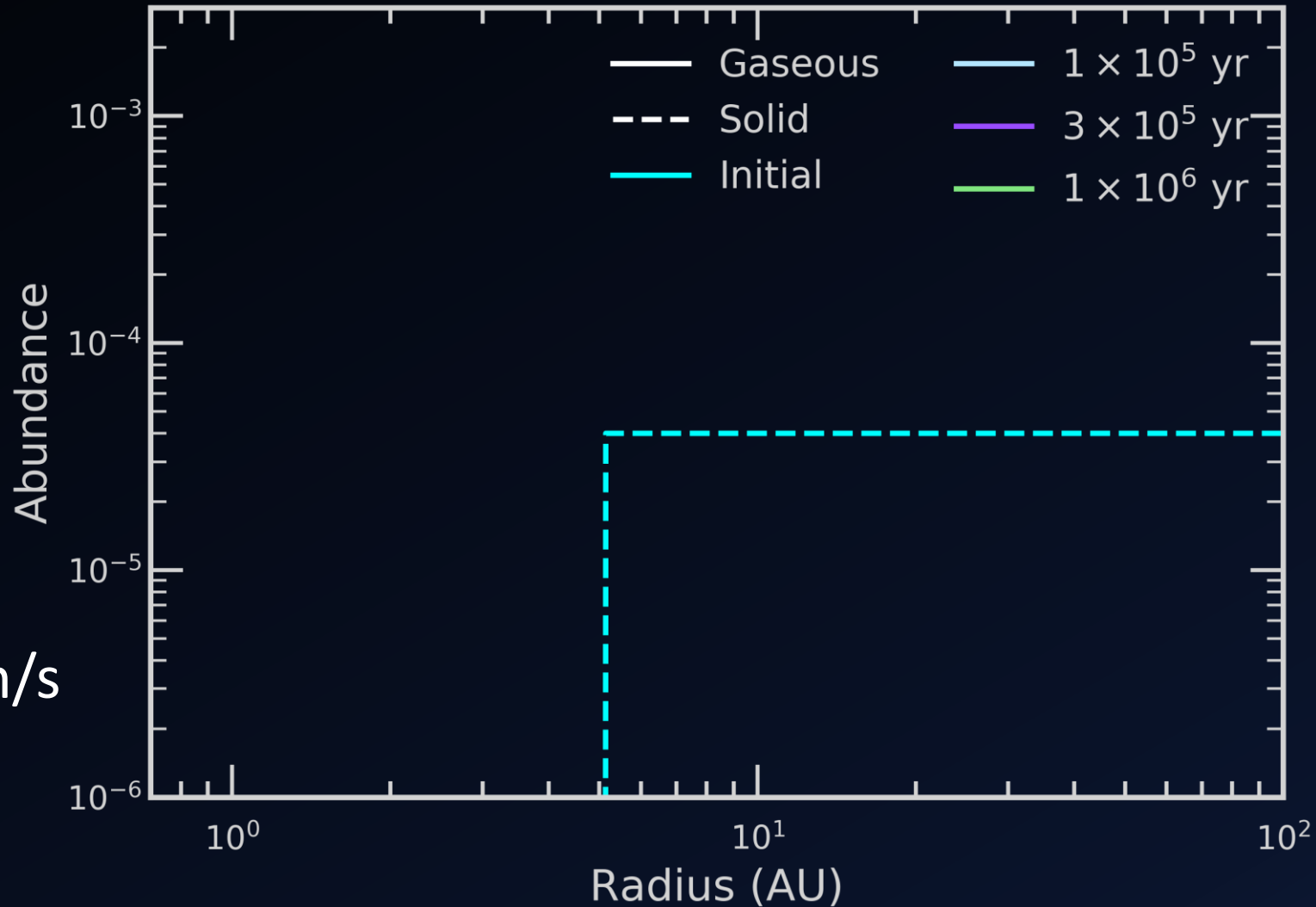
Results – without radial drift of pebbles

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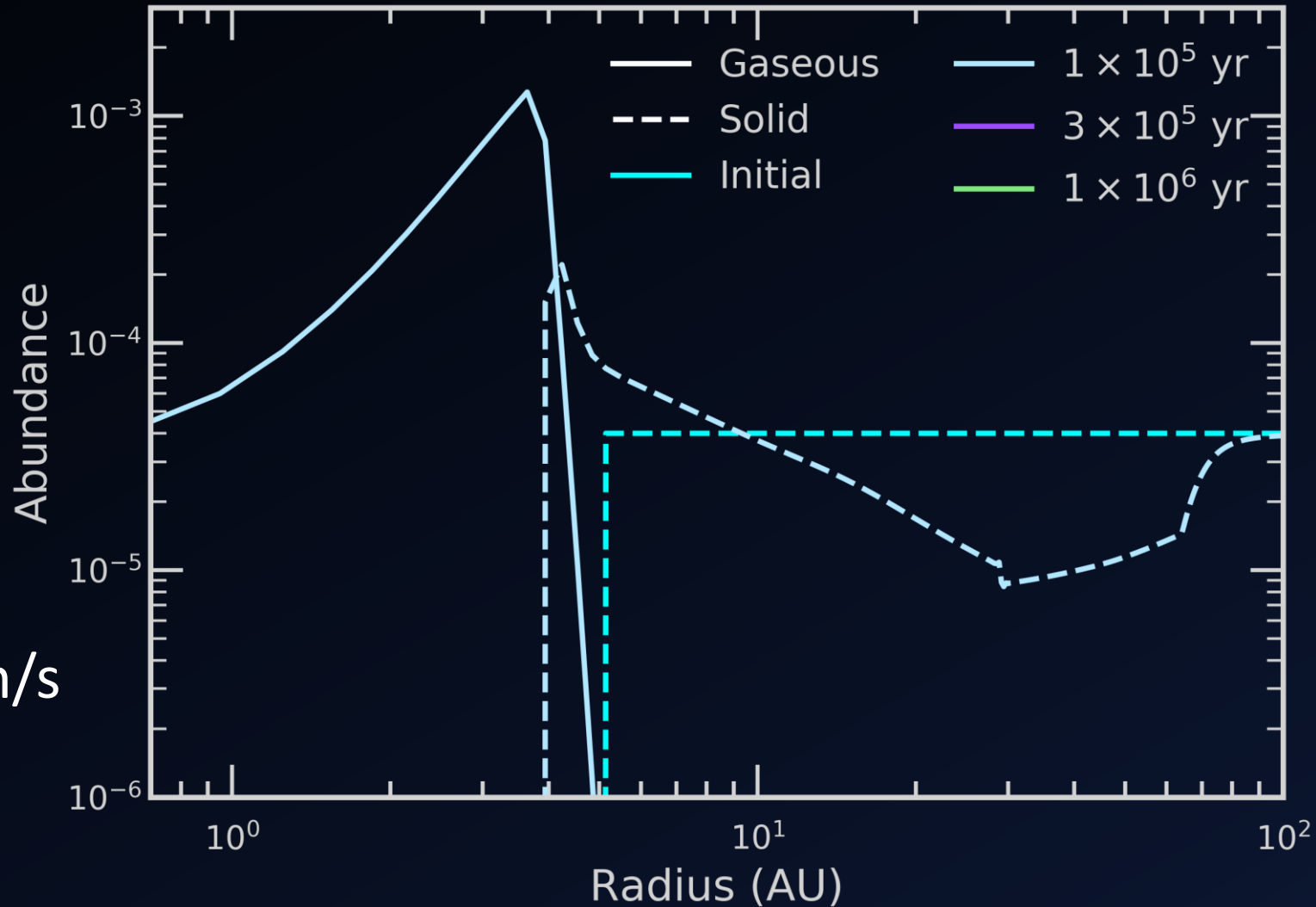


Results - with radial drift of pebbles

$\alpha = 10^{-3}$
 $v_{frag} = 10 \text{ m/s}$

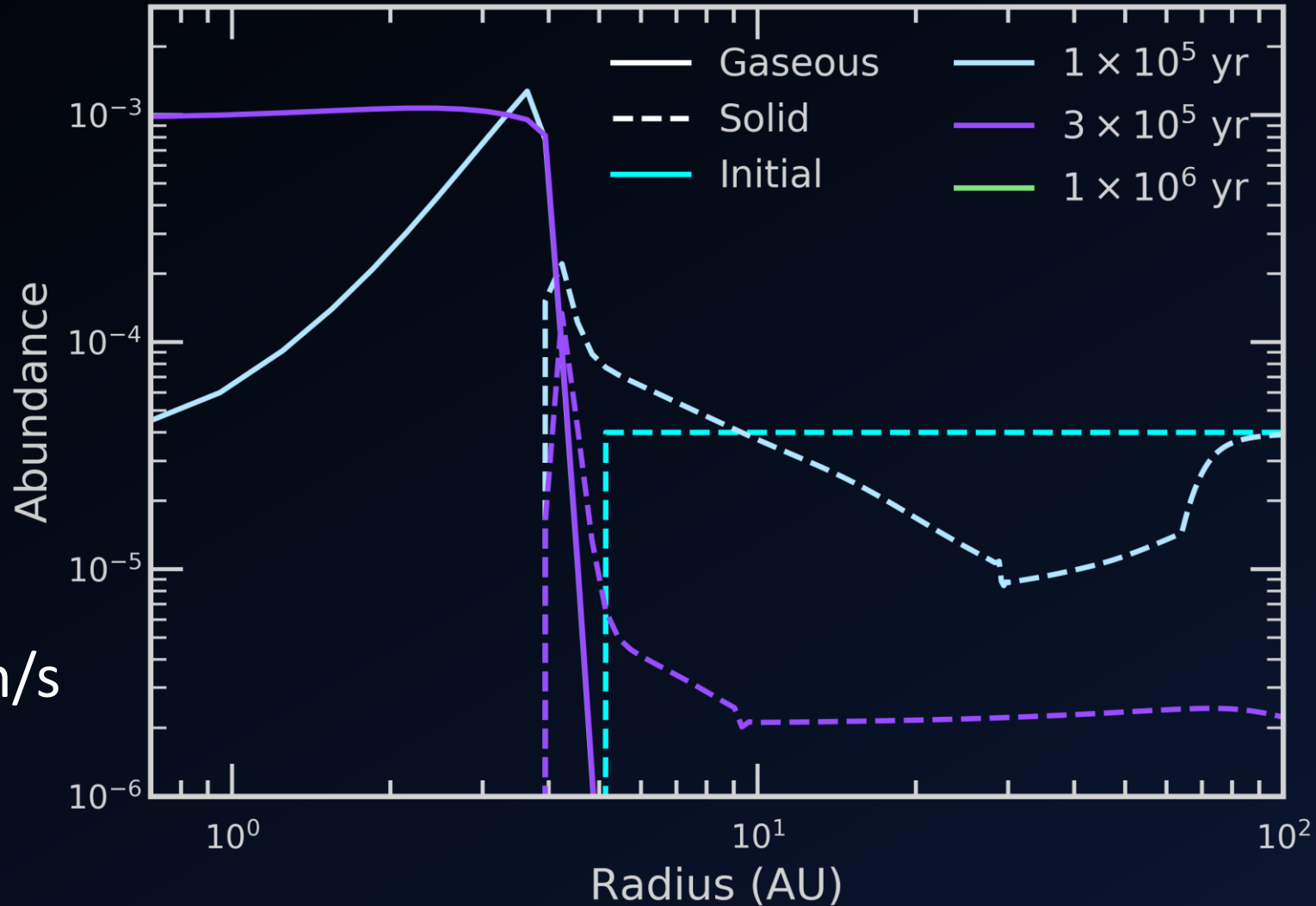


Results - with radial drift of pebbles



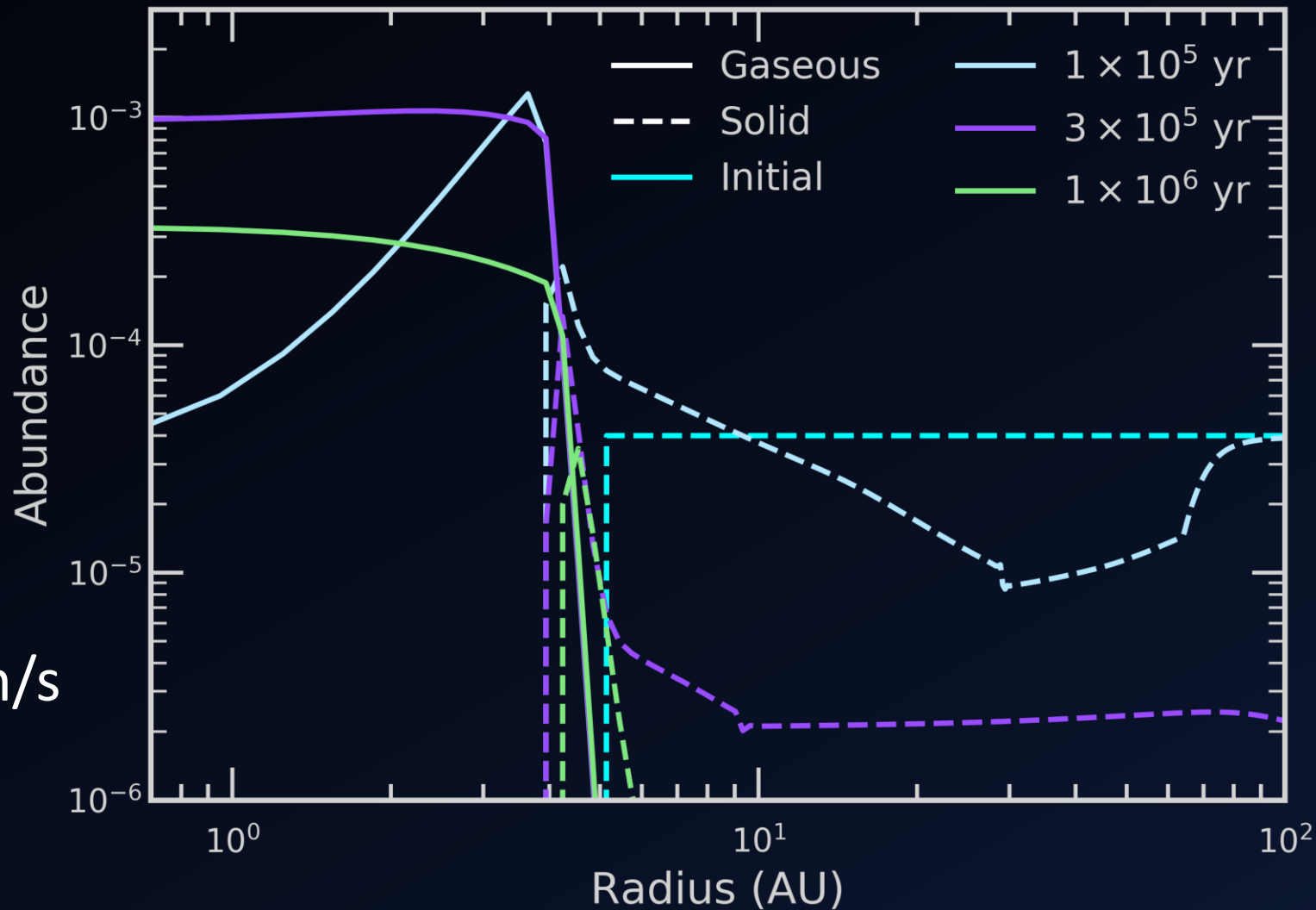
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Results - with radial drift of pebbles



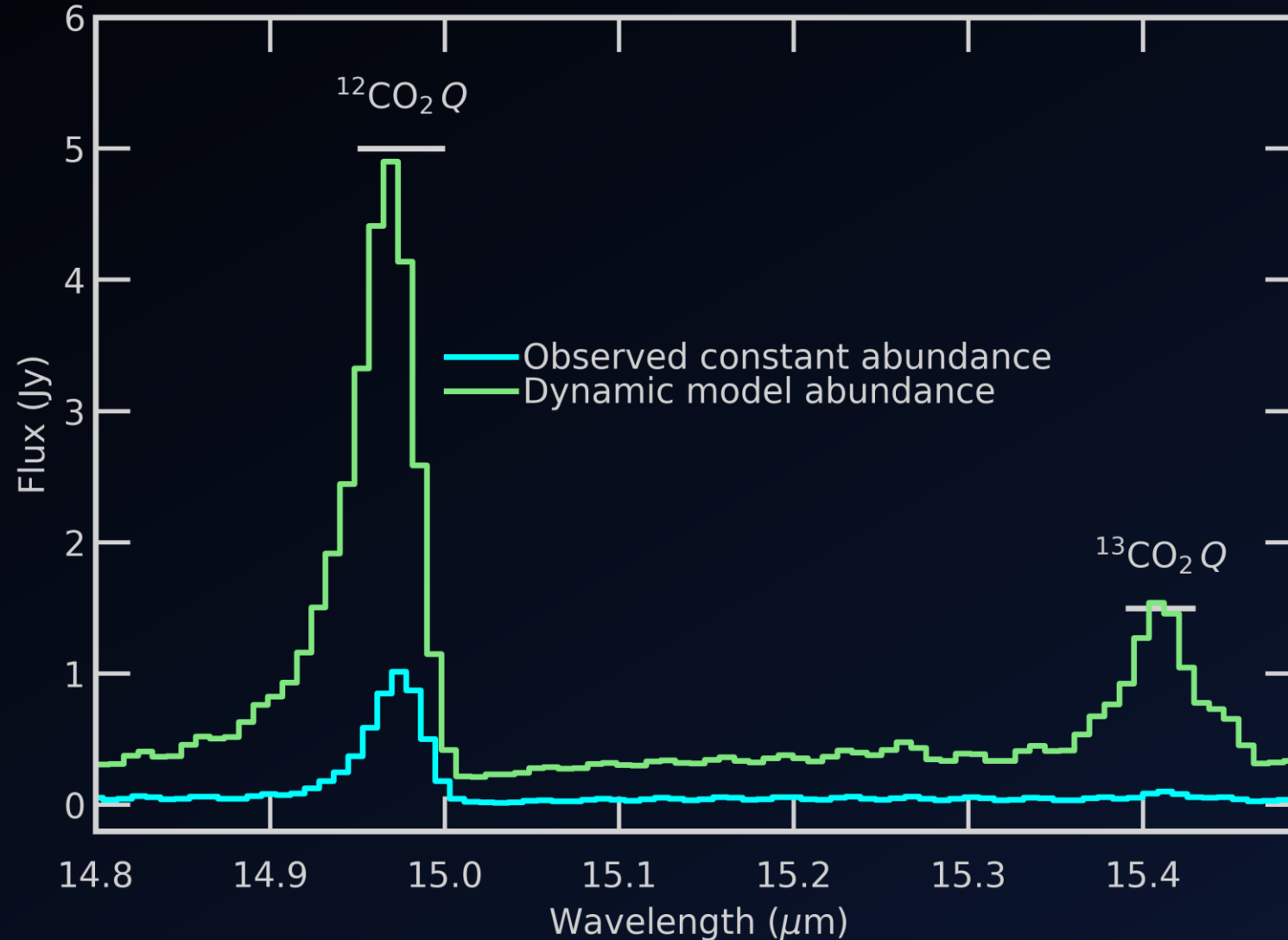
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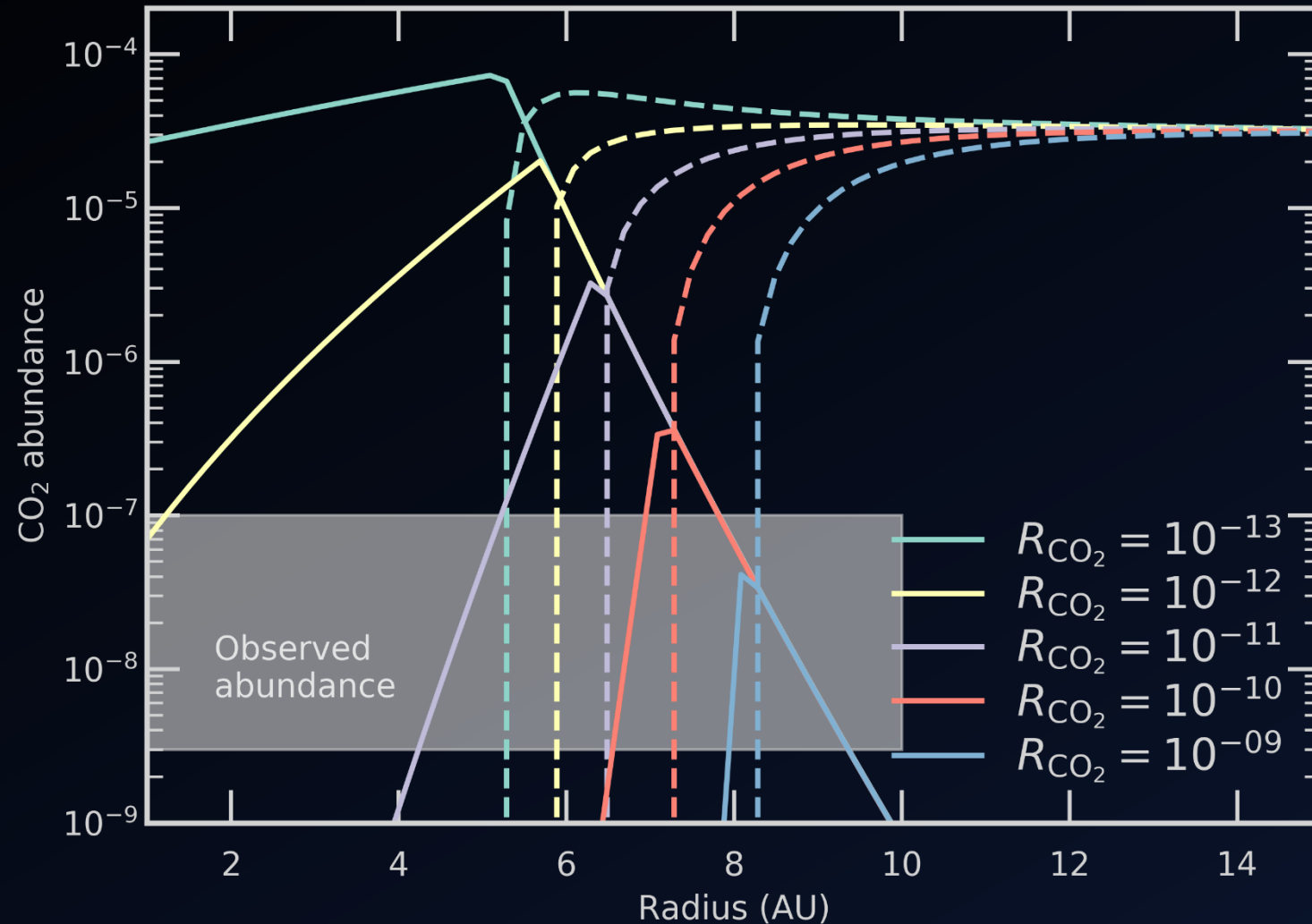
High CO₂ abundance not seen with *Spitzer*-IRS



Need for an explanation

- Lower the CO₂ abundance in the inner disk
 - Remove CO₂ from the ice
 - Lower the flow of grains by 99% or more
 - **Destroy CO₂ quickly in the inner disk gas**
- Hide the CO₂ from view
 - **Slow vertical mixing**
 - **Optically thick UV dominated layer**

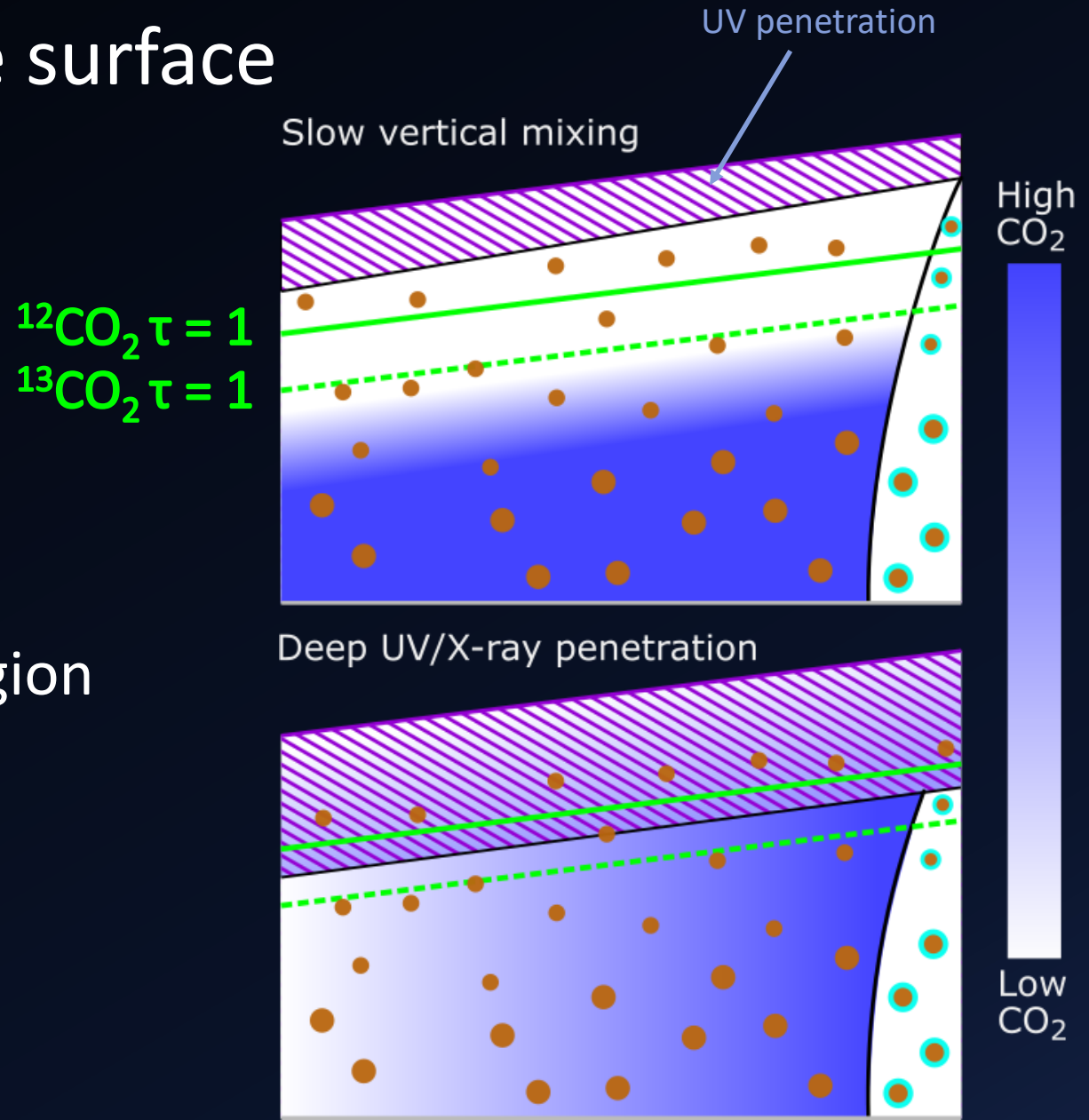
Destruction in the gas-phase



Destruction rate
of 10^{-10} needed
No mechanism
identified

Only low abundance in the surface

- Weak mixing
 - $\alpha = 10^{-6}$ for 1 Myr mixing timescale at iceline
- Low abundance in IR probed region
 - Deep UV/X-ray destruction



Conclusions

- CO_2 is far more abundant in the outer disk than in the inner disk
 - Can be useful for restricting radial transport rates
- $^{13}\text{CO}_2$ line fluxes are sensitive to radial abundance variations
- Radial accretion flow increases the CO_2 abundance in the inner disk
 - Expected increase not seen in Spitzer-IRS data
 - Radial drift predicts even higher CO_2 abundances at early times
- Abundant CO_2 is most likely hidden from our view
 - Test with JWST and $^{13}\text{CO}_2$
 - Need tracers that probe deeper into the disk