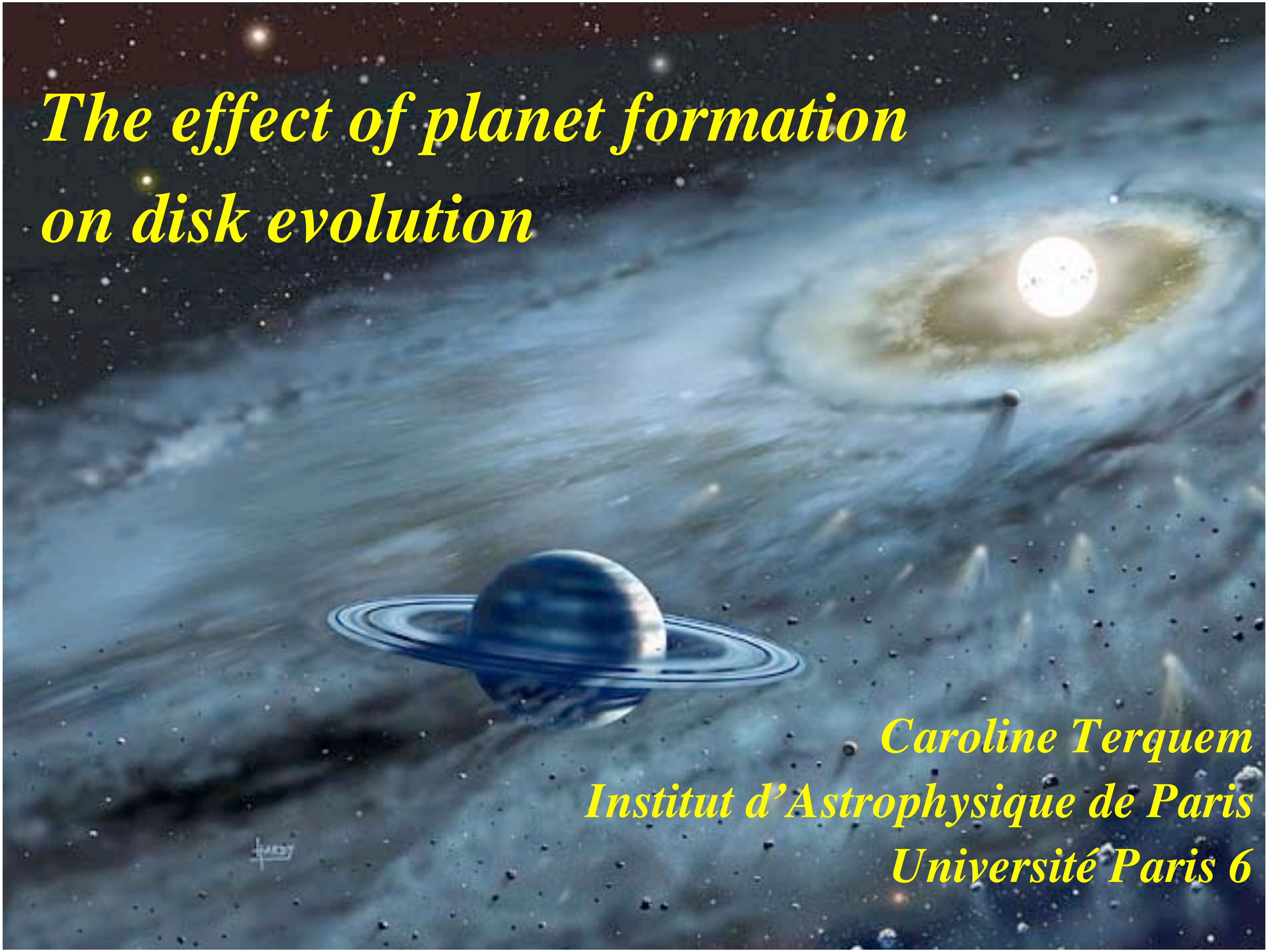
The effect of planet formation on disk evolution



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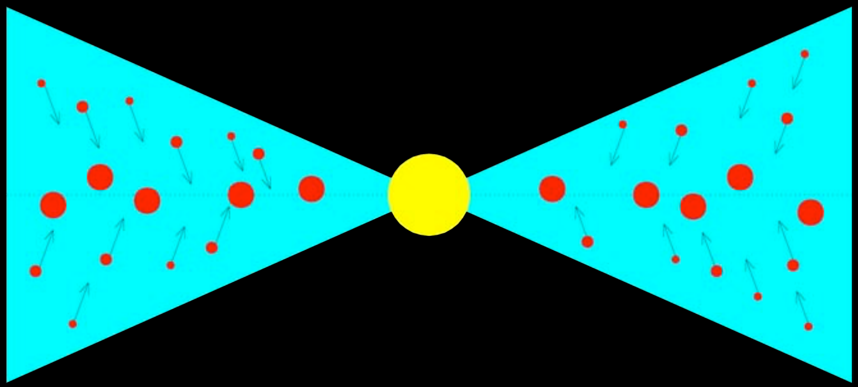
Two issues:

- Early stages: sedimentation of the dust → effect on the disk ionization fraction / turbulence

- Later stages: once the planet is formed → effect on the disk structure / mass accretion

Dust sedimentation



Without gas, the dust would oscillate around the midplane with the frequency Ω_K

Gas drag → damping with a characteristic timescale « $1/\Omega_K$

With no turbulence:

- damped oscillations and sedimentation, growth to 0.1-1 m
- timescale: < 10^4 years

With turbulence:

growth to 0.1-1 cm only, no sedimentation

✓ Planet formation : requires sedimentation

✓ Observations: suggest presence of grains high up

Disk ionization

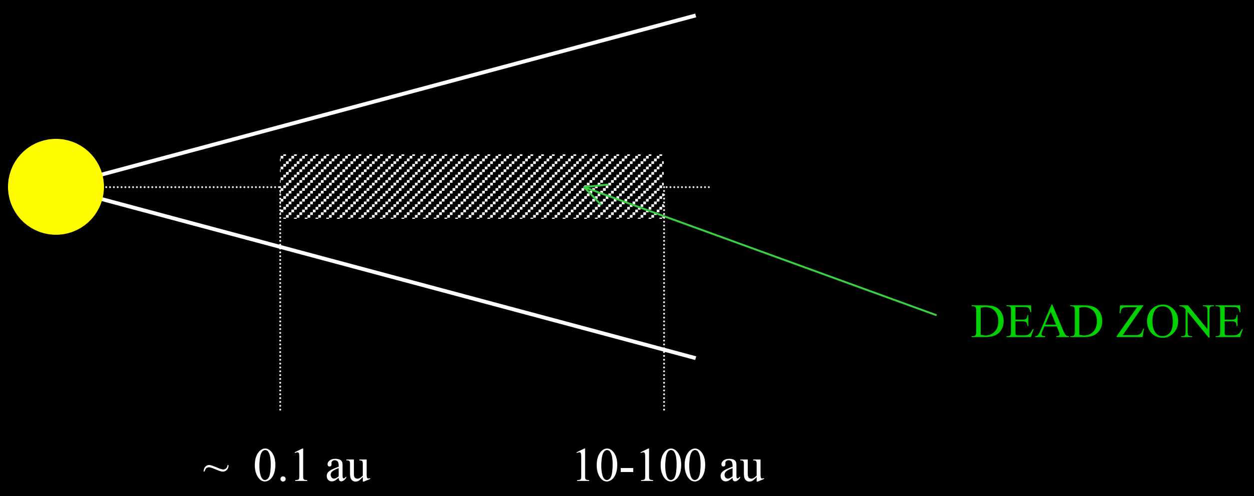
- Ionization:
  - thermal (inner disk)
  - X-rays
  - (cosmic rays)
- Recombination:
  - metal ion + electron → metal atom : <u>slow</u>
  - molecular ion + electron → molecule : <u>fast</u>

dust grain + X-ray ↔ metal atom

molecular ion + metal atom → molecule + metal ion

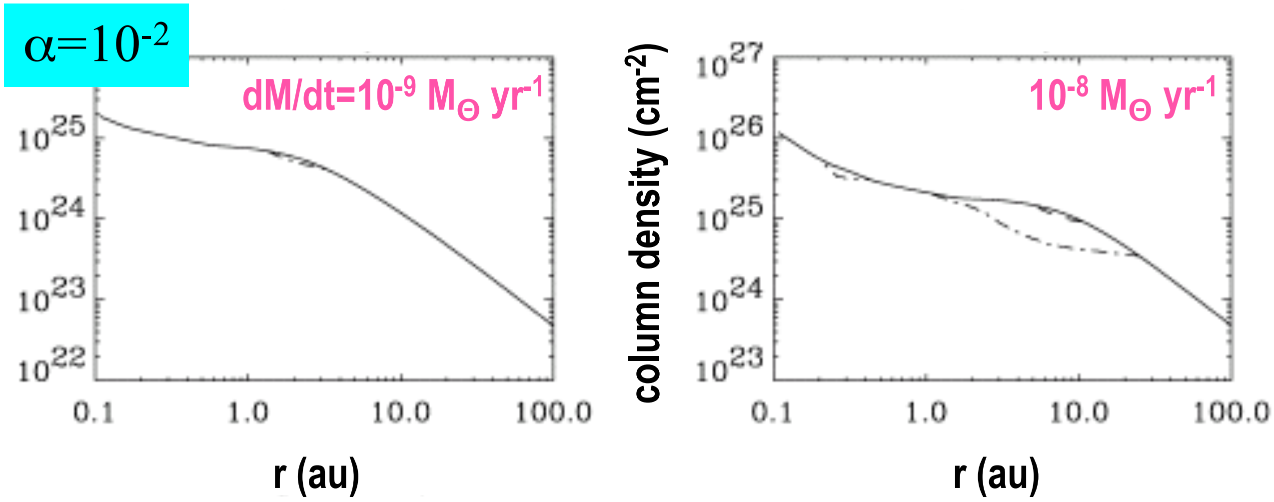
(Gammie 1996, Glassgold et al. 1997, Sano et al. 2000, Fromang, Terquem & Balbus 2002)

Dead zones

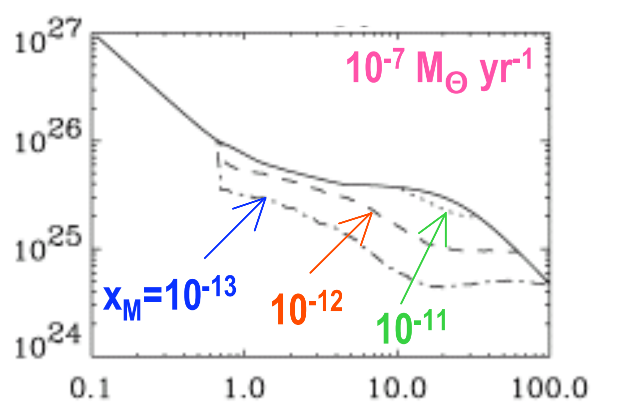


(Gammie 1996, Glassgold et al. 1997, Sano et al. 2000, Fromang, Terquem & Balbus 2002)

But see Inutsuka and Sano (2005) $\longrightarrow$ fully ionized disks

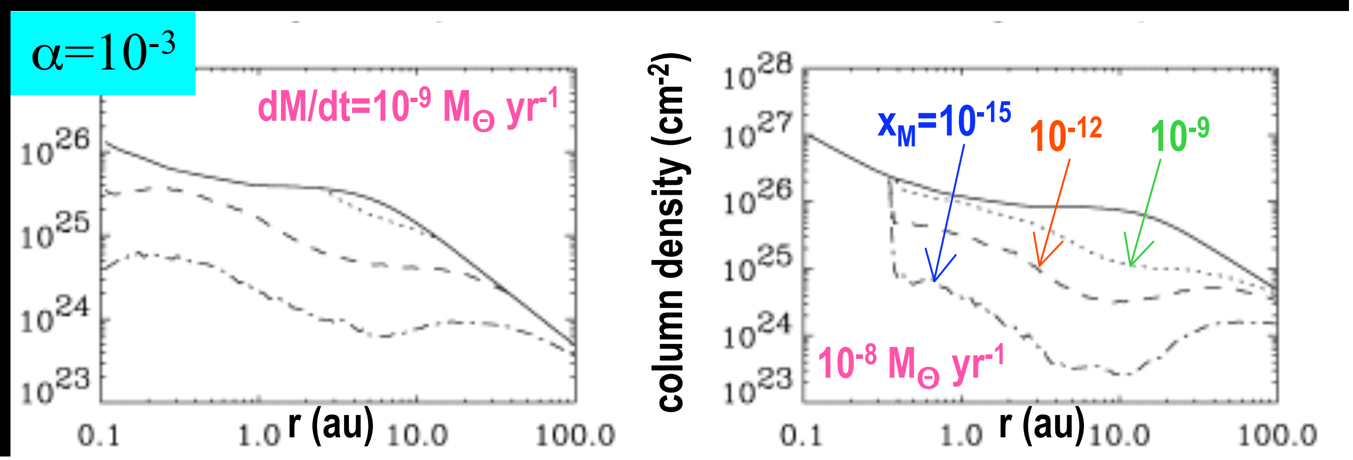


Disk ionization



x_M: abundance of metal atoms
Cosmic abundance ~ 10^{-7}

(Fromang, Terquem & Balbus 2002)

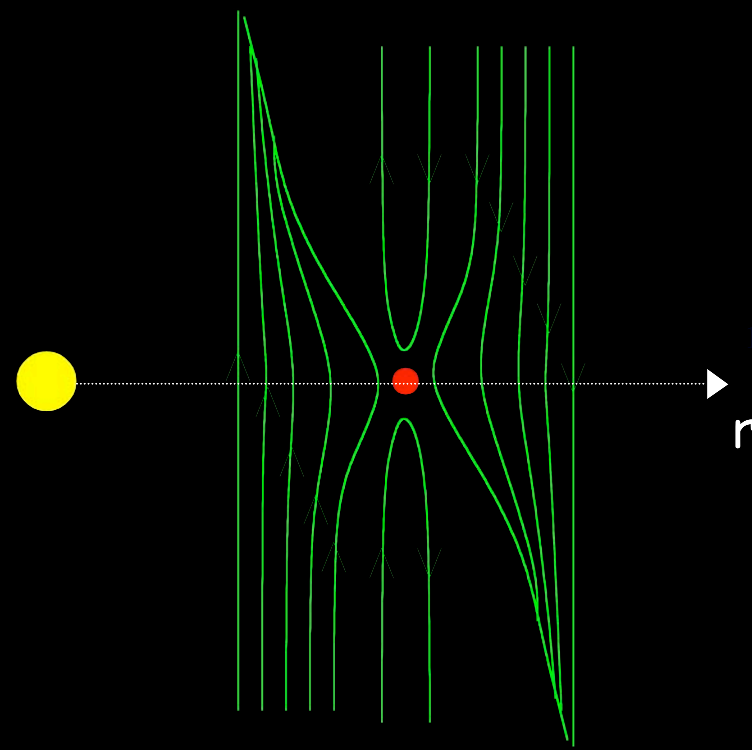


Type II migration

The planet opens up a ***gap*** and is locked into the disk viscous evolution process

—> migration occurs on **the viscous timescale ~ 10^5 ans**

$$t(yr) = \frac{1}{\alpha}\left(\frac{r}{H}\right)^2 \Omega^{-1} = \frac{0.2}{\alpha}\left(\frac{r}{H}\right)^2 \left(\frac{r}{au}\right)^{3/2}$$



(Goldreich & Tremaine '80, Papaloizou & Lin '84)

Once a giant planet is formed:

• If enough mass left in the vicinity of the planet, migration and accretion of the disk until the planet reaches the inner boundary. Then magnetospheric accretion may still proceed. The planet does not affect the disk evolution.

• If not enough mass left, migration is slow and accretion through the gap may be reduced → accretion onto the star slows down