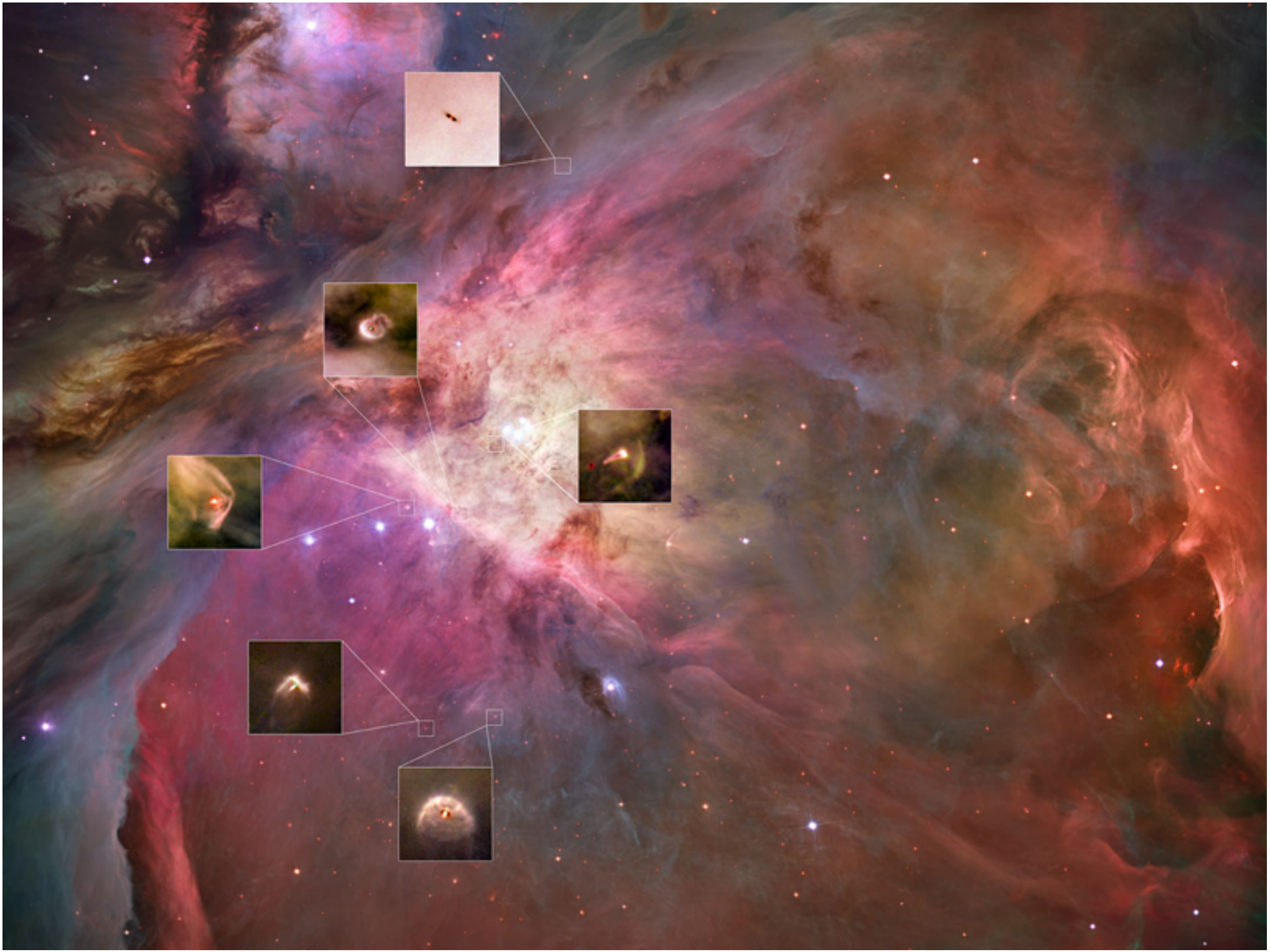
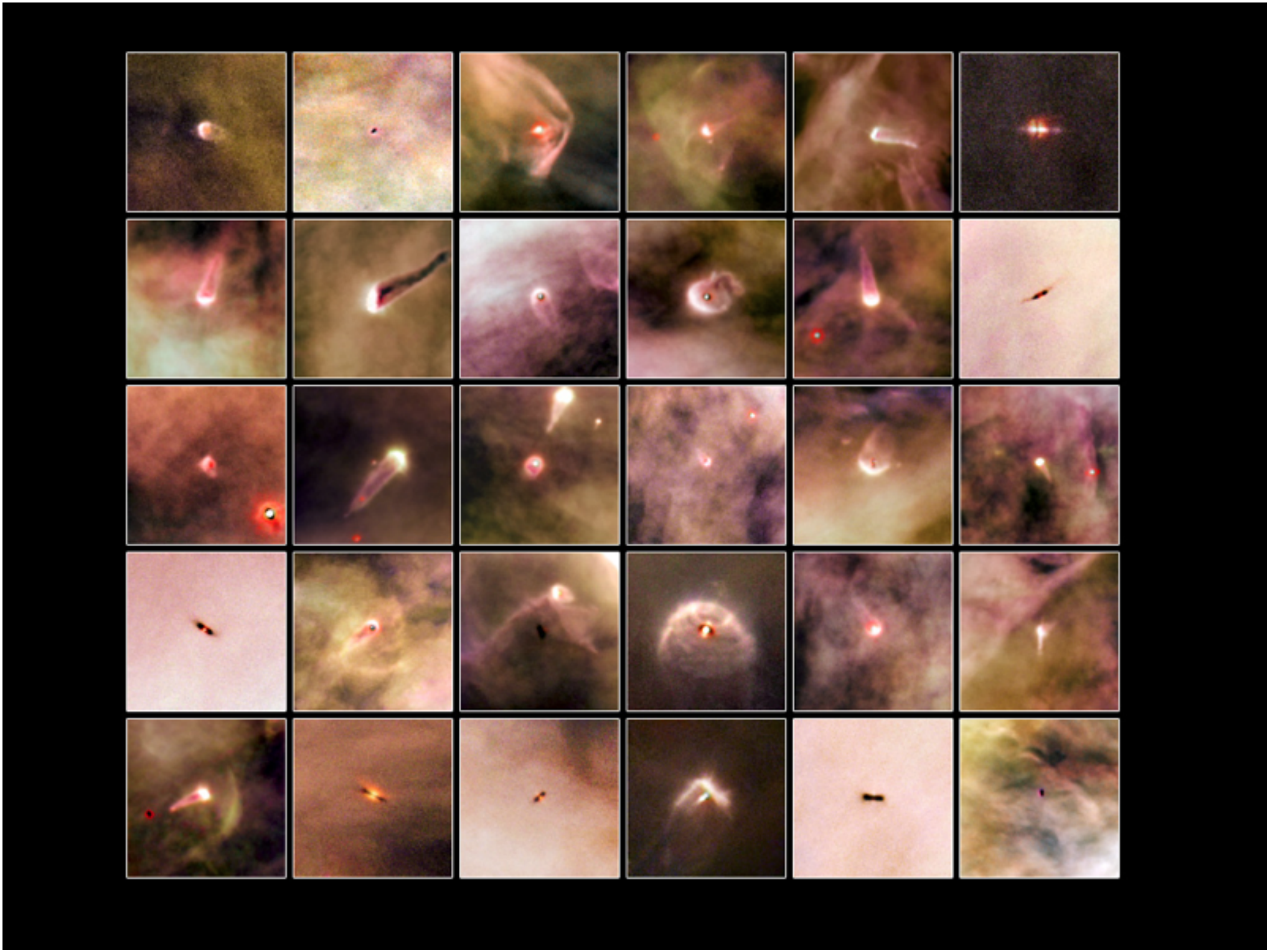
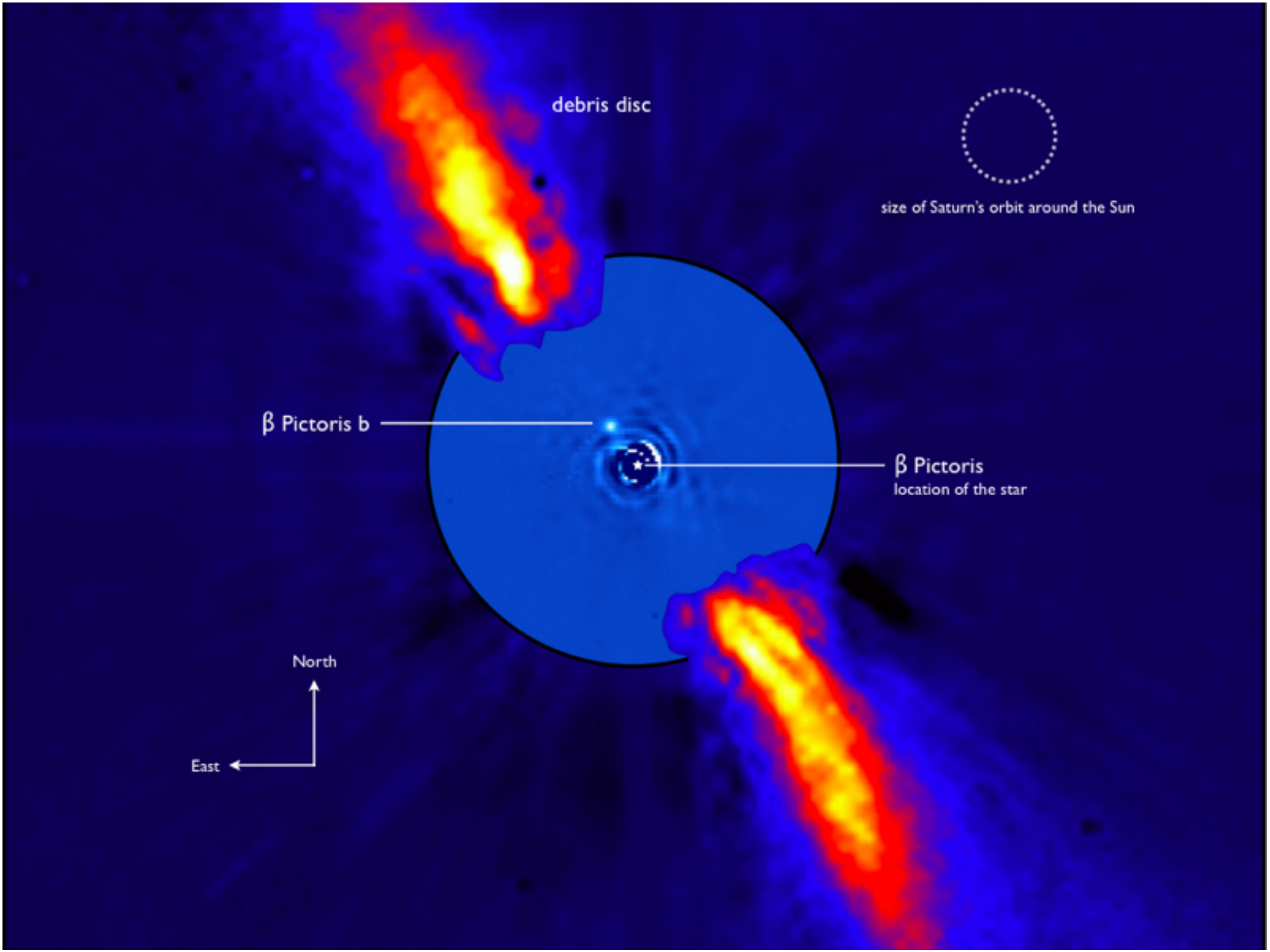
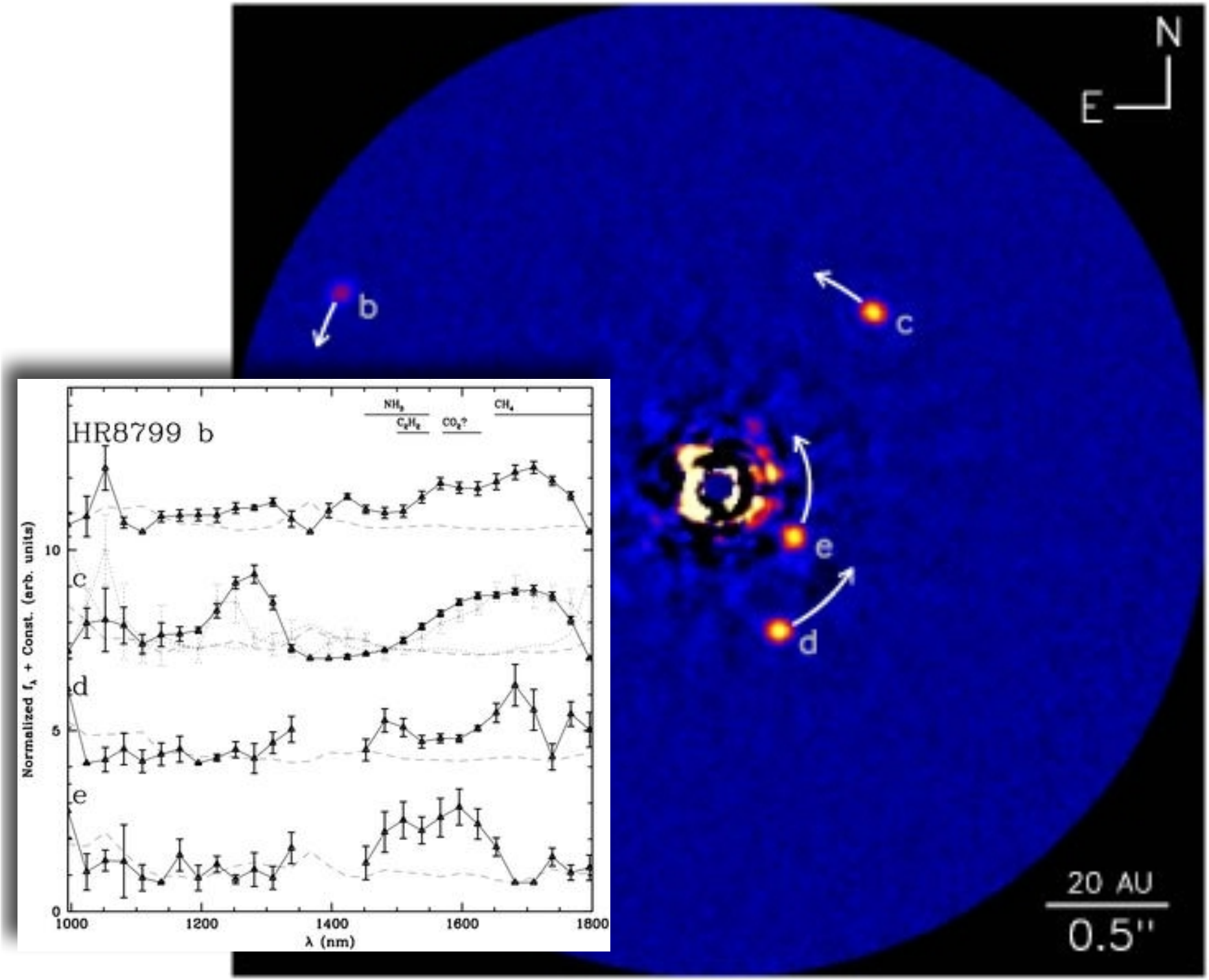
On the chemical compositions of disks, stars and planets

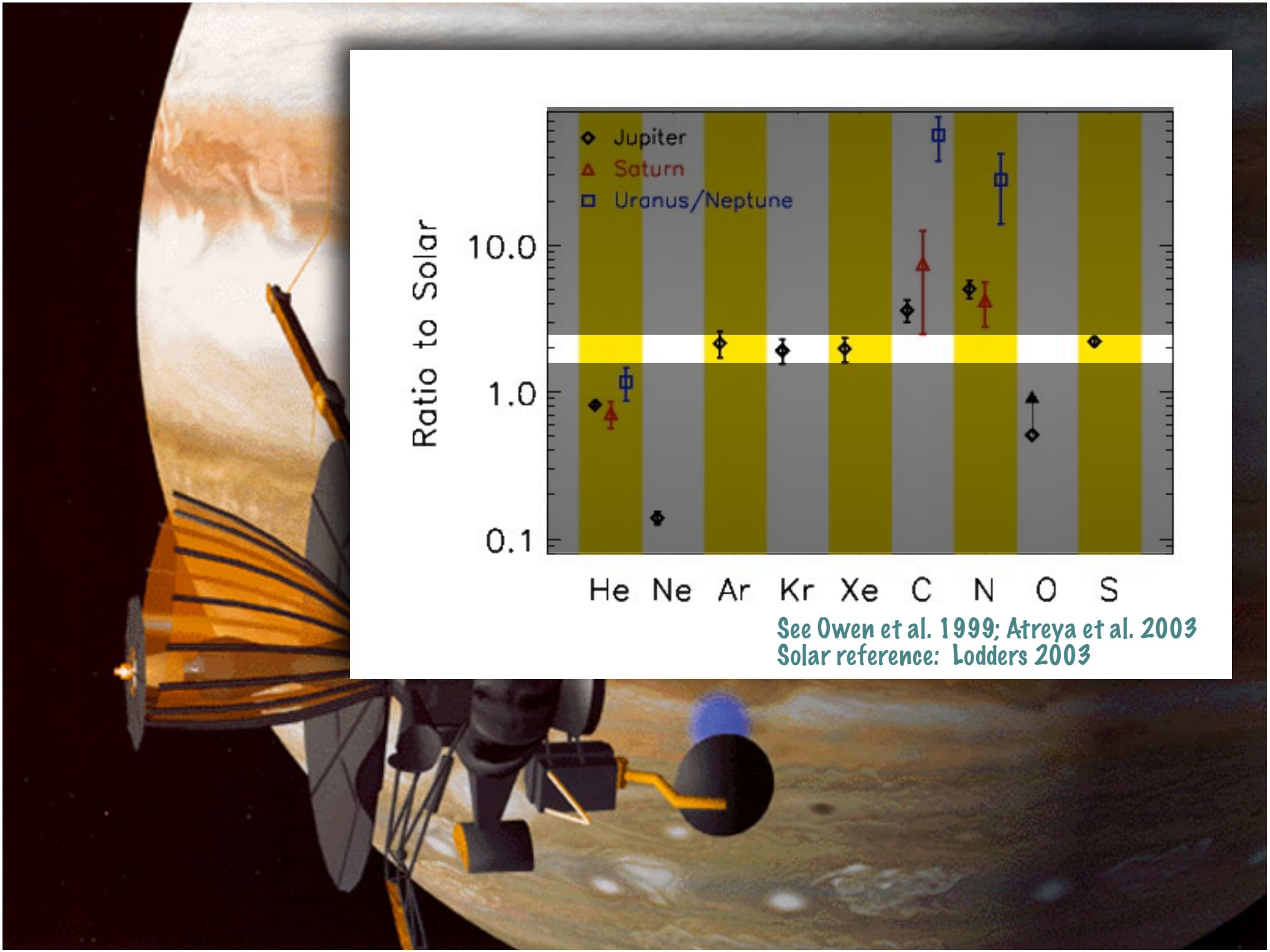
Tristan Guillot (OCA, Nice) & Shigeru Ida (Tokyo Tech)





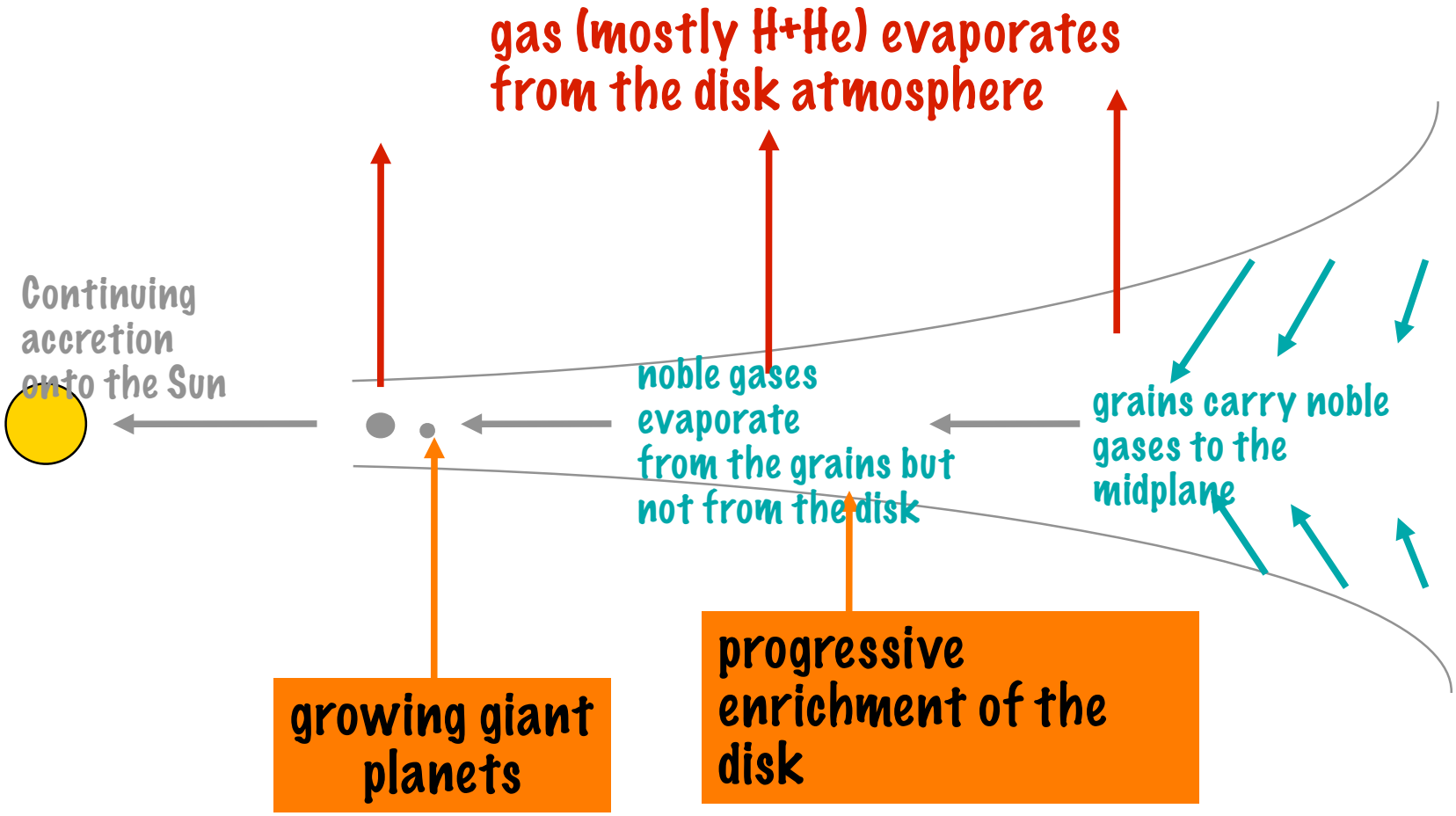

debris disc
size of Saturn's orbit around the Sun
β Pictoris b
β Pictoris
location of the star
North
East


N
E
b
c
e
d
20 AU
0.5''
HR8799 b
NH3
C2H2
CO2?
CH4
Normalized fλ + Const. (arb. units)
λ (nm)
1000
1200
1400
1600
1800
0
5
10
c
d
e



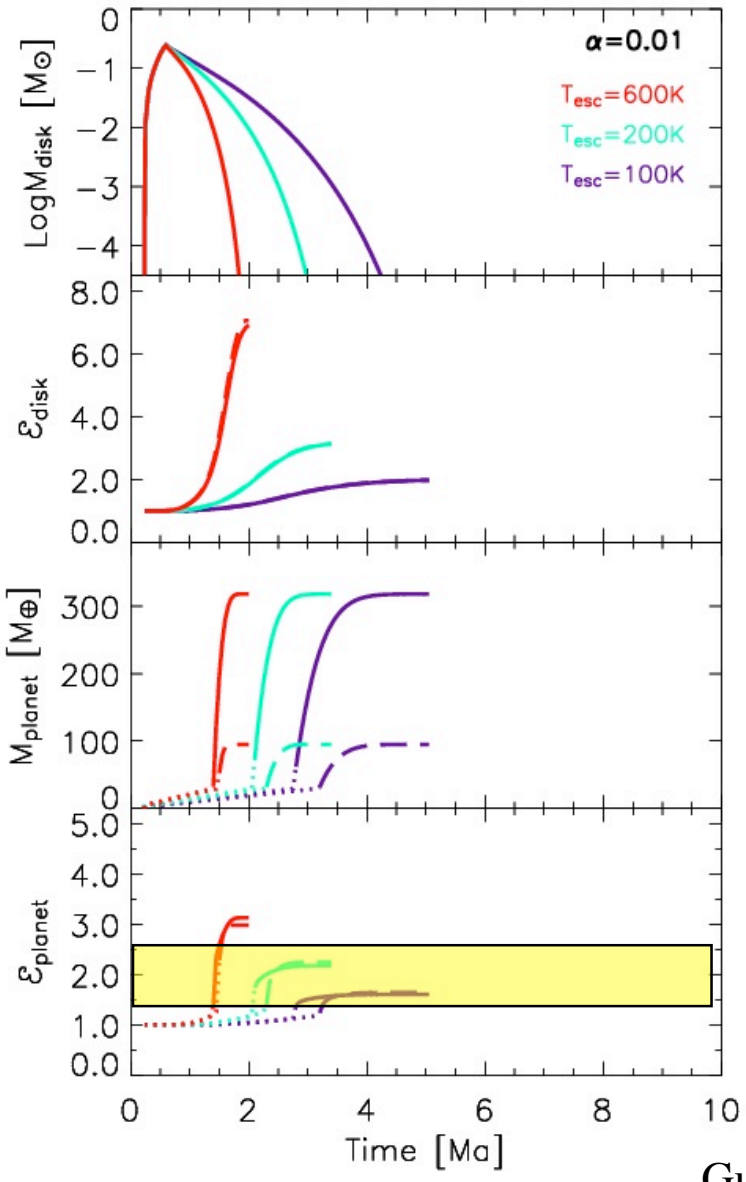
See Owen et al. 1999; Atreya et al. 2003
Solar reference: Lodders 2003

Explaining the noble gases in Jupiter



Explaining the noble gases in Jupiter

Evaporation
FUV externe



Disk mass

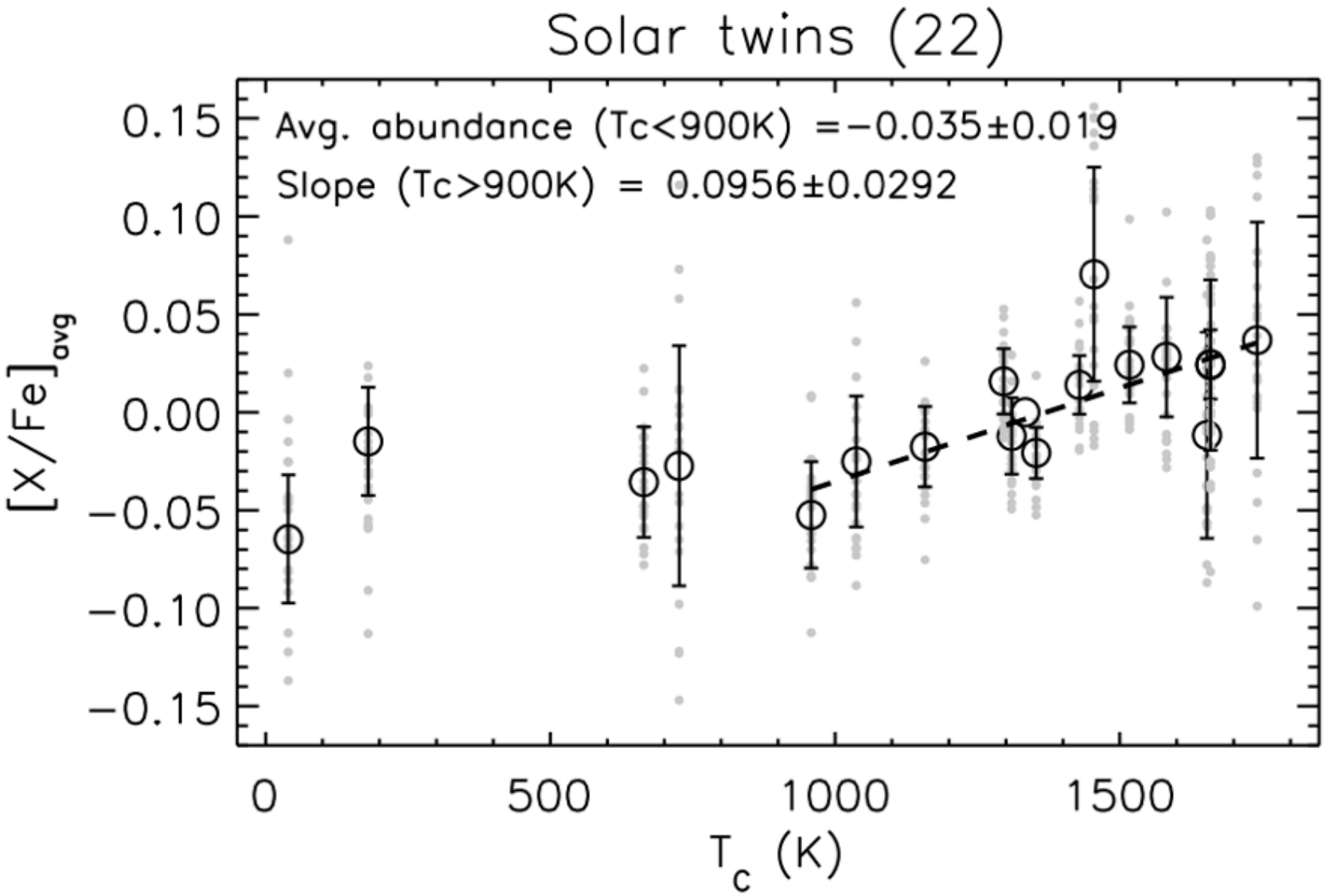
Disk enrichment

Planet mass

Planet enrichment
Jupiter: plain
Saturn: dashed

Guillot & Hueso (MNRAS, 2006)

Observation II: The Sun's abundance



Ramirez, Melendez & Asplund (A&A 2009)
see also Ramirez et al. (2010), Melendez et al. (2012)

Explaining the Sun vs. solar twin abundances

- Chambers (2010) shows that the difference between the Sun and solar twins amounts to 4 earth masses less of Earth-like + chondritic material accreted in the Sun.
  - This assumes a present-day outer CZ.
- If planet-formation is ubiquitous, difference between the Sun and other stars must be due to its giant planets

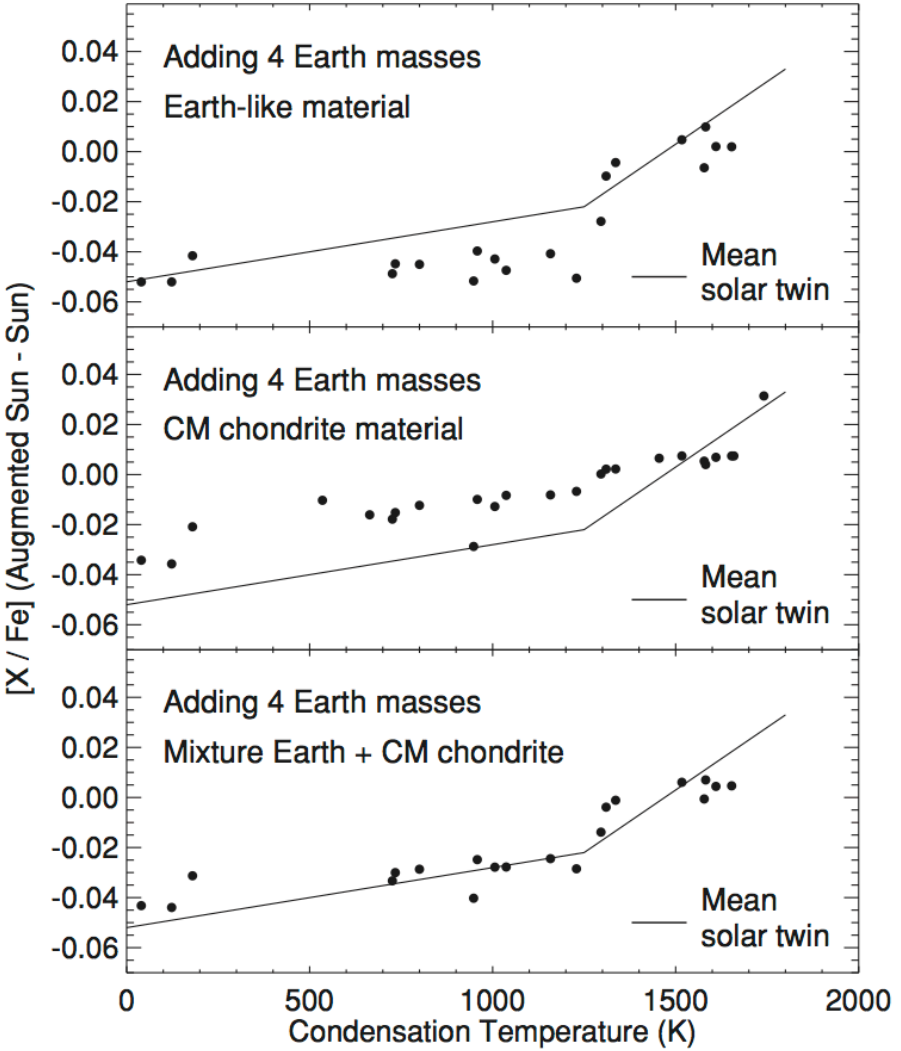
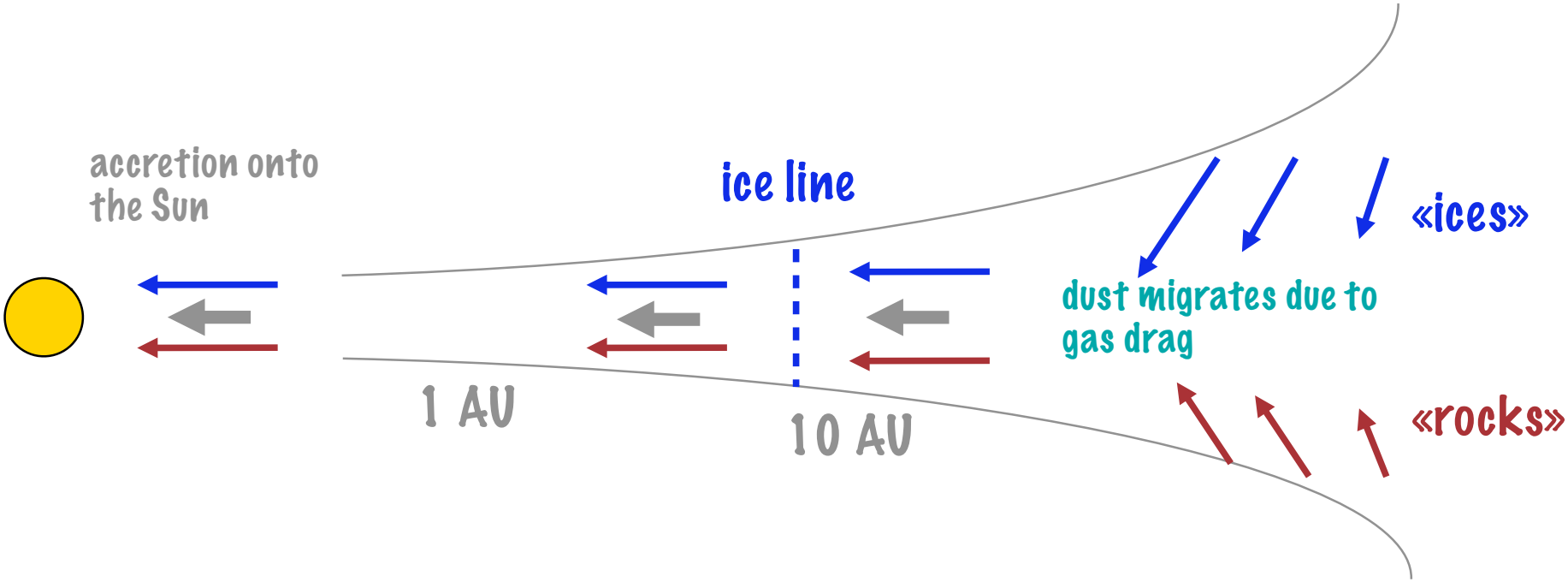


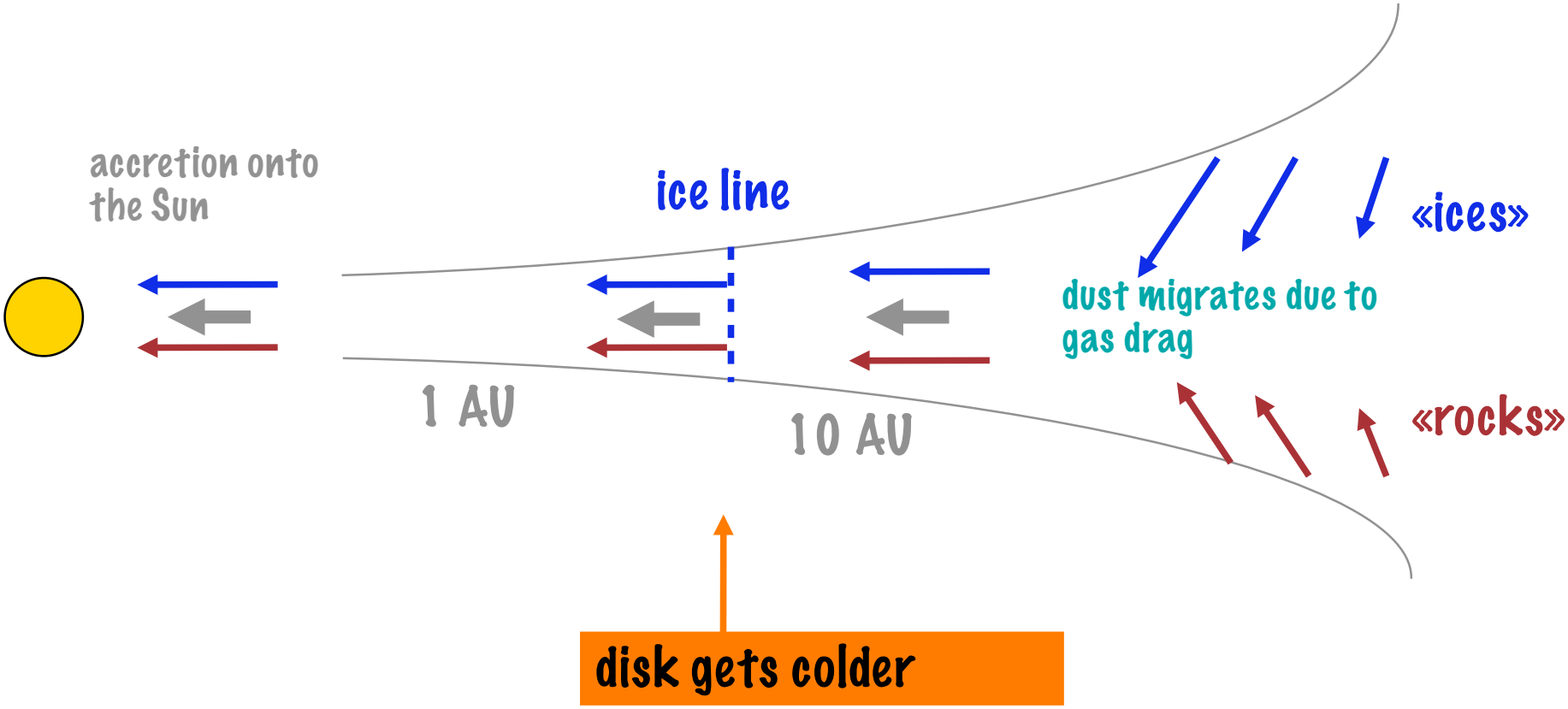
Figure 2. Composition of the solar photosphere when 4 $M_{\oplus}$ of refractory-rich material is added to the solar convection zone, compared to the unmodified Sun. Abundances are normalized with respect to Fe. The line segments show rms fits to the mean abundance pattern for 11 solar twins found by Meléndez et al. (2009).

Evolution of the dust and gas



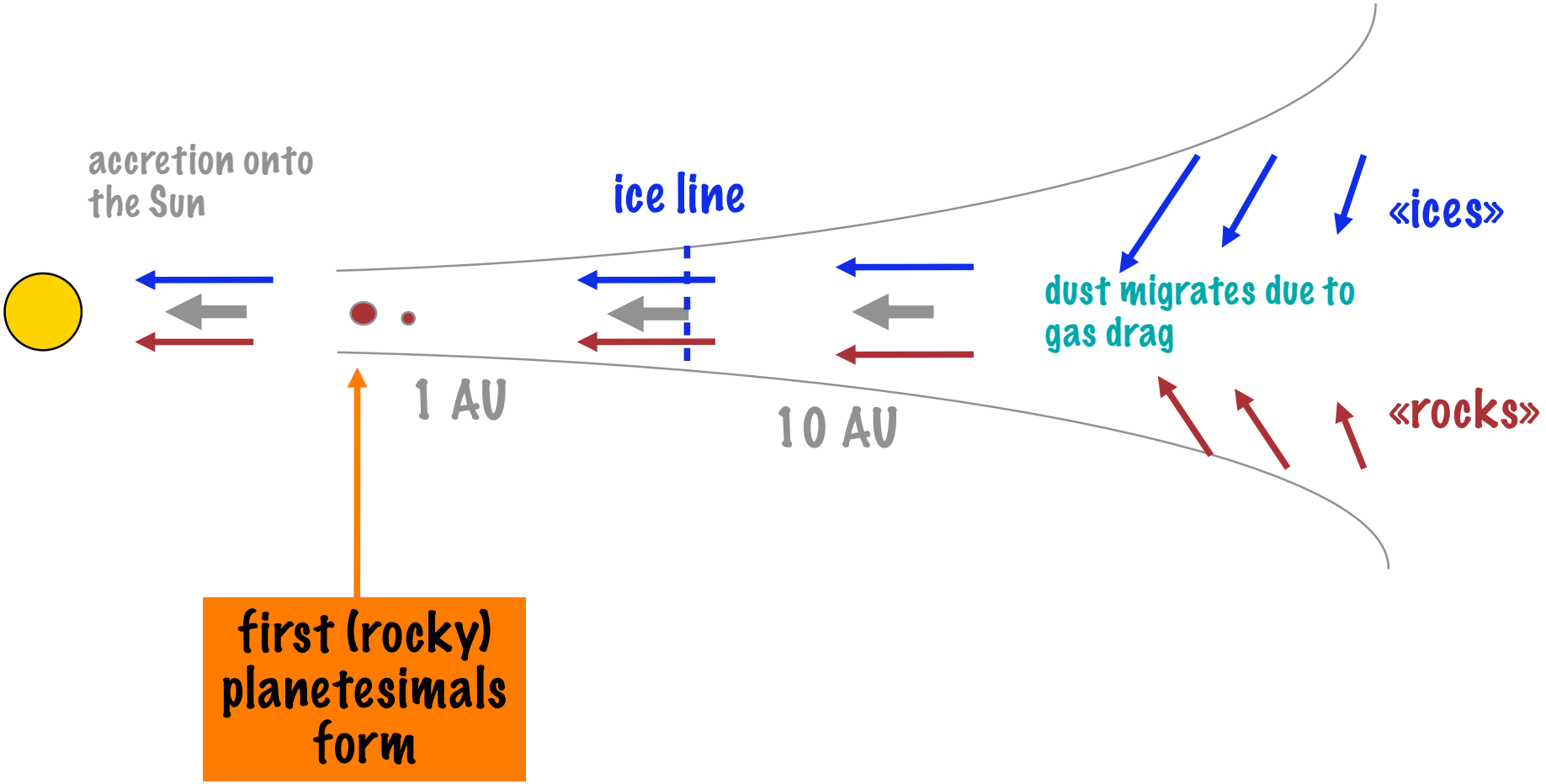
Guillot & Ida, in preparation

Evolution of the dust and gas



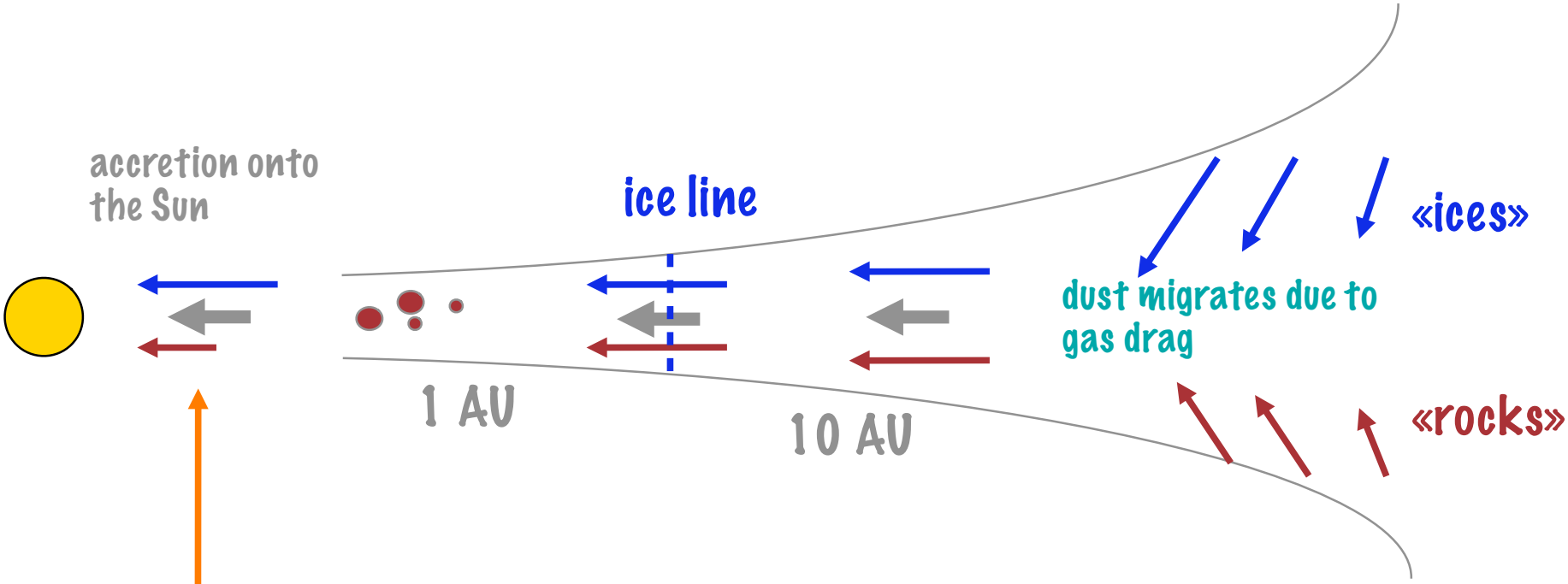
Guillot & Ida, in preparation

Evolution of the dust and gas



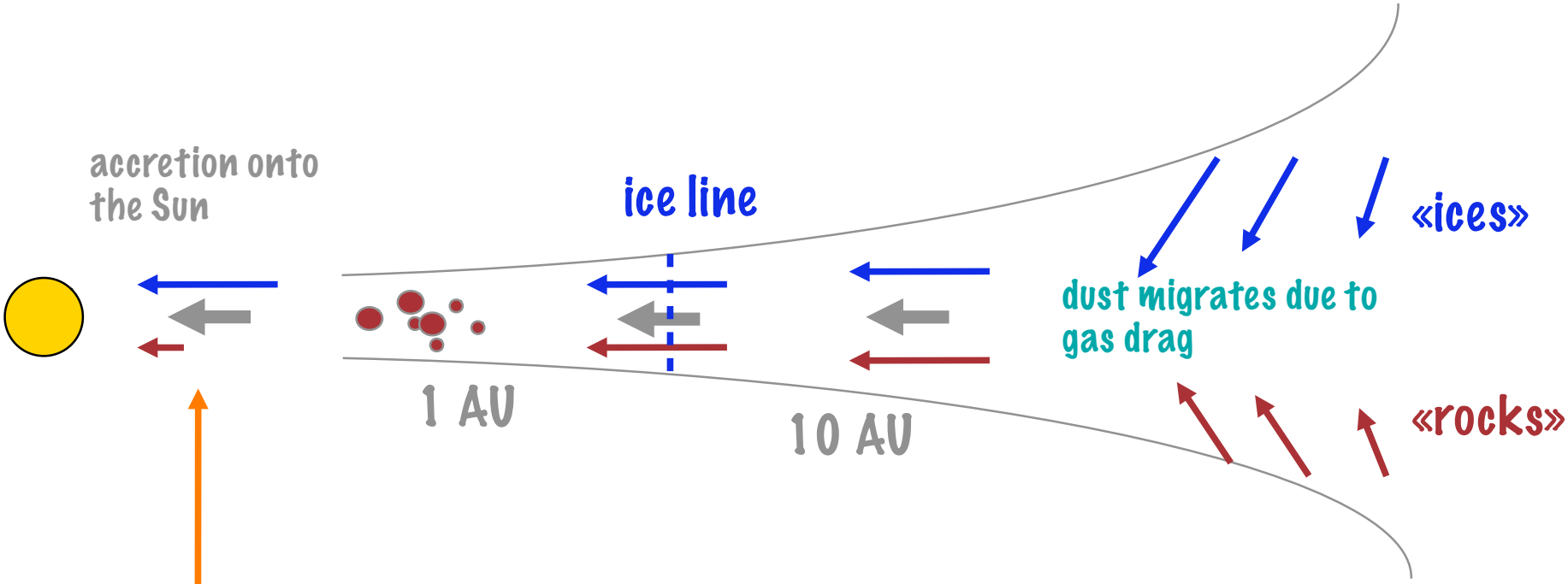
Guillot & Ida, in preparation

Evolution of the dust and gas



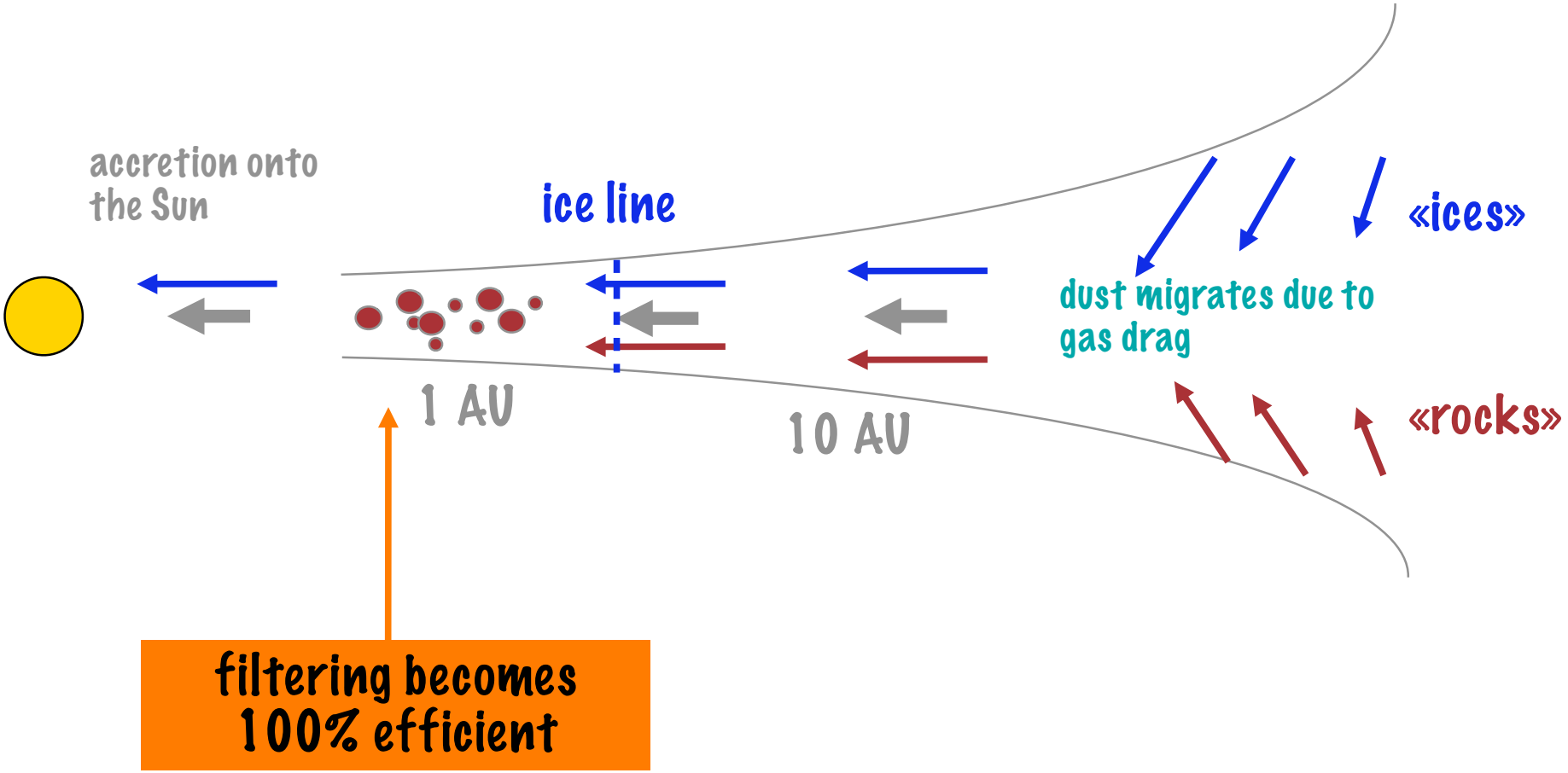
Guillot & Ida, in preparation

Evolution of the dust and gas



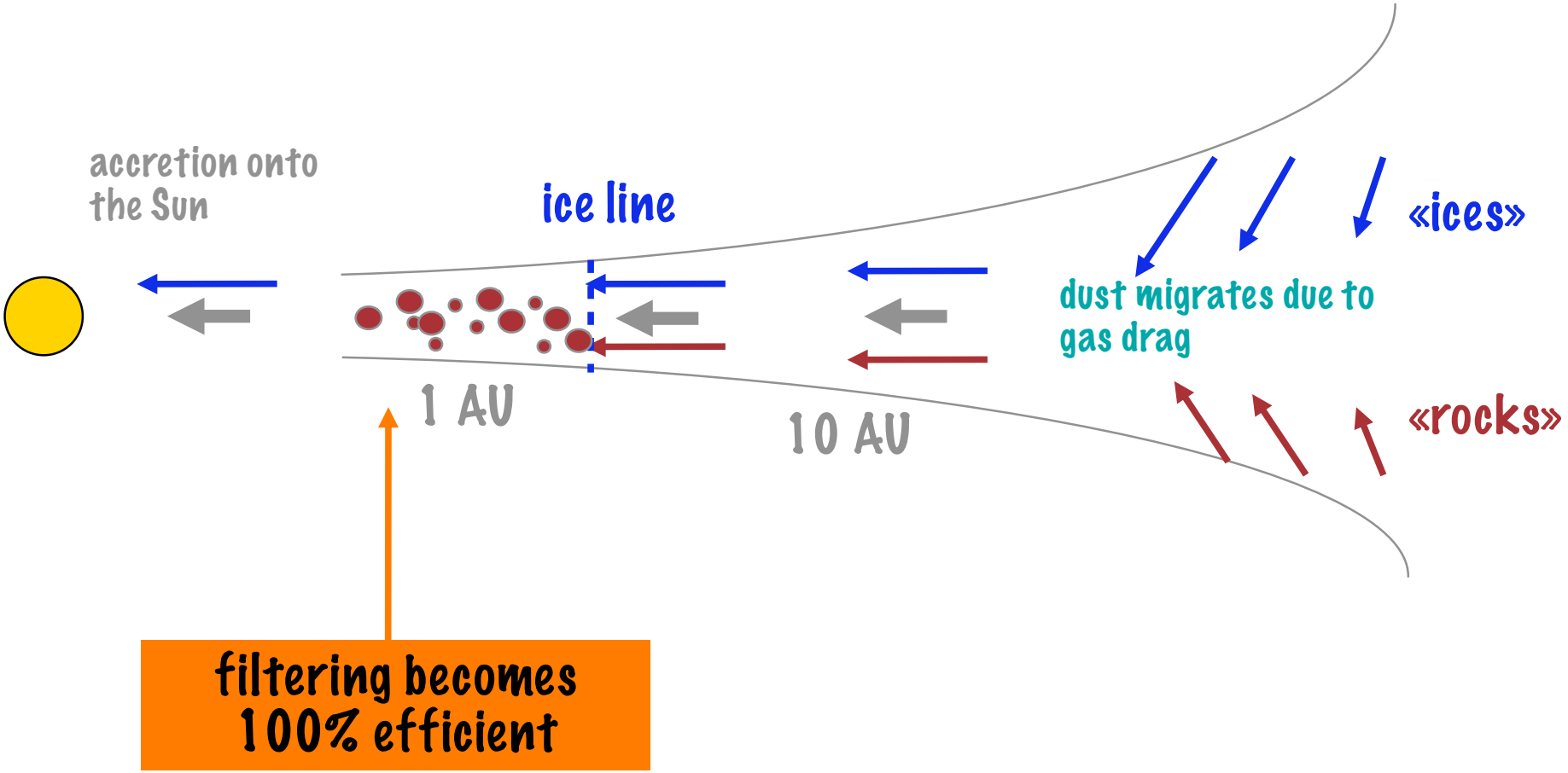
Guillot & Ida, in preparation

Evolution of the dust and gas



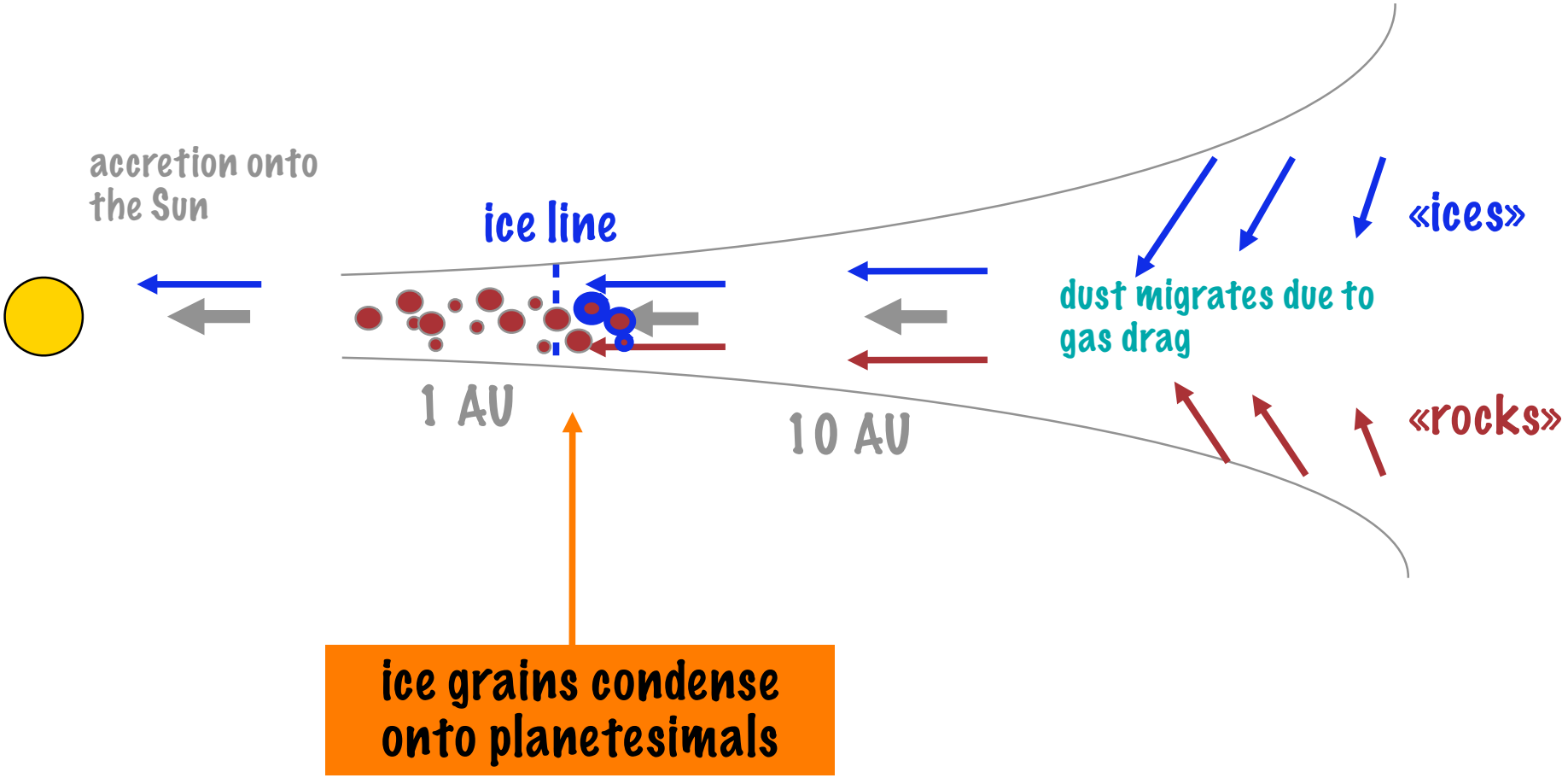
Guillot & Ida, in preparation

Evolution of the dust and gas



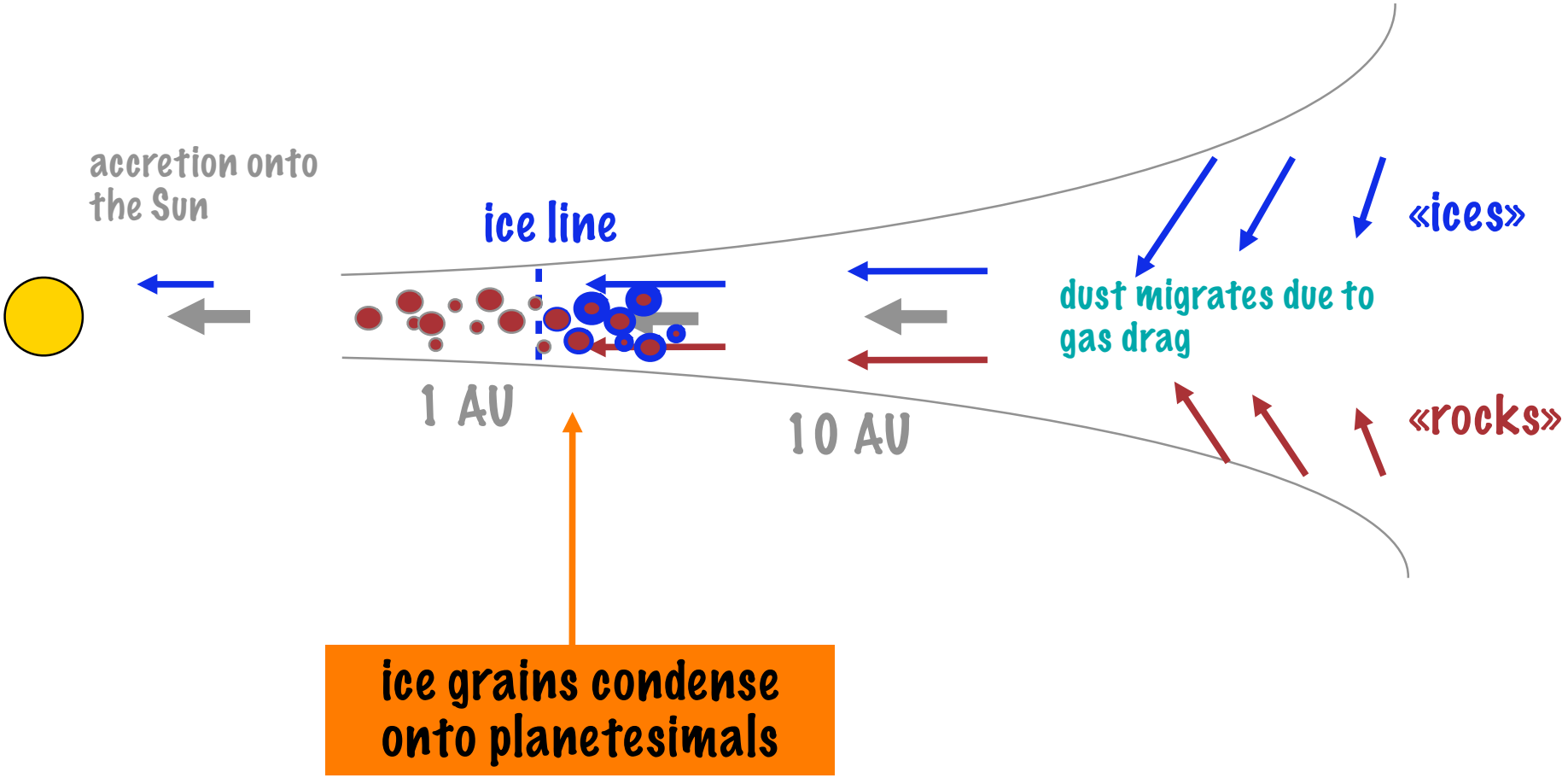
Guillot & Ida, in preparation

Evolution of the dust and gas



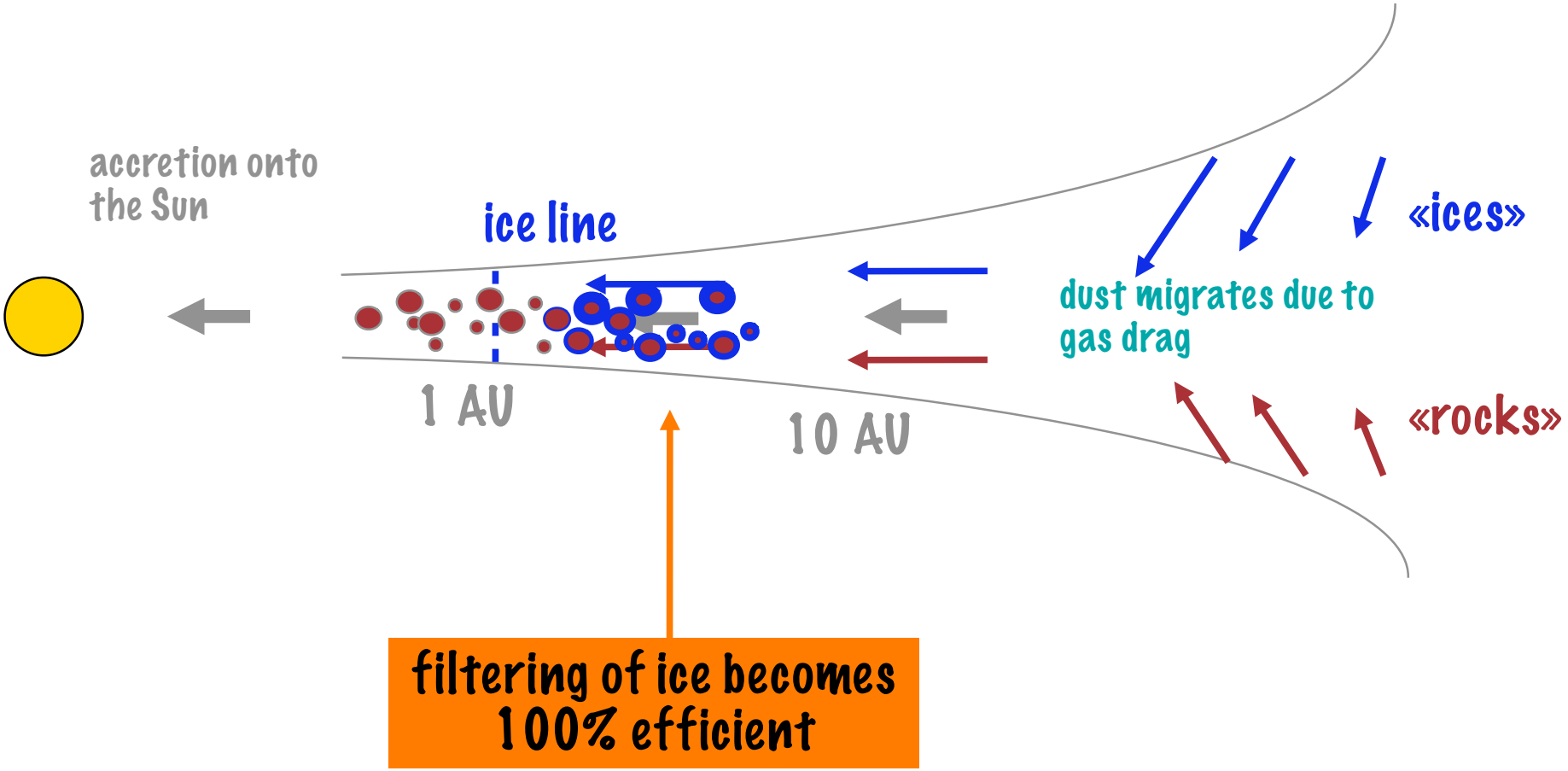
Guillot & Ida, in preparation

Evolution of the dust and gas



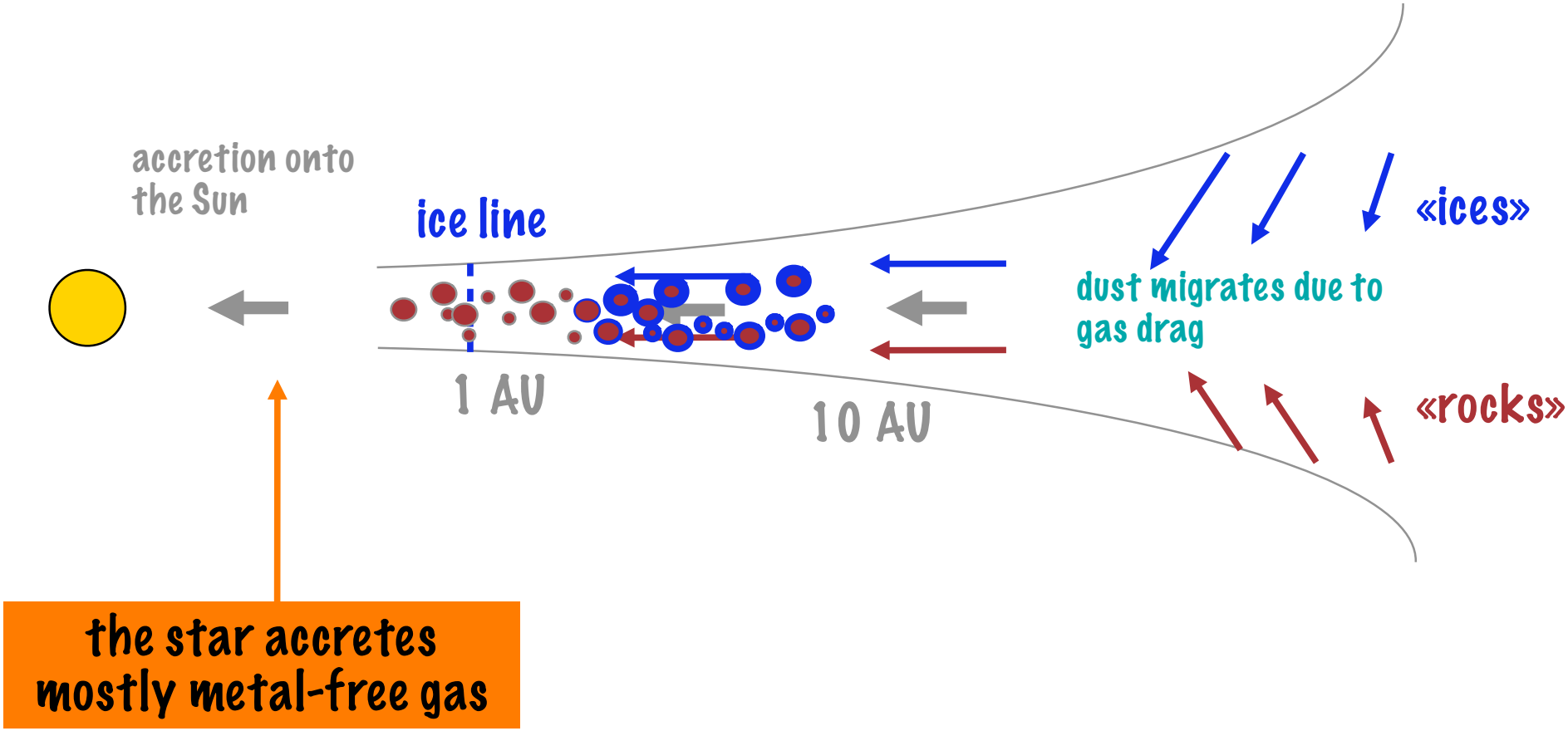
Guillot & Ida, in preparation

Evolution of the dust and gas



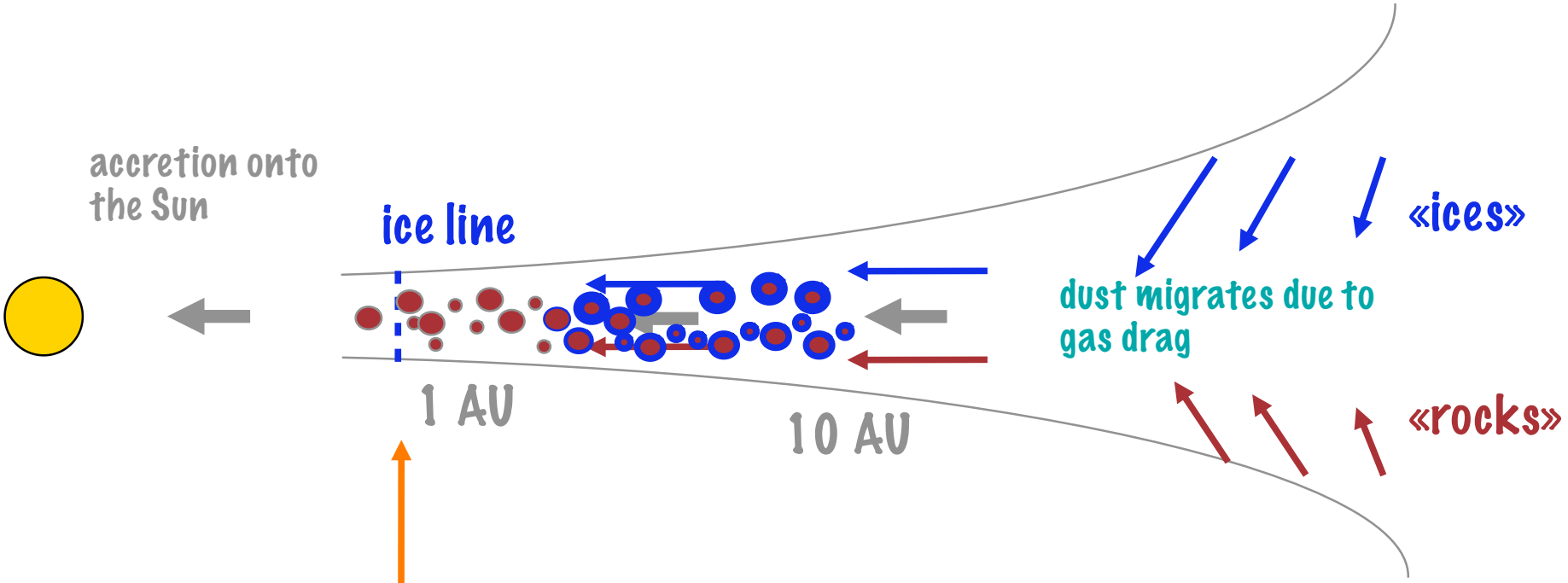
Guillot & Ida, in preparation

Evolution of the dust and gas



Guillot & Ida, in preparation

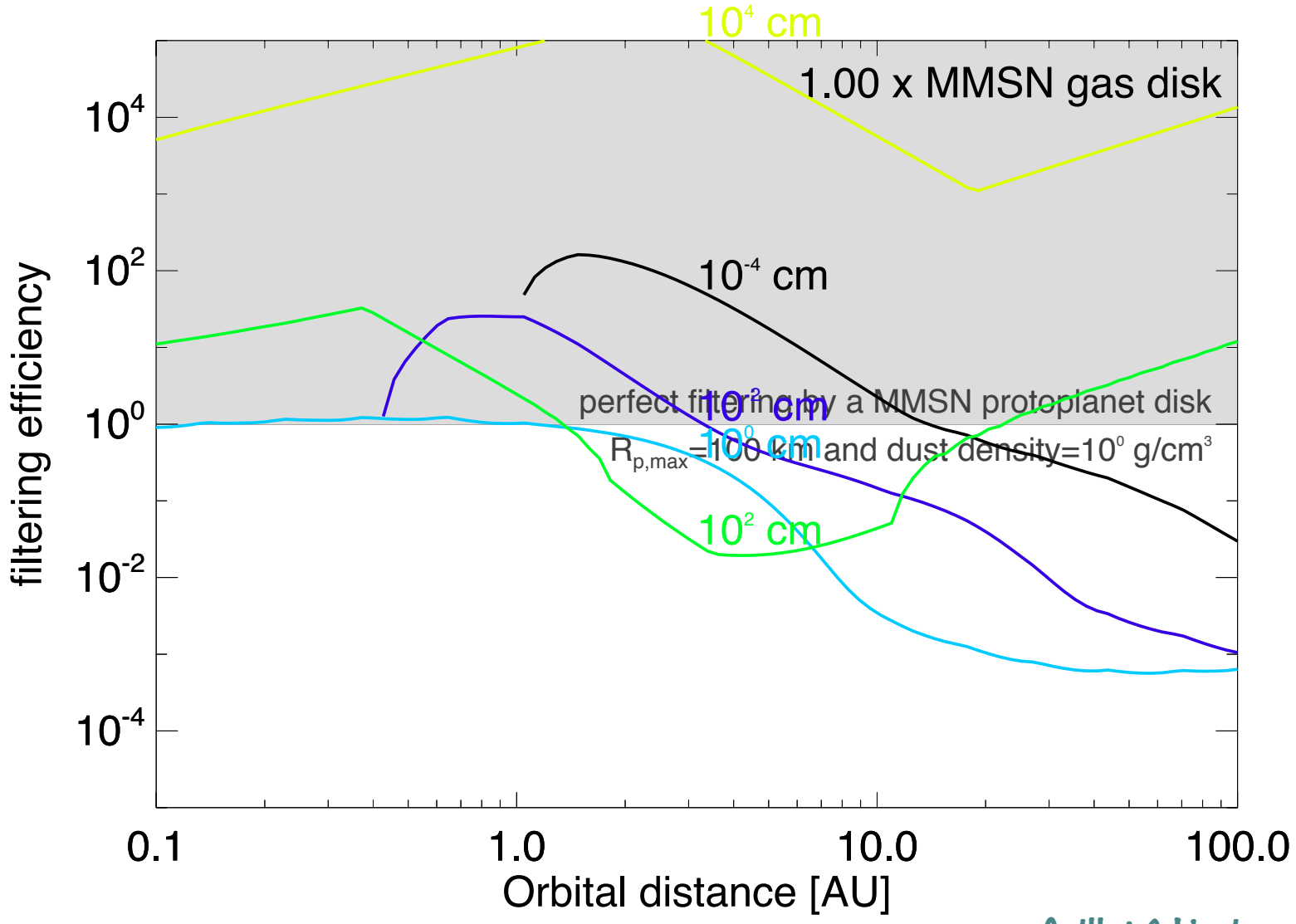
Evolution of the dust and gas



the ice line has moved beyond 1 AU but planetesimals there contain no water

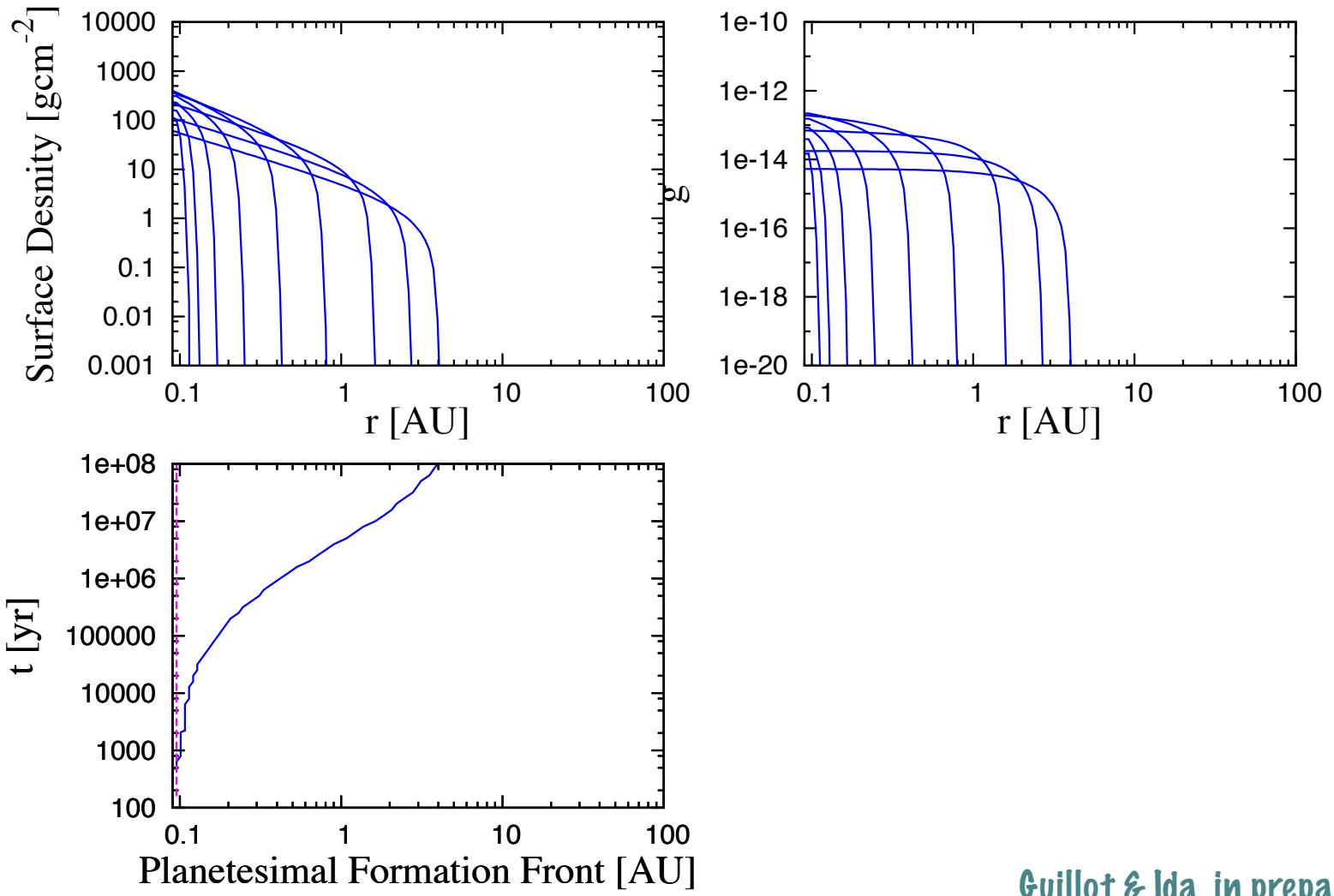
Guillot & Ida, in preparation

Filtering efficiency



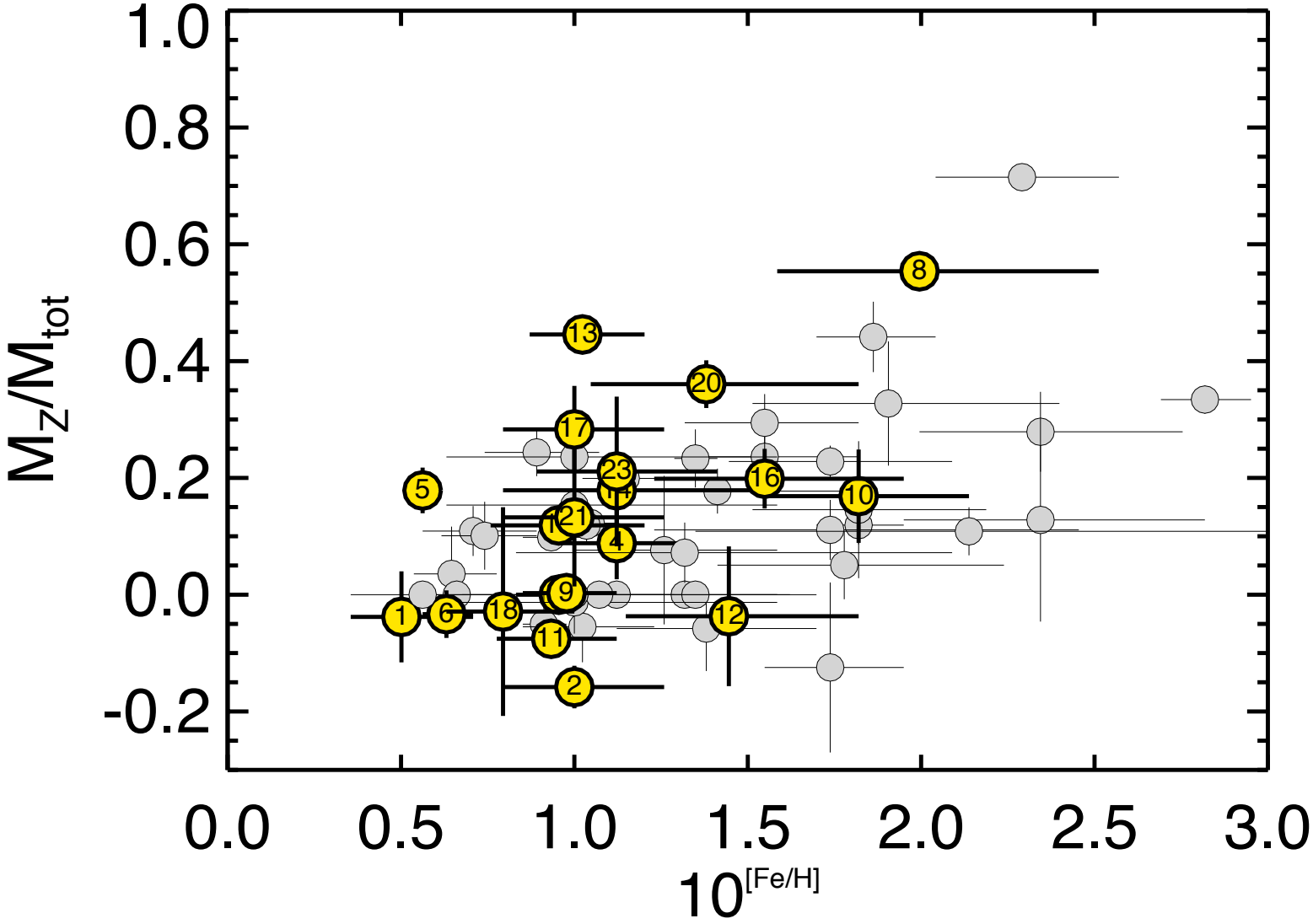
Guillot & Ida, in preparation
see Ormel & Klahr 2010,
Sekiya & Takeda 2003

Evolution of the planetesimal formation front



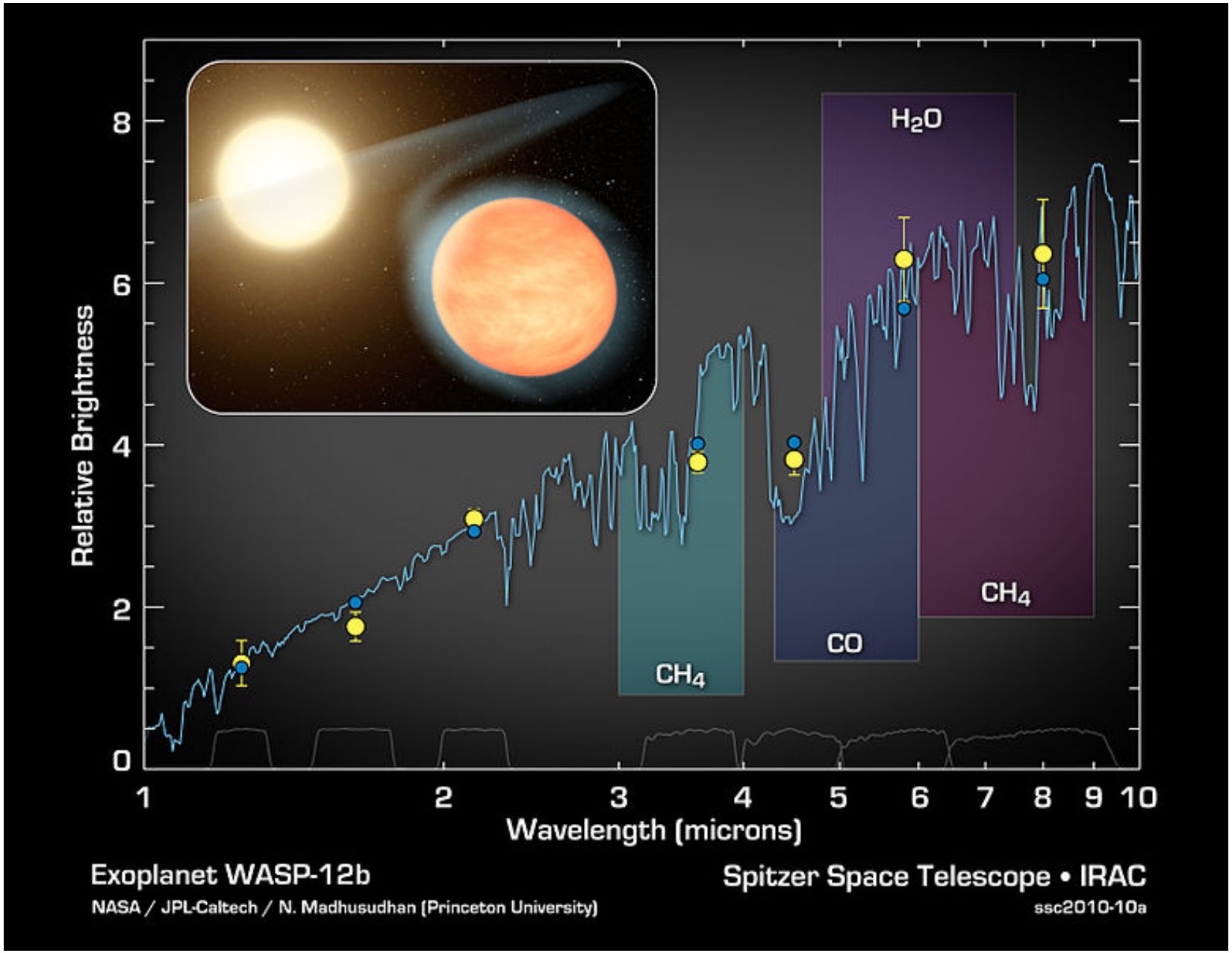
Guillot & Ida, in preparation

Compositions of exoplanets: global



Moutou et al. (Icarus 2013)
see also Guillot et al. (2006), Guillot (2008), Burrows et al. (2007), Laughlin (2011), Miller & Fortney (2011)...

Compositions of exoplanets: atmospheres



Conclusion

- **Rich** confrontation between Solar System, exoplanetary science and general astronomy
- We have the **building blocks** for **planet formation** but are missing some crucial pieces
- We have the possibility to **directly image** planets, including when they are being formed!
- **Measurements of compositions** of stars, planets, protoplanetary disks are becoming **possible**.