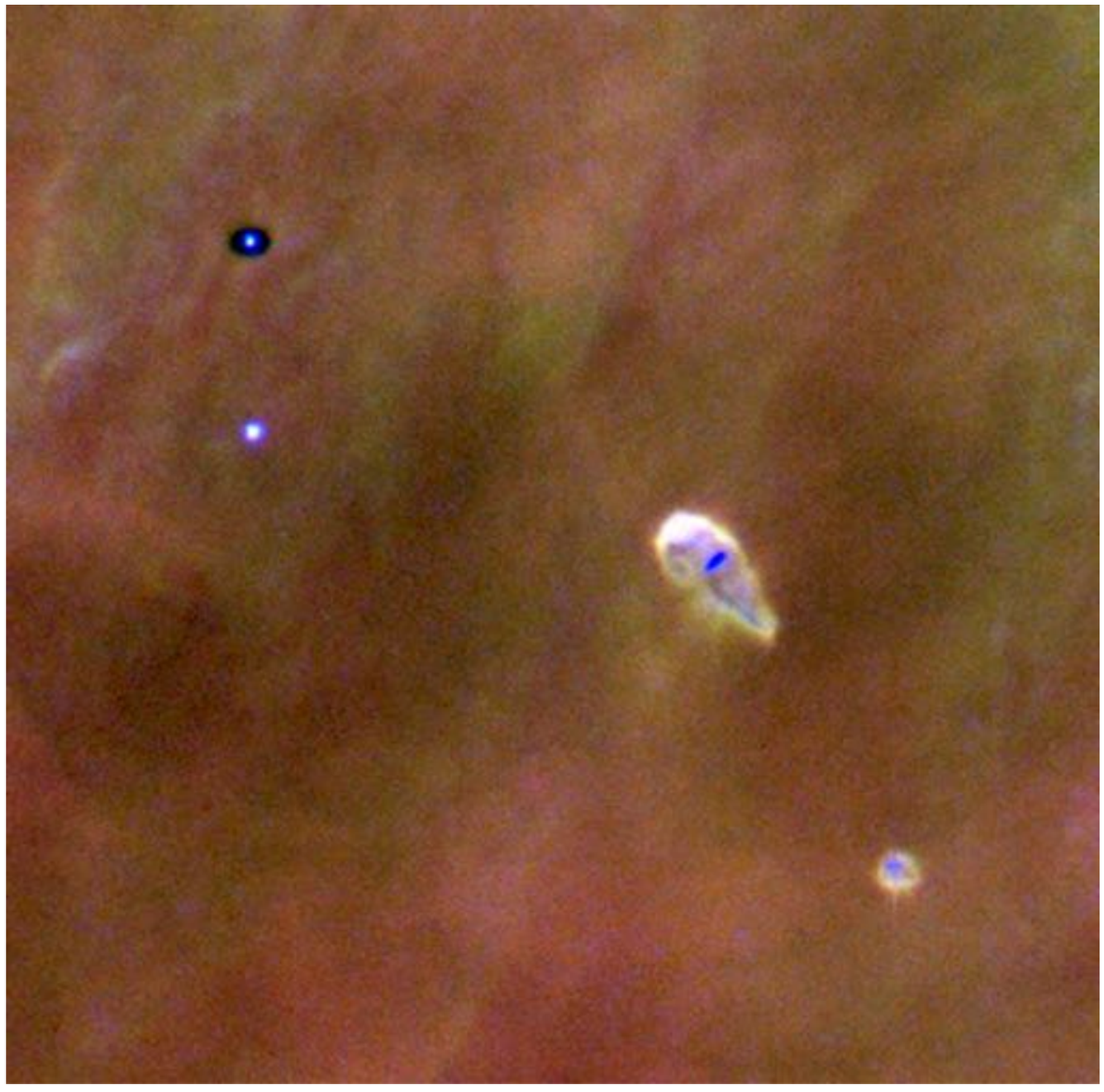
Protoplanetary disks with JWST



Olivier Berné (IRAP, CNRS and Univ. Toulouse)

SF2A 2015 / Toulouse / Jun 3 2015

How is this presentation biased ?

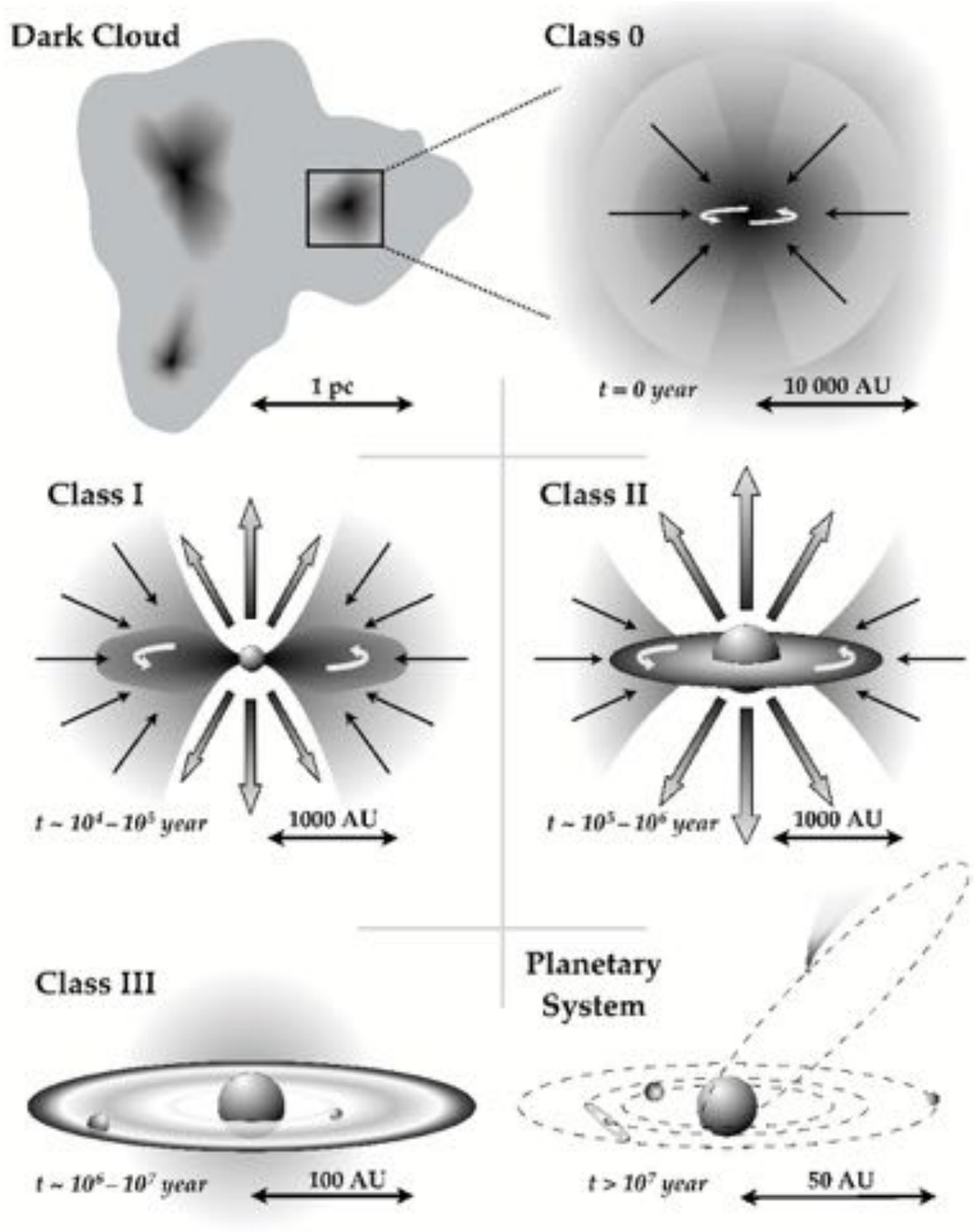
There will be a lot of ALMA/NOEMA vs JWST
(see also general discussion in the ALMA/NOEMA synergy with other facilities tomorrow in S14)

I will speak mostly about what can be done with MIRI

I will show examples of disks around mostly Ae/Be stars
(because they are extended and bright in the mid-IR, but most of what I will say applies to T-tauri stars)

I will not talk much about PAHs in disks
(see presentation of P. Pilleri)

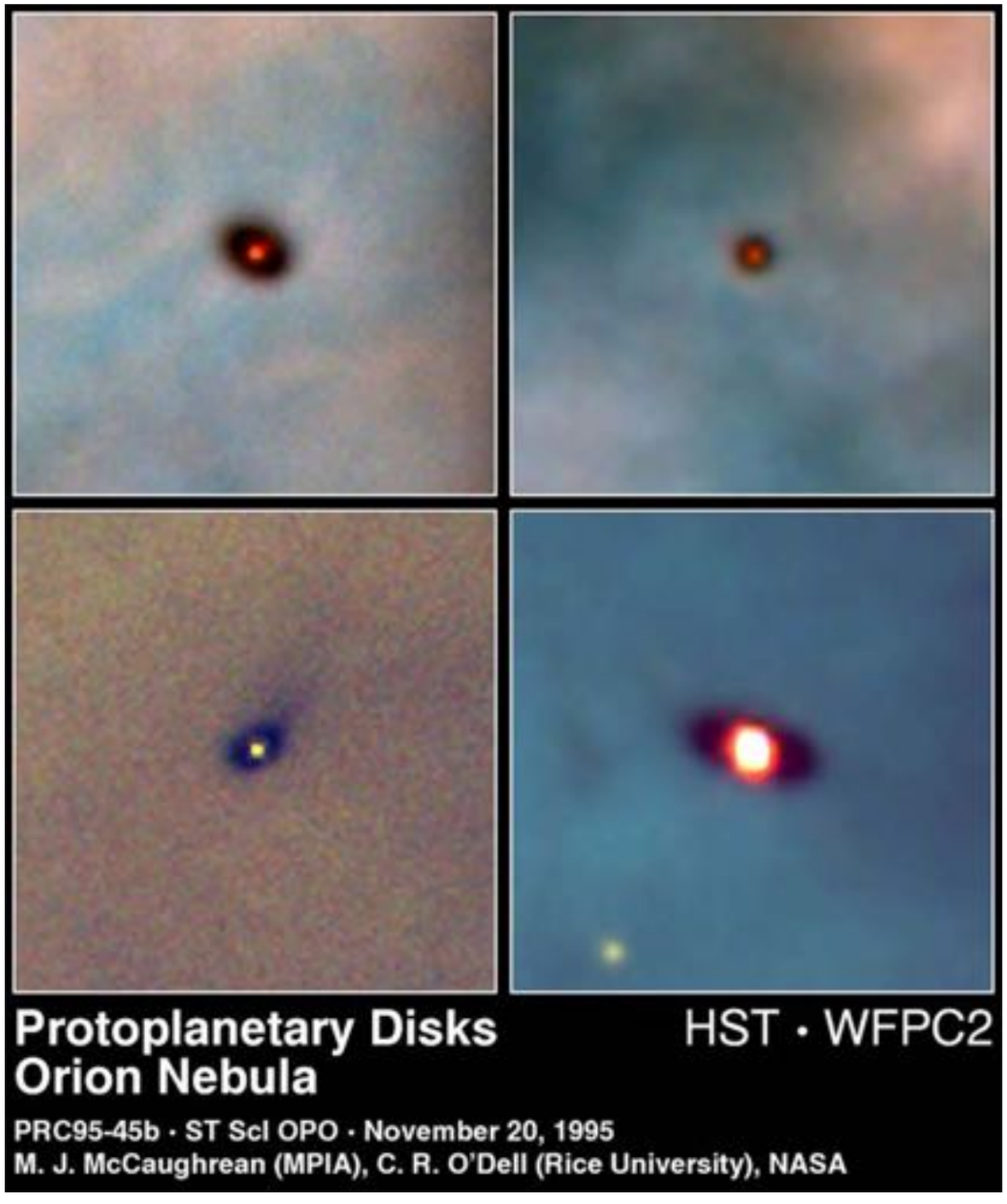
Context : star and planet formation



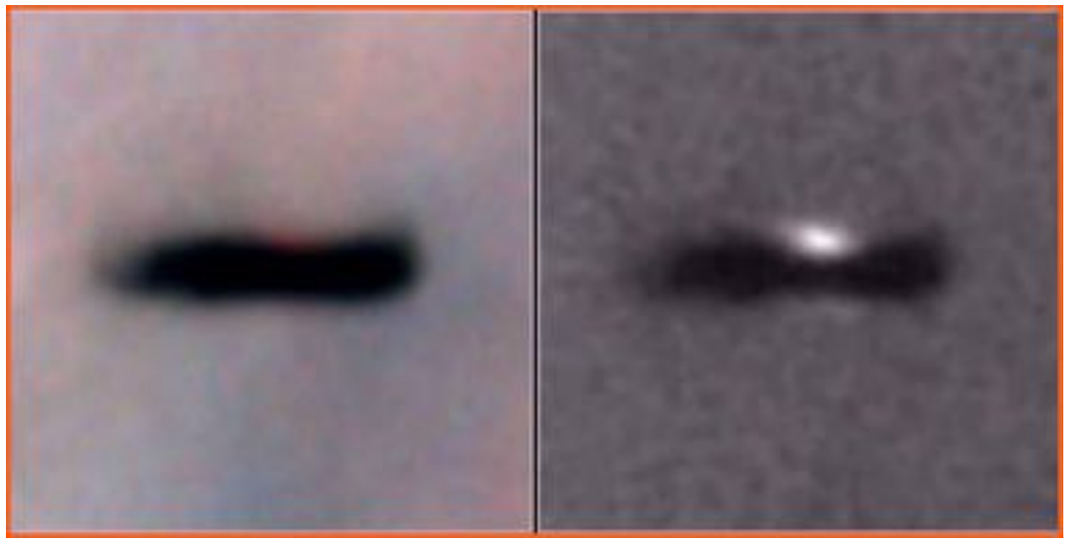
[Shu 1989] [Frieswijk, PhD, 2008]

Direct observations of disks

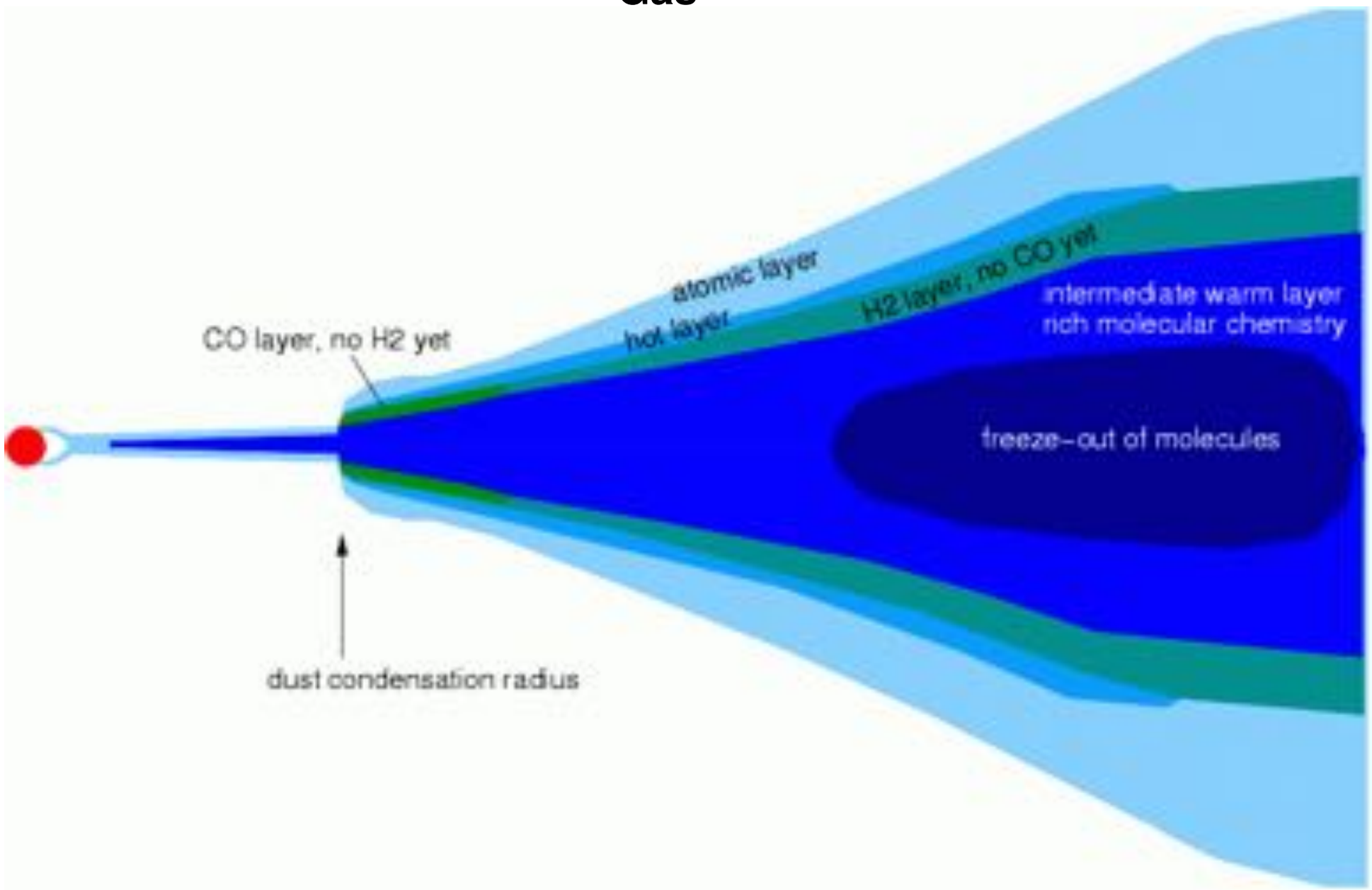
Face on



Edge on

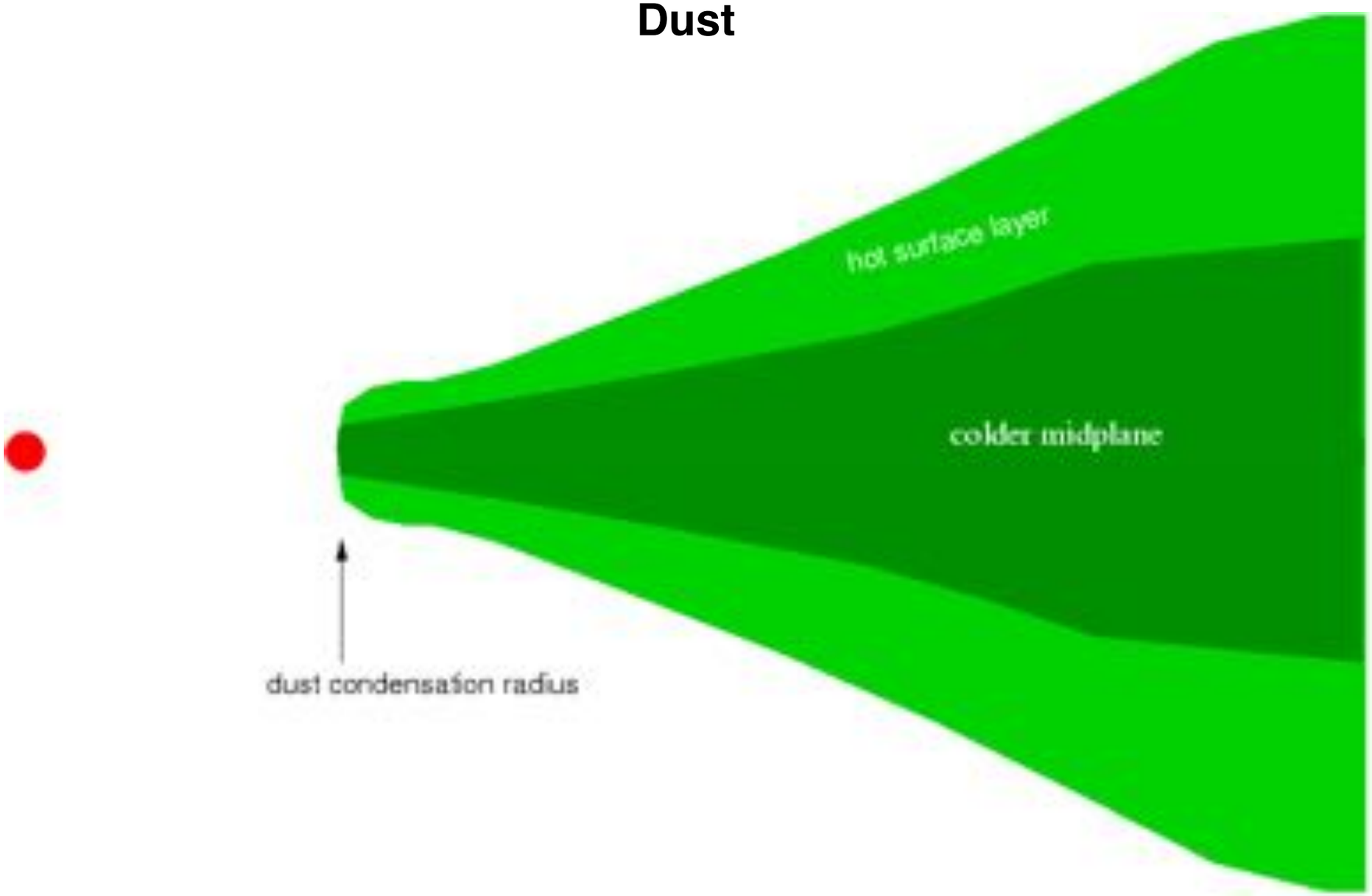


Morphology and structure



Courtesy of I. Kamp

Morphology and structure



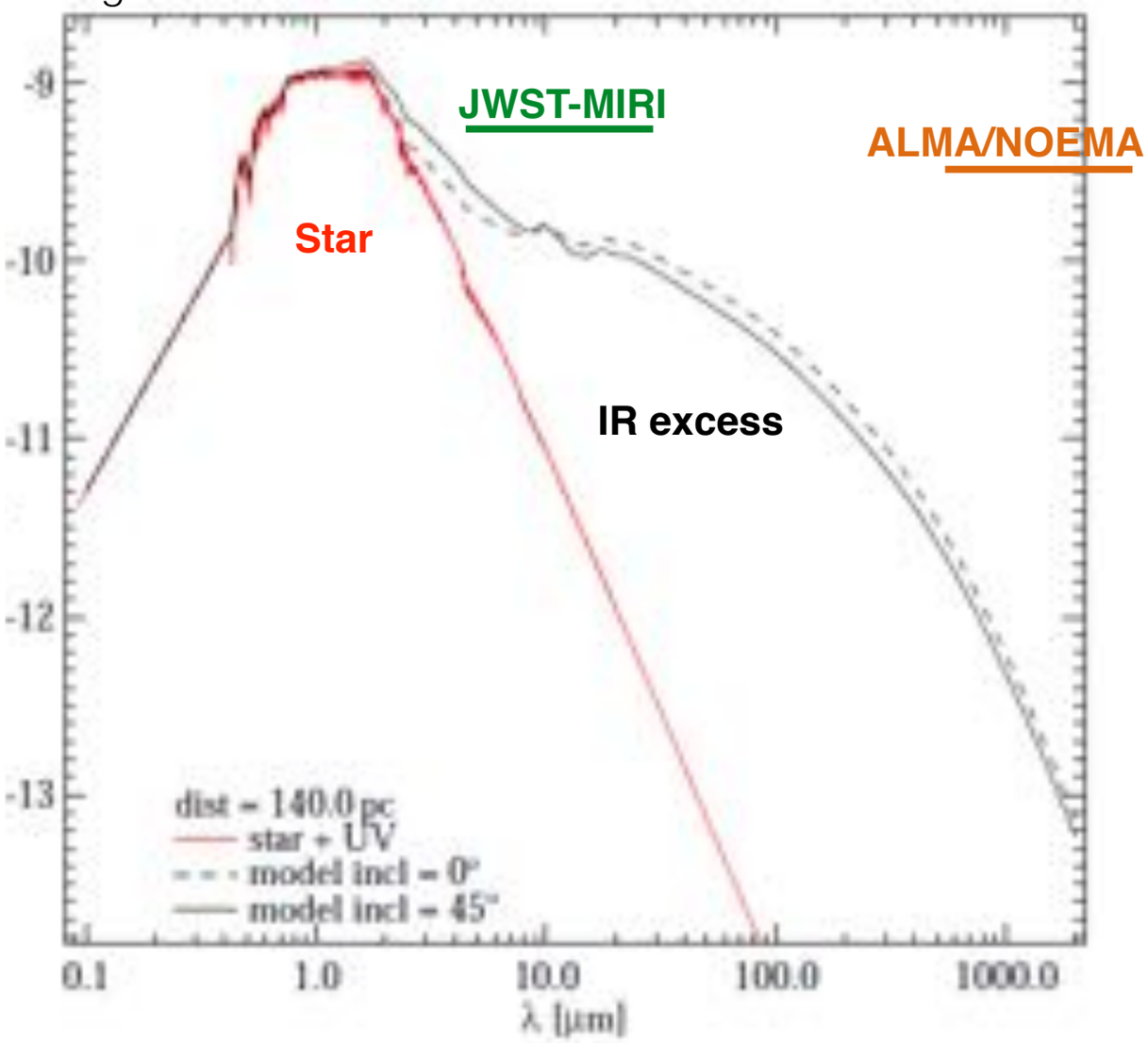
Courtesy of I. Kamp

What are the key questions ?

- **How do planets form ?**
  - Understand the evolution of dust properties : growth, chemical structure
  - Understand the dynamical evolution of dust and gas : formation of structures, photo-evaporation
  - Direct observations of protoplanets embedded in their disks
- **What is the chemical inventory at the place and moment planets form ?**
  - Identify the species present in disks, and where they are in the disks
  - Evidence chemical evolution of disks

How do planets form : understand the evolution of dust

Fig. from P. Woitke



ALMA/NOEMA

- **Cold dust**

-> large grains in the disk mid-plane

-> these grains are likely to be decoupled from the gas

JWST-MIRI

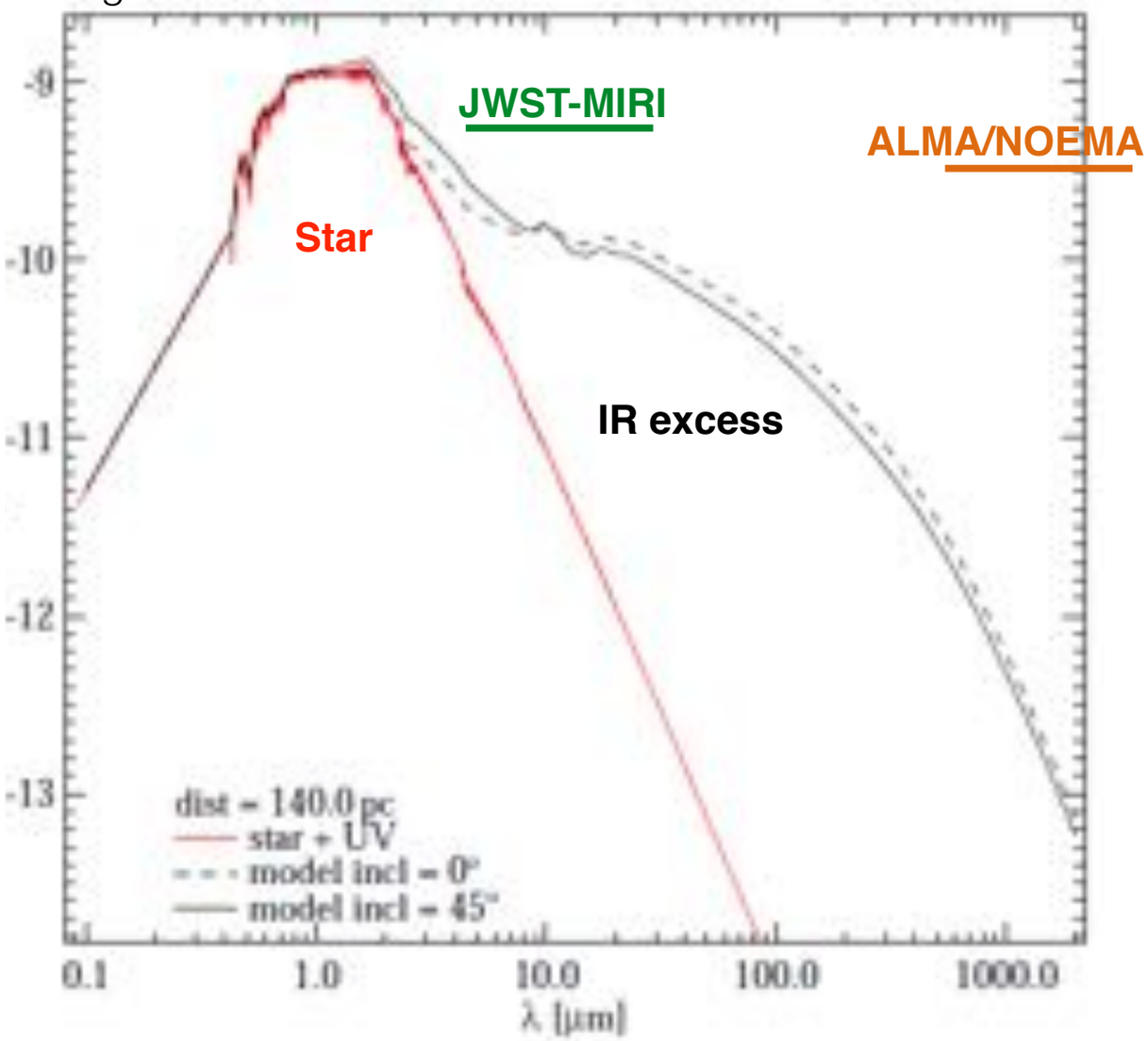
- **Hot dust :**

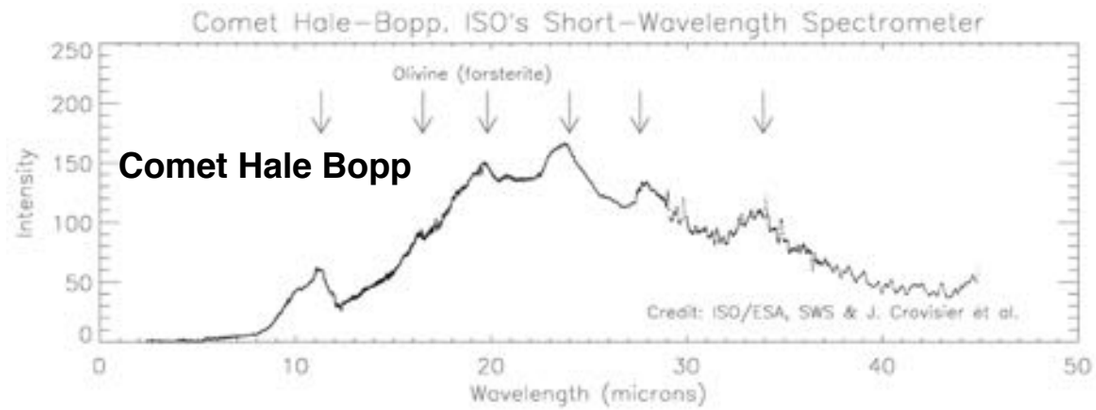
-> Either large hot grains close to the star : dust composition

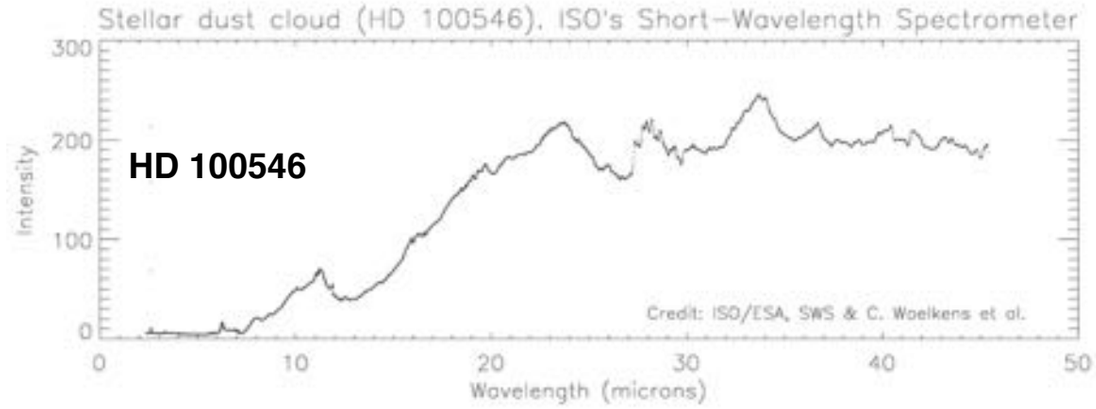
-> Or small (hot) dust grains, coupled to the gas in the upper layers of the disk

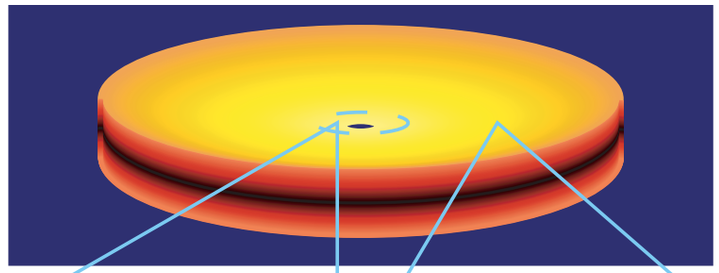
How do planets form : understand the evolution of dust

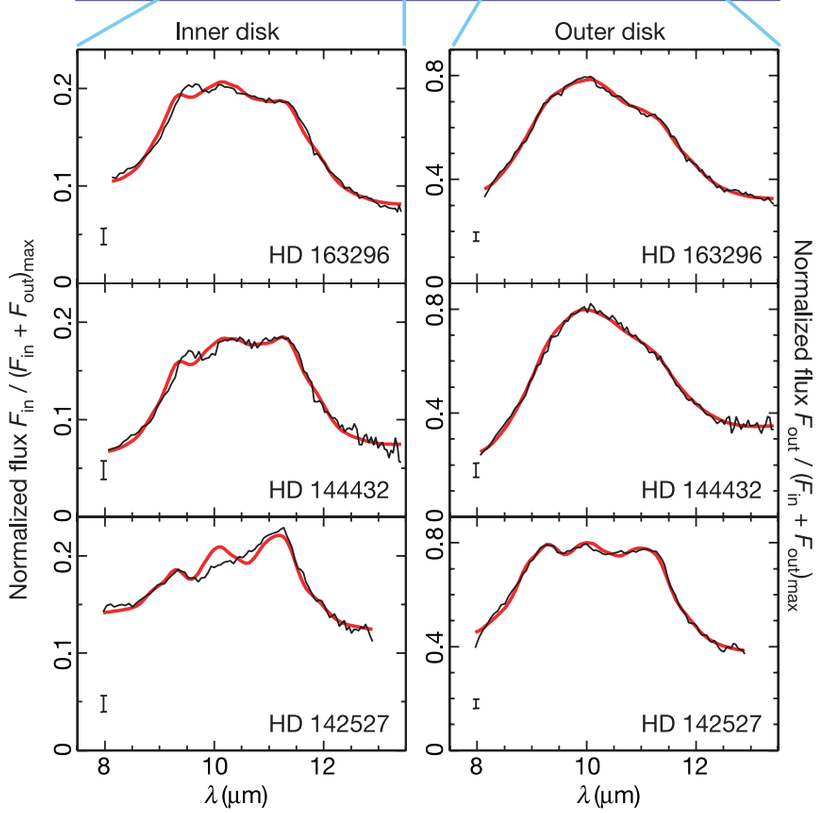
Fig. from P. Woitke







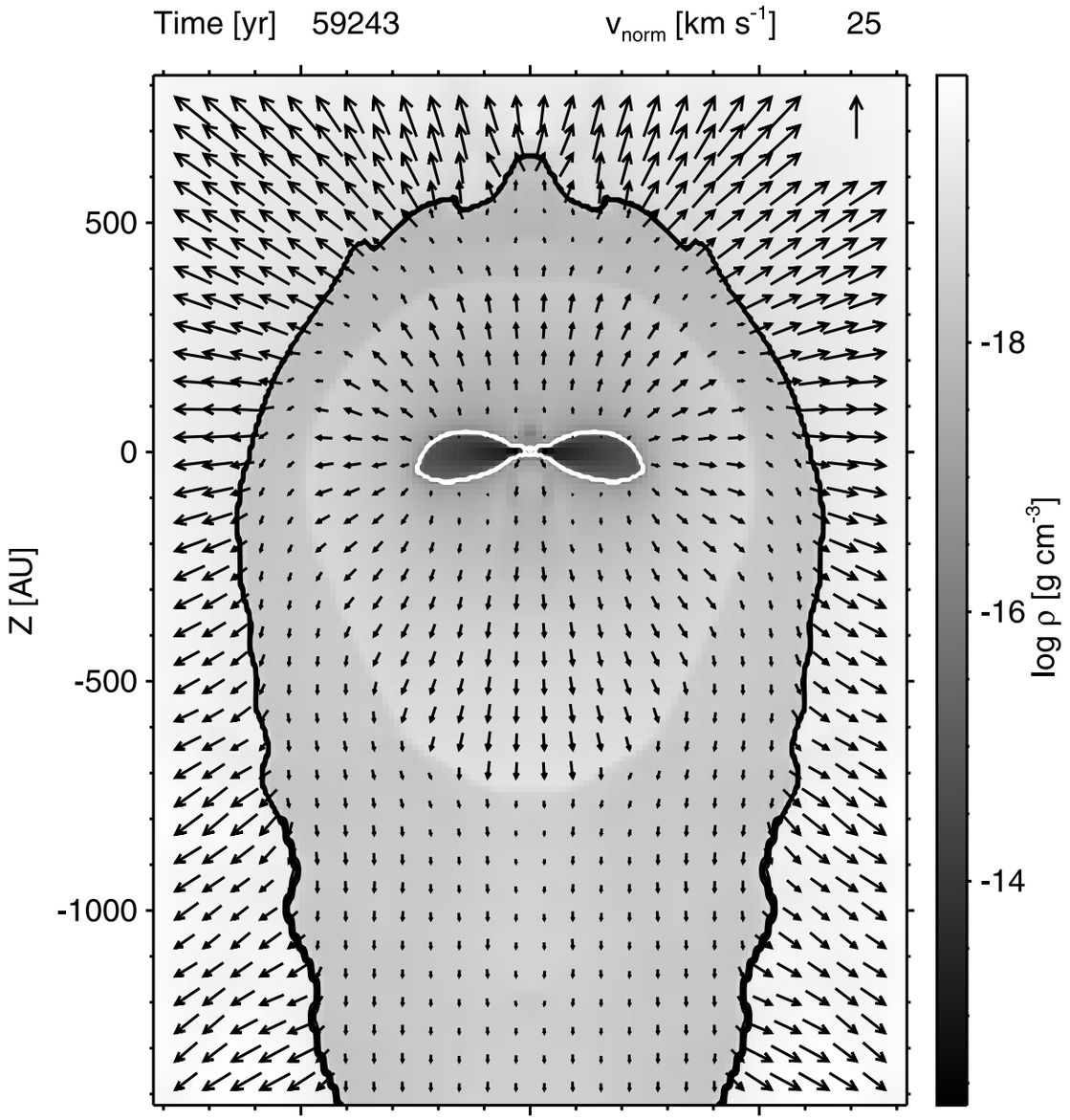




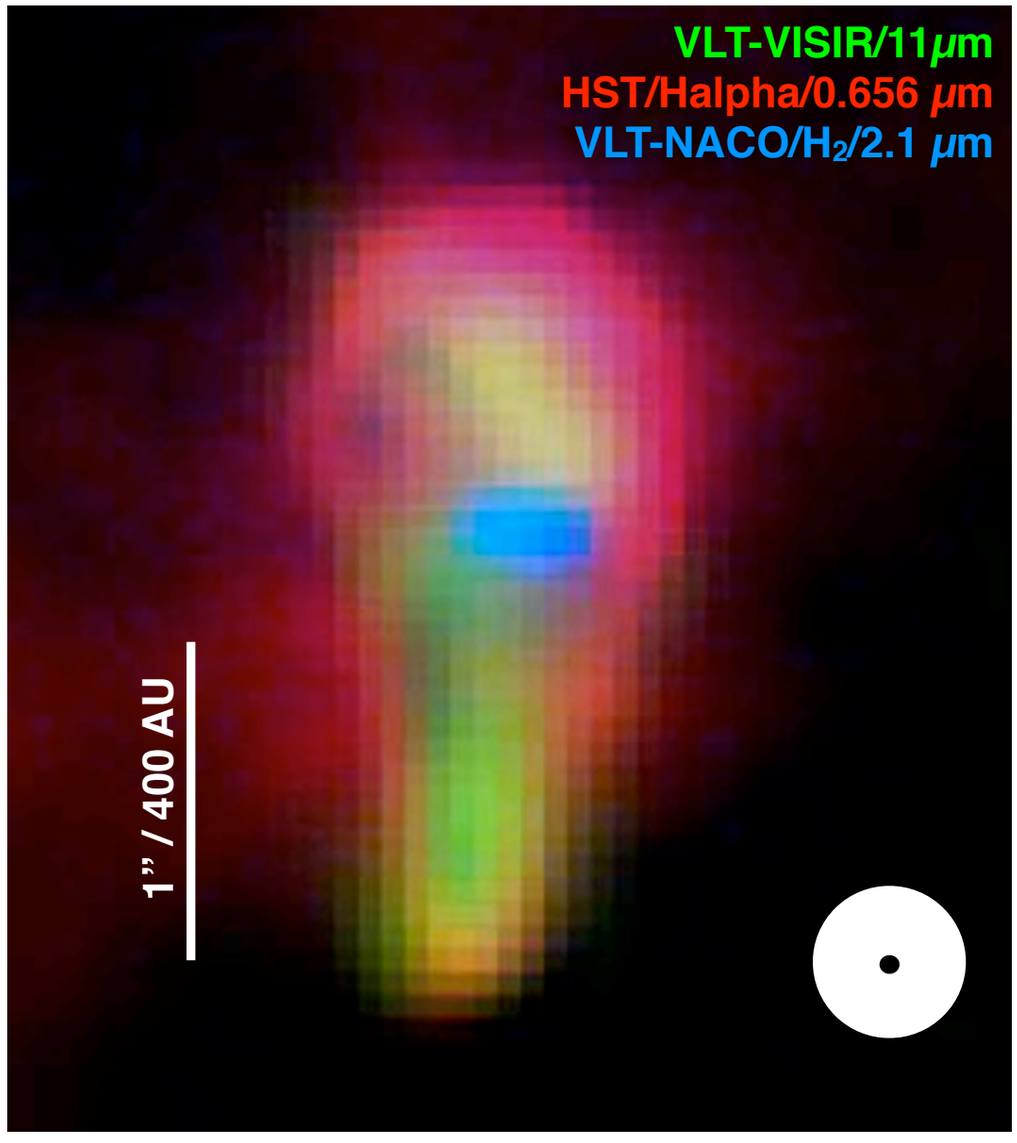
van Boekel et al.

How do planets form : understand the dynamical evolution of dust and gas

Model of a disk irradiated by a nearby massive star [Richling & Yoke 2000]



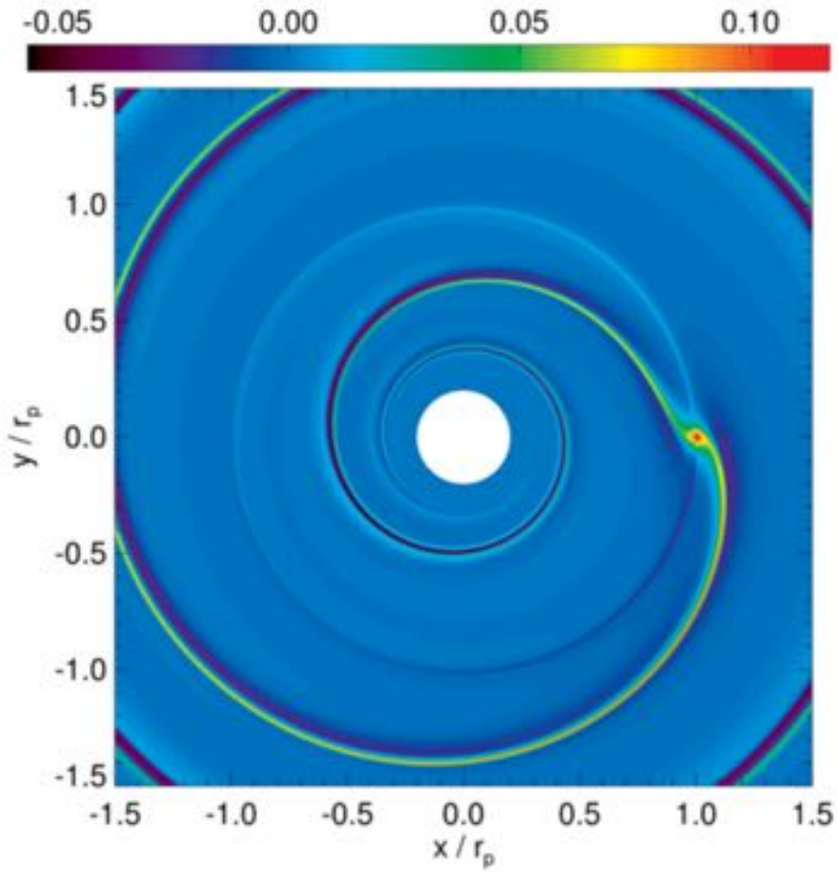
Observations in Orion [Vicente et al. 2013]



cf. presentation of J. Champion on proplyds in S09

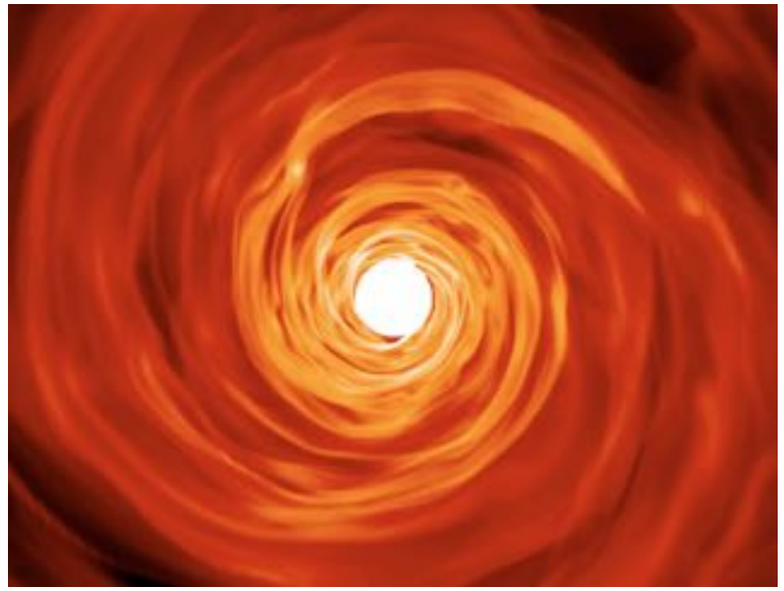
How do planets form : understand the dynamical evolution of dust and gas

Spiral density waves generated by a planet

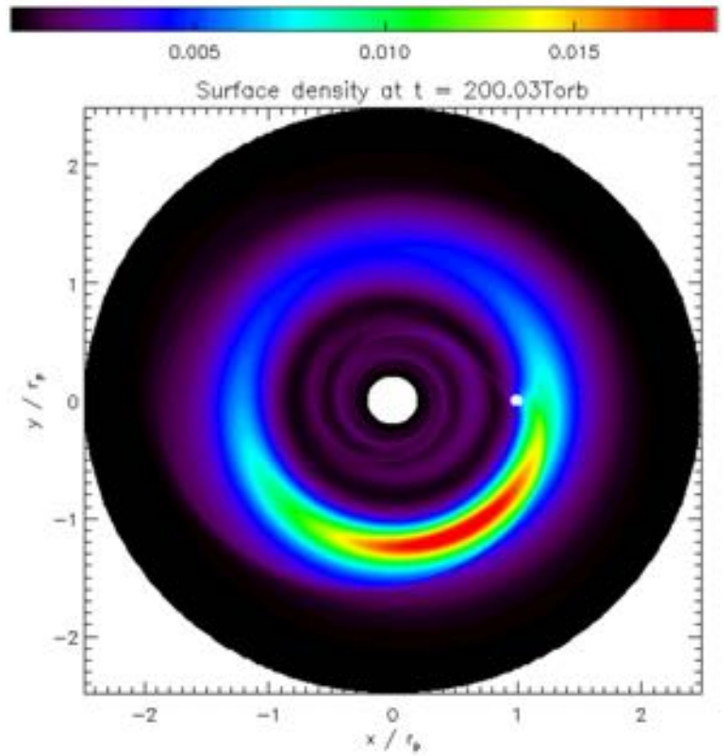


[Baruteau et al. PPVI 2014]

Spiral density waves generated by the gravitational instability



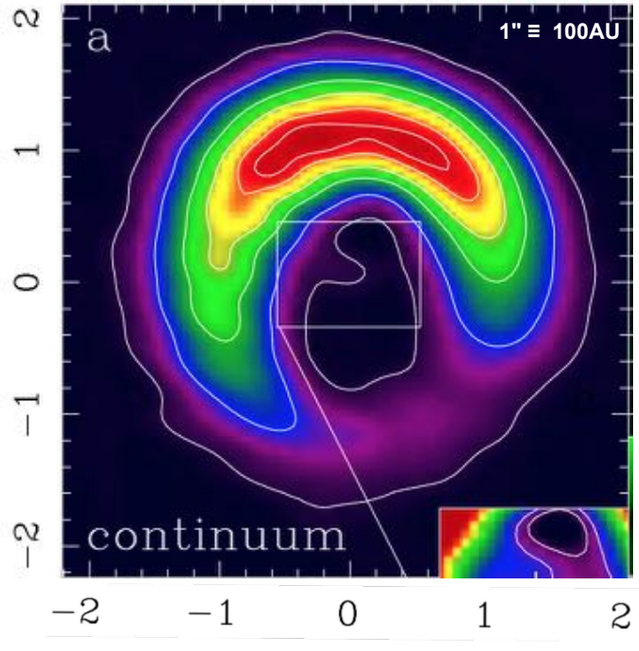
Lopsided dust concentration due to the Rossby wave instability



[Baruteau priv. com.]

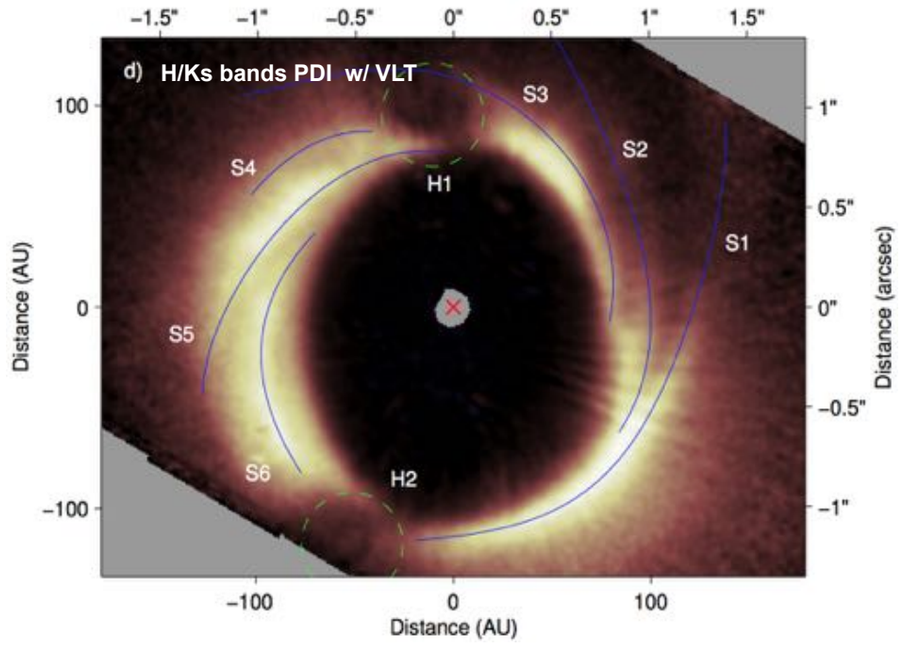
How do planets form : understand the dynamical evolution of dust and gas

HD 142157



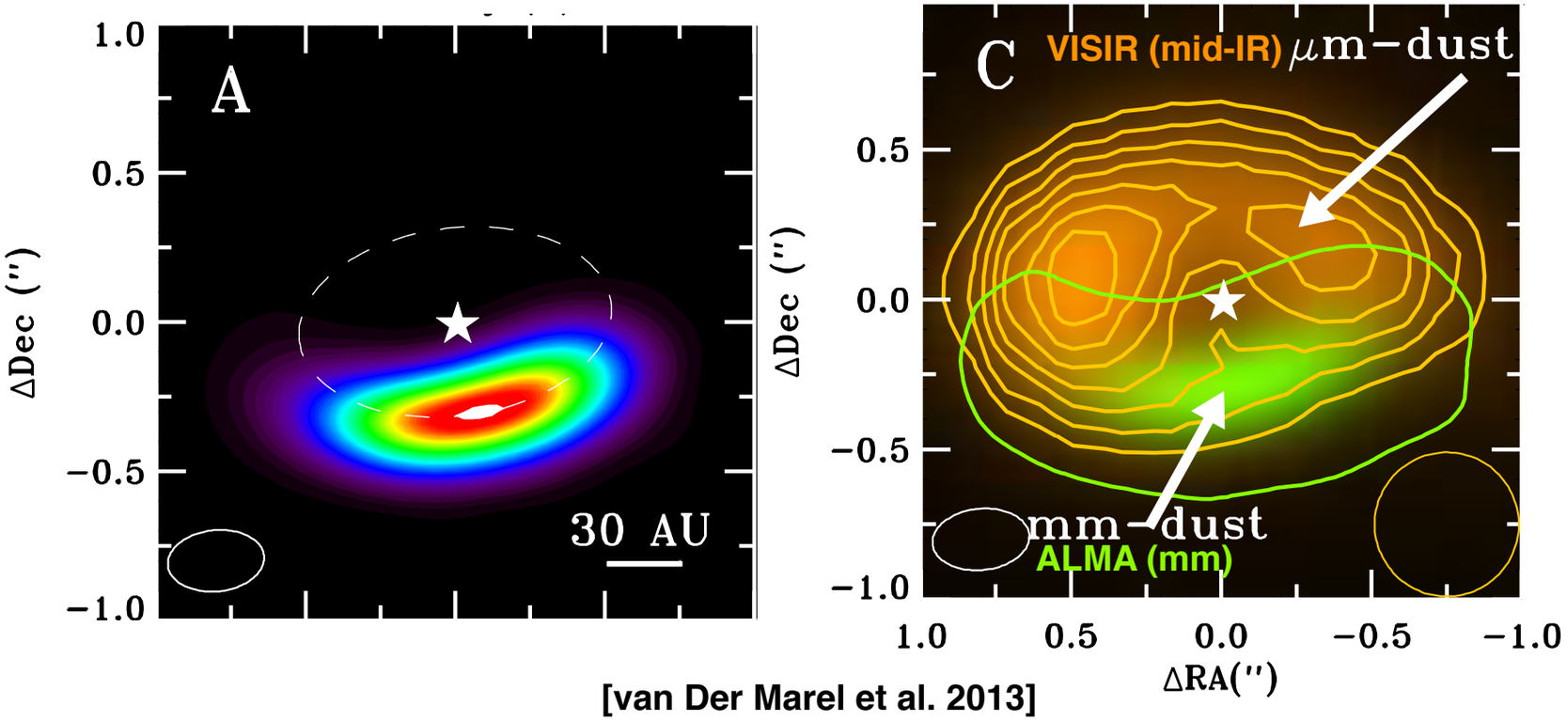
[Cassasus et al. 2013]

Near IR



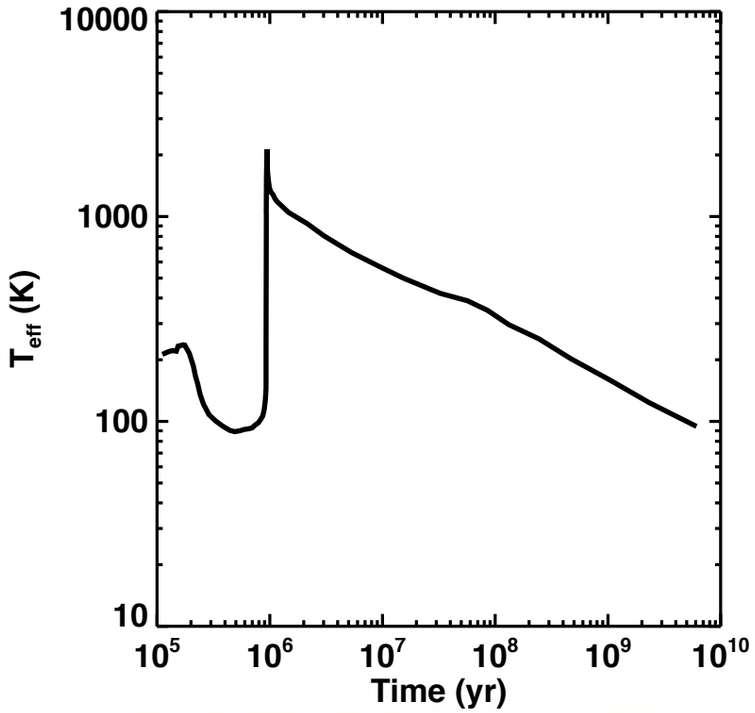
[Avenhaus et al. 2014]

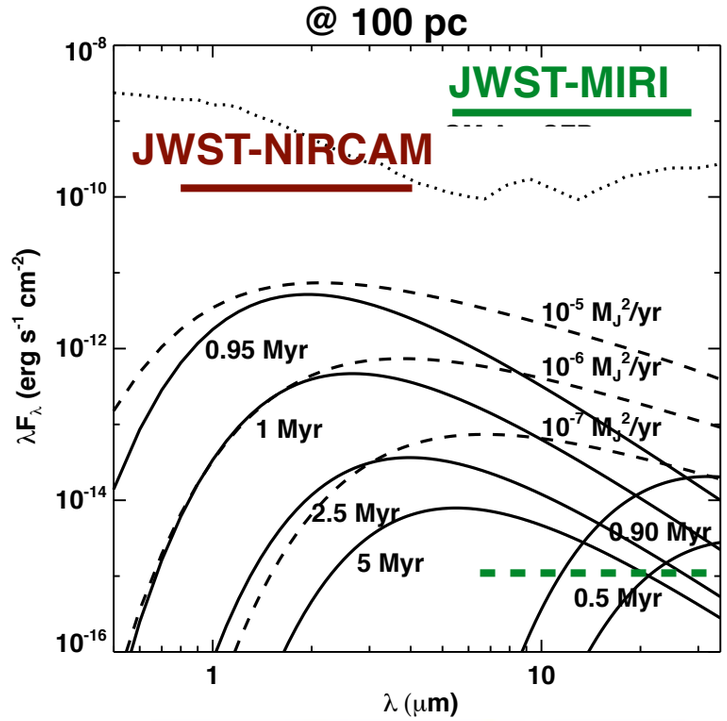
IRS 48



[van Der Marel et al. 2013]

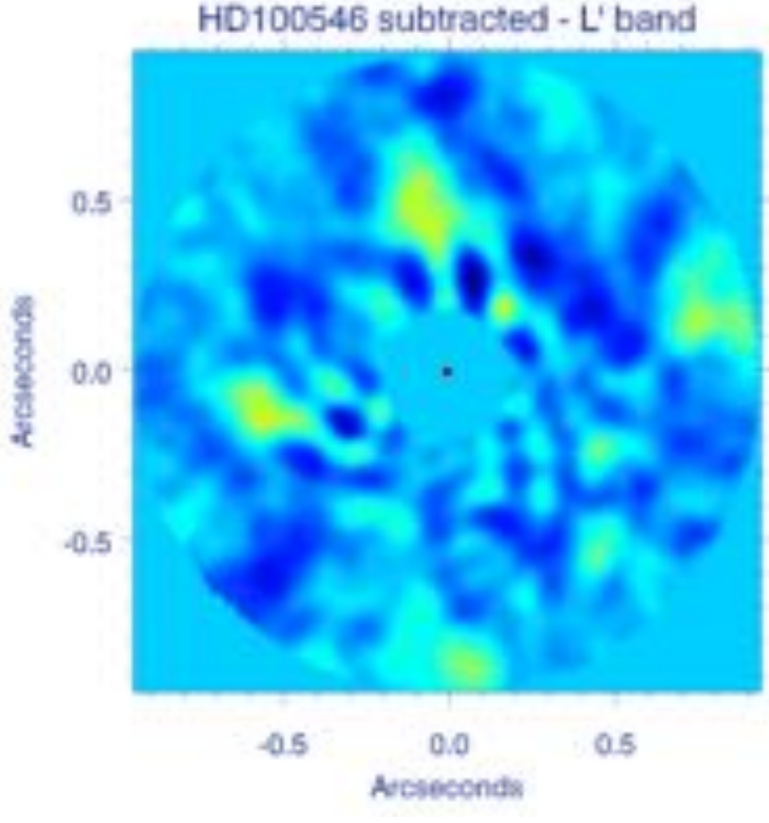
How do planets form : direct observation of protoplanets

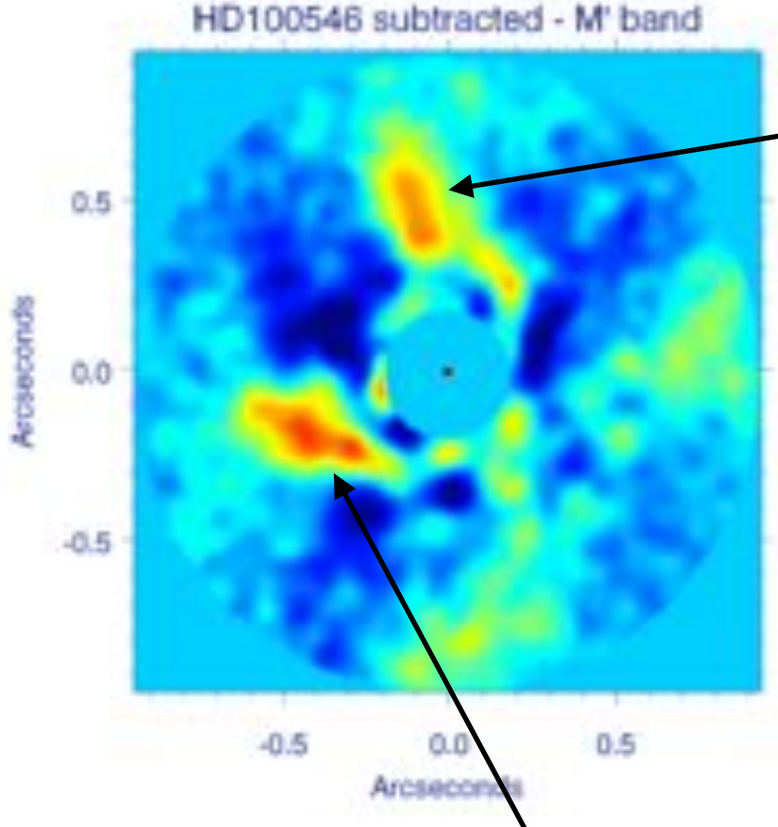




[Eisner 2015]
[Zhu 2014]

1 sigma/pixel in 20 minutes



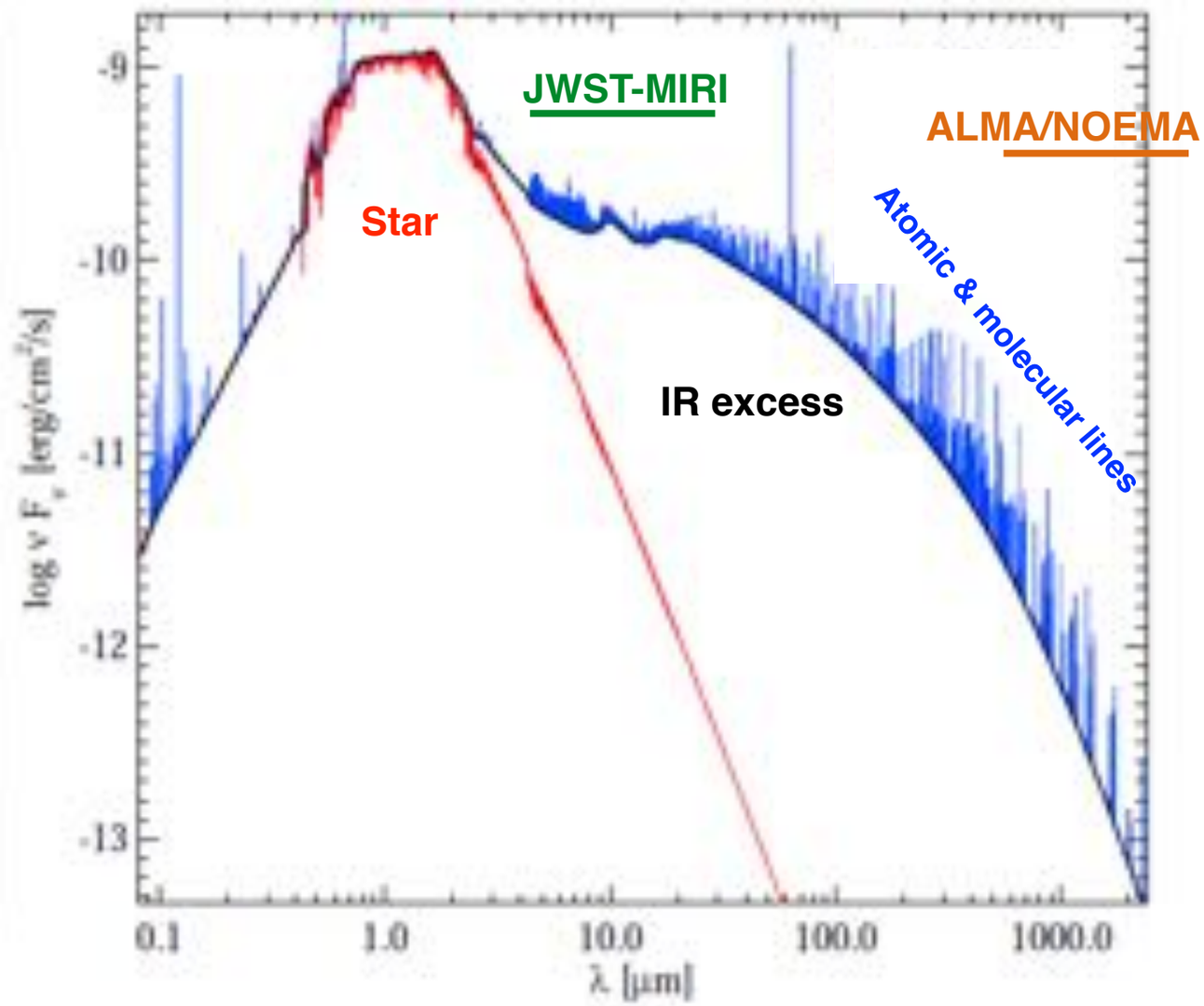


Protoplanet ?
Temp ~ 1000 K
Mass : ~ 1-15 M_{Jup}

[Quanz et al. ApJL 2013, 2015]

Spiral

Chemical inventory: what are the species present in disks ?



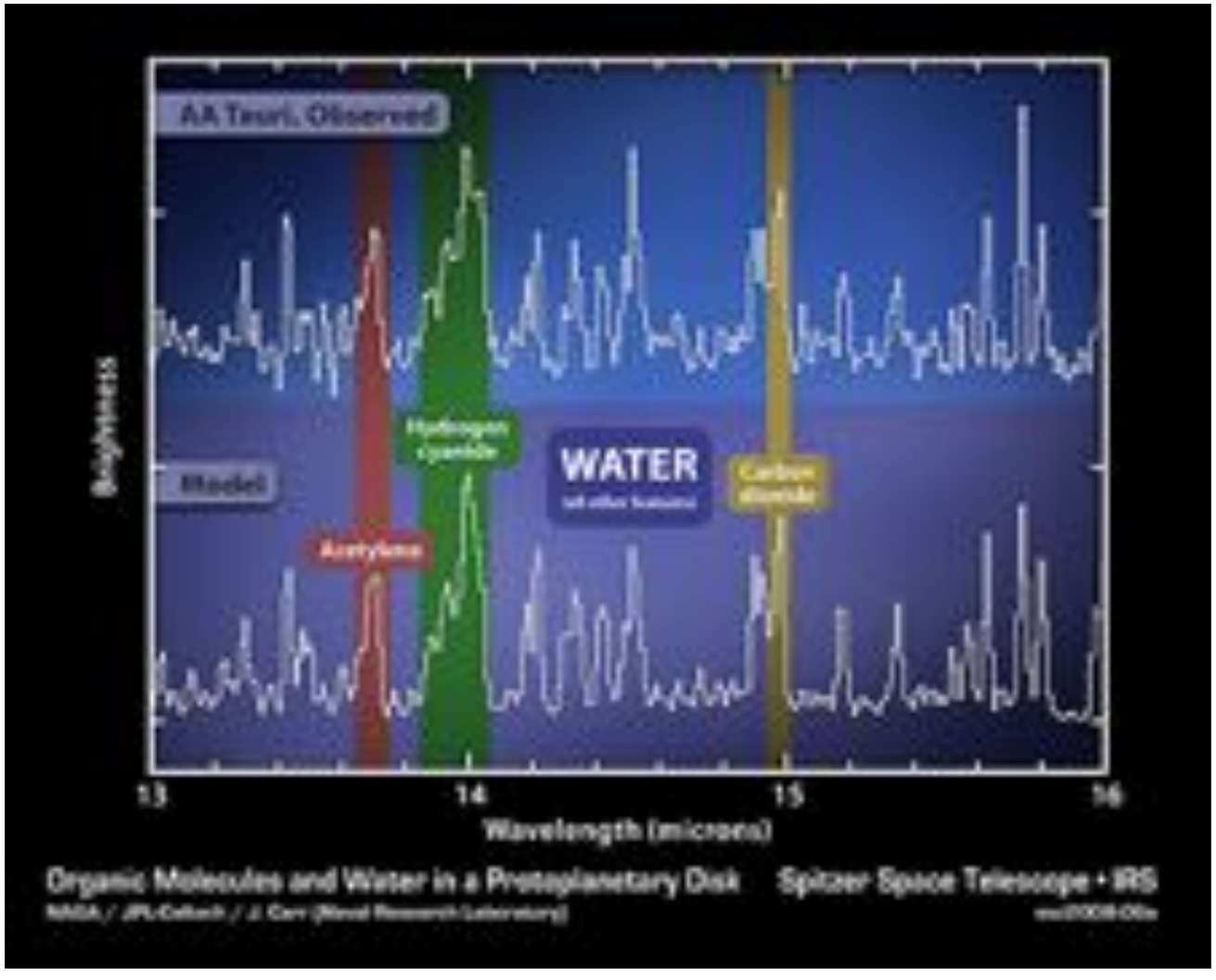
ALMA/NOEMA

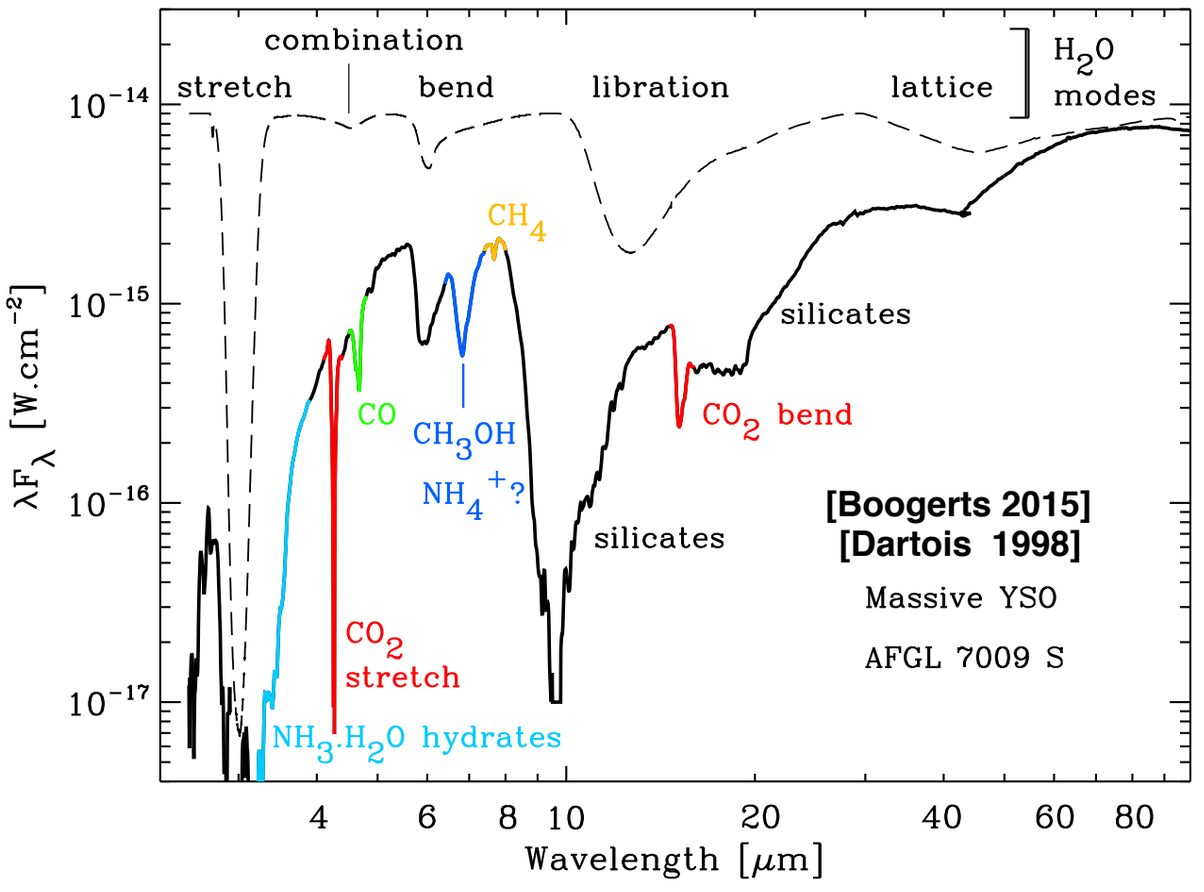
- Rotational transitions from molecules with dipole moment
- Cold molecular gas

JWST-MIRI

- Vibrational transitions from molecules (including molecules with no dipole moments)
- Warm molecular gas
- Molecules present in ices covering dust grains

Chemical inventory: what are the species present in disks ?

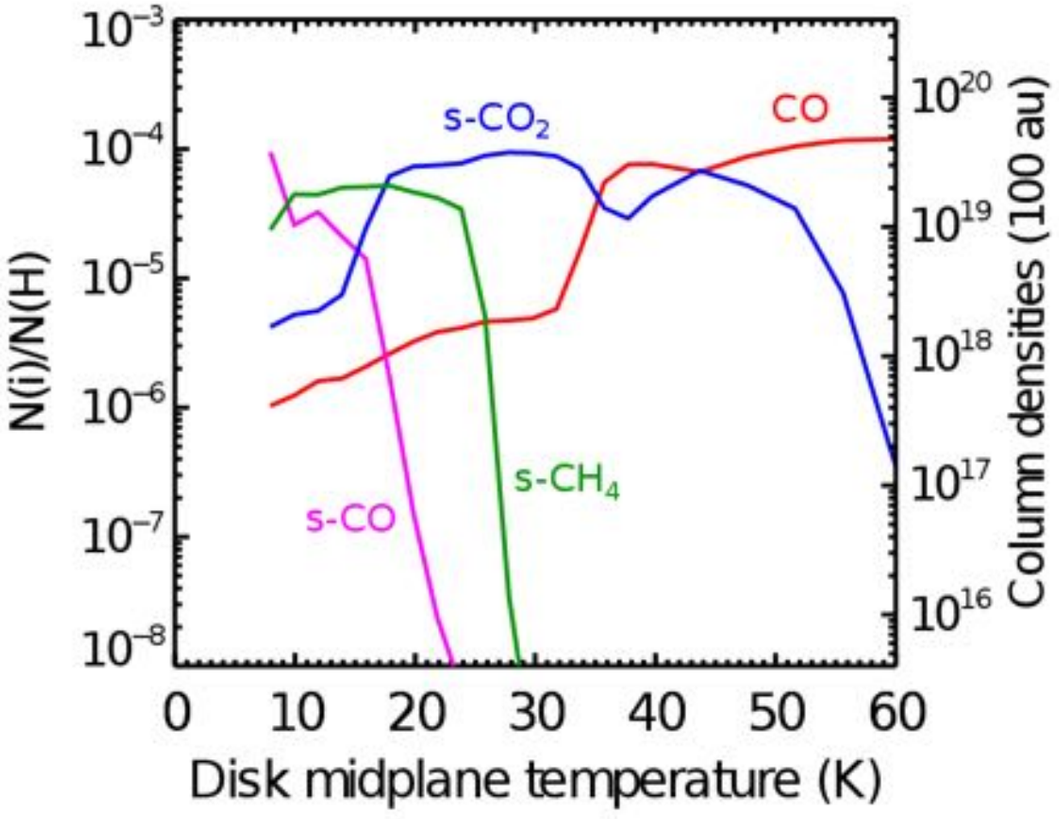




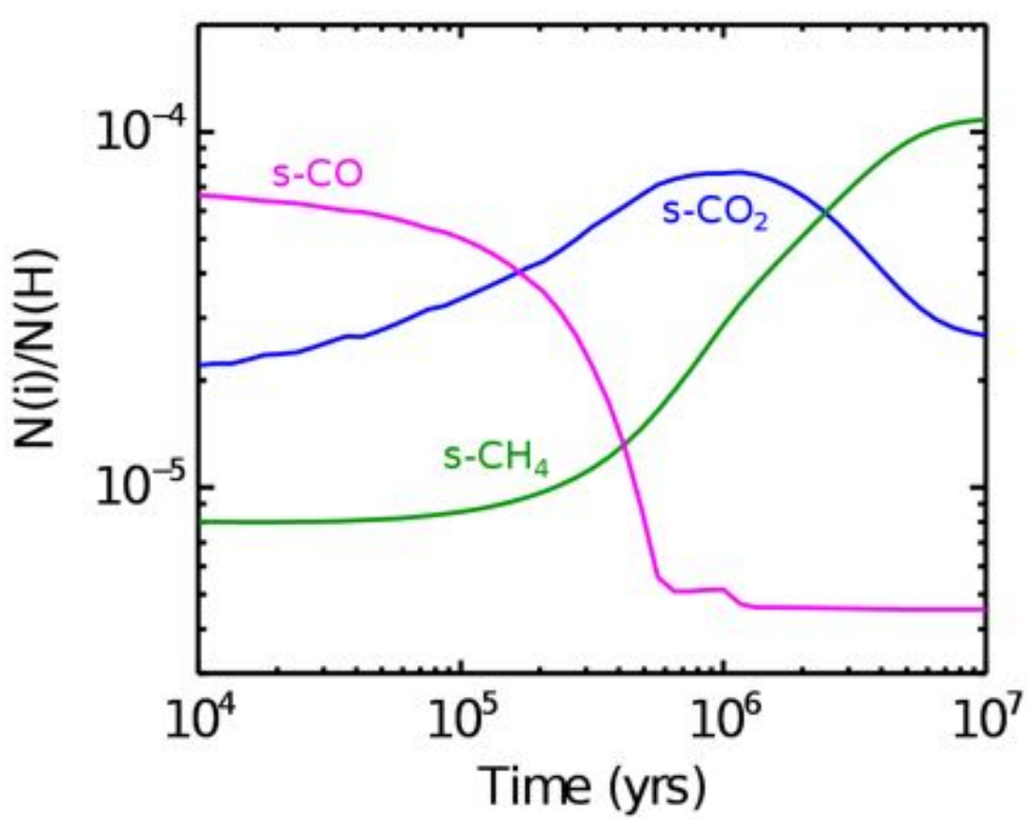
- Spatially resolved observations of the chemical composition
- Sensibility to key species which are very difficult (water) or impossible (like molecular hydrogen/acetylene/carbon dioxide/methane/ethylene/benzene) to observe in the (sub-)mm
- Sensitive to the UV photo-chemistry (largely unexplored) in the gas and in the ices

Chemical inventory: how do disks chemically evolve ?

Dependance with mid plane Temp.



Dependance with time



[Reboussin et al. A&A 2015 accepted]

End