

Chemical changes during transport from cloud to disk

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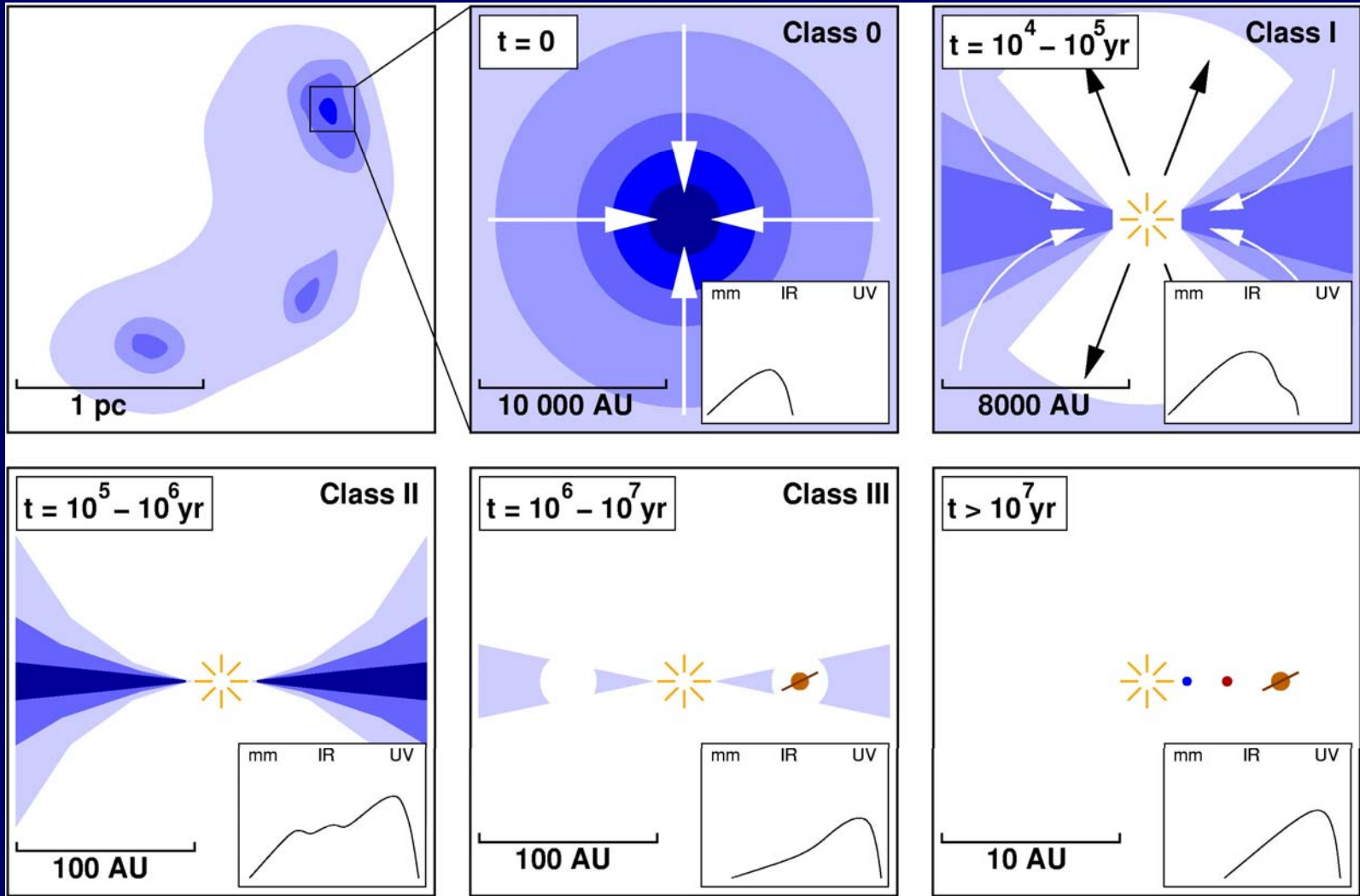


Ewine van Dishoeck, Steve Doty,
Michiel Hogerheijde, Christian Brinch

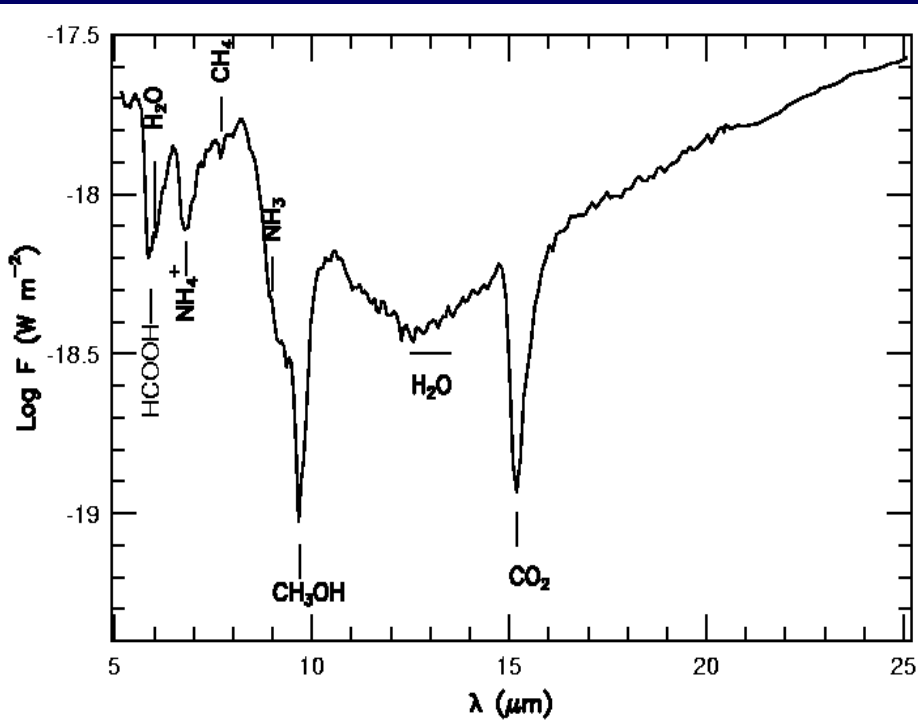


Star and planet formation

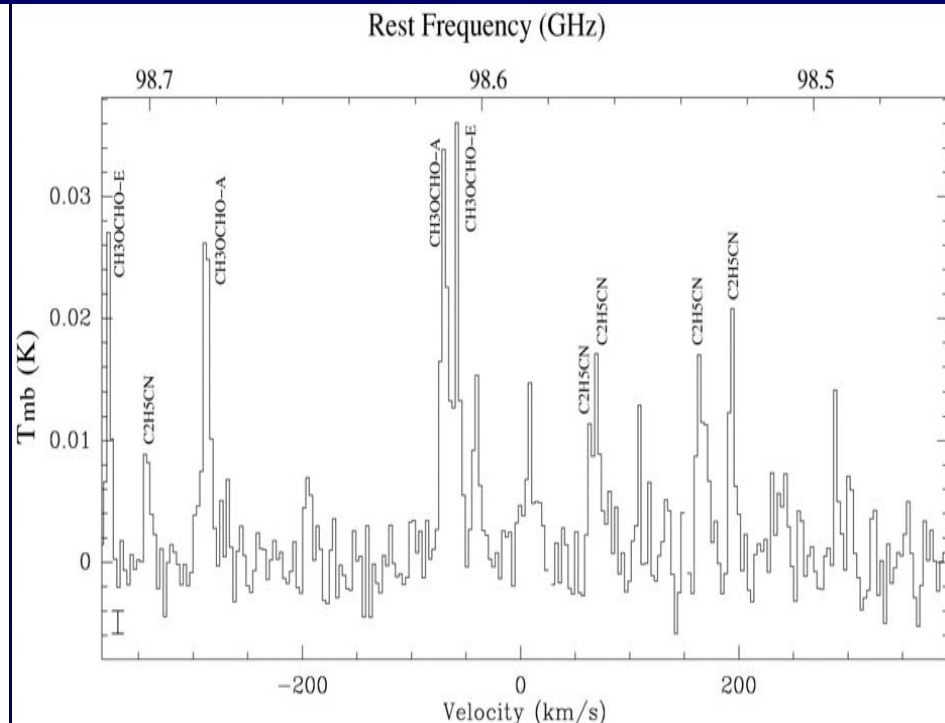
(low-mass stars)



Chemical complexity



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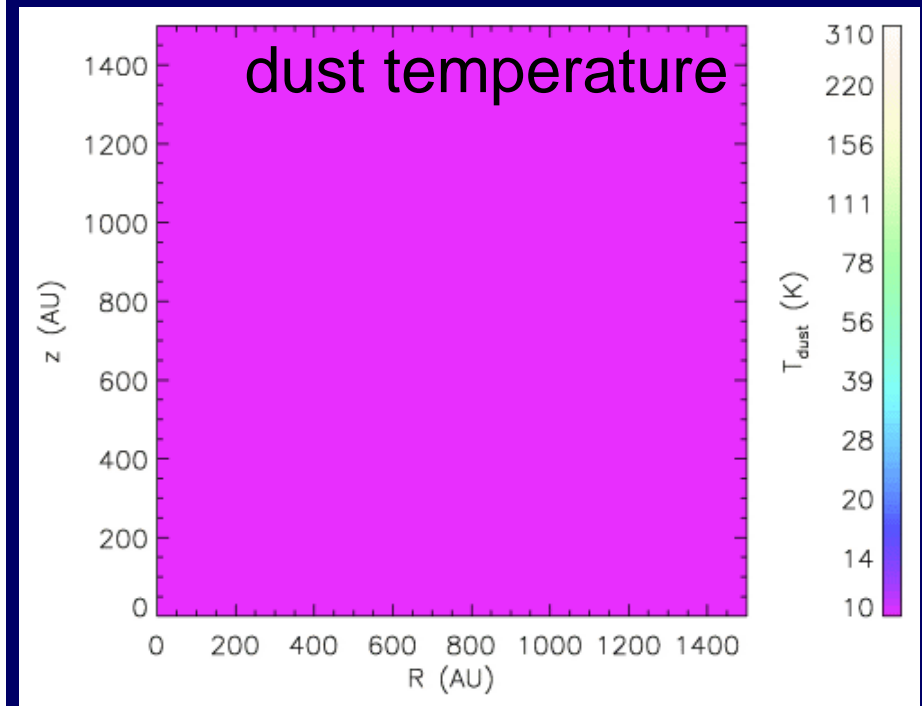
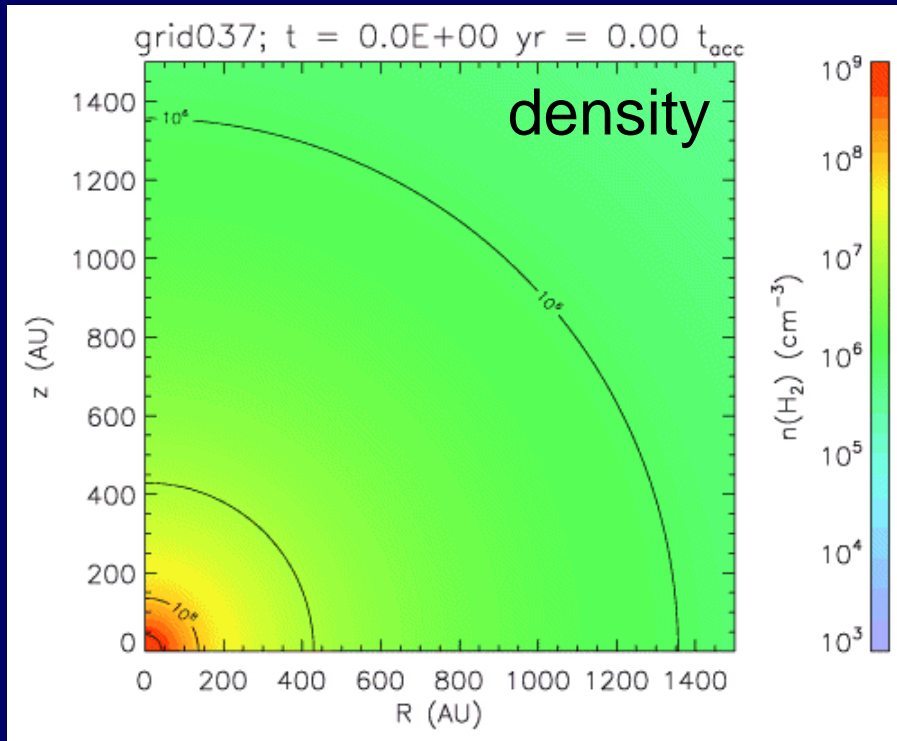
Hot core

Key questions

- During star formation, matter accretes from the parent cloud (envelope) onto a circumstellar disk
- Where exactly does it end up?
- What is its chemical history when it reaches some point of interest in the disk?
- What is the chemical composition of the disk at the end of the infall phase?

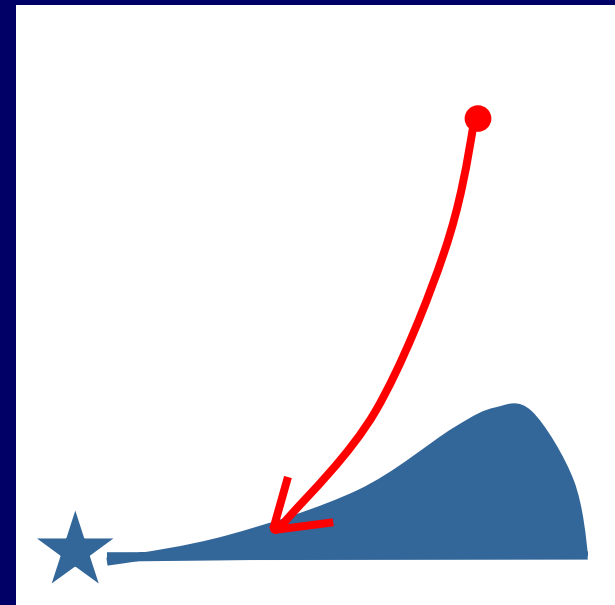
Analytical star formation models

- Density models: Shu (1977), Terebey, Shu & Cassen (1984)
- Dust temperature (important!) from full radiative transfer

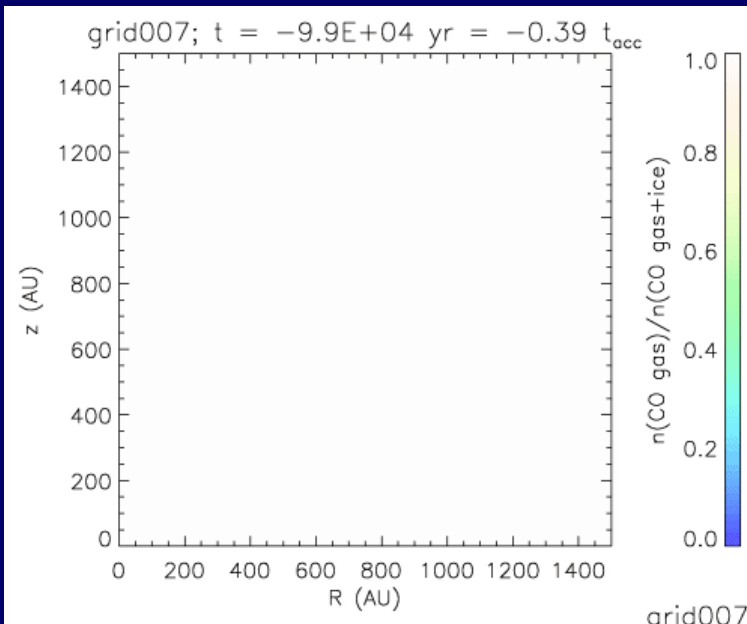


Chemistry from envelope to disk

- Need to solve chemistry dynamically
- Our model: first semi-analytic model to follow chemistry from envelope to disk
 - Static pre-collapse phase
 - n , v , T from physical models
 - Follow individual parcels
- Physics compare well with hydrodynamical models
(Brinch, van Weeren et al. in prep.)



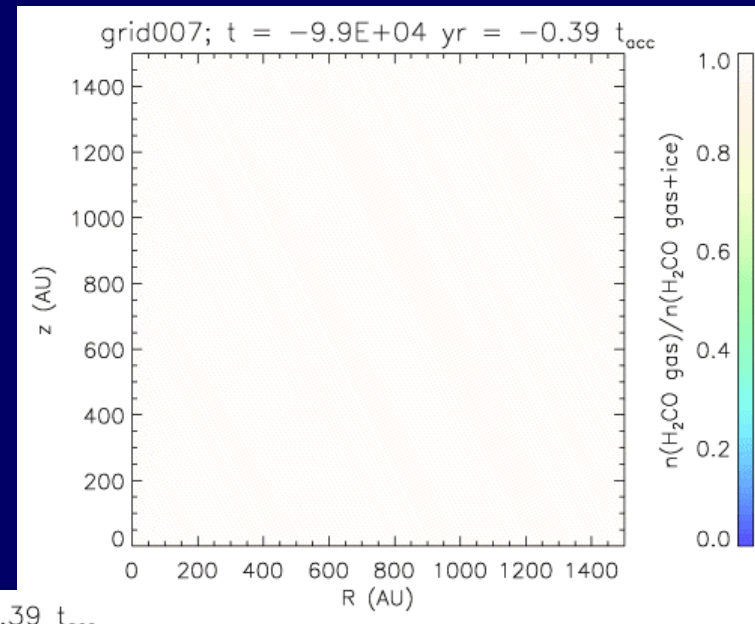
Gas & ice: CO, H₂CO, H₂O



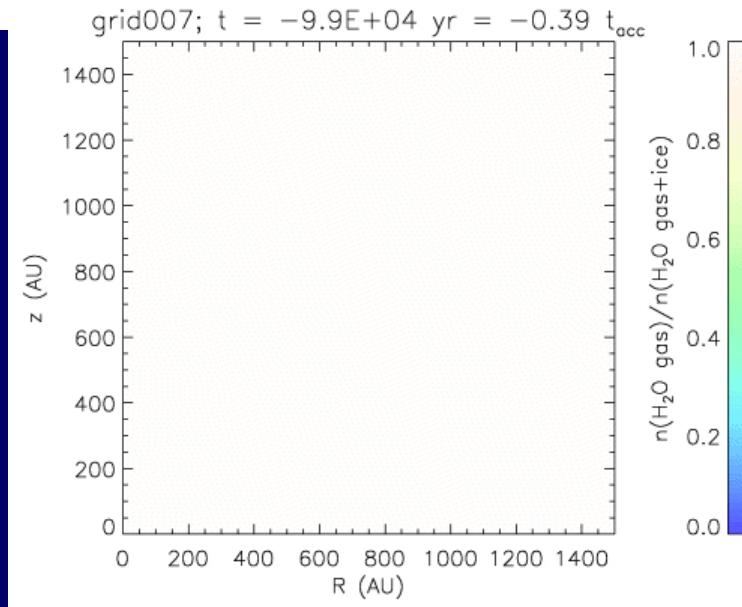
blue:
all ice

white:
all gas

black:
outflow



H₂CO

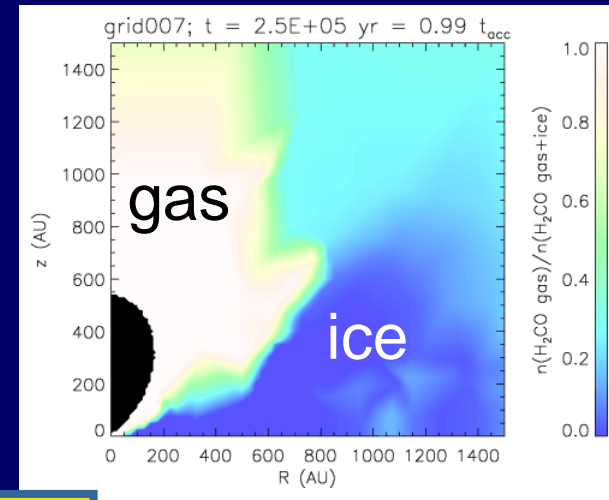
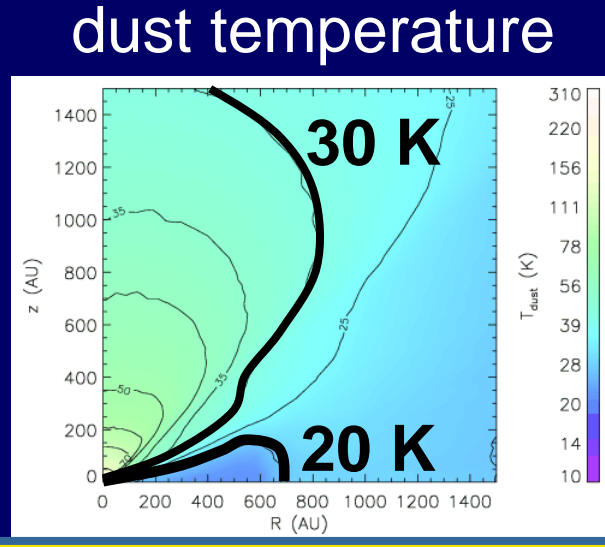
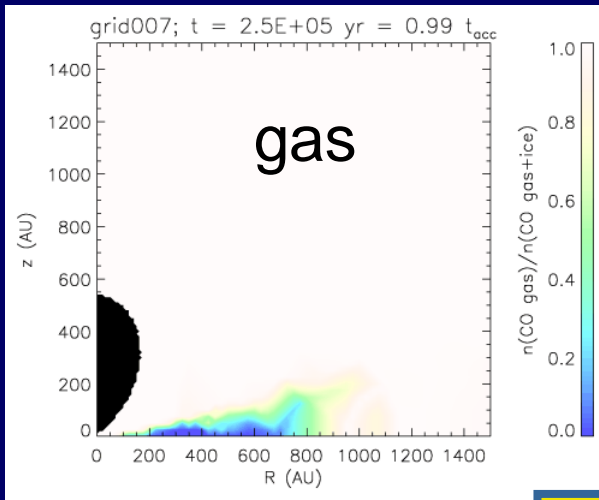


H₂O

CO

- CO desorbs during infall, re-adsorbs in disk below 20 K
- H₂O remains solid
- H₂CO is intermediate

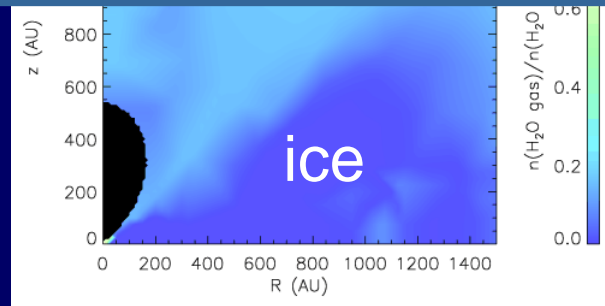
Gas & ice at end of infall



CO

- CO solid in disk below 20 K
- H₂O solid in disk, partly gas above
- H₂CO solid in disk below 30 K

If complex organics are present during infall, H₂O gas/ice ratio is upper limit to their gas/ice ratio

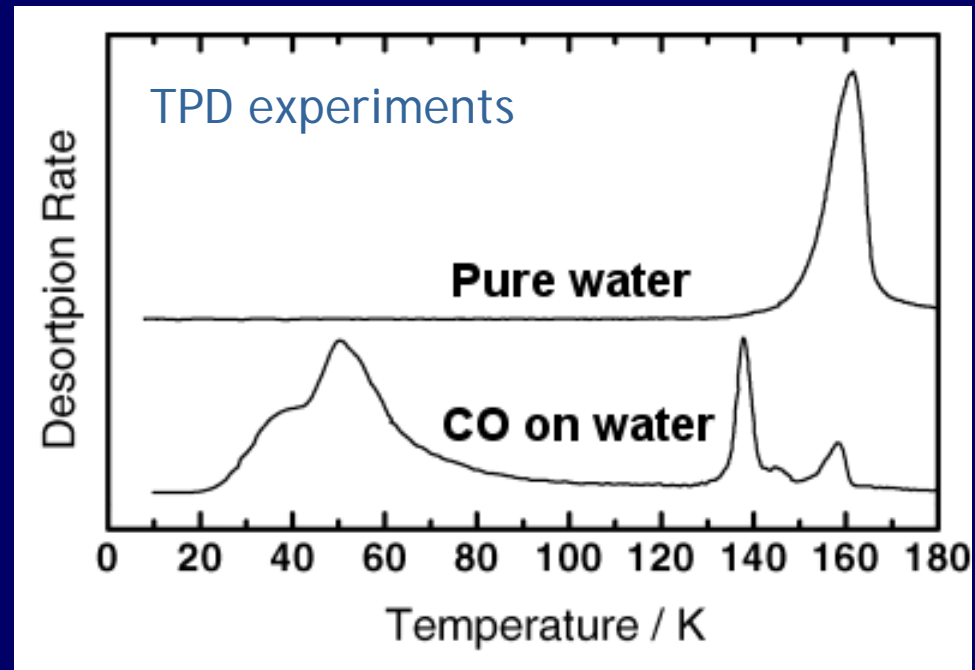


H₂O

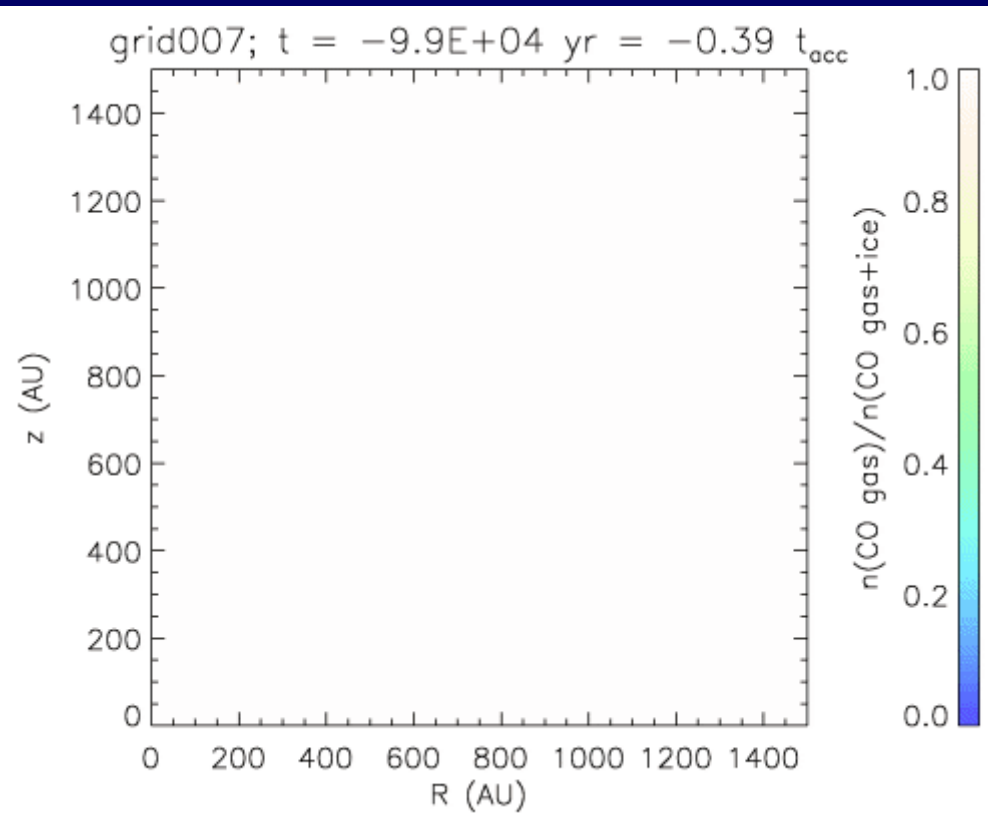
H₂CO

Closer to reality: ice mixtures

- Astrophysical ices are mixed
- H₂O most abundant ice → desorption of other ices depends on H₂O
- Depending on binding energy, up to four desorption channels are possible
- We can model this with multiple ice flavours



One vs. four flavours of CO

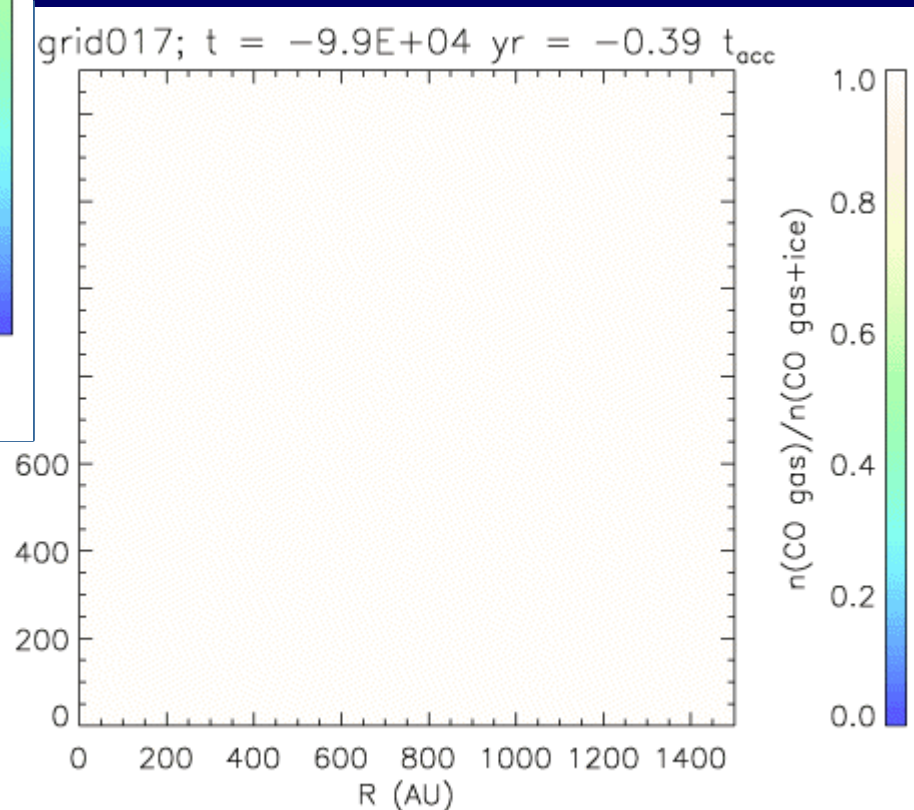


1 flavour of CO

Some CO now desorbs at higher temperatures, so the ice fraction is larger

blue: all ice white: all gas black: outflow

4 flavours of CO



Complex organics formation

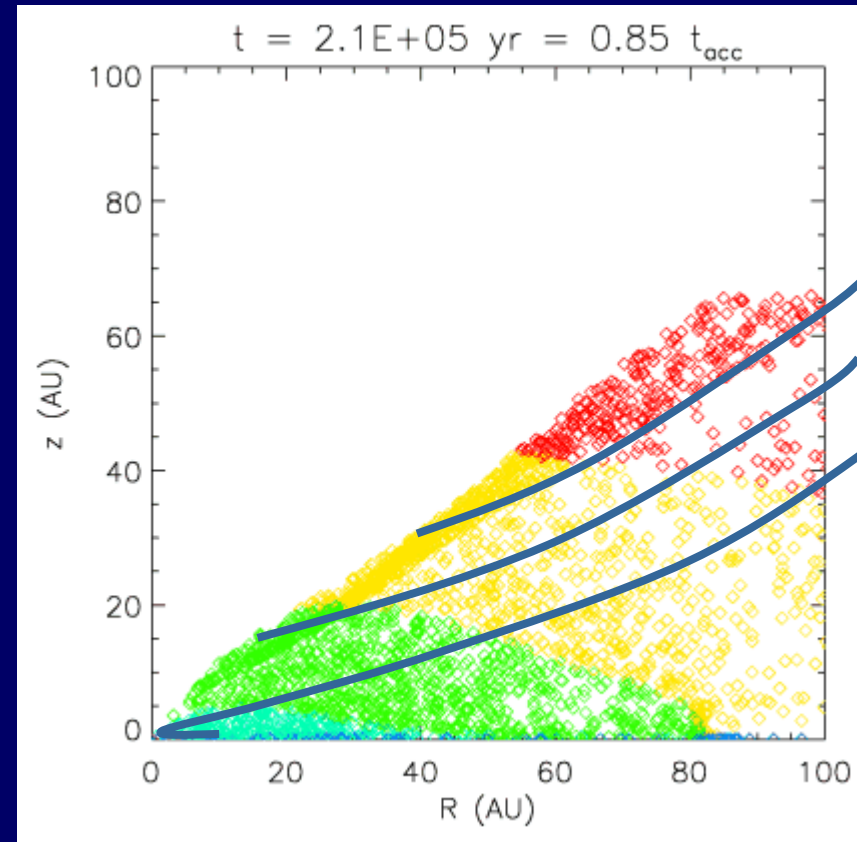
(Garrod & Herbst 2006)

- Some complex organics, e.g. CH_3OH , are formed on grains before collapse
- They desorb along with H_2O or at higher temperatures
- If formed this way, they will mostly remain as ice when entering the disk
- Larger organics, e.g. HCOOCH_3 , require 20-60 K for efficient formation

If a parcel goes through a 20-60 K region, does it spend enough time there to form complex organics?

Complex organics in disk

- Disk is layered: new material is deposited on top
- Parcels near midplane came in closer to the star
- Most material in planet-forming zone spends several 10^4 yr at 20-60 K
- Complex organics probably abundant in planetary building blocks



Blue parcels entered the disk first, followed by green, yellow and red

Conclusions

- Gas and ice abundances change as material accretes onto the disk:
 - CO ice desorbs during infall, re-adsorbs in disk below 20 K
 - H₂O ice remains solid, except within a few AU
 - H₂CO ice partially desorbs, then re-adsorbs
- CH₃OH gas/ice follows H₂O if formed before collapse
- Complex organics seem to be abundant early on in planet-forming zones