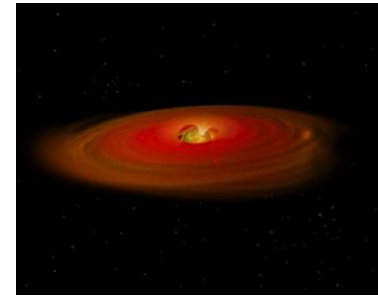
Chemical evolution from cores to disks



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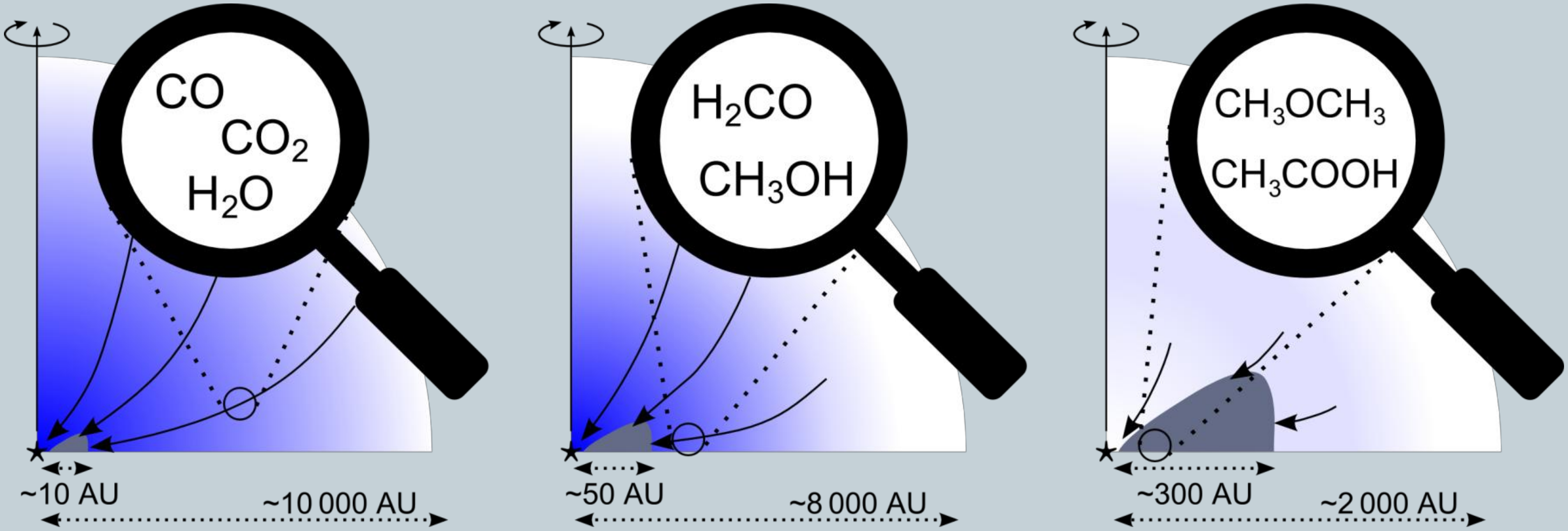
NWO

Sterrewacht Leiden

Main features of this study

- One model from pre-stellar core to circumstellar disk
- Two-dimensional, axisymmetric
- Study chemical evolution
  - Composition of cometary and planetary building blocks
  - Chemistry affects physics: temperature, MRI, ...
  - Diagnostic tool



Motivation

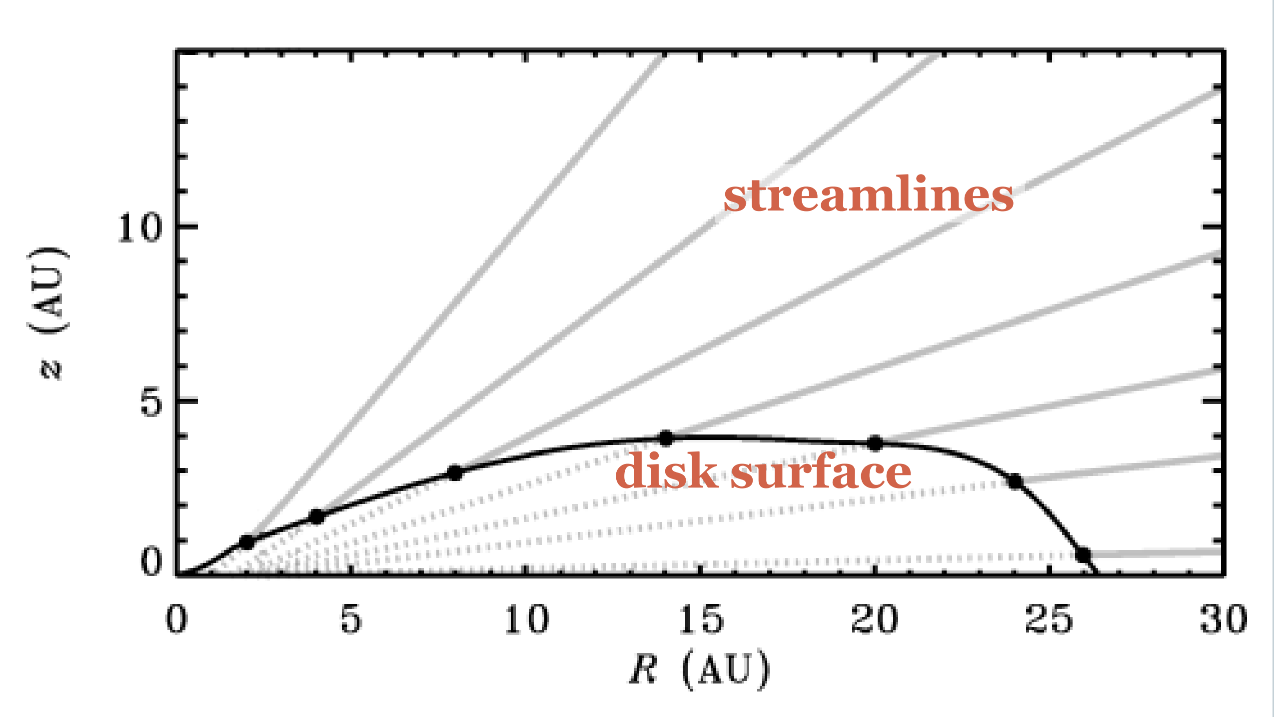
- How do size and mass of disk evolve?
- When is the disk first formed?
- How does matter flow from envelope to disk?
- What fraction of cometary ices is truly pristine?

- Existing models
  - treat only the envelope or only the disk, or both in 1D
  - often approximate temperature

Analytical star formation model in 2D

- Fast to run, high resolution, easy to change initial conditions
  Cloud mass (M_o), rotation rate (Ω_o), sound speed (c_s), ...
- Density & velocity: inside-out collapse
  Shu (1977), Terebey, Shu & Cassen (1984)
- Dust temperature (important!) from full radiative transfer
  RADMC: Dullemond & Dominik 2004
- Physics compare well with hydrodynamical models
  Yorke & Bodenheimer 1999, Brinch et al. 2008a,b
- Density profiles compare well with observations
  Jørgensen et al. 2009

From one to two dimensions

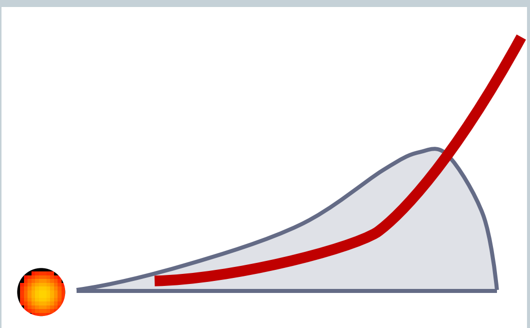


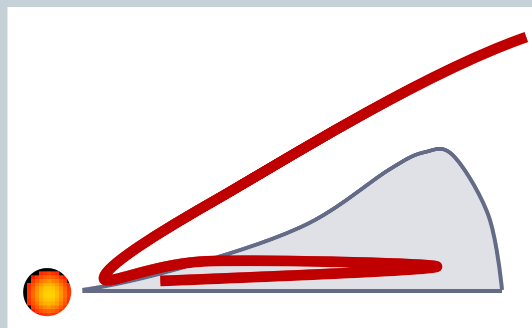
- Previous collapse models treated disk as completely flat
- Include vertical structure: accretion occurs further out
- Accretion shock is weak, except in very inner part

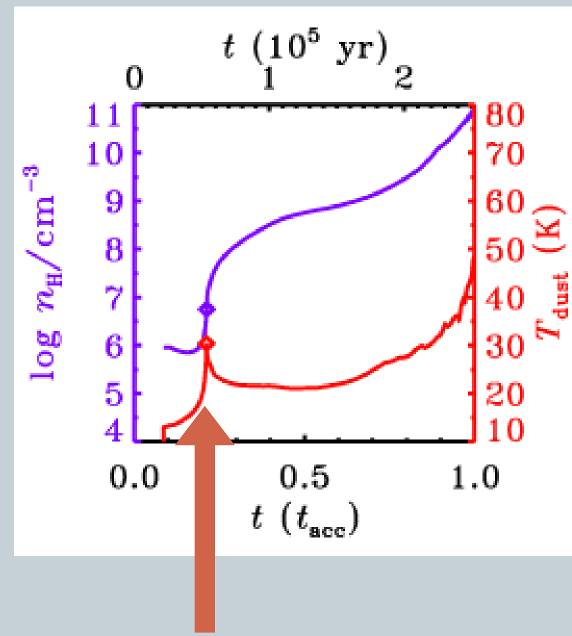
Visser & Dullemond (subm.)

Infall trajectories

- Need to solve chemistry dynamically: compute n, T along many trajectories



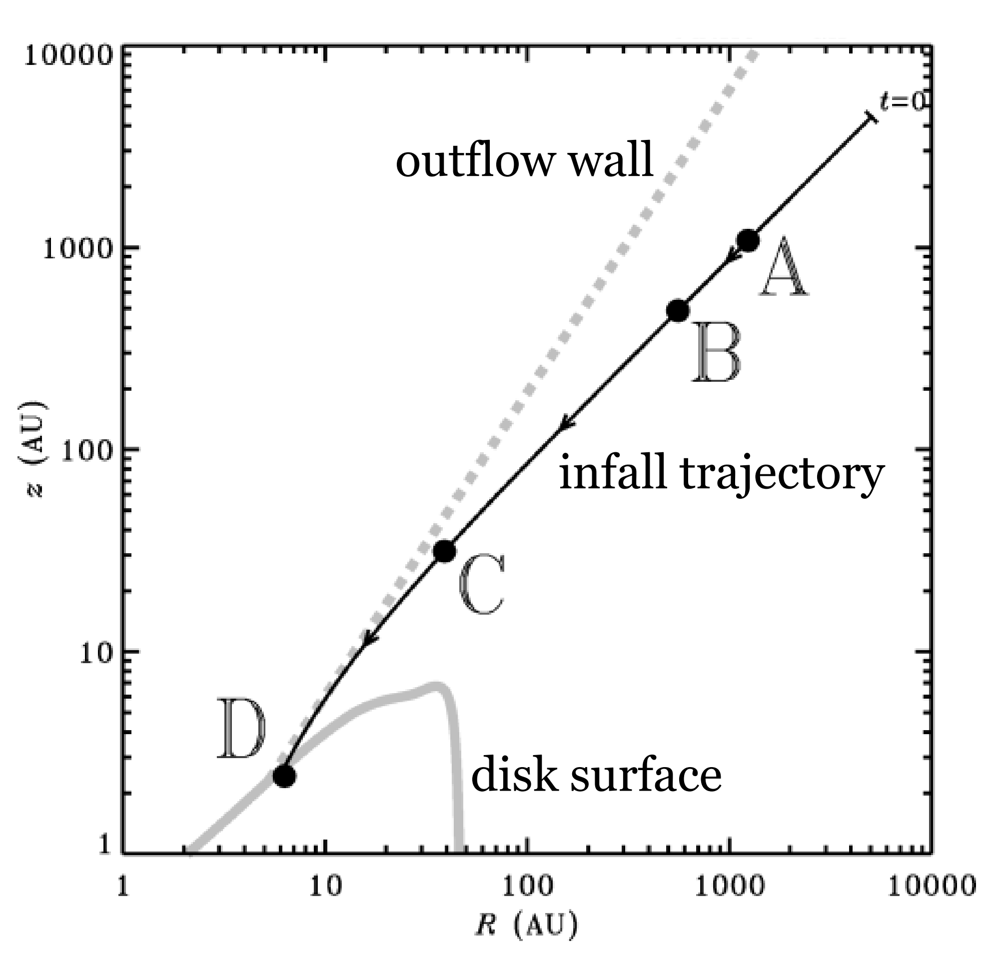




entering disk

- Many different trajectories
- Jump in n, T upon entering disk

Chemical evolution along one trajectory



A: volatiles evaporate (e.g. CO, N_2)

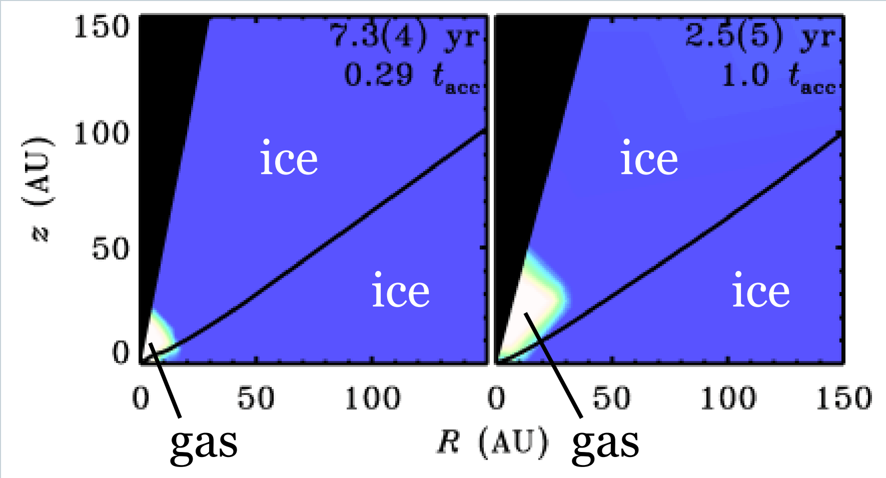
B: intermediates evaporate (e.g. CH_4, NO)

C: other ices evaporate (e.g. H_2O, NH_3, CH_3OH) photodissociation of many species

D: some species reformed

Visser et al. (in prep.)

Gas and ice: H_2O



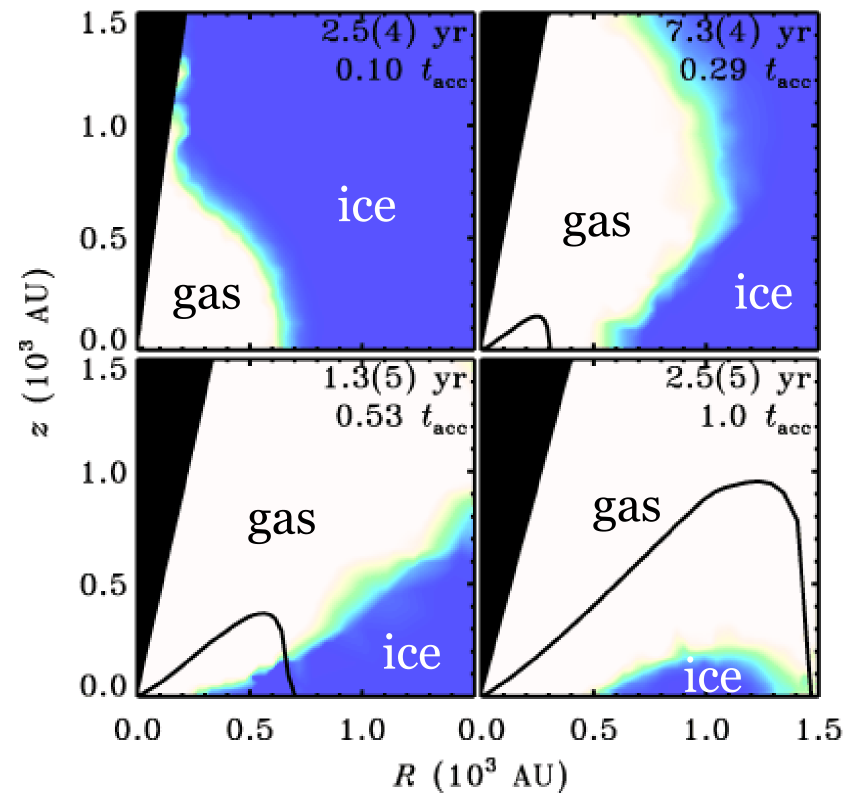
blue: all ice
white: all gas
black: outflow
black curve: disk surface

M_0 = 1.0 M_{sun}
$\Omega_0 = 10^{-13}$ s^{-1}
c_s = 0.26 km s^{-1}

- H_2O remains solid except inner ~5 AU
- H_2O in comet-forming zone, depending on parameters:
  - *either* unprocessed
  - *or* evaporated and re-frozen

Visser et al. (2009)

Gas and ice: CO



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$M_0 = 1.0\ M_{sun}$
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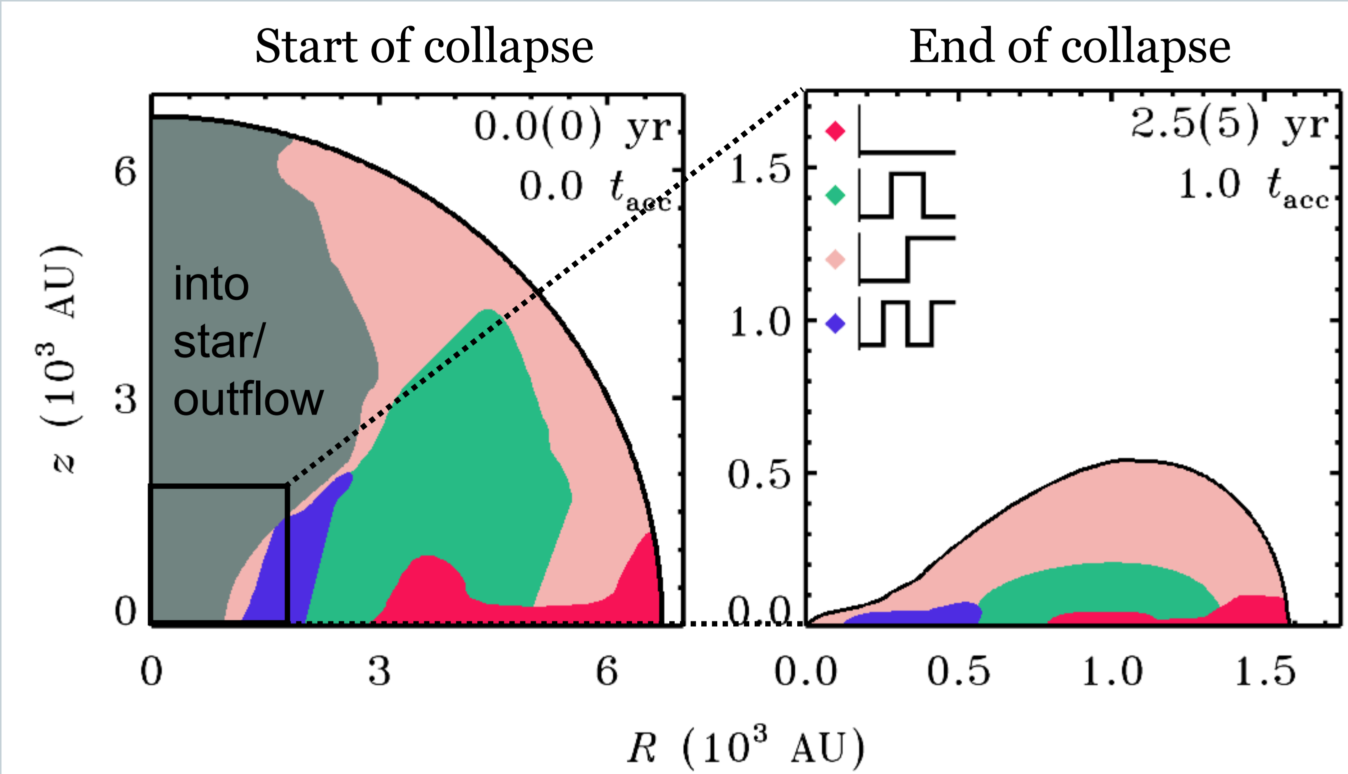
CO desorbs during infall, re-adsorbs in disk below 18 K

Visser et al. (2009)

Chemical zones: CO gas/ice



M_0 = 1.0 M_{sun}
Ω_0 = 10^{-13} s^{-1}
c_s = 0.26 km s^{-1}

Red: CO remains adsorbed (pristine!)

Green: CO desorbs and re-adsorbs

Pink: CO desorbs and remains desorbed

Blue: multiple desorption/adsorption

Visser et al. (2009)

Conclusions

- First model to go from pre-stellar cores to circumstellar disks in 2D
- Masses and densities compares well with hydro simulations and SMA observations
- Great tool for chemical evolution
- Disk is divided into zones with different chemical histories
  - Outer part pristine, inner part processed

Future work

- Compute line profiles
  - Compare with observations by SMA, JCMT, IRAM 30m, ...
  - Analyse water data from Herschel (WISH key program)
  - Make predictions for ALMA
- Add grain-surface chemistry
  - Formation of complex organics
- Add isotope-selective CO photodissociation
  - New model: Visser, van Dishoeck & Black (2009)