Chemical evolution from cores to disks

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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 ($M_0$), rotation rate ($\Omega_0$), 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

Visser et al. (2009), Visser & Dullemond (subm.), Visser et al. (in prep.)
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

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

Visser et al. (2009), Visser et al. (in prep.)
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$_2$O, NH$_3$, CH$_3$OH)
photodissociation of many species

D: some species reformed
Gas and ice: $\text{H}_2\text{O}$

- $\text{H}_2\text{O}$ remains solid except inner $\sim 5$ AU
- $\text{H}_2\text{O}$ in comet-forming zone, depending on parameters:
  - either unprocessed
  - or evaporated and re-frozen

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

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

Visser et al. (2009)
Gas and ice: CO

CO desorbs during infall, re-adsorbs in disk below 18 K

Visser et al. (2009)

blue: all ice
white: all gas
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$M_0 = 1.0 \, M_{\text{sun}}$
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Chemical zones: CO gas/ice

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)

\[ M_0 = 1.0 \, M_{\text{sun}} \]
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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)