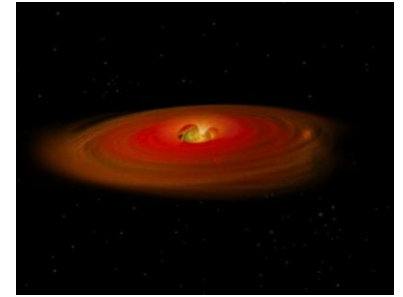




# Chemical evolution from cores to disks



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Dullemond, Jes Jørgensen, Christian  
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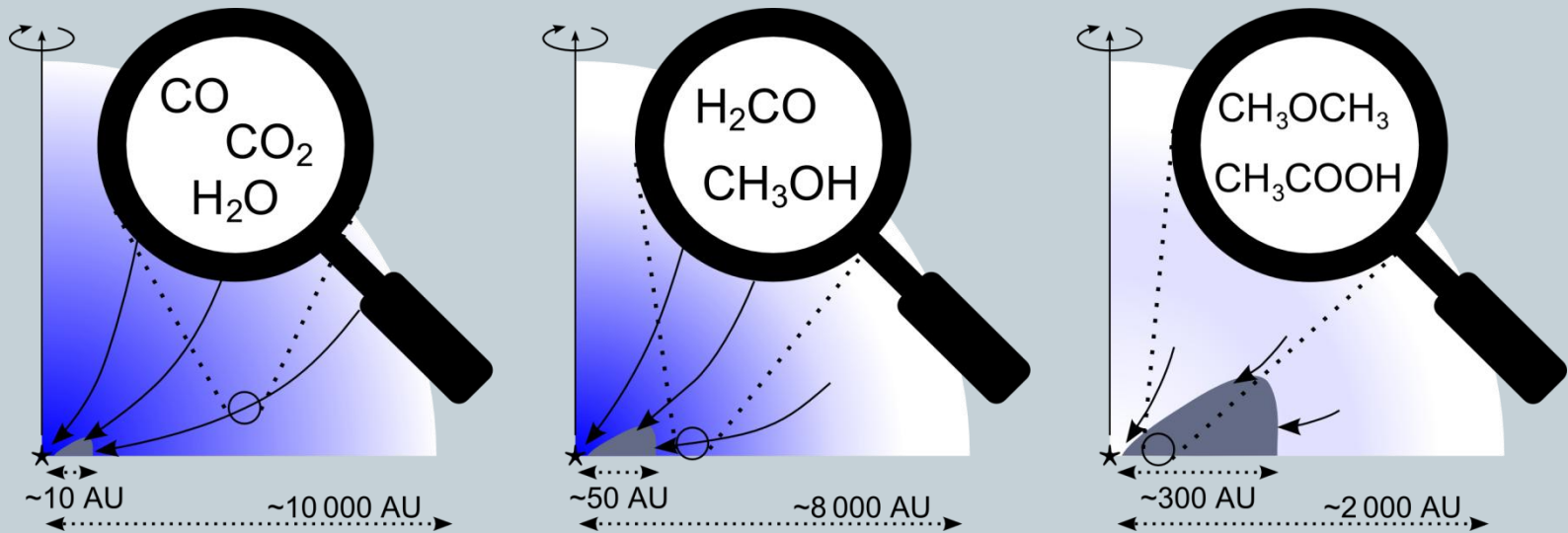
**November 3, 2009**



# 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



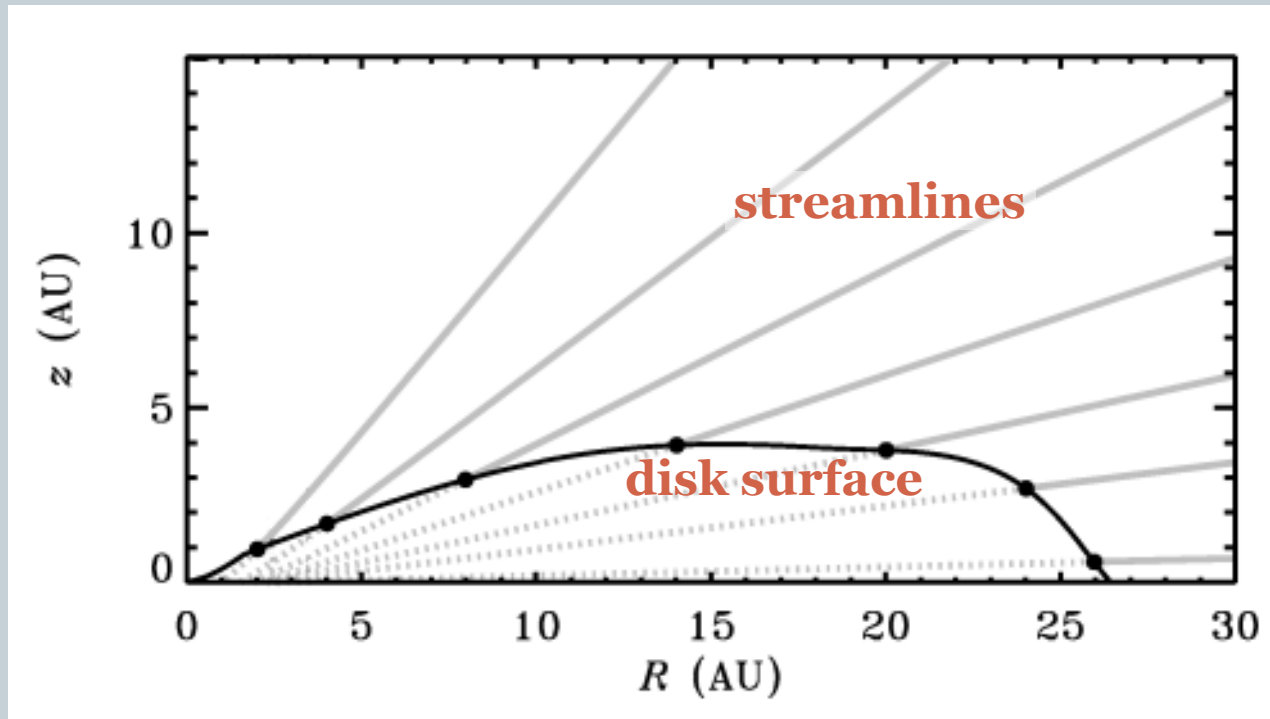
- How do size and mass of disk evolve?
- When is the disk first formed?
- How does matter flow from envelope to disk?
- What fraction of cometary ices is truly pristine?
  
- Existing models
  - treat only the envelope or only the disk, or both in 1D
  - often approximate temperature

# Analytical star formation model in 2D



- Fast to run, high resolution,  
easy to change initial conditions  
Cloud mass ( $M_{\odot}$ ), rotation rate ( $\Omega_{\odot}$ ), 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

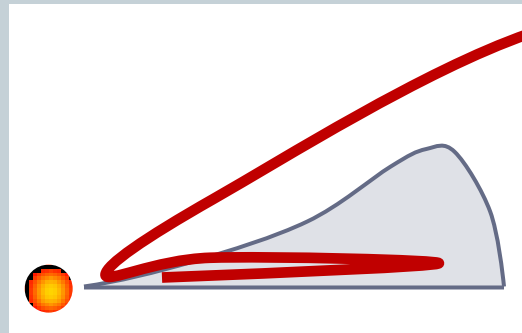
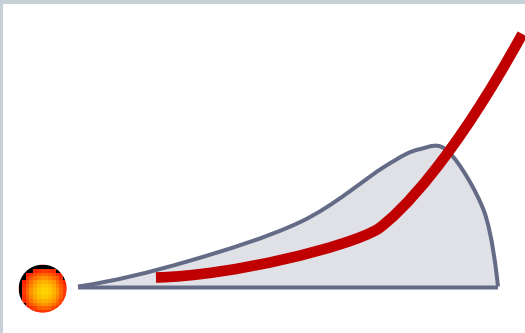


- Previous collapse models treated disk as completely flat
- Include vertical structure: accretion occurs further out
- Accretion shock is weak, except in very inner part

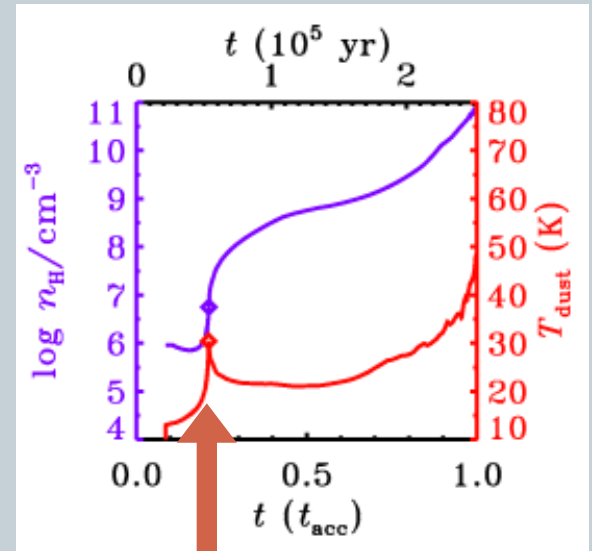
# Infall trajectories



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

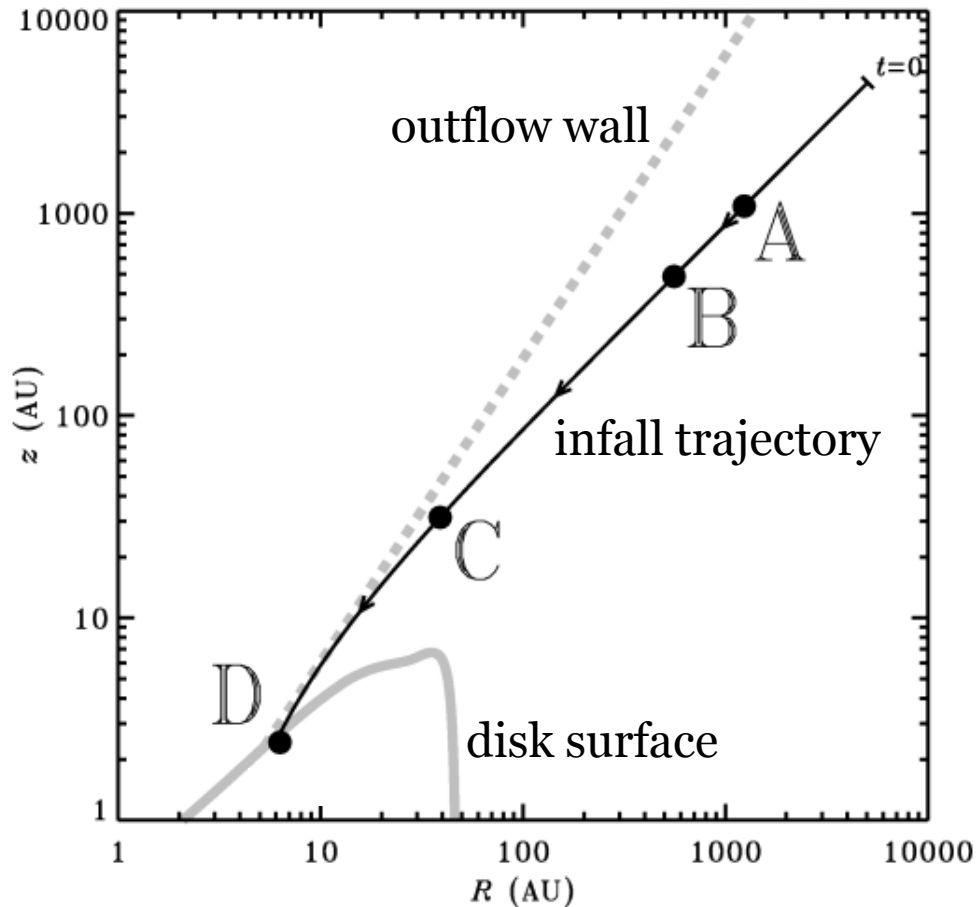


- Many different trajectories
- Jump in  $n$ ,  $T$  upon entering disk



entering disk

# Chemical evolution along one trajectory



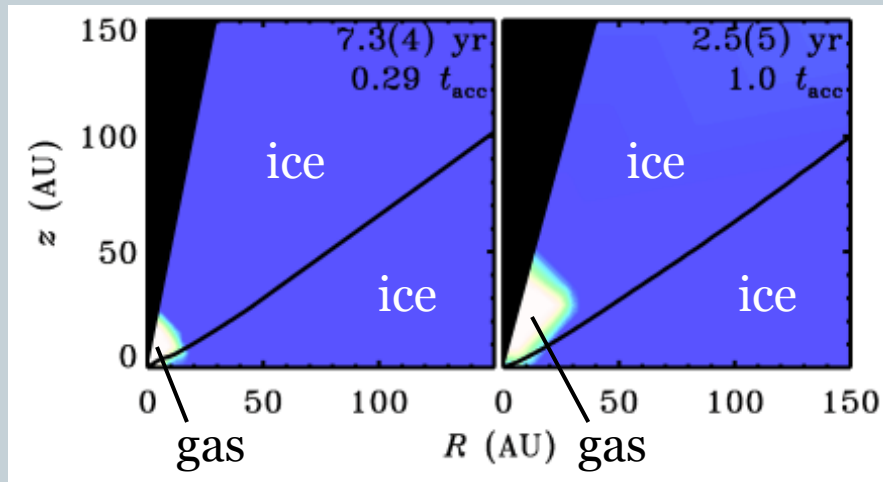
A: volatiles evaporate  
(e.g. CO, N<sub>2</sub>)

B: intermediates evaporate  
(e.g. CH<sub>4</sub>, NO)

C: other ices evaporate  
(e.g. H<sub>2</sub>O, NH<sub>3</sub>, CH<sub>3</sub>OH)  
photodissociation of  
many species

D: some species reformed

# Gas and ice: H<sub>2</sub>O

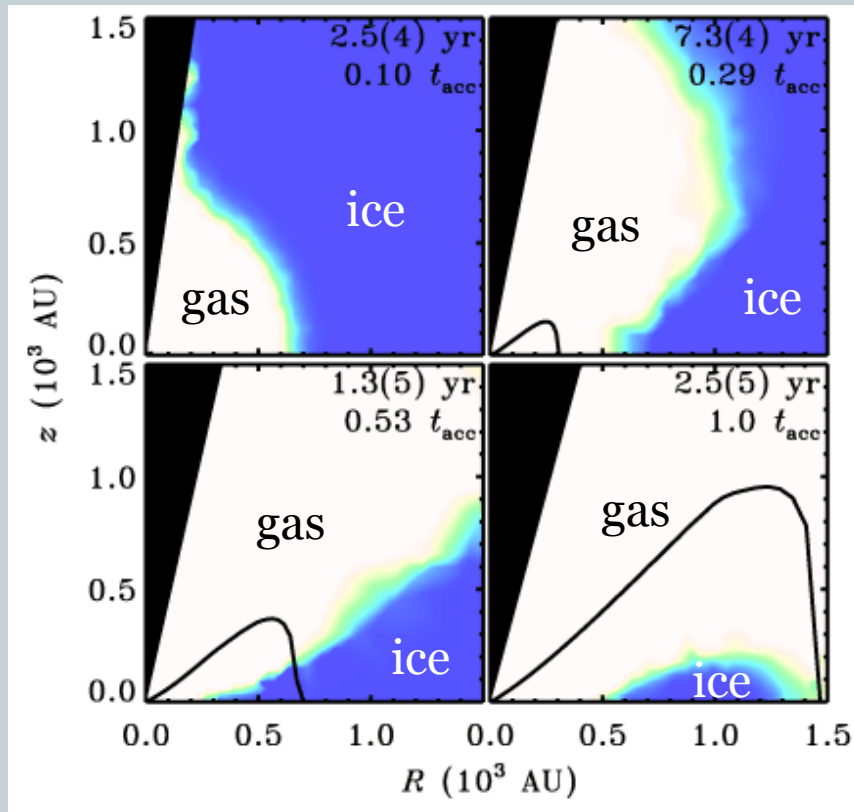


blue: all ice  
white: all gas  
black: outflow  
black curve: disk surface

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

- H<sub>2</sub>O remains solid except inner ~5 AU
- H<sub>2</sub>O in comet-forming zone, depending on parameters:
  - *either* unprocessed
  - *or* evaporated and re-frozen

# Gas and ice: CO

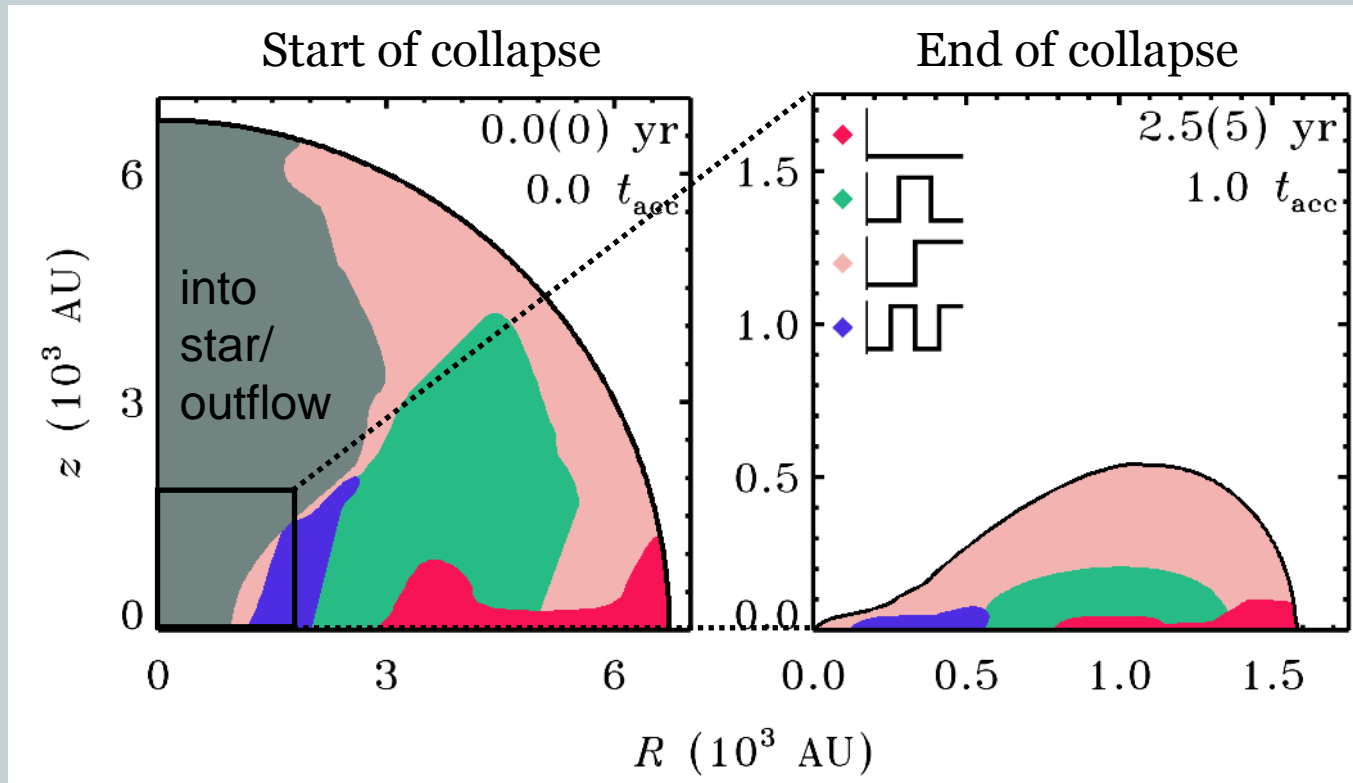


blue: all ice  
white: all gas  
black: outflow  
black curve: disk surface

$$M_{\text{O}} = 1.0 M_{\text{sun}}$$
$$\Omega_{\text{O}} = 10^{-13} \text{ s}^{-1}$$
$$c_{\text{s}} = 0.26 \text{ km s}^{-1}$$

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

# Chemical zones: CO gas/ice



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

Red: CO remains adsorbed (pristine!)

Green: CO desorbs and re-adsorbs

Pink: CO desorbs and remains desorbed

Blue: multiple desorption/adsorption

# 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)