

CHEMICAL HISTORY

OF MOLECULES IN CIRCUMSTELLAR DISKS

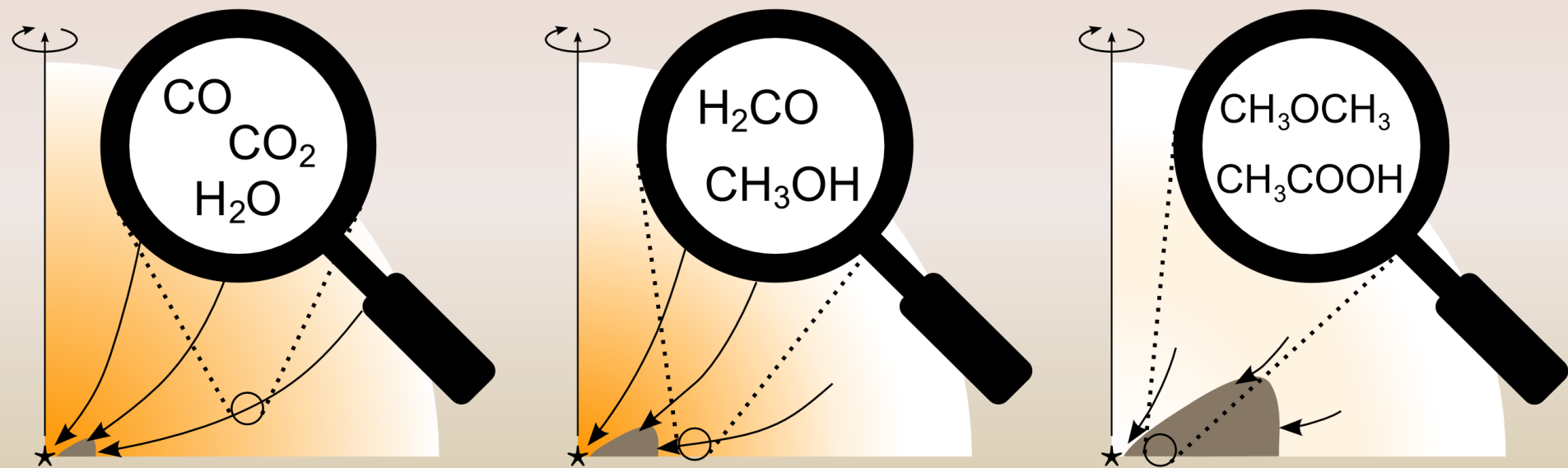
Ruud Visser
University of Michigan

Ewine van Dishoeck, Steve Doty, Ted Bergin

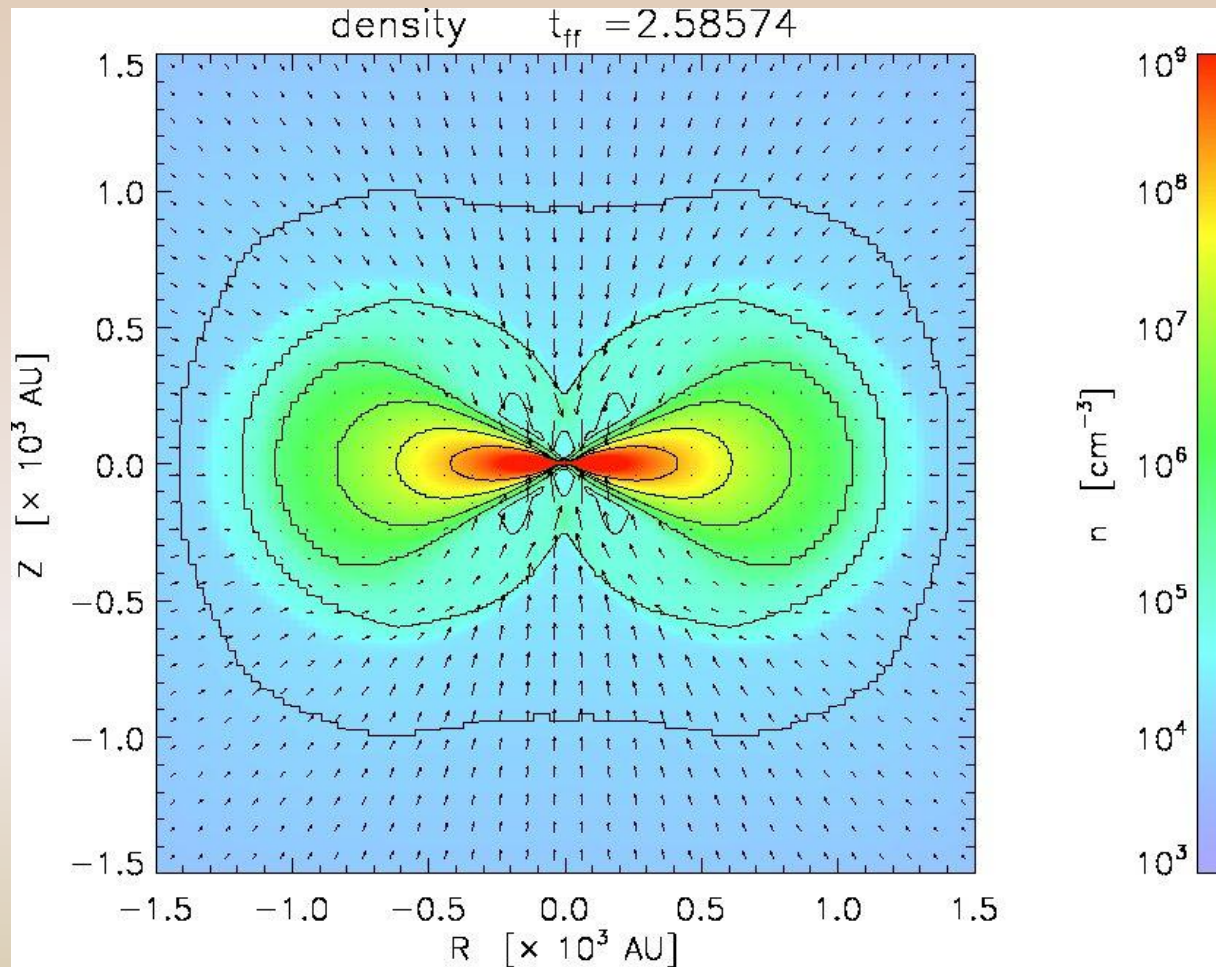
June 1, 2011

CHEMICAL EVOLUTION IN 2D: WHY BOTHER?

- ✗ Need to understand chemistry to probe physics
- ✗ Disk and inner envelope not spherically symmetric



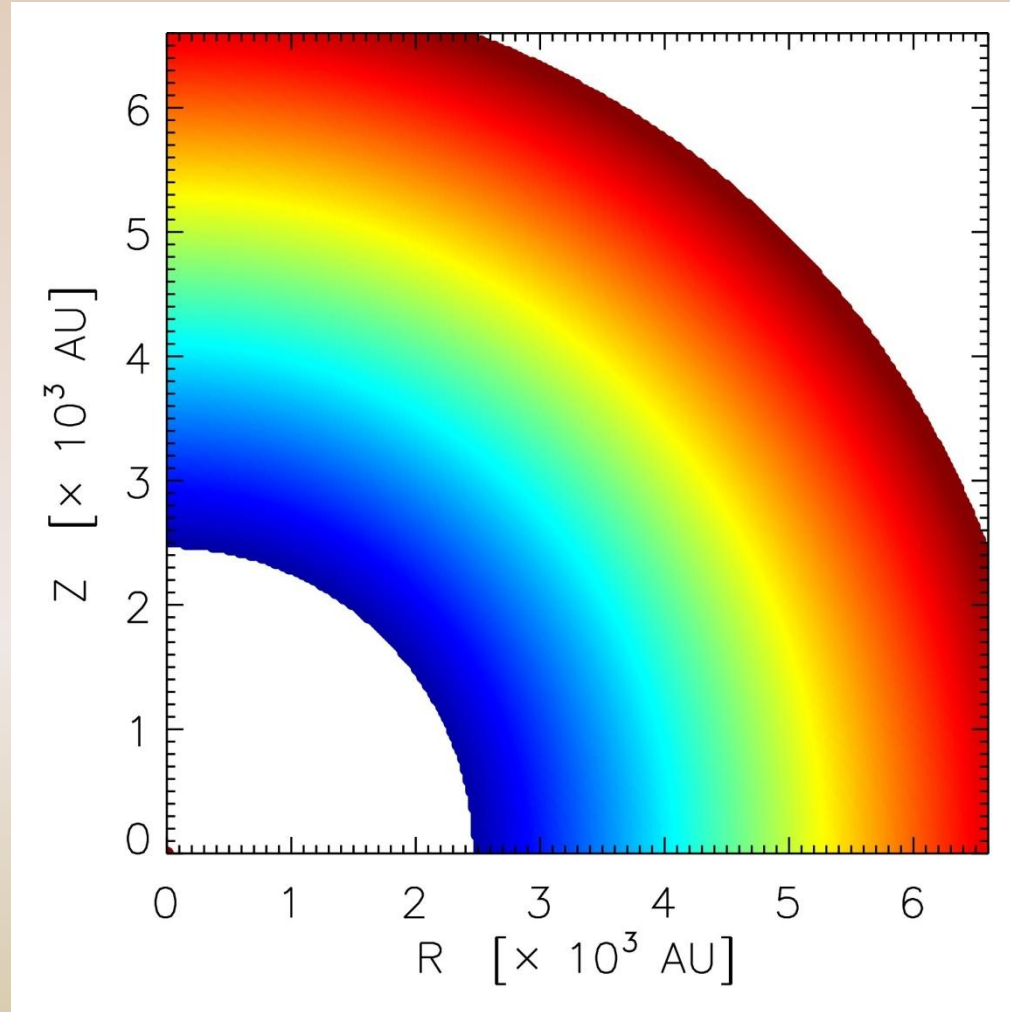
HYDRODYNAMICAL SIMULATION OF COLLAPSING CORE



- Recipe of Yorke & Bodenheimer (1999)
- Formation of J-type star
- Cloud mass: $1 M_{\odot}$
- Rotation: 10^{-13} s^{-1}

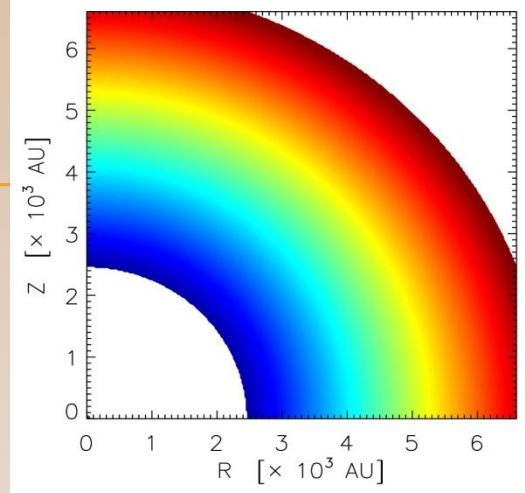
Brinch et al. (2008a,b)

FLOW OF MATTER



FLOW OF MATTER

Infalling parcels in a collapsing core
by Reinout van Weeren

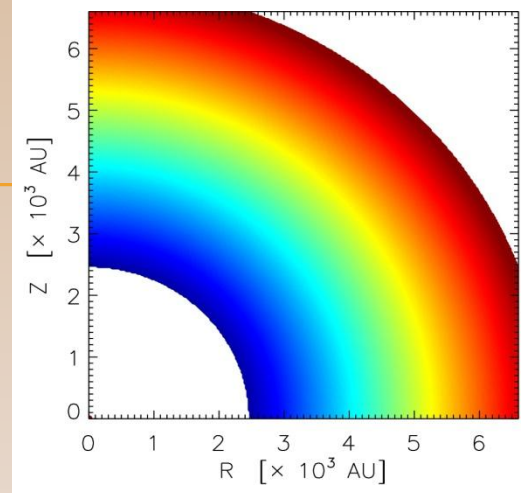
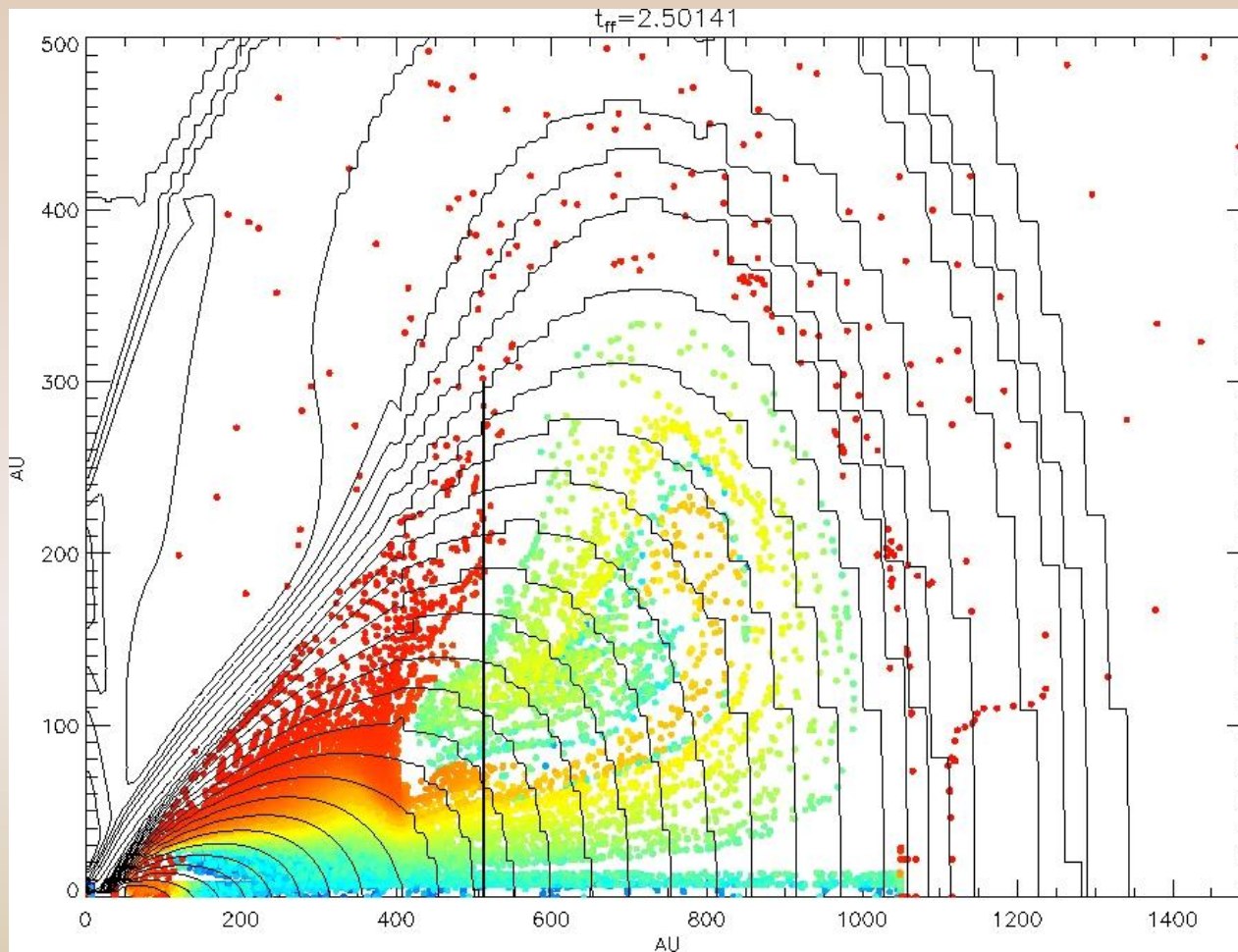


Note:

- Spreading of disk
- Accretion on top and at outer edge
- Inner envelope ends up at midplane
- Outer envelope ends up at surface

van Weeren et al. (2009)

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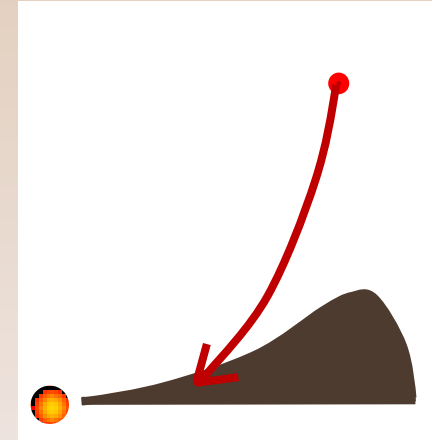
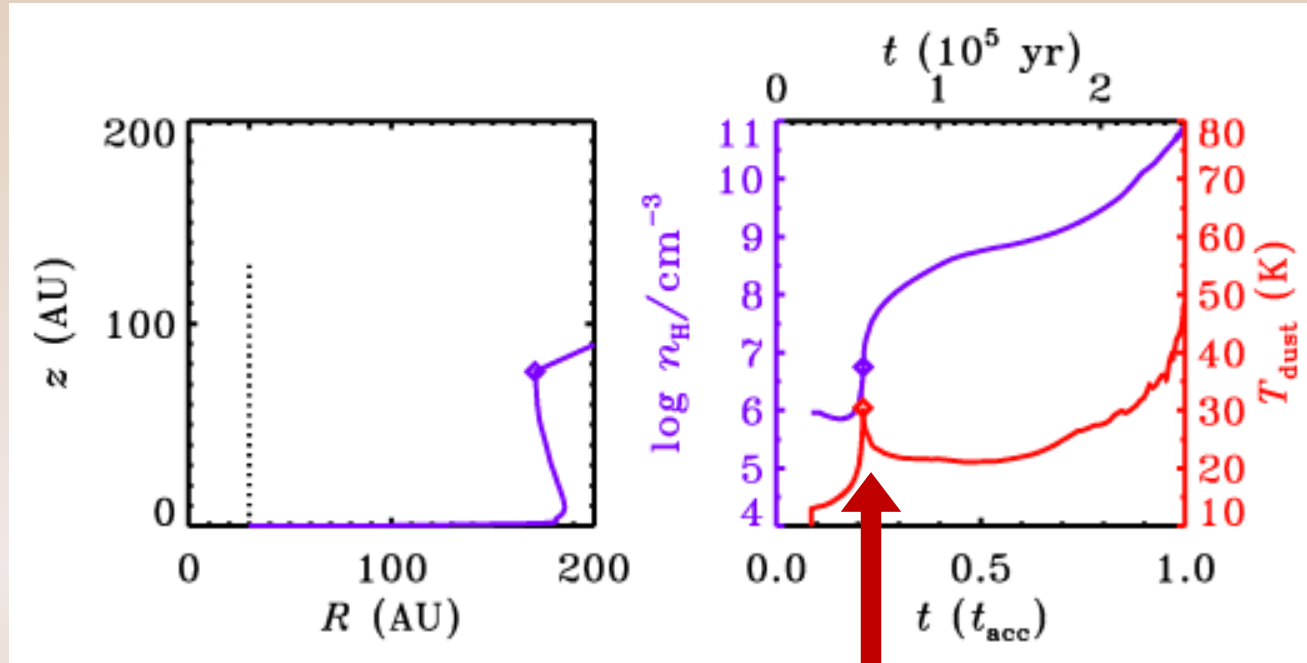
SEMI-ANALYTICAL 2D STAR FORMATION MODEL

Visser et al. (2009)

- ✘ Fast to run, high resolution,
easy to change initial conditions
Cloud mass, rotation rate, sound speed, ...
- ✘ 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 HD models
Yorke & Bodenheimer (1999), Brinch et al. (2008a,b)
- ✘ Density profiles compare well with observations
Jørgensen et al. (2009)

CHEMICAL EVOLUTION

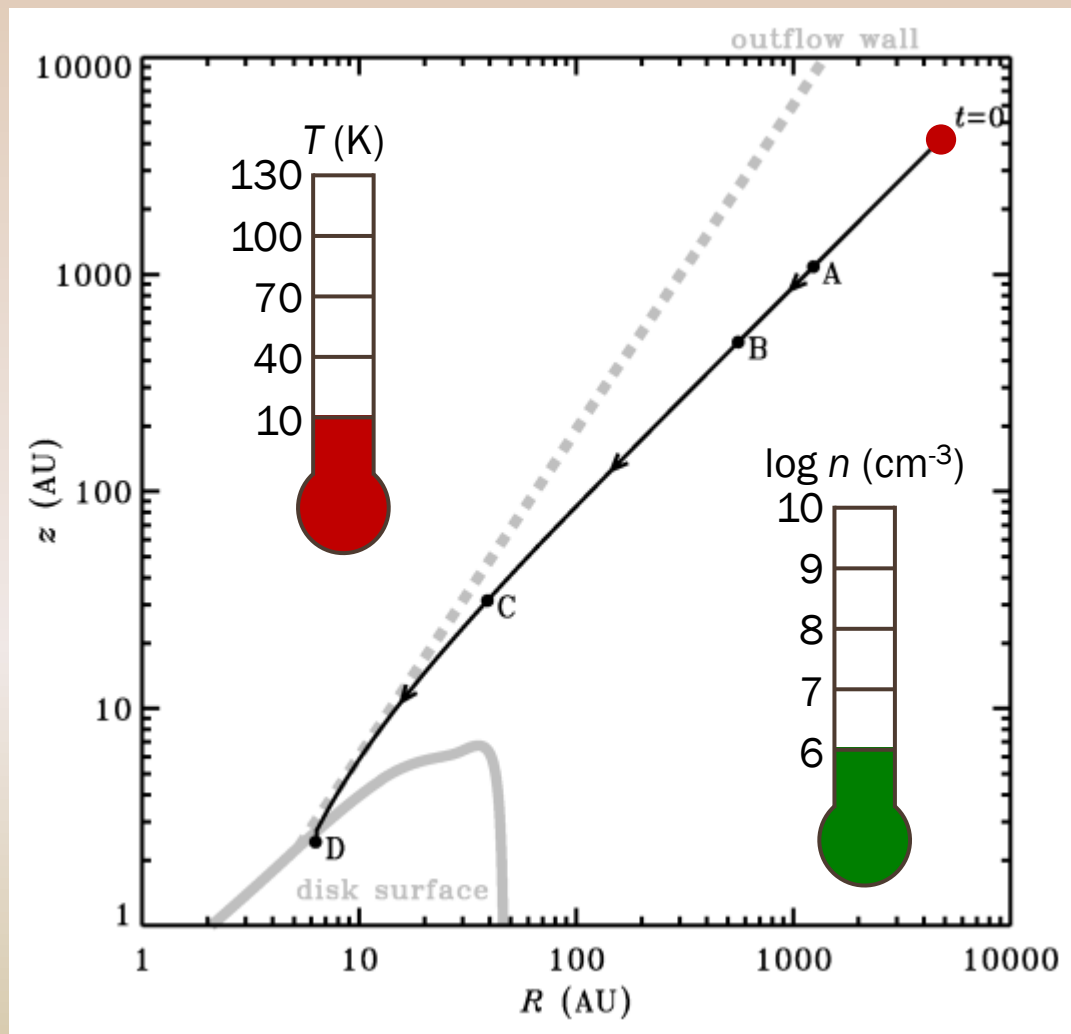
- ✘ Compute n , T along many trajectories



- ✘ Jump in n , T upon entering disk
- ✘ n increases by factor of $\sim 10^5$ overall,
 T increases to 40–500 K, depending on trajectory

CHEMICAL EVOLUTION ALONG ONE TRAJECTORY

Visser et al. (subm.)

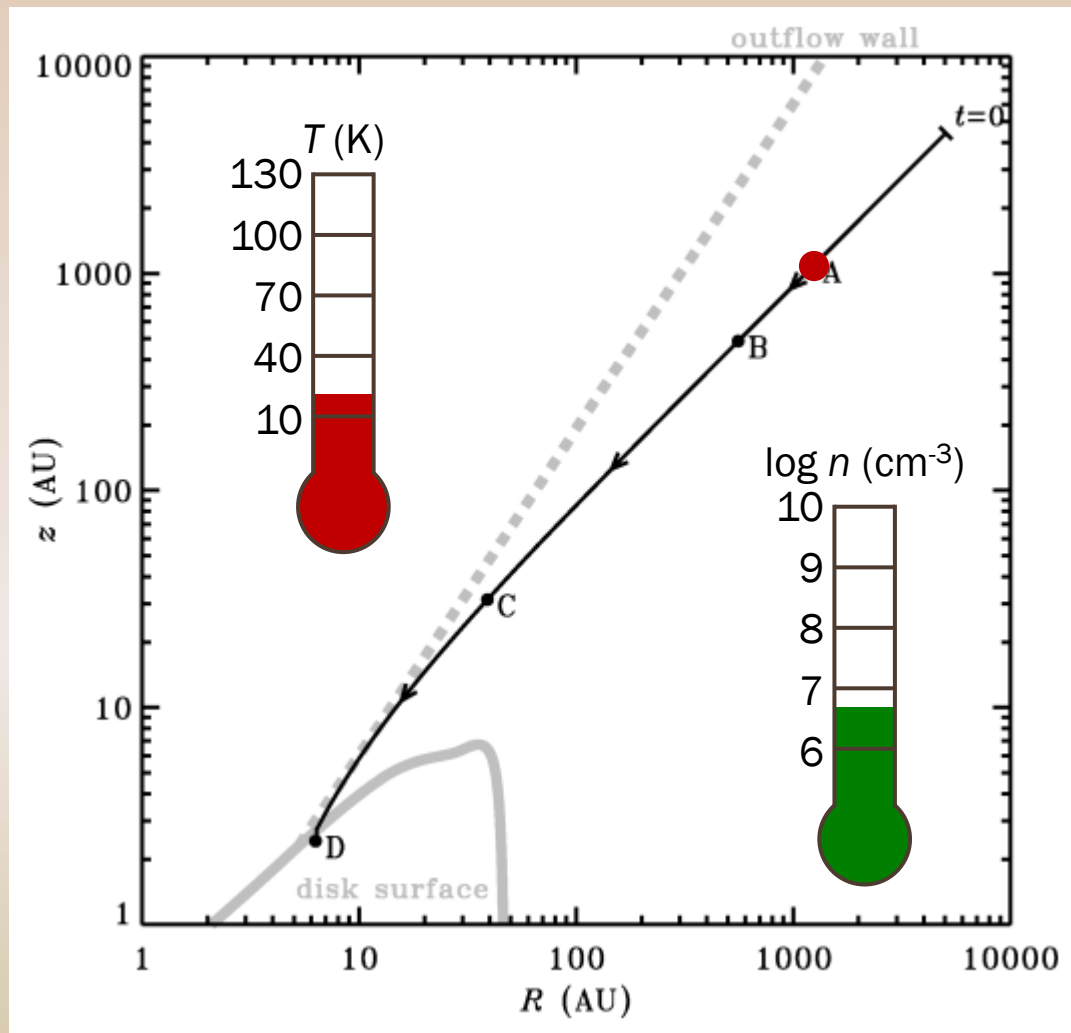


Point A:

- ✗ CO, N₂, O₂ evaporate
- ✗ HCO⁺, N₂H⁺ formed
- ✗ H₂O, CH₄, NH₃, NO remain frozen

CHEMICAL EVOLUTION ALONG ONE TRAJECTORY

Visser et al. (subm.)

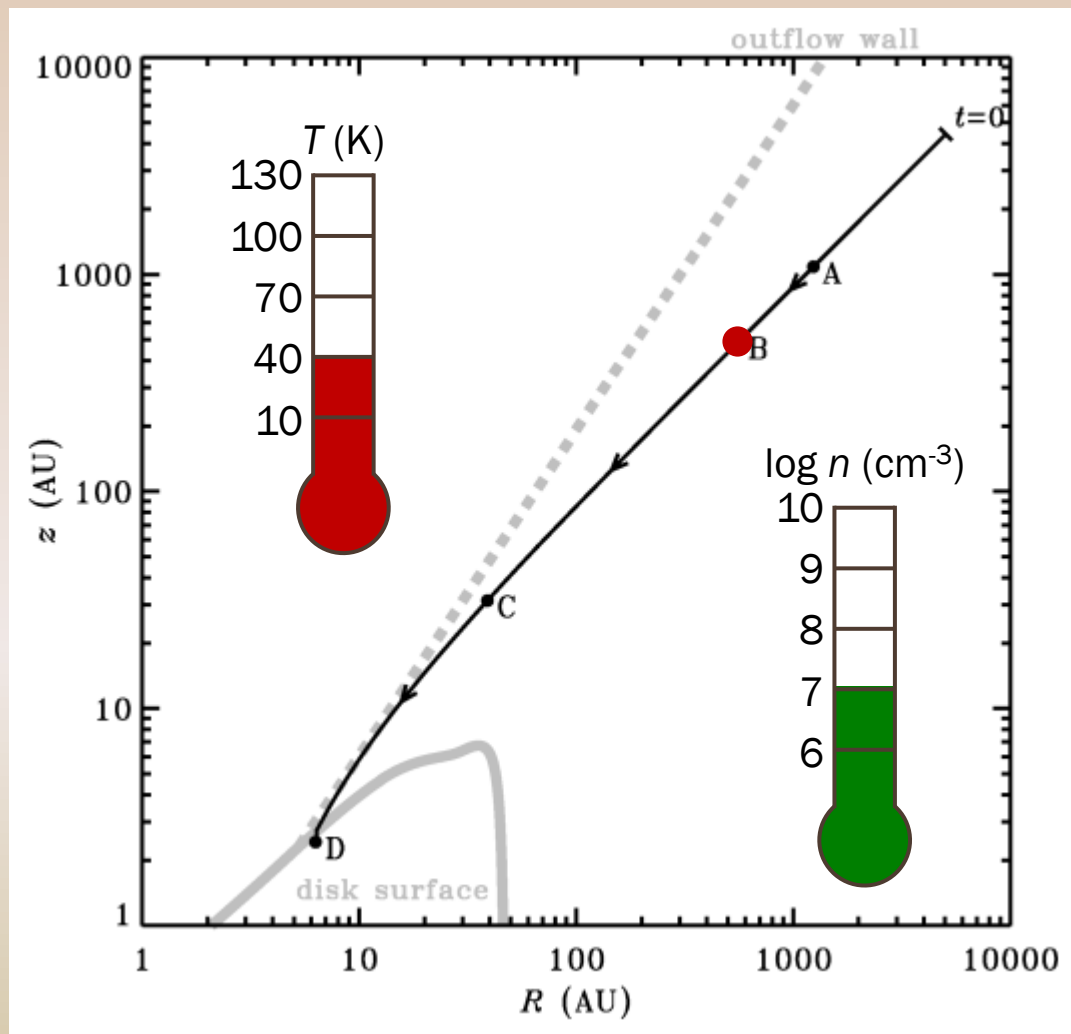


Point B:

- ✗ CH_4 , NO evaporate
- ✗ CO, N_2 , O_2 remain in gas
- ✗ H_2O , NH_3 remain frozen

CHEMICAL EVOLUTION ALONG ONE TRAJECTORY

Visser et al. (subm.)

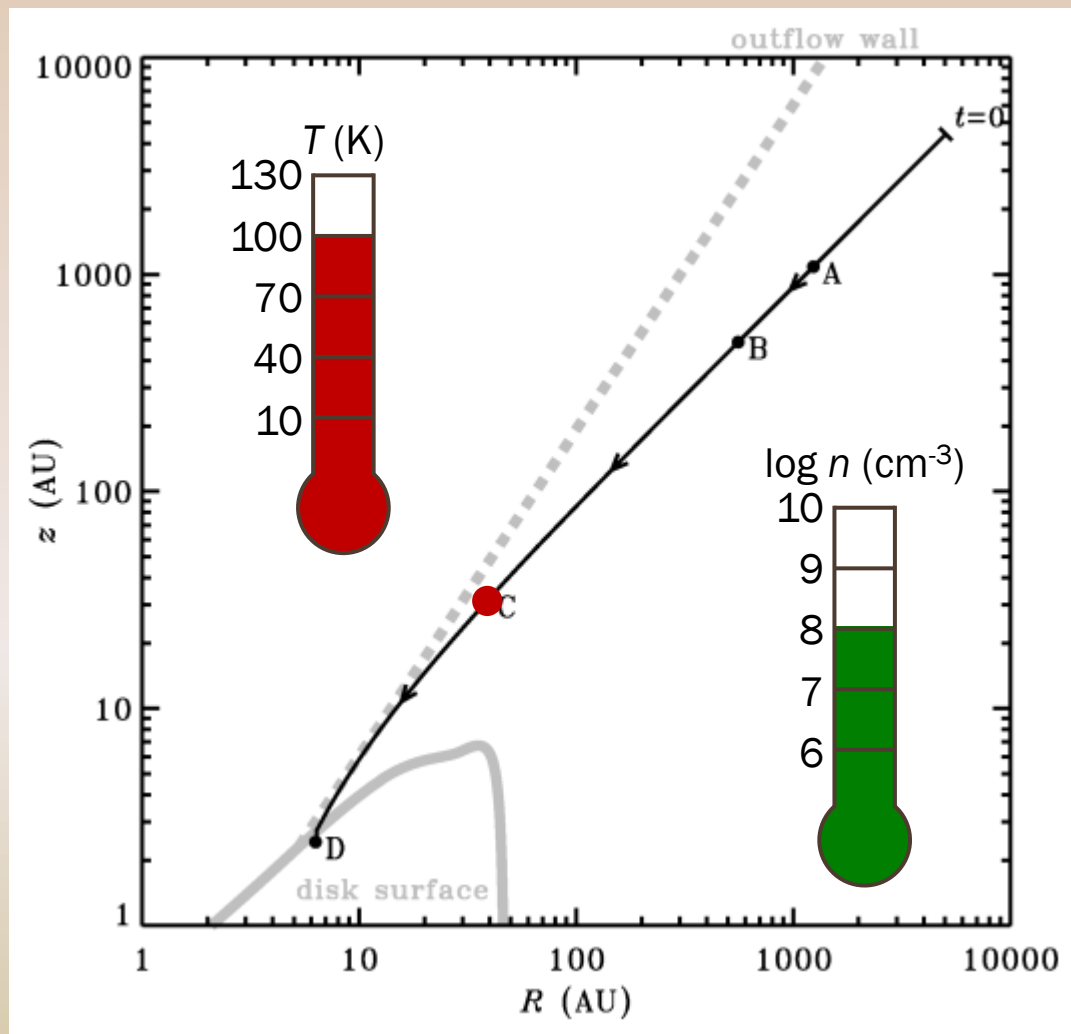


Point C:

- ✗ NH_3 , H_2O evaporate
- ✗ NH_3 , H_2O , O_2 , CH_4 photodissociated
- ✗ CO , N_2 may survive

CHEMICAL EVOLUTION ALONG ONE TRAJECTORY

Visser et al. (subm.)

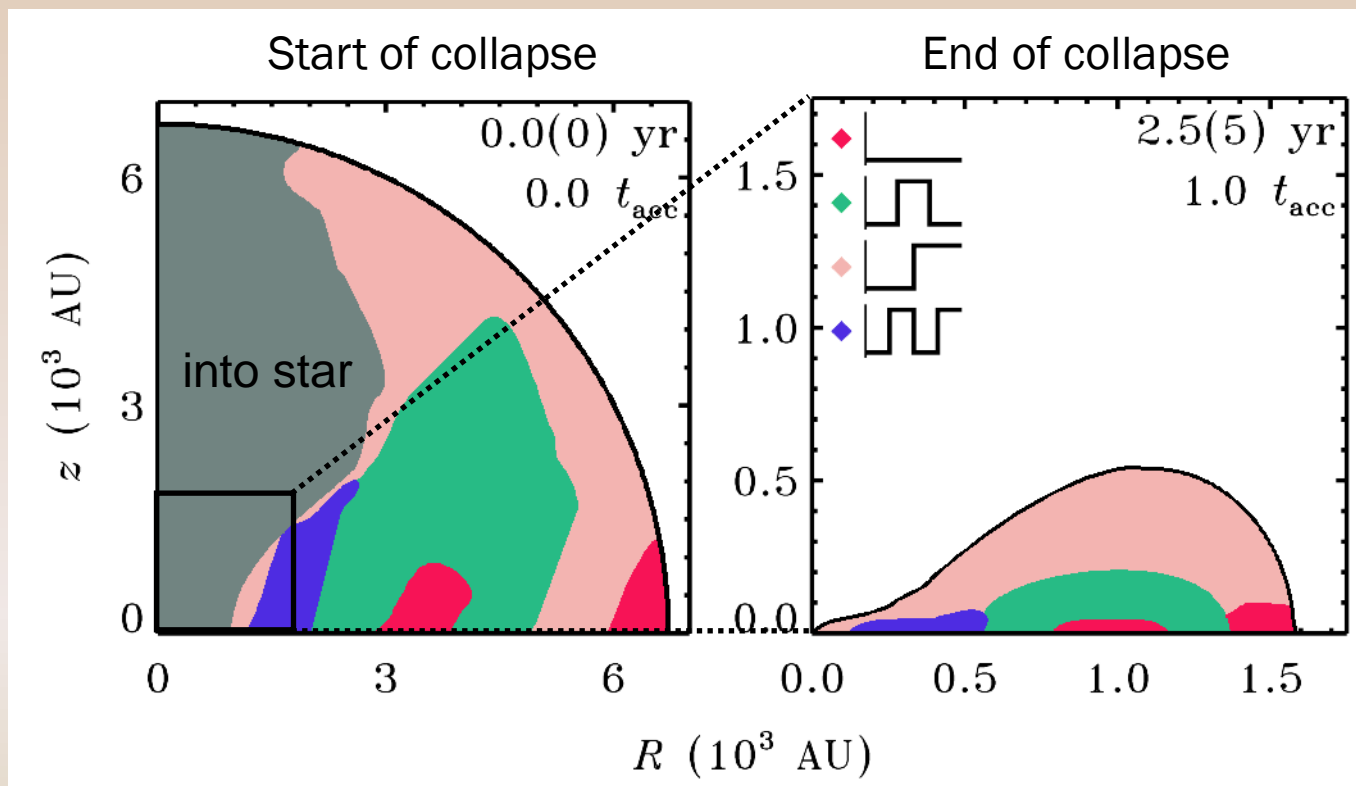


Point D:

- ✘ Some NH_3 , H_2O , CH_4 reformed
- ✘ CO , N_2 most abundant

CHEMICAL STRATIFICATION: CO GAS/ICE

Visser et al. (2009)



Red: CO remains adsorbed (pristine!)

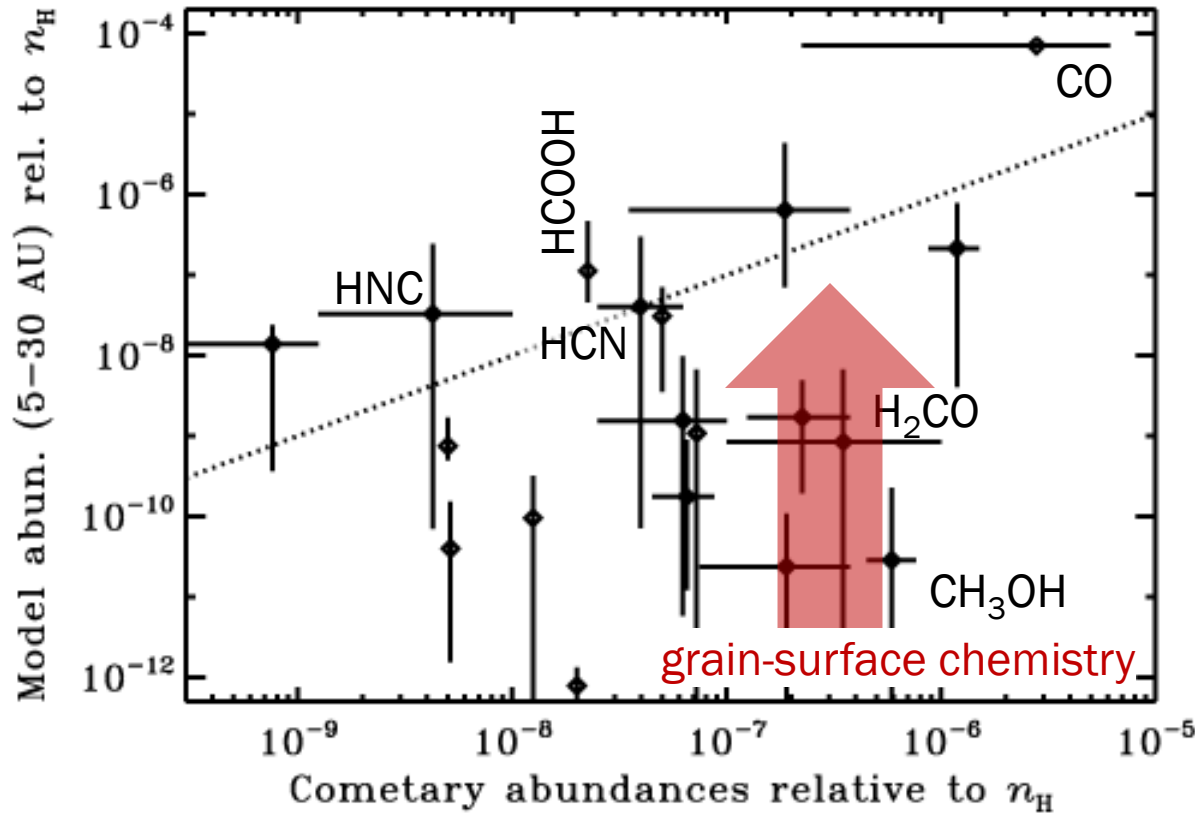
Green: CO desorbs and re-adsorbs

Pink: CO desorbs and remains desorbed

Blue: multiple desorption/adsorption

IMPLICATIONS FOR COMETS

Visser et al. (subm.)



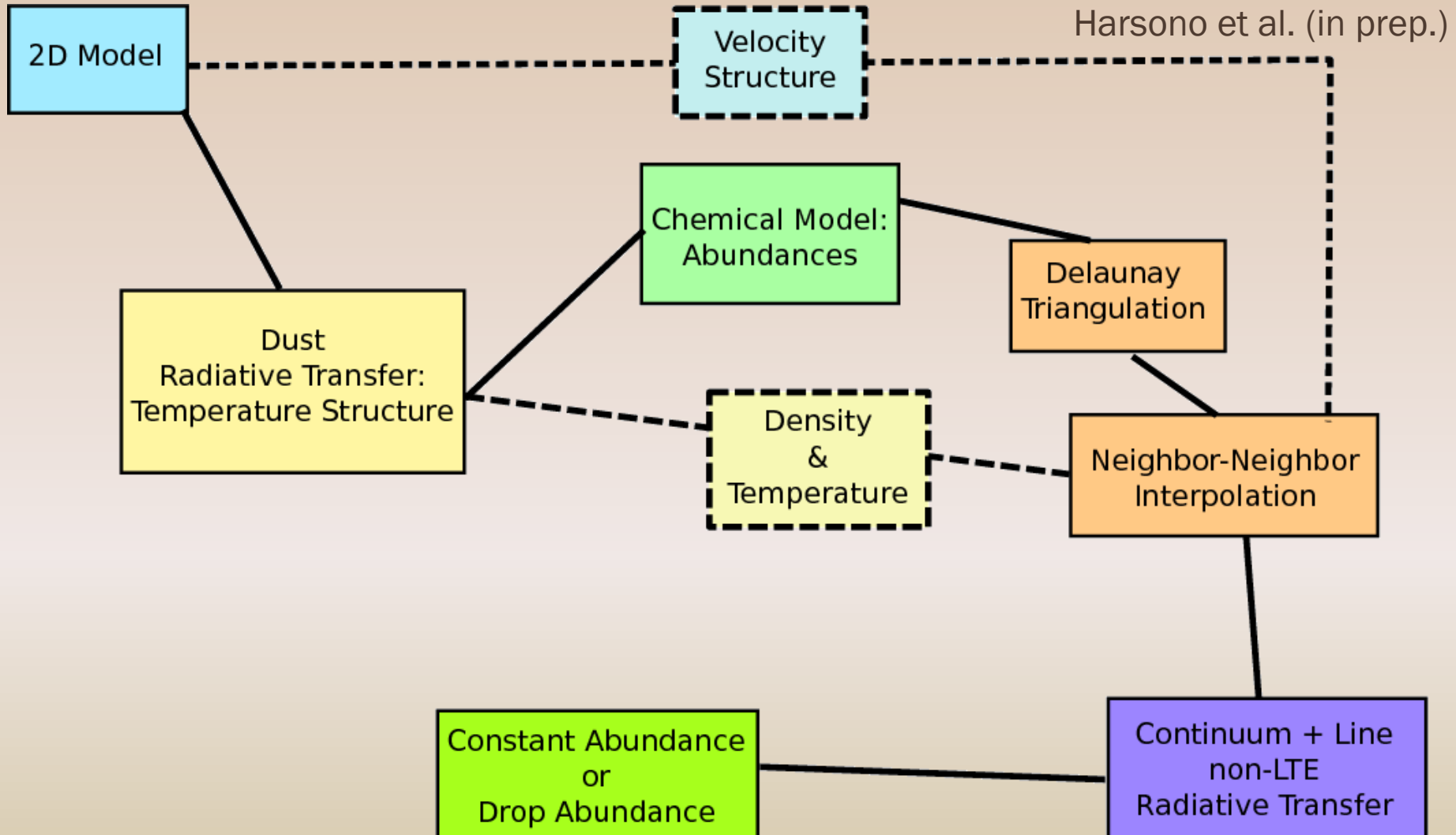
- ✘ Many model abundances differ from cometary abundances
- ✘ Suggestive of mixing or grain-surface chemistry?

IMPLICATIONS FOR COMETS

Visser et al. (subm.)

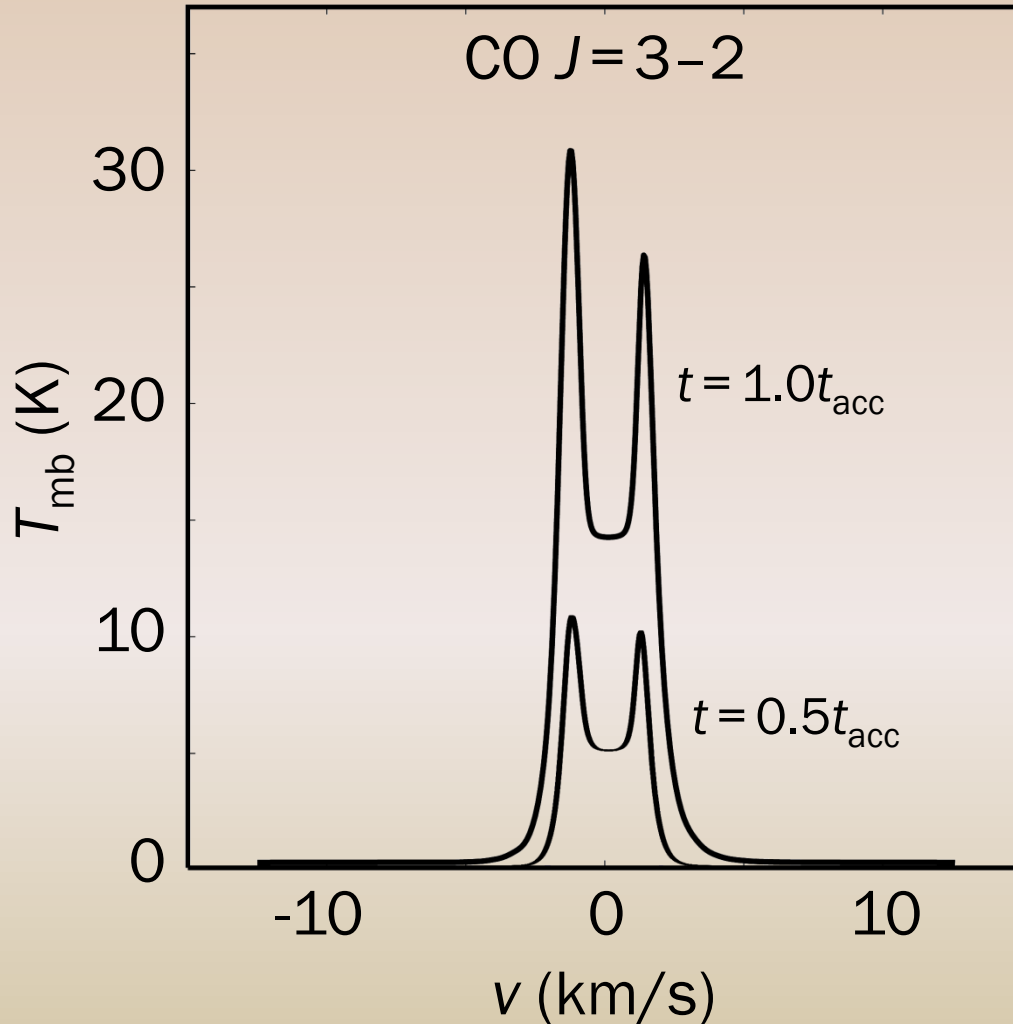
- ✘ Model vs. observations:
 - Poor match with comet-forming zone
 - Good match with outer disk
- ✘ Points to mixed origin of cometary material
- ✘ More evidence:
 - Crystalline silicates in comets
 - H₂O o/p ratio in comets vs. disks

LINK WITH OBSERVATIONS OF EMBEDDED YSOs



LINK WITH OBSERVATIONS OF EMBEDDED YSOs

Harsono et al. (in prep.)



- ✘ Intensity increases as envelope gets warmer
- ✘ Velocity structure to be compared with observations

CONCLUSIONS

- ✘ Important to do core collapse and disk formation in 2D
- ✘ Model predicts chemical stratification in embedded disk phase
 - Test with ALMA
- ✘ Model provides more evidence for mixed origin of cometary material