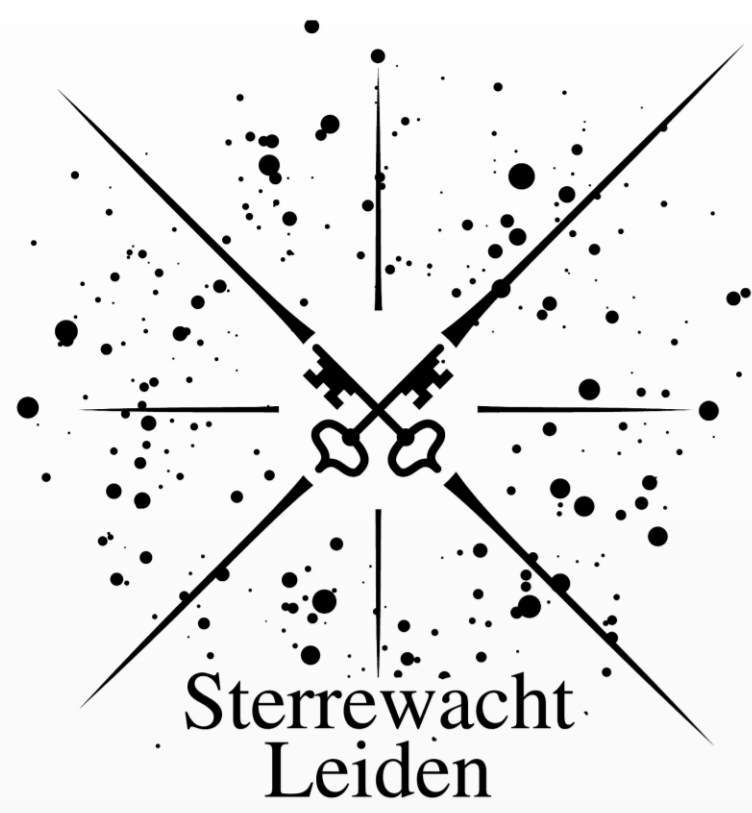


Chemical transport from cloud to disk

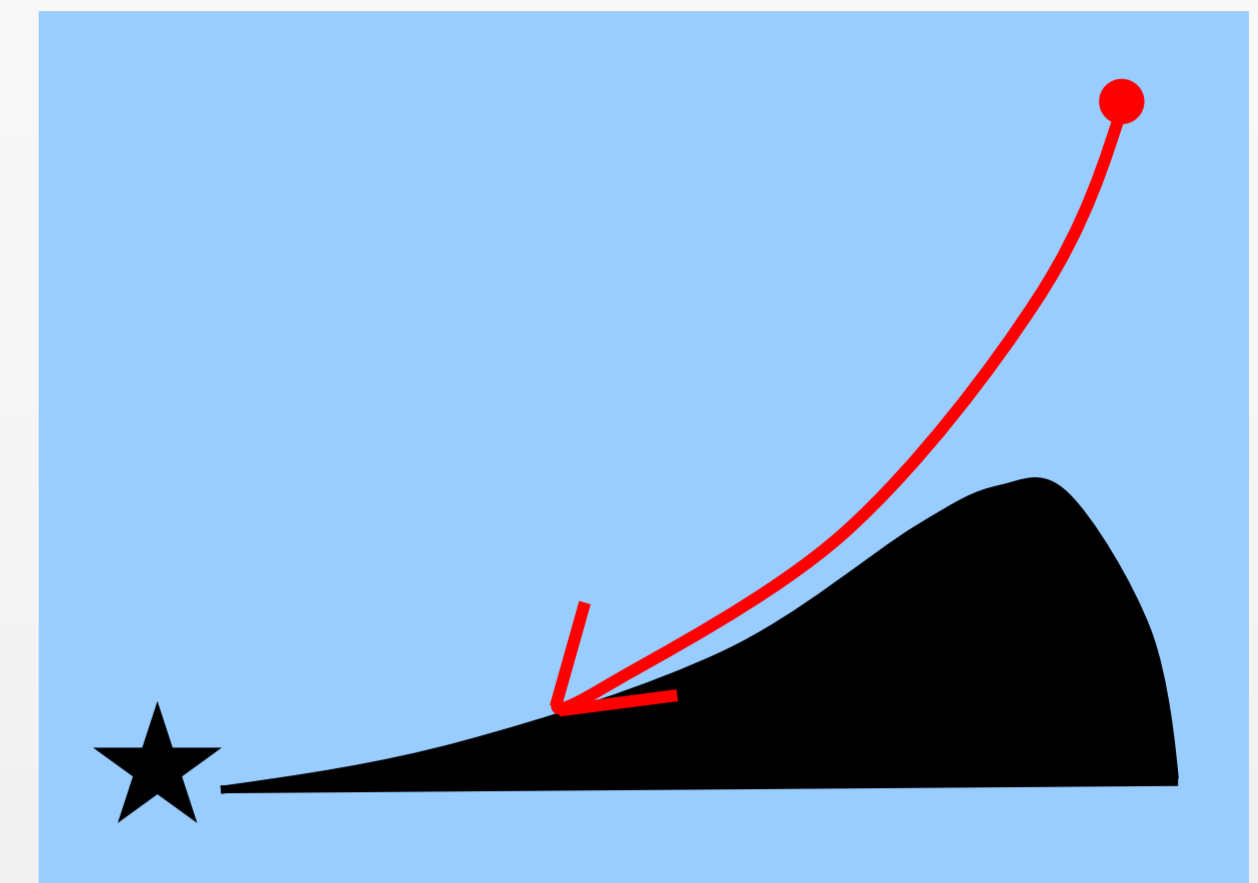


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Summary

- First semi-analytical model to follow chemistry from collapsing cloud into circumstellar disk
- Full time-dependent treatment of the temperature structure
- CO evaporates during collapse, re-adsorbs onto grains inside the disk
- Water is frozen out onto grains almost everywhere
- Material ending up in the planet- and comet-forming zones is probably rich in organic material



The model

- Two-dimensional, axisymmetric
- Inside-out Shu collapse with rotation^{1,2,3}
- Radial velocities in the disk from viscous evolution^{4,5}
- Vertical hydrostatic equilibrium assumed for the disk⁶
- Dust temperature in cloud and disk from full radiative transfer⁷
- Gas temperature assumed to be equal to the dust temperature everywhere

Standard parameters

- Initial cloud mass: 1.0 M_{Sun}
- Cloud radius: 6700 AU
- Sound speed: 0.26 km s⁻¹
- Solid-body rotation rate: 10⁻¹³ s⁻¹
- Initial uniform temperature: 10 K
- Accretion time: 2.5 × 10⁵ yr

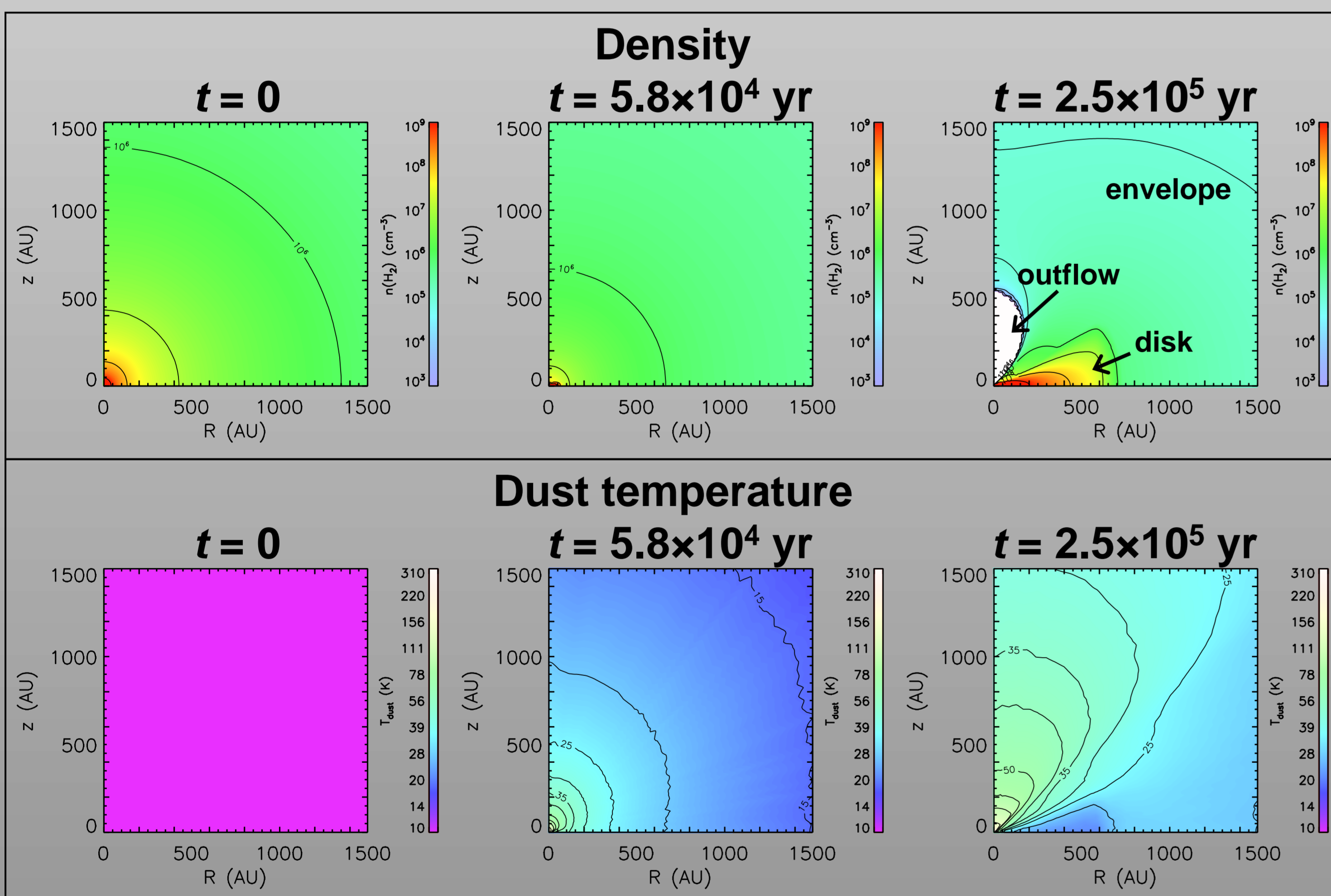
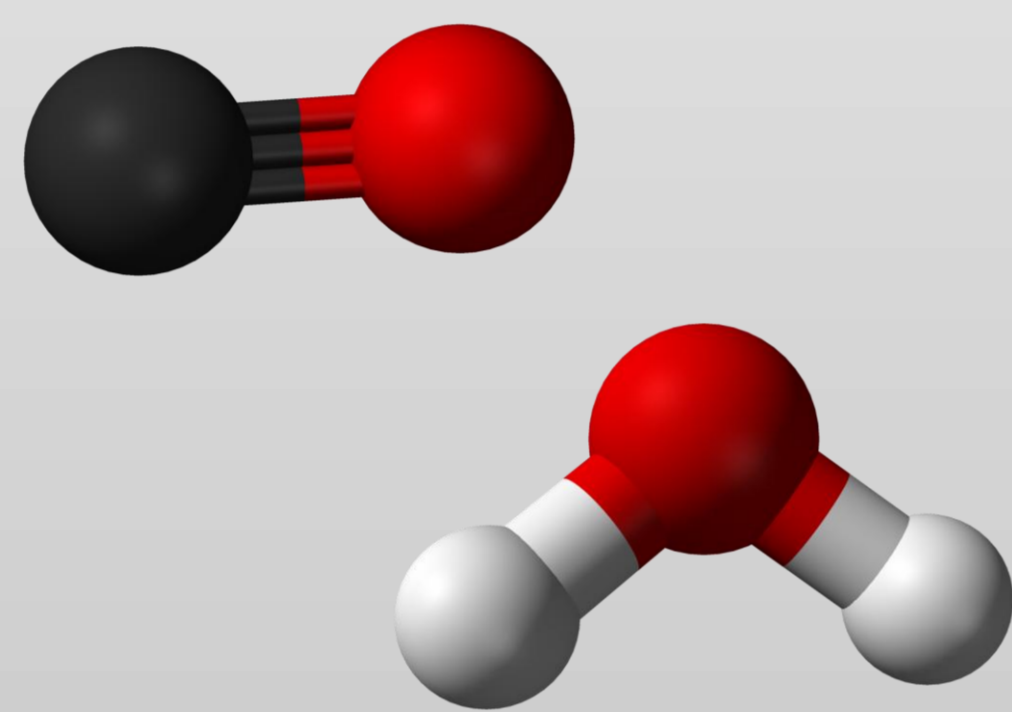


Fig. 1 Density and temperature evolution in standard model

Upper three panels: Total gas density in the template model at three time steps. The density profile is perfectly spherical at the onset of collapse and the disk becomes ever more dominant as the collapse proceeds. An evacuated cavity appears near the poles at $\sim 10^5$ yr and gradually grows in size.

Lower three panels: Dust temperature at the same time steps. The cloud is initially isothermal at 10 K and begins to heat up from the centre when the protostar turns on. The disk remains cold at all times.

Results: gas (white) and ice (blue)

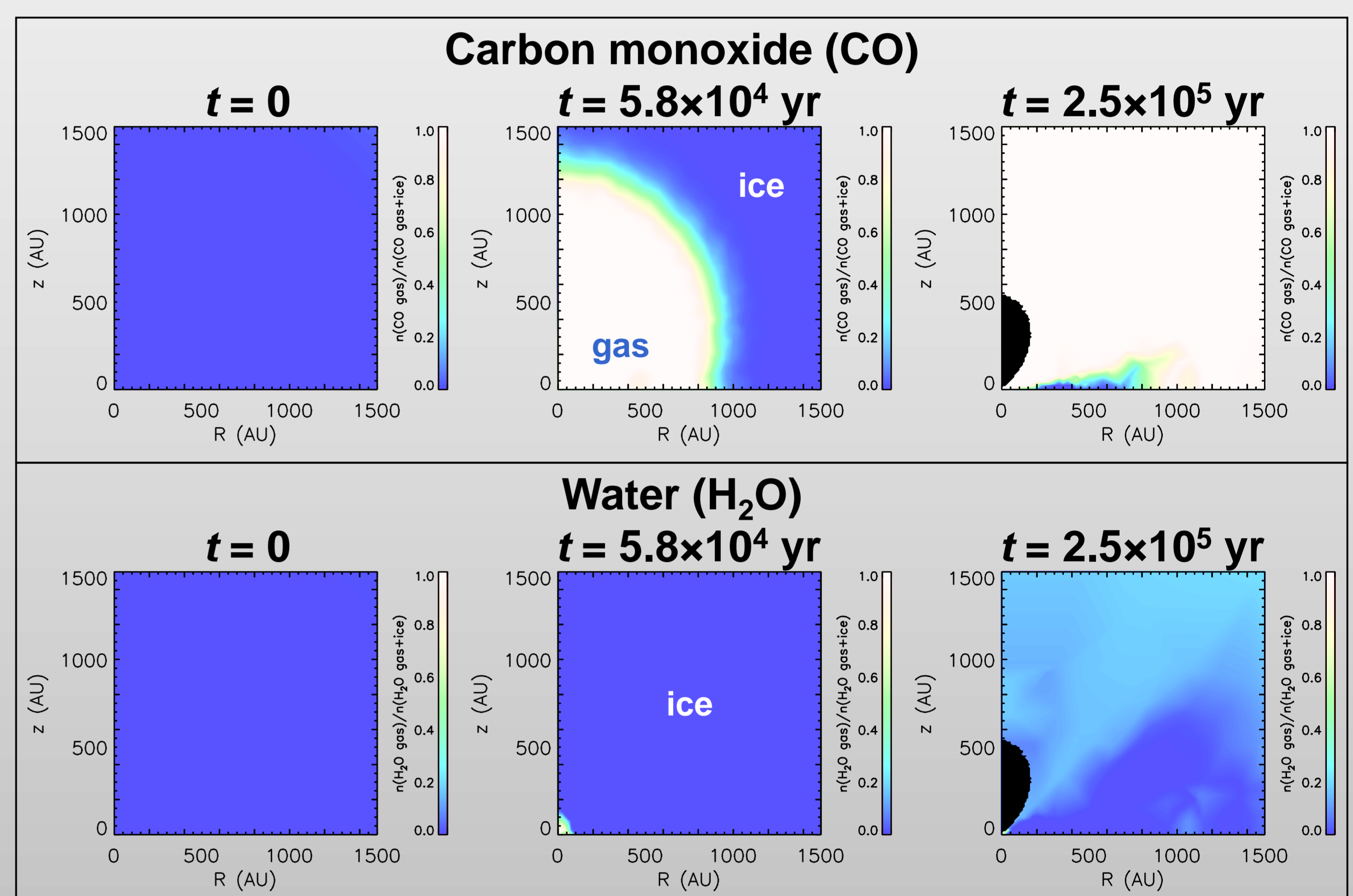


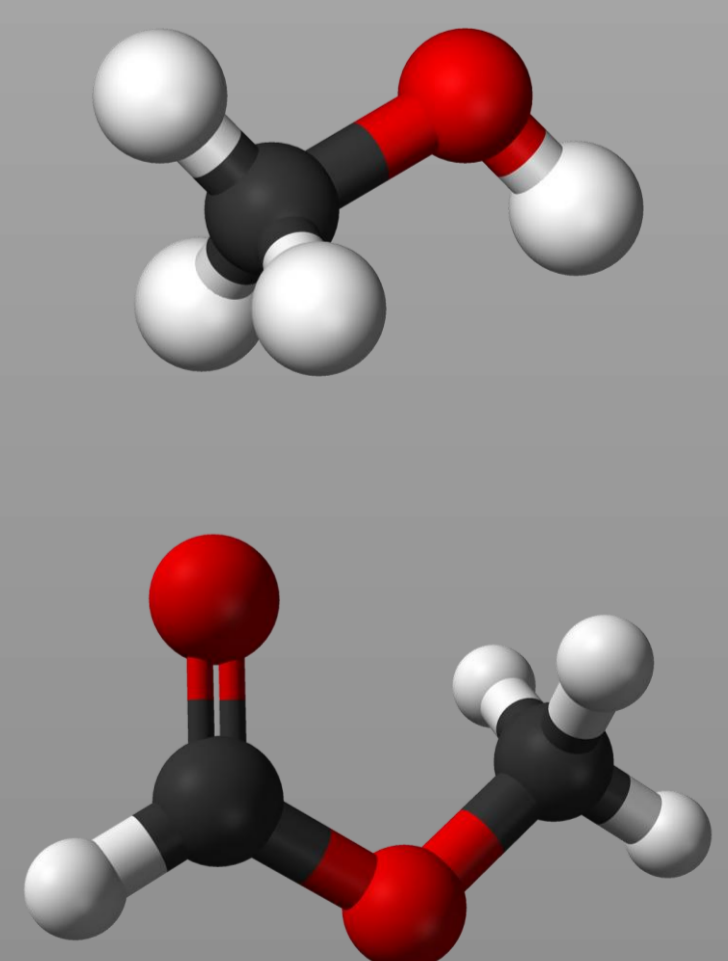
Fig. 2 CO and H₂O gas/ice evolution in template model

Upper three panels: Fraction of CO gas w.r.t. the total CO abundance in the template model at the same three time steps as used in Fig. 1. All CO within 1500 AU is frozen out at the onset of collapse. It desorbs during the collapse due to heating from the protostar and re-adsorbs in the sub-20 K parts of the disk.

Lower three panels: Fraction of H₂O gas w.r.t. the total H₂O abundance at the same time steps. Almost all H₂O remains frozen out throughout the collapse.

Towards more complex species

- Small organics (e.g. methanol, CH₃OH) likely to be formed before the onset of collapse⁸
- Once formed, gas/ice behaviour comparable to water
- Infalling material passes through 20-60 K zone before accreting onto the disk
- Probably sufficient for formation of complex organics (e.g. methyl formate, HCOOCH₃)⁸
- Once formed, gas/ice behaviour comparable to water
- Full chemical network will be run in the near future to further explore the question of complex organics



References

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