Chemical Evolution of Protoplanetary Disks with Dust Substructures

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Outline

Introduction

The Bigger and the Smaller Picture

- How planets like the Earth are formed.
- ..
- How does the chemistry change in planet formation processes.
- ..
- This work.

The Specific Questions

- How does the chemistry evolve in protoplanetary systems?
- What compounds should we expect to find around different types of systems and /or planets?

Science Case

Science Case

Dust Substructures in Planet Formation

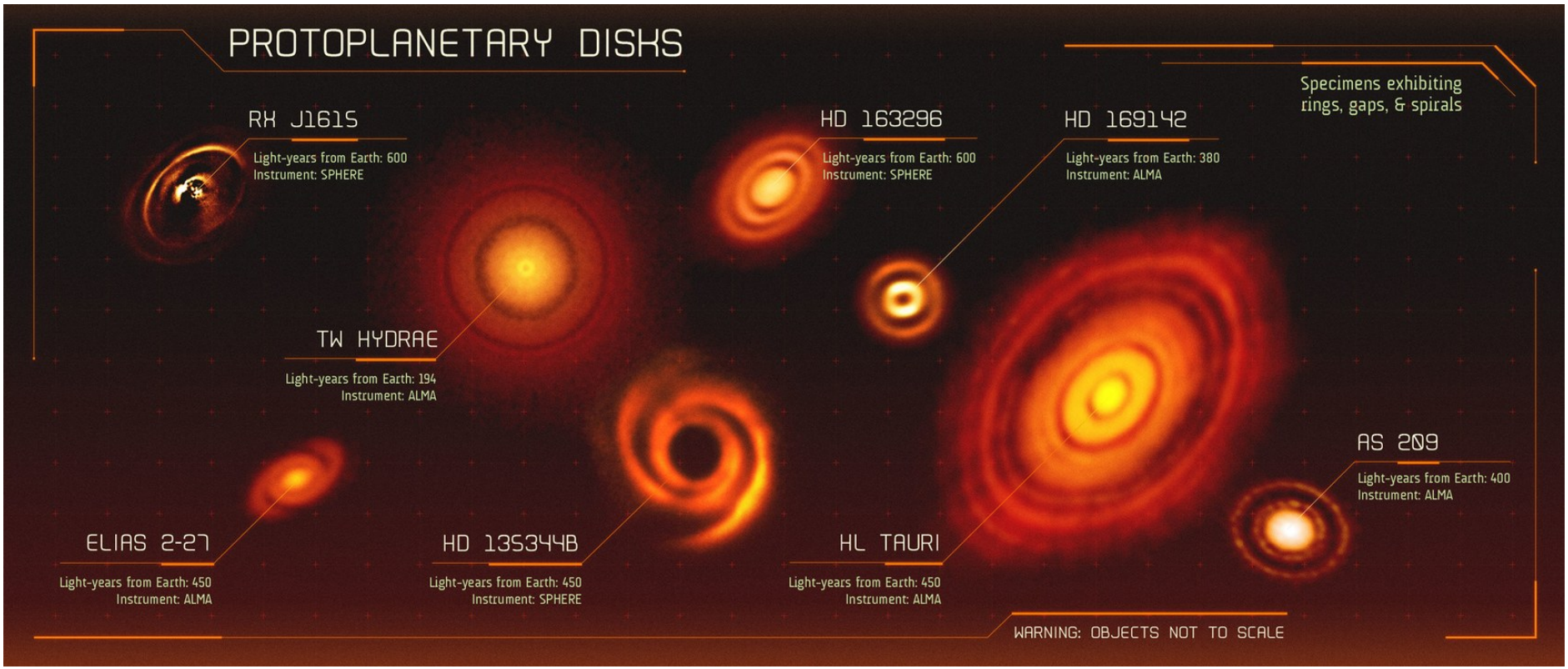
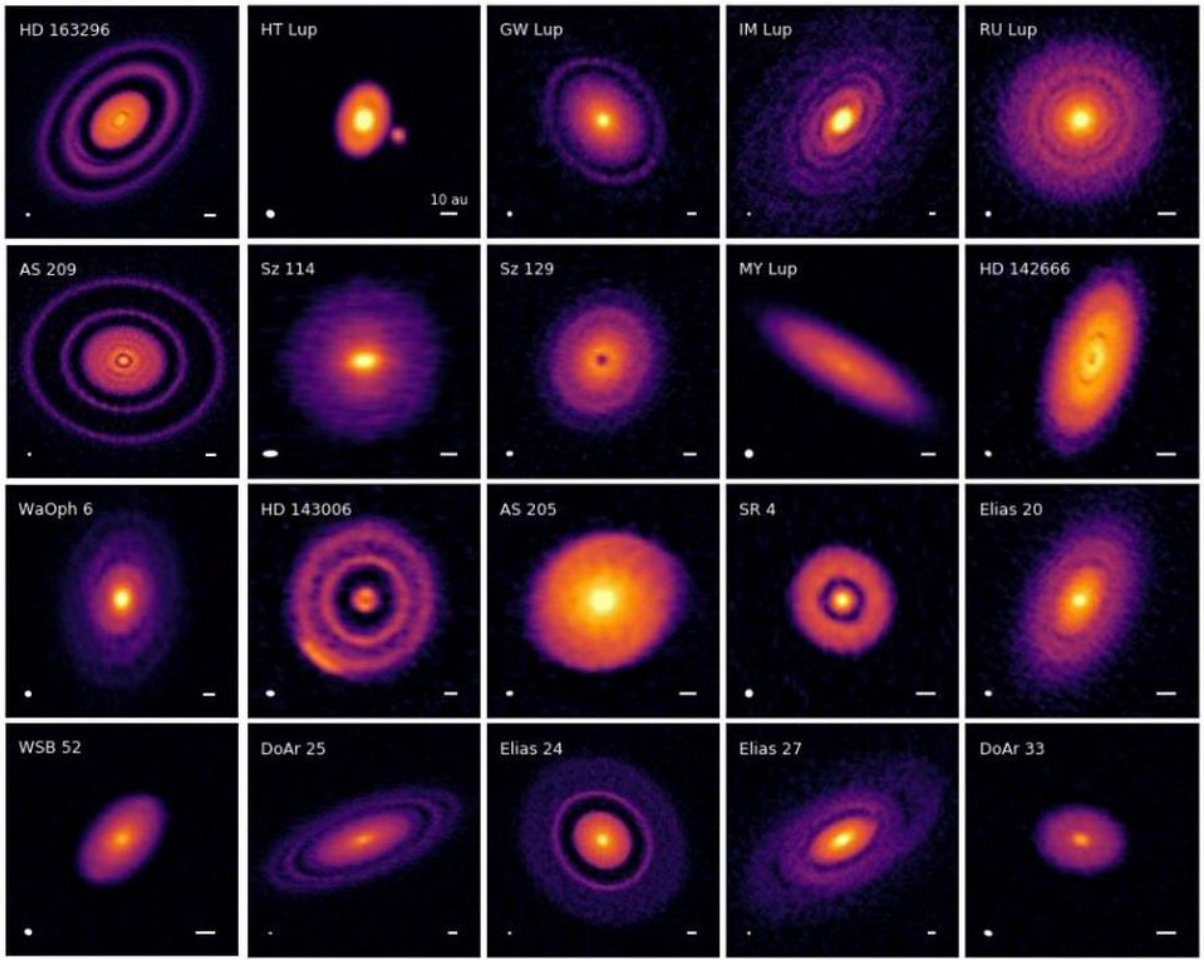


Image Credit: ESO

Dust Substructures II

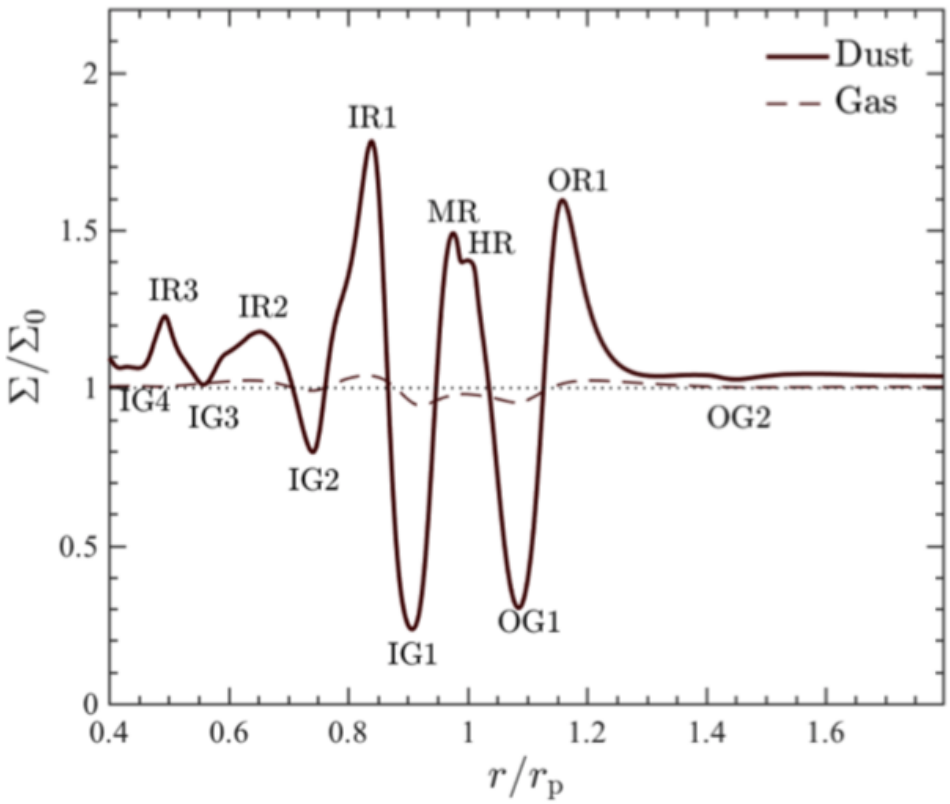


(DSHARP,Andrews+, 2018)

Dust substructures seem to be common in protoplanetary disks, particularly the axis-symmetric ones.

What makes dust substructures so important?

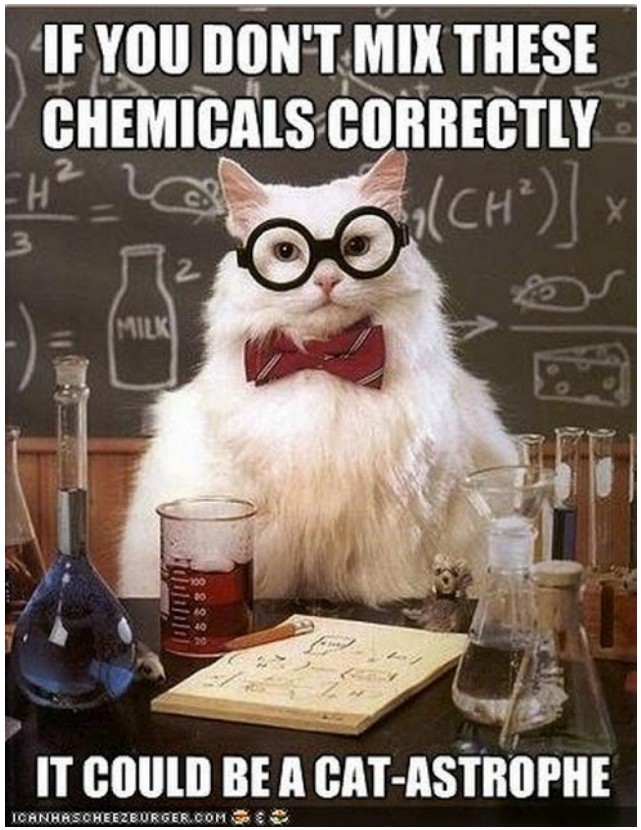
- Dust substructures could be signatures of ongoing planet formation (among other options).
- Chemistry-rich places.
- Possible places for the formation of rocky cores.
- **Gap**: Local Depletion of material.
- **Ring**: Local enhancement of surface density.

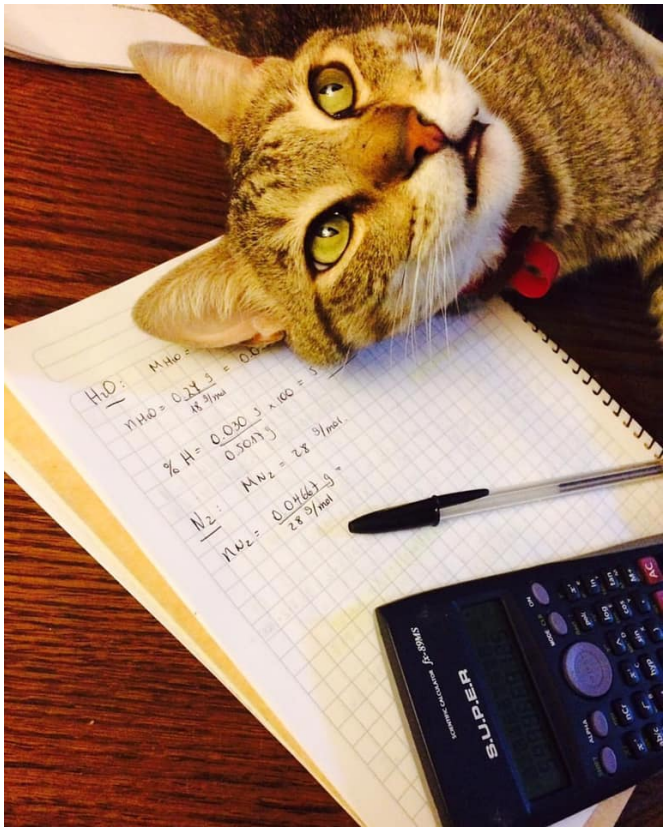


(Dong+, 2018)

Chemical Evolution in Disks?

How will dust substructures change the chemistry?



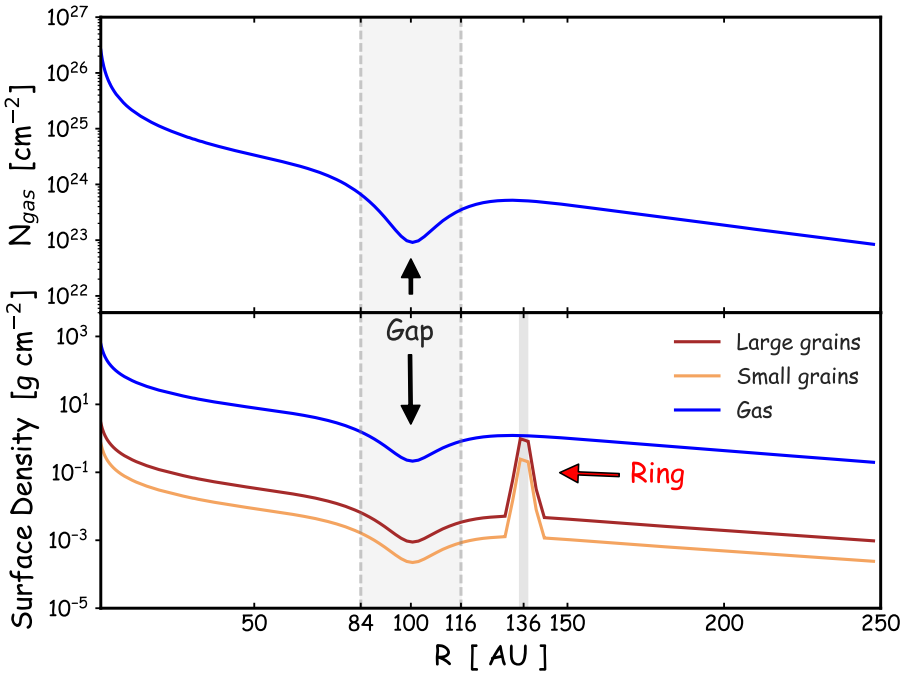


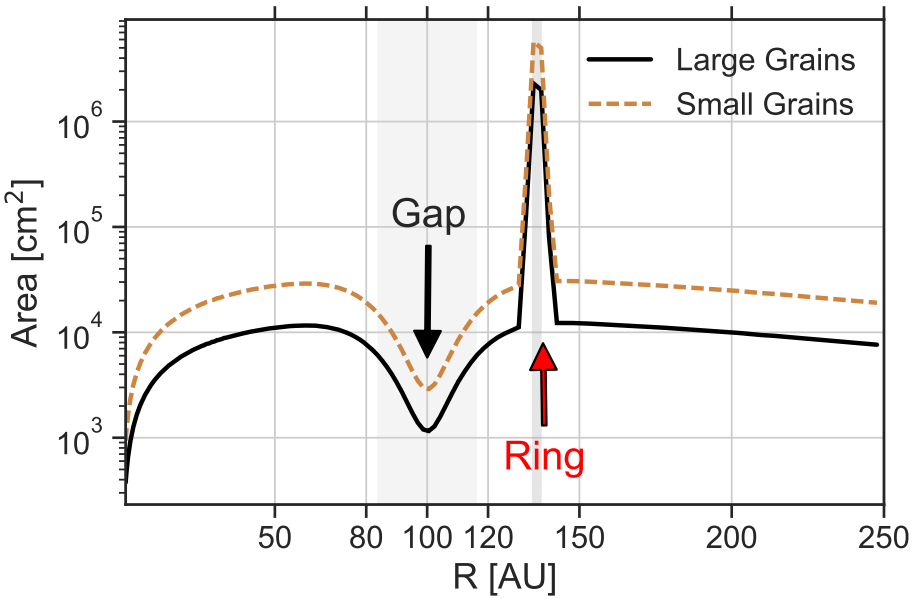
Chemical Evolution in Disks?

- Changes in temperature will enhance the creation of more complex molecules.
- The disk could be optically thinner/thicker to high energy photons in those substructures.
- What's the composition on those zones?
  How will that change the final composition of the planets that may form there?

Models

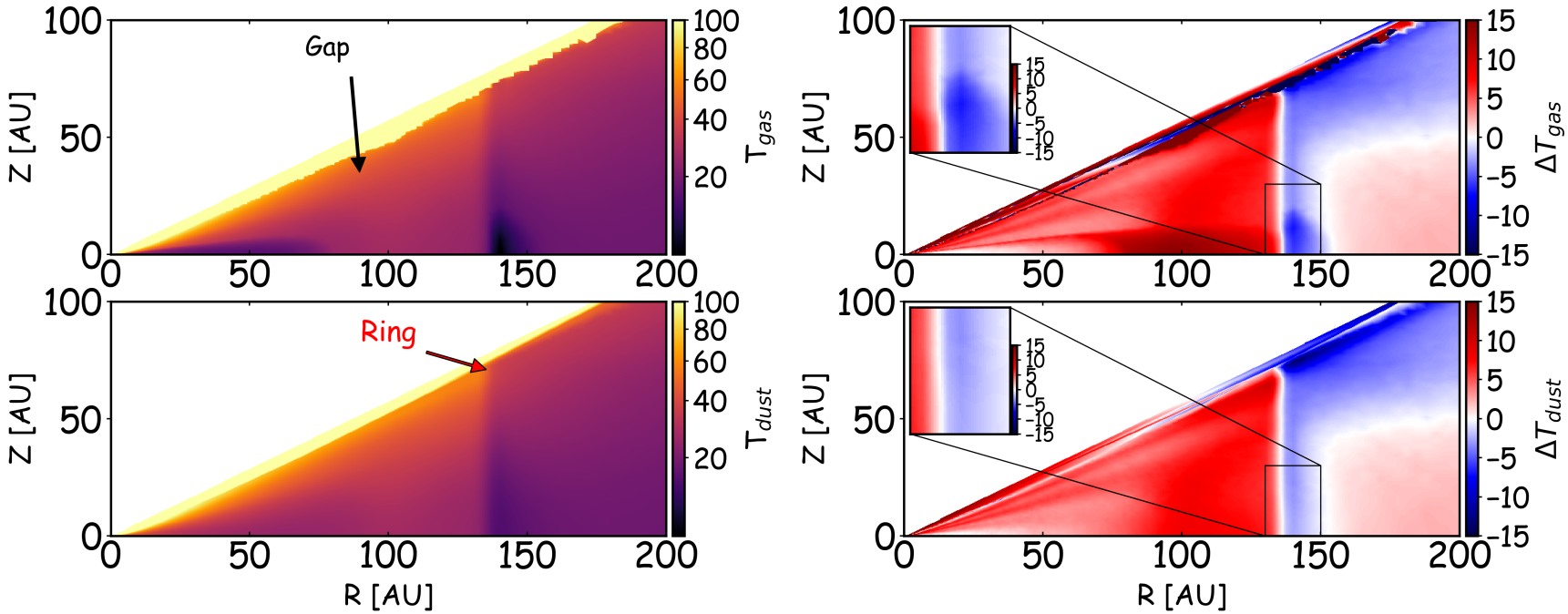
We run thermo-chemical models with a state-of-the-art code, RAC2D (Du+ 2017). Our models include gaps and rings to see the change in the chemical and thermal structure.





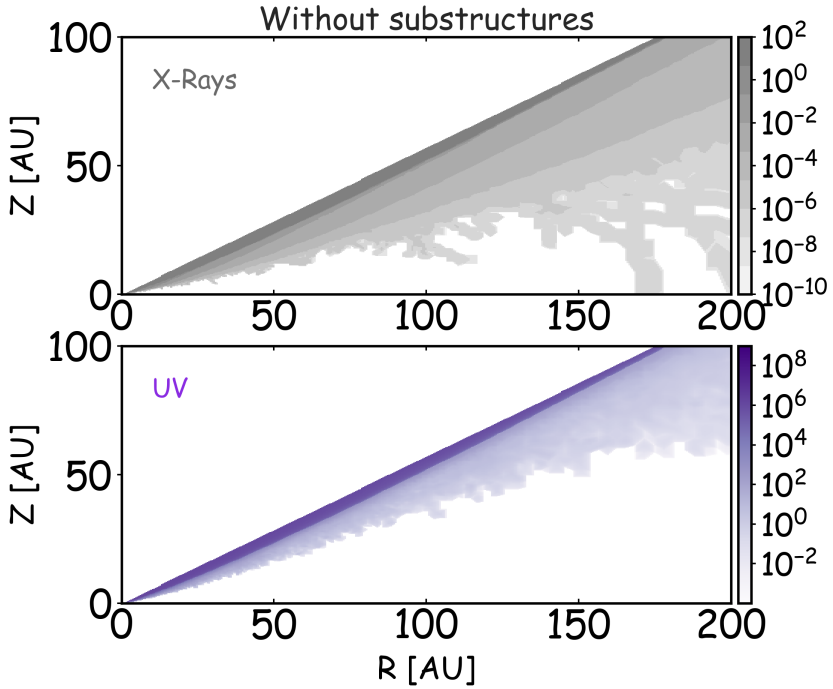
Thermal Changes

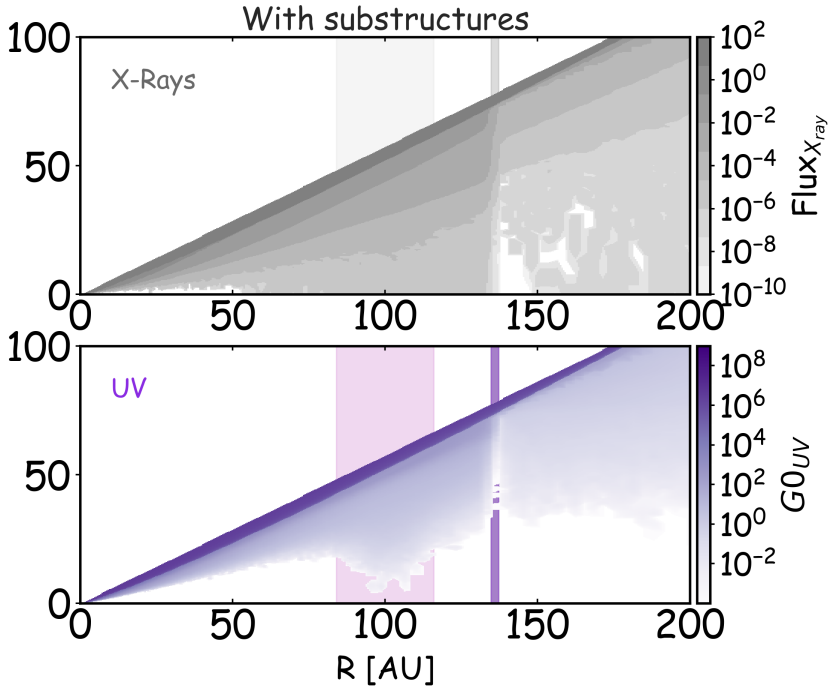
There are thermal changes associated with both substructures. Rings cooled the disk through shielding of UV and X-ray radiation, while the gap makes the disk more transparent to those wavelenghts.



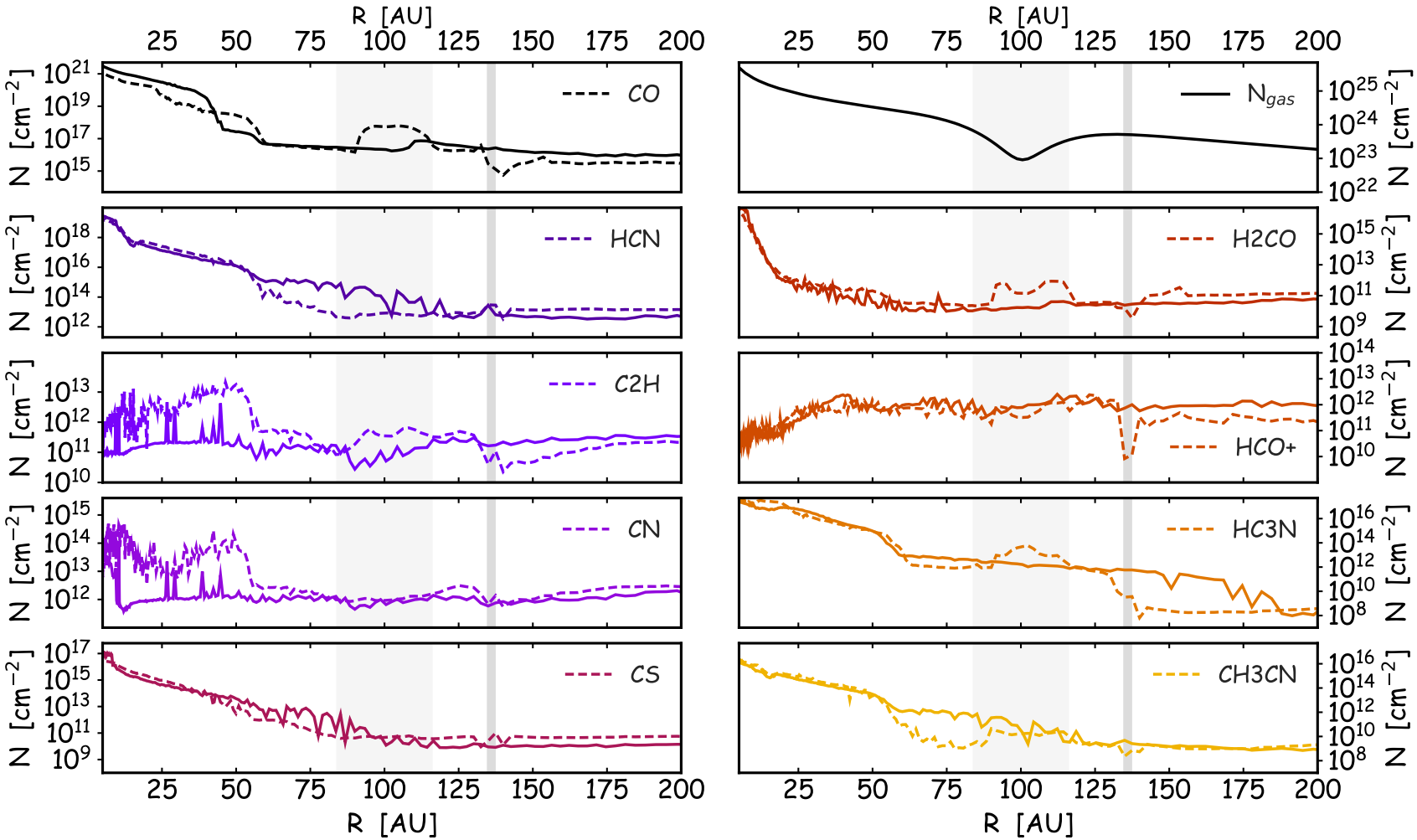
UV and X-ray Penetration

The change in high energy radiation will not only heat the gas and dust, but it will either increase or decrease the photodissociation or photodesorption in their locations.

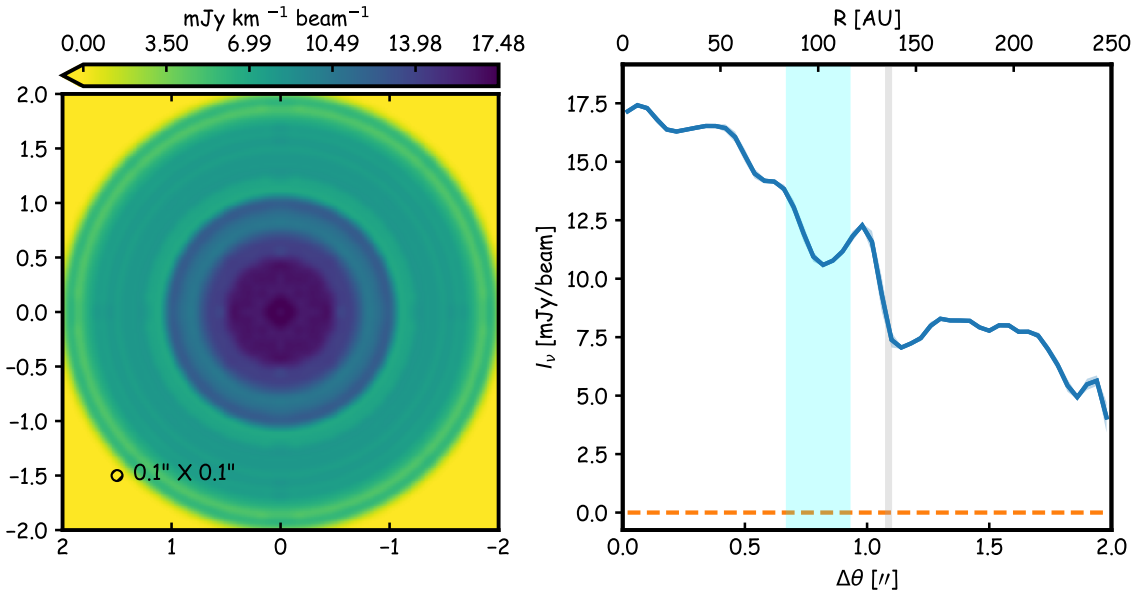




Column Densities Profiles

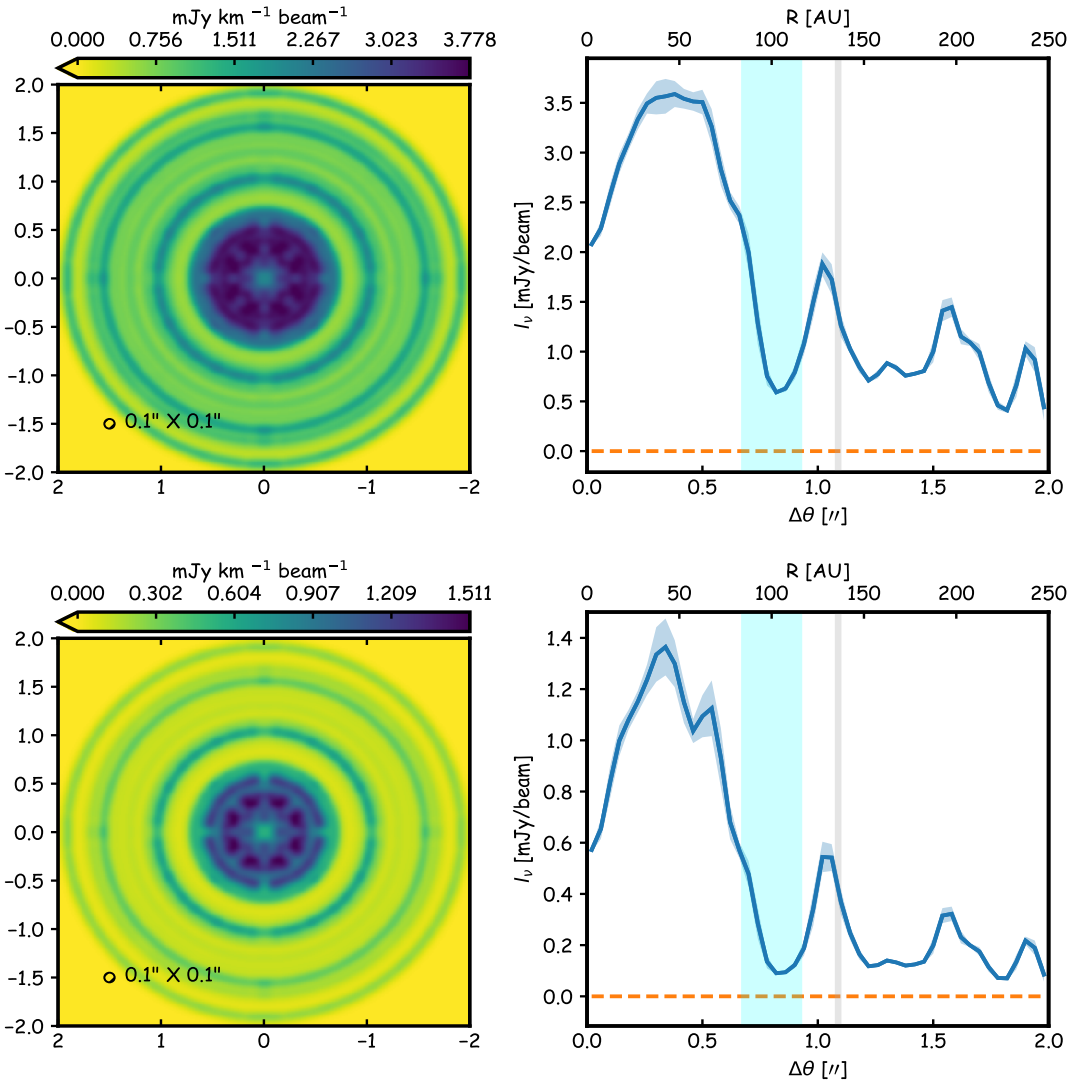


Predictions for Line Emission, CO



We look to make predictions of line emission and also match observed lines. Some of the structure is recovered in line emission. Although, it will depend on the molecule and the line.

CO Isotopologues



The Future

- Increasing resolution with different abundances. Is the final result strongly dependant on abundances?
- Include several dust substructures in the same model.
- Reproduce emission profiles for existing disks and test for predictions (ALMA Large Program).

Summary

- Dust substructures are common on protoplanetary disk, thus in the planet formation process.
- Dust substructures play a major role in the abundances and chemistry of protoplanetary disks.
- In gaps, high energy photons penetrate deeper in the disk, photoionizing and photodissociation the midplane, heating it up.
- Rings shield the disk to high energy photons, cooling it down, changing the chemistry towards the formation of more complex molecules.