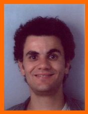
The survival of molecules in cavities of transition disks



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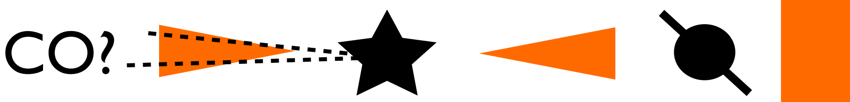


Motivation

The bulk mass of **gas in holes of transition disks** is cold (T≲200 K)

ALMA can observe this cold gas for the first time thanks to its high angular resolution and sensitivity

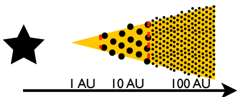
Knowledge of the amount of gas in the holes is needed to **distinguish between different scenarios of dust removal** and to **constrain theories of planet formation**

1. Transition disks

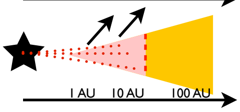
A **particular class of protoplanetary disks**, which show a lack of mid-IR excess in their SED and holes in submillimeter images (e.g. Andrews et al. 2011)

The hole is associated with the dispersal of the disk. **Different mechanism** for the formation of the hole are under discussion:

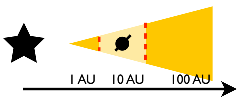
Grain-growth → gas in the cavity



Photoevaporation → removes gas in the cavity



Planet-disk interaction → reduces gas in the cavity (depending on the mass of the planets)



The amount of gas left in the cavity determines if (giant gas) planet formation can still proceed.

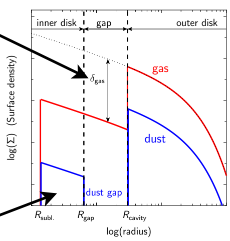
2. Thermo-chemical models

Thermo-chemical model by Bruderer et al. 2012

- *3D Monte Carlo dust radiative transfer* (diffusion solver for optically thick midplane)
- *Chemical network* (~ 120 Species, 1500 reactions) with detailed treatment of UV photodissociation, freeze-out evaporation, H_2 formation on PAHs, ...
- *Non-LTE excitation of atoms and molecules* including the effects of IR-UV pumping, excitation of OI(1D) by OH dissociation, ...
- *Thermal-balance* to calculate the gas temperature

Density structure not derived from observations, use a **simple analytical prescription** following Andrews et al. 2011.

Main parameter: δ_{gas}, the gas depletion within the cavity



We calculate models **with/and without optically thick dusty inner disk** (transition disks vs. pre-transition disks)

References

Bruderer, S.; van Dishoeck, E. F.; Doty, S. D. & Herczeg, G. J. 2012, A&A 541, A91

Bruderer, S. 2013, submitted

Andrews, S. M.; Wilner, D. J.; Espaillat, et al. 2011, ApJ 732, 42

Results / conclusions

We have developed **new thermo-chemical models for the dust free cavity of transition disks**

CO can survive down to very low gas masses in the cavity (fraction of an Earth mass)

Observing the CO isotopologues is crucial to constrain the gas mass in the cavity

ALMA can trace gas masses down to a fraction of the Earth mass with regular ~ 1h observations

3. Survival of CO in the cavity

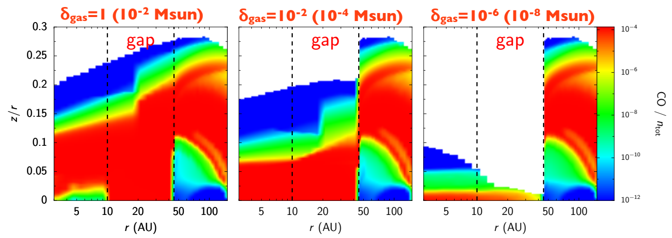
CO as tracer of the gas mass in the cavity:

+ CO has a **simple chemistry**
+ Low-J CO lines have **low critical densities and low level energy**
+ ALMA can observe CO at **high angular resolution** and sensitivity for **isotopologues**

But: Does CO survive in the strongly UV exposed cavity?

Example model: Herbig disk (10 L_{sun}) with a 50 AU radius cavity. Total disk mass 3 x 10^{-2} M_{sun} (δ_{gas} = 1)

The C^+ / CO transition shifts down with δ_{gas}, the amount of gas in the cavity:

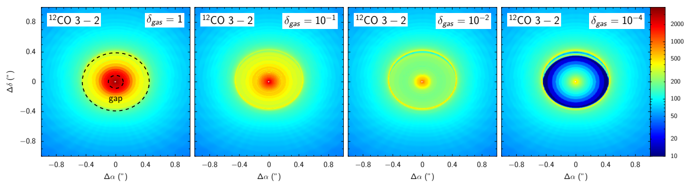


Some CO can still **survive for very low amounts of gas in the gap** (1 % of M_{Earth})

If the stellar UV radiation is **not shielded by a dusty inner disk,** CO is dissociated at a factor of 100 higher gas mass

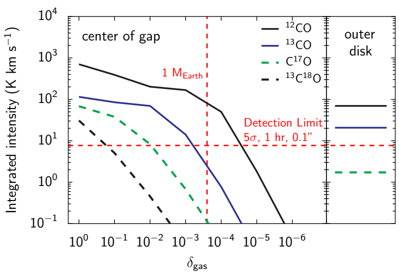
4. Predictions for ALMA

CO lines, observable by ALMA, are **optically thick for large amounts of gas in the cavity.** Integrated intensity does not change much with δ_{gas}



→ Crucial to **observe CO isotopologues** (^{13}CO, $C^{18}O$, $C^{17}O$ and $^{13}C^{18}O$) to constrain the gas mass in the cavity

Integrated intensity of CO 3-2 isotopologues in the centre of the gap (~25 AU) and the outer disk (100 AU):



ALMA can detect CO corresponding to gas masses of a fraction of an Earth mass (0.1 M_{Earth})