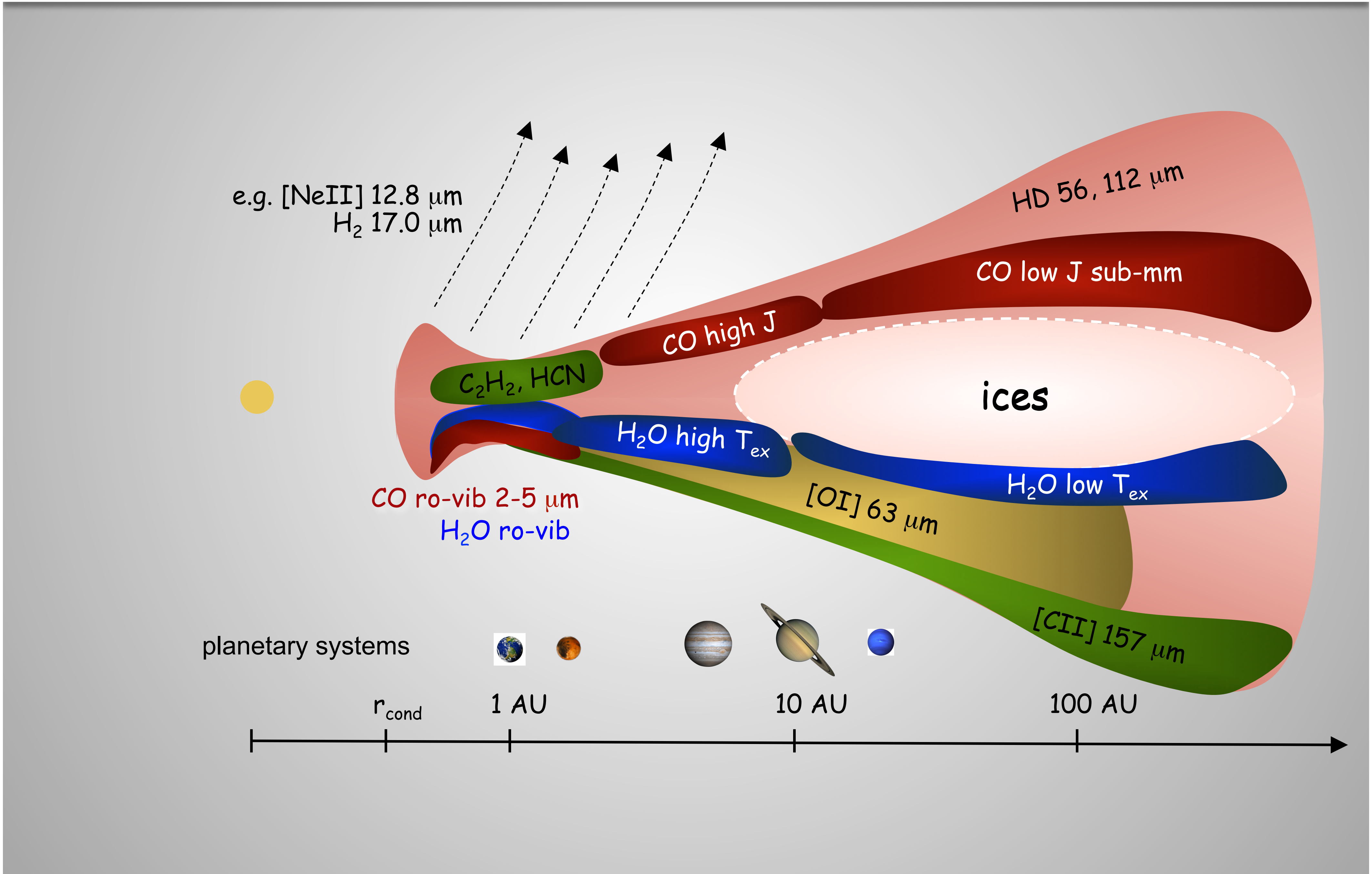
university of groningen / faculty of mathematics and natural sciences / kapteyn astronomical institute

CO ro-vibrational diagnostic from the inner regions of protoplanetary disks

Inga Kamp, Rosina Hein Bertelsen, Wing-Fai Thi, Rens Waters, Peter Woitke, Koen Maaskant

Observations in the near-IR



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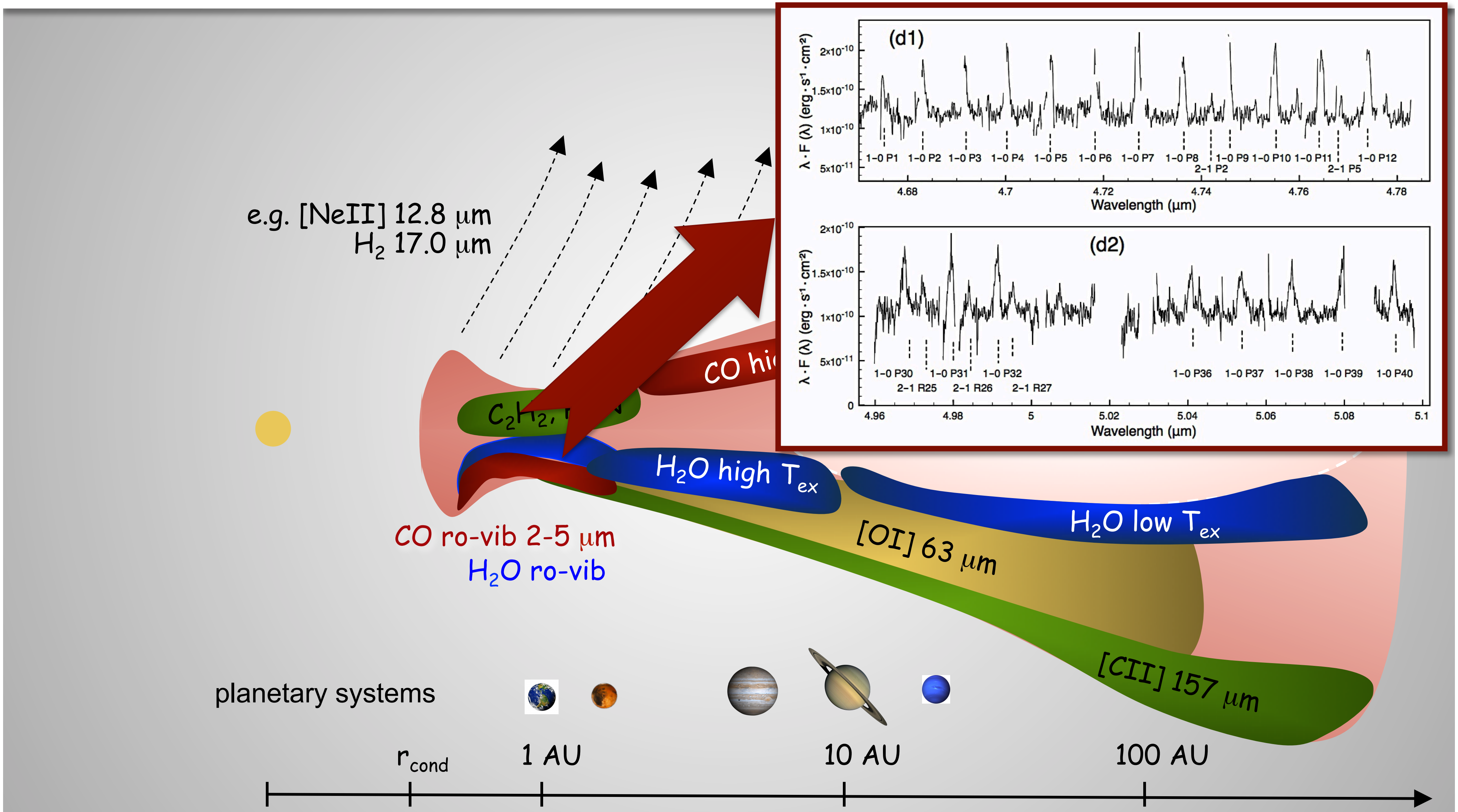
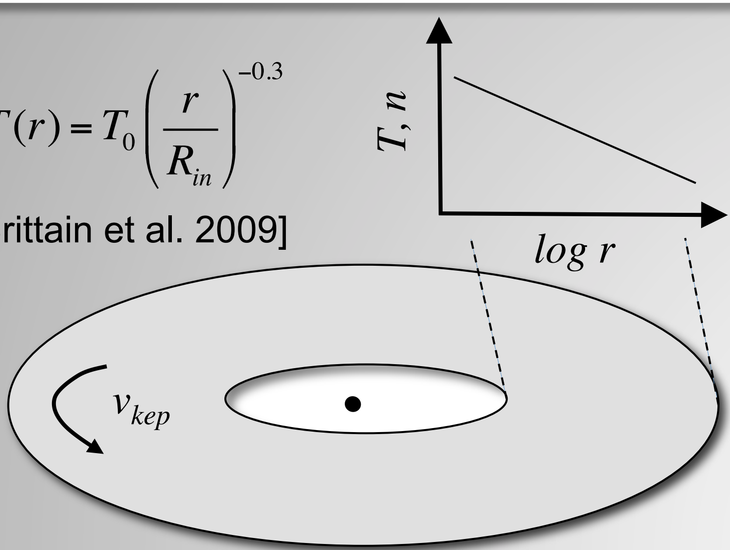


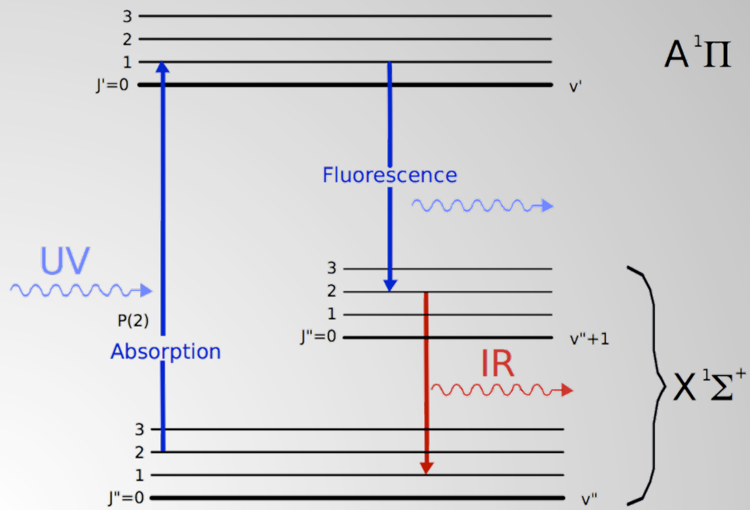
[figure top: Garufi et al. 2014; CO ro-vib observational work by Brittain et al. 2003, 2007, 2009, Blake & Boogert 2004, Goto et al. 2006, 2012, Pontoppidan et al. 2011, Bast et al. 2011, van der Plas et al. 2009, 2010, 2015, Hein Bertelsen et al. 2014]

Relevance of UV for CO ro-vib disk emission

$$T(r) = T_0 \left(\frac{r}{R_{in}} \right)^{-0.3}$$

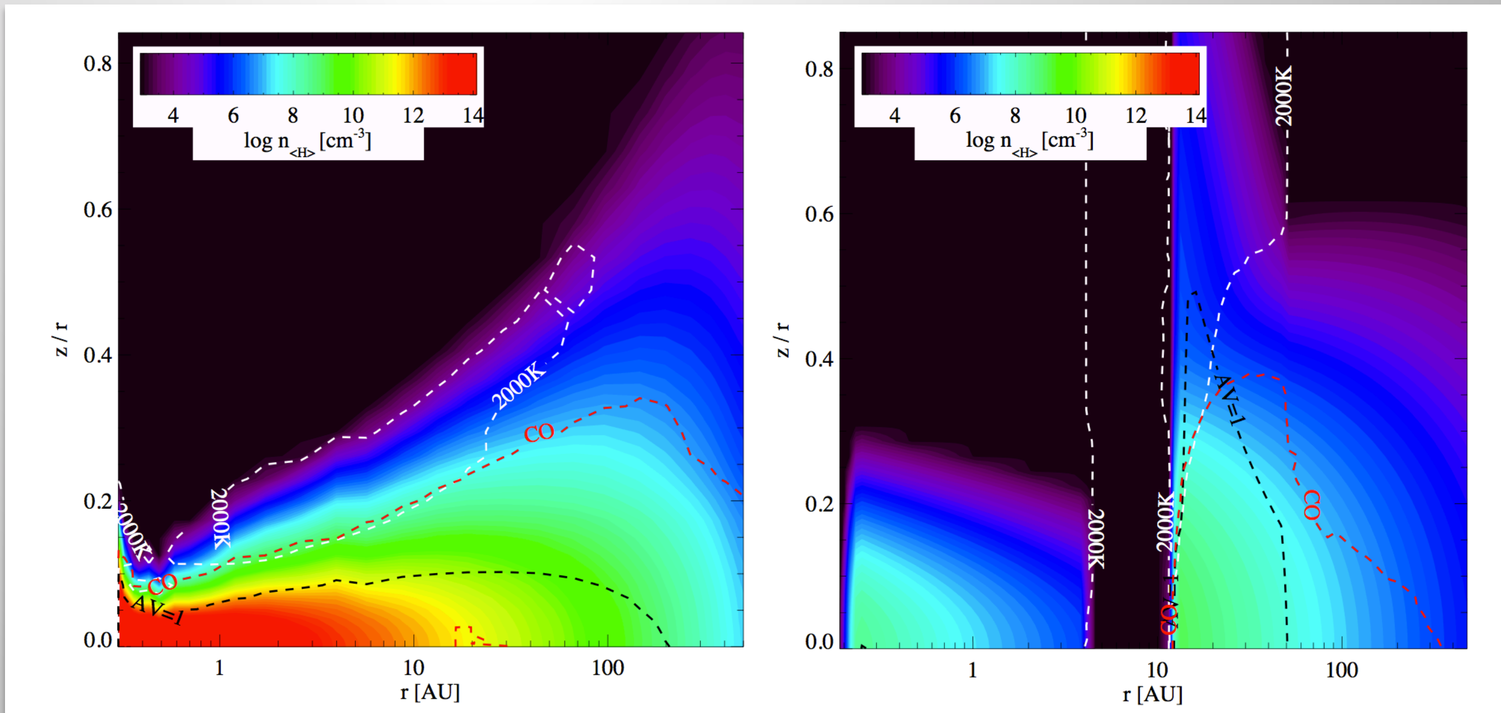
[Brittain et al. 2009]





[ProDiMo: Woitke, Kamp, Thi 2009, CO ro-vib: Thi et al. 2012]

Location of CO in a disk is not a free parameter, but determined by the gas temperature (formation) and photodissociation (destruction - UV)



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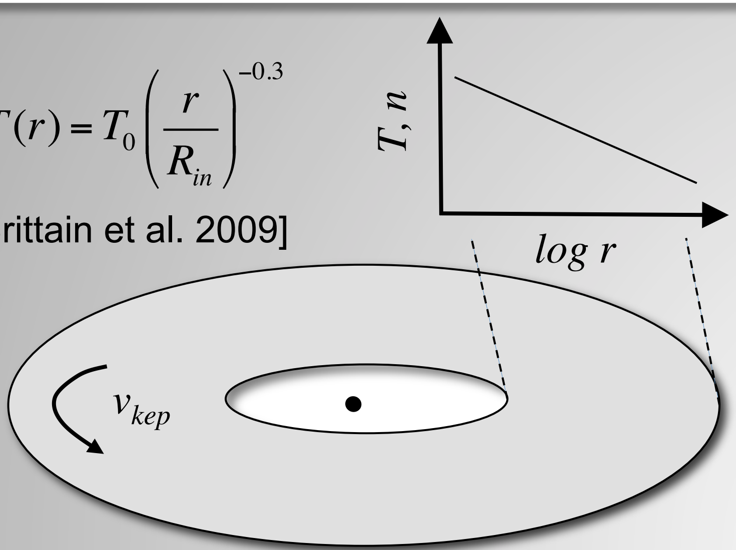

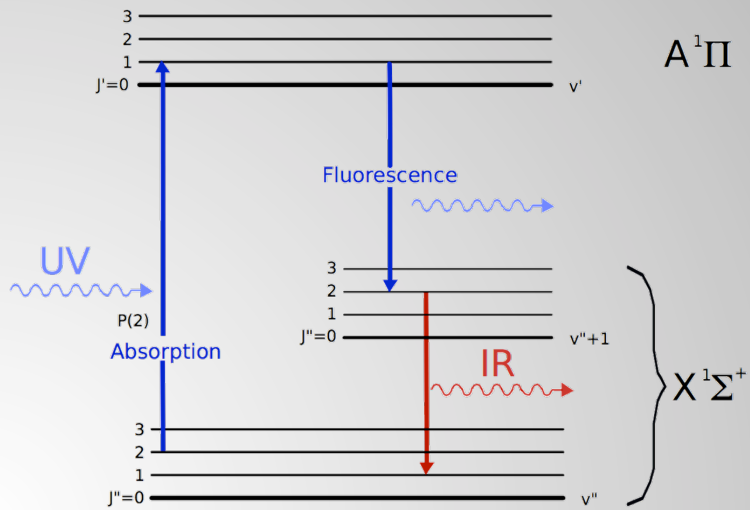

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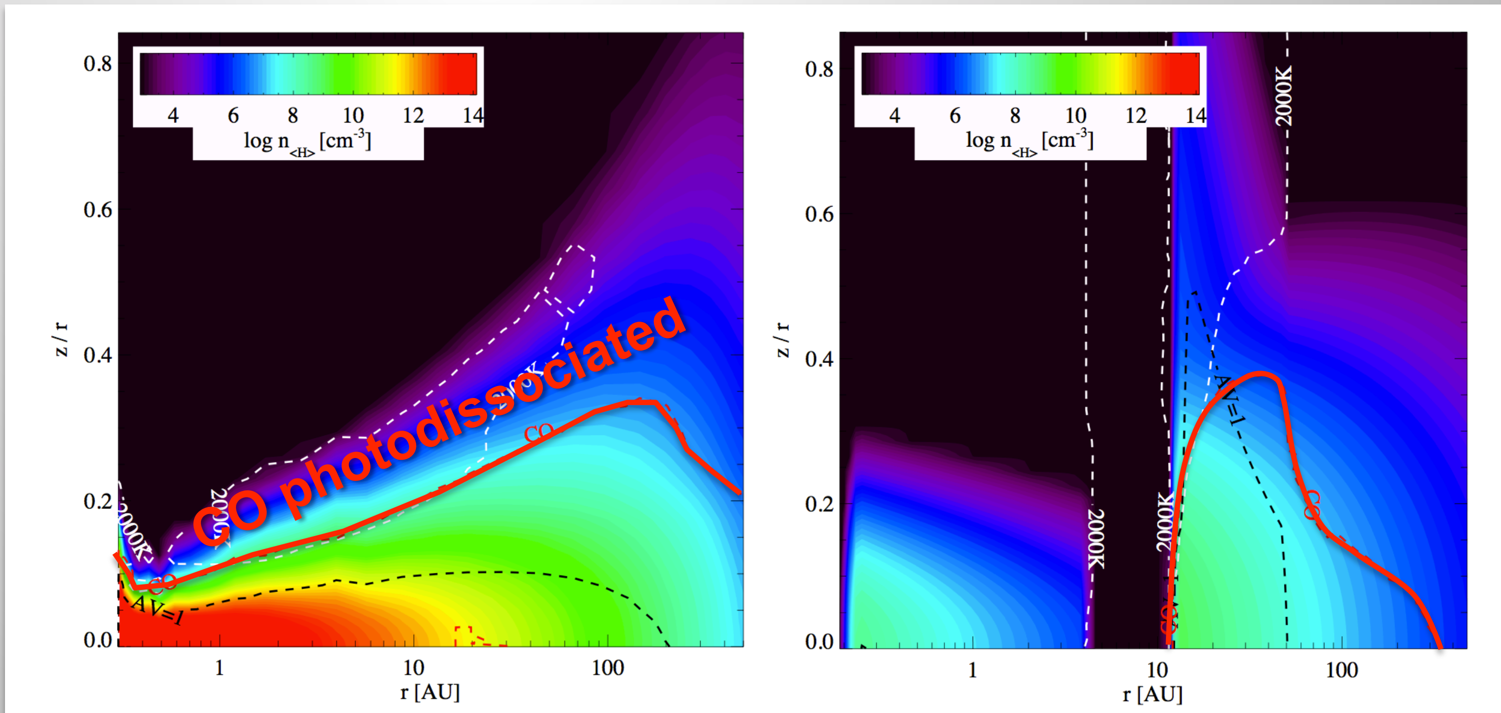

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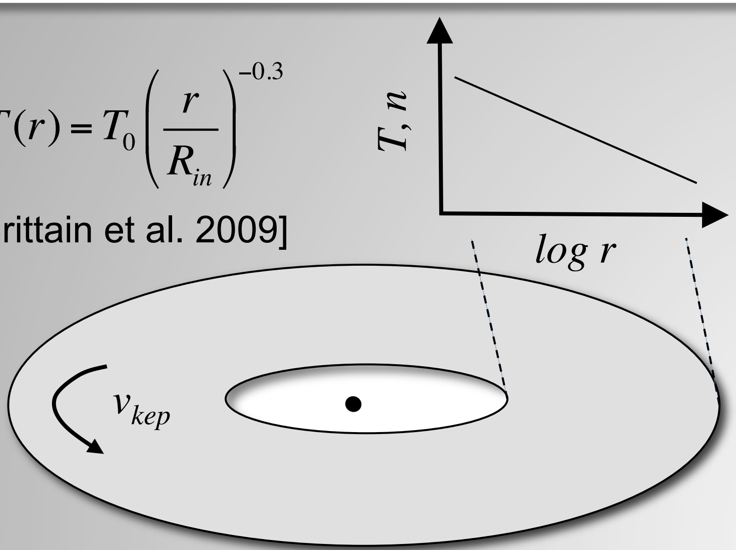

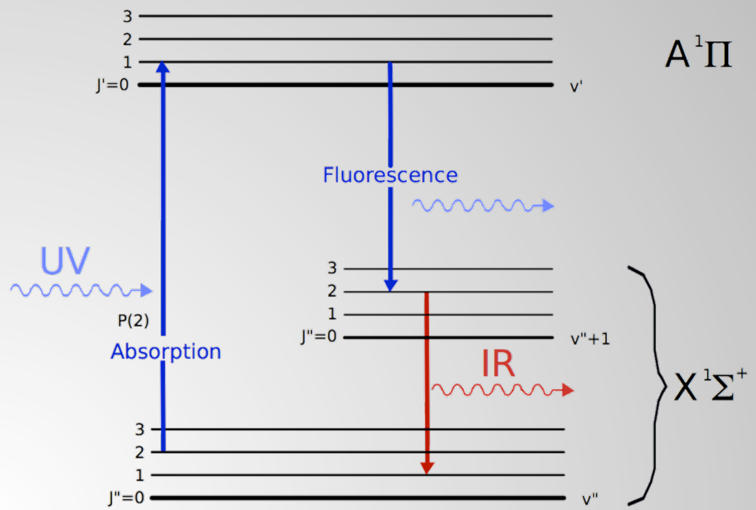

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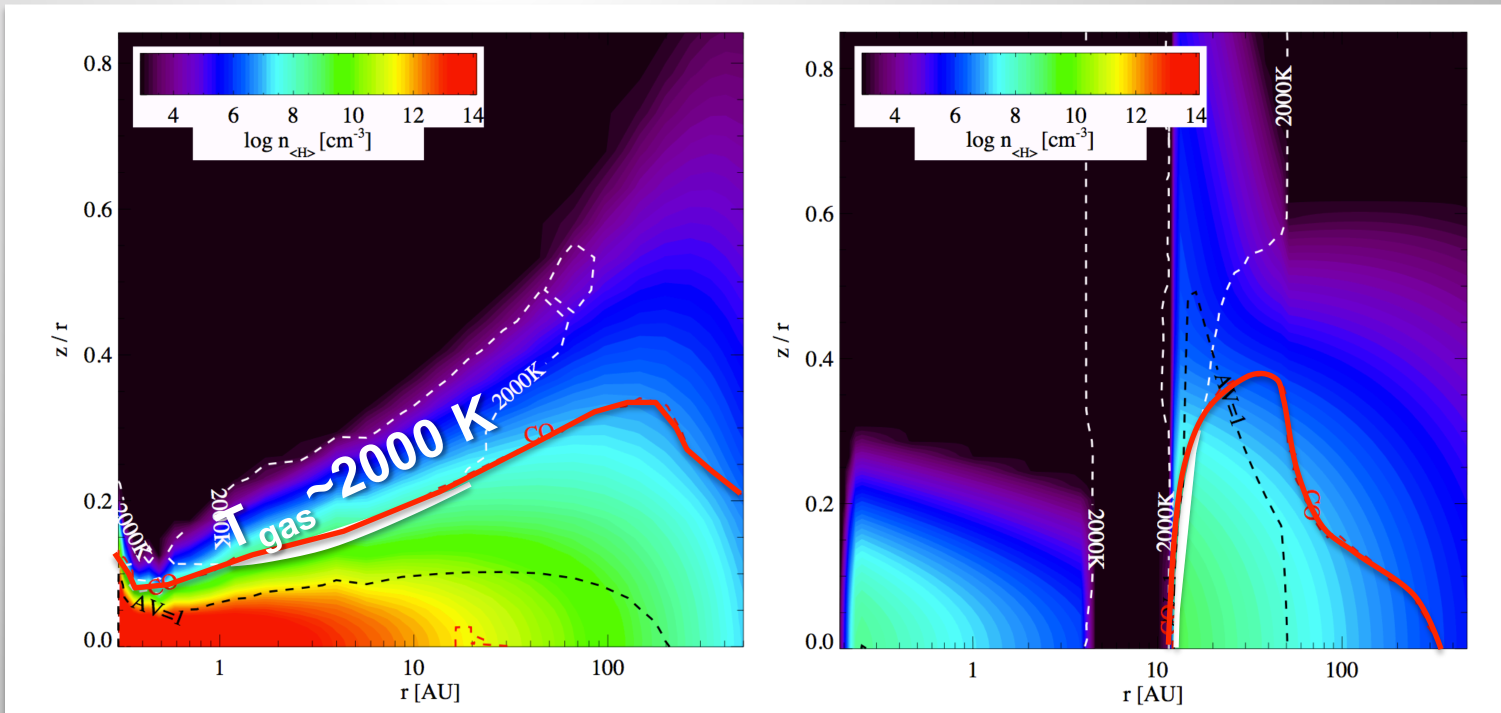

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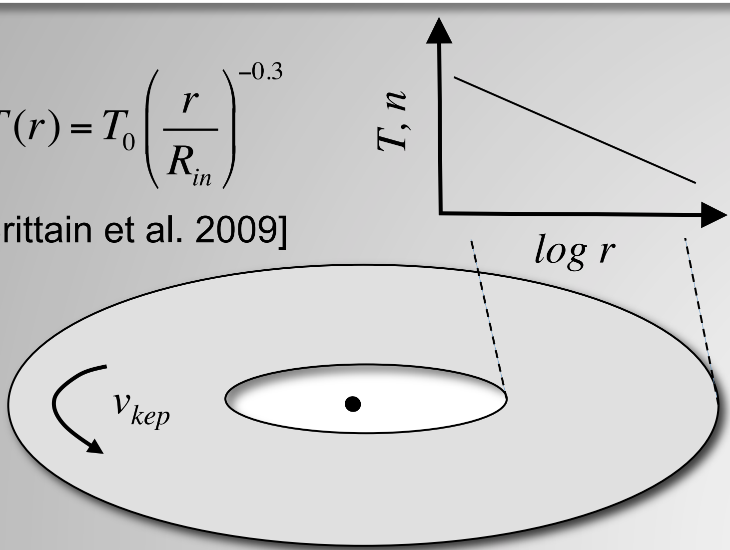

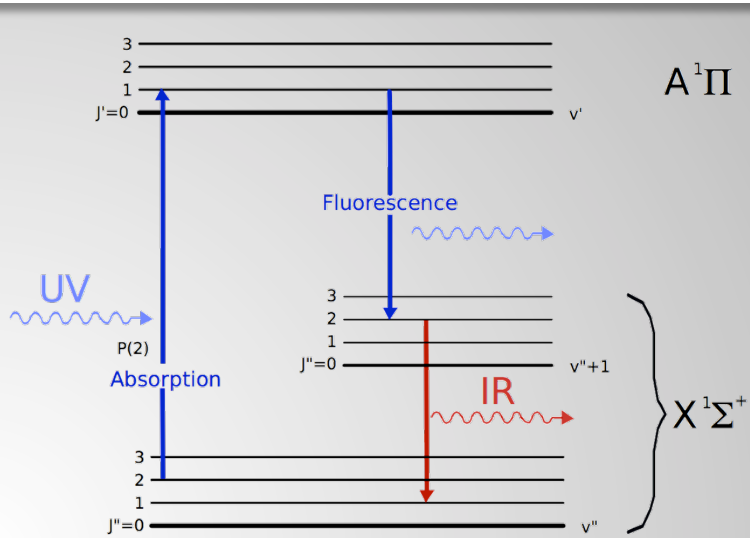

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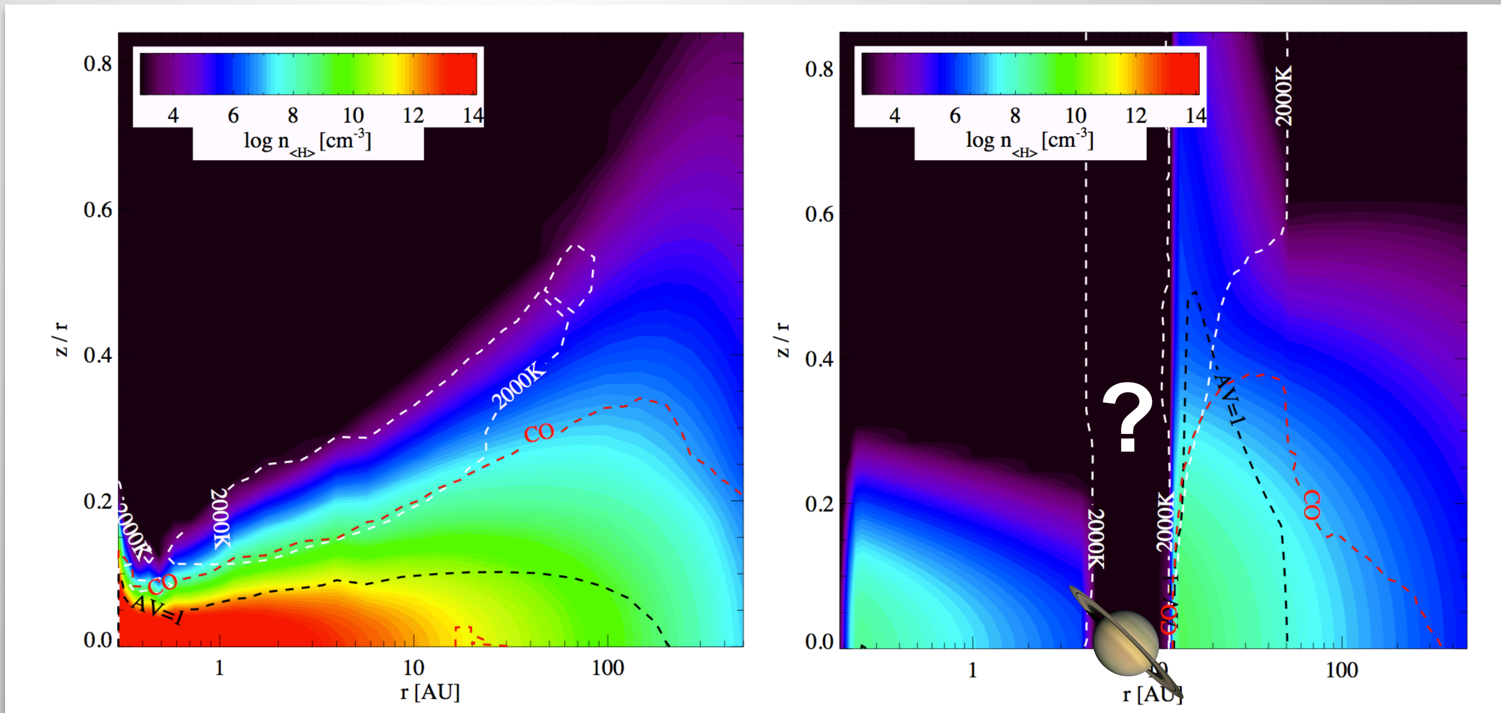

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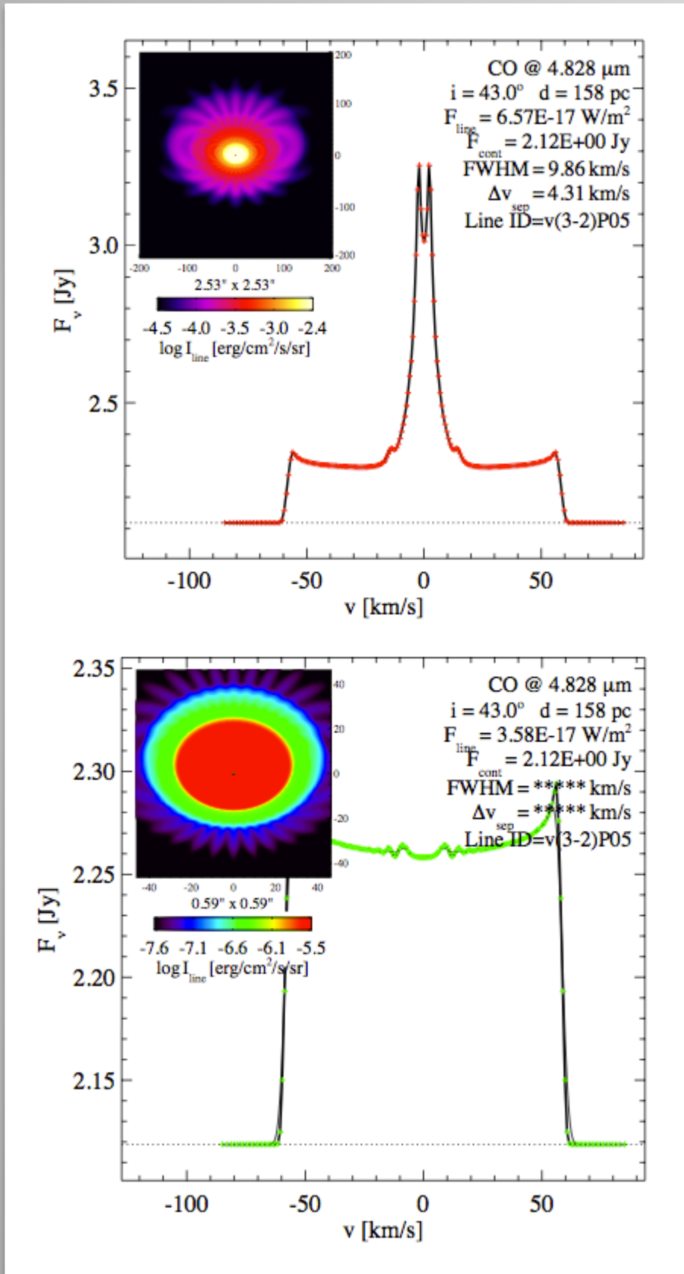
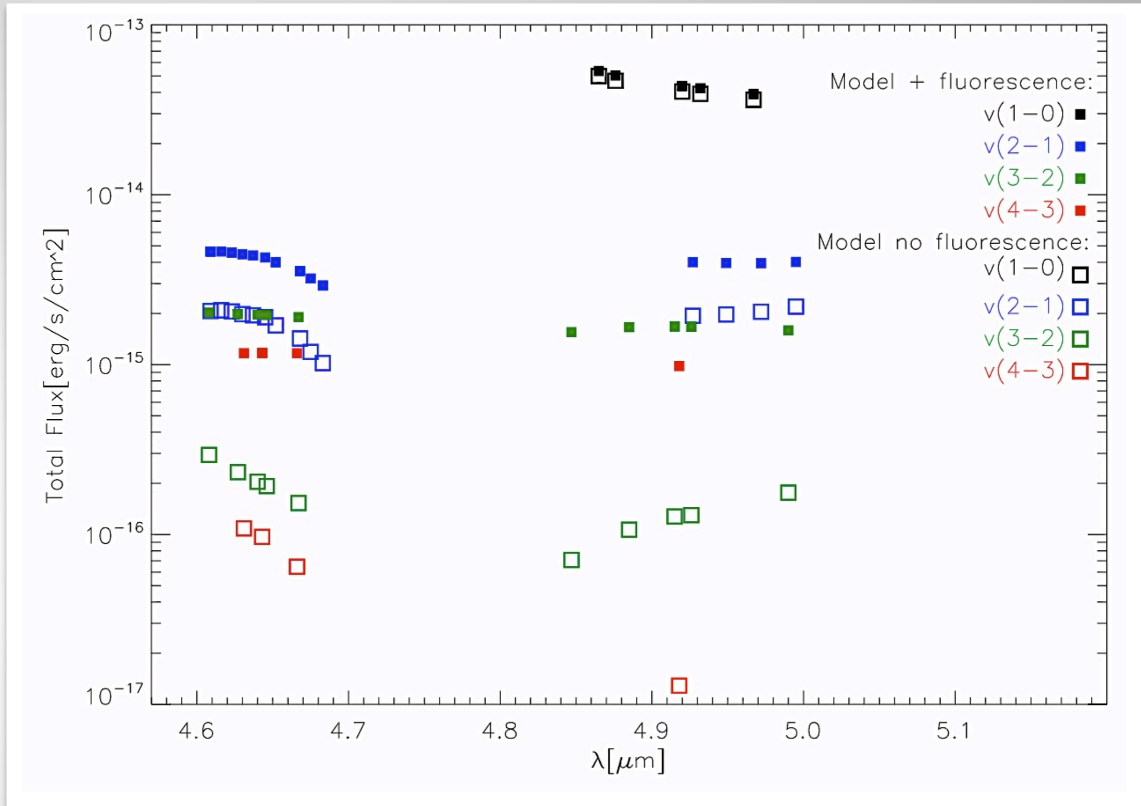
The role of CO ro-vib fluorescence





Fluorescence populates higher v-bands at the expense of the fundamental v=1-0 band

=> band ratios change

[Thi et al. 2012, Hein Bertelsen et al. 2014]

Line fluxes also depend on emitting area

=> fluxes stay, noses come and go…

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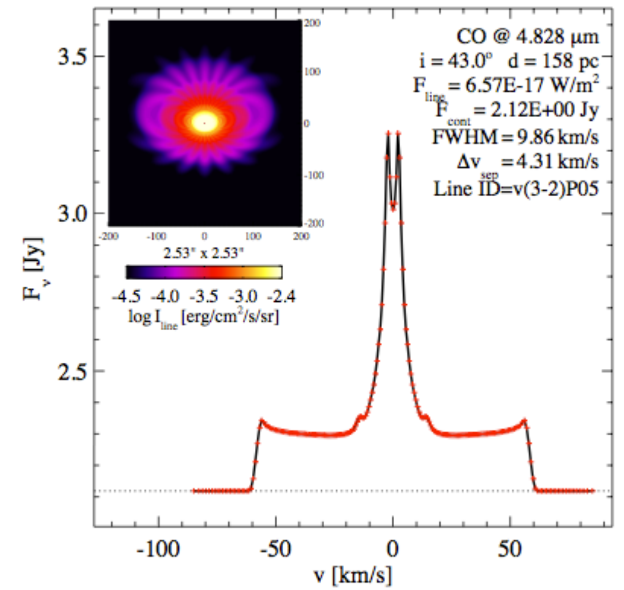

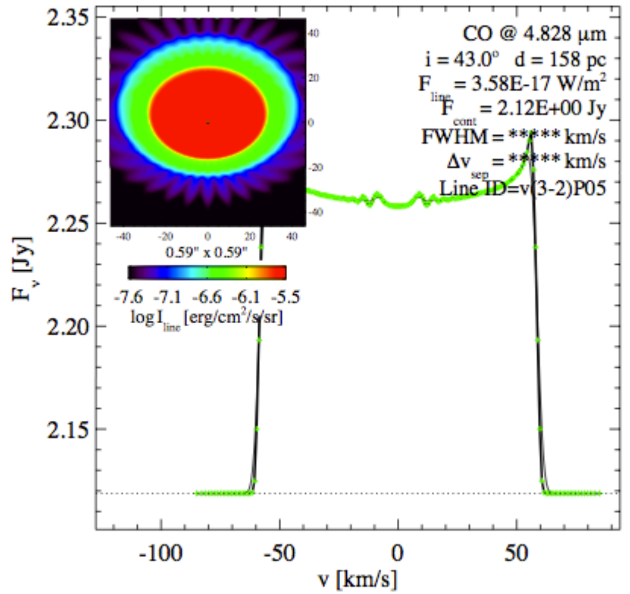

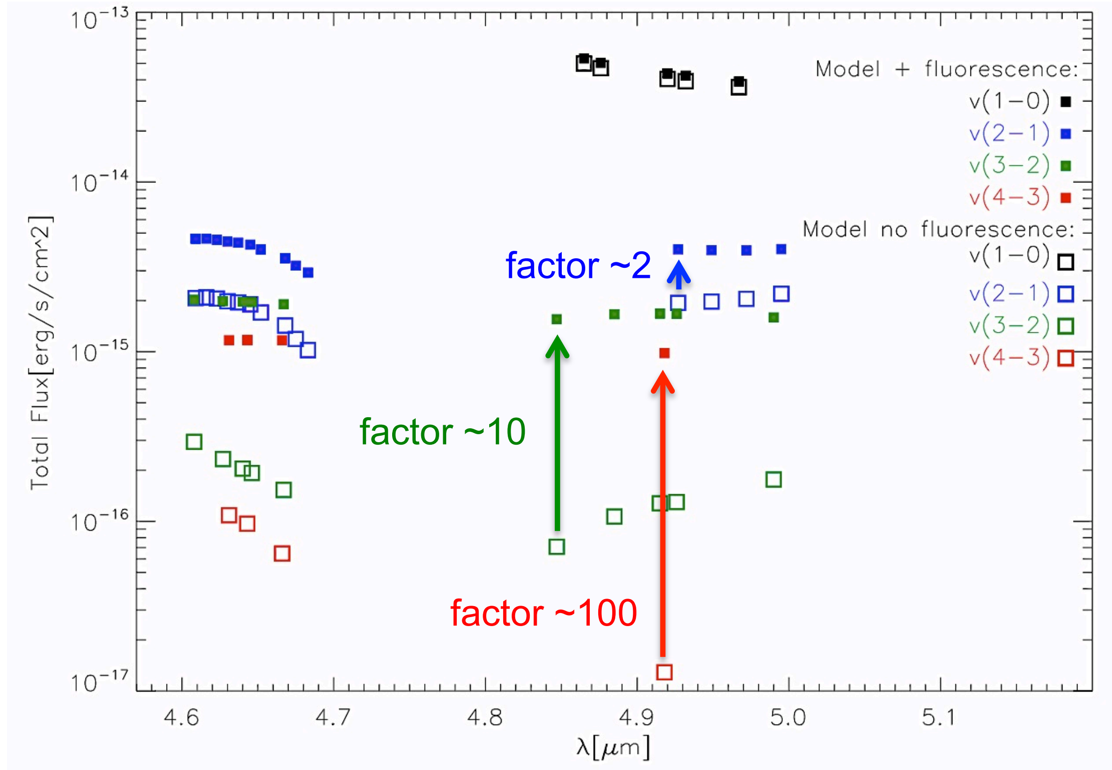

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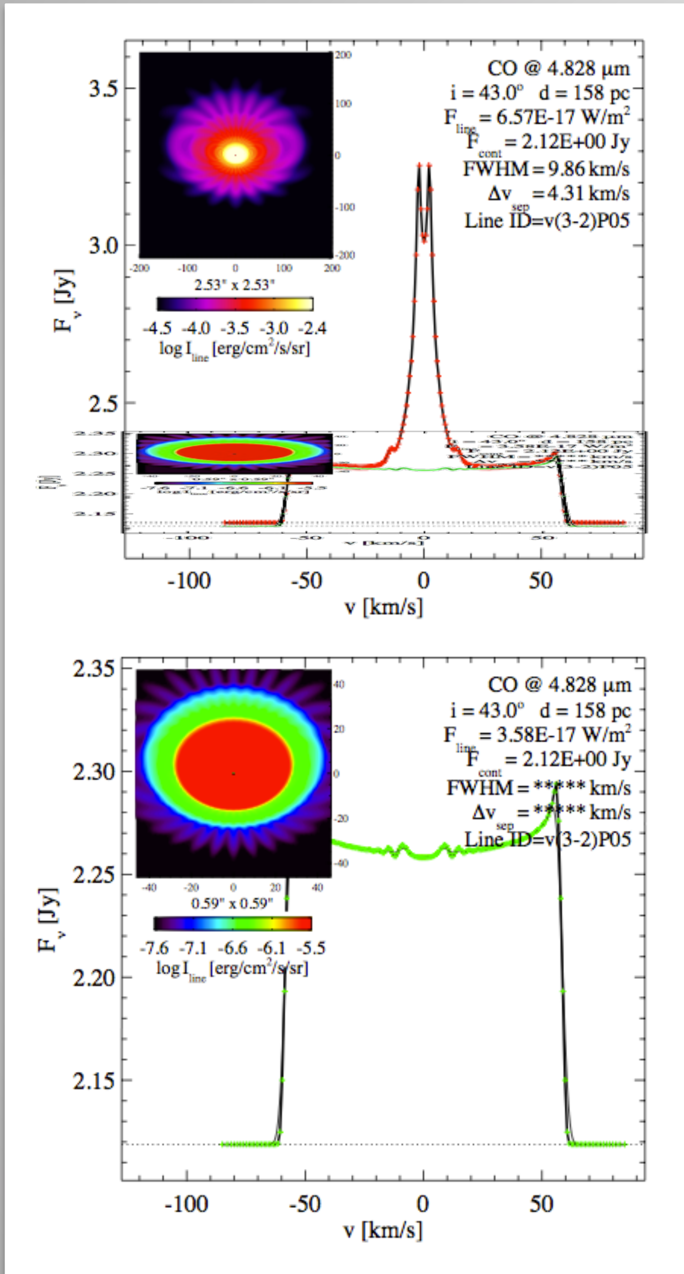

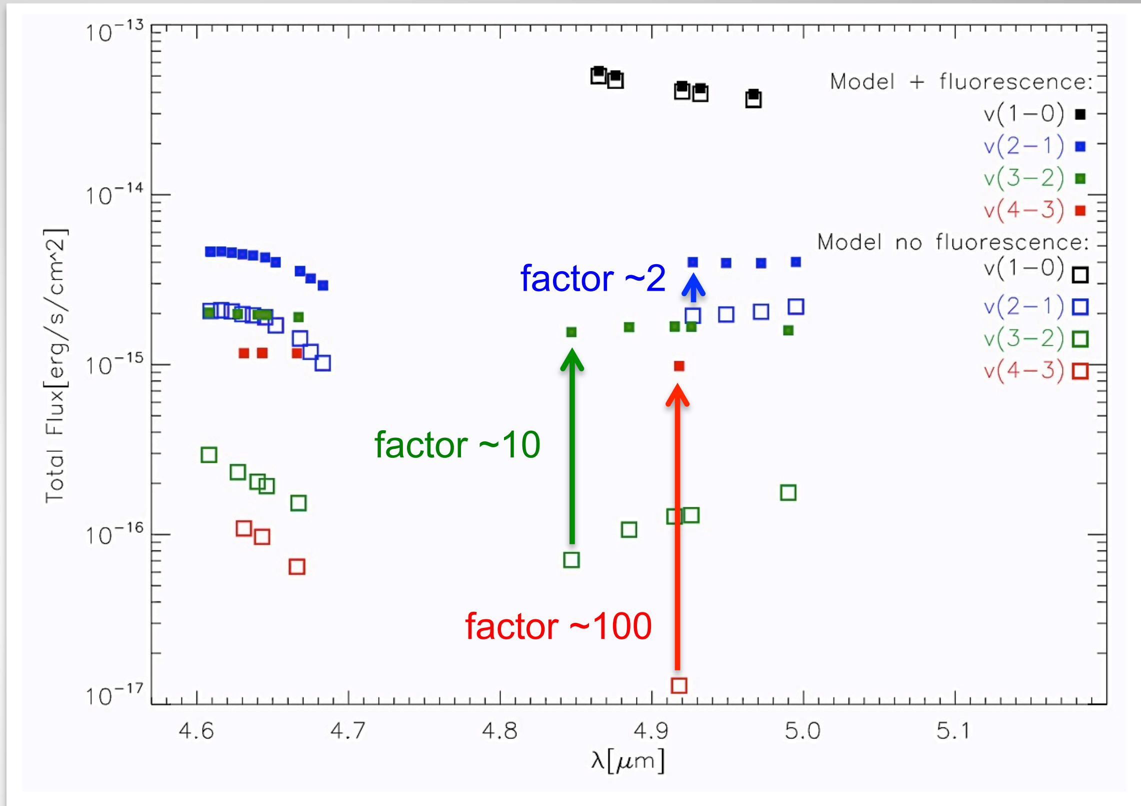

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CO ro-vib characteristics

CO ro-vib fluxes fairly flat versus wavelength (factor <3 between low & high J)

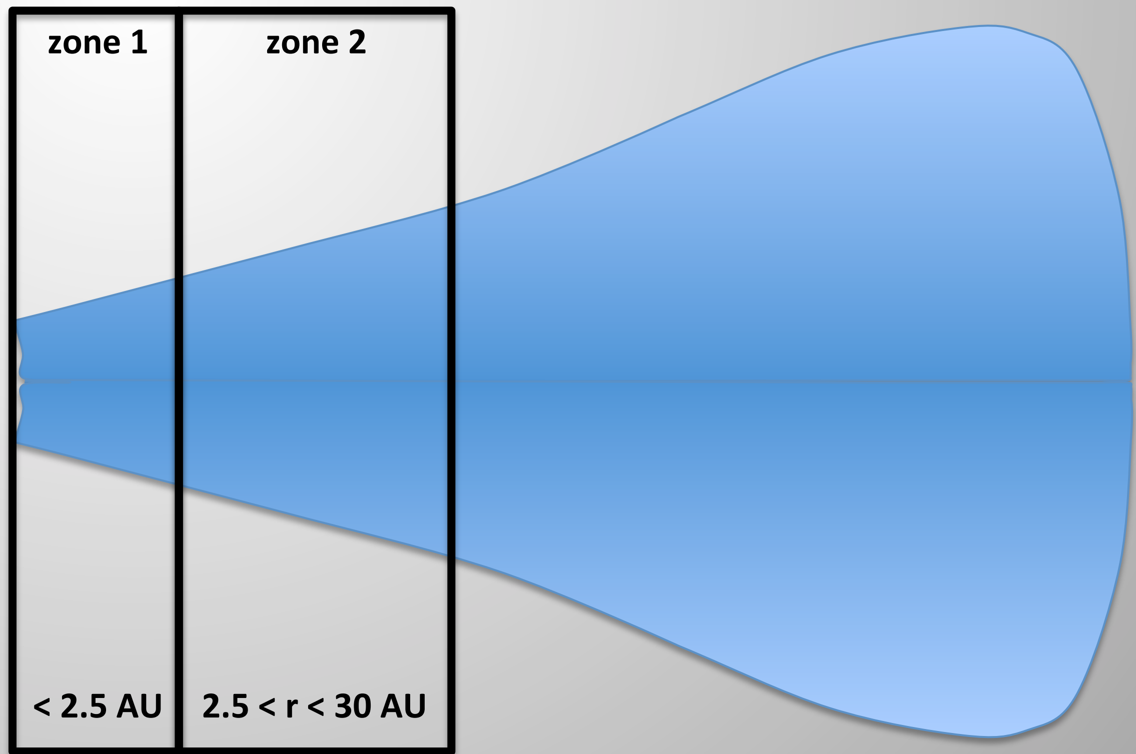
[HD100546: CRIRES, Hein Bertelsen et al. 2014, HD163296: CRIRES, Hein Bertelsen et al. submitted; HD135344B: CRIRES Carmona et al. 2014; to be checked for larger Herbig sample: van der Plas et al. 2015]

FWHM either flat with J or increasing with J => signature of gaps?

[Hein Bertelsen et al. in prep., van der Plas et al. 2015]

Grid of generic models based on HD97048 properties [Maaskant et al. 2013]:

- lower the dust content in zone 1 and/or 2
- lower the dust and gas content in zone 1 and/or 2
- change the flaring angle of the entire disk



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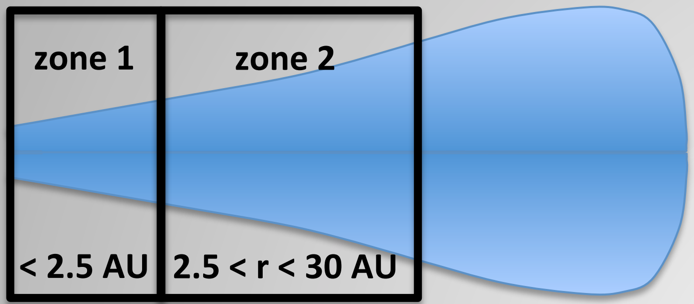
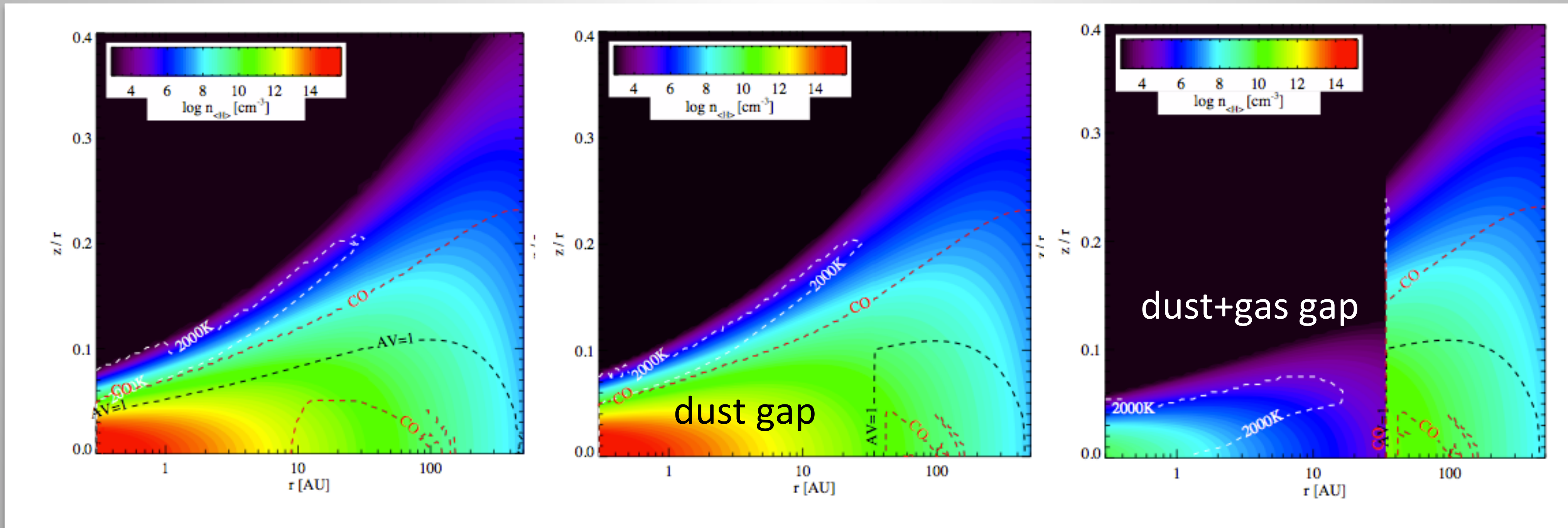


CO can self-shield and does not need dust to protect it

Below a critical gas mass (column density), CO cannot exist

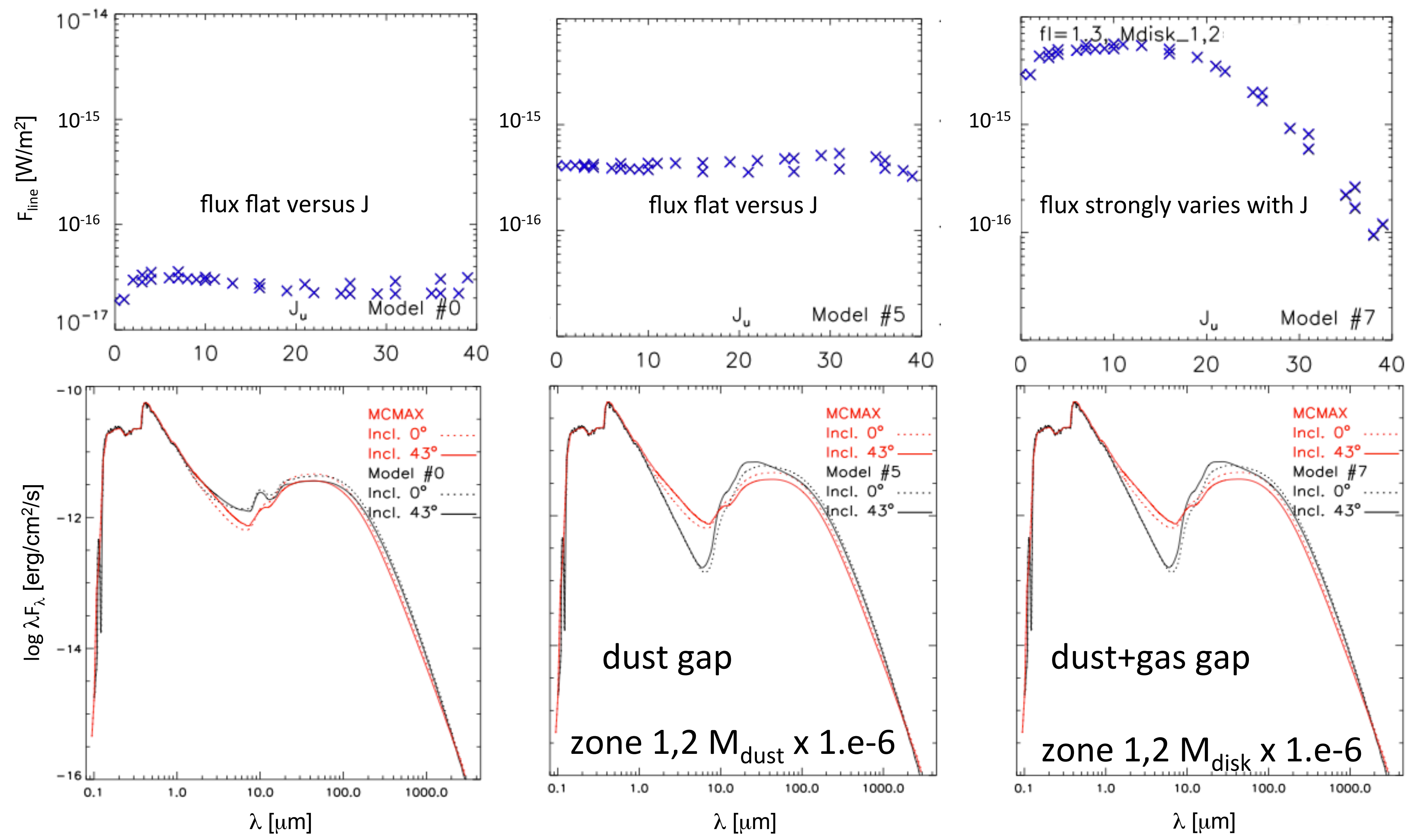


zone 1,2 M_{dust} x 1.e-6

zone 1,2 M_{disk} x 1.e-6

CO ro-vib characteristics

removing the inner gas (!), CO ro-vib fluxes go up by 1-2 orders of magnitude



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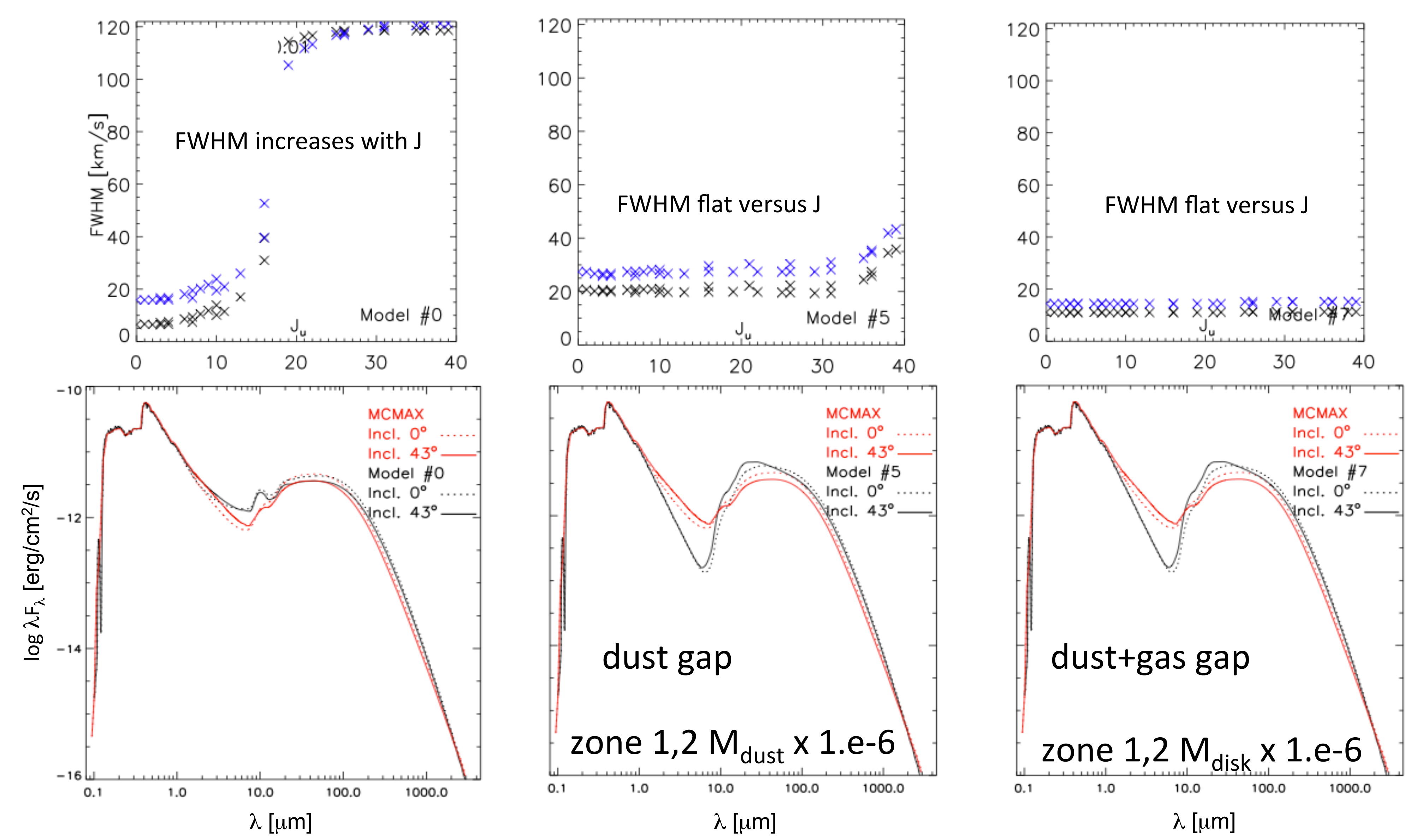

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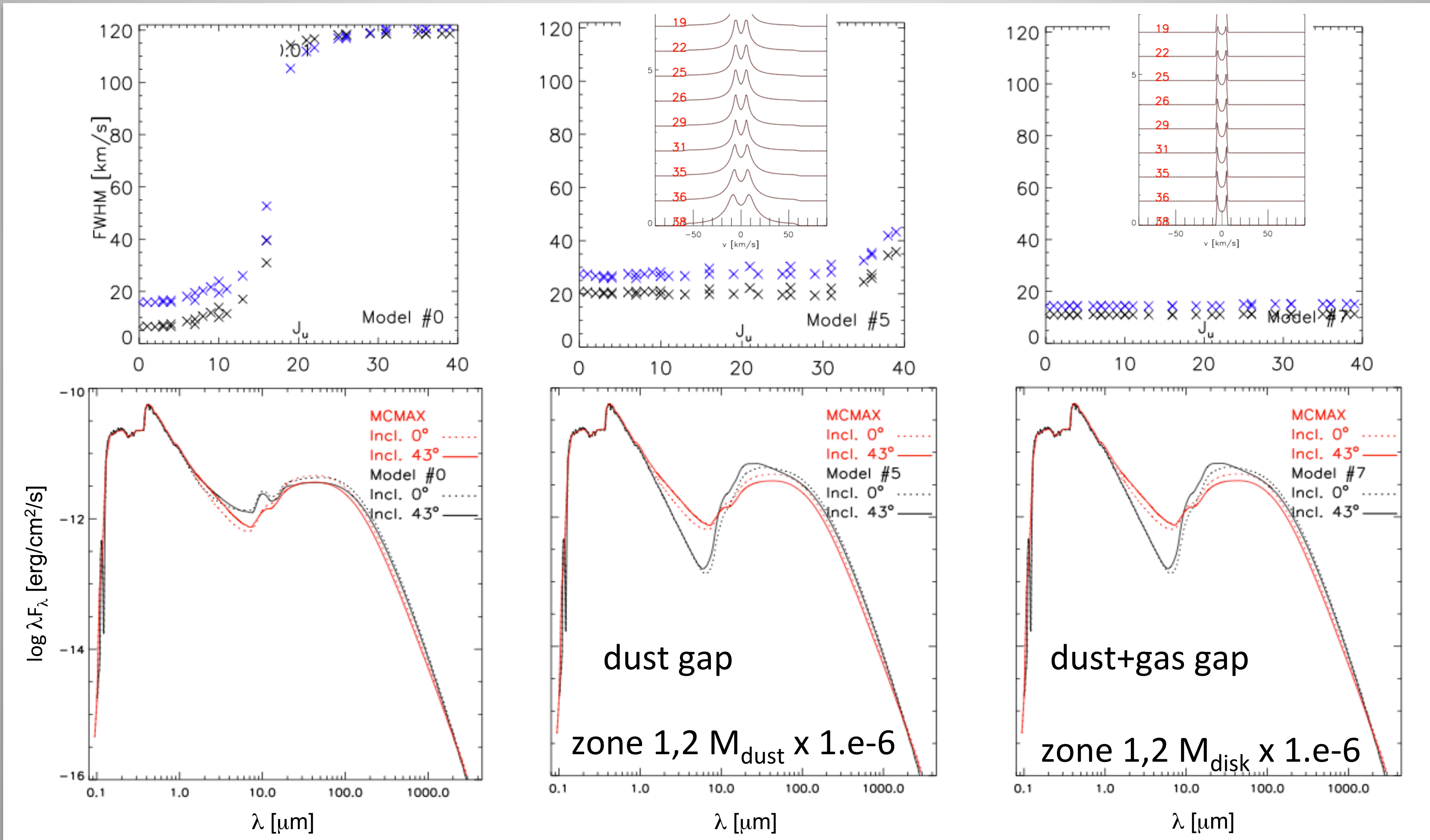

CO ro-vib diagnostics for planet formation

CO cannot live anywhere in a disk

=> photodissociation data, dissociative collisions with hot H, H_2, He

CO cannot emit anywhere in a disk

=> collision rates

If we understand where CO exists and what its excitation is, we can invert the problem and draw conclusions on the detailed inner disk structure

=> planet forming region

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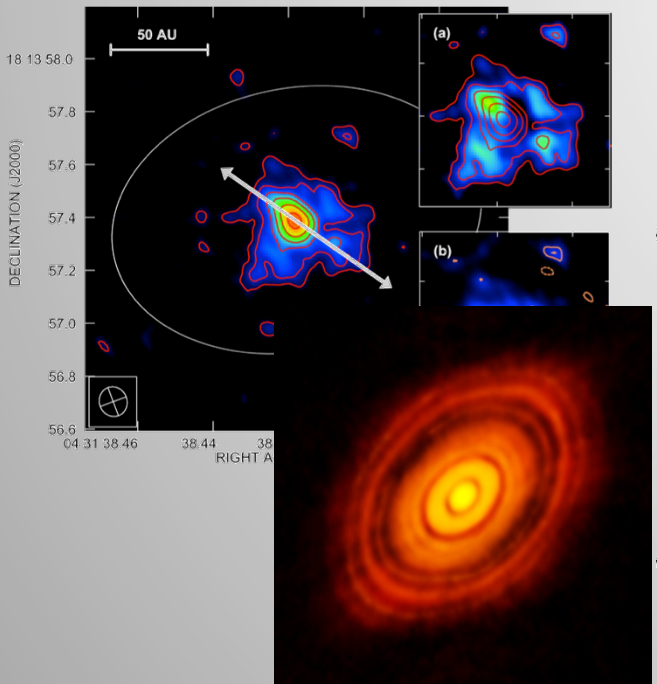
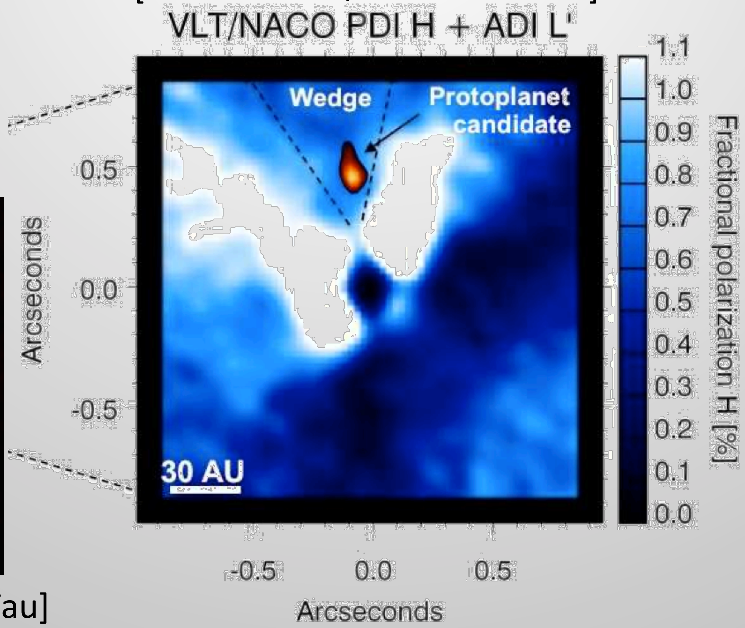
=> planet forming region, they are there !

[VLA: Greaves et al. 2008]

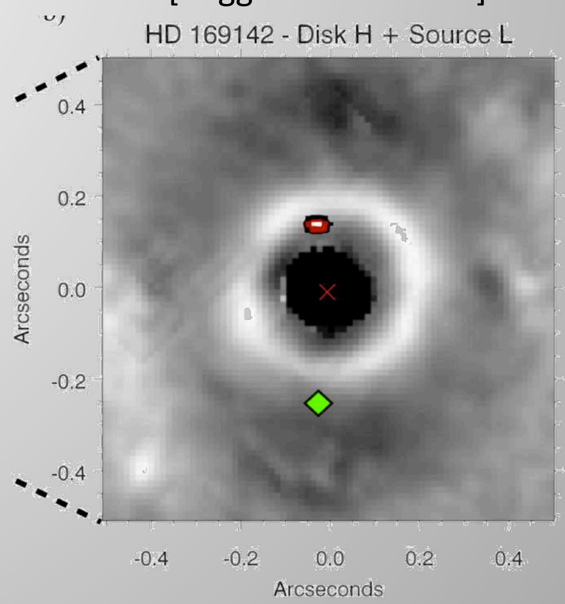


[ALMA: disk around HL Tau]

[HD100546: Quanz et al. 2013]

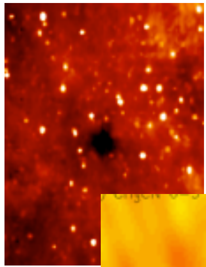
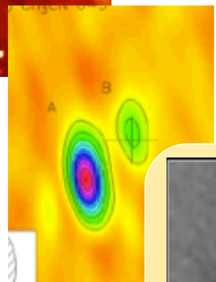


[Reggiani et al. 2014]



COST Action CM1401: Our Astrochemical History

In a nutshell !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$6K \lesssim T \lesssim 15K$
Complex organic molecules detected

Protostellar core
$10K \lesssim T \lesssim 700K$
COMs detected

Protoplanetary disk
$10K \lesssim T \lesssim 3000K$
simple molecules, PAHs detected

Solar system oldest objects, fossil record, water transport

Present day Earth
bio-chemistry

Star and planet formation

Chemical evolution, reactivity & increasing complexity

Working groups on:

- Gas-phase chemistry
- Icy surface chemistry
- Photo-chemistry
- Isotope chemistry

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Scientific Kick-Off Meeting:
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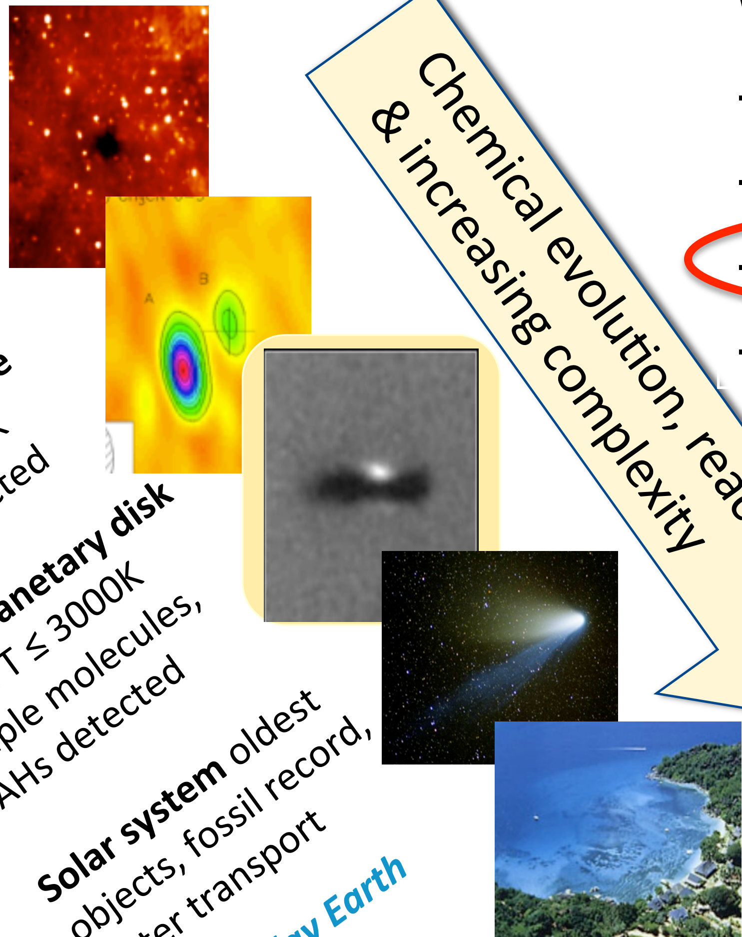

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