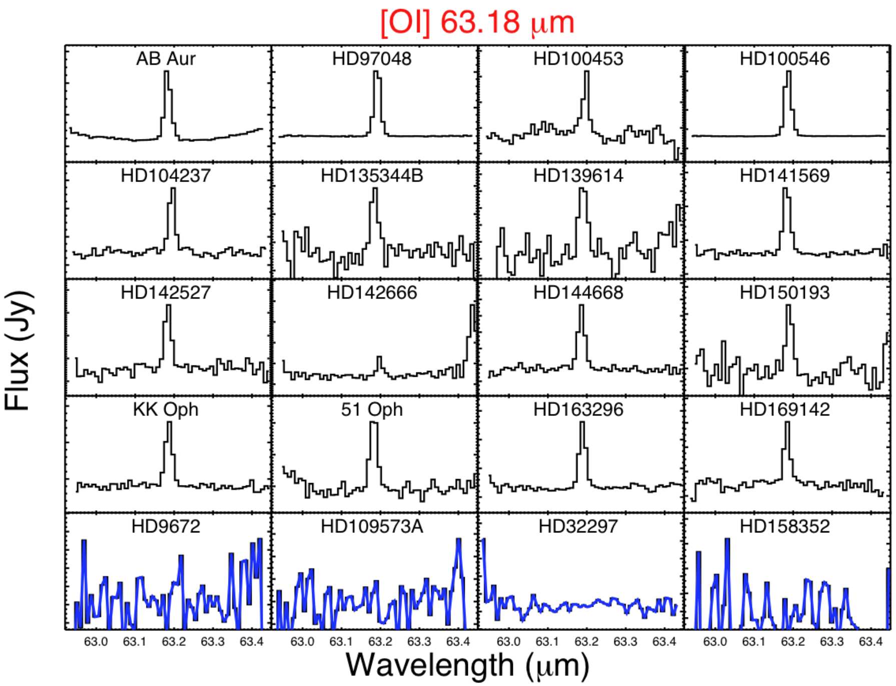
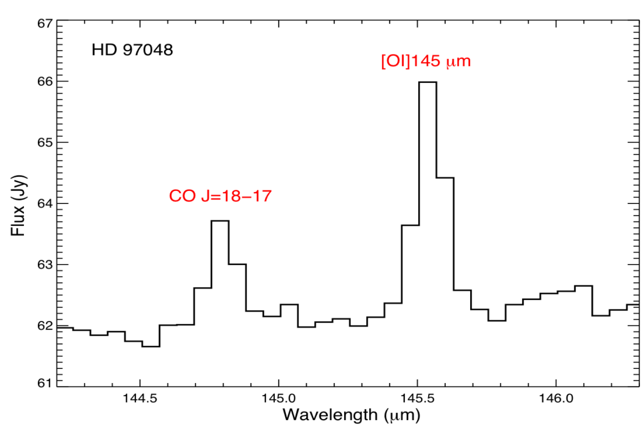
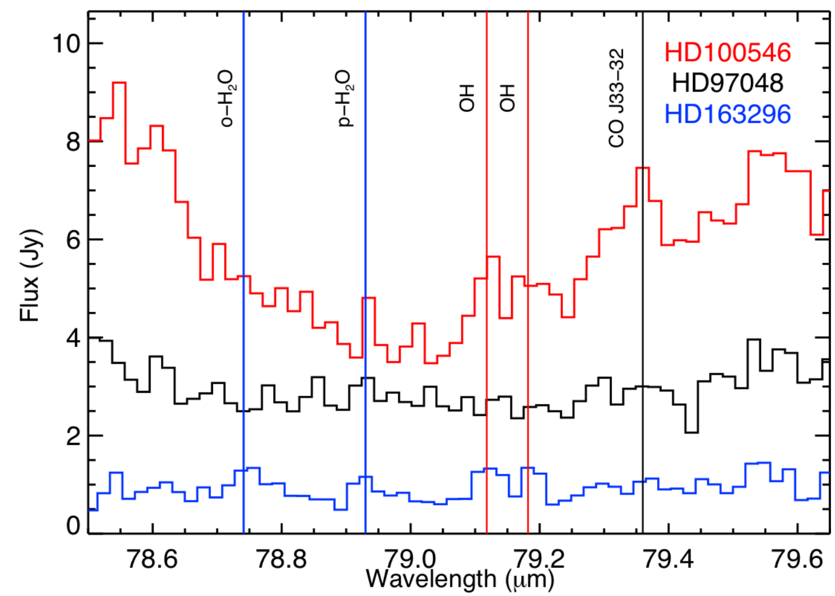
GASPS' view of protoplanetary discs around intermediate-mass stars



Gwendolyn Meeus
UAM Madrid





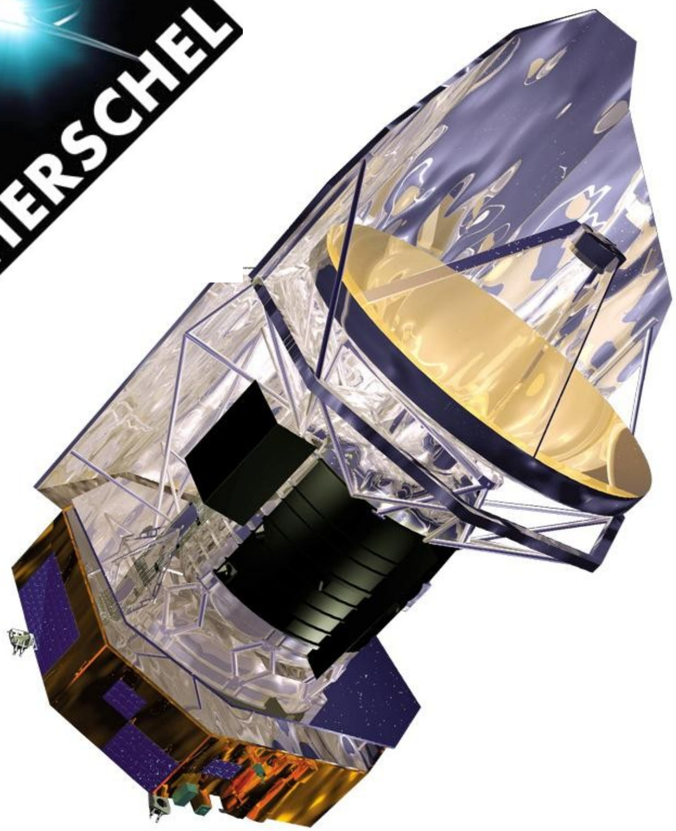
Protoplanetary discs around Herbig Ae/Be stars

Thanks to my Collaborators:

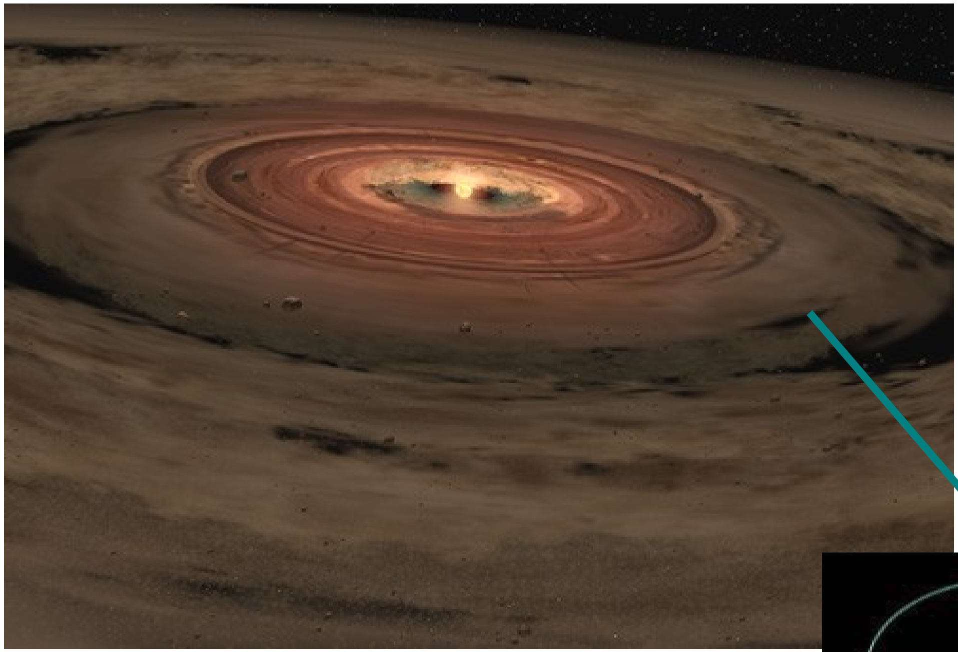
B. Montesinos, I. Mendigutía, I. Kamp, W.F. Thi,
C. Eiroa, C.A. Grady, G. Mathews, G. Sandell,
C. Martin-Zaïdi, S. Brittain, W.R.F. Dent,
C. Howard, F. Ménard, C. Pinte, A. Roberge,
B. Vandenbussche and J.P. Williams

Outline

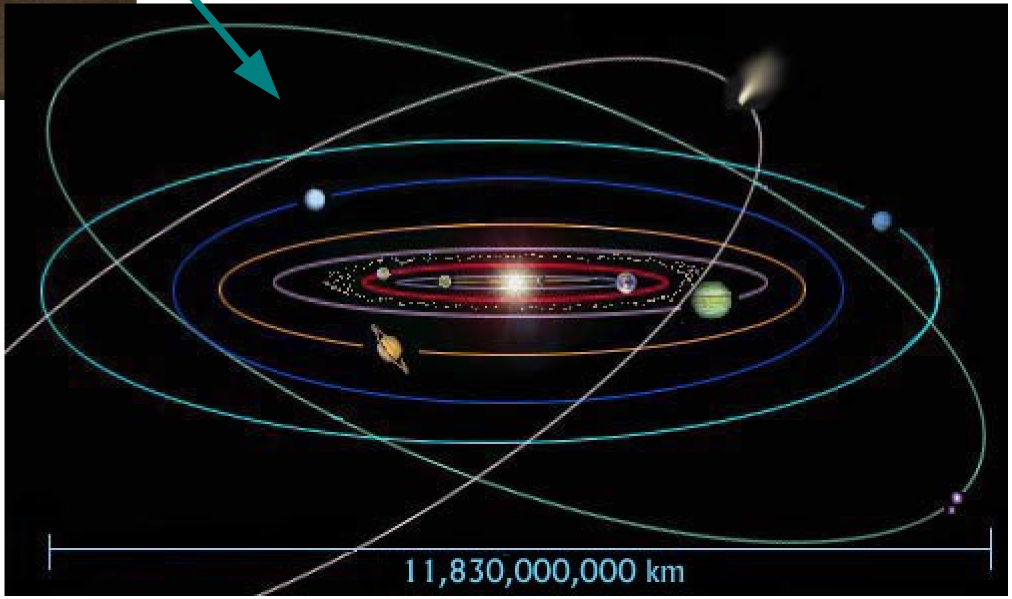
- Goals & Sample
- Detected lines
- Correlations with [OI]
- Disc modelling
- Conclusions



Protoplanetary discs ⇒ Planetary system



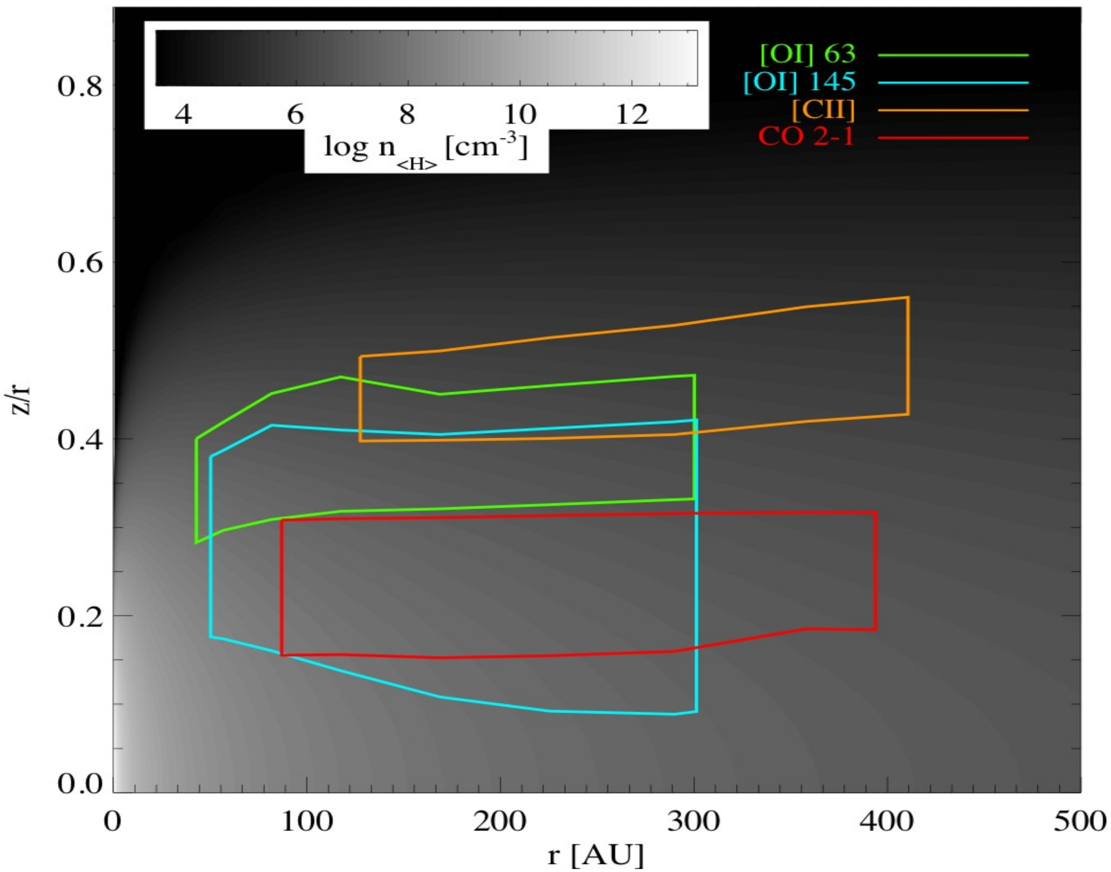
From a gas and dust-rich disc to a planetary system



Herbig Ae/Be Sample

- 20 Herbig Ae/Be stars, 5 debris discs
- Spectral types between B9.5 and F4 (T_{eff} between 10500 and 6250 K)
- Emission lines of Hα
- IR excess due to disc emission (dust and gas)
- Low level of accretion
- 9 Flared (group I), 11 flat (group II) discs

Different gas species & transitions trace different regions in disc



Important transitions in far-IR

-Fine structure lines of atoms:

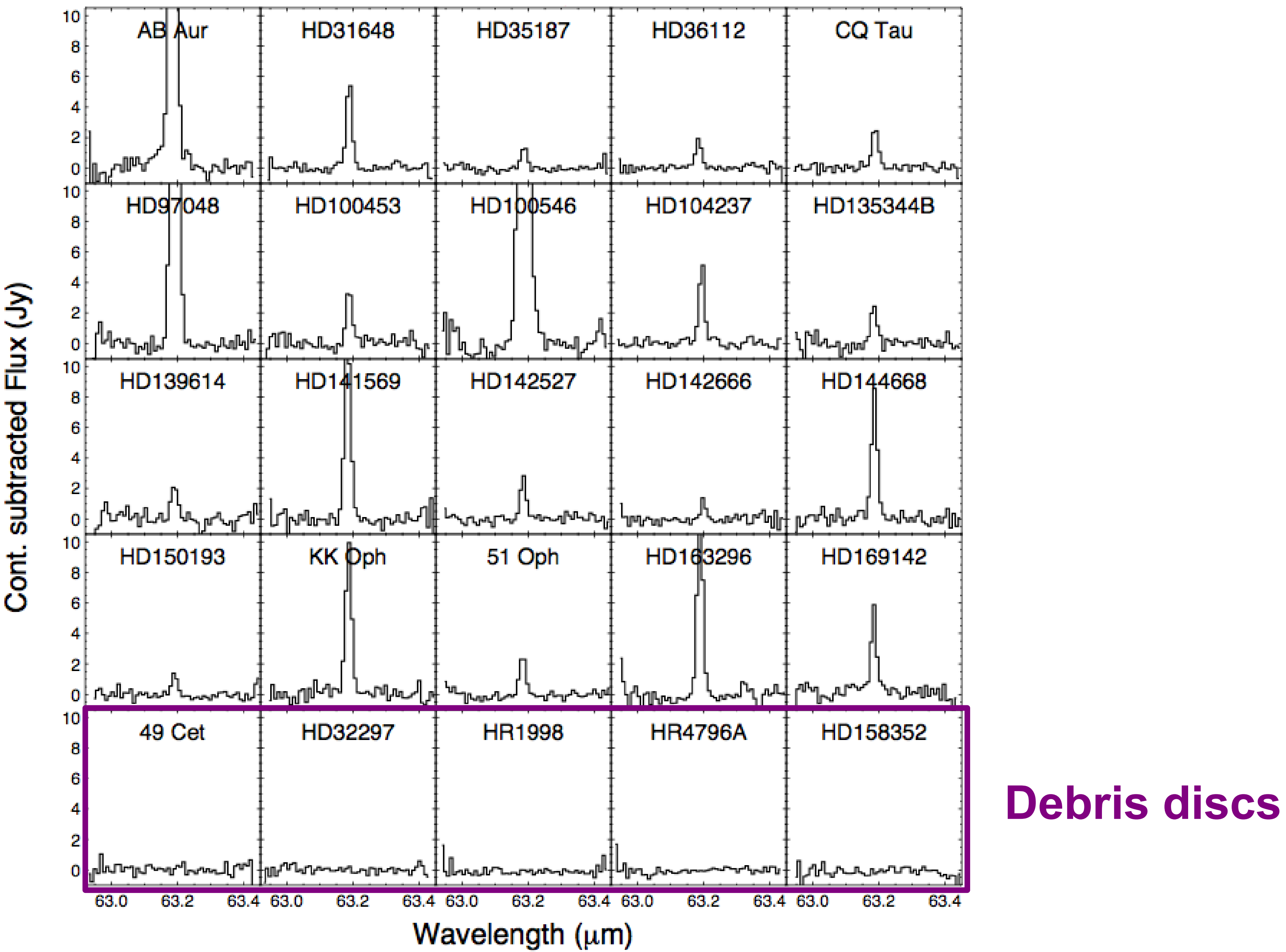
[OI] 63.2 and 145.5 μm
[CII] 157.7 μm

-Rotational lines of molecules:

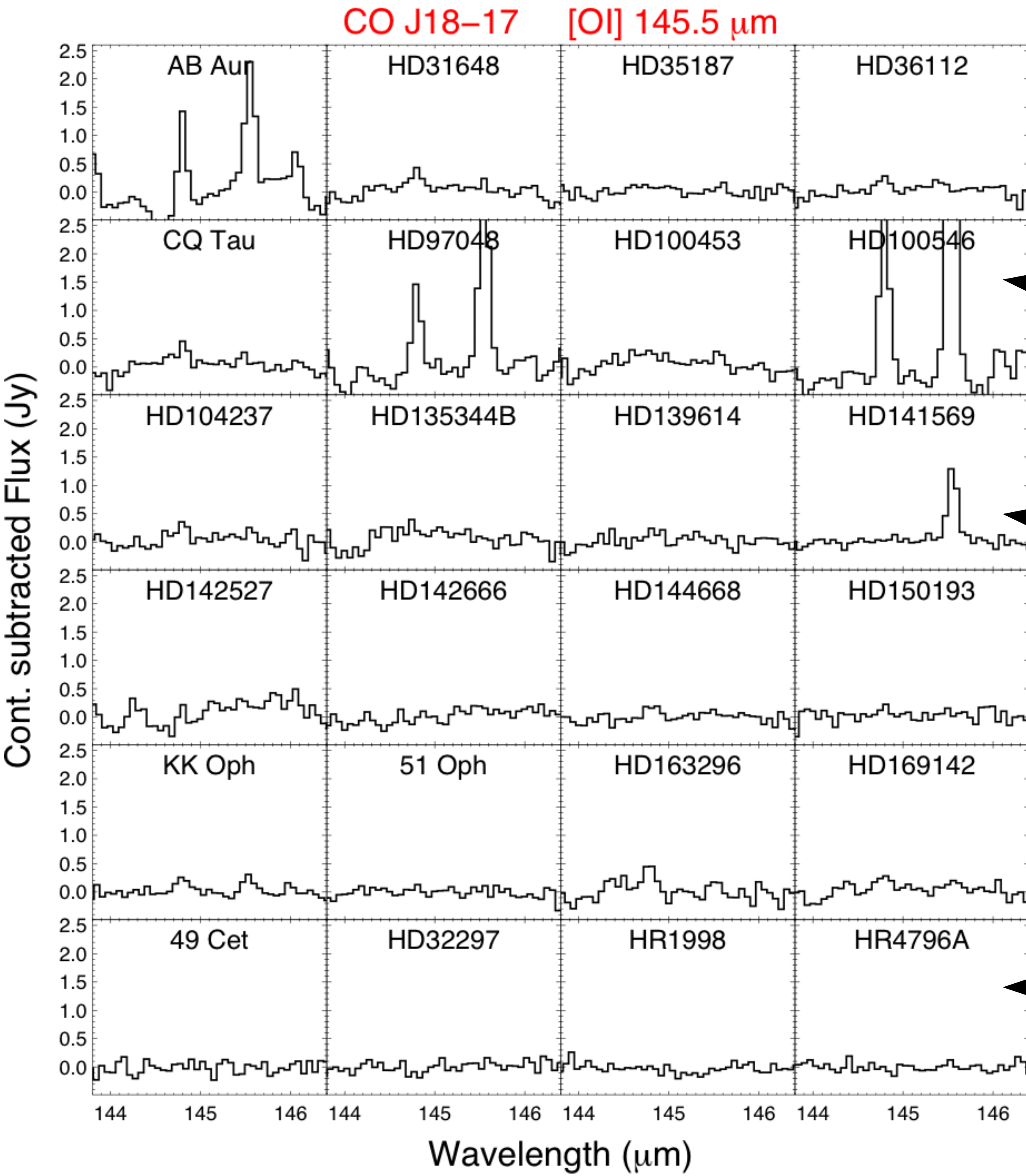
CO middle to high J-lines
OH (OH + H_2 → H_2O + H)
H_2O

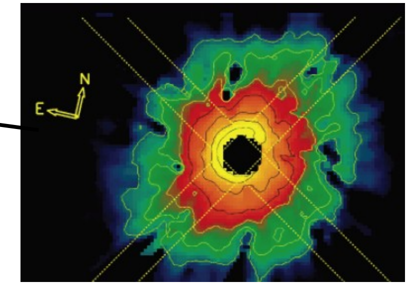
Far-IR lines trace gas in the *OUTER DISC*

[OI] 63.2 micron: variety in strength

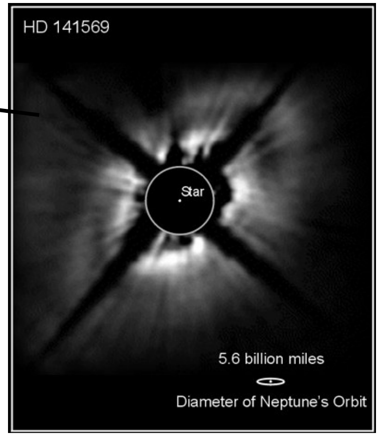


[OI] 145 μm: less frequent

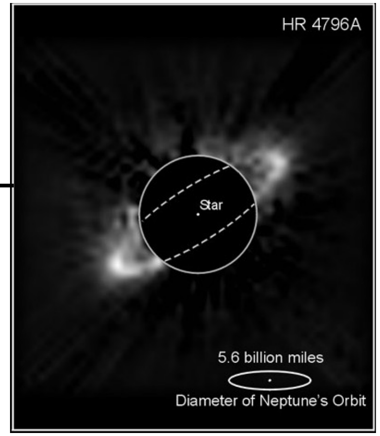




Gap,
hot wall



A lot of gas dissipated
Transitional



Debris disc

HAEBEs: line detections

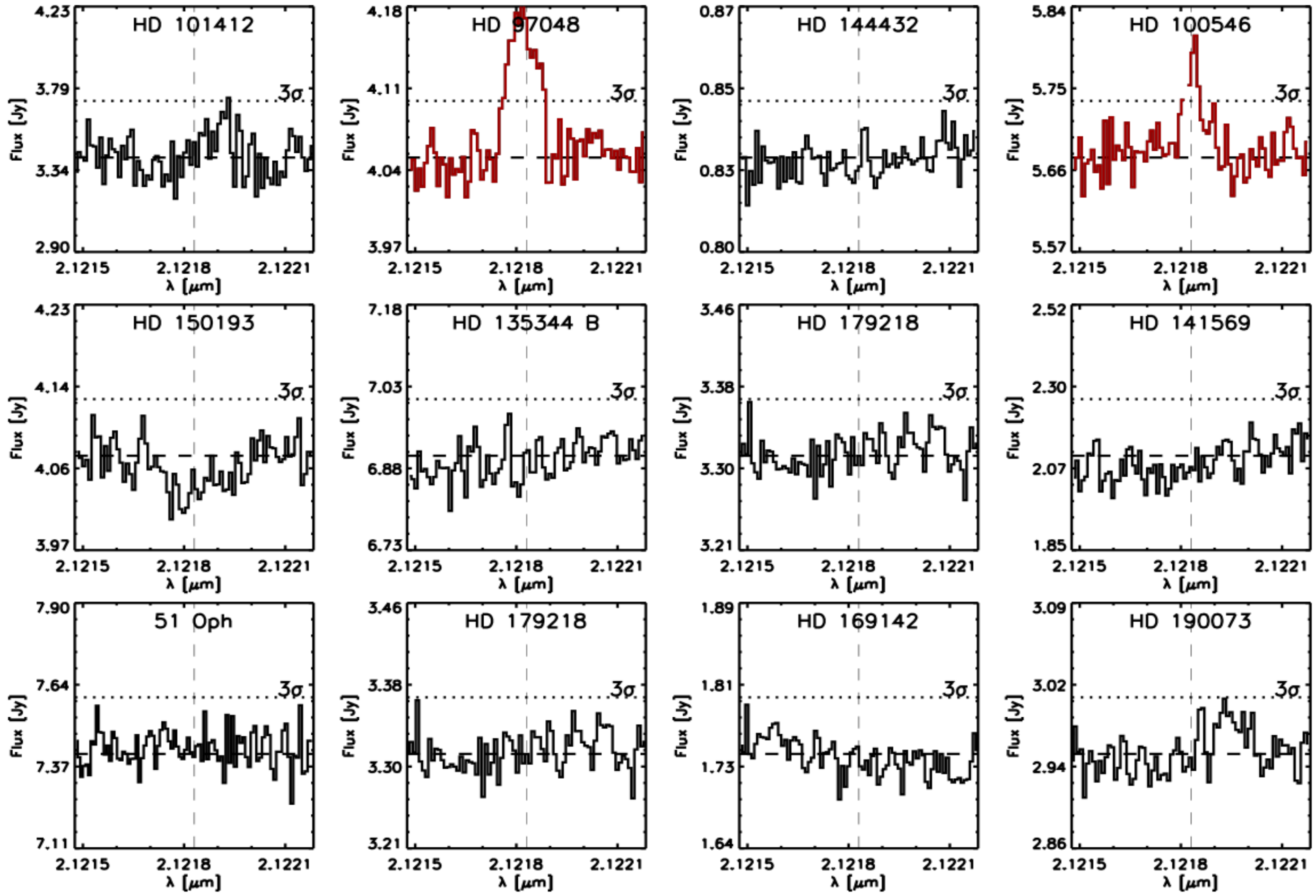
Out of 25 line scans – [OI] 63 µm:

- All (20) HAEBEs show feature in emission, line absent in (5) debris discs.

Out of the 20 HAEBE range scans:

- 6 HAEBEs show [CII] in emission, often BG (30%) contaminated.
- 5 HAEBEs show [OI] 145 µm (25%)
- 8 HAEBEs show CO J=18-17 (40 %)

H_2 1-0 S(1) transition at 2.12 µm: only detected in HD97048 & HD100546



+ H_2 0-0 S(1) at 17.035 µm detected in HD97048 & AB Aur

Carmona et al. 2011, Martin-Zaïdi et al. 2007 & Bitner et al. 2007

Line (non-)detections give clues about gas in surface layers disc

When T_{gas} ~ T_{dust}, weak lines produced by thermal excitation

CO rot.-vib. at 4.7 μm: AB Aur, HD97048 & HD100546: **T_{Rot} ~ 1000 K**
HD141569: **T_{Rot}~ 200 K** (kinetic T of gas) & H_2 absent

Brittain et al. 2007, van der Plas, 2009, +PhD Thesis

H_2 detected only in UV-strong objects: AB Aur, HD97048, HD100546

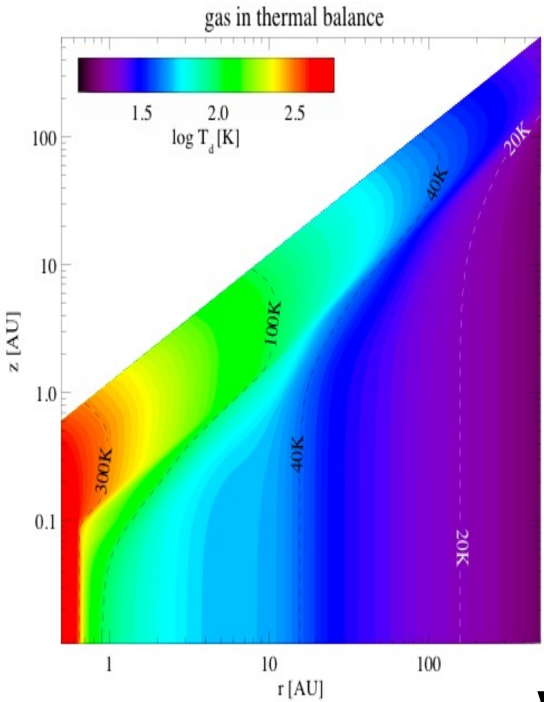
L_{PAH} important for thermal budget: highest AB Aur, HD97048 & HD100546

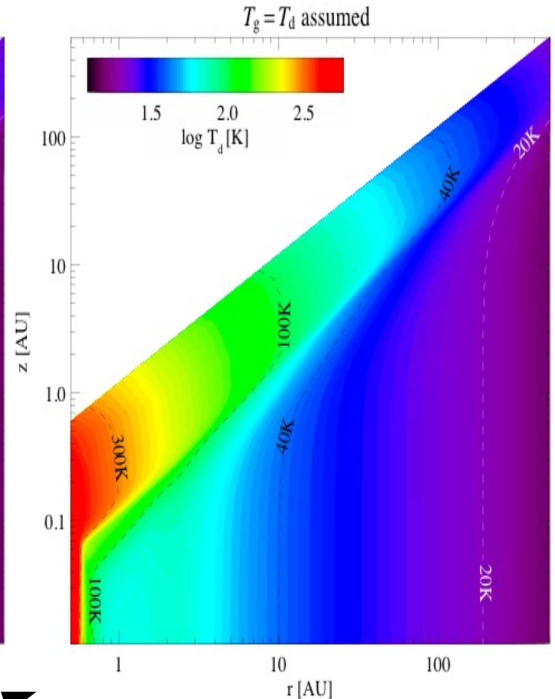
⇒ more direct heating of upper layer (more flaring)

If non-LTE, UV Fluorescence (T_{vib} > 5000 K) => T_{gas} >> T_{dust}

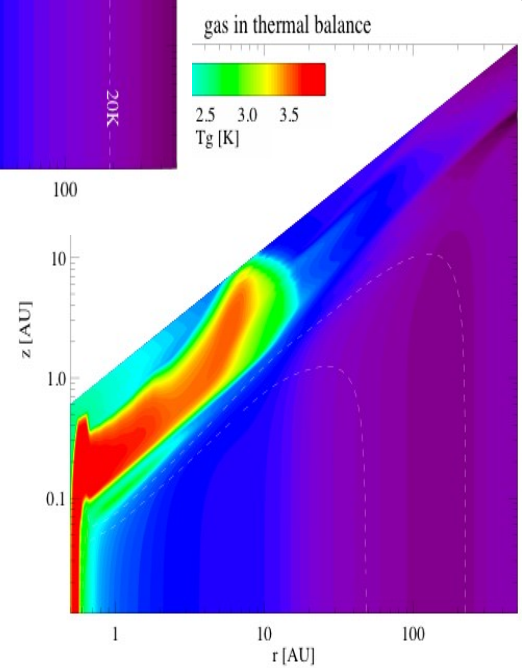
CO T_{vib} >> T_{rot} in flaring discs - similar in flat discs v*an der Plas, PhD Thesis*

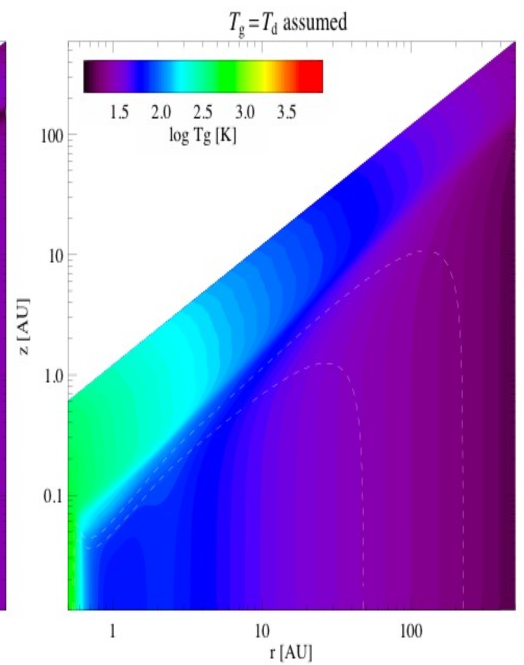
Non-LTE: Gas and dust de-coupled





Gas Temperature distribution

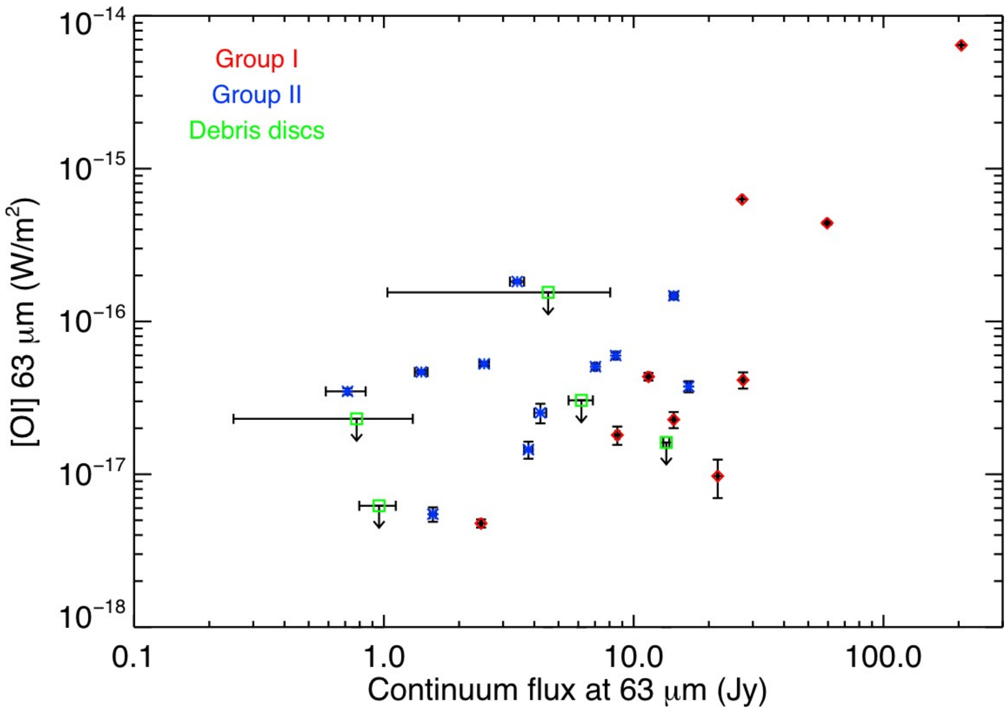


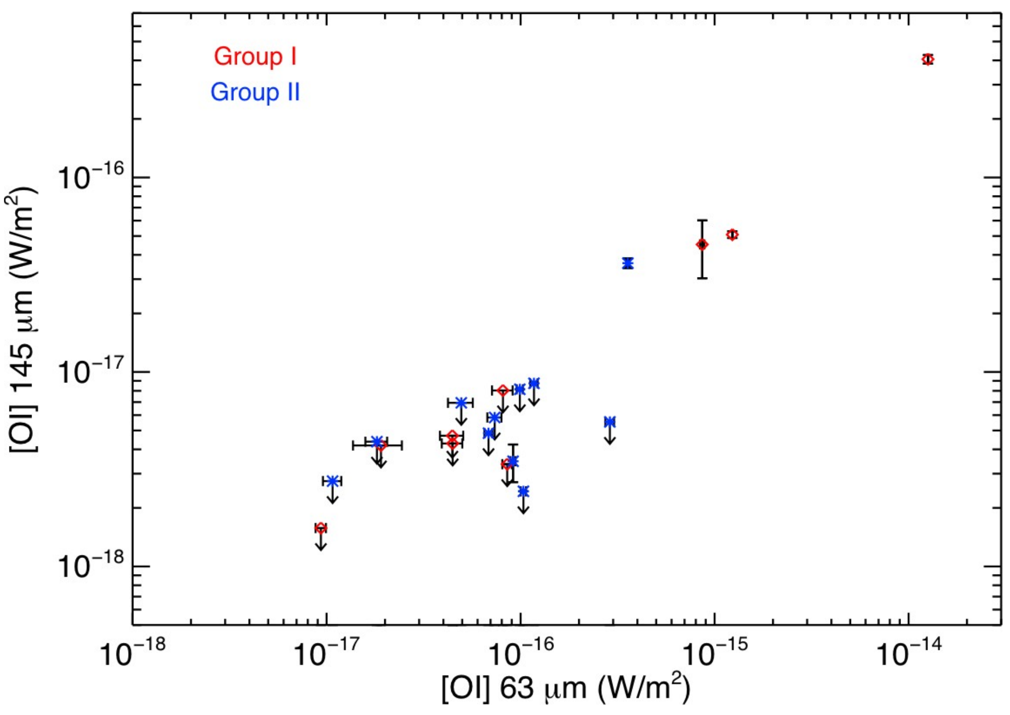


Dust Temperature distribution

Kamp et al. (2009)

Trends with [OI] 63 μm line flux

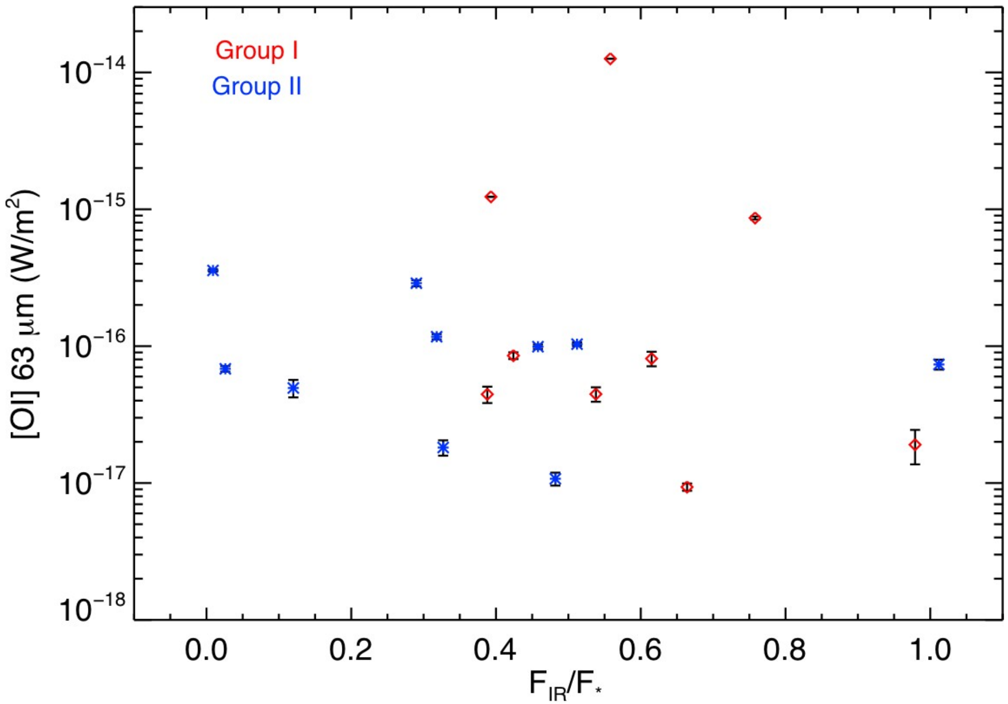


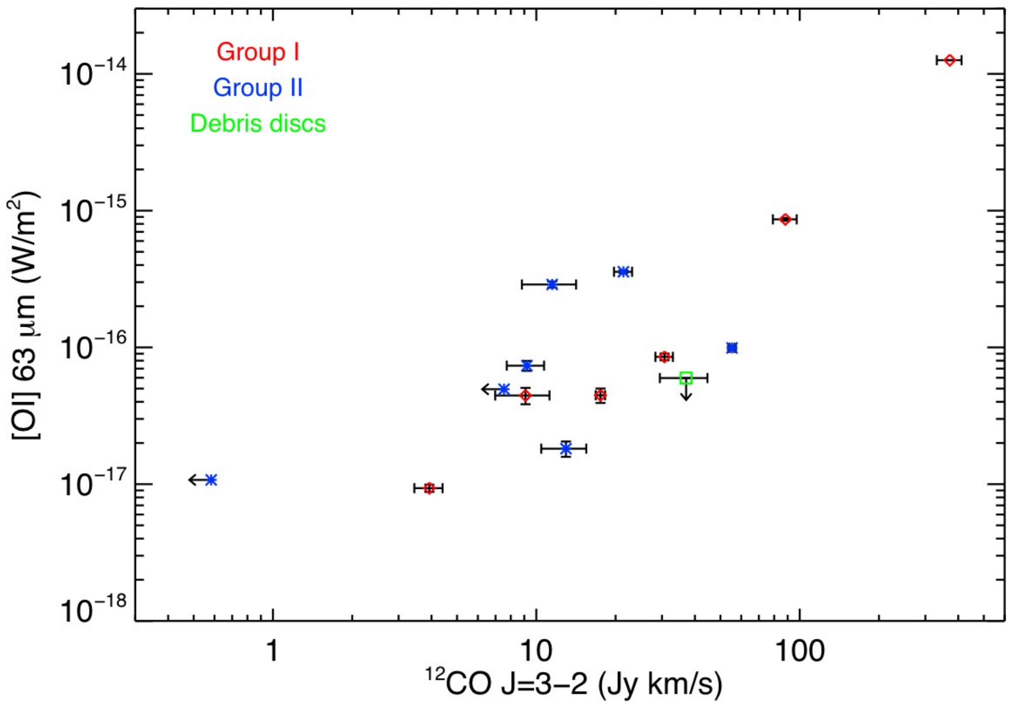


FIR continuum

[OI]145 μm

IR excess and CO J=3-2 line flux

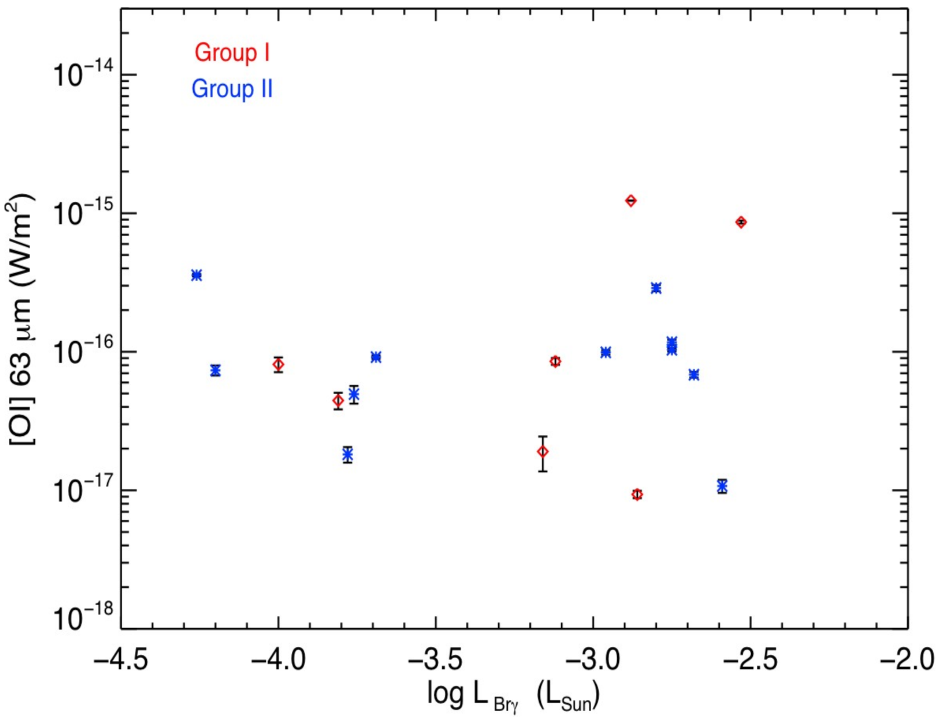


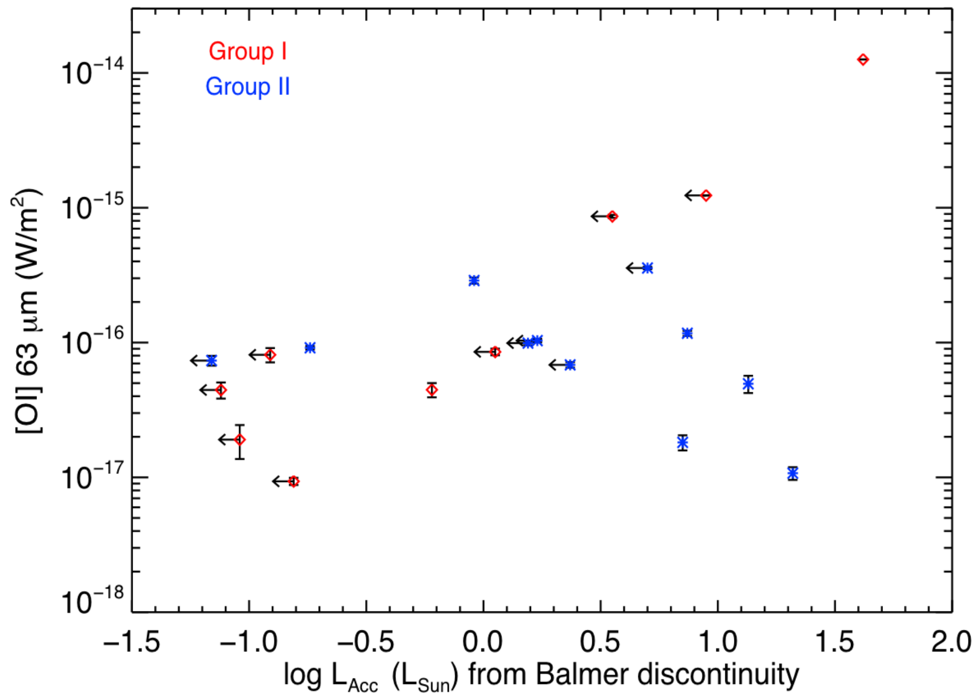


Warm & Cold Dust

Cold Gas

Accretion indicators (1)

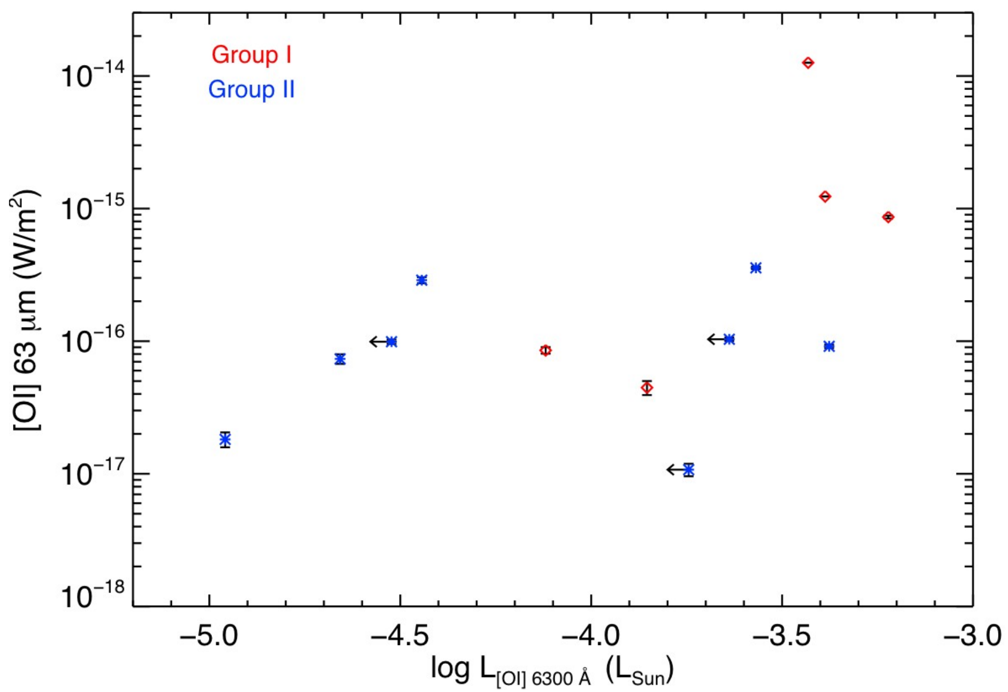


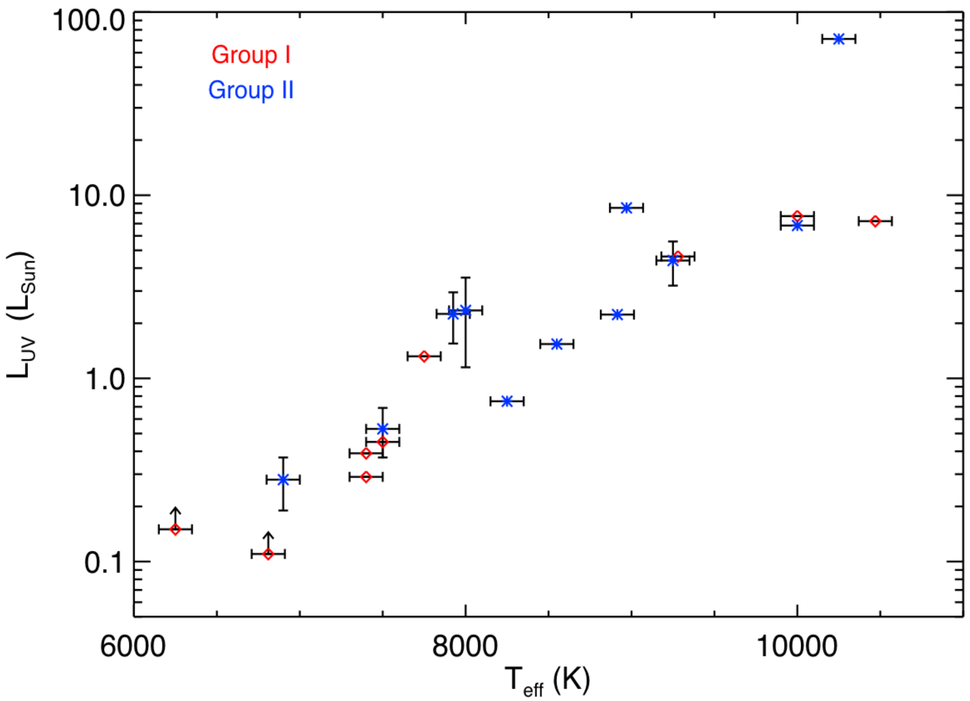


Brγ Luminosity

Excess at Balmer Discontinuity

Accretion indicators (2)

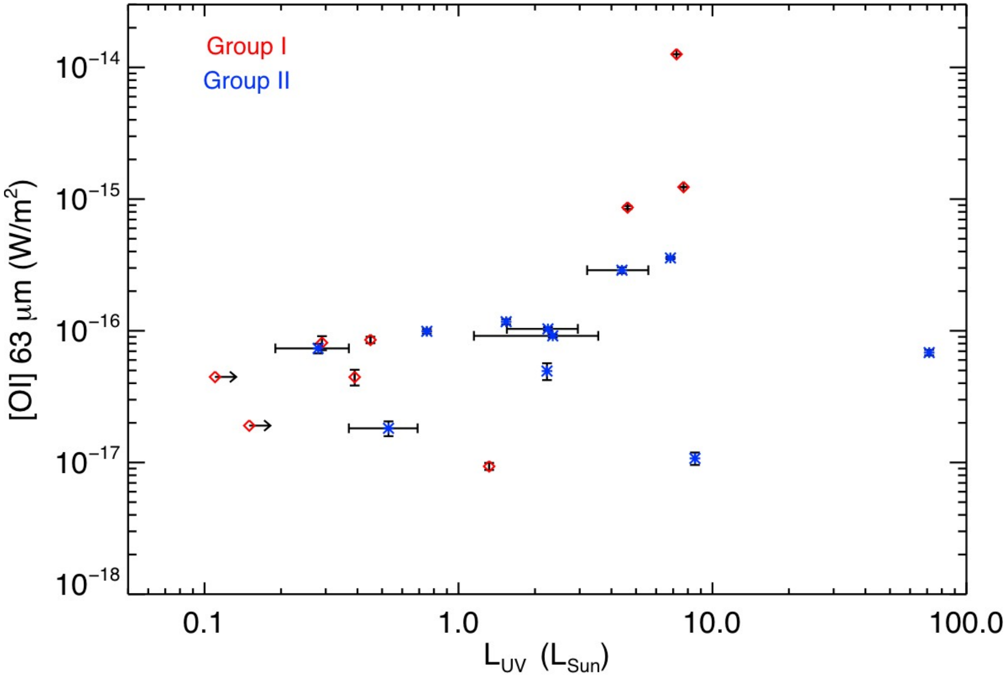




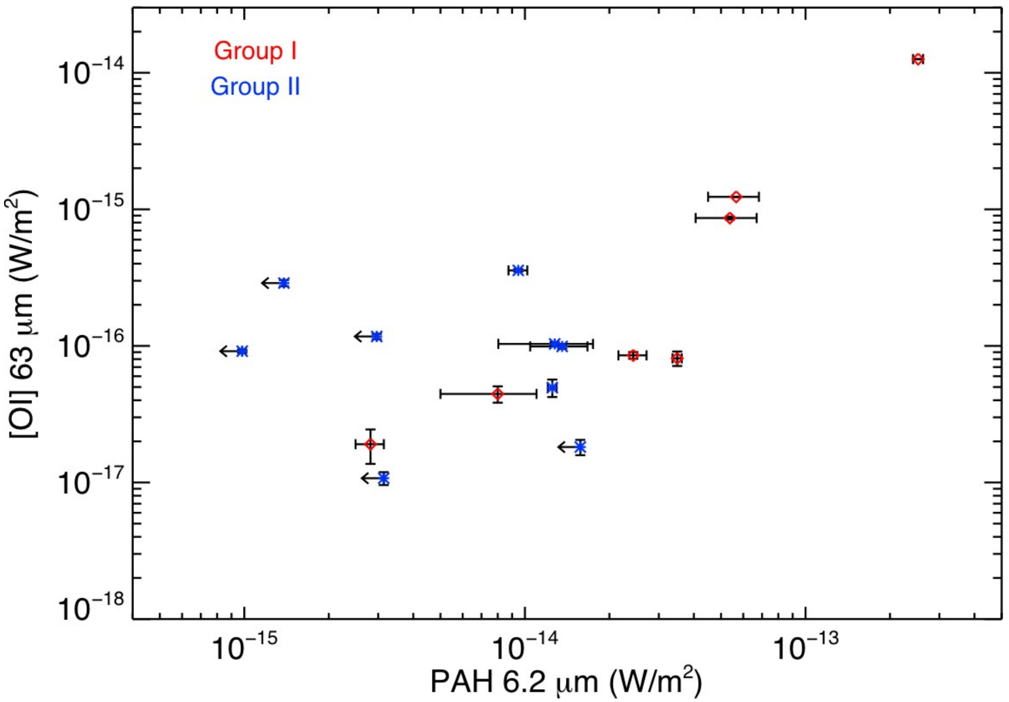
L [OI]6300 Å (not necessarily acc.)

L_{UV} versus T_{eff}

UV and PAH Luminosity

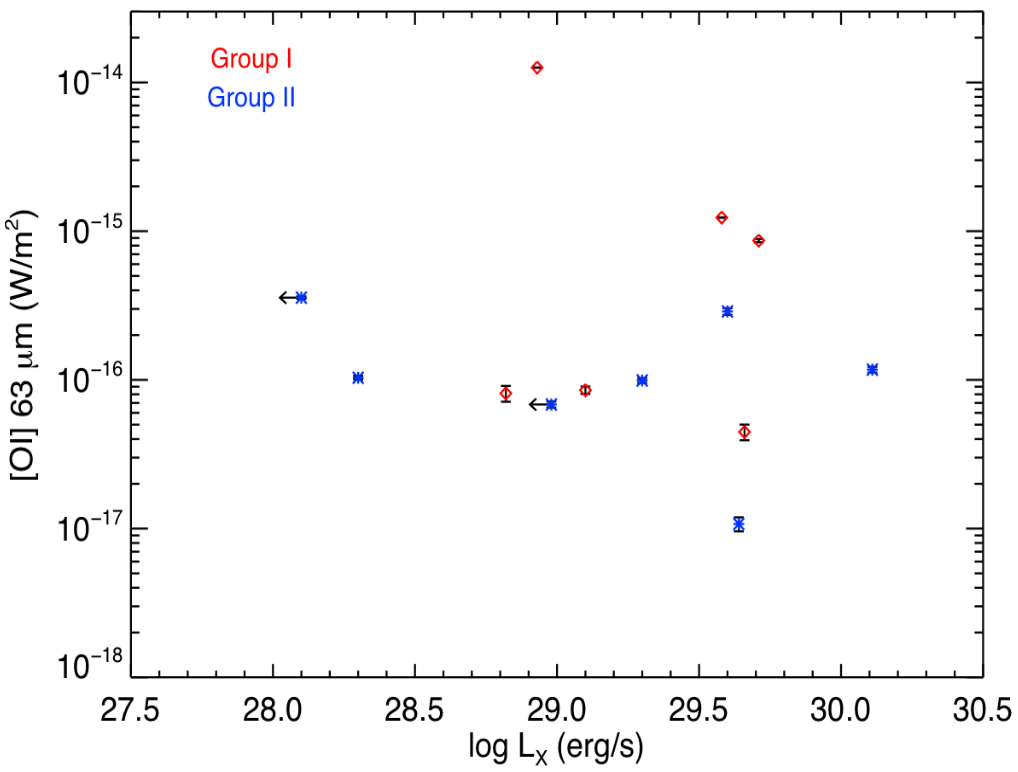


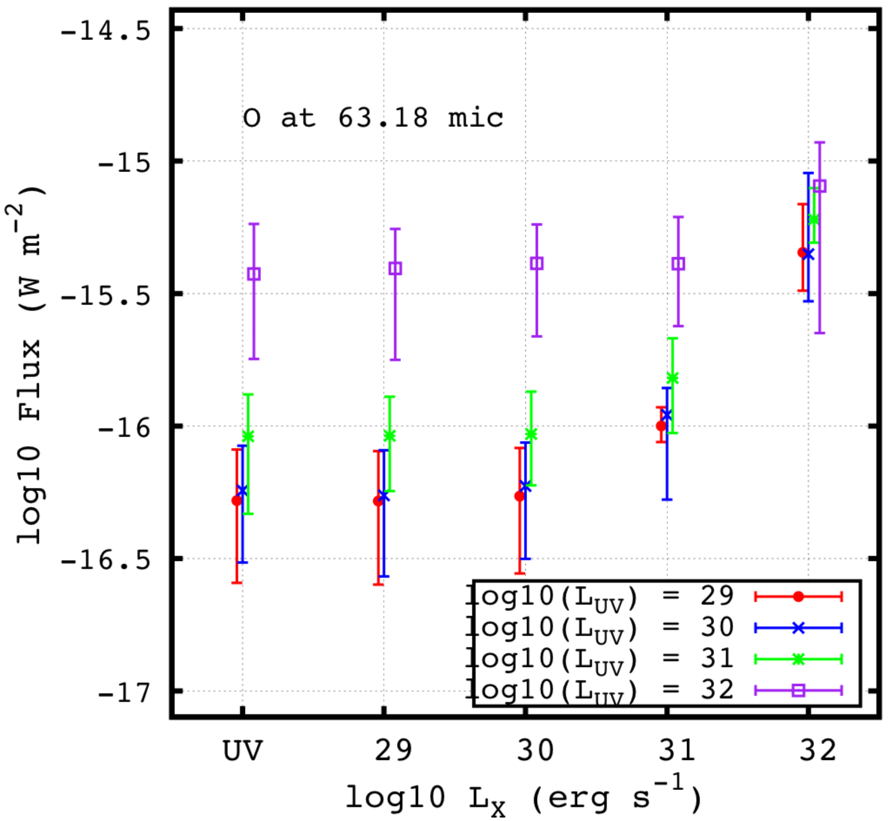
[OI] versus L_{UV}



[OI] versus L_{PAH}

[OI] 63 μm vs. X-ray Luminosity





[OI] versus L_X

Predicted Line flux

Aresu et al. 2011, + in preparation

Disc modelling tools

MCFost

Monte Carlo radiative transfer, calculates continuum in 3D

Fit observed photometry (SED) and images simultaneously

Output: disc structure and dust thermal profile. Can include gaps and/or puffed-up inner rim.

Can also produce scattered light/thermal images, polarisation maps, visibilities

Pinte et al. 2006, 2009

ProDiMo

Thermo-chemical model in hydrostatic equilibrium, UV chemistry, ice formation, non-LTE heating & cooling

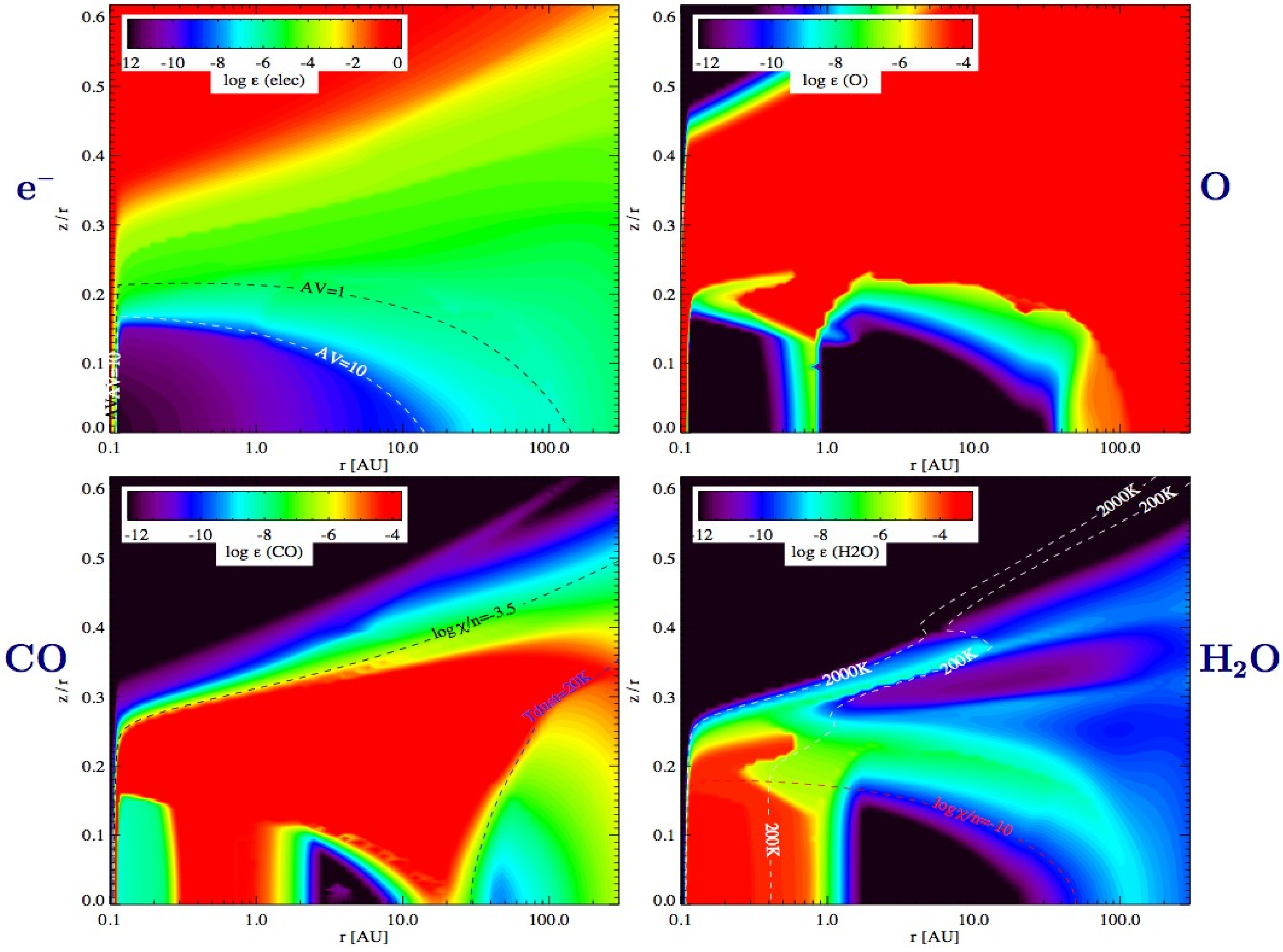
Calculates gas thermal balance and chemistry, input disc structure MCFost, UV flux important

Output: thermal structure and location of different species, prediction of line intensities

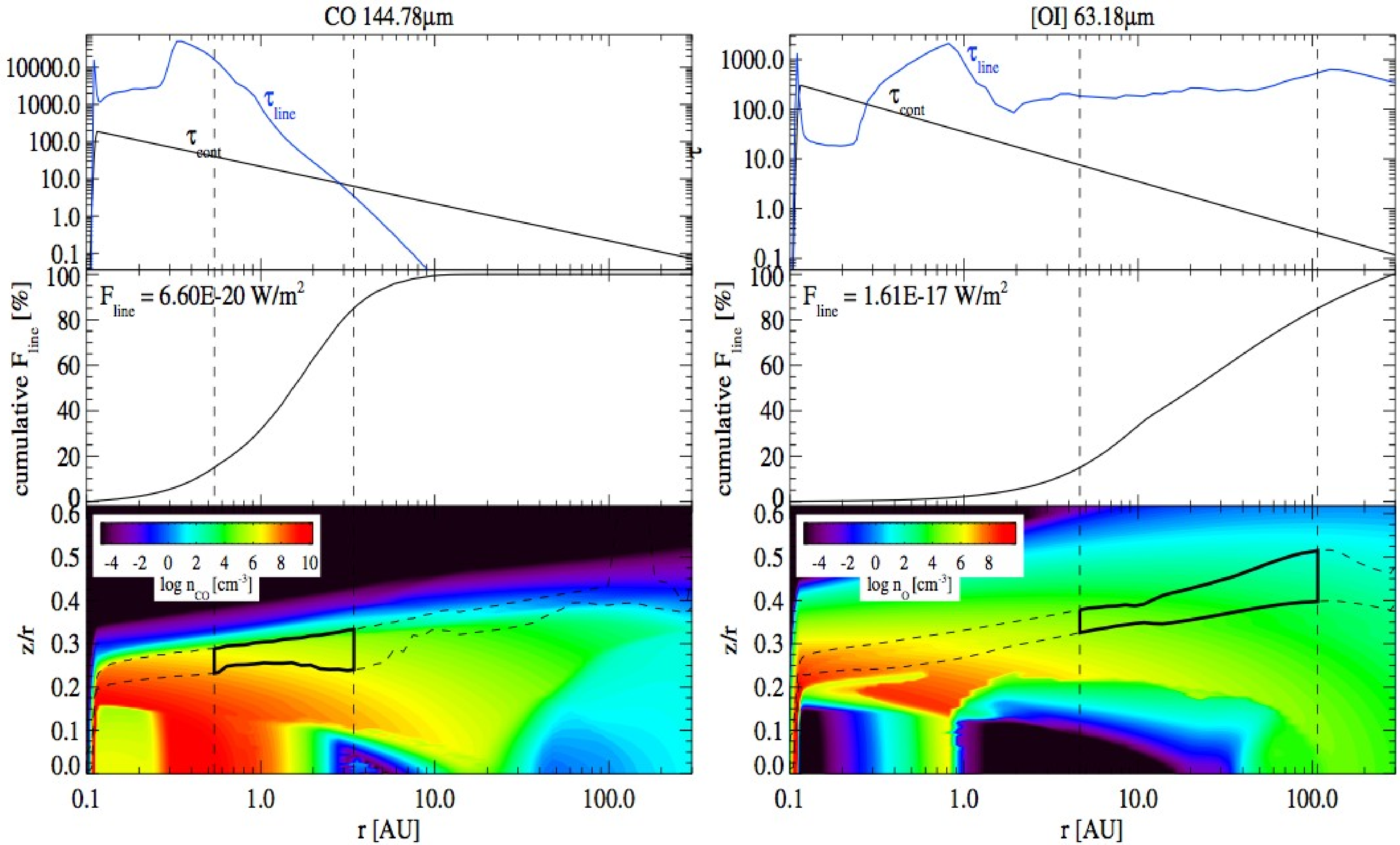
+ Dentgrid: 300000 disc models with a wide range of stellar & disc parameters

Woitke et al. 2009, 2010; Kamp et al. 2010, 2011; Thi et al. 2011

Chemical structure: typical HAEBE disc



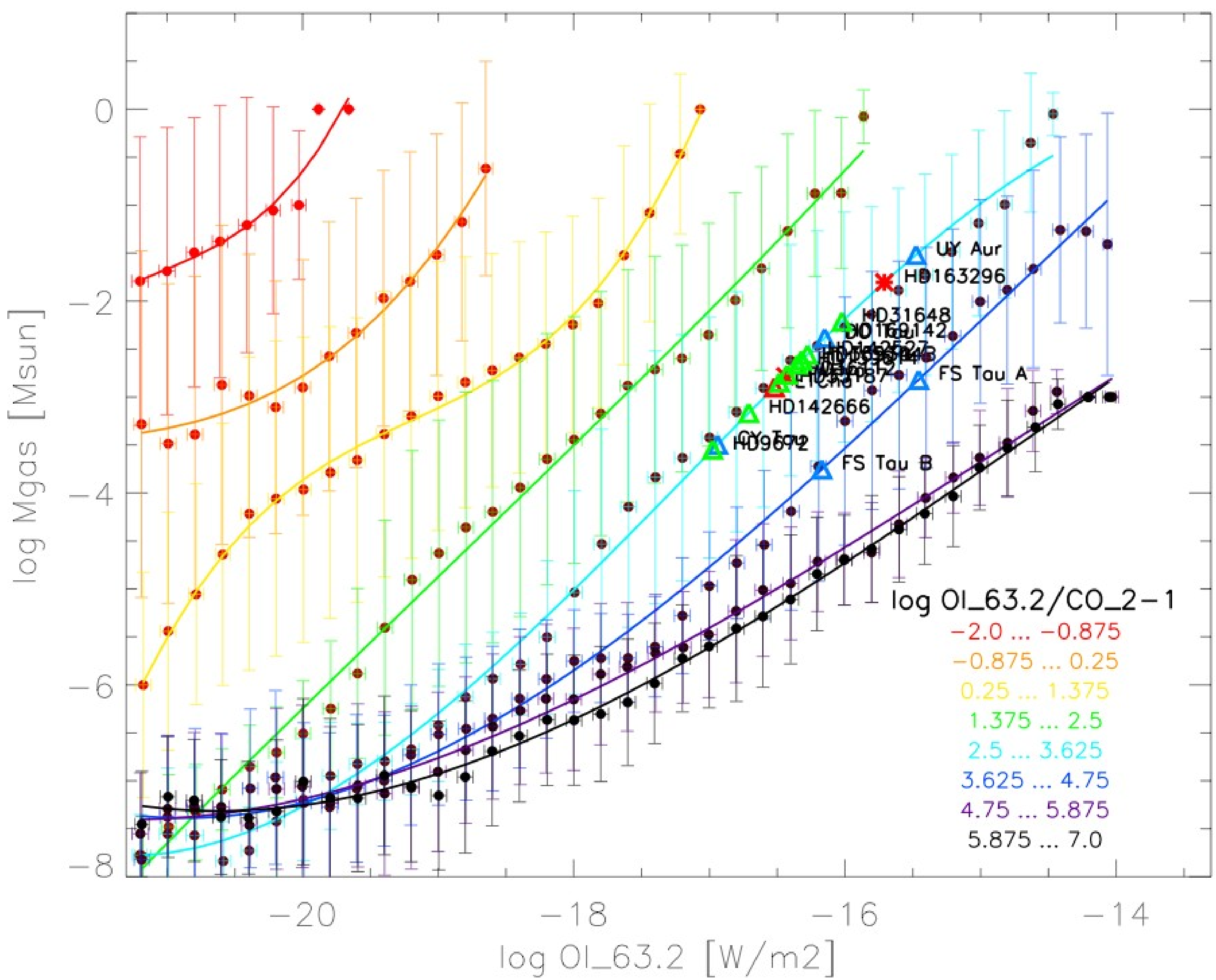
Where does the observed emission come from?



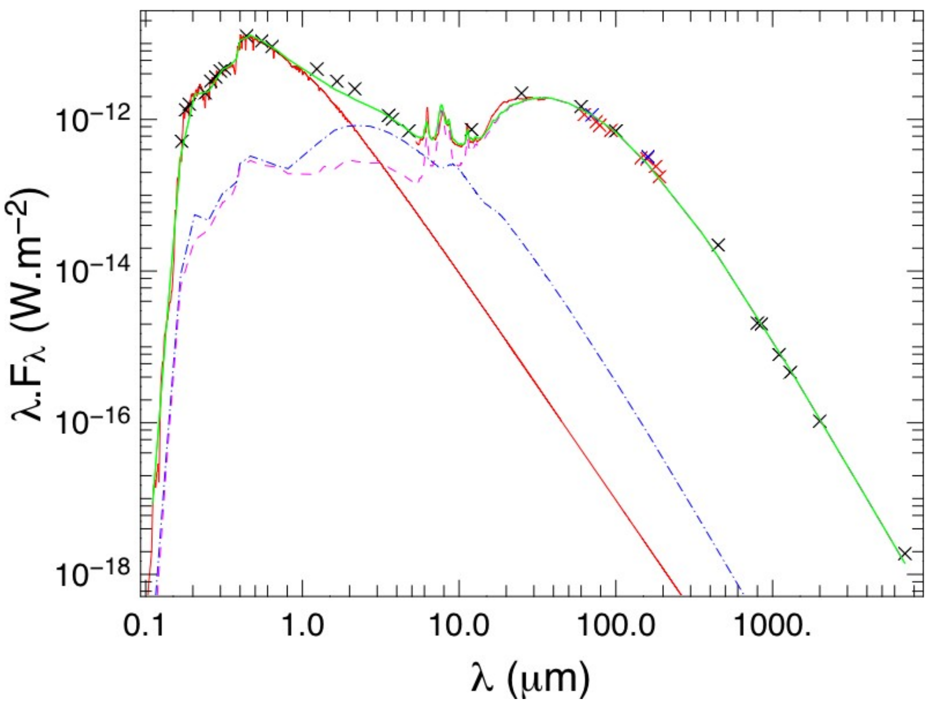
- high excitation temperature (here 657 K)
- in front of optically thick dust

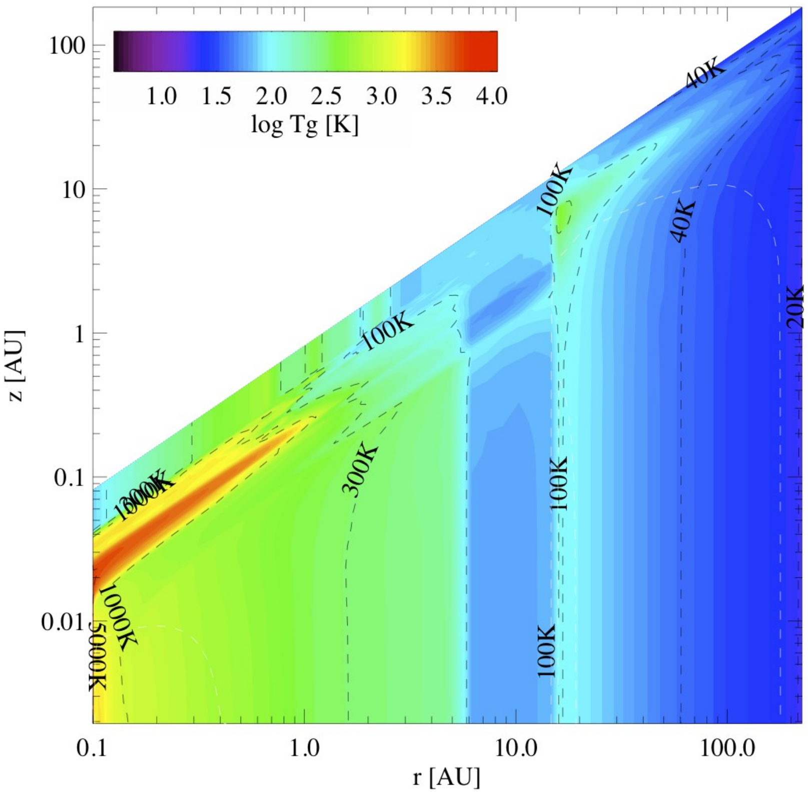
- optically **thick**
- emission from $r \lesssim 100$ AU

Comparison with the DENT grid (Kamp, Woitke, Thi 2009-2011)



Case study: HD169142 (A5Ve,145 pc, 6 Myr)





Disc structure: might host gap, beyond that (20-200 AU) continuous structure in which dust and gas are well-mixed.

Not a unique solution!

Meeus et al. (2010)

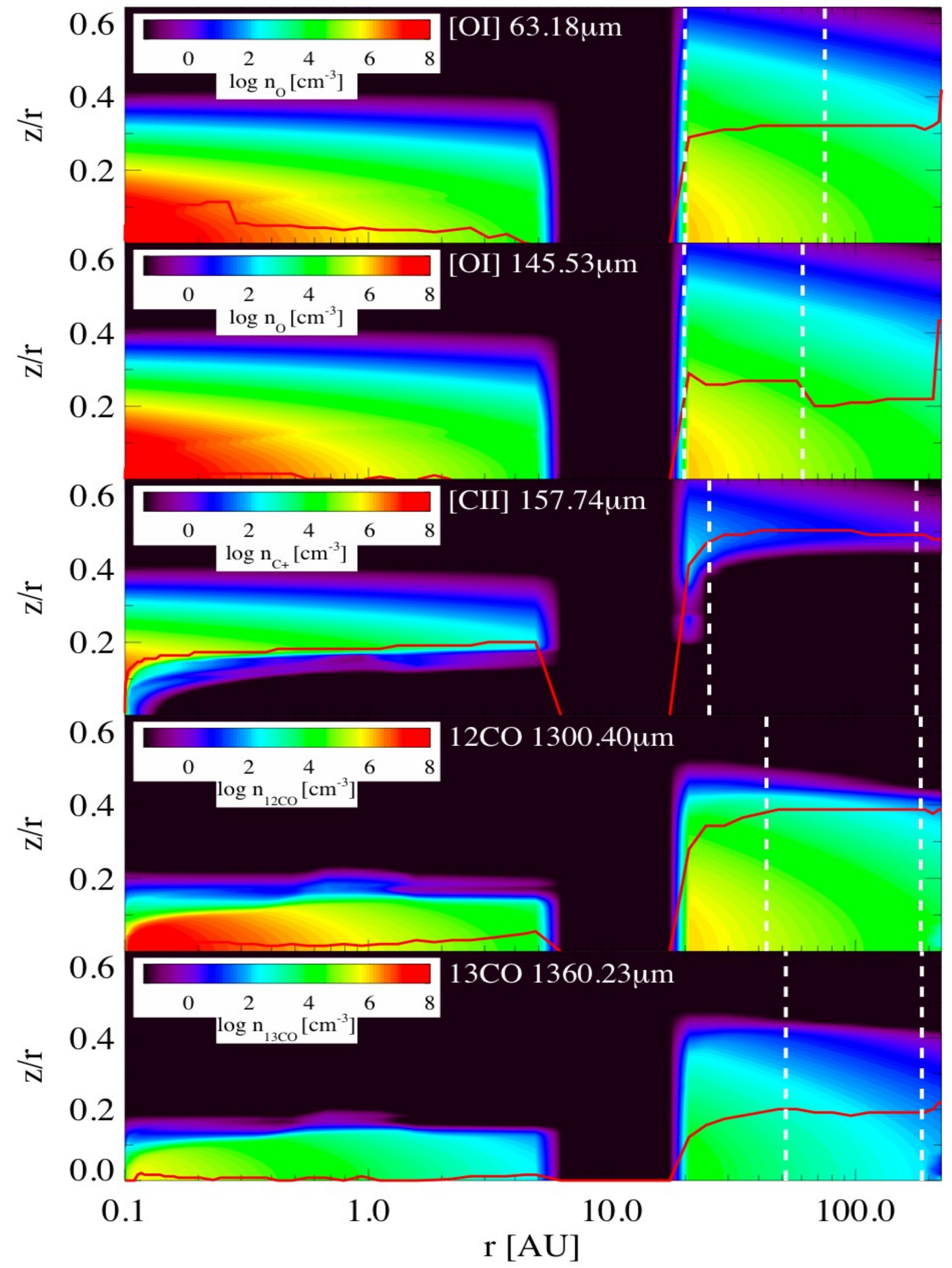
Dust modelling (McFost): gap at ~ 10 AU

Different gas transitions trace different regions

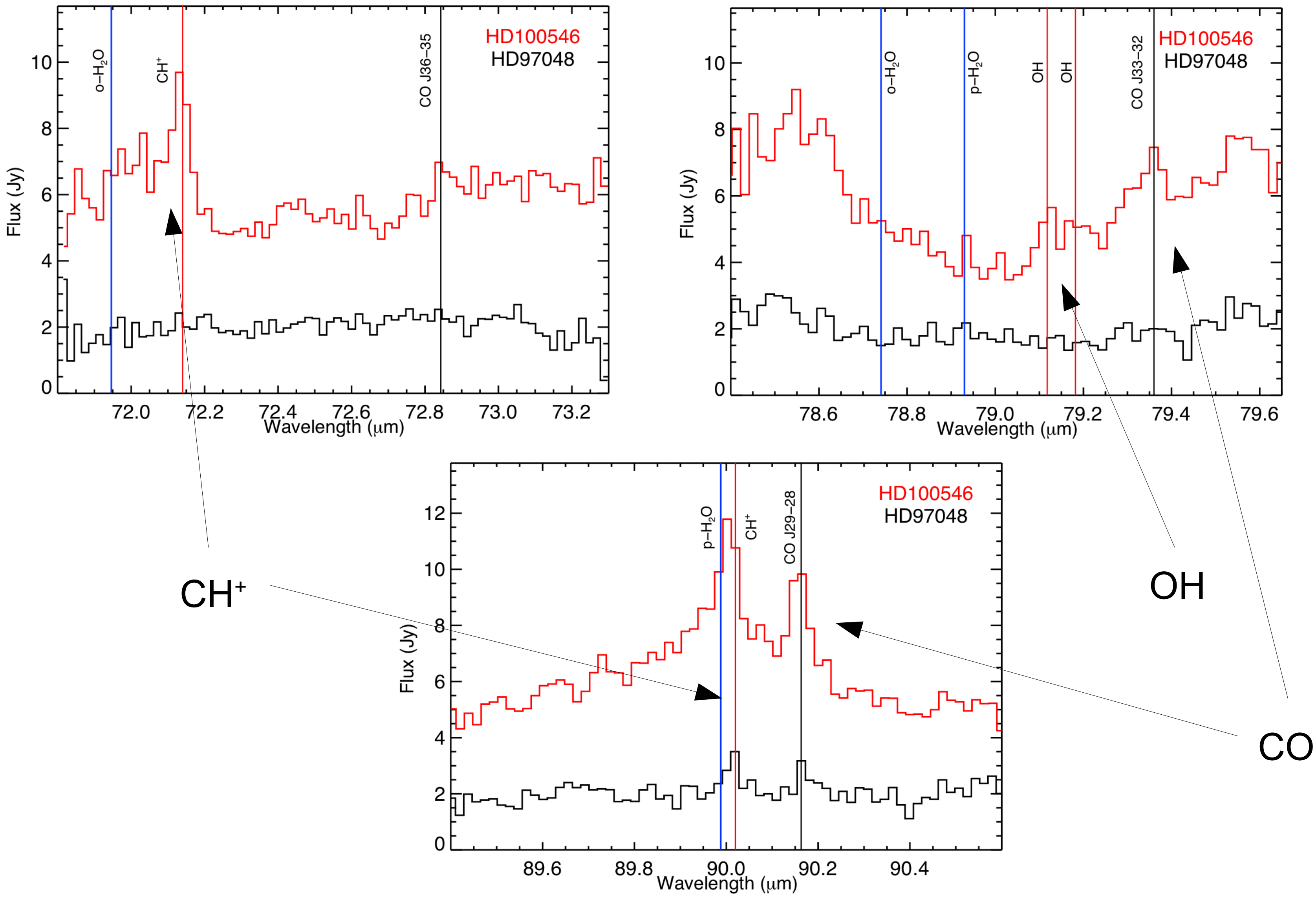
Mm CO observations essential ingredient

Gas/dust ratio 20-50, M_{gas} 3-7 x 10^{-3} M_{sun}
⇒ still a gas-rich disc

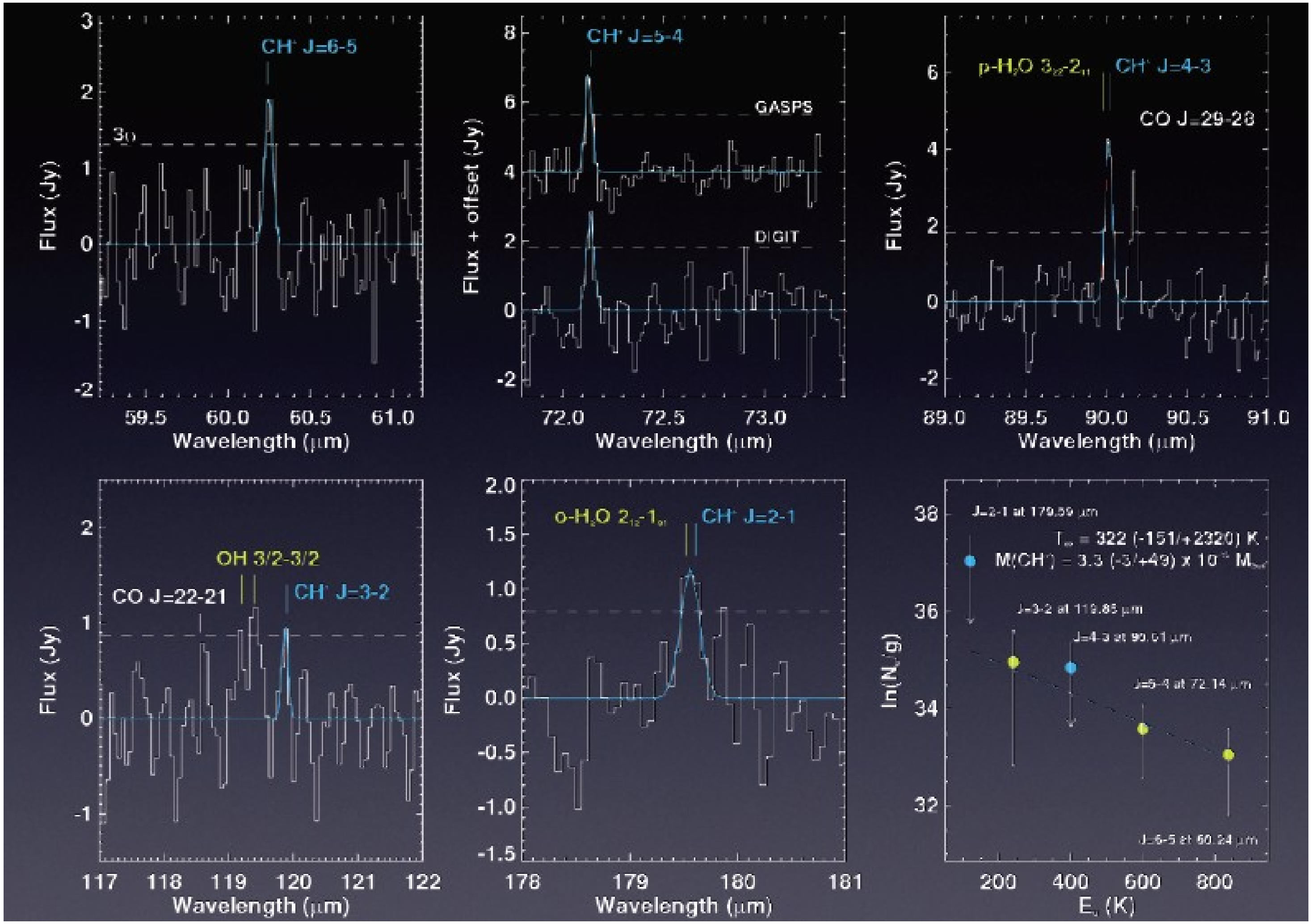
Meeus et al. (2010)



The richest spectra: HD97048 & HD100546



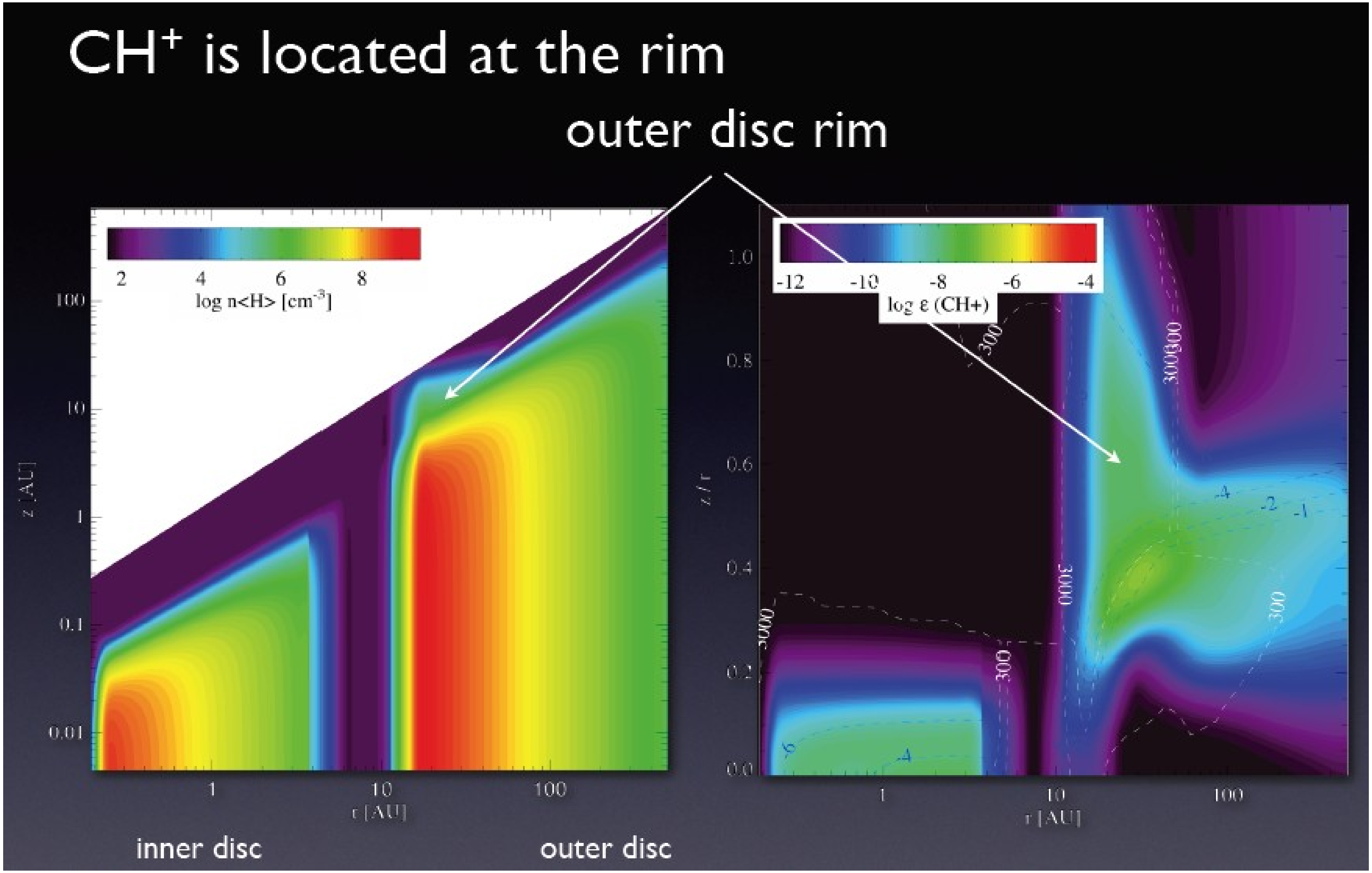
First CH^+ detection in a HAEBE



Main CH^+ formation reaction: $C^+ + H_2 \rightarrow CH^+ + H$, efficient at a few 100 K.

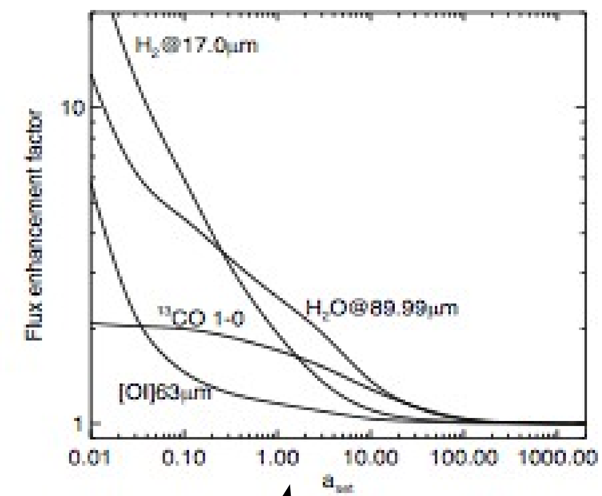
Thi, Ménard, Meeus et al. 2011; DIGIT data from *Sturm et al. 2010*

HD100546: modelled with ProDiMo

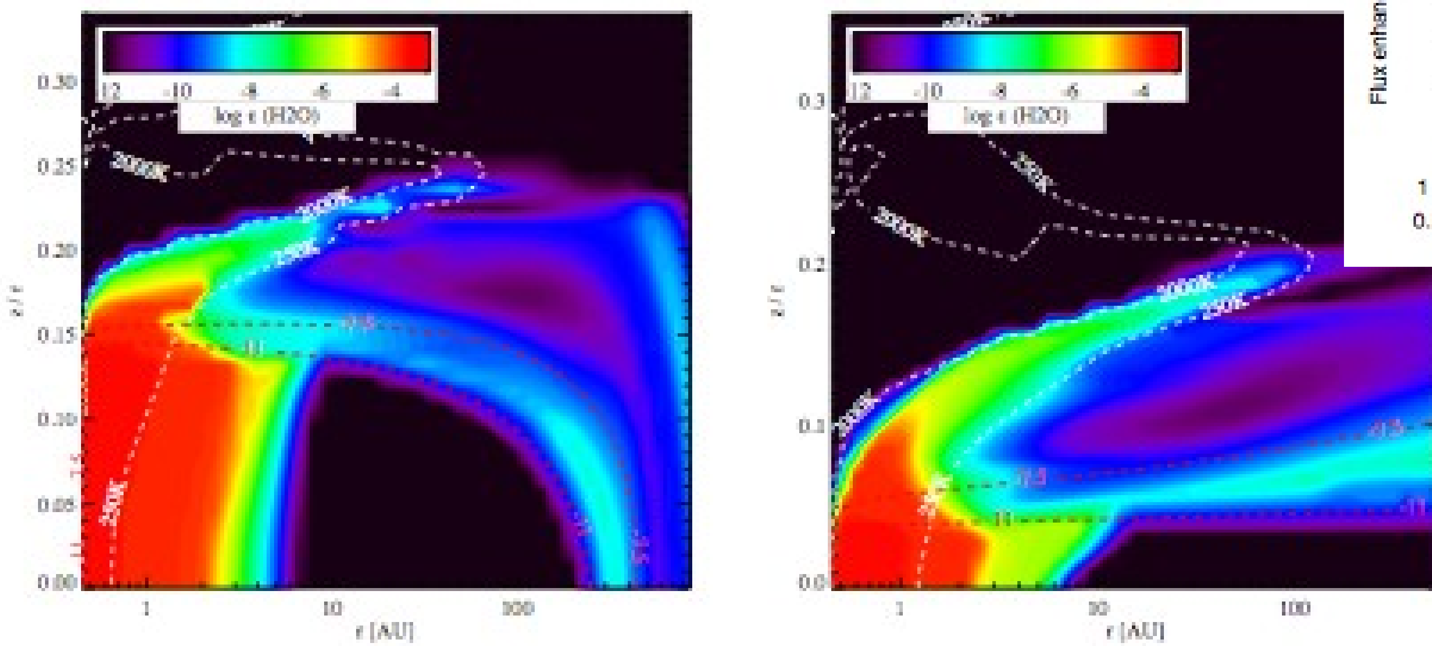


HD163296: strong evidence for settling

The smaller the grain size affected by settling - indicating more settling - the stronger the line (minimum grain size affected "a_{set}")



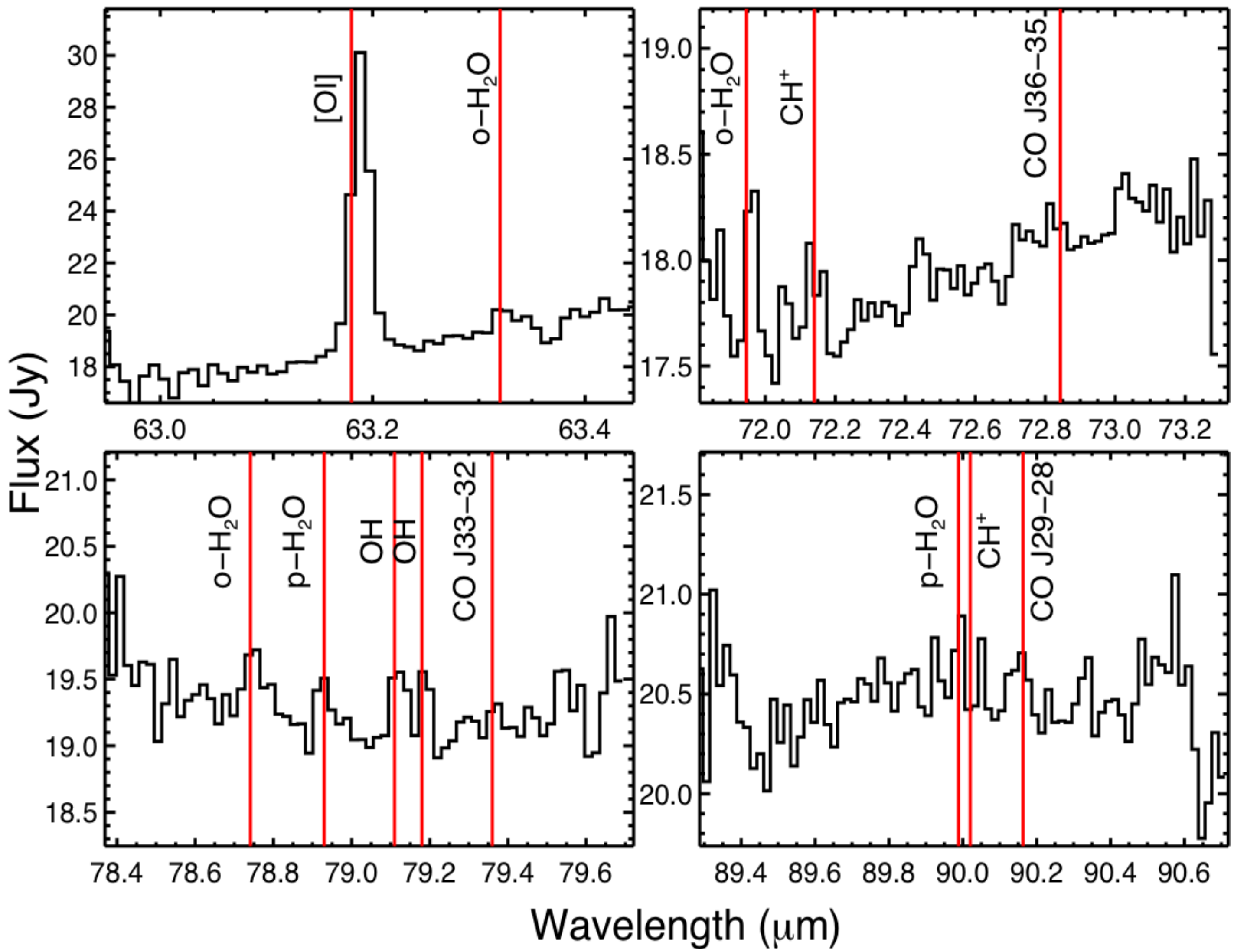
Effect of settling on line flux



The location of H_2O in a non-settled and settled disc. When the hot gas region shifts downwards, its density increases, causing an increase in line flux.

Tilling, Woitke, Meeus et al. (2011)

HD163296: first H_2O detection in a HAEBE



Summary

- [OI]63 is by far the strongest line observed, [OI]145 factor 10-20 weaker
- [CII] contamination is a complicated issue
- CO J=18-17 only detected in 8 objects
- OH and CH^+ detected in 2 HAEBEs
- H_2O detected in 1(!) HAEBEs, seen in TTS (*Rivière-Marichalar et al. 2012*)
- In HAEBEs, UV heating is important factor, unlike X-rays in TTS
- Detailed modelling of physics & chemistry crucial to understand disc
  (soon: AB Aur - *Woitke*, HD97048 - *Meeus*, 51 Oph & HD141569A - *Thi*)

The future: disc chemistry with ALMA
fifty 12m antennas working together at mm λ


The End