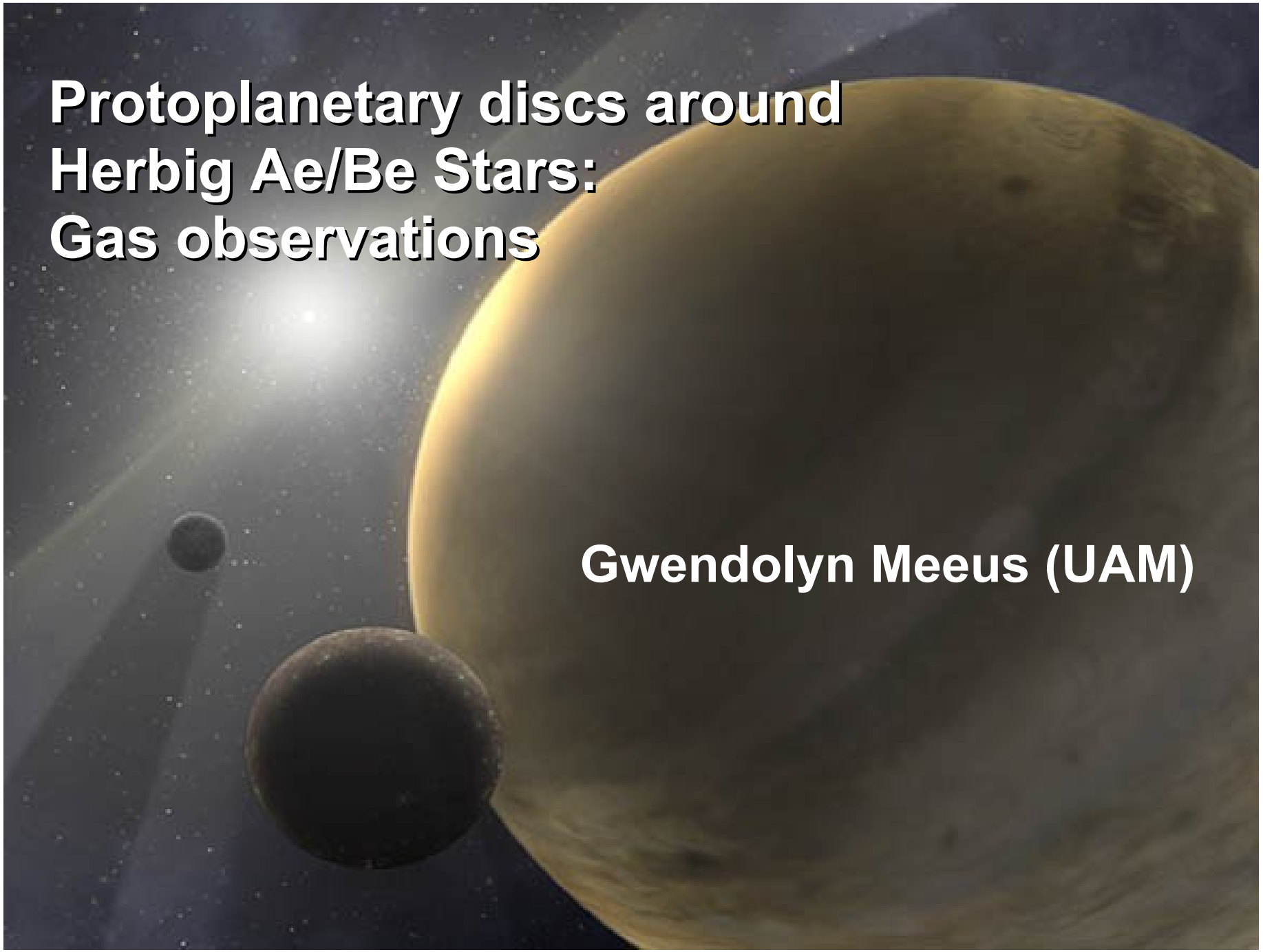


Protoplanetary discs around Herbig Ae/Be Stars: Gas observations

Gwendolyn Meeus (UAM)

Thanks to my collaborators

Jean-Charles Augereau
Jeroen Bouwman
Bill Dent
Andrés Carmona
Carlos Eiroa
Carol Grady
Benjamin Montesinos
Christophe Pinte
Göran Sandell
Bernhard Sturm
Wing-Fai Thi
Bart Vandenbussche
Peter Woitke

Team members of GASPS and DIGIT

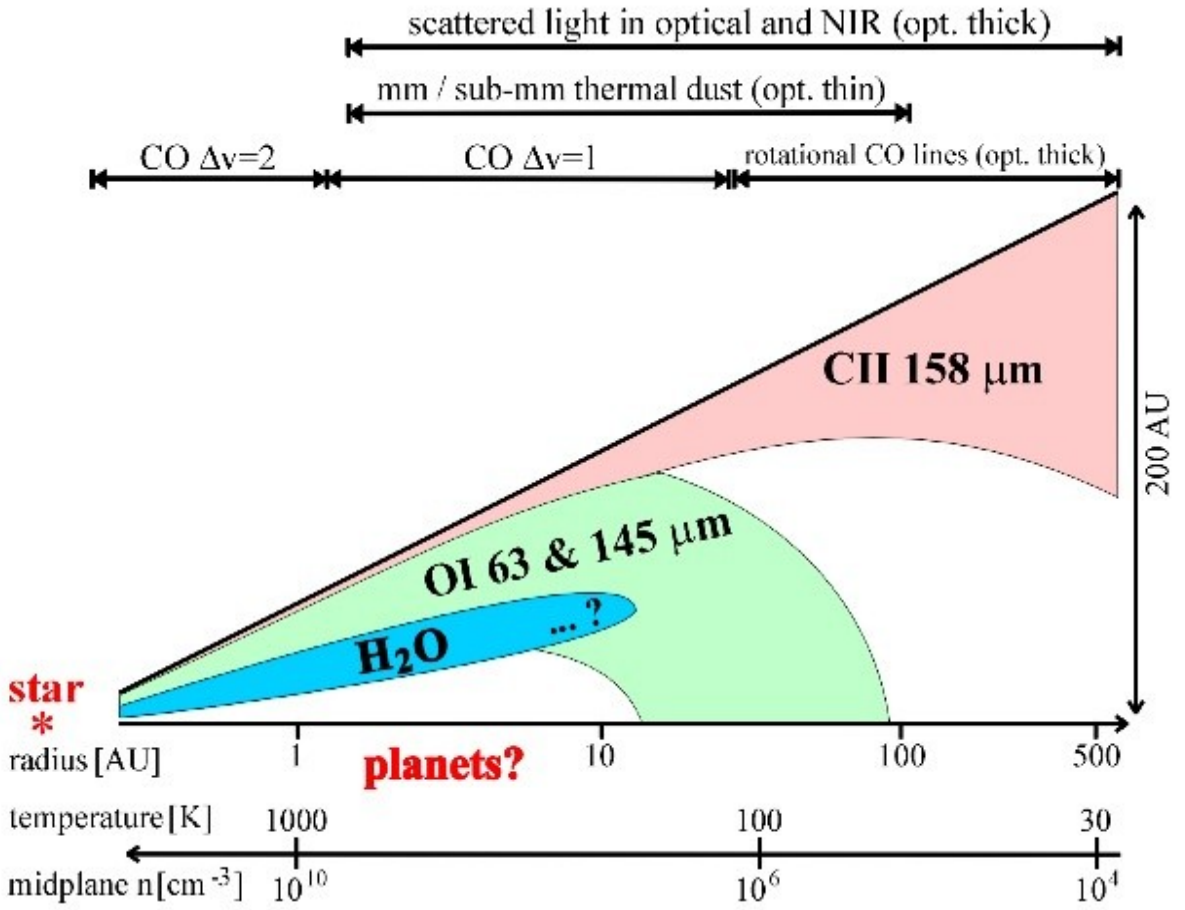
Motivation

- Discs are birth sites of planets
- Gas giant planets form within the first 10 Myr
- How does gas dispersal work? What timescale?
  ⇒ understanding of thermal balance and disc chemistry needed, and their dependency on stellar properties
- Gas lines are brightest in the far-IR
  ⇒ Herschel perfectly suited

Outline

- GASPS observations of Herbig Ae/Be stars
- Comparison with other properties
- HD169142: a case study
- DIGIT observations of HD100546
- Conclusions

Different gas species & transitions trace different regions in disc



GASPS observations

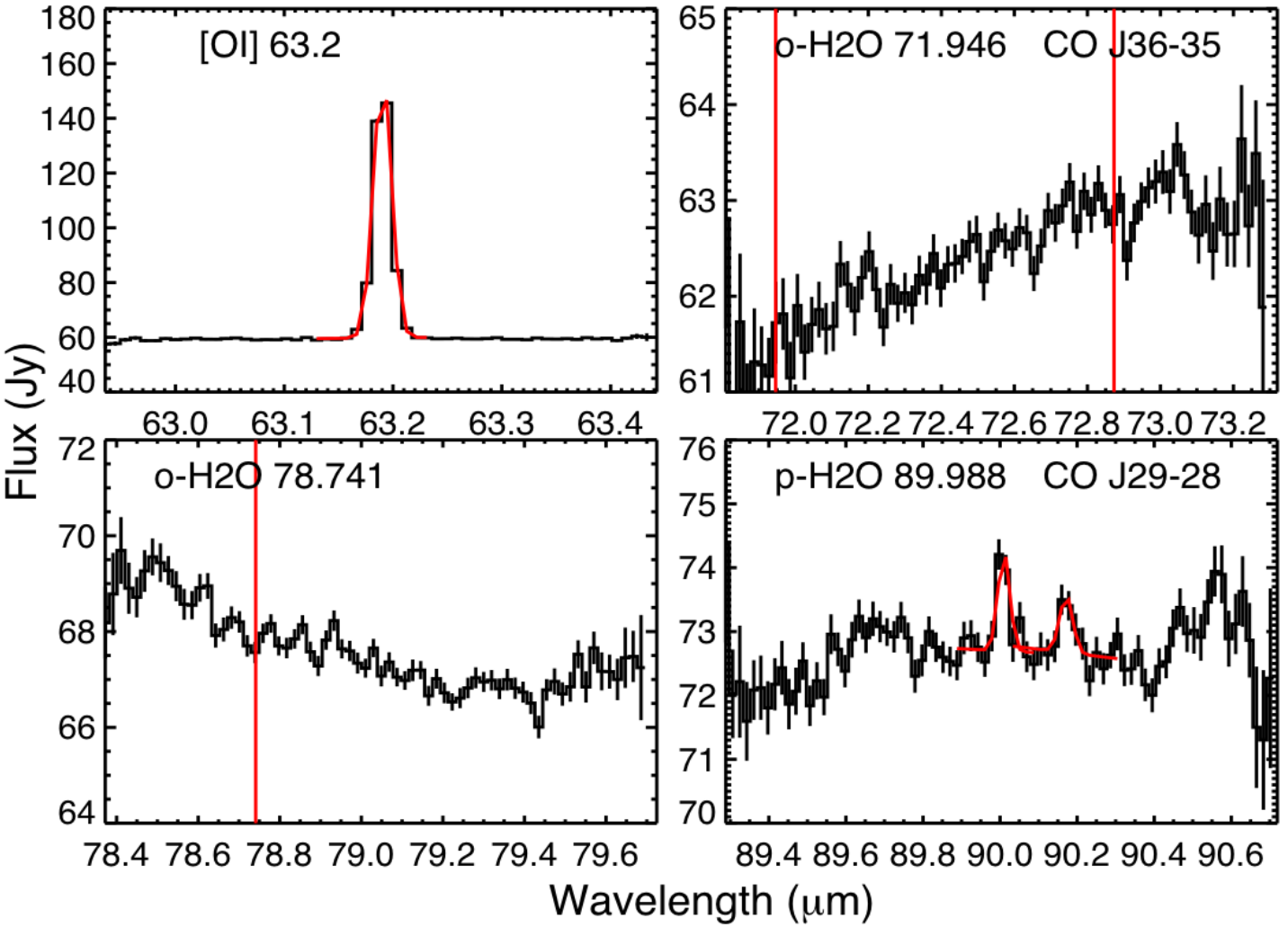
GASPS (PI Bill Dent)

26 objects in Herbig Ae/Be sample
5 more 'evolved' (transitional discs)

PACS settings targeted at main gas lines:
CO, [CII], H_2O and [OI]

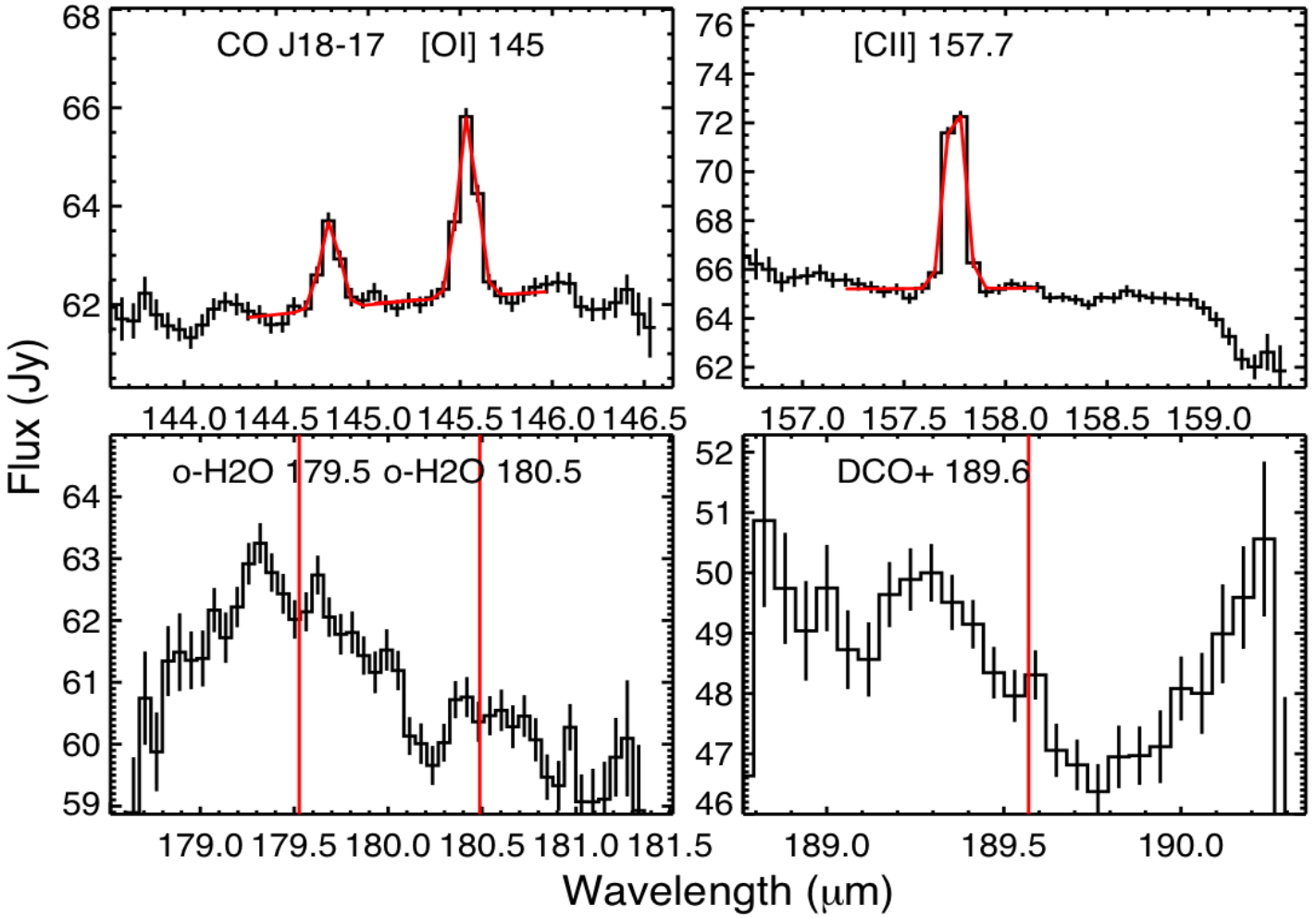
Observations trace gas in the **OUTER DISC**

HD97048 in the 'blue'

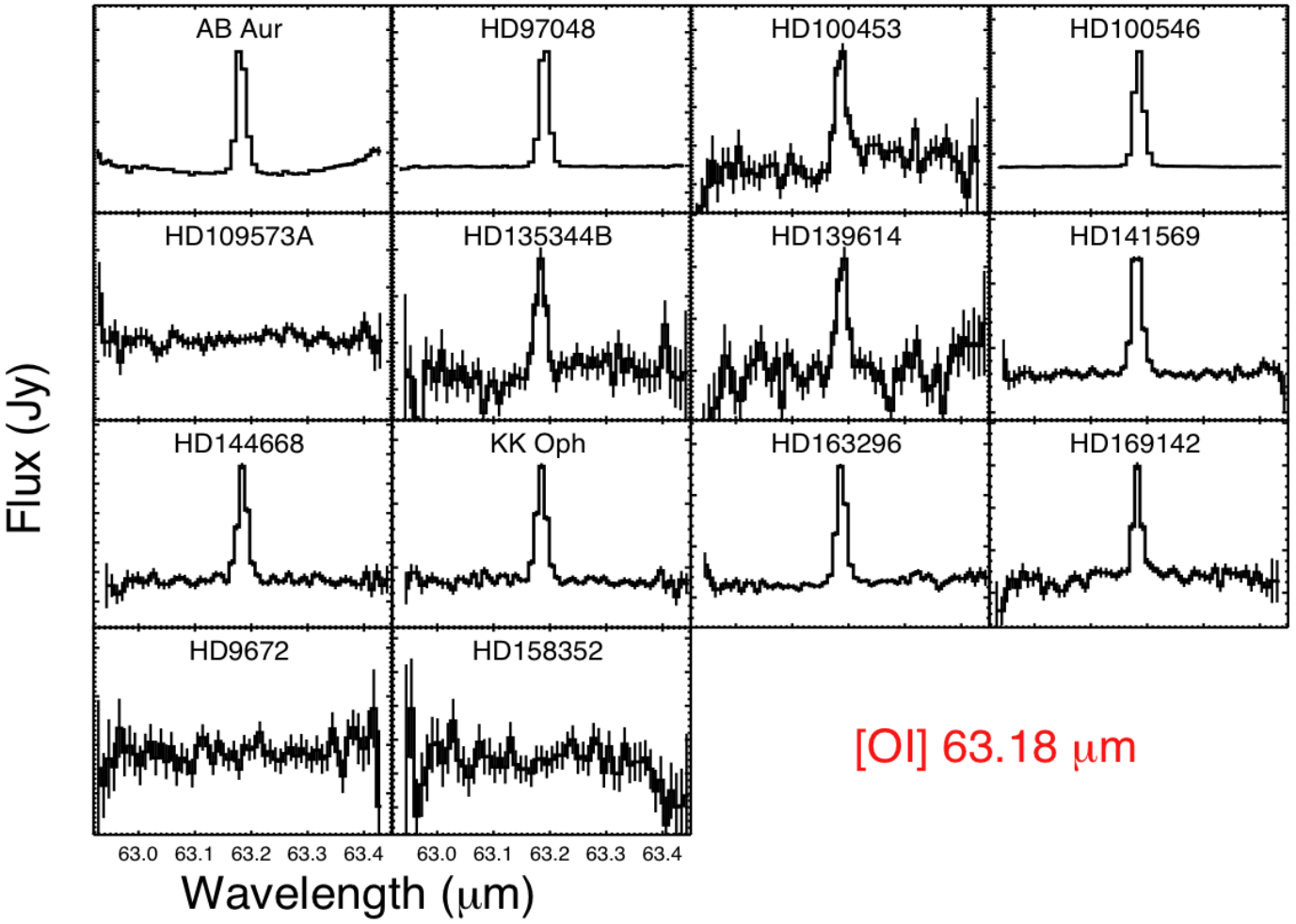


Detection of p-H_2O, not o-H_2O, o/p ratio chemistry clue

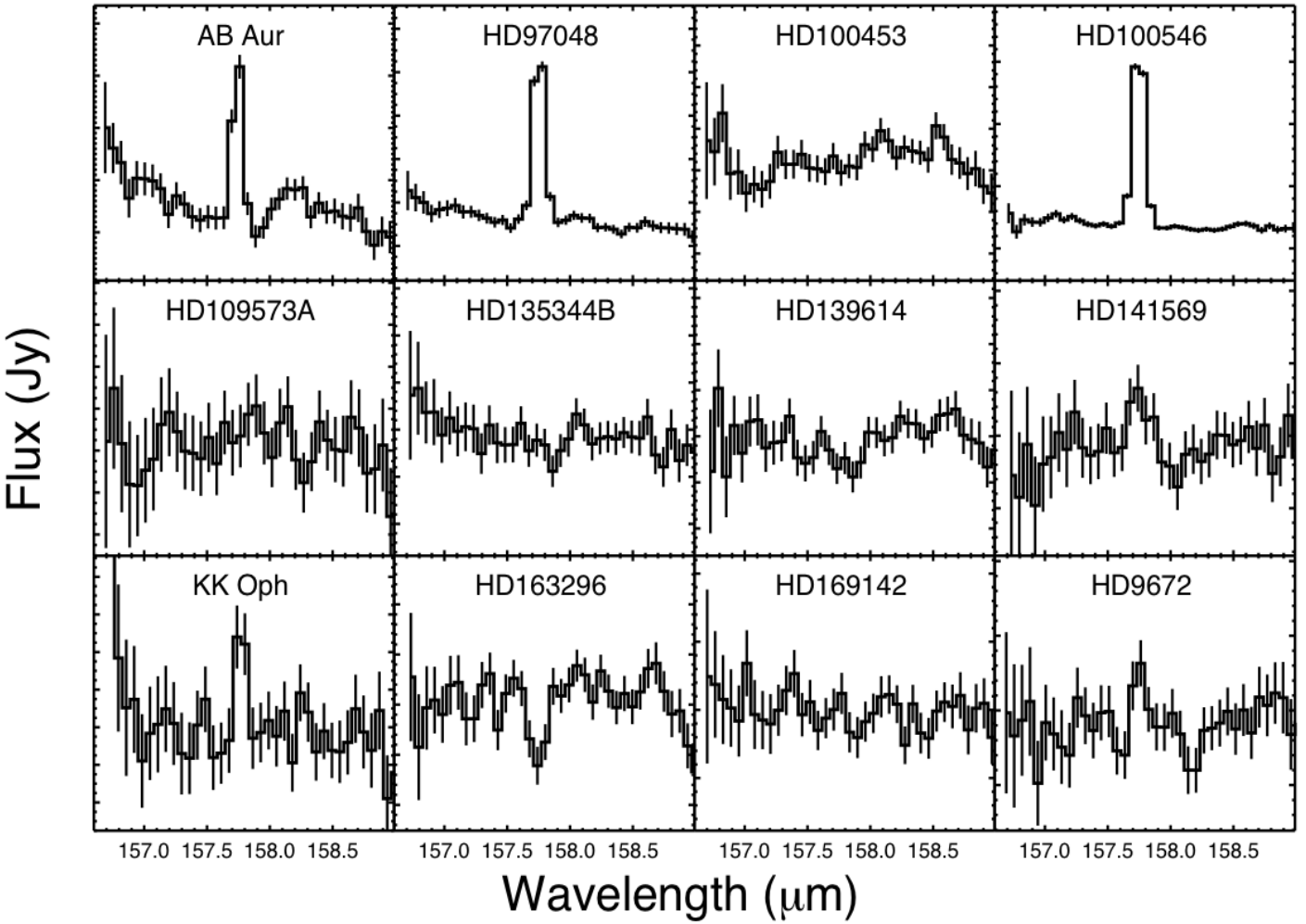
HD97048 in the 'red'



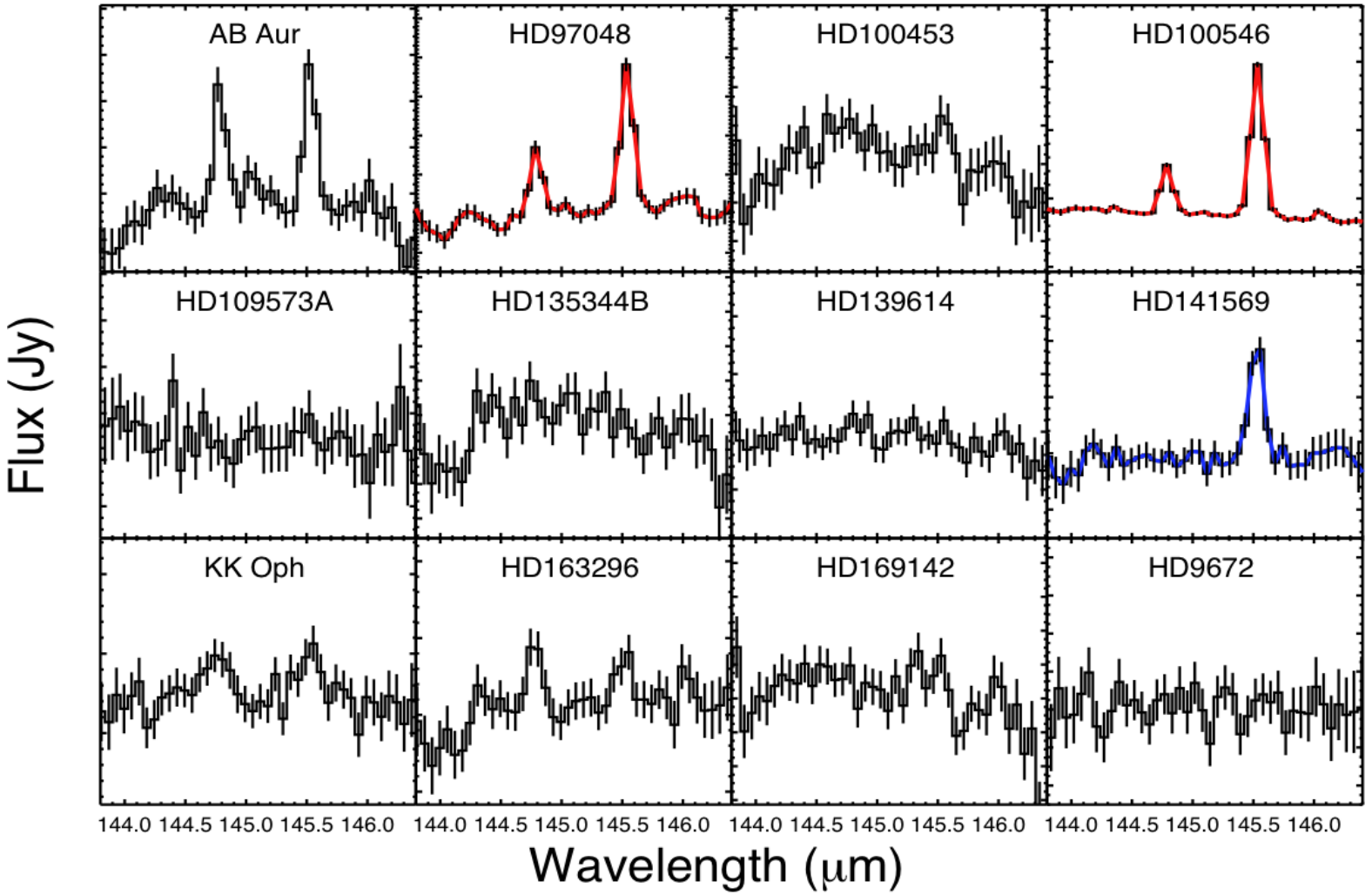
The sample at [OI] 63.2 micron



The sample at [CII] 157.7 micron

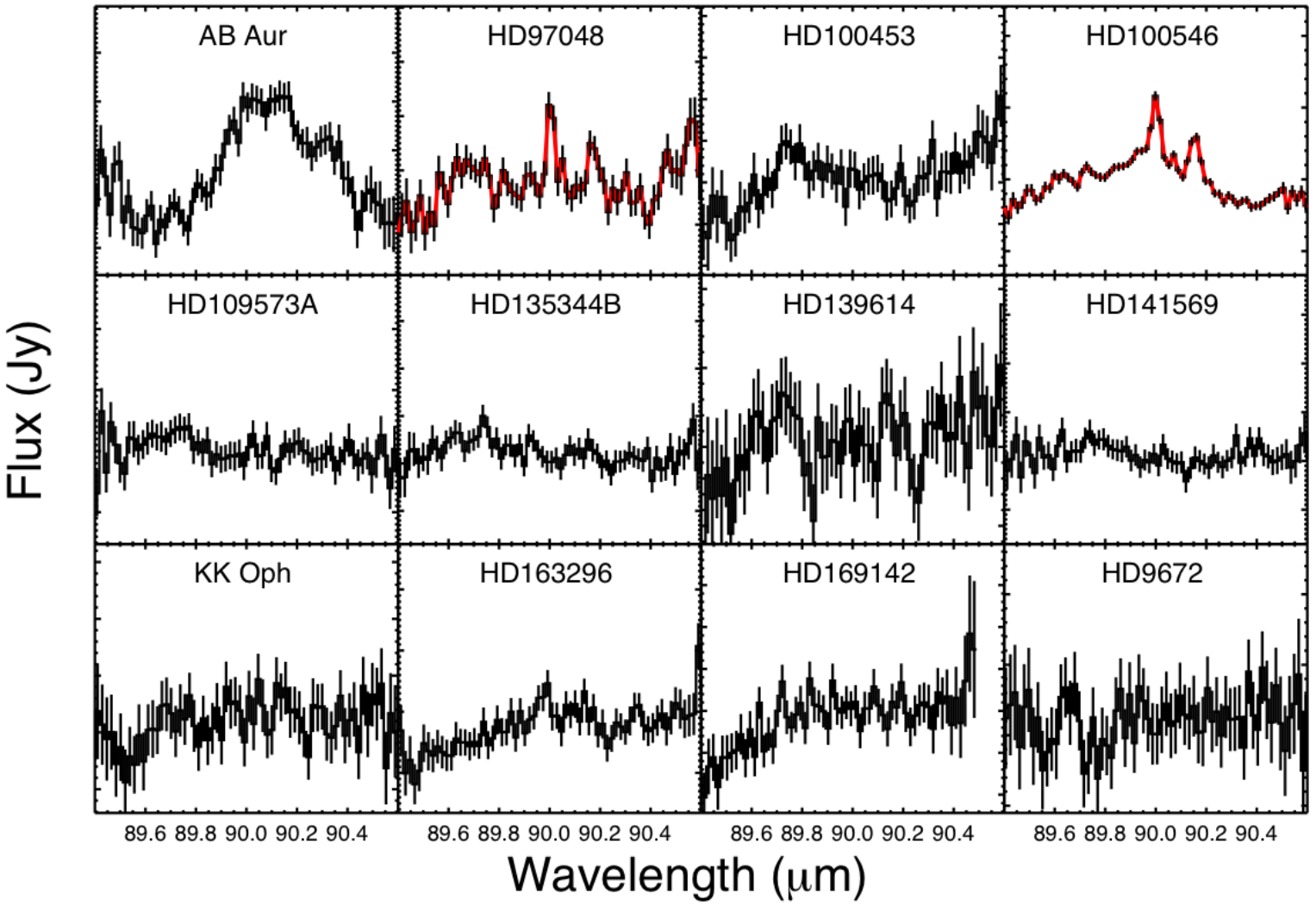


CO J=18-17 and [OI] 145.5 μm



CO dissociation in more tenuous environments? Or Temp. effect?

p-H_2O 89.988 μm and CO J=29-28



Molecular gas in surface layers disc

- Prediction of the hotter, opt. thin surface layer around opt. thick colder midplane (*Chiang & Goldreich 1997*):

For H_2 in near- and mid-IR:

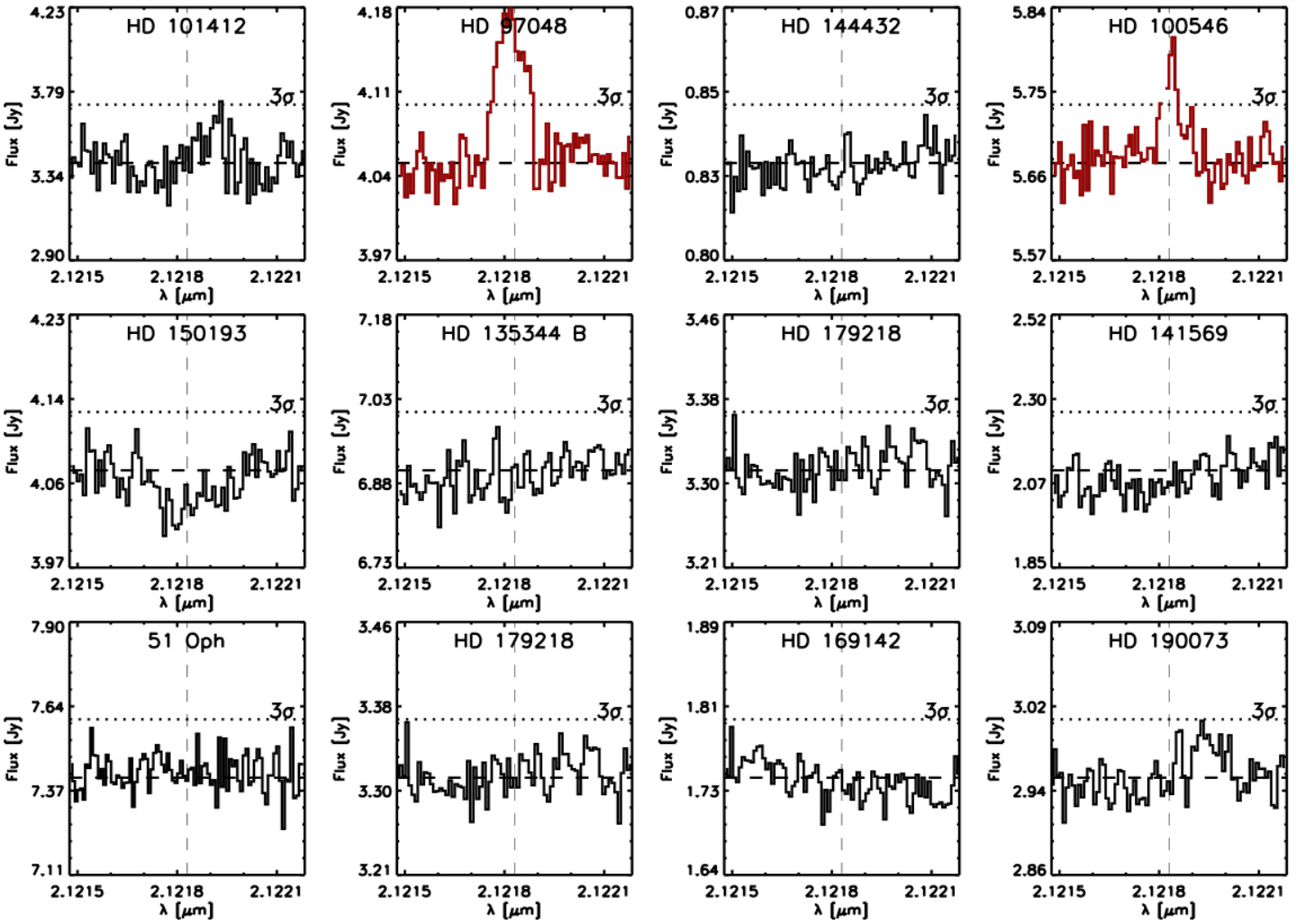
$T_{gas} \sim T_{dust}$, thermal excitation produces weak lines

- Detection only in few UV-strong objects

$\Rightarrow$ excitation by direct heating, and $T_{gas} >> T_{dust}$

(*Martin-Zaïdi et al. 2007, Carmona et al. 2008*)

H_2 1-0 S(1) Transition at 2.12 μm



Carmona et al. **Poster 7:2**

HD97048 & HD100546 vs. HD141569

Similar spectral types but HD141569 is a transitional disc

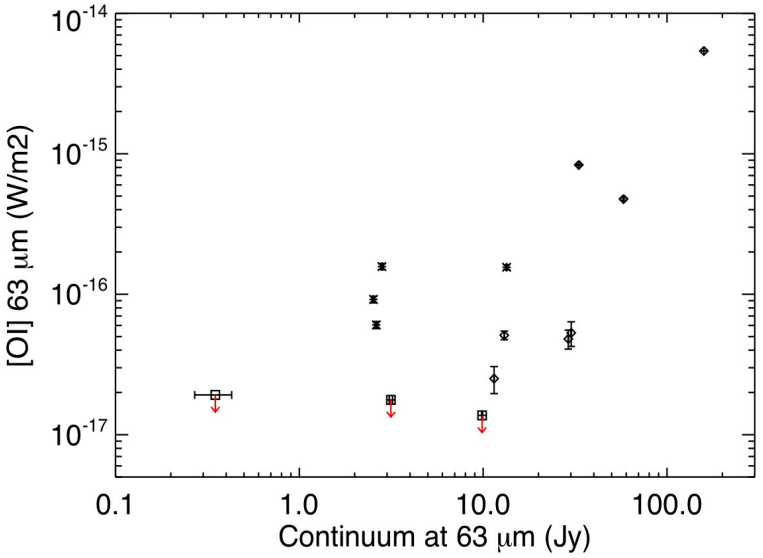
CO rotational-vibrational transitions at 4.7 μm:
All 3 stars: T_{Vib} > 5600 K ⇒ UV fluorescent emission

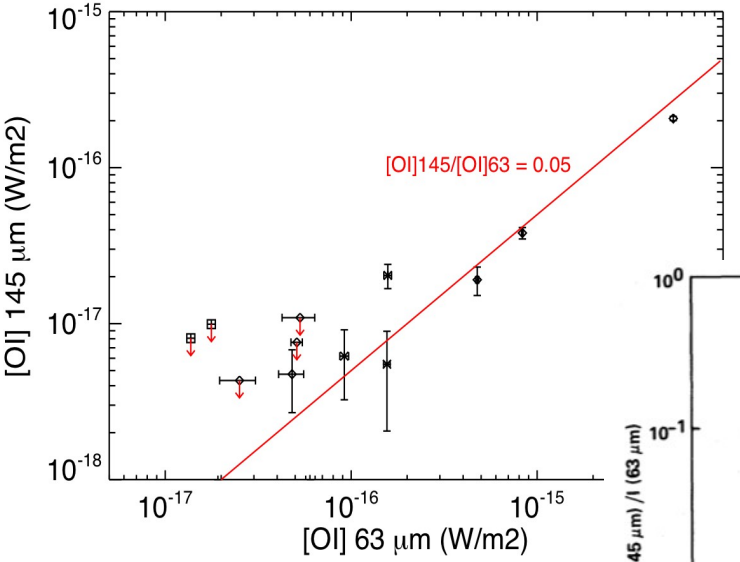
HD141569: T_{Rot} ~ 200 K (kinetic T of gas)
HD97048 & HD100546: T_{Rot} ~ 1000 K

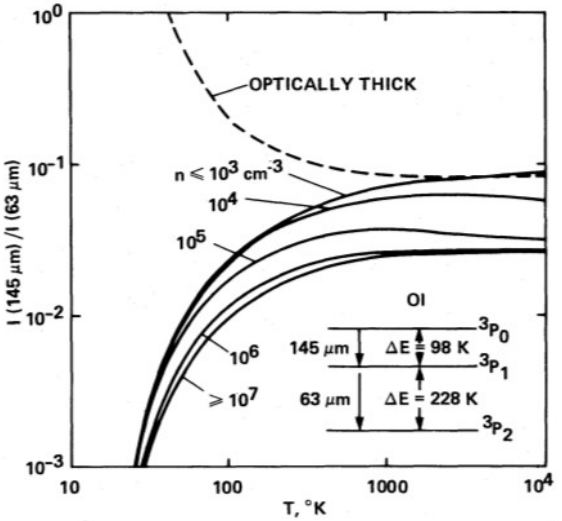
PAH important for thermal budget:
30x more L_{PAH} in HD97048 & HD100546
⇒ more direct heating of upper layer, more flaring

(Brittain et al. 2009, Van der plas et al. 2009 & private communication)

Trends with [OI] 63 μm line fluxes



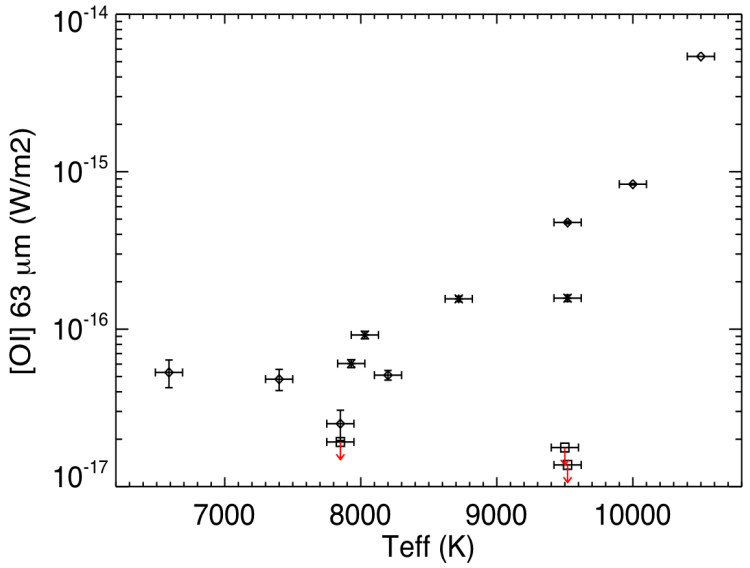


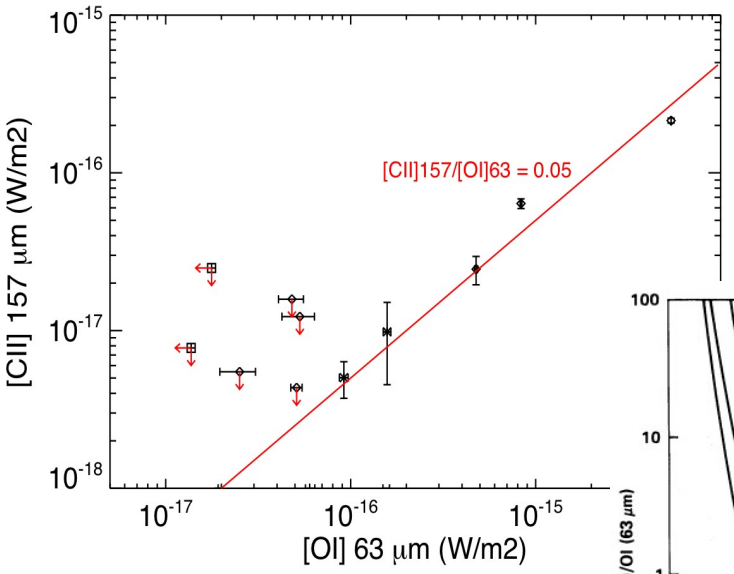


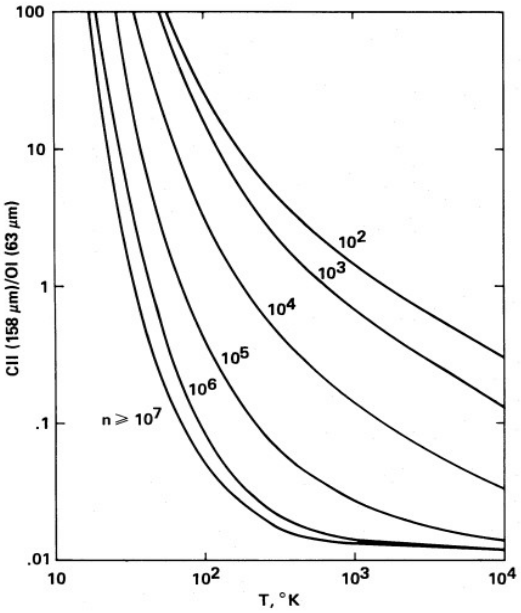
[OI]145/[OI]63 < 0.05 ⇒ opt. thin lines (T ~ few 100 K)

(*Tielens & Hollenbach 1985*)

Effective T [CII] 157.7 μm







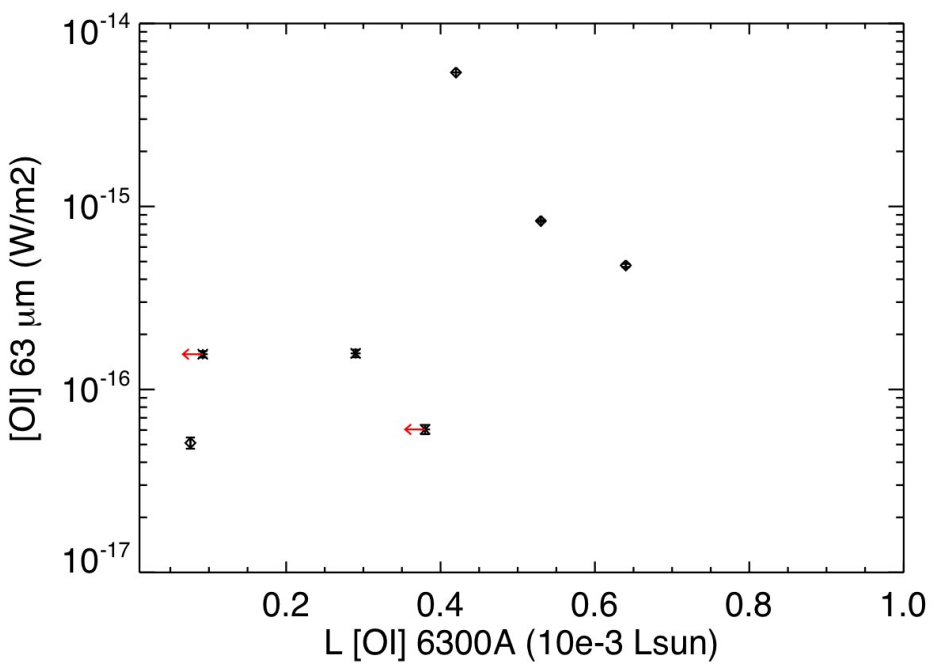
[OI]63 μm line flux increases with T_{eff}

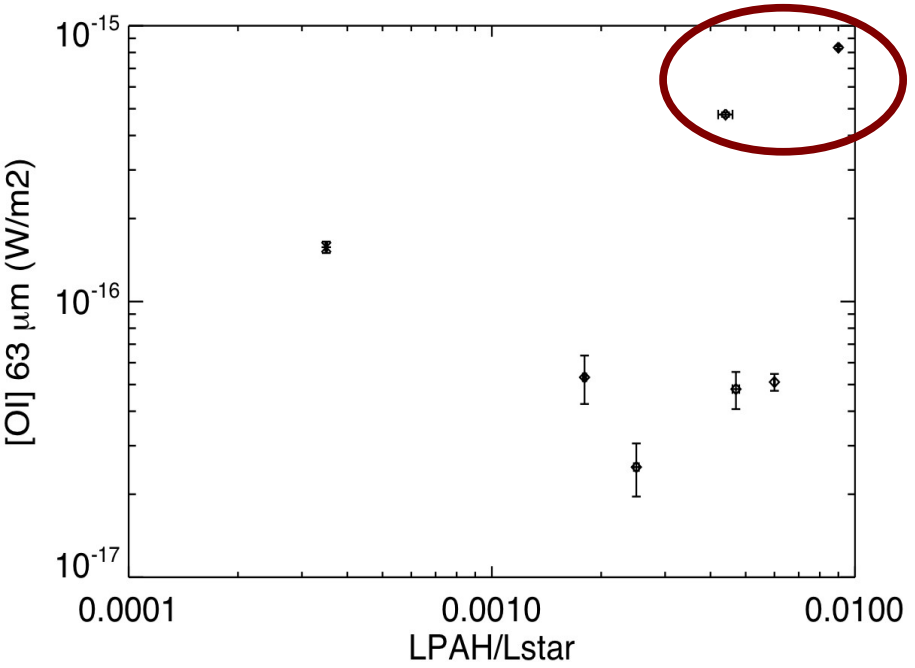
[CII]/[OI] not dependent on [OI] line flux

⇒ If density similar in HAEBEs, T_{gas} not dependent on T_{eff}

(*Tielens & Hollenbach 1985*)

[OI] 6300 A PAH luminosity



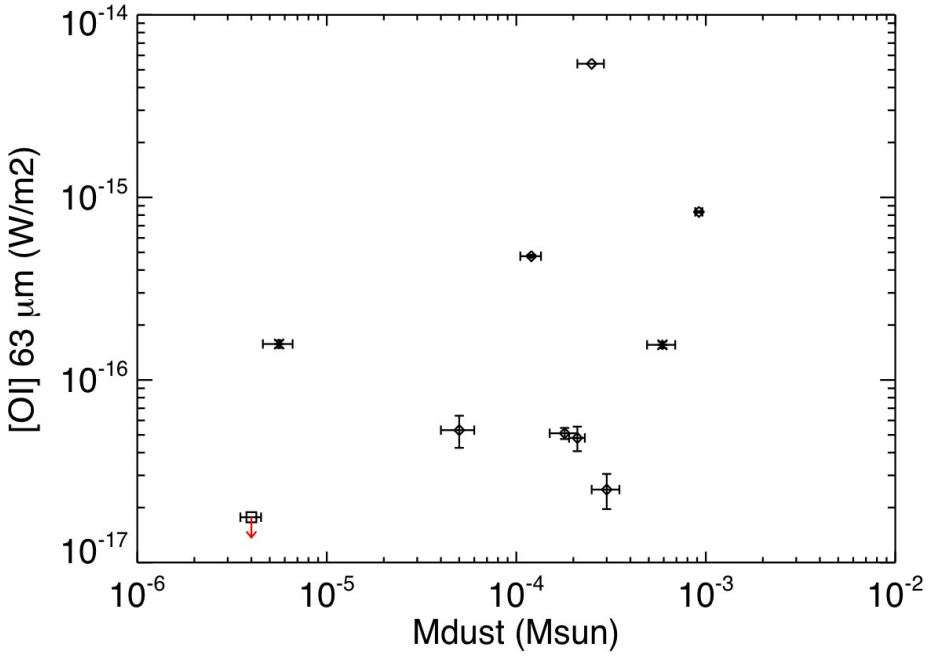


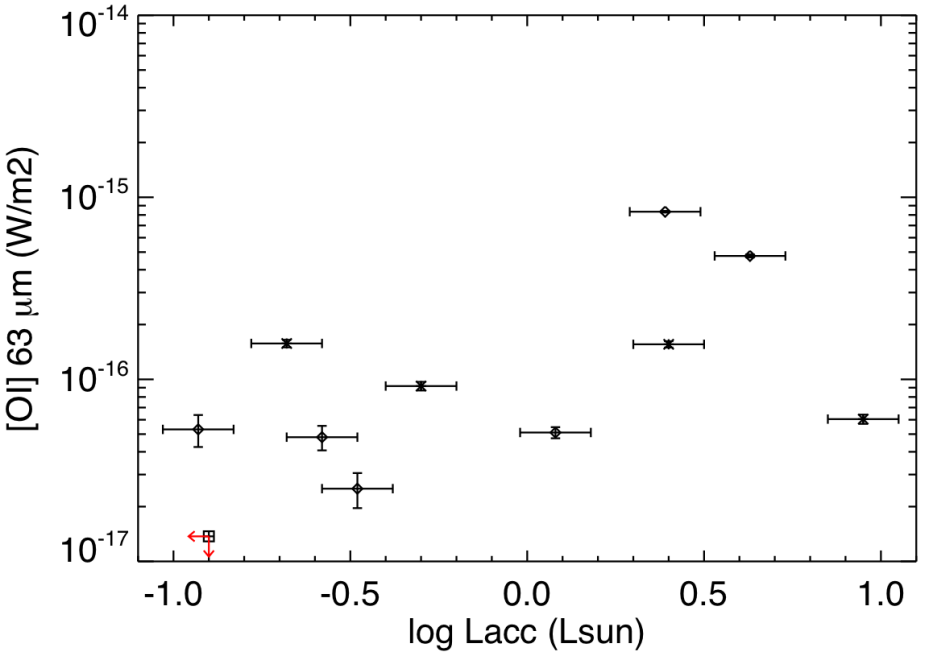
[OI] 6300 Å in surface layers (up to 100 AU), origin in UV photodissociation of OH and H_2O, correlated to flaring and L_{PAH}

Highest [OI] 63 line fluxes for highest L_{PAH}

([OI]6300 Å from *Acke et al. 2005*; PAH data from *Acke et al. 2010*)

Dust Mass Accretion Rate

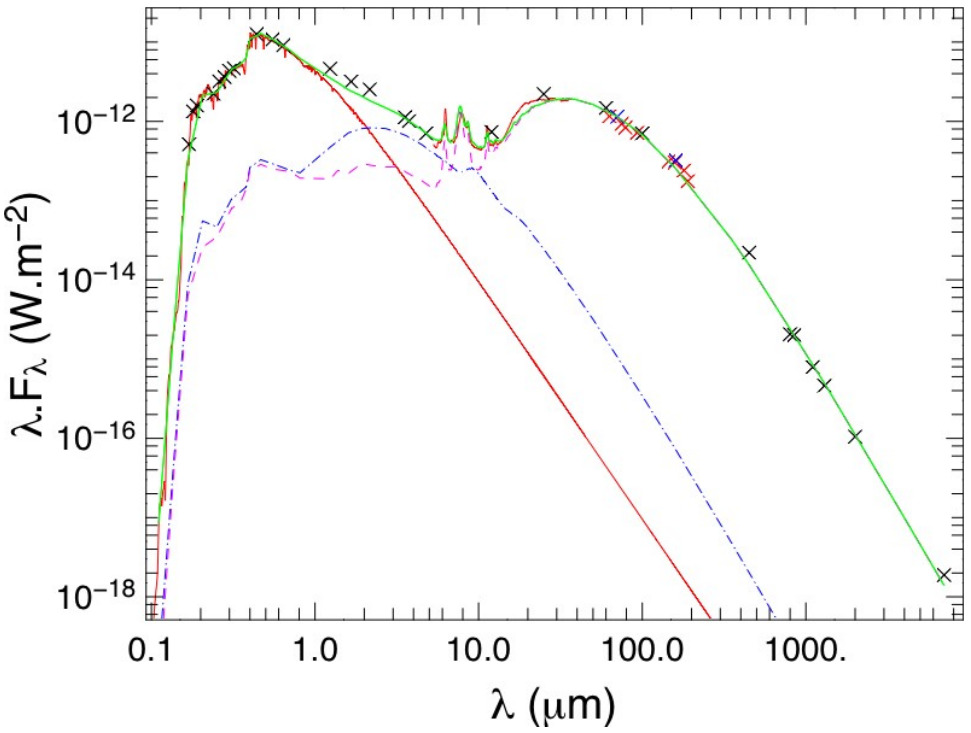




[OI] 63 μm line flux not dependent on M_{dust} derived from mm data (*Panic et al. 2009; Dent et al. 2005*)

Higher [OI] 63 μm line flux for higher L_{acc} *(Garcia-Lopez et al. 2006)*

First case study: HD169142



Fit photometry and images simultaneously with radiative transfer code MCFost (*Pinte et al. 2006, 2009*)

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

Not a unique solution!

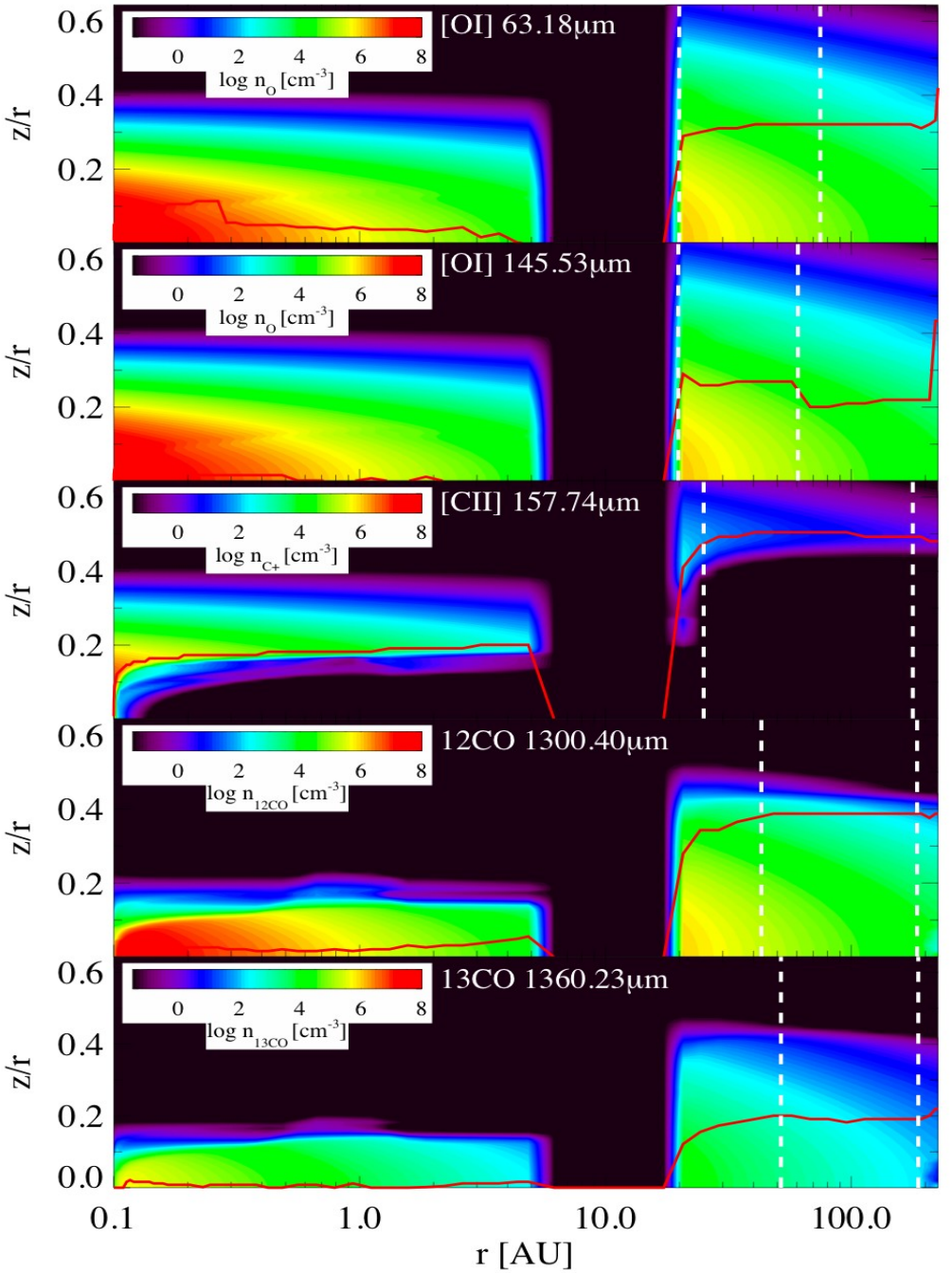
Gas thermal balance and chemistry with ProDiMo (*Woitke et al. 2009, Kamp et al. 2010*)

Different gas transitions trace different regions

Mm CO observations essential ingredient

Gas/dust ratio 22-50, M_{gas} 3-7 x 10^{-3} M_{sun}
⇒ still a gas-rich disc

Meeus et al. (2010)



Dust, Ice and Gas in Time

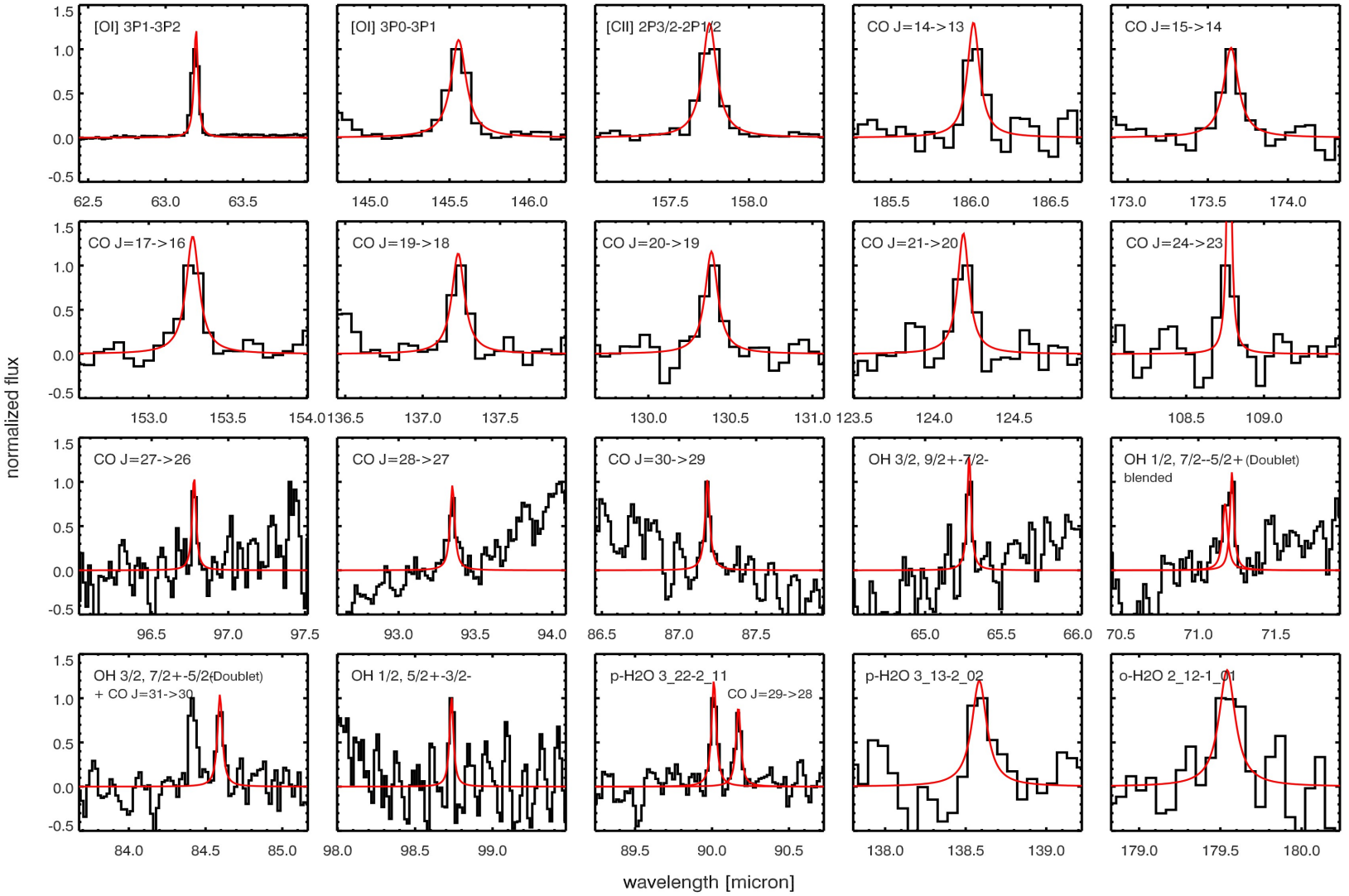
DIGIT (PI Neal Evans)

Besides embedded sources, sample also includes T Tauri and Herbig Ae/Be stars.

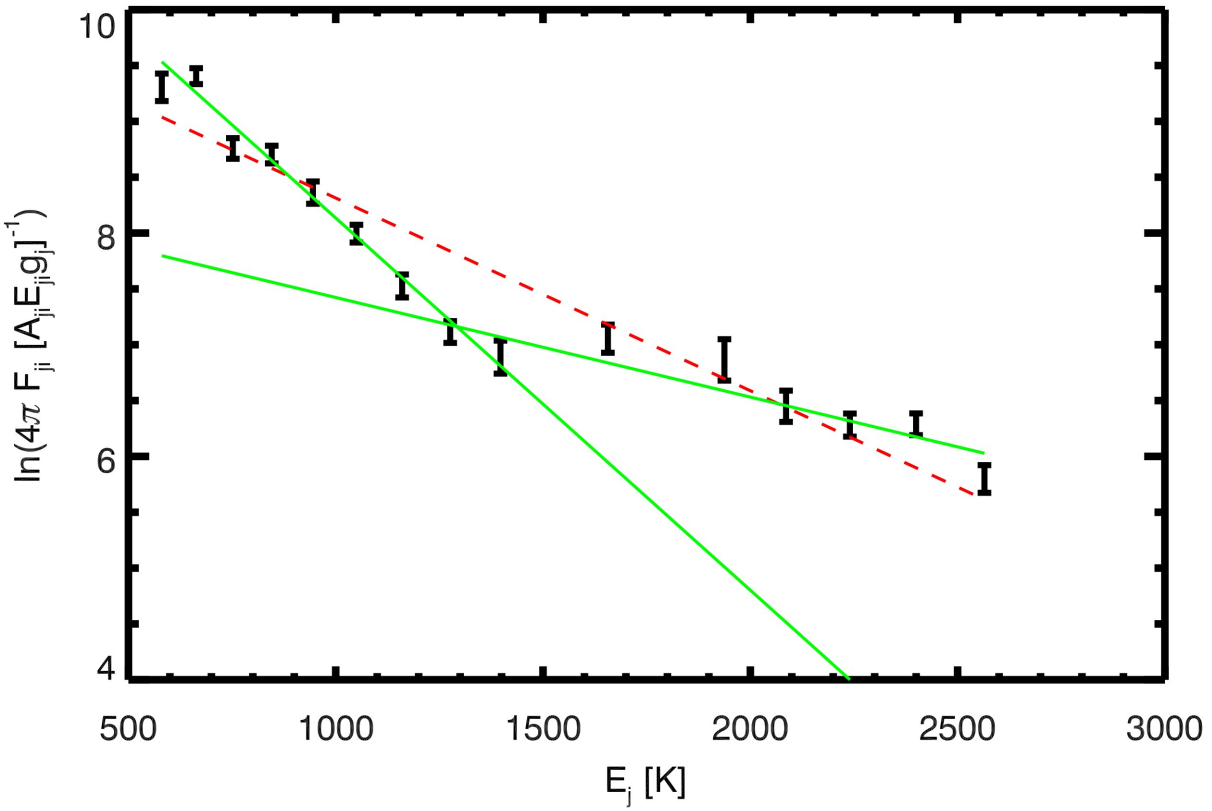
16 HAEBEs get full SED scans ⇒ covering a large part of rotational transition ladders (CO,...) and possible discovery of new solid state features

+8 HAEBEs scanned over the forsterite feature at 69 μm

Detected gas lines in HD100546



CO rotational diagram: Warm gas in the disc of HD100546



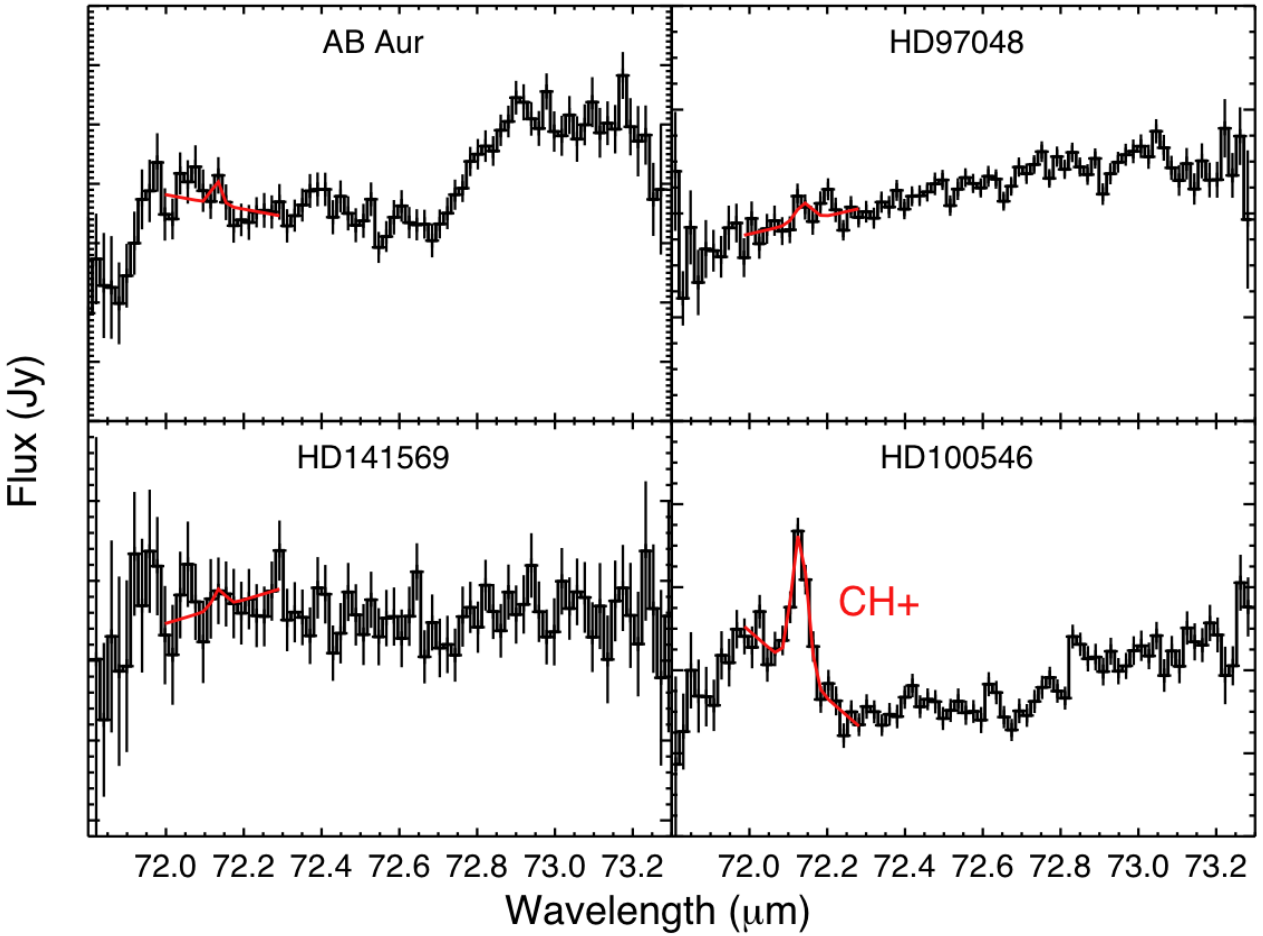
1 Temp. Fit: T_{Rot} = 580 ± 14 K

2 Temp. fit: T_{Rot} = 800 ± 100 K & T_{Rot} = 300 ± 12 K

Optical depth effect?

Sturm et al. (2010)

First CH^+ (J=5-4) detection in HAEBEs

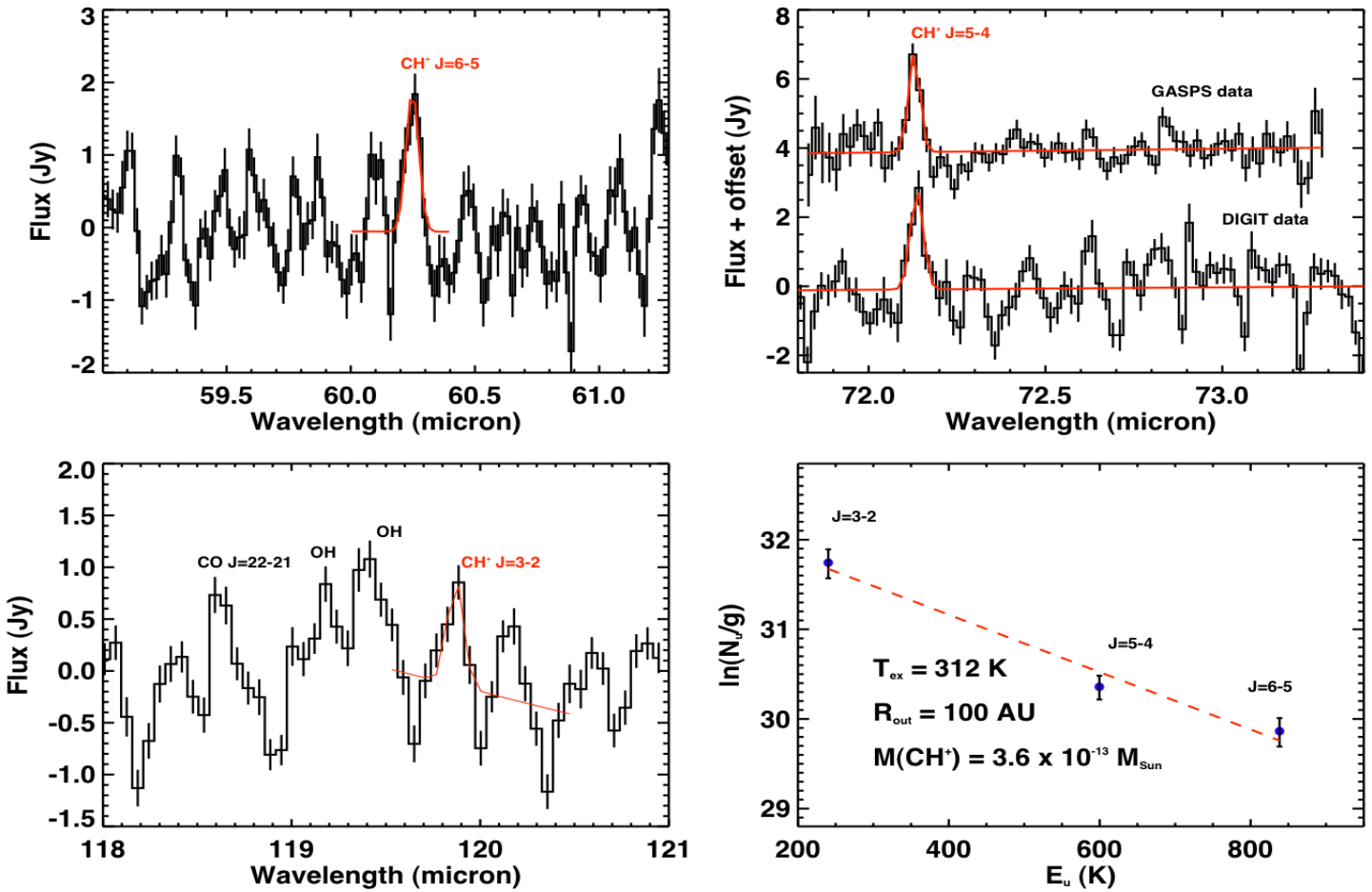


$C+ H_2 \rightarrow CH + H$

Efficient reaction only when H_2 vibrationally excited or a few 100 K

CH^+ can lead to CH_4, HCN and C_2H_2

CH^+ in the disc of HD100546



Thi et al., to be submitted

Conclusions

- Gas lines in Herbig Ae/Be discs show a wide variety in line strengths, surprisingly not that many detected

- Ratio between line fluxes can be a diagnostic of UV flux, Temperature (PAH presence) and/or density

- Detailed modelling of the disc, using both Herschel and multi-wavelength data is essential to understand the disc, mm CO observations necessary to determine disc mass

- Protoplanetary disc chemistry is another essential ingredient in understanding gas dispersal mechanisms

Future directions

Detailed modelling of the individual sources, using:

- Multi-wavelength photometry and imaging
- IR interferometry
- Mm observations of CO and continuum

Poster 3 by Lyo: SMA imaging of HD135344B
Poster 10 by Honda: COMICS/Subaru imaging of AB Aur

... ALMA will be helpful 'tool' to complement Herschel!

Herschel and PACS are great, many thanks to everyone who made this project possible!


The End

HD100546