

# Catalogue of Herschel-PACS spectroscopic observations of Young Stellar Objects: the jet-disc contribution

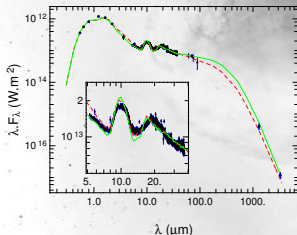
*P. Riviere-Marichalar*



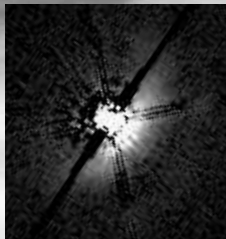
*ALMA/Herschel Archival Workshop, Garching, April 2015*

# Protoplanetary discs

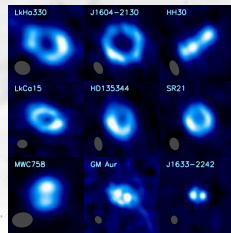
- Discs of gas and dust surrounding young stars. Birthplace for planets
- **Dust: IR-excess.**
  - ▶ SED modelling
  - ▶ Scattered light
  - ▶ Resolved thermal emission
- **Gas: spectroscopy at many wavelengths**



SED: dust  
Pinte+ (2008)



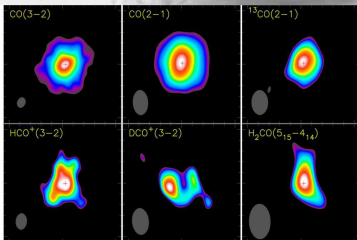
Scattered light  
imaging: dust  
Pinte+ (2008)



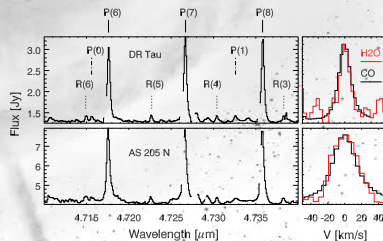
Continuum thermal  
emission: dust  
Williams and Cieza (2009)

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- Dust: IR-excess.
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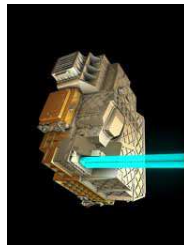
Sub-mm spectroscopy: gas  
Williams and Cieza (2009)



Near-IR spectroscopy: gas  
Salyk+ (2008)

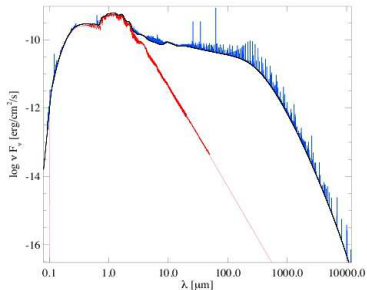
# PACS spectroscopy

- Far-IR spectroscopy in the 50-200  $\mu\text{m}$
- Two modes: line- and range-scan
- Emission from species such as: O, H<sub>2</sub>O, CH<sup>+</sup>, OH, [CII]
- PACS IFU: spatial information
- Many PACS programs to observe gas in protoplanetary discs:  
GASPS, DIGIT, WISH, ...
- More than 300 YSOs observed with PACS spectroscopy



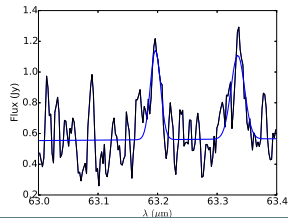
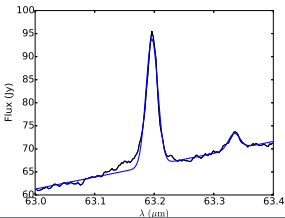
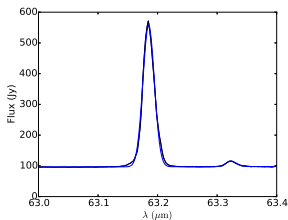
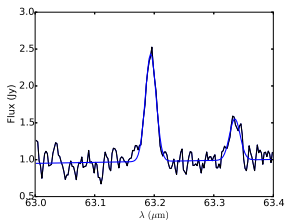
# Observations of [OI]

- The most frequent far-IR line emission from discs
- Brightest far-IR line in discs (Gorti & Hollenbach 2008)

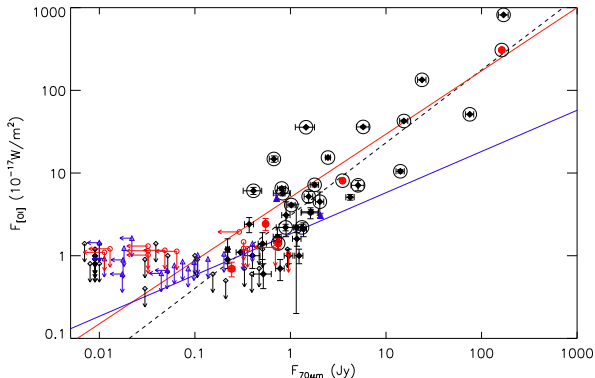


## ...and water!

- 24% of gas-rich discs show water emission (Riviere-Marichalar+ 2012)



# [OI] emission: the disc-jet contribution

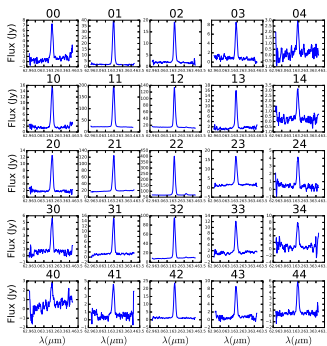


Howard+ 2013, Riviere-Marichalar+ 2015

- YSOs with outflows (or jets) show higher [OI] for the same flux at  $70 \mu\text{m}$
- The difference is more pronounced for bright continuum sources
- Both the **jet** and the **disc** contribute to [OI] emission
- The line flux is upper limit to disc emission

# Extended [OI] emission

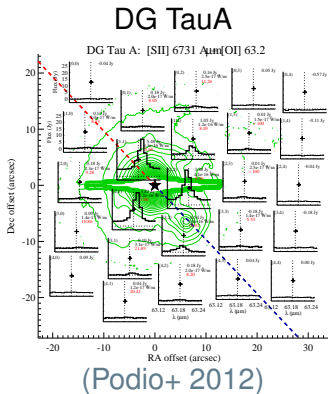
## T Tau



- Extended emission along the jet direction
- Podio+ (2012): test extended emission. Compare continuum-to-line ratio in the 24 spaxels with that of the central one
- Podio+ (2012): *"The extended atomic emission may be produced by fast J-shocks"*



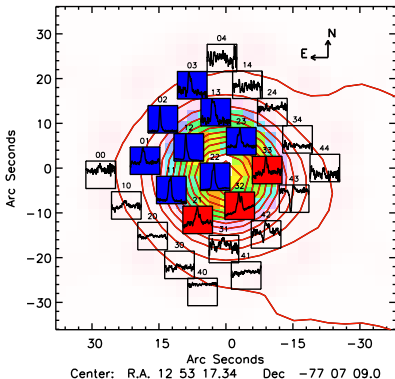
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# Extended [OI] emission

## DK Cha

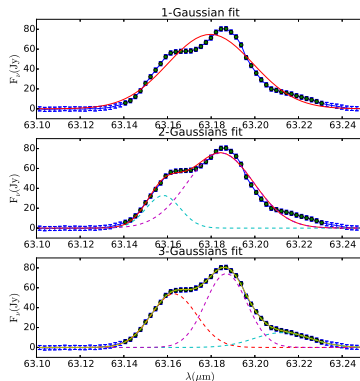


(Riviere-Marichalar+ 2015)

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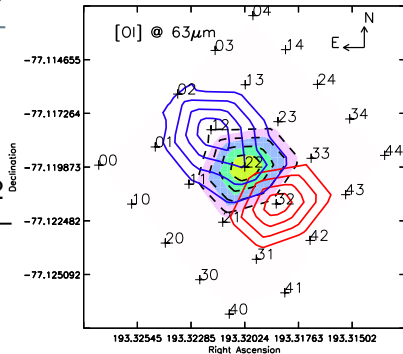
## [OI]: multiple components

- DK Cha: multiple components observed (Riviere-Marichalar+ 2015)
  - ▶ Low-velocity (-51–52 km/s, rest-frame?) component (disc?, stellar wind?)
  - ▶ High-velocity, red- (126–222 km/s) and blue-shifted (-70 – -177 km/s) components (jet?)
- Spatial distribution of the components



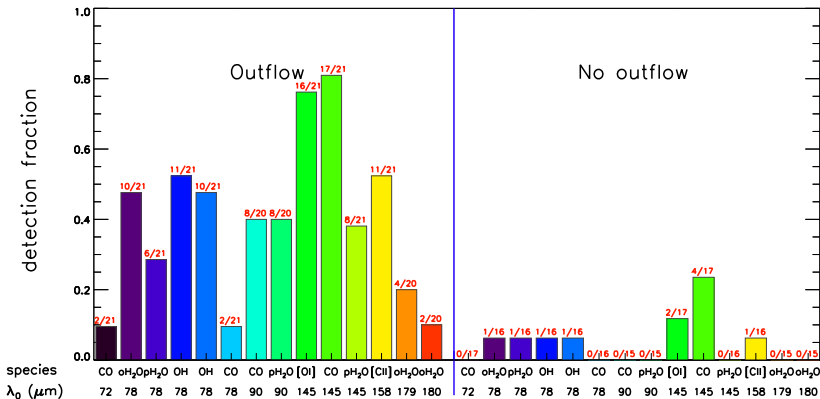
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(Riviere-Marichalar+ 2015)

# Other lines?



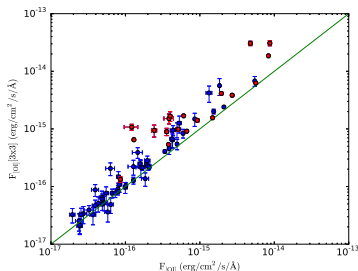
(Alonso & Riviere-Marichalar, to be submitted)

- ~ 330 observations of YSOs at 63  $\mu\text{m}$ : [OI] and o-H<sub>2</sub>O
  - ▶ Ages: 3–30 Myr (plus some old DD)
  - ▶ Class 0, I, II, III, transition discs, debris discs
  - ▶ Spectral types A to M
- Test extended emission
- Understand jet and disc contribution
- Evolutionary timescales
- Future prospects: extend to range spectroscopy: CO, OH, H<sub>2</sub>O, [CII],...

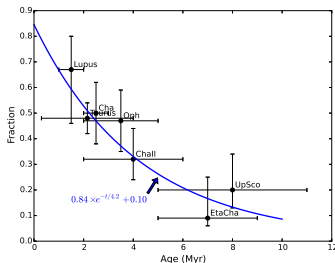
Table 1. Sample of YSOs observed with *Herschel*-PACS

| Source name    | RA<br>(deg) | Dec<br>(deg) | Sp. type | Disc type | Association |
|----------------|-------------|--------------|----------|-----------|-------------|
| –              | –           | –            | –        | –         | –           |
| HD 105         | 1.468958    | -41.753067   | G0       | DD        | TucHor      |
| HD 3003        | 8.182958    | -63.0315     | A0       | DD        | TucHor      |
| HD 3670        | 9.736267    | -52.534284   | F5       | DD        | ColA        |
| HD 9672        | 23.657412   | -15.676359   | A1       | DD/HAeBe  | Argus       |
| tau Ceti       | 26.017      | -15.937472   | G8.5     | DD        | Field?      |
| HD 16743       | 39.781511   | -52.934806   | F1       | DD        | Age=1.5Gyr  |
| L1448-MM       | 51.412083   | 30.734833    | -        | -         | -           |
| IRAS03245+3002 | 51.912917   | 30.217528    | -        | Jet?      | -           |
| L1455-IRS3     | 52.001667   | 30.133694    | -        | I         | Per         |
| HBC 347        | 52.409875   | 24.510556    | K1       | III       | Taurus      |
| HD 21997       | 52.973542   | -25.614139   | A3       | DD        | Field?      |
| eps Eri        | 53.232667   | -9.45825     | K2       | DD        | -           |
| IRAS03301+3111 | 53.303333   | 31.356722    | K0-M3    | I         | Per         |

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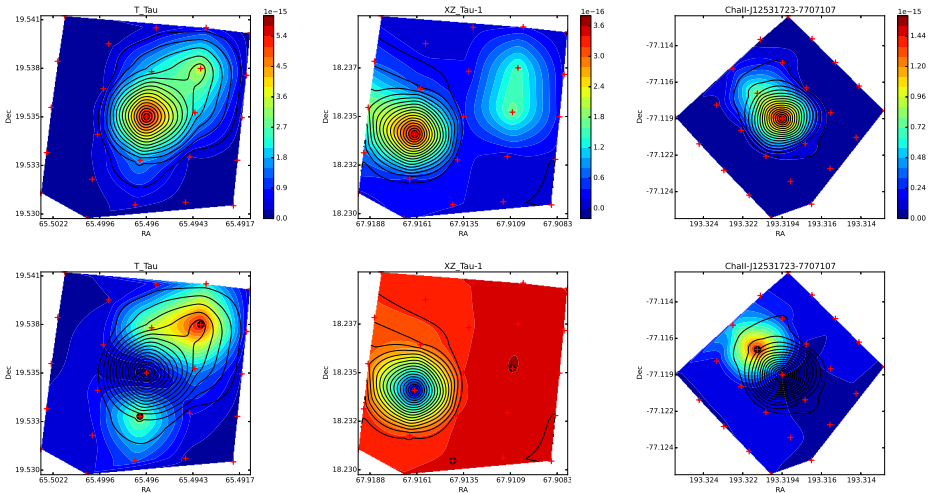


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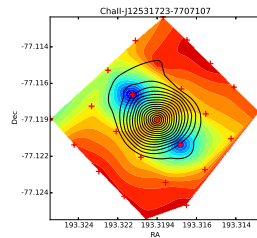
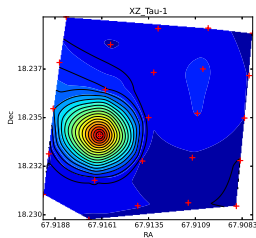
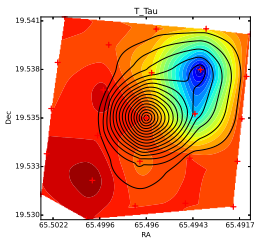
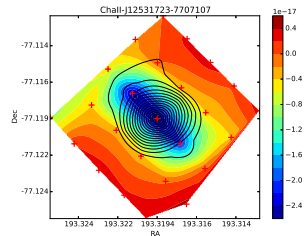
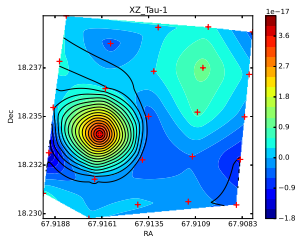
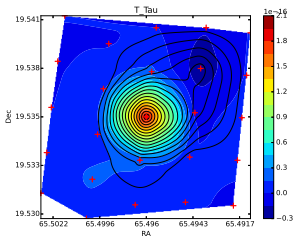




# OI spatial distributions

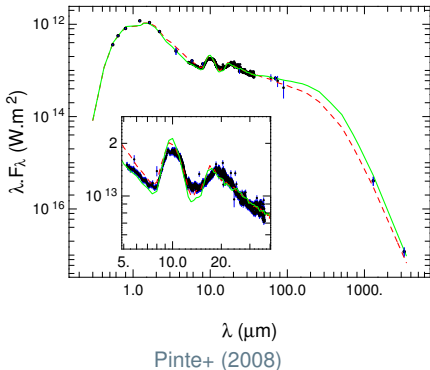


# H<sub>2</sub>O spatial distributions



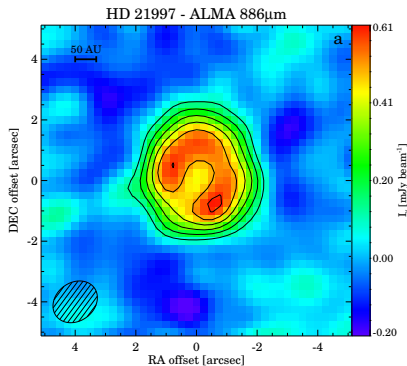
# A global picture: many parameters, many observations

- SED:  $M_{\text{dust}}$ ,  $\epsilon$ ,  $a_{\text{min}}-r_{\text{in}}$ ,  $p...$
- Thermal image, scattered light image:  $R_{\text{in}}$ ,  $R_{\text{out}}$ ,  $\epsilon$ 
  - ▶ Need for high spatial resolution to access inner disc: **ALMA!**, Sphere...
- Spectroscopy: gas composition and dynamics,  $\beta$ ,  $f_{\text{UV}},...$ 
  - ▶ Gas and dust can have different spatial distribution: **ALMA!** to trace gas VS dust
- Polarimetry: dust composition and size



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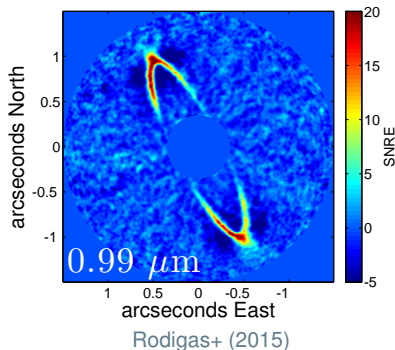
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Moór + (2013)

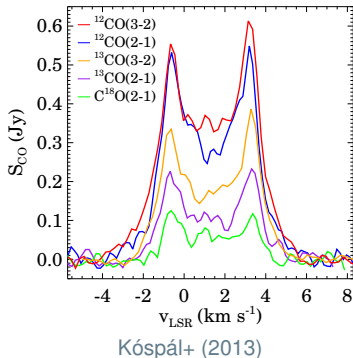
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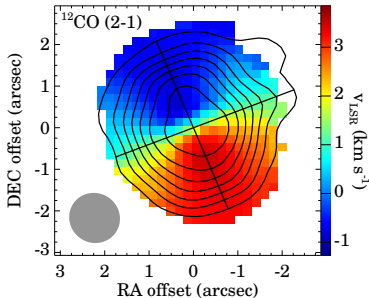
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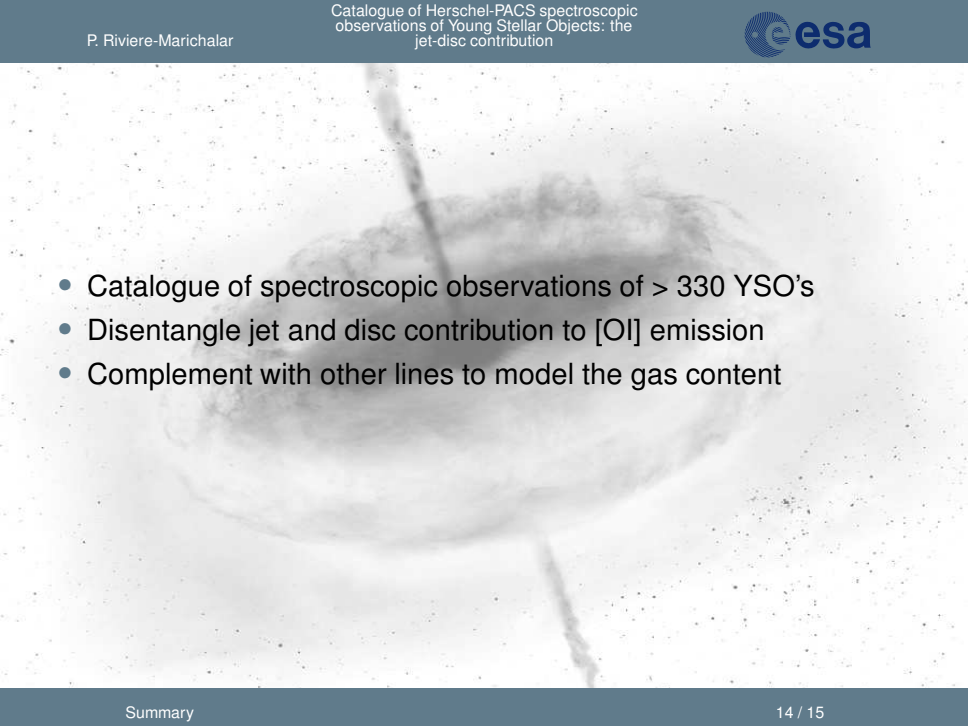


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Kóspál+ (2013)

- 
- The background of the slide is a grayscale astronomical image of a young stellar object (YSO). It shows a central bright region surrounded by a diffuse, irregularly shaped cloud of gas and dust. Two prominent, narrow jets of material are seen extending outwards from the central region, one pointing towards the top and one towards the bottom. The overall appearance is that of a protostar in the early stages of its formation.
- Catalogue of spectroscopic observations of  $> 330$  YSO's
  - Disentangle jet and disc contribution to [OI] emission
  - Complement with other lines to model the gas content



A grayscale astronomical image showing a protoplanetary disk (proplyd disk) around a young star. The disk is seen at an angle, appearing as a flattened, glowing ring of dust and gas. A bright jet of gas is visible extending from the poles of the disk towards the viewer. The background is filled with numerous small, distant stars.

Thanks for your attention