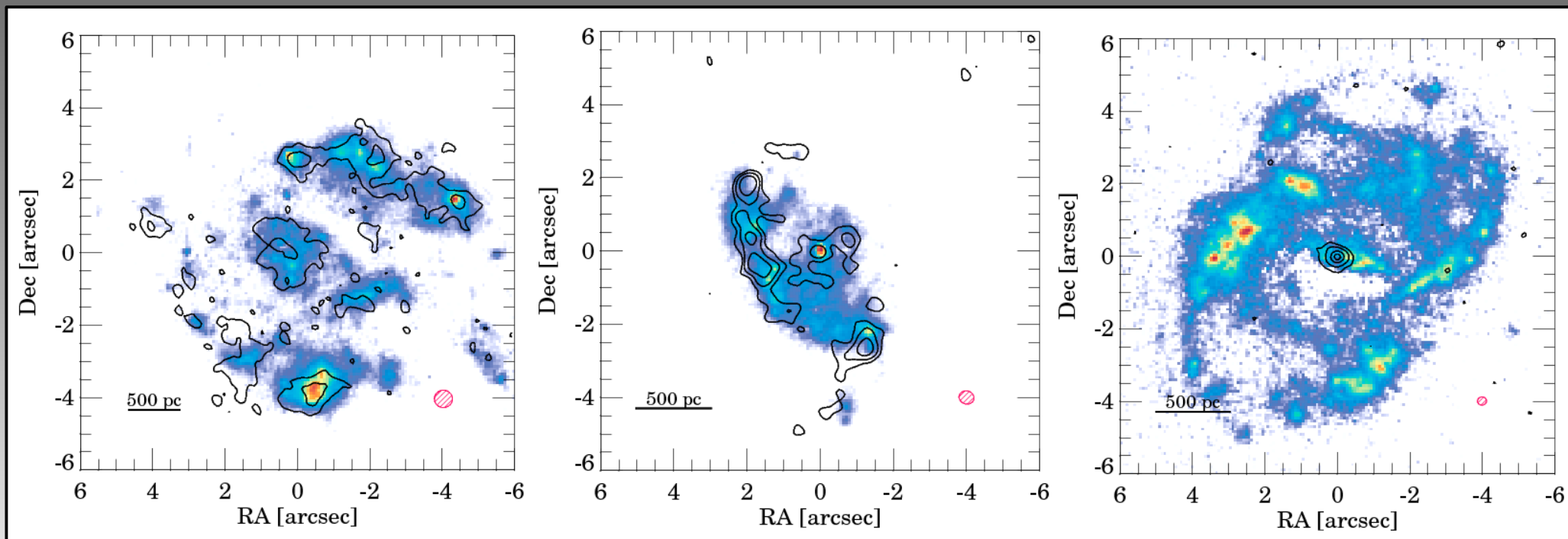


Sub-mm Star-formation Tracers in Dusty Galaxies

Miguel Pereira Santaella

L. Colina, S. García-Burillo, B. Emons, J. Piqueras López, et al.



Manchester, 2017

Sample U/LIRGs

- Sample of 6 U/LIRGs observed with ALMA at 1.3mm and 0.25'' beam

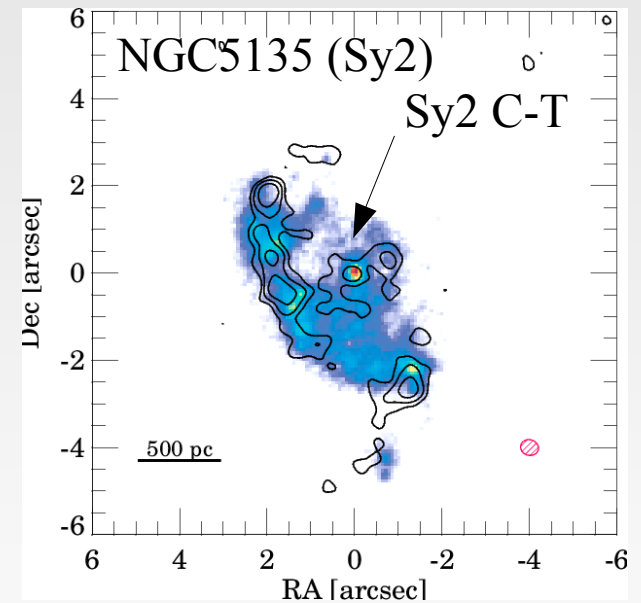
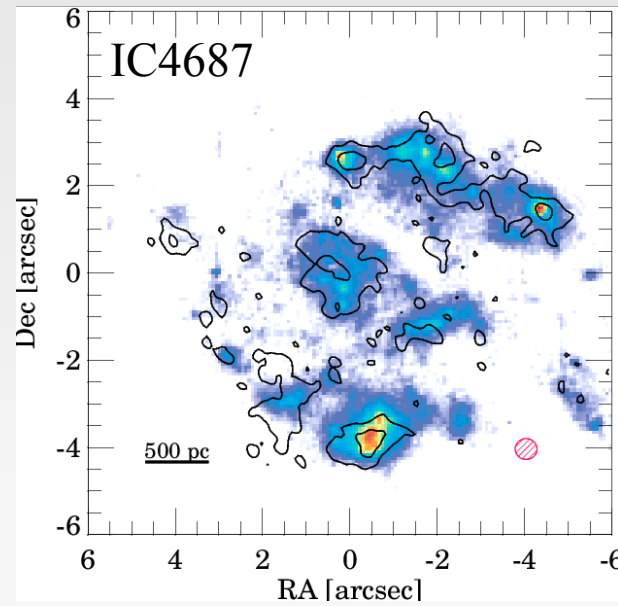
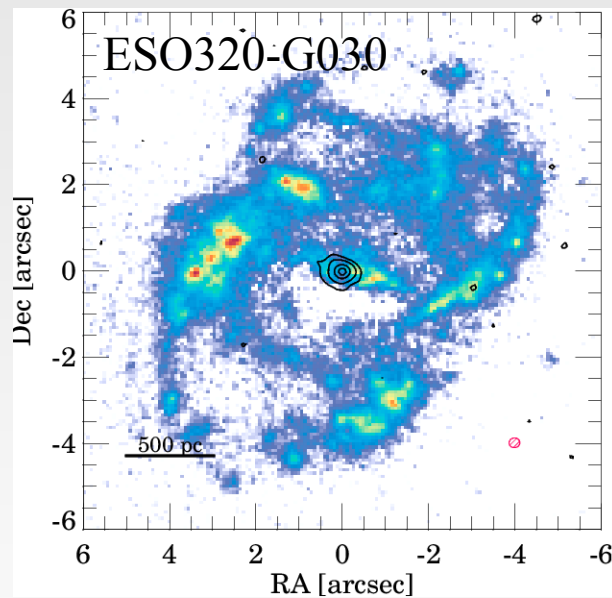
3 LIRGs

$\log L(\text{IR}) \sim 11.3-11.5$

$d \sim 50-70$ Mpc – beam ~ 70 pc

SF dominated

2 isolated spirals, 1 interacting pair



Background: Pa α HST/NICMOS ([Alonso-Herrero+06](#))

Contours: 1.3mm ALMA continuum ([P-S+16b,+16a,+17 in prep.](#))

Sample U/LIRGs

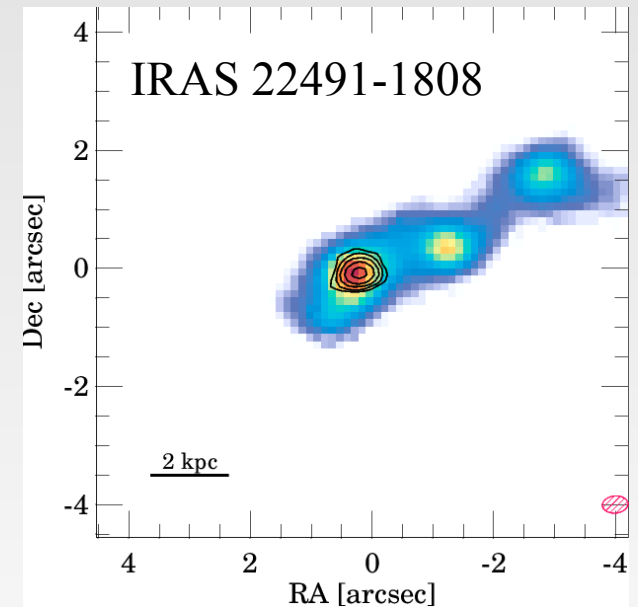
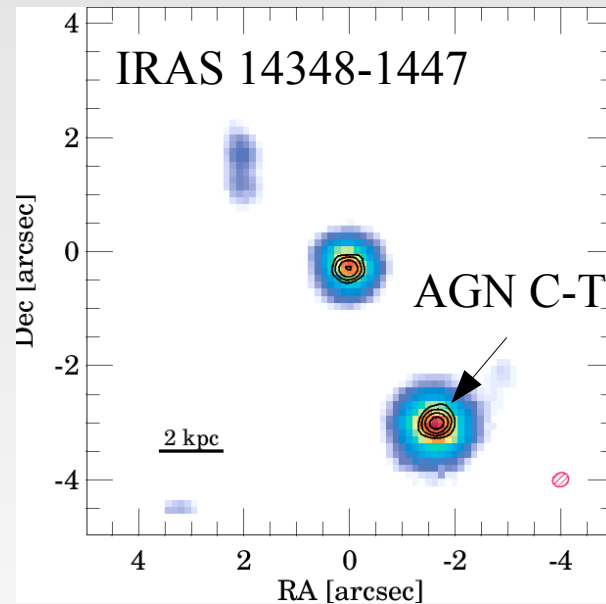
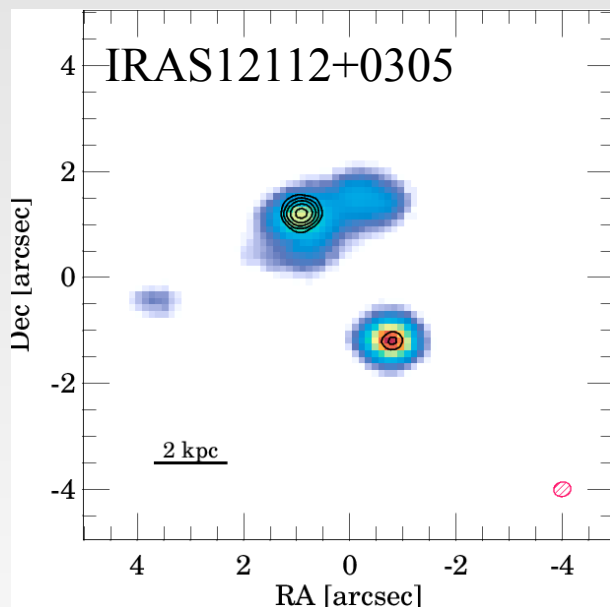
3 ULIRGs

$\log L(\text{IR}) \sim 12.2\text{-}12.4$

$d \sim 350 \text{ Mpc}$ – beam $\sim 400 \text{ pc}$

SF dominated

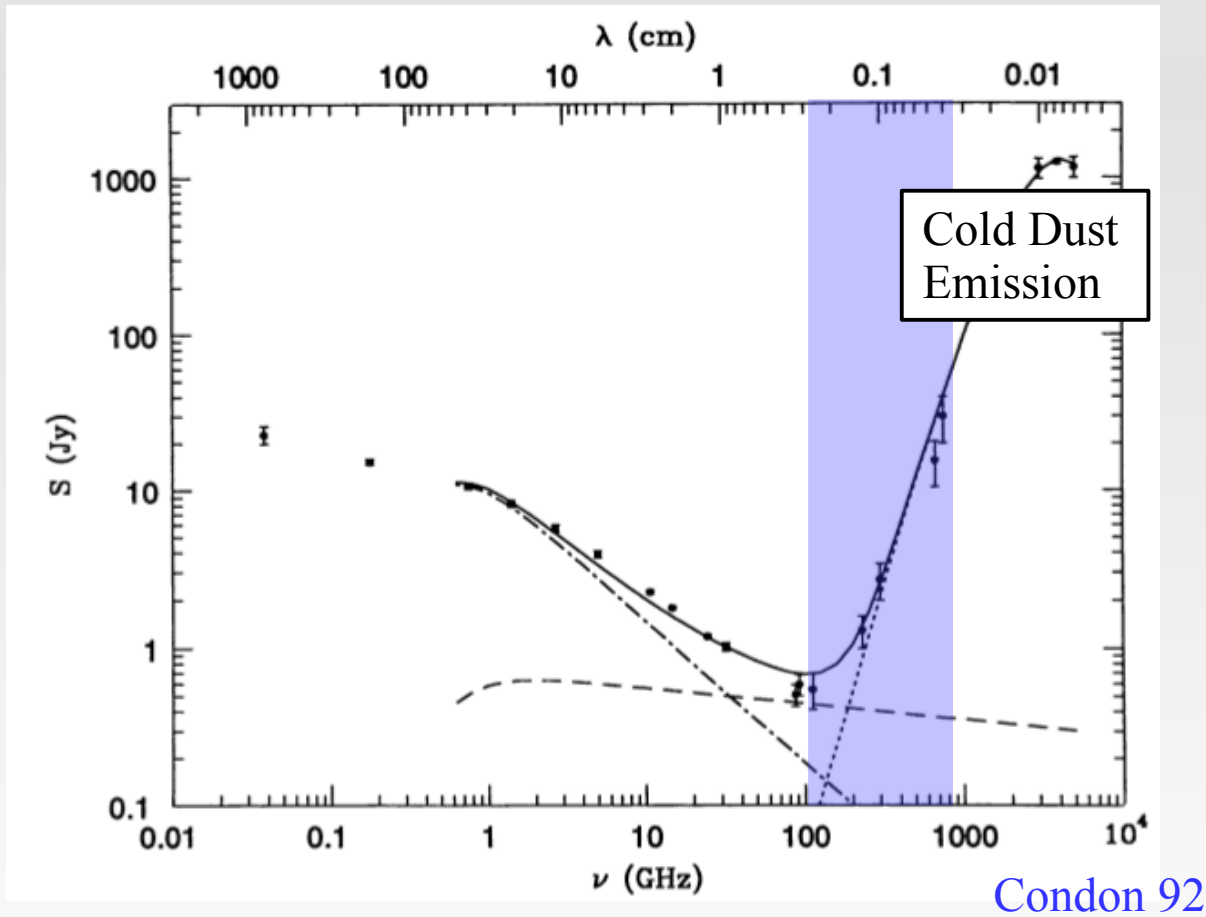
2 components spatially resolved



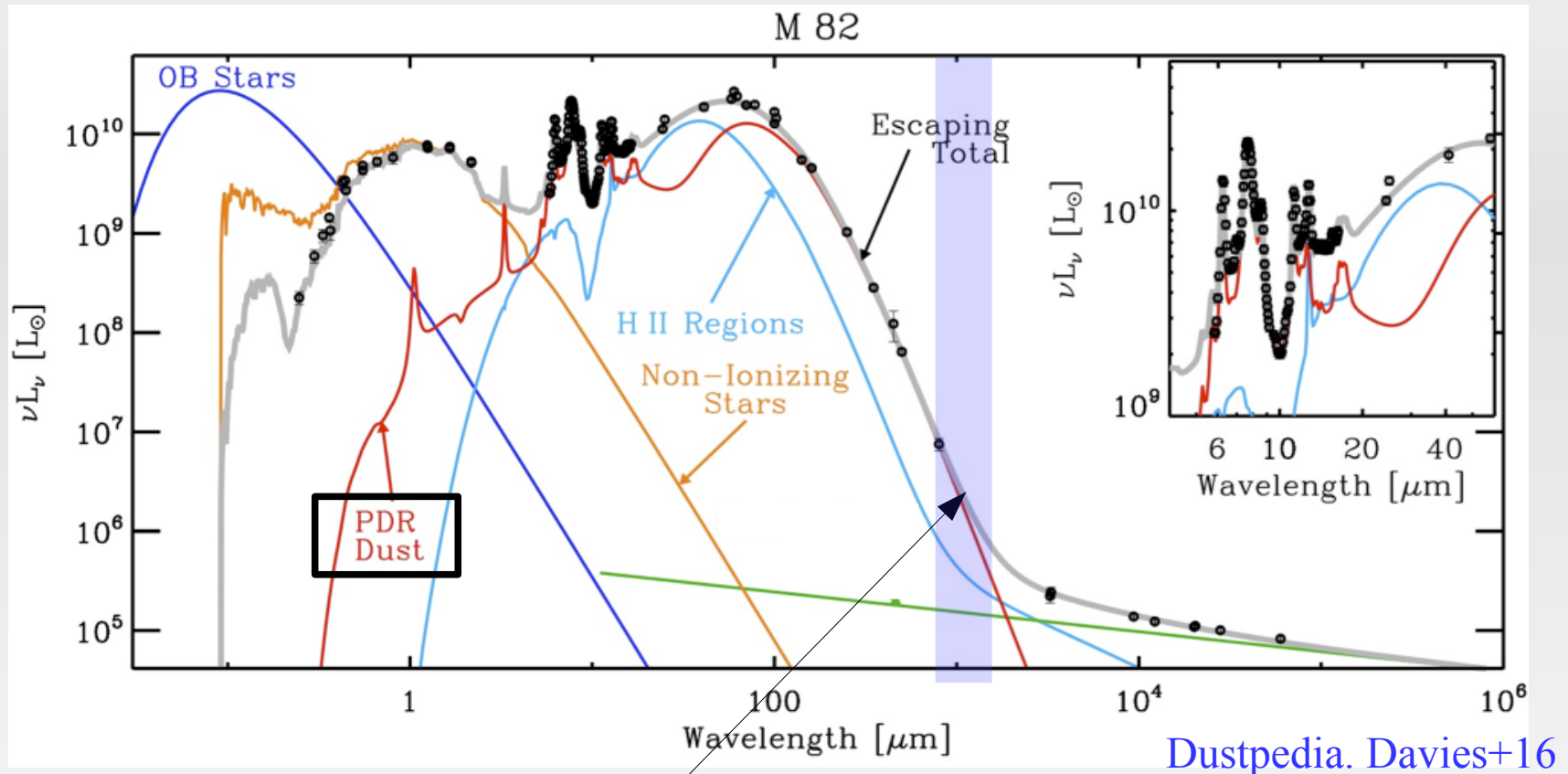
Background: Pa α SINFONI (Piqueras-López+12)

Contours: 1.3mm ALMA continuum (P-S+17 in prep.)

SFR tracers: 1.3mm continuum



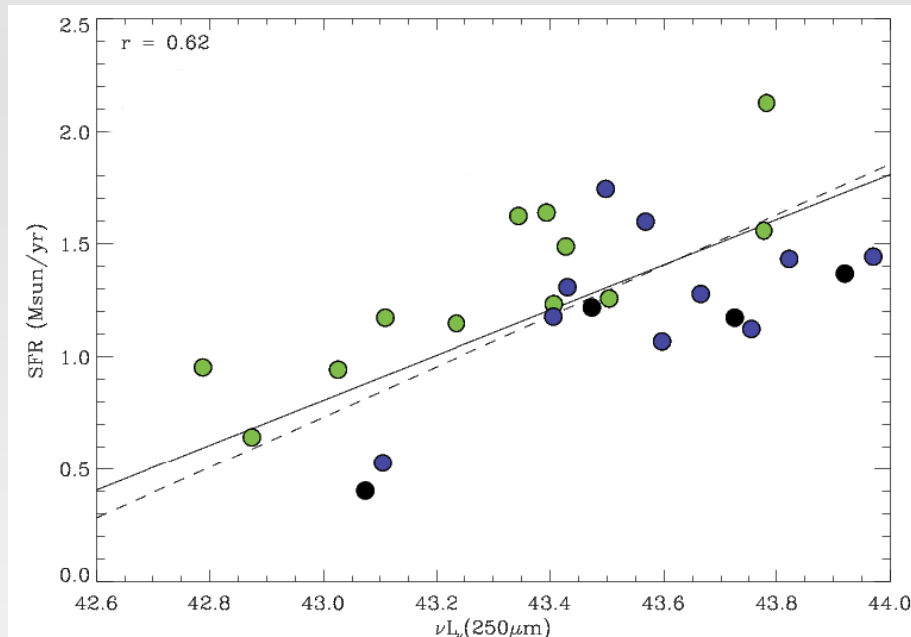
SFR tracers: 1.3mm continuum



1.3mm continuum

1.3mm SFR calibration for LIRGs

- SED fitting of 29 local LIRGs including Herschel/SPIRE data (P-S+15)

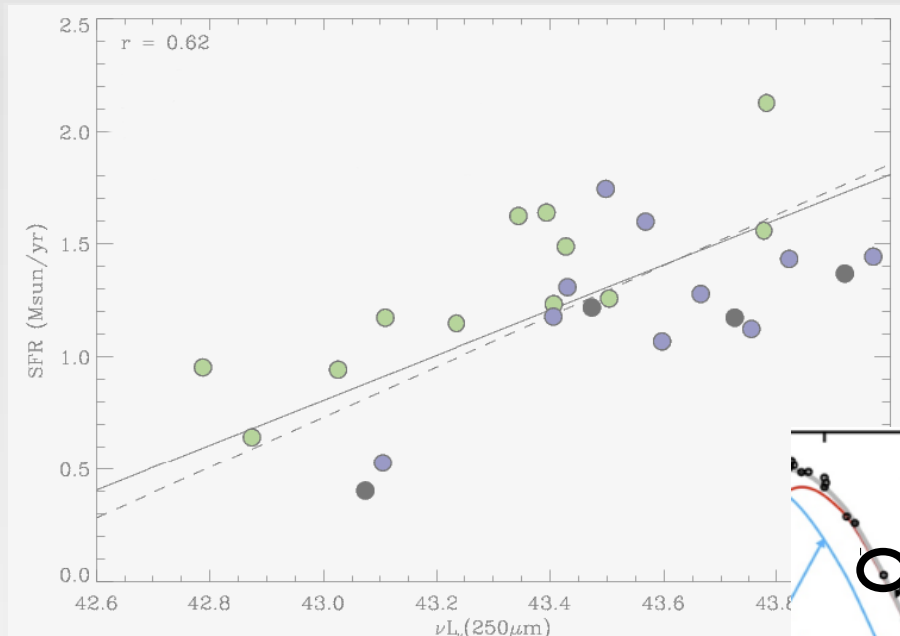


$$\log \text{SFR}/(\text{Msun}/\text{yr}) = \log(L (250\mu\text{m})/(\text{erg}/\text{s})) - 42.2$$

0.3 dex

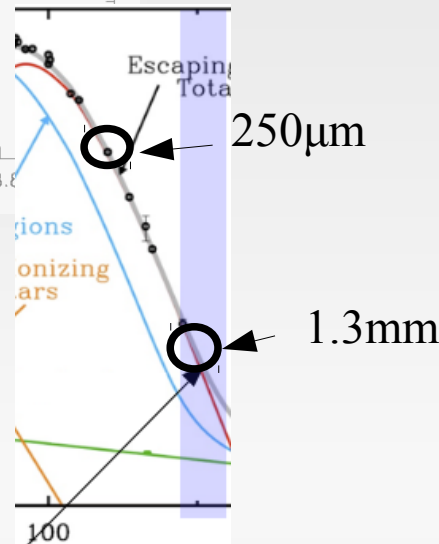
1.3mm SFR calibration for LIRGs

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$$\log \text{SFR}/(\text{Msun/yr}) = \log(L (250\mu\text{m})/(\text{erg/s})) - 42.2$$

0.3 dex

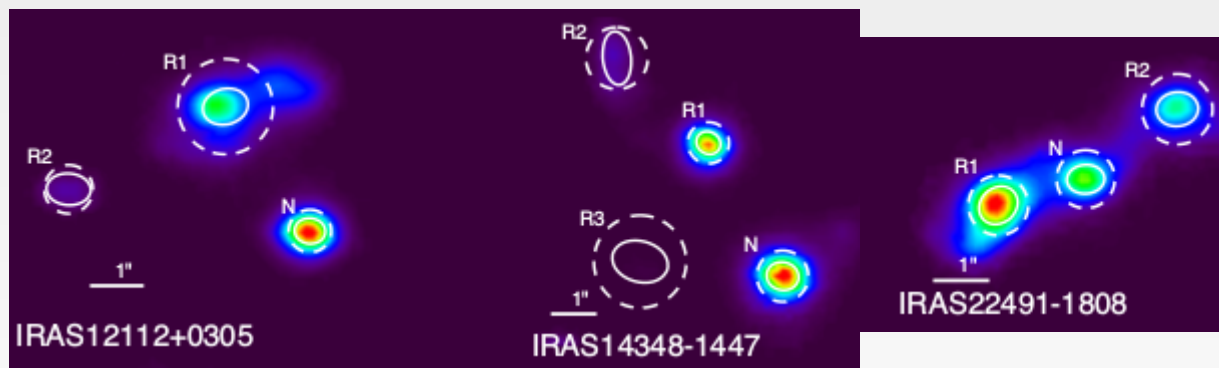
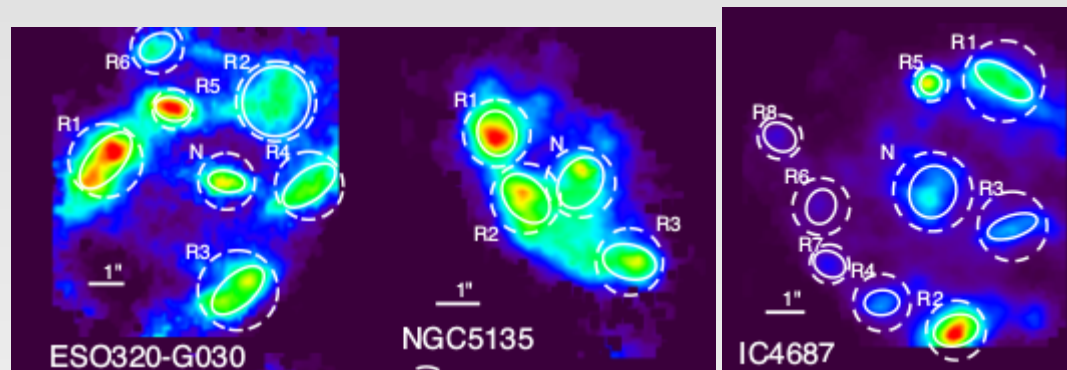


Assume a modified BB with $\beta=1.5$

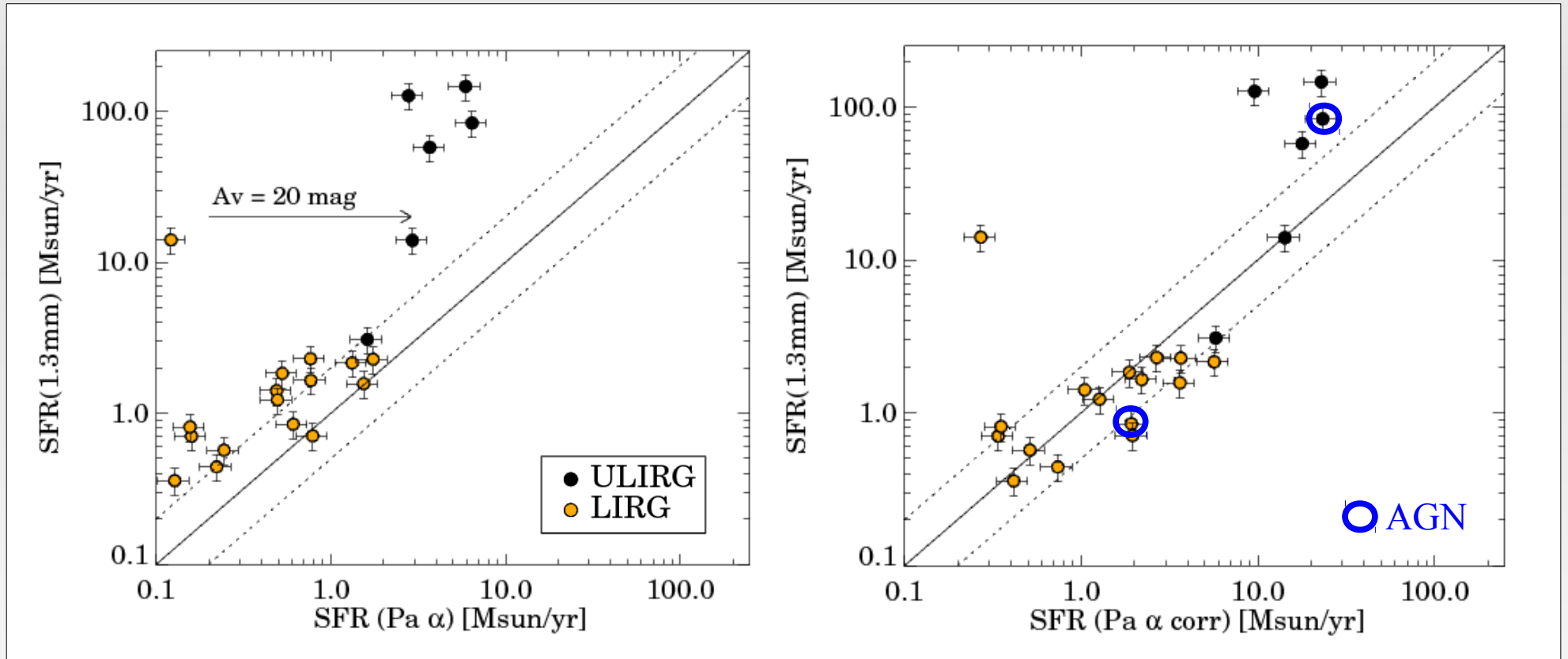
$$\log \text{SFR} = \log(L(1.3\text{mm})) - 39.2$$

Region selection

- Select regions **30** based on Br γ and Pa α maps obtained with near-IR IFS VLT/SINFONI (Piqueras-López+16)

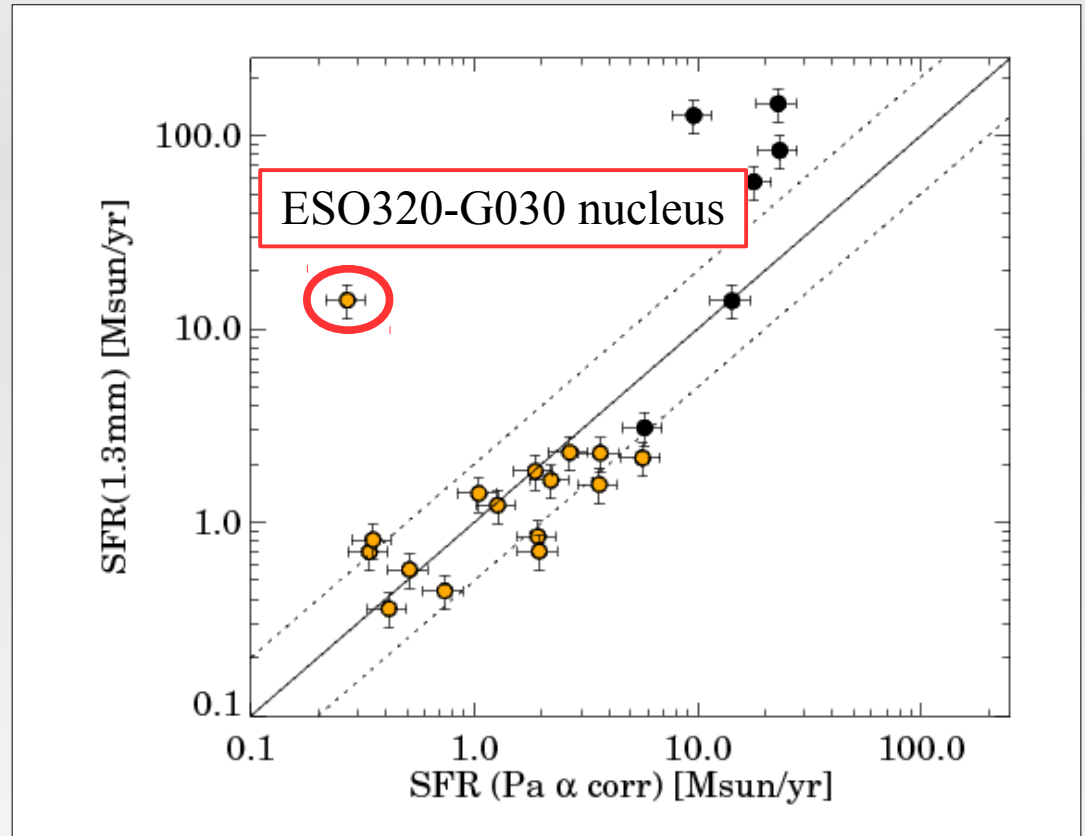
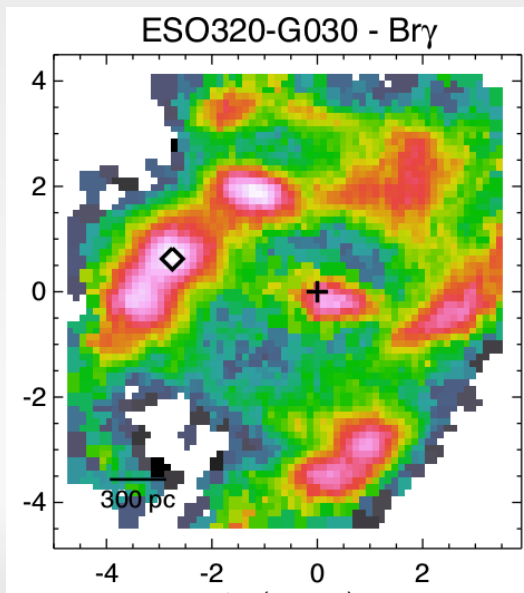
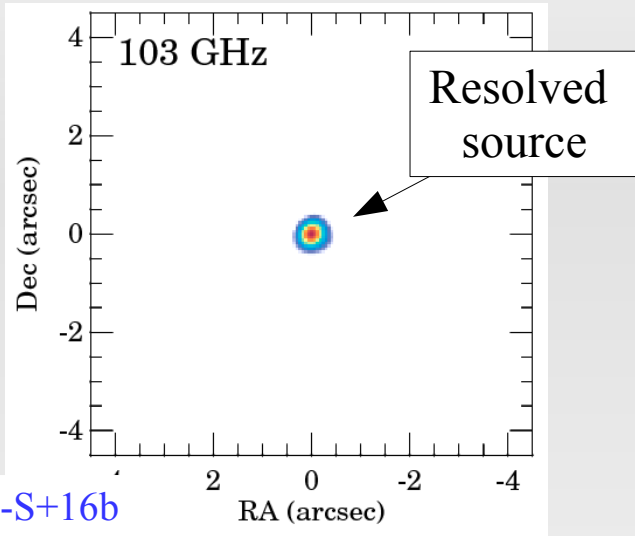


1.3mm vs Pa α : SFR



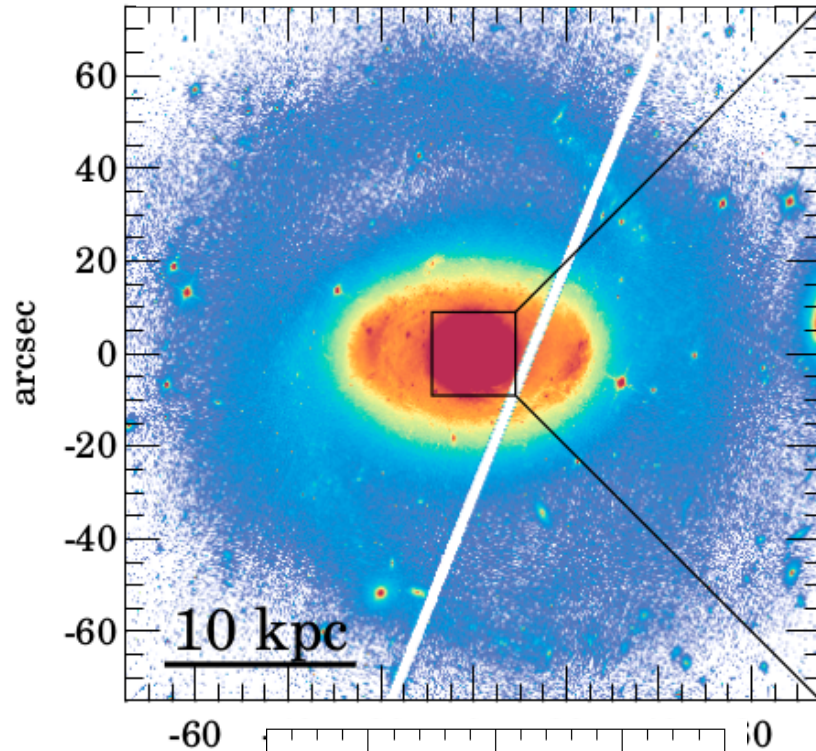
- $A_v \sim 1 - 20$ mag from $\text{Br}\gamma/\text{Br}\delta$ and $\text{Pa}\alpha/\text{Br}\gamma$ (Piqueras-López+13)
- Obscured SF, free-free and non-thermal radio contribution

1.3mm vs Pa α : SFR

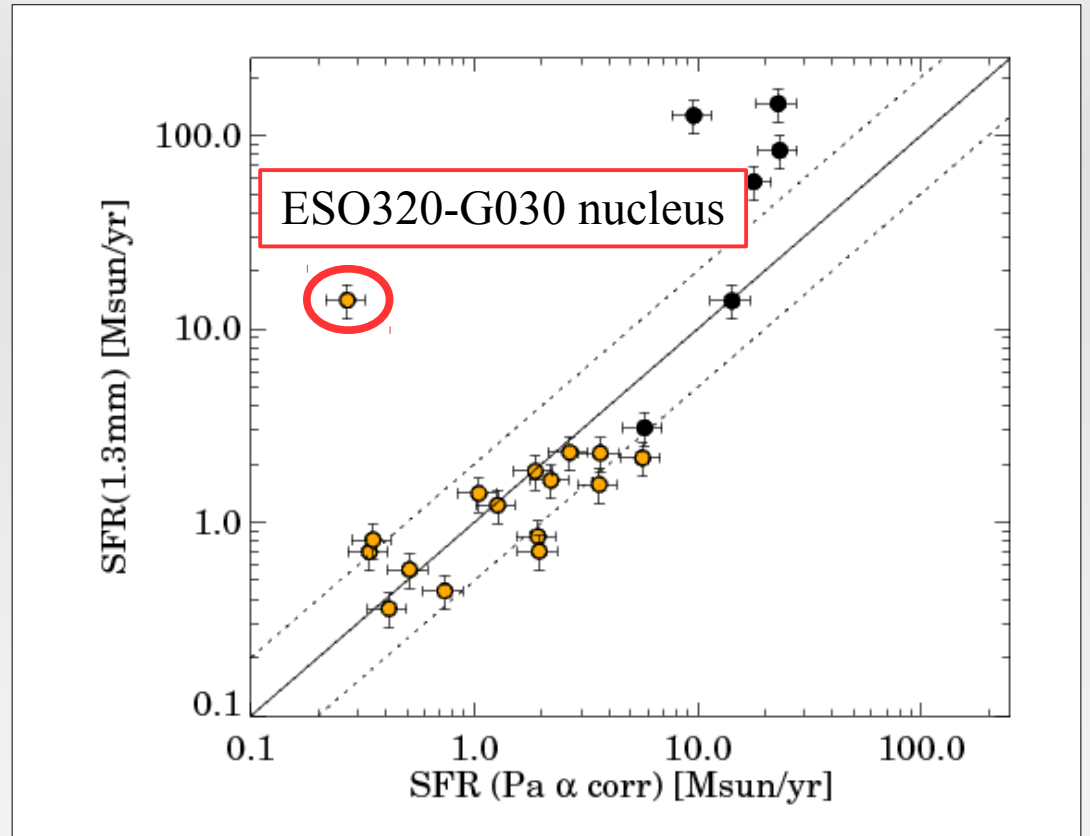
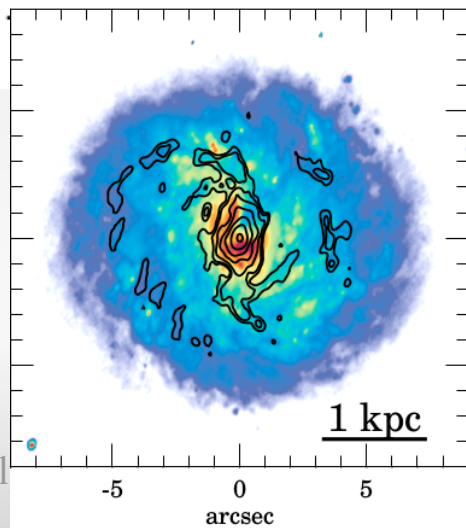


1.3mm vs Pa α : SFR

Deprojected HST/ACS F814W

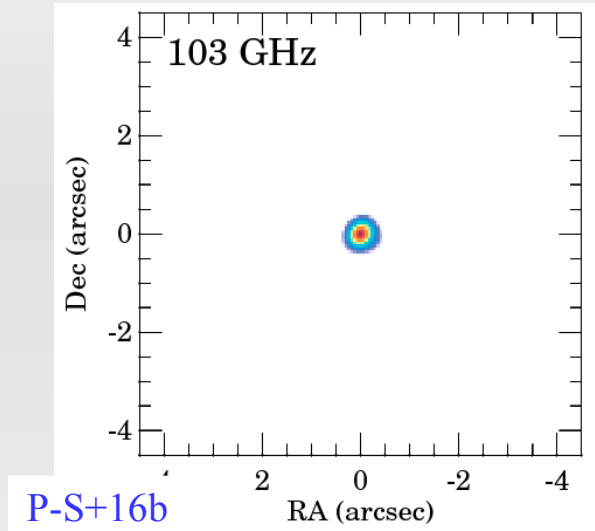
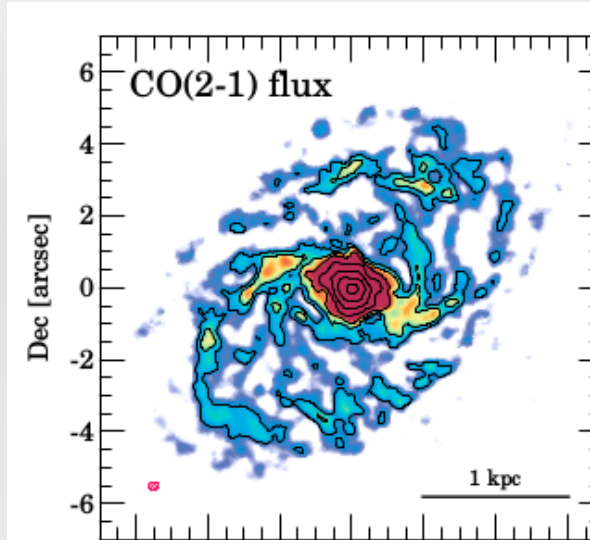
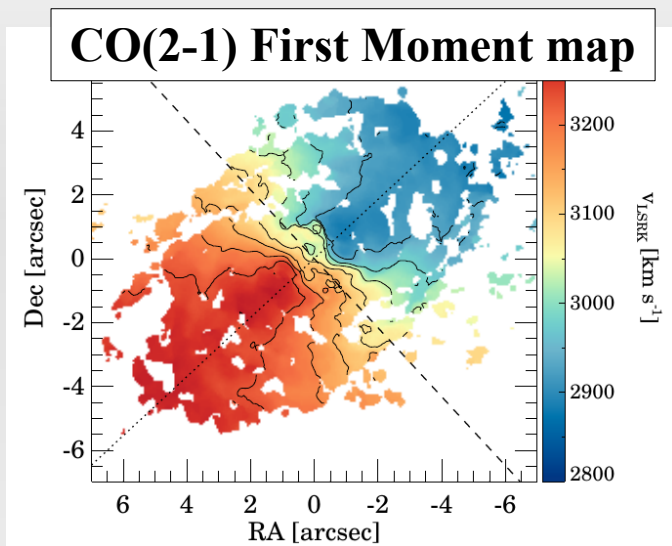


P-S+16b



- Isolated spiral galaxy.
- $\log(\text{LIR}/L_{\text{sun}}) = 11.3$

0.4-3mm continuum: ESO320

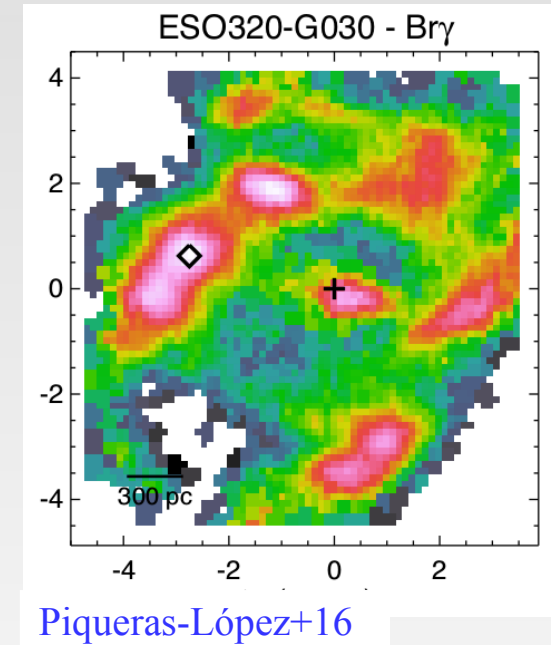
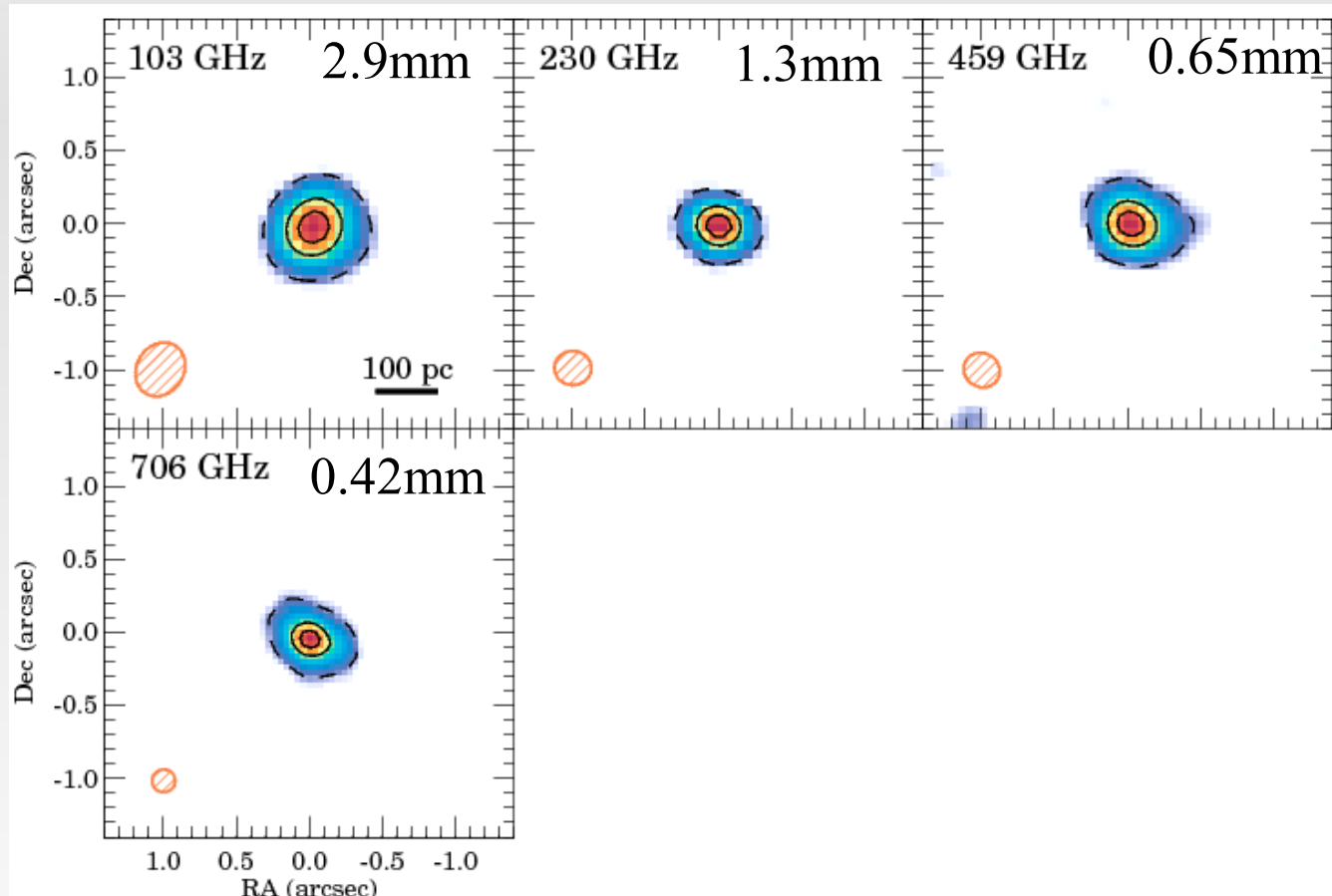


AGN?

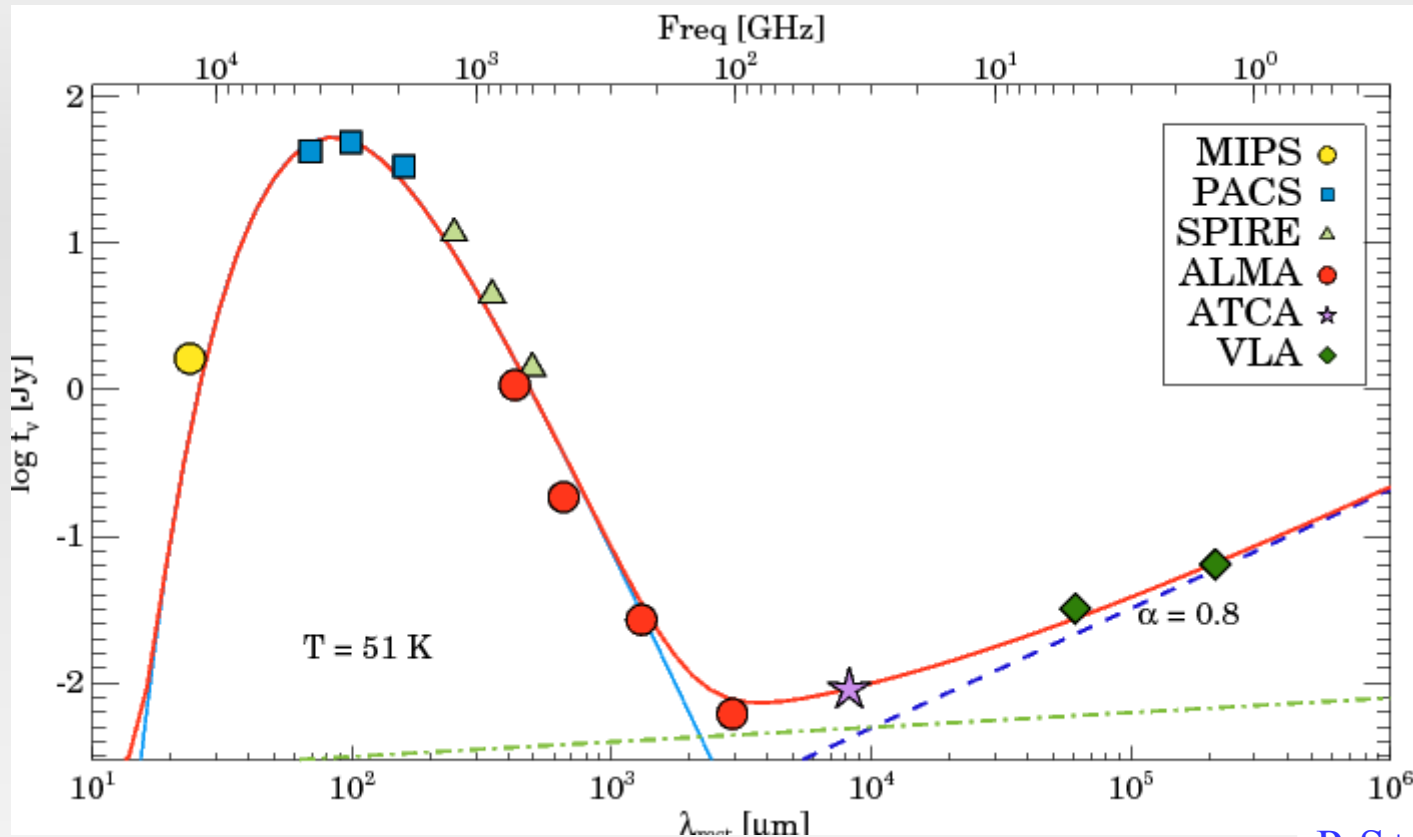
- no mid-IR high-ionization lines ✗
P-S+10
- no strong X-ray emission ✗
P-S+11
- no mid-IR hot dust continuum ✗
Alonso-Herrero+12
- no bright radio emission ✗
Baan+06
- Classified as HII from optical ✗
van den Broek+91
- Size 65 pc at 233 GHz ✗
P-S+16

0.4-3mm continuum: ESO320

- Band 3, 6, 8 and 9 ALMA data



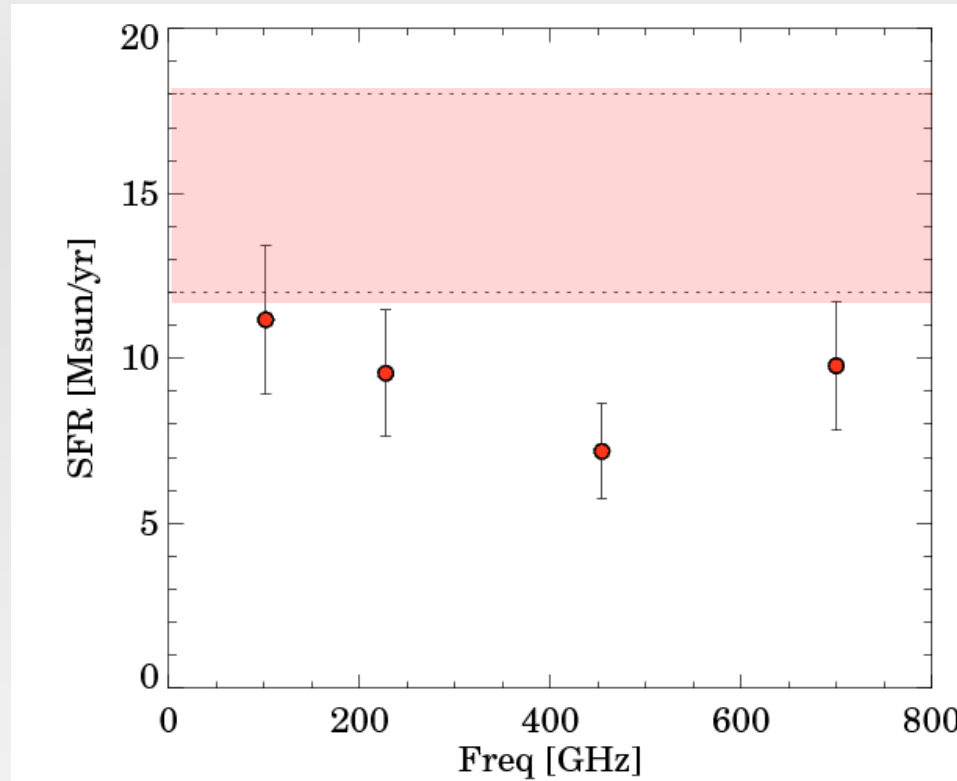
0.4-3mm continuum: ESO320



P-S+16b

- Free-free emission contribution: 70% @ 3mm, 15% @ 1.3mm
< 5% for shorter wavelength

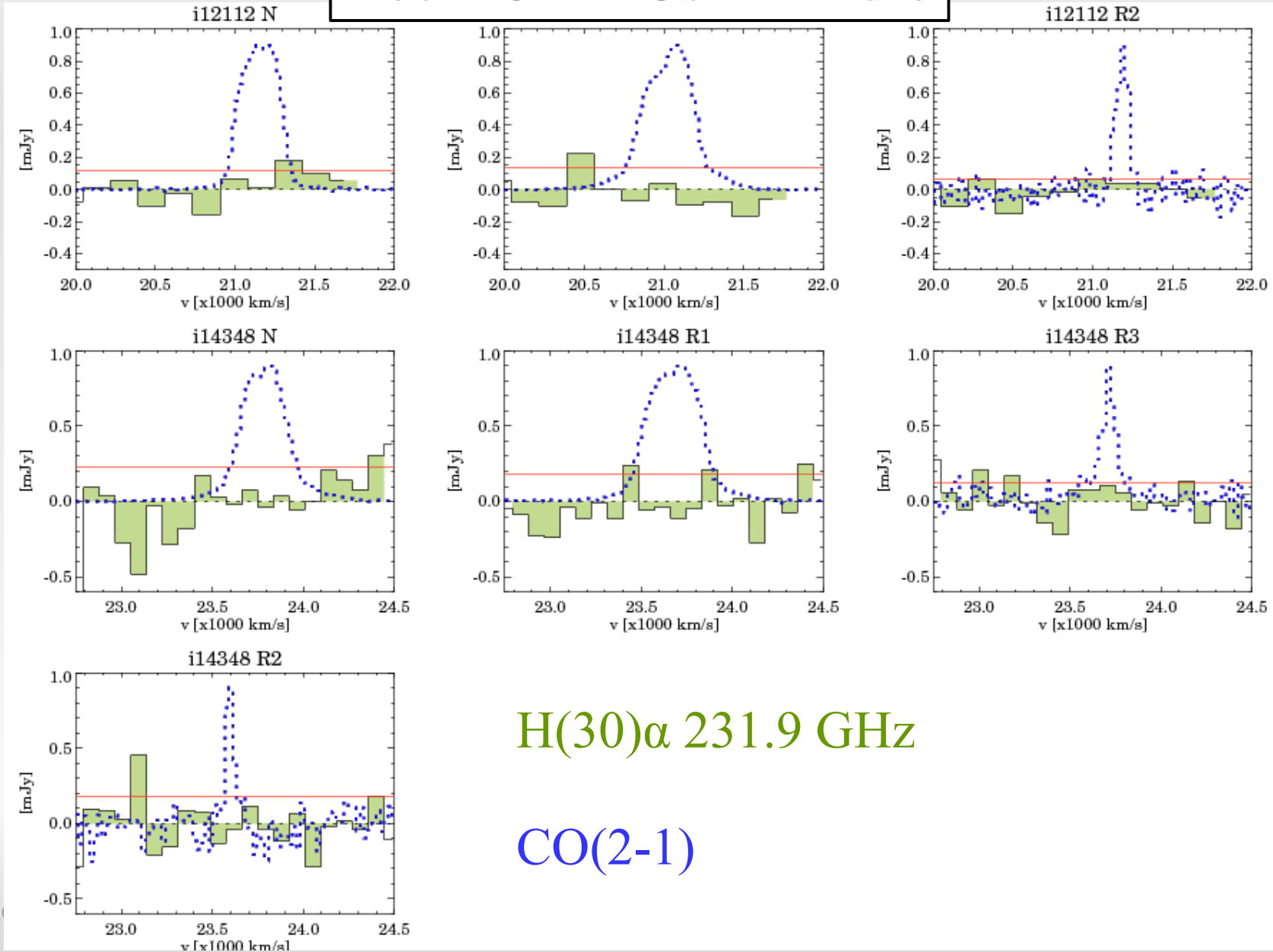
0.4-3mm continuum: ESO320



- 9 ± 2 Msun/yr from sub-mm continuum
- 13 ± 2 Msun/yr from L(IR) - Br γ map (P-S+16b)

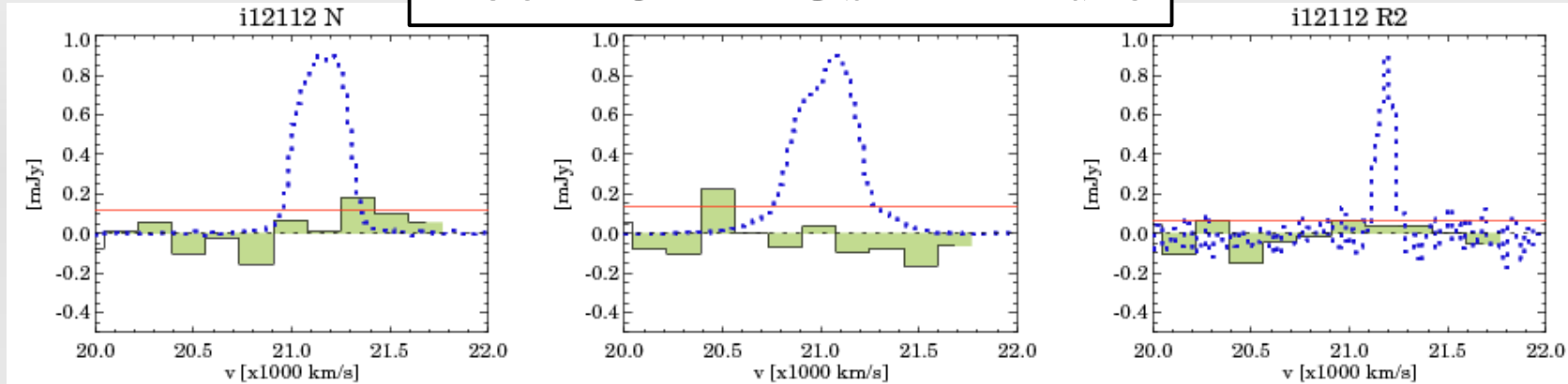
H radio recombination lines: H(30) α

Local ULIRGs – Band 6



H radio recombination lines: H(30) α

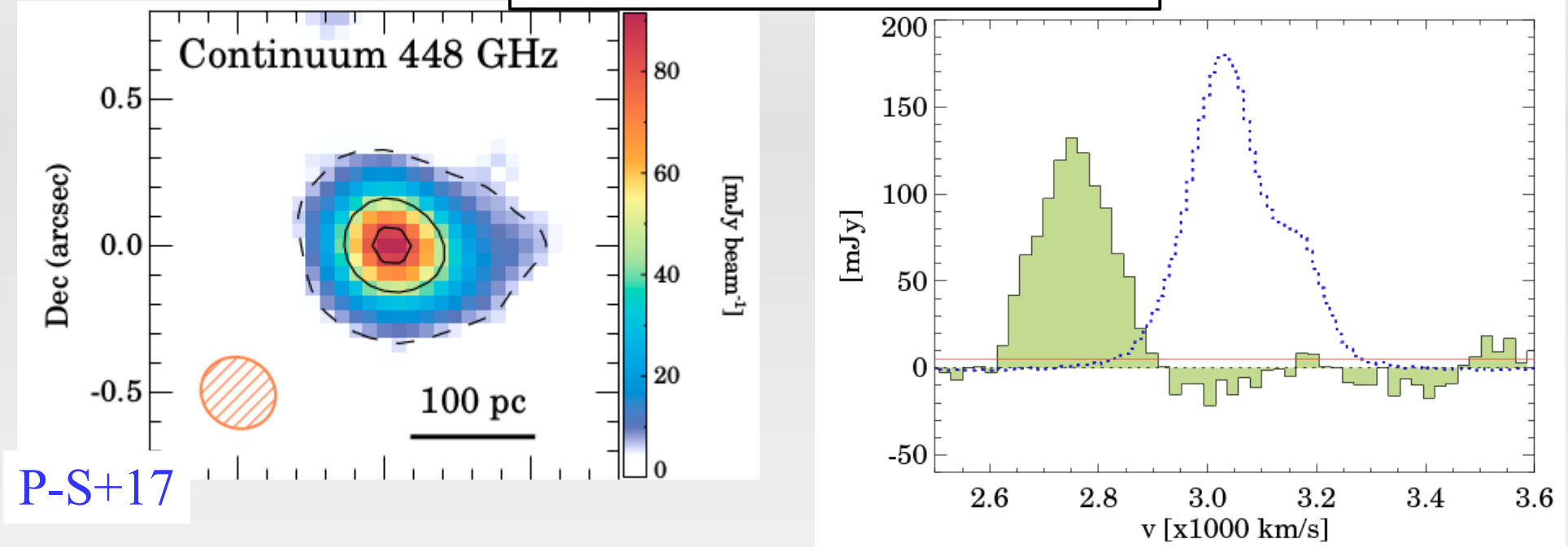
Local ULIRGs – Band 6



- 3σ upper limit < 70 mJy km/s for individual regions
- for SFR = 20-100 M_{\odot} /yr at 350 Mpc
H(30) α ~ 15 -50 mJy km/s (Scoville & Murchikova 13)

H radio recombination lines: H(24) α

ESO320-G030 – Band 8

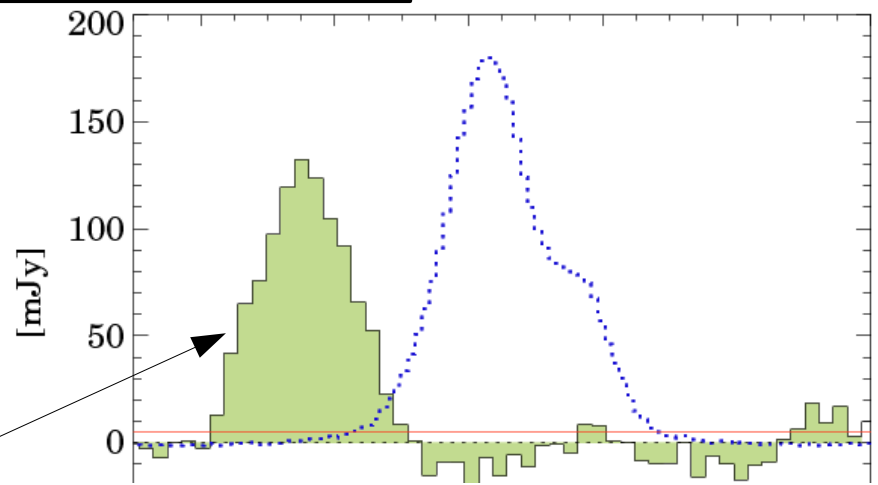
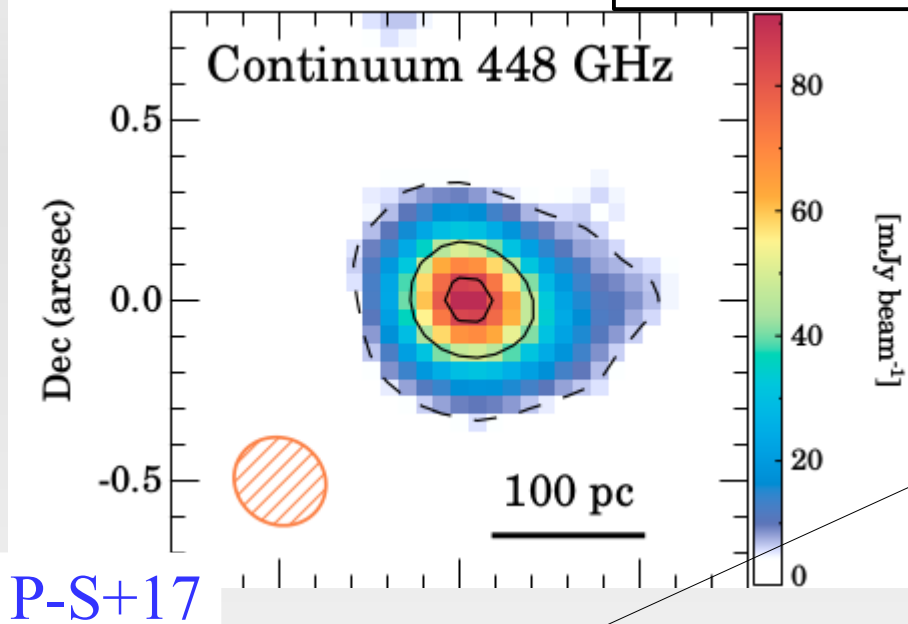


P-S+17

- 3σ upper limit < 700 mJy km/s
- for SFR = 10 Msun/yr at 50 Mpc
H(24) α @ 447.5 GHz ~ 500 mJy km/s

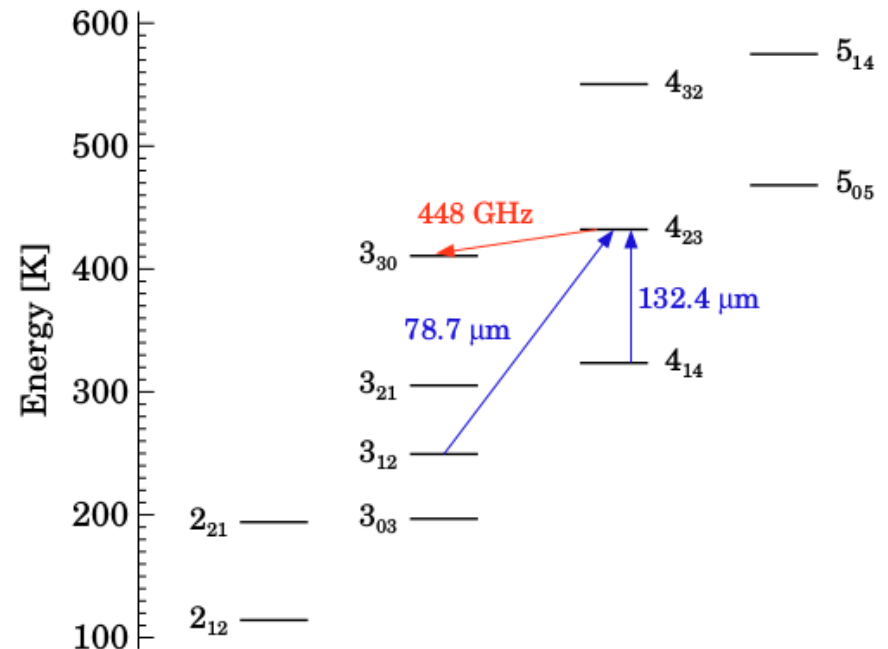
H radio recombination lines: H(24) α

ESO320-G030 – Band 8



First detection in space of
 $\text{H}_2\text{O } 4_{23} - 3_{30}$ 448.0 GHz
 P-S+17 A&A letters 601 L3

Herschel > 6''
 ALMA 0.05''



Summary

- Sub-mm continuum as SFR tracer
 - Compatible (within the uncertainties) with near-IR recombination lines for LIRGs
 - Can trace obscured SF in U/LIRGs
 - Free-free and non-thermal contribution
- Radio recombination lines