Herschel M33 Extended Survey
First results

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Pasadena, 4 November 2010

HERM33ES

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The HERM33ES project

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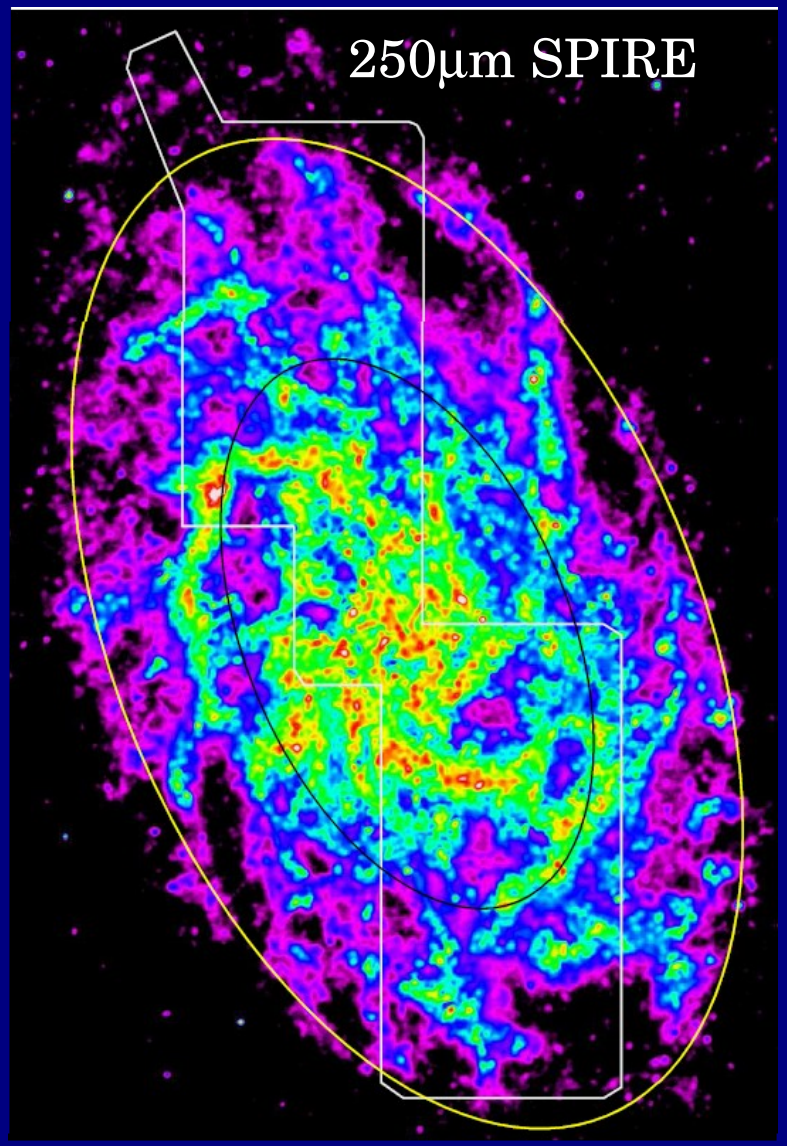
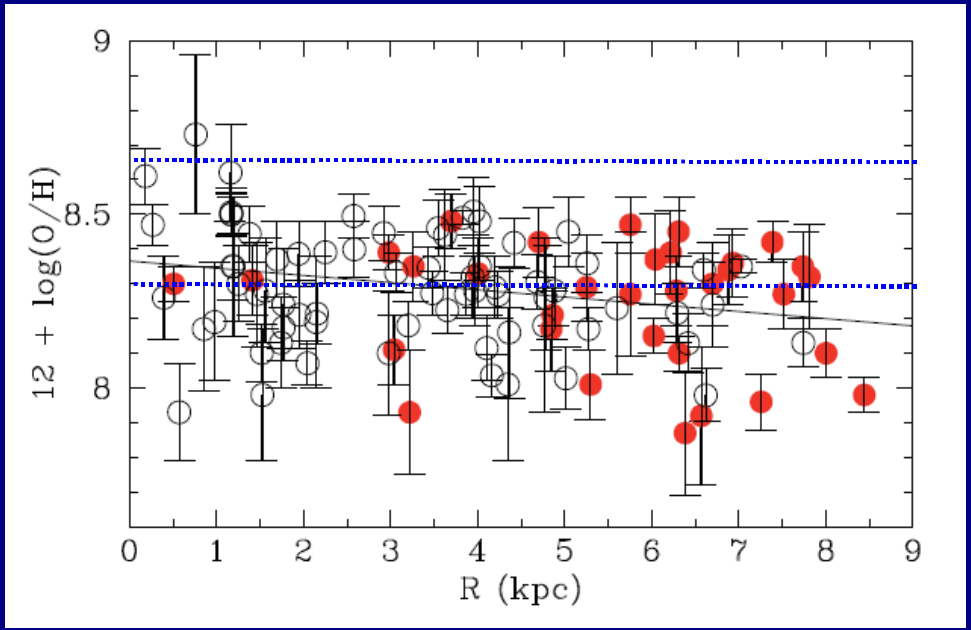
The HERM33ES project



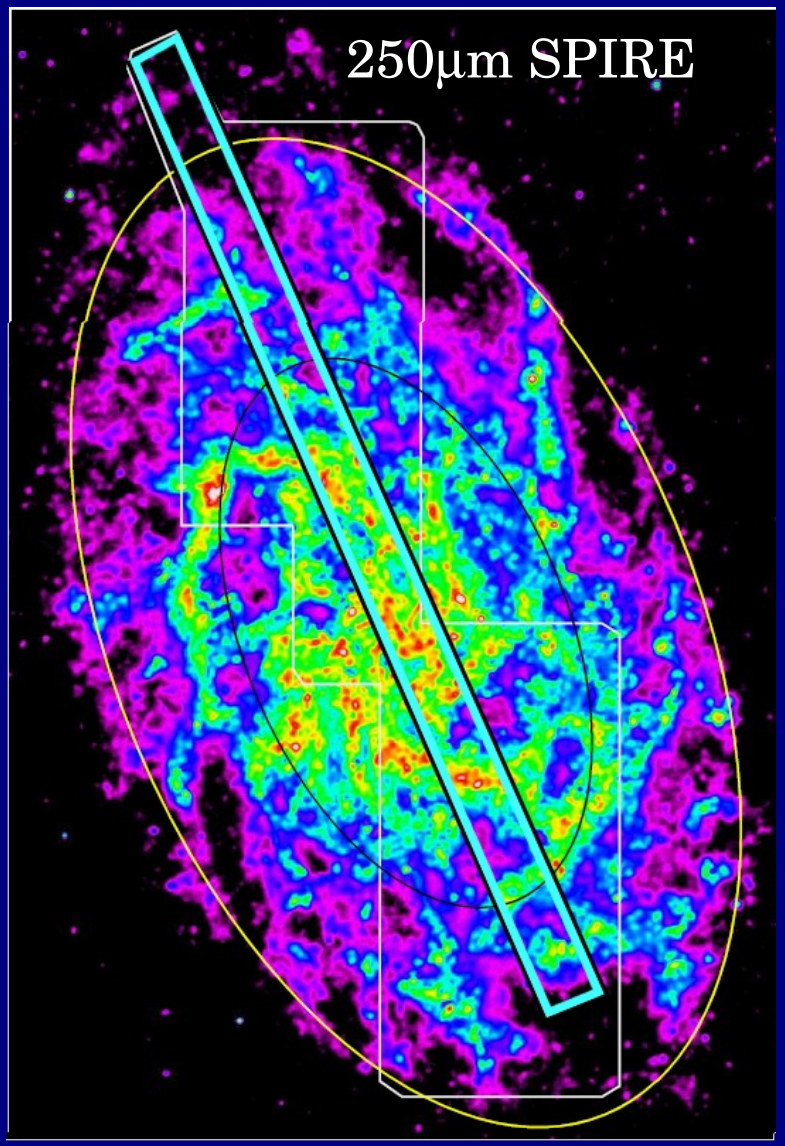
M33:

- nearest late-type spiral galaxy 840kpc, 12” = 50pc
- Low inclination of 56deg
- gas rich
- several giant HII regions
- average radiation field
- mostly unperturbed galaxy note giant HI bridge connecting M31 and M33
- About half solar metallicity with large variations



Magrini et al. 2009

The HERM33ES project



Herschel "Open Time Key Project" with 191 hours:

Entire Galaxy:

6h PACS & SPIRE photometry 70'x70' (100 - 500μm) (done)

Strip along major axis out to 8kpc:

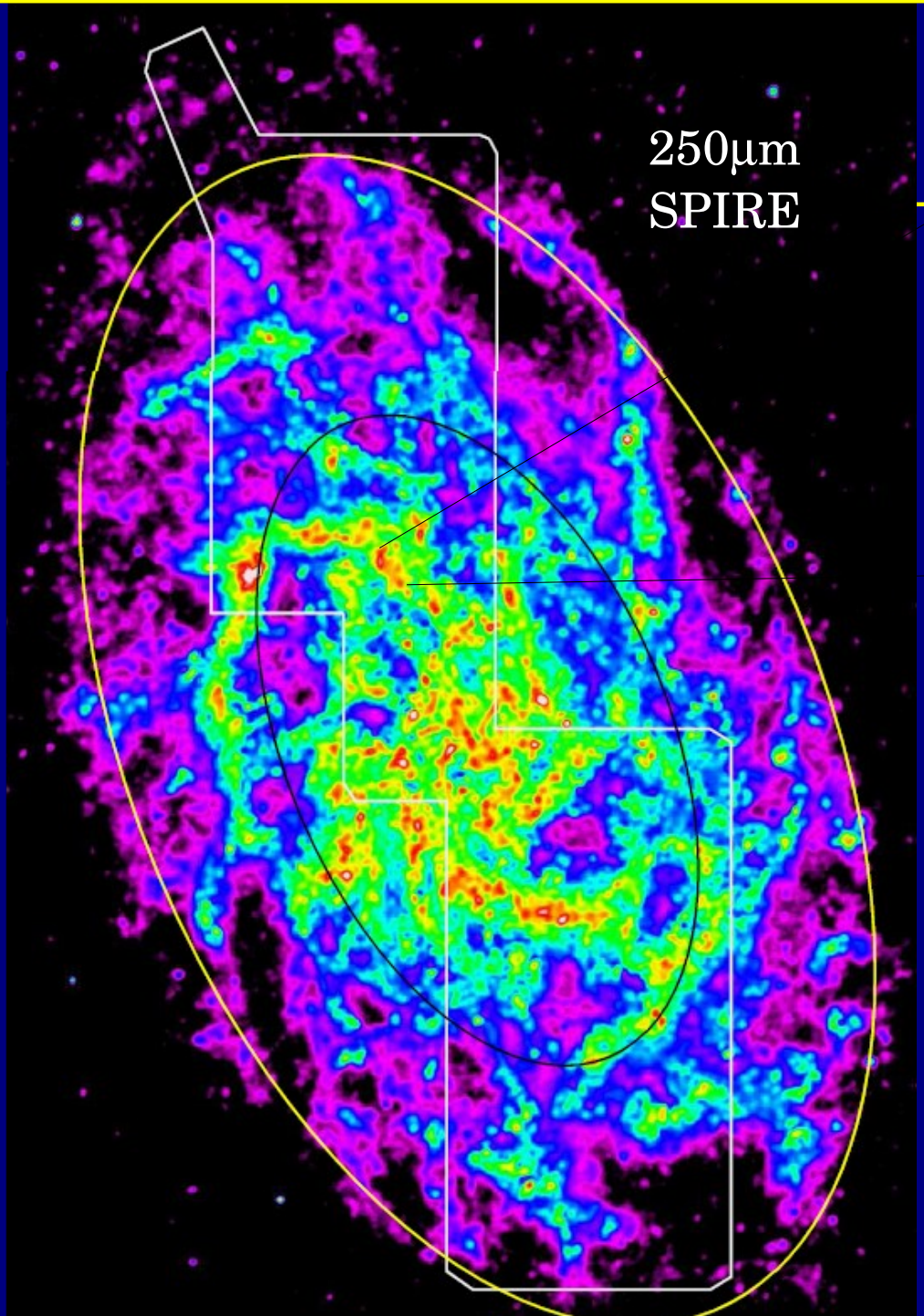
42h PACS spectroscopy: 51-73, 103-220μm: [CII]158, [OI]63,145, [NII]122,205 (1h done)

143h HIFI spectroscopy [CII]158μm (1h done)

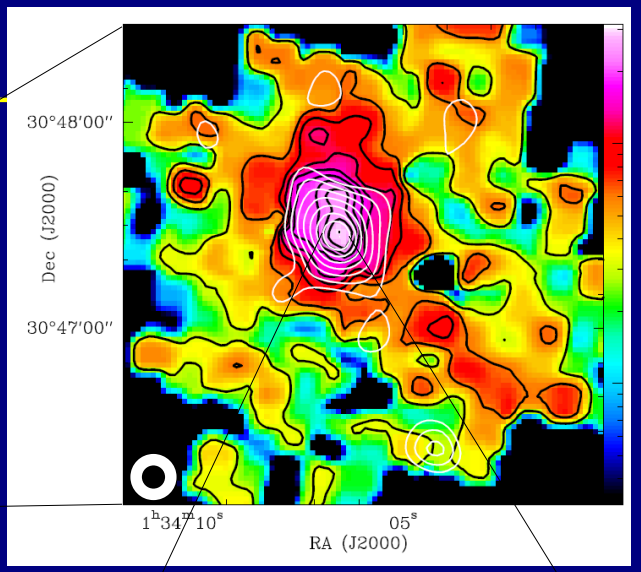
Key science:

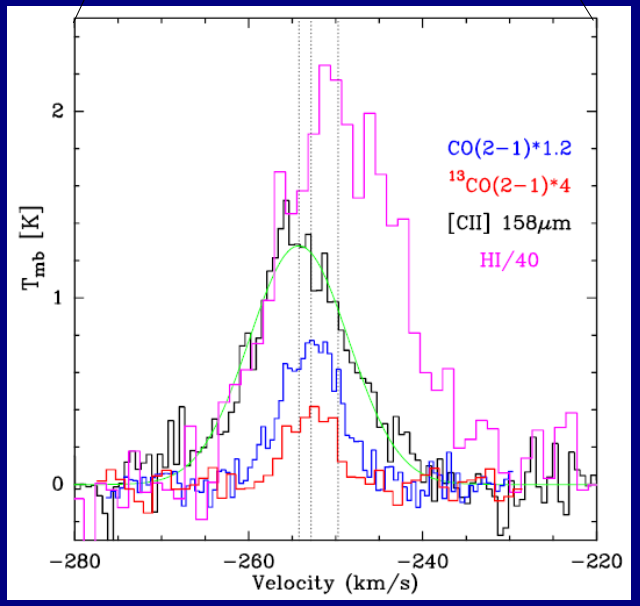
- Study the phases of the ISM: molecular, atomic, ionized
- Energy balance of the ISM: cooling & heating mechanisms
- Extinction free tracers of star formation dust TIR continuum, [NII], [CII]
- Formation of molecular clouds: HII/HI/H2 interface regions

First Herschel observations



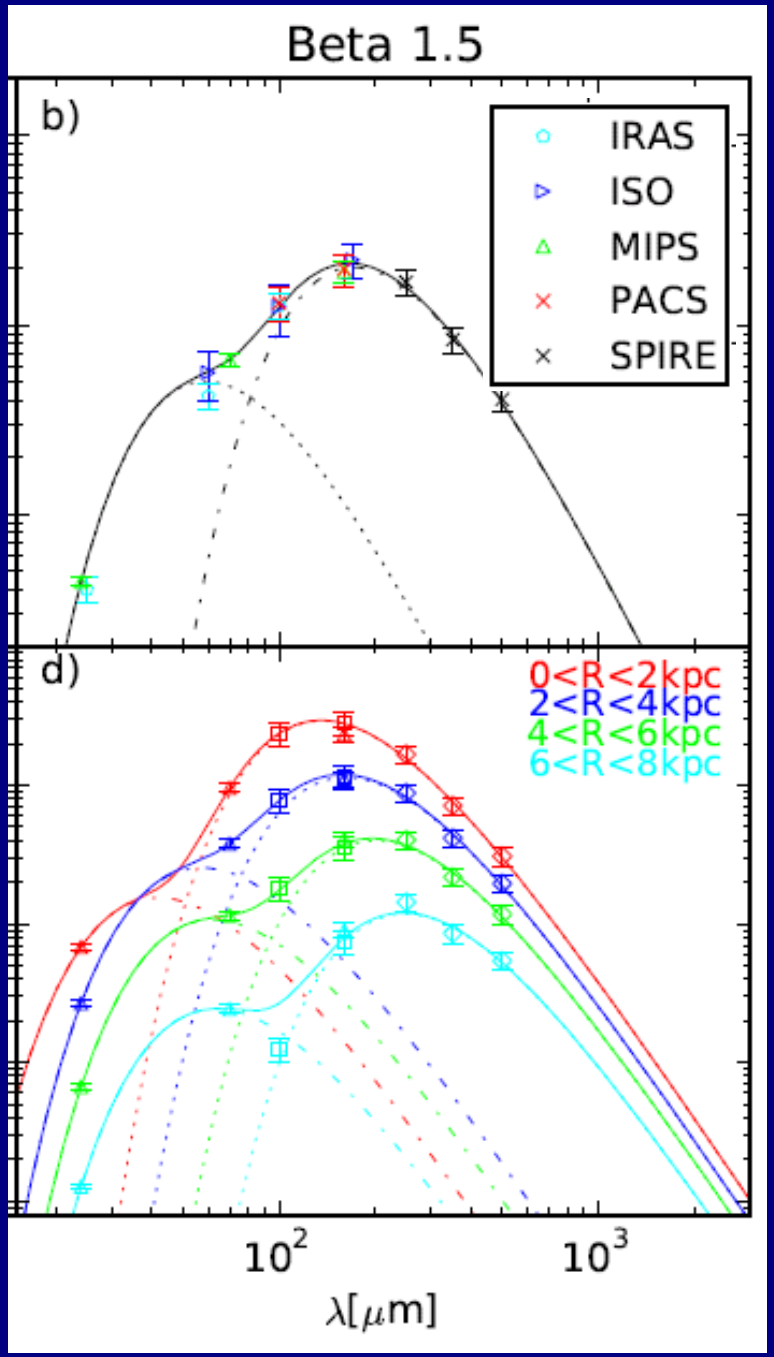
[CII], [OI] PACS





[CII]
HIFI

PACS & SPIRE : Azimuthal Averages



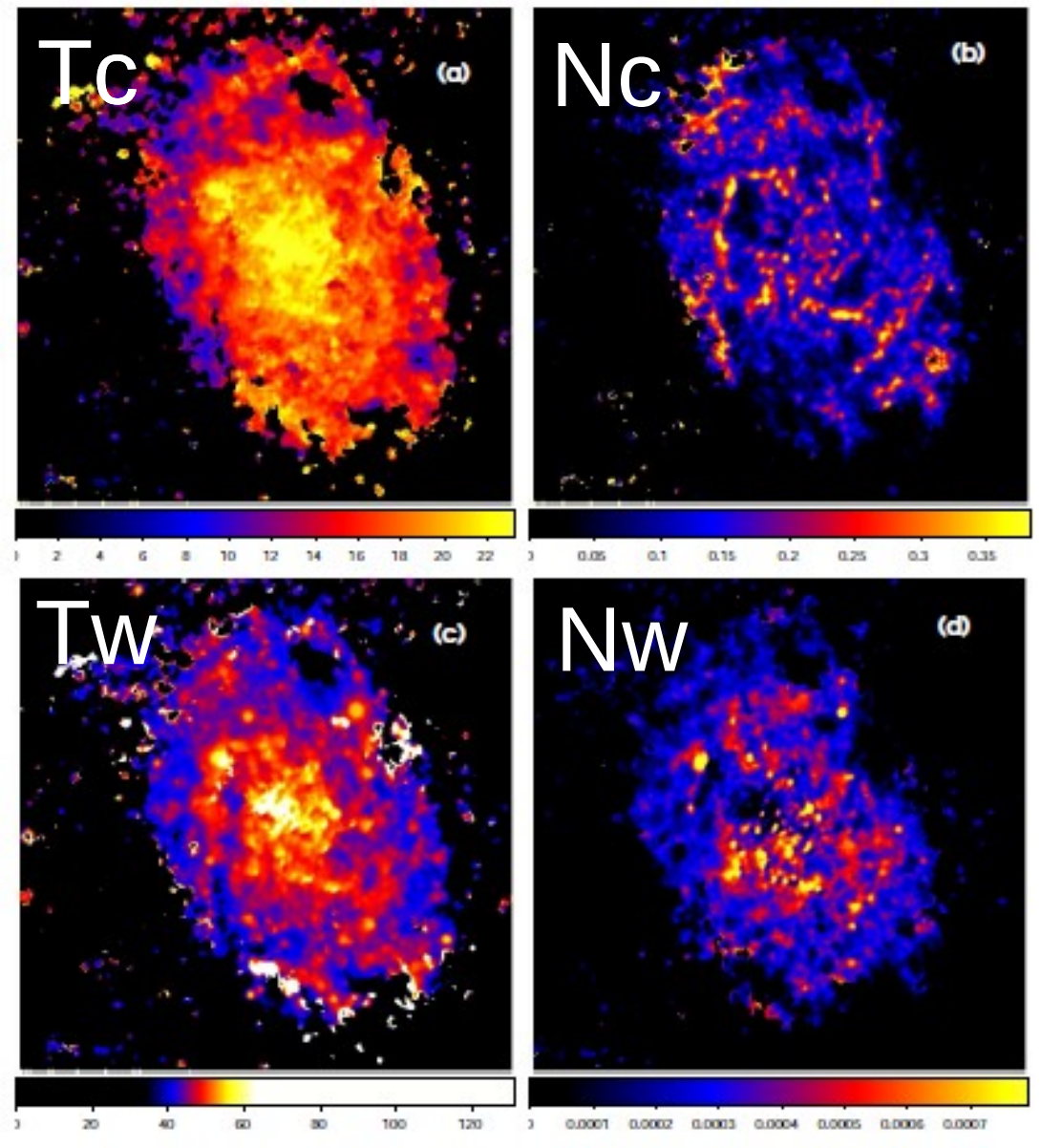
$$S_\nu = M_c B(\nu, T_c)\kappa_\nu + M_w B(\nu, T_w)\kappa_\nu$$
$$\kappa_\nu = 0.04\,(\nu/250\mathrm{GHz})^\beta \quad \text{(Kruegel \&Siebenmorgen 1994)}$$

	Total	(1)	(2)	(3)	(4)
Two-component fits with $\beta = 1.5$					
T_c/[K]	19	24	20	16	13
T_w/[K]	55	77	57	52	51
M_c/[10^6 $M_\odot$]	10	1.2	3.0	4.6	4.9
M_c/M_w	500	3800	480	730	2200
$\chi^2_{\rm red}$	0.14	0.10	0.12	0.20	1.8
$M_{\rm gas}/M_c$	200	190	150	120	160

- 24μm – 500μm
- Two grey-body components needed
- Cold component:
  temperatures drop from 24K in inner parts to 13K in the outer regions.
- The warm component is not well constrained
- 1 < β < 2 provide reasonably well fits

Kramer, Xilouris et al. 2010

T & N maps at 160pc resolution



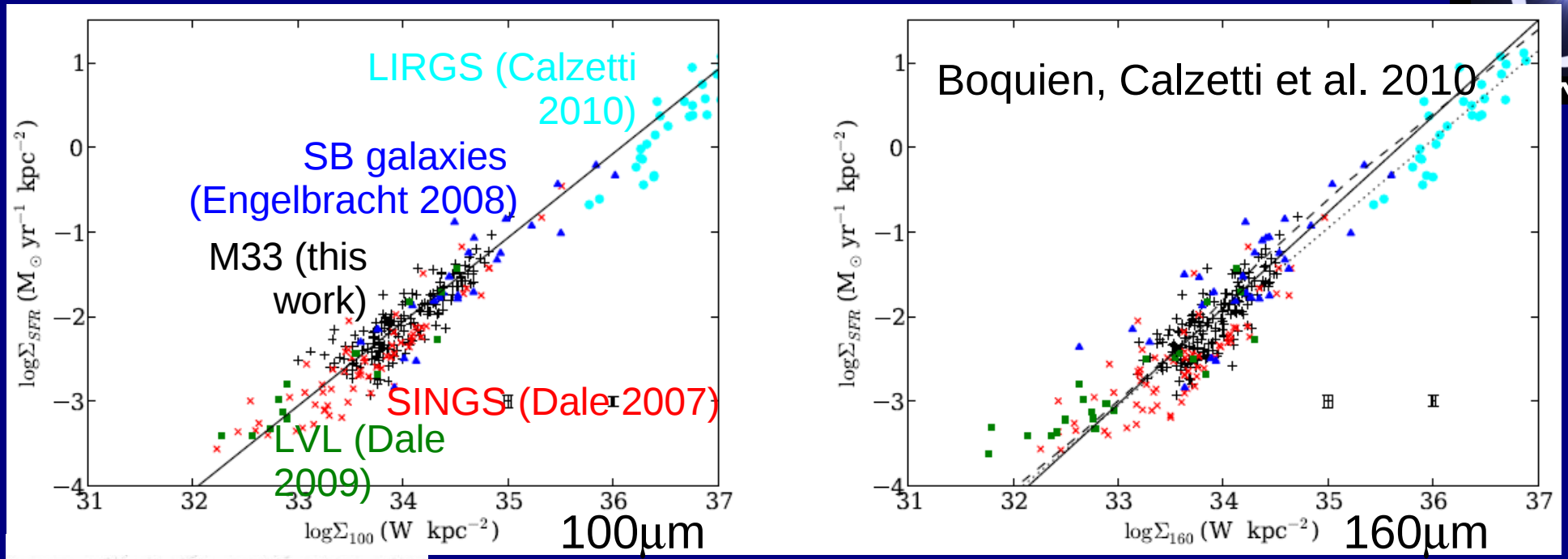
Two-component grey-body fits to data at 24, 100, 160, 250, 350, 500μm

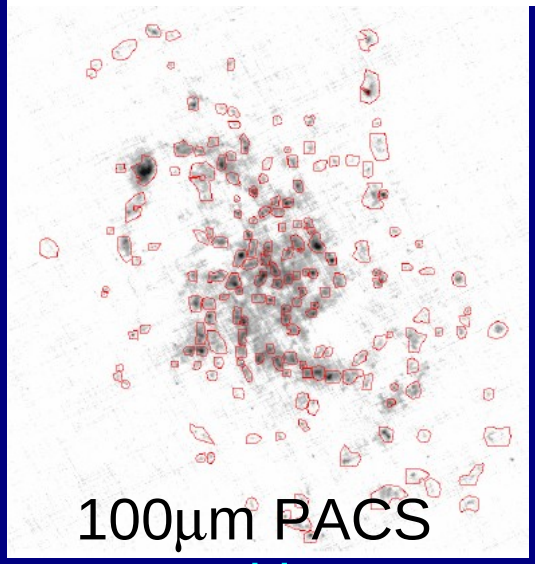
Preliminary results:
+ Cold dust traces spiral arms.
+ Warm dust traces bright HII regions.

Caveat:
+ degeneracy of fits at individual positions, warm component often ill defined

Xilouris, Tabatabaei et al. 2010 in prep.

PACS: Spatially resolved SFR tracer





100μm PACS map with identified regions

$$\log \Sigma_{SFR} = (0.99 \pm 0.03) \log \Sigma_{100} - (35.84 \pm 0.83)$$
$$\log \Sigma_{SFR} = (1.12 \pm 0.03) \log \Sigma_{160} - (40.42 \pm 0.99)$$

Individual SF regions exhibit similar scaling as entire galaxies.
100μm and 160μm fluxes are linear estimators of the star formation rate (Boquien et al. 2010). 250μm fluxes as well (Verley et al. 2010). Only 25% of total 160mm flux identified in 179 sources, indicating large-scale diffuse non-ionizing emission.

Dust Emissivity

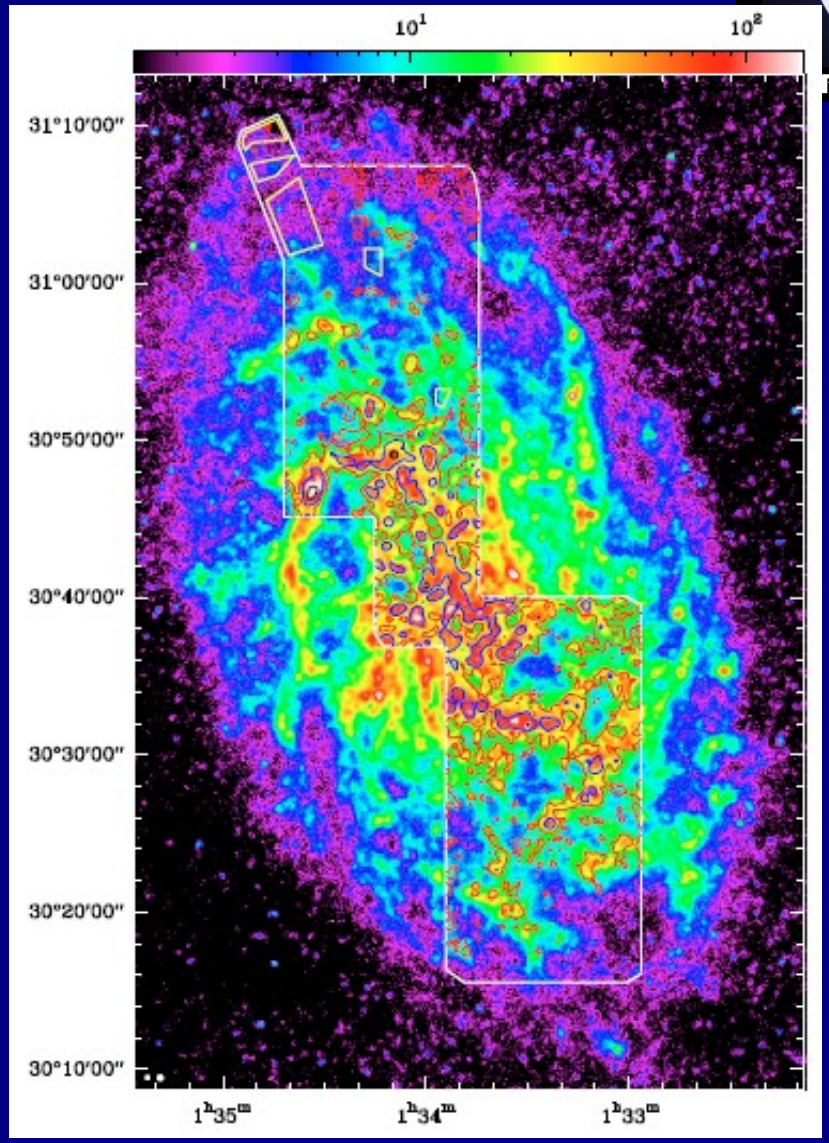
$$N_{\rm tot} = N_{\rm HI} + N_{\rm H_2} = S_\nu / (\sigma\ B_{\nu,T})$$

Where CO is not detected, we derive σ, the dust cross-section per H-atom from the SPIRE 350μm flux, the dust temperature, and N(HI).

The found σ values are in general lower than the solar value of 1.1 10^{-25} cm^2 per H-atom.

We find a radial gradient between the inner 4kpc and the outer disk near 7.5kpc, from 0.8 to 0.5 times the solar value.

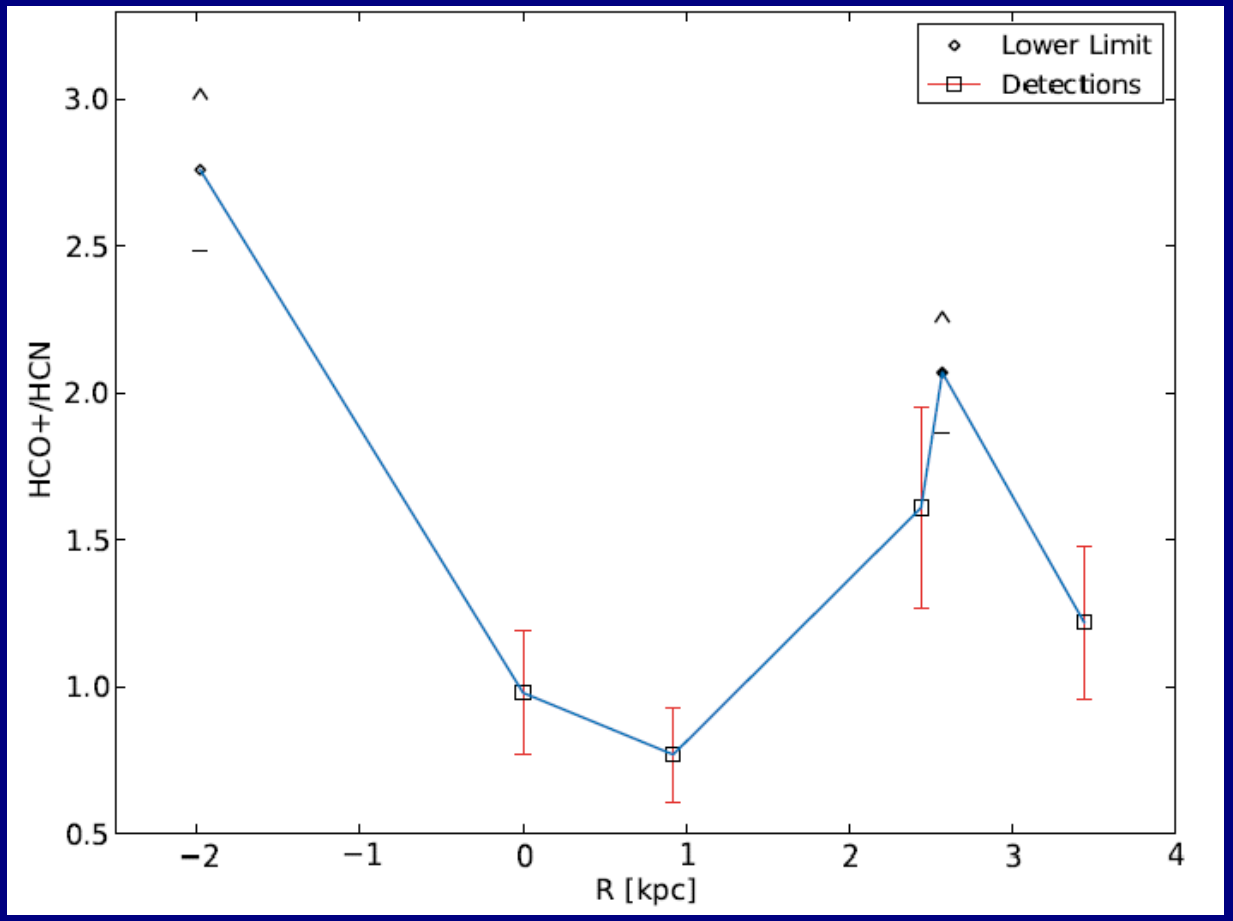
Construct map of $N(H_2)$ from the dust and HI, to compare with $N(H_2)$ map from CO 2-1.
Dark molecular gas ?



SPIRE 250μm + 30m CO 2-1

see Braine, Gratier et al. 2010

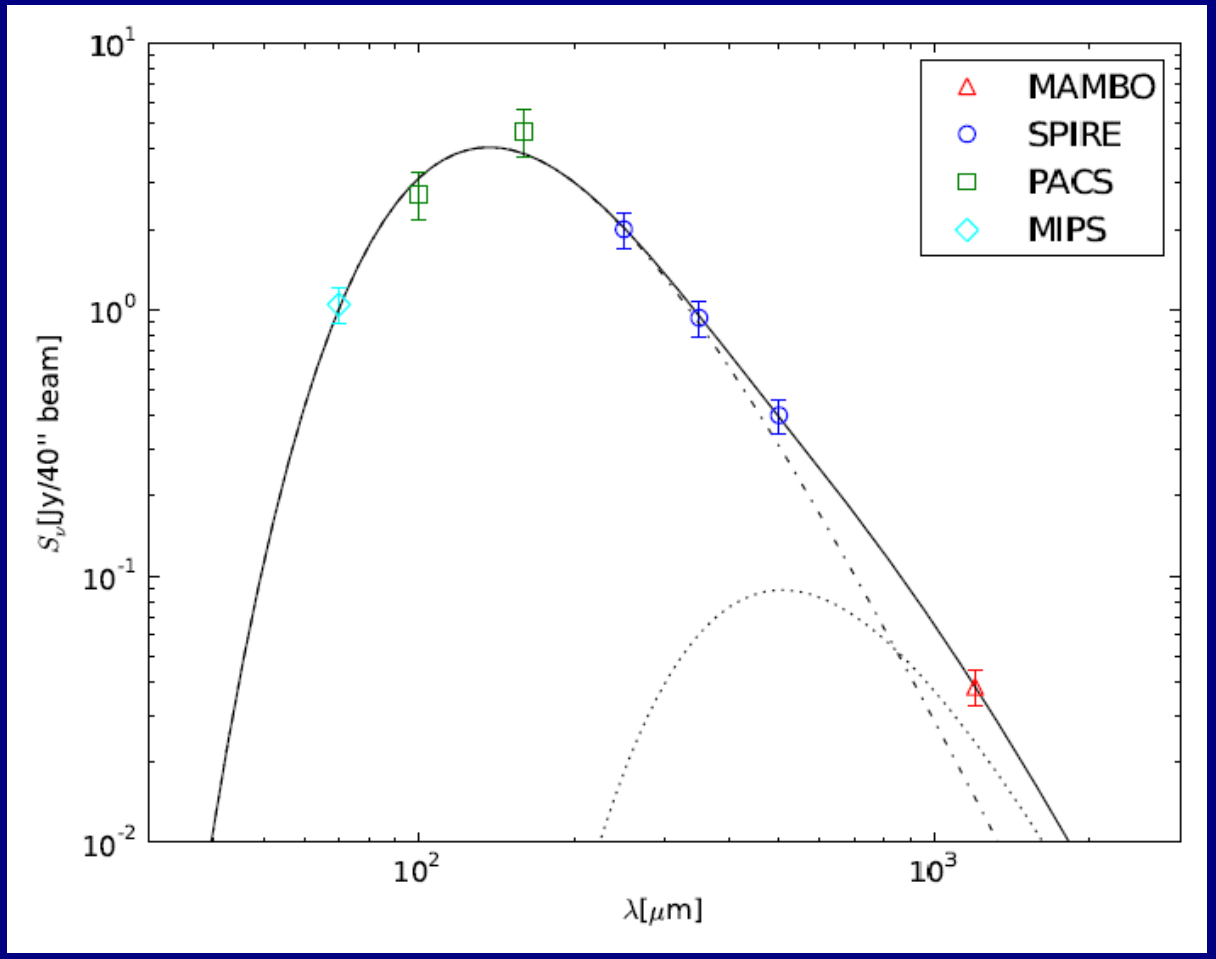
HCN & HCO^+: dense gas tracers



- HCO^+/HCN is high in the spiral arms, but low in the center & interarm regions
- Possible link to **star formation** and **photon dominated chemistry**
- Possible link also to low N/H abundance in M33 and **metallicity** gradient

(Buchbender, Gonzalez et al. in prep.)

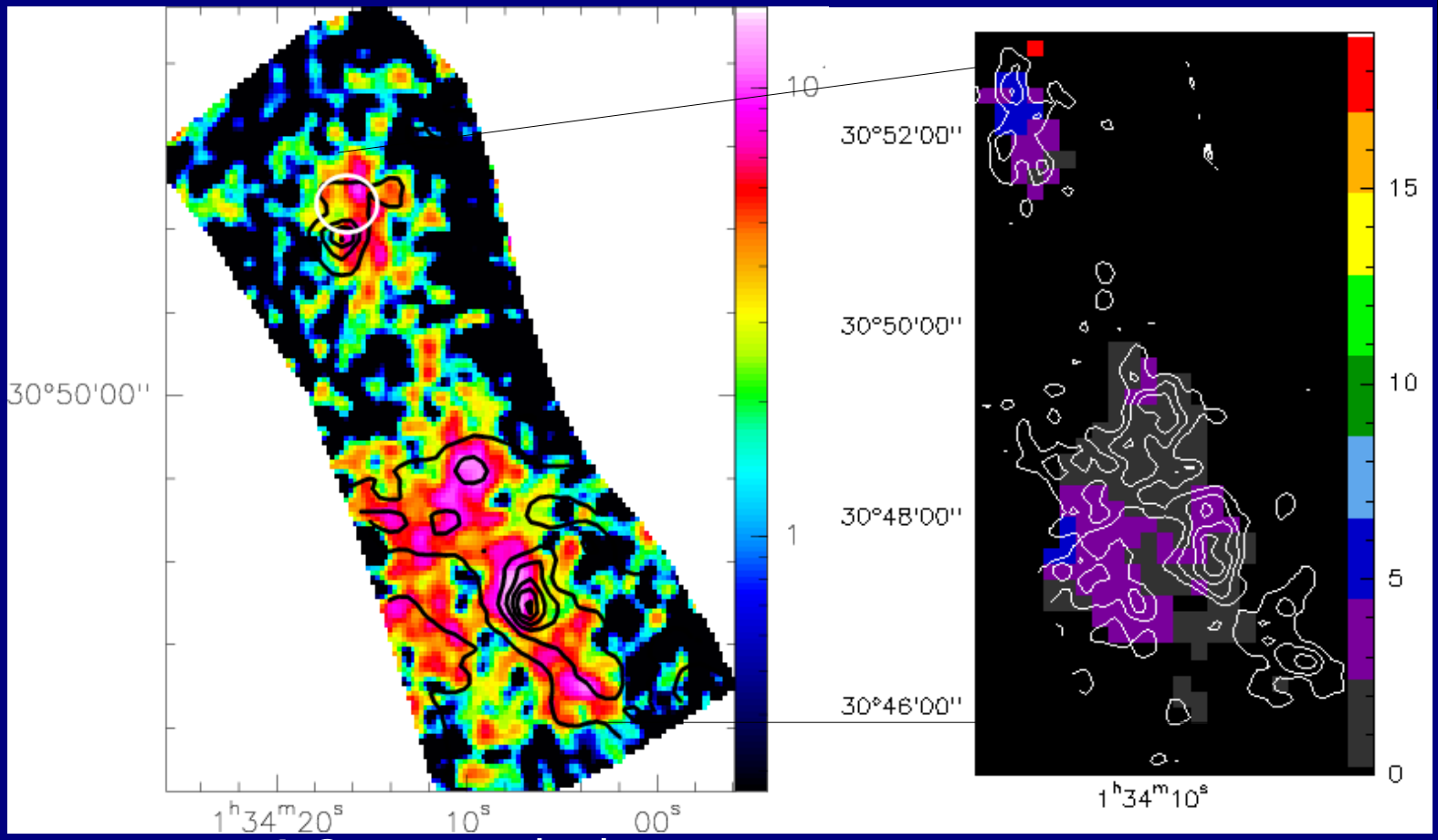
Excess of emission at mm–wavelengths



1.2mm flux of 37.8 +/-4.8 mJy/(40”beam) is only slightly “contaminated” by

- CO emission: 1.1mJy/(40” beam), i.e. **<3%** (Gratier et al.)
- free-free emission: 0.8mJy/(90” beam), i.e. **<2%**
- synchrotron emission: 0.17mJy/(90” beam), i.e. **<0.5%** (Tabatabaei et al.)

Excess of emission at mm–wavelengths



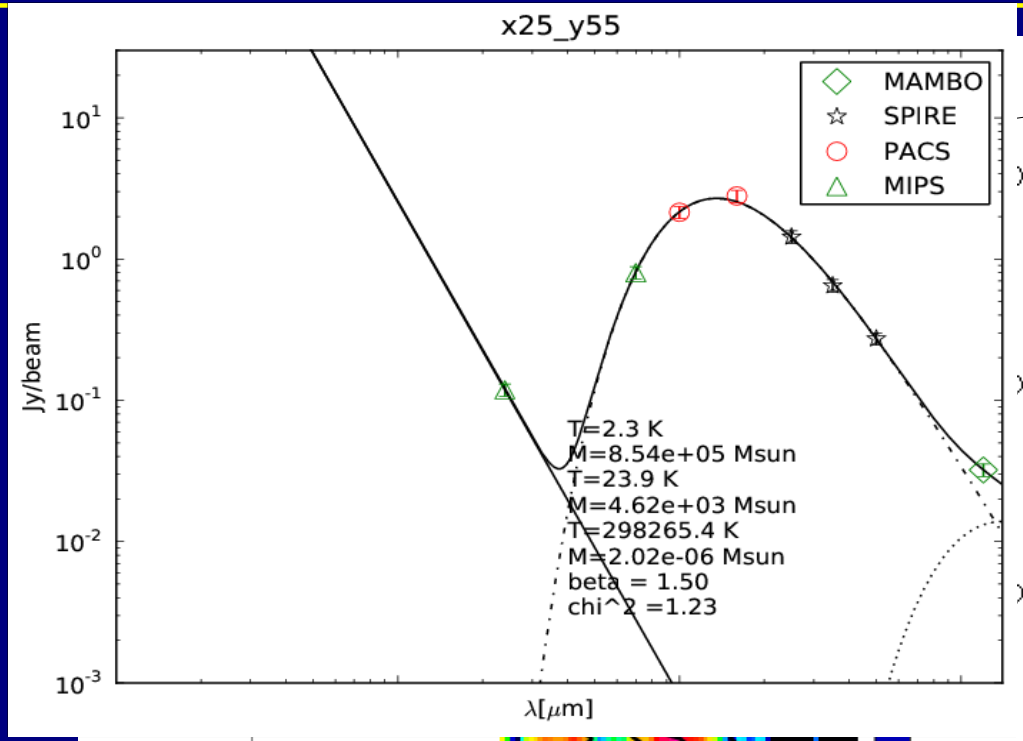
1.2mm emission
vs
160 microns

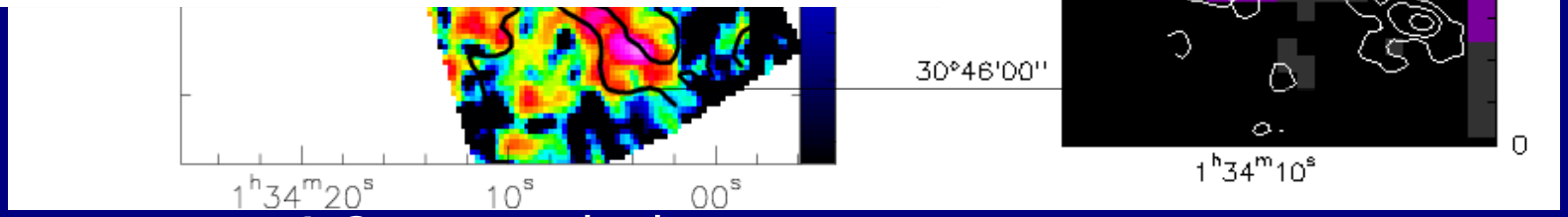
Very cold component
temperature

Resolve and relate the mm-excess with other physical properties. Testbench for the different models: amorphous grains, spinning dust,...

Quintana-Lacaci et al. in preparation.

Excess of emission at mm–wavelengths





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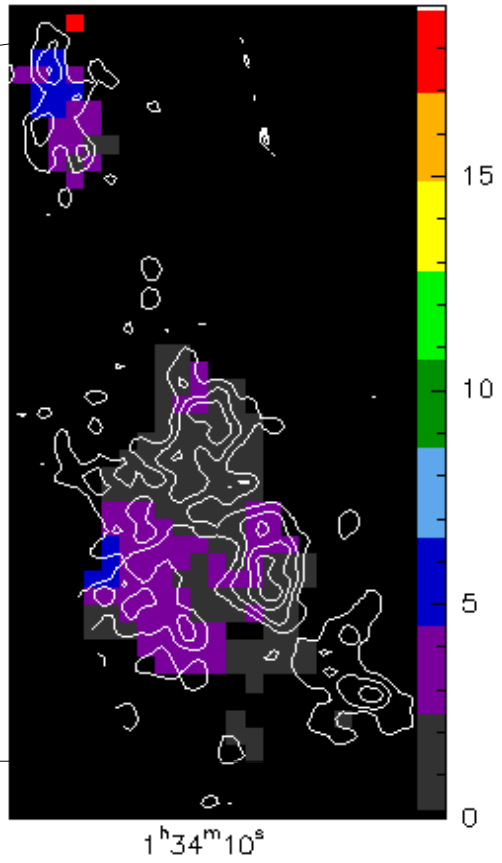

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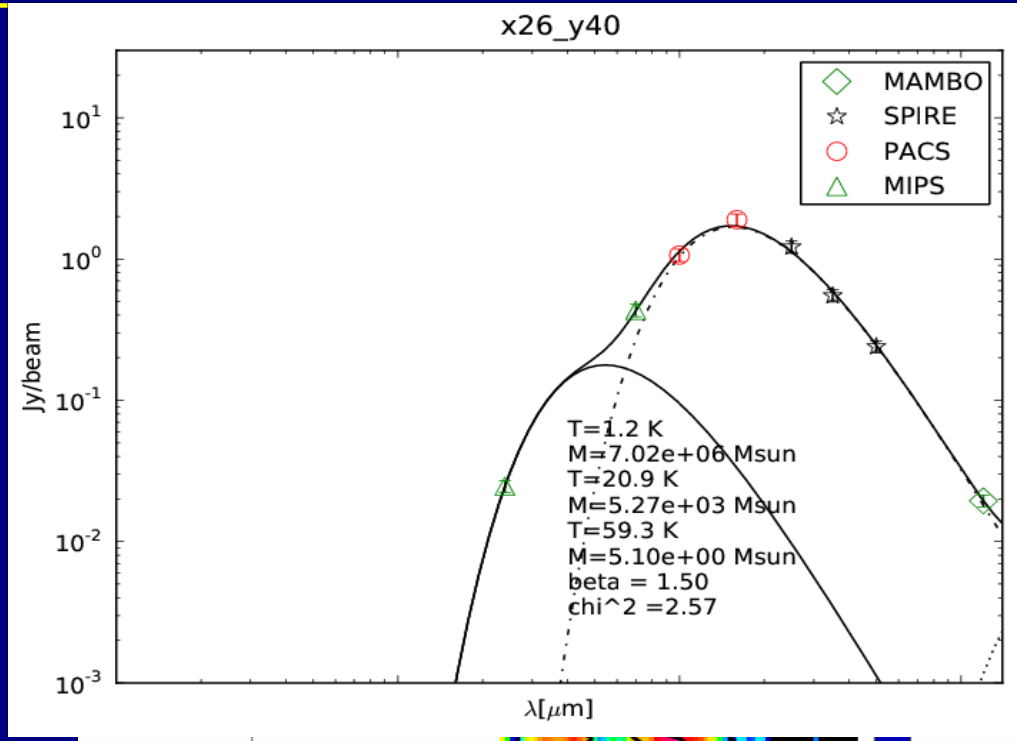

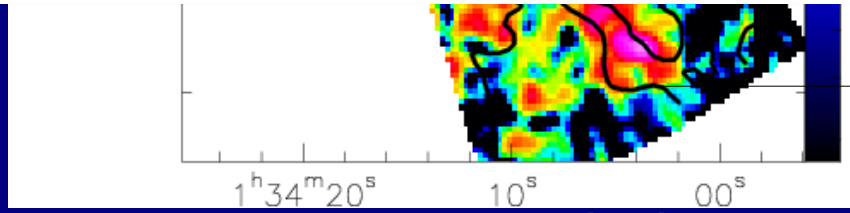

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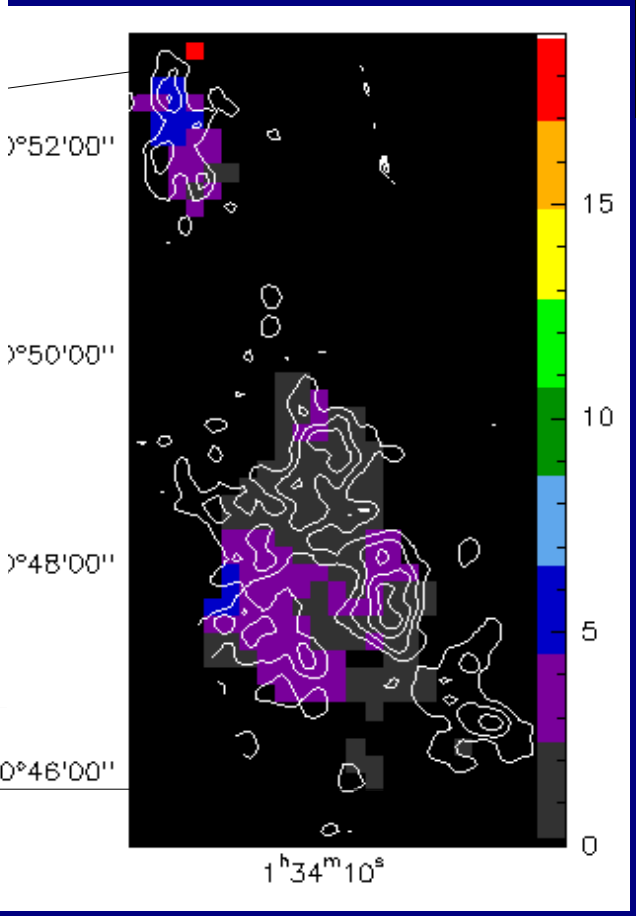

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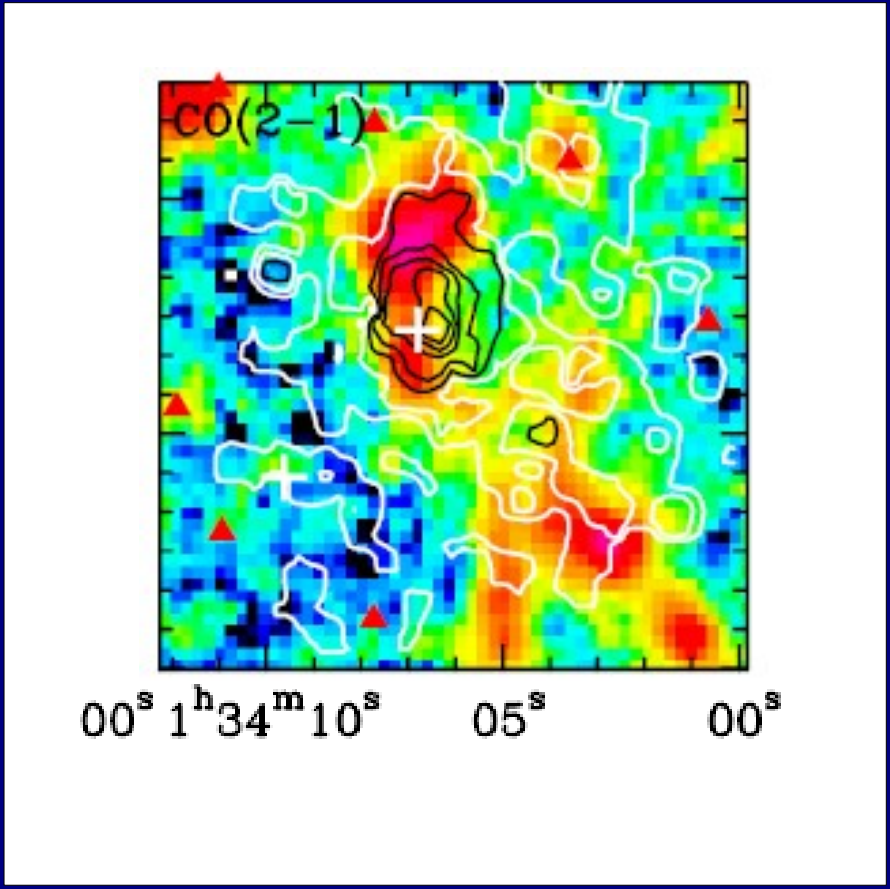
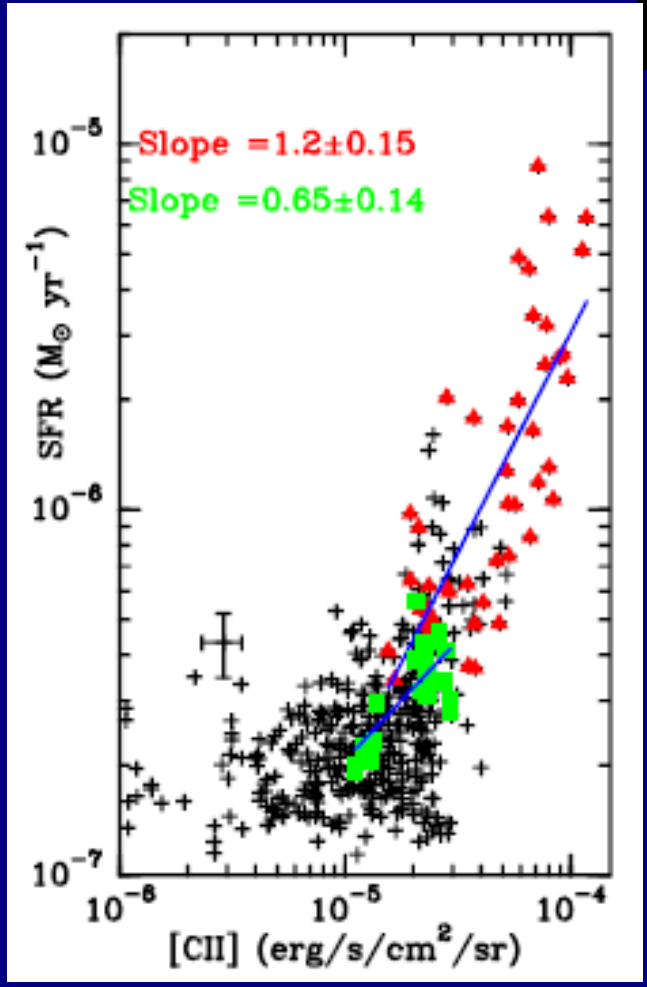
Quintana-Lacaci et al. in preparation.

SFR traced by [CII]



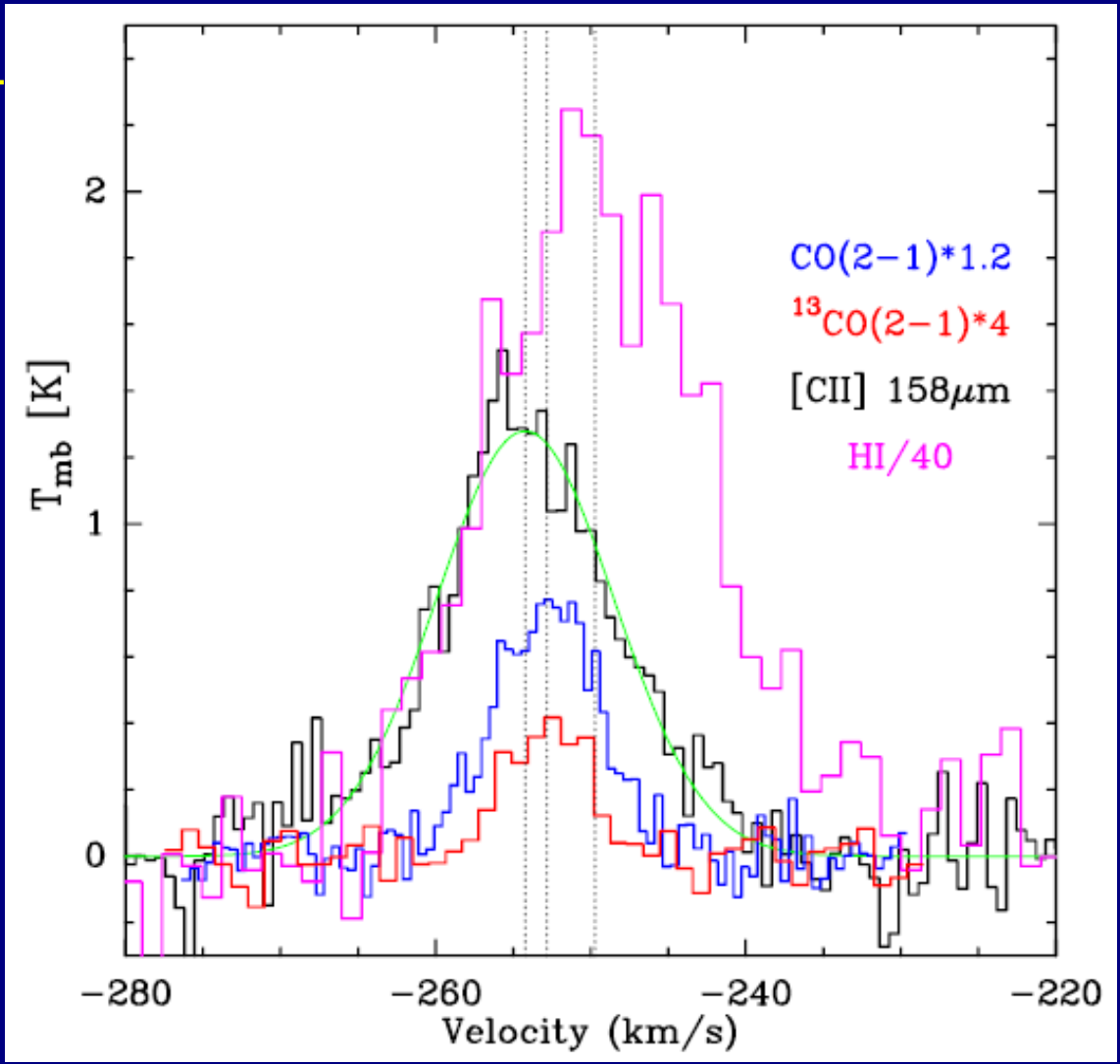
Contours: [CII] PACS
+ H II regions



[CII] traces SFR at scales of 50 pc

Mookerjea et al. in preparation.

[CII] Obseved with HIFI



Spectra at the center of the HII region

[CII] integrated intensity agrees within 12.5% with nearest PACS observation at 3” distance.

[CII] spectrum is broader and shifted relative to the CO and HI spectra

[CII] spectrum taken with HIFI, together with CO IRAM-30m spectra, and a VLA HI spectrum, all at ~12” angular resolution.

Mookerjea, Kramer et al. in prep.

HerM33es: First results

- Radial drop of dust temperatures in M33 from 24 to 13K

- Cold component traces spiral arms, warm component traces HII regions

- 100μm emission traces star formation

- The dust cross section σ is subsolar. Varying with metallicity ?

- HCO^+/HCN varies over 0.7 to 2.7. Enhancement due to PDRs ?

- Excess millimeter emission tracing very cold dust ?

- [CII] emission traces star formation on scales of 50pc

Four papers in the A&A special issue, several in preparation

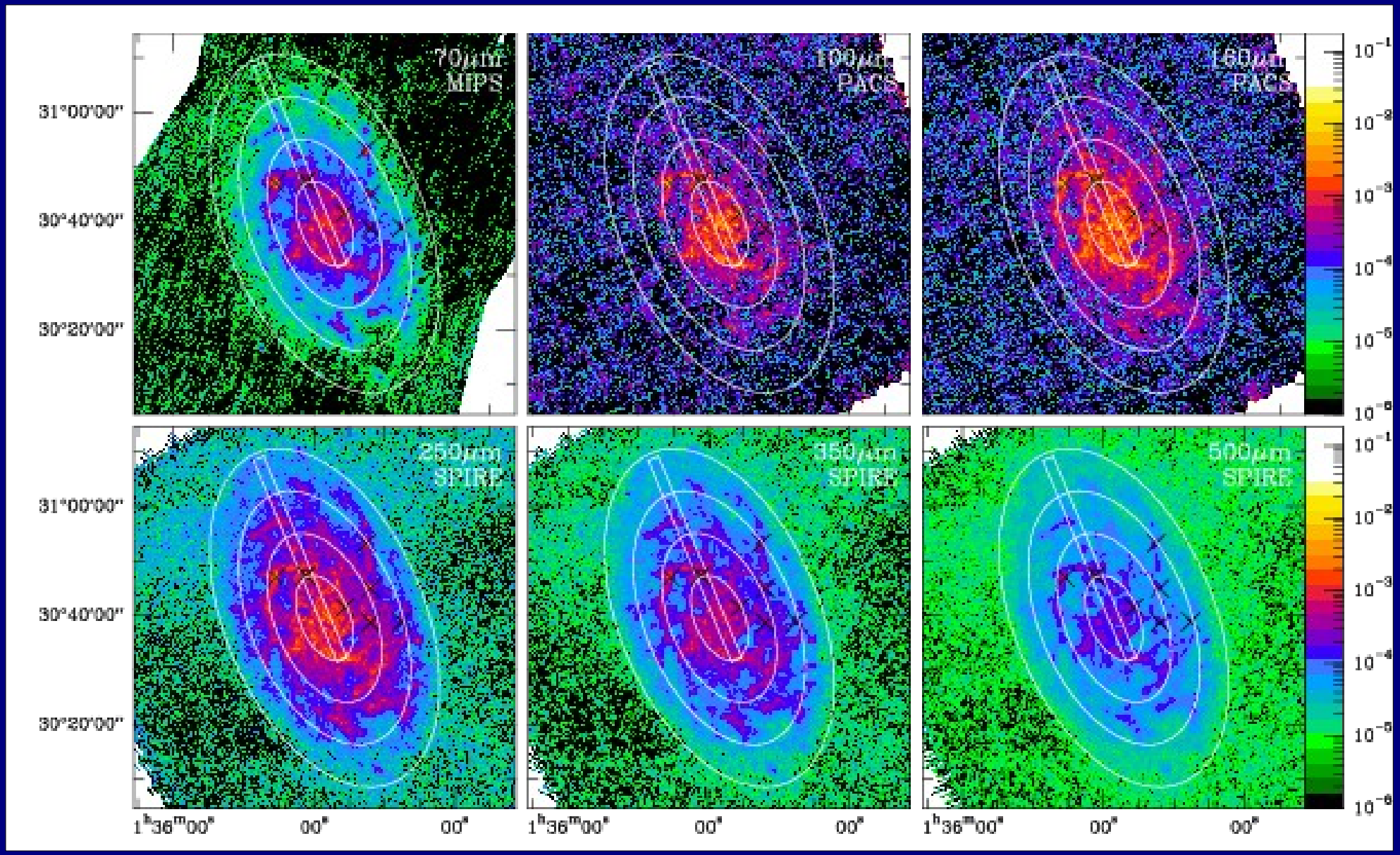
THANK YOU !!!!!!

Hola Guillermo,

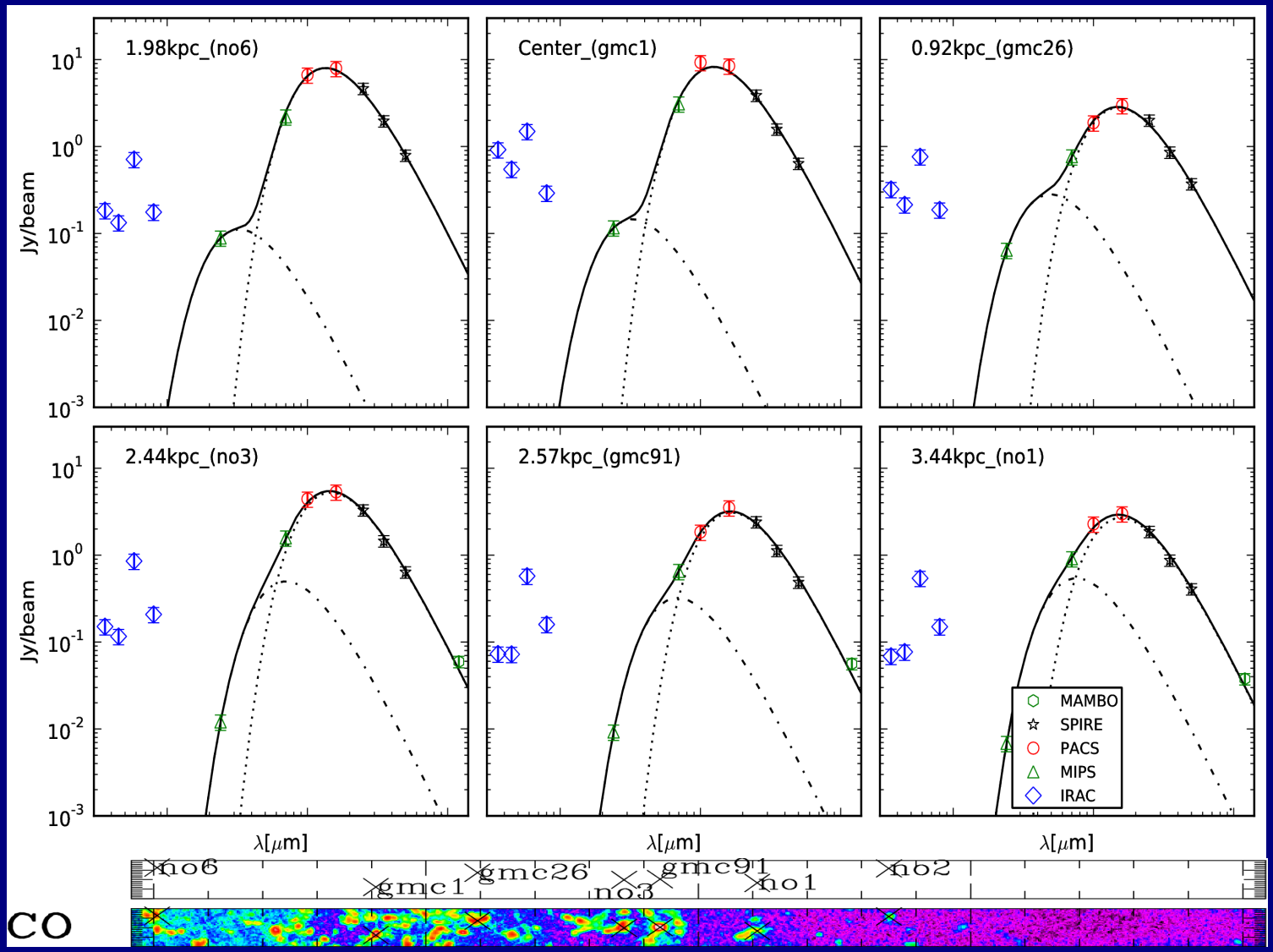
thanks for the nice draft. Just a few comments:
Did you correct for ff and CO emission for all positions observed with MAMBO, to create the map of cold dust temperatures on page 11 ?
What was the beta value used for the fit ?
Could you show some more SEDs, at positions where there is very much or very little excess ?

PACS & SPIRE Scan Maps

Resolutions at 100, 160, 250, 350, 500μm: 7”, 11”, 18”, 26”, 36”



SED of the Cold Dust



β fixed: 1.5

Position	T_c
no6	24
gmc1	26
gmc26	22
no3	23
gmc91	19
no1	21

Quintana-Lacaci et al. in prep.