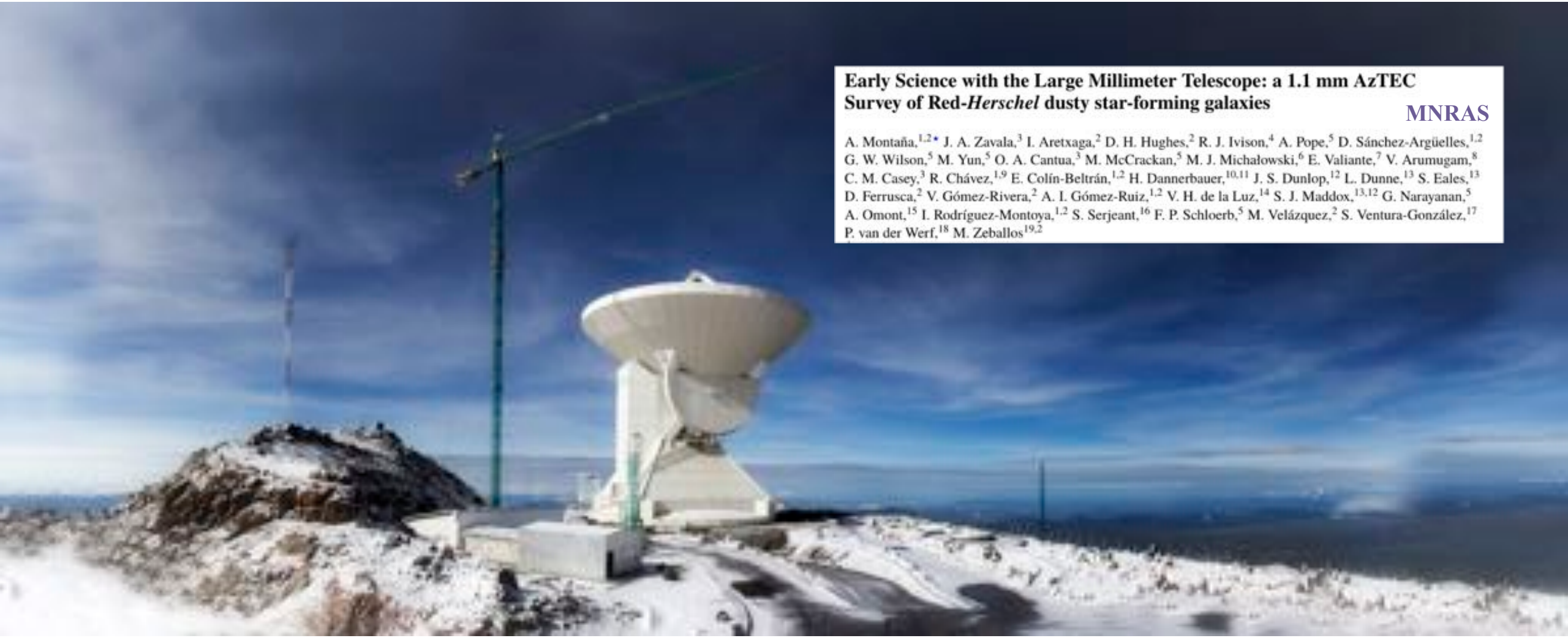
A 1.1 mm AzTEC Survey of Red-*Herschel* dusty star-forming galaxies



Early Science with the Large Millimeter Telescope: a 1.1 mm AzTEC Survey of Red-*Herschel* dusty star-forming galaxies

MNRAS

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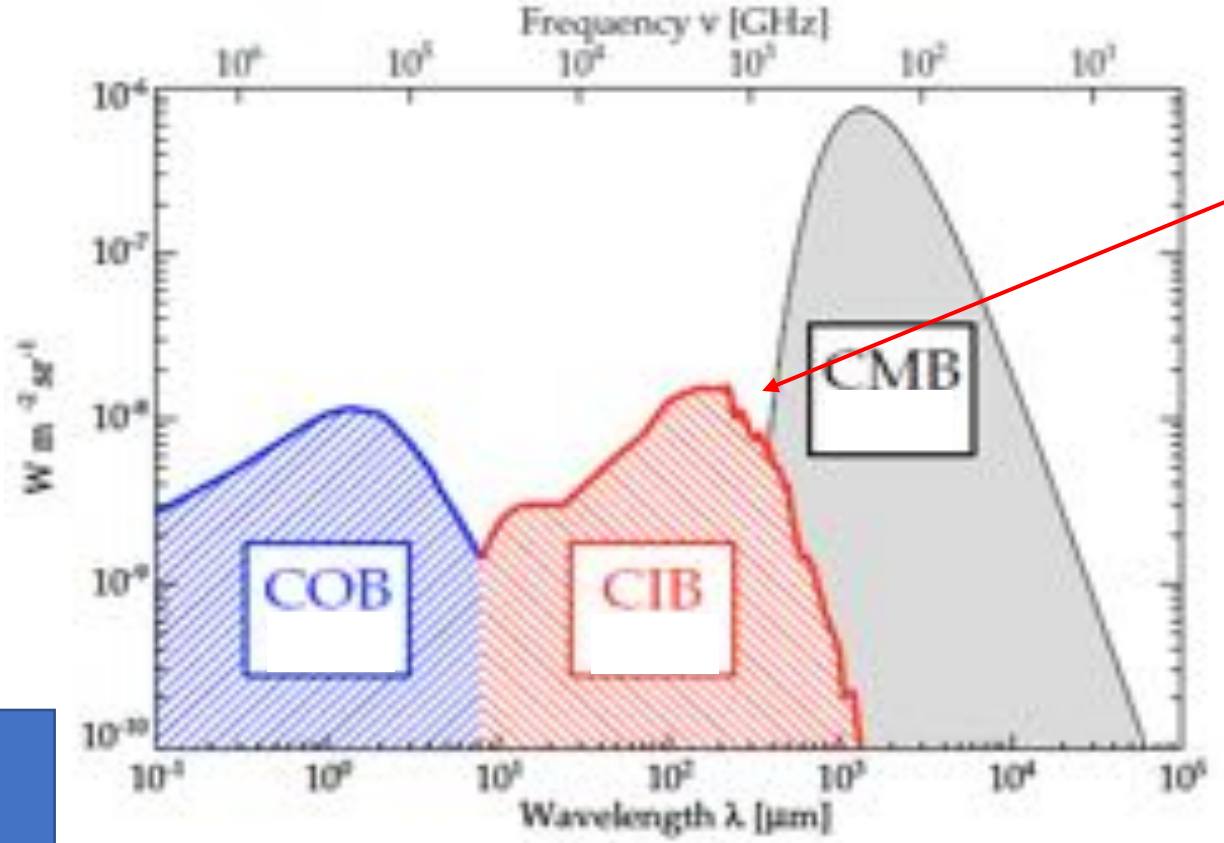
Catedrático CONACYT-INAOE/GTM

IRyA - Mayo 25, 2021

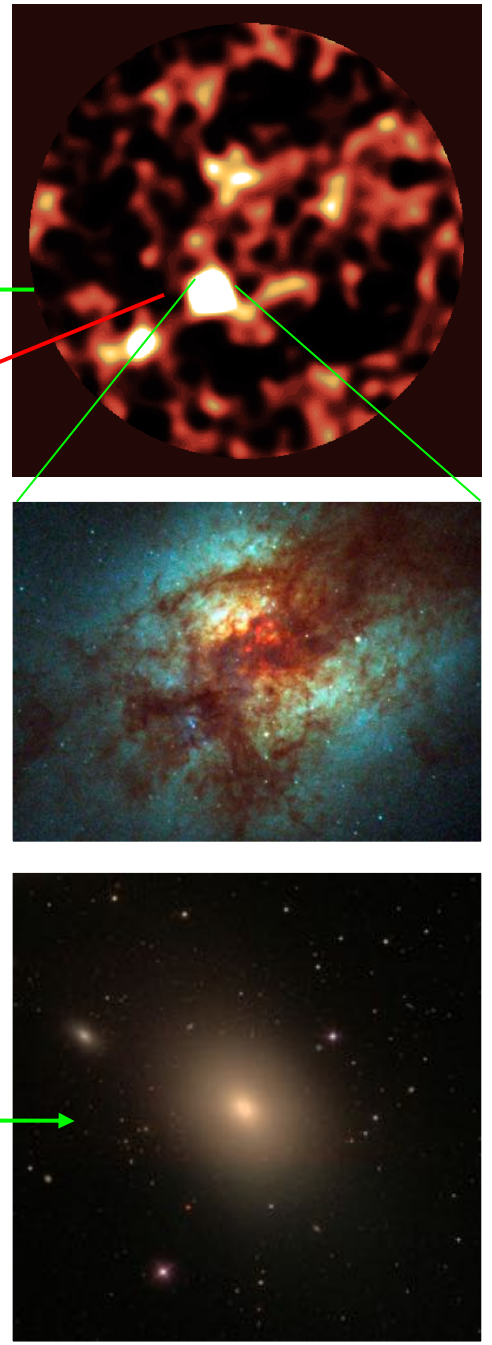
Sub-Millimeter Galaxies (SMGs)

Smail et al. 1997;
Hughes et al. 1998;
Barger et al. 1998

- High redshift population
  (z ~ 2-3)
- High IR luminosities
  ($L_{IR} \sim 10^{12} - 10^{13}\ L_{\odot}$)
- Star Formation Rates
  (SFR ~ 100 – 1000 $M_{\odot}$/yr)
- Dusty
  ($M_{dust} \sim 10^{8\text{-}9}\ M_{\odot}$)



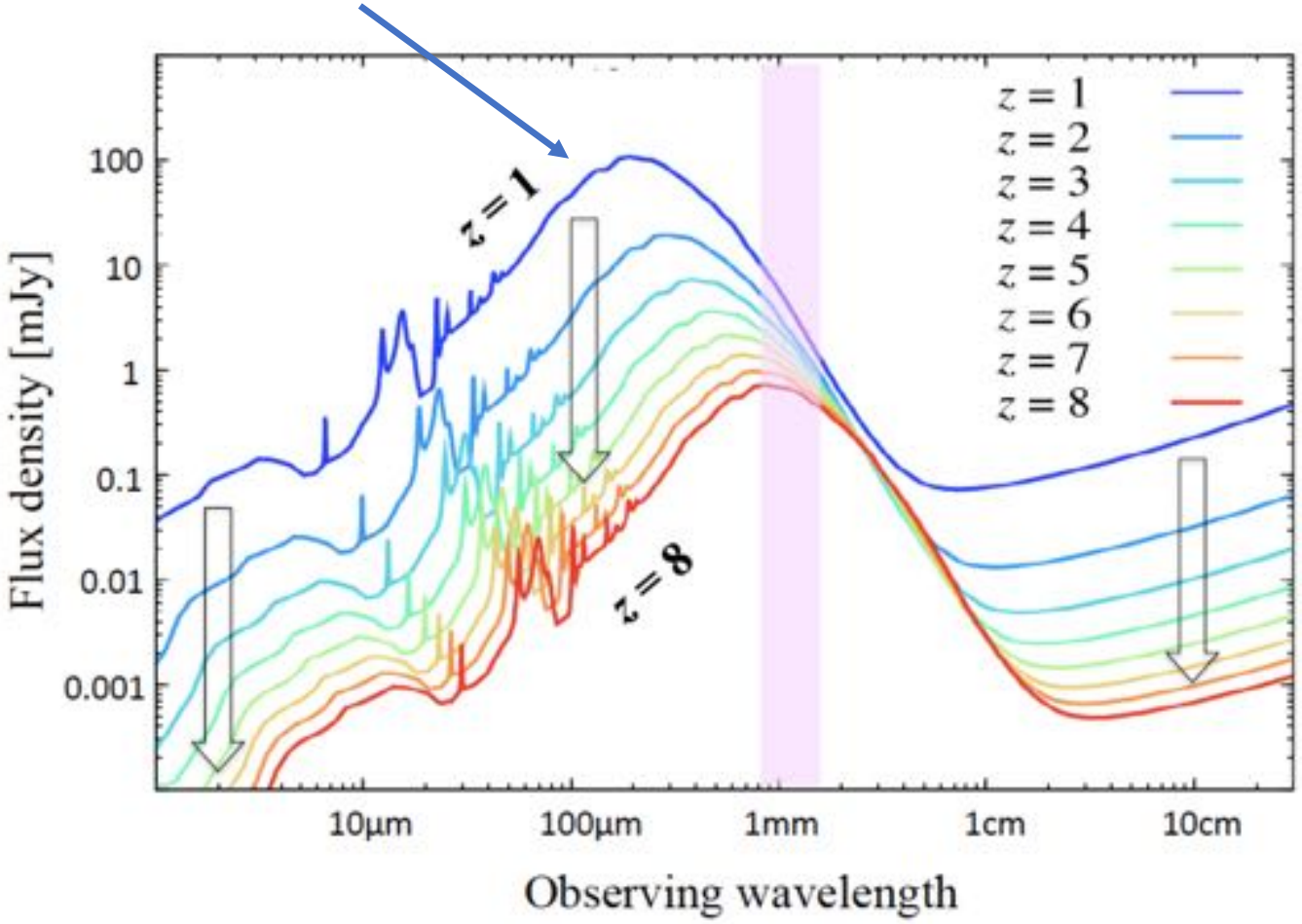
High-z ULIRGs (?)
Massive Elliptical progenitors (?)



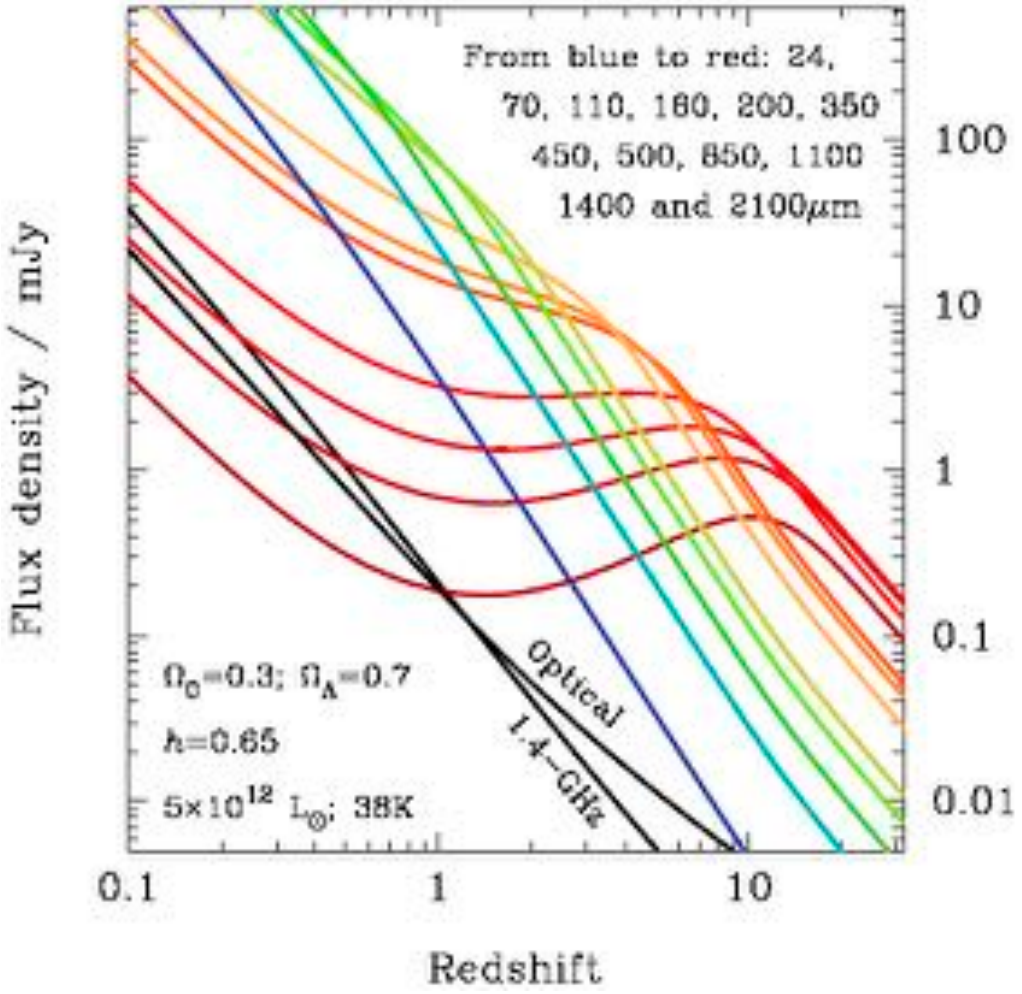
02/17

Negative *k* correction

Thermal dust emission

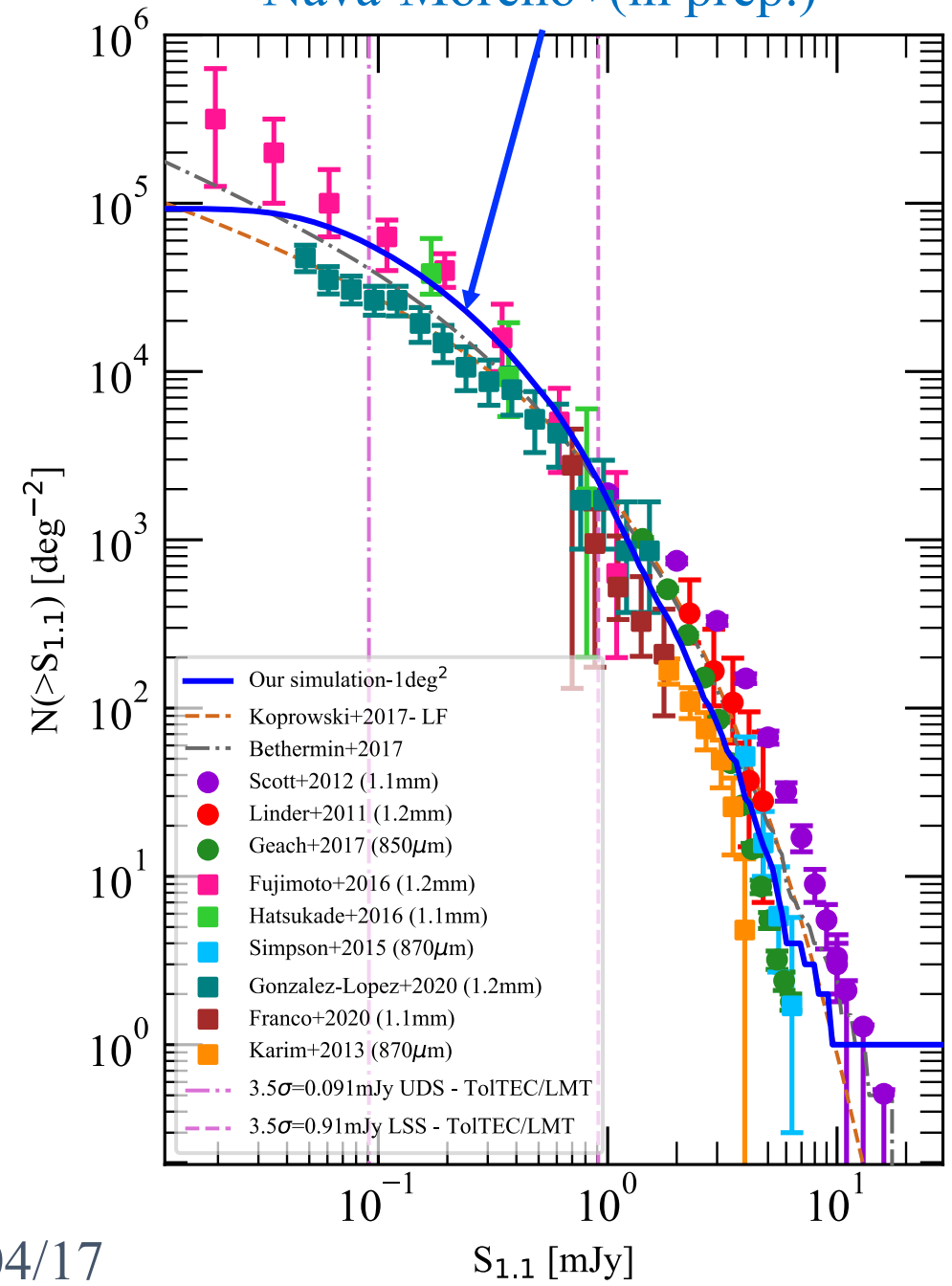


Kohno+2010



Blain+2002

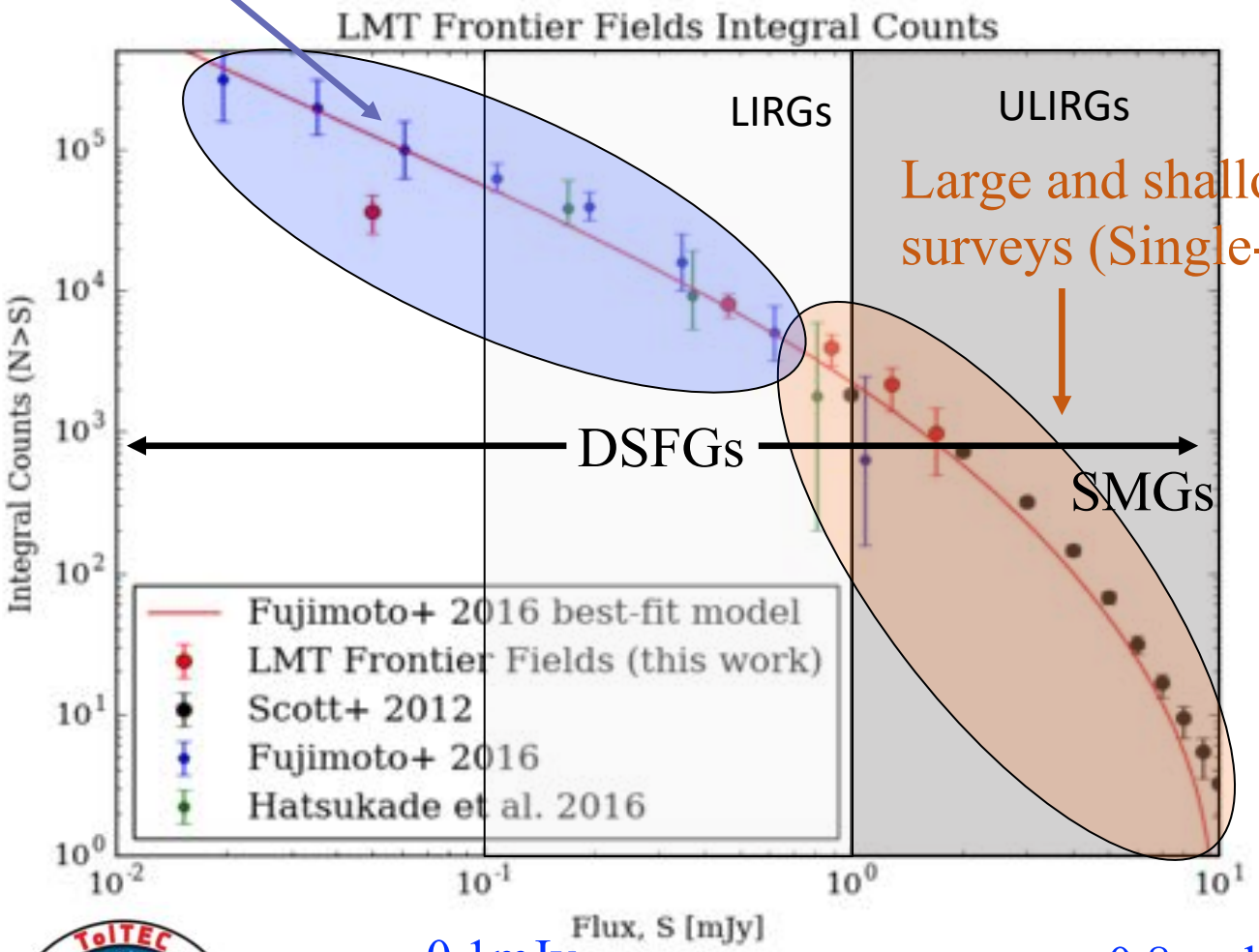
Nava-Moreno+(in prep.)



Deep and small surveys
(Interferometers, grav. lensing)

Montaña+(in prep.)

@1.1mm



Large and shallow surveys (Single-dish

~0.1mJy ~0.8sq.deg

UDF

~1mJy ~50sq.deg

LSSF

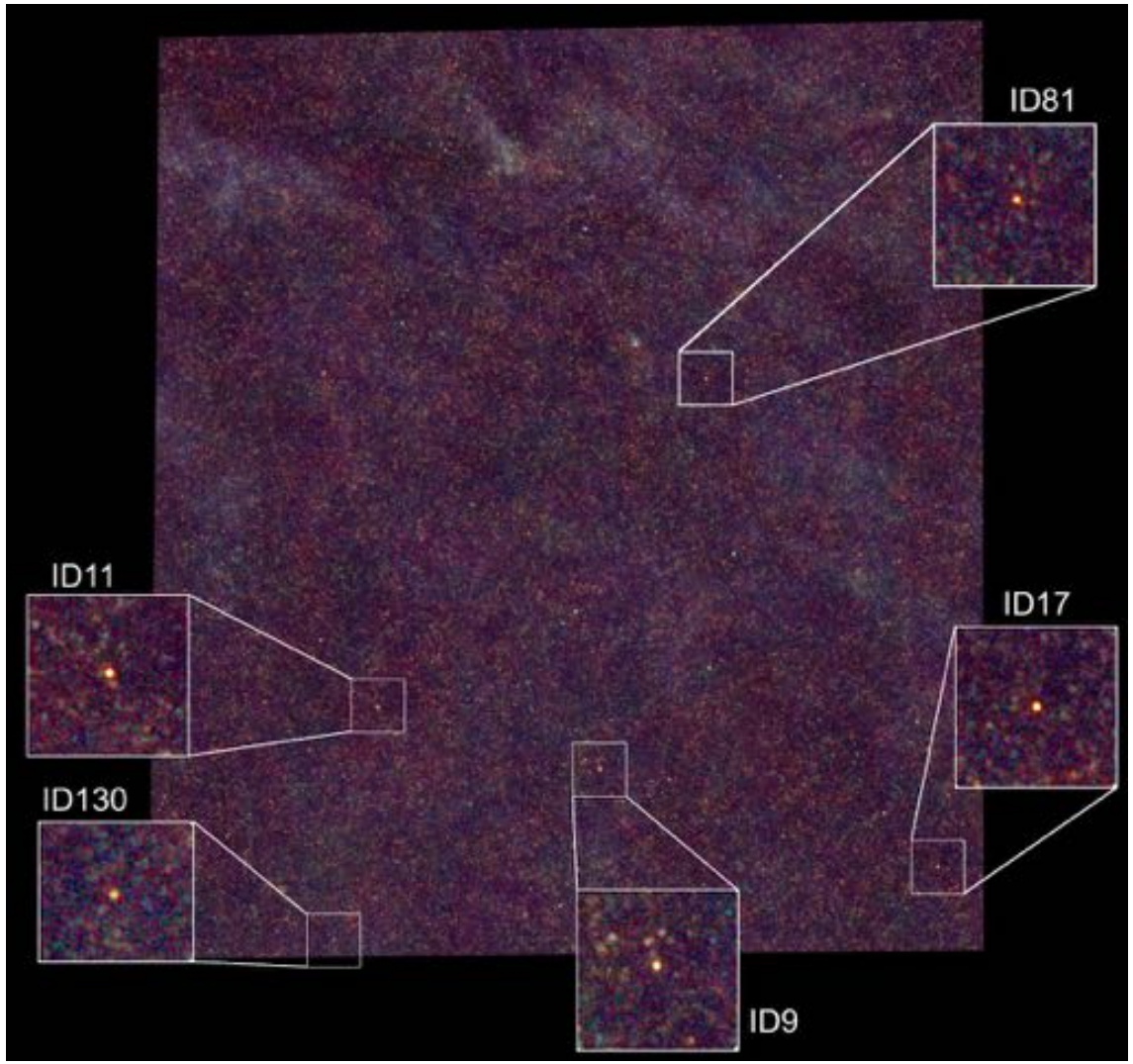
04/17

Herschel-ATLAS (*H*-ATLAS) ➞

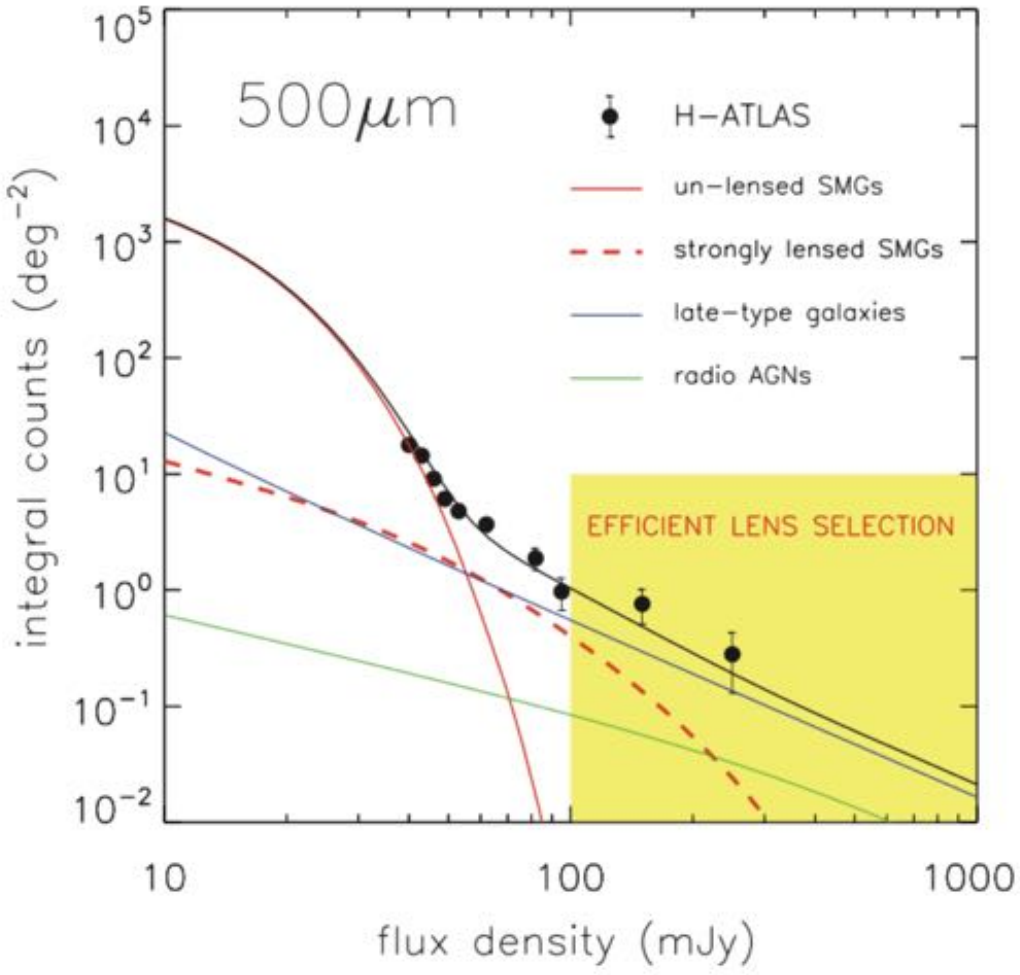
~ 600 sq.deg in 5 fields

Eales+2010; Valiante+2016

PACS: λ = 100 y 160 μm
SPIRE: λ = 250, 350 y 500 μm
1σ = 7.4, 9.4 and 10.2 mJy
FWHM = 17.8”, 24.0” y 36.6”



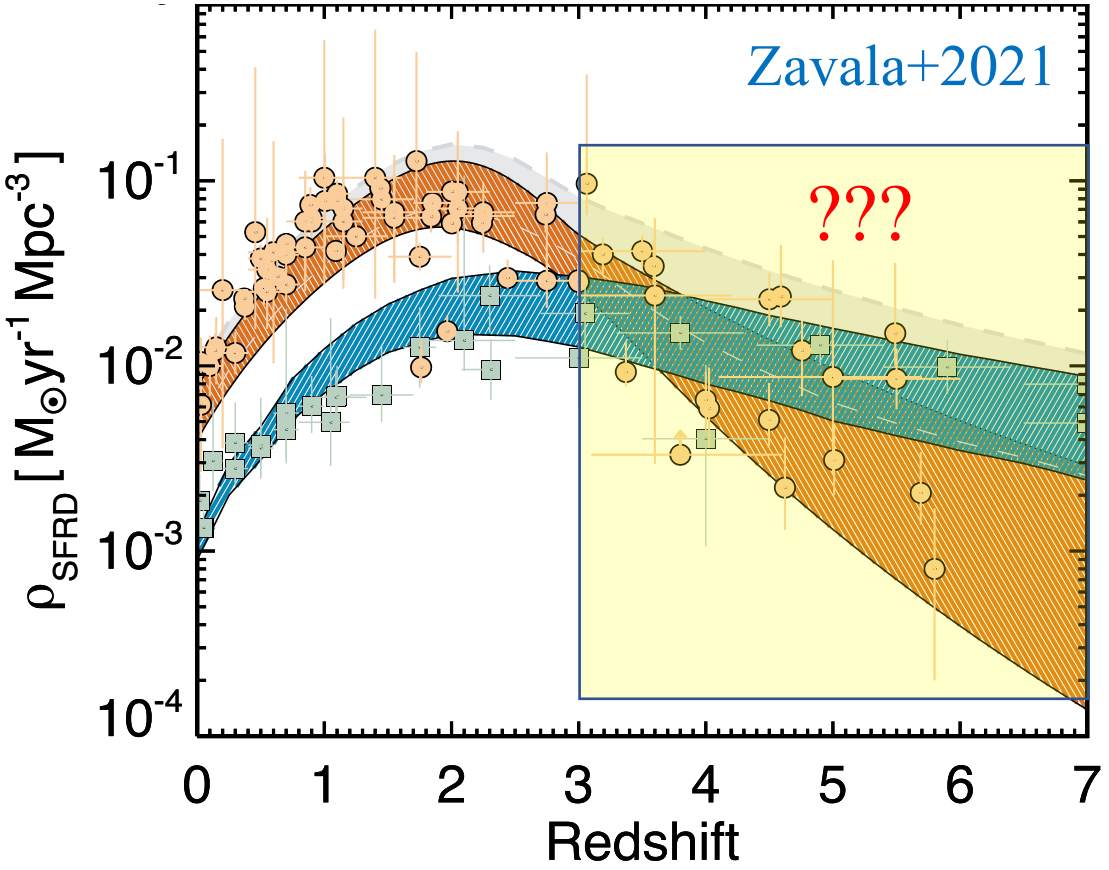
The *Herschel* 500μm counts Negrello+2010



Planck
SPT
ACT

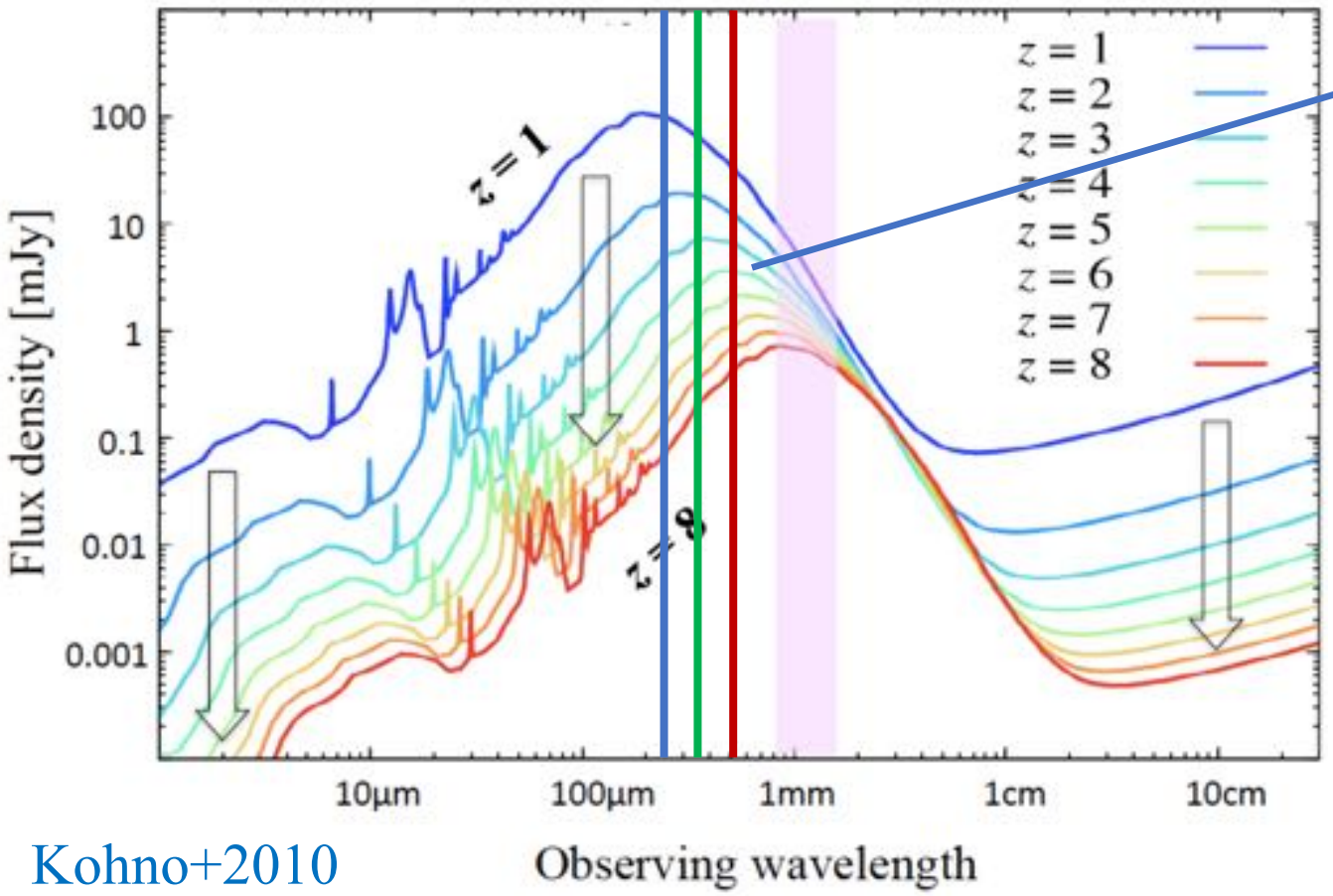
Sub-Millimeter Galaxies (SMGs / DSFGs)

- Distribution at z > 4?
- Space density?
- Contribution to the SFRD at z > 4?
- Are they really progenitors of massive ellipticals?
- What triggers their high SFR?
- Mergers or extreme discs?
- How do they trace the LSS (bias)?
- What is the roll of environment in their evolution?



Selecting high-z candidates

SPIRE: λ = 250, 350 y 500 μm



Kohno+2010

500μm risers ➟ z > 4 candidates

The *H*-ATLAS sample of (ultra)red sources

Ivison+2016

7961 candidates

$S_{500}/S_{250} > 1.5$ and $S_{500}/S_{350} > 0.85$

$SNR_{500} > 3.5$

2725 eyeballed

22% rejected due to confusion

1.1mm AzTEC follow-up of *H*-ATLAS (ultra)red sources.

Early Science with the 32m-GTM (2014-2015)

Observations

FWHM ~ 9.5”

$< 1\sigma > = 1.5 \pm 0.5$ mJy

Sample

100 (93) ultra-red candidates

$S_{500}/S_{250} > 2$ and $S_{500}/S_{350} > 1$

$SNR_{500} > 5$

35 mJy $< S_{500} <$ 80 mJy

Cross-checked with radio, NIR and optical.

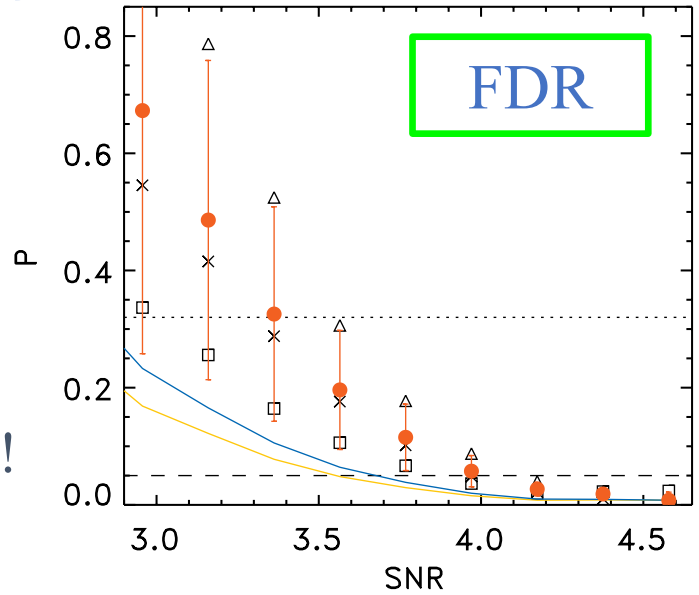
Source detection

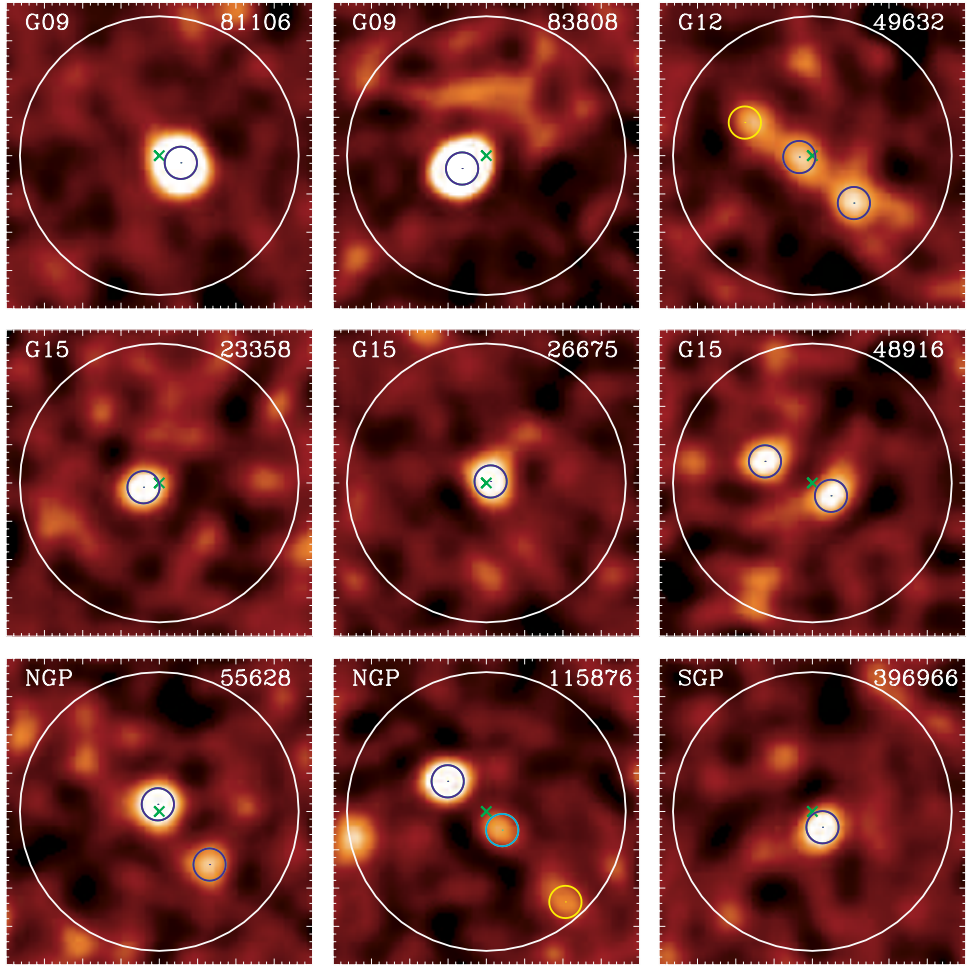
Above 4σ

40/93 ➟ 43% individual

8/93 ➟ 9% multiples

45/93 ➟ 48% non-detections!!!

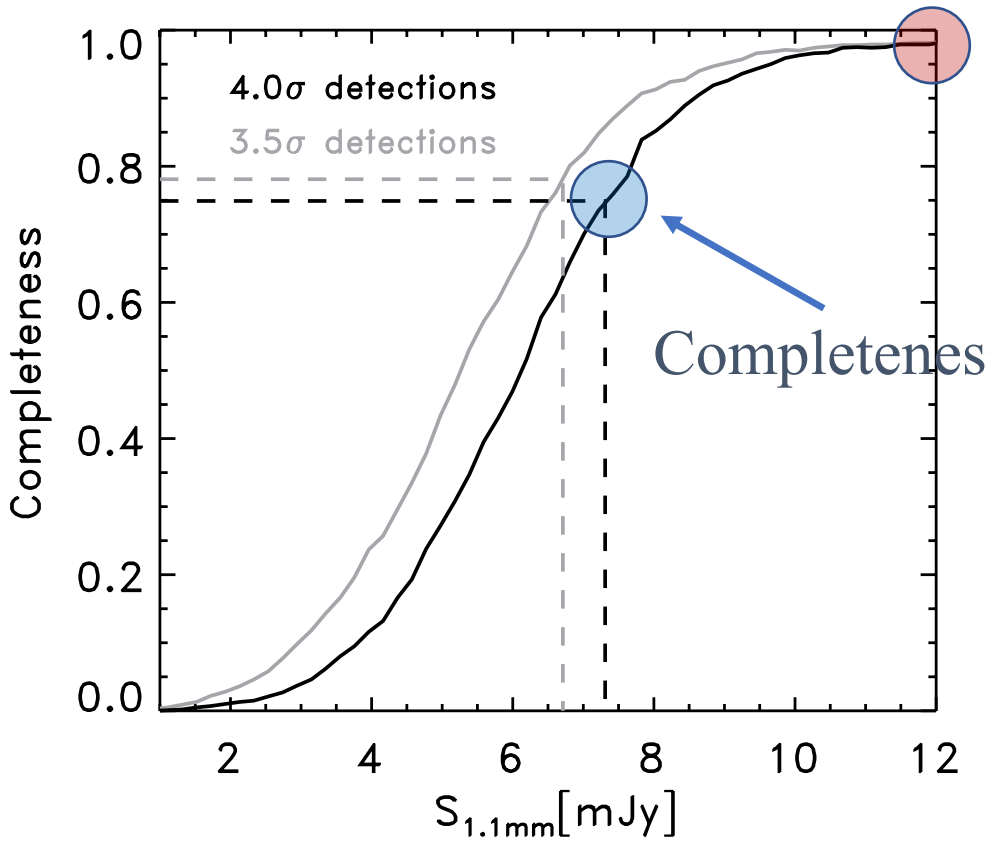




80”x80” postage-stamps (r~2arcmin)

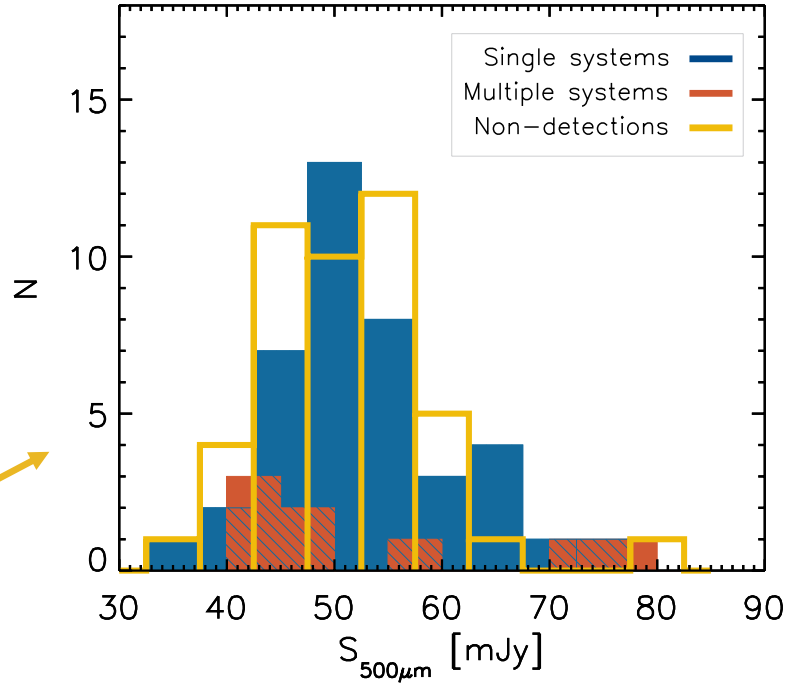
r_{search} = 36.6” (> FOV than interferometers)

Non-detections

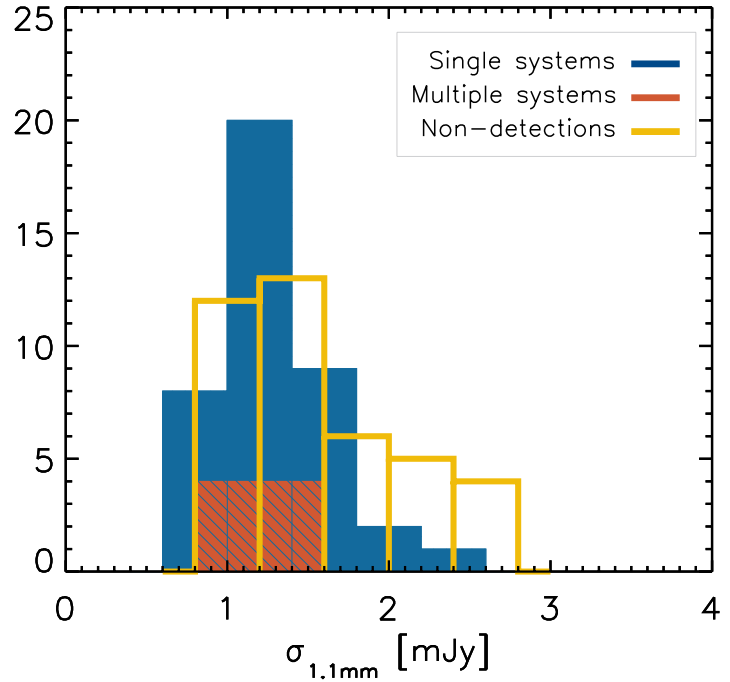


Completeness if S_{500} extrapolated to 1.1mm

Completeness from $< S_{1100} >$



Non-detections are not correlated with S_{500} or $\sigma_{1.1mm}$



- Multiple systems
- Steep RJ slopes (?)

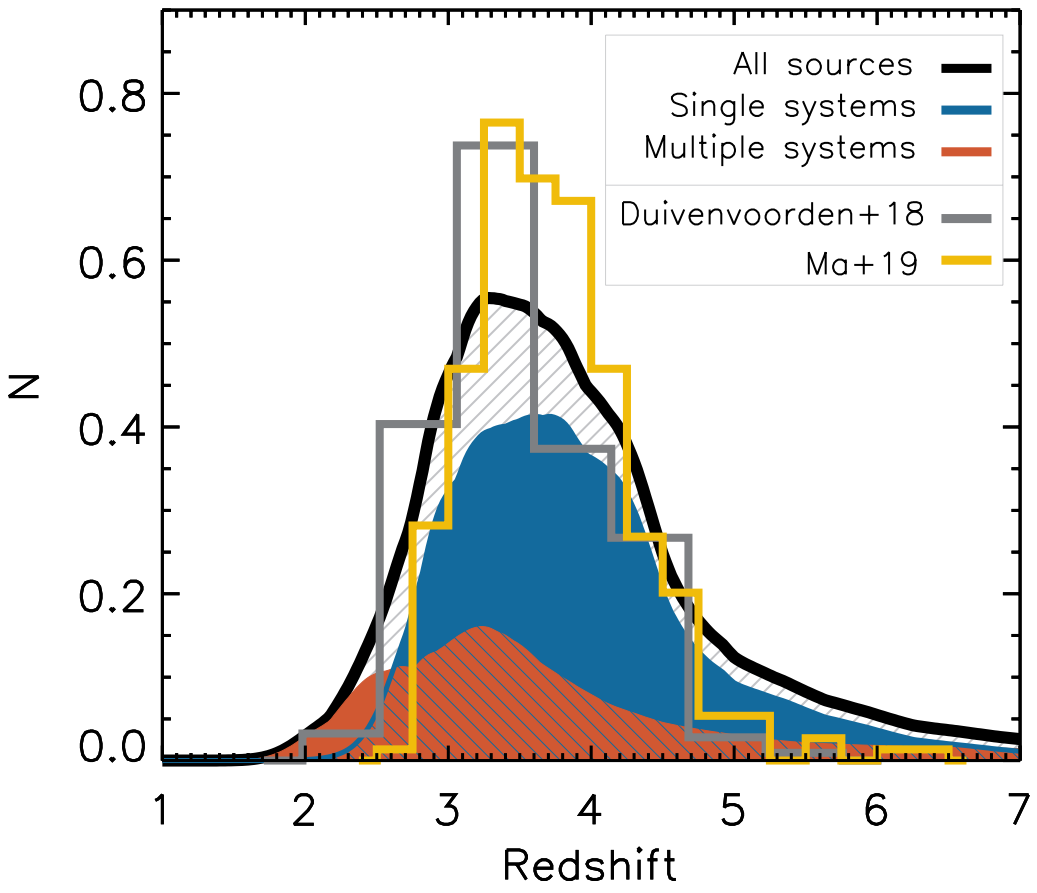
9% - 50%

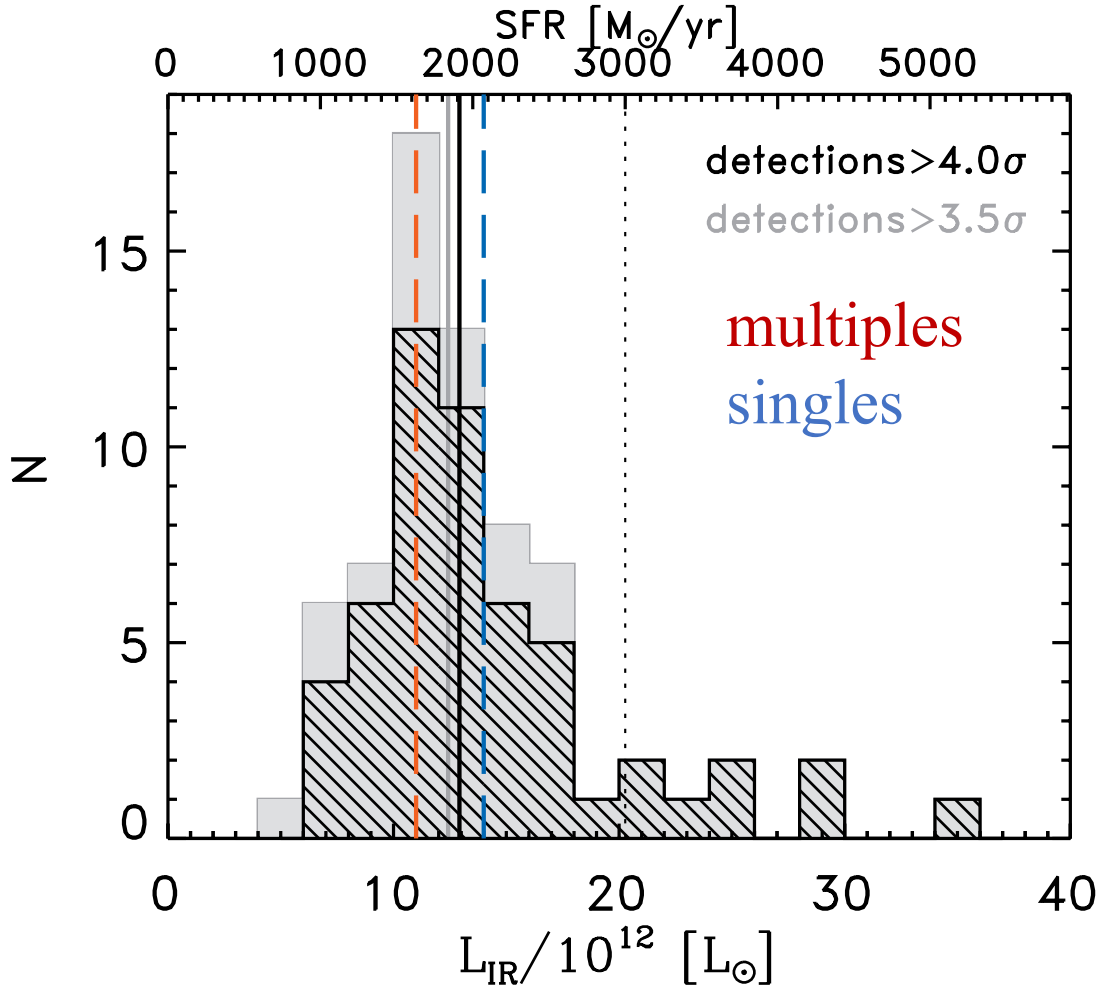
18% - 60%

+higher resolution multiplicity

Photo-z and L_{IR}

Using AzTEC and deblended *Herschel* photometry





< z > = 3.6 (3.8 vs 3.5)

85% @ z > 3

33% @ z > 4

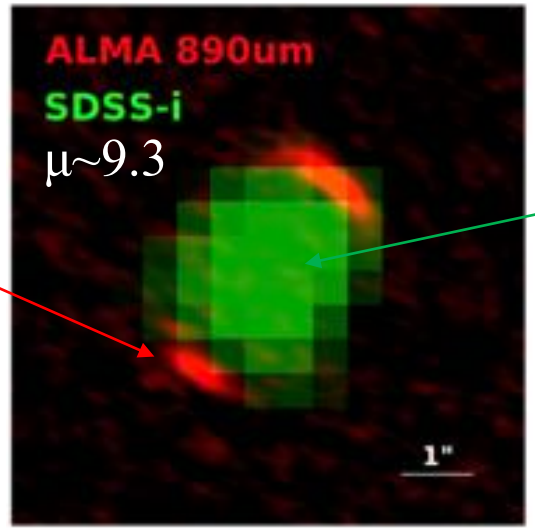
18 robust z > 4 candidates

< L_{IR} > ~ 1.3x10^{13} $L_\odot$

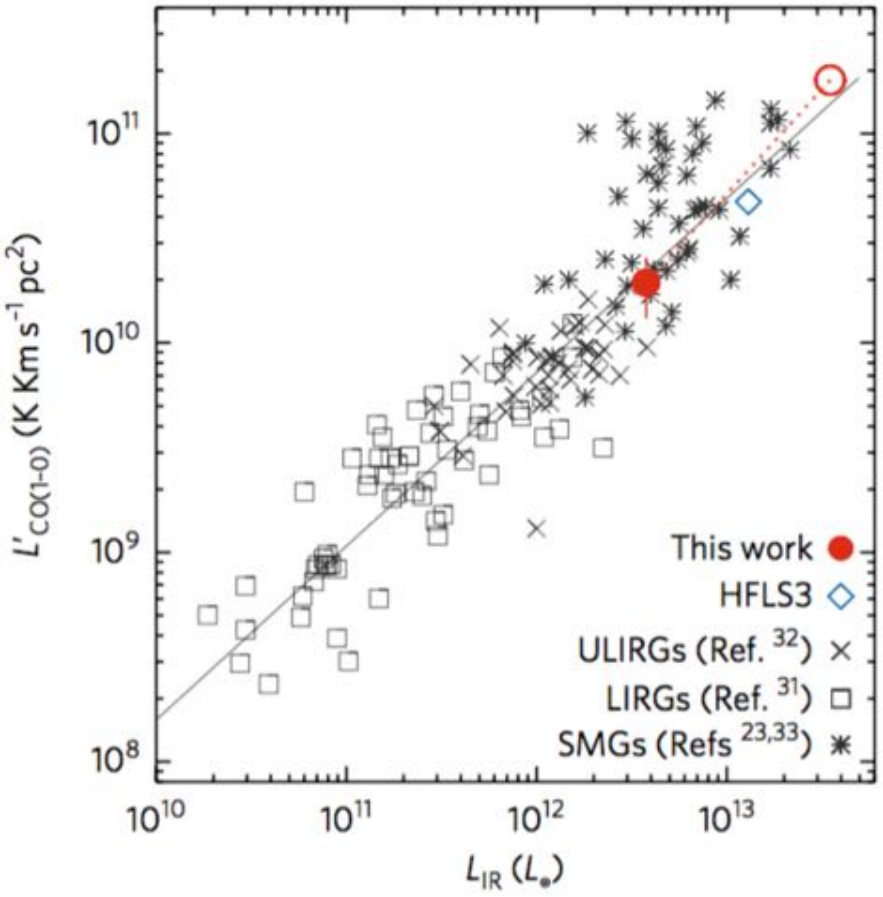
8 extreme candidates

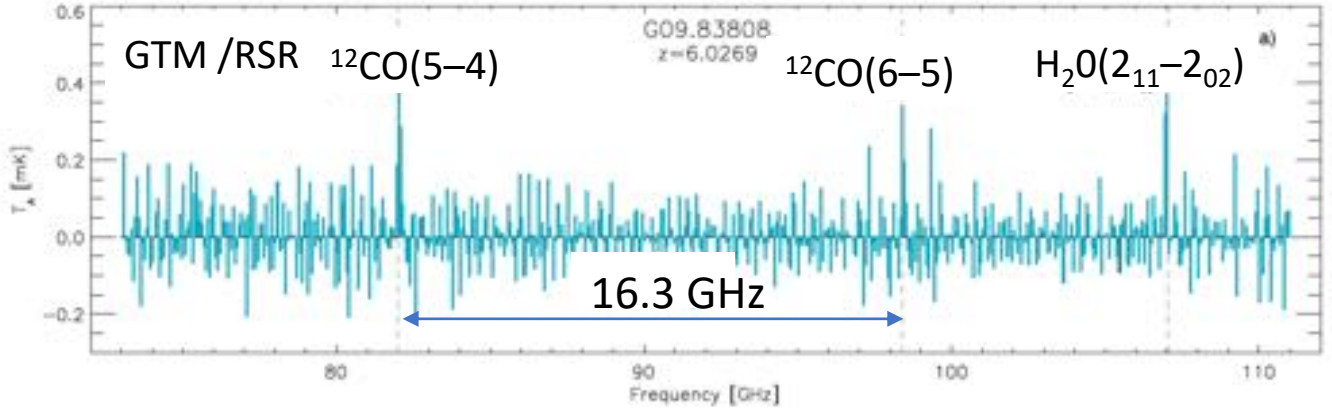
G09.83808 @ z = 6.03

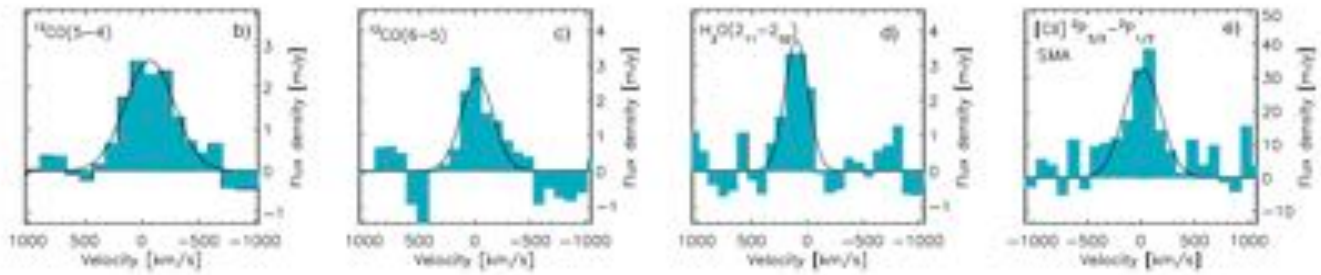
Zavala+2018



"Lens" @ z=0.77







SFR = 380 $M_\odot$/yr

SF efficiency comparable to local ULIRGS

RSR (3mm) and SMA (1mm) follow-up

RSR 3mm follow-up

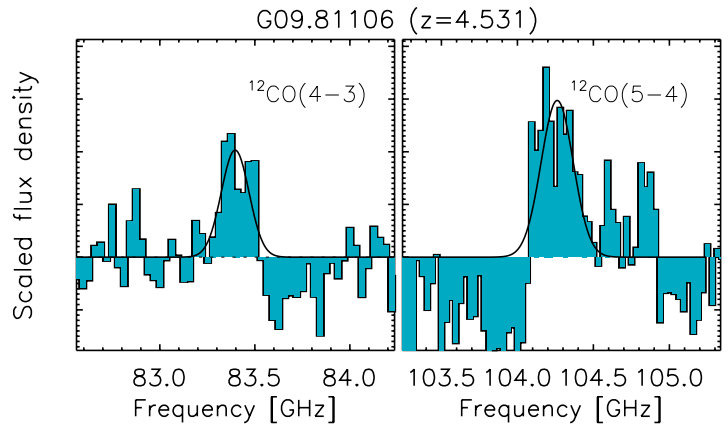
Physical properties
(Marianela Quirós, MSc thesis)

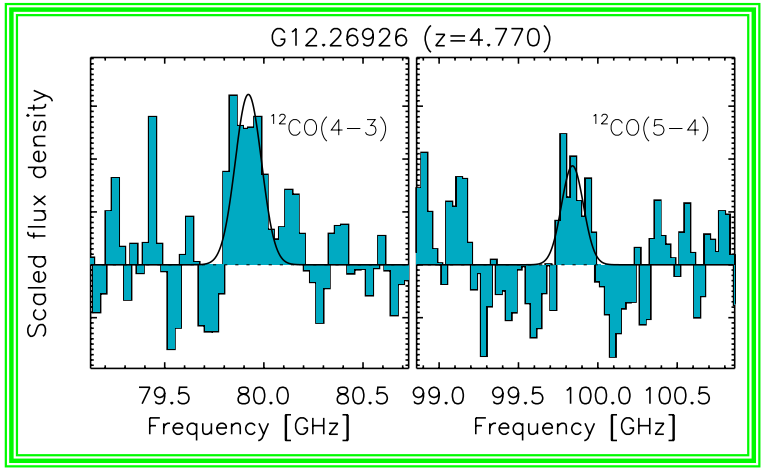
$< T_{dust} > \sim 48$ K
$< \beta > \sim 1.7$
$< M_{dust} > = 1.2 \times 10^9\ M_\odot$

$n_{H2} = 3.2 - 7.9\ cm^{-3}$
$< M_{gas} > = 1.9 \times 10^{11}\ M_\odot$

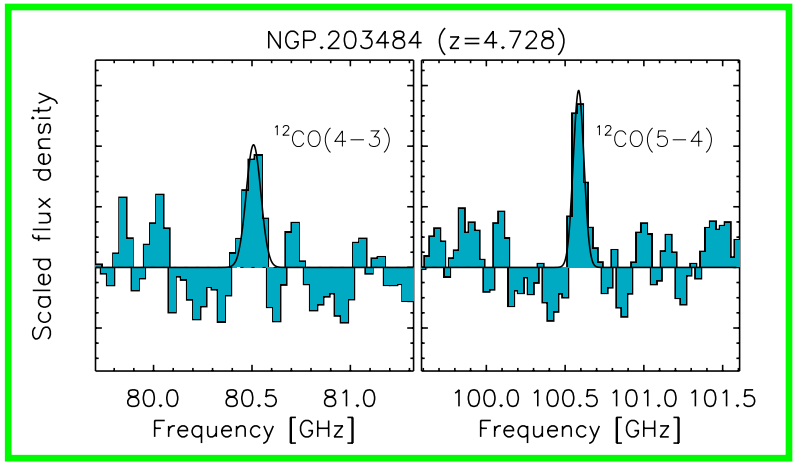
SFR = 2400 – 5200 $M_\odot$/yr
$\tau_{dep} = 30 - 82$ Myr

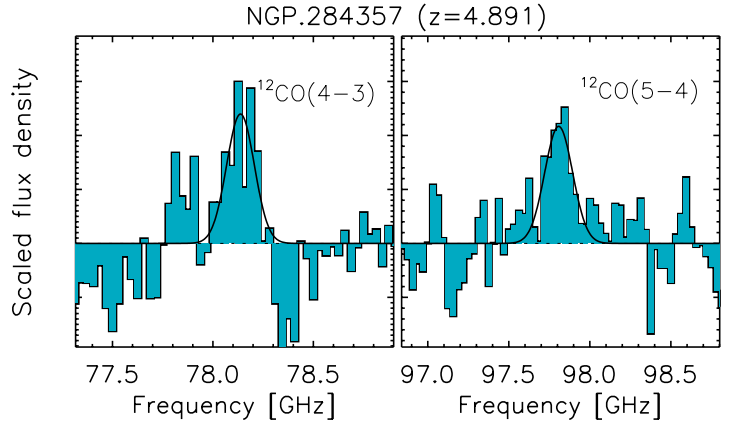
SLEDs: 2mm B4R/LMT
VLA

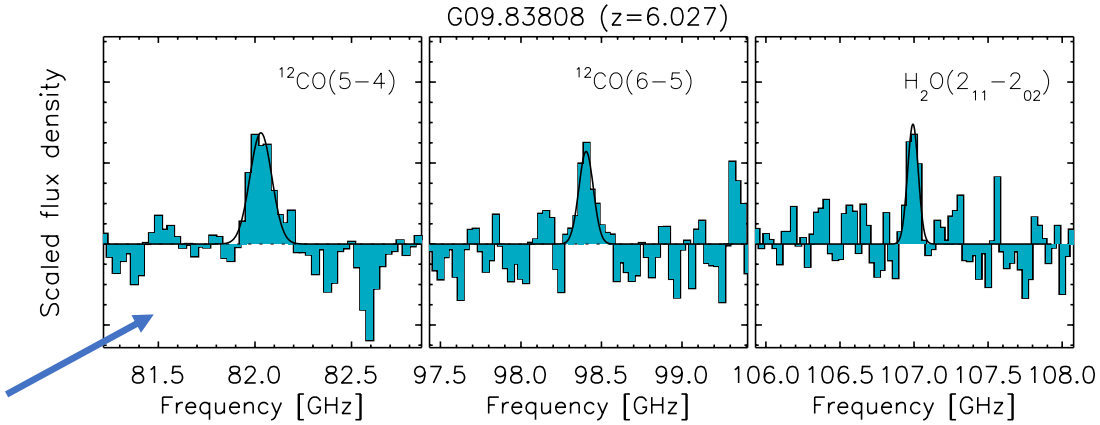


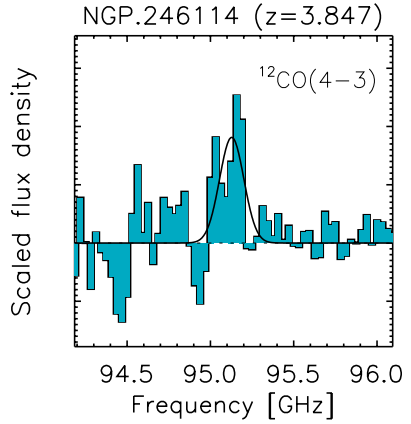


50m-LMT







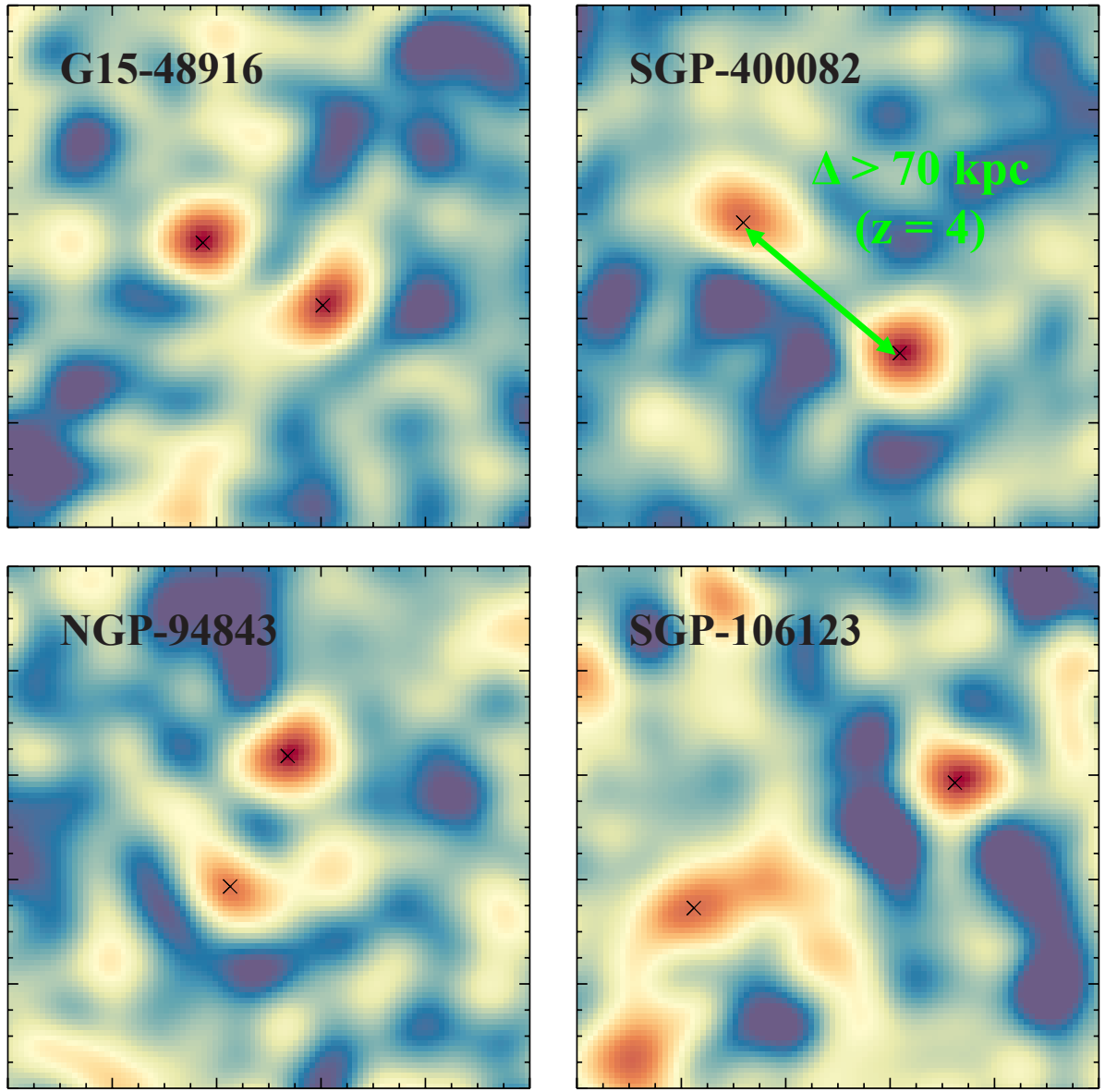


Fudamoto+2017

Zavala+2018

Physically Interacting Systems & Overdensities

$\Delta z < 0.06$



23 AzTEC "serendipitous" detections
But only ~4 are expected given the total survey area (~720 sq.arcmin).

Probability ~ 8×10^{-12}

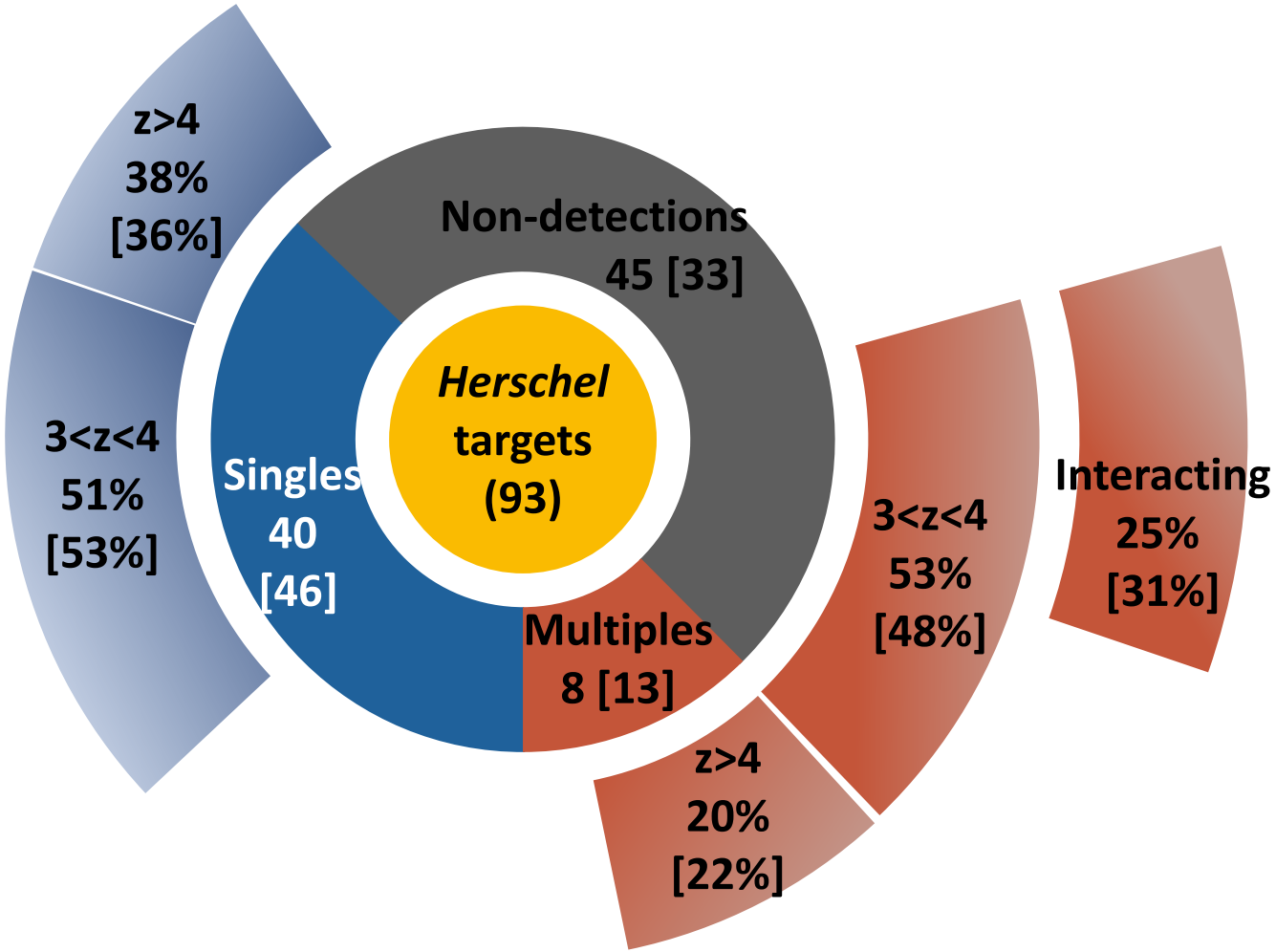
Overdensity parameter = 4.75
(in agreement with Lewis+2018)

Are some of these red-Herschel associated with high-z galaxy overdensities?

ALMA/LMT follow-up (please!)

pre-coalescence galaxy pairs?

Summary & Conclusions



Multiplicity

9% (18%) - 50% (60%)

~25% no longer "red" (Ma+2019)

Larger multiplicity fraction in the brighter (S_{500}>60mJy) targets.

Redshifts

$< z > = 3.6$ (3.8 vs 3.5)

85% @ $z > 3$ / 33% @ $z > 4$

Properties

$< L_{IR} > \sim 1.3 \times 10^{13}\ L_{\odot}$

SFR = 900 – 5200 $M_{\odot}$/yr

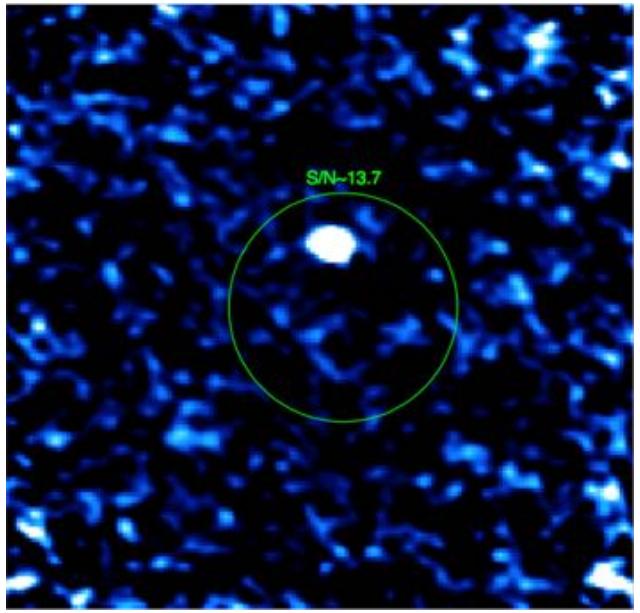
Population at $4 < z < 6$

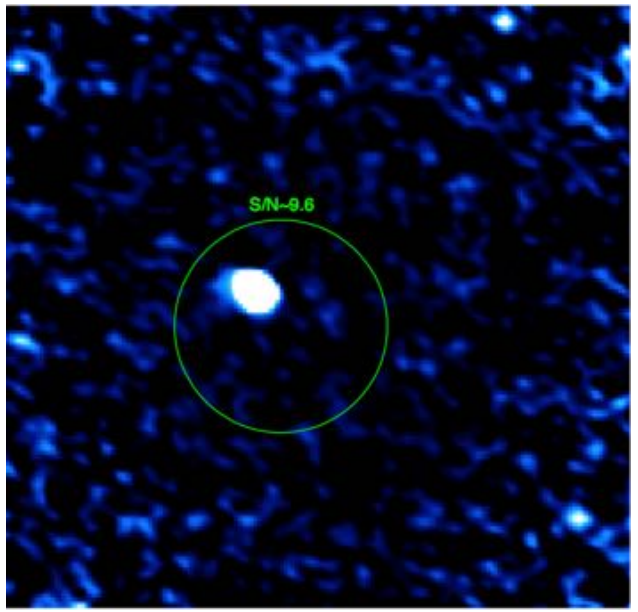
Space density = 3×10^{-7} Mpc^{-3}

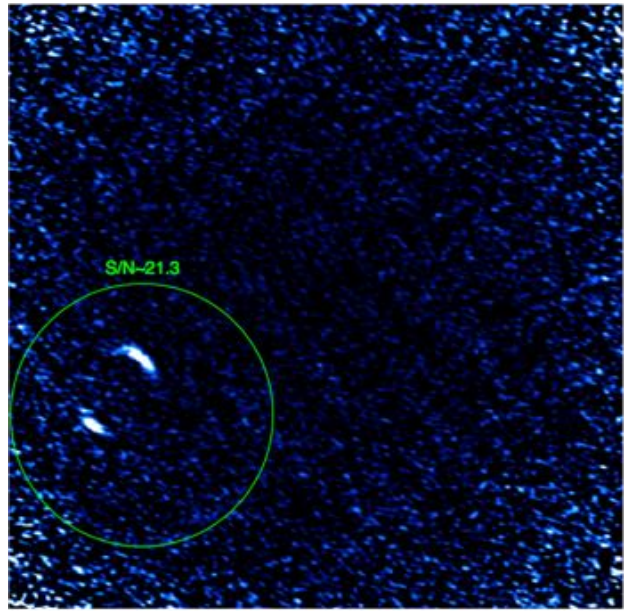
SFRD > 8 x 10^{-4} $M_{\odot}$/yr/Mpc^{-3}

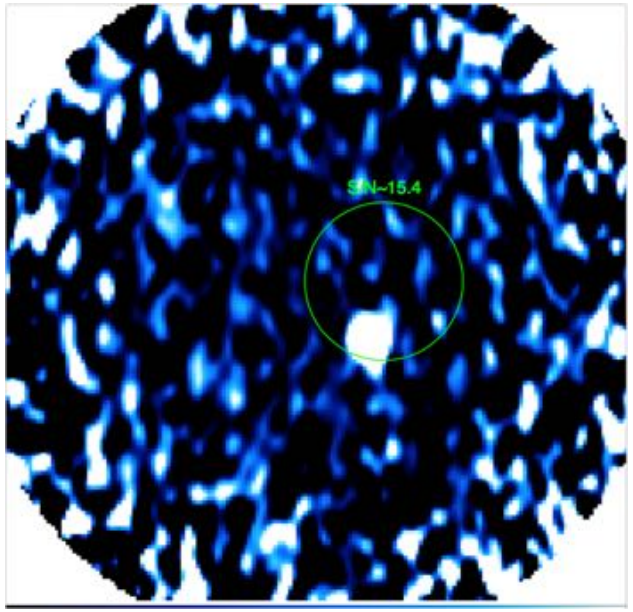
- 2 new z_{spec}>4 + 4 confirmed
- Catalogue with deblended photometry + sub-samples

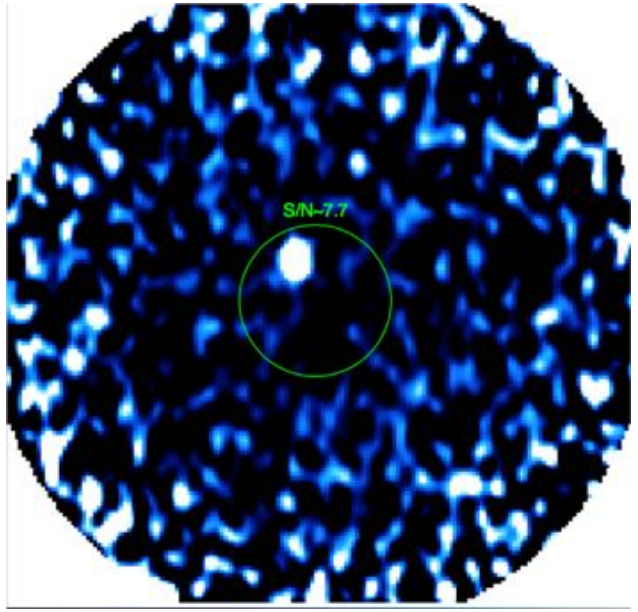
Bonus track (work in progress)

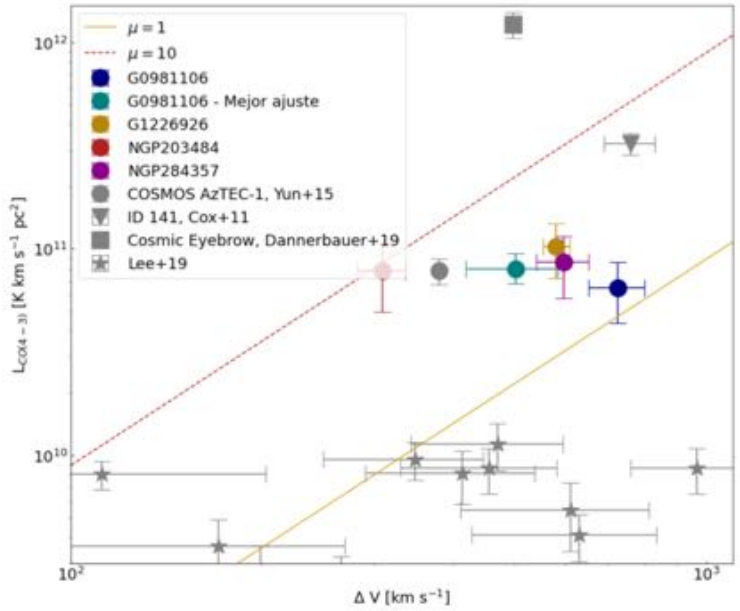












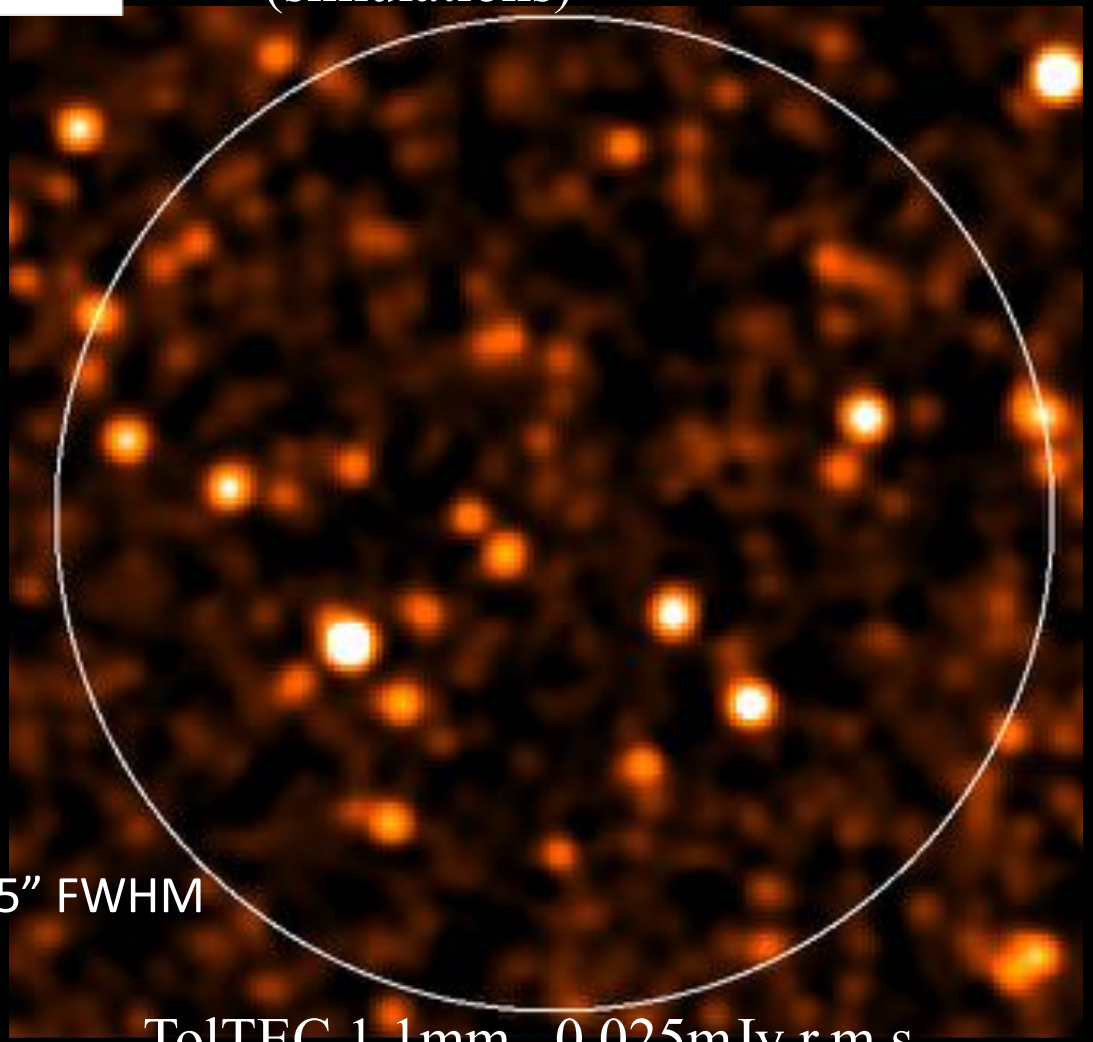
toltec.astro.umass.edu/

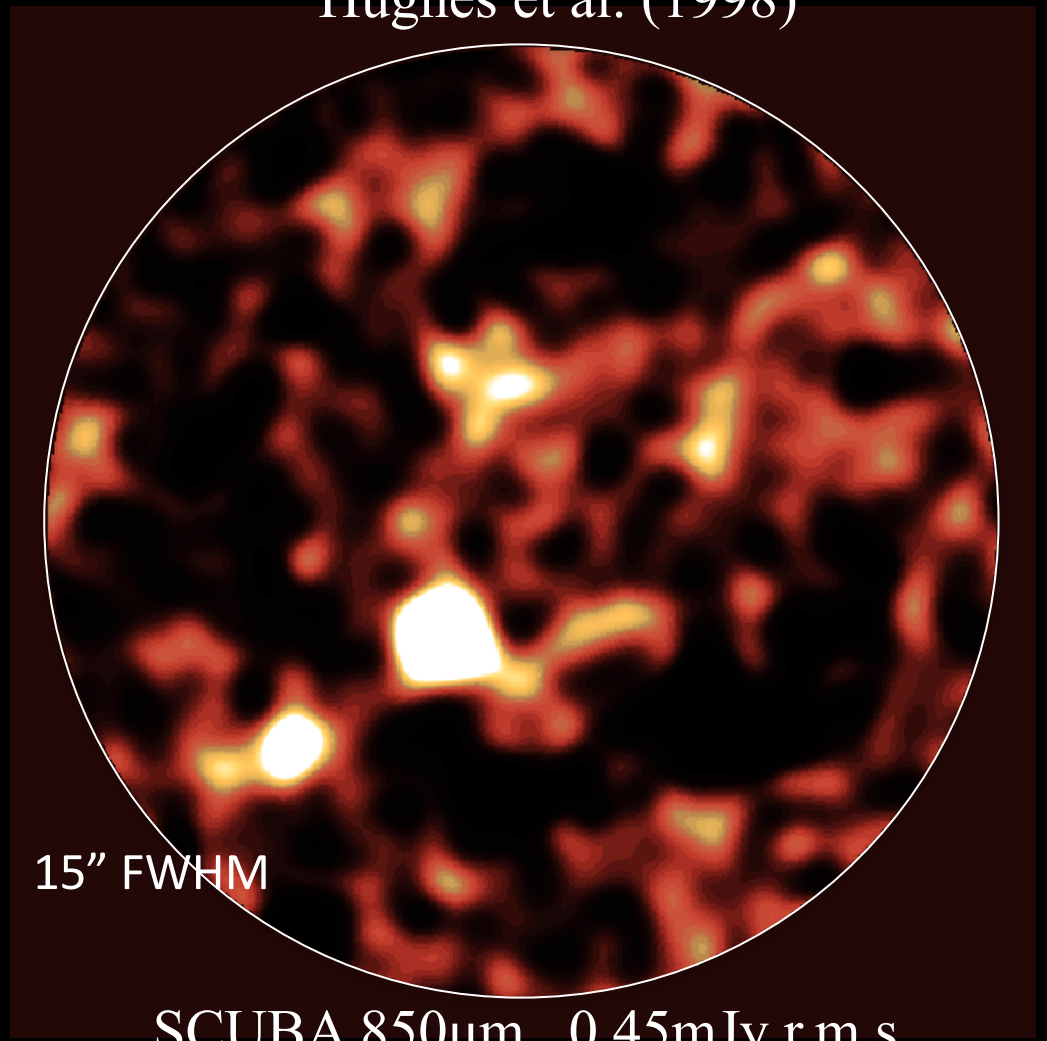
GTM 50-m / TolTEC (advertisement)

GTM/TolTEC 1.1mm
(simulations)

6 sq. arcmin

JCMT/SCUBA 850μm HDF survey
Hughes et al. (1998)





TolTEC 1.1mm, 0.025mJy r.m.s.
100 fuentes > 3σ

SCUBA 850μm, 0.45mJy r.m.s.
5 fuentes > 3σ

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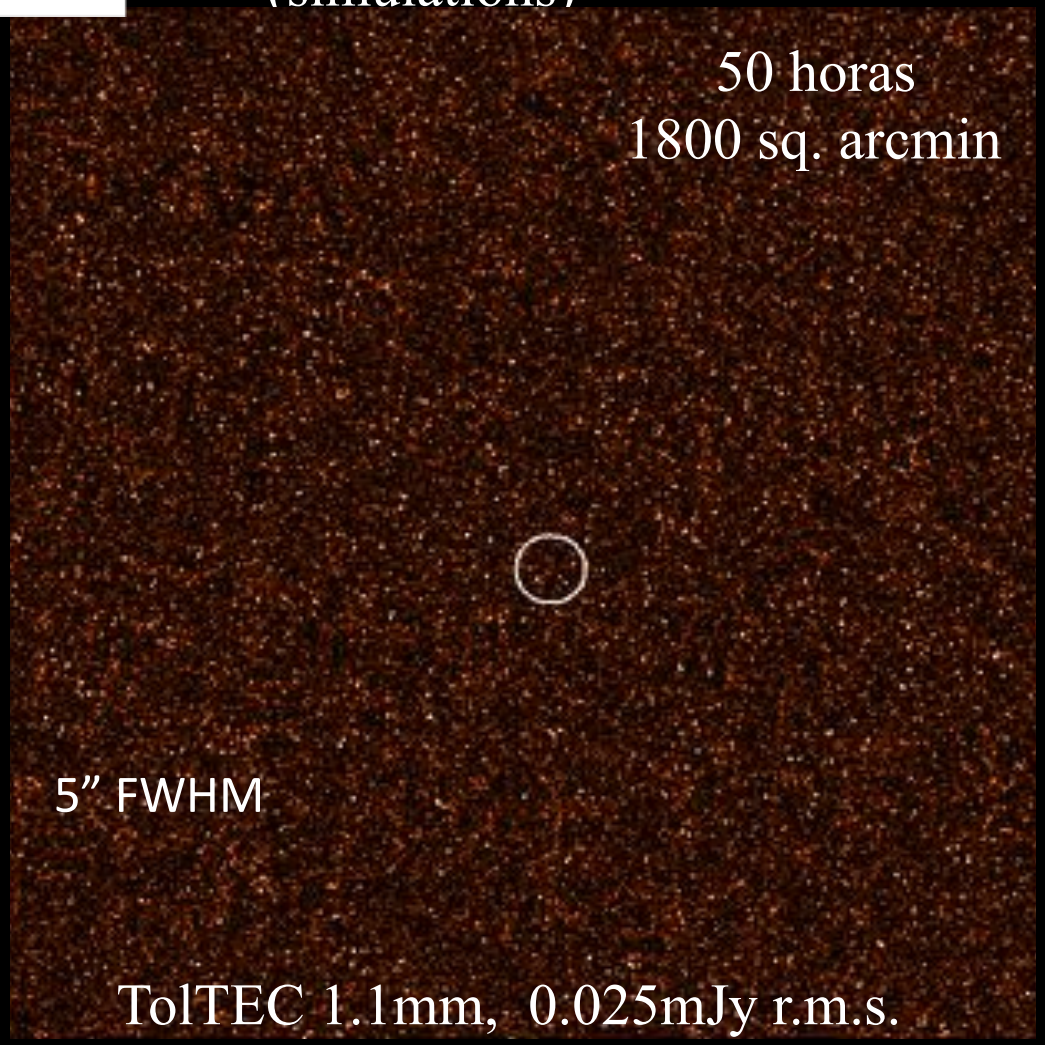
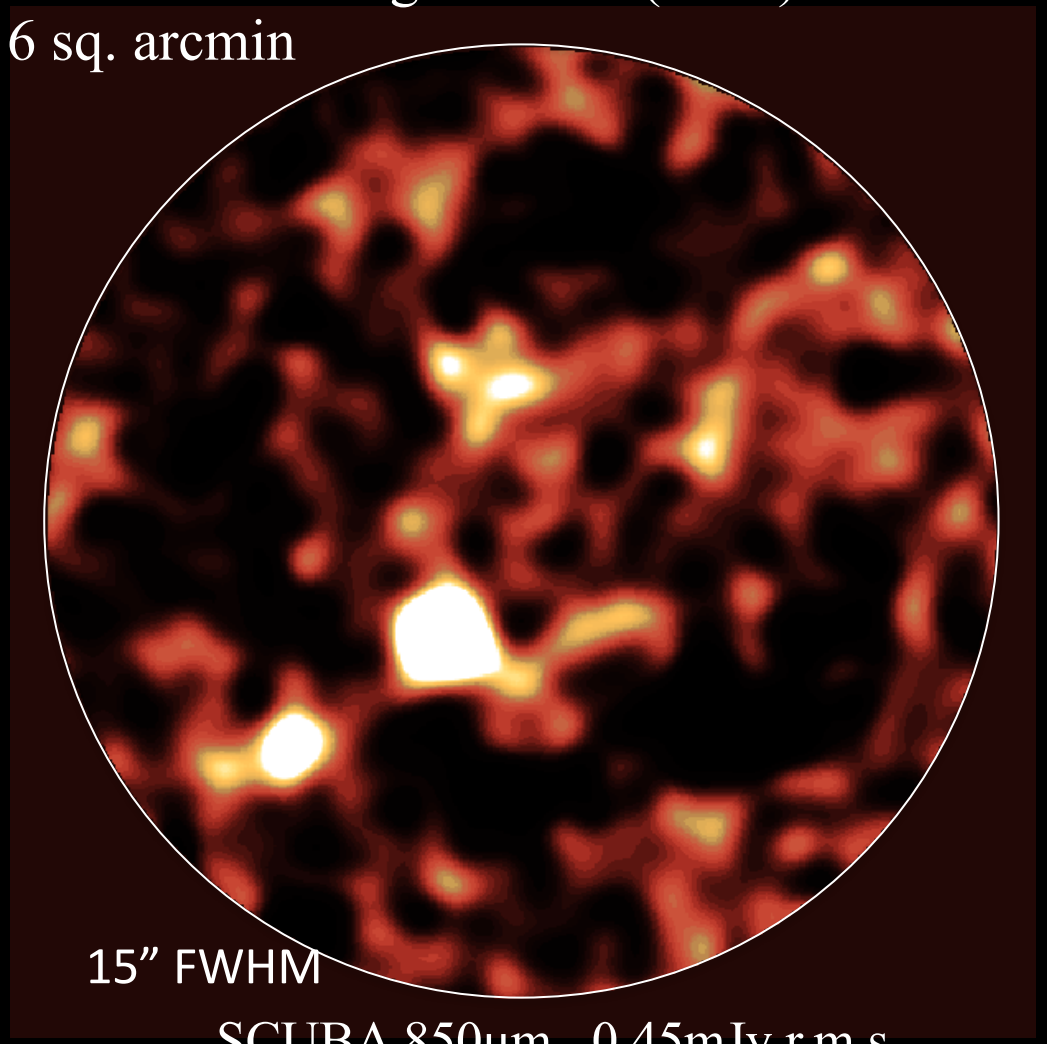
GTM 50-m / TolTEC (advertisement)

GTM/TolTEC 1.1mm
(simulations)



25,000 fuentes > 3σ + 1.4 & 2.0mm!!!

JCMT/SCUBA 850μm HDF survey
Hughes et al. (1998)

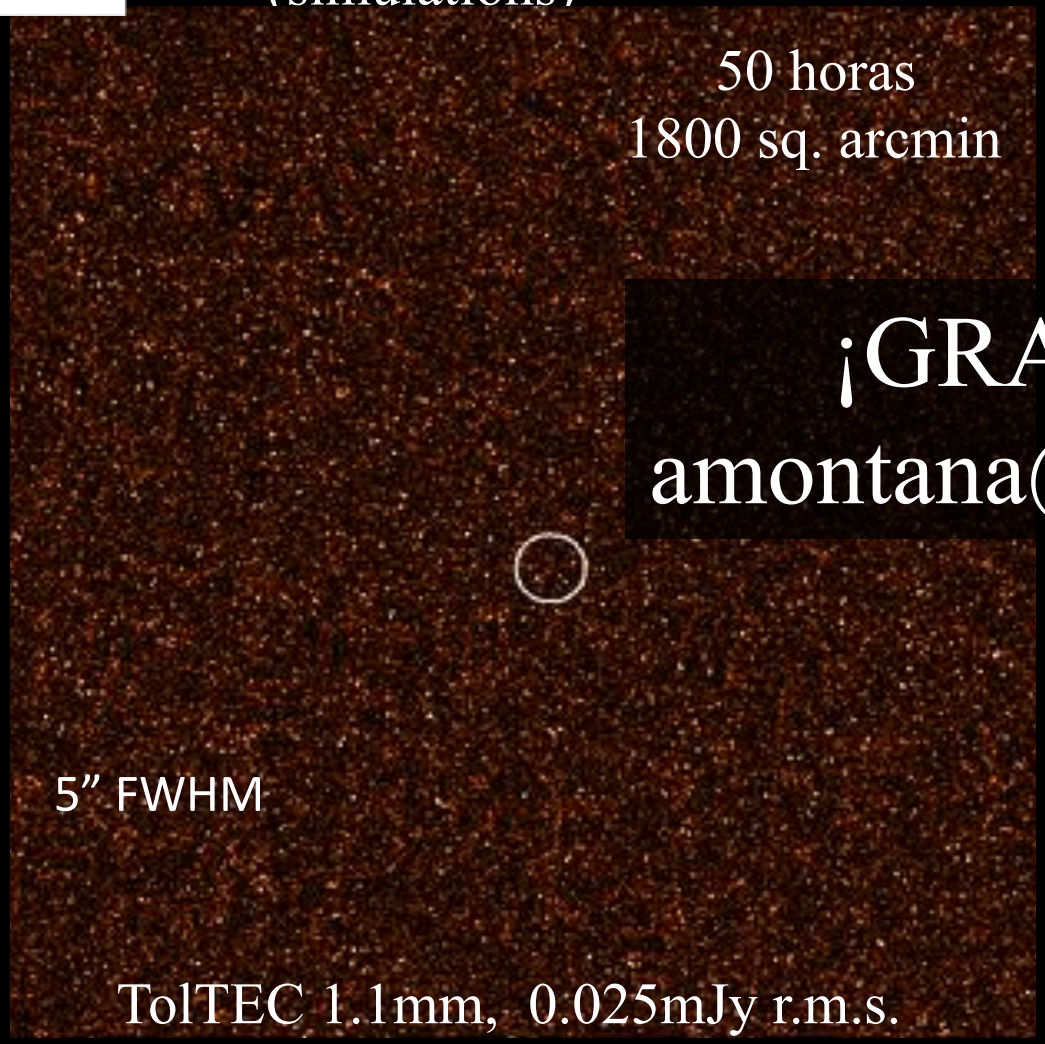


SCUBA 850μm, 0.45mJy r.m.s.
5 fuentes > 3σ

toltec.astro.umass.edu/

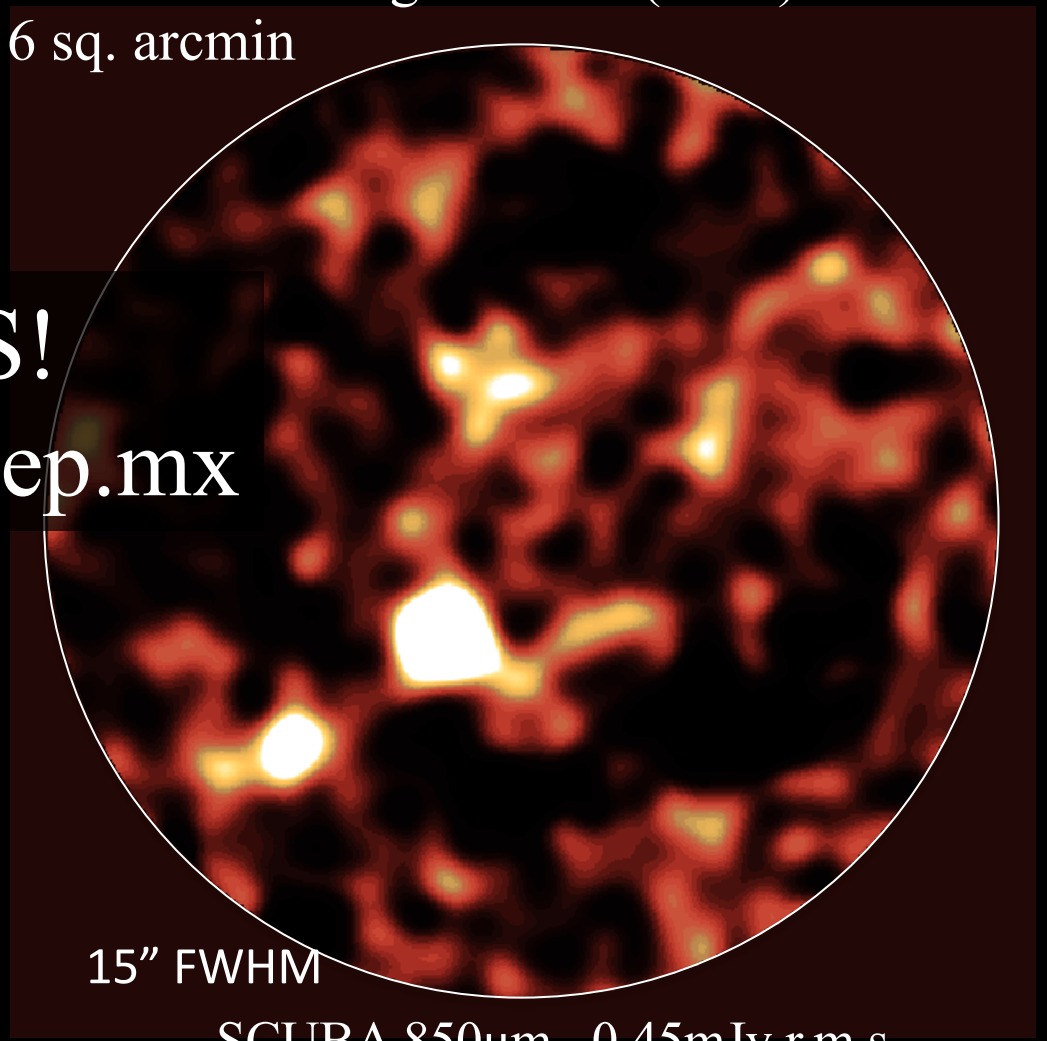
GTM 50-m / TolTEC (advertisement)

GTM/TolTEC 1.1mm
(simulations)



25,000 fuentes > 3σ

JCMT/SCUBA 850μm HDF survey
Hughes et al. (1998)



5 fuentes > 3σ

¡GRACIAS!

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