Recent studies of submillimetre galaxies in the COSMOS field

I) Physical properties and environment of z>4 SMGs

II) (Sub)mm interferometric imaging of a sample of COSMOS/AzTEC SMGs

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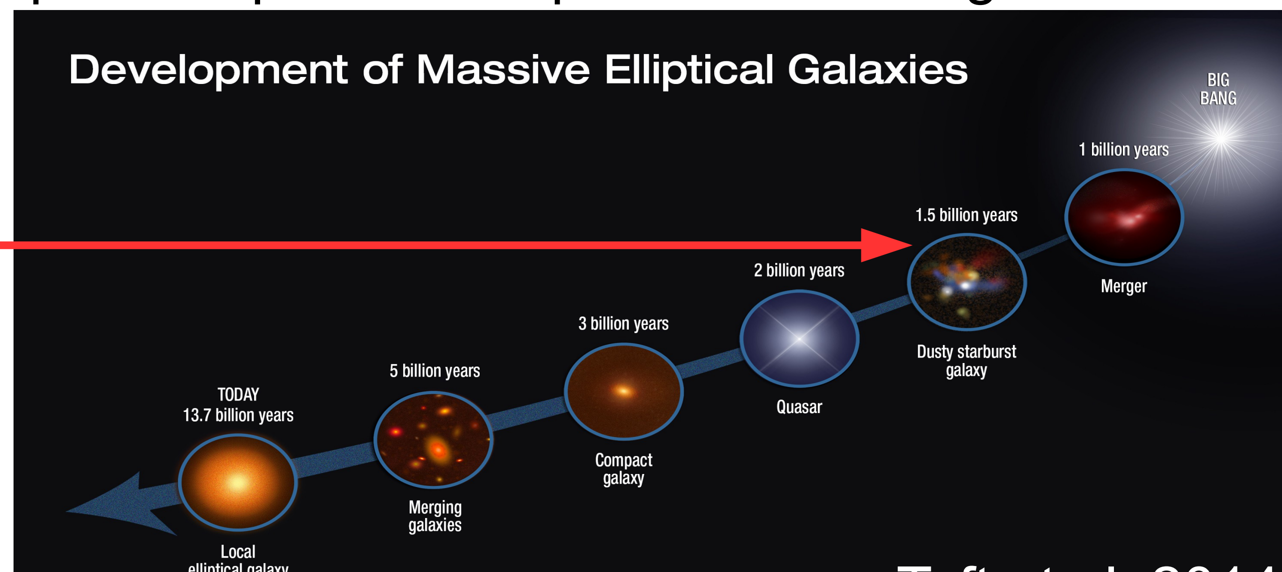
Charlottesville, Virginia (USA), 6 Aug 2014

SMGs

- very high IR luminosities of $L_{IR} \sim 10^{12}$- $10^{13}\,L_{\odot}$ ⇒ **dusty objects**
- very high SFRs: ~100-1000 $M_{\odot}\,yr^{-1}$ ⇒ **starbursts** (triggered by mergers ?)
- the bulk of SMGs at ***z* ~ 2.2-2.5** (e.g. Chapman et al. 2005; Casey et al. 2013; Simpson et al. 2014)
- the high-*z* (*z* > 3-4) SMG population provides important knowledge of galaxy formation/evolution

Precursors of massive elliptical galaxies ?



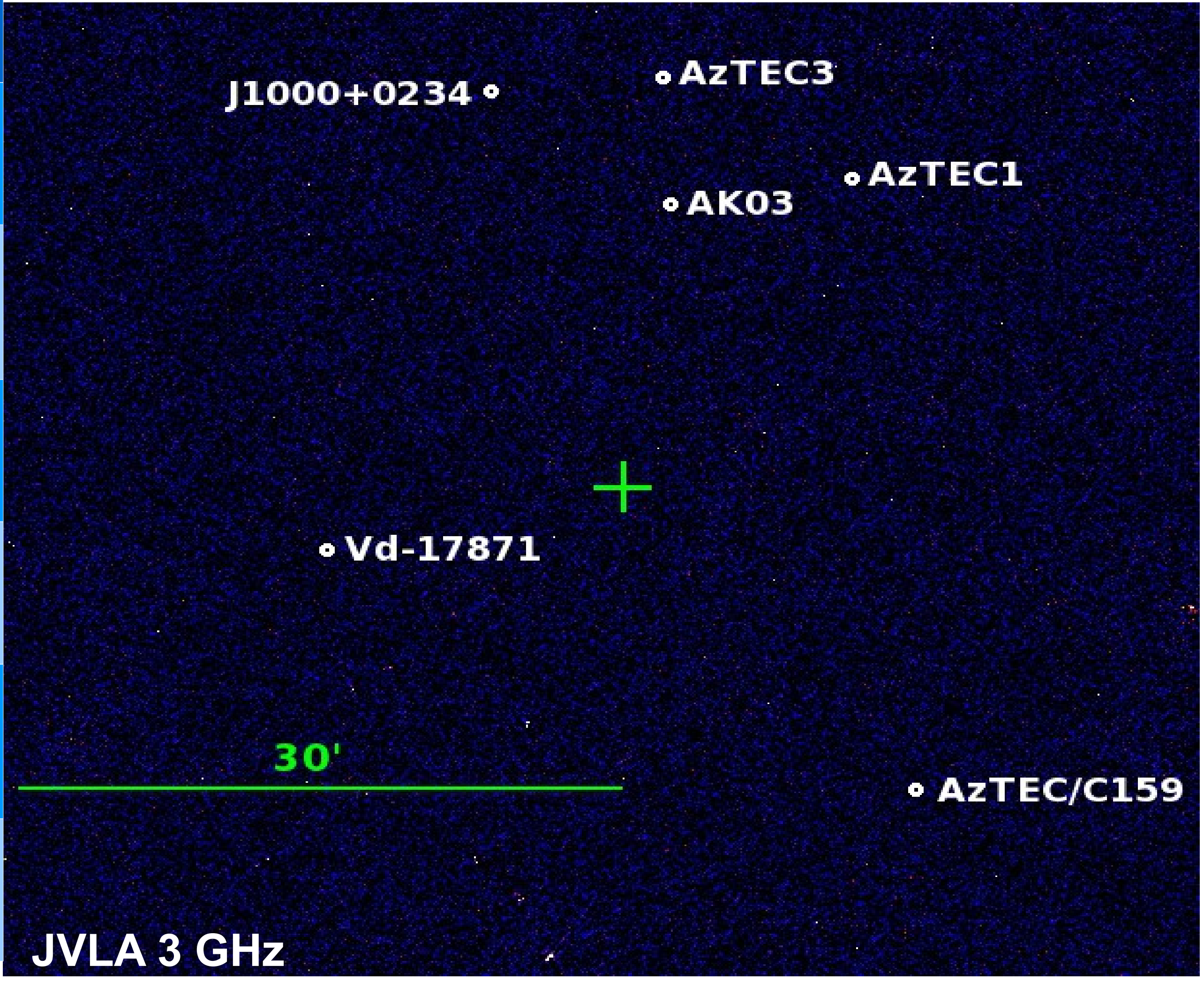
Toft et al. 2014

Credit: NASA/ESA/Niels Bohr Institute/STScI

Source sample

6 SMGs in the COSMOS field with $z_{spec} \in [4.542, 5.298]$

Source	z_{spec}	Reference
J1000+0234	4.542	Schinnerer et al. 2008
AzTEC/C159	4.569	*This work*: V. Smolčić et al., in prep.
Vd-17871	4.622	A. Karim et al., in prep.
AzTEC1	4.640	Smolčić et al. 2011
AK03	4.747	*This work*: V. Smolčić et al., in prep.
AzTEC3	5.298	Capak et al. 2011

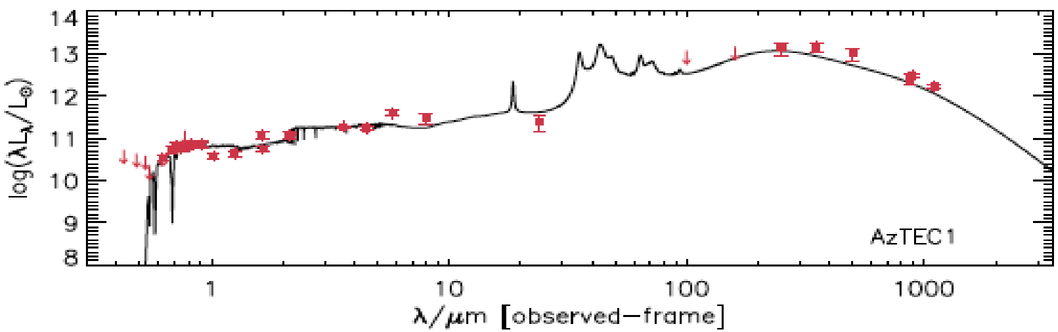


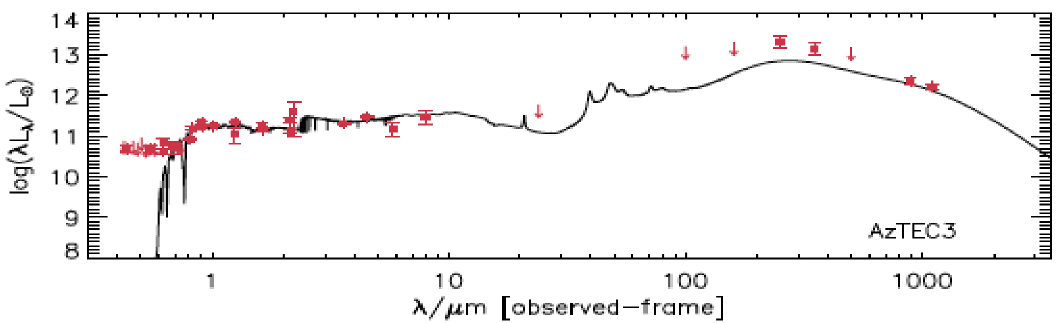
SEDs

Three different methods

MAGPHYS

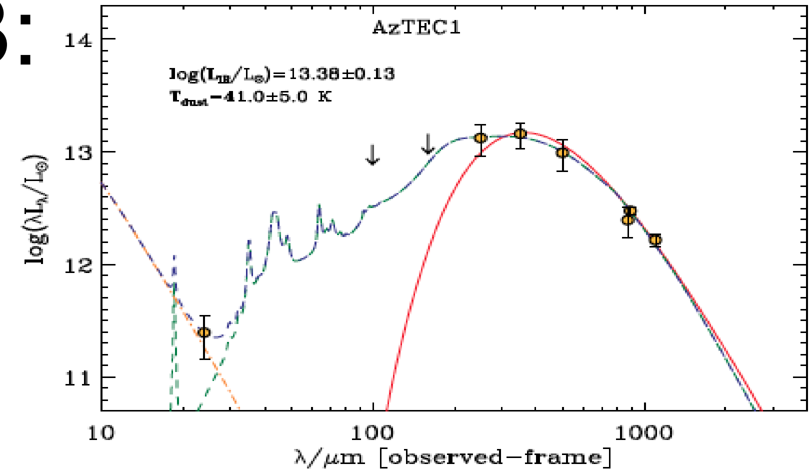
(da Cunha et al. 2008):

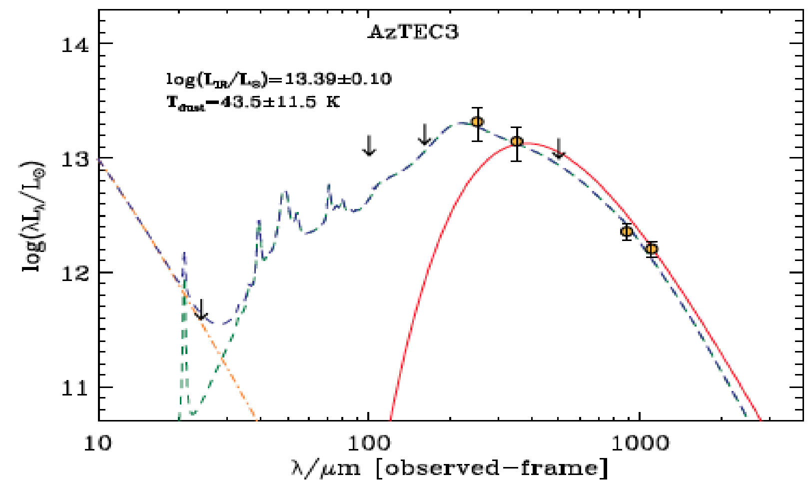




- starburst models
- normal galaxy models for AK03

Draine & Li (2007) dust model + MBB:





	t_{form}	$M_{\star}$	T_{dust}	M_{dust}^{DL07}	L_{IR}^{DL07}	SFR
	Myr	10^{11} $M_{\odot}$	K	10^{9} $M_{\odot}$	10^{13} $L_{\odot}$	$M_{\odot}$ yr^{-1}
Range	~110-710	~0.5-4	~39-48	~1-5	~0.5-2.5	~450-2500
Median	~200	~1.0	~42	~2	~0.9	~915
Mean	~280	~1.4	~43	~3	~1.3	~1300

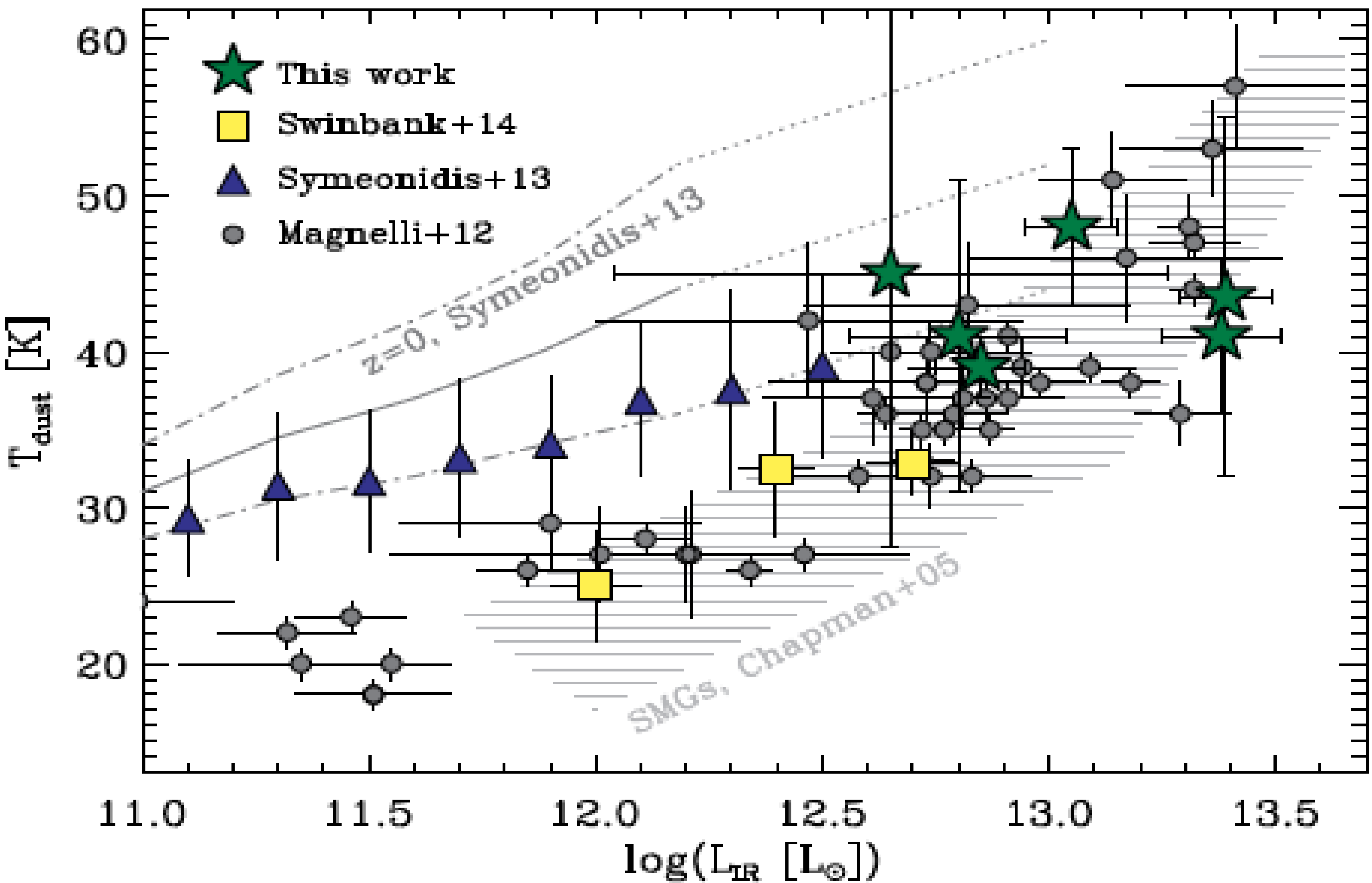
young systems

high stellar masses

relatively warm dust

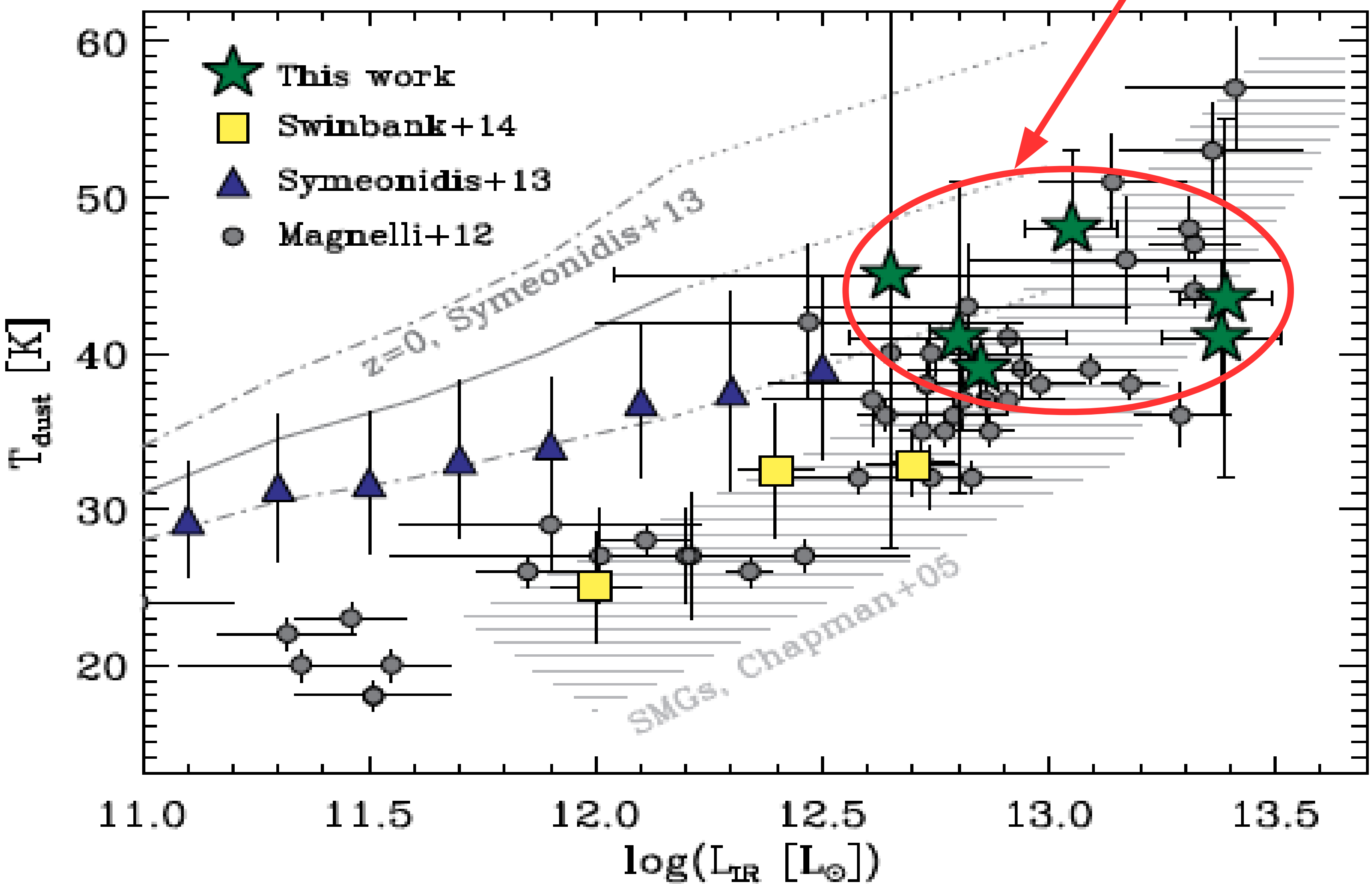
HyLIRGs

starbursts (Chabrier IMF)

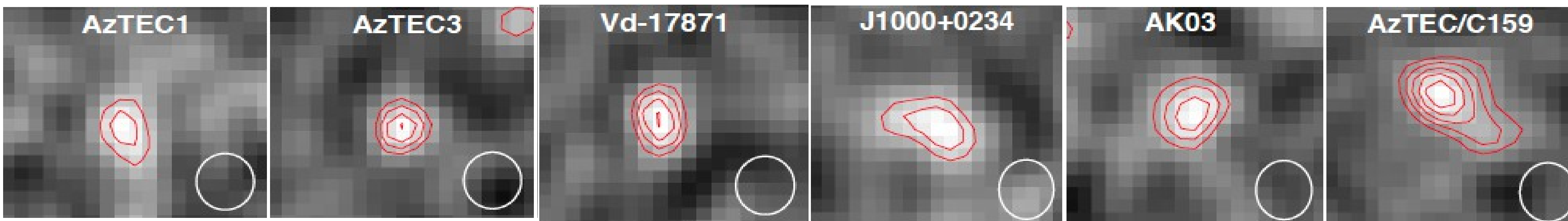


This work
Swinbank+14
Symeonidis+13
Magnelli+12
z=0, Symeonidis+13
SMGs, Chapman+05
T_{dust} [K]
log(L_{IR} [$L_{\odot}$])
60
50
40
30
20
11.0
11.5
12.0
12.5
13.0
13.5

The $z > 4.5$ SMGs follow the $L_{IR} - T_{dust}$ relationship



Radio characteristics

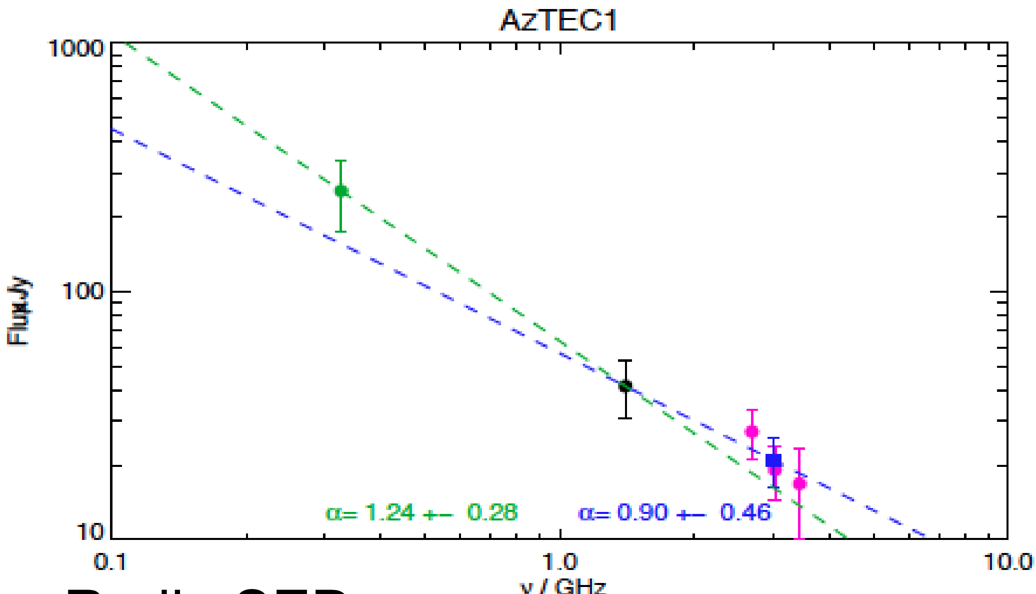


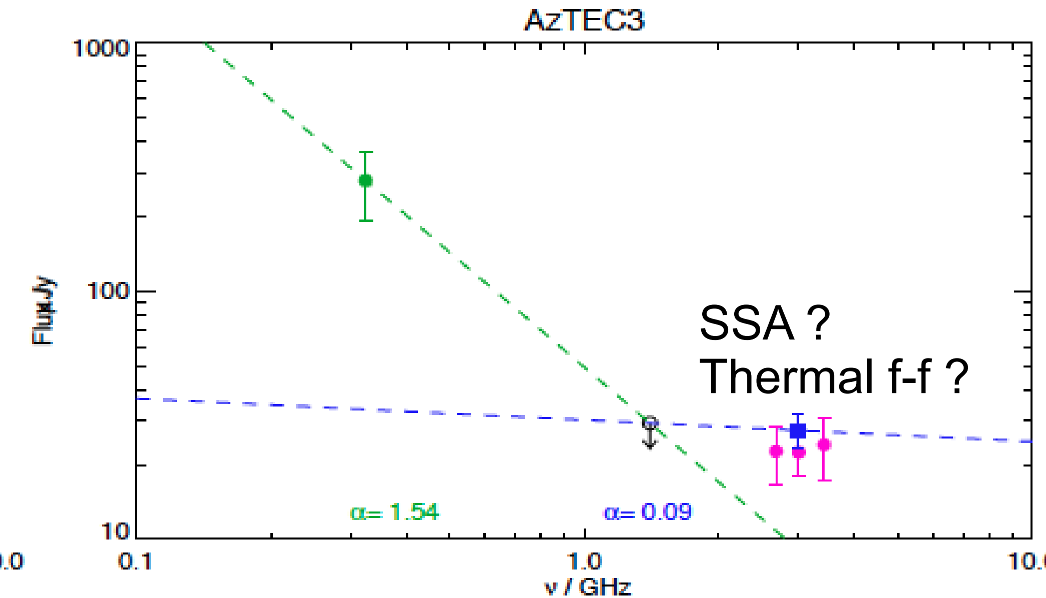
Unresolved | **Marginally resolved** | **Resolved: 0.94" x 0.46" = 6.2 x 3.0 kpc^2 (FWHM)**

JVLA-COSMOS 3 GHz imaging at 0.6" x 0.7" (PI: V. Smolčić)

Image courtesy: NRAO/AUI and NRAO

Median radio-emitting size:
0.63" x 0.35" ~ 4.1 x 2.3 kpc^2
⇒ ~ extent of SF in lower-*z* SMGs and local normal galaxies,
but > in local ULIRGs





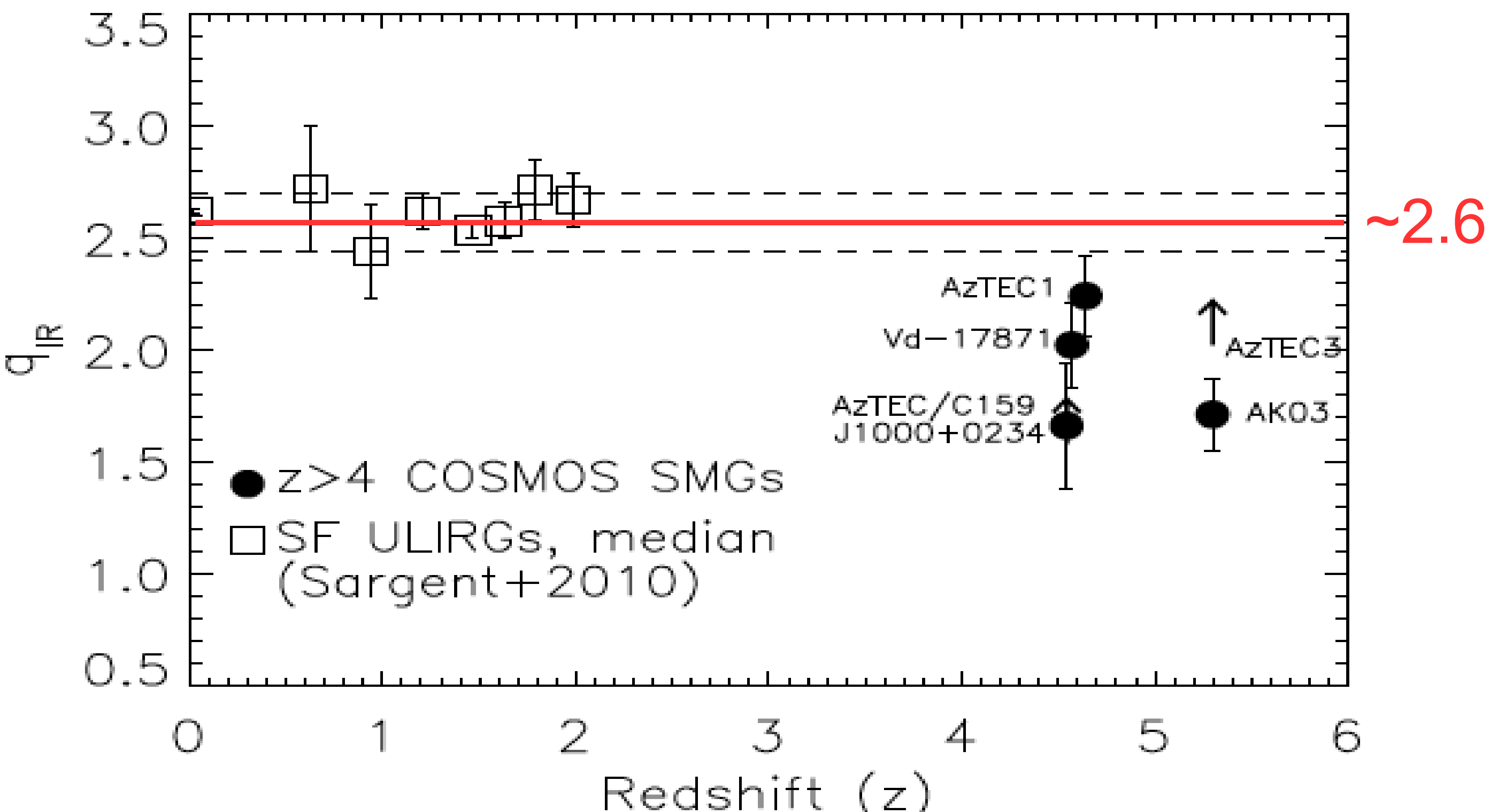
Radio SEDs:
- **GMRT 325 MHz** (A. Karim+, in prep.)
- **VLA 1.4 GHz**
- **JVLA 3 GHz**

$\alpha_{radio} \Rightarrow L_{1.4GHz}$

Source	$\alpha^{325MHz}_{1.4GHz}$	$\alpha^{1.4GHz}_{3GHz}$	$L_{1.4GHz}$ [W Hz^{-1}]
AzTEC1	1.24 ± 0.28	0.90 ± 0.46	$1.4 \pm 0.4 \times 10^{25}$
AzTEC3	> 1.54	> 0.09	$< 3.1 \times 10^{25}$
AzTEC/C159	0.76 ± 0.19	0.83 ± 0.17	$1.4 \pm 0.4 \times 10^{25}$
J1000+0234	> 1.11	0.98 ± 0.38	$< 1.2 \times 10^{25}$
Vd-17871	0.88 ± 0.24	1.1 ± 0.3	$1.1 \pm 0.4 \times 10^{25}$
AK03	0.82 ± 0.20	1.54 ± 0.27	$1.4 \pm 0.4 \times 10^{25}$

$$L_{1.4\mathrm{GHz}} = \frac{4\pi D_{\mathrm{L}}^{2}}{(1+z)^{1-\alpha}} S_{325\mathrm{MHz}} \left(\frac{1400\ \mathrm{MHz}}{325\ \mathrm{MHz}}\right)^{-\alpha} \rightarrow$$

$$q_{\mathrm{IR}} = \log\left(\frac{L_{\mathrm{IR}}}{3.75\times10^{12}\ \mathrm{W}}\right) - \log\left(\frac{L_{1.4\mathrm{GHz}}}{\mathrm{W\ Hz^{-1}}}\right)$$



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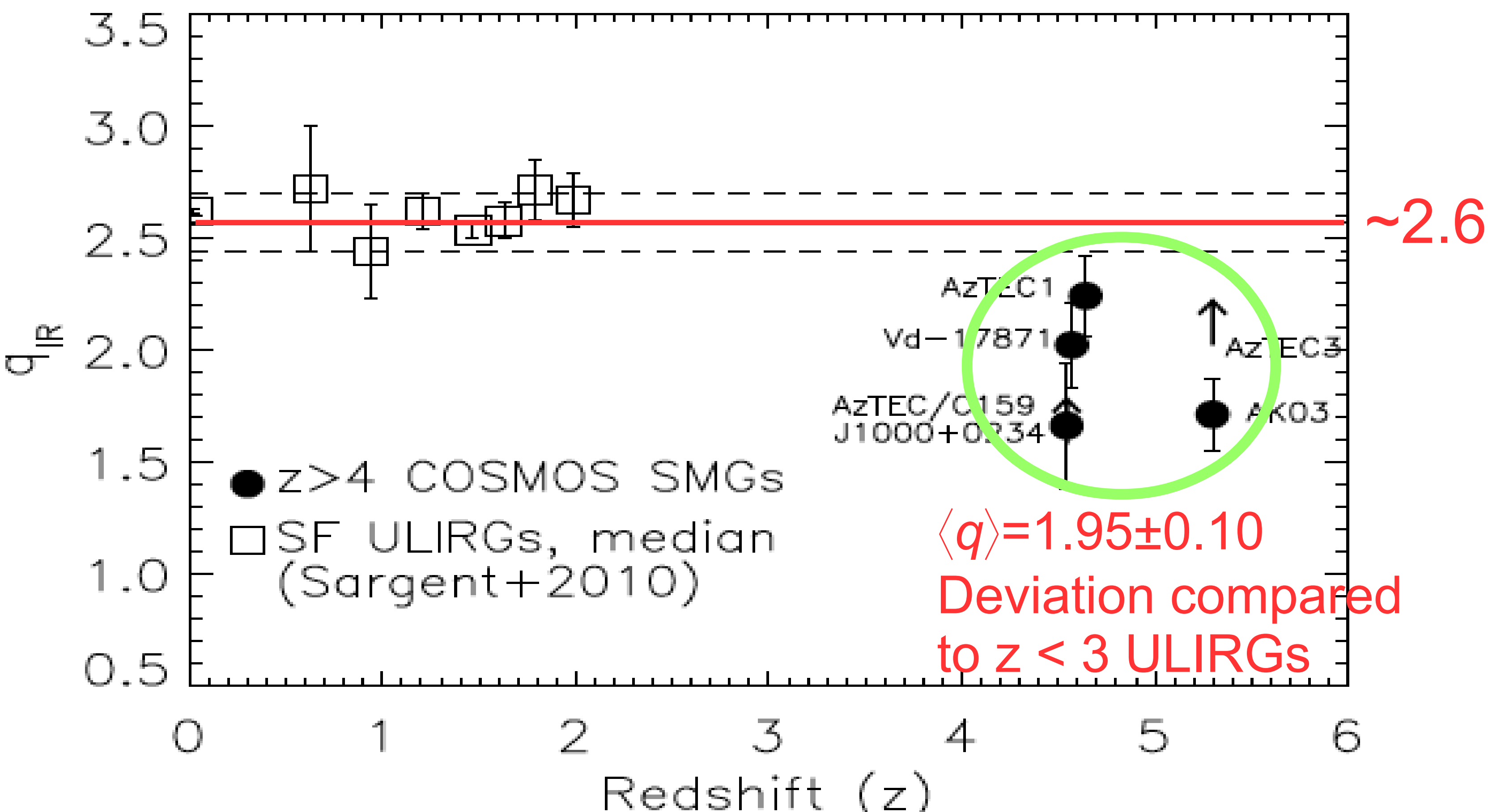
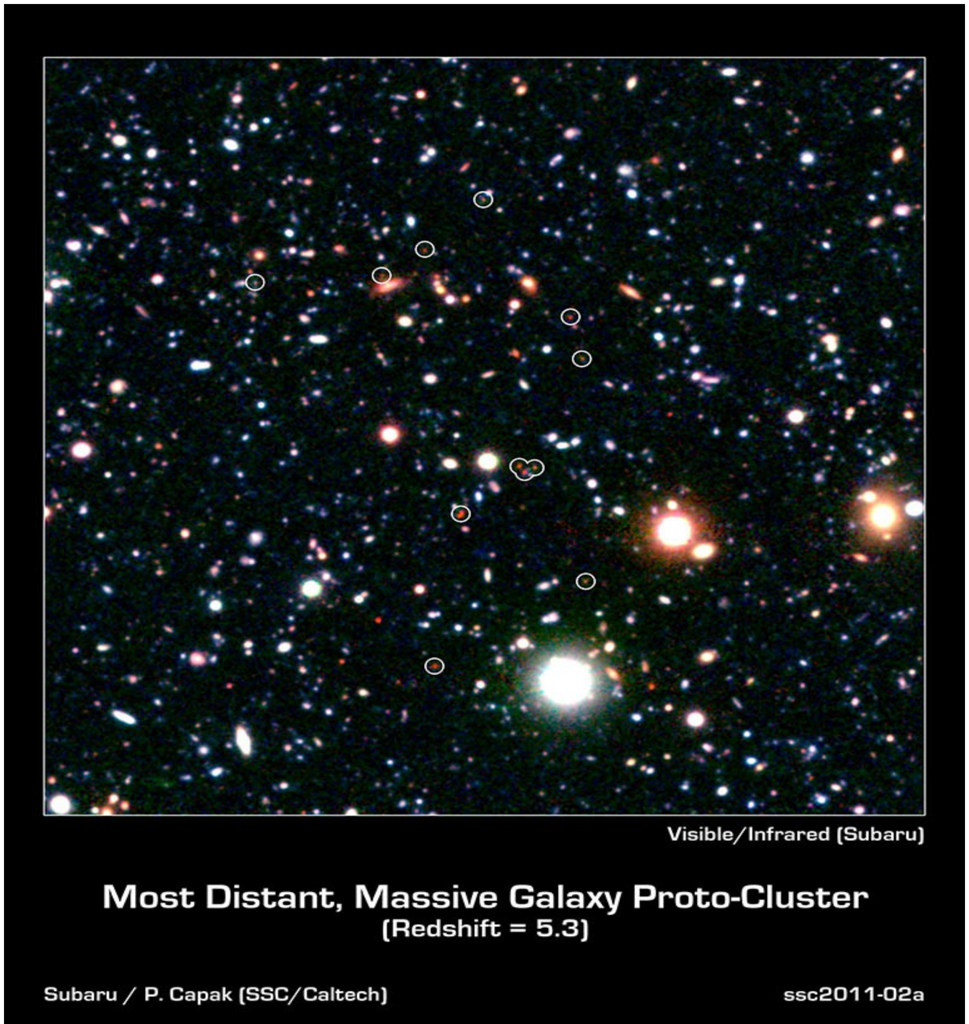
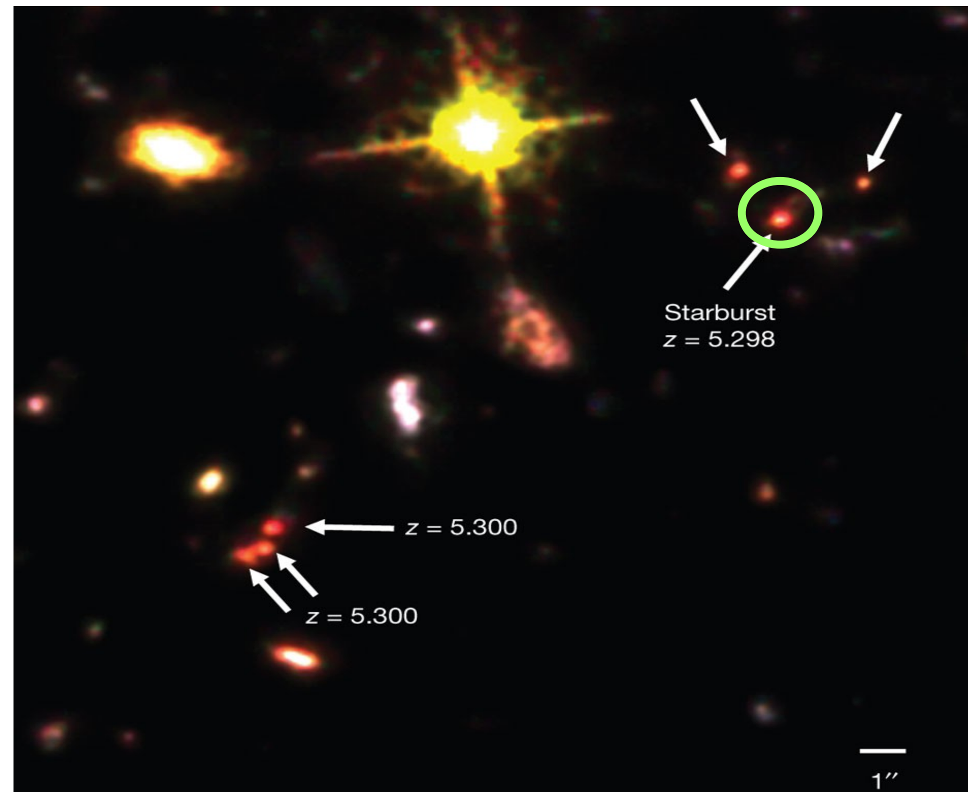


Environments



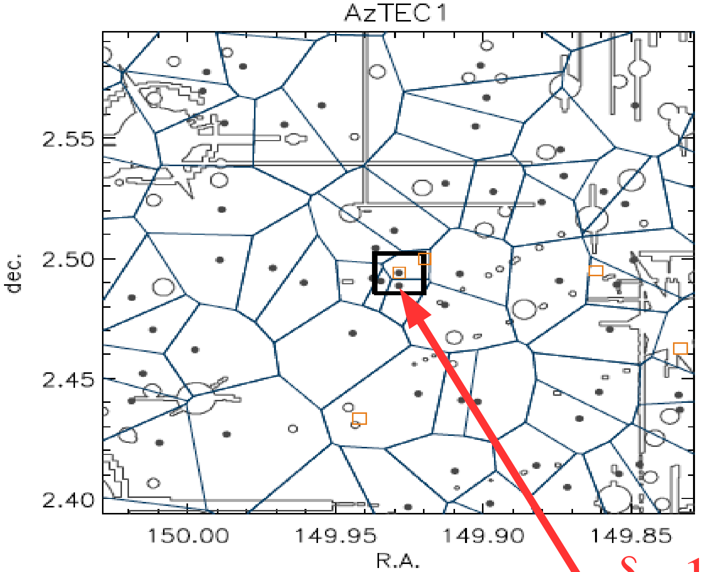
AzTEC3 sits in a protocluster

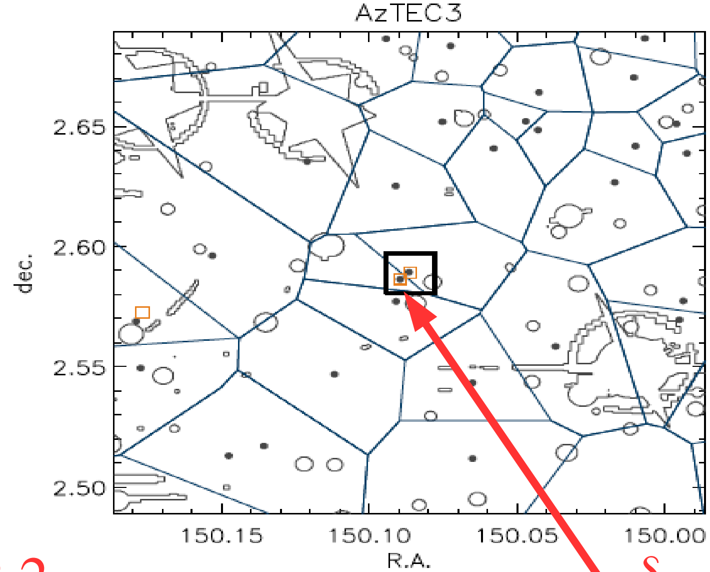


Credit: Capak et al. 2011 / Nature

Surface density of galaxies: Voronoi tessellation

(photo-z bin used: $\Delta z_{phot} = \pm 0.3$)

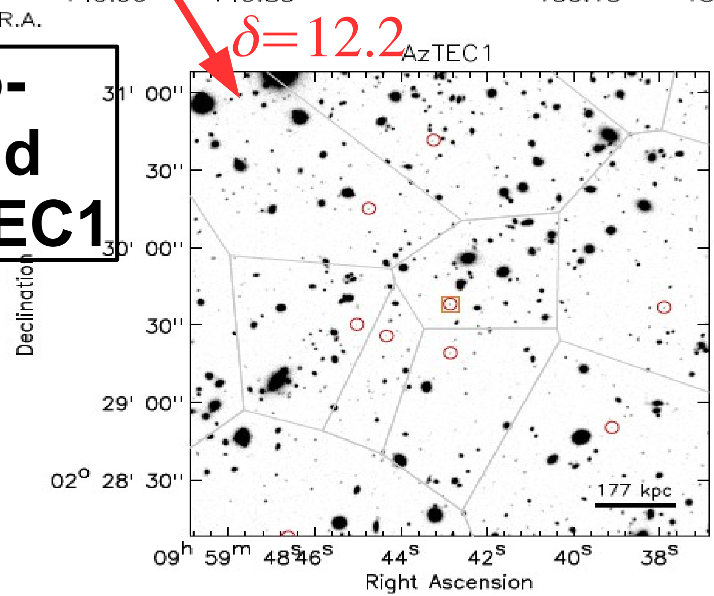


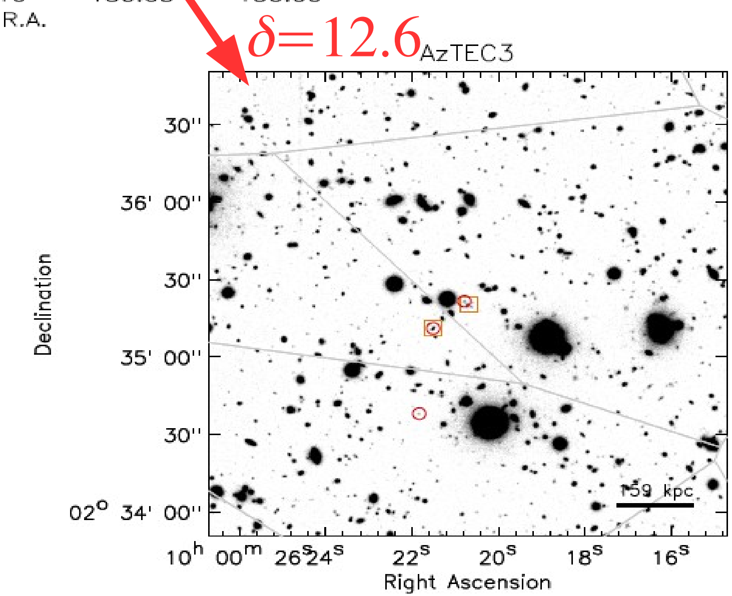


The COSMOS photo-z catalogue is accurate enough to identify overdensities at z > 4

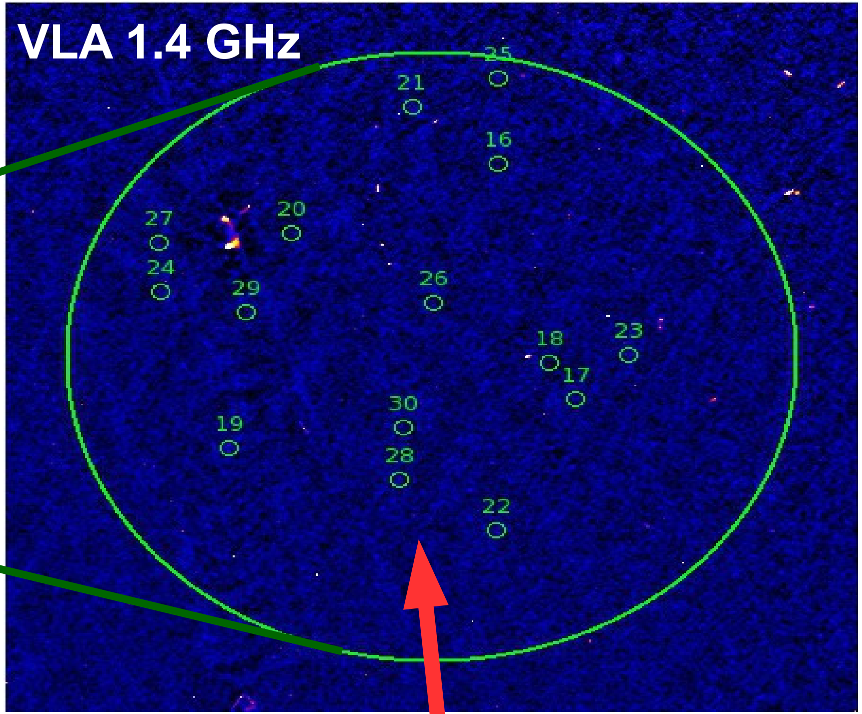
Previously known protocluster associated with AzTEC3 (Capak et al. 2011)

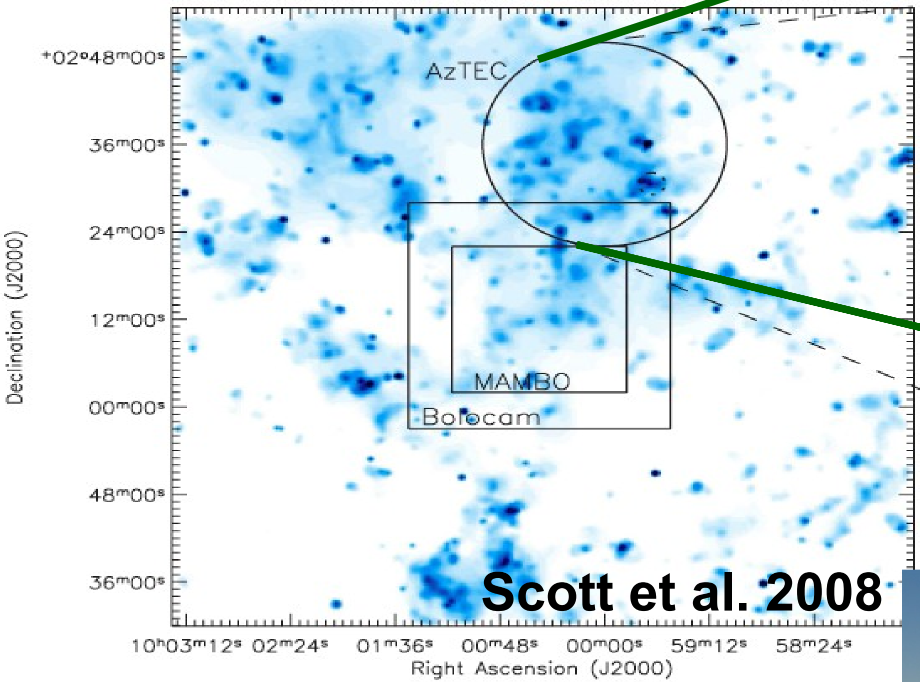
A new proto-cluster found around AzTEC1

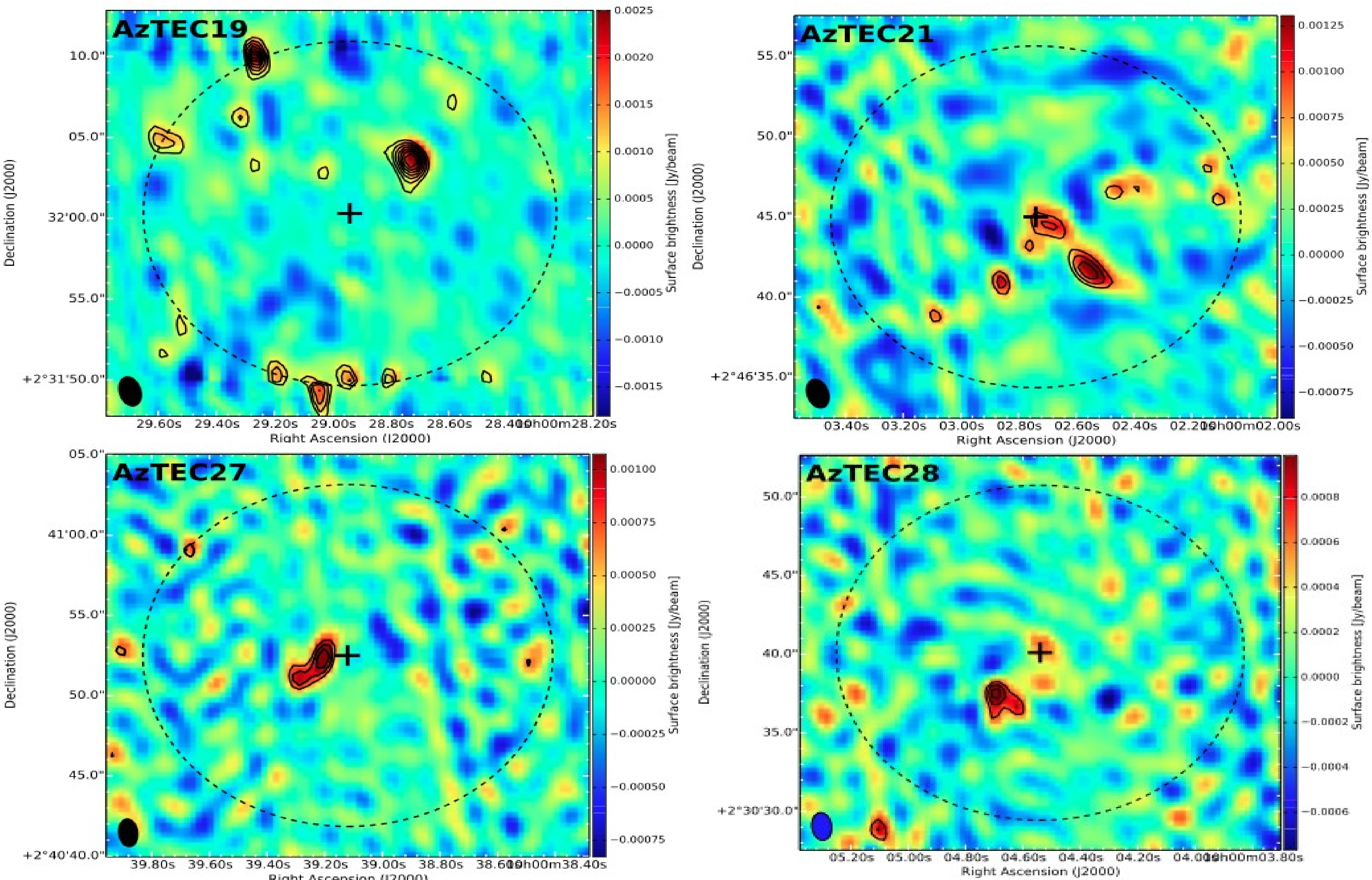




PdBI 1.3 mm follow-up of JCMT/AzTEC16-30



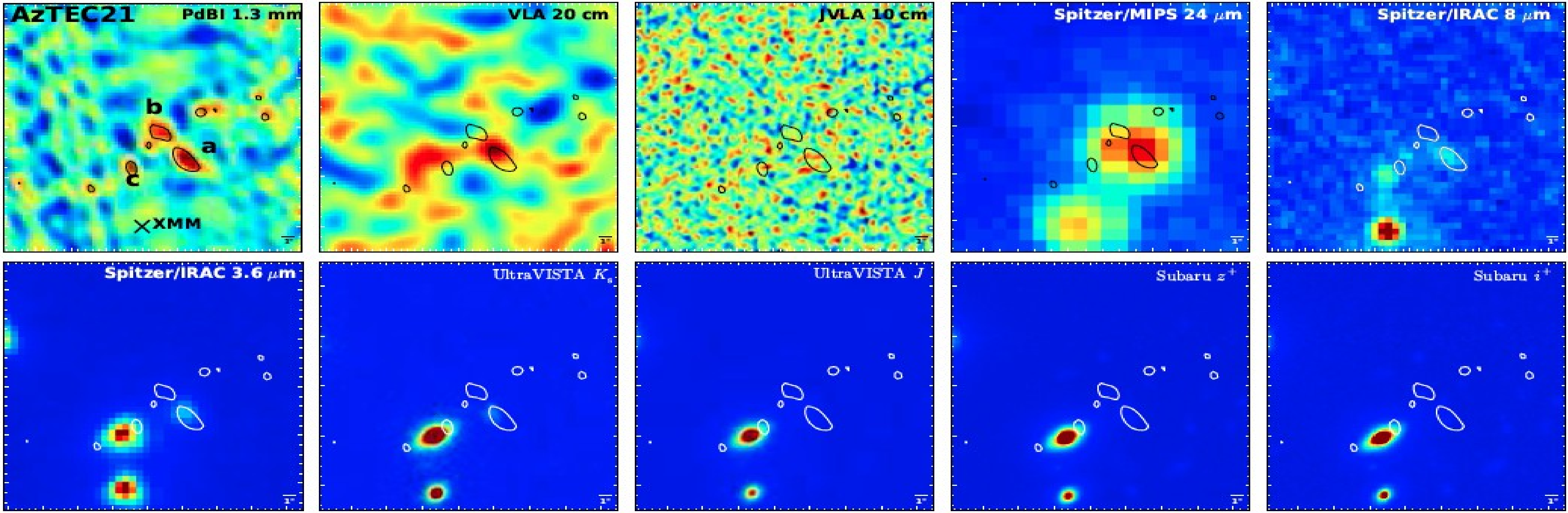


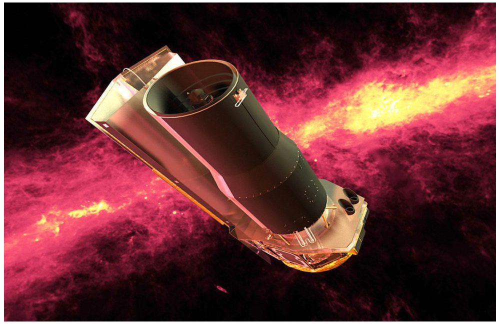


Miettinen et al., in prep.

- typical beam size: **1.8” x 1.1”** (cf. 18” with JCMT/AzTEC)
- 1σ rms noise: **~0.2 mJy beam^{-1}**

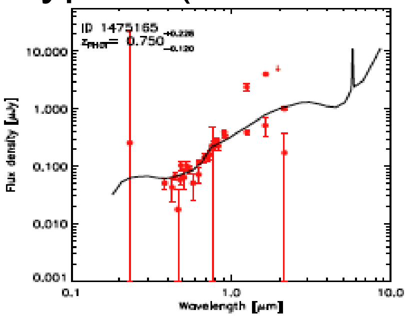
Counterpart identification

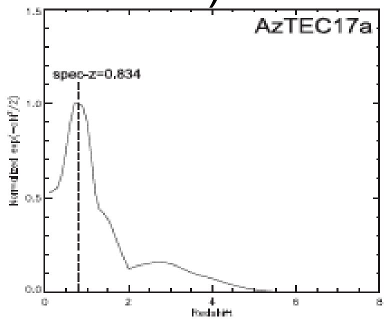




Redshift analysis

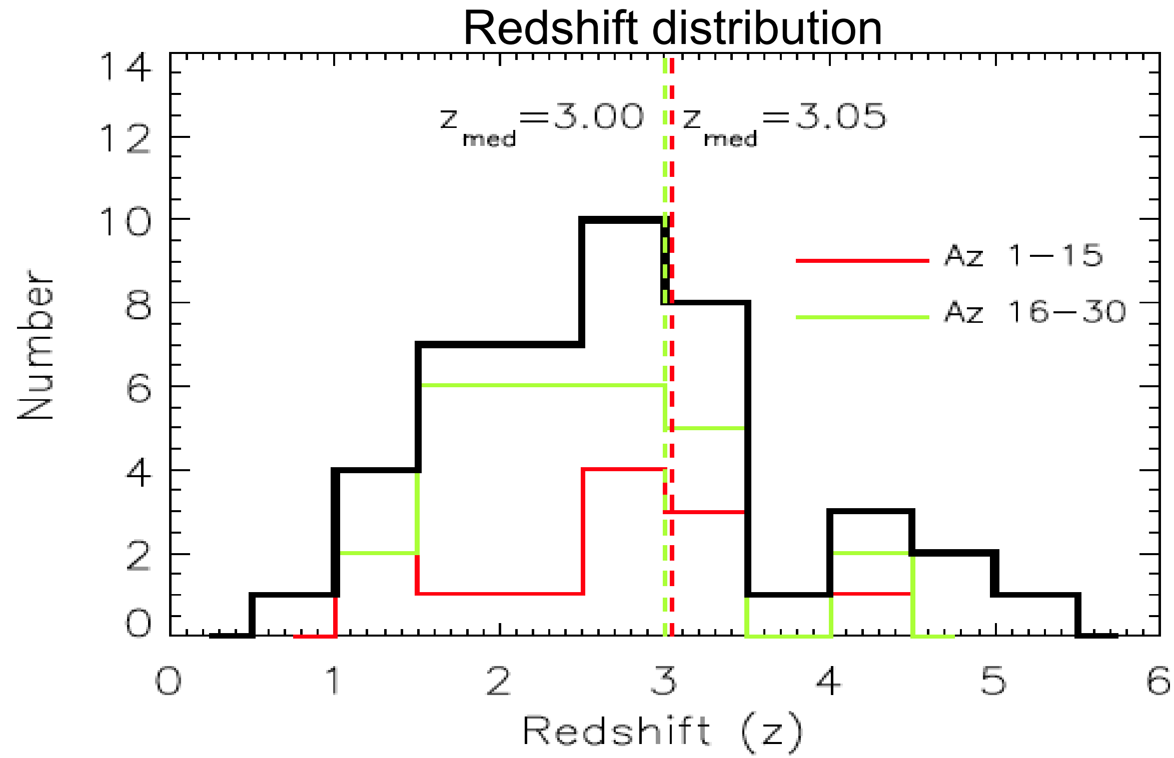
1) Photometric redshifts from HyperZ (Bolzonella et al. 2000)





2) Spectroscopic redshifts (mostly among AzTEC1-15)

3) Redshifts from the radio/submm flux density ratio (Carilli & Yun 1999, 2000)



Az1-15: $\langle z \rangle$=3.31$\pm$0.35, median(z)=3.05$\pm$0.44

Az16-30: $\langle z \rangle$=3.06$\pm$0.16, median(z)=3.00$\pm$0.20

Combined sample:
z_{median}=3.05$\pm$0.24

Summary

cf. the workshop theme 2d

- Physical properties of the studied z>4.5 SMGs put them at the high end of the L_{IR} -T_{dust} relation
- Extent of SF ~ that in lower-z SMGs
- Overdensities associated with AzTEC1 and -3
  - No evidence of that for the rest of the sources (which are “clumpy”)
- Heterogeneous sample ➞ different evolutionary stages ?
- AzTEC1-30 are now followed-up with (sub-)mm interferometers (SMA, PdBI, ALMA)

With ALMA:
- dust continuum emission @ higher resolution
- high-res. spectral line imaging

⇒ sizes, morphologies, gas kinematics, chemical properties

ESO/C. Malin