SMA Follow-Up of Aztec Sources

SUBMILLIMETER ARRAY OBSERVATION OF HIGH REDSHIFT GALAXIES

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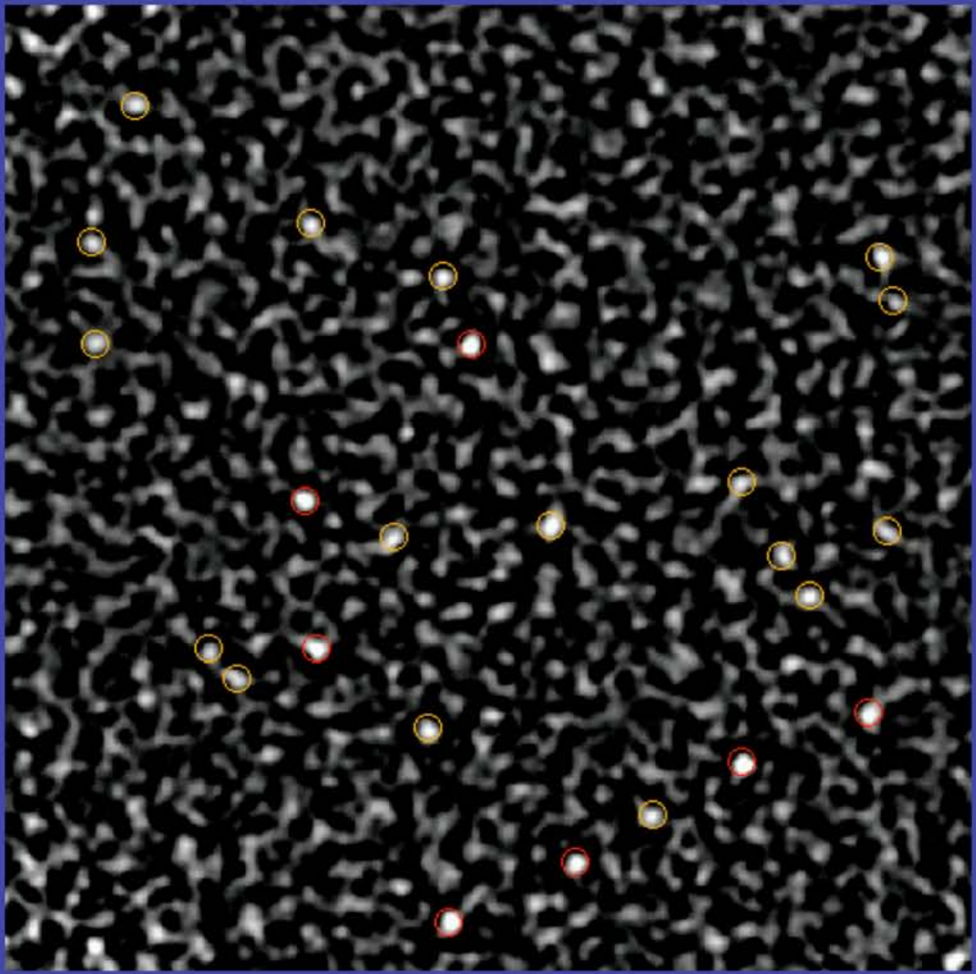
INTRODUCTION

- Millimeter and submillimeter (submm) observations are critical to our understanding of galaxy birth and evolution in the early Universe.
- Studies of the diffuse far-IR and millimeter cosmic background radiation have shown this radiation is due to discrete sources dominated by luminous and ultraluminous infrared/submm galaxies at high redshift ($z > 2$).
- Multiwavelength studies of these galaxies have shown that they are massive, young objects in the process of formation, with very high star formation rates.
- However progress in understanding these galaxies has been hampered by their faintness at optical wavelengths and the poor angular resolution (~ 15 arcsec) of submm cameras.
- SMA and Spitzer Space Telescope (infrared) observations of these galaxies can provide new insight into the true nature of these sources.

OBSERVATIONS

- AzTEC camera observations (1.1 mm wavelength; 18 arcsec resolution) on the JCMT of the COSMOS field (0.15 deg^2) detected 44 submm galaxies (SMGs) above 3.5σ.
- SMA interferometric observations (890 μm wavelength; 2 arcsec resolution) of the seven brightest AzTEC sources detected all seven SMGs and pinpointed their location to 0.2 arcsec.
- Follow-up observations by HST (ACS), SPITZER (IRAC and MIPS), and Very Large Array (VLA) revealed the detailed properties of these sources.



The AzTEC/COSMOS Survey
(Scott et al. 2007)

AzTECs

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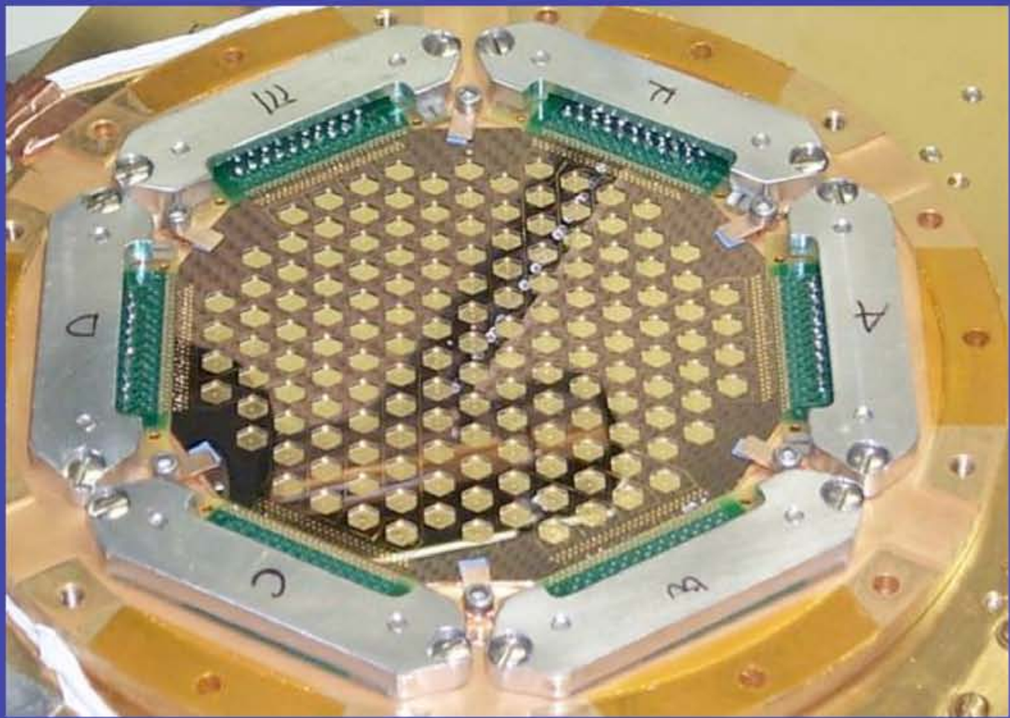
The AzTEC Instrument

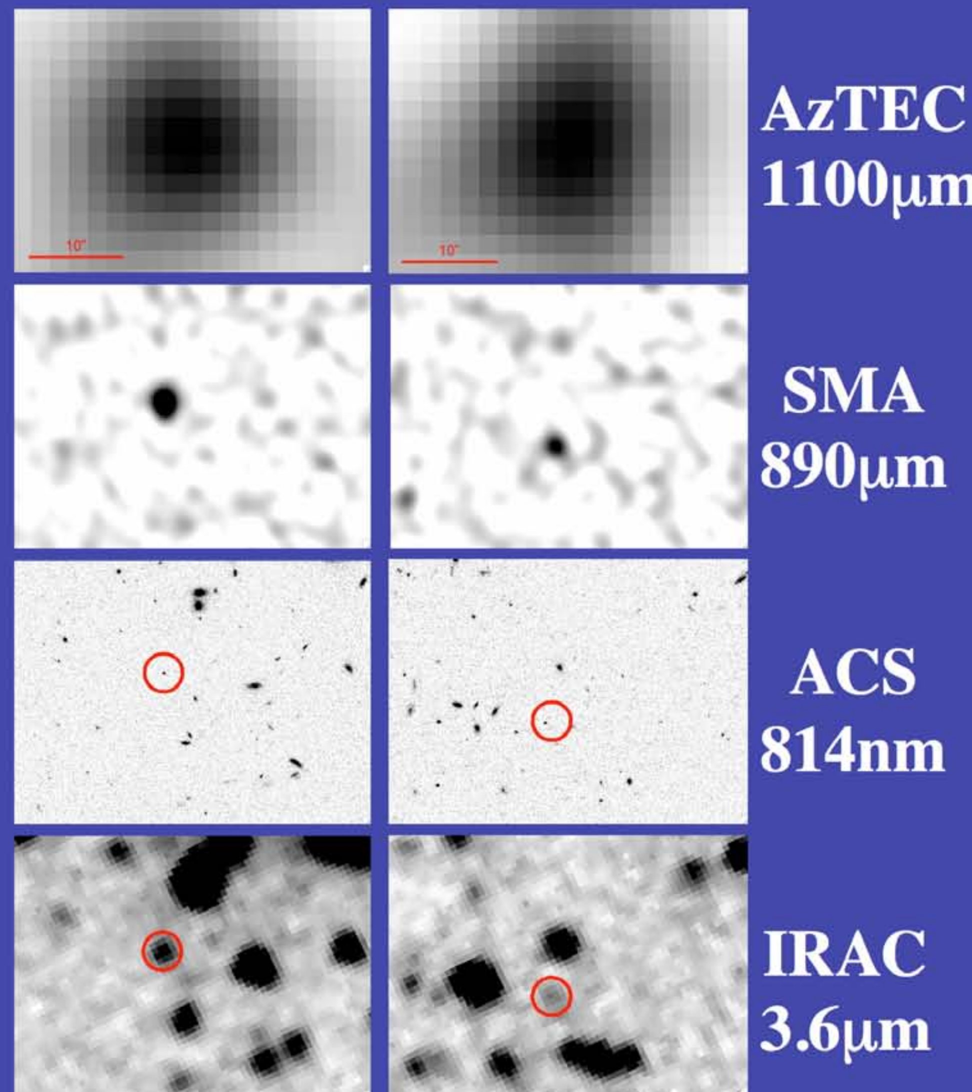
- AzTEC is a bolometer camera (designed for imaging)
- Designed for the LMT, but given time on JCMT after SCUBA broke
- 1.1mm continuum emission
- Much larger field of view and higher throughput
- Poor resolution (beam ~ 18" FWHM)
- AzTEC has detected more SMGs in two years than all previous surveys

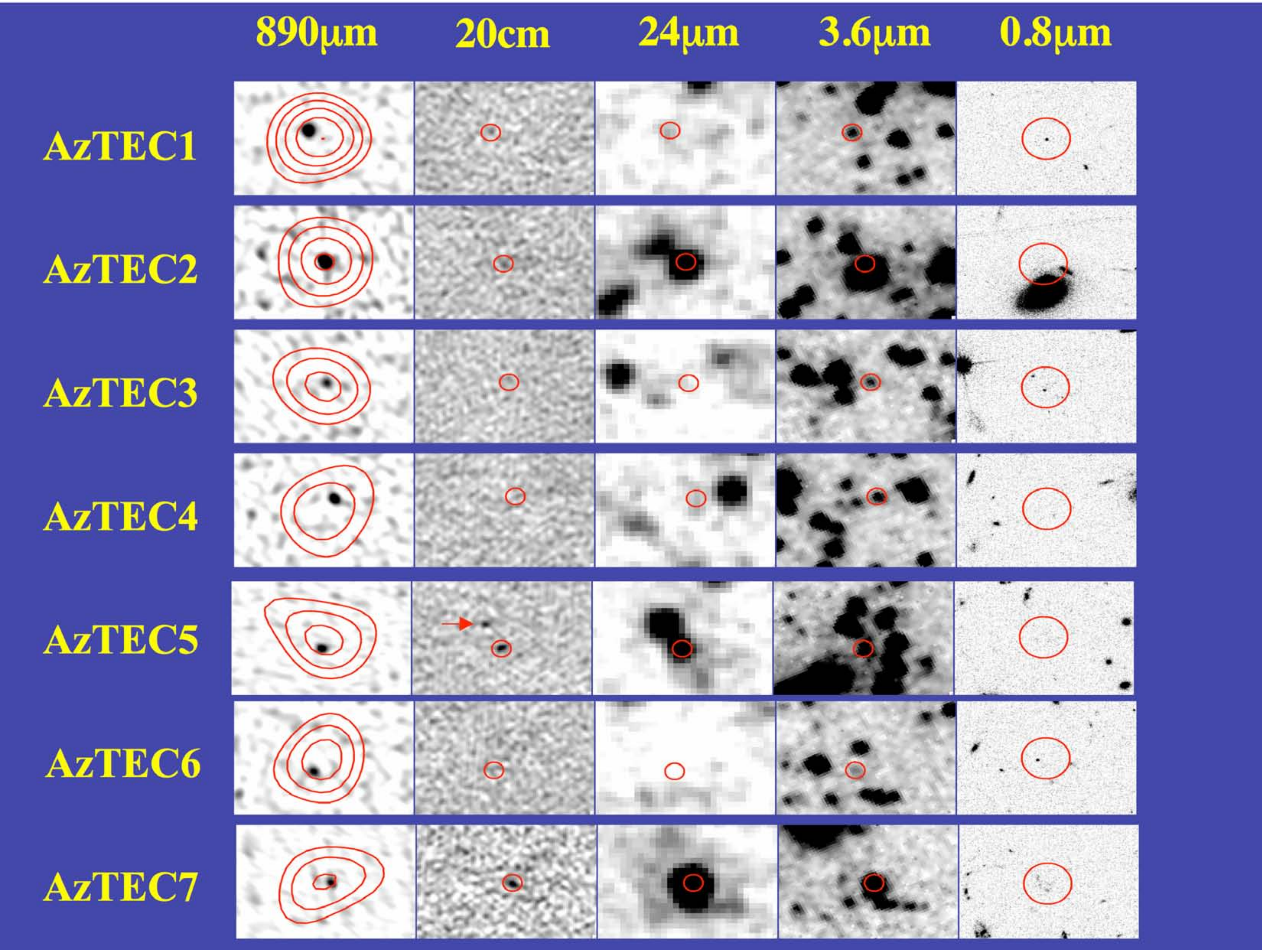


144 element spiderweb bolo array – S. Golwala

Extreme Starbursts in the Early Universe: SMA/AzTEC Observations of Submillimeter Galaxies

- Of the seven SMGs detected, five are radio-quiet.
- For the five radio-quiet sources (< 60 μJy), the submm, infrared and optical properties of these counterparts suggest high redshift.
  - High submm/radio fluxes
  - Submm sizes < 1.2 arcsec
  - Very low IRAC fluxes
  - Lack of optical flux
  - No MIPS detection at 24 μm
- These results are evidence for a population of extreme starburst galaxies when the universe was less than 16% of its current age (z > 3).




890μm
20cm
24μm
3.6μm
0.8μm
AzTEC1
AzTEC2
AzTEC3
AzTEC4
AzTEC5
AzTEC6
AzTEC7

RESULTS

- We detect _all 7_ sources at high significance (>6σ) at 890μm with the SMA
- Positions accurate to ~0.2"
- All sources have an IRAC counterpart coincident with the SMA detection
- The radio quiet sources do not have 24μm counterparts
- Only two/three sources have likely optical counterparts
- All sources are single point sources out to longest baselines; max angular size of ~1.2" means max physical scale of ~8-10 kpc

PHOTOMETRY OF SMA/AzTEC SOURCES

Table 2. Photometry of SMA/AzTEC Sources

	$F_{1100\mu m}$ (mJy)	$F_{890\mu m}$ (mJy)	$F^a_{3.6\mu m}$ (μJy)	$F^a_{4.5\mu m}$ (μJy)	$F_{5.8\mu m^a}$ (μJy)	$F^a_{8.0\mu m}$ (μJy)	$F^b_{24\mu m}$ (μJy)	F^c_{20cm} (μJy)
AzTEC1	11.4 ± 1.4	15.6 ± 1.1	4.6 ± 1.0	4.6 ± 1.4	< 11.2	17.6 ± 8.1	< 93	42 ± 12
AzTEC2[d]	9.2 ± 1.4	12.4 ± 1.0	...	...	...	...	...	45 ± 12
AzTEC3	7.7 ± 1.3	8.7 ± 1.5	3.9 ± 1.0	3.6 ± 1.4	< 11.2	< 13.4	< 93	< 36
AzTEC4	6.5 ± 1.3	14.4 ± 1.9	4.8 ± 1.0	5.1 ± 1.4	12.4 ± 6.7	19.6 ± 8.1	< 93	< 36
AzTEC5	7.7 ± 1.3	9.3 ± 1.3	8.8 ± 1.0	9.0 ± 1.4	11.6 ± 6.7	32.7 ± 8.0	158 ± 31	140 ± 30
AzTEC6	8.1 ± 1.3	8.6 ± 1.3	2.4 ± 1.0	2.4 ± 1.4	< 11.2	< 13.4	< 93	< 36
AzTEC7	7.9 ± 1.5	12.0 ± 1.5	52.1 ± 1.0	52.1 ± 1.0	80.6 ± 6.7	63.4 ± 8.0	535 ± 31	170 ± 53

[a]Fluxes are measured in a 3″ radius aperture. Errors and flux limits are the 3σ rms and 5σ rms fluctuation within that aperture respectively. Aperture corrections were done to the IRAC calibration radius of 12″.

[b]Fluxes were measured in a 5″ radius. Errors and flux limits are σ and 3σ respectively, estimated using a Monte Carlo analysis.

[c]Flux limits are at 3σ.

[d]IRAC and MIPS are confused with a bright foreground object.

ASTROMETRY OF SMA/AzTEC SOURCES

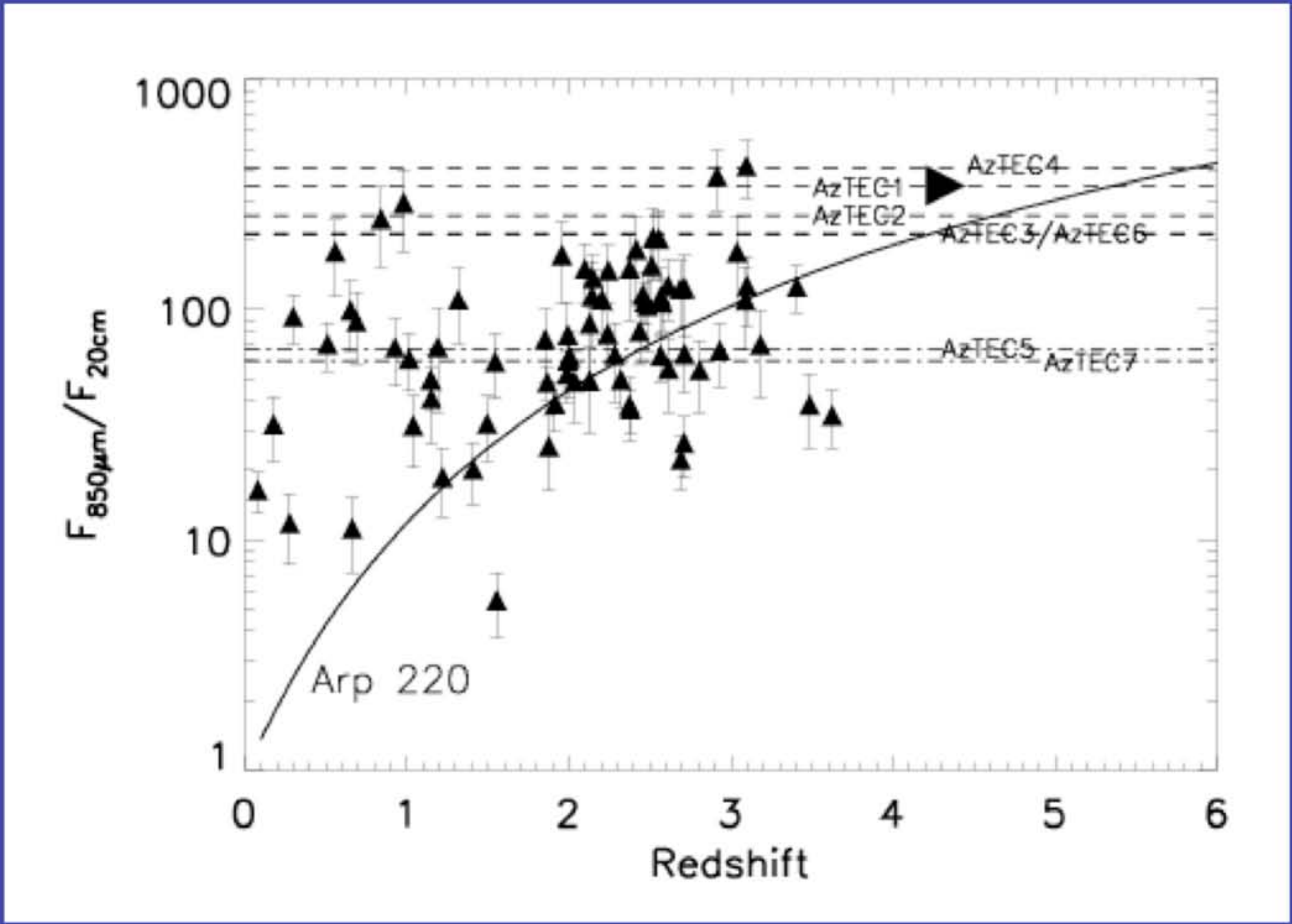
Table 1. Astrometry of SMA/AzTEC Sources

	Name	$\sigma(\alpha)$	$\sigma(\delta)$	AzTEC Offset	IRAC Offset[a]
AzTEC1	AzTEC J095942.9+022938.2	0.11″	0.20″	3.3″	0.3″
AzTEC2	AzTEC J100008.0+022612.2	0.13″	0.23″	0.3″	... [b]
AzTEC3	AzTEC J100020.7+023520.5	0.19″	0.31″	1.6″	0.9″
AzTEC4	AzTEC J095931.7+023044.0	0.15″	0.24″	3.5″	0.5″
AzTEC5	AzTEC J100019.8+023204.3	0.16″	0.11″	1.7″	0.8″
AzTEC6	AzTEC J100006.5+023837.7	0.19″	0.28″	2.8″	0.7″
AzTEC7	AzTEC J100018.1+024830.5	0.24″	0.29″	1.5″	0.5″

[a]IRAC has an astrometric uncertainty of $\sim 0.2''$ and an angular resolution of $\sim 2.1''$.

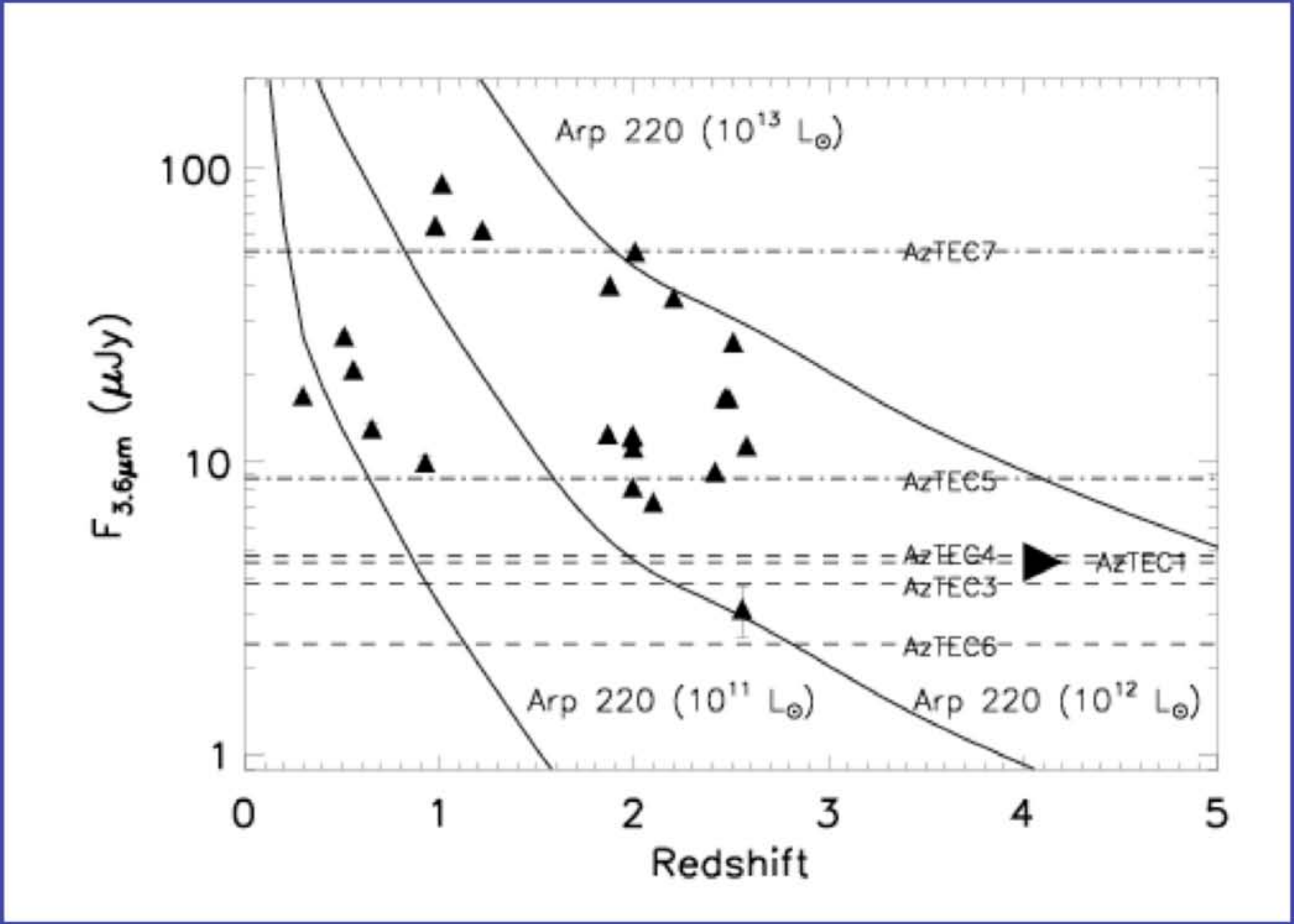
[b]IRAC counterpart is confused with a bright foreground object.

RADIO/SMM FLUX RATIOS



Consistent with higher average/median redshift

IRAC COUNTERPARTS



Consistent with higher average/median redshift

CONCLUSIONS

- Detected a complete, flux limited sample of SMGs at high angular resolution
- Radio-quiet sources appear to be at higher redshift than radio-loud sources
  - Chapman redshift distribution is a lower-limit
- Brightest SMGs are compact; size scales analogous to local ULIRGs
- Population of higher redshift SMGs that contribute significantly to observed number counts
  - Constraints on galaxy formation models; have to have massive starbursts at early times
  - Constraints on dust formation models; how to make enough dust given short age of the system
  - Are the brightest SMGs at higher redshift?

FUTURE WORK

- Very deep Spitzer follow-up (approved)
  - Proposal accepted to image radio-quiet sources with IRAC, MIPS, and IRS to get better handle on the redshift
- Expand the sample (approved)
  - Program accepted to do SMA followup of AzTEC sources in MS0451; are SMGs in the field like SMGs in a biased environment
- Resolve SMGs with large baselines
  - Get a better constraint on size scales
  - Compare to merger models