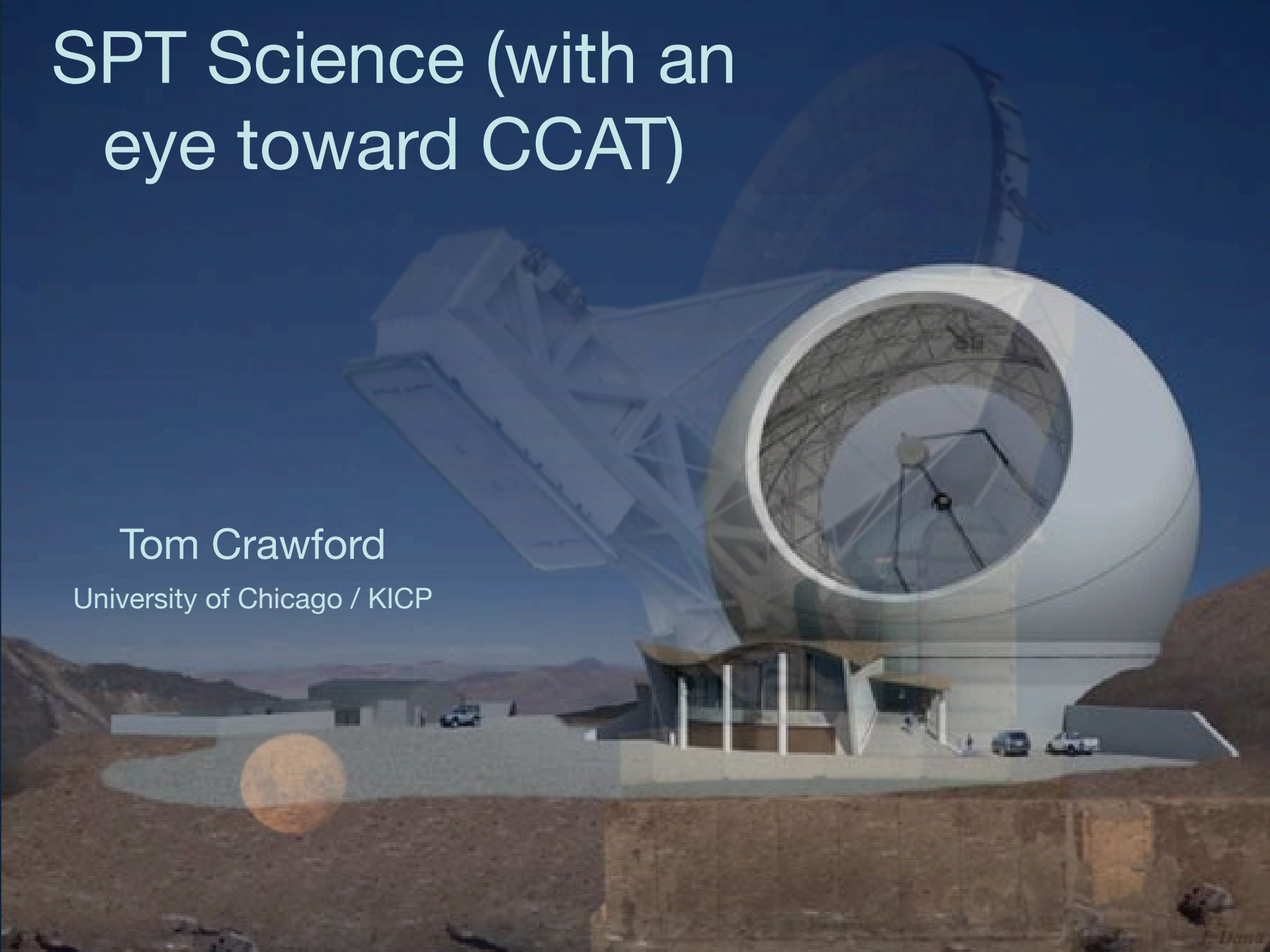
SPT Science

Tom Crawford

University of Chicago / KICP

Photo credit: J. Dana Hrubes

SPT Science (with an eye toward CCAT)



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Outline

I. Intro / motivation (quick!)

II. Galaxy cluster science

III. CMB anisotropy science

IV. High-z dusty galaxy science

Outline

I. Intro / motivation (quick!)

II. Galaxy cluster science

III. CMB anisotropy science

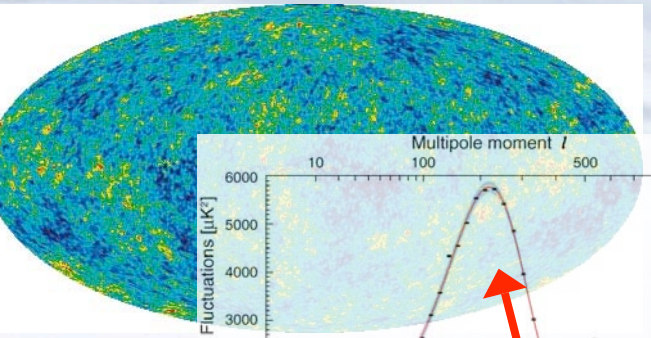
IV. High-z dusty galaxy science

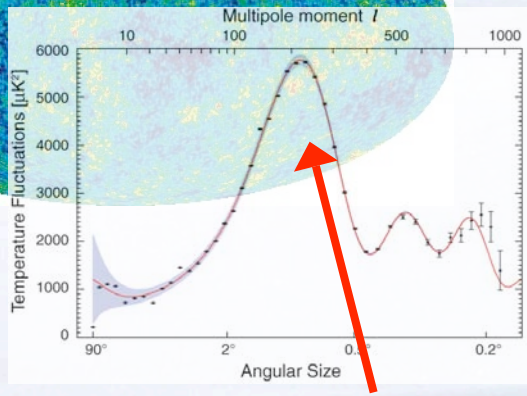
V. The Future?

Outline

I. Intro / motivation (quick!)

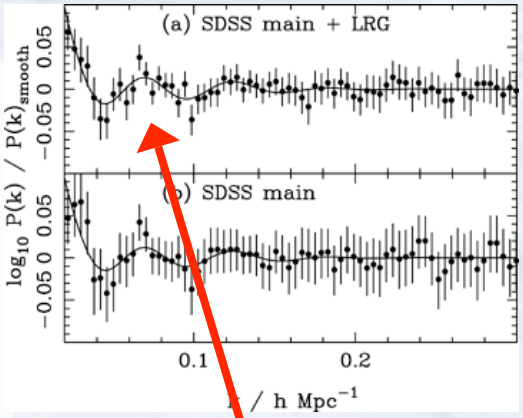
We Live in a Universe Dominated by Dark Energy



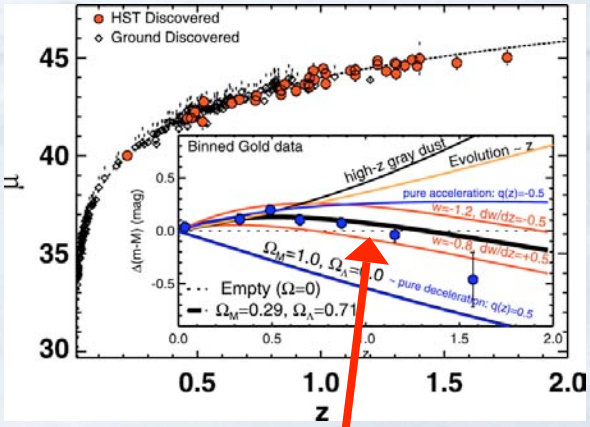


Komatsu et al 2008

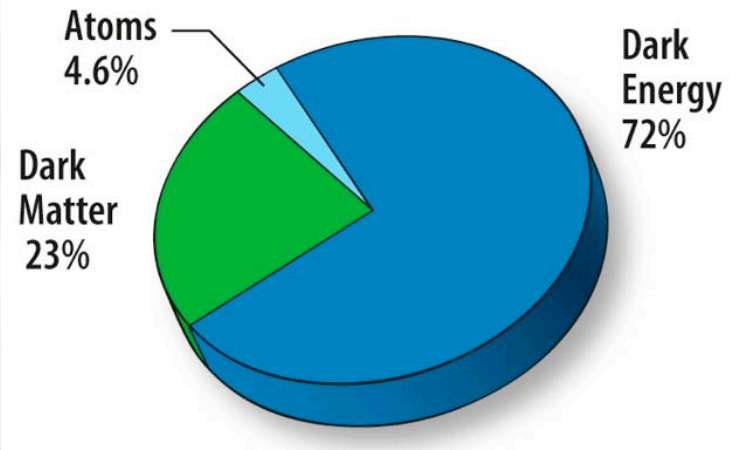
Percival et al 2007



Riess et al 2007



CMB + Large Scale Structure + SNe Ia



We live in a flat universe whose density is dominated dominated by dark energy

$$\Omega_\Lambda = 0.721 \pm 0.015$$

... but what is dark energy?

Dark Energy Constraints with Clusters of Galaxies

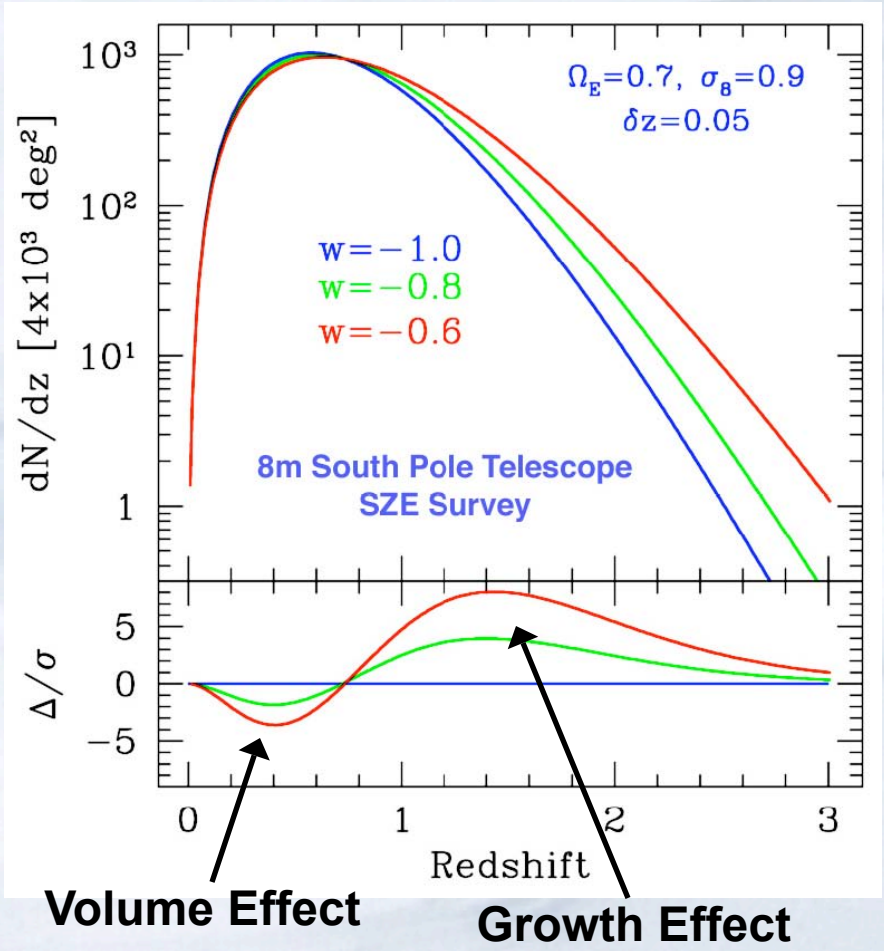
Cluster Abundance, dN/dz

$$\frac{dN}{d\Omega dz} = n(z)\frac{dV}{d\Omega dz}$$

Depends on:
Matter Power Spectrum, *P(k)*
Growth Rate of Structure, *D(z)*

Depends on:
Rate of Expansion, *H(z)*

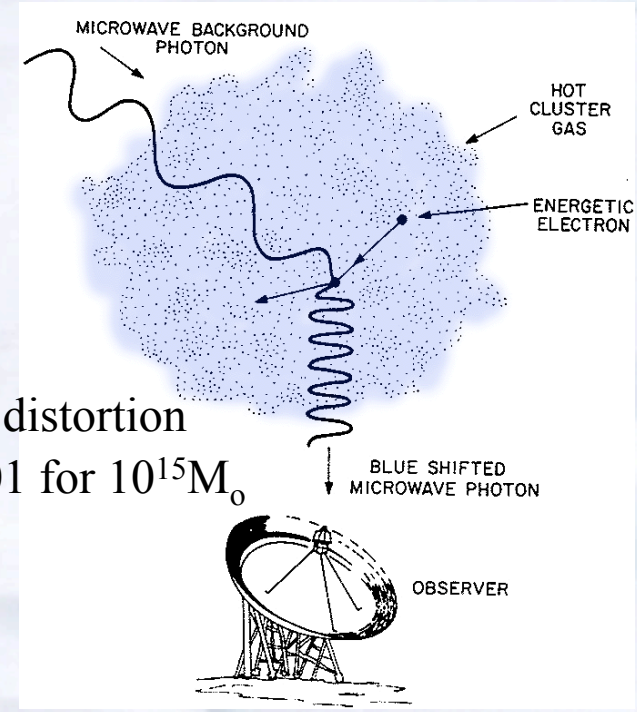
Credit: Joe Mohr



For fixed Ω_{DE} and less negative *w*:

1. Fewer clusters at low redshift, due to decreased volume surveyed
2. More clusters at high redshift, due to decreased growth rate

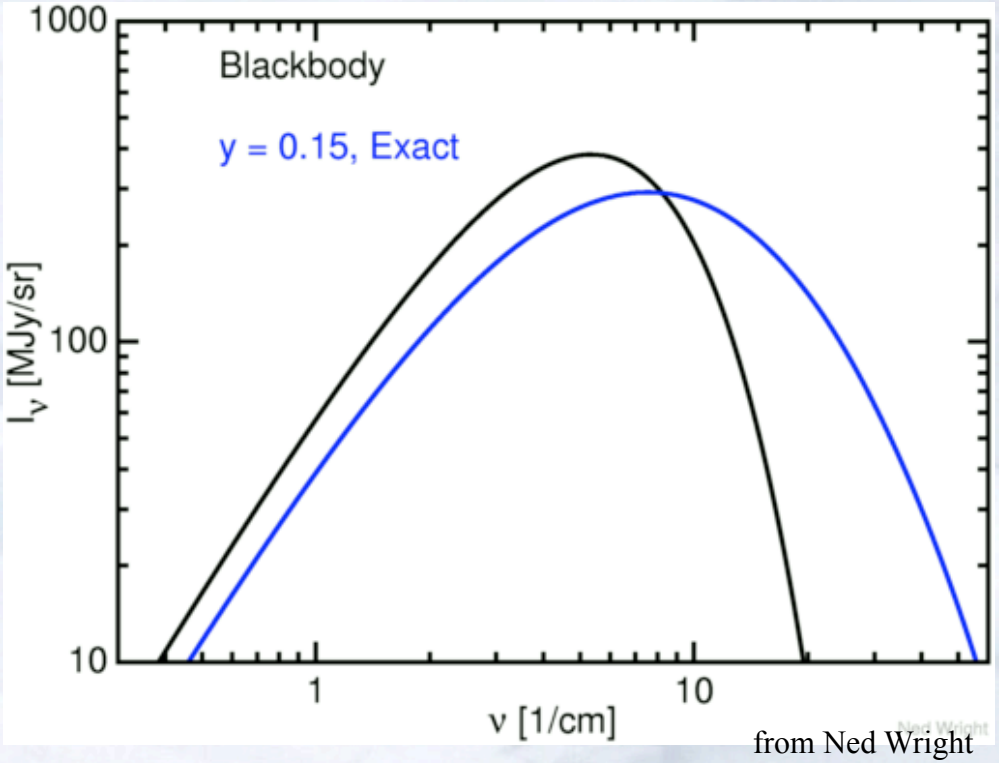
The Sunyaev-Zel'dovich Effect



Small distortion

$\tau_e \sim 0.01$ for $10^{15} M_o$

from Leon Van Speybroeck



from Ned Wright

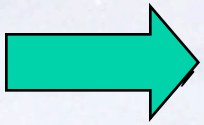
Redshift independent: $\frac{\Delta T_{SZE}}{T_{CMB}} \propto \int n_e T_e dl$

T. Crawford, *SPT Science*, CCAT meeting, November 13, 2010

Requirements for an SZ cluster-finding machine

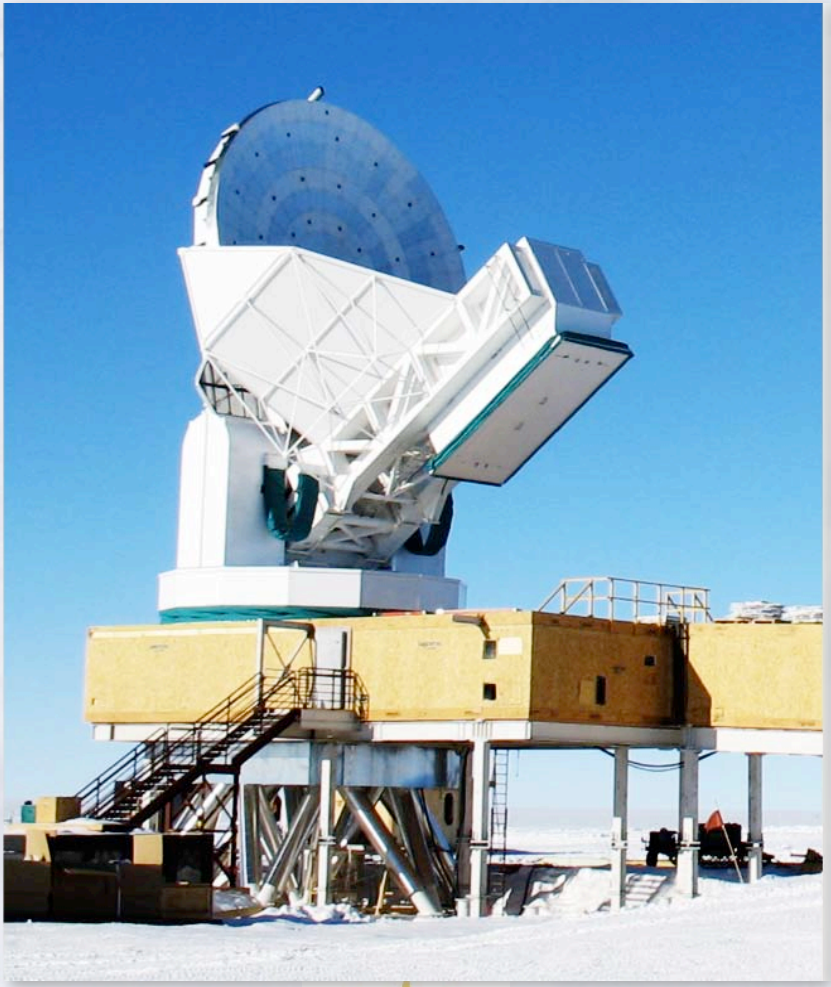
- **Resolution**
  - 1' is well-matched to typical cluster size at these redshifts
  - At 150 GHz this means you need a 8-10 meter dish

- **Mapping Speed**
  - (# of elements) / noise^2
  - At 150 GHz (from the ground), bolometers have reached photon background limit to sensitivity
  - Previous SZ/CMB instruments have on the order of tens of pixels (e.g. – ACBAR =16, QUAD = 31 pixels, ...)



Need more background-limited detectors!!!

The South Pole Telescope (SPT)



Sub-millimeter Wavelength Telescope:

- 10 meter telescope (1' FWHM beam at 150 GHz)
- Off-axis Gregorian optics design
- 20 microns RMS surface accuracy
- 1 arc-second pointing
- Fast scanning (up to 4 deg/sec in azimuth)

SZ receiver:

- 1 sq. deg FOV
- ~960 background limited pixels
- Observe in 3+ bands between 95-220 GHz simultaneously with a modular focal plane

Funded by NSF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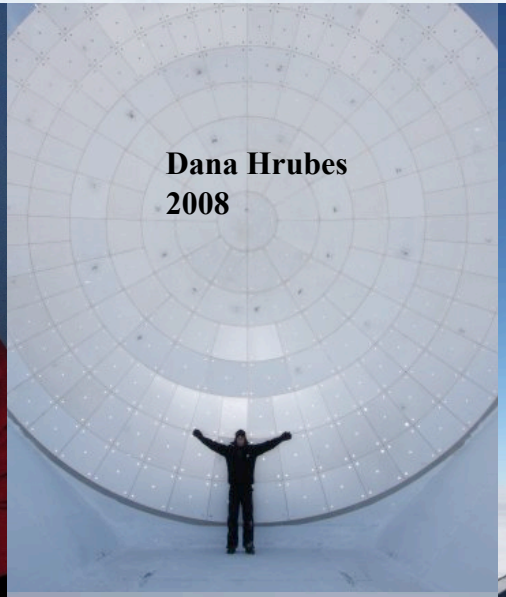
BERKELEY LAB
SPT Collaboration

SPT Heroes Gallery


Dana Hrubes and
Daniel Luong-Van
2010 AND 2011!!


Dana Hrubes
2008


Keith Vanderlinde
2008

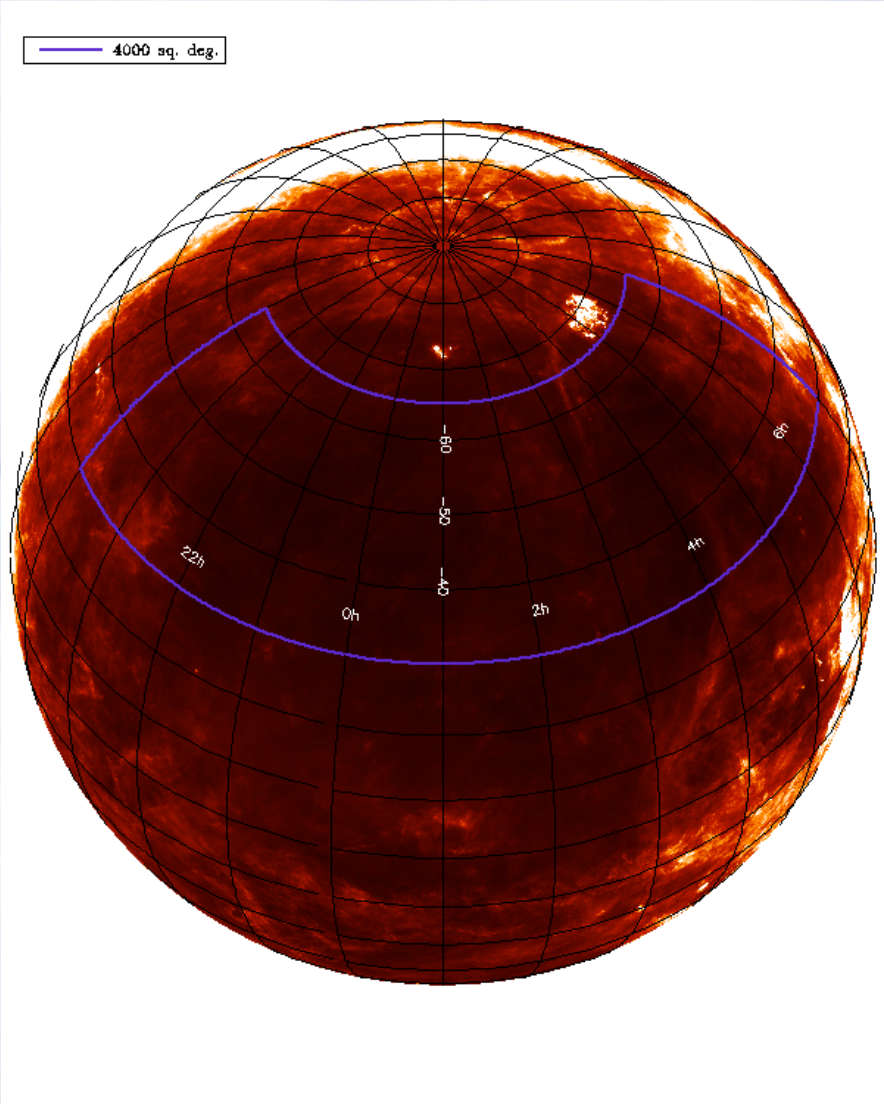

Steve Padin
2007


Zak Staniszewski
2007


Ross Williamson and
Erik Shirokoff
2009

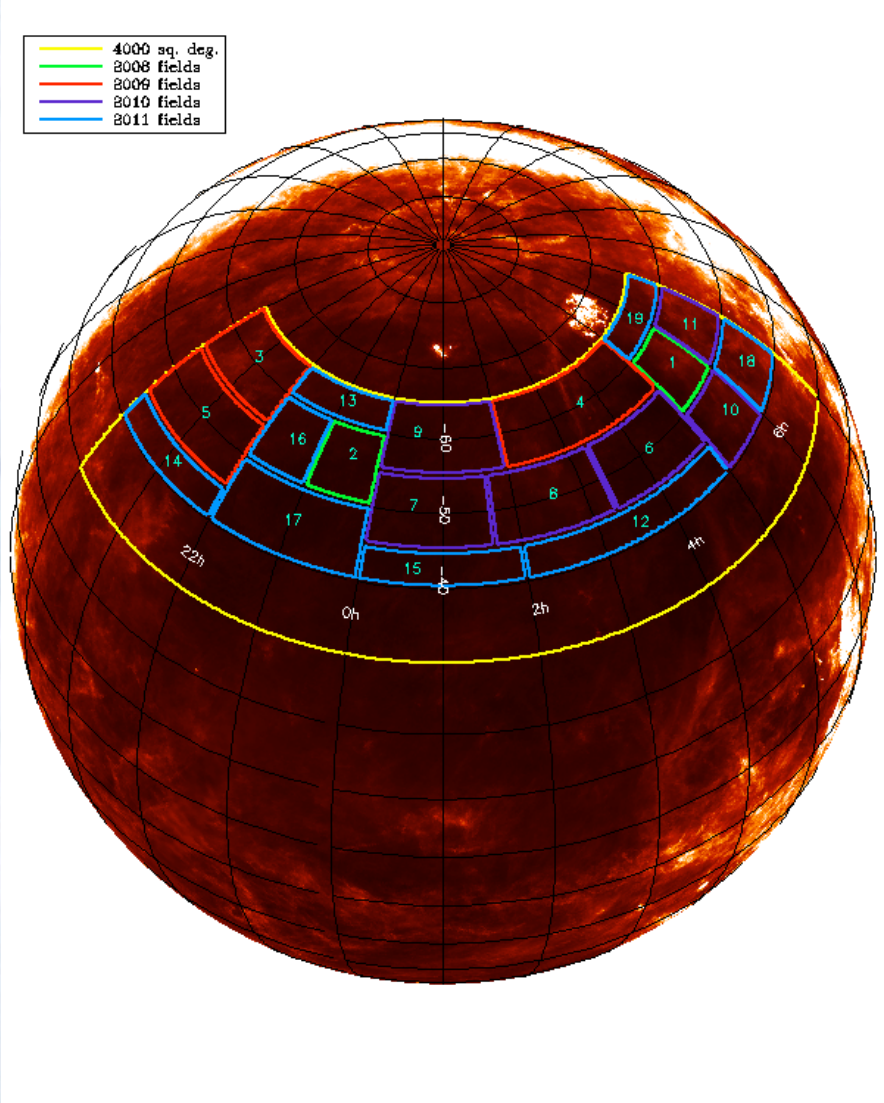
The Survey

- Limited to Southern Celestial Hemisphere.
- Galactic dust emission drives to 20h < RA < 7h.
- Atmospheric emission drives to observing elevations > 30deg.
- Leaves us ~4000 contiguous square degrees.



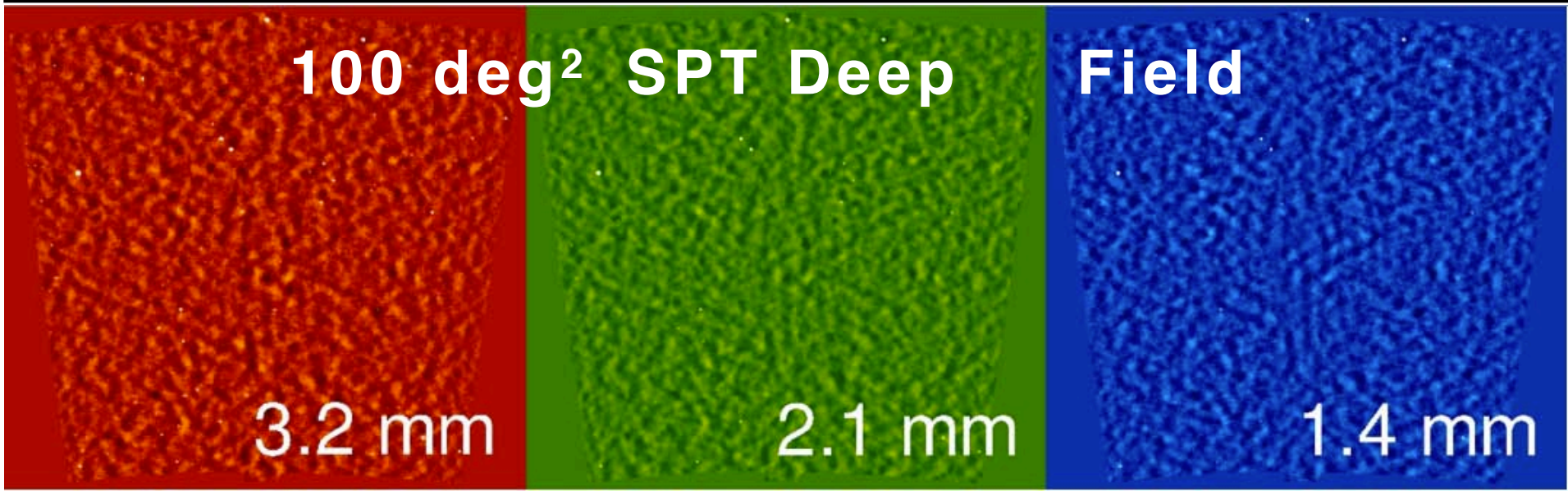
The Survey

- So far have mapped >1500 square degrees to survey depth (and have peeked at the rest).
- Full survey will be ~2500 square degrees. (concentrate on higher-latitude / more-negative-dec regions)



SPT Survey Area and Depth

	2008	2x220 3x150	2009 -- 2011	1x220 4x150 1x90	SPT Deep Field	done!	+ 3 months	???
band [GHz]	RMS [uK-arcmin]	RMS [mJy/beam]	RMS [uK-arcmin]	RMS [mJy/beam]	RMS [uK-arcmin]	RMS [mJy/beam]	RMS [uK-arcmin]	RMS [mJy/beam]
90	-	-	40	2.0	40	2.0	20	1.0
150	18	1.3	18	1.3	13	0.9	8	0.6
220	40	3.4	80	6.8	35	3.0	30	2.6
area [deg^2]	200		2300		100		100	



Outline

II. Galaxy cluster science

SPT has found hundreds of new clusters!

Observing year	Area surveyed (square degrees)	Candidates above 5 sigma	Candidates above 4.5 sigma	Candidates above 5 sigma w/redshifts	Candidates above 4.5 sigma w/ redshifts
2008	~200	22	39	21	28
2009	~600	75	142	67	94
2010 (so far)	~600	104	165	43	51
TOTAL	~1400	201	346	131	173

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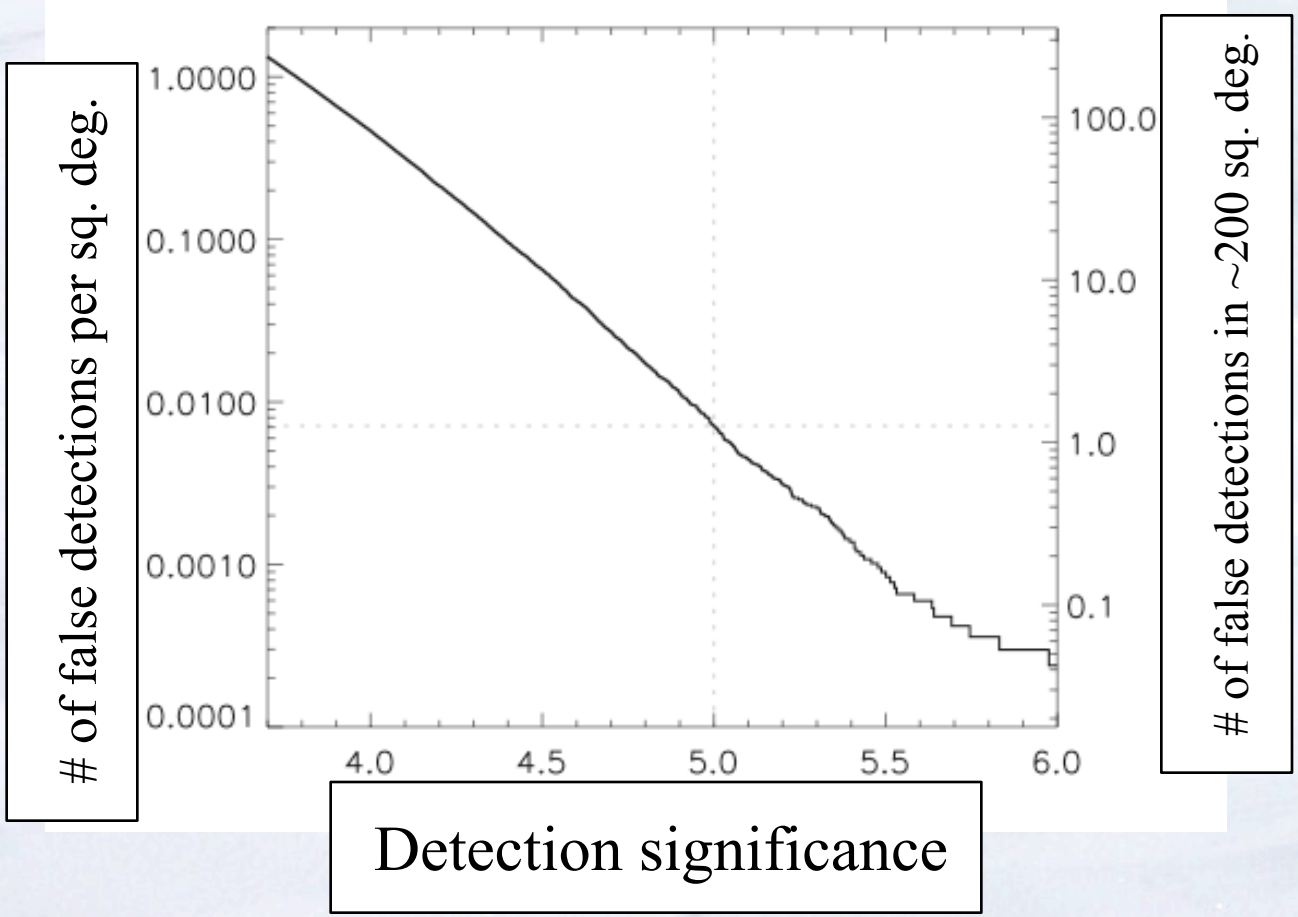
SPT cluster detections are robust



- Simulations predict ~10 false positives above S/N=5 in entire survey (~100 above S/N=4.5).
- Borne out by optical/IR/x-ray follow-up of first catalog (only 1 spurious detection out of 22 in first ~200 sq. deg.)

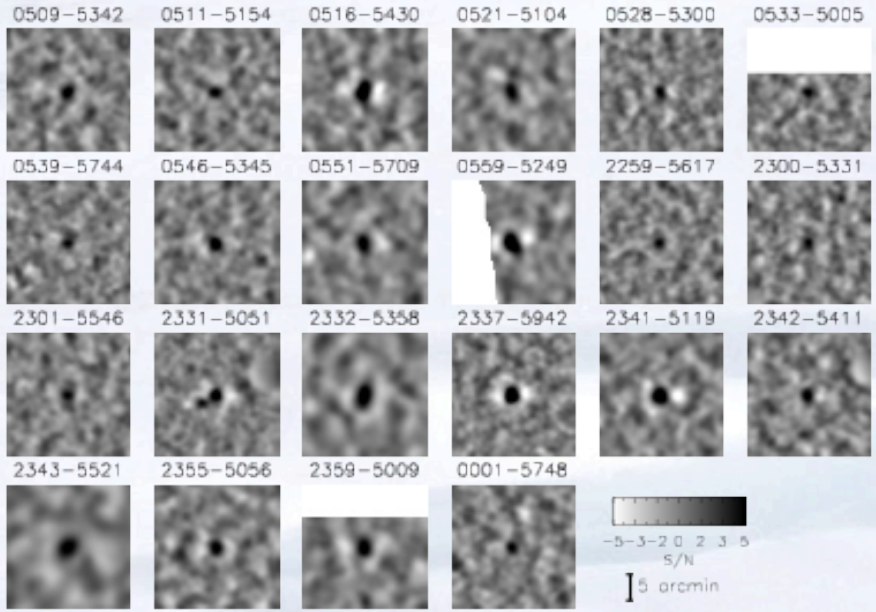
SPT clusters are all massive

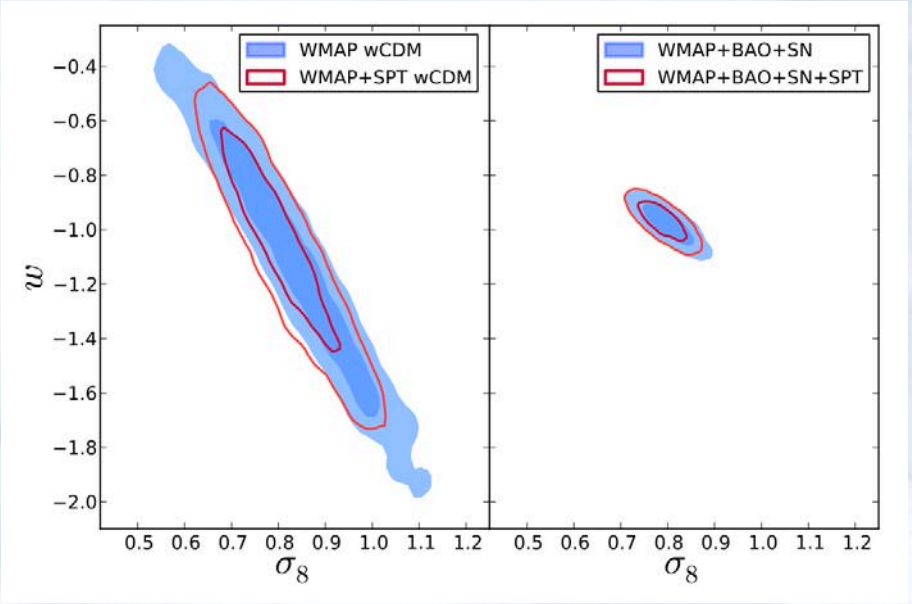
TABLE 3
CLUSTER MASSES FROM $M_{500} - Y_X$ AND $M_{500} - T_X$ RELATIONS

Name	z	r_{500}[a] kpc	M_{500,Y_X} $10^{14} M_\odot$	M_{500,T_X} $10^{14} M_\odot$	$M_{500,SZ,V10}$[b] $10^{14} M_\odot$
J0000-5748	0.74	950	5.32 ± 1.16	6.74 ± 5.14	$2.89 \pm 0.61 \pm 0.41$
J0509-5342	0.4626	1062	5.43 ± 0.60	6.71 ± 3.40	$4.26 \pm 0.74 \pm 0.60$
J0516-5430	0.2952	1463	11.84 ± 1.25	12.34 ± 2.13	$6.48 \pm 0.95 \pm 1.13$
J0528-5300	0.7648	775	2.97 ± 0.89	3.05 ± 4.00	$2.83 \pm 0.60 \pm 0.38$
J0533-5005	0.8810	656	2.06 ± 0.53	2.25 ± 1.71	$2.71 \pm 0.56 \pm 0.37$
J0546-5345	1.0665	840	5.33 ± 0.62	5.25 ± 1.13	$3.25 \pm 0.51 \pm 0.44$
J0551-5709	0.4230	948	3.56 ± 0.43	3.00 ± 0.85	$4.10 \pm 0.75 \pm 0.58$
J0559-5249	0.6112	1043	6.40 ± 0.54	7.07 ± 1.49	$5.03 \pm 0.74 \pm 0.70$
J2331-5051	0.5707	972	4.70 ± 0.51	4.91 ± 1.36	$4.63 \pm 0.73 \pm 0.66$
J2332-5358	0.32	1134	5.66 ± 0.48	6.69 ± 1.08	$5.19 \pm 0.85 \pm 0.83$
J2337-5942	0.7814	1046	7.43 ± 0.90	8.10 ± 2.18	$6.32 \pm 0.84 \pm 0.97$
J2341-5119	0.9983	847	5.06 ± 0.66	5.20 ± 1.69	$4.05 \pm 0.58 \pm 0.63$
J2342-5411	1.08	647	2.47 ± 0.32	2.39 ± 0.63	$2.65 \pm 0.50 \pm 0.37$
J2355-5056	0.35	1014	4.18 ± 0.43	4.26 ± 1.57	$4.17 \pm 0.80 \pm 0.63$
J2359-5009	0.76	816	3.45 ± 0.67	4.97 ± 2.61	$3.32 \pm 0.60 \pm 0.46$

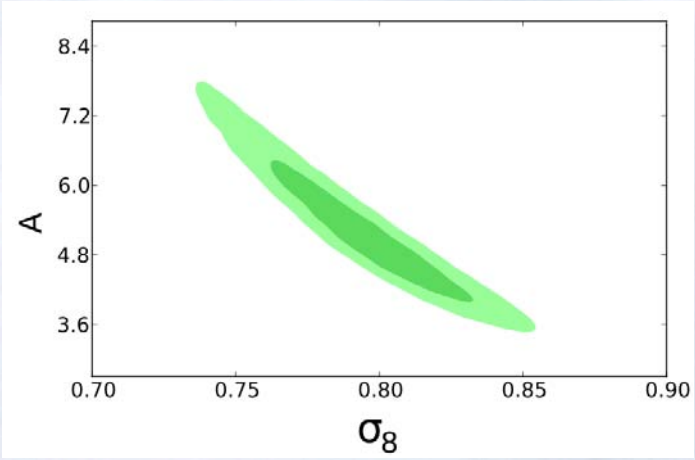
All optically confirmed SPT clusters with x-ray measurements show strong signal and temperatures consistent with massive clusters ($\geq 2\times10^{14}$ solar masses).

First cosmological results with SZ clusters: Vanderlinde et al., 2010





- 21 clusters
- slightly improve on WMAP-only
- constraints limited by scaling relation uncertainties



Clusters and CCAT

- Lower noise:
  - lower in cluster mass function -> lots more clusters
- Higher resolution:
  - resolve core radius, enabling robust total Y measurement.
  - detect & remove point sources.
- Deep multicolor imaging:
  - high S/N on CMB in all bands.
  - kinetic SZ in individual clusters?

Outline

III. CMB anisotropy science

CMB anisotropy I: Large angular scales

- ~800 square degrees of 2008-2009 150 GHz data.
- cosmic-variance-limited to ℓ~2300.

Keisler, et al. (2011, in prep.)

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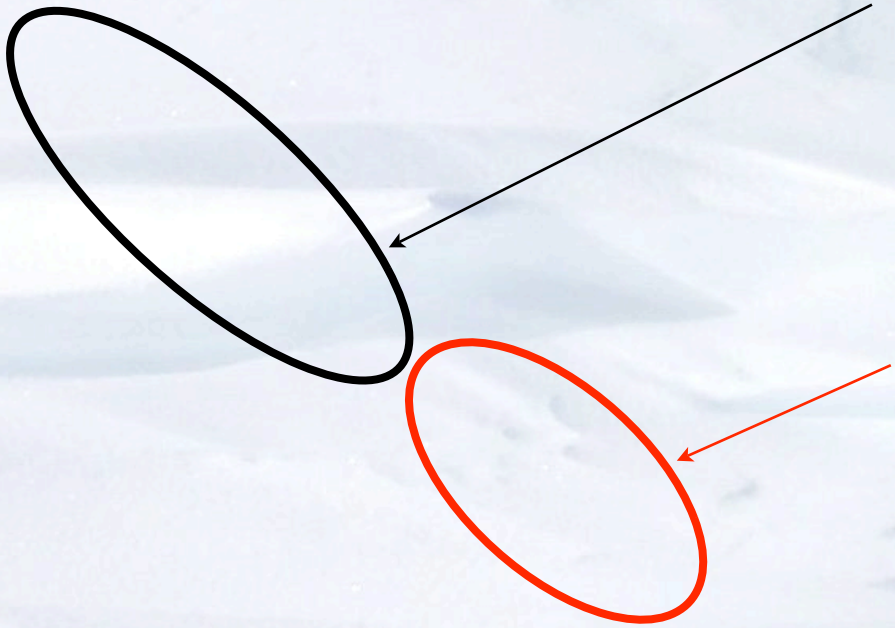
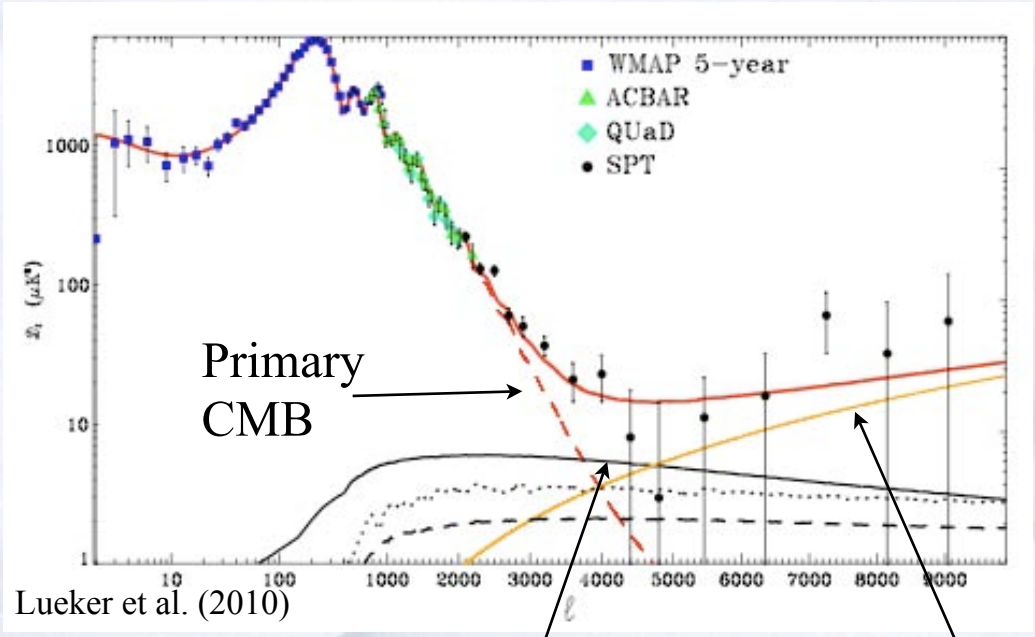


Planck will nail this forever

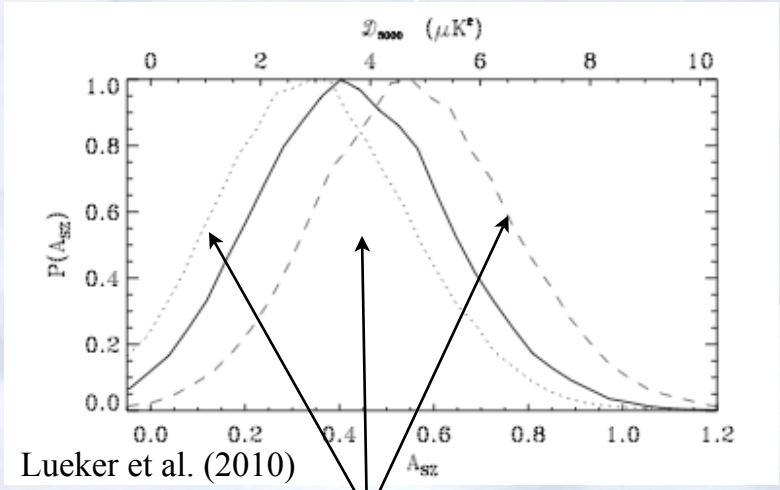
Lots of interesting stuff to do here.

Keisler, et al. (2011, in prep.)

CMB anisotropy II: Small angular scales



Lueker et al. (2010)



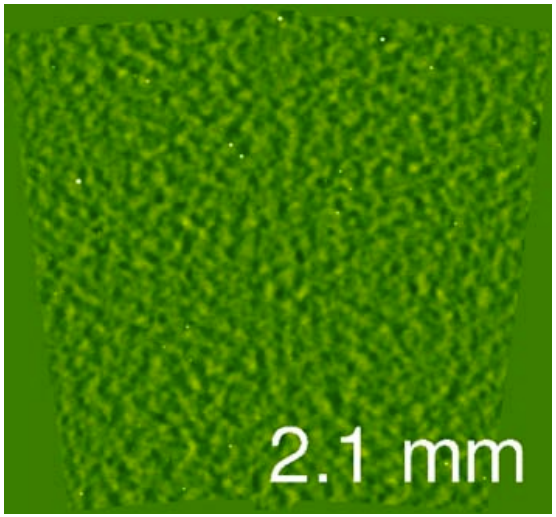
Lueker et al. (2010)

Likelihood of thermal SZ power for 3 kSZ possibilities

Measuring the Epoch of Reionization

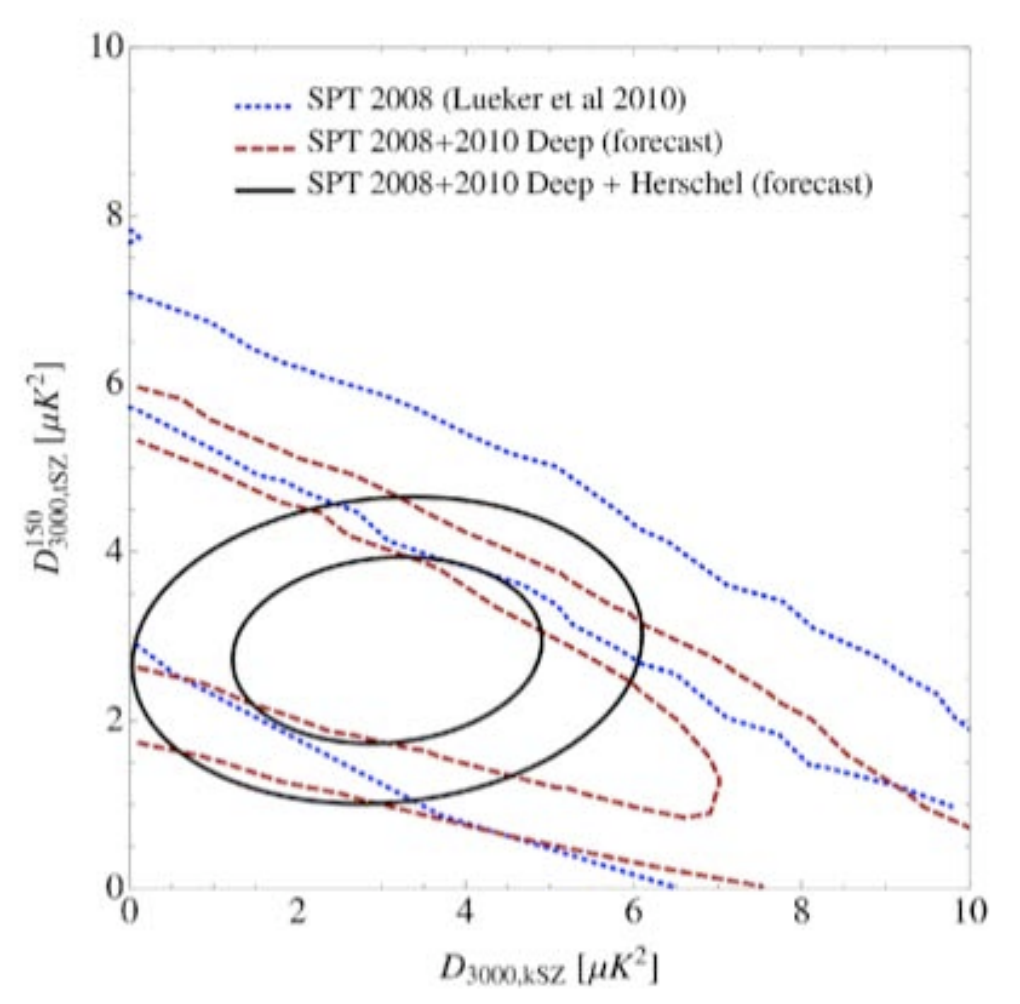
Herschel-SPIRE + SPT deep field

- **SPIRE maps are nearly confusion limited in a single observation.**
- **SPT 100 deg^2 deep field is the deepest mm map in existence and will remain so for the next decade.**
- **We have been granted 79 hours to map a 100 deg^2 field.**
- **The SPT Deep Field will be enable many statistical measurements of large scale structure and the high redshift universe.**



The HOTAC called this proposal a "must-do"

CMB anisotropy II: Small angular scales



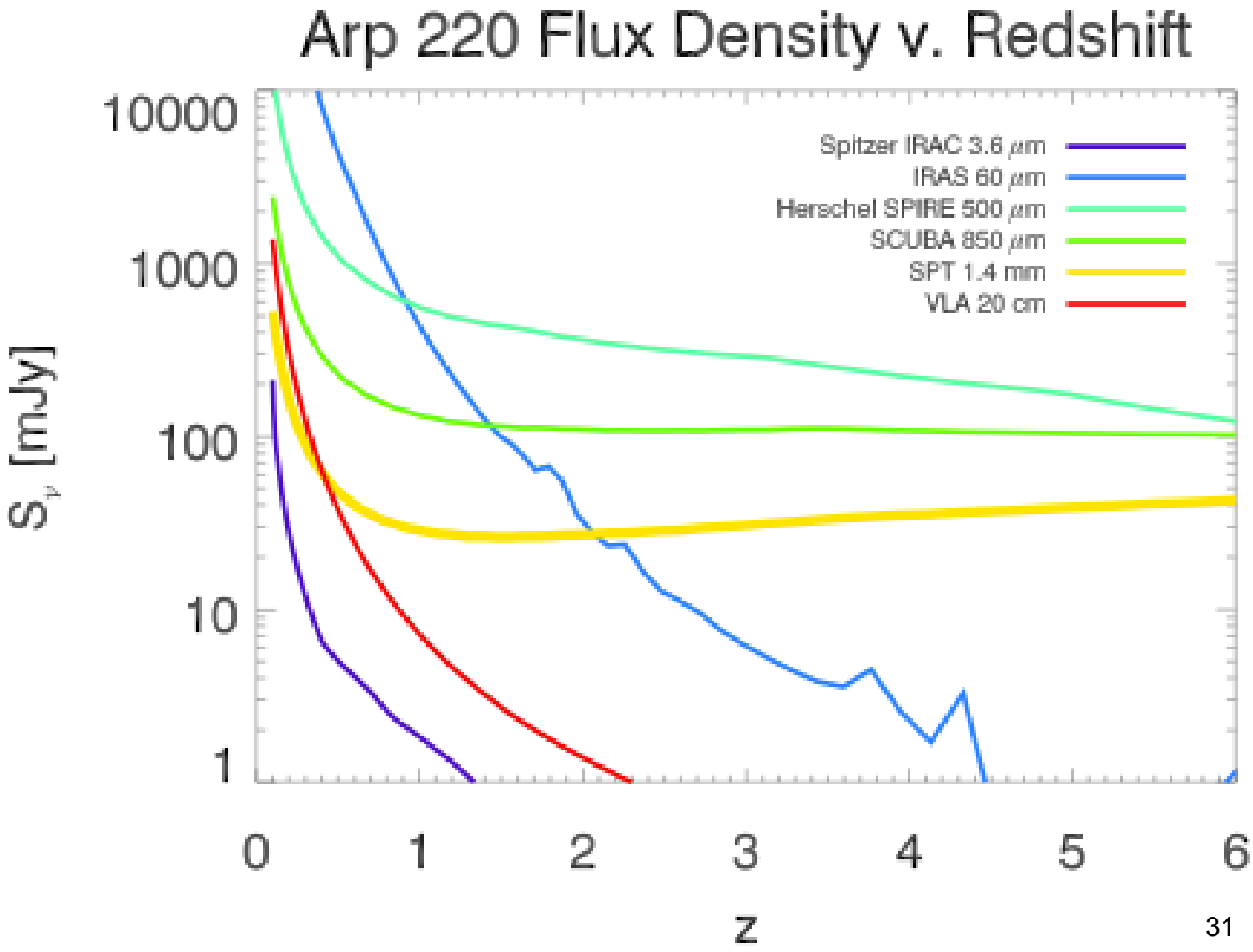
- projections for 100 square degrees of deep 0.5mm, 1.4mm, 2.0mm, 3.2mm data
- what could CCAT add here...

Outline

IV. High-z dusty galaxy science

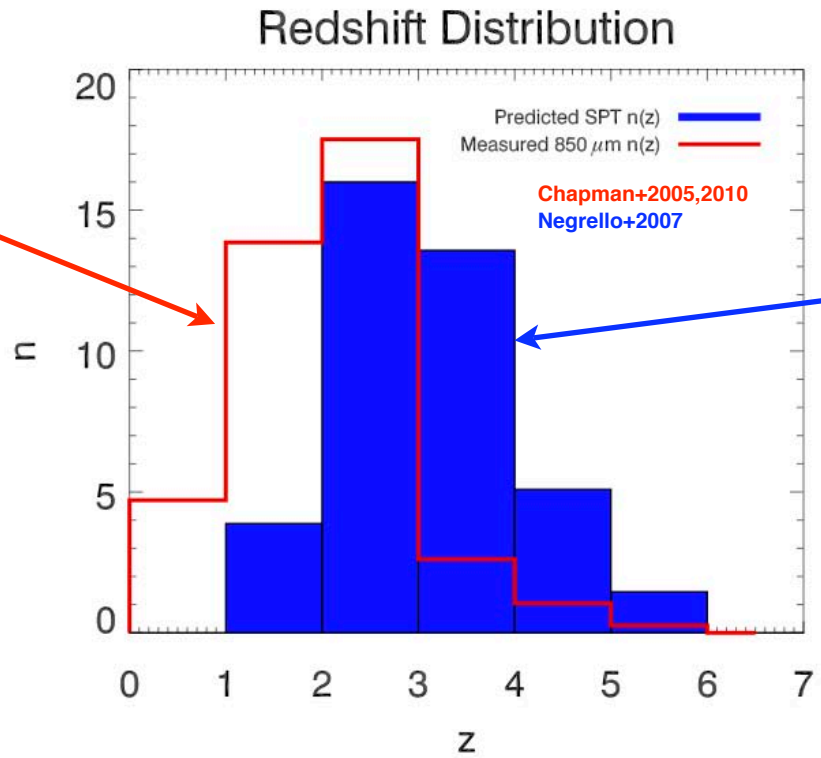
[Sub-] mm magic

First pointed out in Blain & Longair 1993



Redshift distribution predictions

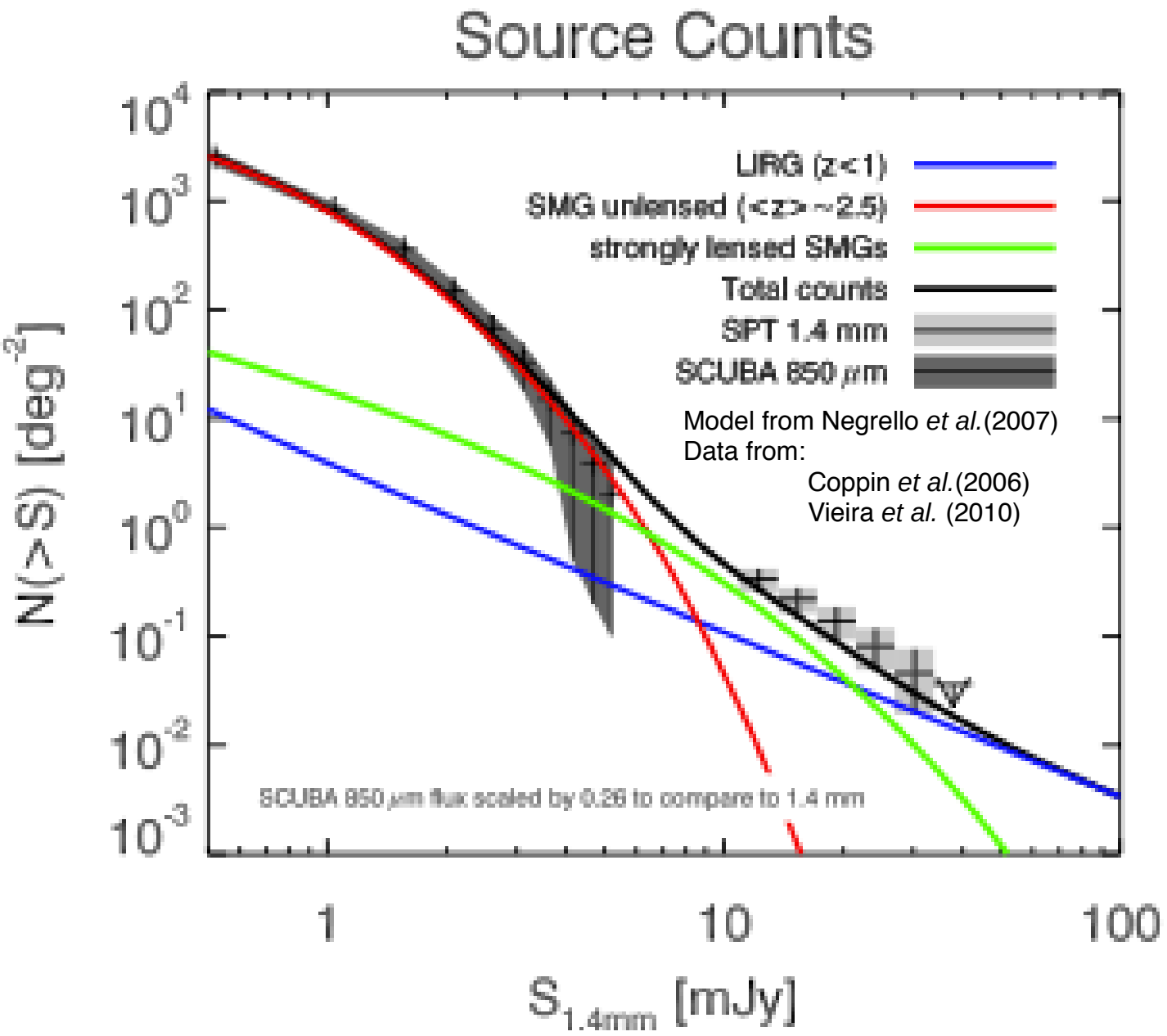
~1/2 of these sources should be at z>3

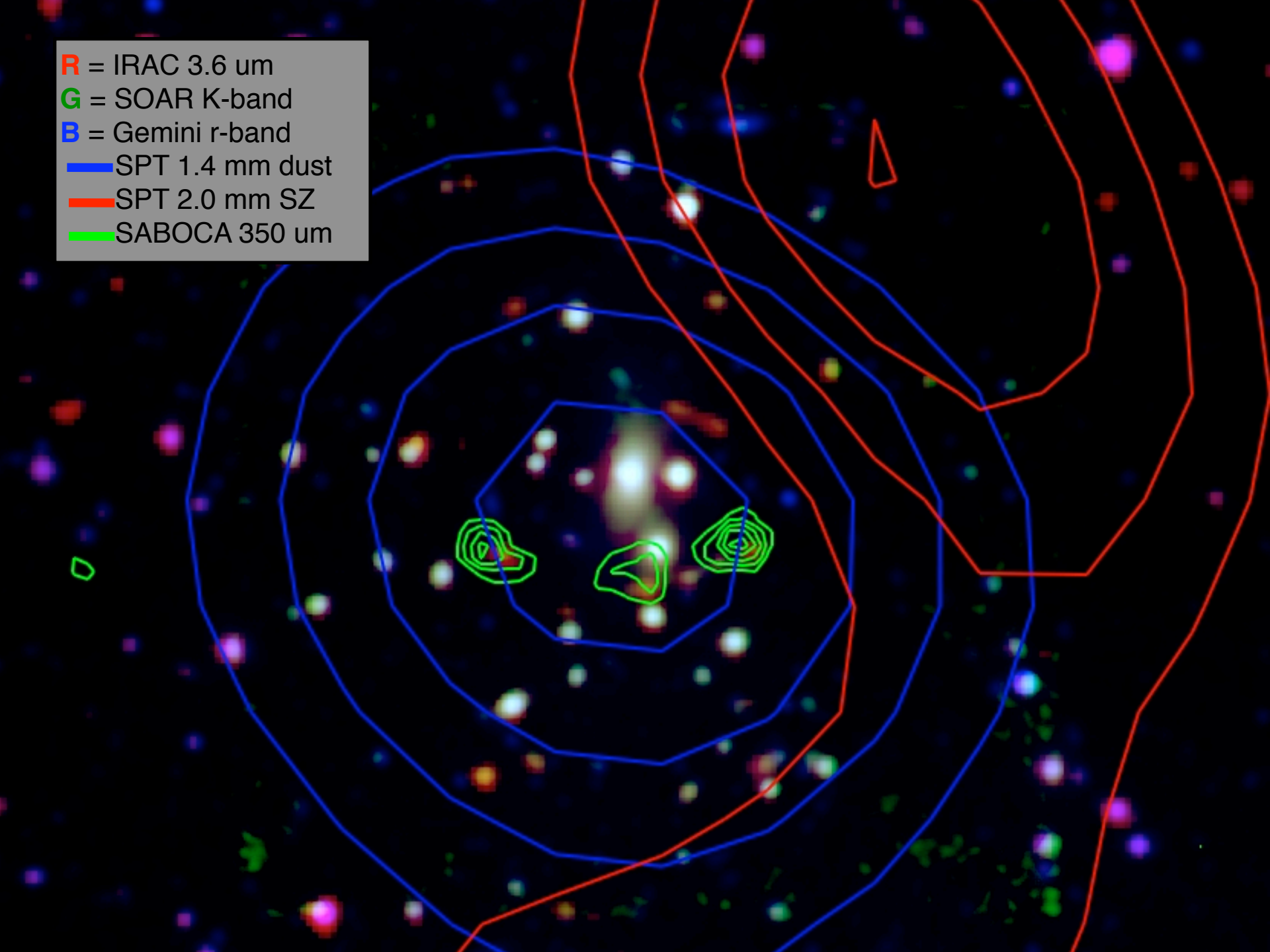


SCUBA sources

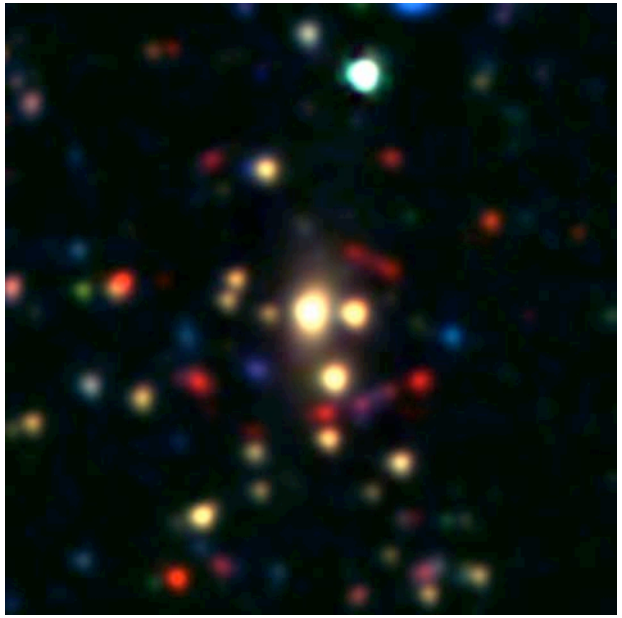
SPT sources (predicted)

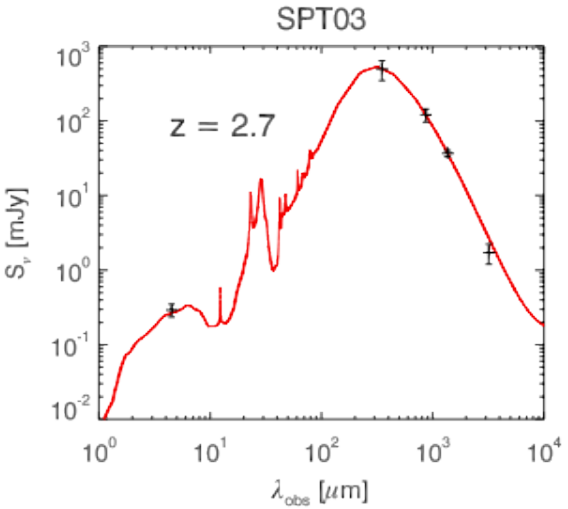
- ***longer-wavelength*** surveys preferentially select ***high redshift objects***.
- High redshift sources have a ***higher probability of being strongly lensed***.
- Mapping ***wide areas*** leads to a greater chance for discovering ***rare, luminous (or lensed) objects***.


Source Counts
LIRG (z<1)
SMG unlensed (<z> ~2.5)
strongly lensed SMGs
Total counts
SPT 1.4 mm
SCUBA 850 μm
Model from Negrello et al.(2007)
Data from:
Coppin et al.(2006)
Vieira et al. (2010)
SCUBA 850 μm flux scaled by 0.26 to compare to 1.4 mm
N(>S) [deg^-2]
S1.4mm [mJy]
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
1
10
100


R = IRAC 3.6 um
G = SOAR K-band
B = Gemini r-band
SPT 1.4 mm dust
SPT 2.0 mm SZ
SABOCA 350 um

SMG03





lens @ z=0.404

Confirms VLT Ly-alpha redshift

Outline

V. The Future?

Near-term (mid-term?) plans for the SPT

2010-2011: Finish SZ survey

2012-2014: CMB polarimeter at 2.0 and 3.2 mm.

2015-beyond: ???

- the telescope and site are submm quality, so.....

Thanks!

Photo credit: Keith Vanderlinde