Current results from SPT

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CAERDYDD
Colorado
University of Colorado at Boulder
BERKELEY LAB
SPT Collaboration

South Pole Telescope

10 m mm-wave (3 different wavelengths) telescope at the south pole

- extremely dry
- very stable
- good support

Chicago Colorado
UC Berkeley Case Western
McGill Harvard
UC Davis Munich +++

South Pole Telescope

10m telescope

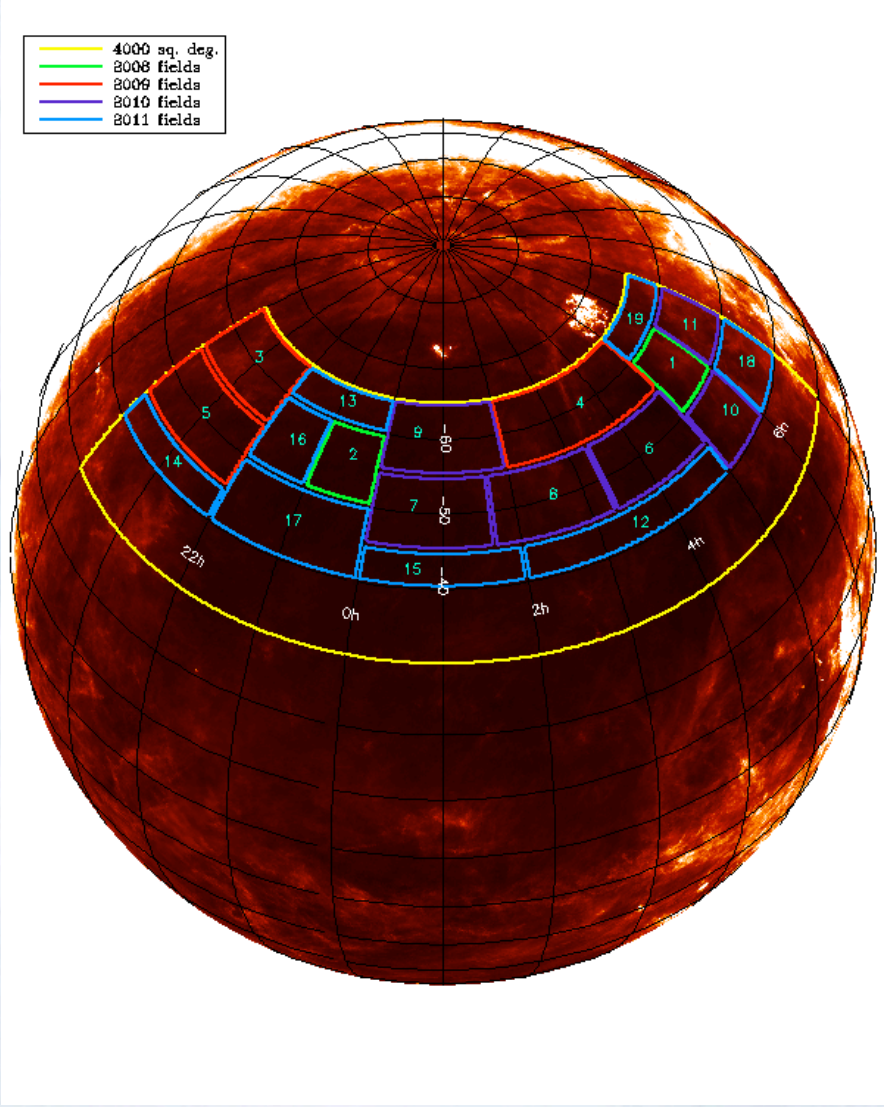
~1000 detectors
90, 150, 220 GHz

~1' resolution

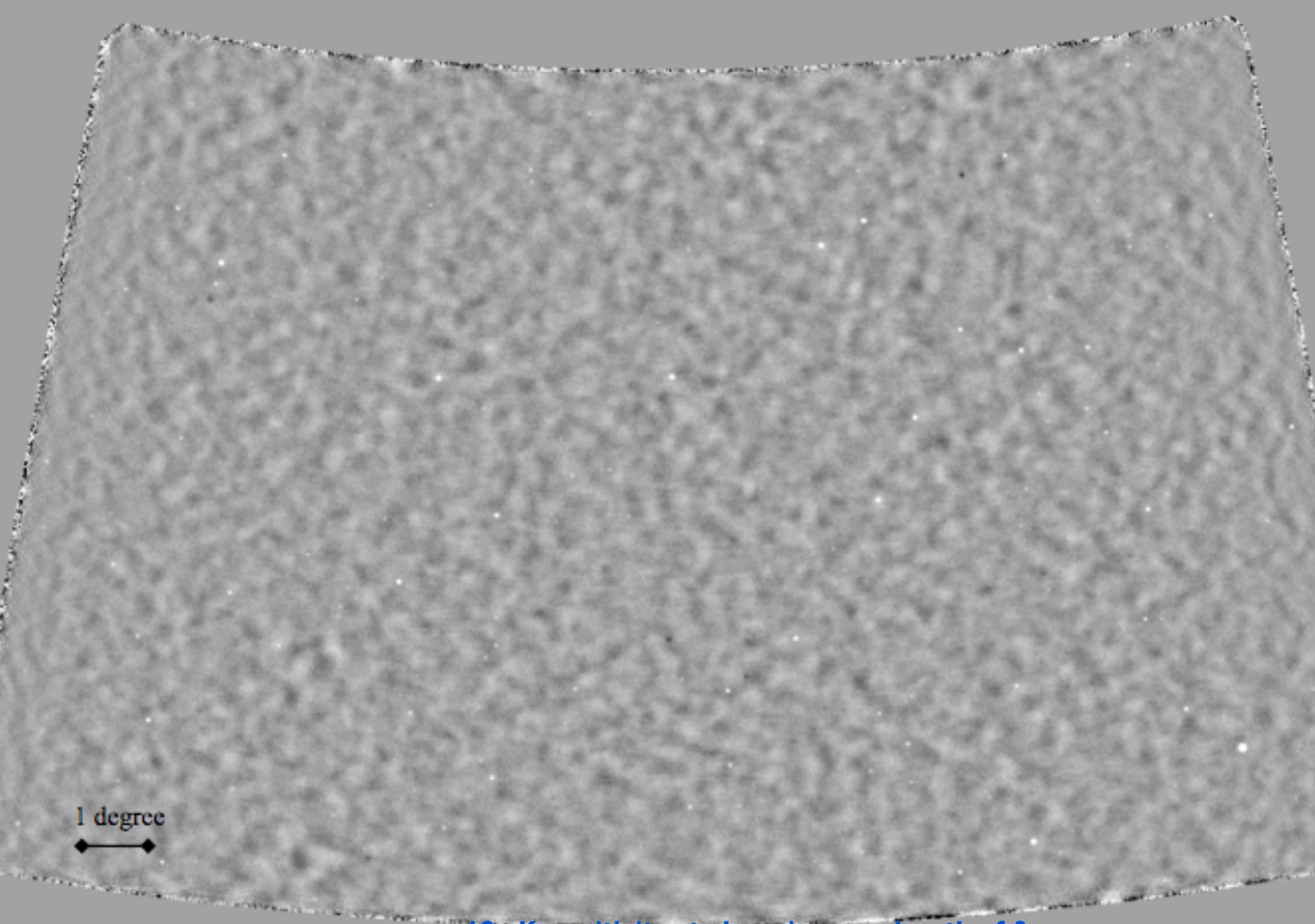
Season	bands [GHz]	area [deg^2]	150 GHz Depth [μK-arcmin]
2007	90+150	40	80
2008	150+220	180	18
2009	90+150+220	565	18
2010	90+150+220	>500	18
2011	90+150+220	>500	18
Total	**90+150+220**	**2500**	**18**

The Survey

- So far have mapped ~1400 square degrees to survey depth (18 uK at 150 GHz)
- Full survey will be ~2500 square degrees. (concentrate on higher-latitude / more-negative-dec regions)



slide by T. Crawford

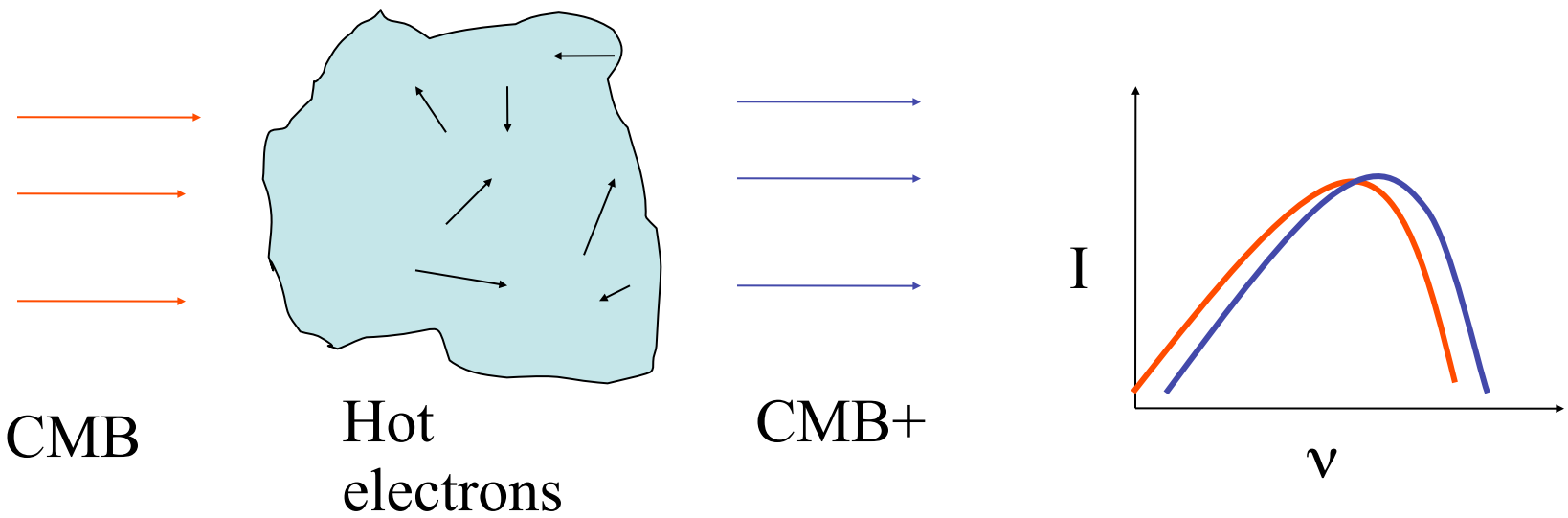


18 uK sensitivity at observing wavelength of 2 mm
roughly same resolution as your eye

SPT Science

- Galaxy Clusters
  - Studies of individual clusters Plagge
  - Finding new clusters to track cosmic growth Vanderlinde Williamson
- Dusty galaxies Vieira; Hall
  - mm-wave studies of the cosmic infrared background
  - new population of strongly lensed high-z star forming galaxies
- CMB measurements Keisler, Shirokoff, Lueker
- Weak lensing of the CMB van Engelen

Thermal Sunyaev-Zel'dovich Effect

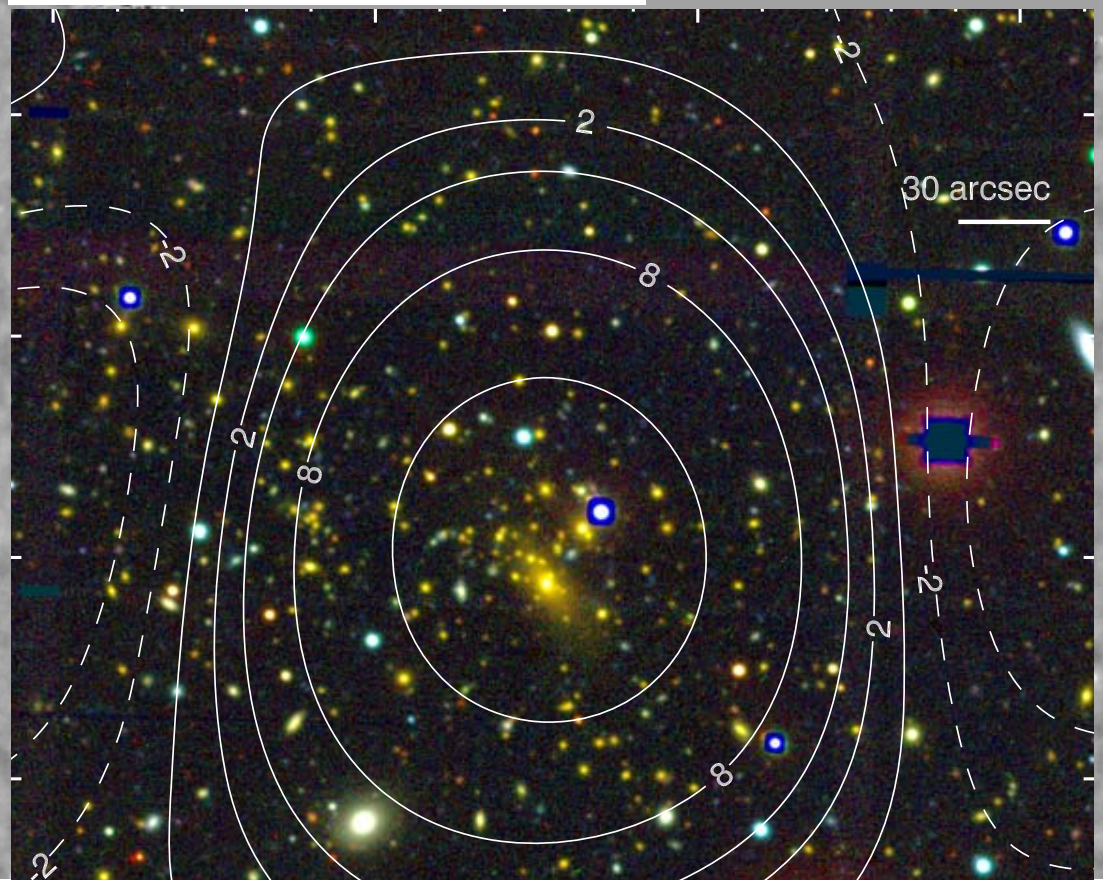


Optical depth: $\tau \sim 0.01$

Fractional energy gain per scatter: $\frac{kT}{m_e c^2} \sim 0.01$

Typical cluster signal: ~500 uK

Image by Will High in recent paper by Williamson et al



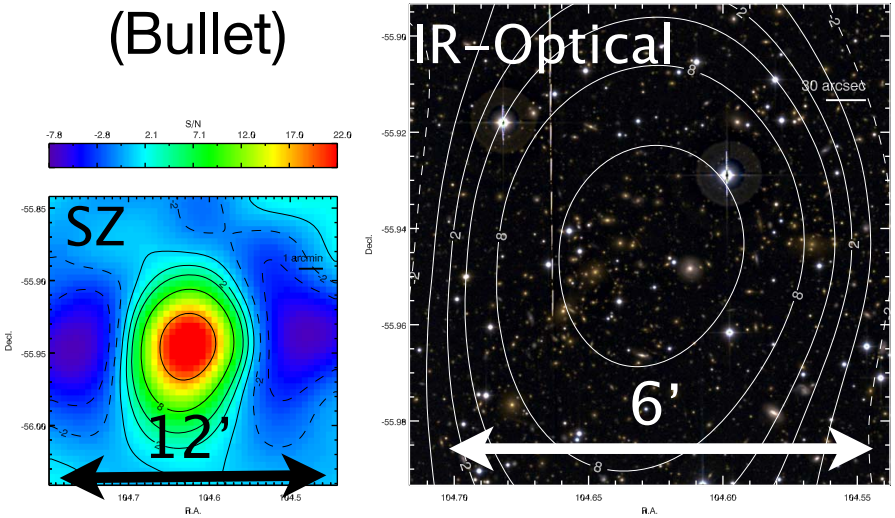
One of the heaviest objects in the universe
>10^{15} solar masses

patch of isolated cosmic fog

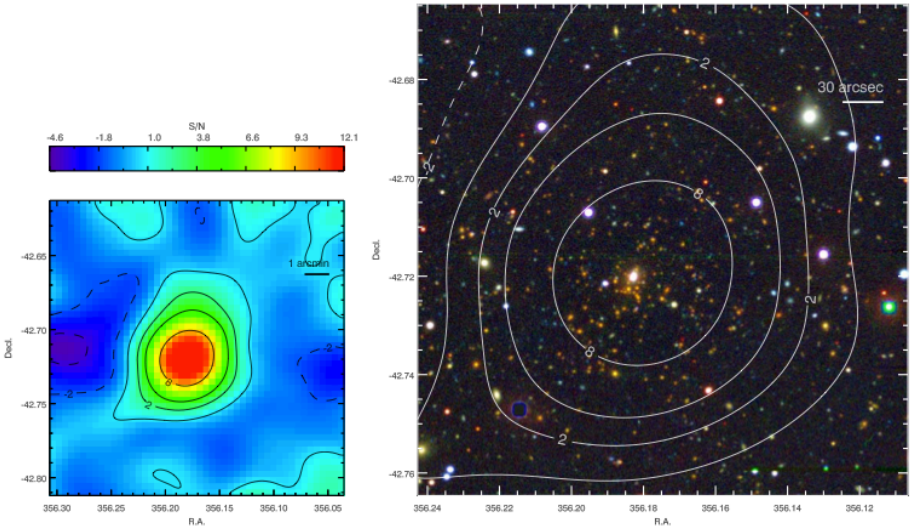
1 degree

SPT Cluster Images

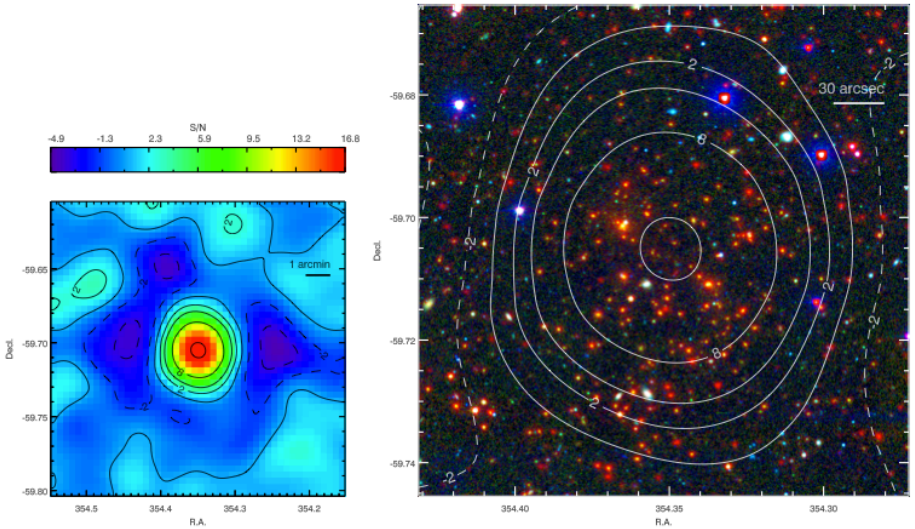
0658-5556 (z=0.30)
(Bullet)



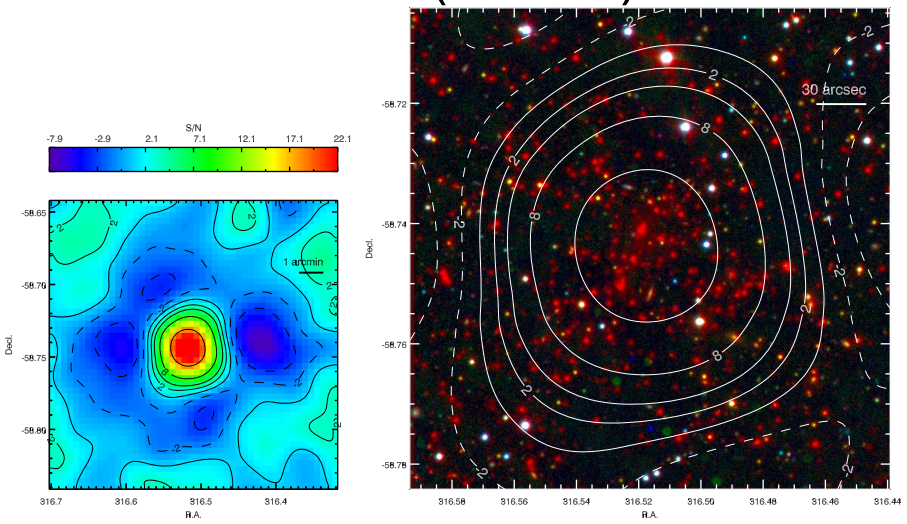
2344-4243 (z=0.62)



2337-5942 (z=0.78)



2106-5844 (z=1.13)

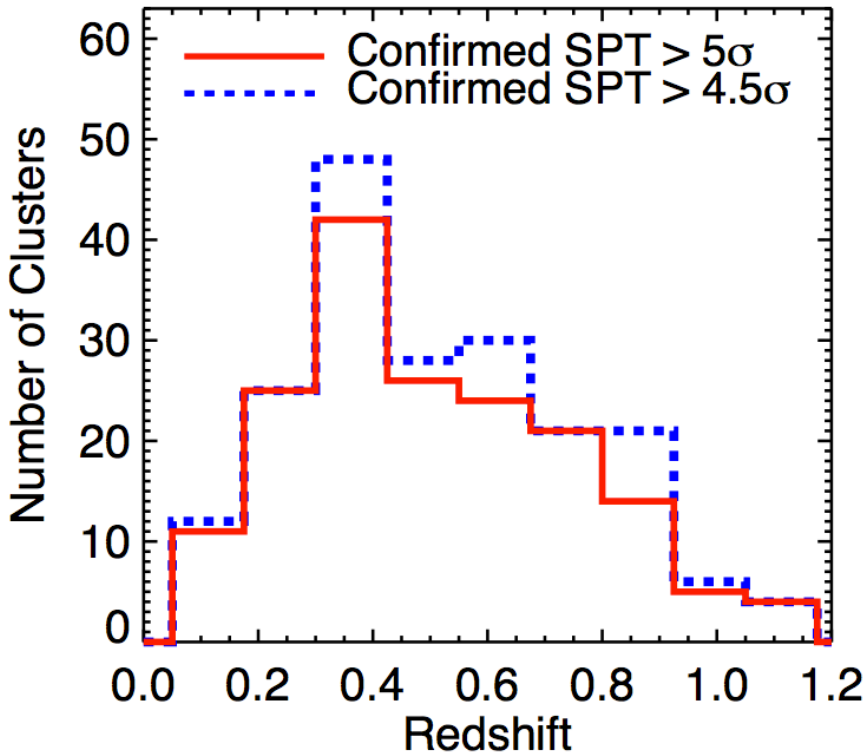


Williamson et al 2011, arXiv:1101.1290

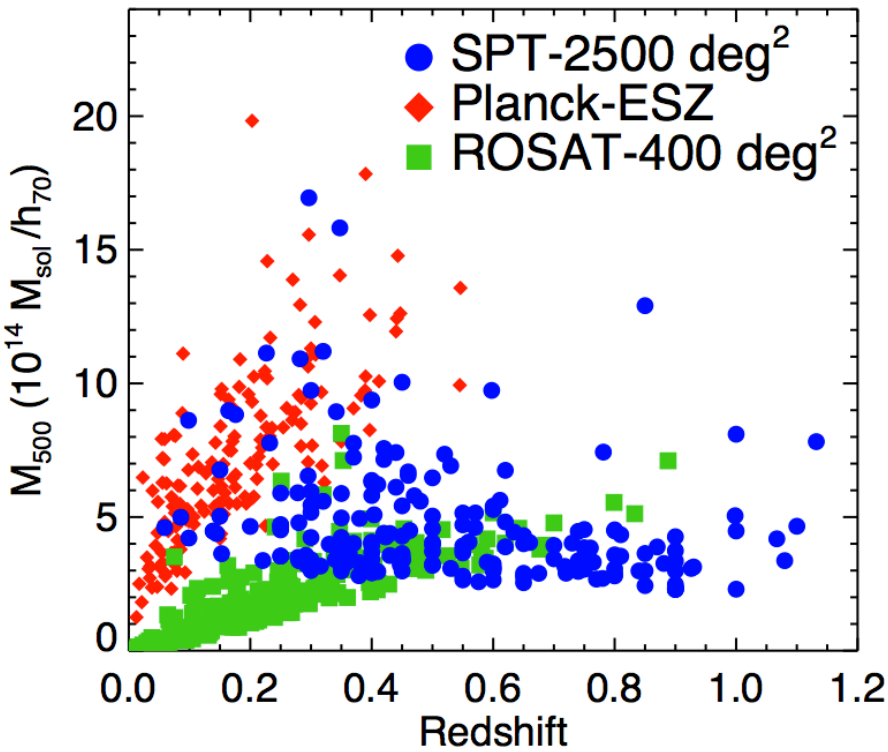
slide from Brad Benson

SPT Cluster Sample Properties

Redshift Histogram



SZ Mass vs Redshift

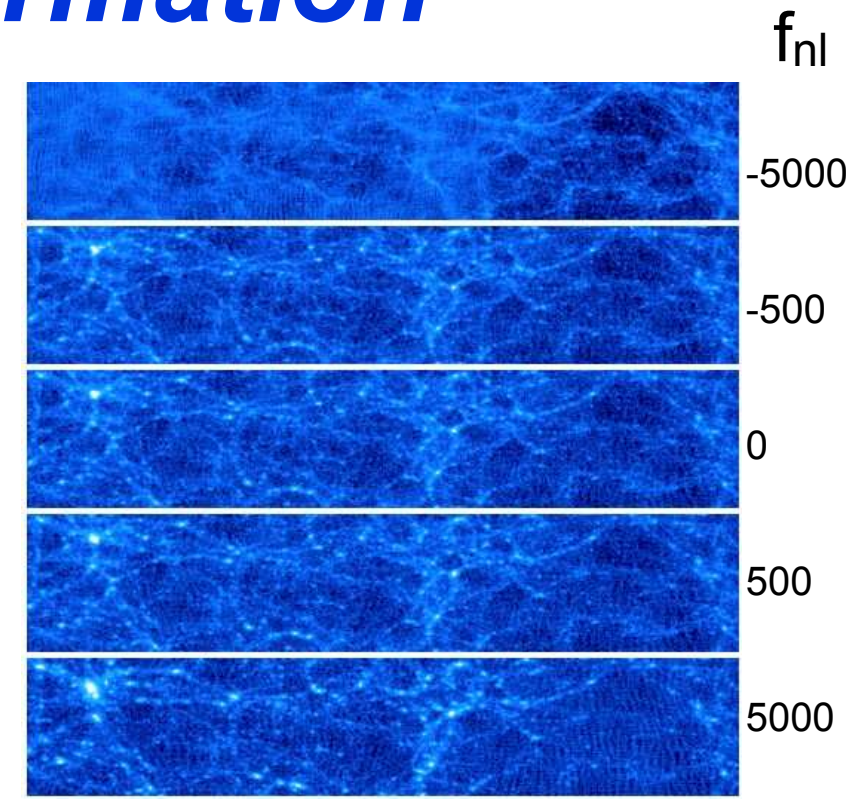


- Optically confirmed ~300 clusters, ~80% newly discovered
- High redshift: $\langle z \rangle$ = 0.55 and ~20-25% of clusters at z > 0.8
- Optical measurements also confirm ~95% purity at S/N = 5
- Mass threshold flat/falling w/ redshift: $M_{500}(z=0.6) > \sim 3\times10^{14}\ M_{sol}/h_{70}$

slide from Brad Benson

Non-Gaussianity and structure formation

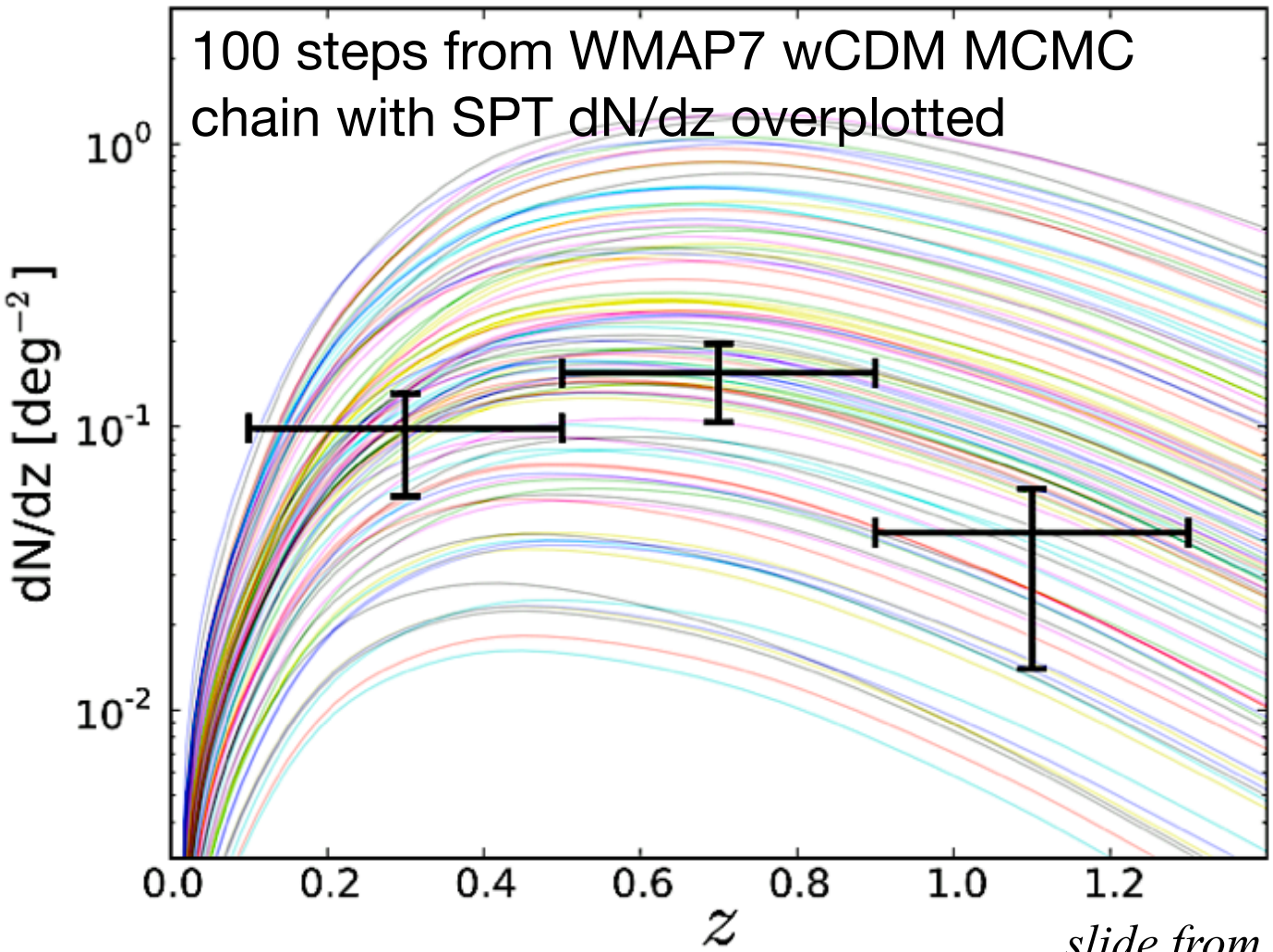
- large non-Gaussianity in initial conditions visible in large scale structure
- CMB (e.g., WMAP) probes larger scales than most large scale structure studies



Dalal et al 2008

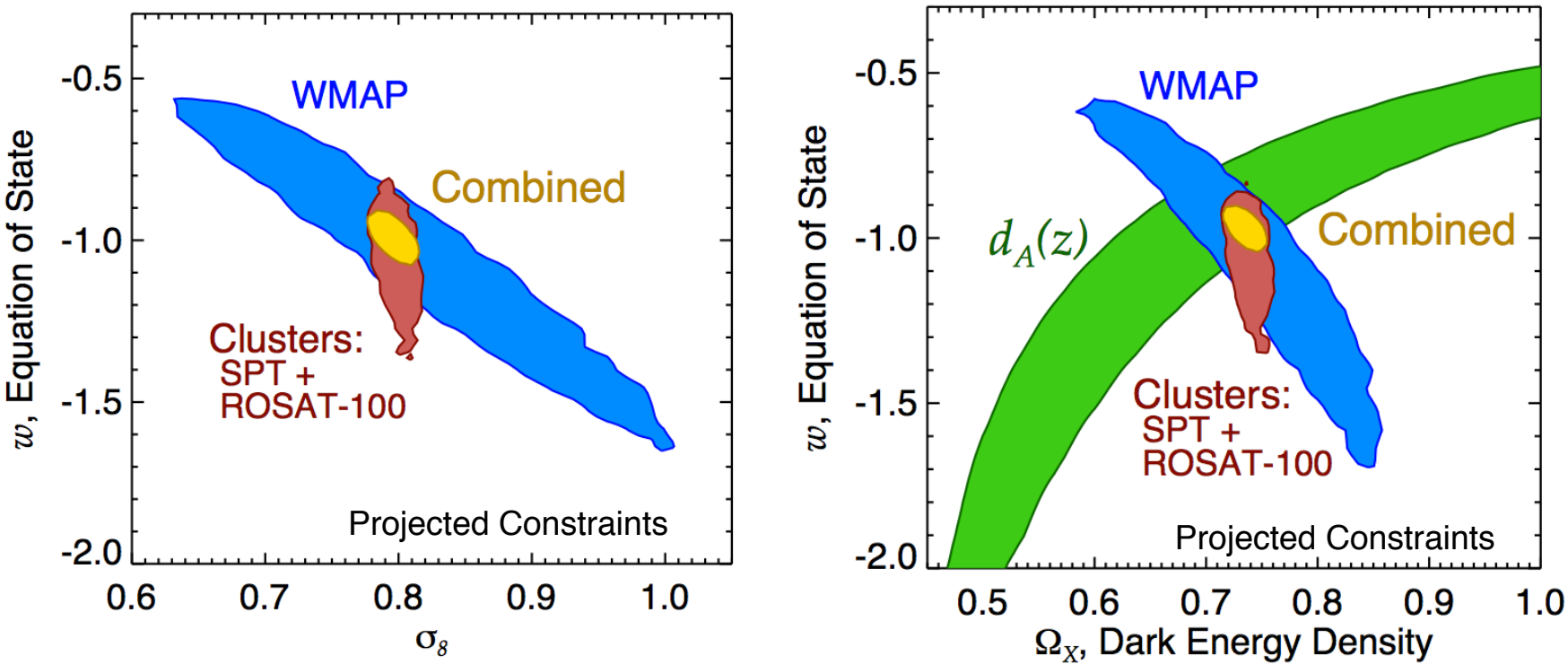
Cluster dN/dz

First SPT Cosmological result (Vanderlinde et al 2010), used SPT's first 21 clusters to constrain cosmology



slide from Brad Benson

SPT Cosmological Constraints with X-rays

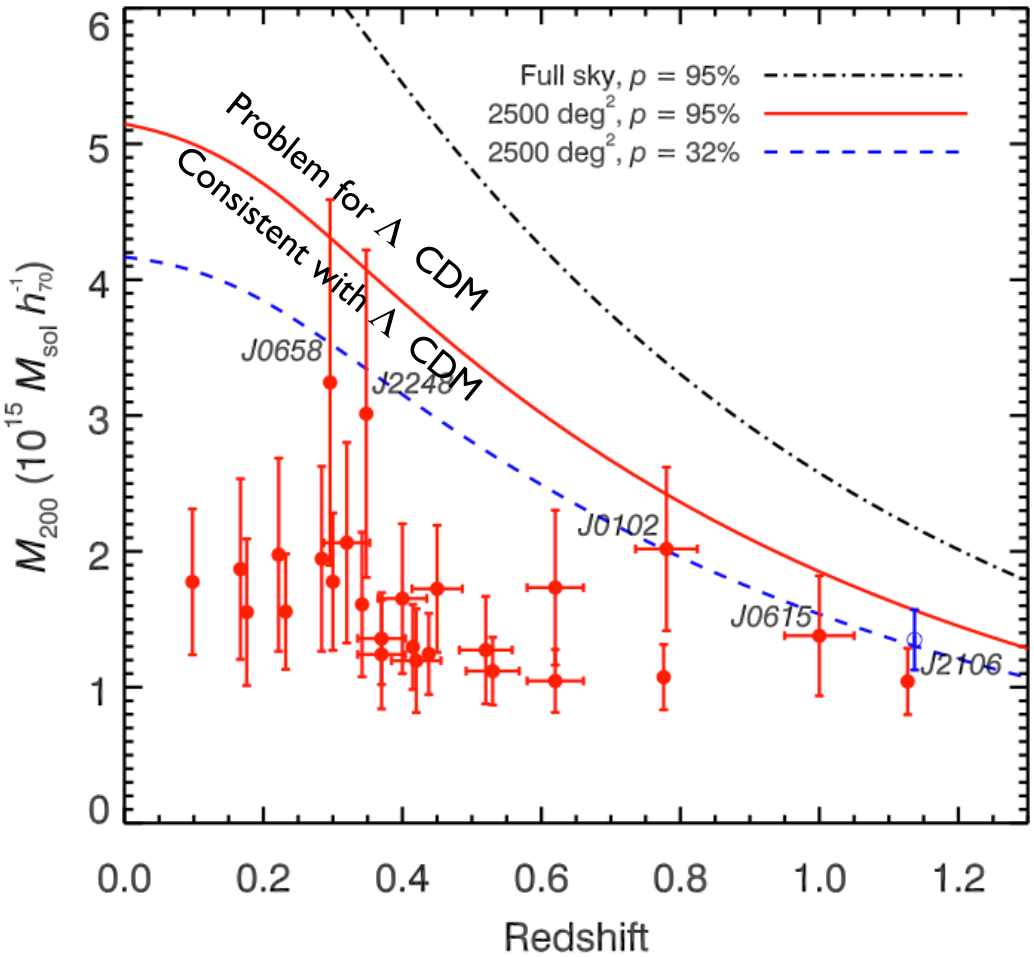


SPT 2500 deg^2 survey will detect ~440 clusters at S/N > 5. With mass calibration uncertainty of 5% mean and 10% evolution (z=0.0-to-1.0), will constrain σ_8 to +/-1.2% and w to +/-4.6%

- independent of geometric cosmological constraints (SN, BAO)
- 3.3% systematic uncertainty in w from mass calibration

slide from Brad Benson

Tests of ΛCDM and Non-Gaussianity



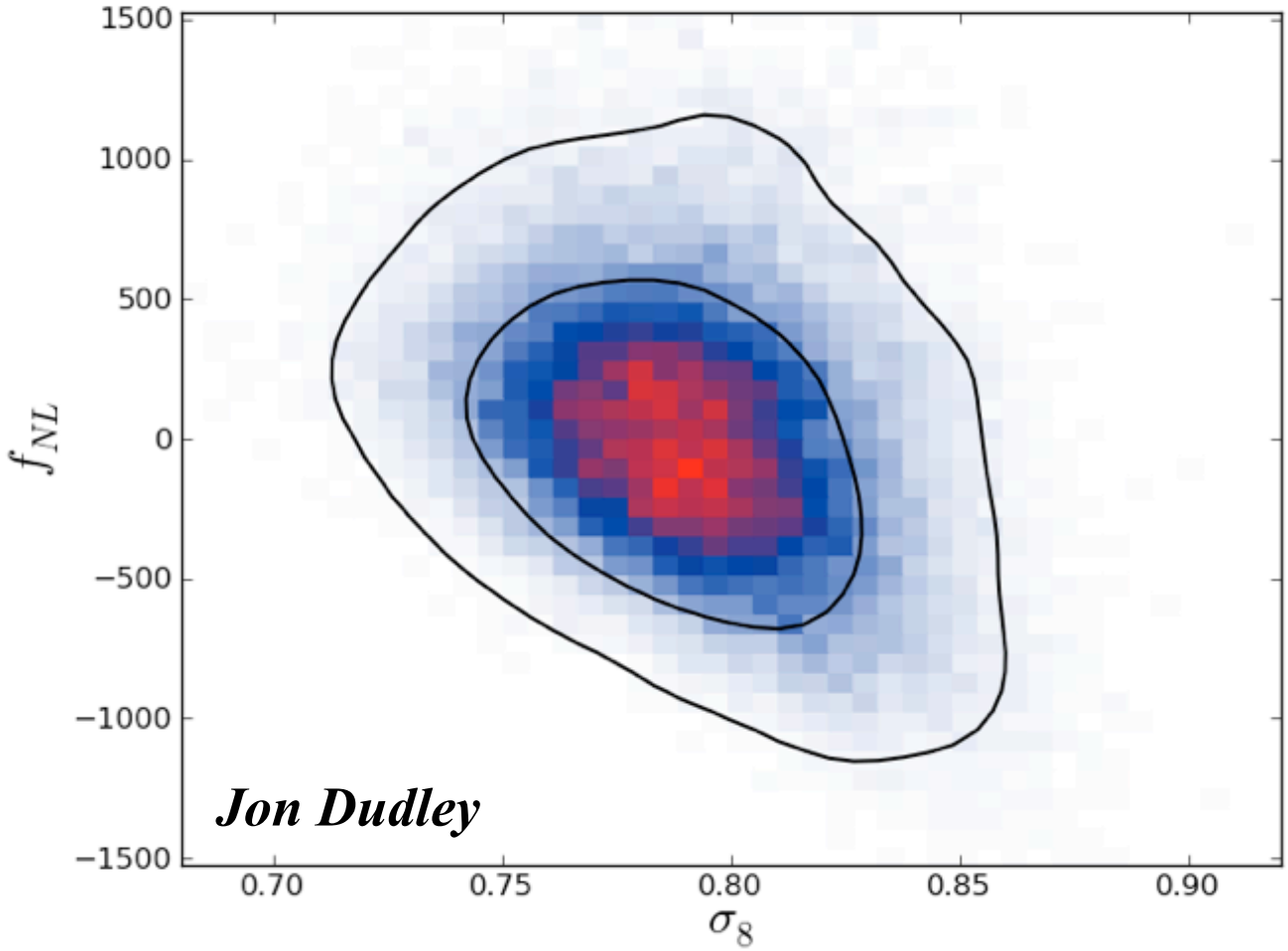
- SPT provides a clean uniform nearly redshift independent selection over a large area
- Catalog of 26 most significant clusters from full 2500 deg^2 survey
- Even a single massive cluster could indicate tension with ΛCDM (Mortonson, Hu, Huterer 2010), however:
  - consistent with ΛCDM
  - consistent with Gaussian density fluctuations (f_{NL}=20 +/- 450)

Williamson et al 2011, arXiv:1101.1290

slide from Brad Benson

No Signs of Non-Gaussianity

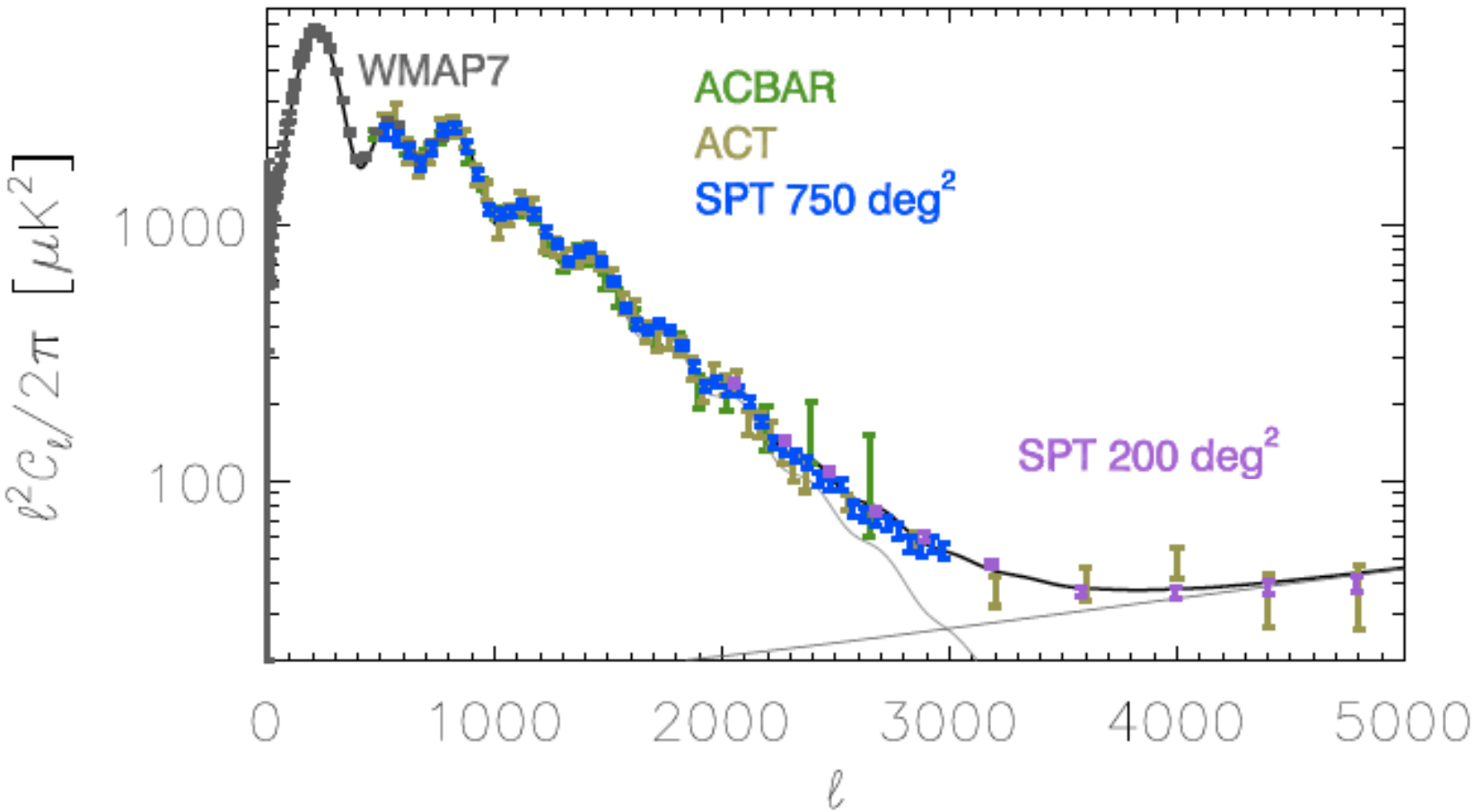
- things look remarkably Gaussian
- huge clusters at z~1 turn out to be expected in LCDM, this is just the first time anyone has seriously looked



f_{NL}=20 +/- 450

CMB Power Spectrum

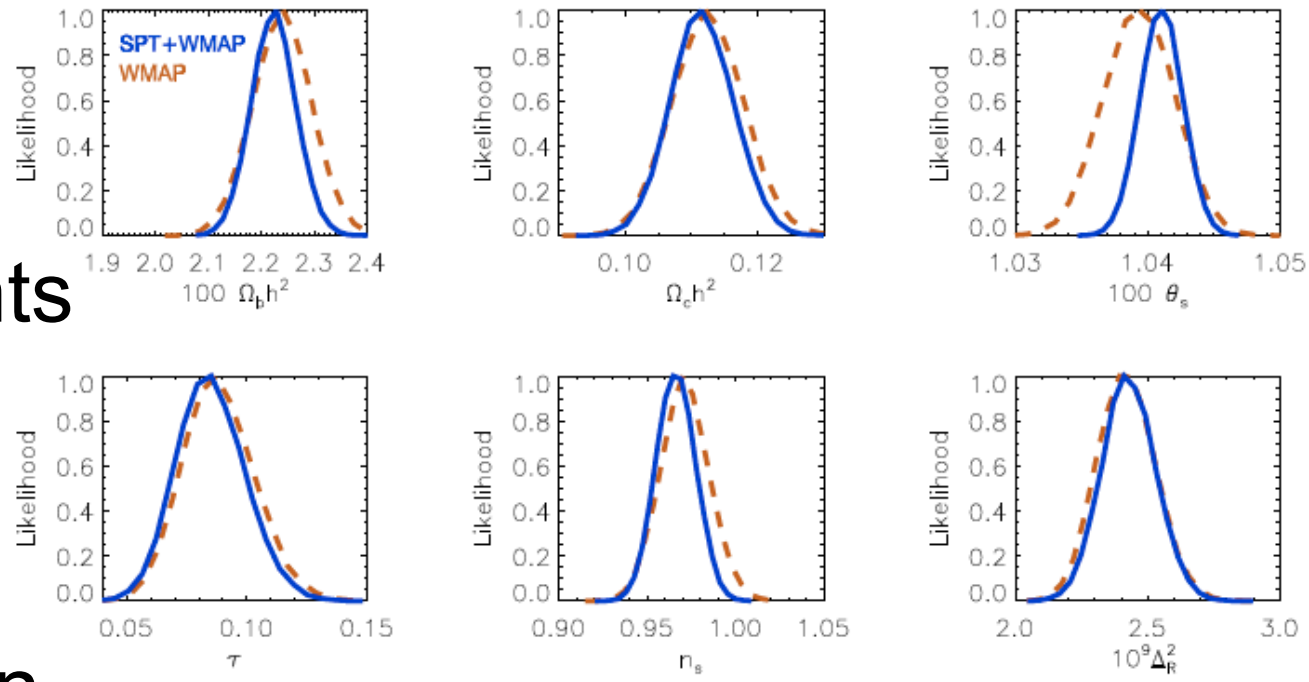
Plot by Ryan Keisler



Ryan Keisler; Christian Reichardt; Erik Shirokoff

Vanilla LCDM

- extending power spectrum measurements by factor of 2 leads to modest constraints on LCDM



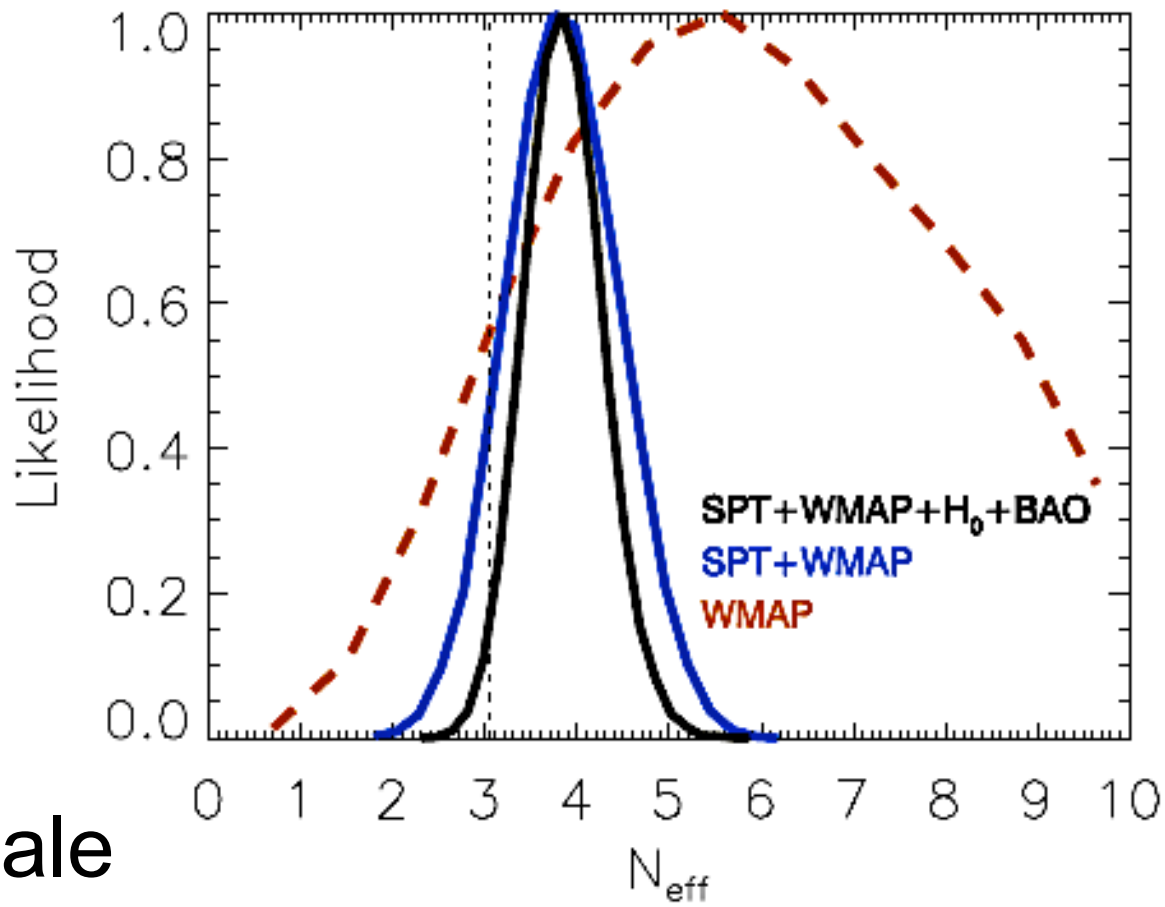
Keisler et al 2011

Testing the model:

e.g Number of "neutrinos"

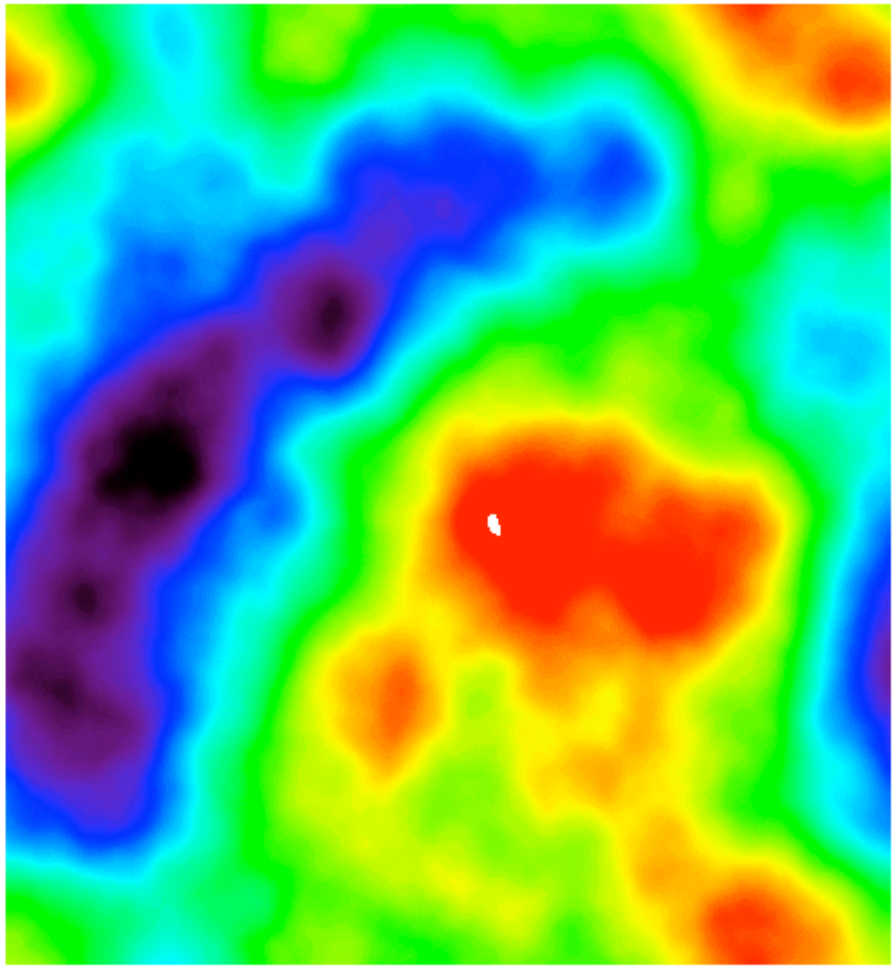
- hints that there could be an excess of relativistic particles
- neutrinos affect damping scale and acoustic scale

Keisler et al 2011

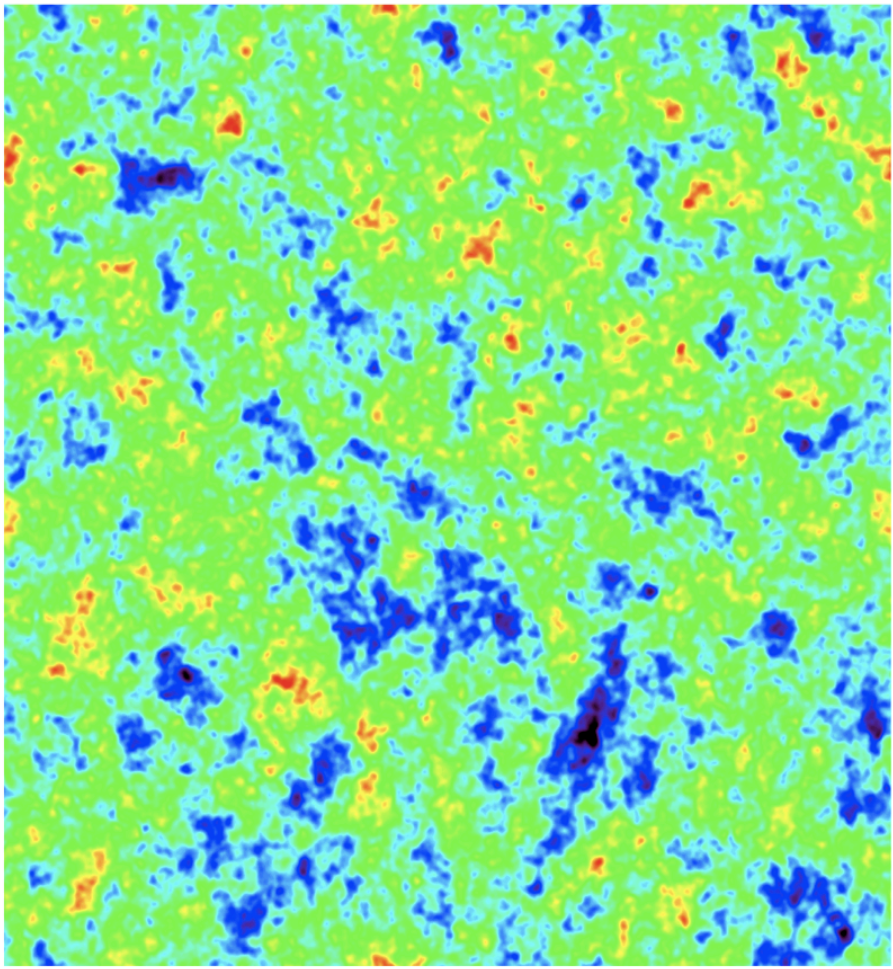


Lensing of the CMB

17°x17°



lensing potential

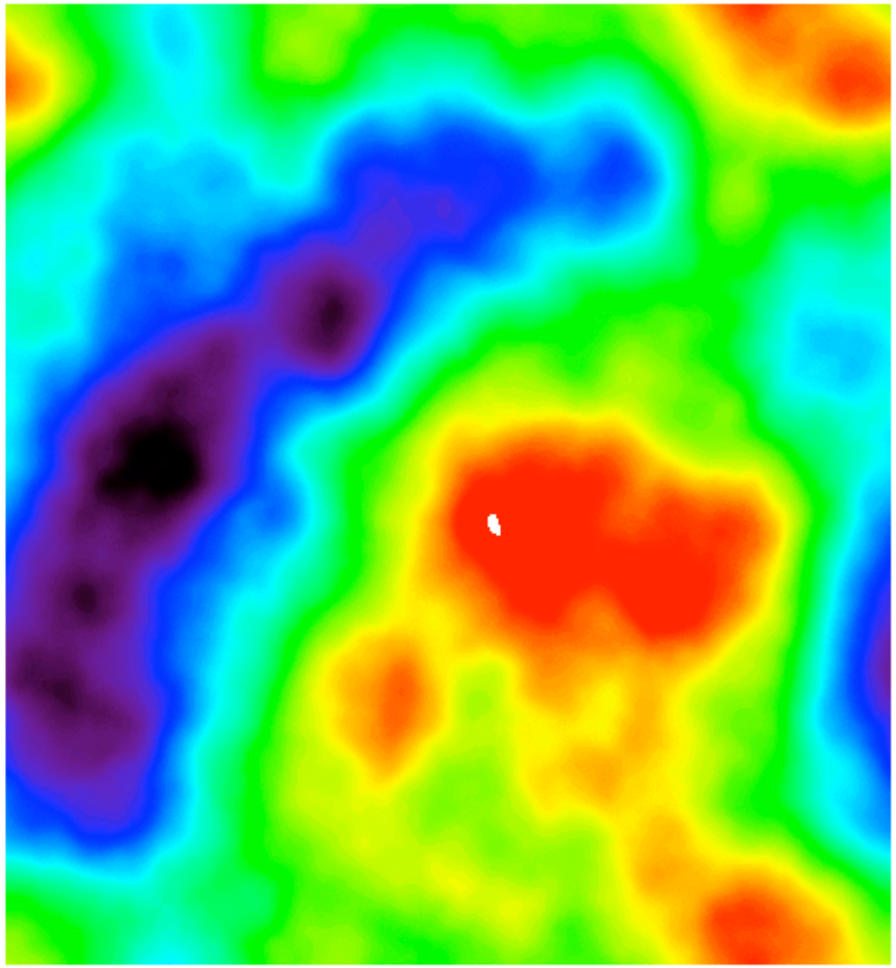


unlensed cmb

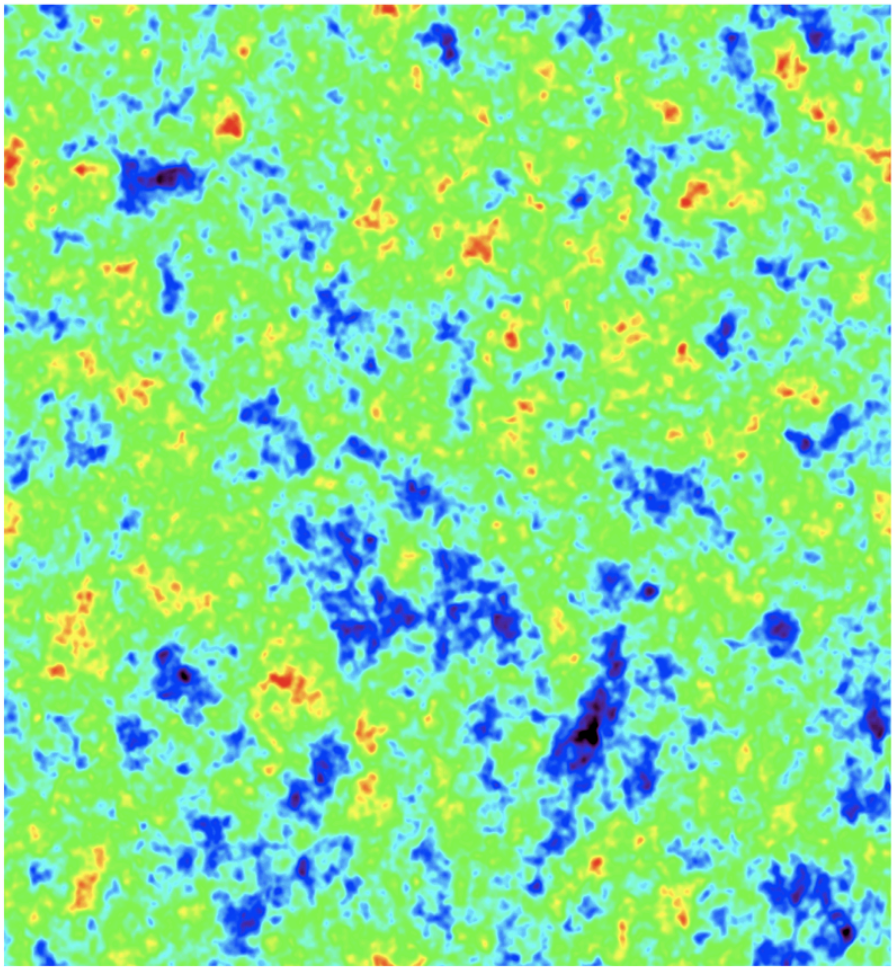
from Alex van Engelen

Lensing of the CMB

17°x17°



lensing potential

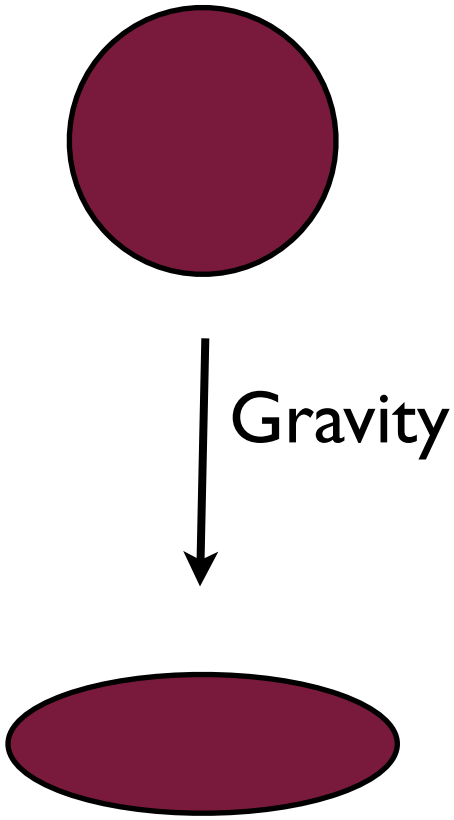


lensed cmb

from Alex van Engelen

Lensing simplified

- gravitational potentials distort shapes by stretching, squeezing, shearing



Lensing simplified

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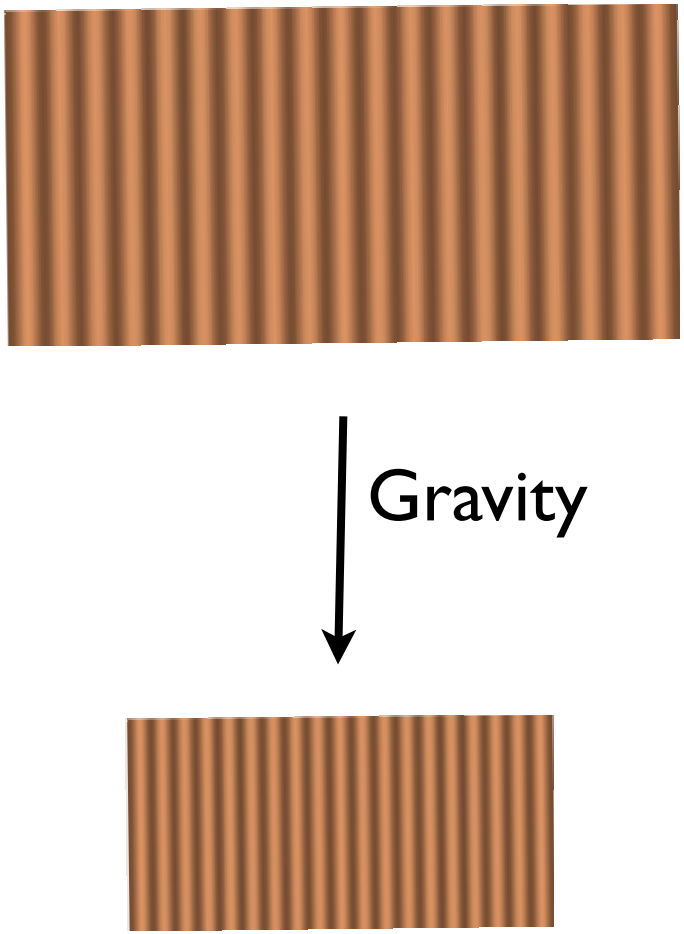
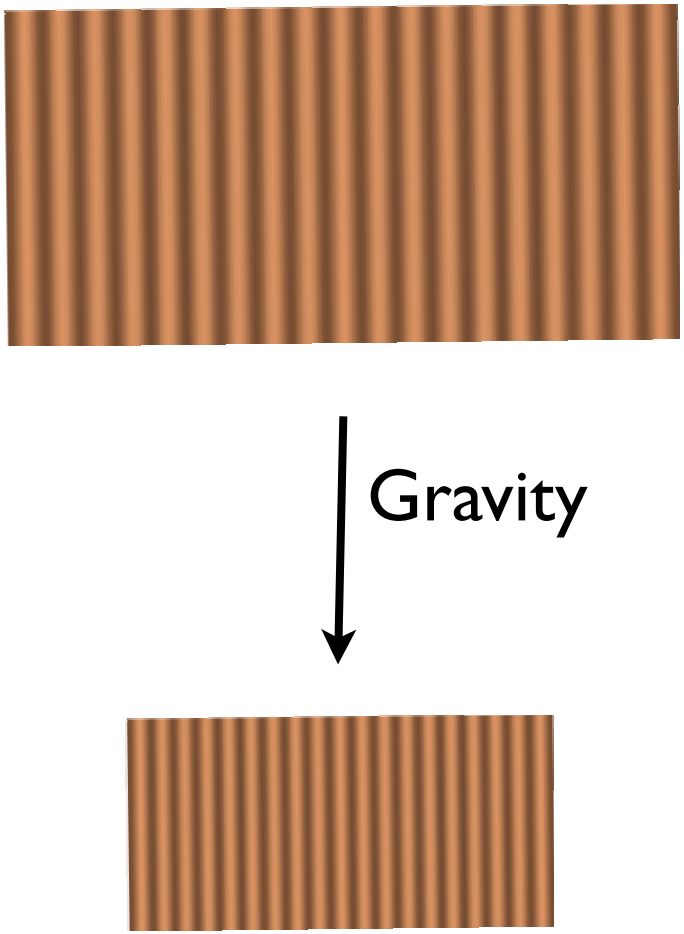


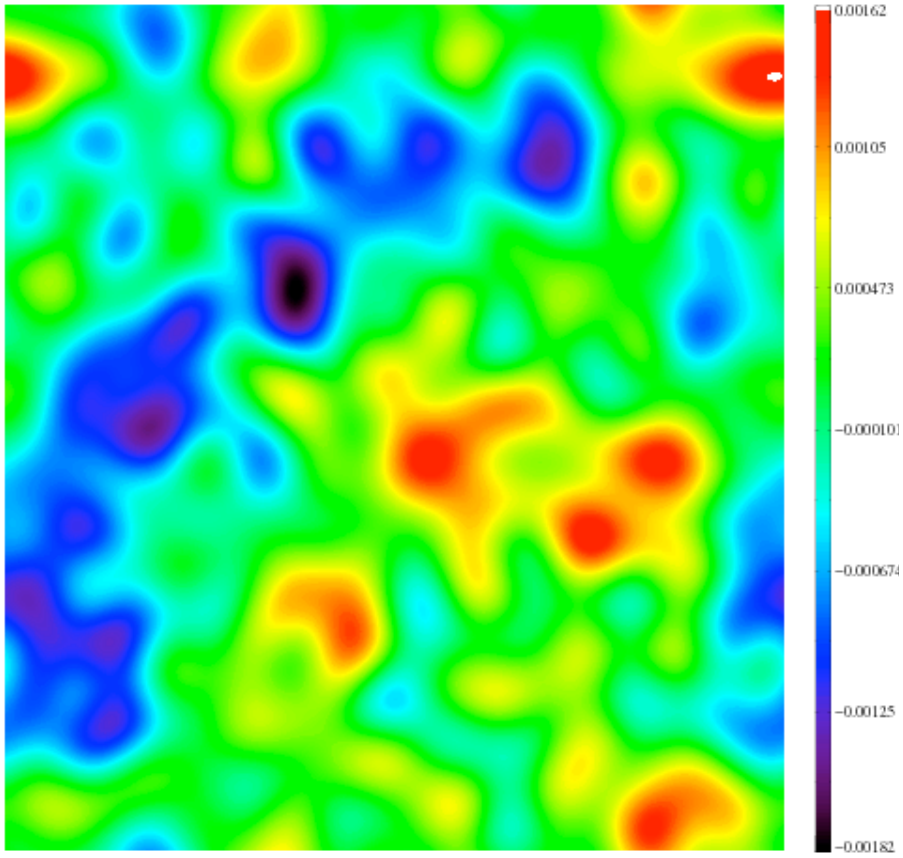
Lensing simplified

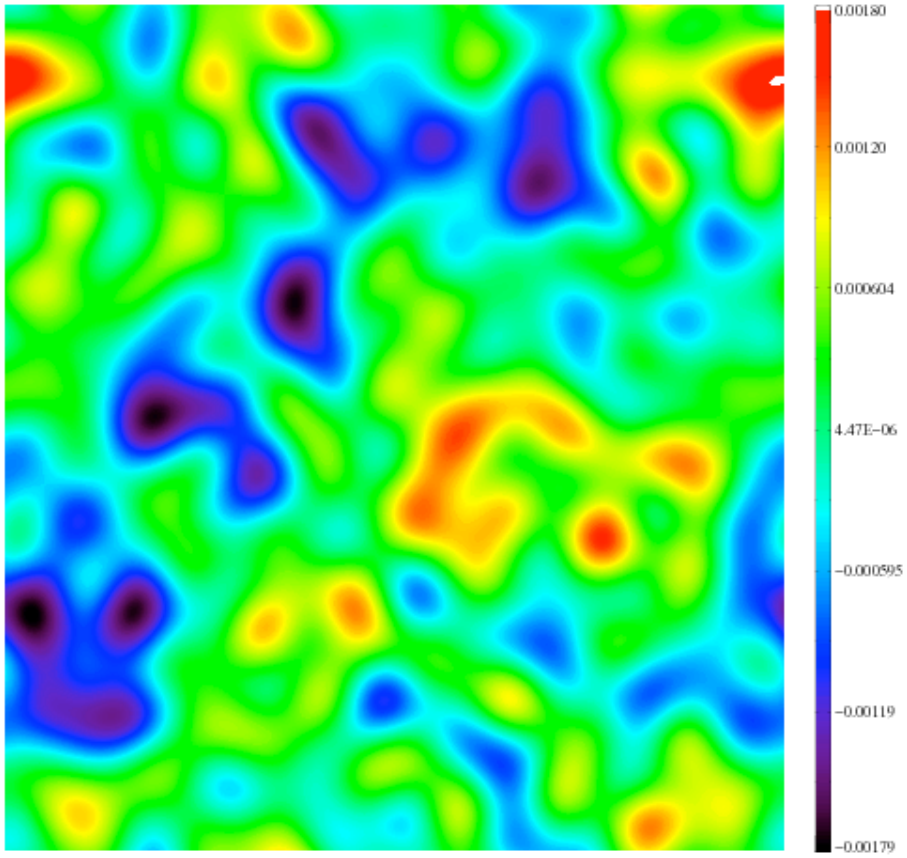
- where gravity stretches, gradients become smaller
- where gravity compresses, gradients are larger



Simulated reconstructions

- Input and recovered deflection angle maps, 17°x17°
  - filtered for display at l < 200



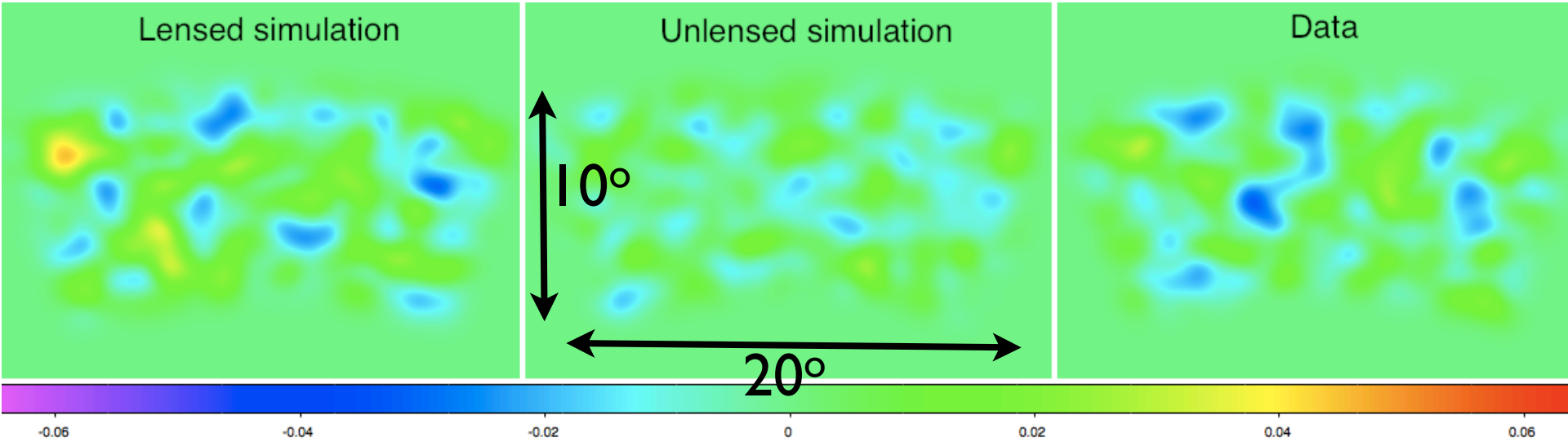


from Alex van Engelen

Input

Recovered at 15 uK' white, 1'

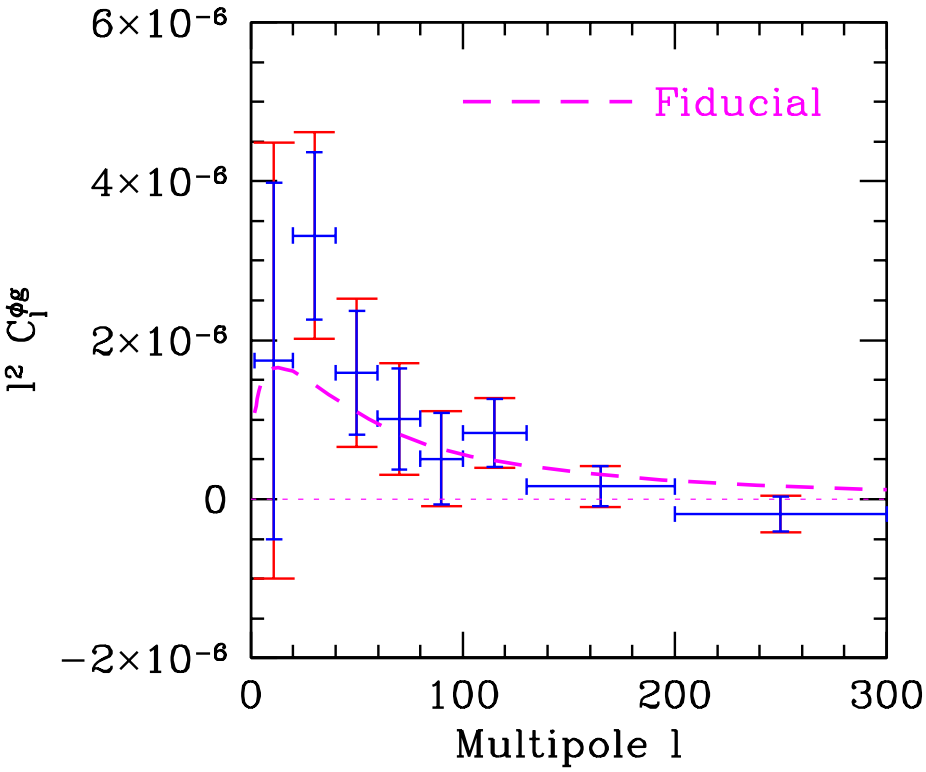
Mapping the universe



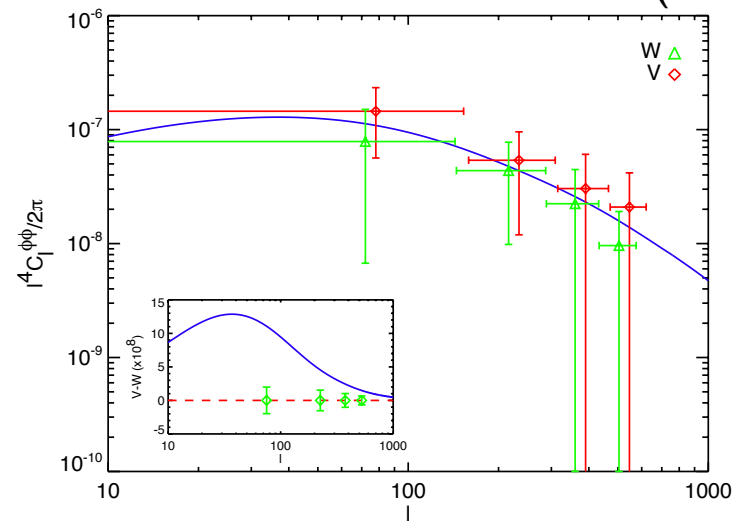
- SPT making maps of total matter (including dark matter) between z=0-1100

CMB Lensing Detections

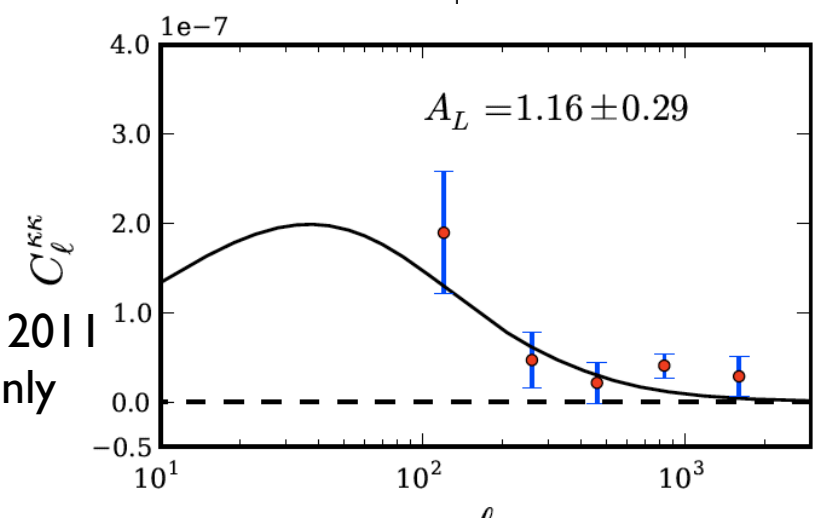
Smidt et al 2011
WMAP only
(1.9σ)



Smith et al 2007
WMAPxNVSS
(3.4σ)

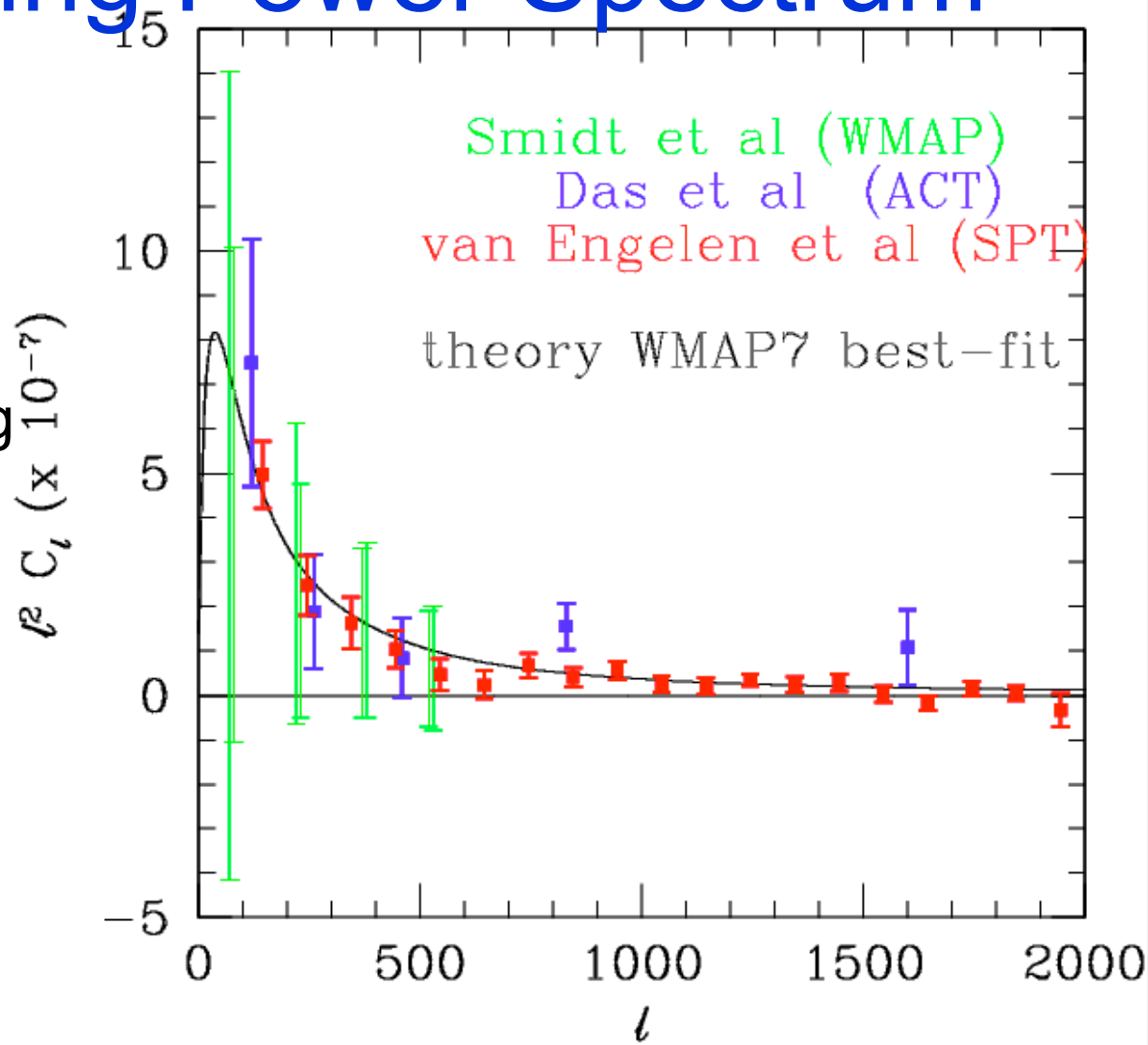


Das et al 2011
ACT only
(4σ)



SPT Lensing Power Spectrum

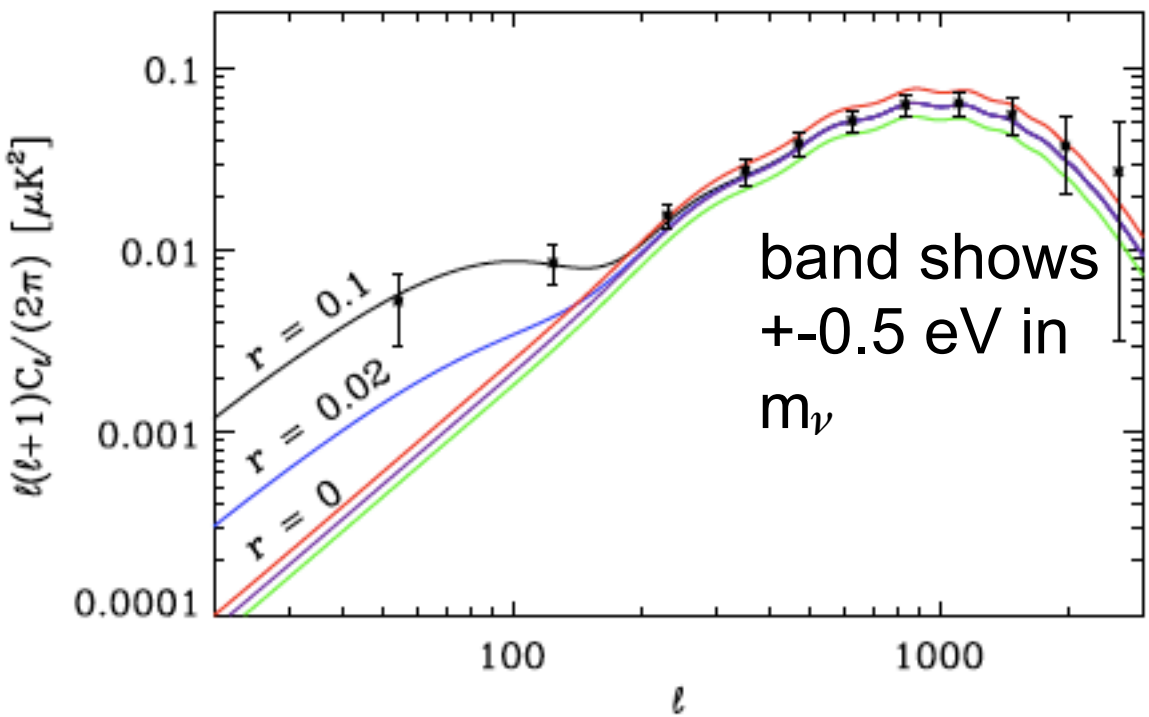
- high significance detection of non-Gaussianity in the CMB induced by gravitational lensing
- based on ~1/5 of SPT area, single-frequency only, heavily-filtered
- project >30 σ detection with 2500 deg^2 survey



van Engelen et al, coming soon!

SPT-Pol Lensing

- gravitational lensing signal should be relatively easy to see in CMB B-modes
- in principle, measure sum of neutrino masses to ~0.1 eV
- polarization upgrade coming to SPT at end of 2011



Summary

- SPT is nearly done the temperature survey
  - next: ***<u>SPT-Pol</u>***
- Large cluster catalog for cosmological searches for physics beyond standard ΛCDM
  - *Vanderlinde 2010, Williamson 2011, Benson in prep*
- precise power spectrum measurements for testing LCDM and searching for new physics
  - *Keisler 2011, Shirokoff 2011, Lueker 2010*
- detection of gravitational lensing through non-Gaussianity of CMB
  - van Engelen in prep