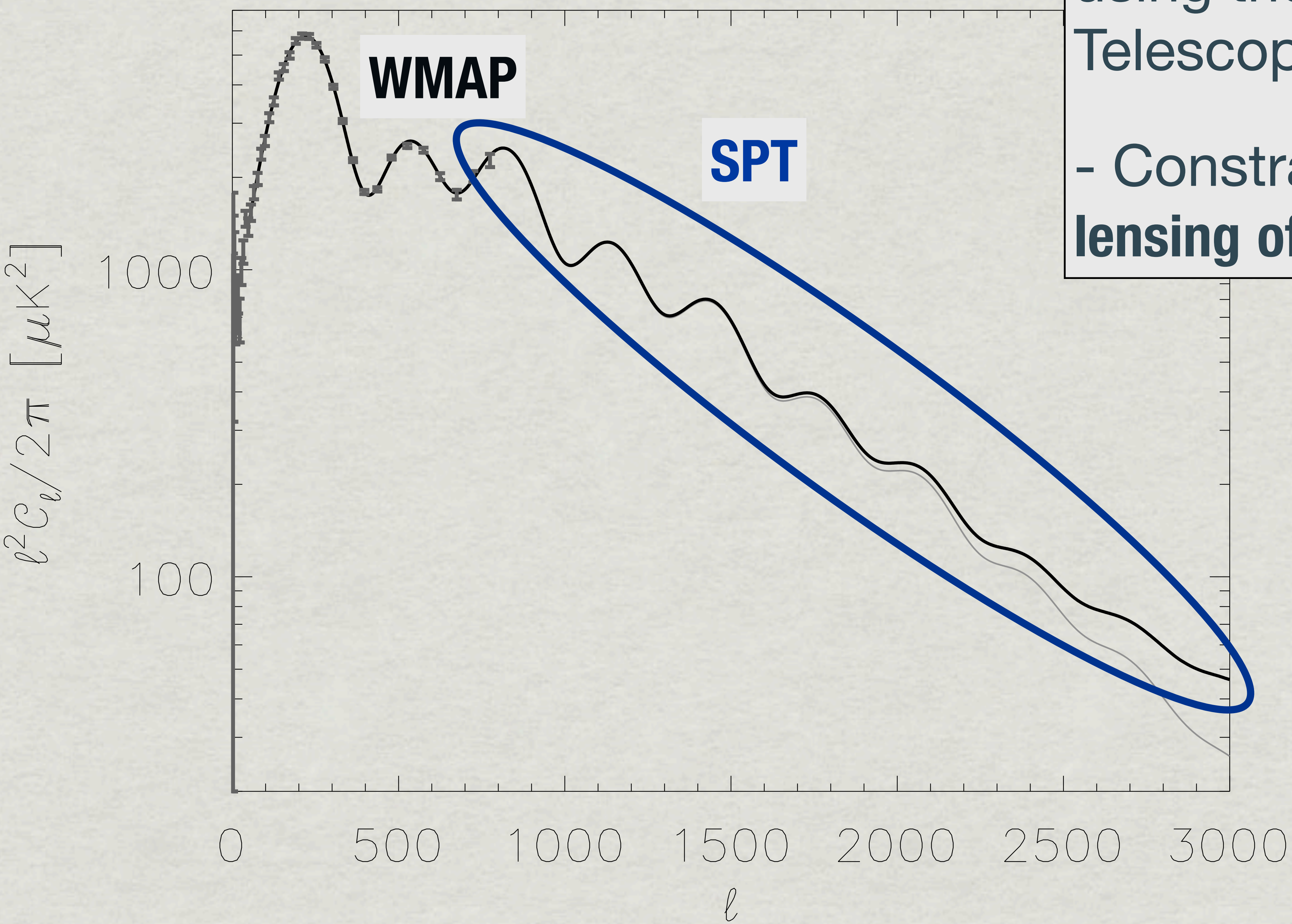
Measuring the CMB Damping Tail with SPT

Ryan Keisler
University of Chicago

South Pole Telescope, photo by Keith Vanderlinde

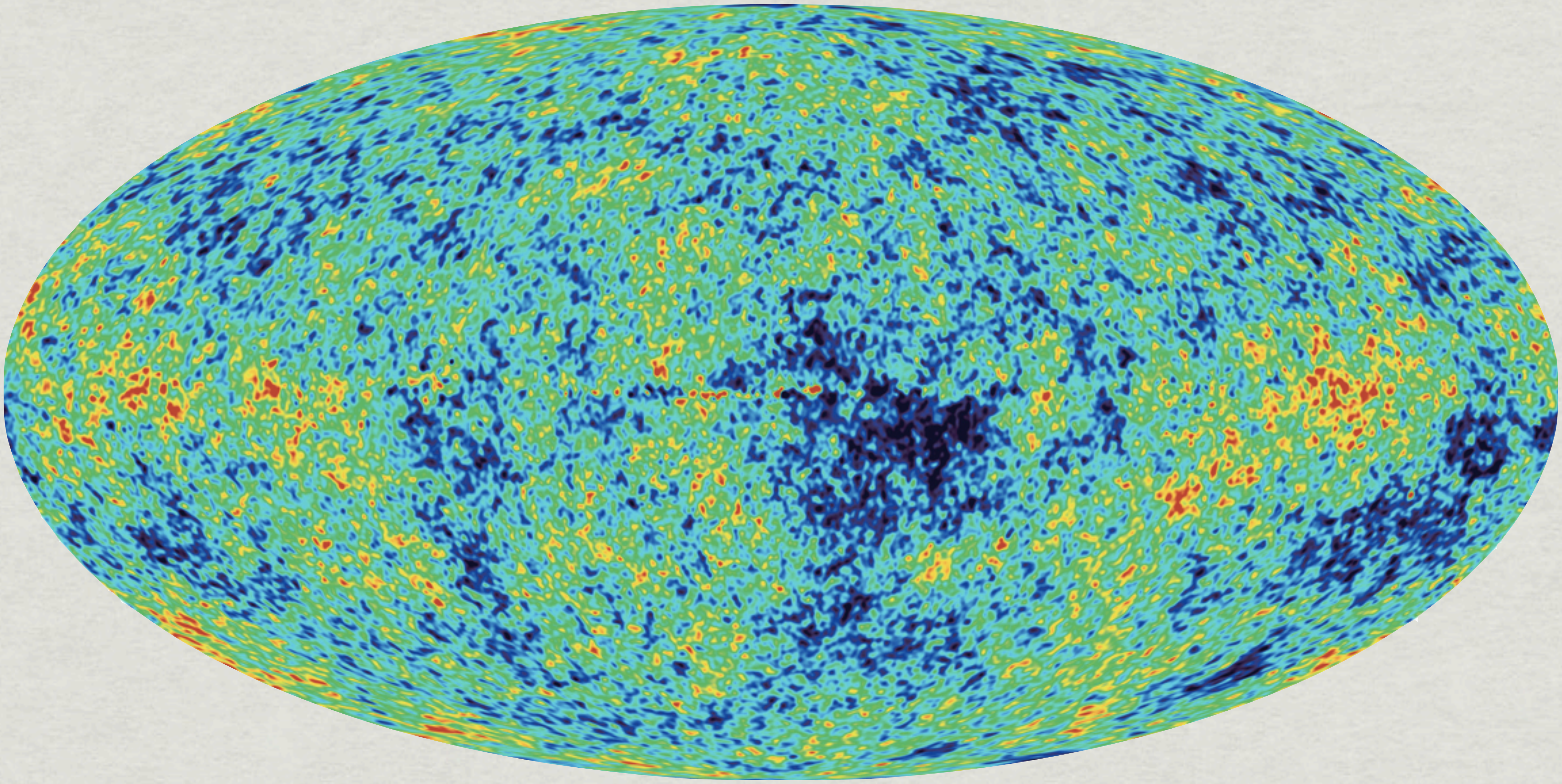
Overview



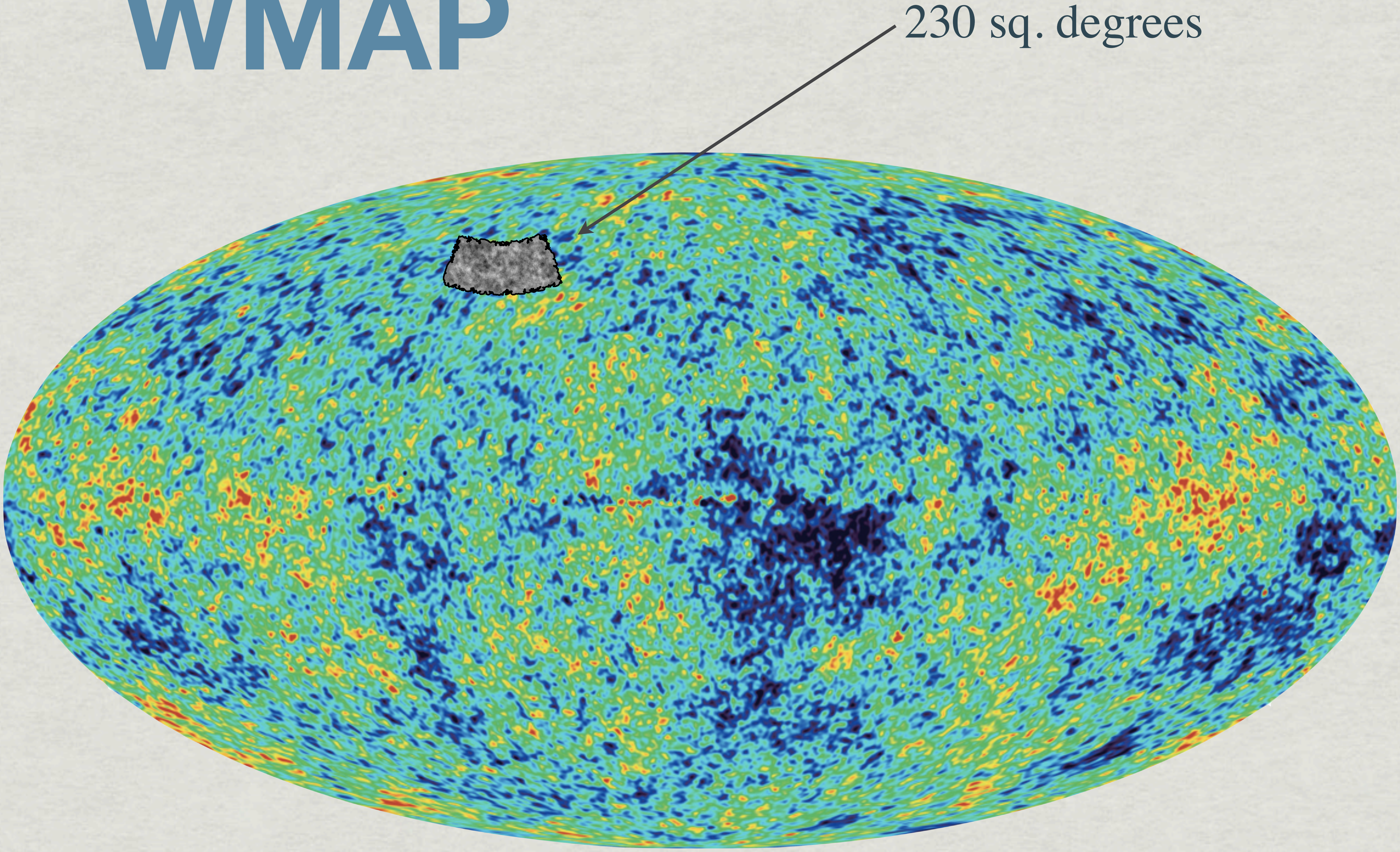
- New measurement of **CMB TT power spectrum** using the South Pole Telescope.

- Constraints on **lensing of the TT spectrum.**

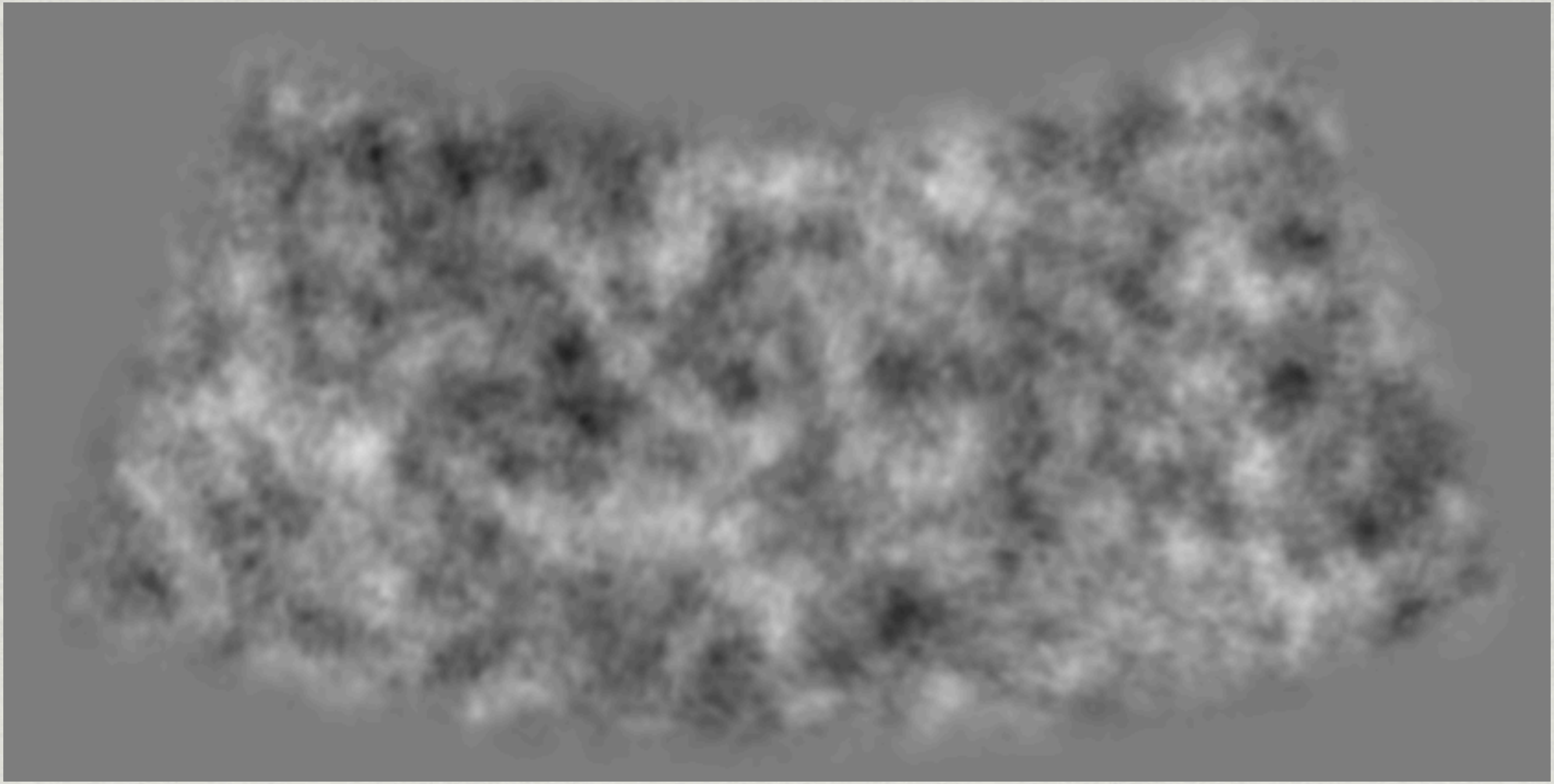
WMAP



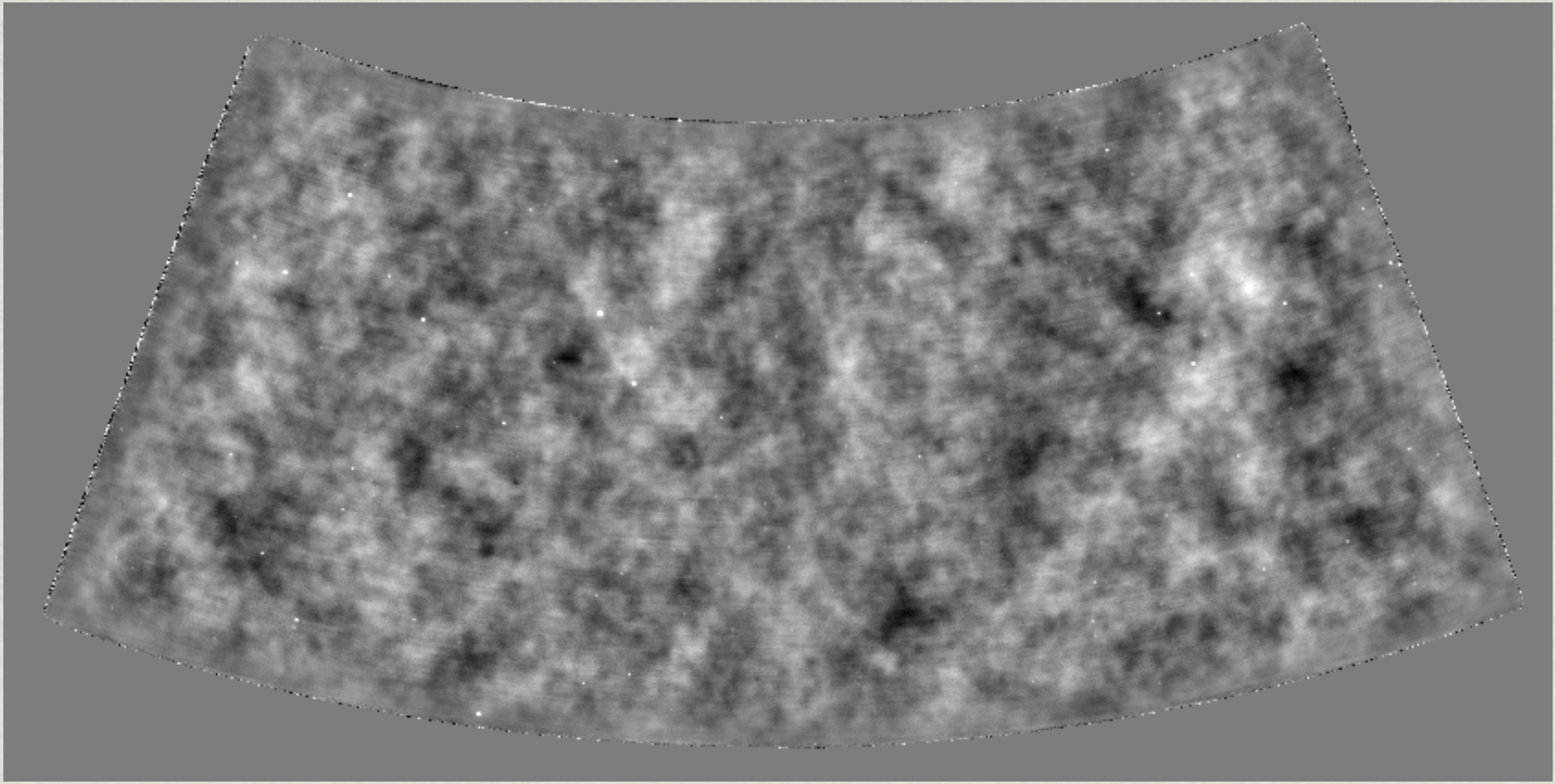
WMAP



WMAP



SPT



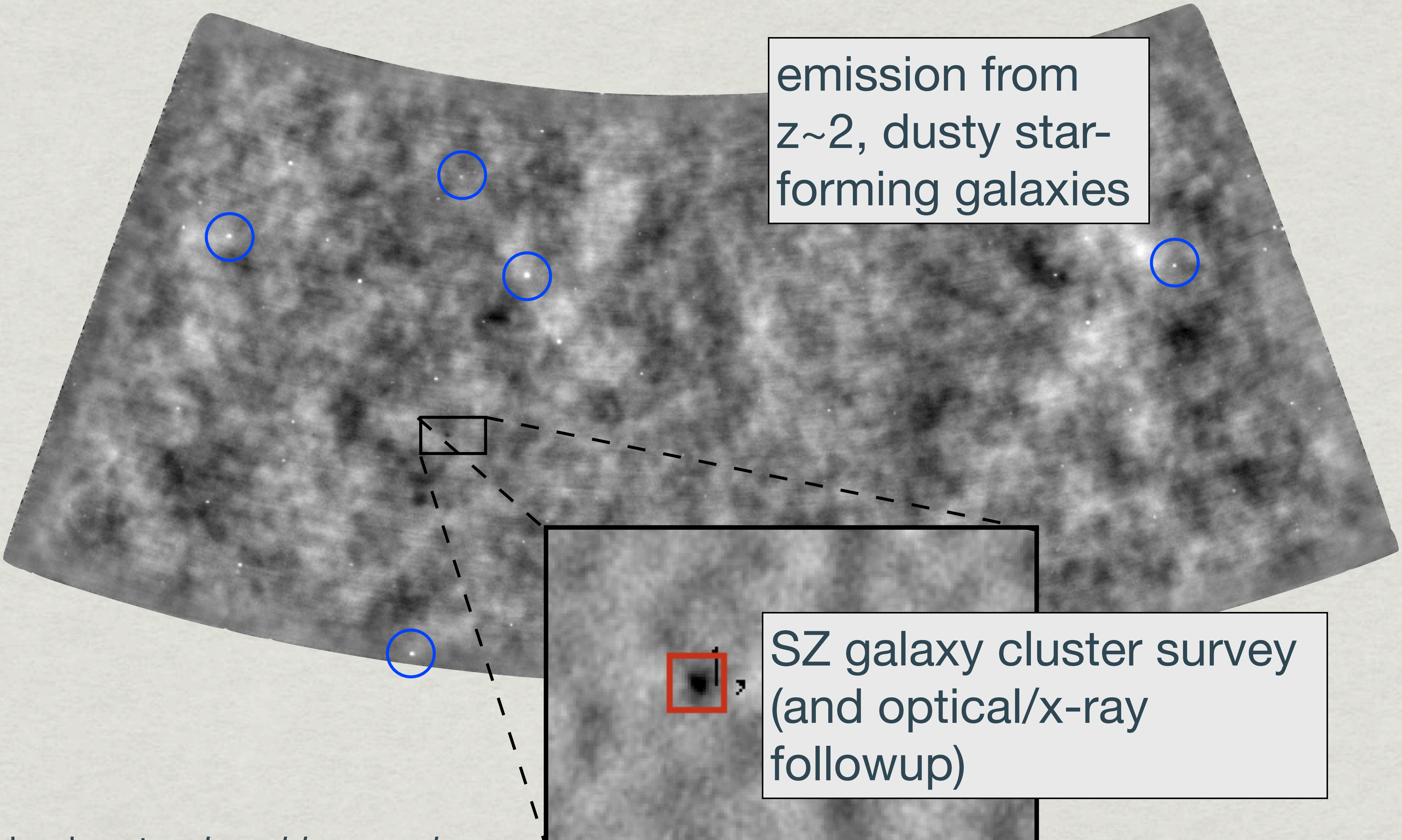
The South Pole Telescope

- 10 meter primary mirror
- 1000 pixel camera
- 3 bands (95, 150, 220 GHz)
- 1 arcminute resolution
- Deployed February 2007, will complete **2500 deg2** survey by end of 2011.

Chicago
Berkeley
Case Western
McGill
Boulder
Harvard
Caltech
Munich
Michigan
Arizona
...

photo by Dana Hrubes

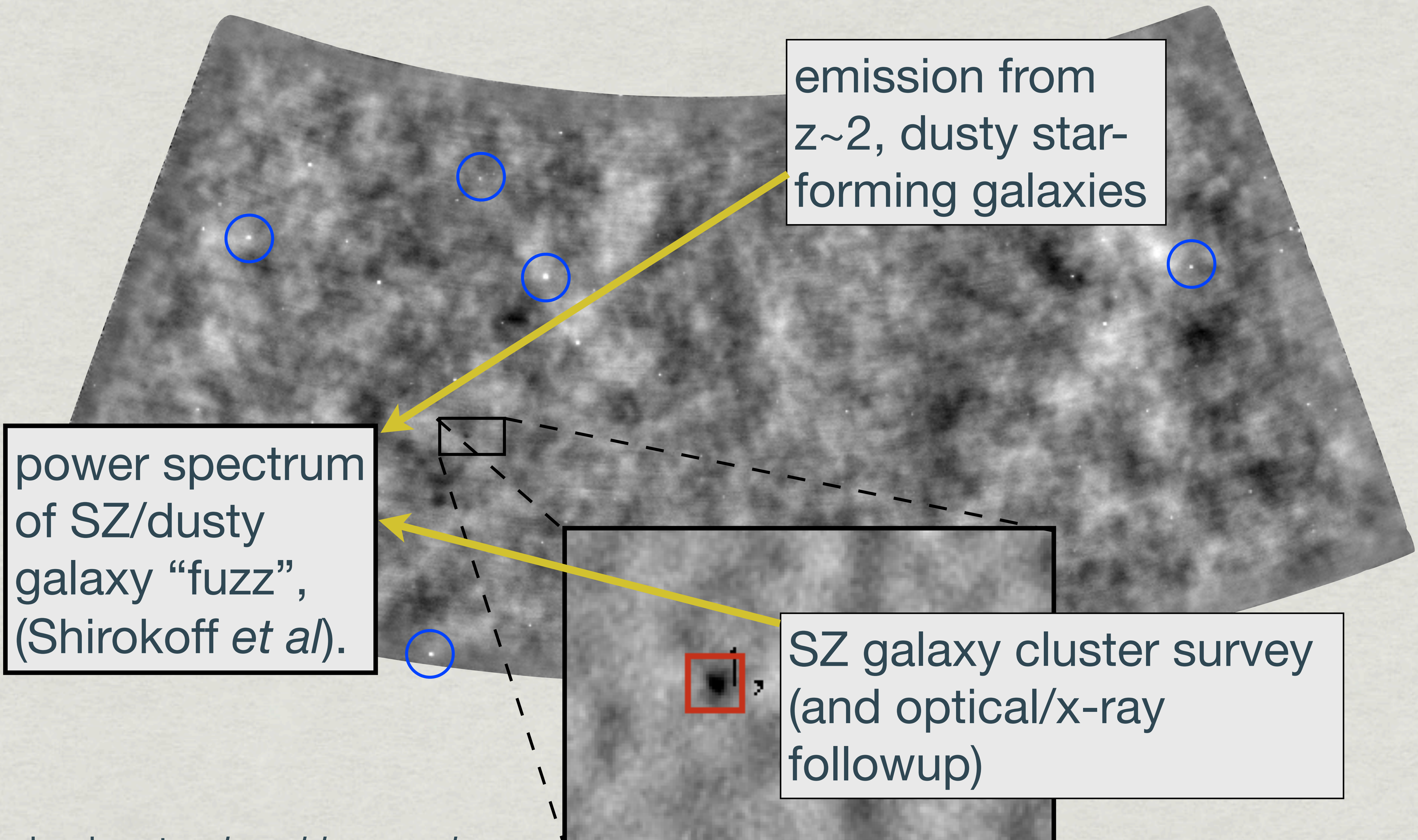
(some) other SPT science:



check out *pole.uchicago.edu*

photo by Dana Hrubes

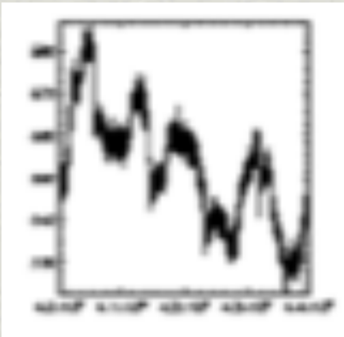
(some) other SPT science:

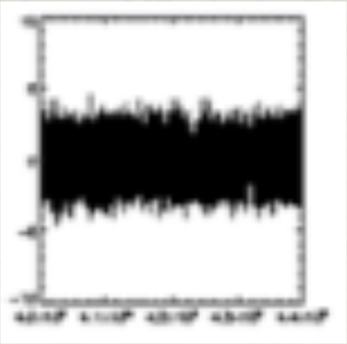


check out *pole.uchicago.edu*

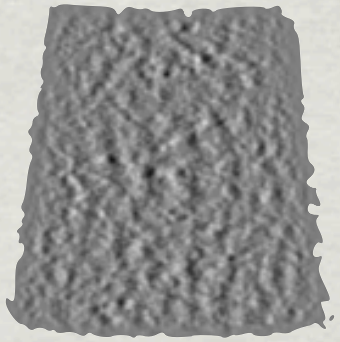
Timestreams to Maps

- **Select raw data: 150 GHz** (~foreground free, low detector noise), **800 sq deg.**



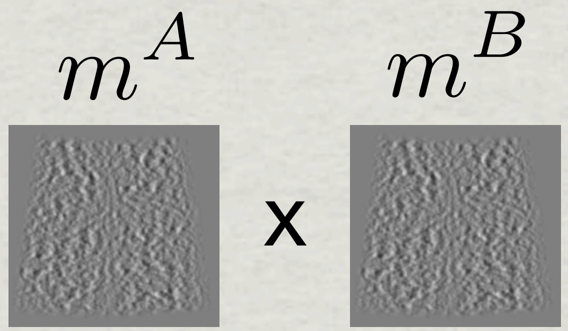


- **High-pass filter timestreams** to remove atmospheric noise.
- **Make maps:** just bin timestreams.



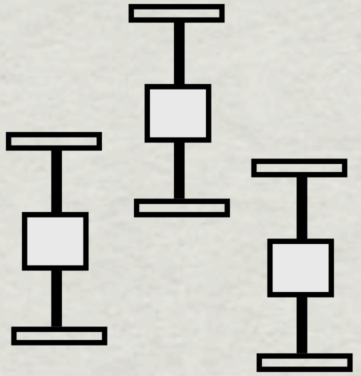
Maps to Power Spectrum

- **Cross-correlate** and **average** all pairs of observations.

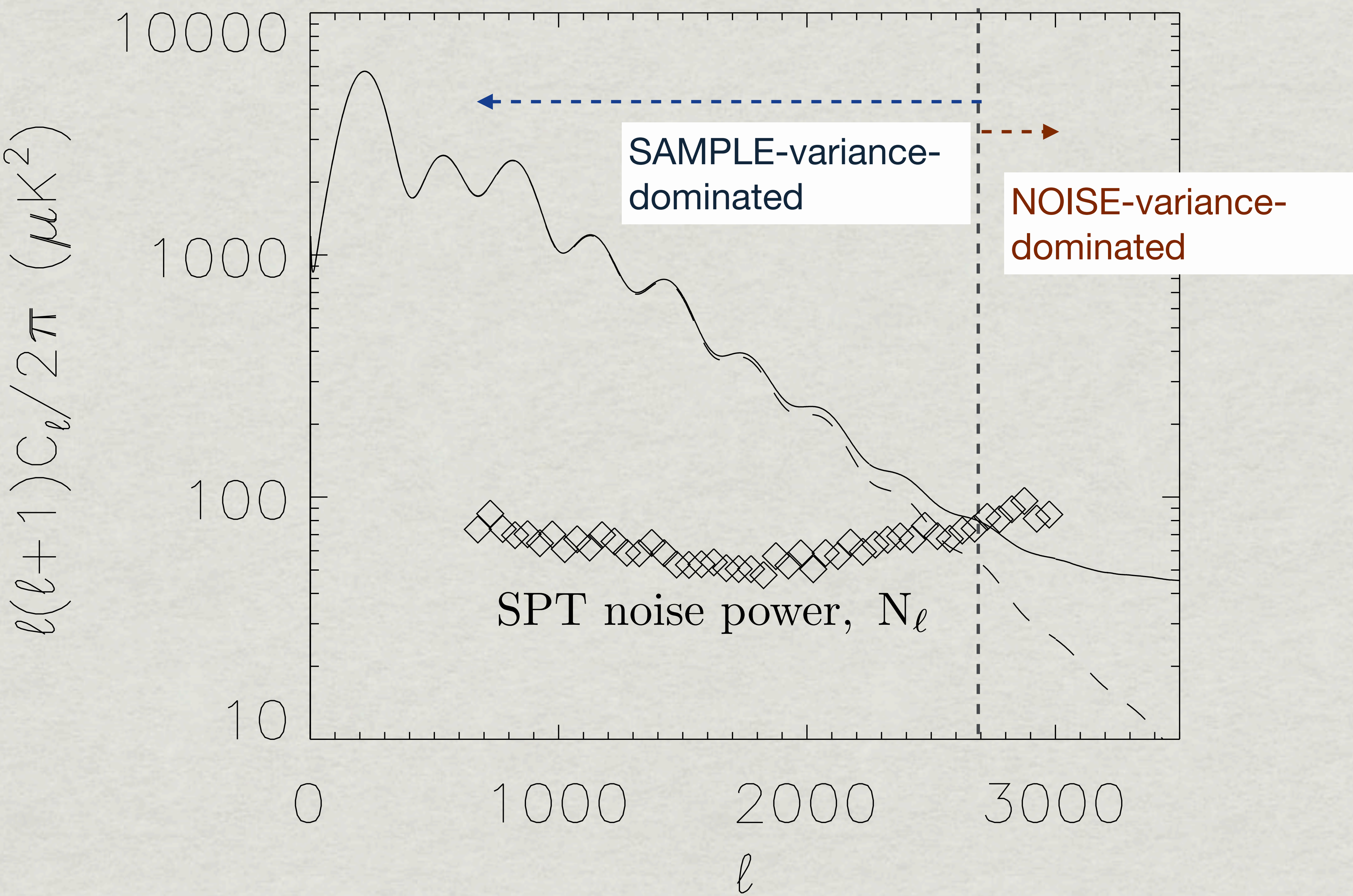


- Correct for **transfer function**, **beam**, **mode-coupling** from finite sky.

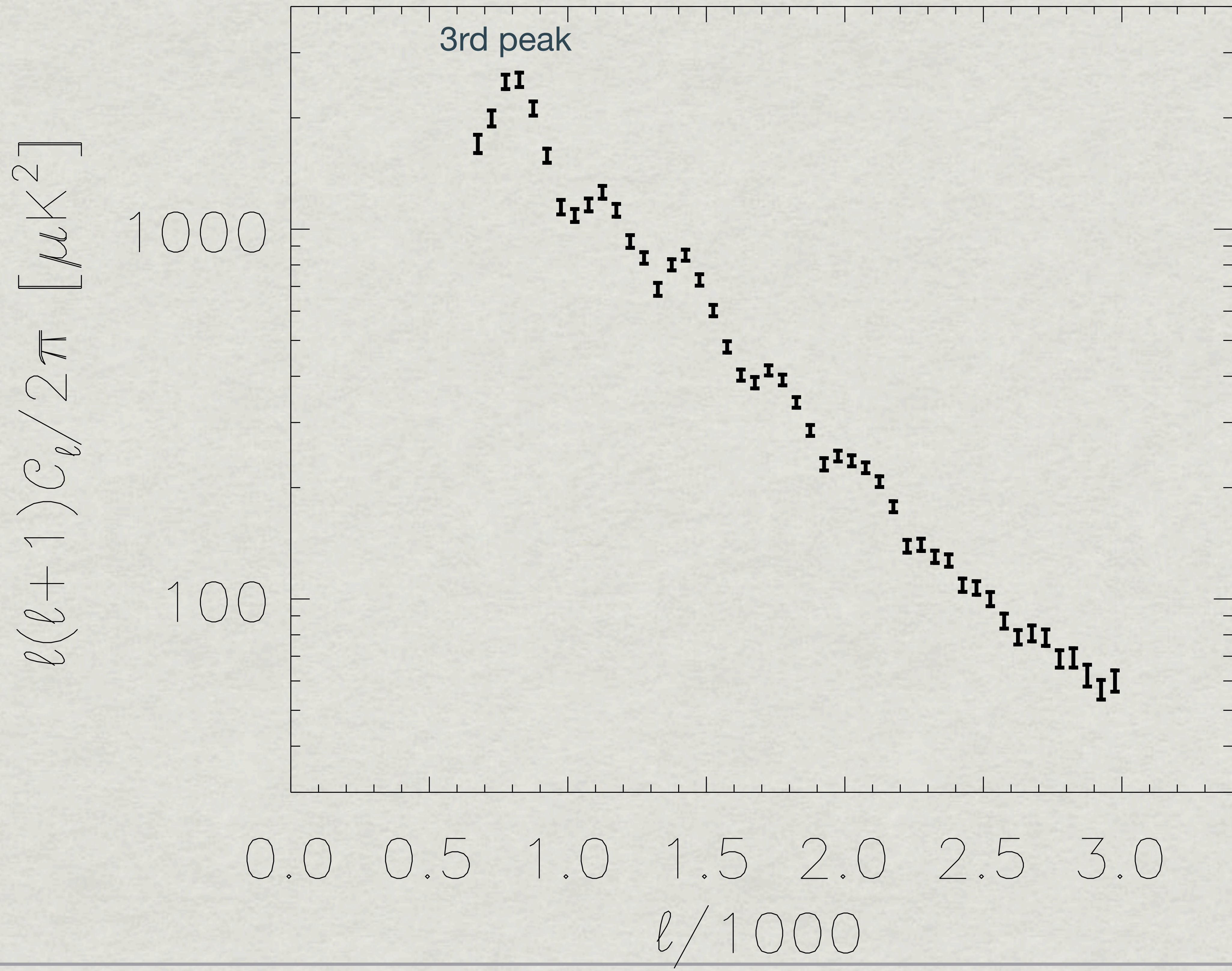
- Estimate **bandpower covariance** from simulations and data.



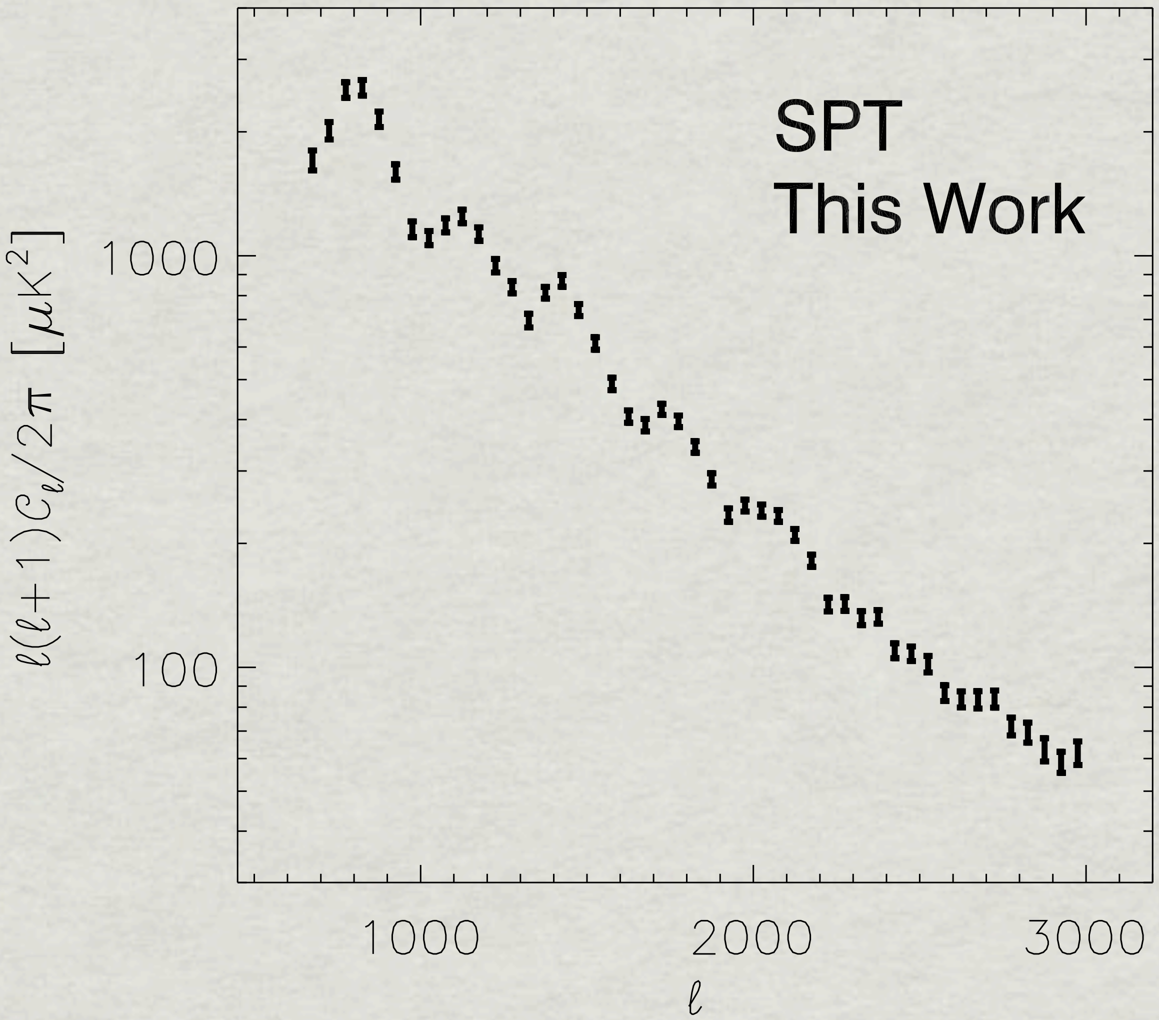
covariance is (mostly) sample-variance-limited

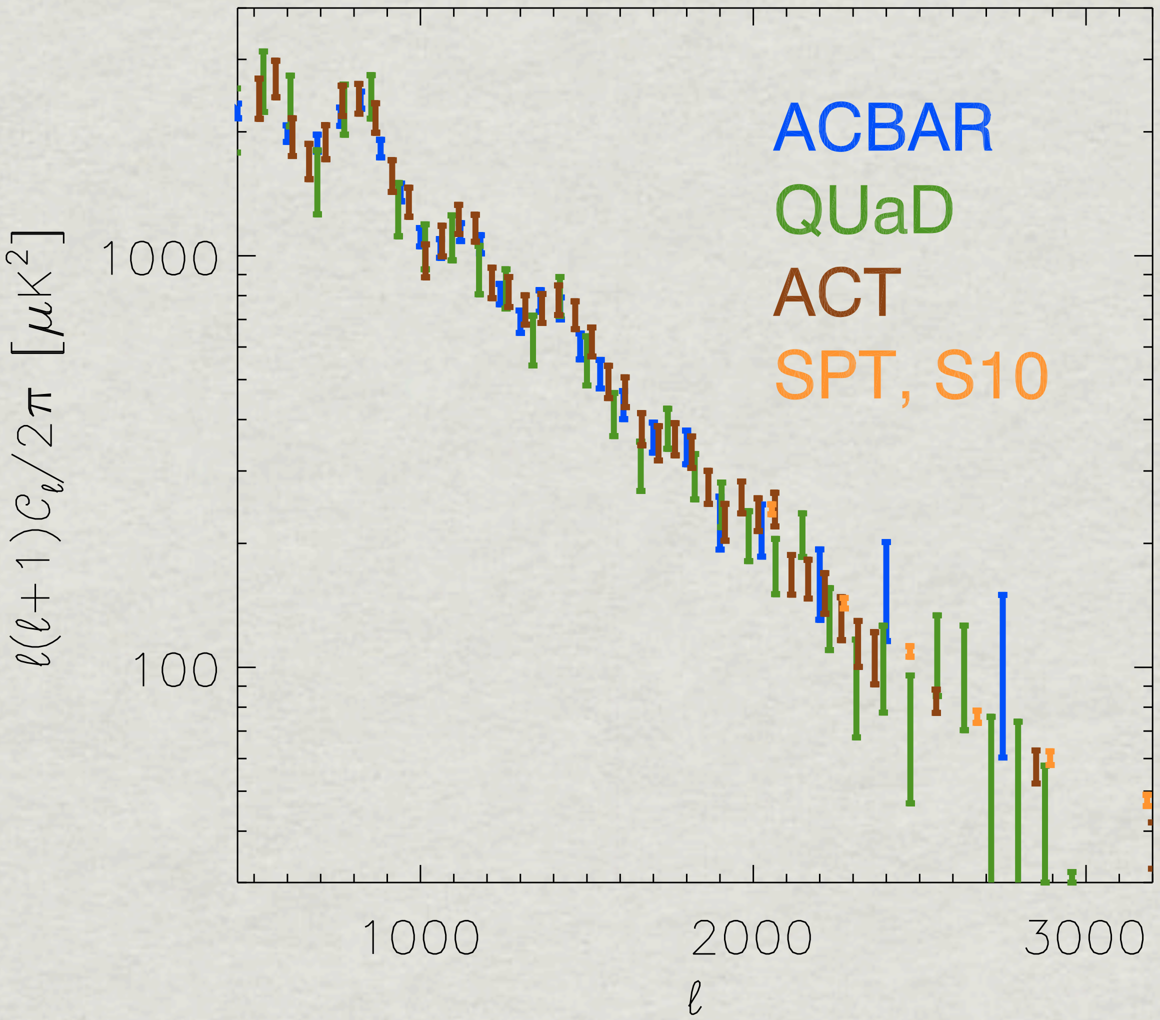


Final Spectrum



Final Spectrum





(preliminary)
Cosmological Analysis

- **MCMC analysis** (cosmoMC/CAMB)
- **Data:**

  - **SPT (this work)**

  - **WMAP 7-year**

Four component model:

- **CMB,** lensed primary CMB from flat ΛCDM, six parameters:
  $\{\Omega_b h^2, \Omega_c h^2, \theta_s, \tau, n_s, \Delta_R^2\}$

- **SZ** (tSZ+kSZ)

- **Poisson** (random point sources)

- **Clustered** point sources.

9 parameters (6 cosmo., 3 “nuisance”)

Four component model:

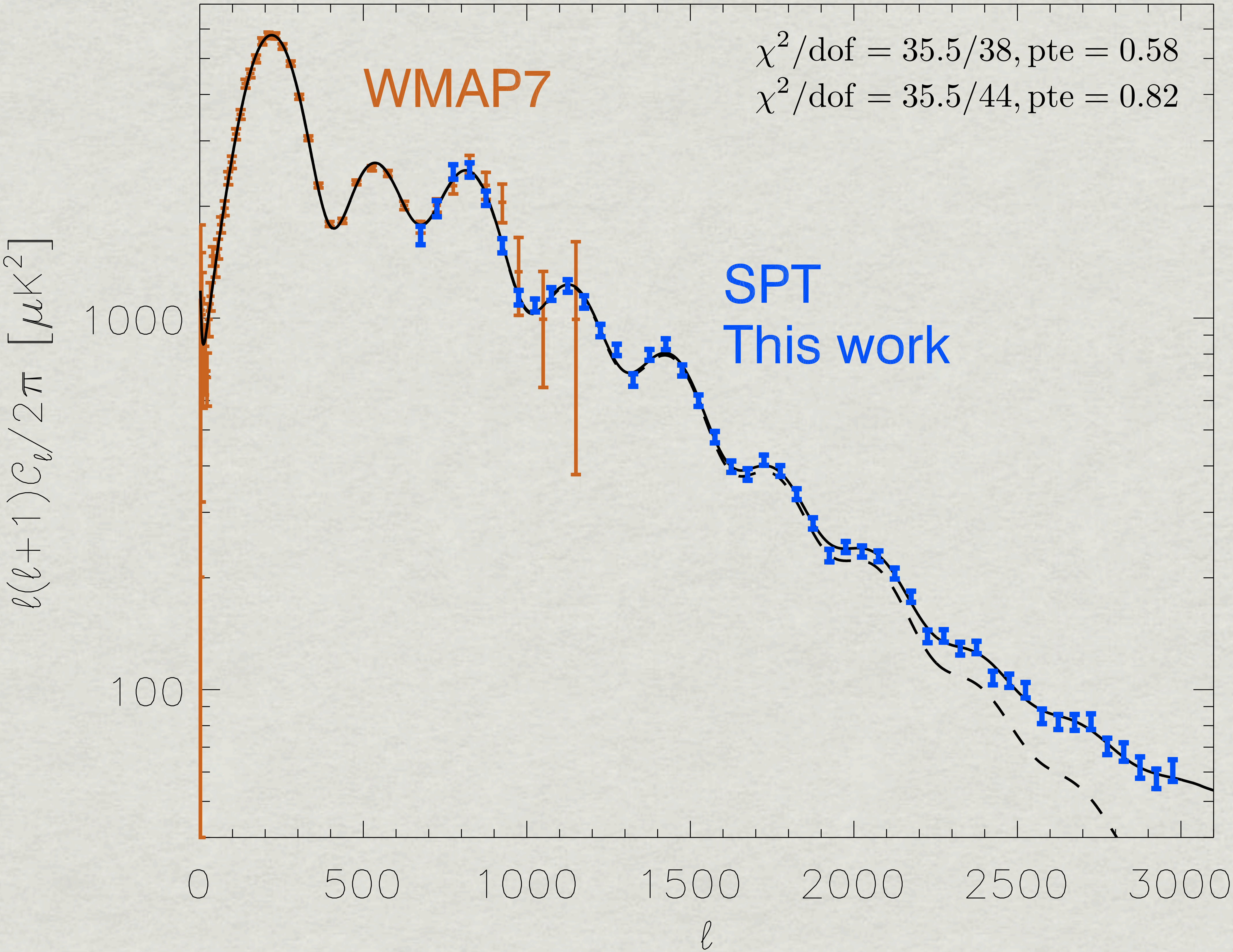
- **CMB,** lensed primary CMB from flat ΛCDM, six parameters:
  $\{\Omega_b h^2, \Omega_c h^2, \theta_s, \tau, n_s, \Delta_R^2\}$

- **SZ**
- **Poisson**
- **Clustered**

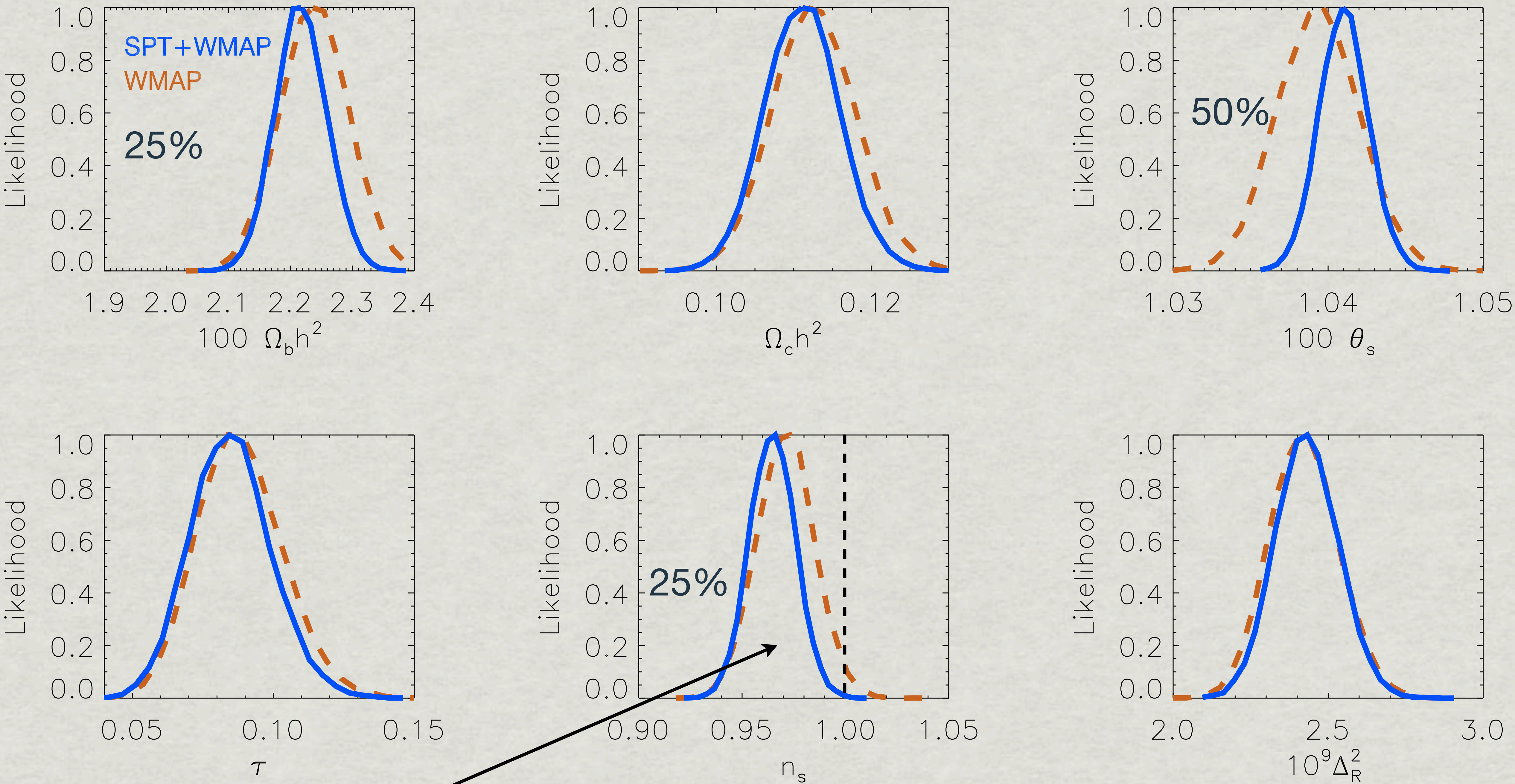
apply conservative **priors** on amplitudes of foreground terms based on measurements by ACT and SPT.

9 parameters (6 cosmo., 3 “nuisance”)

Best-fit Model



SPT provides modest improvement on 6 “vanilla” cosmo parameters

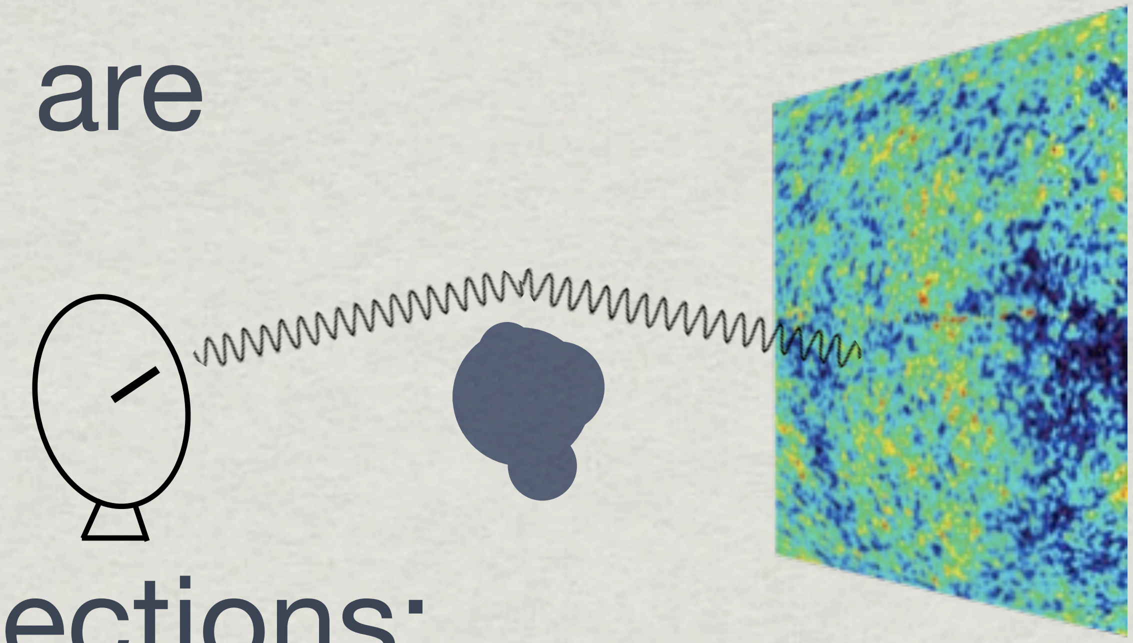


$$n_s = 0.965 \pm 0.011$$

(3.2σ preference for ns<1)

Gravitational Lensing

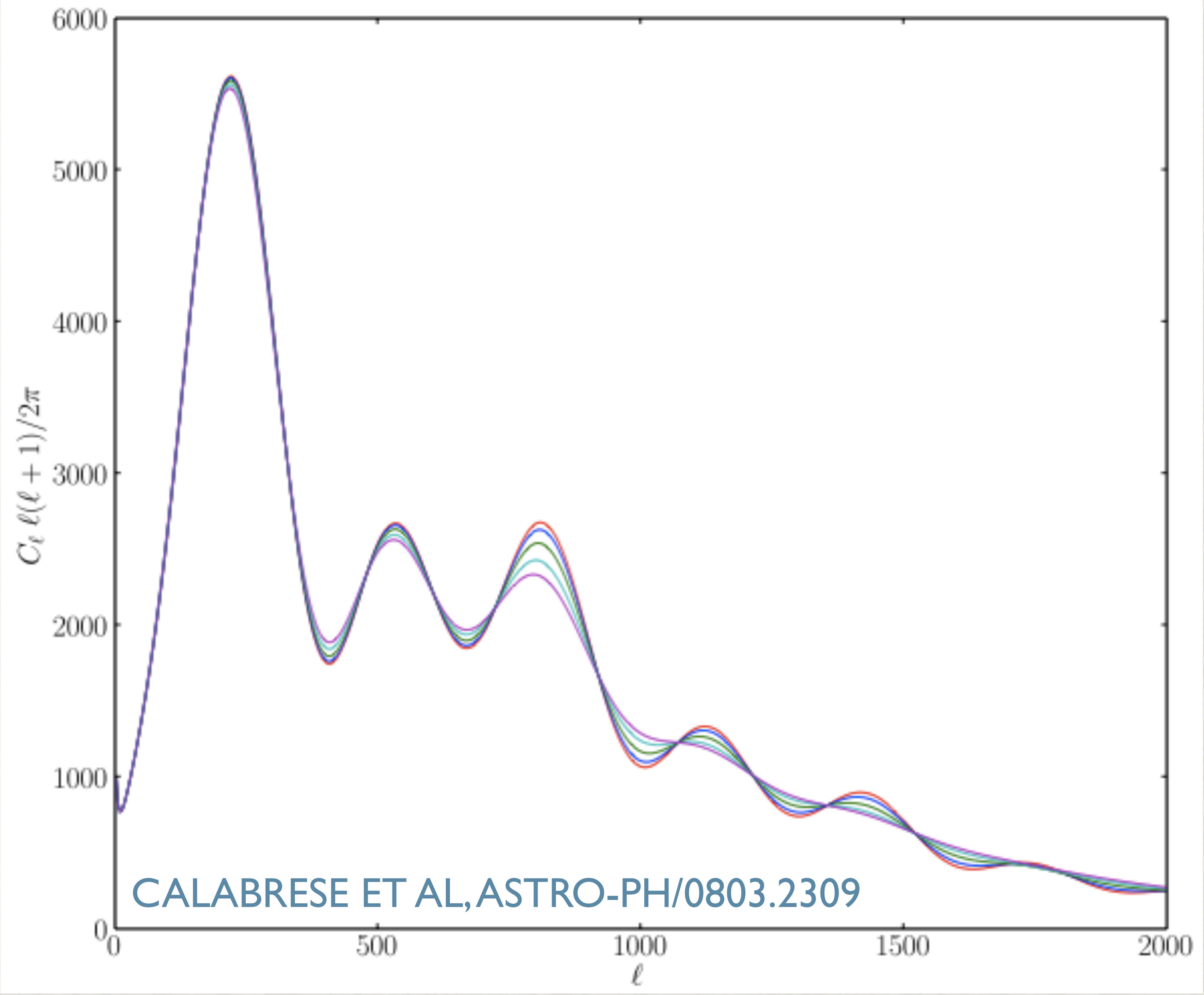
- Paths of CMB photons are distorted by gravity of intervening matter.



- Several recent ~3σ detections:
- CMB x mass tracers (Smith et al, Hirata et al)
- CMB TT Spectrum (Reichardt et al, Calabrese et al, Das et al)
- and a very recent 4σ detection from CMB TTTT Spectrum (Das et al).

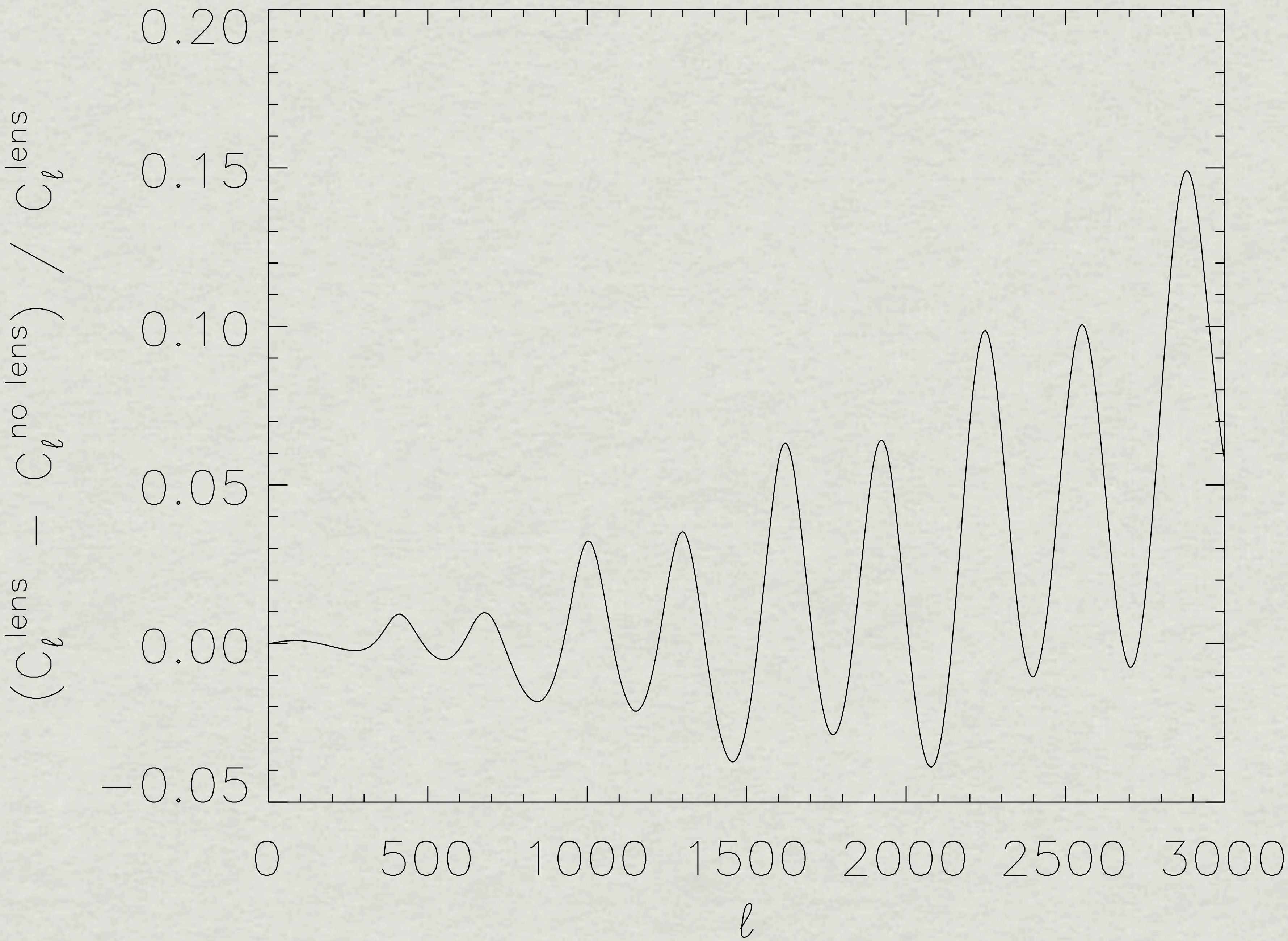
Lensing alters C_ℓ^{TT}

Smooths Acoustic Peaks



Lensing alters C_ℓ^{TT}

Smooths Acoustic Peaks



Simple Lensing Test

- Turn lensing ON/OFF (all other parameters are free).
- compare best-fit likelihoods.

Lensing is preferred at 4.9σ .
(preliminary)

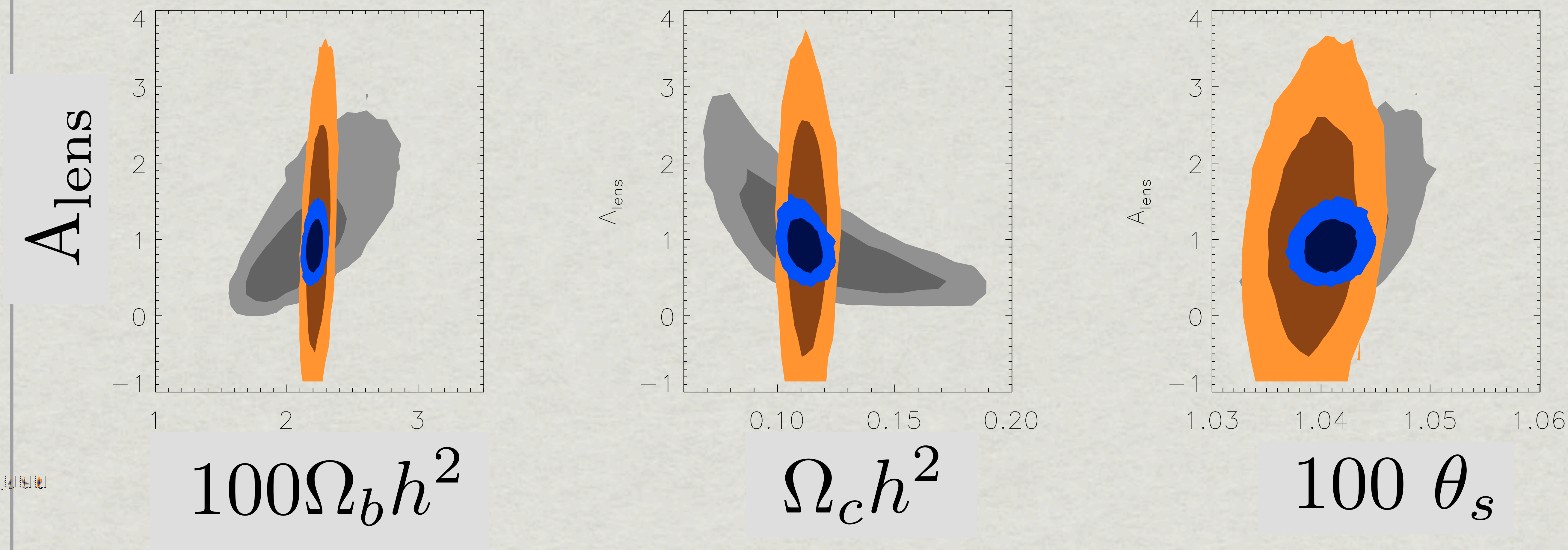
- does not depend on foreground priors.

Is lensing at expected level?

Introduce **A_LENS** which smoothly scales **lensing potential power spectrum**:

$$C_\ell^\psi \rightarrow A_{\rm lens} C_\ell^\psi$$

SPT & WMAP help each other measure A_LENS.

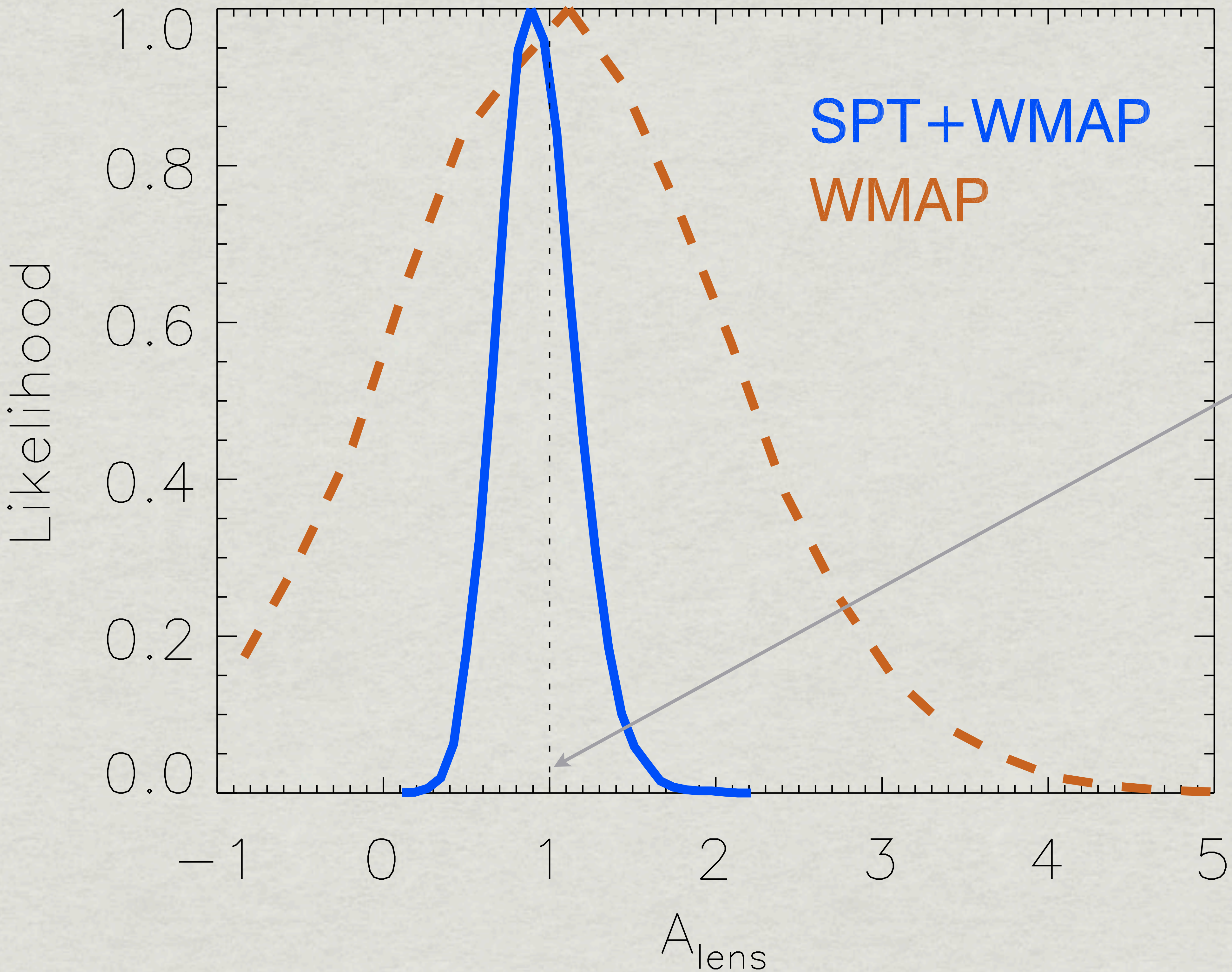


SPT

WMAP

SPT+WMAP

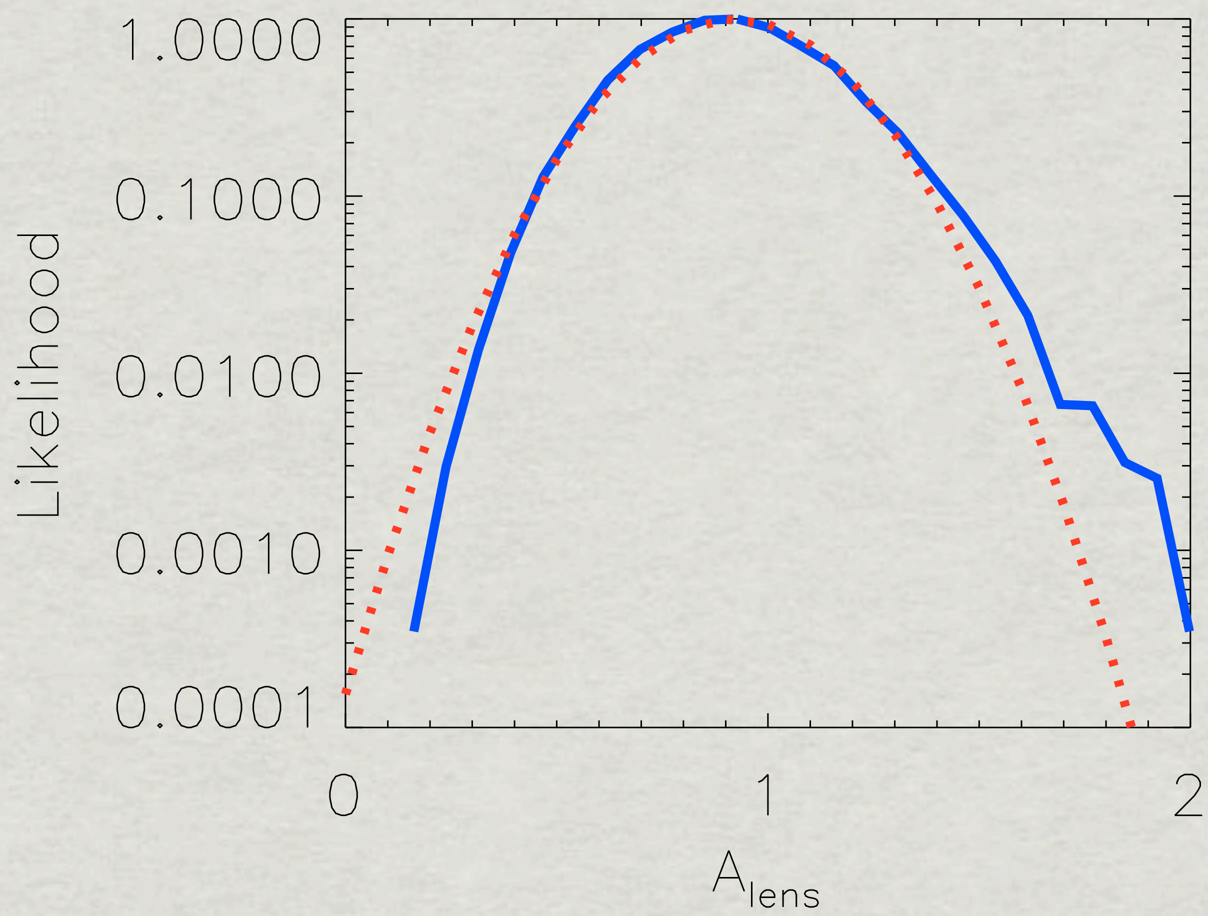
A_lens Constraint



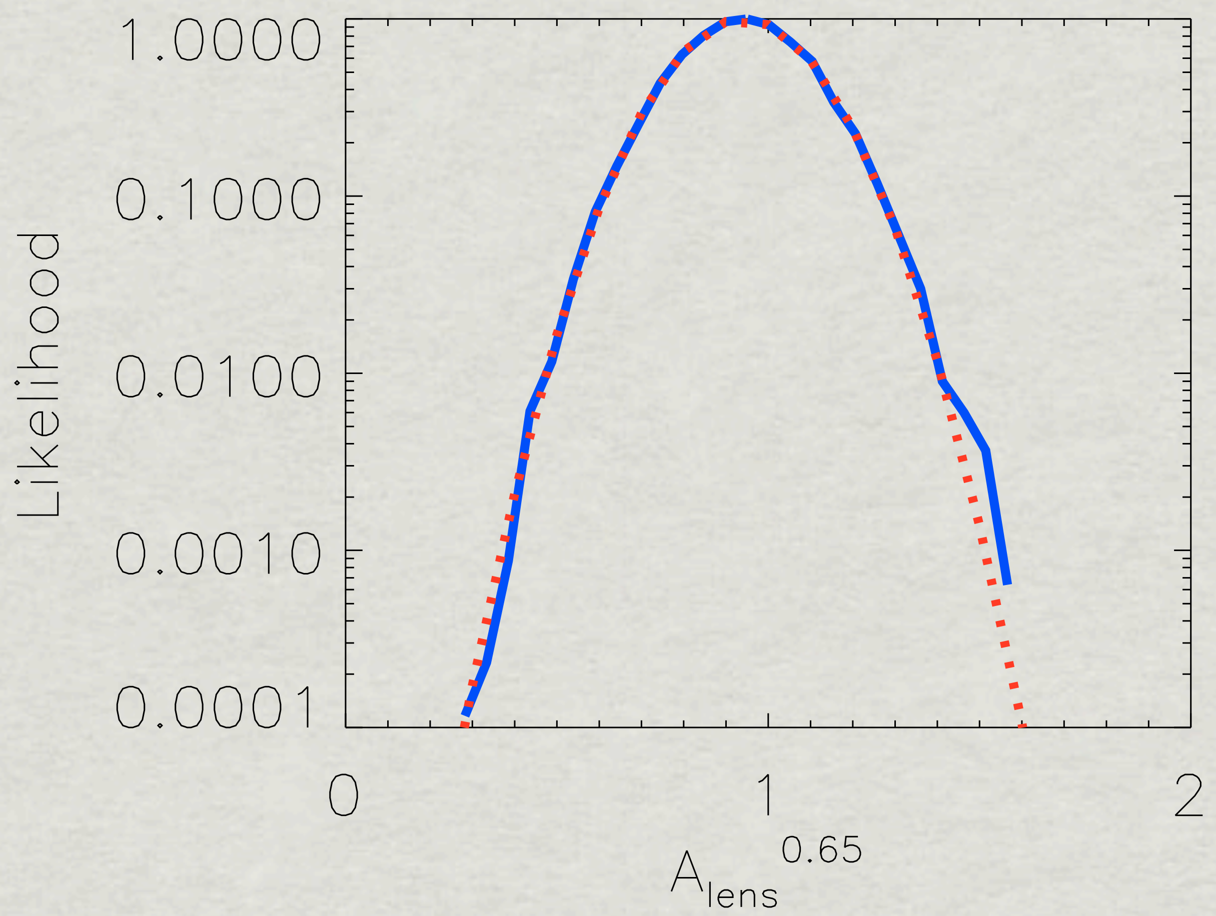
consistent with standard model.

Gaussianize

Likelihood of A_LENS is non-gaussian.



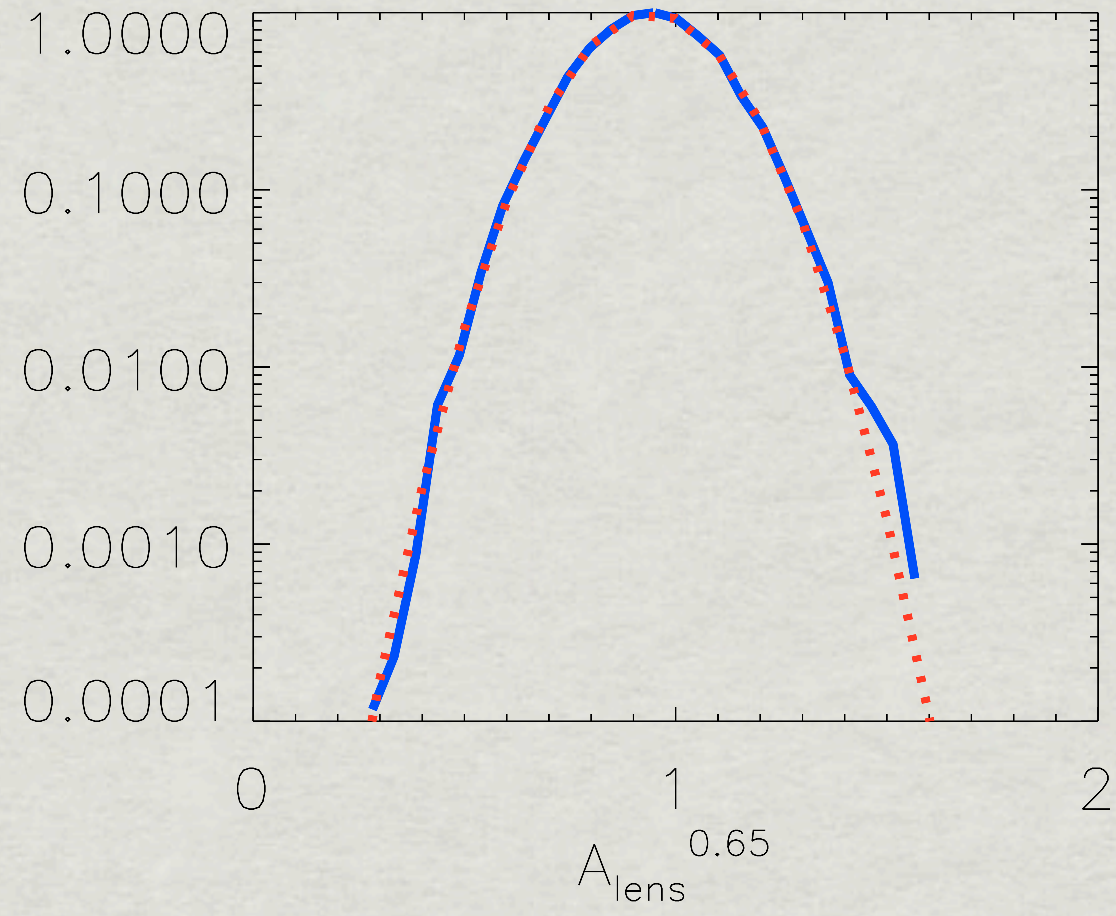
Likelihood of **(A_LENS)^0.65** is pretty gaussian.



A_lens Constraint

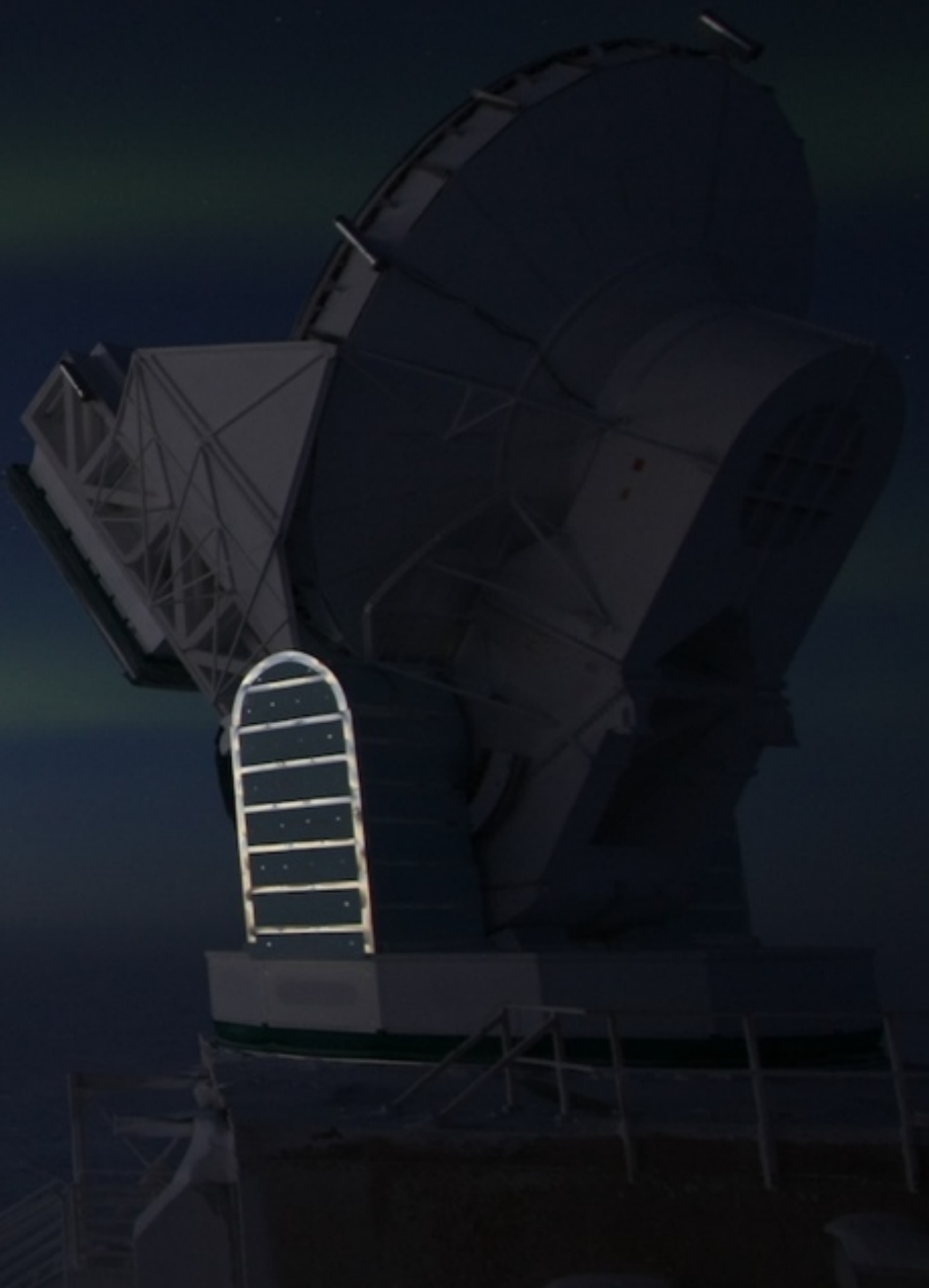
$$(\mathrm{A_{lens}})^{0.65} = 0.94 \pm 0.15$$

- Consistent with standard model (A_lens=1)
- Rejects no lensing at ~6σ.



Conclusion

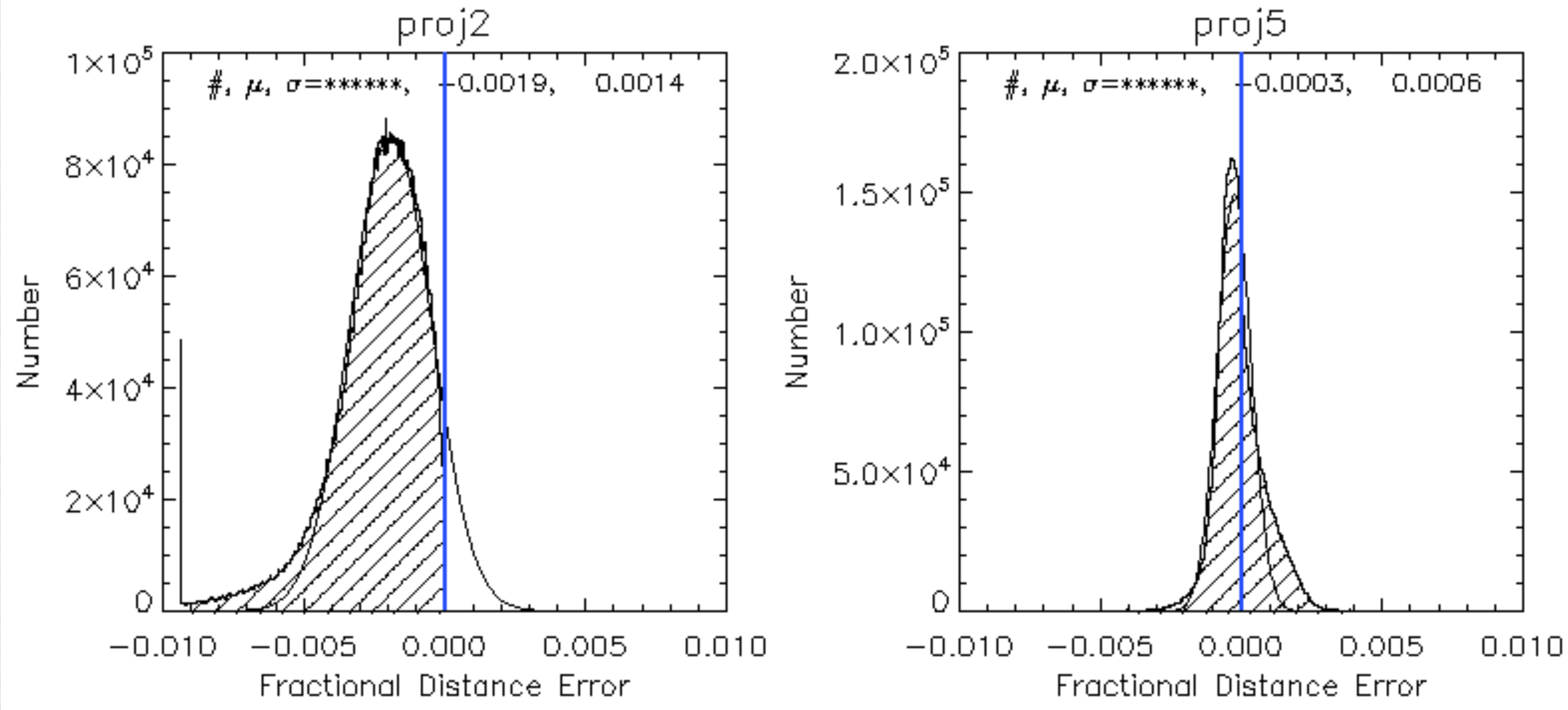
- New measurement of TT damping tail from SPT.
- SPT+WMAP is well fit by flat, ΛCDM cosmology.
- SPT+WMAP strongly detects the effects of gravitational **lensing** in TT at expected level.
- Look for new results from SPT in near future.



Conclusion

* New measurement of TT damping tail from SPT.
* SPT+WMAP is well fit by flat, ΛCDM cosmology.
* SPT+WMAP strongly detects the effects of gravitational lensing in TT at expected level.
* Look for new results from SPT in near future.

distortion from map projection



data vs wiggles