Measuring the CMB Damping Tail with SPT

Ryan Keisler
University of Chicago
Overview

- New measurement of CMB TT power spectrum using the South Pole Telescope.
- Constraints on lensing of the TT spectrum.
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.
(some) other SPT science:

- emission from z~2, dusty star-forming galaxies
- SZ galaxy cluster survey (and optical/x-ray followup)

check out pole.uchicago.edu
(some) other SPT science:

- Power spectrum of SZ/dusty galaxy “fuzz”, (Shirokoff et al).
- Emission from z~2, dusty star-forming galaxies
- SZ galaxy cluster survey (and optical/x-ray followup)

Check out pole.uchicago.edu

Photo by Dana Hrubes
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.
The covariance is (mostly) sample-variance-limited.
Final Spectrum

The graph shows the evolution of $\ell (\ell + 1) C_\ell / 2\pi \, [\mu K^2]$ as a function of $\ell / 1000$. The 3rd peak is indicated on the graph.
Final Spectrum

SPT
This Work

ACBAR
QUaD
ACT
SPT, S10
(preliminary)

Cosmological Analysis

- MCMC analysis (cosmoMC/CAMB)
- Data:
  - SPT (this work)
  - WMAP 7-year
Four component model:

- **CMB**, lensed primary CMB from flat \(\Lambda\)CDM, six parameters:
  \[
  \{\Omega_b h^2, \Omega_c h^2, \theta_s, \tau, n_s, \Delta^2_R\}
  \]

- **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 $\Lambda$CDM, six parameters:
  \[ \{ \Omega_b h^2, \Omega_c h^2, \theta_s, \tau, n_s, \Delta^2_R \} \]

- **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

$\chi^2$/dof = 35.5/38, pte = 0.58
$\chi^2$/dof = 35.5/44, pte = 0.82
SPT provides modest improvement on 6 “vanilla” cosmo parameters

\[ n_s = 0.965 \pm 0.011 \]  
(3.2σ preference for \( n_s < 1 \))
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 $C_{\ell}^{TT}$

Smothers Acoustic Peaks

CALABRESE ET AL, ASTRO-PH/0803.2309
Lensing alters $C_{\ell}^{TT}$ Smooths Acoustic Peaks
Simple Lensing Test

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

Lensing is preferred at $4.9\sigma$. (preliminary)

- Does not depend on foreground priors.
Is lensing at expected level?

Introduce $A_{\text{LENS}}$ which smoothly scales lensing potential power spectrum:

$$C_\ell^\psi \rightarrow A_{\text{lens}} C_\ell^\psi$$
SPT & WMAP help each other measure $A_{\text{LENS}}$. 

\[ 100\Omega_b h^2 \quad \Omega_c h^2 \quad 100 \theta_s \]
A\_lens Constraint

SPT + WMAP

WMAP

consistent with standard model.
Likelihood of $A_{\text{LENS}}$ is non-gaussian.

Likelihood of $(A_{\text{LENS}})^{0.65}$ is pretty gaussian.
A\_lens Constraint

\[(A_{\text{lens}})^{0.65} = 0.94 \pm 0.15\]

• Consistent with standard model (A\_lens=1)

• Rejects no lensing at \(~6\sigma\).
Conclusion

- New measurement of TT damping tail from SPT.

- SPT+WMAP is well fit by flat, $\Lambda$CDM 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, $\Lambda$CDM 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