SPT-3G:
The Next Generation Receiver for Polarized Cosmic Microwave Background Measurements with the South Pole Telescope

Amy N. Bender
on behalf of the SPT-3G Collaboration
DPF 2015
2015-08-05
The South Pole Telescope (SPT)

10-meter sub-mm quality wavelength telescope

100, 150, 220 GHz and 1.6, 1.2, 1.0 arcmin resolution

2007: SPT-SZ
960 detectors
95, 150, 220 GHz

2012: SPTpol
1600 detectors
95, 150 GHz +Polarization

2016: SPT-3G
~16,000 detectors
95, 150, 220 GHz +Polarization

Funded by:
The Cosmic Microwave Background
WMAP
W-band
30 deg$^2$
Planck
143 GHz
30 deg²
SPTpol
150 GHz
30 deg$^2$

CMB Anisotropy
Galaxy Clusters
Dusty Galaxies & AGN
Polarization of the CMB

Seljak & Zaldarriaga 1998

E-modes

Baumann 2009

B-modes

credit: ESA and the Planck Collaboration
The Power of CMB Polarization

\[ \Sigma m_\nu = 0 \]
\[ \Sigma m_\nu = 1.5\text{eV} \]

Large-scales \hspace{2cm} Small-scales

\[ r = 0.24 \]
\[ r = 0.01 \]
4.3σ detection of lensing B-modes in the autospectrum from ~1st year of observations

Currently analyzing 2.5 years of additional data over a larger sky area (extending to lower-ell)
Focal Plane Evolution

Approximate raw experimental sensitivity (µK)

<table>
<thead>
<tr>
<th>Year</th>
<th>Untitled</th>
<th>WMAP</th>
<th>Planck</th>
<th>SPTpol</th>
<th>SPT-3G</th>
<th>CMB-S4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Snowmass; arXiv:1309.5383
The SPT-3G Receiver

- 1.9 deg field of view (2.8 deg$^2$)
- 16,262 Transition-edge sensor bolometers operated at 250 mK
- 3 Observing bands: 95, 150, 220 GHz
- ~20x faster mapping speed than current instrument (SPTpol)
Detector Architecture

- Multichroic dual-polarization pixel (adapted from design from UC Berkeley)
- Broad-band sinuous antenna microstrip in-line filters
- 6 separate TES islands per pixel (3 bands & 2 polarizations)
- 271 pixels fabricated monolithically on a 6” wafer
Multiplexing Readout Architecture

Readout 64 bolometers on single pair of wires using LC resonators to select an AC voltage bias.

Bender et al. 2014, Proc. SPIE 9153
Recent Performance

- **Performance Criteria:**
  - Sensitivity (NET)
  - Stability
  - Crosstalk
  - Uniformity across the focal plane
SPT-3G Cluster Survey Forecasts

- 2500 square degree survey of the CMB for a duration of 4 years
  - 2.5 μK (3.5 μK) in T (P) @150 GHz
  - 4.3 μK (6 μK) in T(P) @ 95/220 GHz
- ~10,000 new galaxy clusters
  - Astrophysics of galaxy clusters
  - Constrain growth of large-scale structure & evolution of dark energy \((w, w_a)\)
  - CMB - cluster lensing to calibrate the mass of clusters

Benson et al. 2014, Proc. SPIE 9153
Mohr 2005
SPT-3G Projected Power Spectrum

- High S/N measurement of gravitational lensing B-modes
- constrain sum of neutrino mass through growth of structure
- de-lensing of inflationary spectrum

2019 Projections

Priors from Planck + BOSS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(r)$</td>
<td>0.011</td>
</tr>
<tr>
<td>$\sigma(\Sigma m)$</td>
<td>0.061 eV</td>
</tr>
</tbody>
</table>

Benson et al. 2014, Proc. SPIE 9153
Summary

• CMB polarization is a powerful cosmological probe

• SPT-3G will map 2500 square degrees of the millimeter-wavelength sky in both temperature and polarization to exciting new depths

  • Both detector and readout technology have made significant advances with a focal plane of ~16,000 detectors

  • Constrain the evolution of dark energy, neutrino mass, and inflationary gravity waves

credit: D. Hrubes