The Design and Integrated Performance of SPT-3G

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APS DPF Meeting, 2021

Outline

1. Describe key features of SPT-3G
2. Report on SPT-3G's integrated performance
3. Highlight <u>a few</u> exciting science goals for SPT-3G


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The Design and Integrated Performance of SPT-3G

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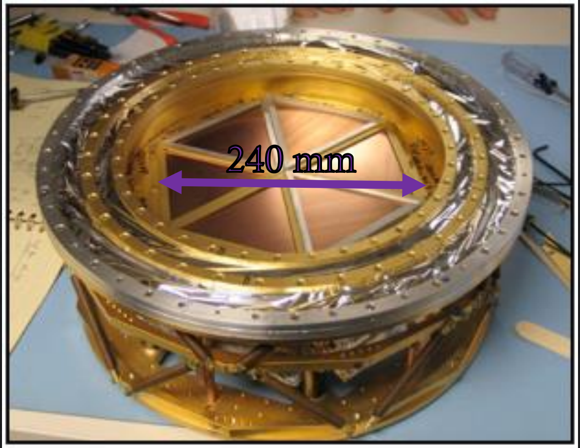
Further details on instrument and performance available in <u>Sobrin et al. (2021)</u>
Manuscript submitted to ApJS, and available on arXiv (2106.11202)

Better CMB Sensitivity → Better Cosmology

Design Drivers:

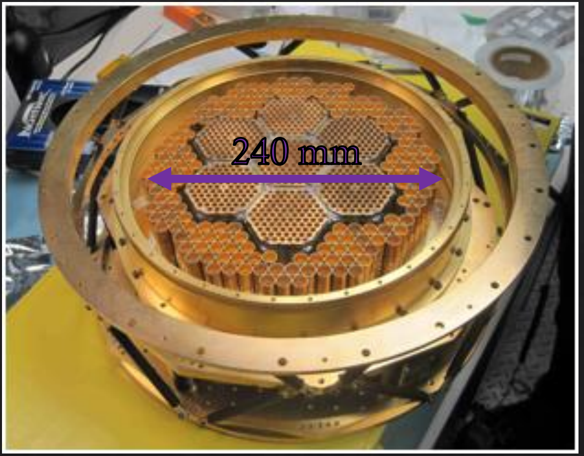
- Noise of CMB signal → Increase detector count
- Foreground contamination → Measure CMB in multiple frequency bands

2007: SPT-SZ
960 Detectors



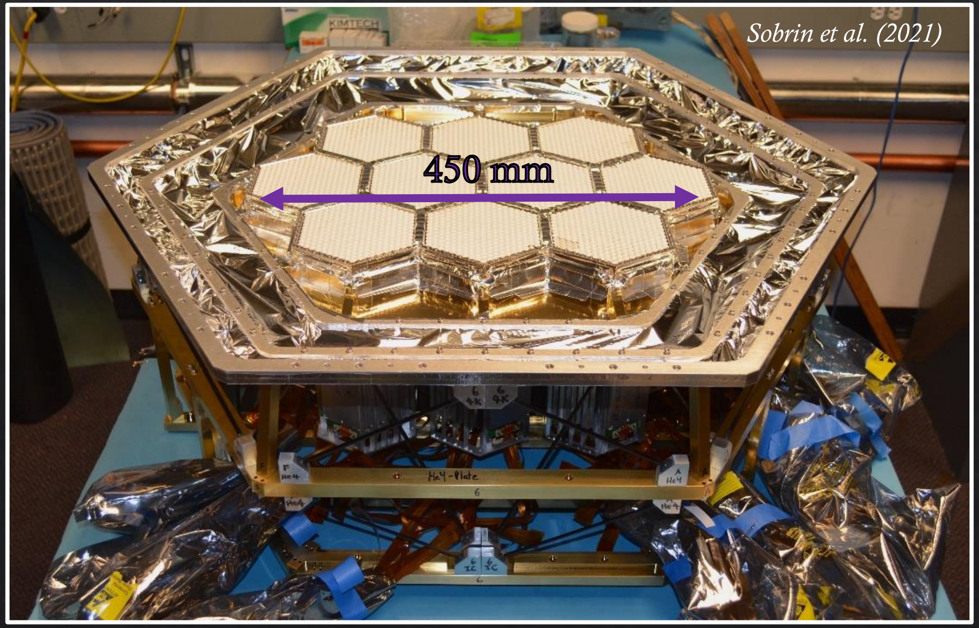
90, 150, 220 GHz

2012: SPTpol
1,500 Detectors



90, 150 GHz + Polarization

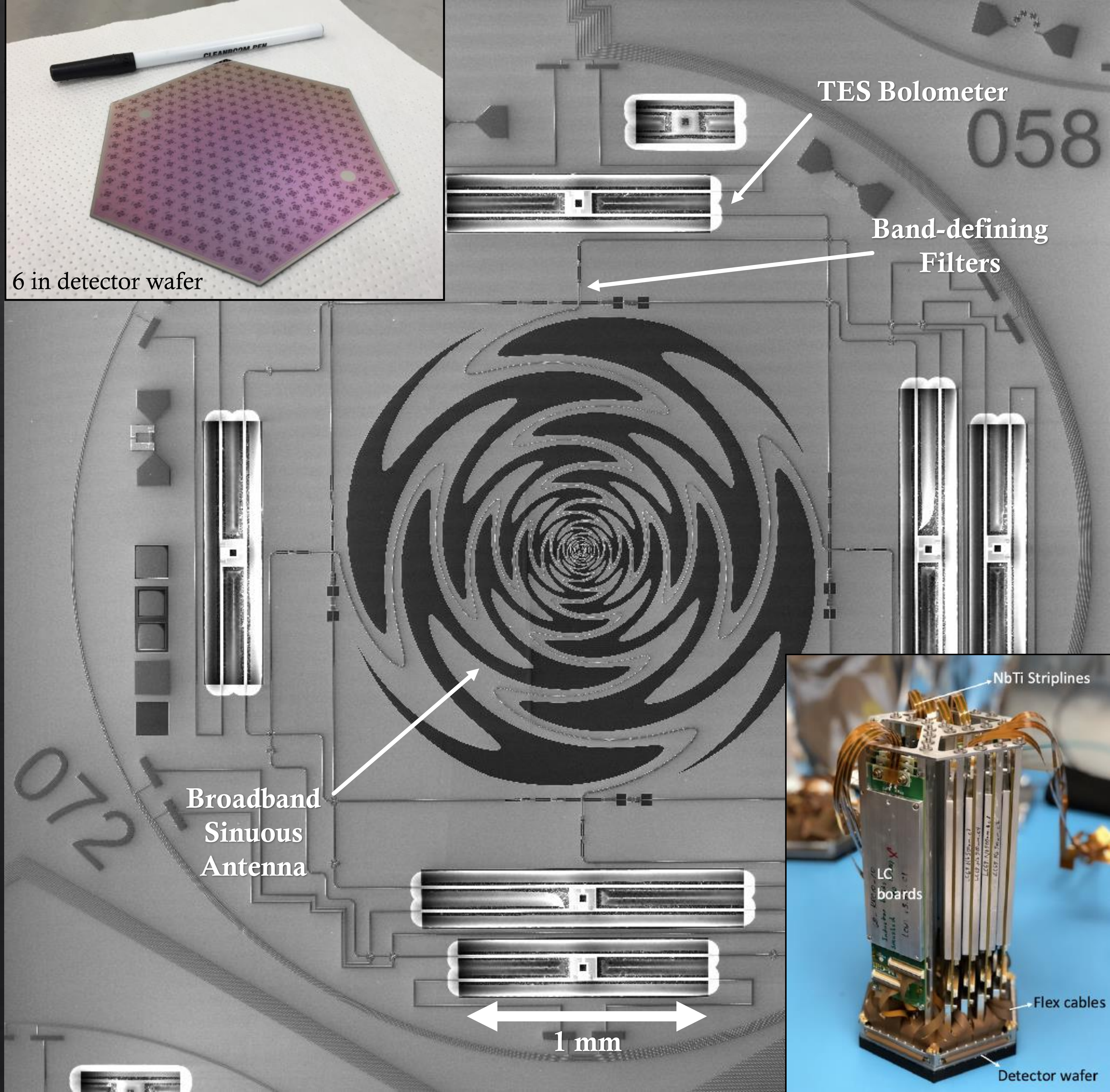
2018: SPT-3G
16,000 Detectors



90, 150, 220 GHz + Polarization

Detectors and Readout

- Broadband sinuous antenna splits by polarization
- In-line band-defining filters further split by observing band
- 6 unique signals (3 bands x 2 polarizations) each terminate on separate transition-edge sensor bolometers (~500 mK)
- 10 detector wafers, each containing 269 pixels
- Groups of 64 detectors are operated and read out using a digital frequency-domain multiplexing system (1.6 – 5.2 MHz resonators with 4K SQUID-based amplifier)



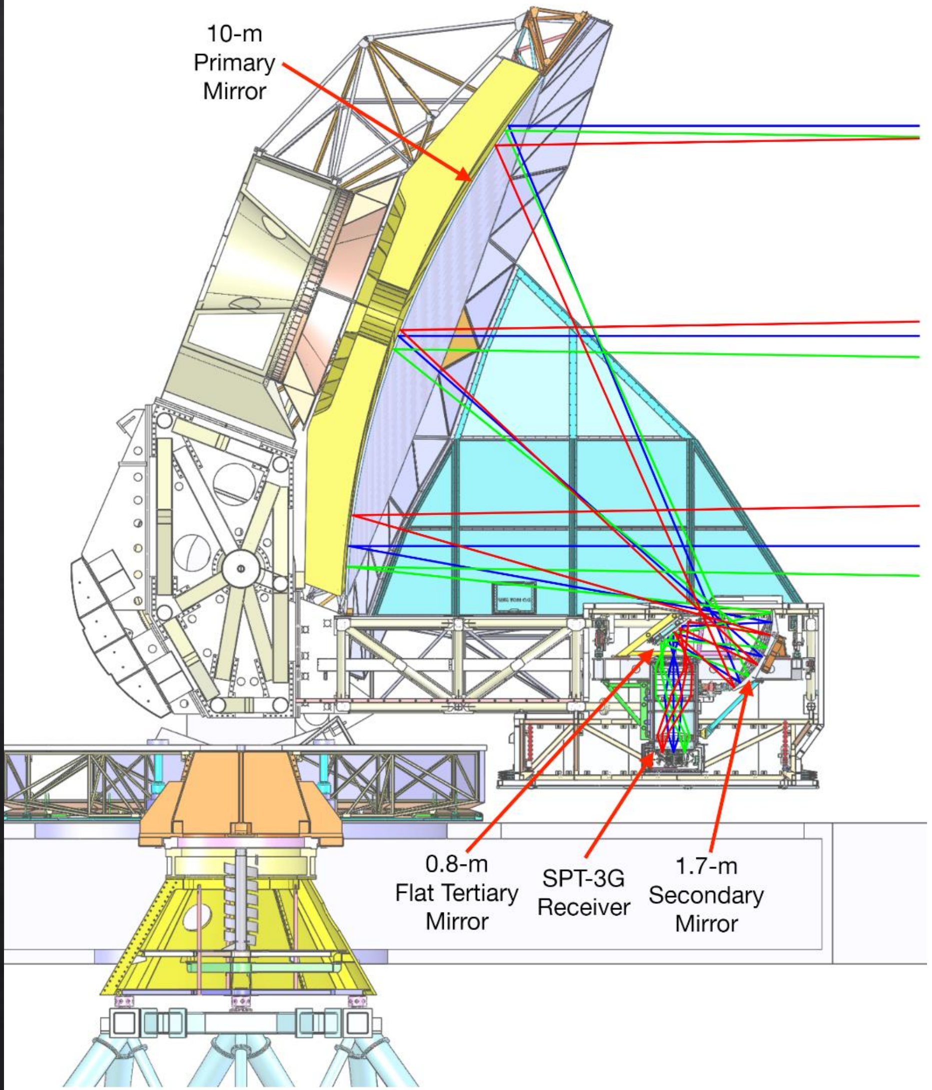
Optics and Cryogenics

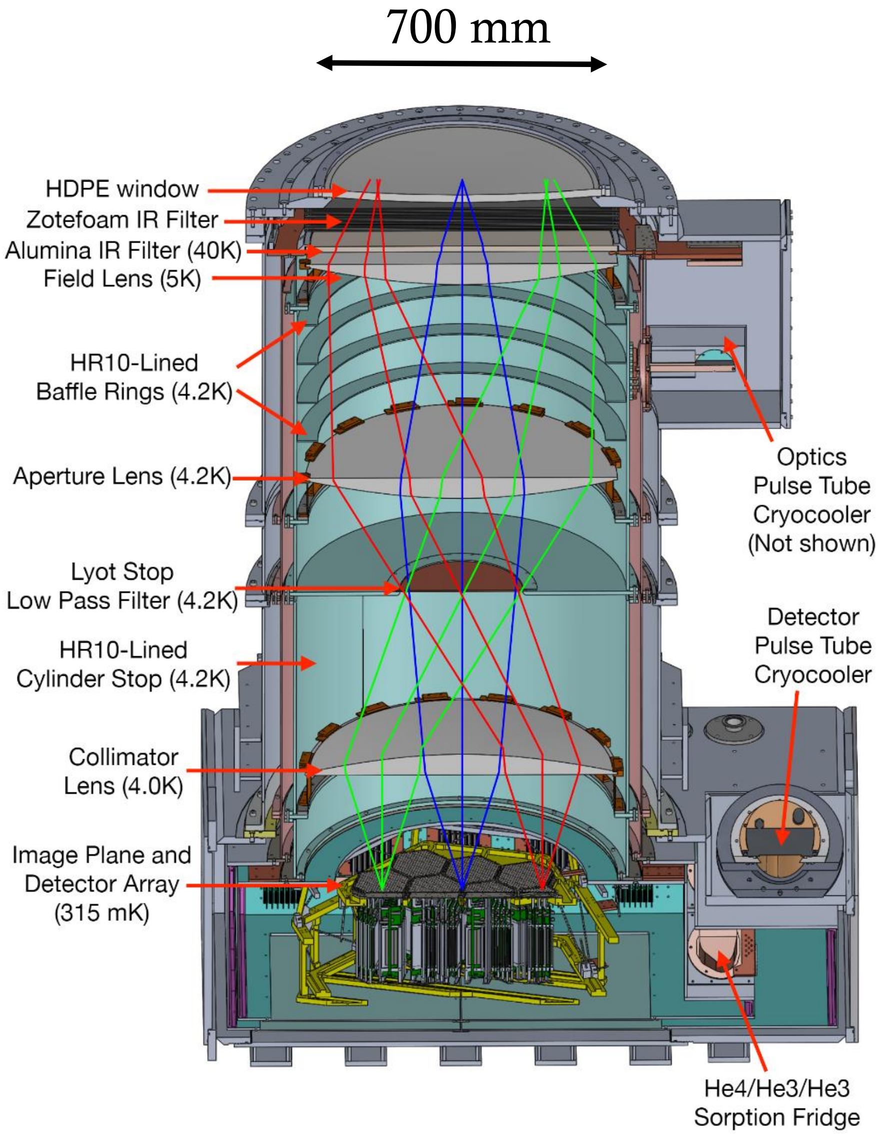
- 700 mm aluminum-oxide lenses reimages Gregorian focus onto flat image plane
- Developed multi-layer PTFE-based anti-reflection coatings

- Optics system elements cooled to decrease extraneous thermal emission
- Receiver designed to mitigate and control stray reflection and scattering

- Achieved:
  2 deg FOV, with 1.2 arcmin FHWM beam response at 150 GHz

Cross-sectional view of telescope and SPT-3G receiver, with ray trace overlaid



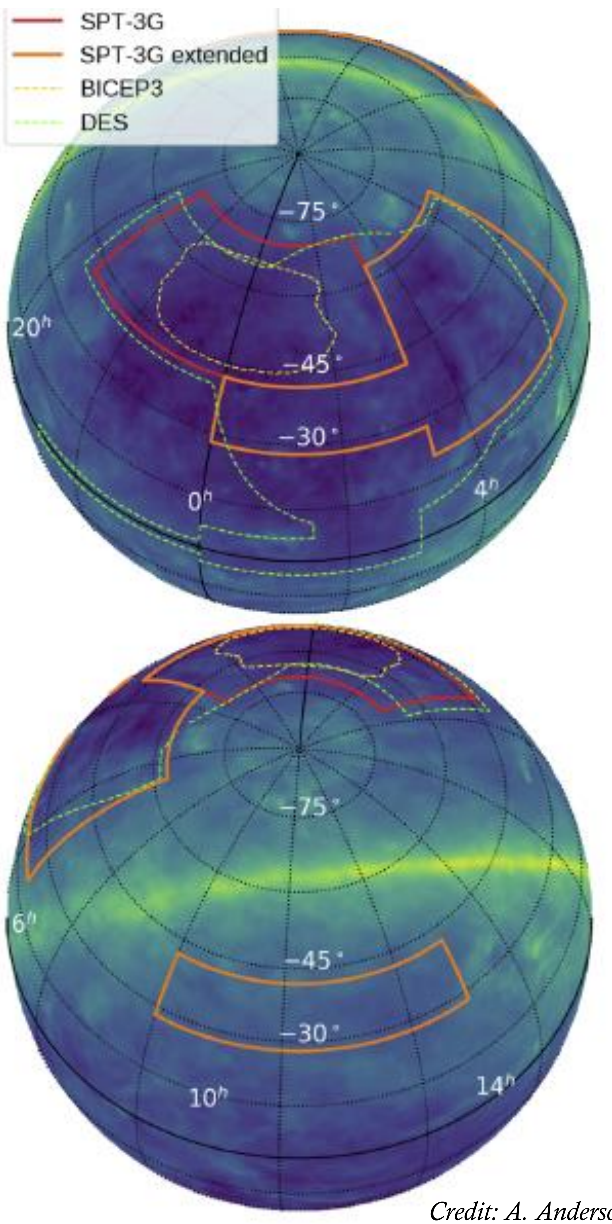


Sobrin et al. (2021)

Observing Strategy

- Consistent observation of 1500 deg^2 area of CMB, overlapping with BICEP3/BICEP Array survey
- During December – March, switch to observing additional fields focused on detecting galaxy clusters

Survey footprints overlaid on Planck thermal dust map



Credit: A. Anderson

SPT-3G's high re-observation cadence allows for:

1. Quickly decreasing noise-levels in coadded CMB maps
2. Probes of time-domain astrophysics.

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Detection of Galactic and Extragalactic Millimeter-Wavelength Transient Sources with SPT-3G

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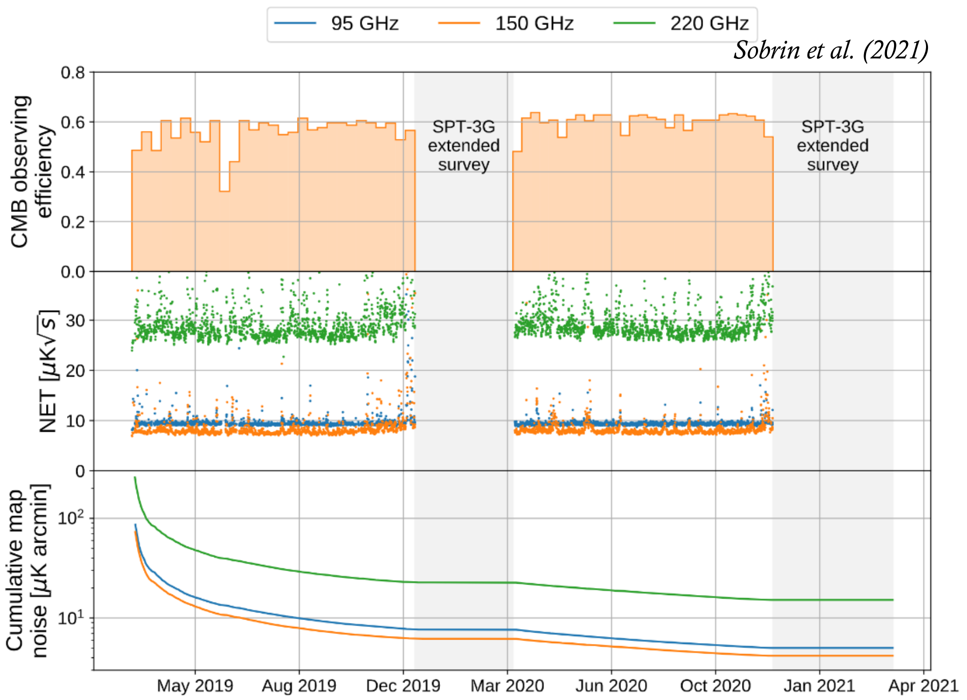
Detection of mm-wave transient sources with SPT-3G (Gunns et al. 2021)
Accepted to ApJ, and available on arXiv (2103.06166)

SPT-3G Integrated Performance

Illustrating observing efficiency, instantaneous sensitivity, and co-added map noise over past 2 years



Consistently high observing efficiency

+ Overall low and stable instrument noise

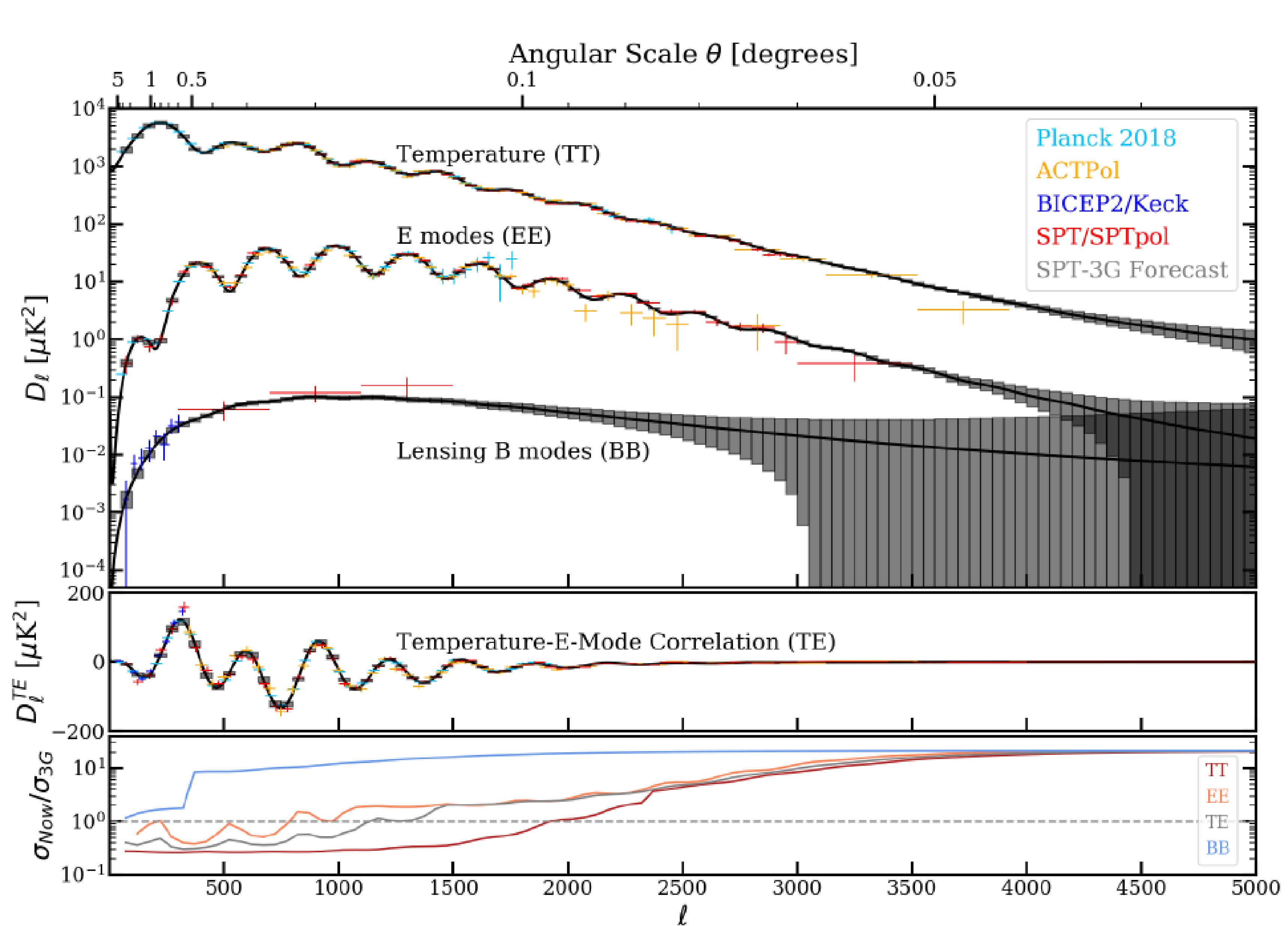
Fast improvement in sensitivity over time

Map Noise in uK-arcmin

	Obs. Years	Area (deg^2)	95 GHz	150 GHz	220 GHz
SPT-SZ	2007-11	2500	40	17	80
SPTpol	2012-16	500	12	5	…
SPT-3G (current)	**2018-20**	**1500**	**5**	**4**	**15**
SPT-3G (full survey)	2018-23	1500	3.0	2.2	8.8

Current and full-survey depths are comparable to future Simons Observatory and CMB-S4 experiment goals over a small fraction of the sky

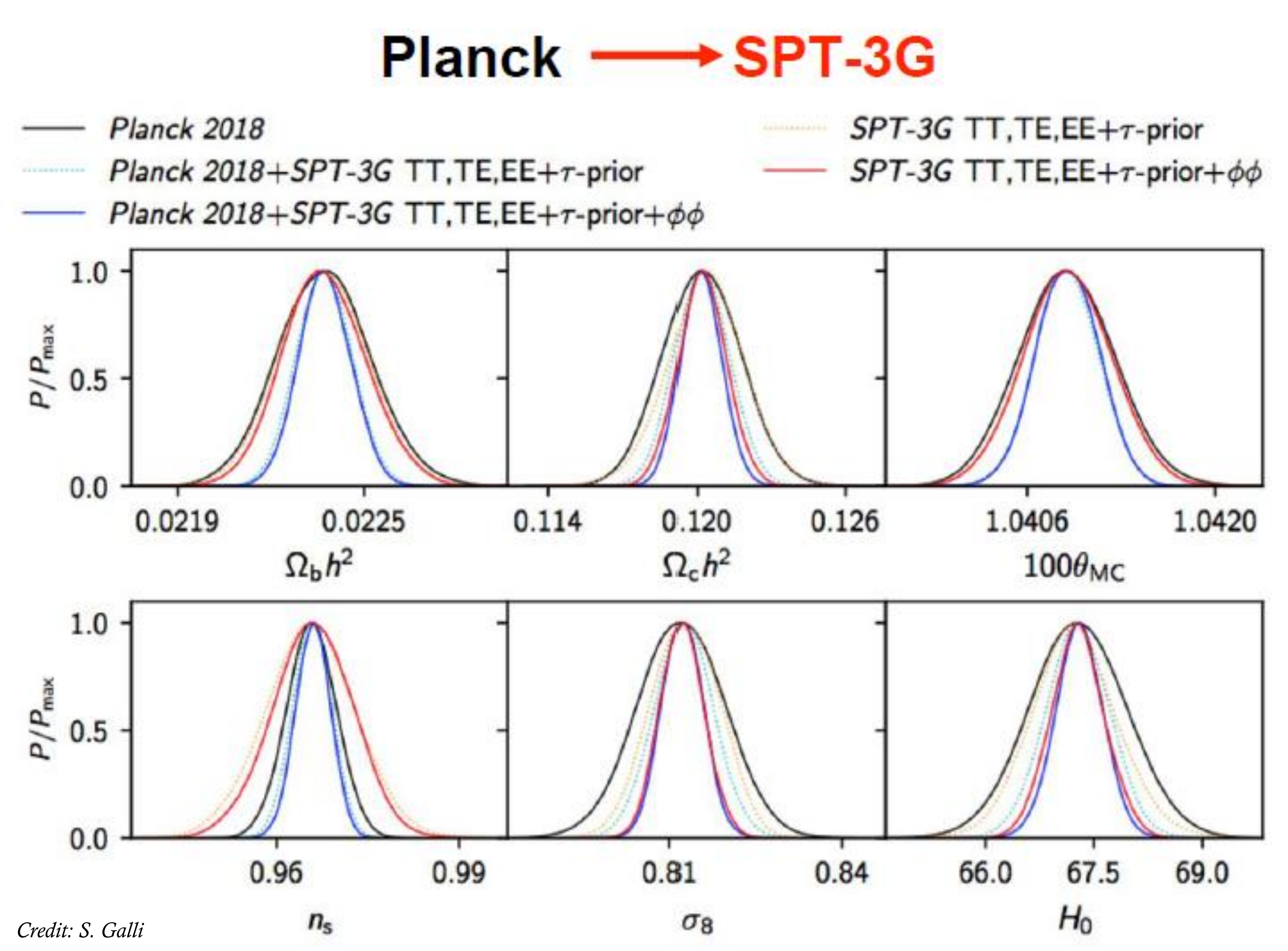
From Maps to Power Spectra



- SPT-3G should improve temperature and polarization auto- and cross-spectra measurements by a factor of ~10 at $\ell > 3000$

- In addition, various combinations of temperature and polarization data will be used to better reconstruct the CMB lensing potential, φ, at high signal-to-noise per mode

From Power Spectra to Constraints



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- In addition, various combinations of temperature and polarization data will be used to better reconstruct the CMB lensing potential, φ, at high signal-to-noise per mode

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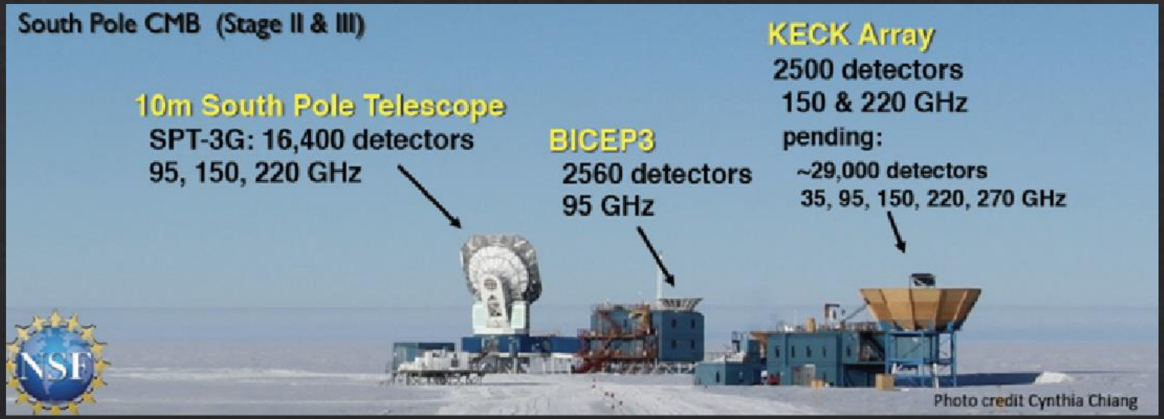
- A combination of Planck + SPT-3G will improve most ΛCDM model parameter uncertainties by a factor of ~2
  - High-ell data will elucidate H_0 and N_{eff} tensions
  - CMB lensing data will provide independent constraints on Σm_ν

Probing Models of Inflation

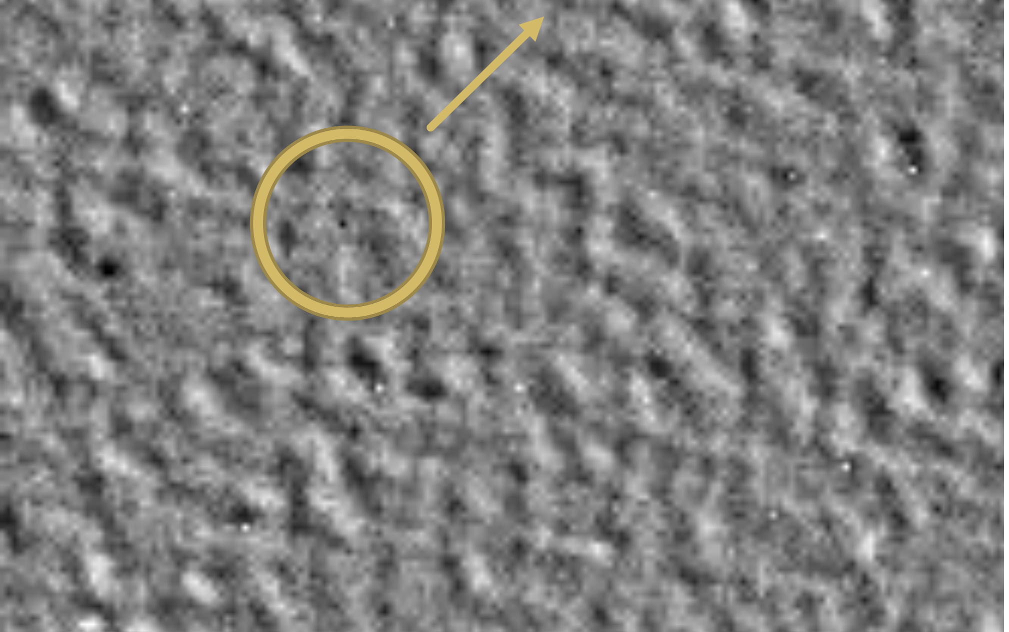
- SPT-3G's measurements of the B-mode polarization signal at high-ℓ will allow the separation of lensed and inflation-originating signals
- These data will be especially useful in concert with BICEP3/BICEP Array data, which provides additional polarization sensitivity at degree scales.



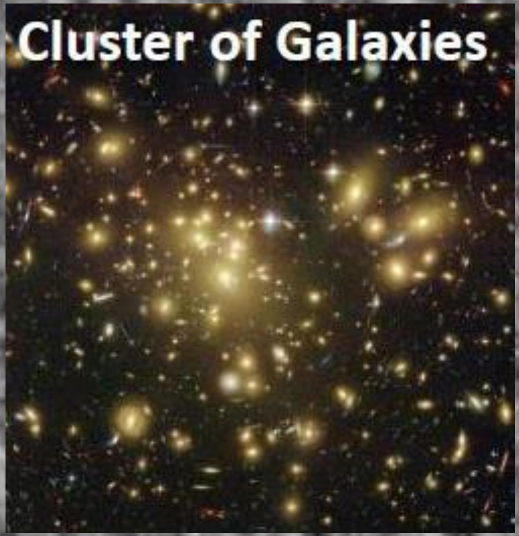
This "de-lensing" of the BB power spectrum will constrain the tensor-to-scalar ratio, r, to $\sigma(r) = 0.002$

See upcoming presentation by Riccardo Gualtieri!

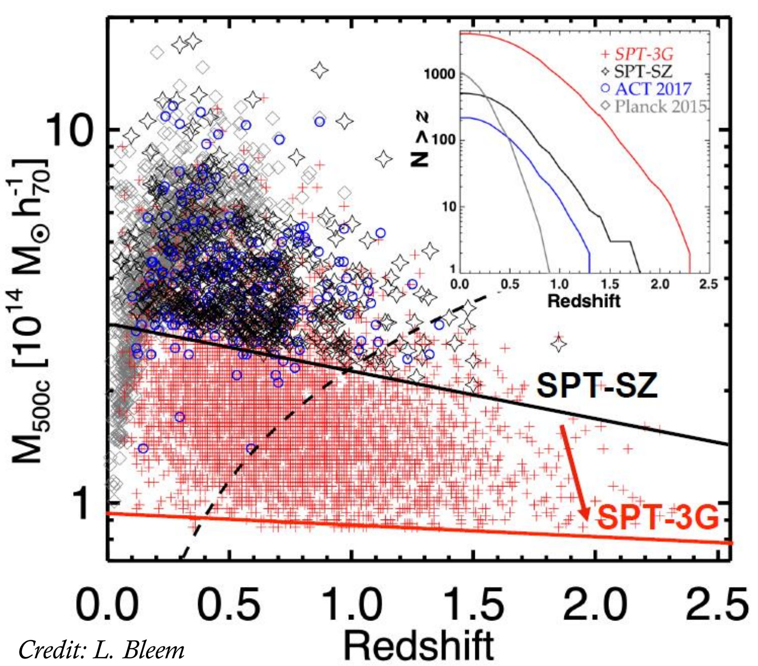
Detecting Galaxy Clusters via the SZ-effect



~100 deg^2 of partial SPT-3G data



Simulation of SPT-3G full-survey cluster sample



Credit: L. Bleem

- SPT-3G will provide a rich sample of high-redshift, mass-limited galaxy clusters
- Full-depth SPT-3G survey is expected to detect ~1000 clusters at z > 1, via the Sunyaev-Zeldovich Effect
- This better dataset of cluster abundance as a function of redshift will improve our understanding of the growth of structure, the nature of dark energy, and the matter power spectrum

Conclusion

- SPT-3G is a high-resolution, multichroic, polarization-sensitive, low-noise CMB instrument

- SPT-3G has been conducting focused observations of the CMB across a 1500 deg^2 field, and already achieved map sensitivity levels that will yield competitive constraints on cosmology

- SPT-3G's full dataset will enable a broad range of astronomy, cosmology, and fundamental physics research prior to CMB-S4