Results and progress of CMB lensing measurements using SPT-3G data

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SLAC National Accelerator Laboratory
May 16, 2024
DPF-Pheno 2024

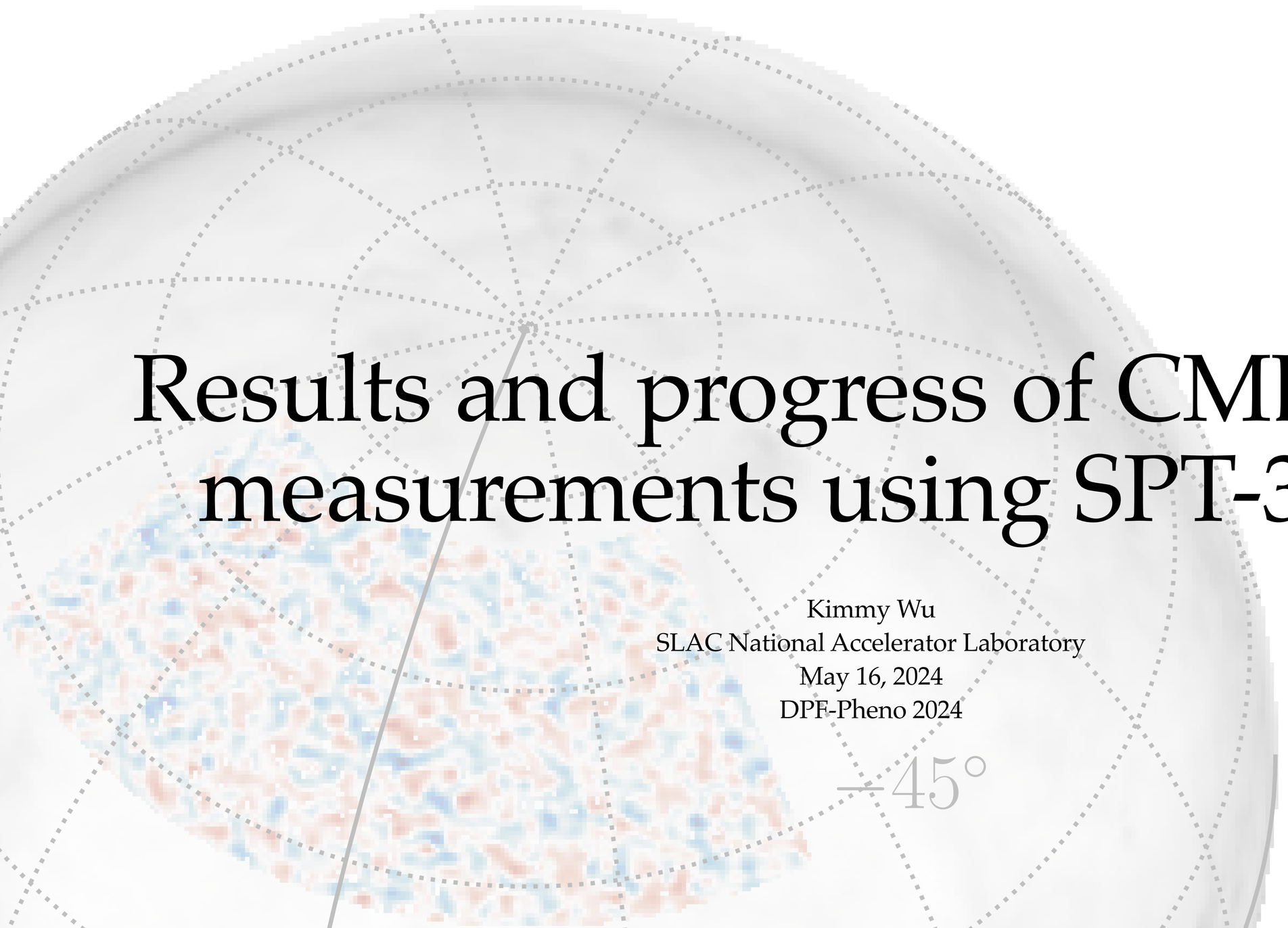
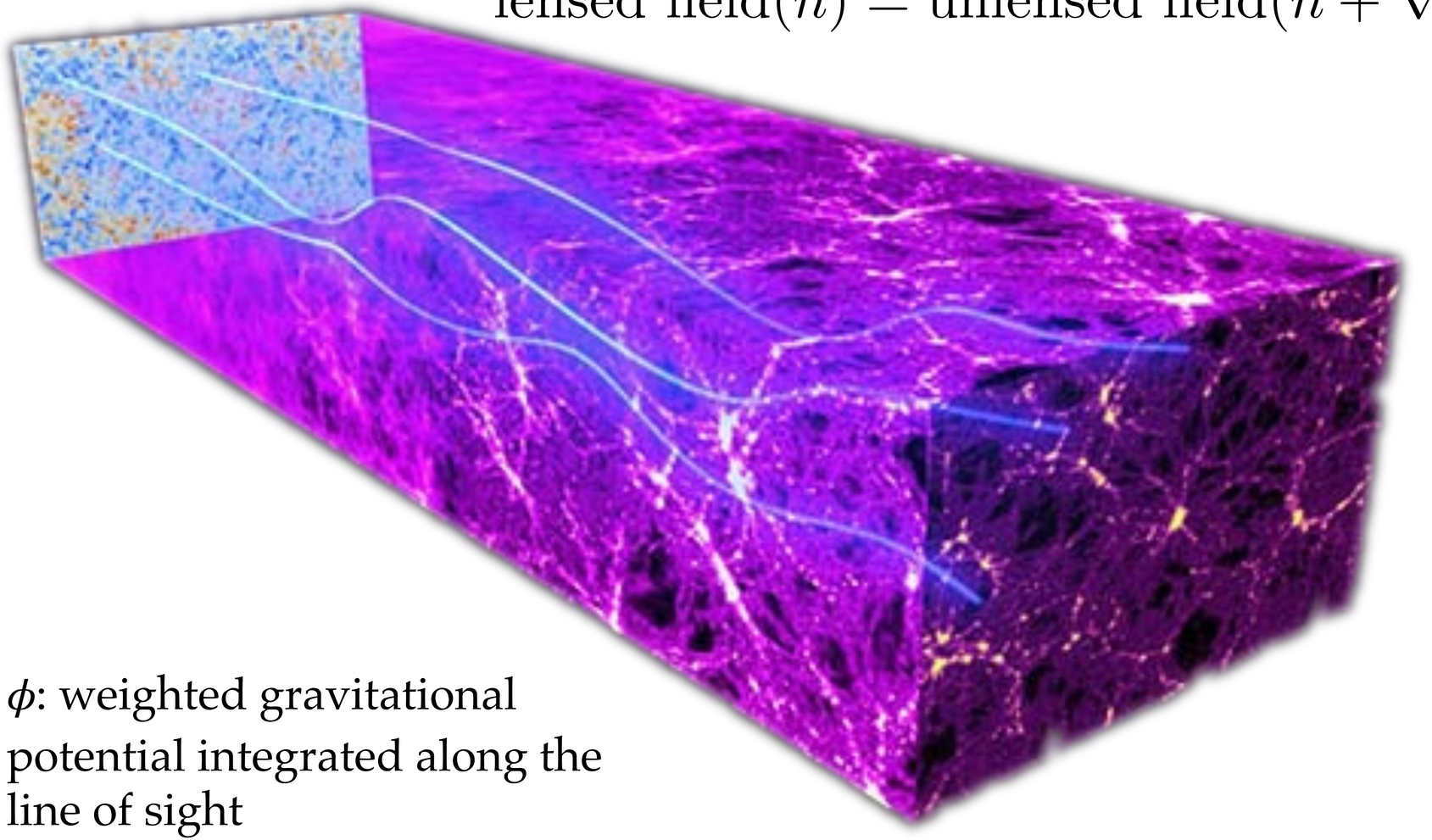


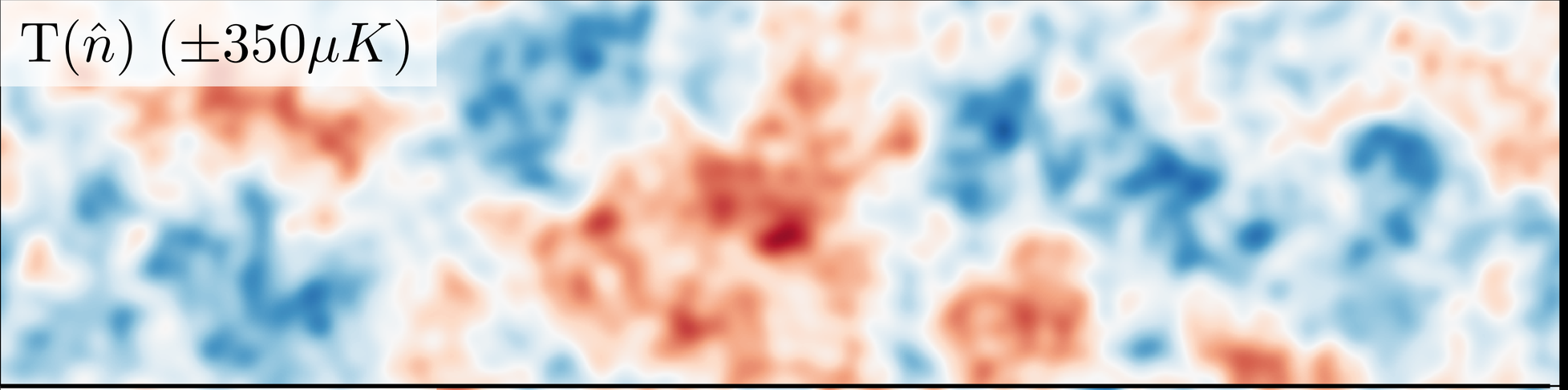
Figure from Pan, Bianchini, **KW** ++ (SPT-3G collaboration, 2308.11608)

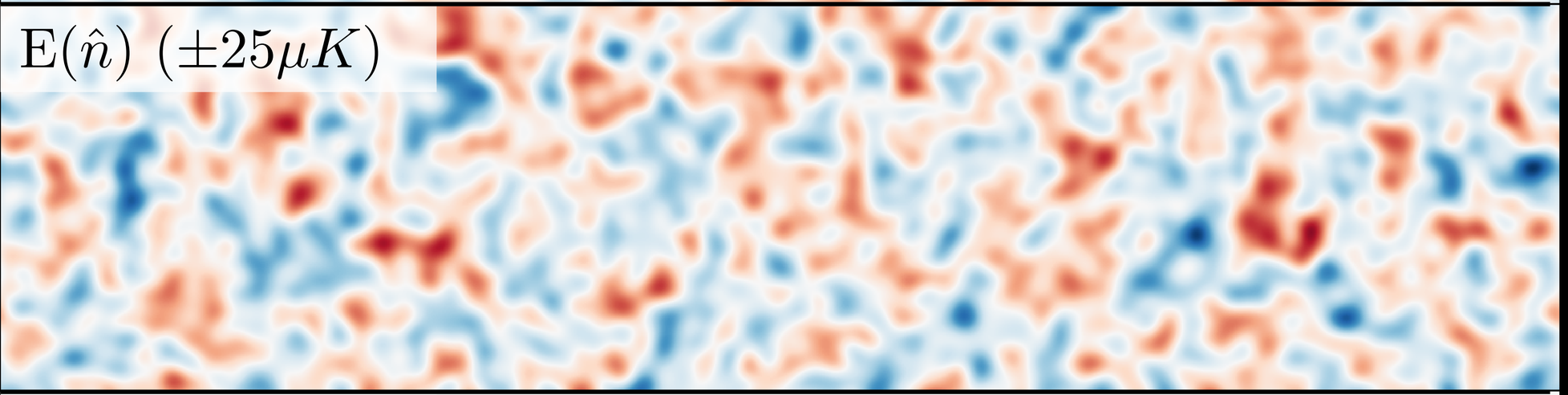
Weak lensing of the cosmic microwave background

$$\text{lensed field}(\hat{n}) = \text{unlensed field}(\hat{n} + \nabla\phi)$$



ϕ: weighted gravitational potential integrated along the line of sight

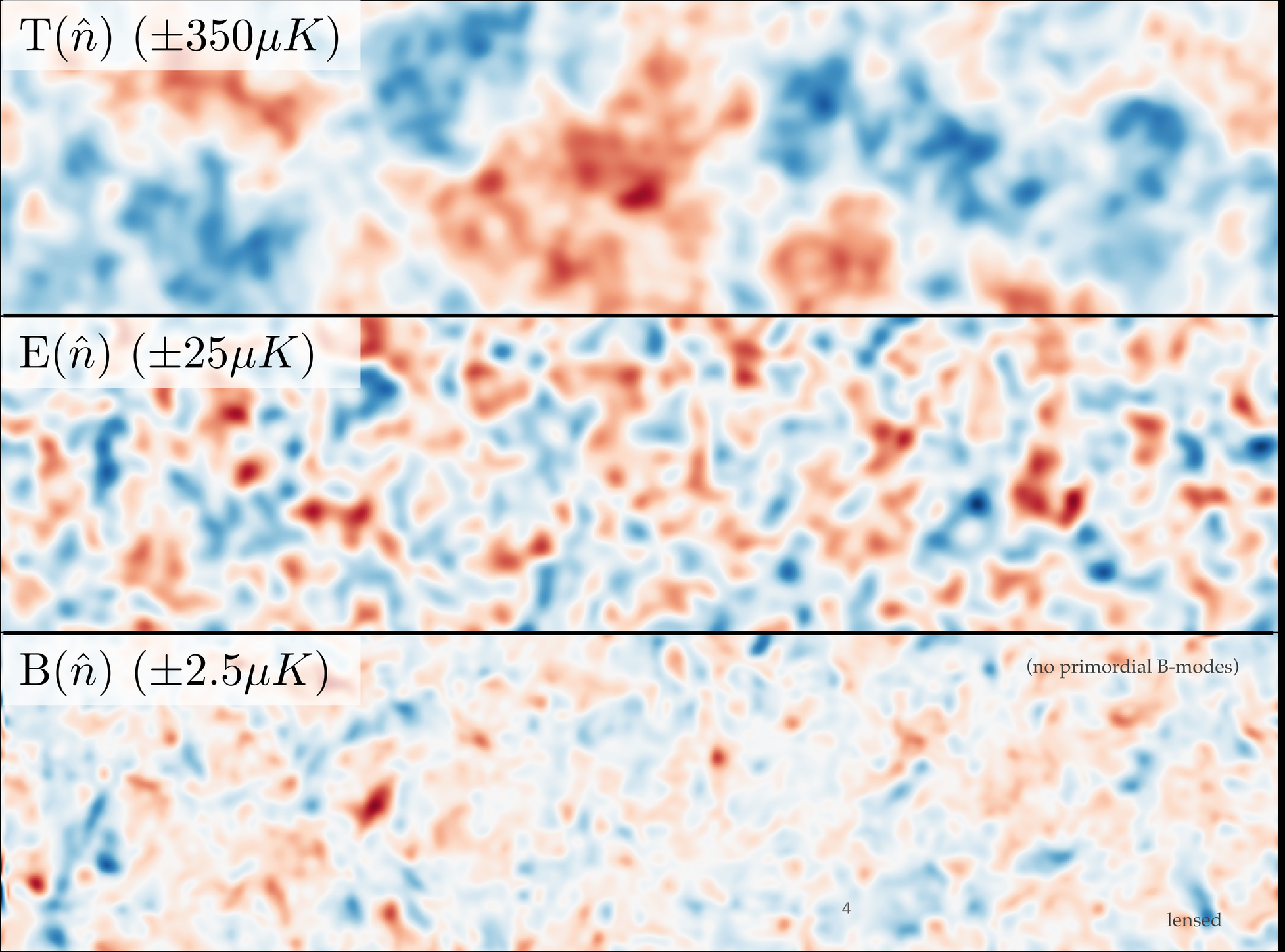




$\mathrm{B}(\hat{n})\ (\pm 2.5\mu K)$

(no primordial B-modes)

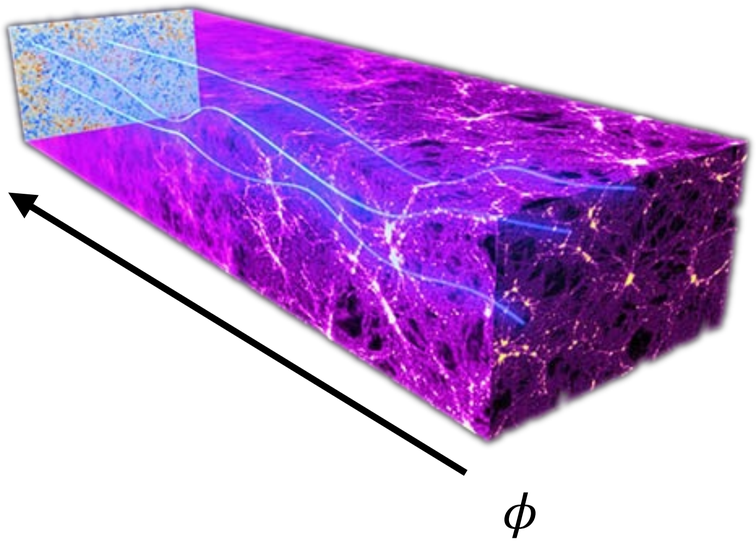
unlensed



(no primordial B-modes)

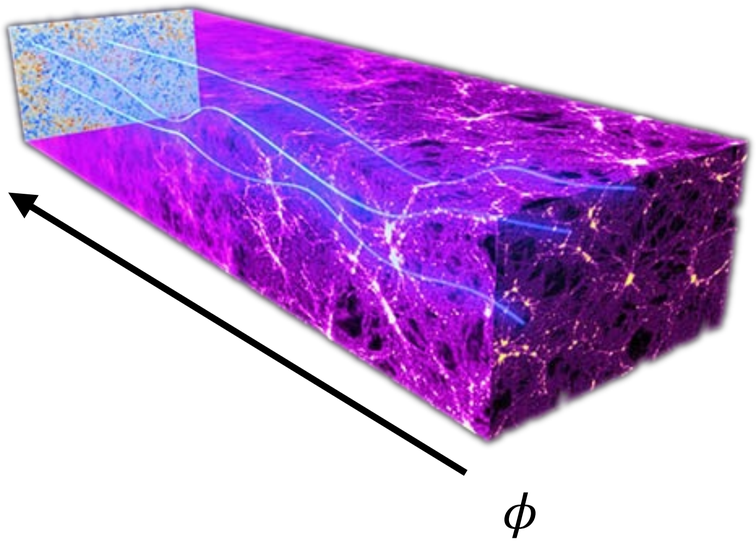
lensed

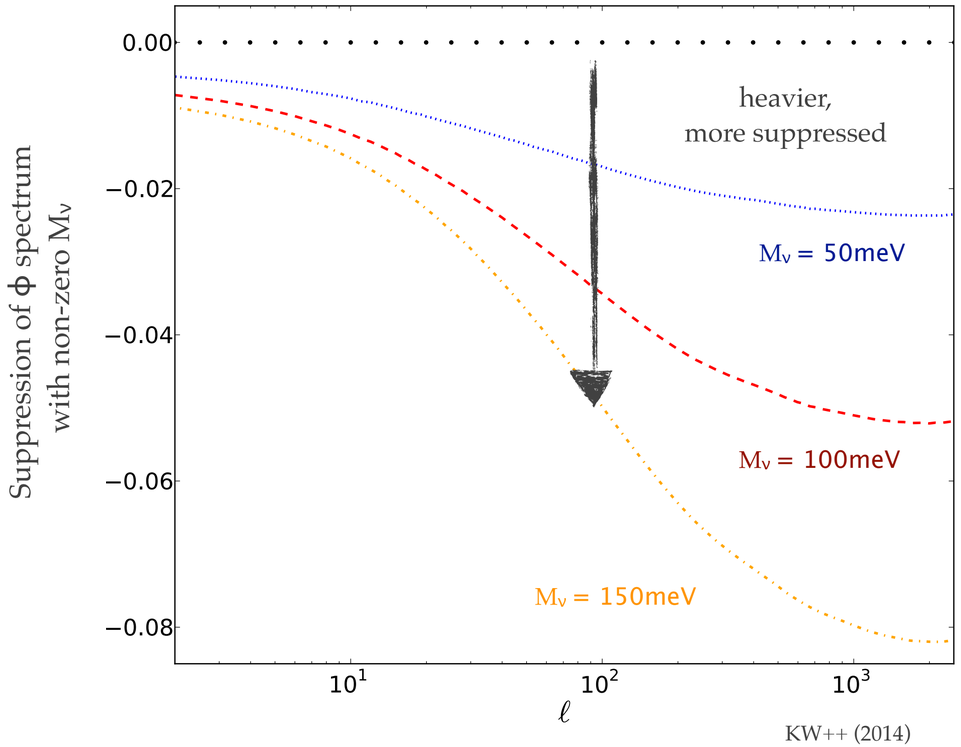
We can use ϕ to constrain late-time physics



ϕ: sensitive to matter density and structure growth; can be used to constrain e.g. sum of neutrino masses, dark matter models, etc.

We can use ϕ to constrain late-time physics





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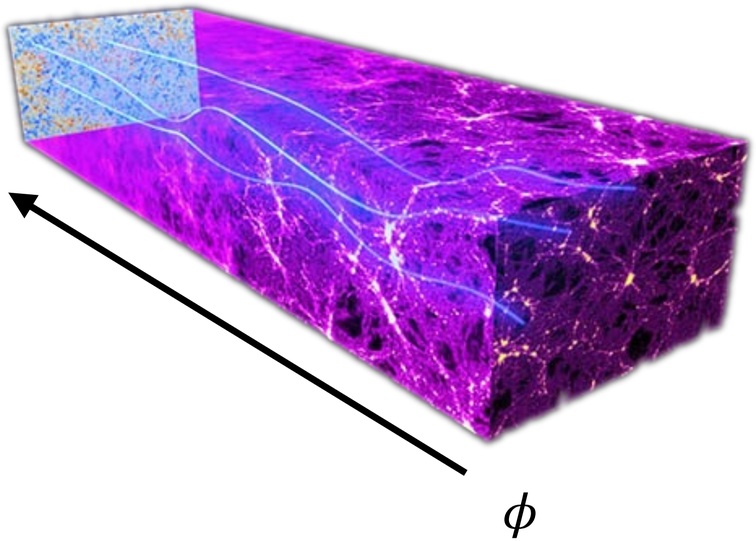

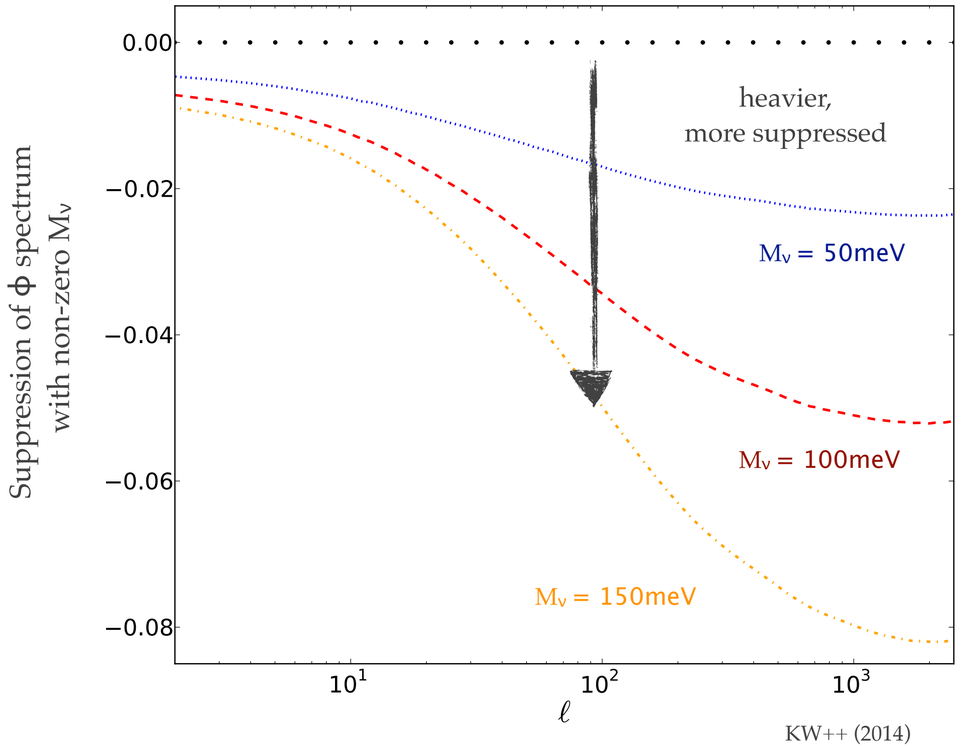

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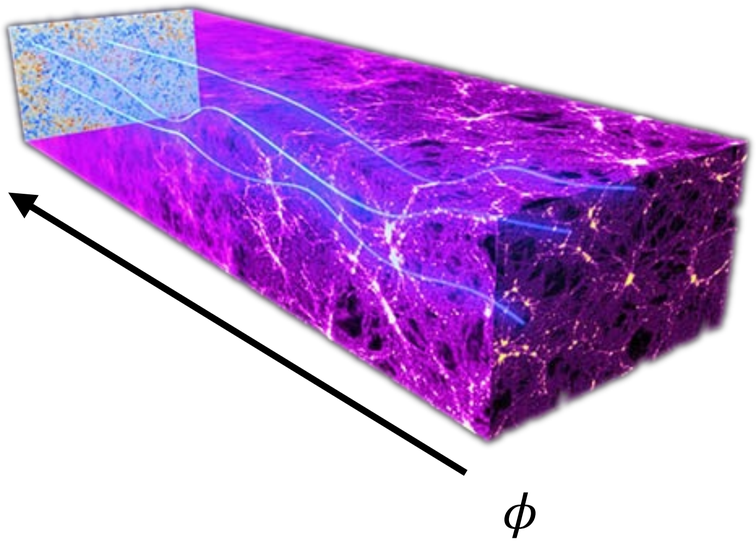

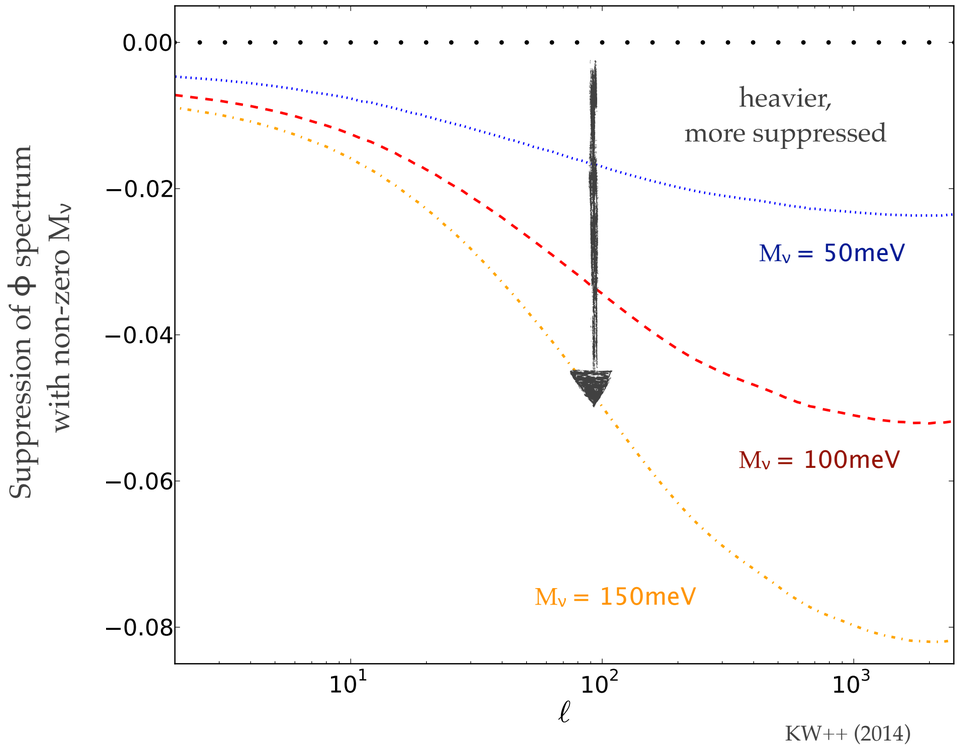

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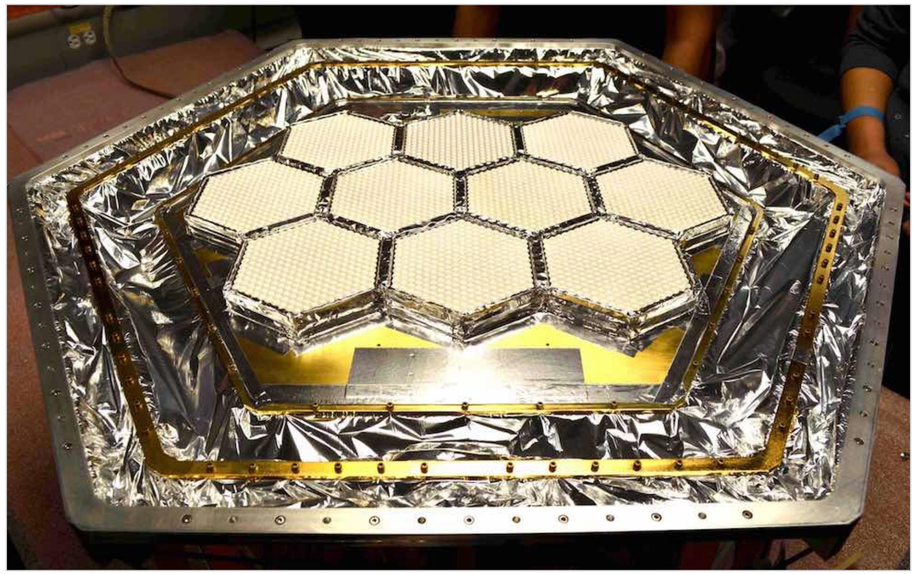
Also important for testing consistency of the LCDM model across redshifts and scales to inform the on-going H_0 and S8 tensions.

South Pole Telescope: SPT-3G



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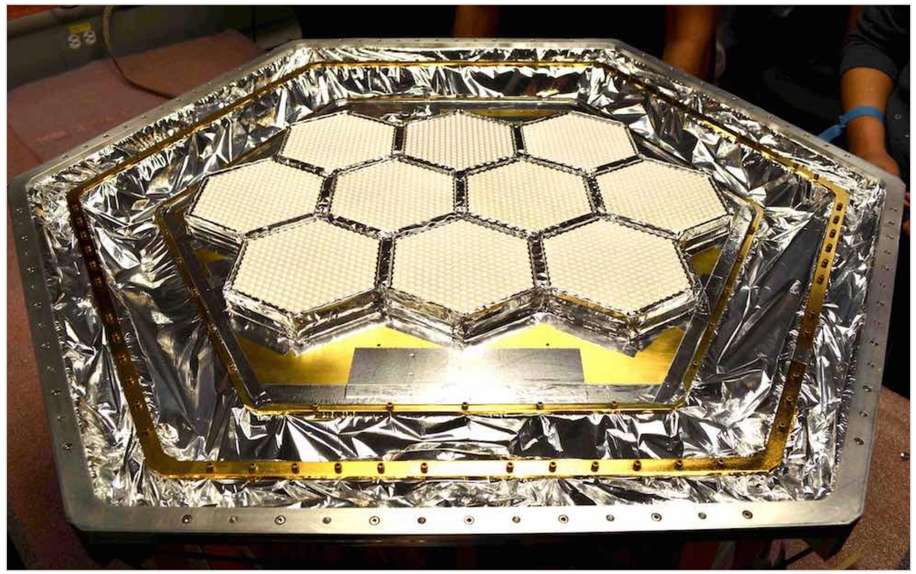
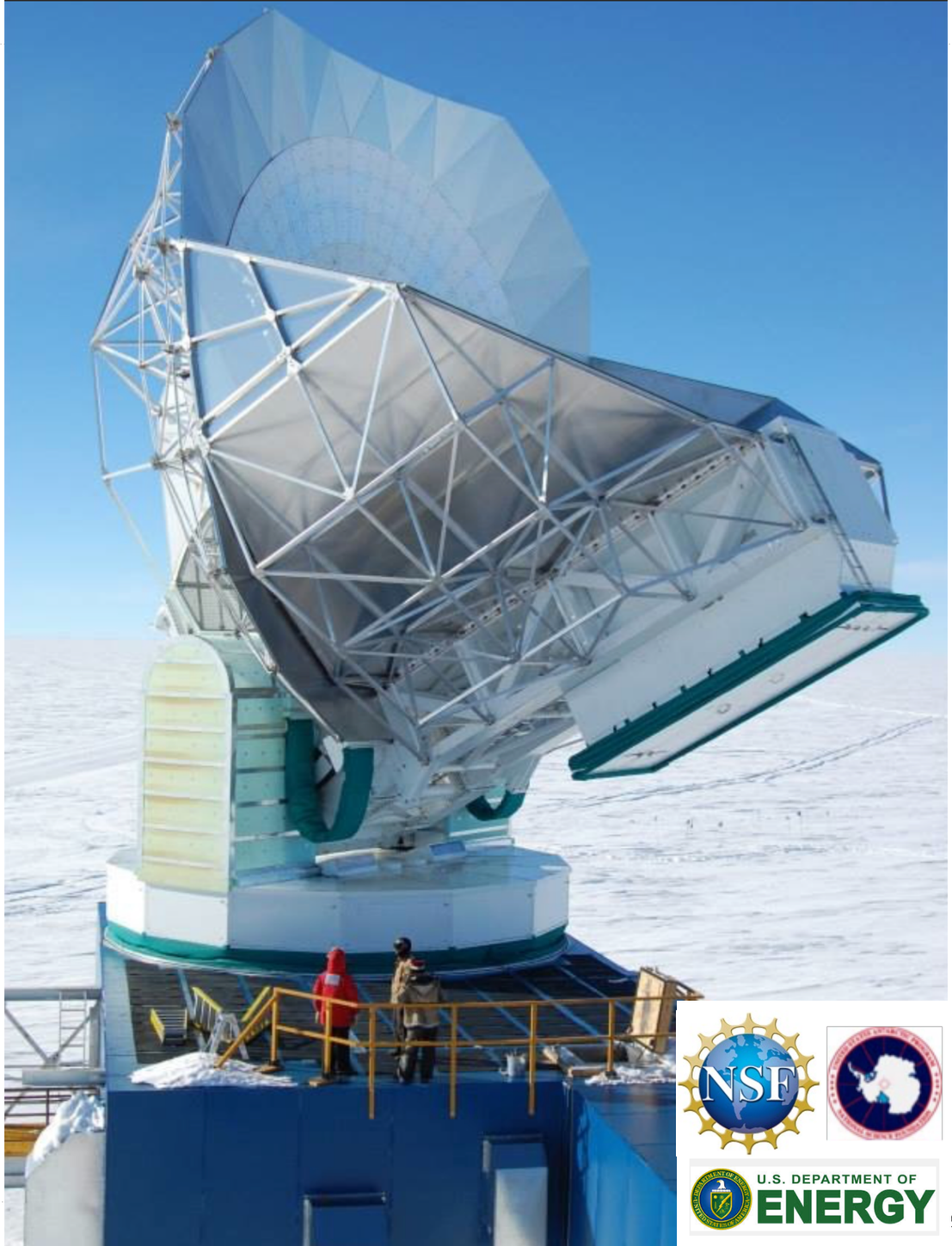


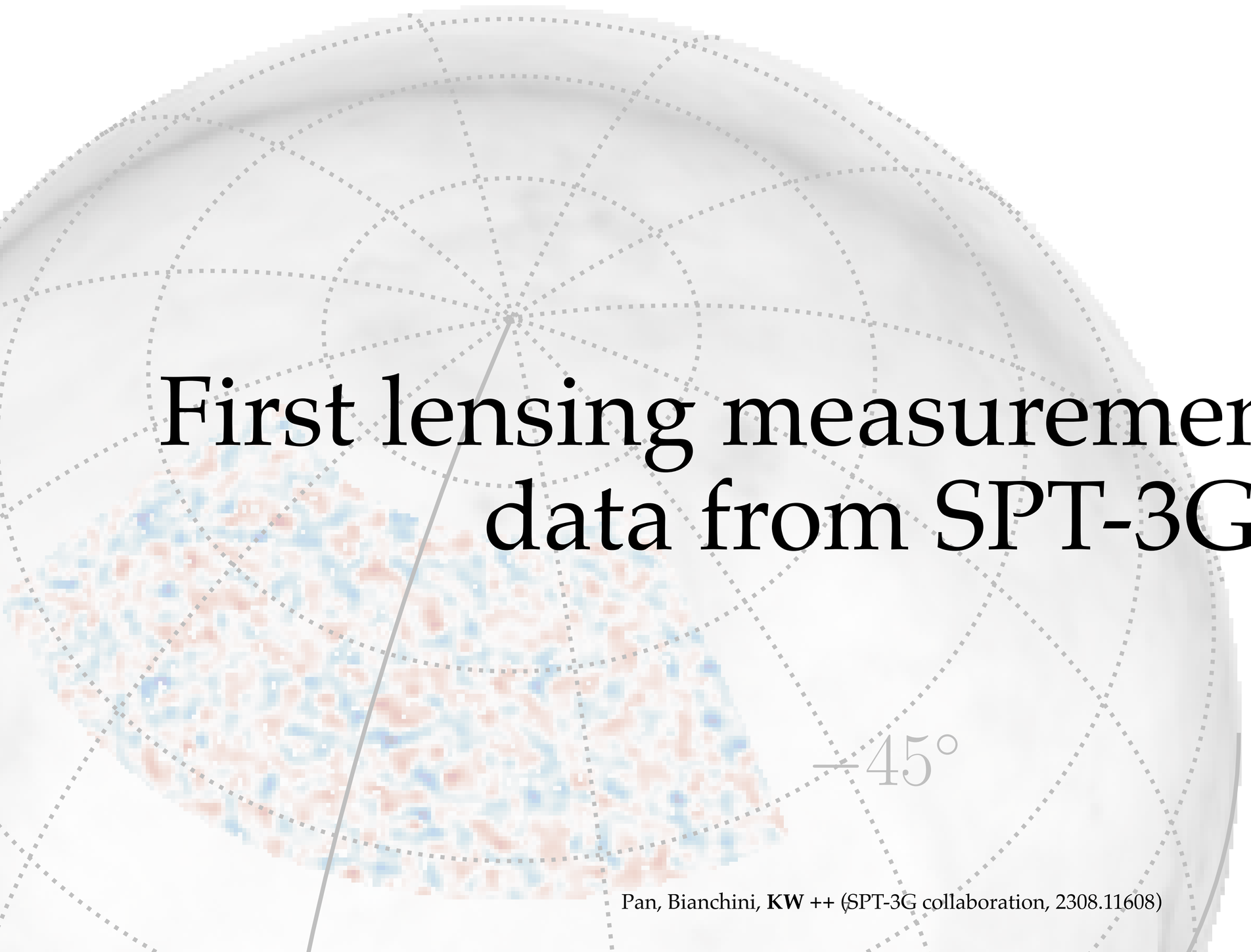
- Highest resolution CMB Telescope (1′).
- Produced the largest deep CMB polarization maps in sub-degree scales.
- High resolution —> better for ϕ reconstruction.



Zhaodi Pan

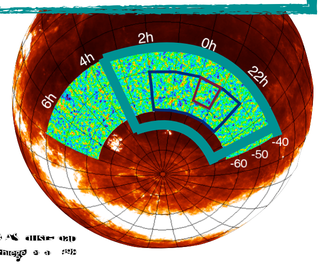
Federico Bianchini

First lensing measurement using data from SPT-3G

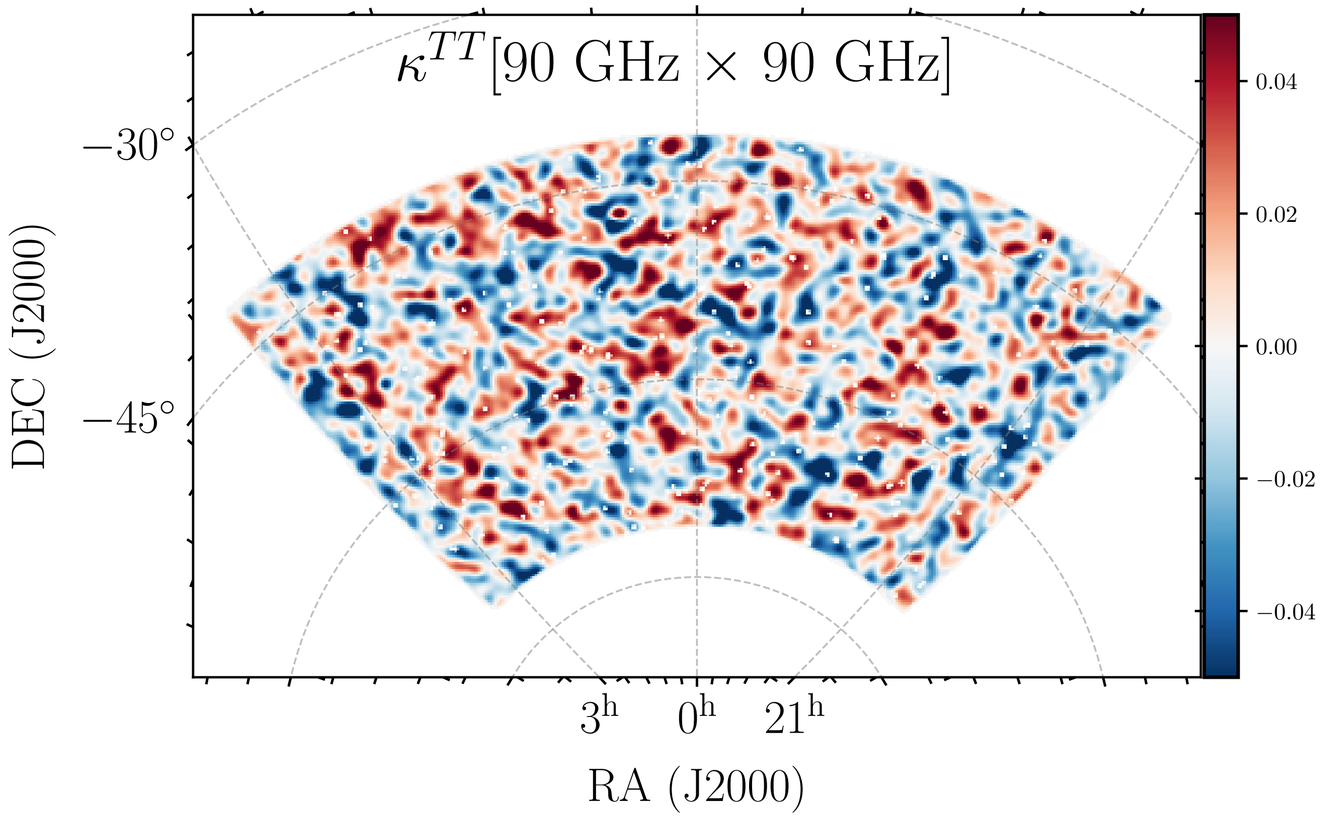


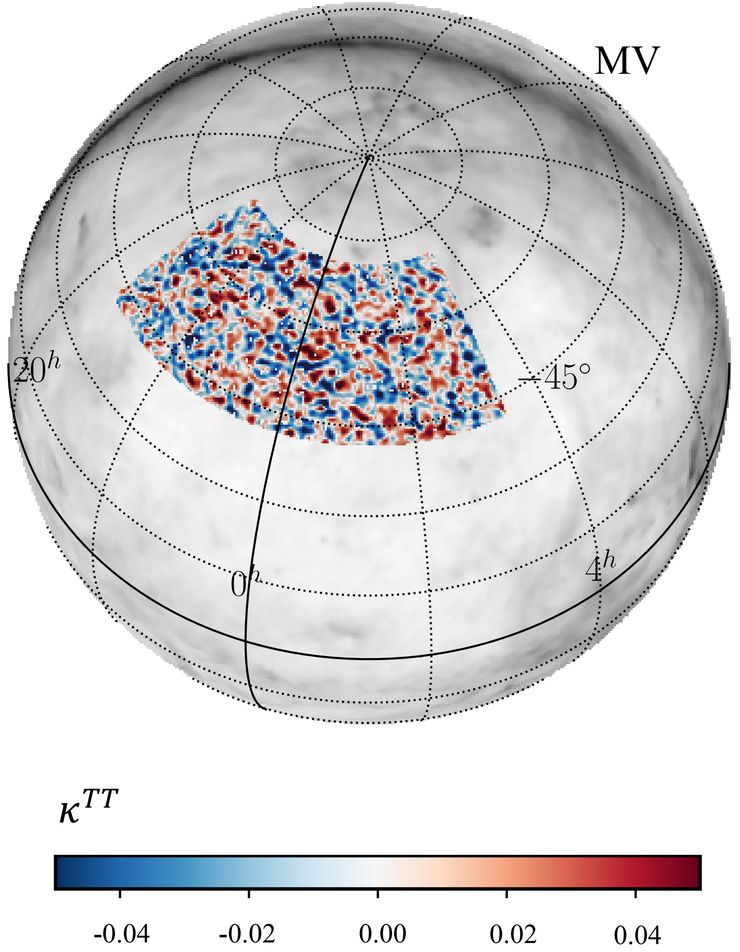
Pan, Bianchini, **KW** ++ (SPT-3G collaboration, 2308.11608)

SPT-3G footprint
1500 deg^2

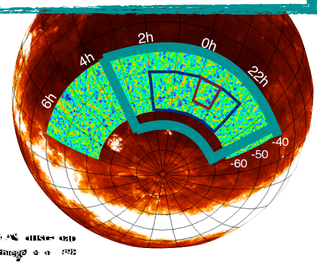


SPT-3G lensing convergence map





SPT-3G footprint
1500 deg²



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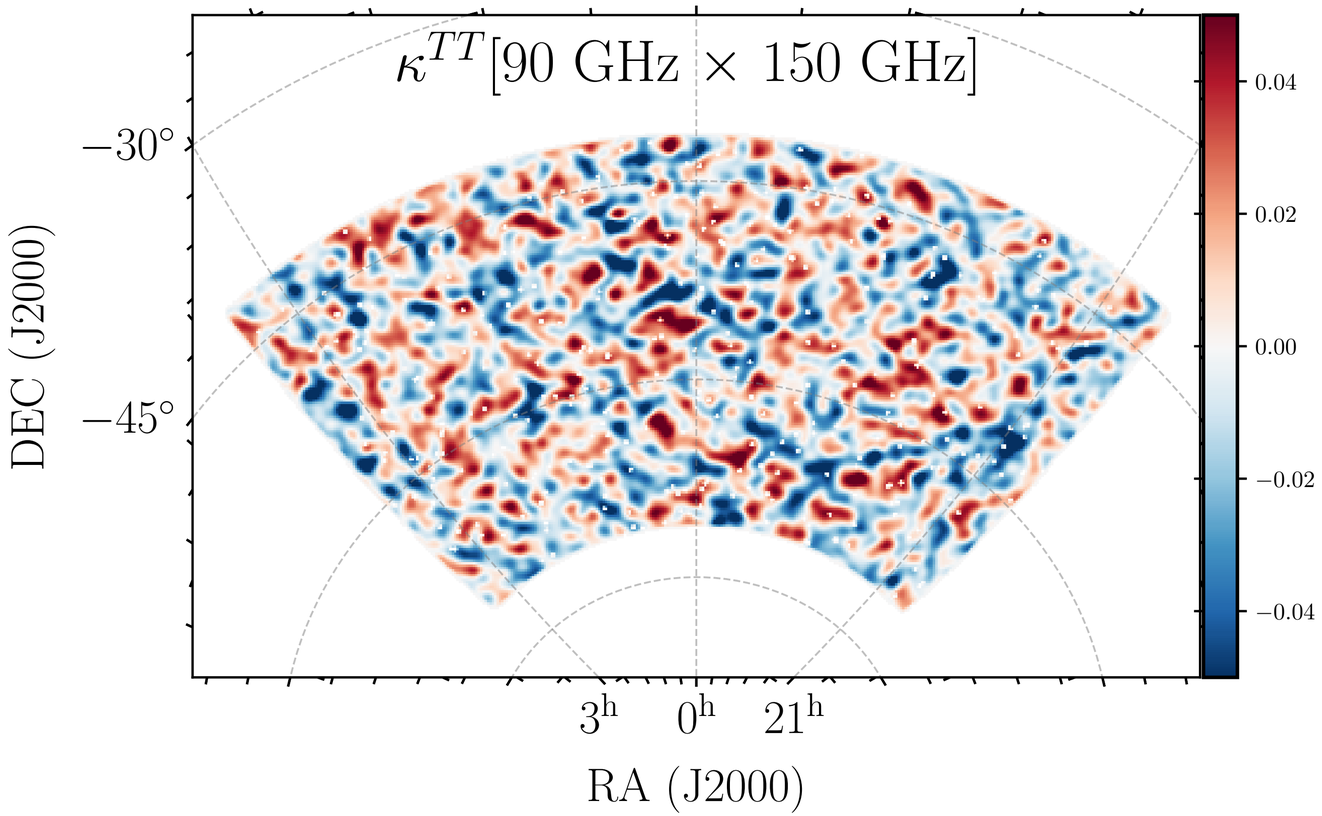

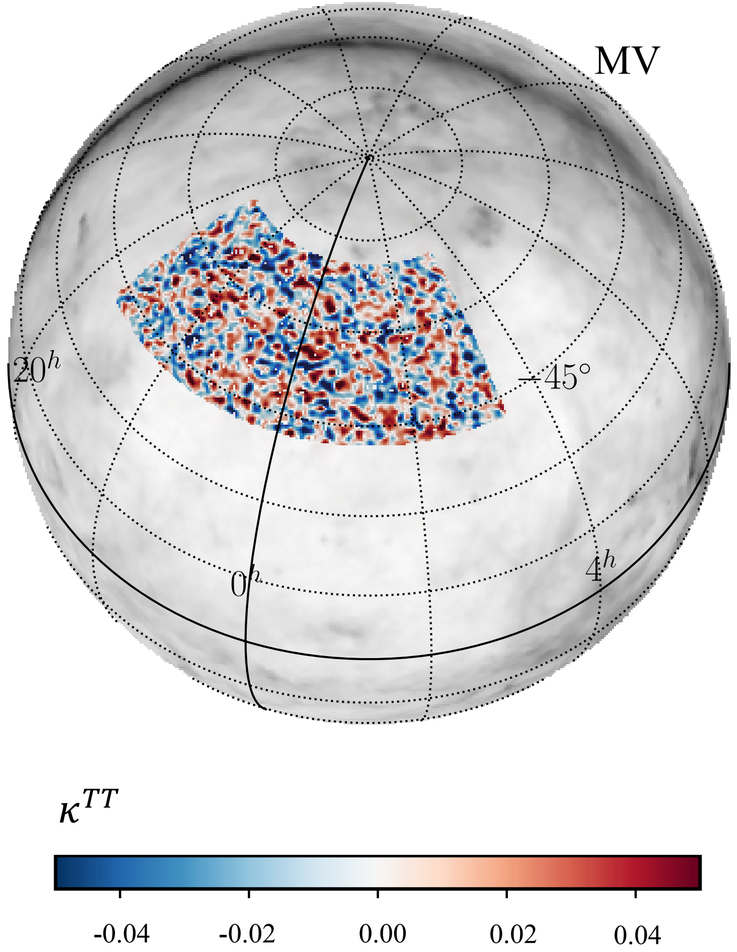

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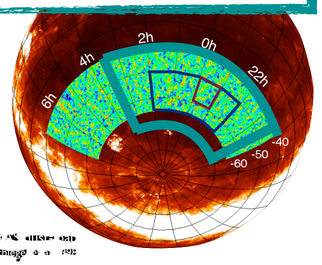
1500 deg²



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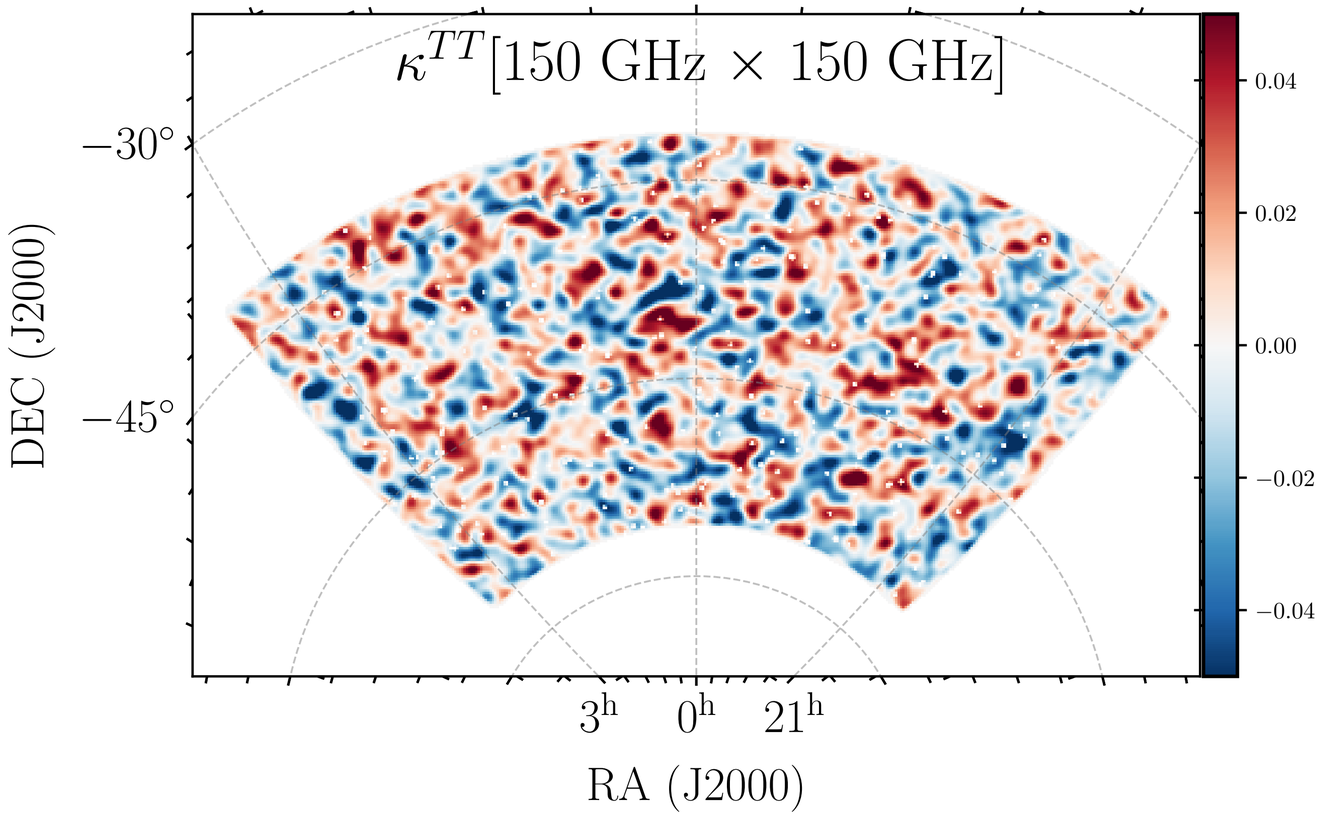
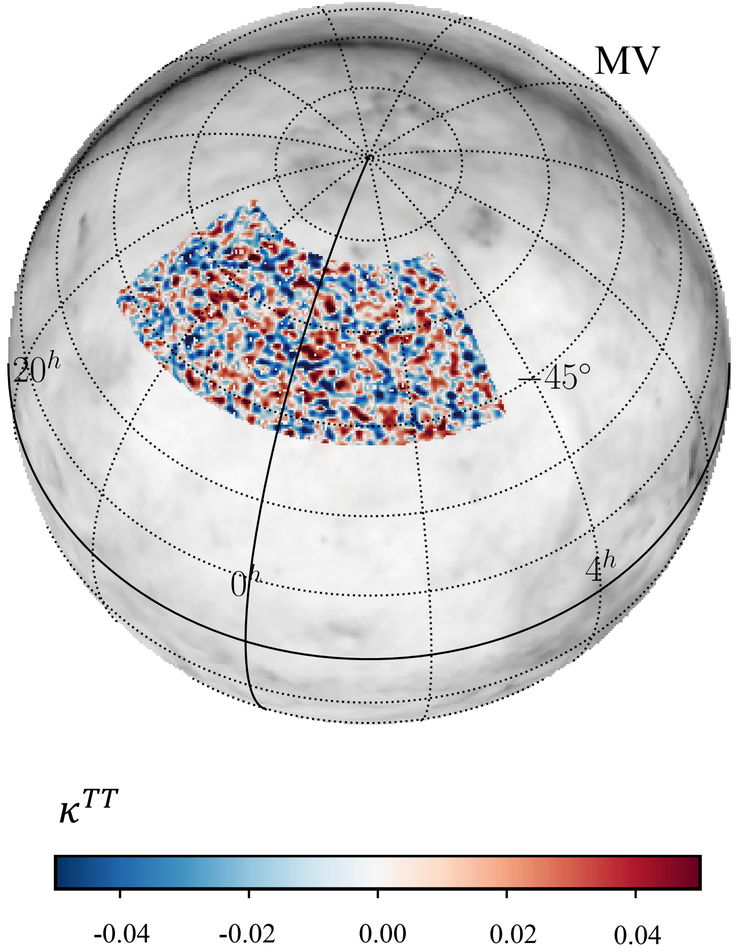
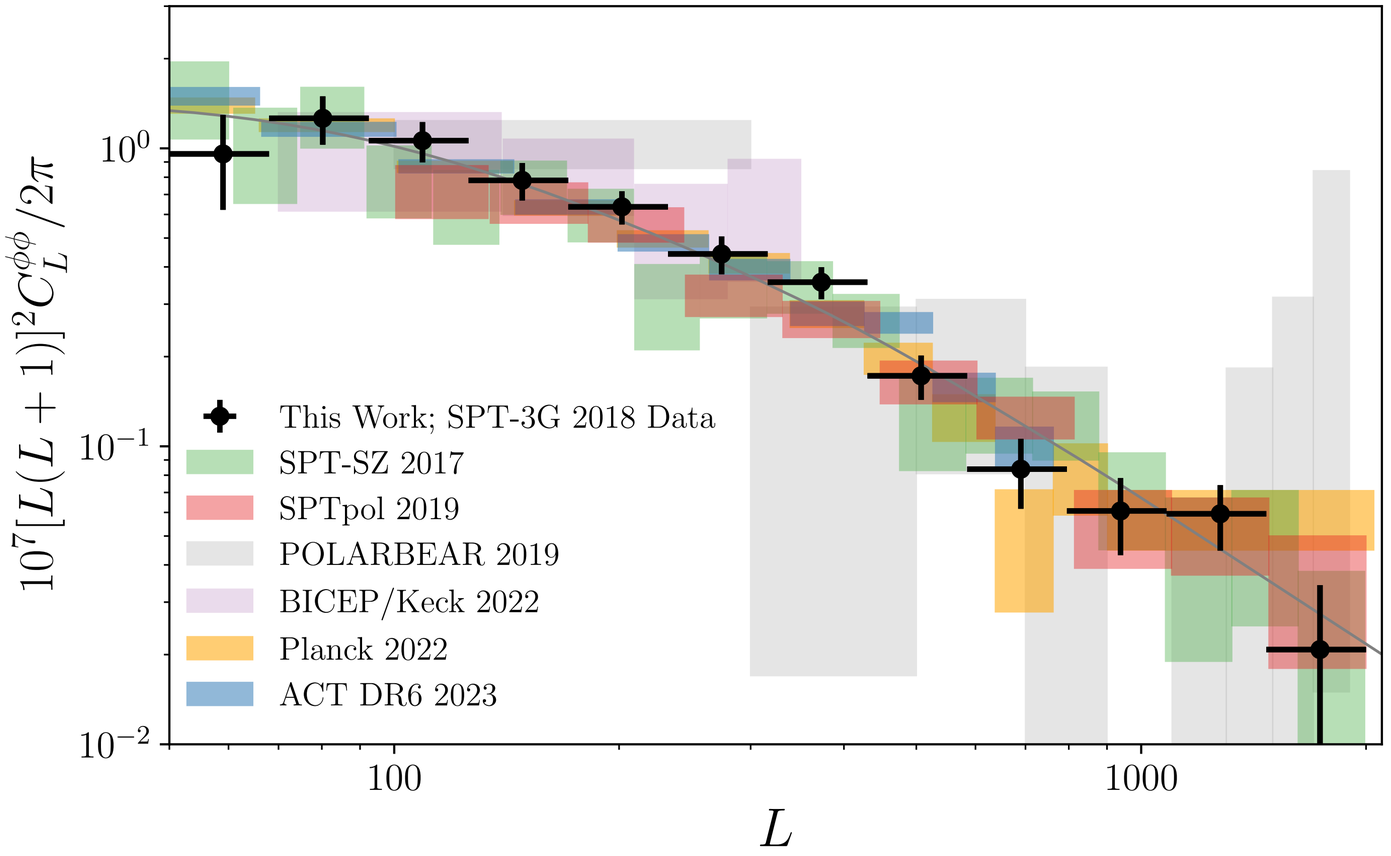




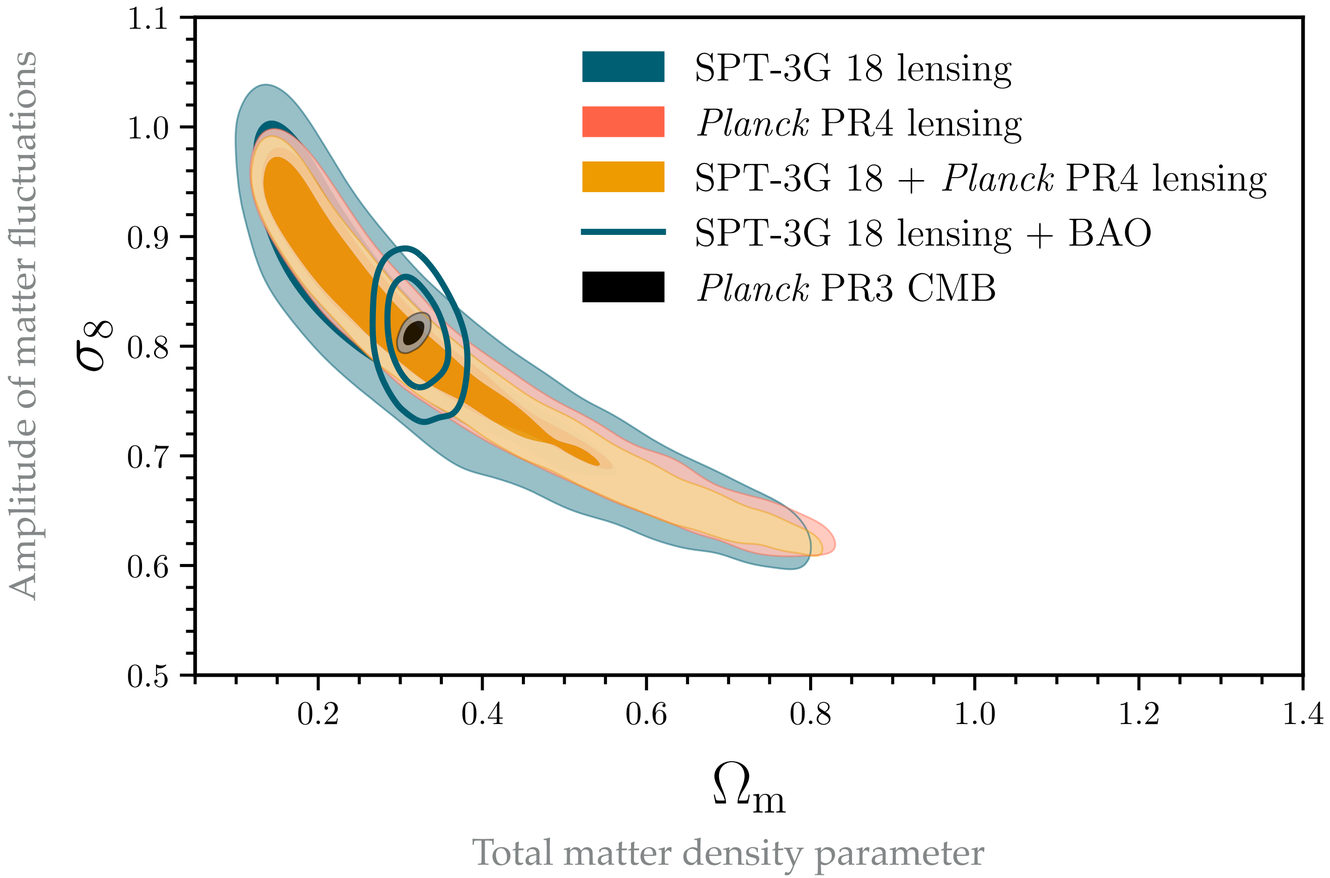
Lensing amplitude from SPT-3G 2018 data

$$A_{\phi\phi}^{MV} = 1.020 \pm 0.060$$

6% measurement;
consistent with LCDM
expectation



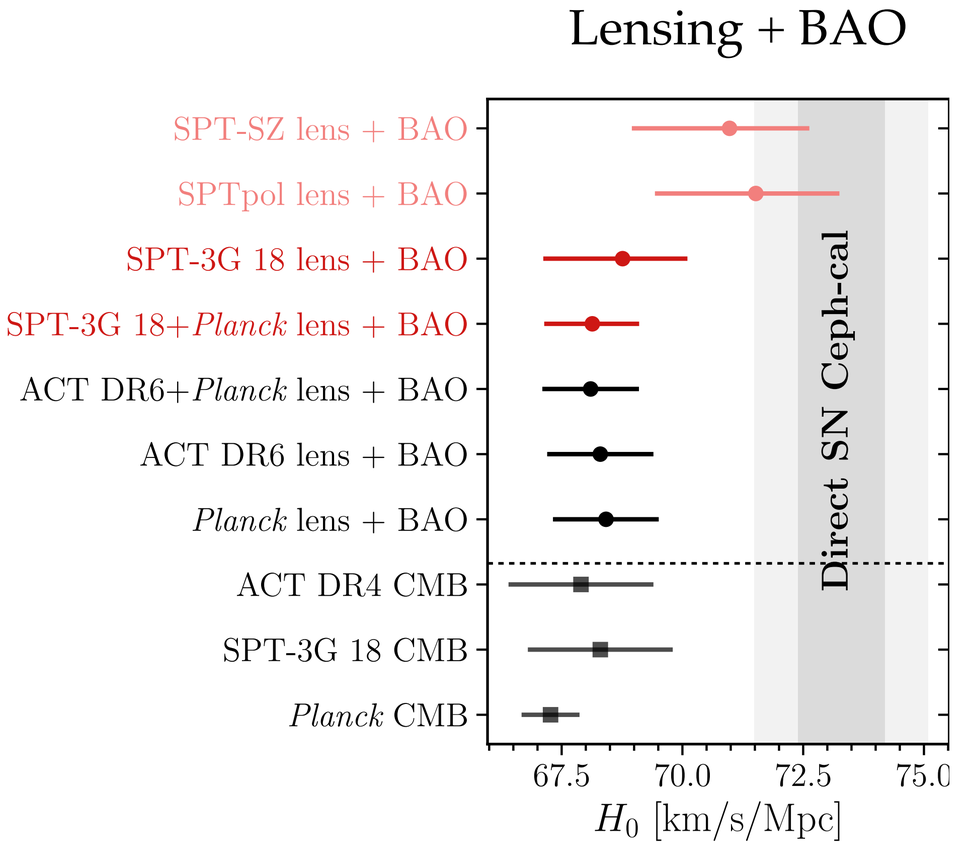
LCDM constraints from SPT-3G 2018 lensing



The shape and amplitude of the CMB lensing spectrum best constrain $\sigma_8\Omega_m^{0.25}$

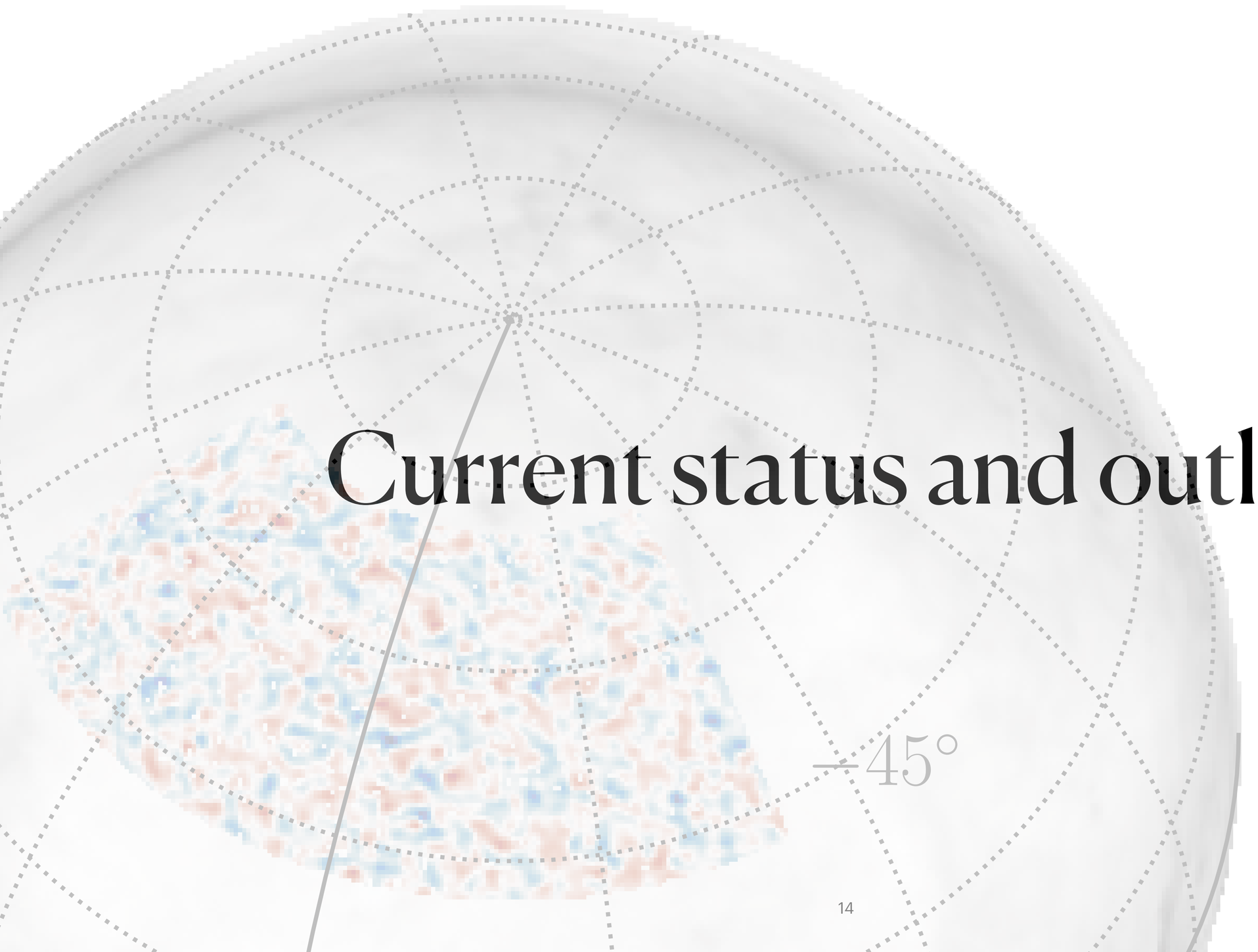
	$\sigma_8\Omega_\mathrm{m}^{0.25}$
SPT-3G 18	0.595 ± 0.026
Planck	0.599 ± 0.016
SPT-3G 18 + *Planck*	0.596 ± 0.014

SPT-3G ϕ addressing H_0 tension



Bulk of information comes from modes not measured previously.

$\sigma(H_0) \sim 1.5$ km/s/Mpc when combined with BAO (2% measurement!)



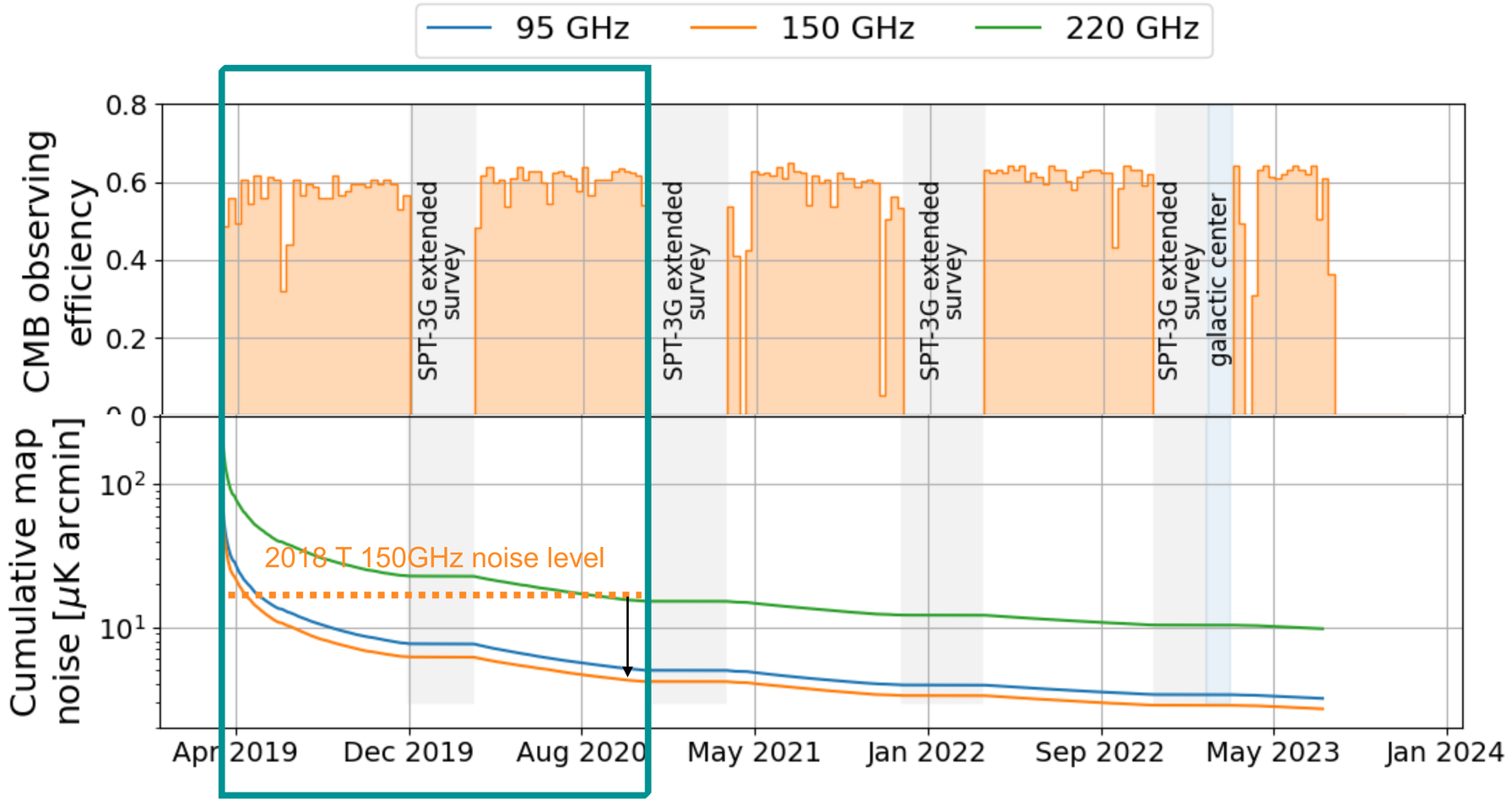
Yuka Nakato

Yuuki Omori

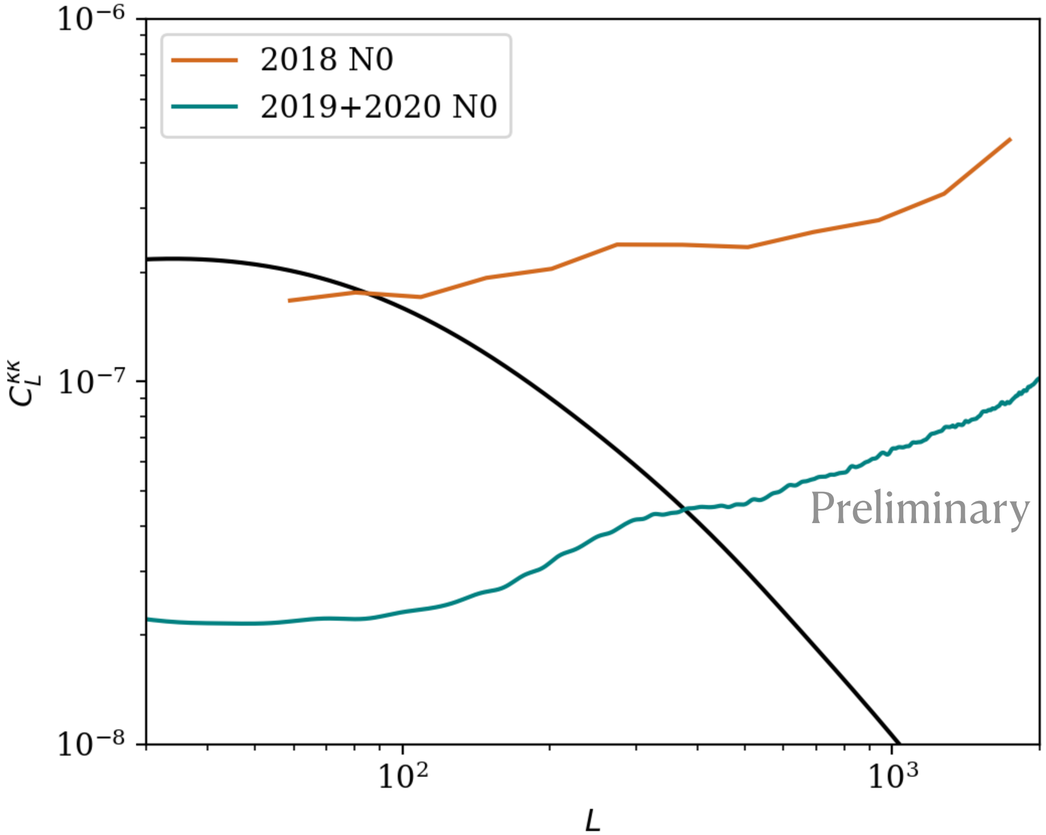
Federico Bianchini

Current status and outlook

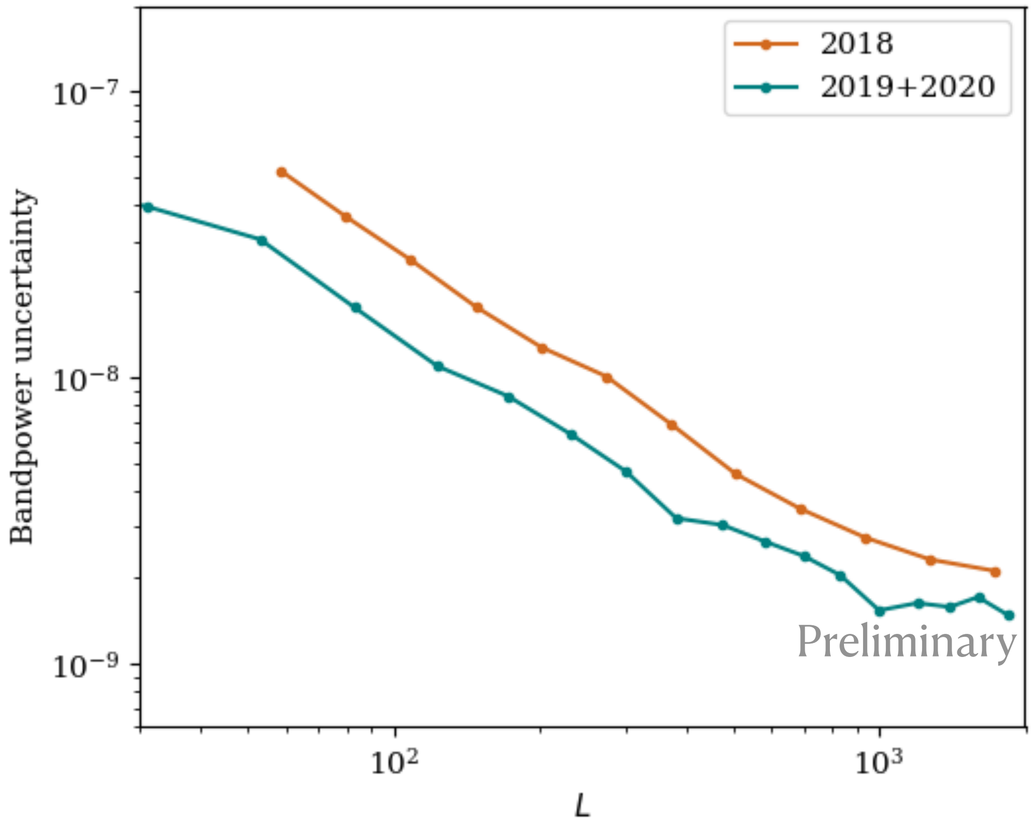
Great receiver performance since 2018



Expected noise and parameter constraints

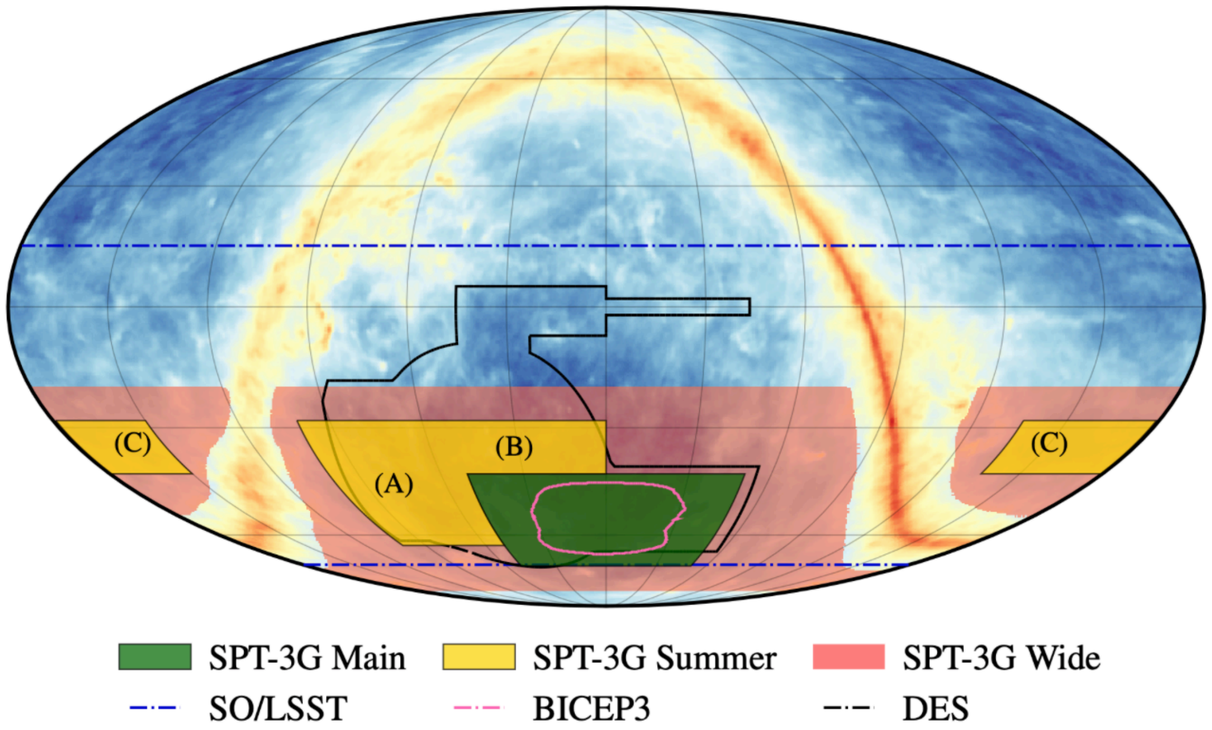


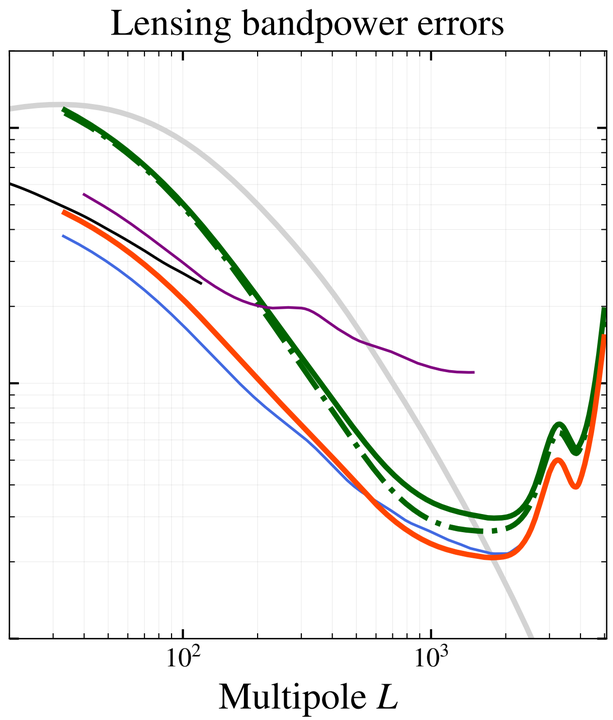
Almost 10x improvement
in the per-mode reconstruction noise from
2018 data to 2019+2020 data set
(Great for delensing for *r* !)



Reduction in uncertainty —>
Improvement in parameter constraints

Observing SPT-3G Wide in 2024: total area ~10000 sq deg





SPT-3G Main

SPT-3G 10k sq. Deg.

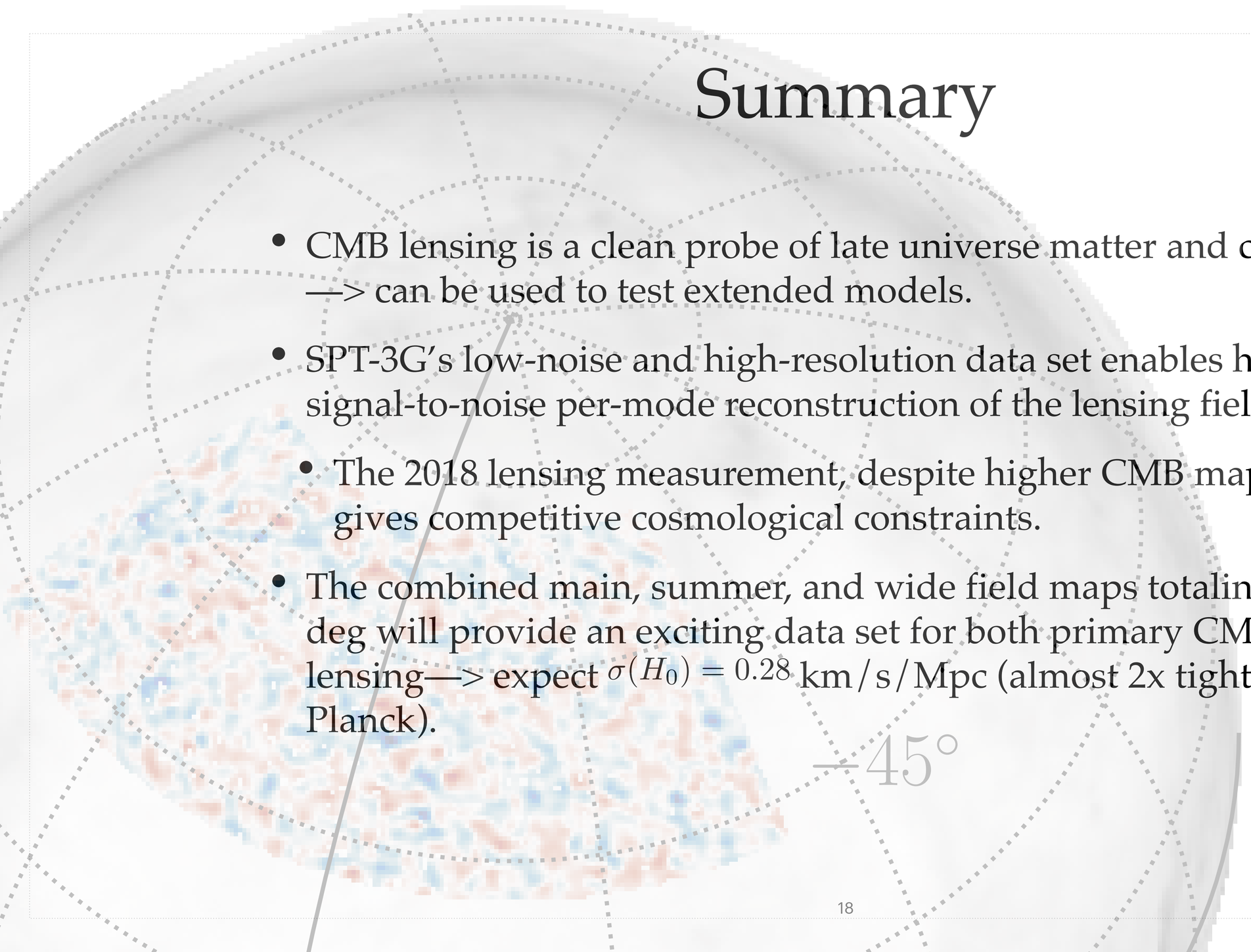
Thinner line are from
Planck PR4,
ACT DR6,
SO forecast

Planck	$\sigma(H_0) = 0.54$ km/s/Mpc
SPT-3G 10k (no lensing)	$\sigma(H_0) = 0.60$ km/s/Mpc
SPT-3G 10k (with lensing)	$\sigma(H_0) = 0.28$ km/s/Mpc

Prabhu++ (SPT-3G collaboration, 2403.17925)

Summary

- CMB lensing is a clean probe of late universe matter and clustering —> can be used to test extended models.
- SPT-3G's low-noise and high-resolution data set enables high signal-to-noise per-mode reconstruction of the lensing field.
  - The 2018 lensing measurement, despite higher CMB map noise, gives competitive cosmological constraints.
- The combined main, summer, and wide field maps totaling 10k sq. deg will provide an exciting data set for both primary CMB and lensing—> expect $\sigma(H_0) = 0.28$ km/s/Mpc (almost 2x tighter than Planck).



Extras

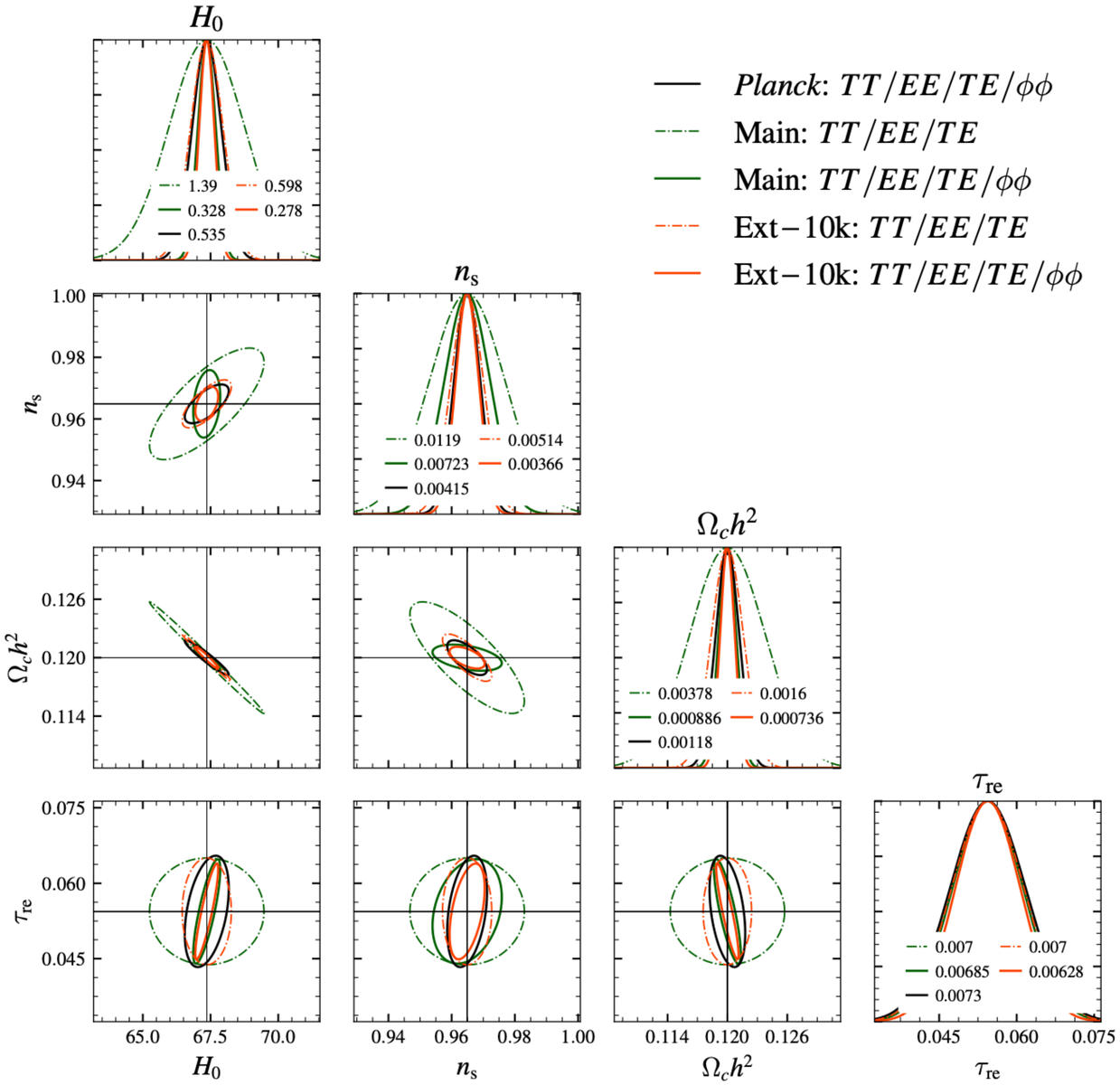


Figure 13. Marginalized 1-dimensional and 2-dimensional 68% contours for Hubble constant(H_0), scalar spectral index (n_s), Cold dark matter density ($\Omega_c h^2$), and optical depth ($\tau_{\rm re}$) with(solid) and without (dashed) lensing for SPT-3G Main (dark green), Ext-10k (dark red) and *Planck* (black). The inclusion of the lensing spectra significantly helps to break the degeneracies especially for the SPT-3G Main survey. The 1 σ errors are listed in the legend.

Prabhu++ (SPT-3G collaboration, 2403.17925)