Neutrino Mass, Inflation, and Dark Energy from CMB Lensing with ACTPol and AdvACT

Prof. Neelima Sehgal
Stony Brook University

CosmoCruise2015
Sept. 3rd, 2015

Outline

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- Intro to ACTPol and AdvACT

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ACTPol / AdvACT

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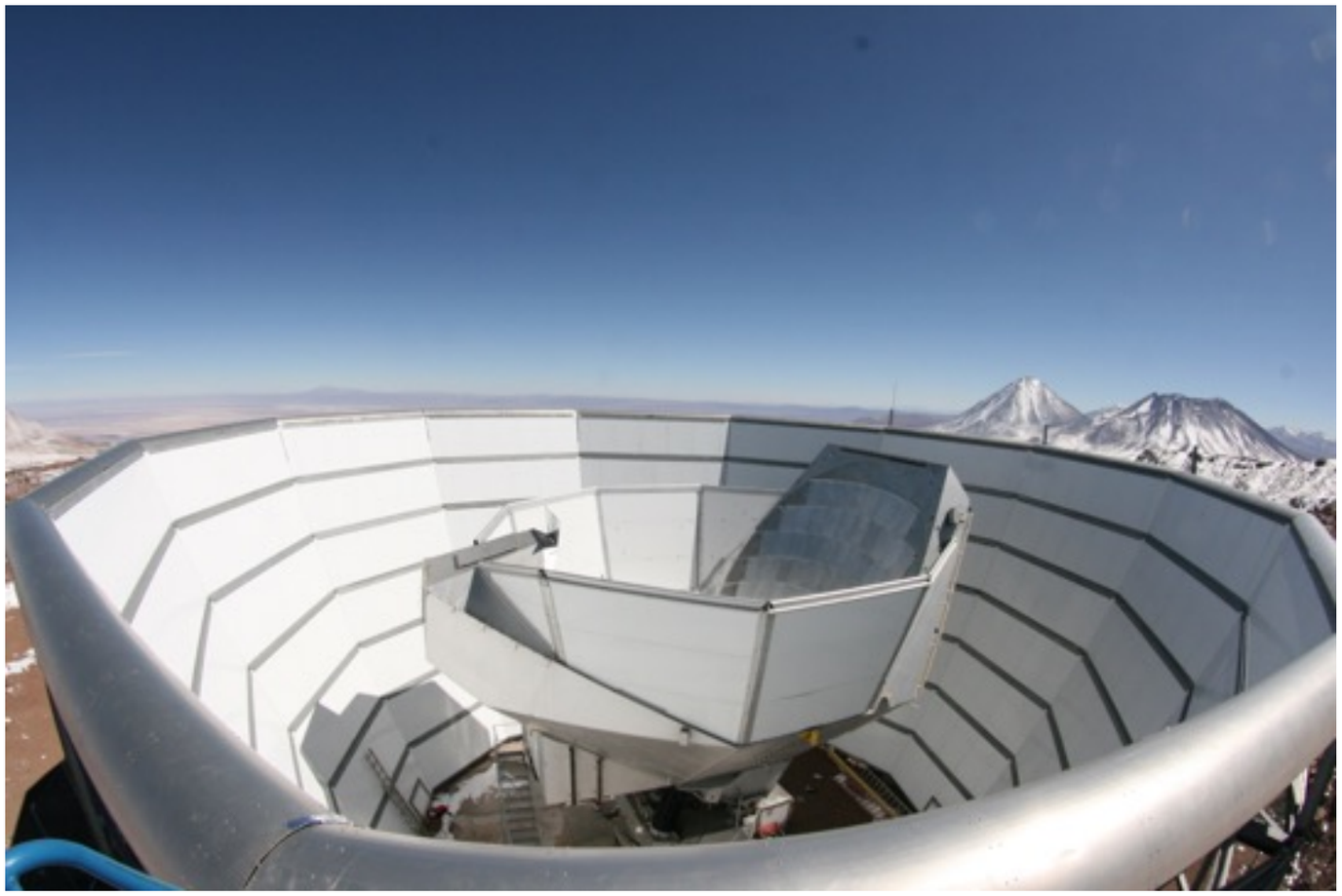

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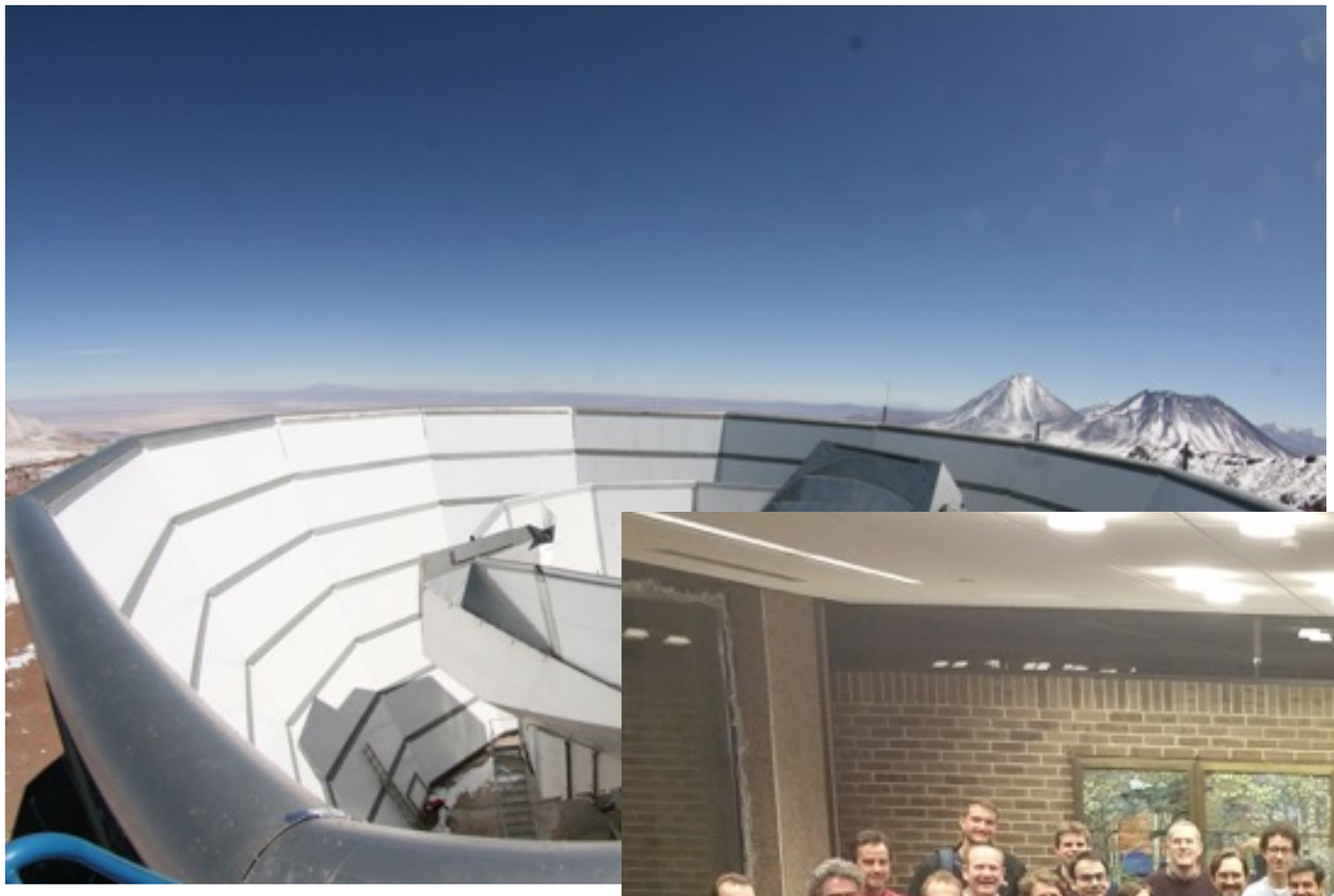

ACTpol / AdvACTpol

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ACTpol / AdvACTpol

ACTpol - Observes from 2013 - 2015

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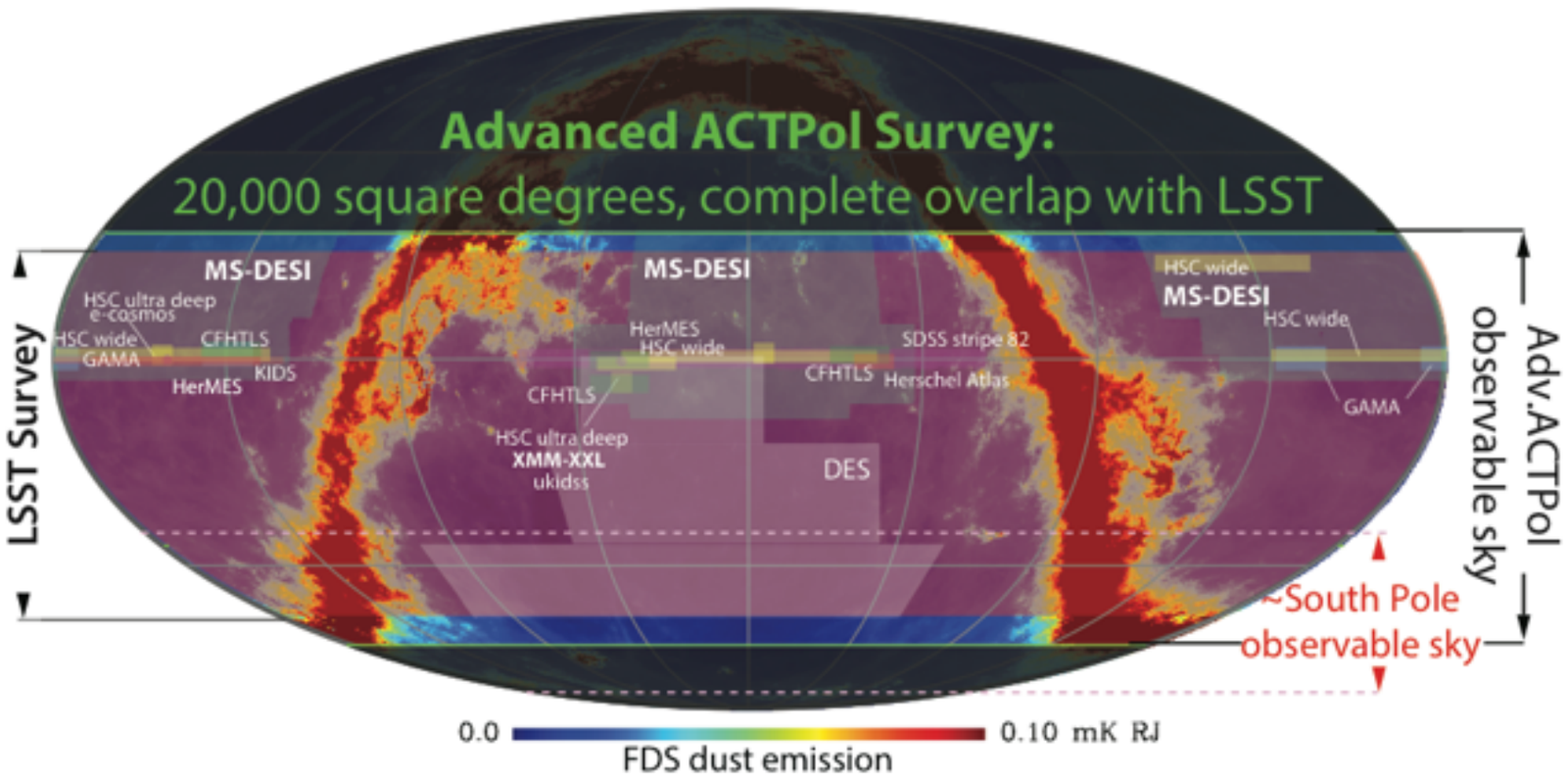

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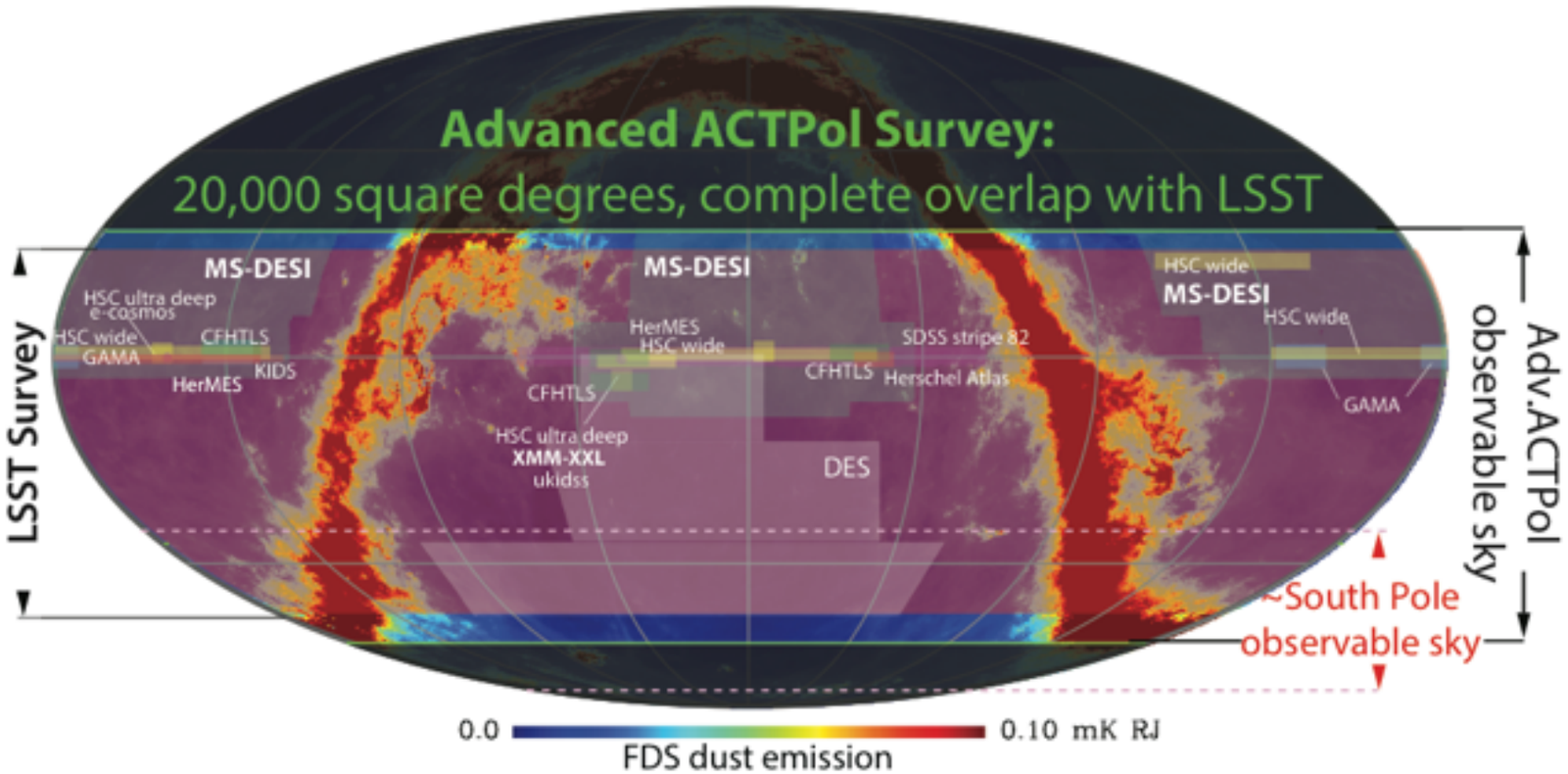

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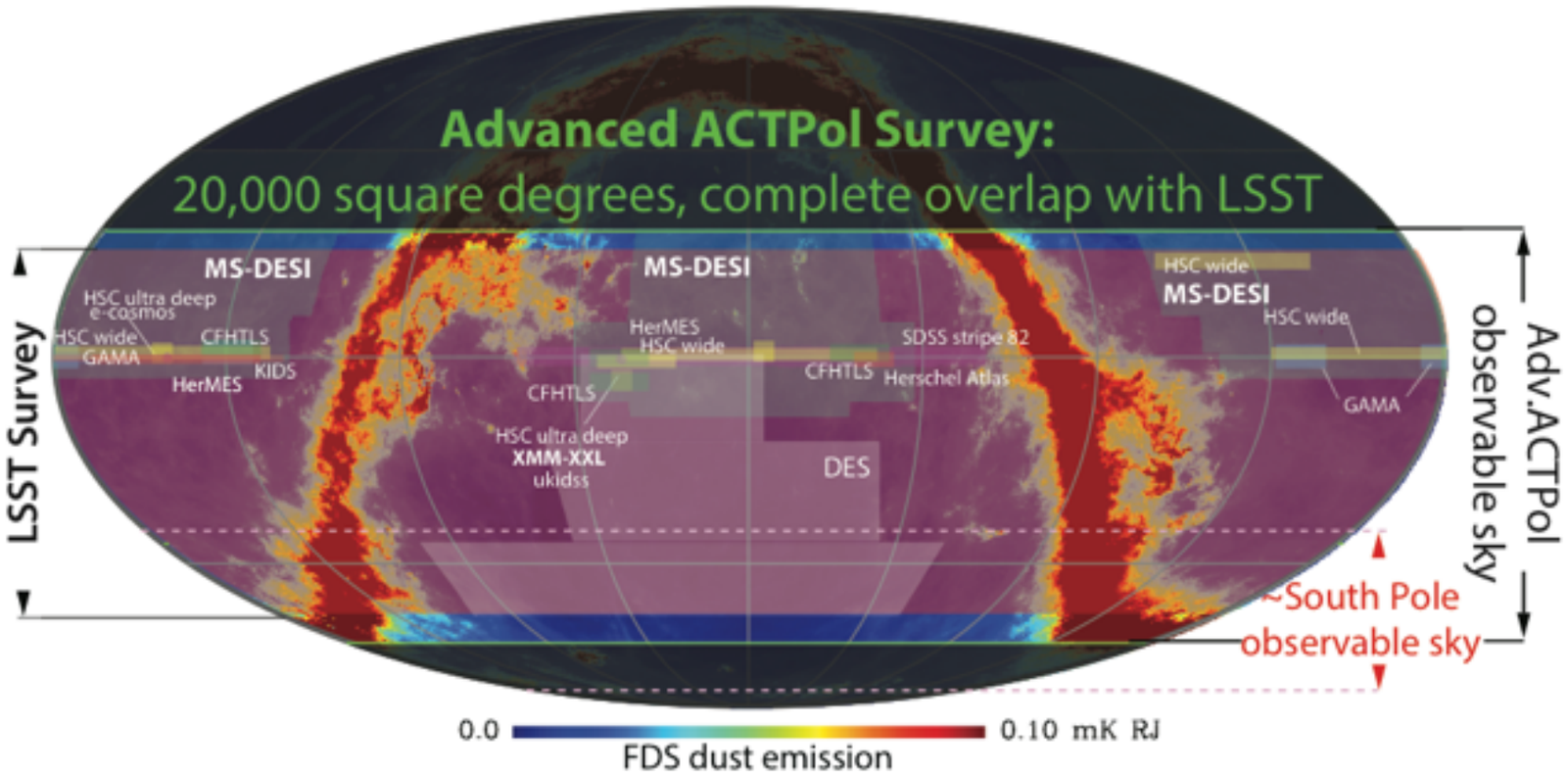

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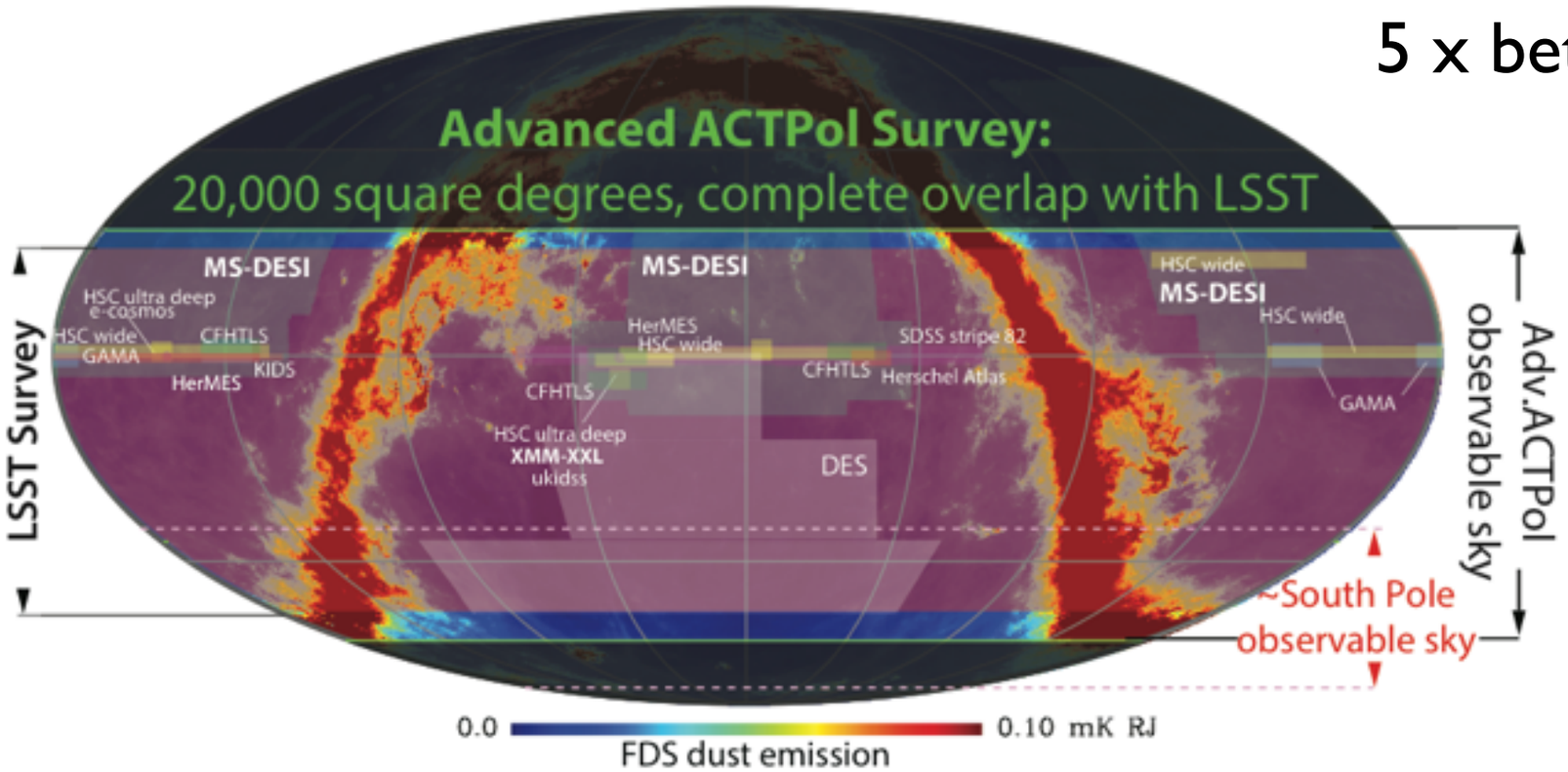

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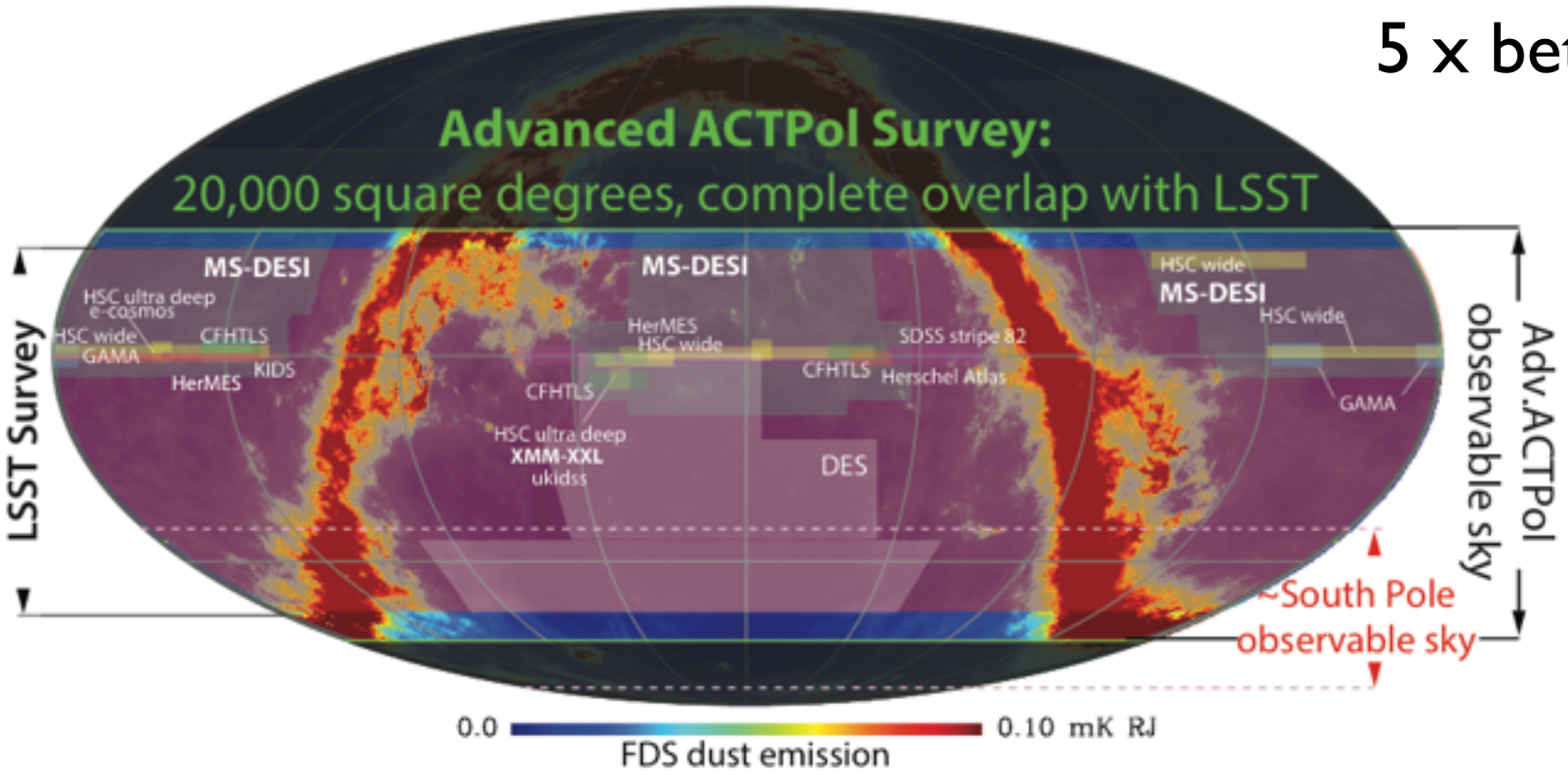

AdvACT funded by NSF MSIP in June 2015

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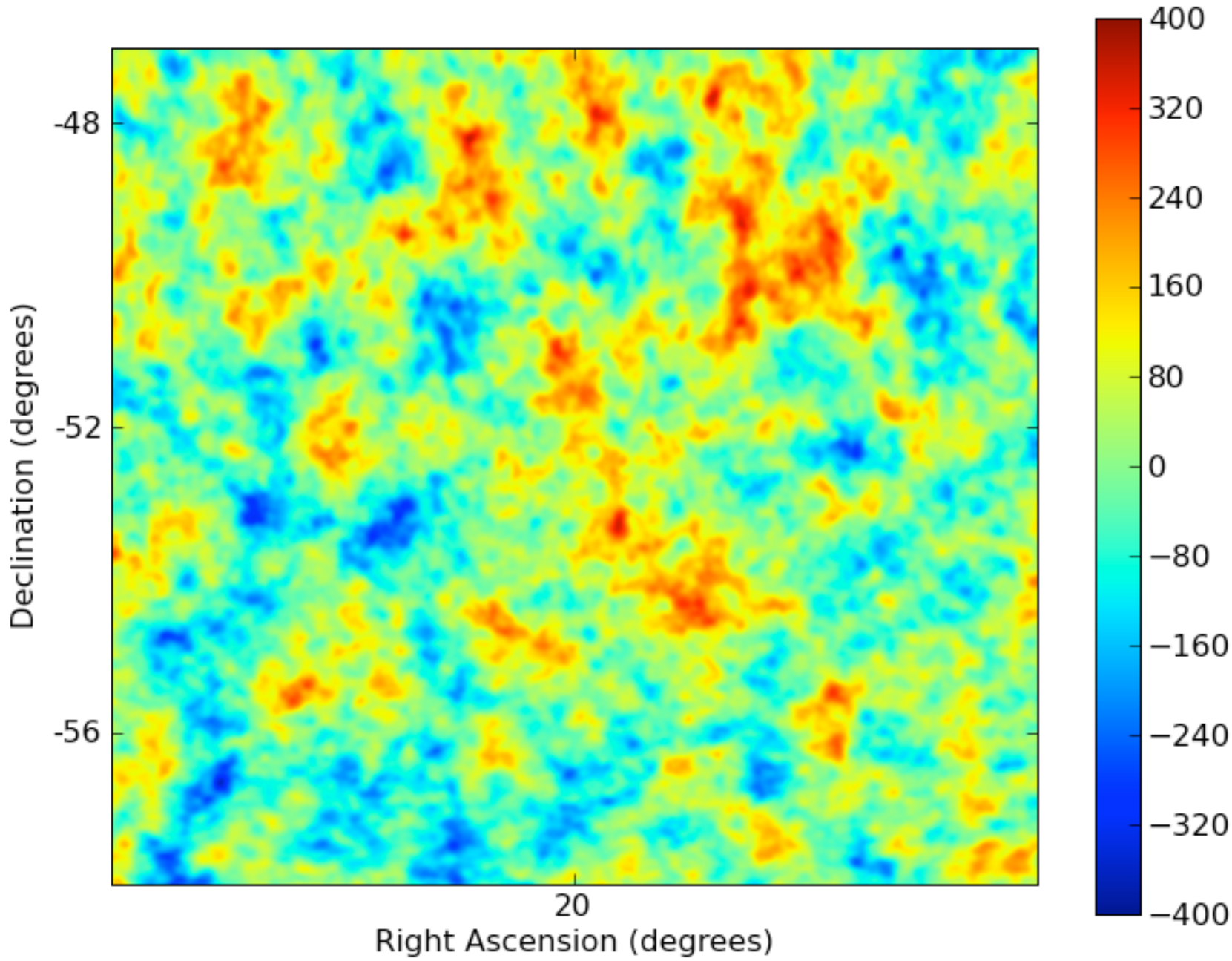
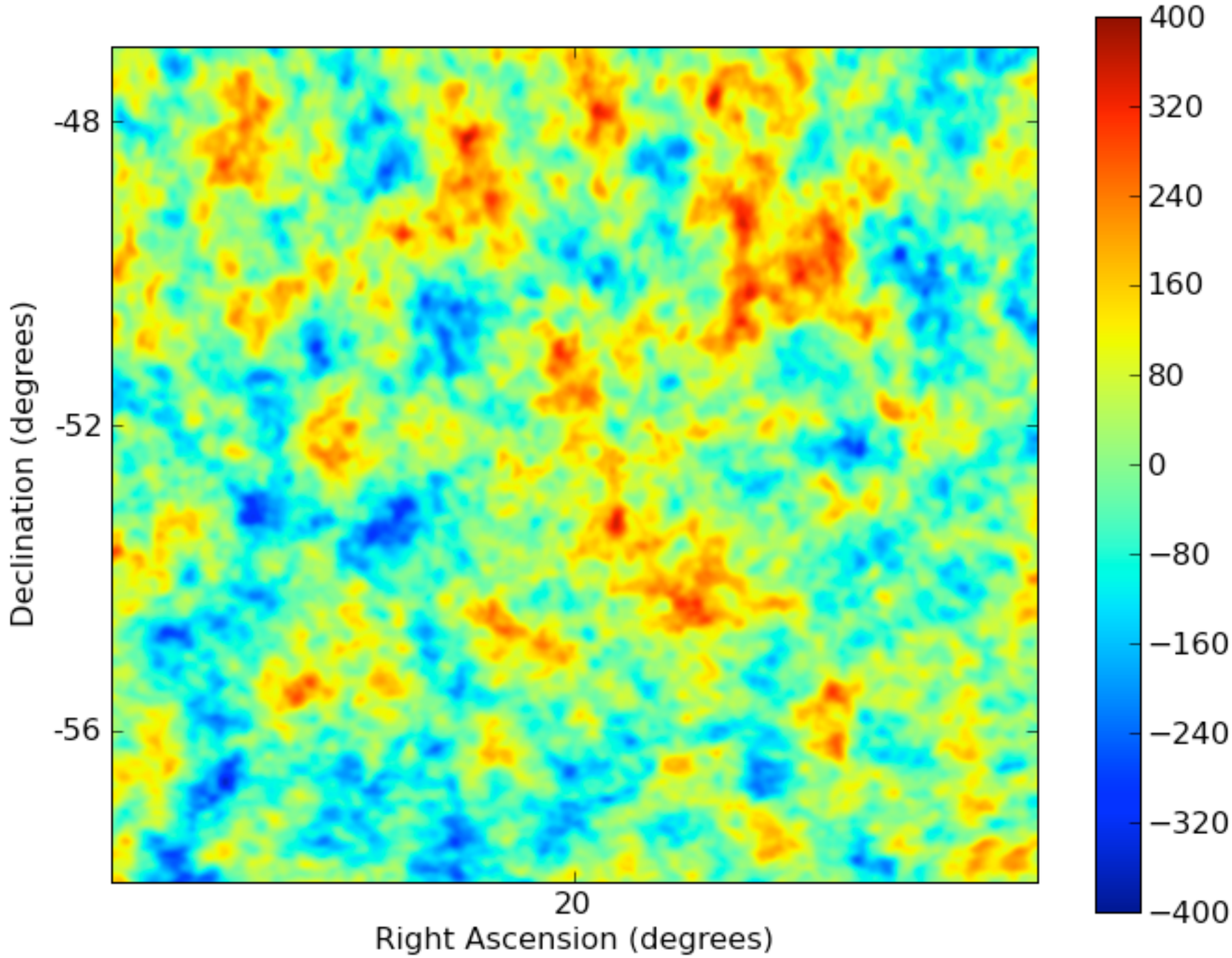
Unlensed CMB



Lensed CMB



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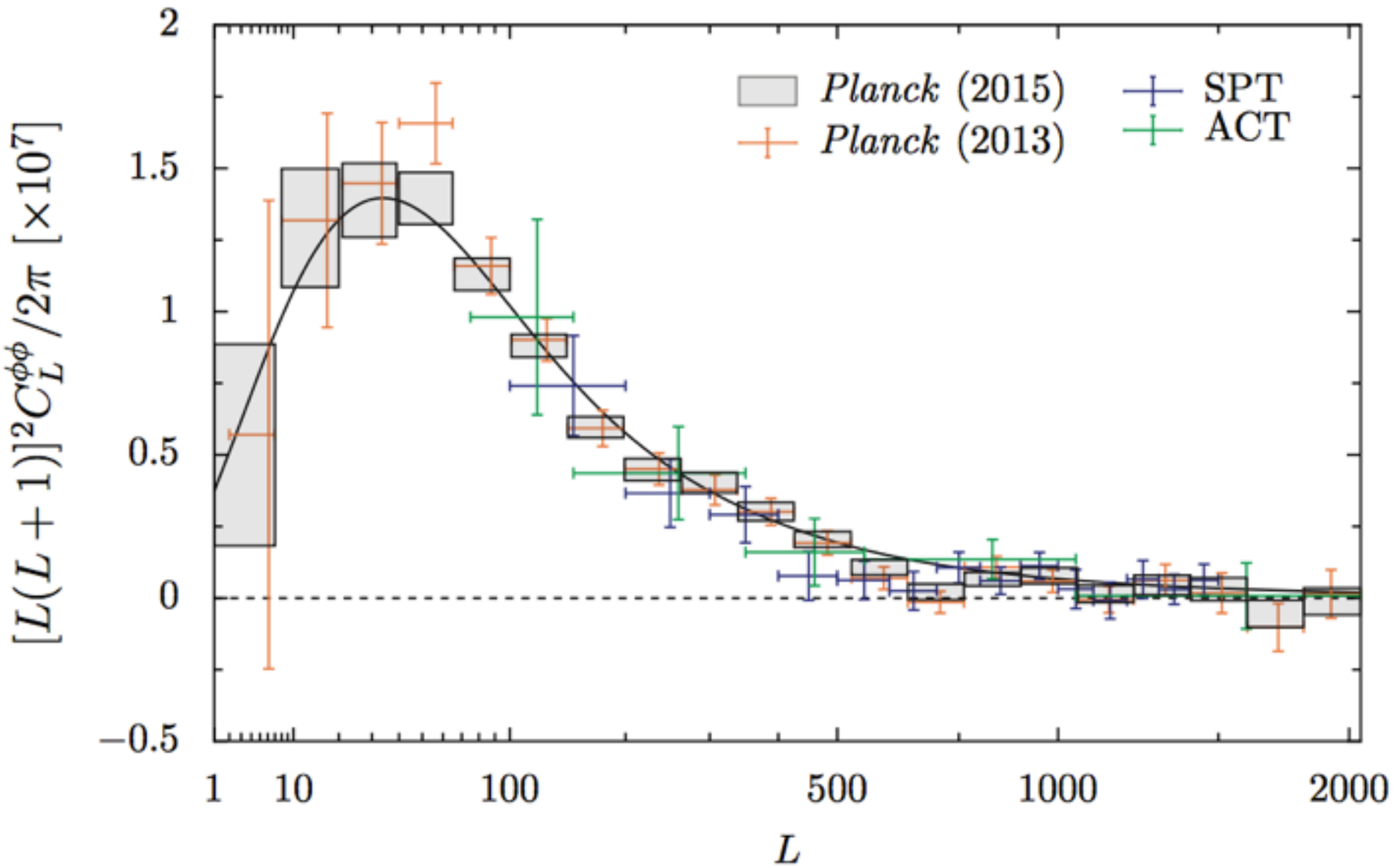
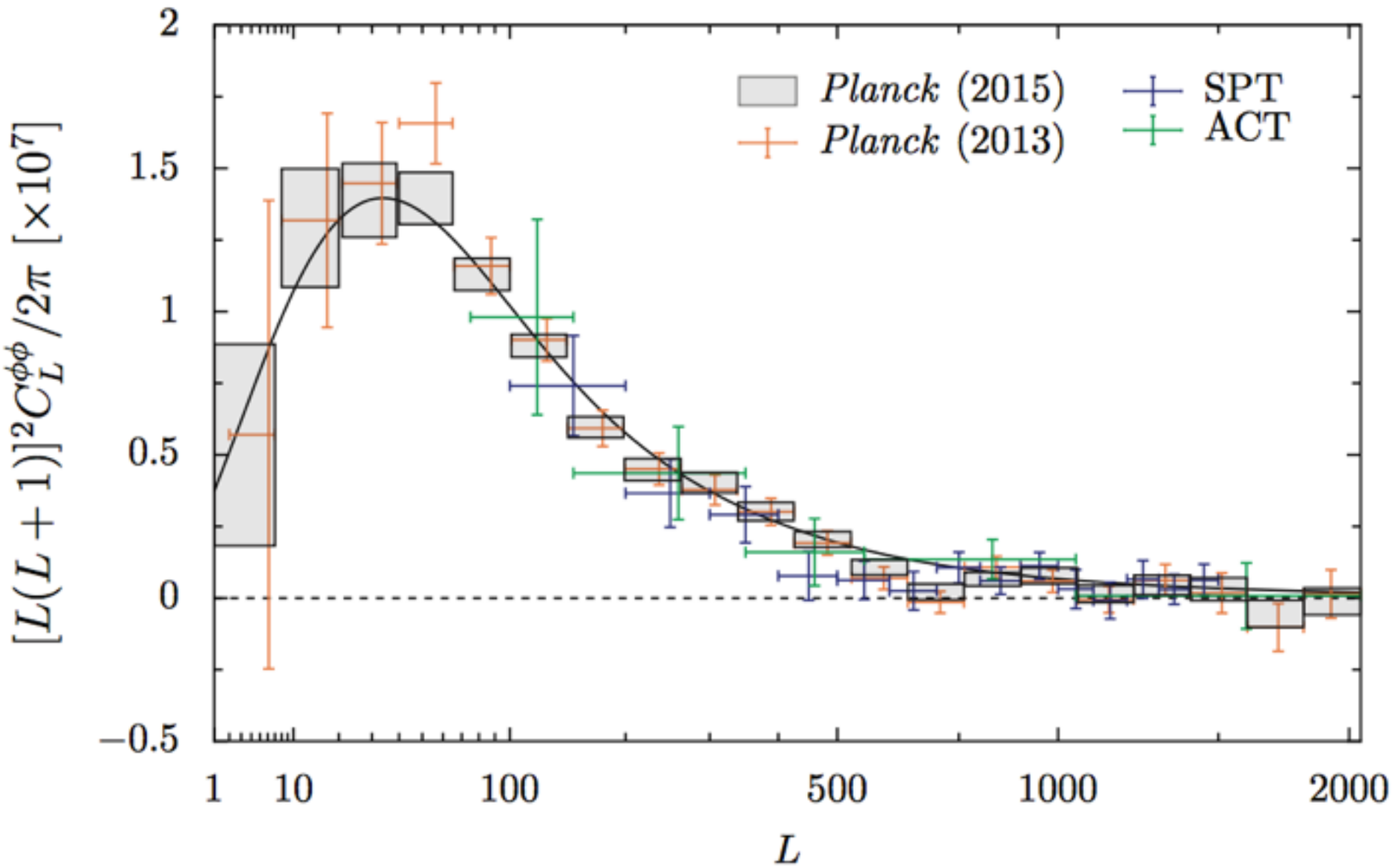
Measurements of CMB Lensing on Large Scales



Planck Paper 15, 2015 (1502.01591)

Measurements of CMB Lensing on Large Scales



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Blanchard & Schneider 1987
(first idea of detectability)

Zaldarriaga & Seljak 1997
(first lensing estimators)

Hu 2001
Hu & Okamoto 2002
(optimal lensing estimators)

Smith, Zahn, Dore 2007
(first indirect detection)

Das et al. 2011 - ACT
(first direct detection)

van Engelen et al. 2012 - SPT
(second direct detection)

Planck Collaboration 2013
(detection with S/N = 25)

Planck Collaboration 2015
(detection with S/N = 40)

CMB Lensing Power Spectrum Sensitive to Neutrino Mass

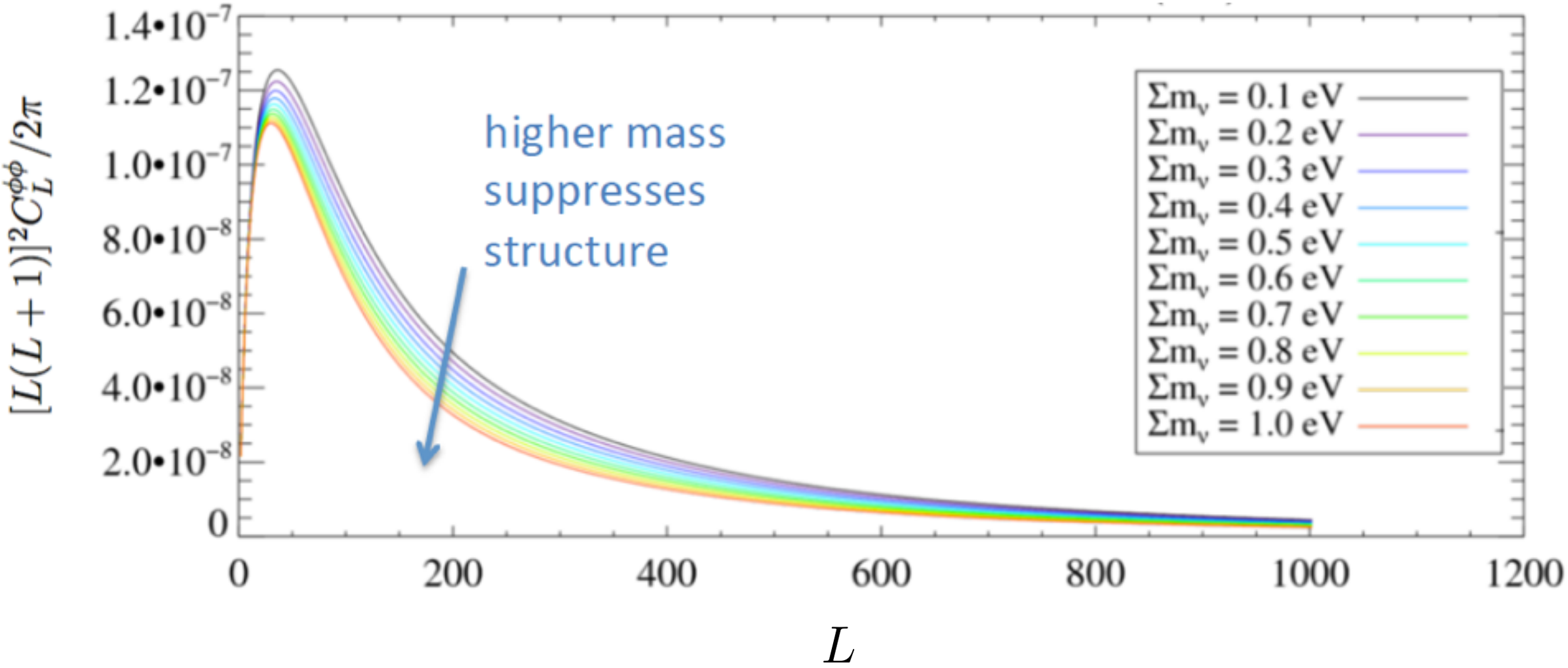
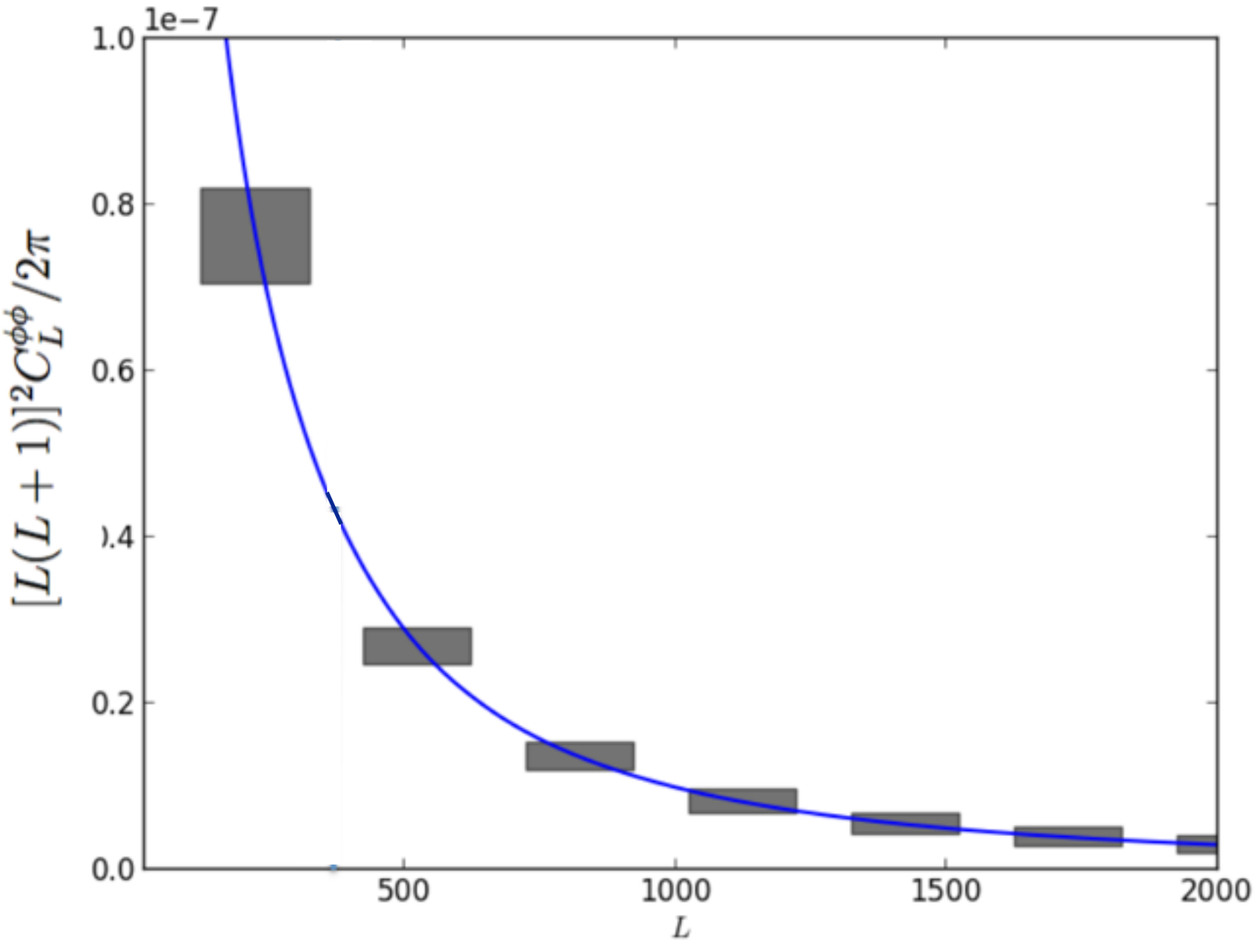


Figure credit: A. van Engelen

ACTPol Season 1 + Season 2 Forecast



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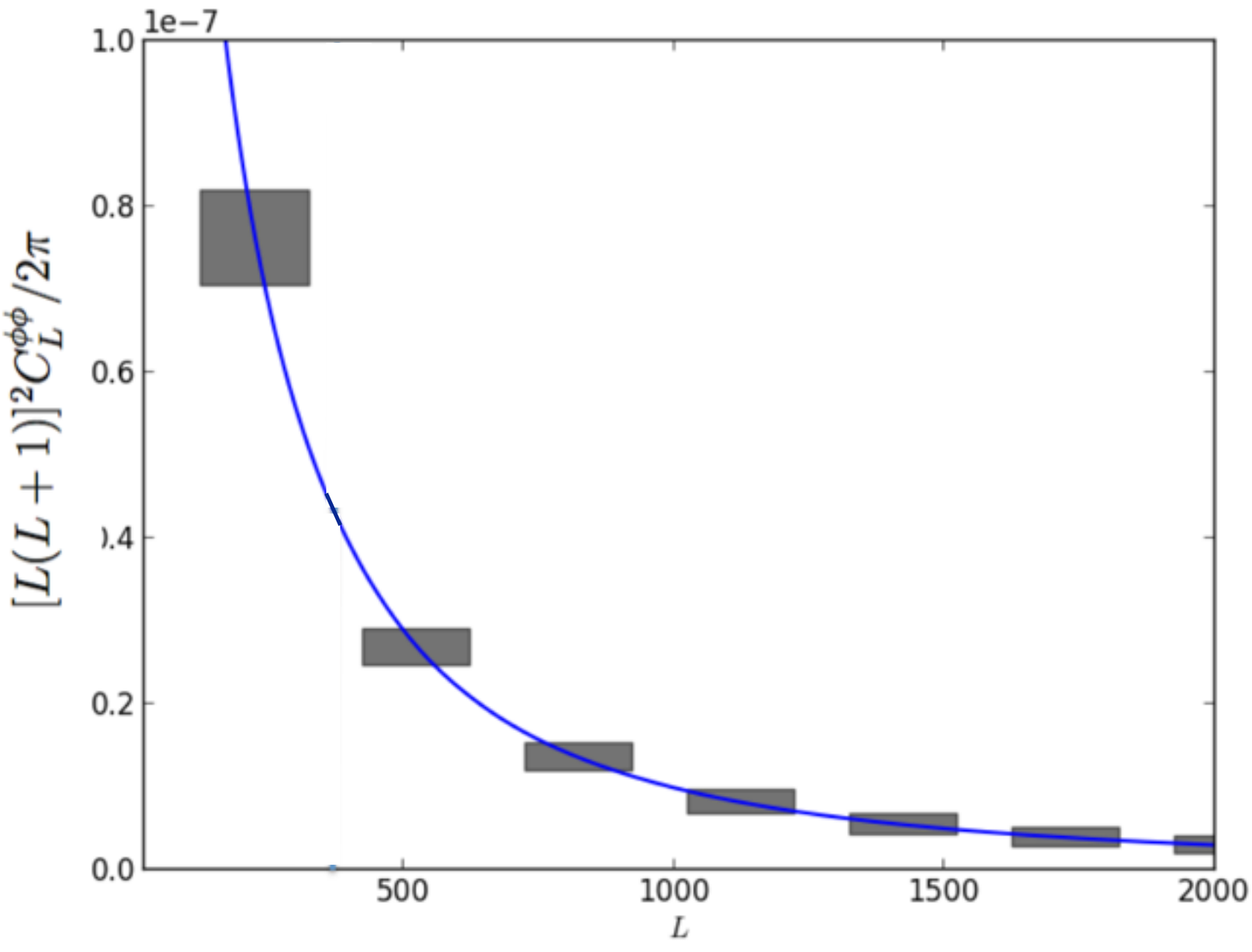
S/N ~ 15
Most S/N from
L > 400

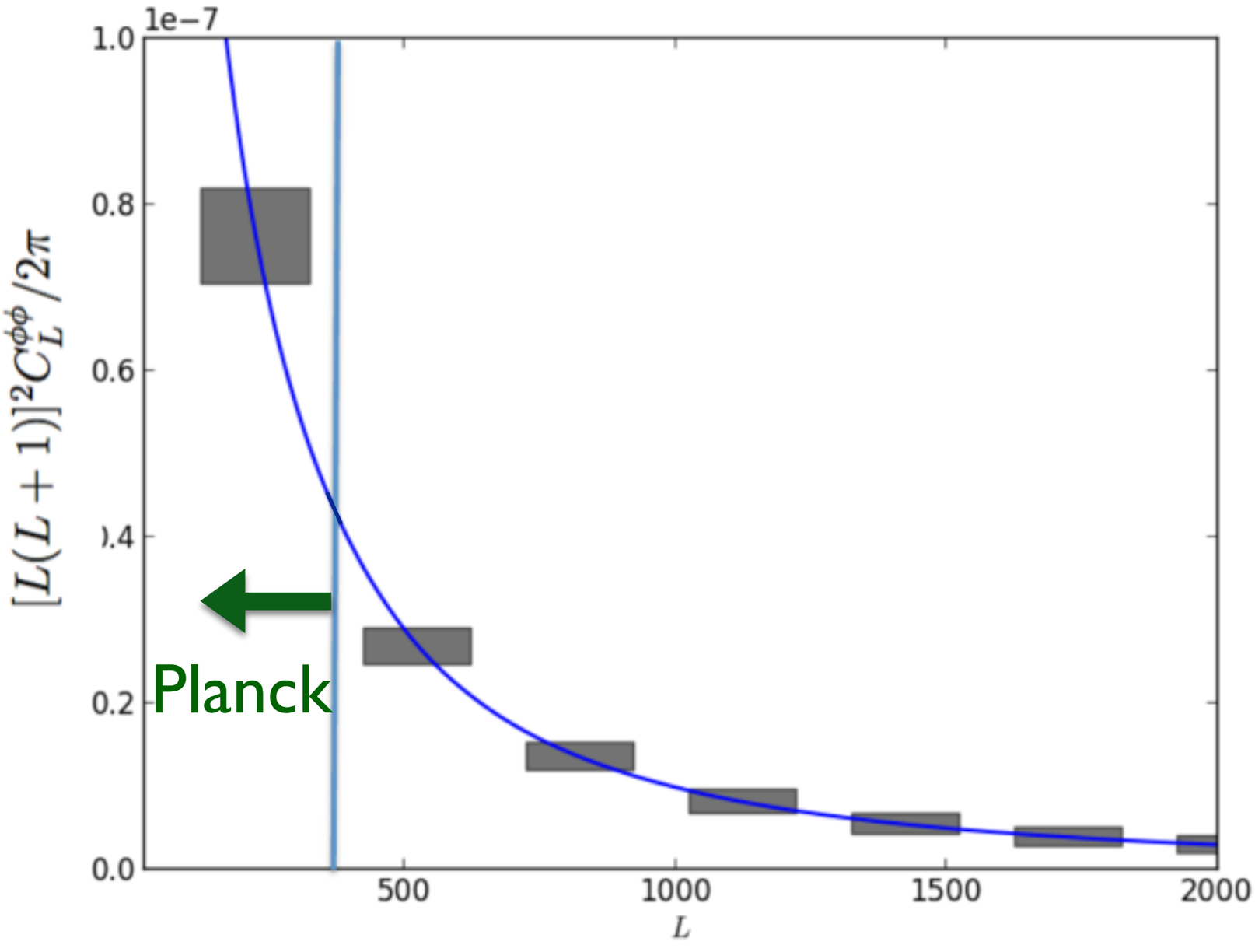


ACTPol Season 1 + Season 2 Forecast

S/N ~ 15
Most S/N from
L > 400

Planck used only L < 400 in cosmological analysis -

Null test failed for L > 400



ACTPol and AdvACT Forecasts

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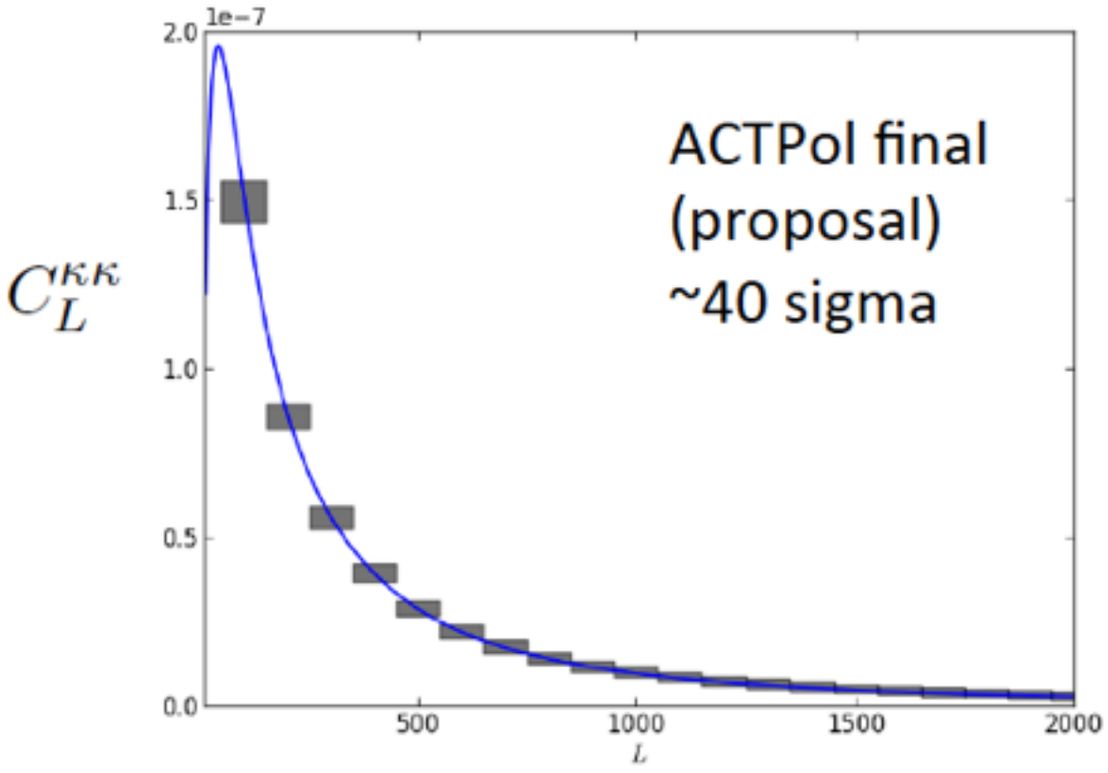

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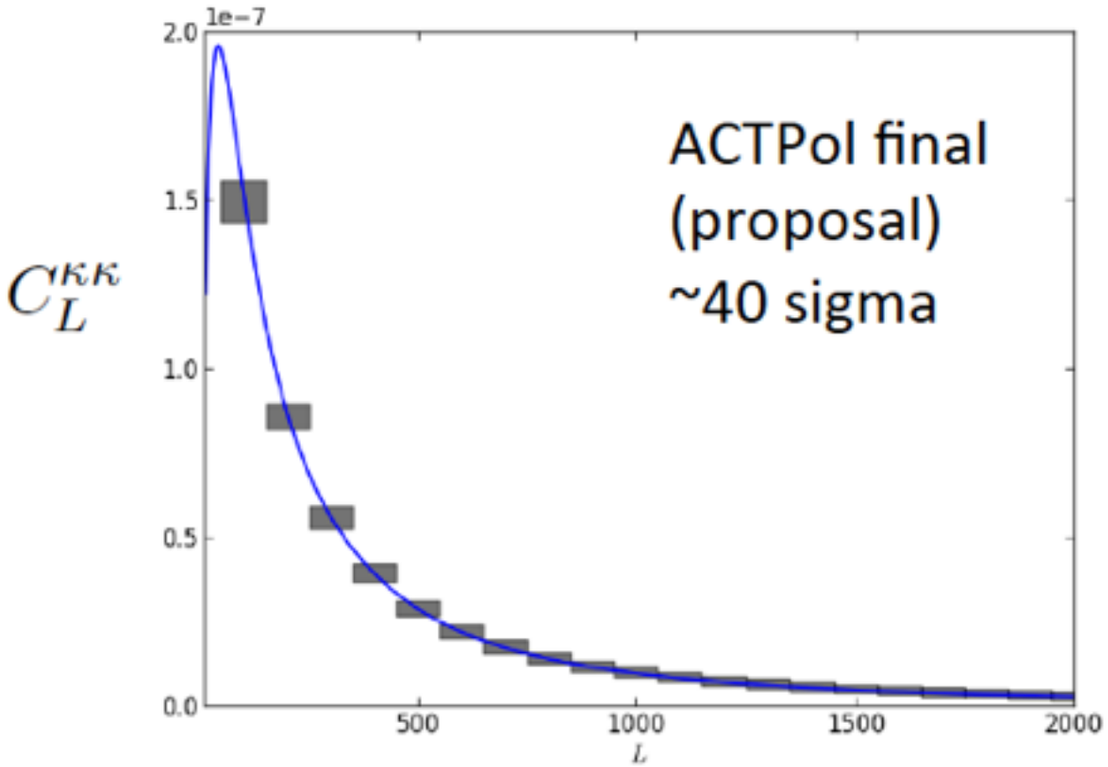

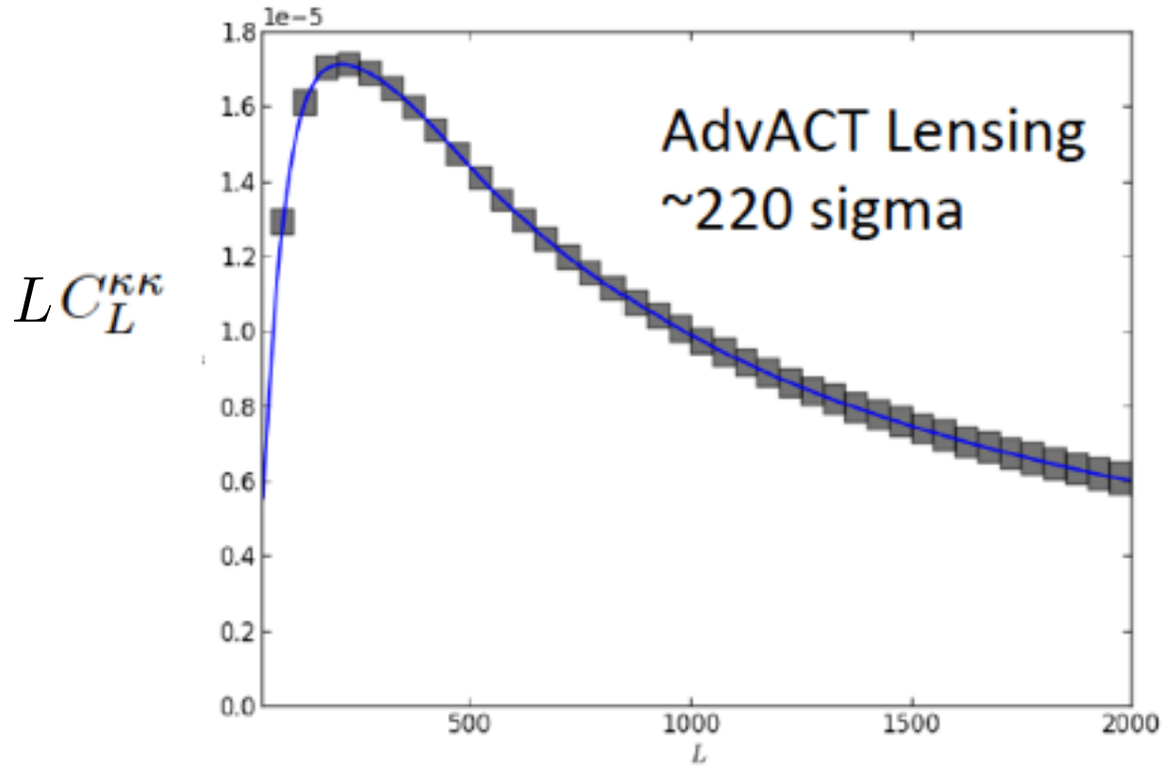

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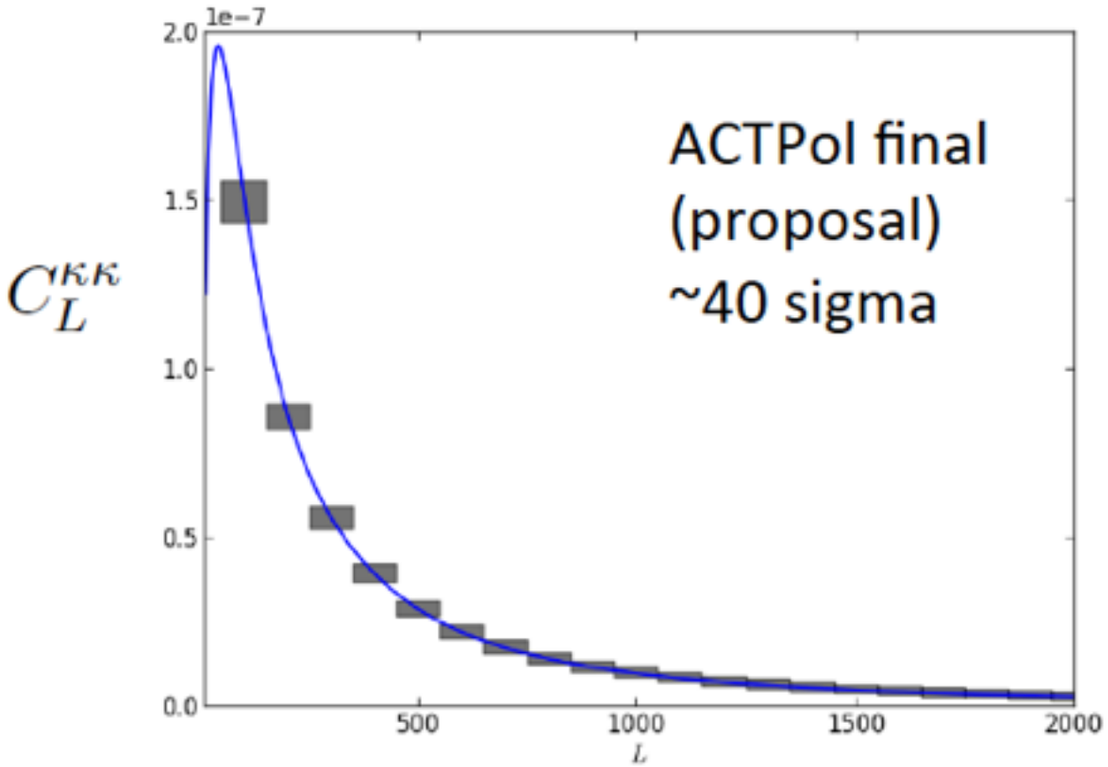

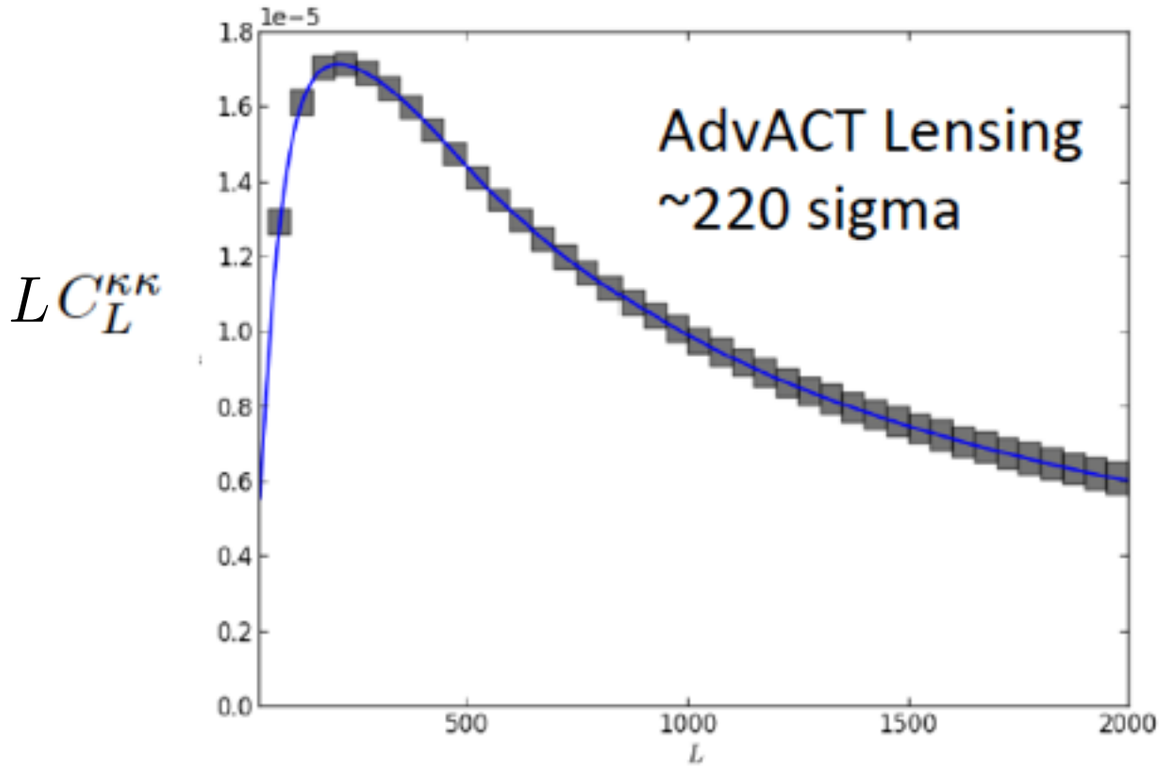

Data Set	f_{sky}	Map noise (μK-arcmin) at 150 GHz	$\sigma(\sum m_\nu)$ (eV) CMB alone	$\sigma(\sum m_\nu)$ (eV) with BAO
Planck	0.8	43	0.20	0.12
ACTPol	0.1	20	0.09	0.06
AdvACT	0.5	7	0.06	0.04

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Delensing Motivation

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- Delensing = undo the lensing of the primordial CMB due to Large-scale structure (LSS)

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Deflection angle

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Projected lensing potential

Deflection angle

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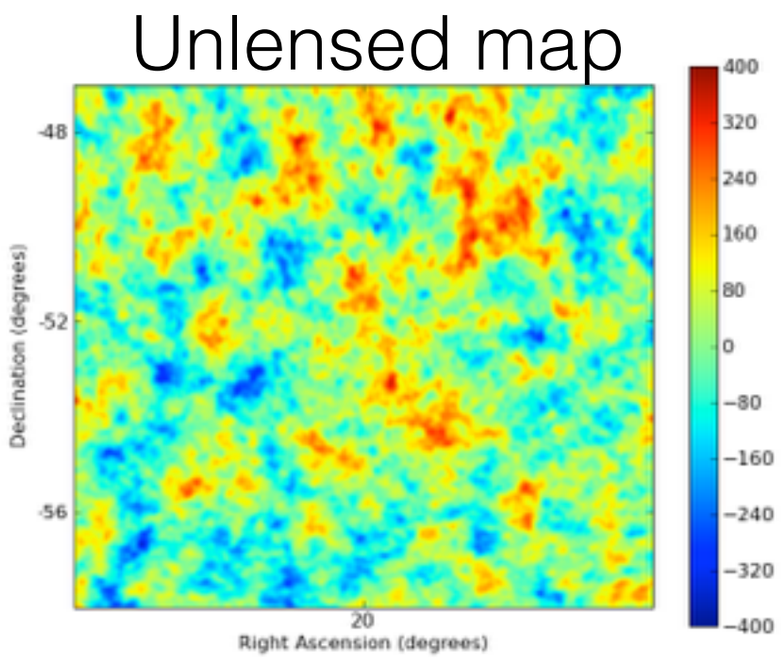

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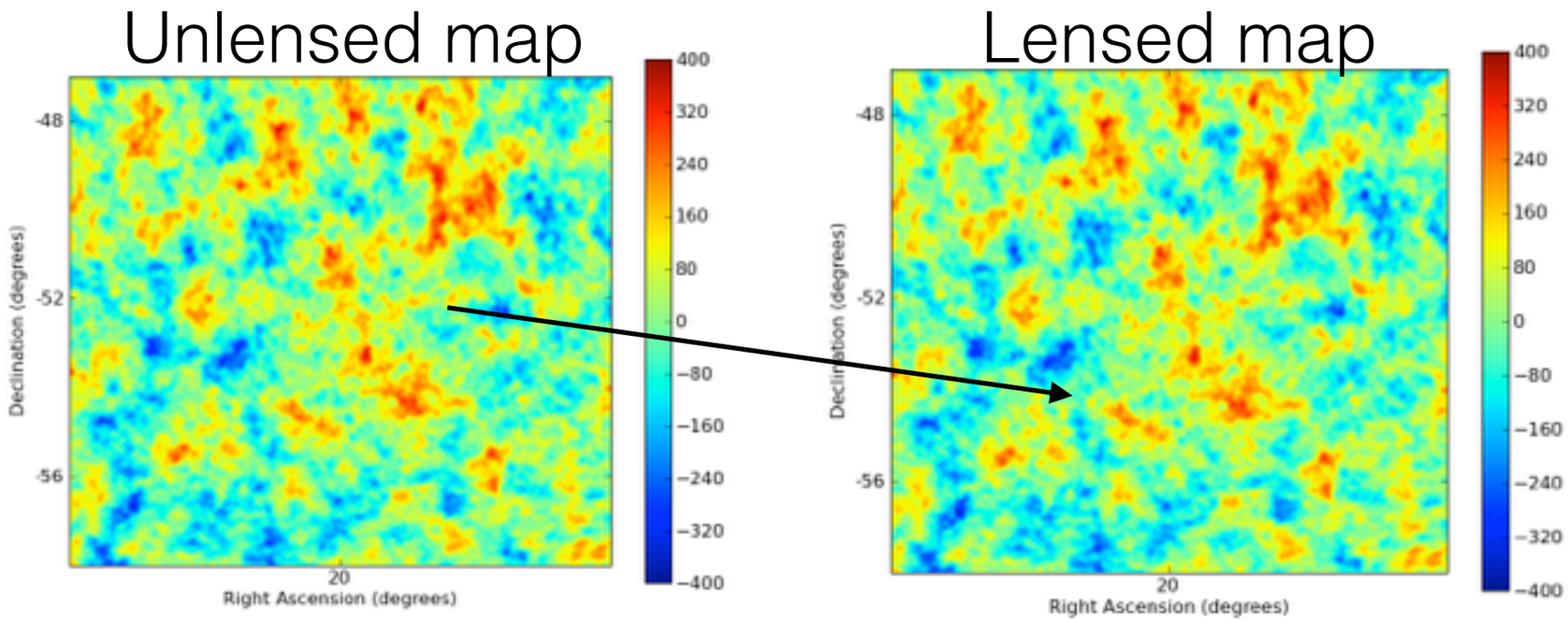

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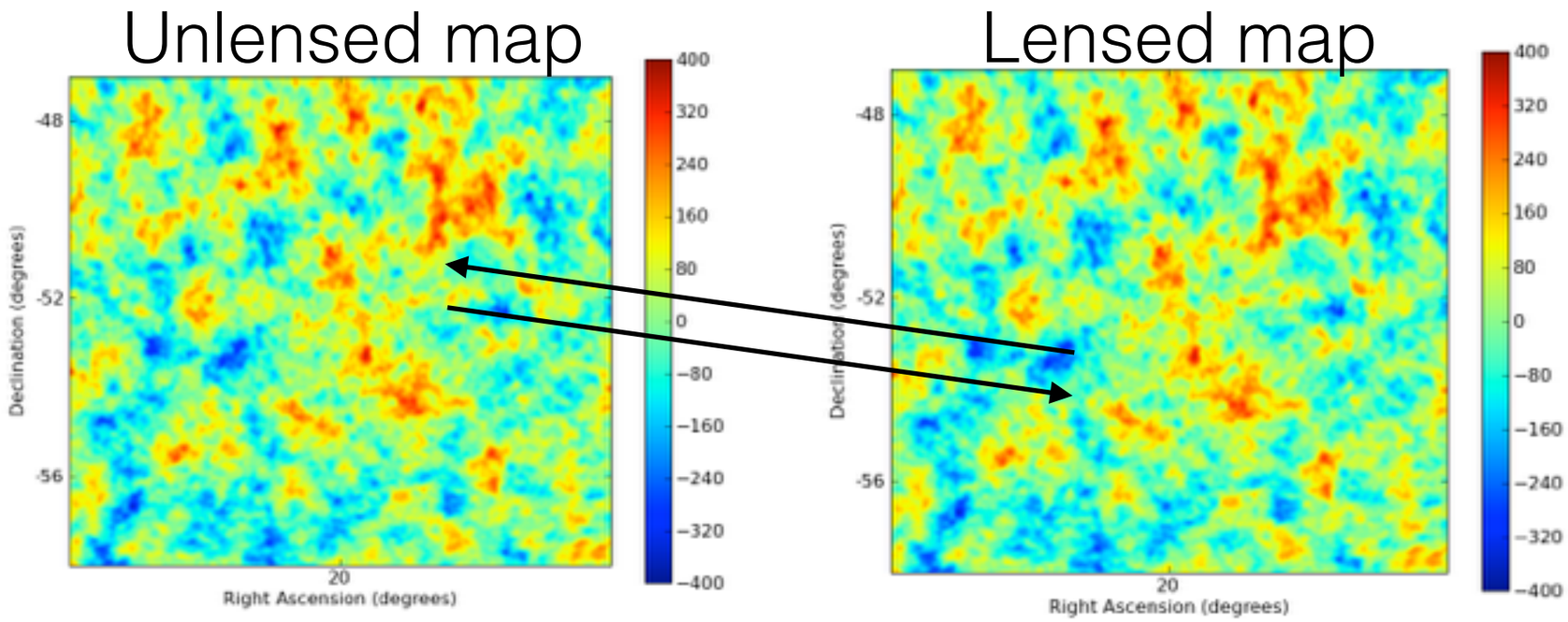

Shift pixels backward using LSS map to reconstruct unlensed CMB

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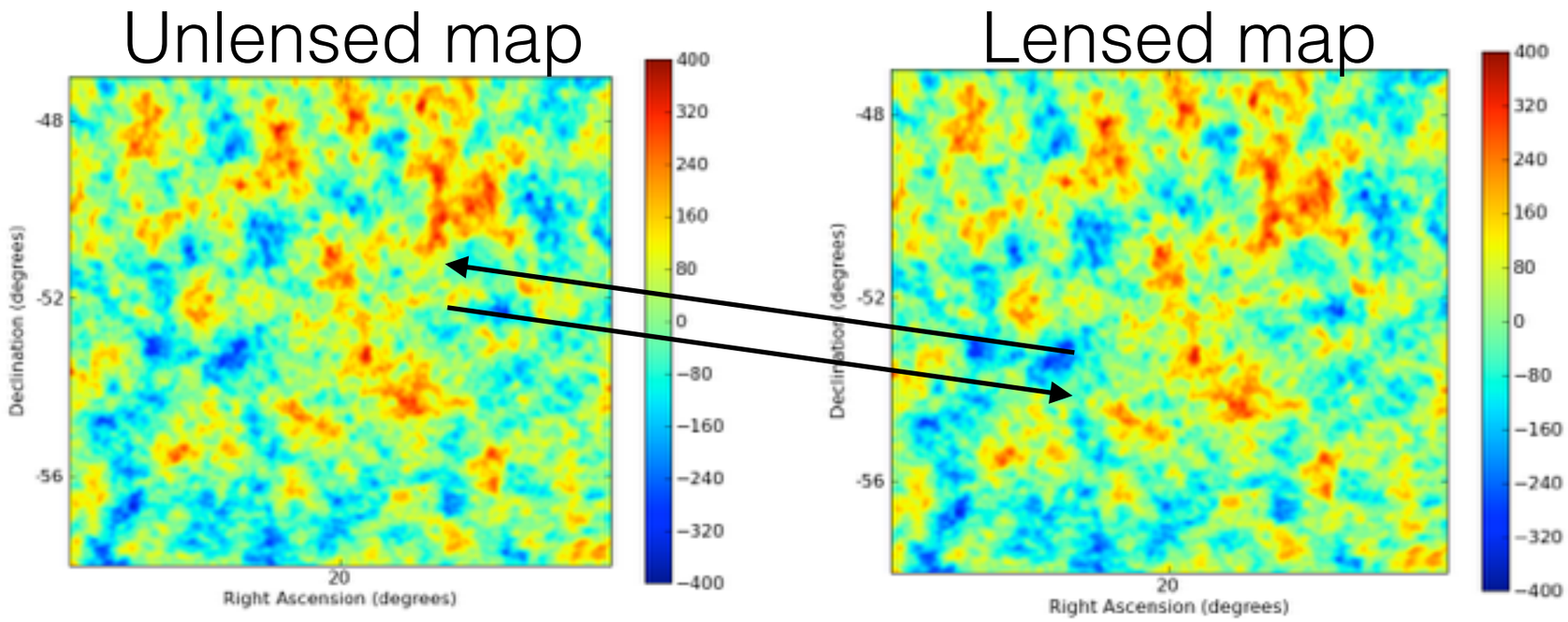

Shift pixels backward using LSS map to reconstruct unlensed CMB

- Need template of LSS from either internal CMB lens map reconstruction and/or LSS tracer like CIB
  (see e.g. Sherwin & Schmittfull, 2015, 1502.05356)

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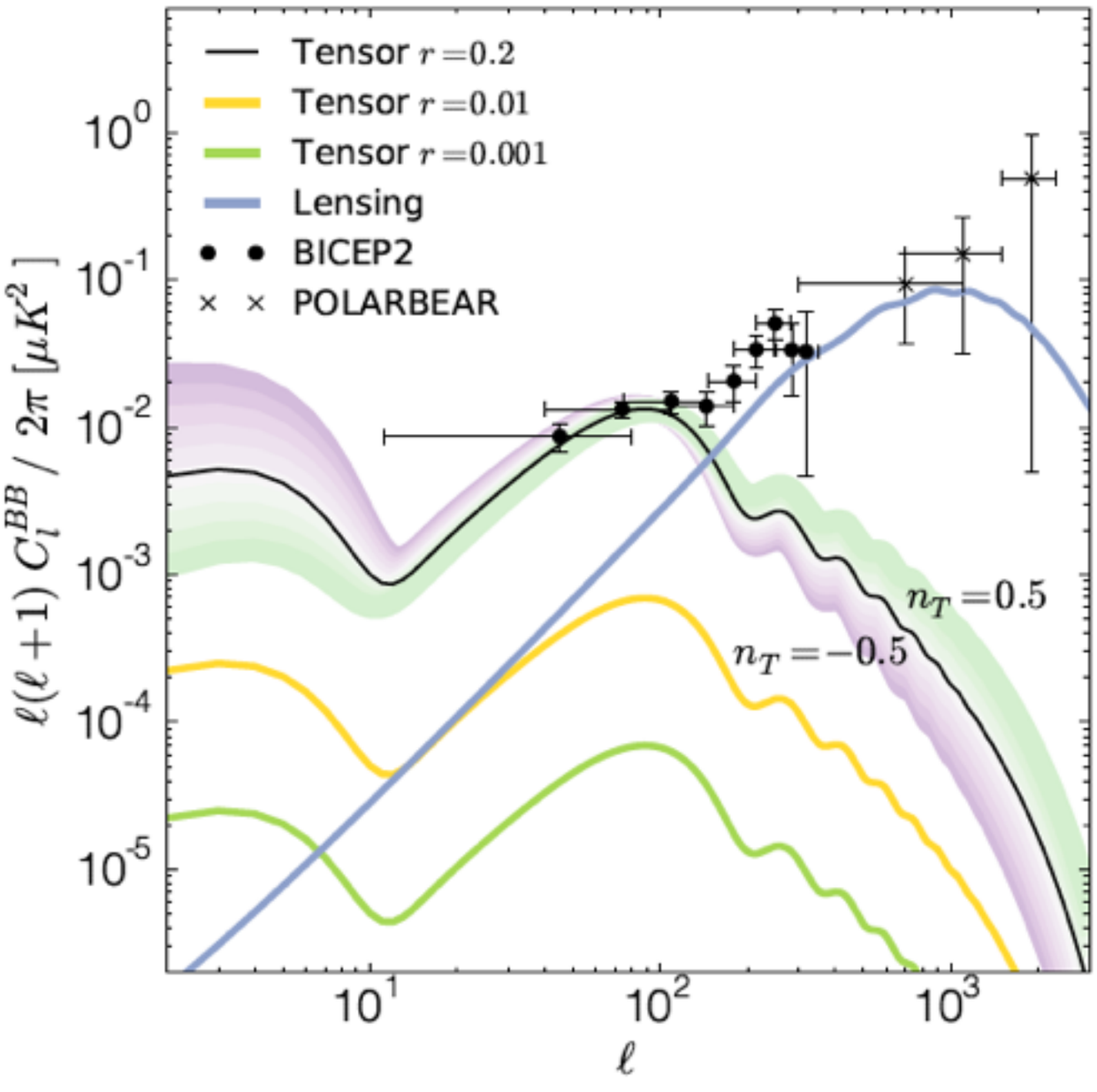
Want to measure the amplitude (r) and scale dependence (n_T) of primordial B-mode power



Simard, Hanson, Holder 2014, 1410.0691

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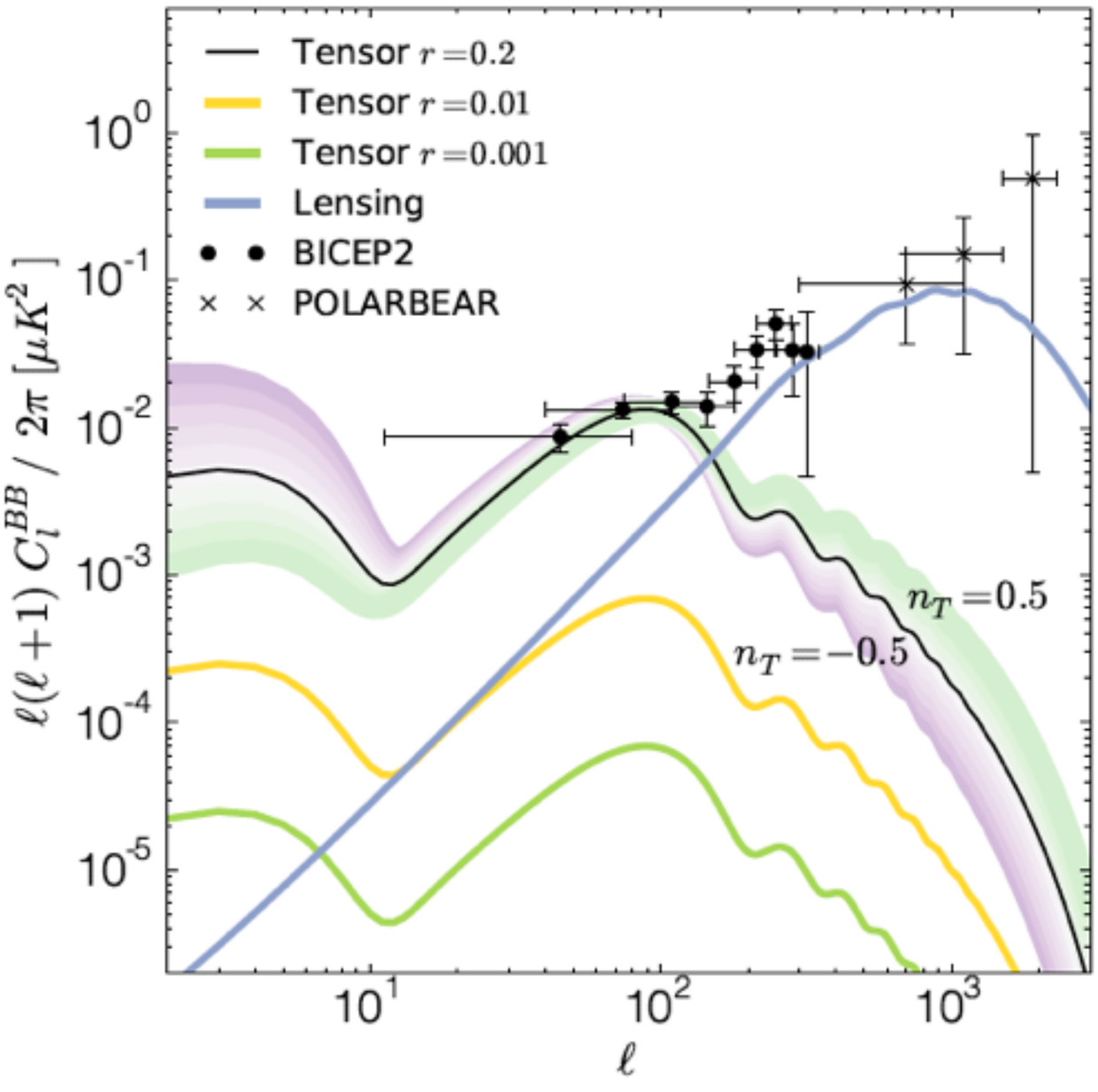
$n_T = -r/8$ is consistency relation of single-field, slow roll inflation



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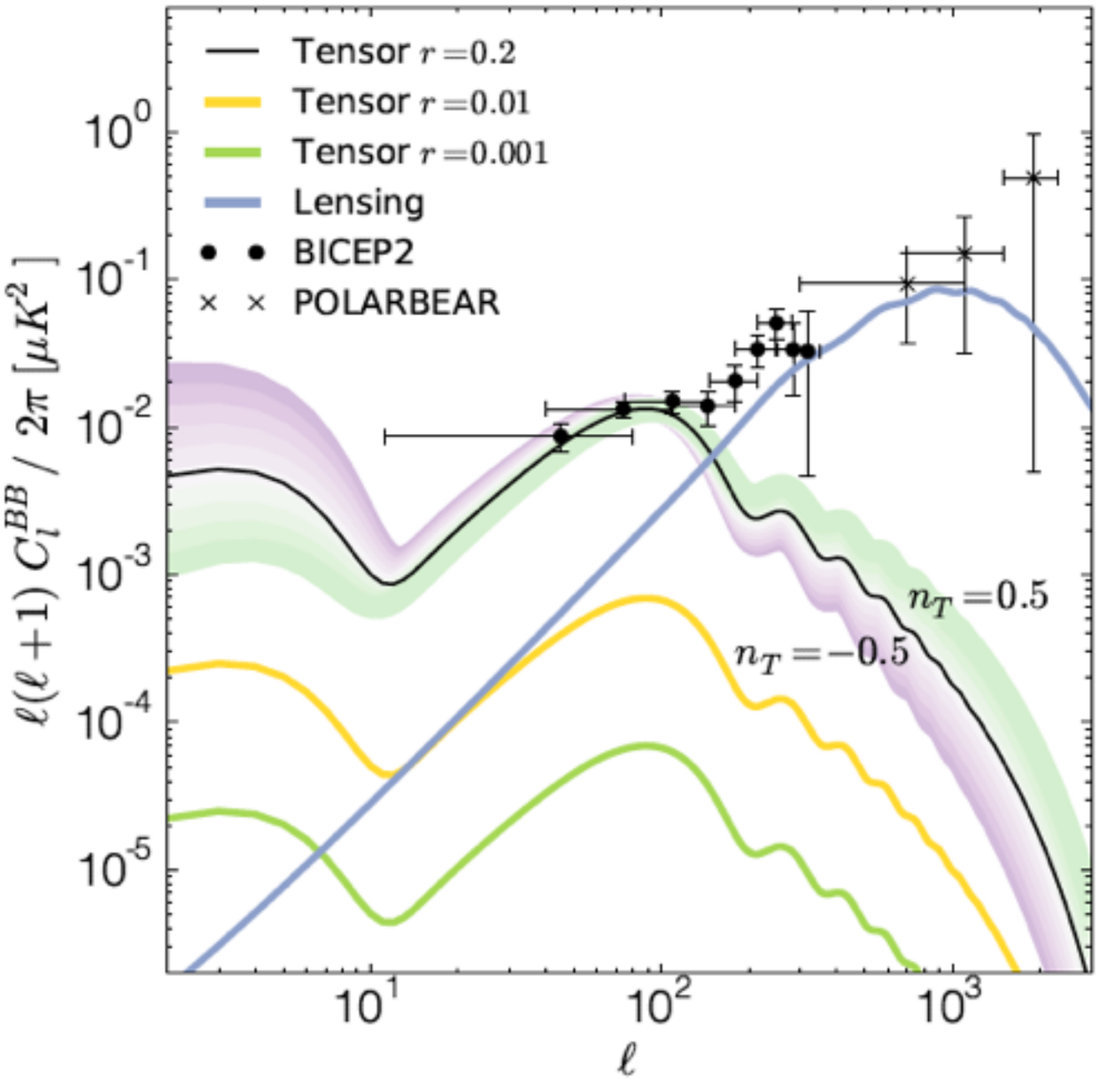
B-modes from gravitational lensing are a contaminant



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$$\sigma(r) \propto \sum_l \sqrt{\frac{2}{(2l+1)f_{\rm sky}}} (C_l^{\rm BB,lens} + N_l^{\rm BB})$$

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  - Need range of scales (100 < l < 1000), including small-scales as they contribute to large-scale B-mode power

ACTPol Season 1 + Season 2 Delensing

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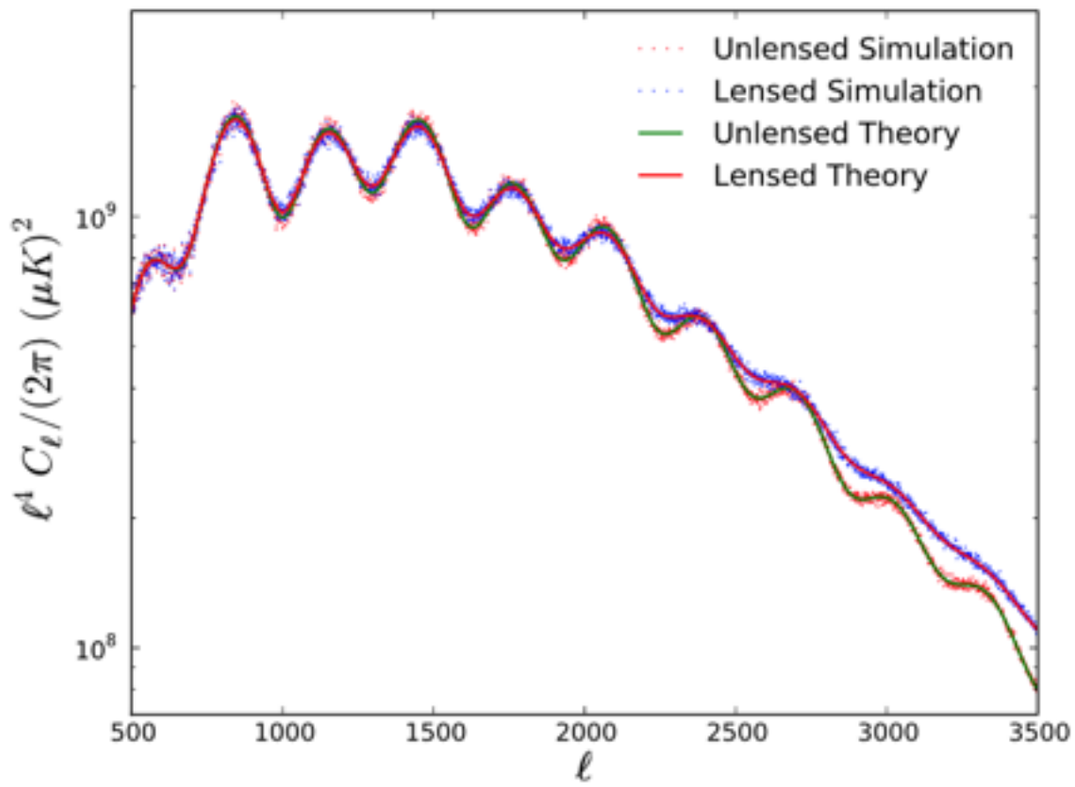

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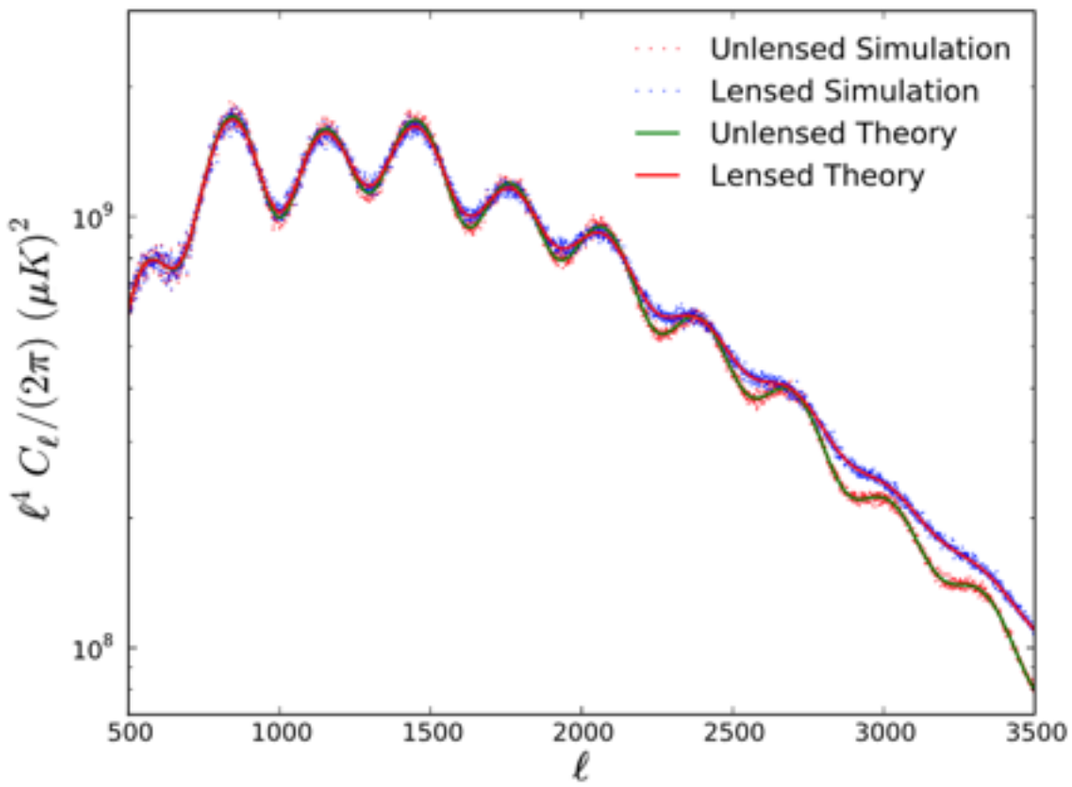
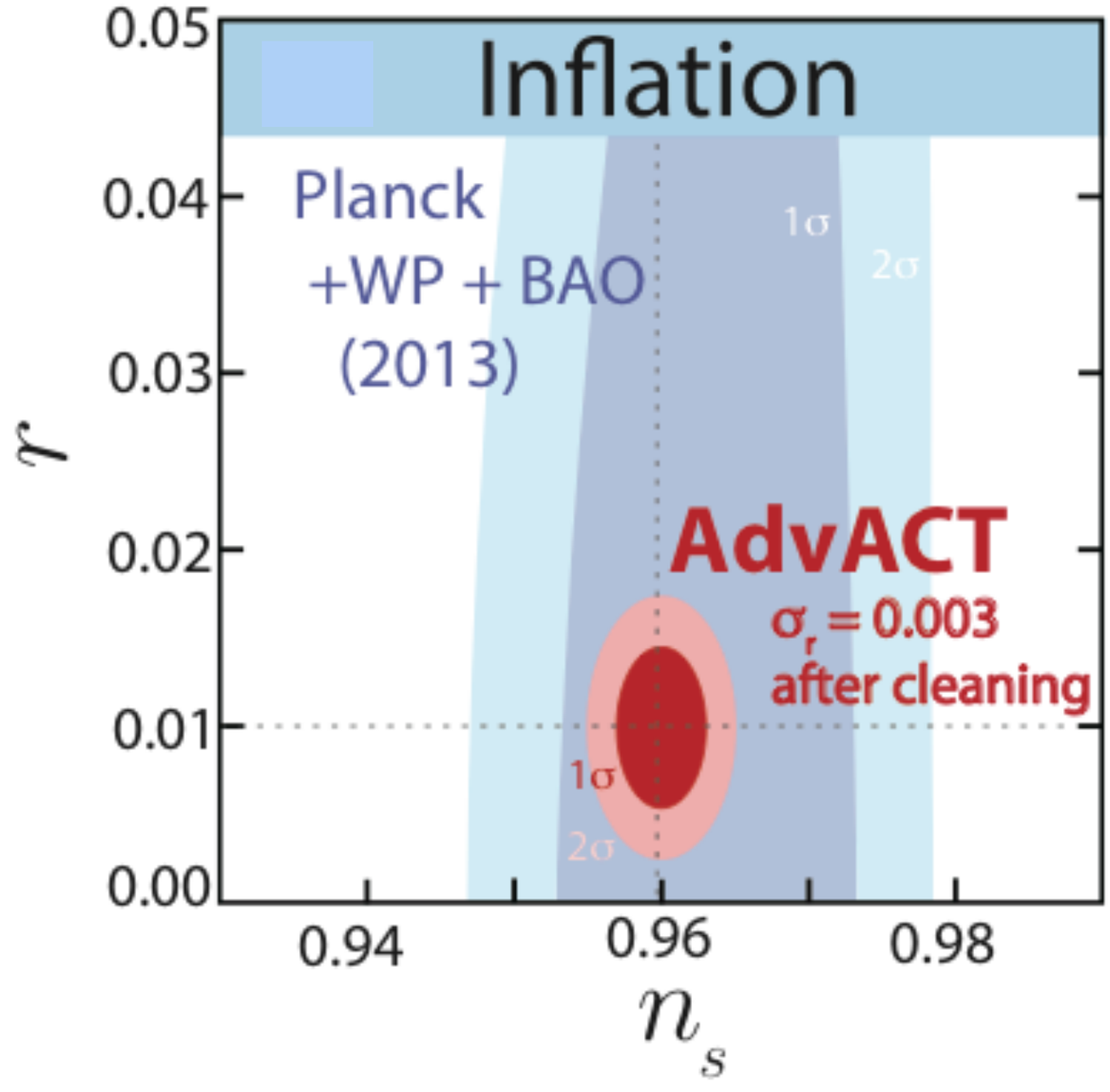


Subtle effect, but existence of peak smearing has already been detected by ACT, SPT, and Planck

AdvACT: Inflation Forecast



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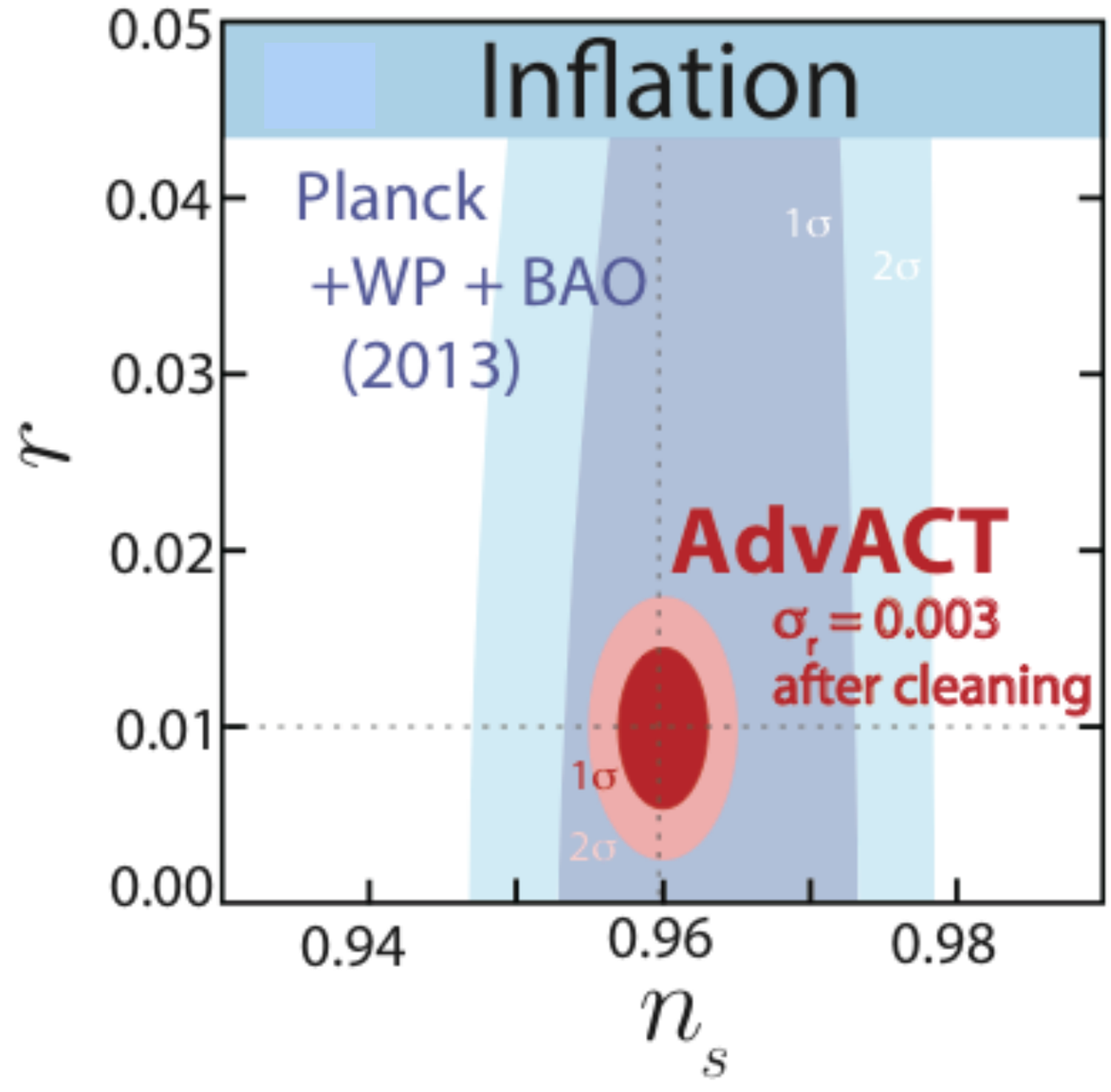
AdvACT will survey
50% of sky



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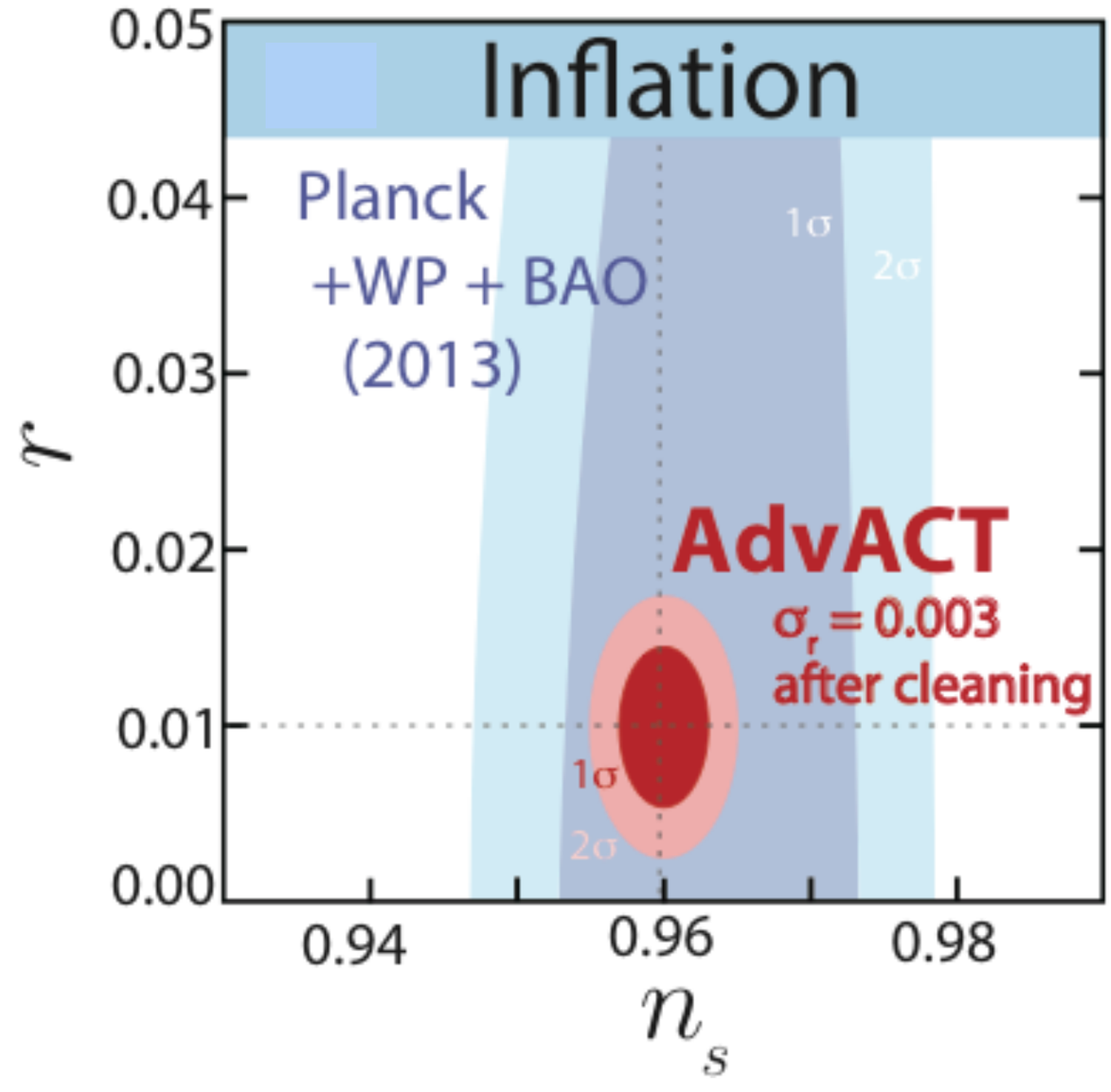

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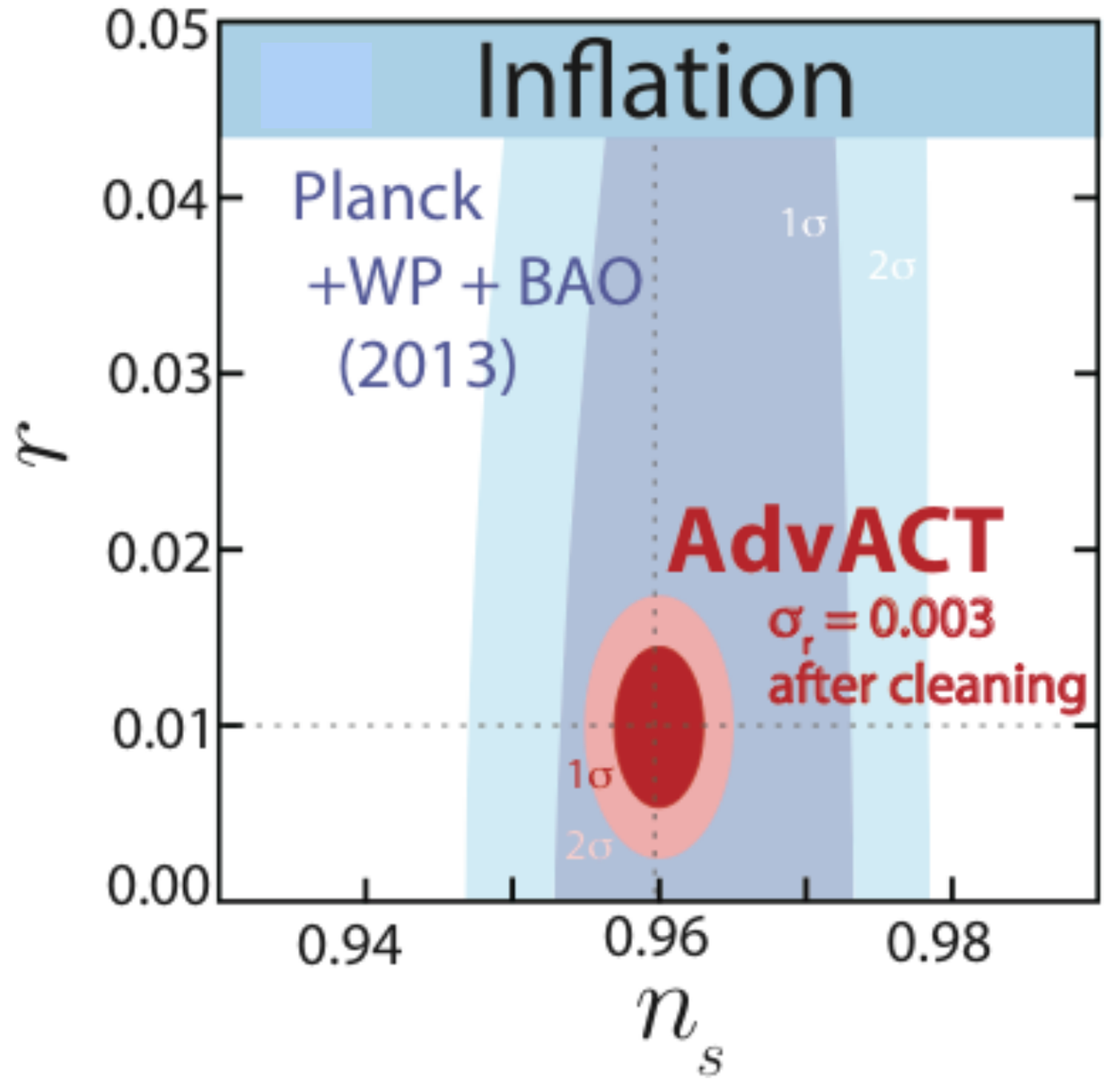

AdvACT: Inflation Forecast

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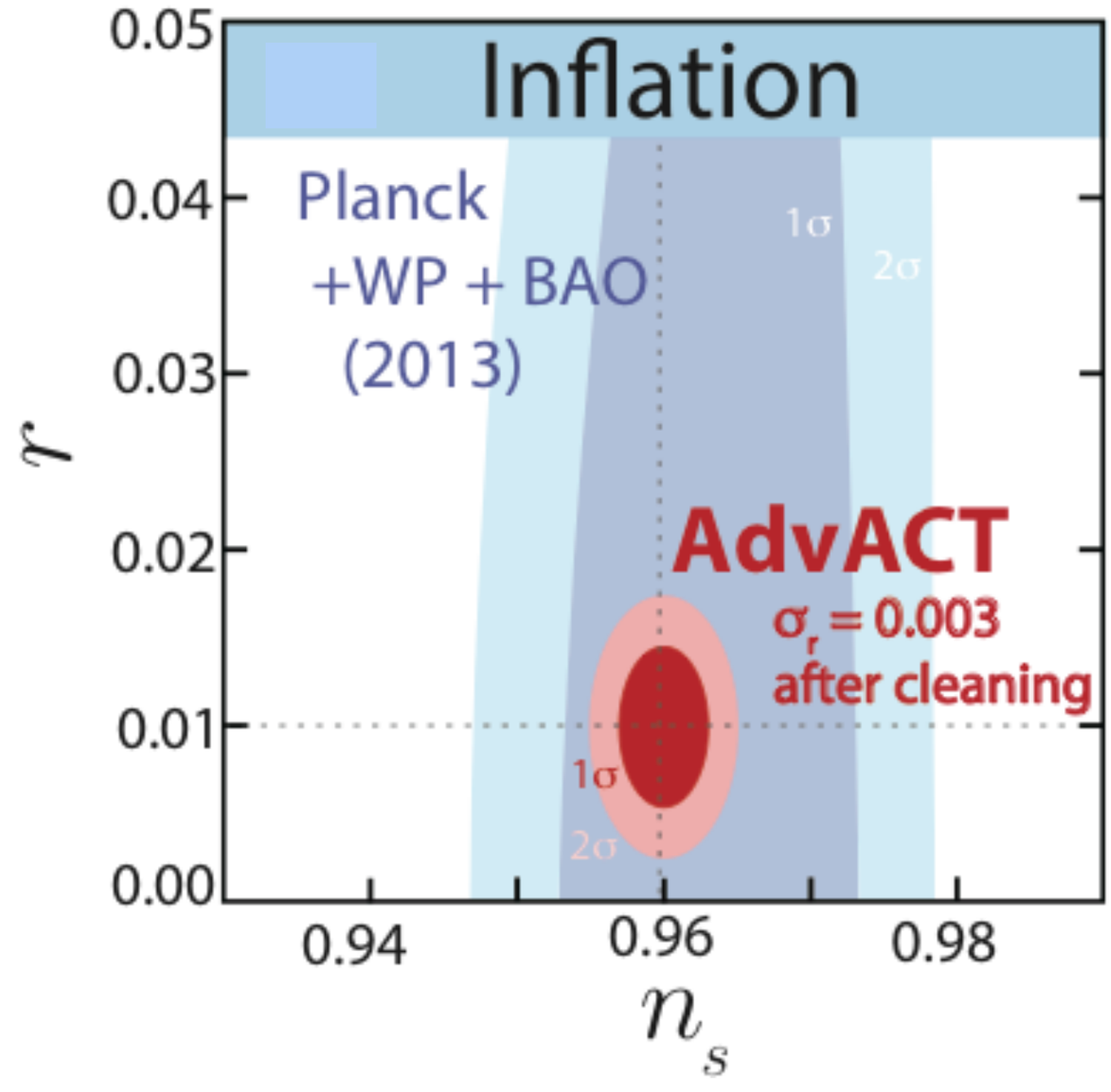
have small-scale CMB
to delens



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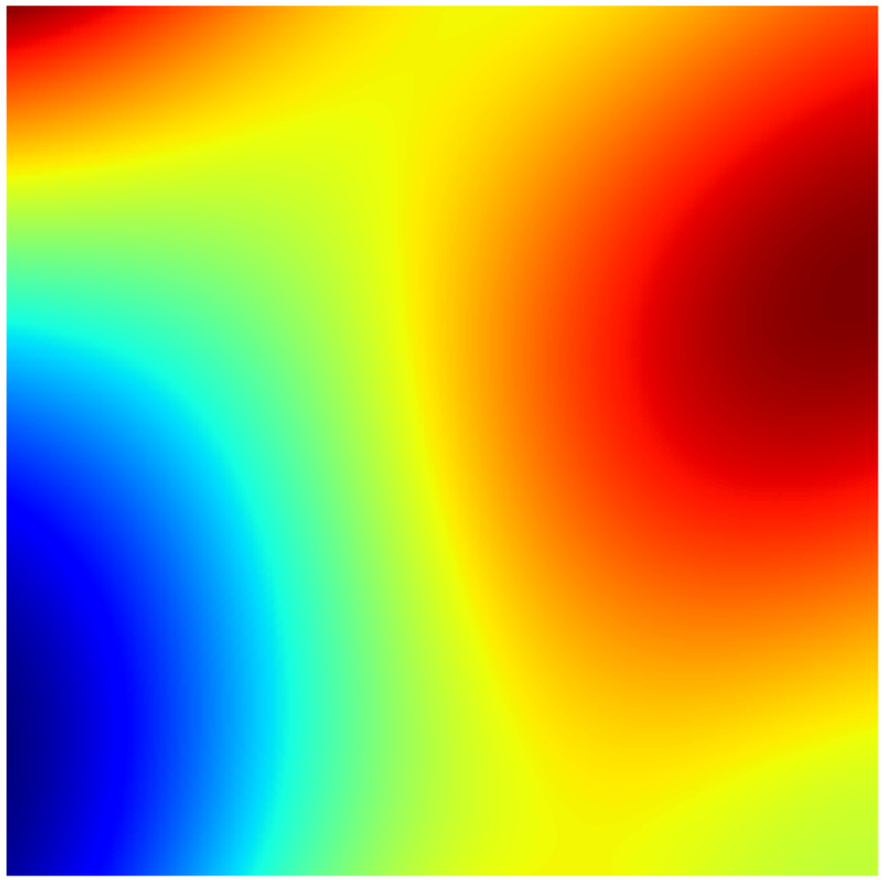
CMB Lensing on Small Scales

Unlensed CMB

Noiseless unlensed CMB sim

20’ x 20’ patch

Mostly gradient



CMB Lensing on Small Scales

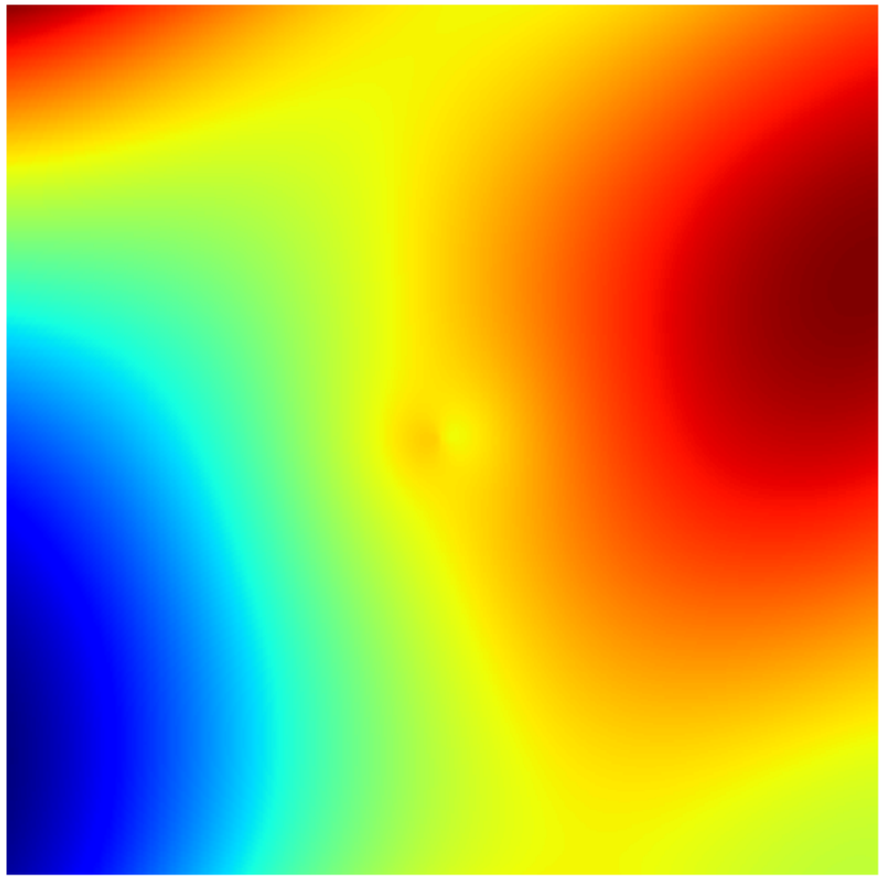
Noiseless lensed CMB sim

20’ x 20’ patch

Lensed by $M_{180} = 2 \times 10^{15}$ Msun

Lensing signal on Mpc / arcmin scales

Lensed CMB



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CMB Lensing on Small Scales

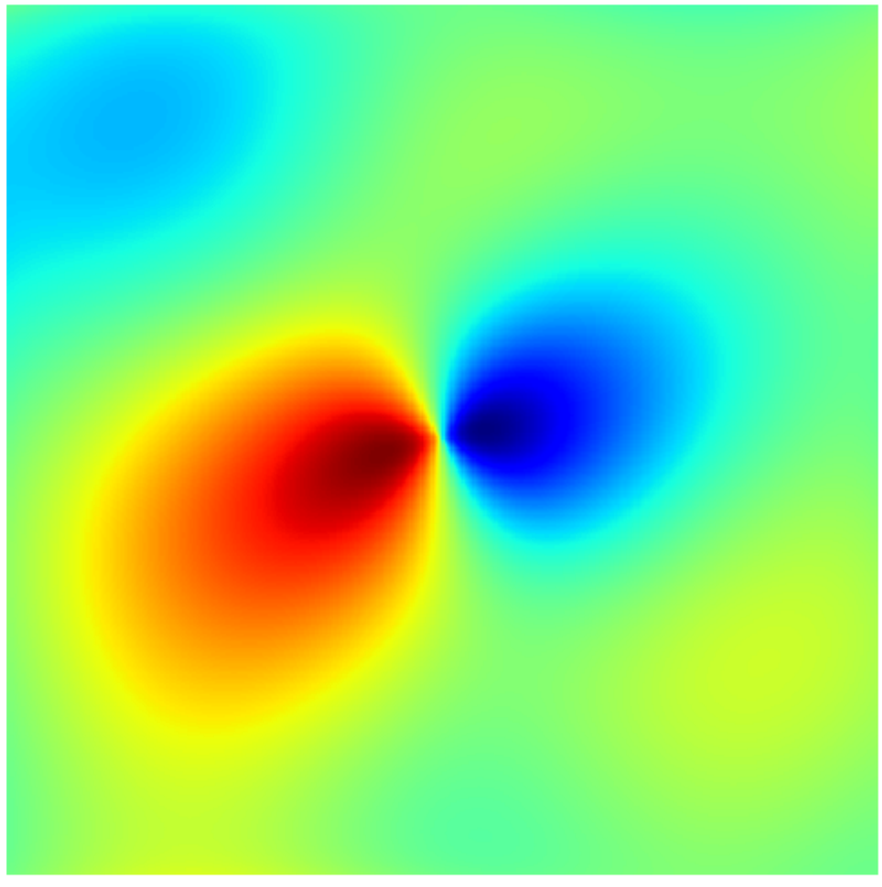
Difference of lensed and unlensed CMB

20’ x 20’ patch

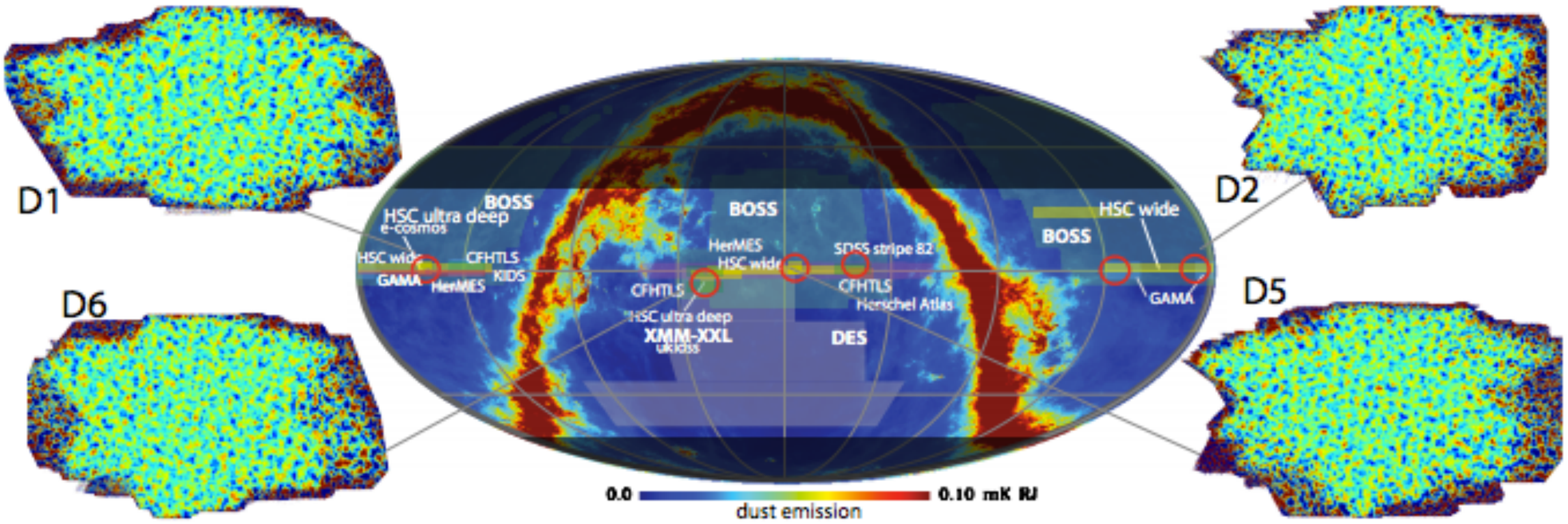
Characteristic dipole along the direction of gradient

Dipole signal is of the order of ~1-10uK

Difference Map



ACTPol First Season Maps



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Stacked ~12,000 CMASS Galaxies

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Stacked ~12,000 CMASS Galaxies

Galaxies from SDSS-III/BOSS DR10

CMASS ("constant mass") galaxies have similar selection as LRGs

Neelima Sehgal, Stony Brook

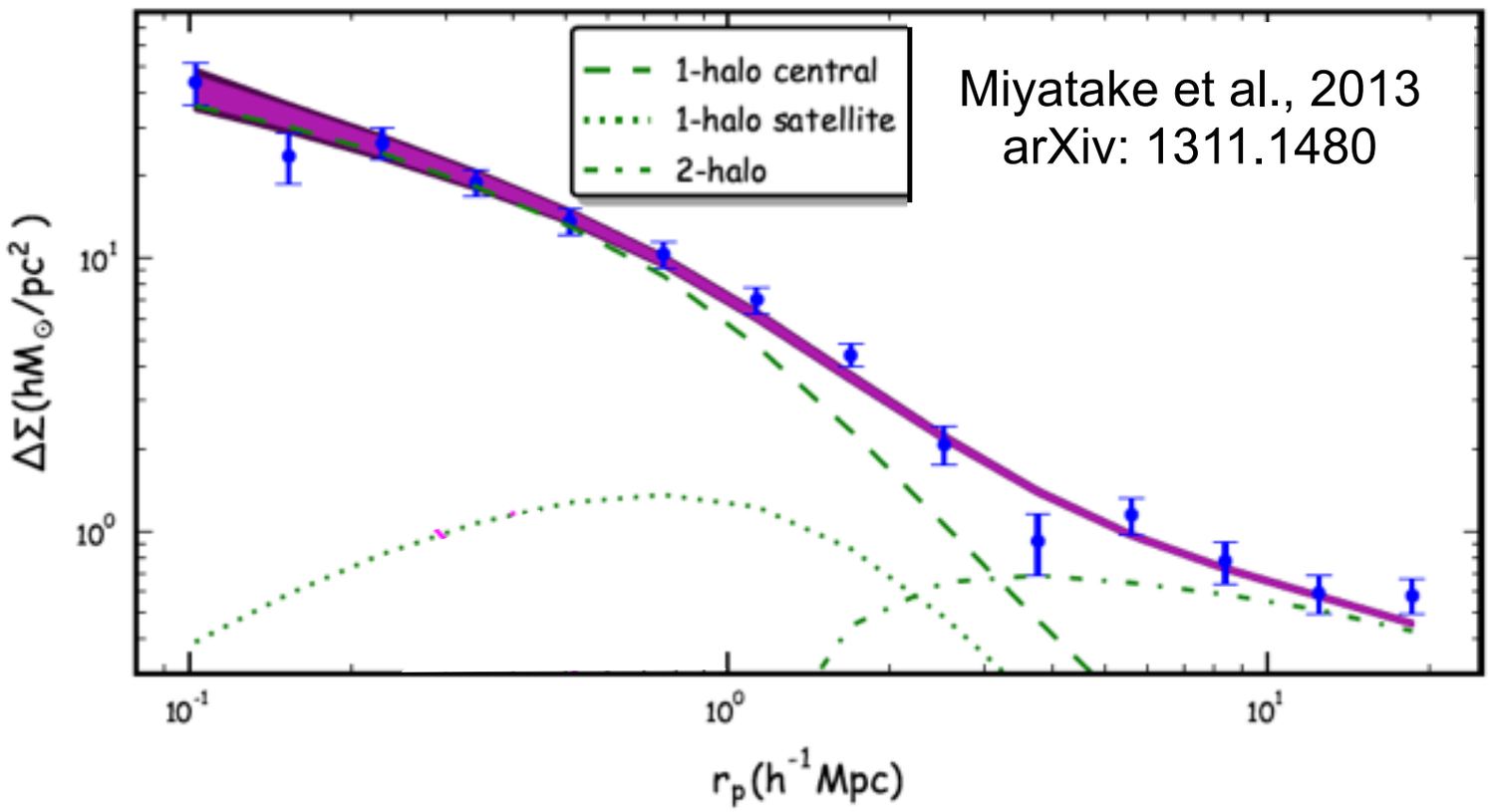
Stacked ~12,000 CMASS Galaxies

Galaxies from SDSS-III/BOSS DR10

CMASS ("constant mass") galaxies have similar selection as LRGs

Galaxies chosen because have optical weak lensing mass estimates

Weak lensing using CFHTLS

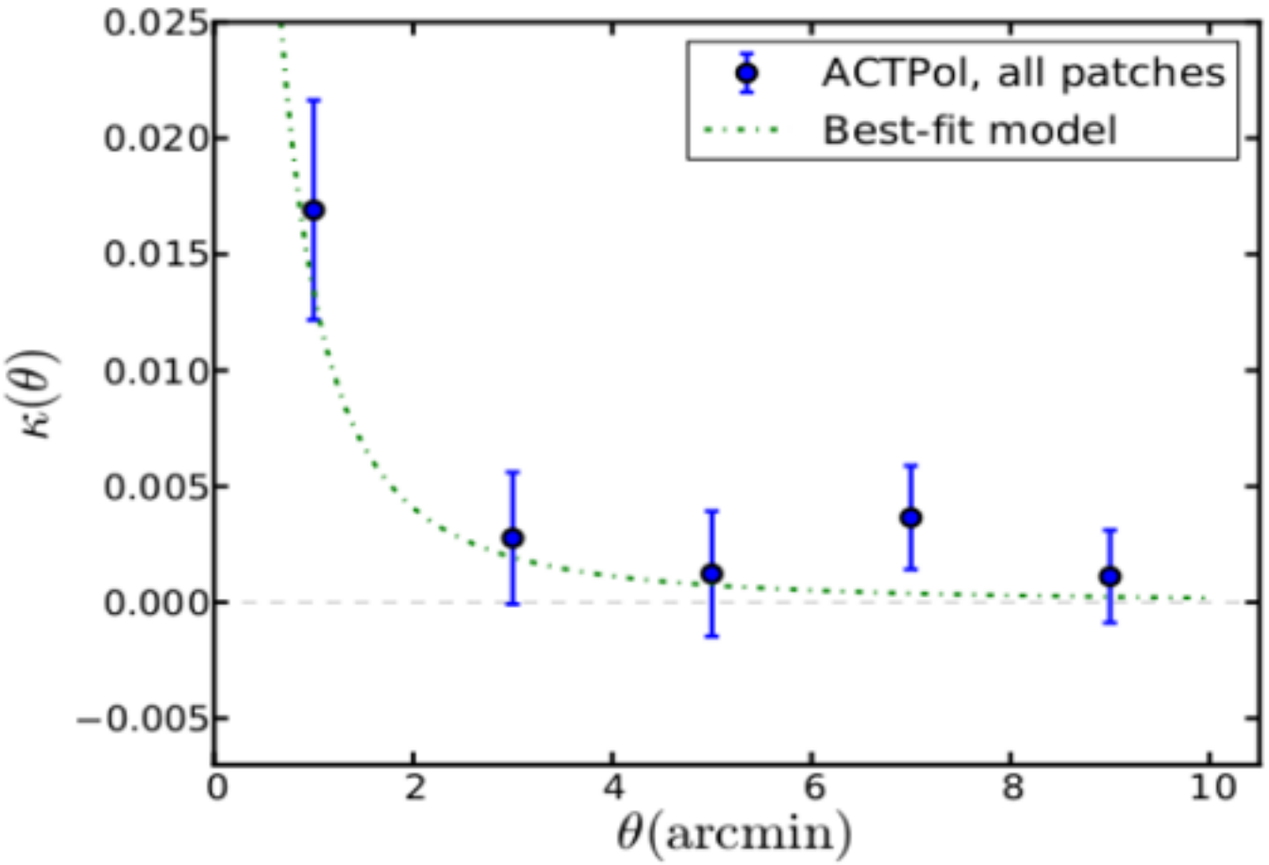


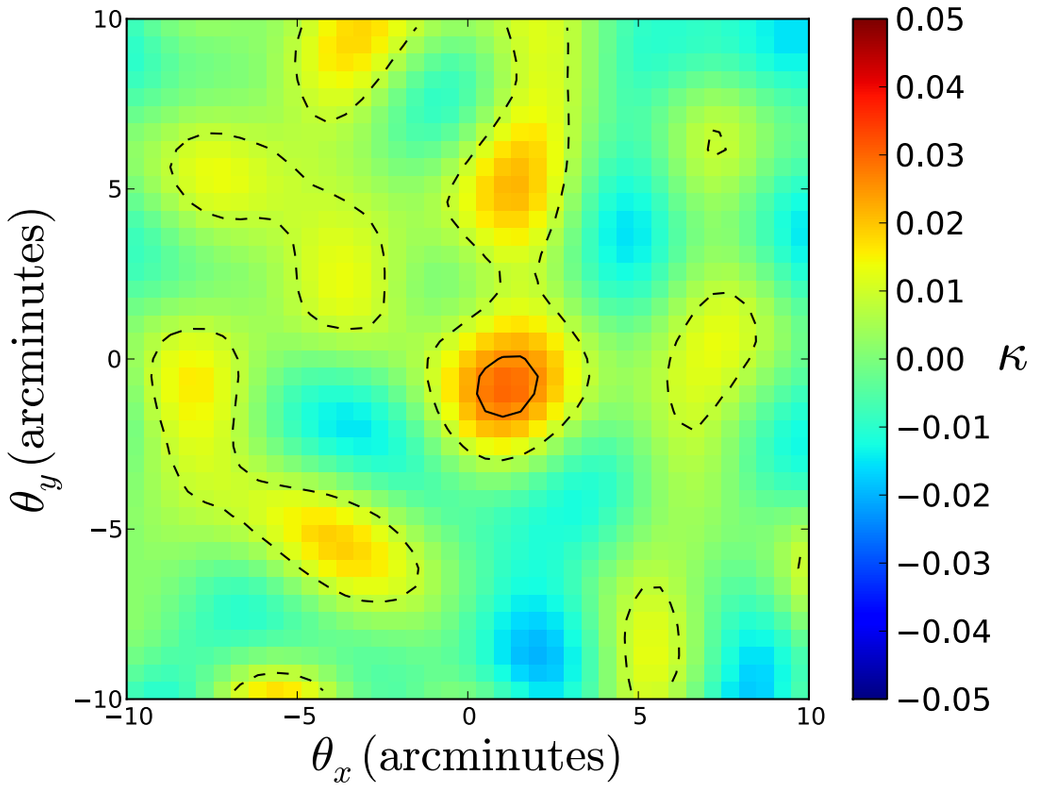
Miyatake et al., 2013
arXiv: 1311.1480

$$M_{200} = (2.3 \pm 0.1) \times 10^{13} h^{-1} M_\odot$$

ACTPol: First Detection of Lensing of the CMB by Dark Matter Halos

Madhavacheril, Sehgal, et. al., 2014, PRL in press, arXiv: 1411.7999





We detect halo lensing from 12,000 stacked CMASS galaxies at S/N of 3.2 sigma

Best fit: $M_{200} = (2.0 \pm 0.7) \times 10^{13} h^{-1} M_\odot$ and $c_{200} = 5.4 \pm 0.8$

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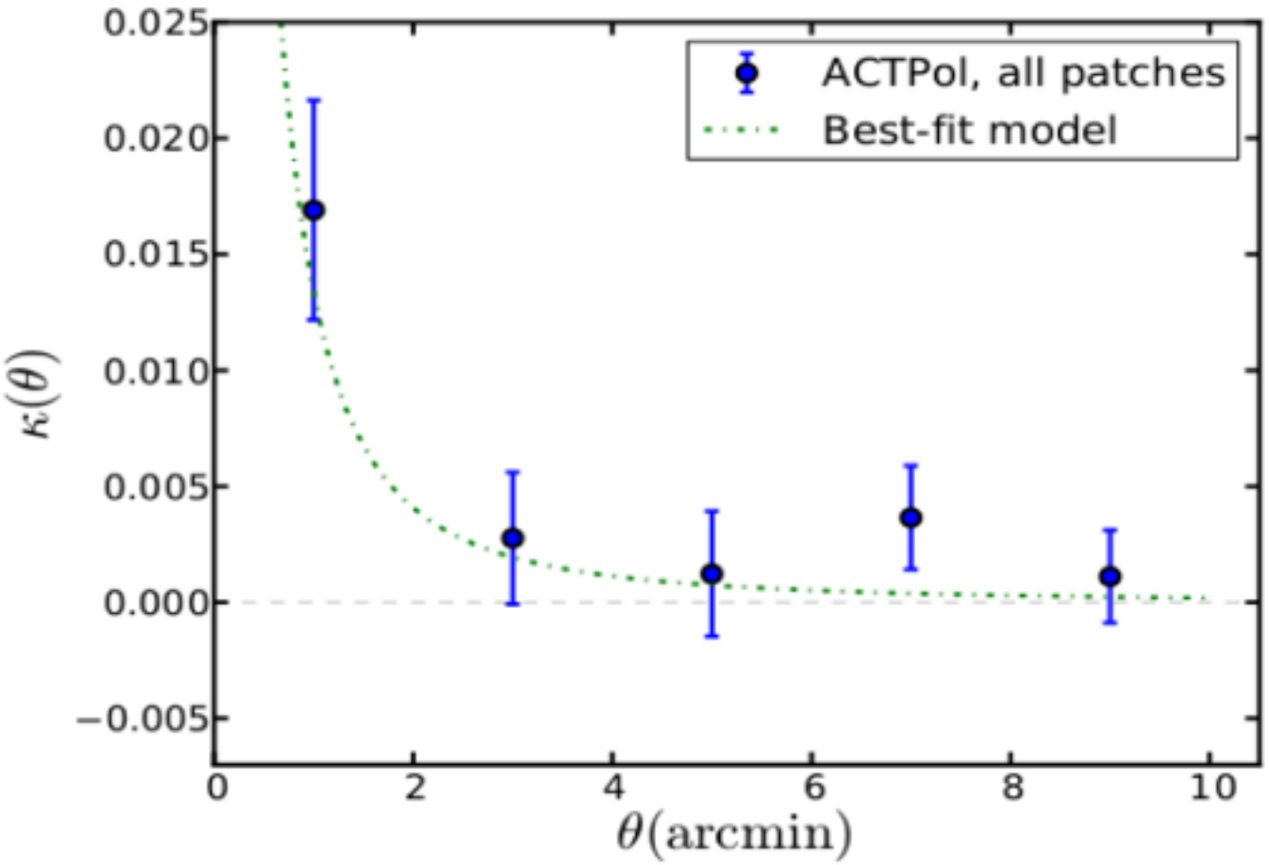

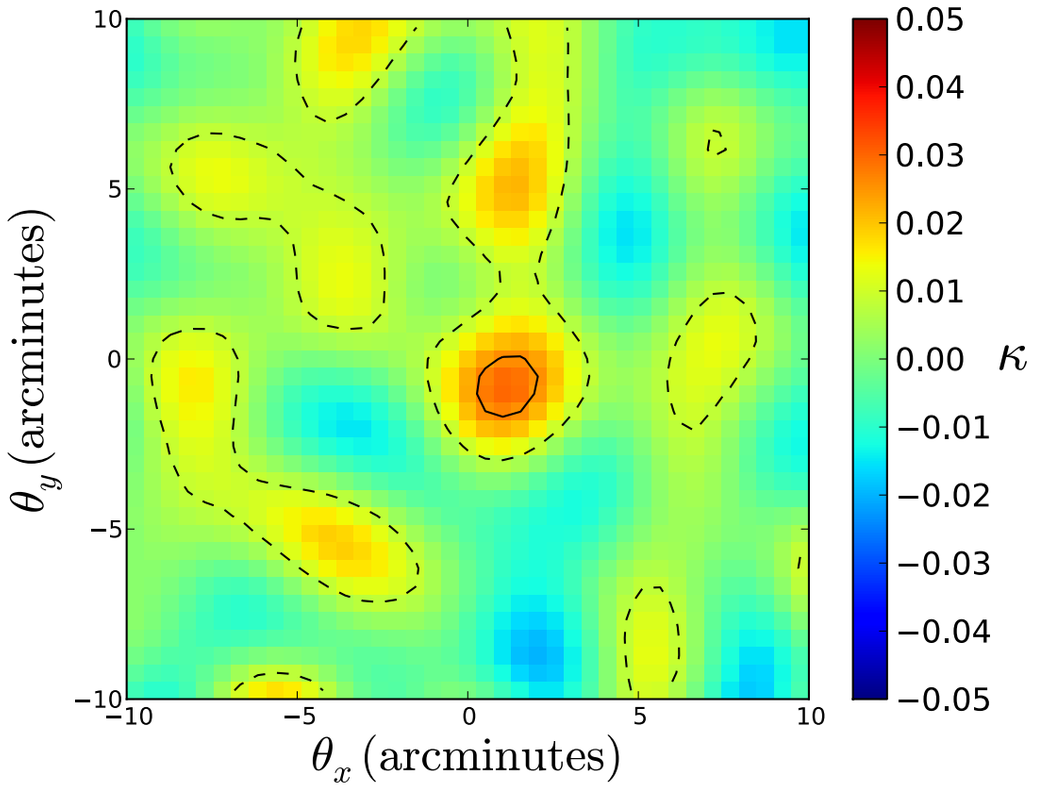

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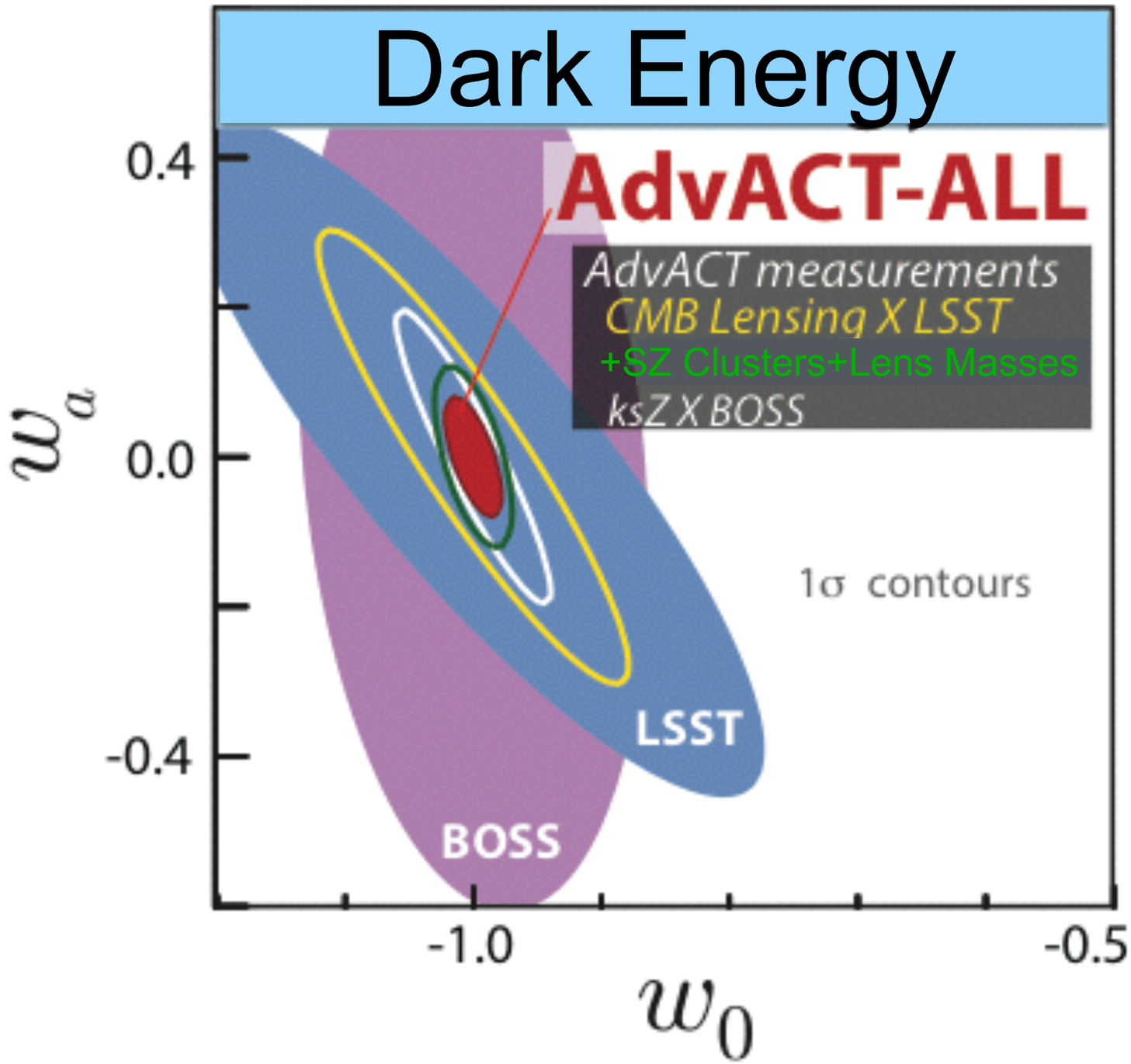
See Mathew Madhavacheril's talk on Friday

AdvACT: Dark Energy Forecast



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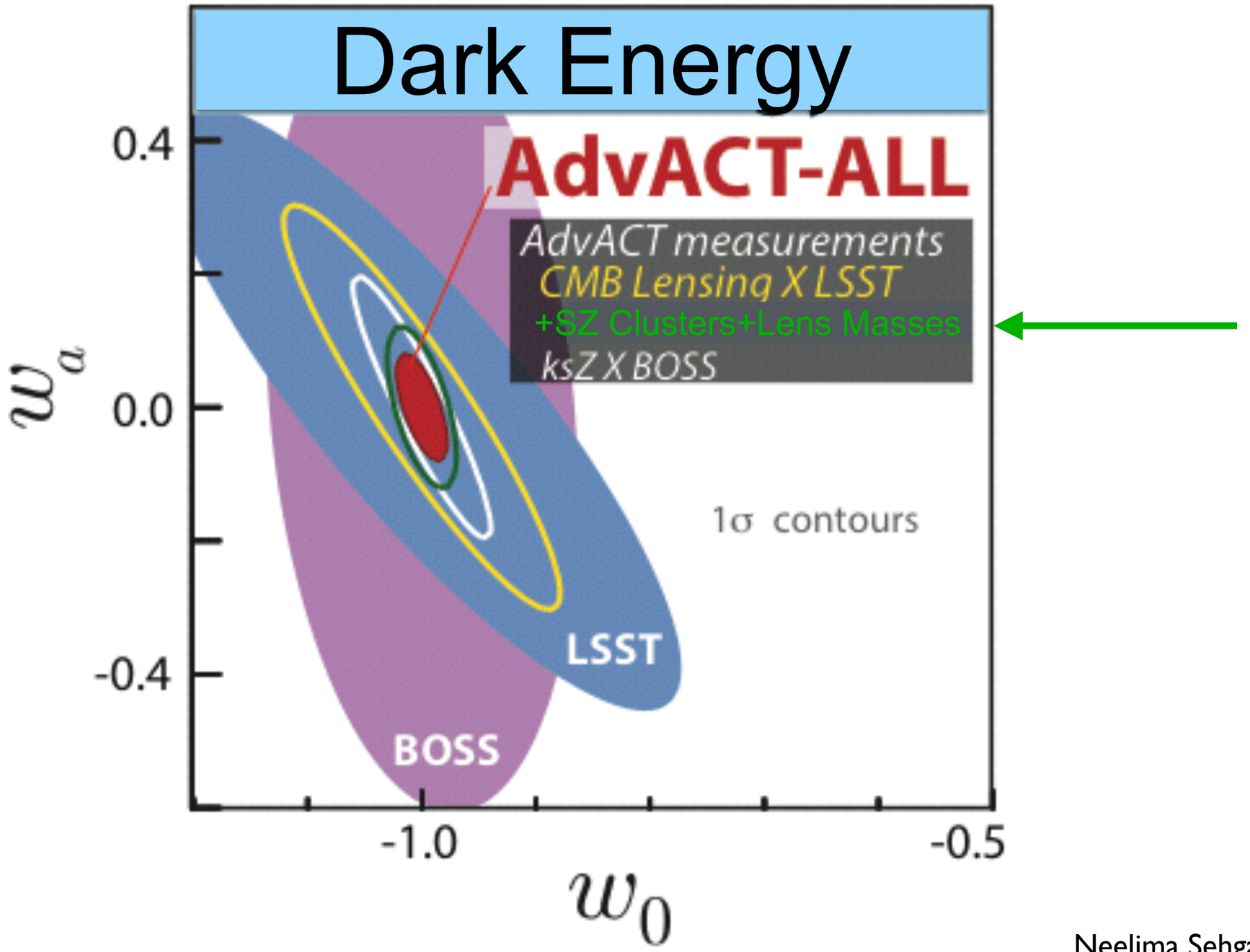

Outline

- Intro to ACTPol and AdvACT
- Neutrino Mass from CMB Lensing
- Primordial Gravity Waves and Delensing
- CMB Halo Lensing as a Probe of Dark Energy
- Conclusion

Conclusion

Conclusion

- ACTPol - 3rd year of observations now

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- AdvACT - observing next year, for 3 years

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Conclusion

- ACTPol - 3rd year of observations now
- AdvACT - observing next year, for 3 years
- Detect neutrino mass with CMB Lensing
- Probe r ~ 0.01 with AdvACT
- Many techniques to explore Dark Energy including new CMB Halo Lensing