

Cosmology with SPT-3G

Cail Daley

CosmoStat, CEA Paris-Saclay

Séminaire postdoc du DAp

March 11, 2025

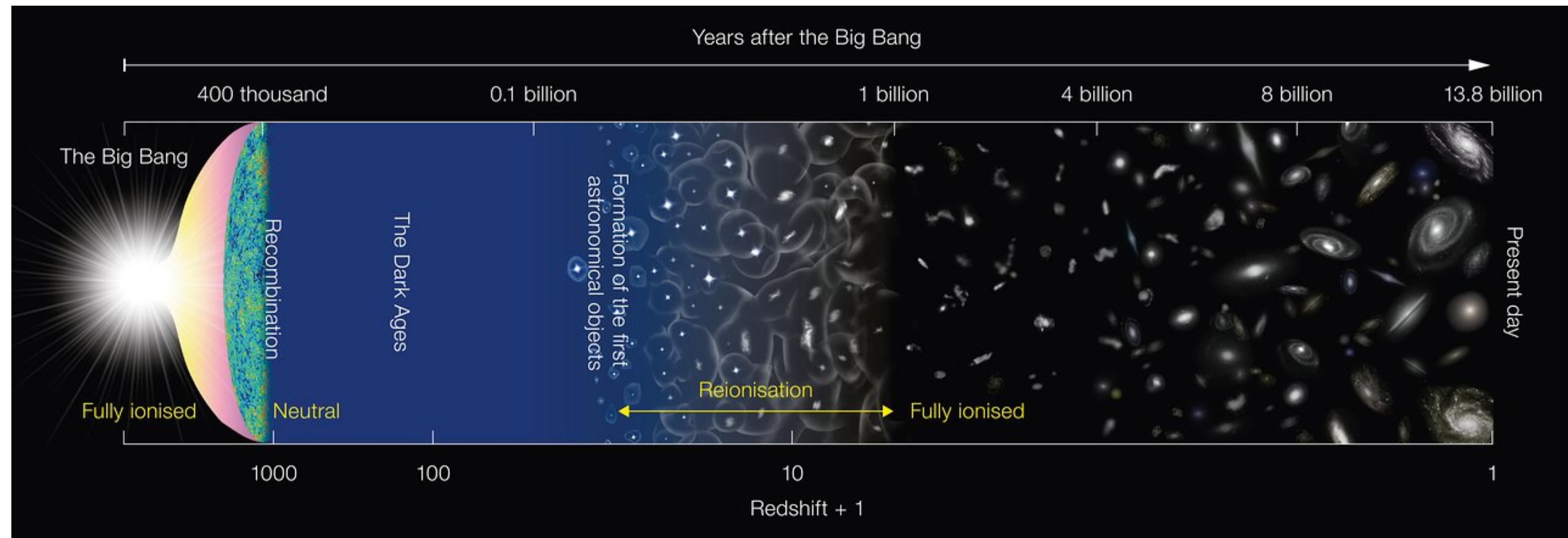


Outline

- Cosmology with the Cosmic Microwave Background (CMB)
- The South Pole Telescope (SPT) and the SPT-3G camera
- Recent and upcoming 2019+2020 SPT-3G results
- Cross-correlations with Euclid

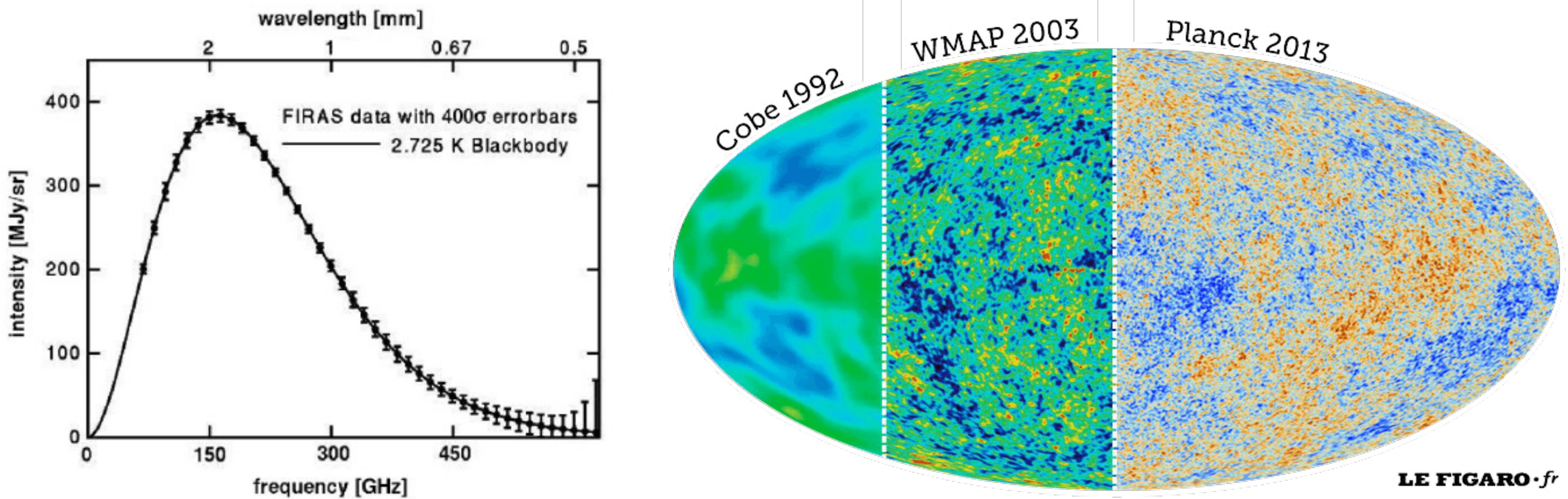
Cosmology with the CMB

most distant observable electromagnetic radiation \implies early-Universe physics
illuminates the Universe's evolution: reionization, structure growth, astrophysics..



NAOJ

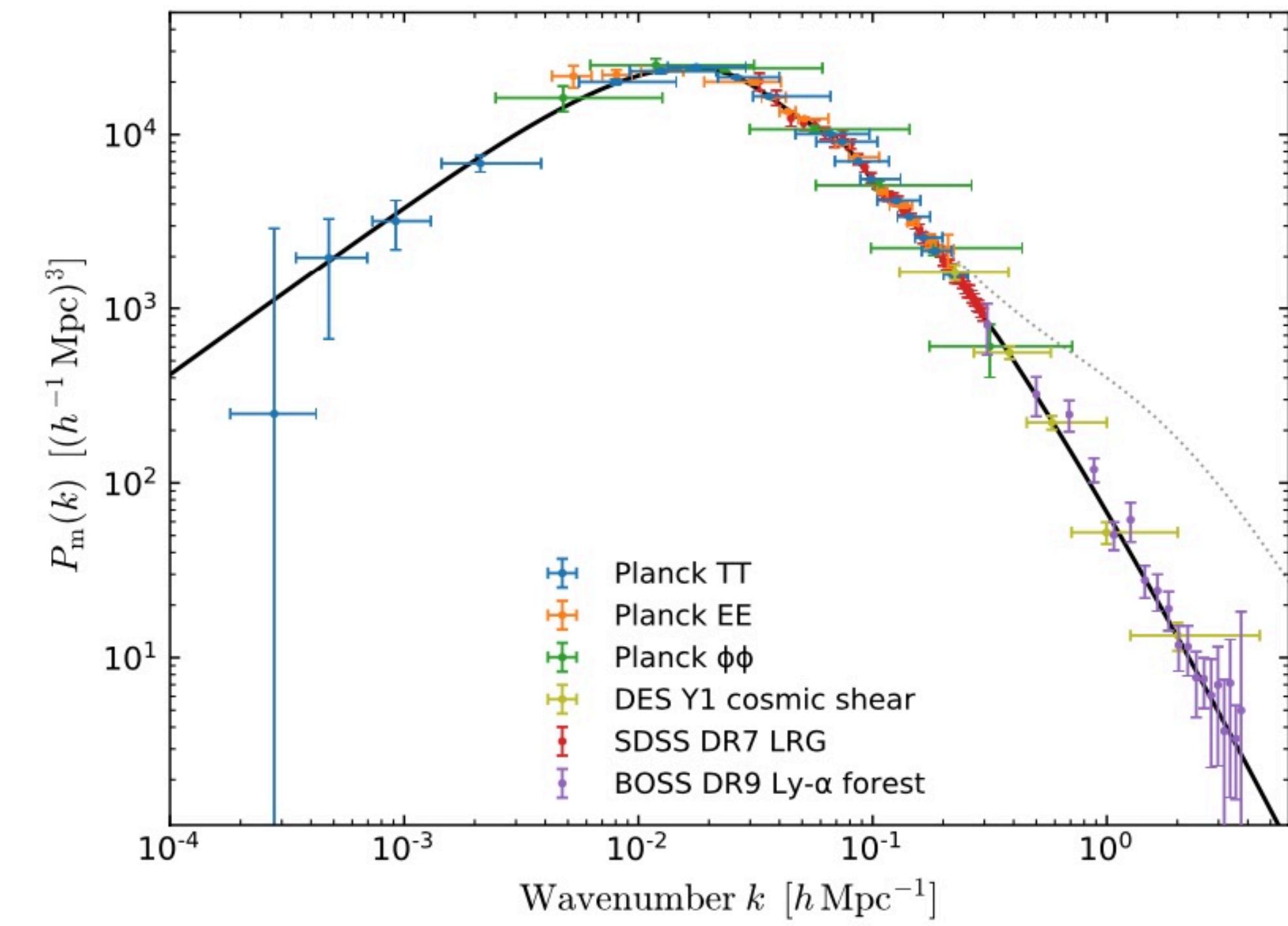
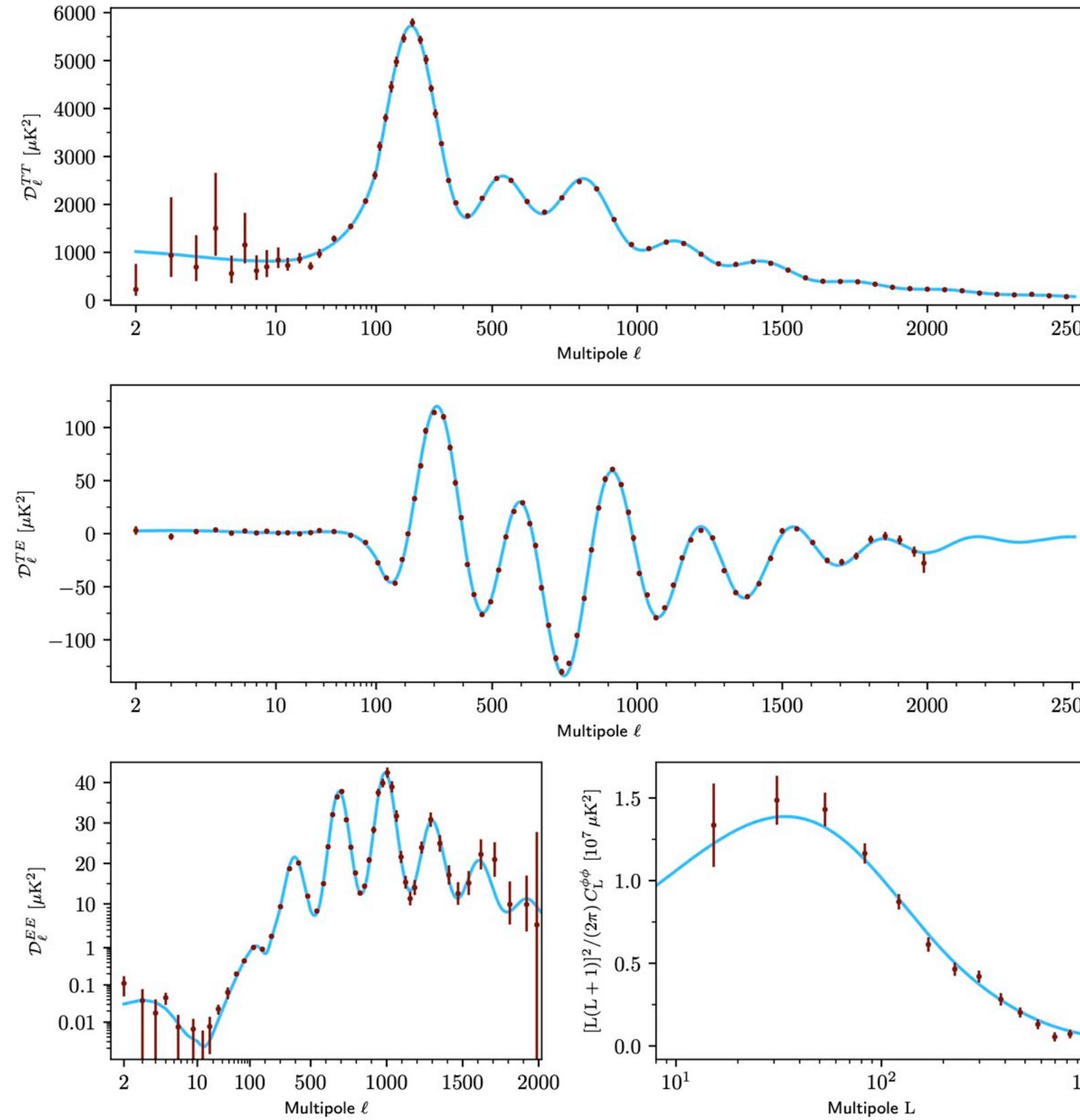
Cosmology with the CMB



Turner (2022): [The Road to Precision Cosmology](#)

Λ CDM Concordance

six-parameter model predicts a wide range of cosmic observables:

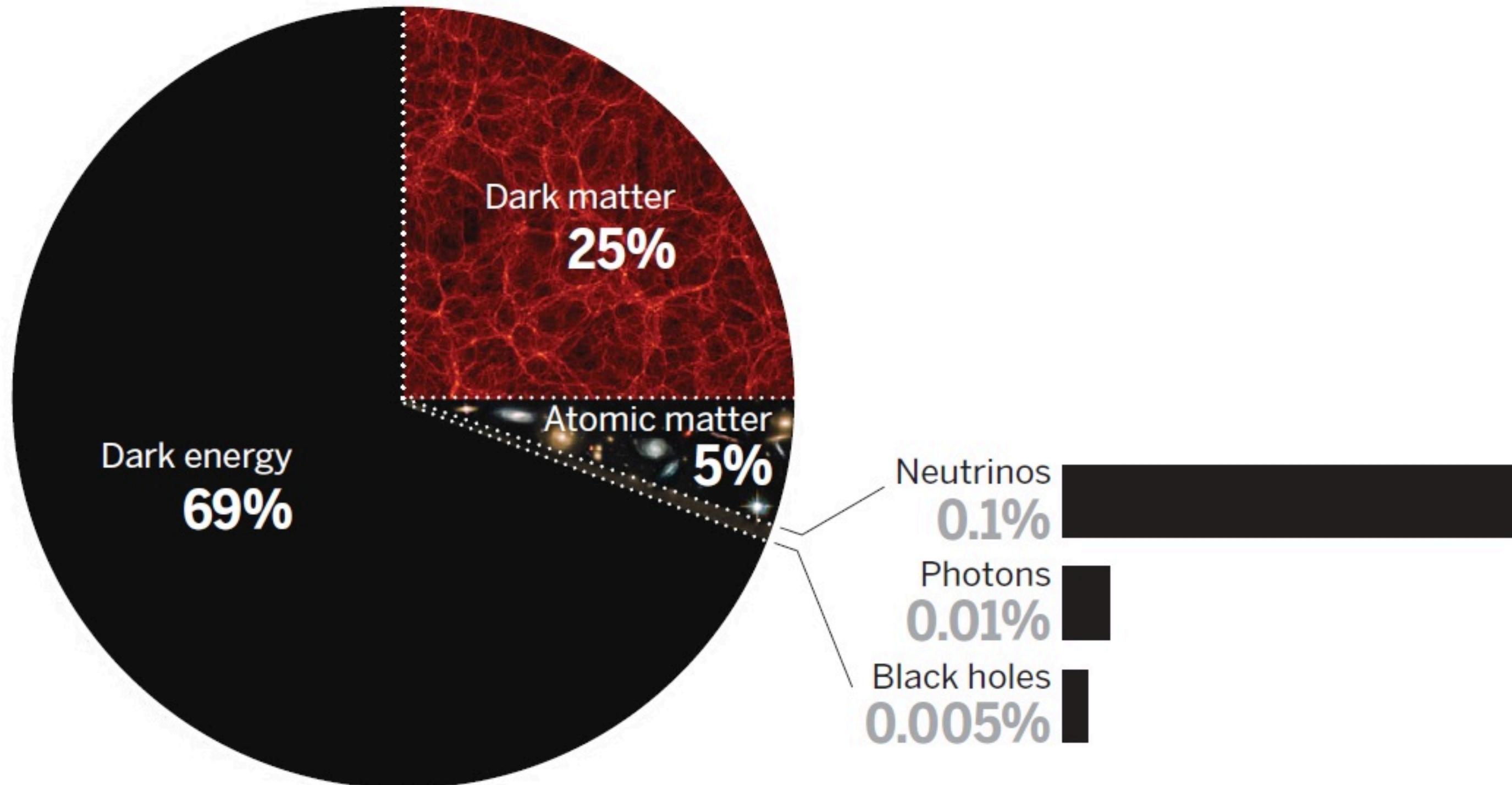


Planck Collaboration (2018)

Λ CDM Phenomenology

The multiple components that compose our universe

Current composition (as the fractions evolve with time)

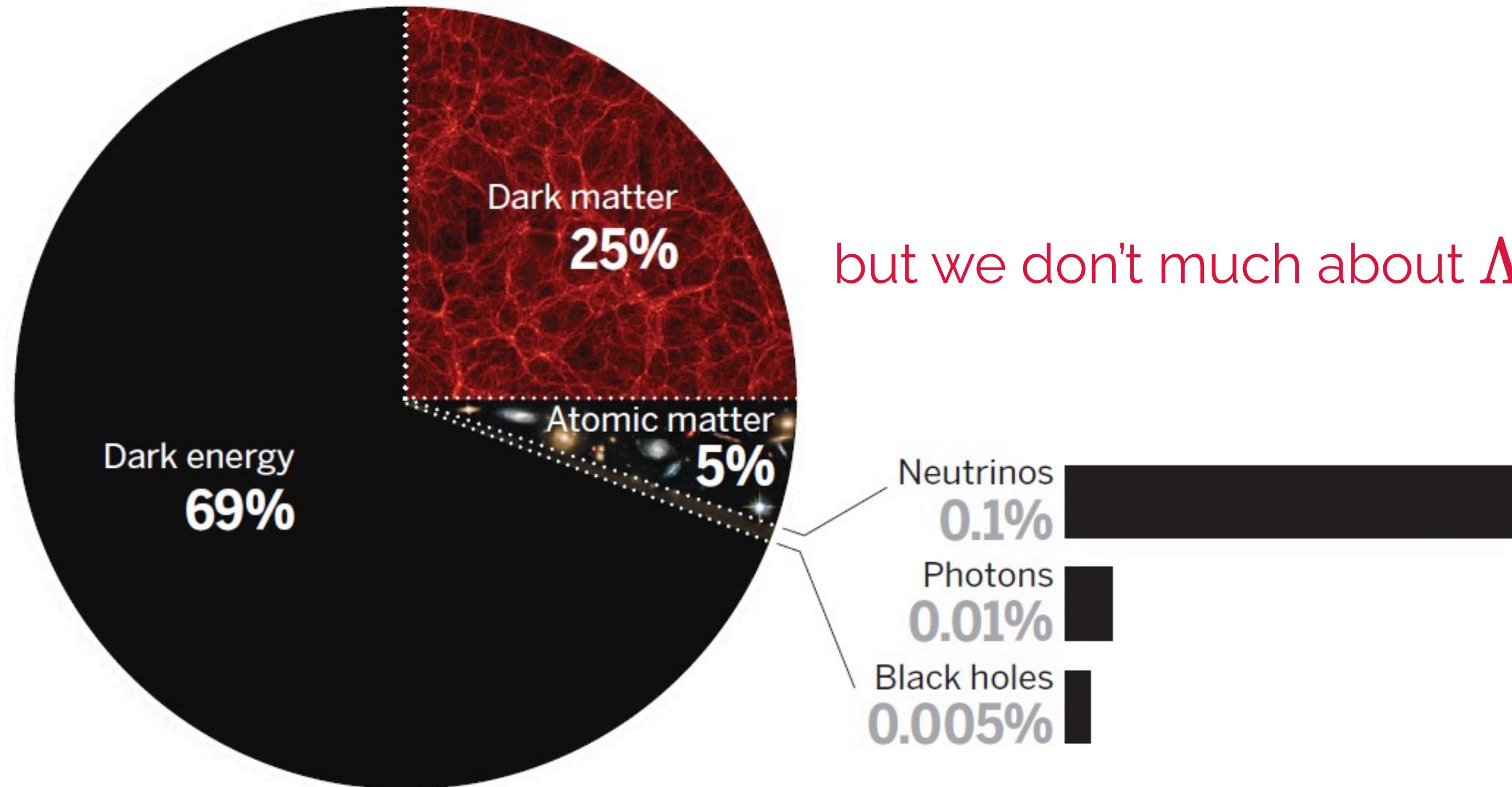


David Spergel / AAAS / Science

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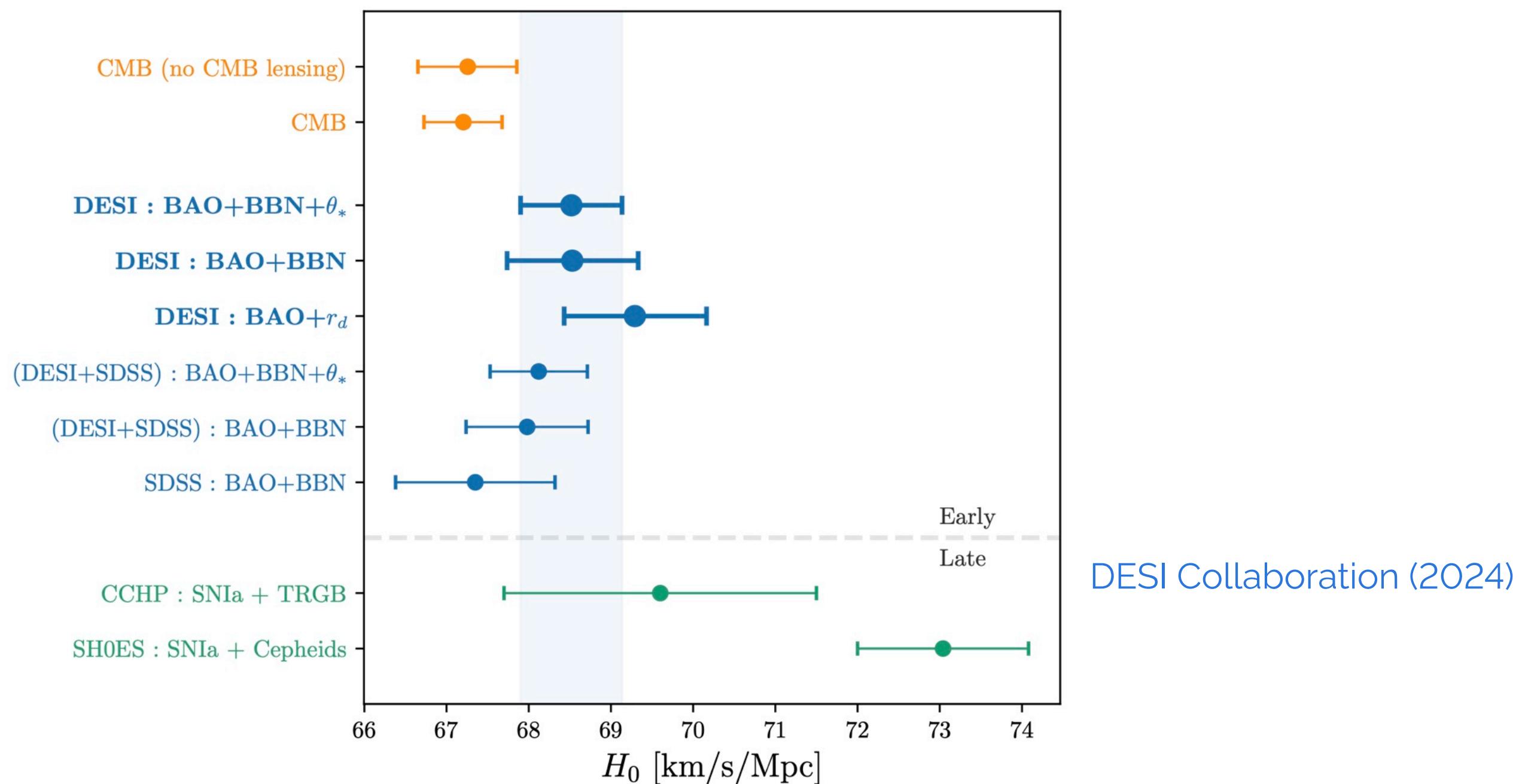


but we don't much about Λ or CDM!

David Spergel / AAAS / Science

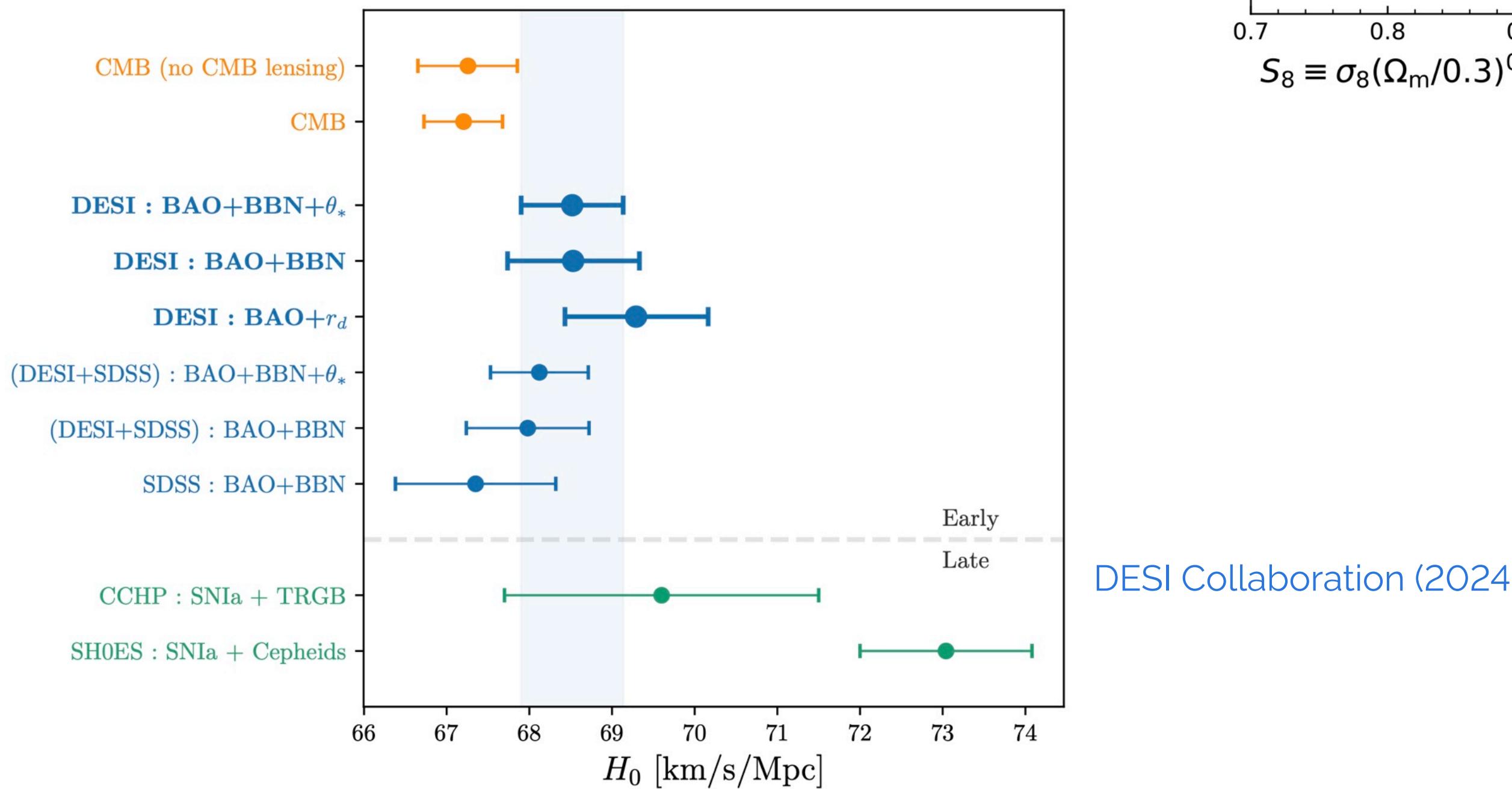
Λ CDM Cracks

- Tensions between early- and late-time measurements of H_0

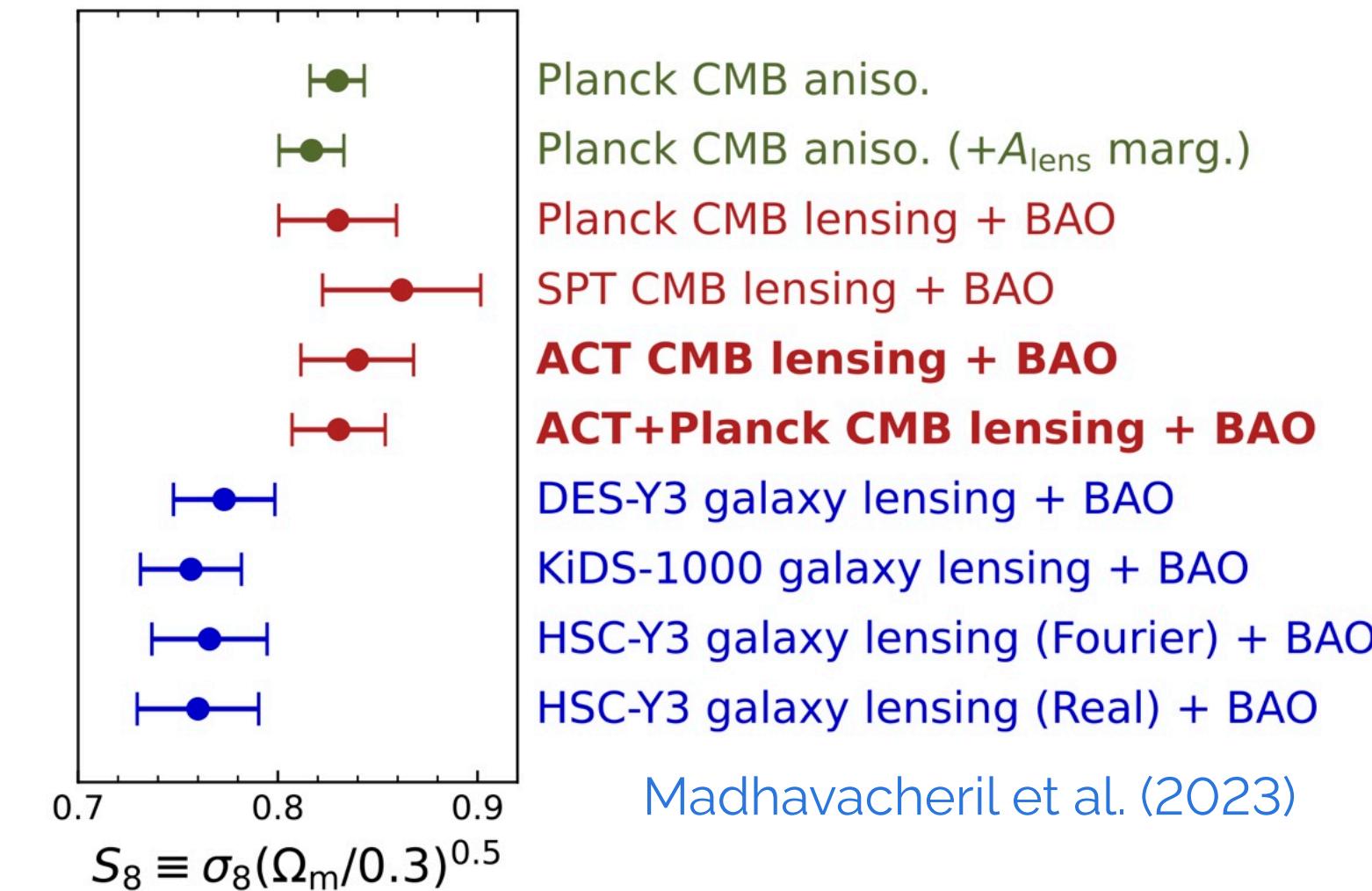


Λ CDM Cracks

- Tensions between early- and late-time measurements of H_0 and S_8 :



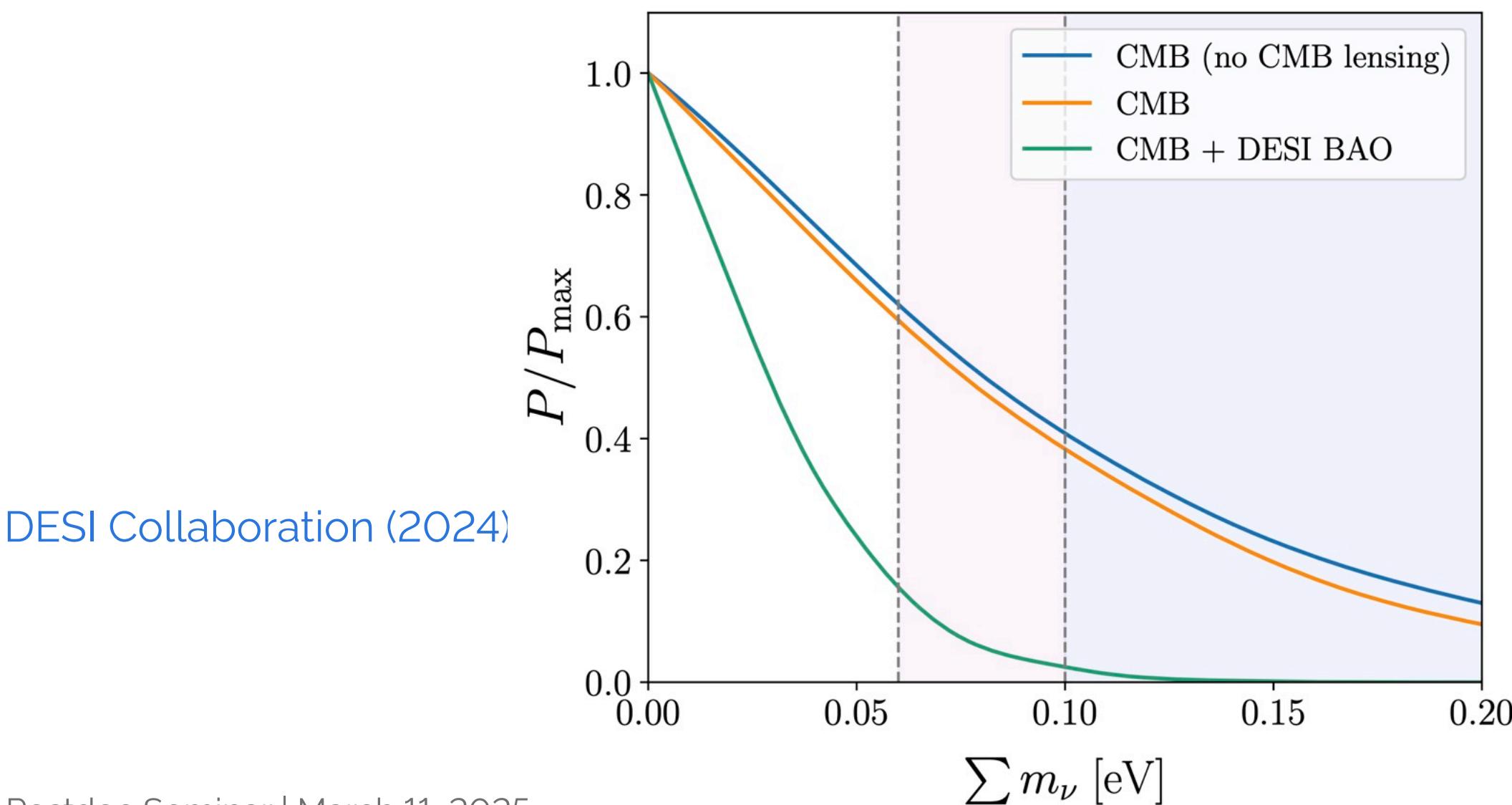
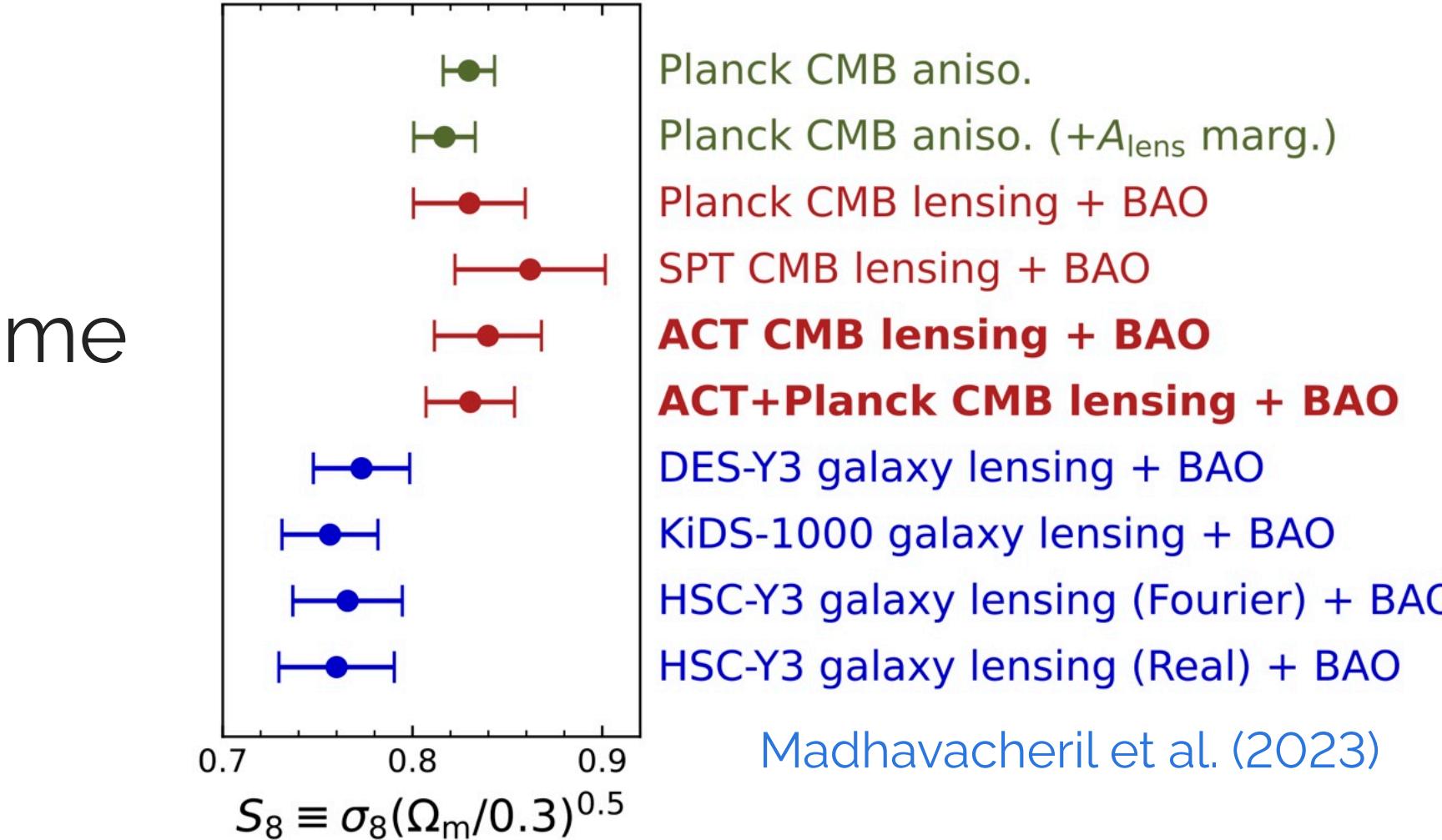
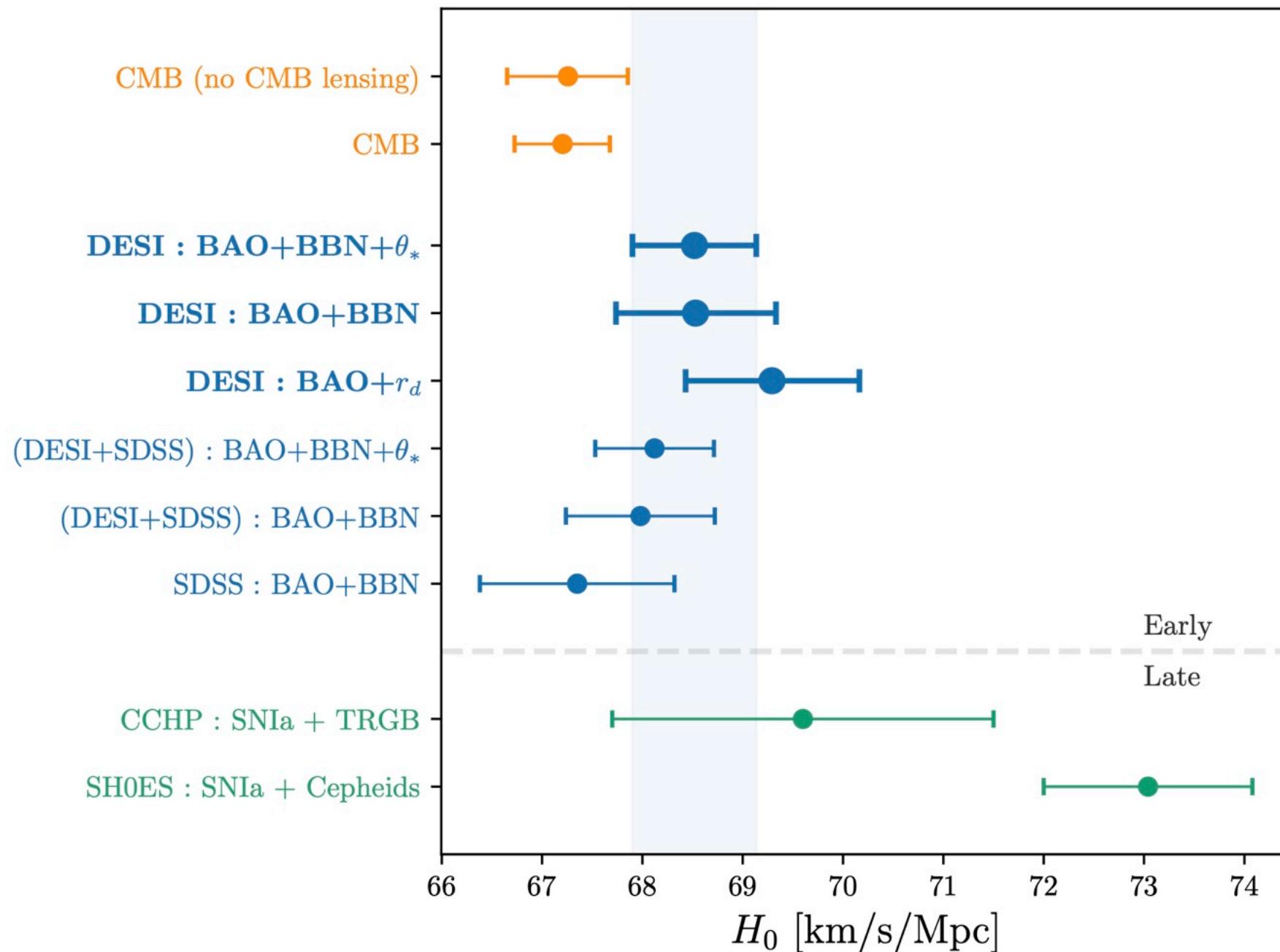
DESI Collaboration (2024)



Madhavacheril et al. (2023)

Λ CDM Cracks

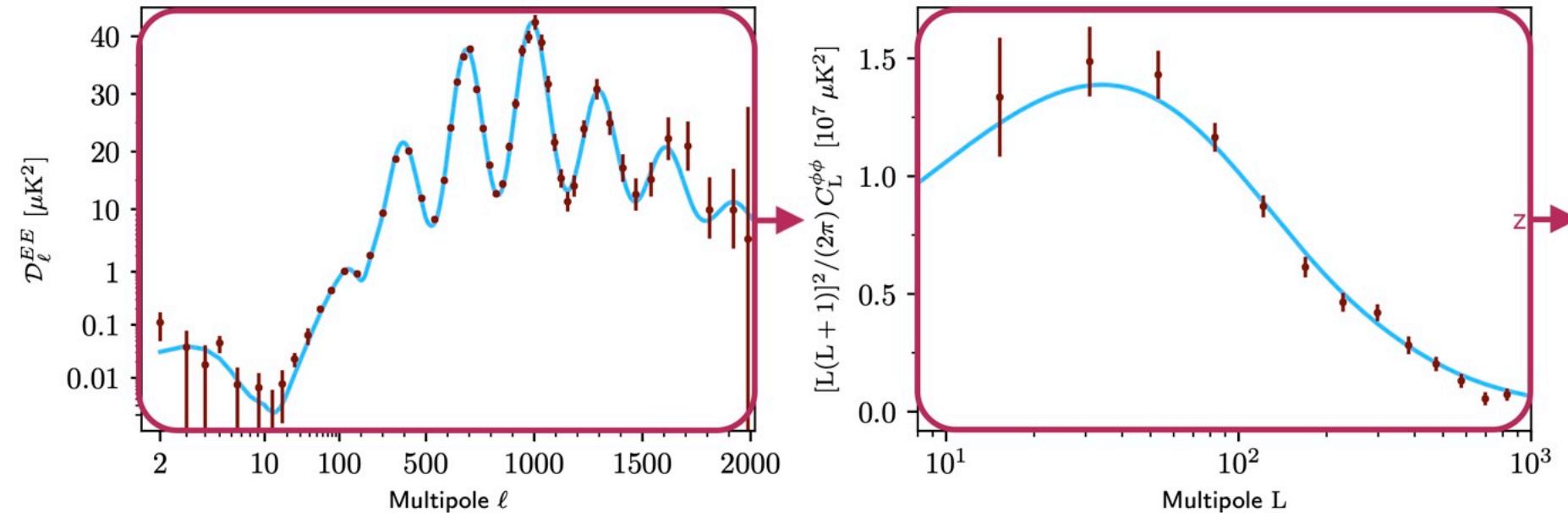
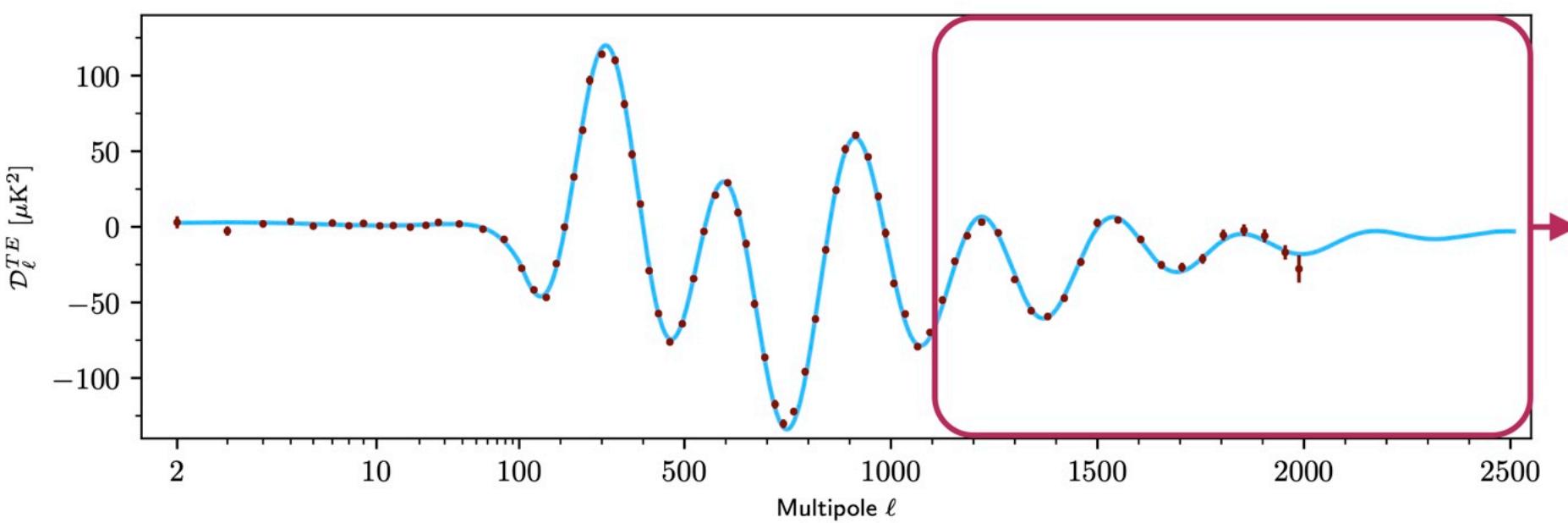
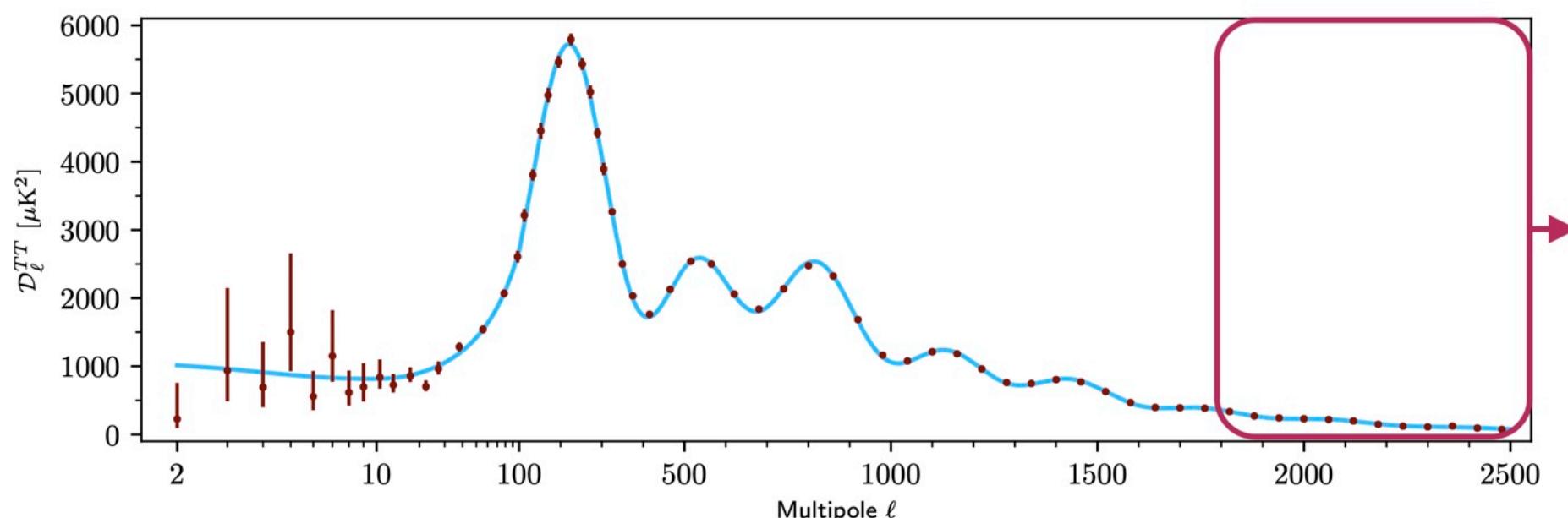
- Tensions between early- and late-time measurements of H_0 and S_8 :
- Low neutrino masses?



The CMB Beyond Planck

Planck is **noise-variance-limited** beyond:

- $\ell > 1800$ in TT, $\ell > 1100$ in TE;
- **everywhere** in EE and lensing ($\phi\phi$).



The CMB Beyond Planck

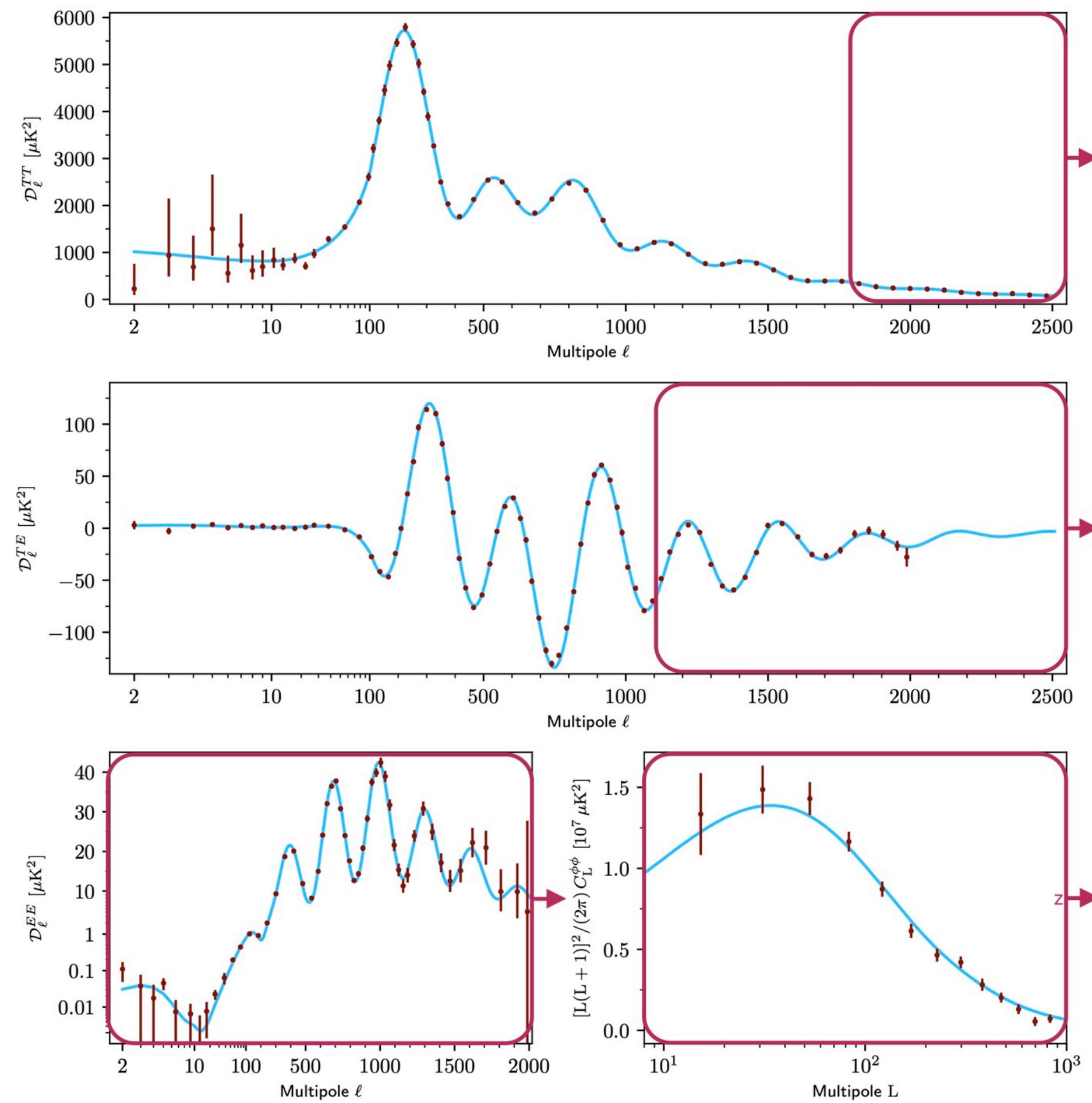
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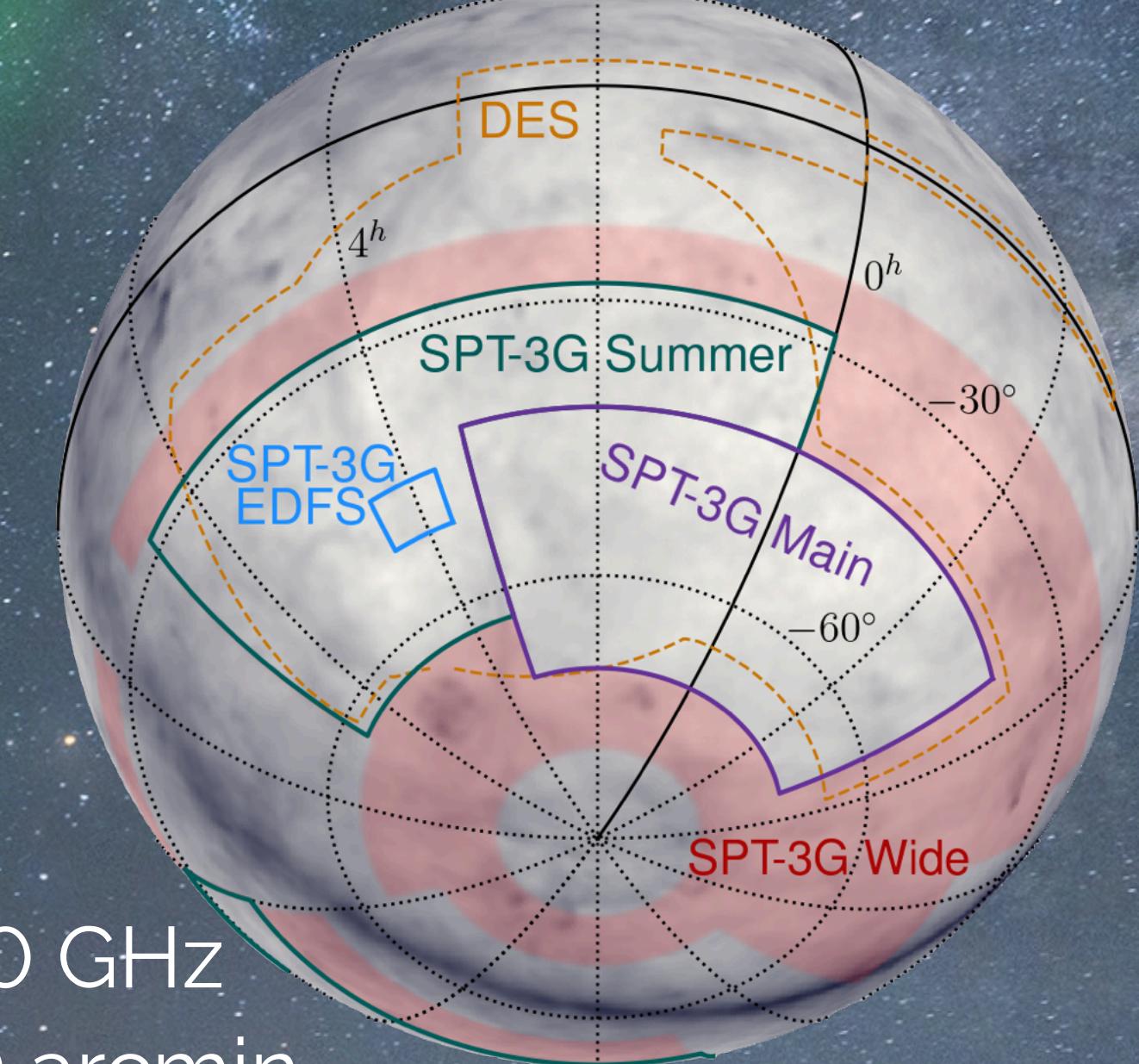


	f_{sky} (effective)	resolution (arcmin)	sensitivity ($\mu\text{K}\text{-arcmin}$)
Planck	0.67	5.0	27
ACT	0.23	1.0	12
SPT	0.035	1.0	1.9
B/K	0.014	21	3

*crude summary of CMB experiments



The South Pole Telescope



3 bands: 95, 150, 220 GHz
resolution: 1.6, 1.2, 1.0 arcmin

SPT-SZ (2007)
~1000 detectors

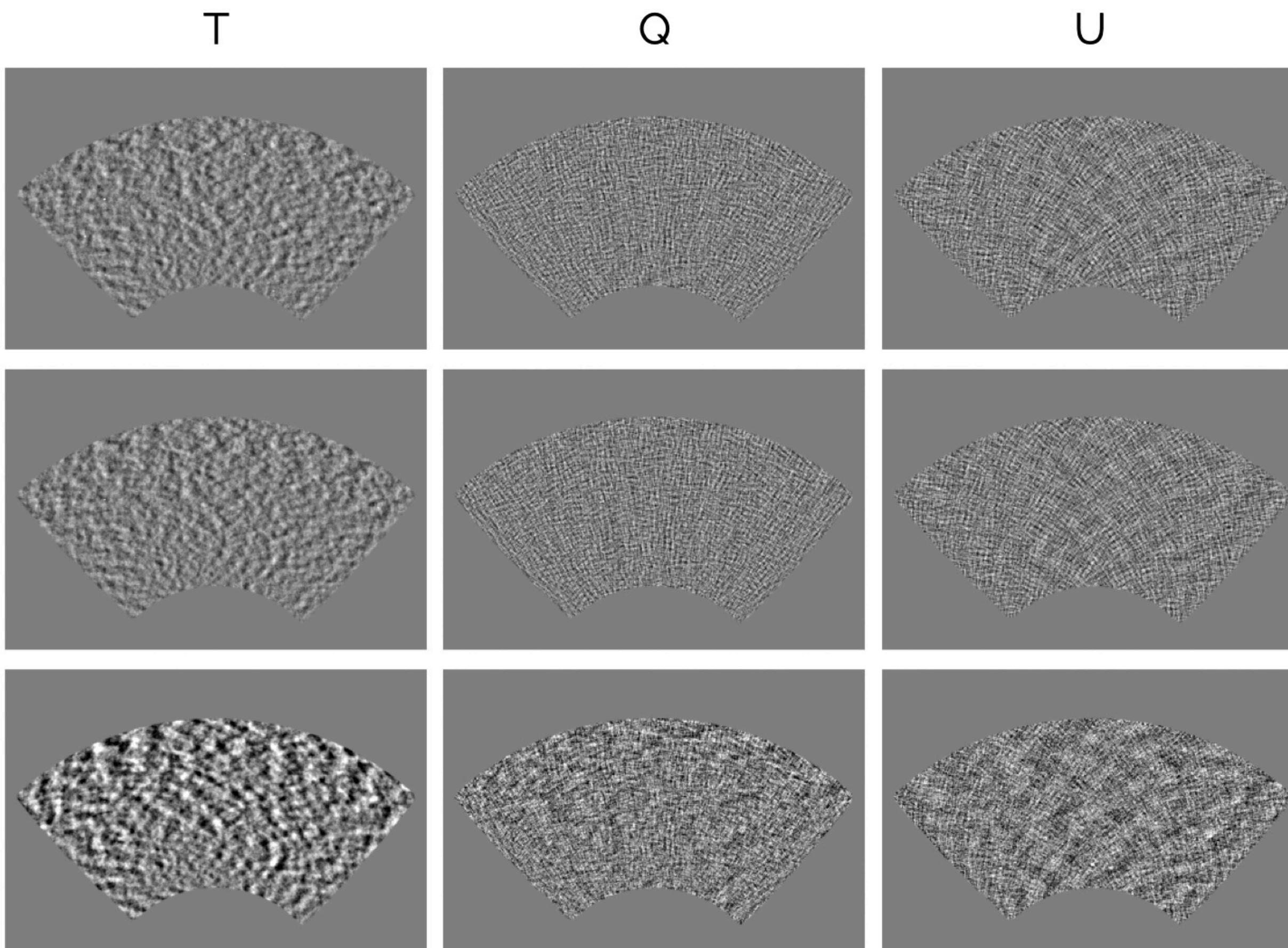
SPTpol (2012)
~1500 detectors

SPT-3G (2017)
~16,000 detectors



2019+2020 Analyses

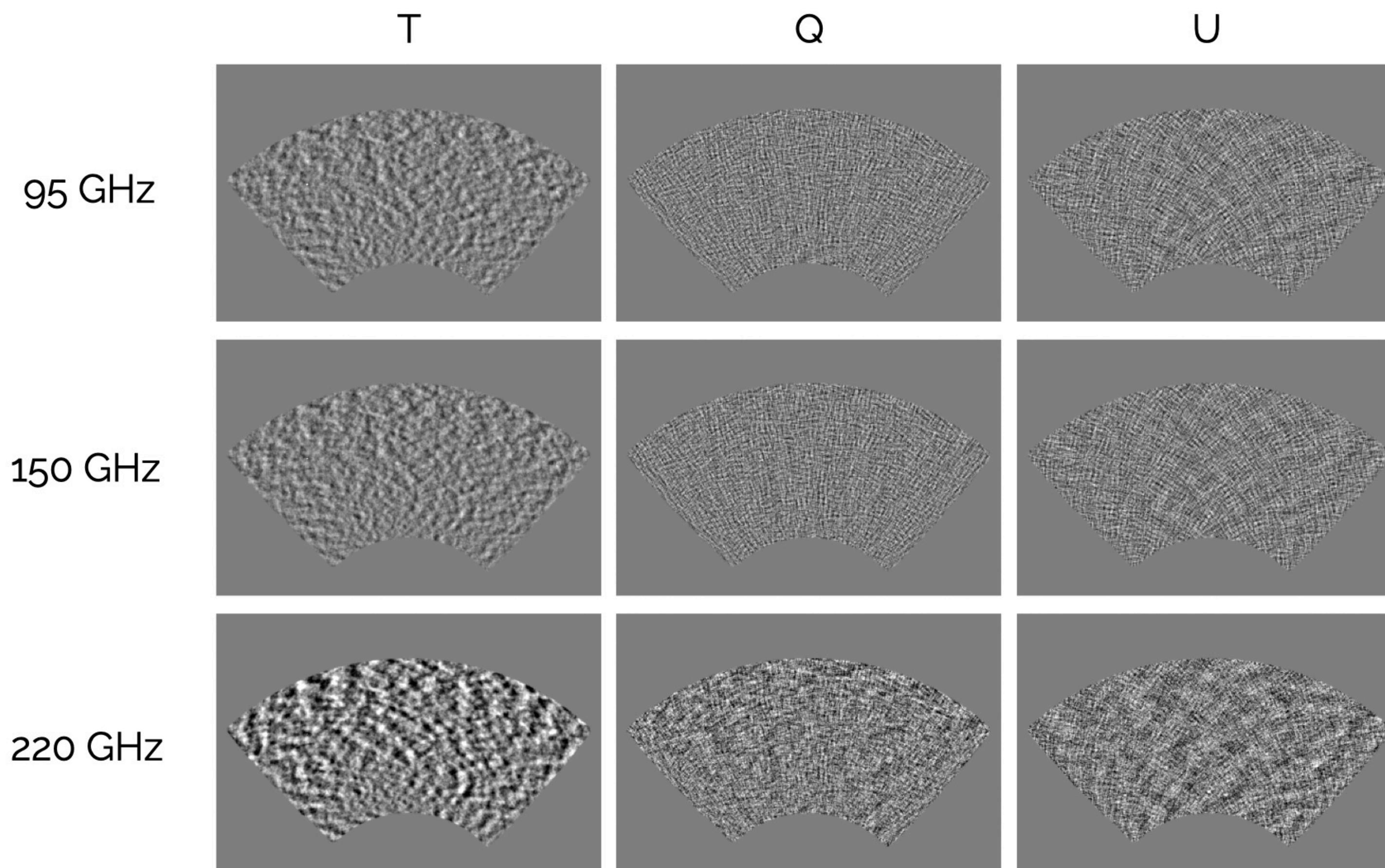
Maps used by three independent pipelines:



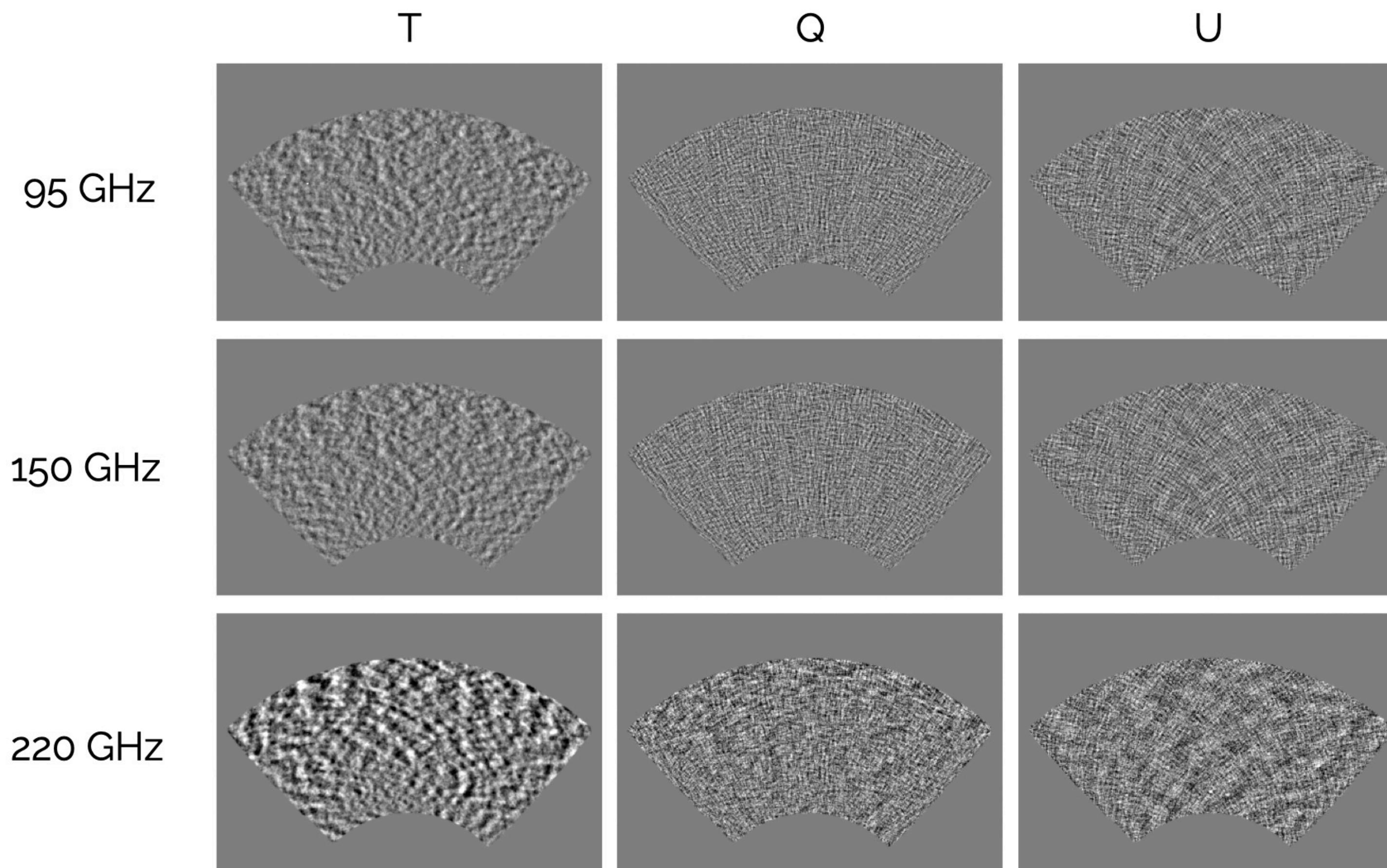
2019+2020 Analyses

Maps used by three independent pipelines:

1. Traditional TT/TE/EE power spectrum



2019+2020 Analyses

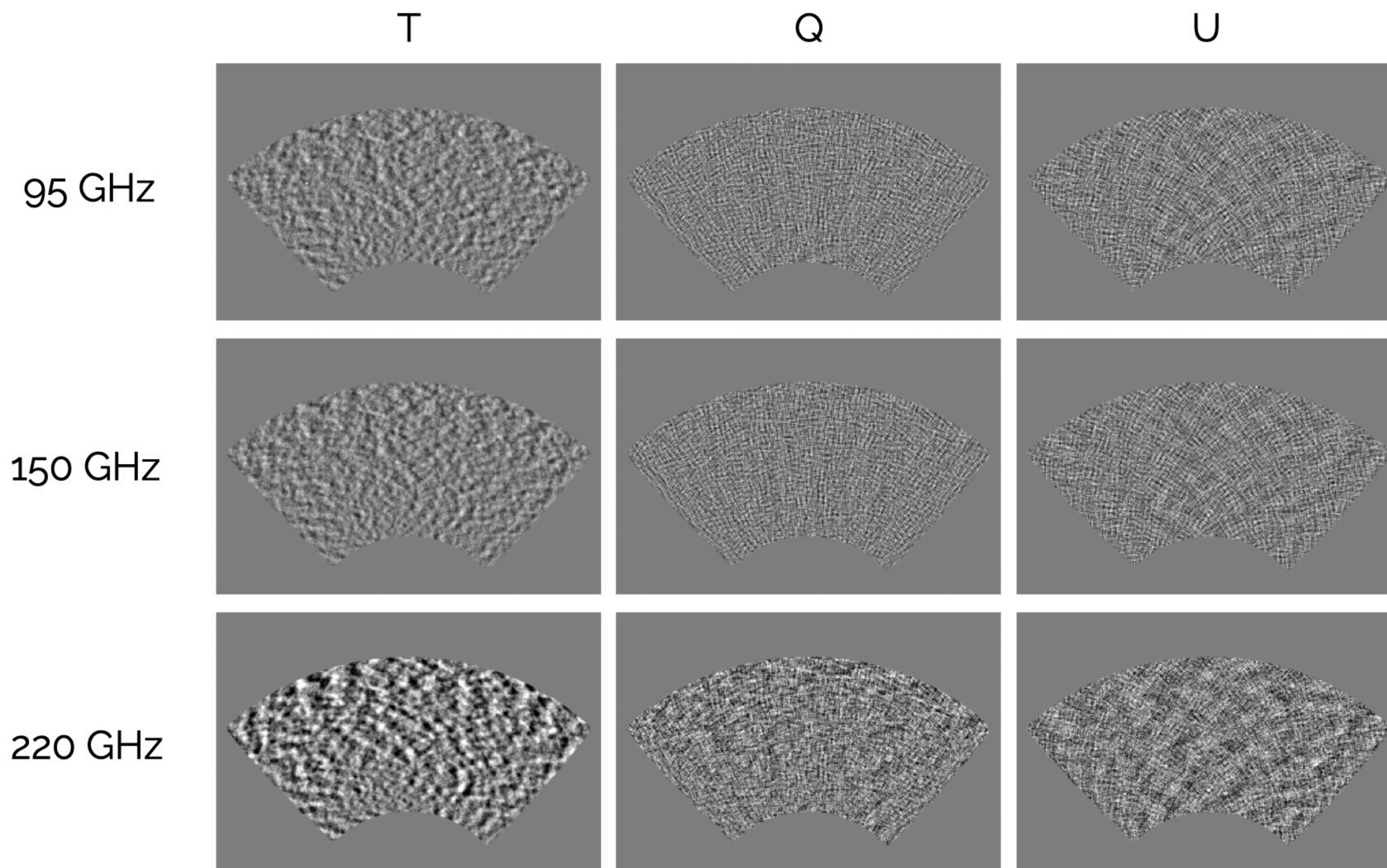


Maps used by three independent pipelines:

1. Traditional TT/TE/EE power spectrum

2. Traditional quadratic estimator (QE) lensing

2019+2020 Analyses



Maps used by three independent pipelines:

1. Traditional TT/TE/EE power spectrum
2. Traditional quadratic estimator (QE) lensing
3. MUSE: Bayesian joint inference of cosmology, systematics, and pixels

MUSE

(Marginal Unbiased Score Expansion)

Accepted as of last week! [arxiv:2411.06000](https://arxiv.org/abs/2411.06000)



Fei Ge



Marius Millea

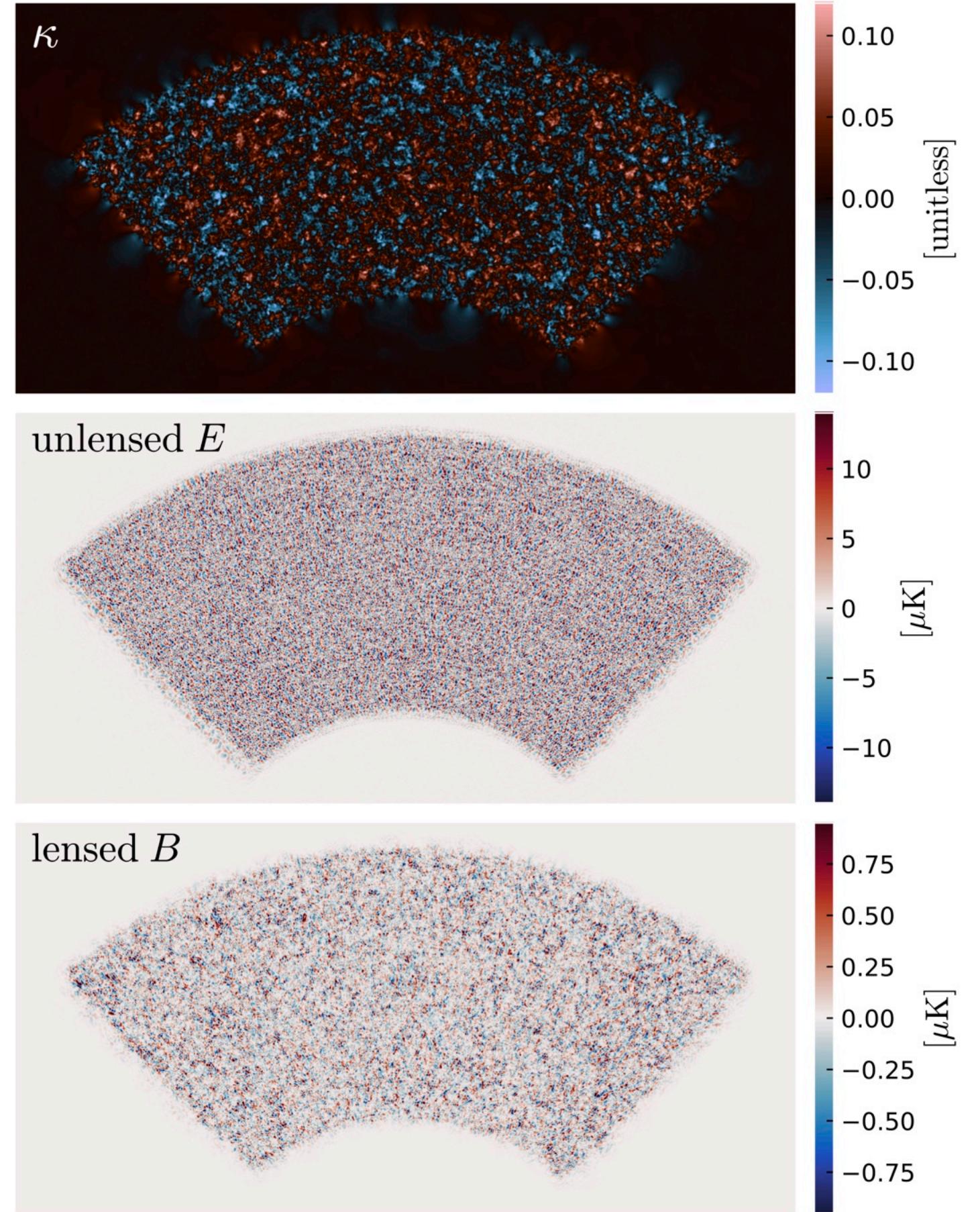
MUSE

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Marginalize over CMB f and lensing ϕ maps/pixels to determine parameters θ :

$$\mathcal{P}(\theta \mid d) = \int df d\phi \mathcal{P}(f, \phi, \theta \mid d)$$



MUSE

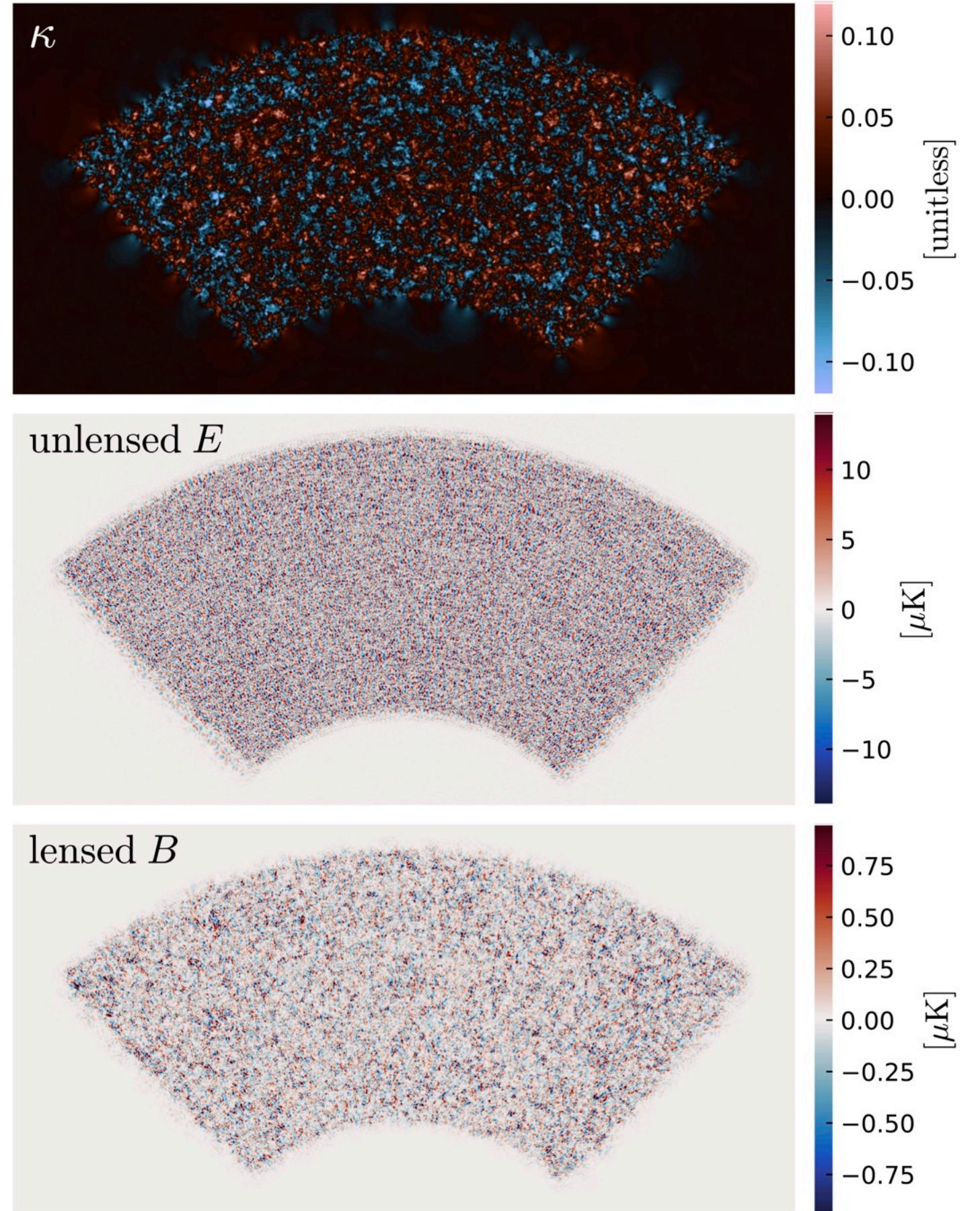
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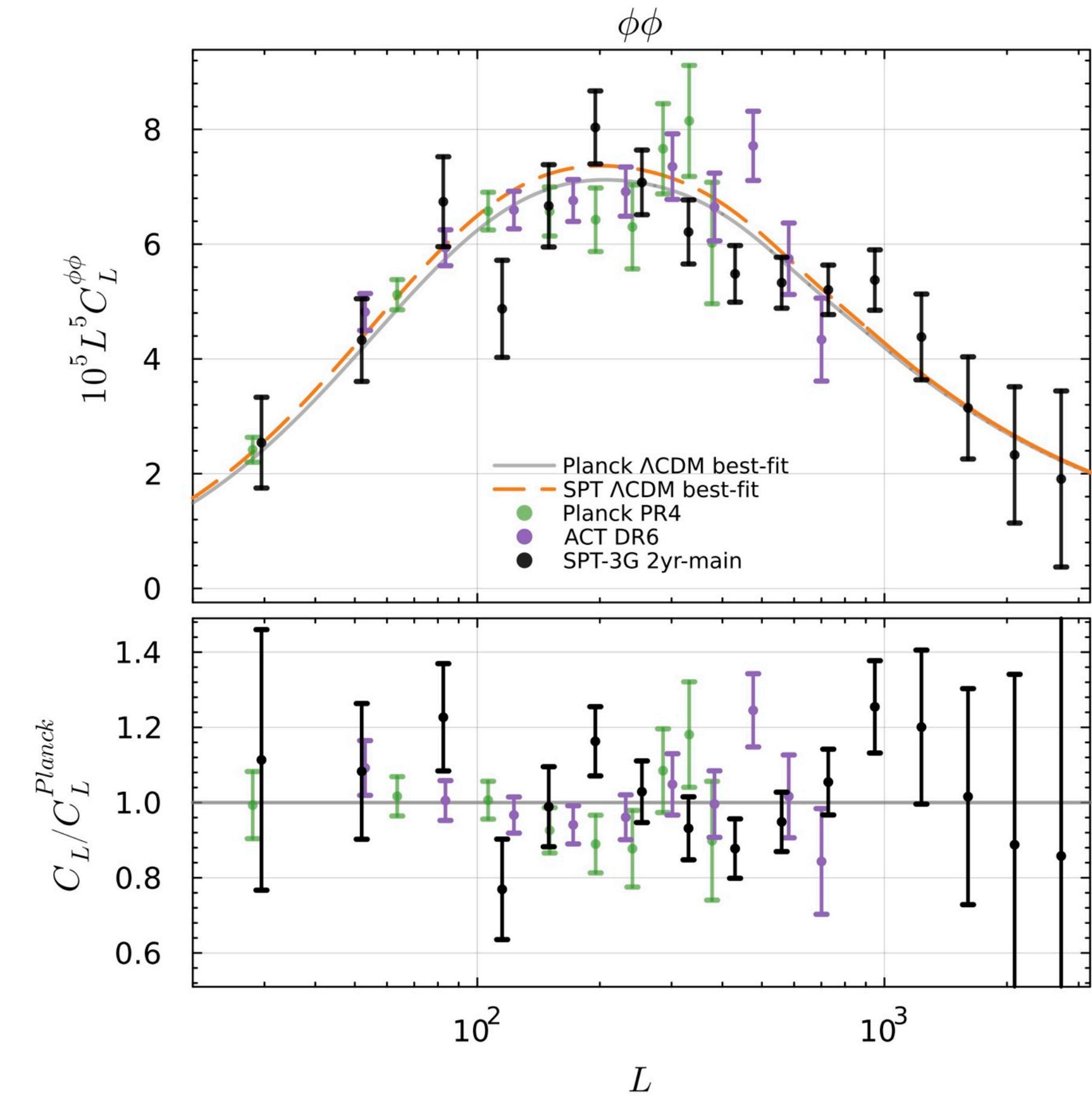
$$\mathcal{P}(\theta \mid d) = \int df d\phi \mathcal{P}(f, \phi, \theta \mid d)$$

Algorithm similar to simulation-based inference (SBI) with semi-analytic compression statistic.



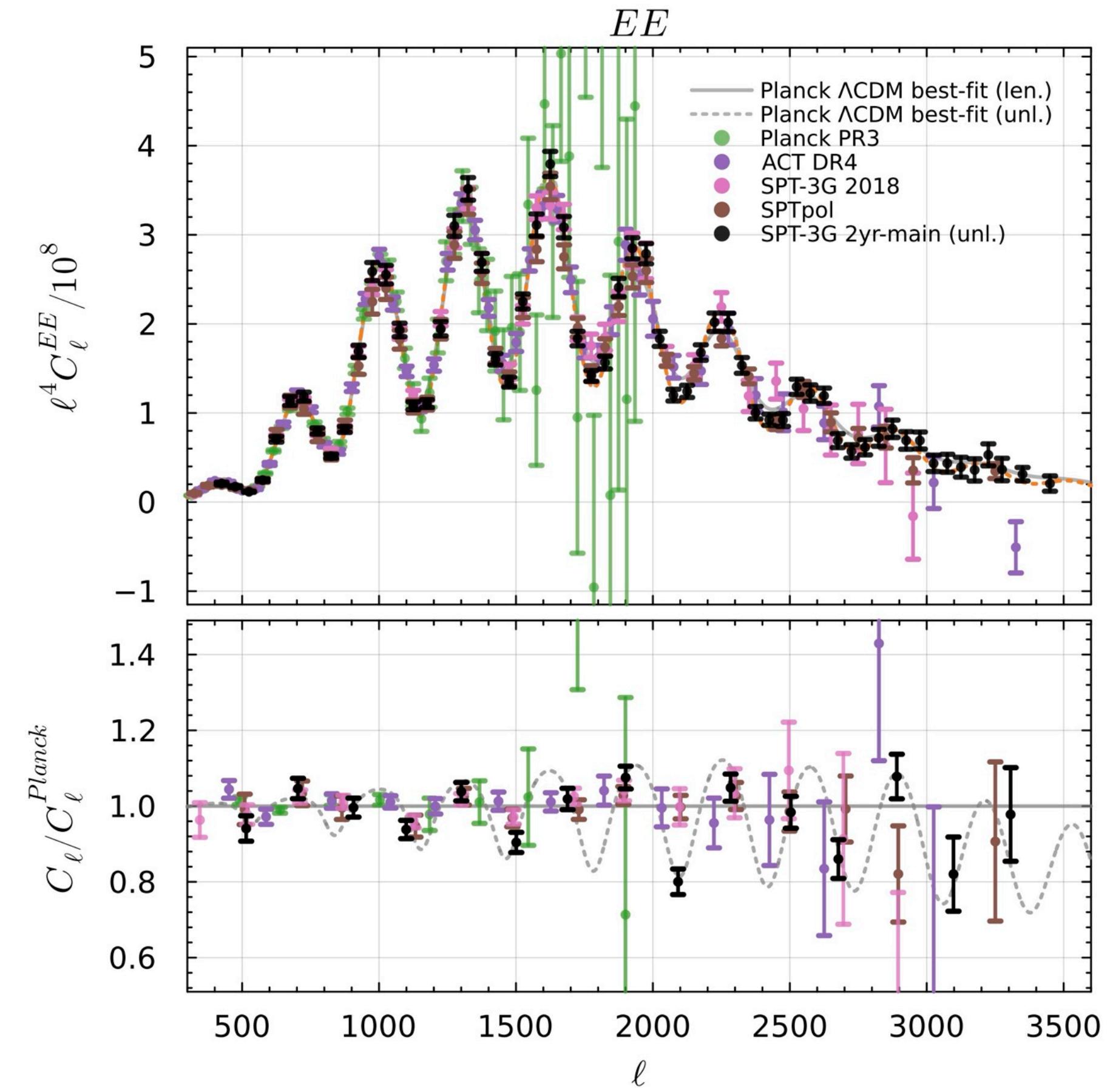
MUSE Results: Bandpowers

EE & $\phi\phi$ bandpowers in agreement
with Λ CDM and Planck.



MUSE Results: Bandpowers

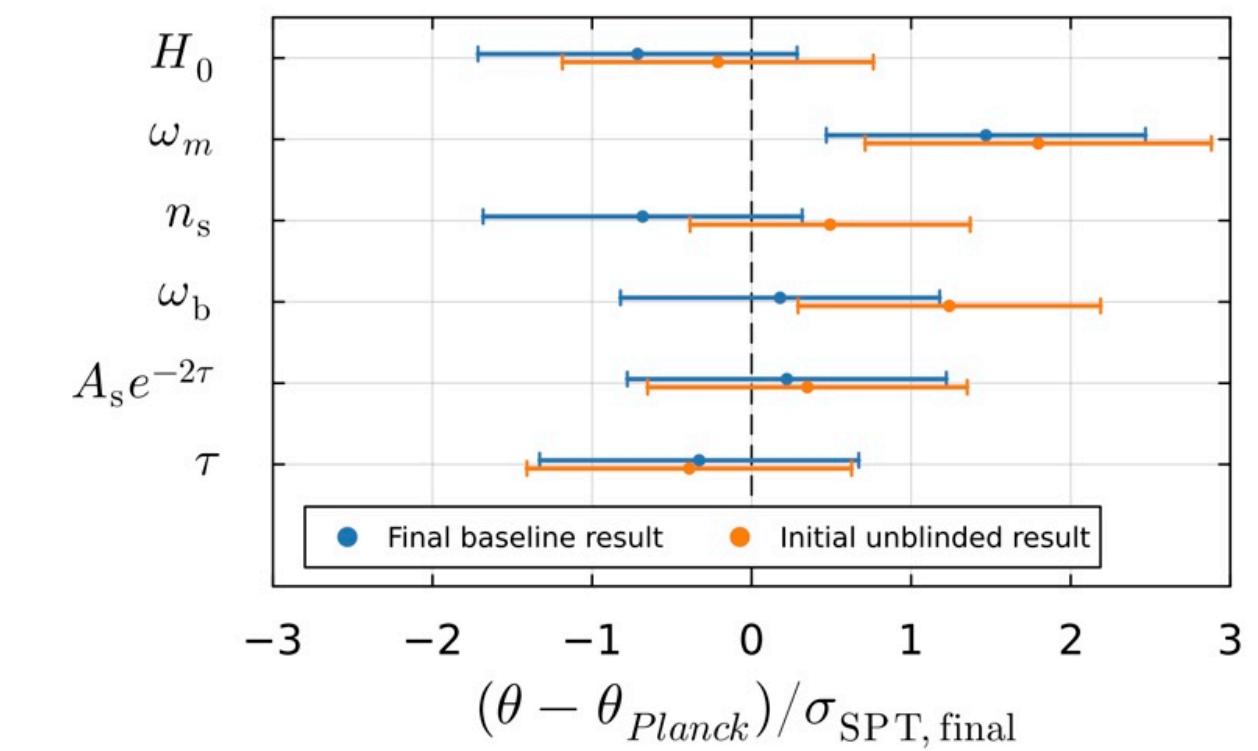
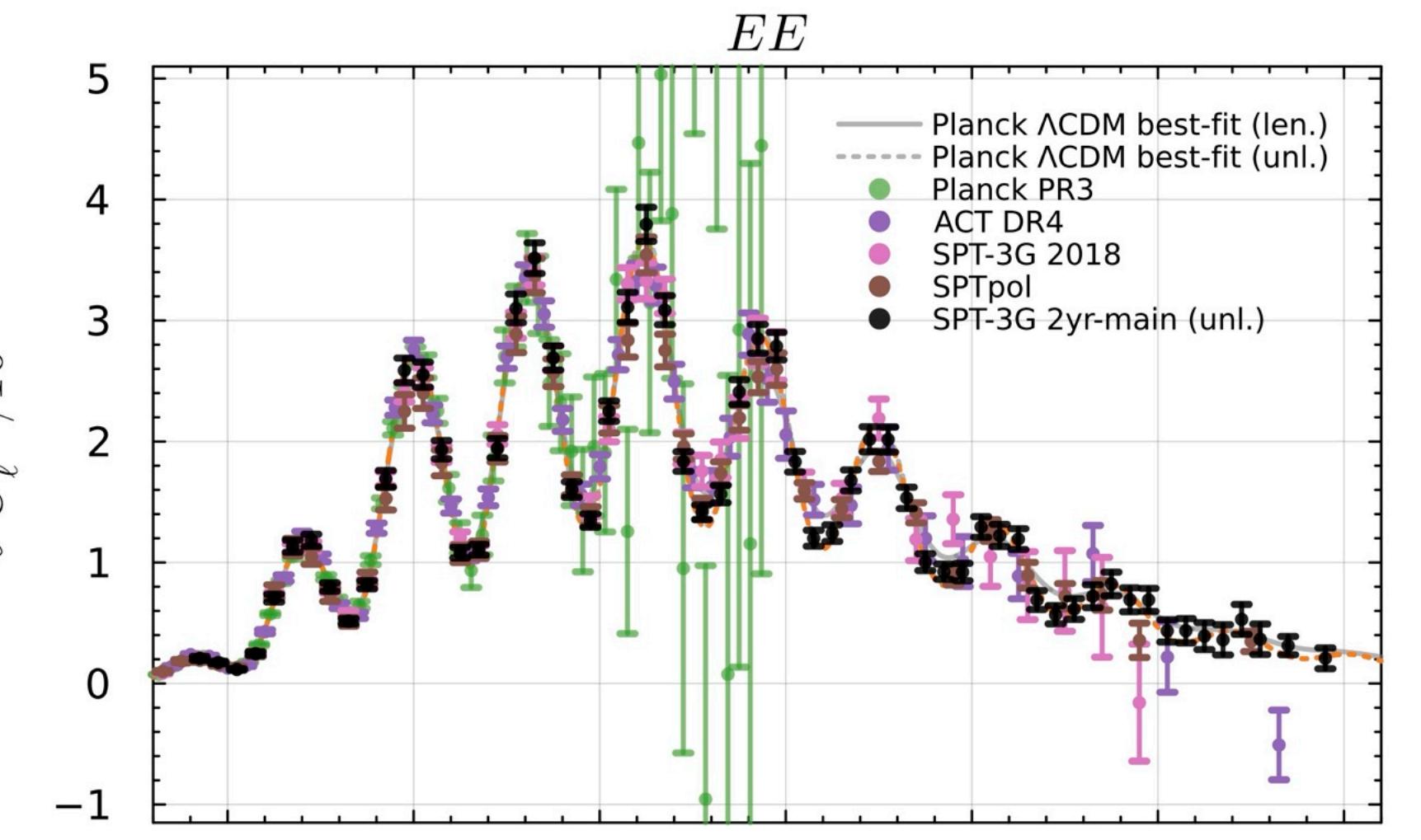
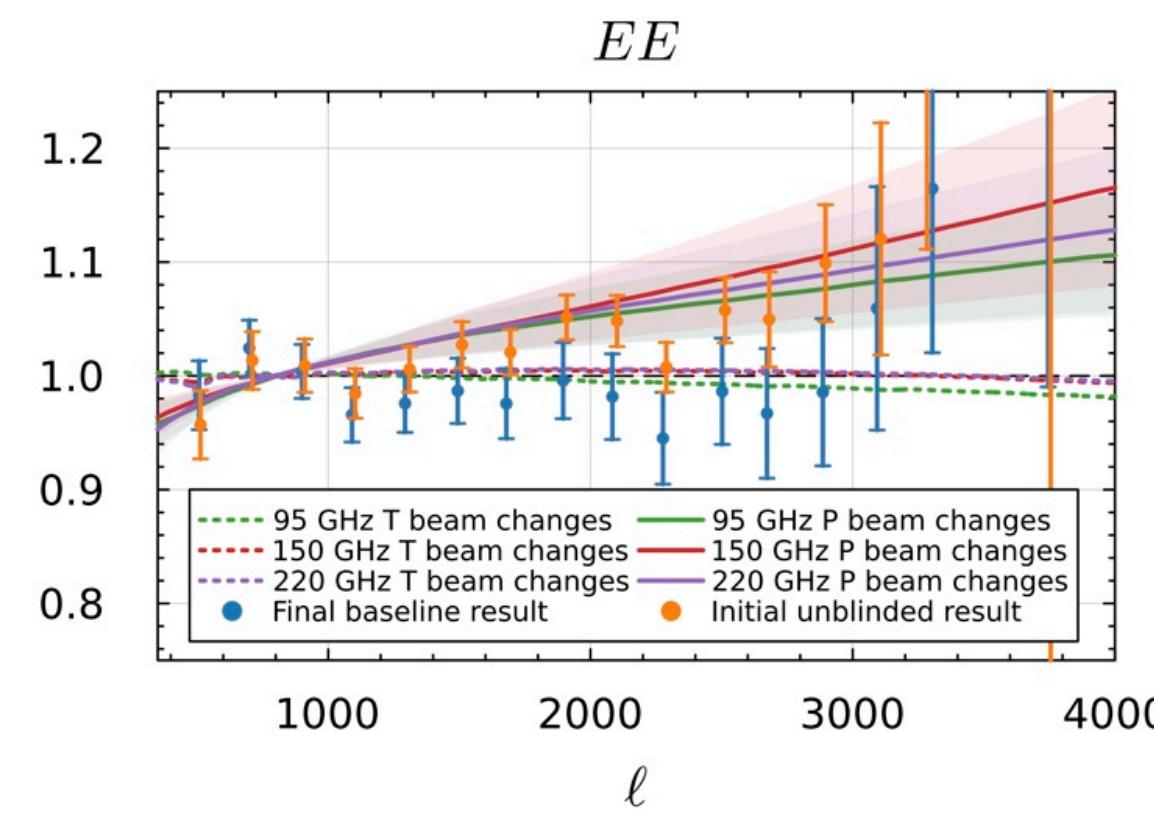
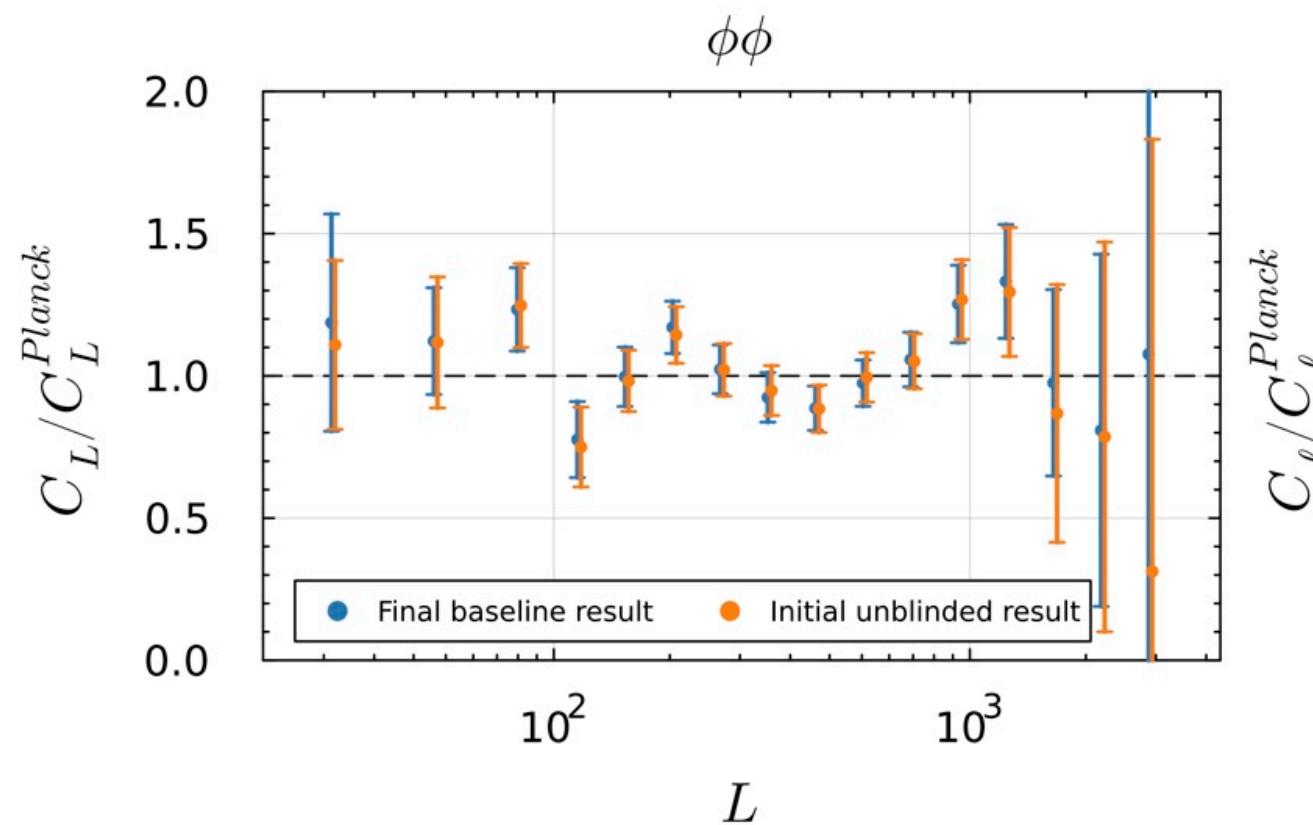
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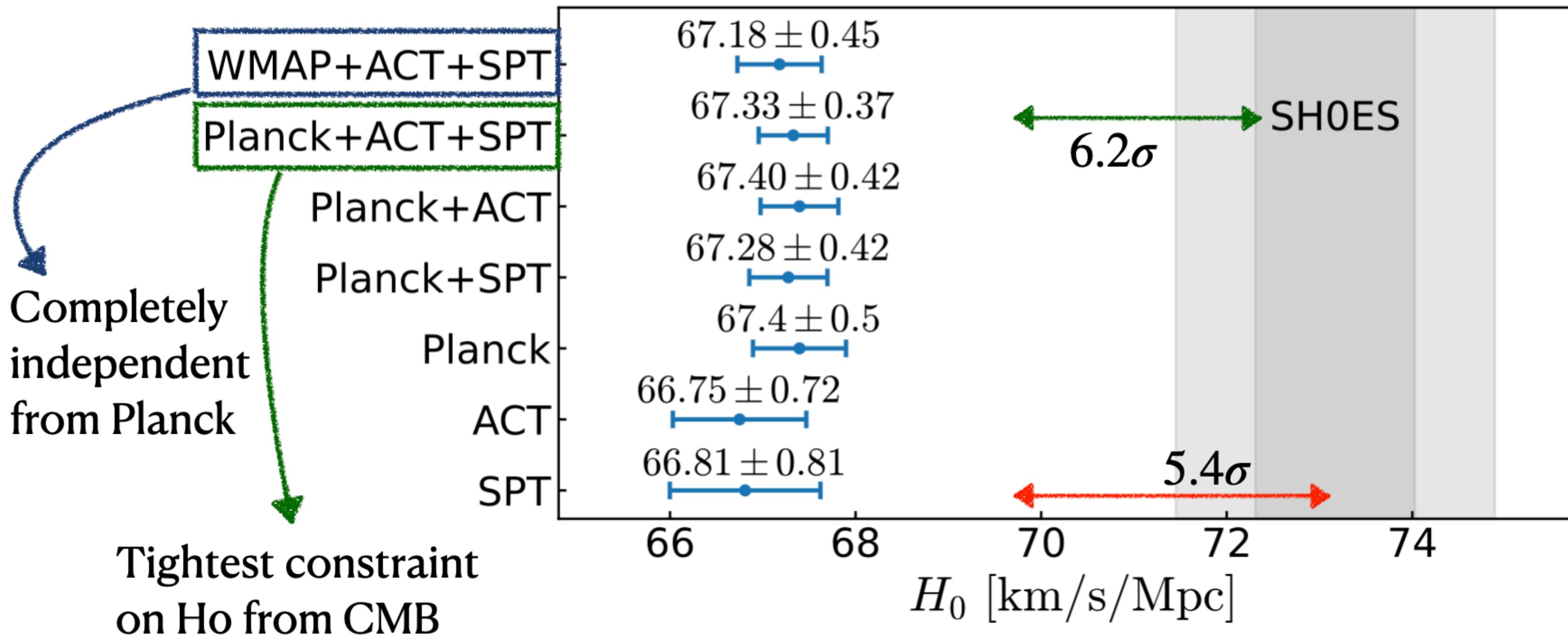
EE & $\phi\phi$ bandpowers in agreement
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Blinded analysis
with post-unblinding beam change:



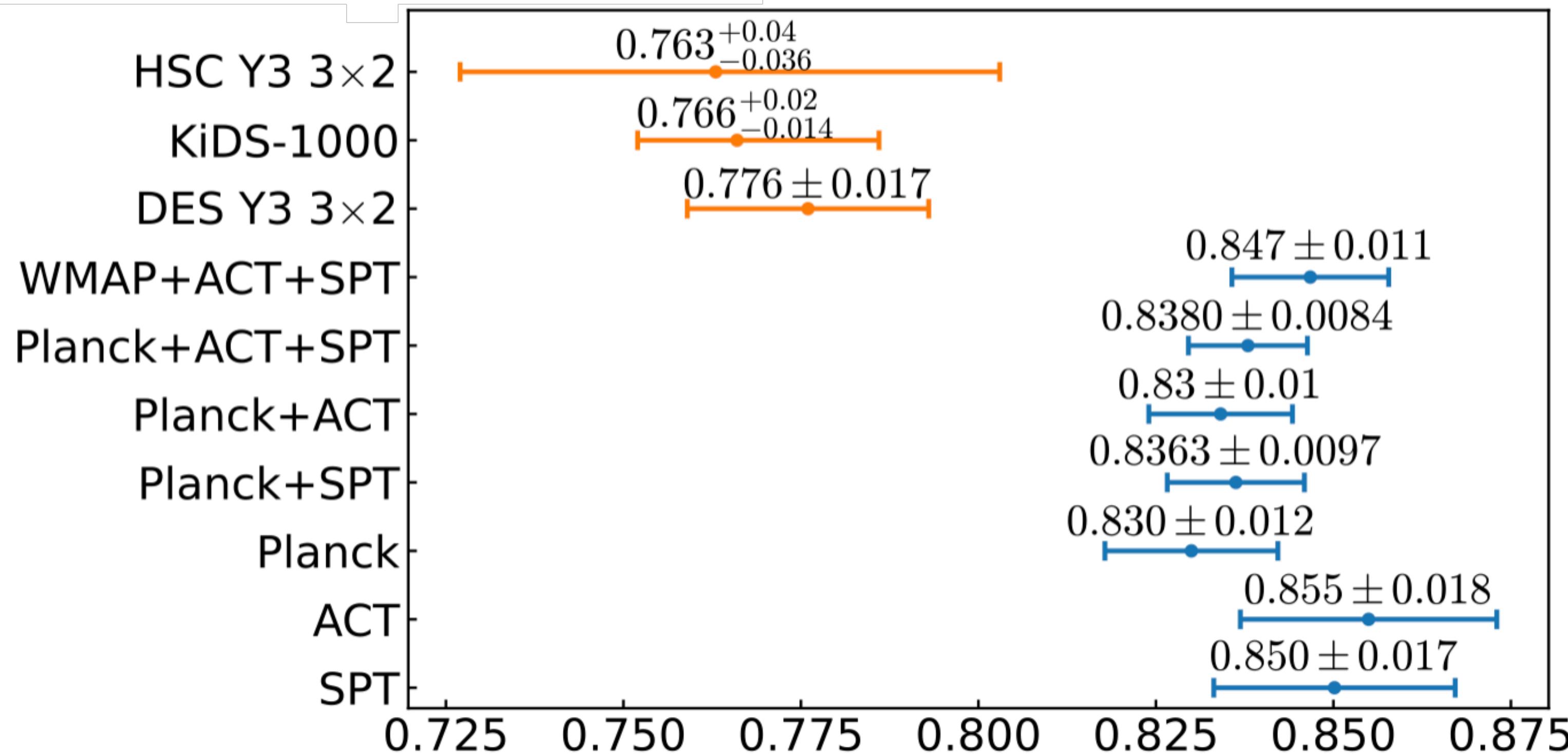
MUSE Results: H_0

WMAP:	TT+TE	[9yr]
Planck:	TT+TE+EE+ $\phi\phi$ (T&P)	[Plik/PR4]
ACT:	TT+TE+EE+ $\phi\phi$ (T&P)	[DR4/DR6]
SPT:	EE+ $\phi\phi$ (P)	[2yr-main]



MUSE Results: S_8

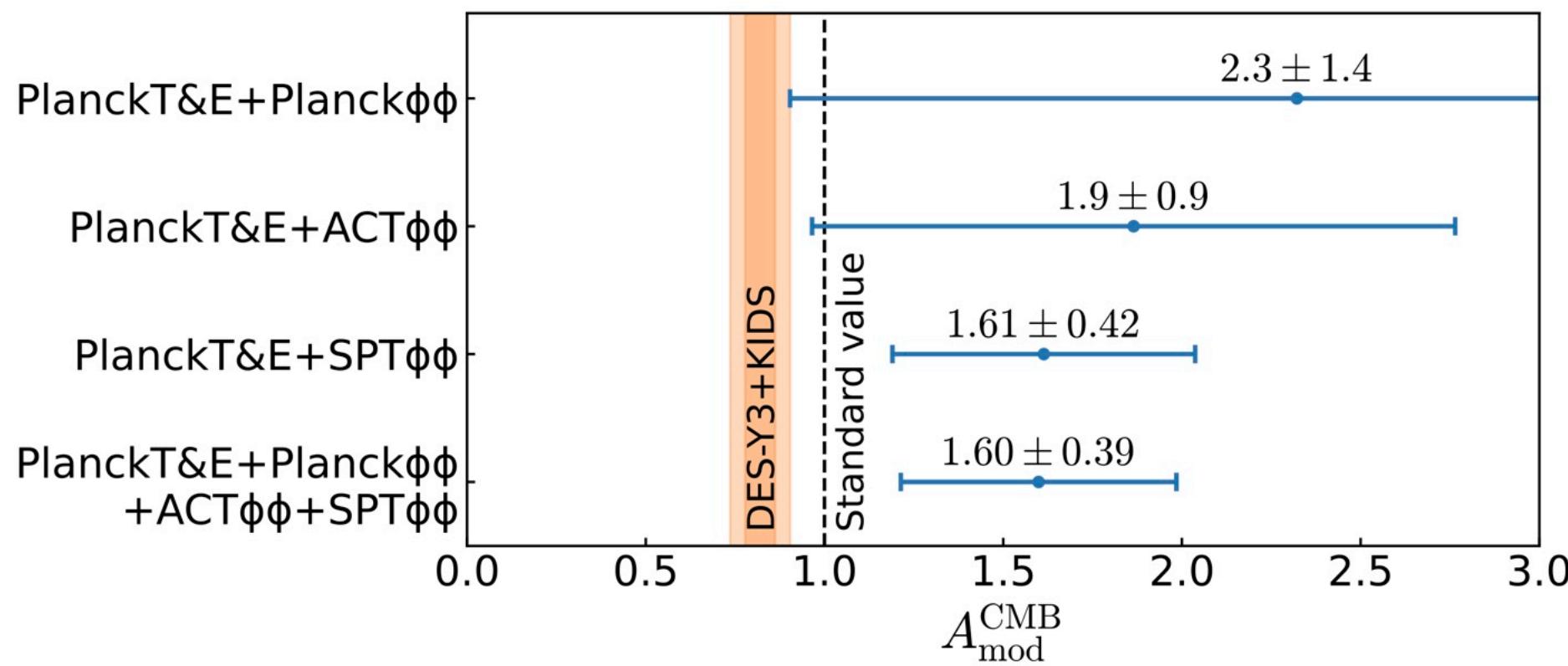
WMAP:	TT+TE	[9yr]
Planck:	TT+TE+EE+ $\phi\phi$ (T&P)	[Plik/PR4]
ACT:	TT+TE+EE+ $\phi\phi$ (T&P)	[DR4/DR6]
SPT:	EE+ $\phi\phi$ (P)	[2yr-main]



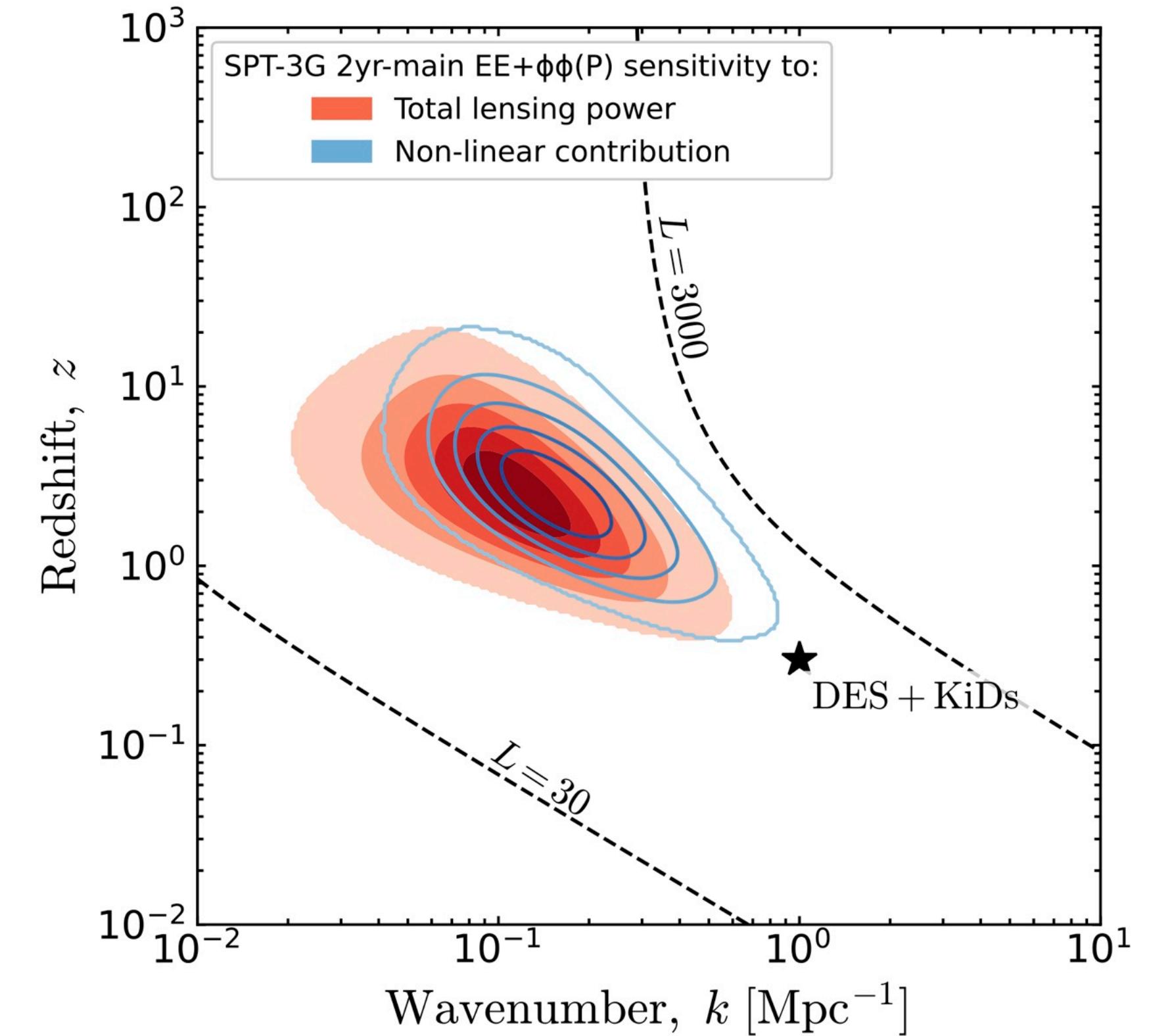
$$S_8 = \sigma_8 \sqrt{\Omega_m / 0.3}$$

MUSE Insights on Structure Growth

A_{mod} to scale the non-linear matter power spectrum:



Planck T&E + SPT $\phi\phi$ gives first 3σ detection of non-linear structure with CMB lensing!

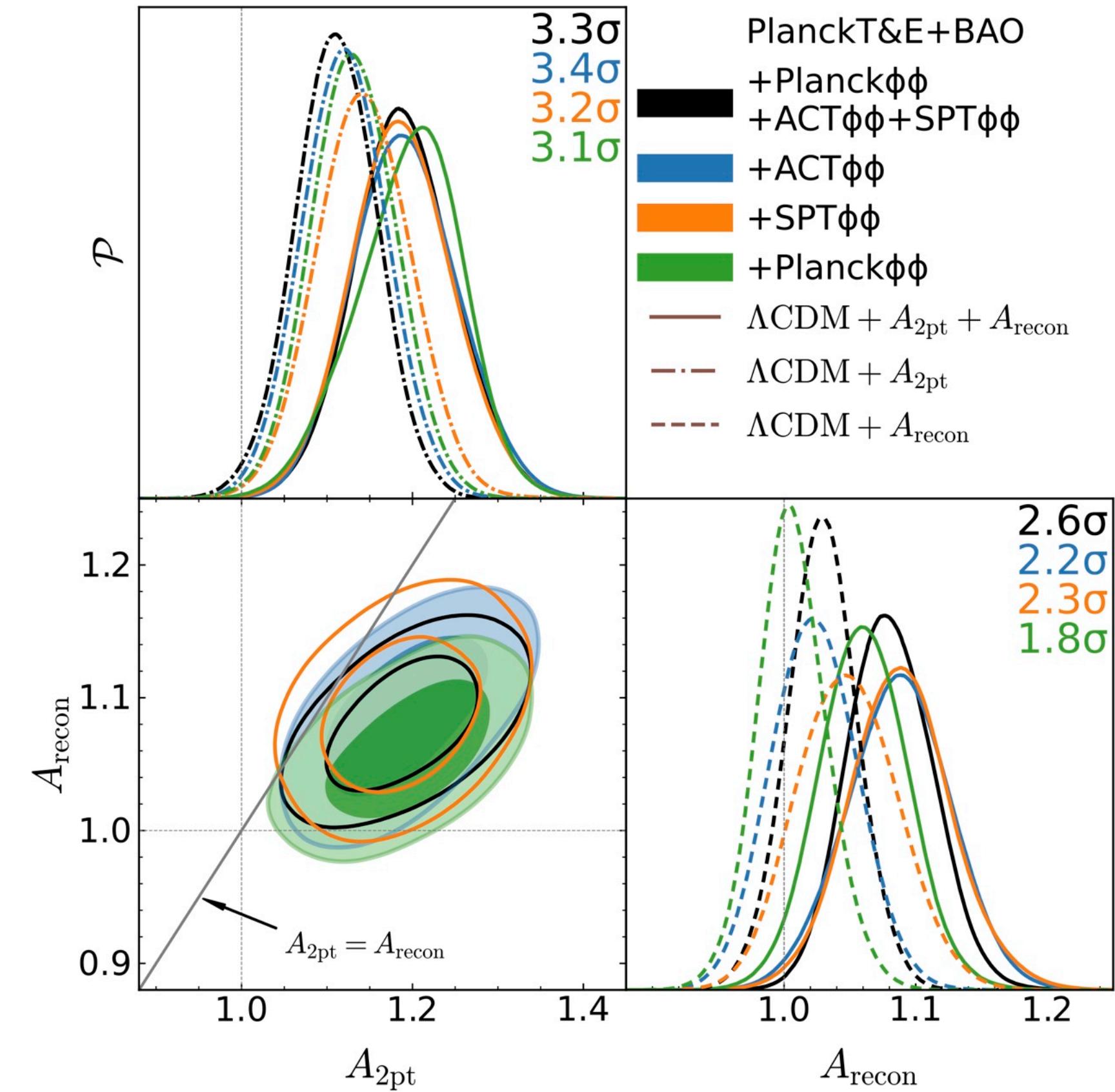


MUSE Insights on Neutrino Mass

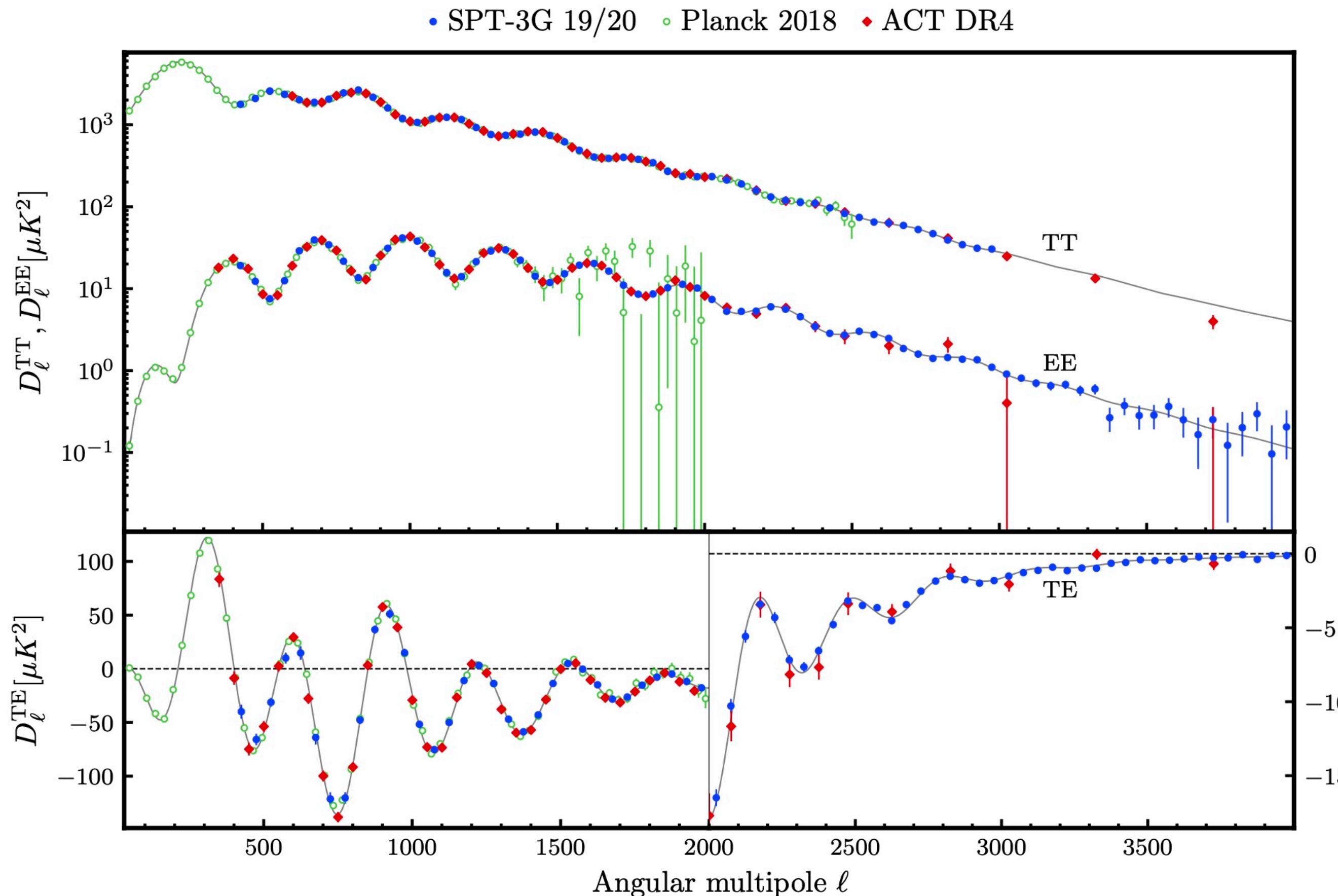
Decreasing neutrino mass **enhances** structure (measured by $\phi\phi$).

CMB prefers more lensing power than predicted by Λ CDM given BAO.
⇒ low $\sum m_\nu$ when allowed to vary.

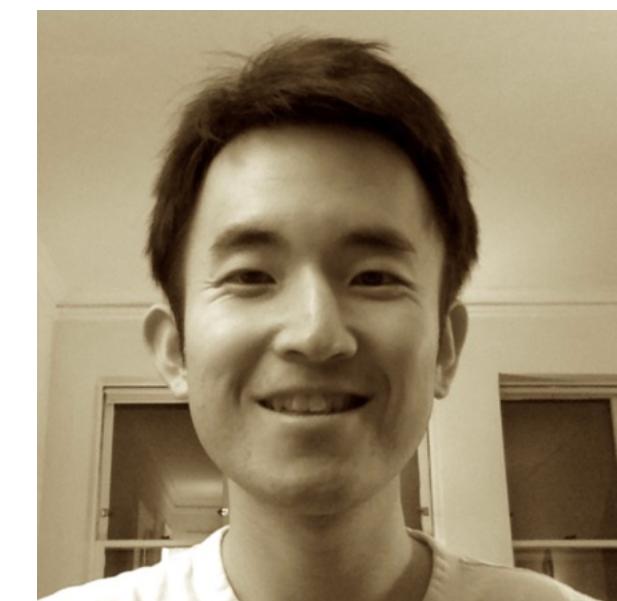
- A_{recon} : scales lensing power used to predict lensed CMB power spectra
- $A_{2\text{pt}}$: scales lensing power used to predict lensed CMB power spectra
- A_{lens} : if $A_{\text{recon}} = A_{2\text{pt}}$



Upcoming 19+20 Results: TT/TE/EE



Etienne Camphuis



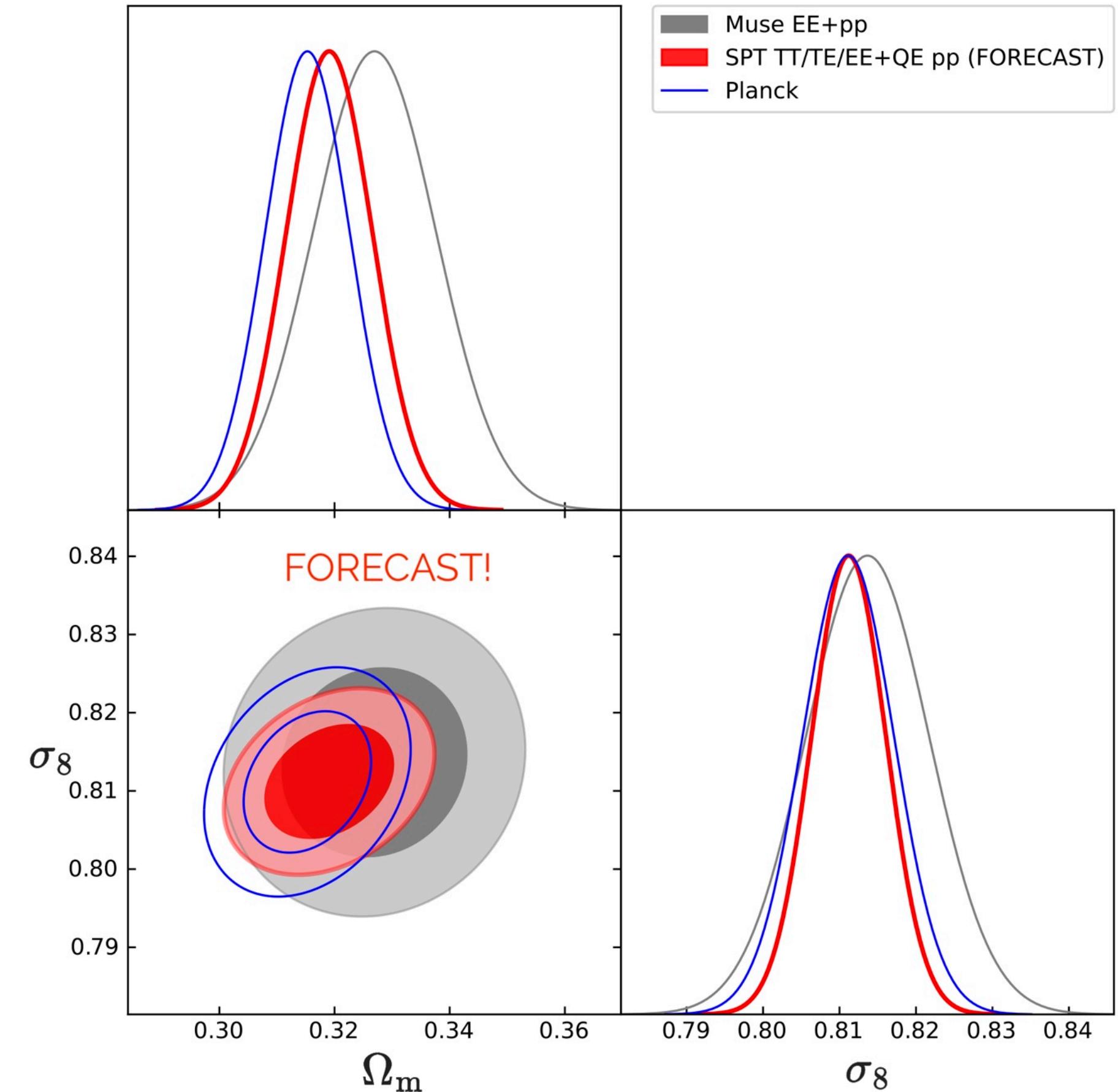
Wei Quan

Upcoming Results: EE/TE/EE/ $\phi\phi$

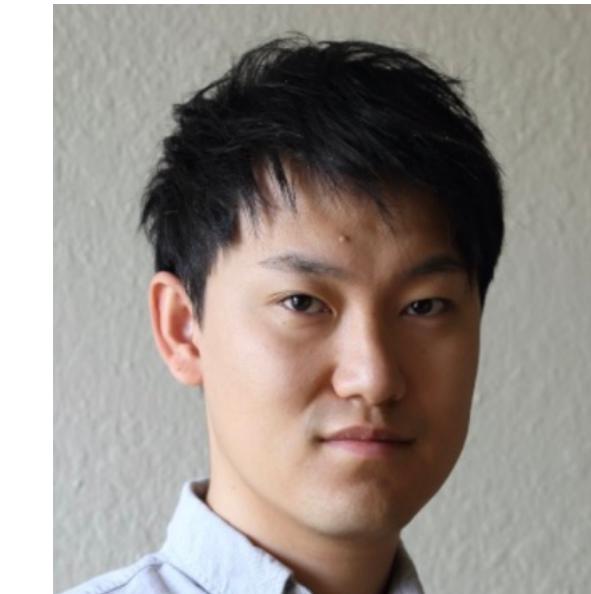
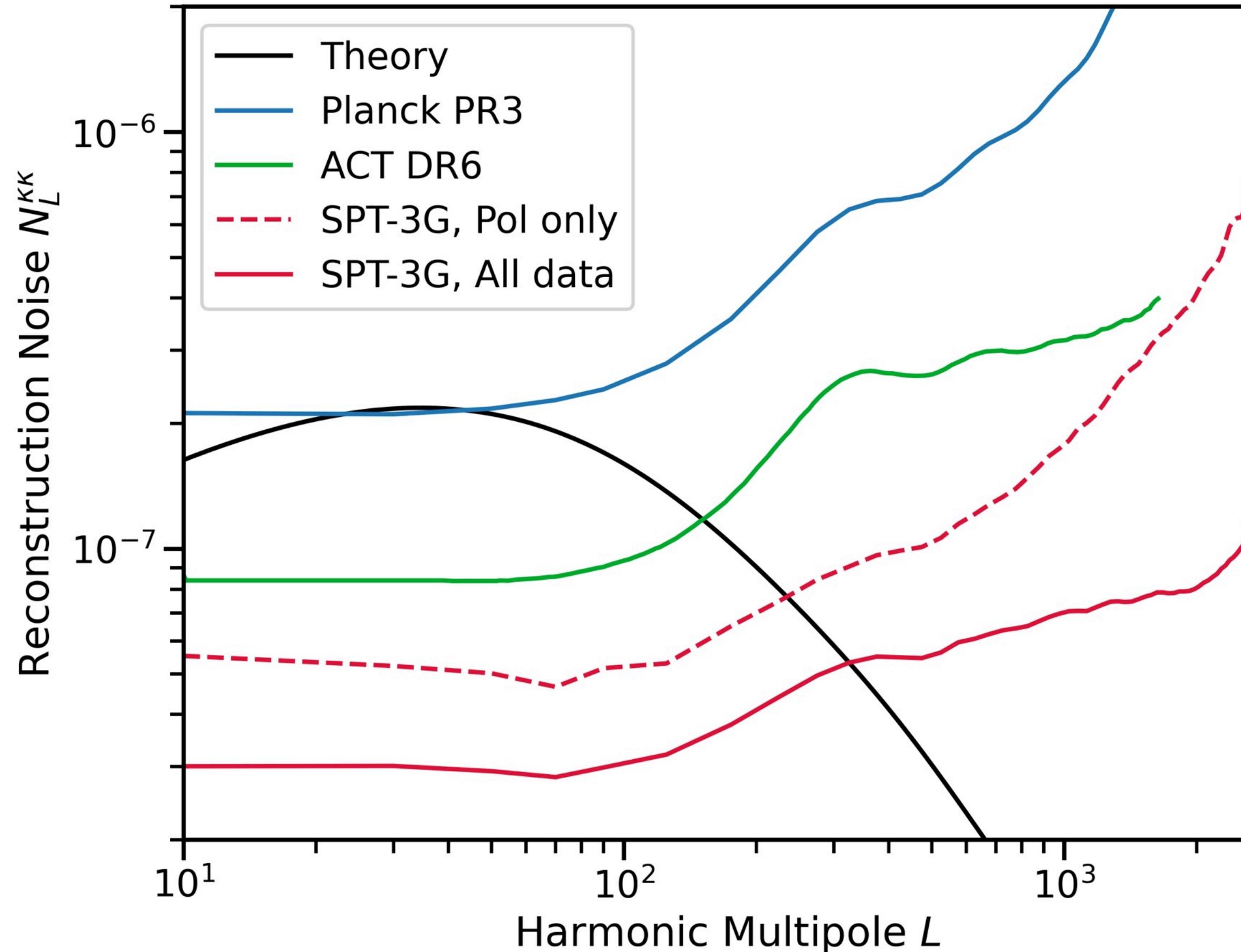
Targeting publication this summer.

As a taste, mock SPT-3G TT/EE/TE + polarization-only lensing compared to MUSE and Planck.

Joint constraints on Λ CDM parameters will be comparable to Planck!



Upcoming Results: 19+20 QE Lensing



Yuuki Omori



Federico Bianchini

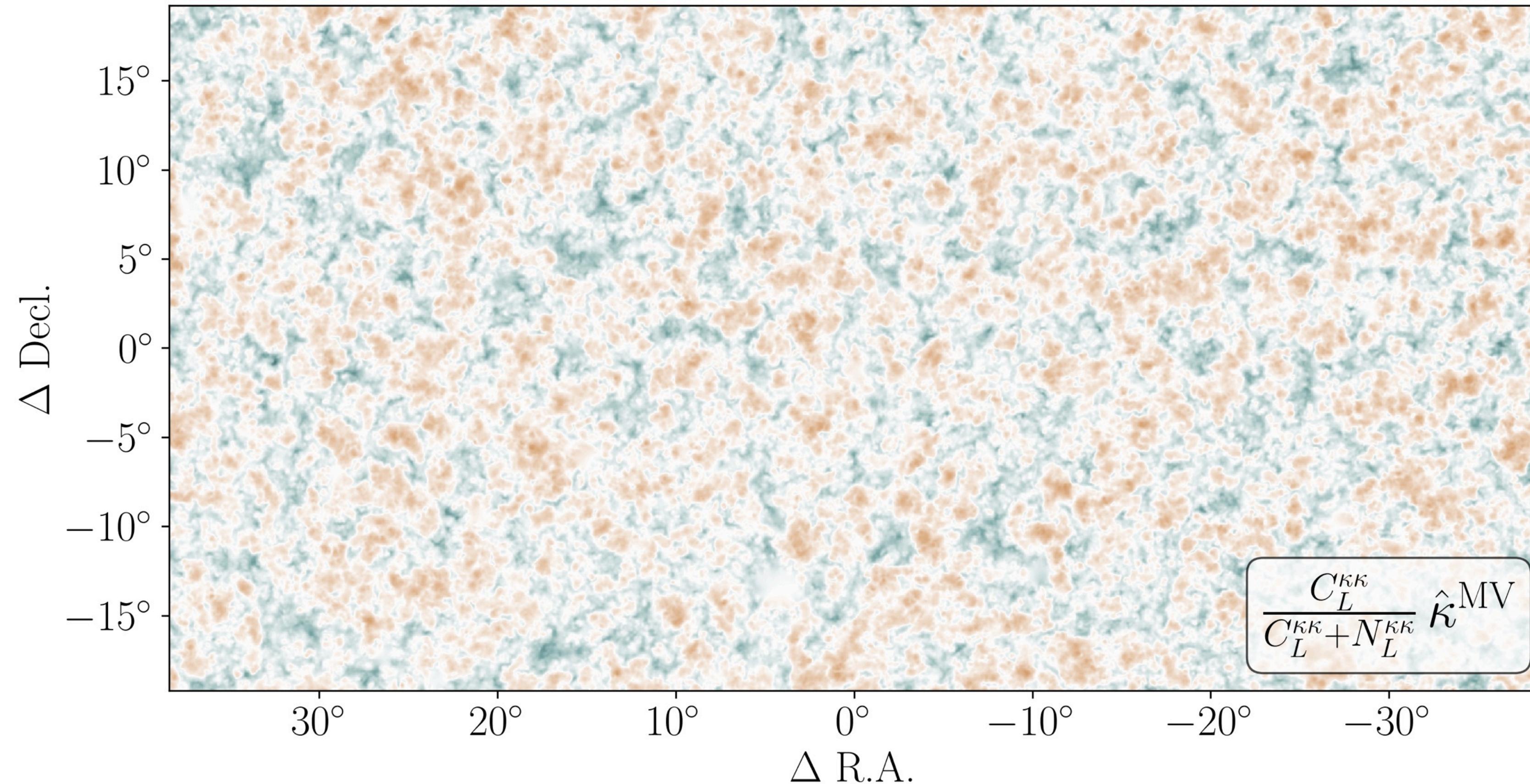
Myself



Yuka Nakato

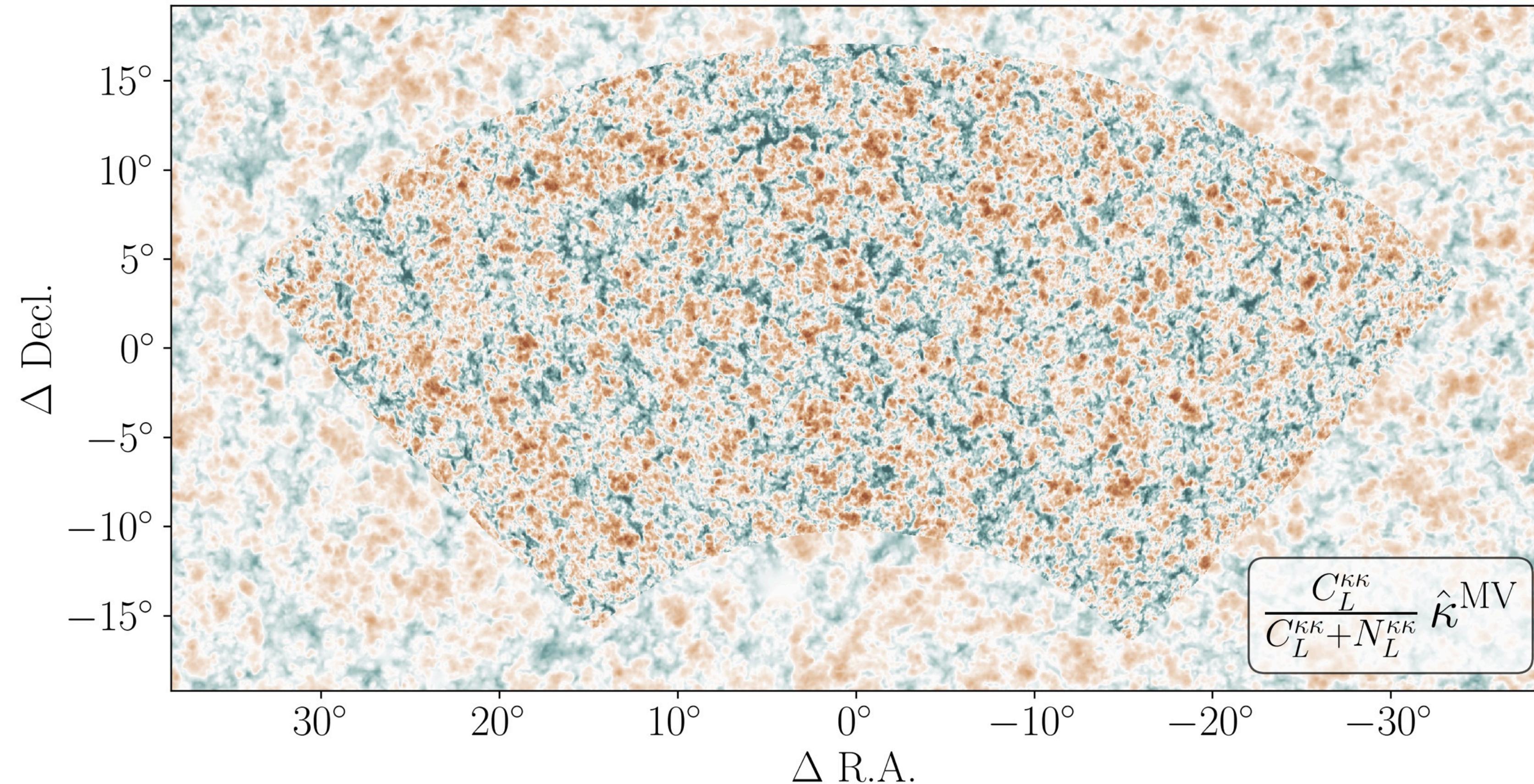
Upcoming Results: 19+20 QE Lensing

Planck Convergence: Signal-Dominated Scales



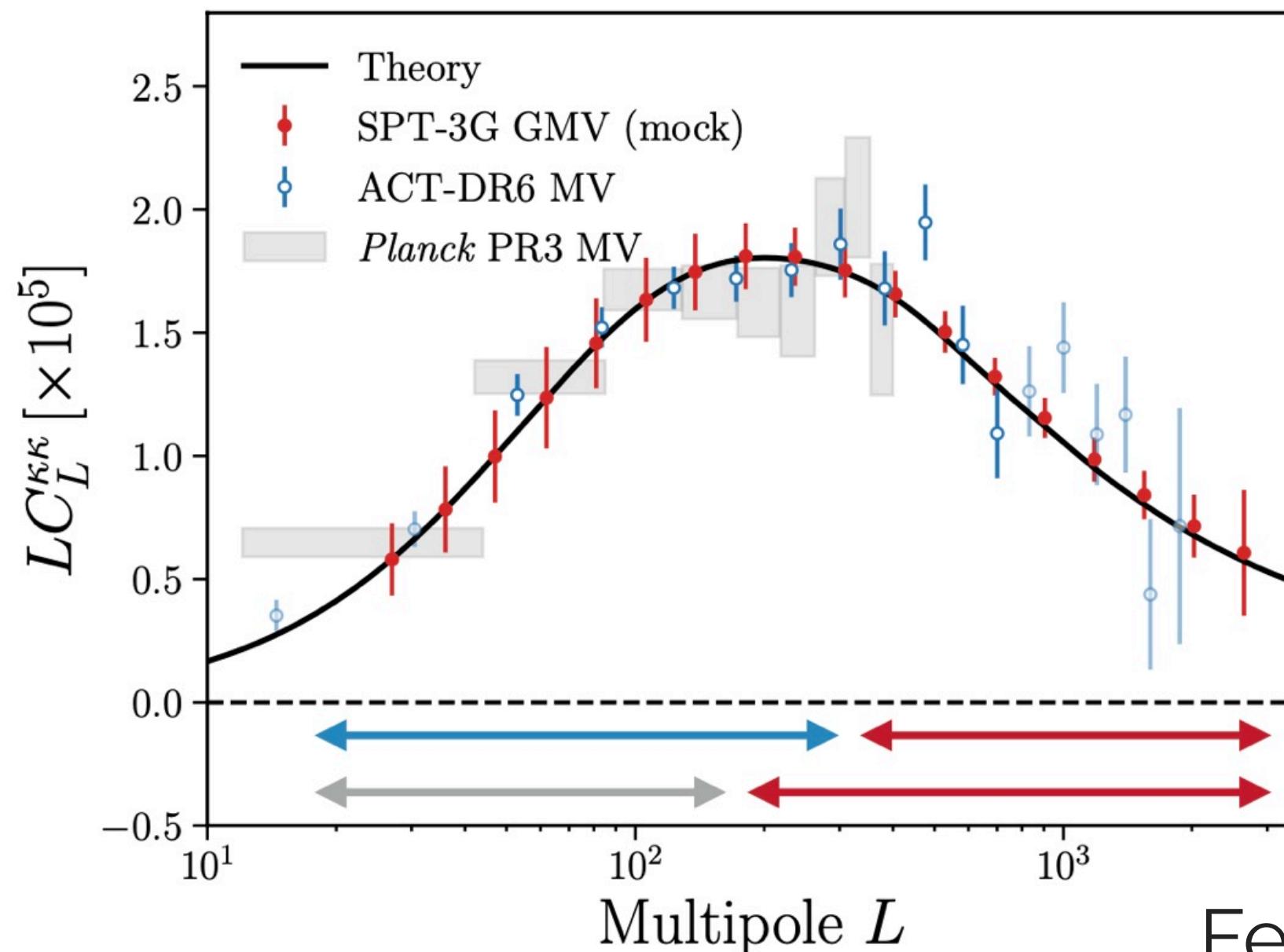
Upcoming Results: 19+20 QE Lensing

SPT vs. Planck Convergence: Signal-Dominated Scales

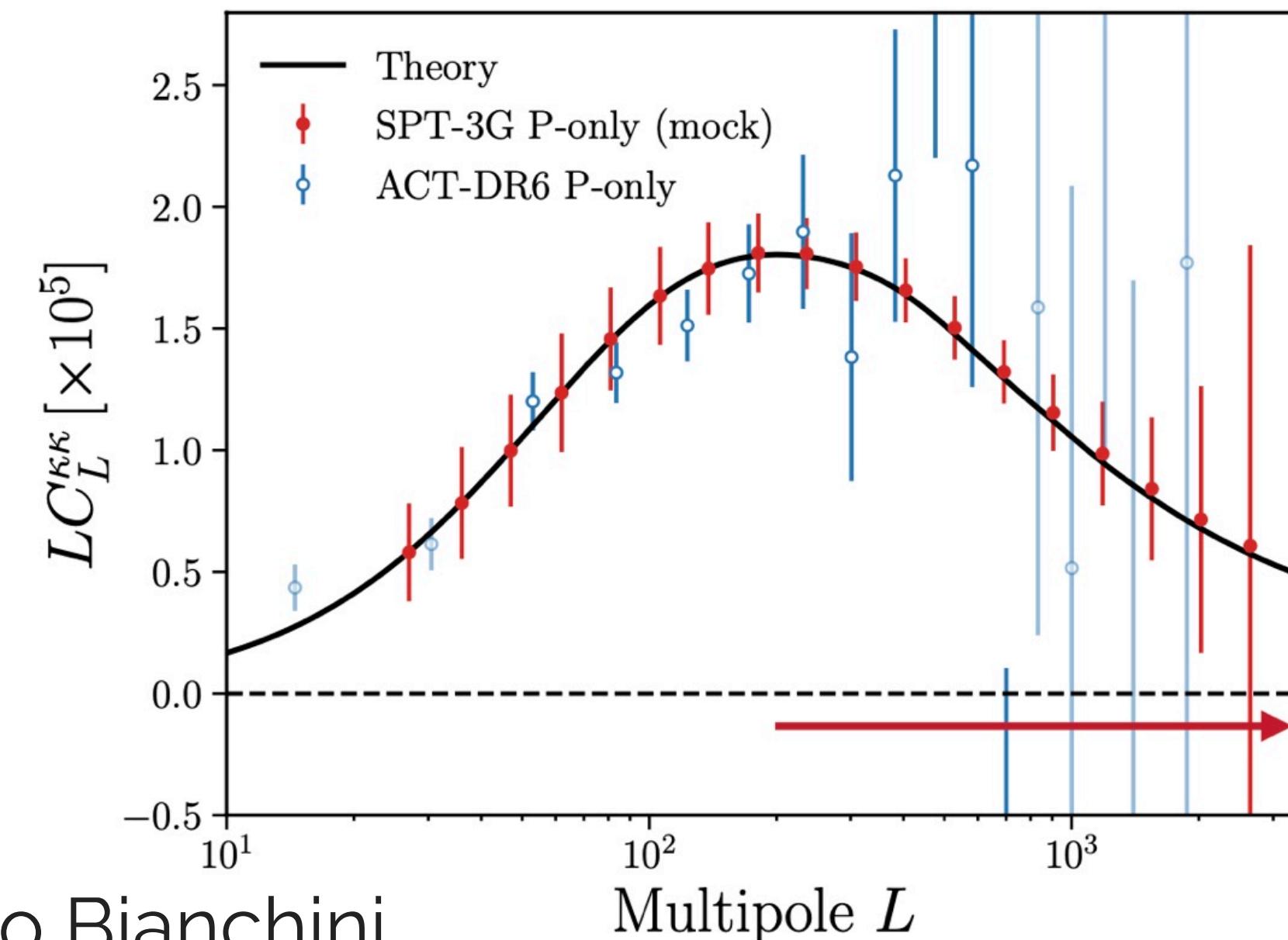


Upcoming Results: 19+20 QE Lensing

Temperature + Polarization



Polarization-only



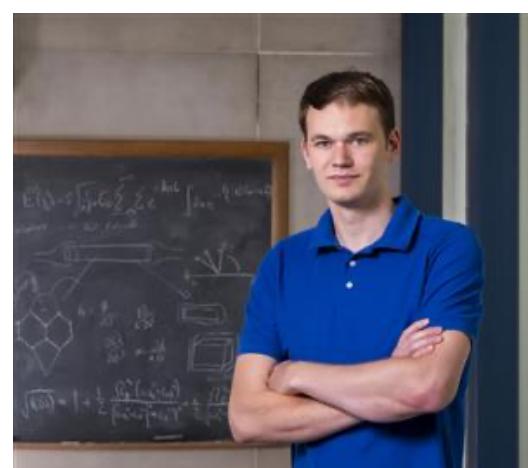
Federico Bianchini

1.3% measurement of σ_8 from SPT-3G lensing + DESI BAO alone!

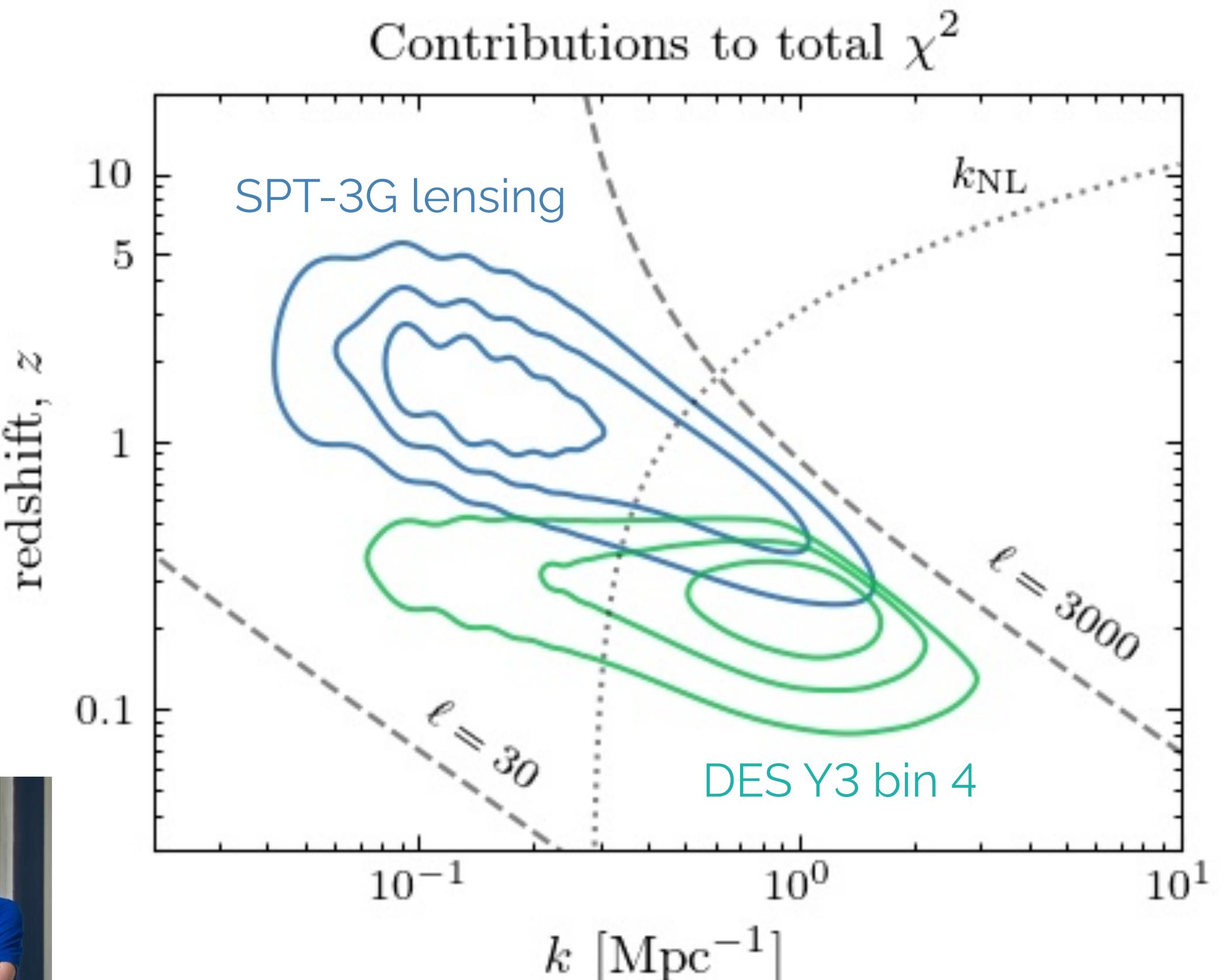
Upcoming Results: Cross-correlations

SPT-3G lensing: large scales, high z
(mostly linear)

Cosmic shear: smaller scales, low z
(mostly non-linear)



Aaron Quellette
Cail Daley | DAp Postdoc Seminar | March 11, 2025

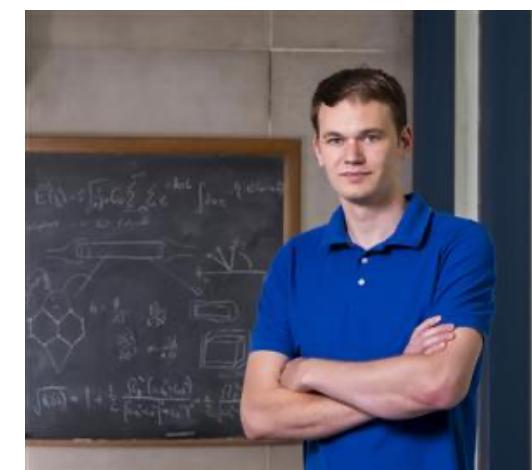


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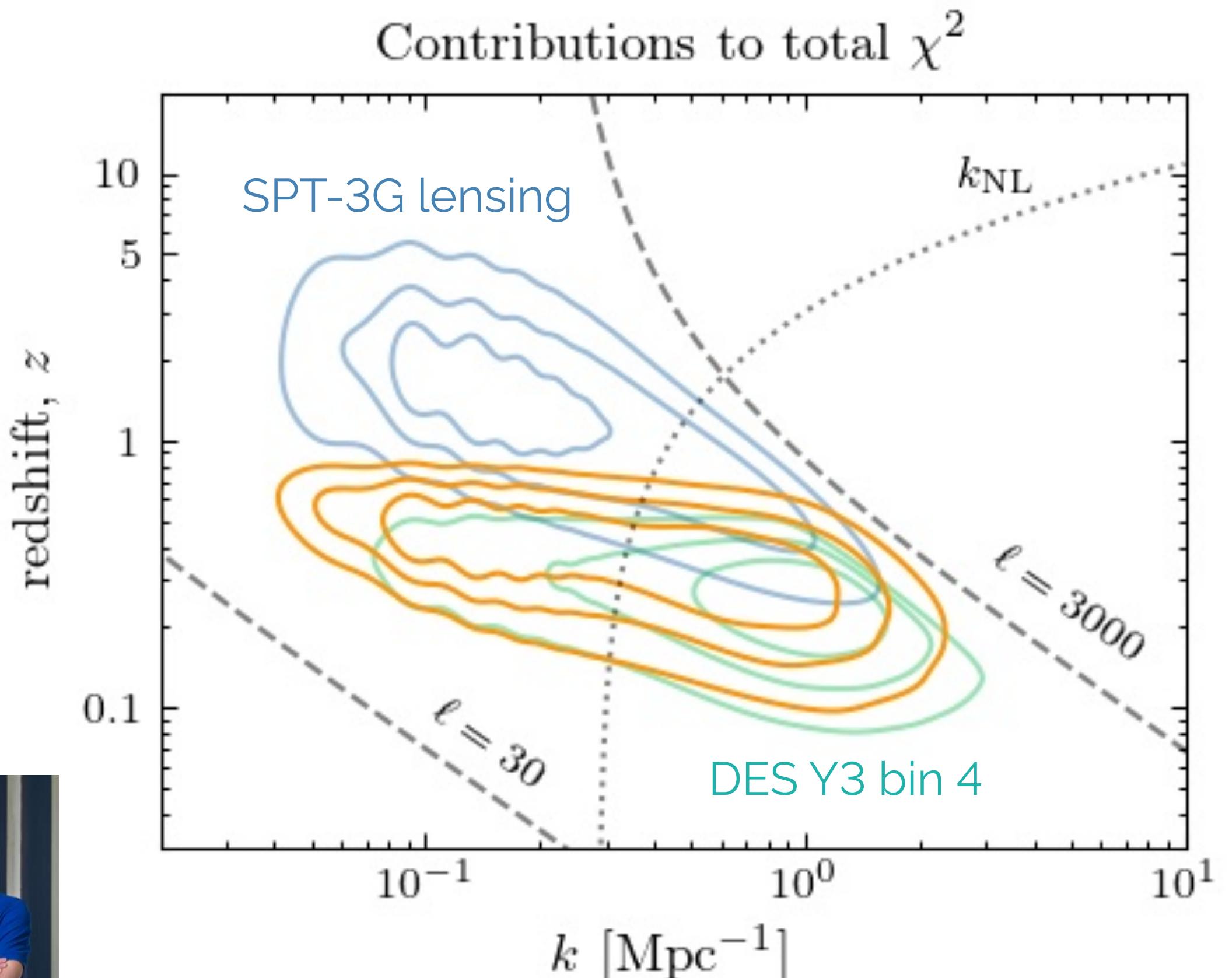
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Cross-correlation bridges the gap



Aaron Quellette
Cail Daley | DAp Postdoc Seminar | March 11, 2025

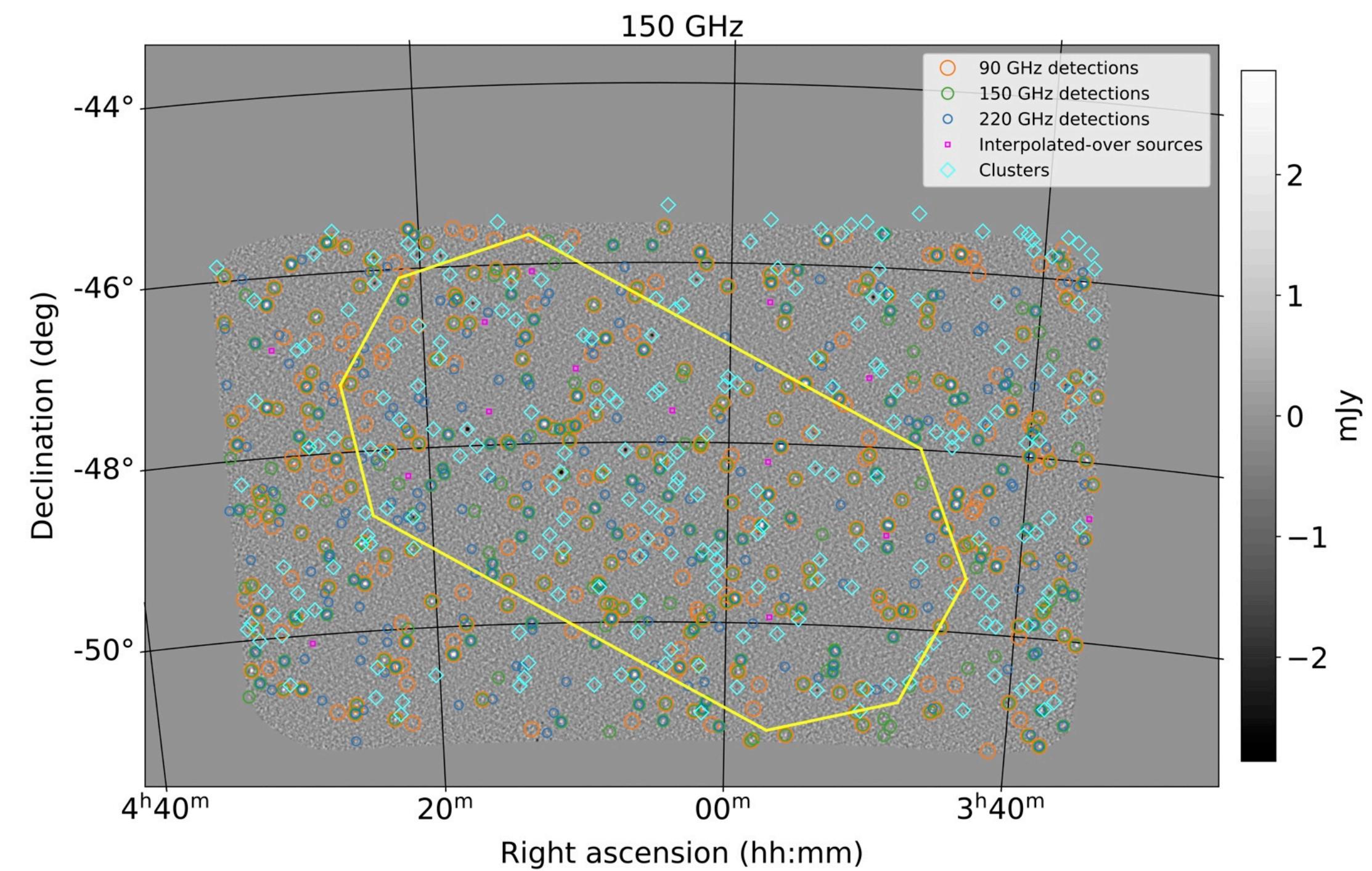
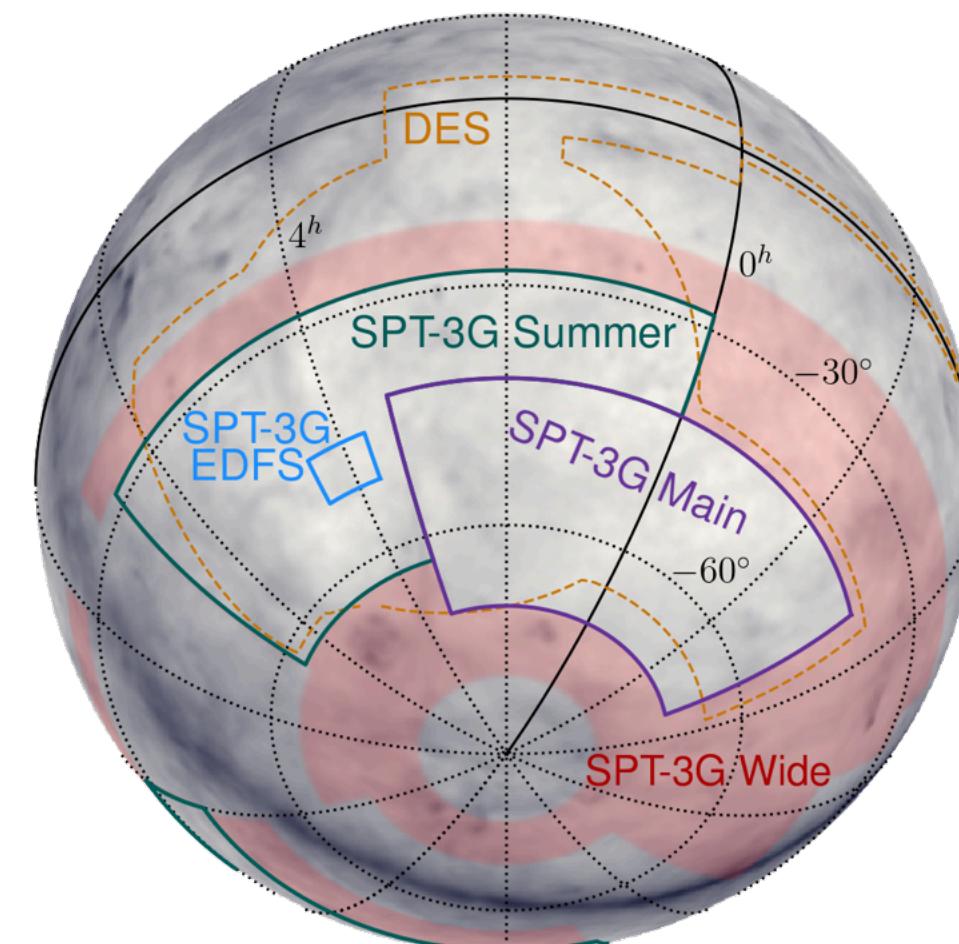


SPT-3G and Euclid

SPT has observed Euclid Deep Field South (EDFS) and is planning a release of:

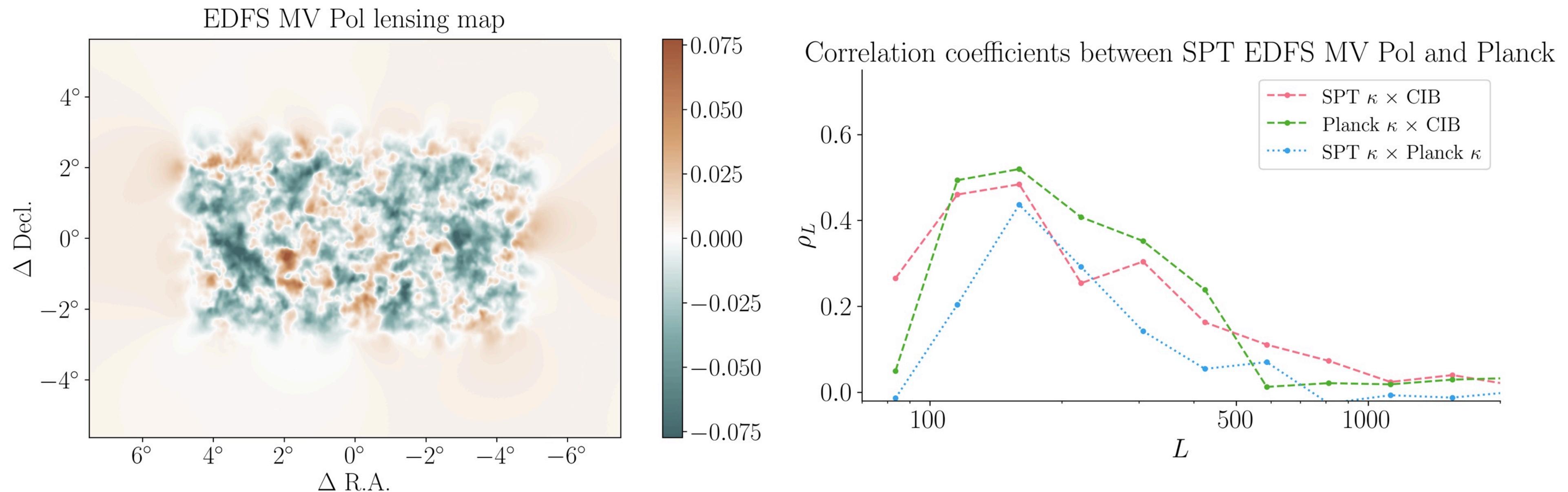
- temperature maps and general products
- emissive source catalogs
- cluster catalogs

~alongside the Euclid Q1 release.



SPT-3G and Euclid

I am working on lensing maps to be cross-correlated with Euclid Q1 data:



Will be useful pathfinding for Euclid DR1+ cross CMB analyses.

Summary & Looking Forward

- The CMB still has a lot to tell us about the Universe:
 - small scales, polarization, lensing
- SPT-3G Main 2019+2020:
 - MUSE polarization-only results are consistent with Planck Λ CDM
 - sharpens questions on neutrino mass/lensing amplitude/structure growth
 - coming temperature+polarization constraints will be comparable to Planck!
- ACT DR6 results next Tuesday! (*March 18th 4 pm CET*)

Thank You!



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