Updates from SPT-3G

K. Benabed - S. Galli - E. Hivon — L. Balkenhol - *E. Camphuis* - F. Guidi - A. Khalife - A. Vitrier
at Institut d'Astrophysique de Paris
On behalf of SPT-3G collaboration

Outline

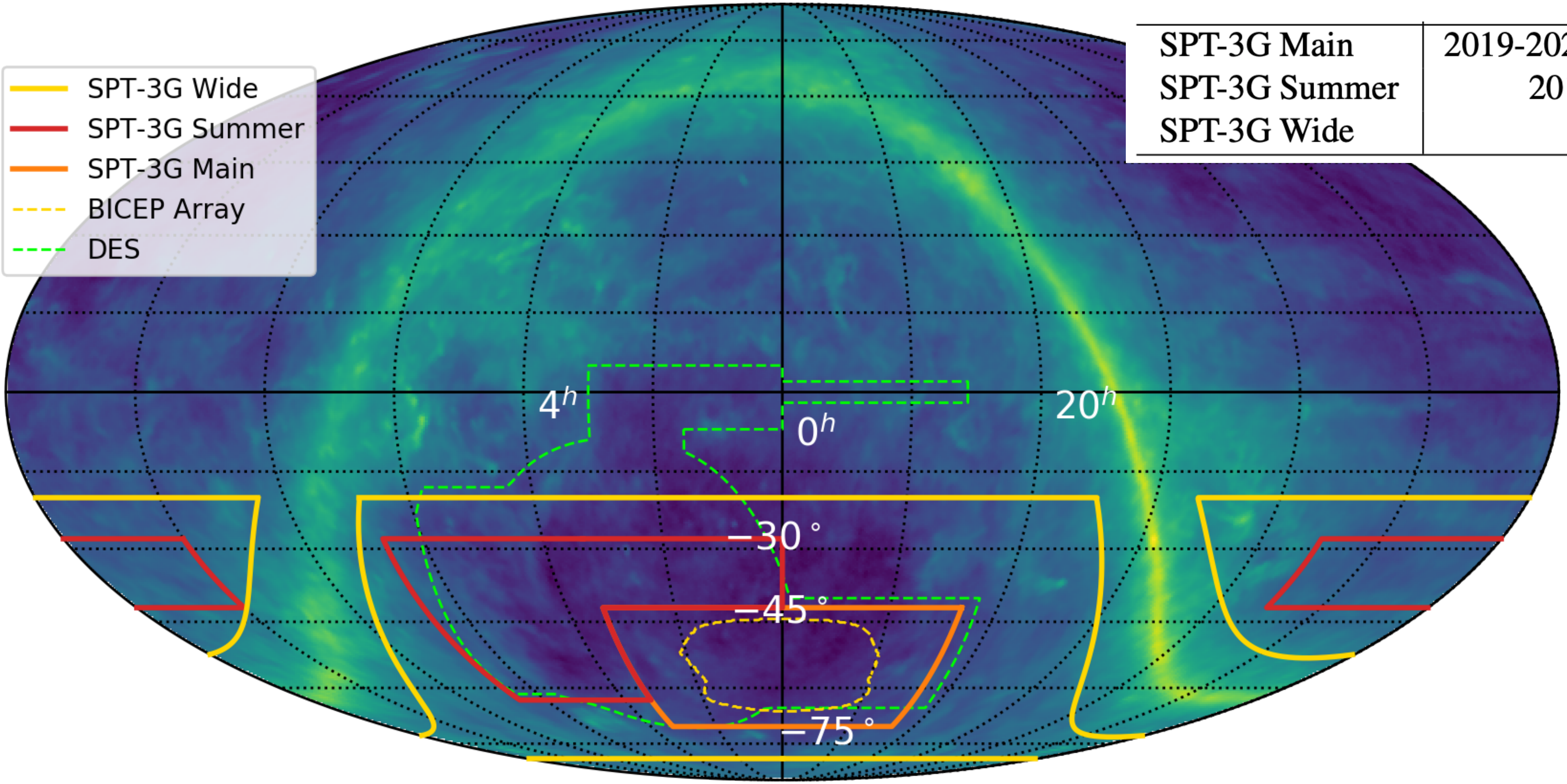
1. Introduction
2. Recent CMB results
3. Focus on upcoming 2019/2020 analyses
4. Full survey prospects
5. Highlighting other analyses

SPT-3G

- 10-meter diameter telescope located at the South Pole
- SPT-3G is the third-generation camera, acquiring data in T/P **with high resolution: 1.6’/1.2’/1.0’** @ 95/150/220 GHz
- More info in Sobrin et al. 2021

Kavli Institute for Cosmological Physics at the University of Chicago

Fields - Total: ~10000 deg2 → 25% of the sky



SPT-3G Main	2019-2023, 2025-2026
SPT-3G Summer	2019-2023
SPT-3G Wide	2024

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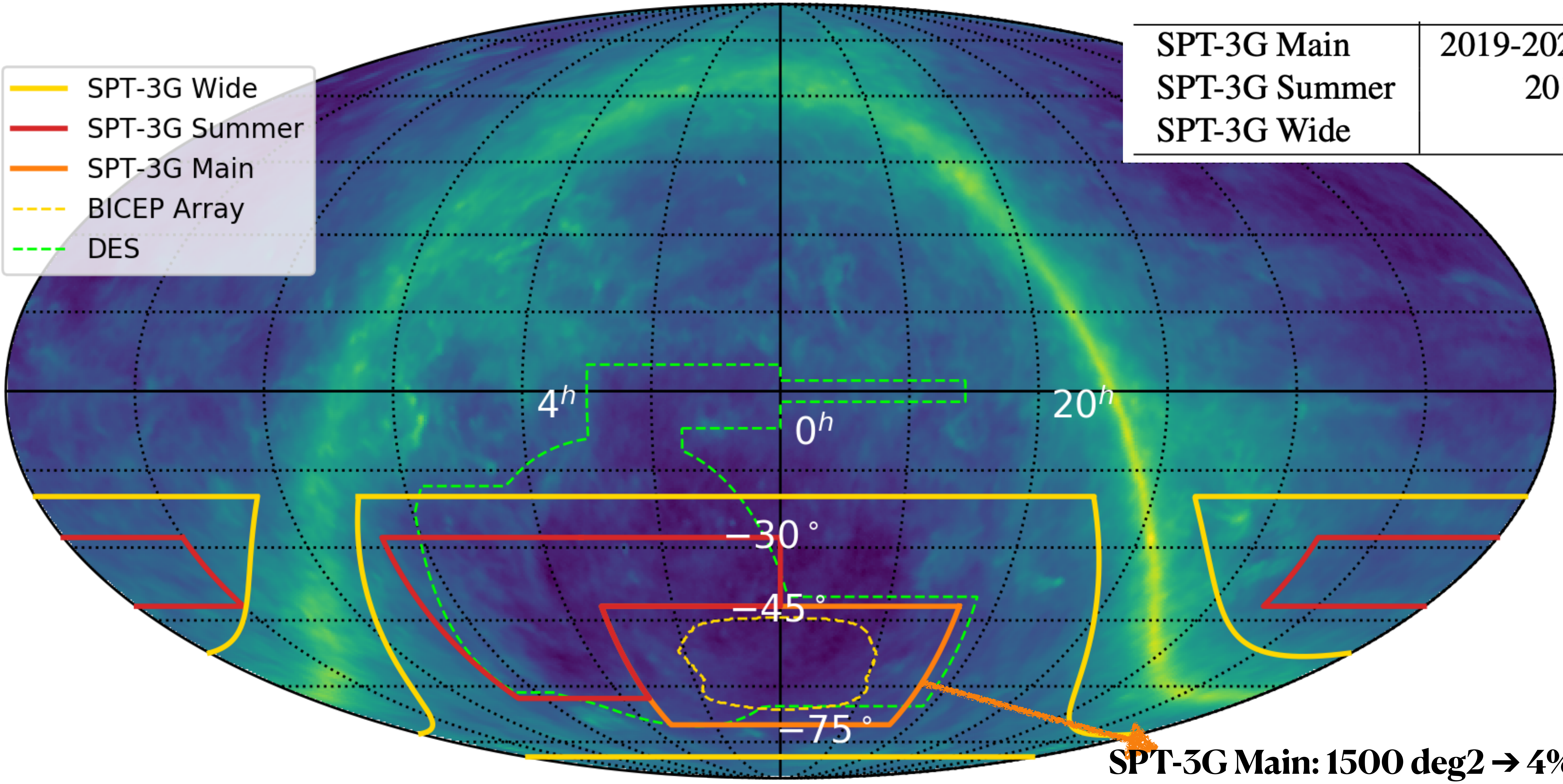
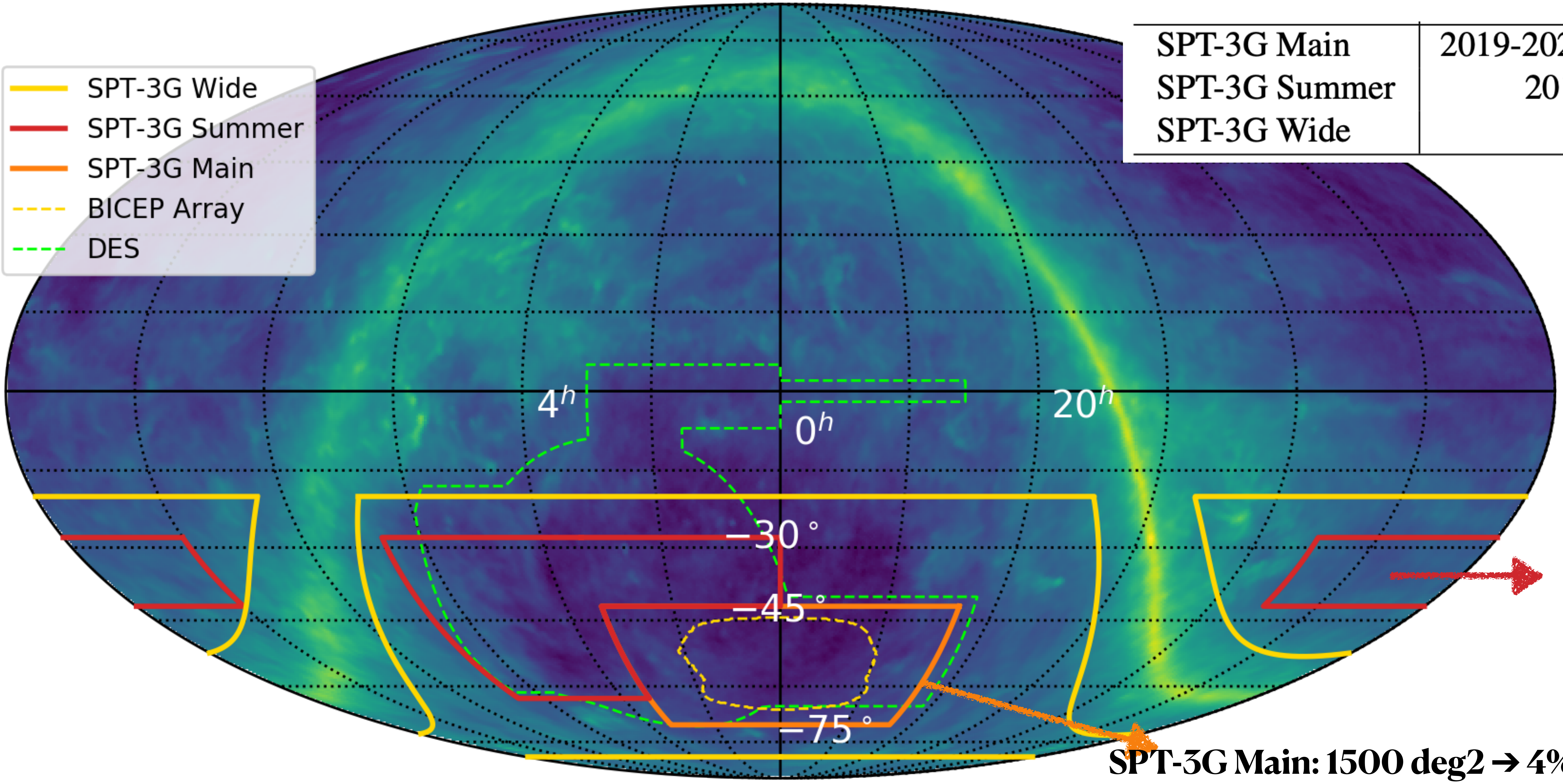


SPT-3G Main	2019-2023, 2025-2026
SPT-3G Summer	2019-2023
SPT-3G Wide	2024

SPT-3G Main: 1500 deg2 → 4%
Winters 2019-23 + 2025-26

Fields - Total: ~10000 deg2 → 25% of the sky

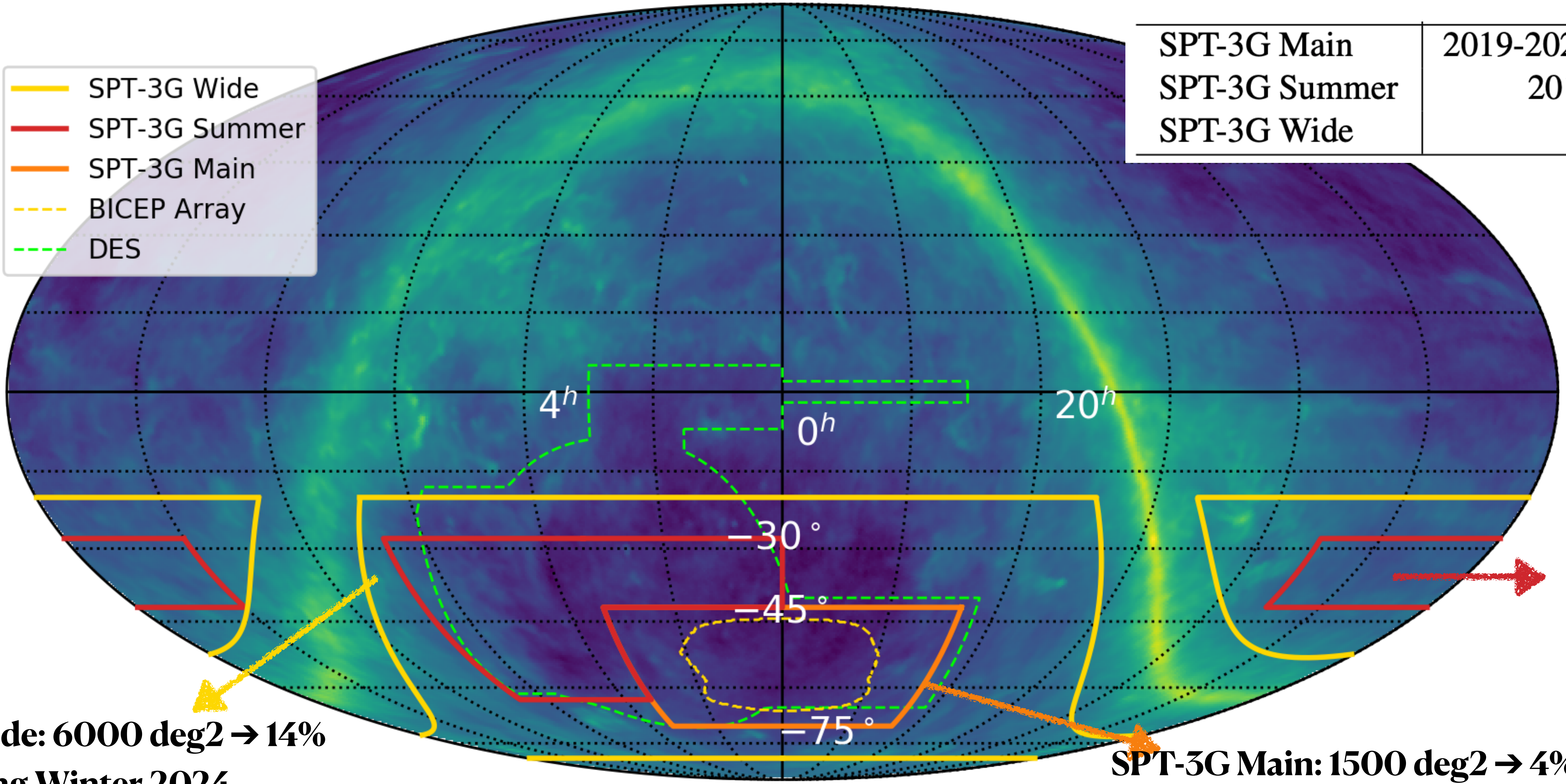


SPT-3G Main	2019-2023, 2025-2026
SPT-3G Summer	2019-2023
SPT-3G Wide	2024

SPT-3G Summer: 2600 deg2 → 7% Summers 2019-23

SPT-3G Main: 1500 deg2 → 4% Winters 2019-23 + 2025-26

Fields - Total: ~10000 deg2 ➔ 25% of the sky



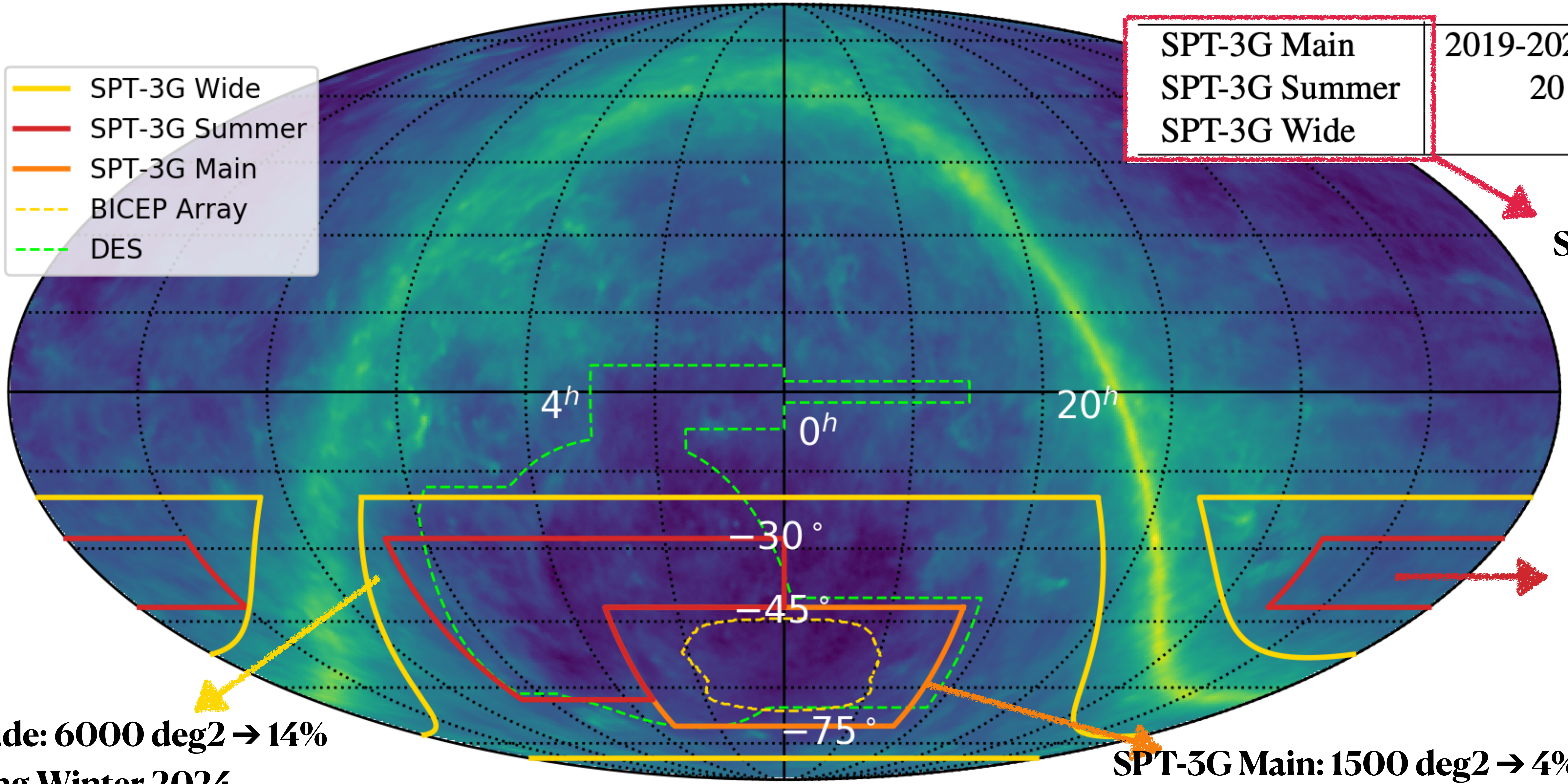
SPT-3G Main	2019-2023, 2025-2026
SPT-3G Summer	2019-2023
SPT-3G Wide	2024

SPT-3G Summer: 2600 deg2 ➔ 7% Summers 2019-23

SPT-3G Wide: 6000 deg2 ➔ 14% during Winter 2024

SPT-3G Main: 1500 deg2 ➔ 4% Winters 2019-23 + 2025-26

Fields - Total: ~10000 deg2 ➔ 25% of the sky



SPT-3G Main	2019-2023, 2025-2026
SPT-3G Summer	2019-2023
SPT-3G Wide	2024

SPT-3G Ext-10k = all fields !

SPT-3G Summer: 2600 deg2 ➔ 7% Summers 2019-23

SPT-3G Wide: 6000 deg2 ➔ 14% during Winter 2024

SPT-3G Main: 1500 deg2 ➔ 4% Winters 2019-23 + 2025-26

SPT Collaboration

Science goals

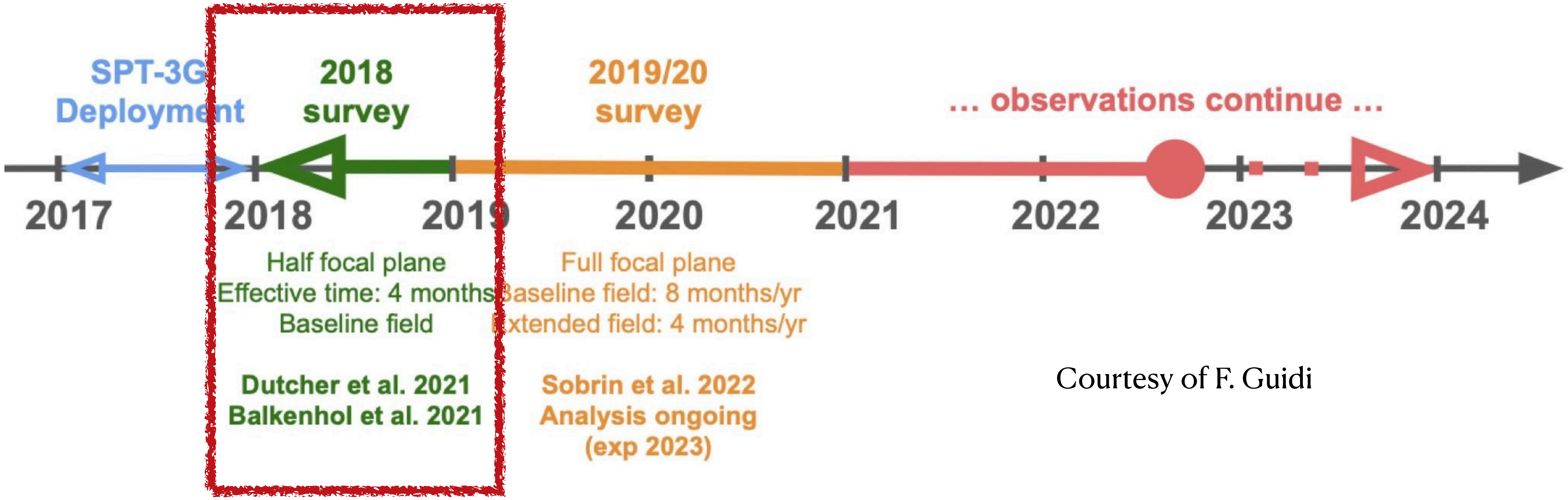
- Delensing in the BICEP/Keck field
- **Cosmological constraints from primary anisotropies**
- CMB Lensing
- High-ell TT, tSZ kSZ
- Low-l BB
- DES x SPT
- Axions, spatially varying cosmic birefringence
- Galaxy clusters, point sources, transients, asteroids, planet 9, etc

At IAP - ERC NEUCosmos

Staff: **Silvia Galli**, Karim Benabed, François Bouchet, Eric Hivon

Monday 5:05	**Postdocs**		**Monday 4:45**	**PhD**
				
Lennart Balkenhol started March 2023	Etienne Camphuis started October 2023 (PhD 2020-2023)	Federica Guidi started October 2021	Ali Khalife started October 2022	Aline Vitrier started October 2023
Likelihood implementation	Winter field analysis	Summer field analysis	Extended models and theory	Wide field analysis

Recent CMB results from SPT-3G



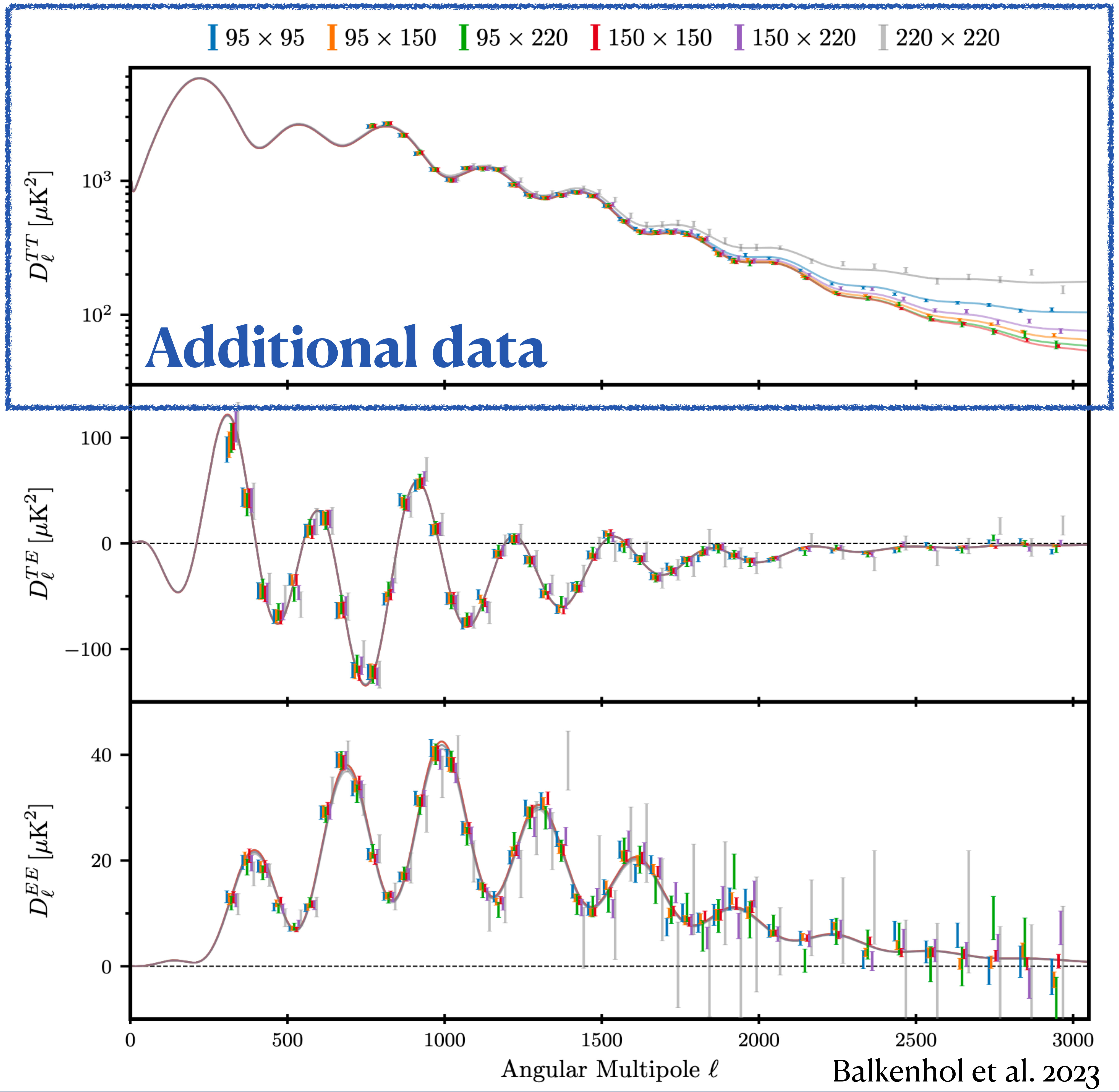
Courtesy of F. Guidi

A Measurement of the CMB Temperature Power Spectrum and Constraints on Cosmology from the SPT-3G 2018 T T /TE/EE Data Set

L. Balkenhol, D. Dutcher, A. Spurio Mancini, A. Doussot, K. Benabed, S. Galli, C. L. Reichardt, E. Hivon, N. Goeckner-Wald and the SPT-3G collaboration

https://journals.aps.org/prd/abstract/10.1103/PhysRevD.108.023510

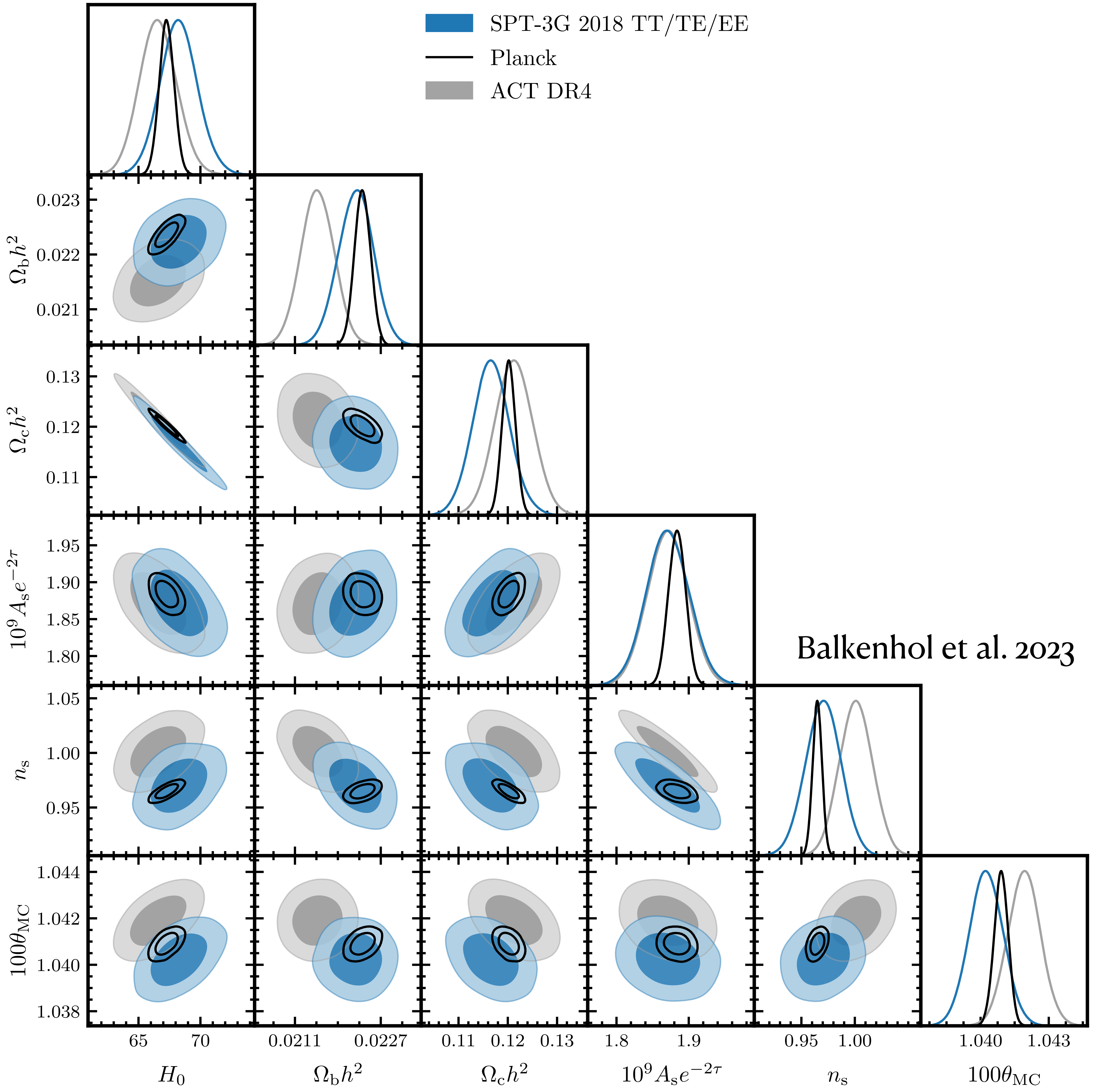
Following slides by L. Balkenhol



Balkenhol et al. 2023

Constraints on ΛCDM

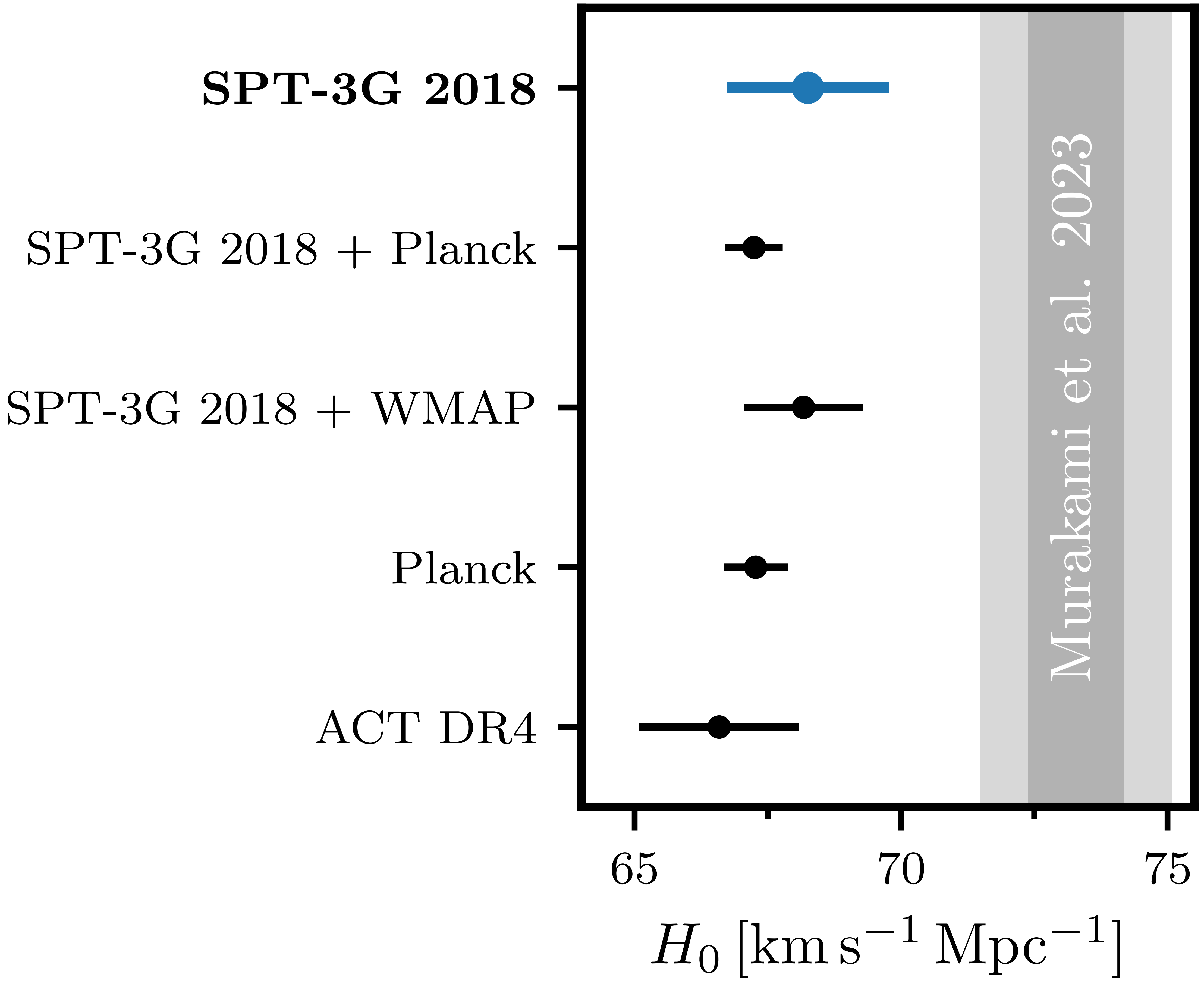
- **Data is well-fit by ΛCDM (PTE = 15%)**
  - **Good agreement with Planck 2018, yet independent**



Balkenhol et al. 2023

Constraints on ΛCDM

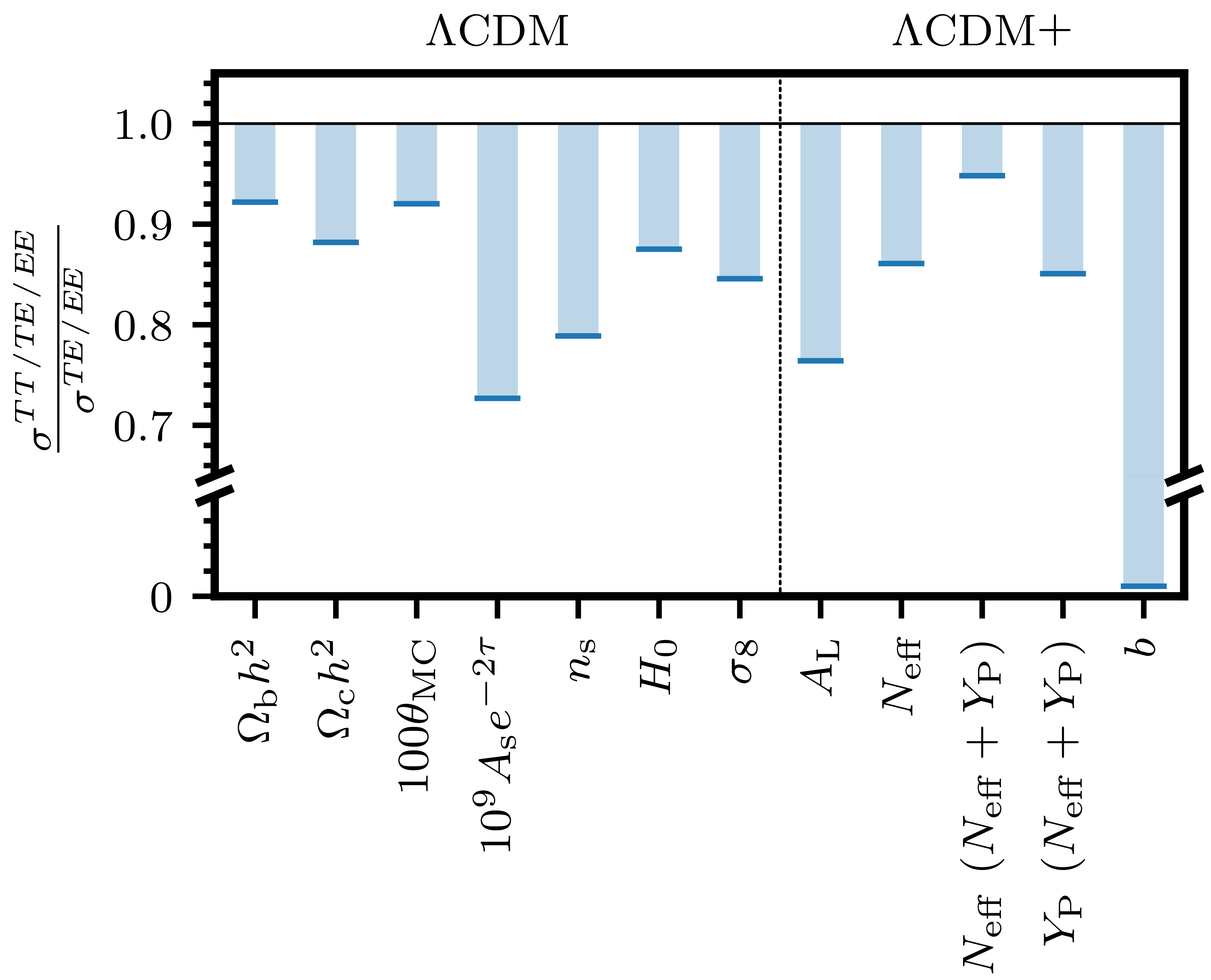
- Data is well-fit by ΛCDM (PTE = 15%)
  - Good agreement with Planck 2018, yet independent
- **Expansion rate**
  $\mathbf{H_0 = 68.3 \pm 1.5\, km/s/Mpc}$



Balkenhol et al. 2023

Constraints on ΛCDM

- Data is well-fit by ΛCDM (PTE = 15%)
  - Good agreement with Planck 2018, yet independent
- Expansion rate
  $H_0 = 68.3 \pm 1.5\,\mathrm{km/s/Mpc}$
- **Addition of TT to TE/EE shrinks error bars by 8-27%**



Balkenhol et al. 2023

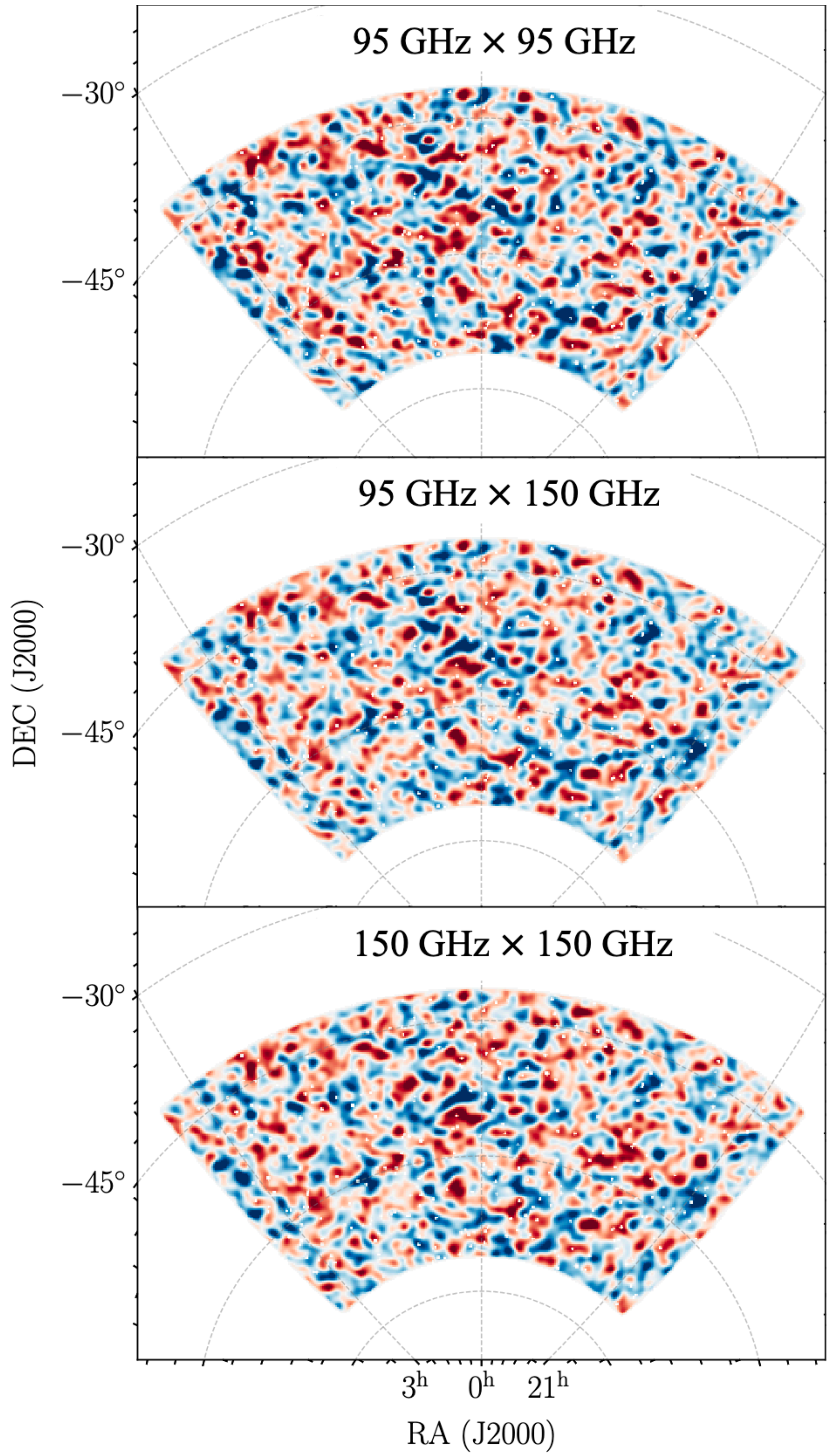
A Measurement of Gravitational Lensing of the Cosmic Microwave Background Using SPT-3G 2018 Data

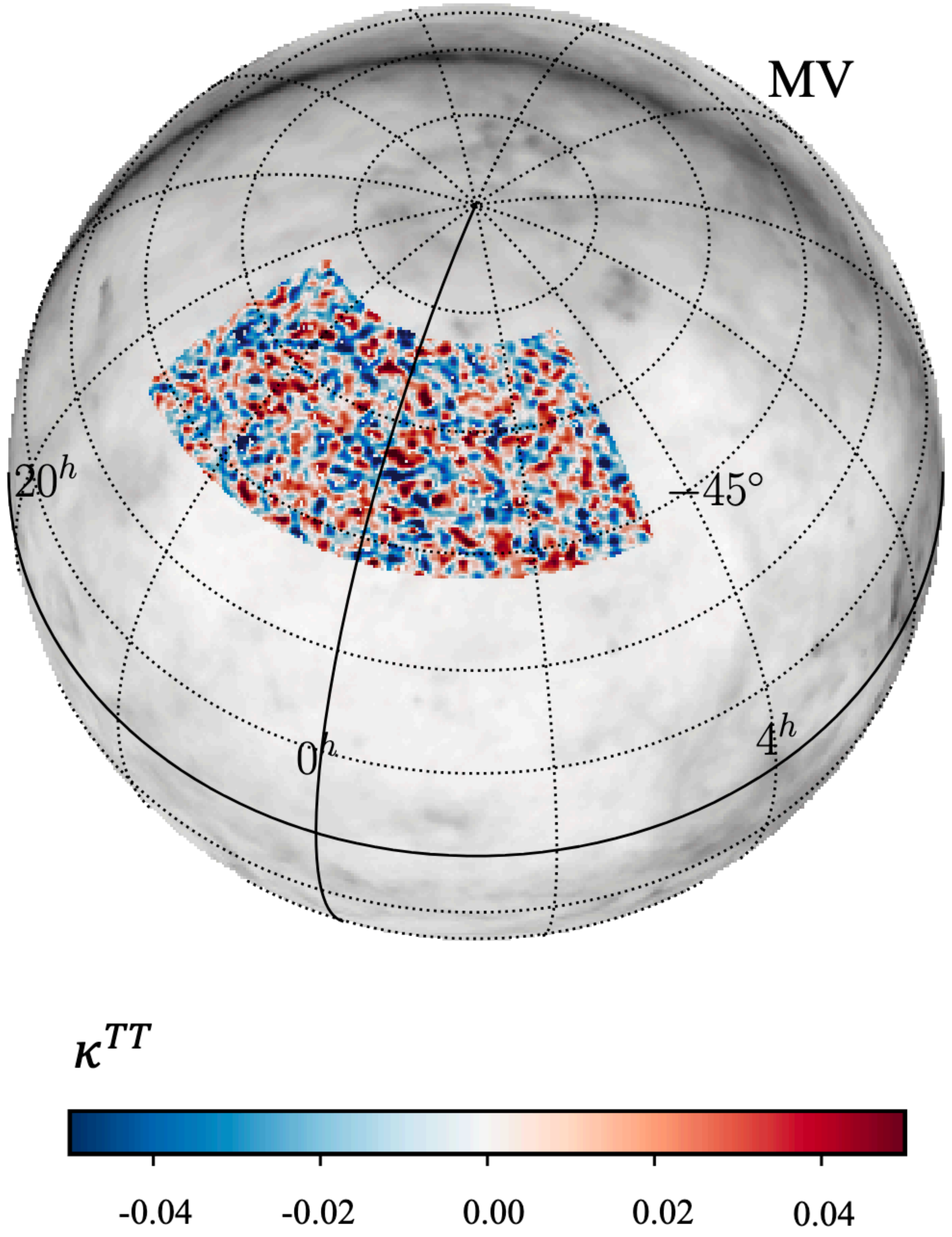
Z. Pan, F. Bianchini, W. L. K. Wu

and the SPT-3G collaboration

https://arxiv.org/pdf/2308.11608.pdf





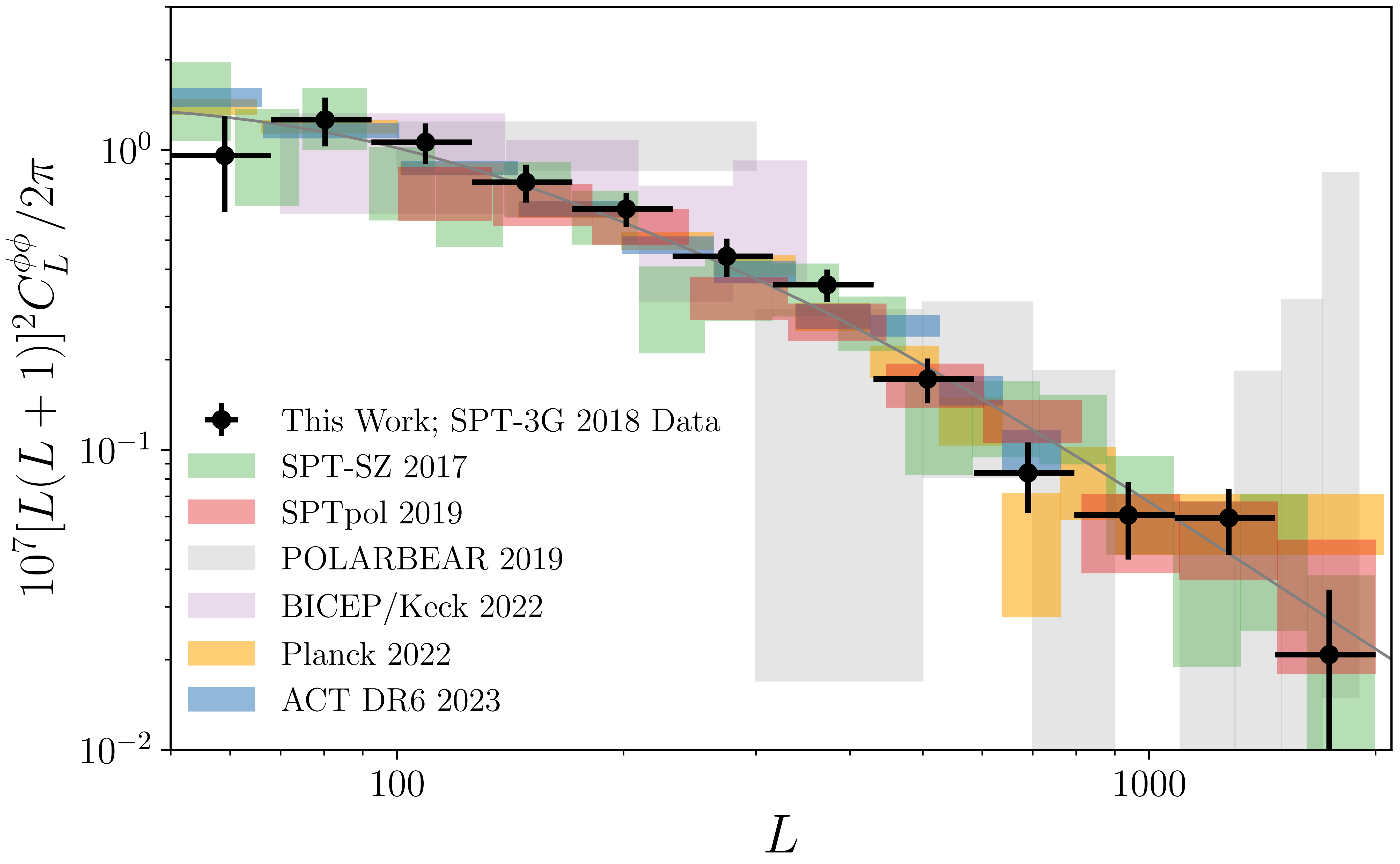


Pan et al., 2023

SPT-3G 2018 Lensing

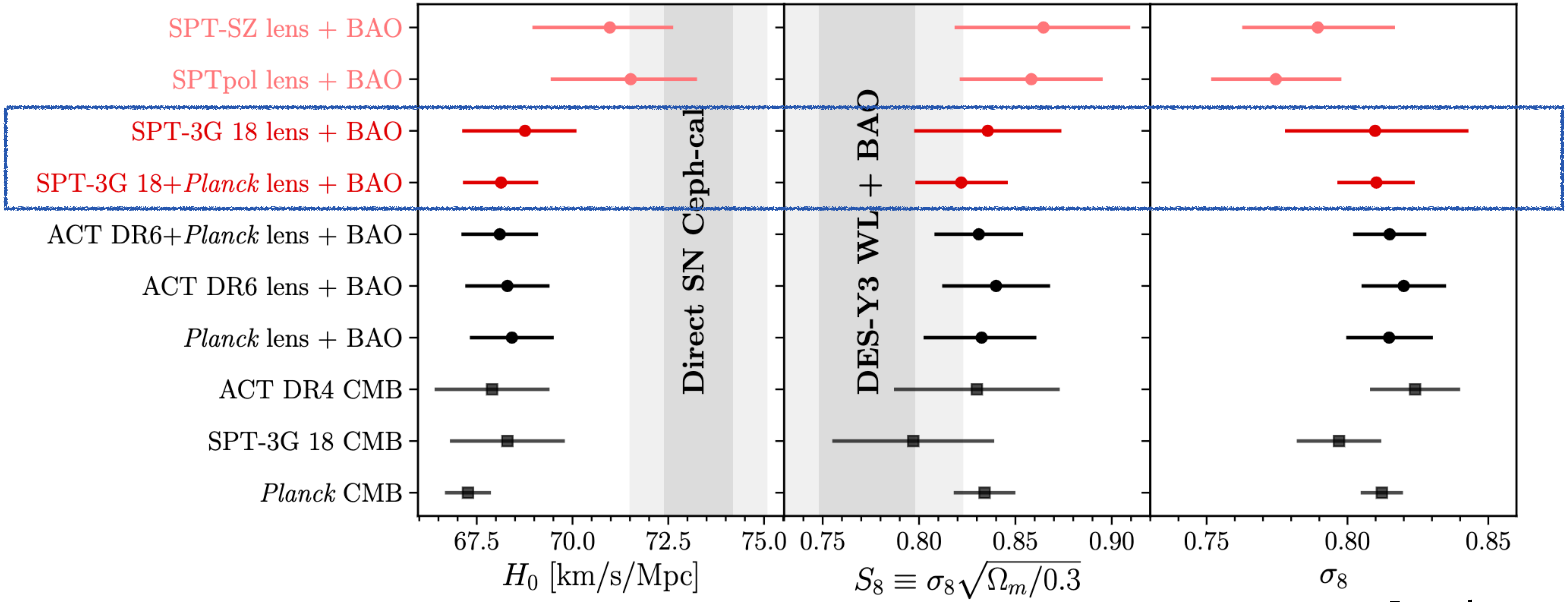
Pan et al. 2023, arXiv:2308.11608

- Gravitational lensing potential power spectrum measurement using temperature multi-frequency information
- Lensing amp: $A = 1.020 \pm 0.060$
- Structure growth w/ BAO data $S_8 = 0.836 \pm 0.039$



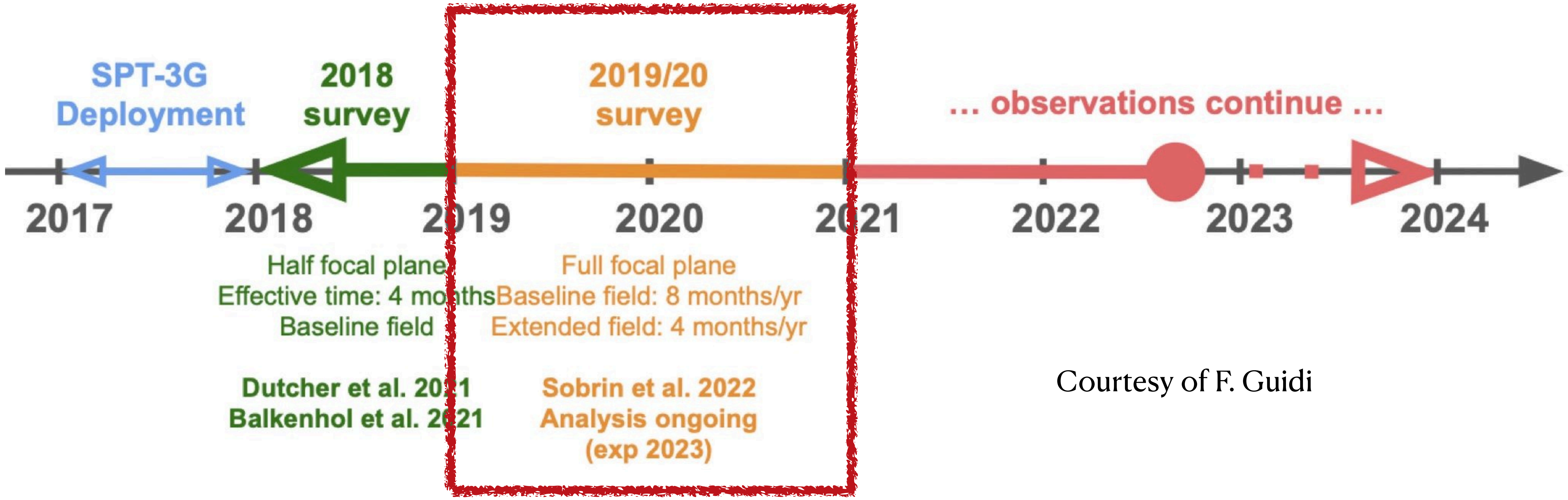
Pan et al., 2023

SPT-3G 2018 Lensing



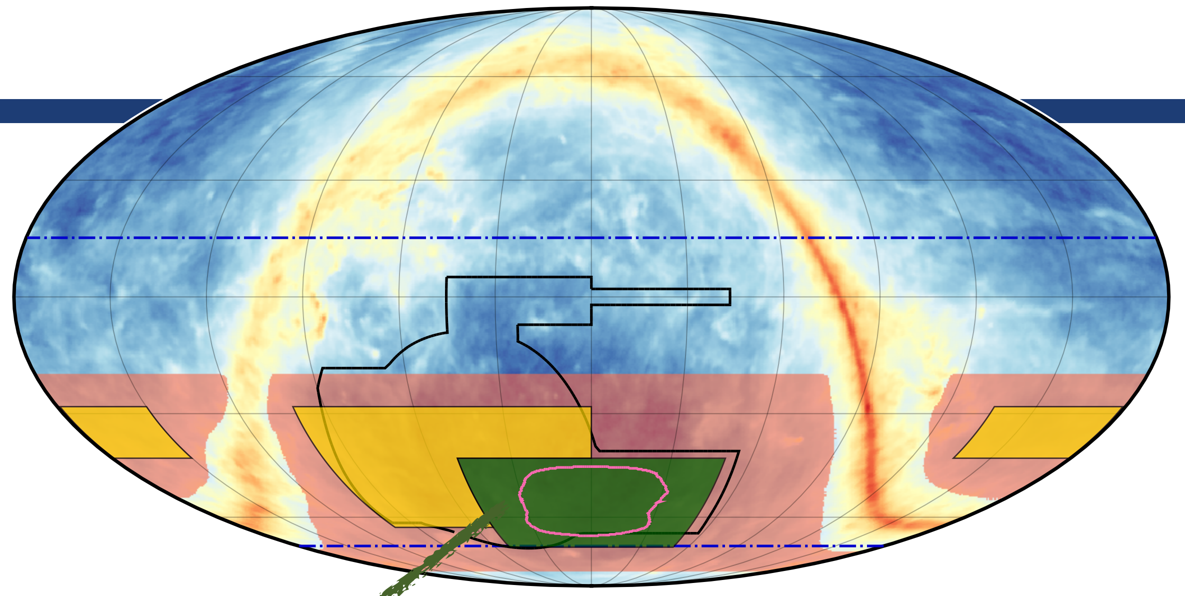
Pan et al., 2023

Focus on 19/20 CMB data



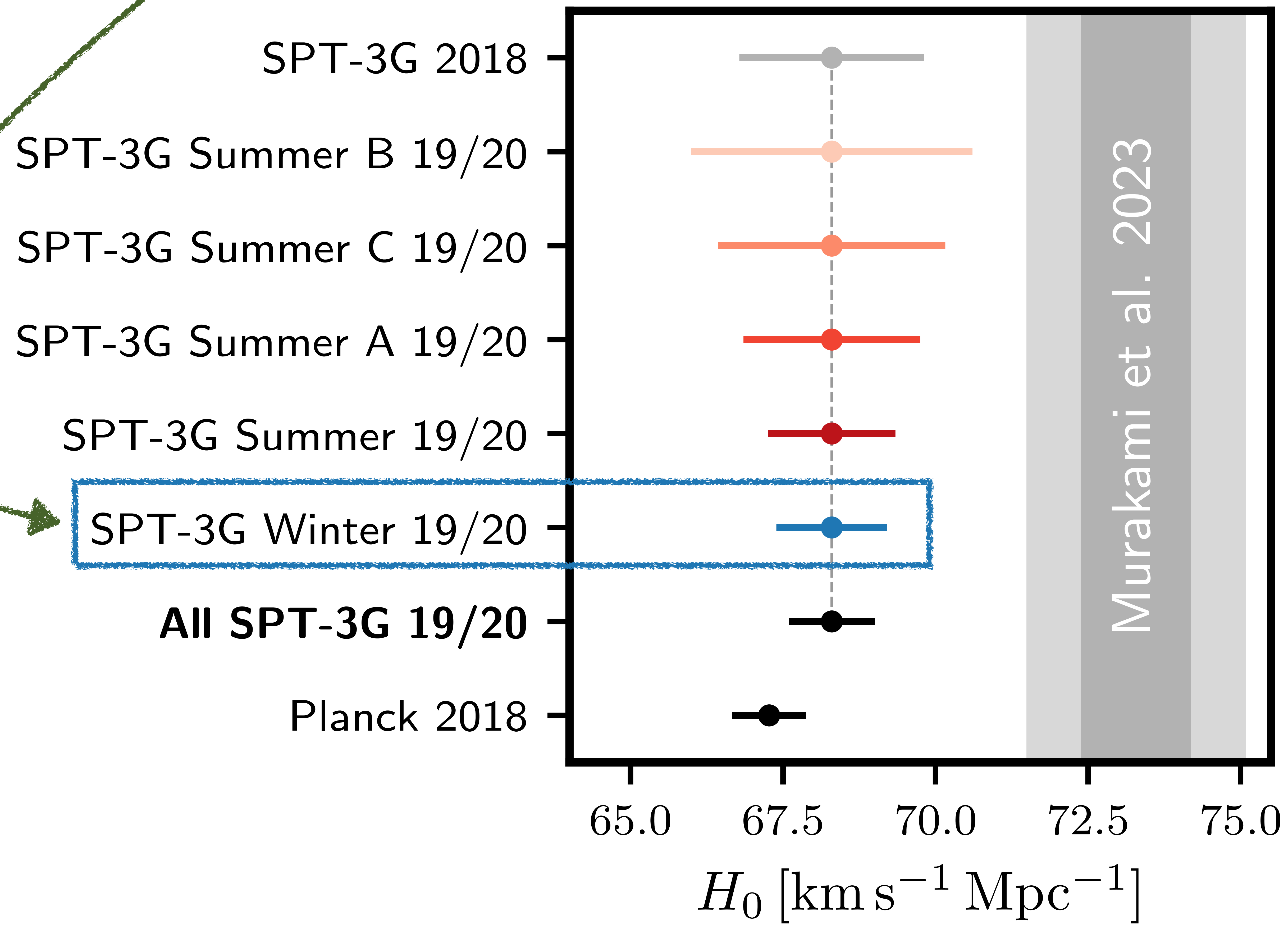
Courtesy of F. Guidi

Focus on 19/20 primary



Forecasts

Plot by L. Balkenhol

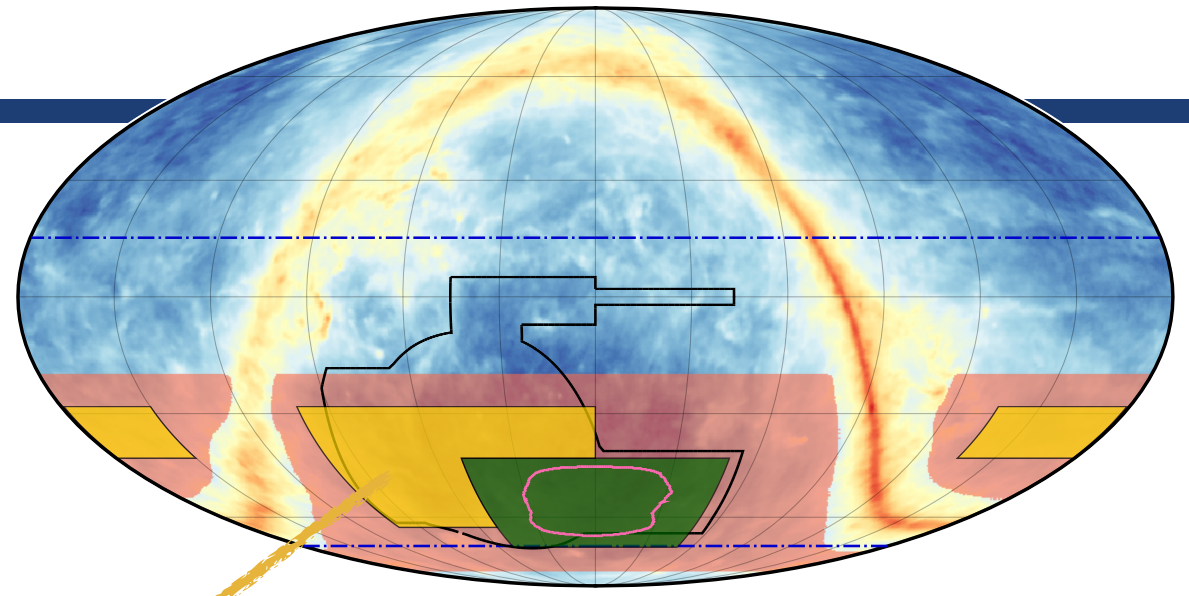


- Main TT/TE/EE alone will yield constraints 50% larger than *Planck*

  Ongoing analysis led by Wei Quan (UC) & EC

  Improved analysis pipeline (curved sky, semi-analytical covariance, inpainting, improved consistency tests and blinding)

Focus on 19/20 primary

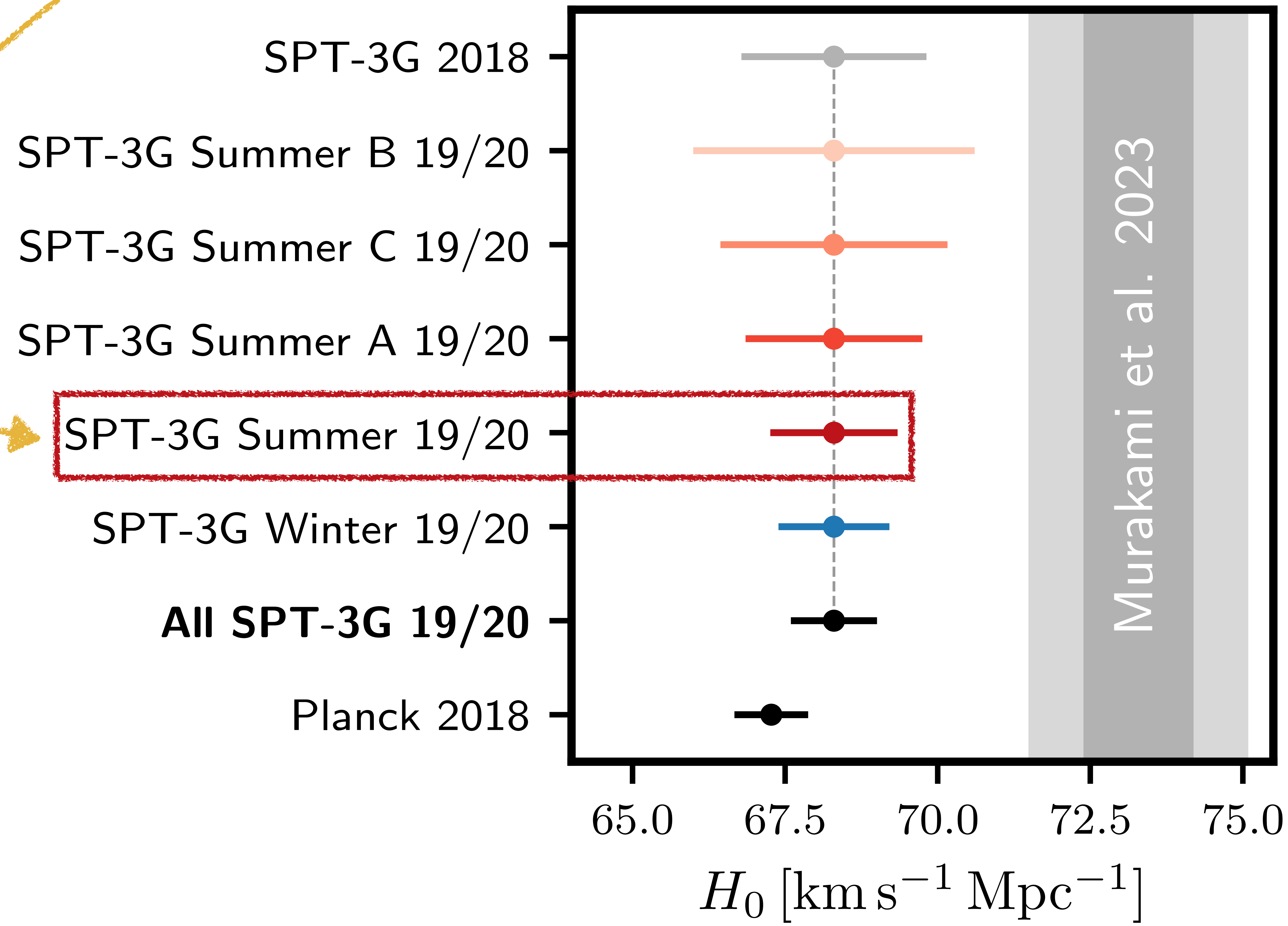


Forecasts

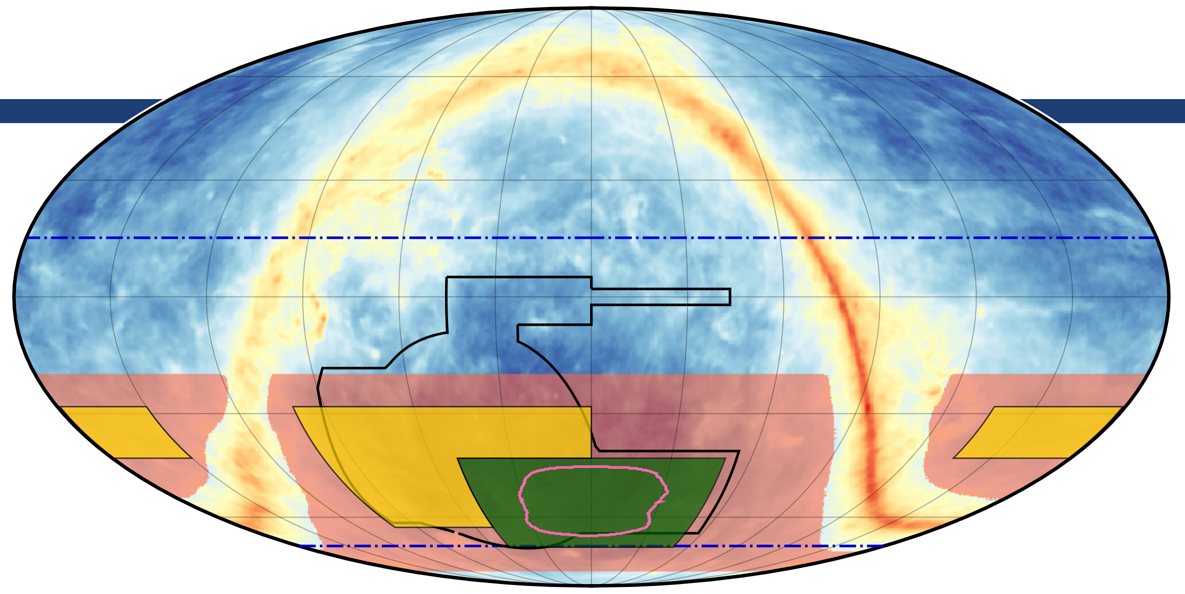
Plot by L. Balkenhol

- Main TT/TE/EE alone will yield constraints 50% larger than *Planck*
- Summer TT/TE/EE will add additional constraining power

  Ongoing analysis led by Federica Guidi.
- Both analyses are independent from *Planck* (only external calibration @ 150GHz)



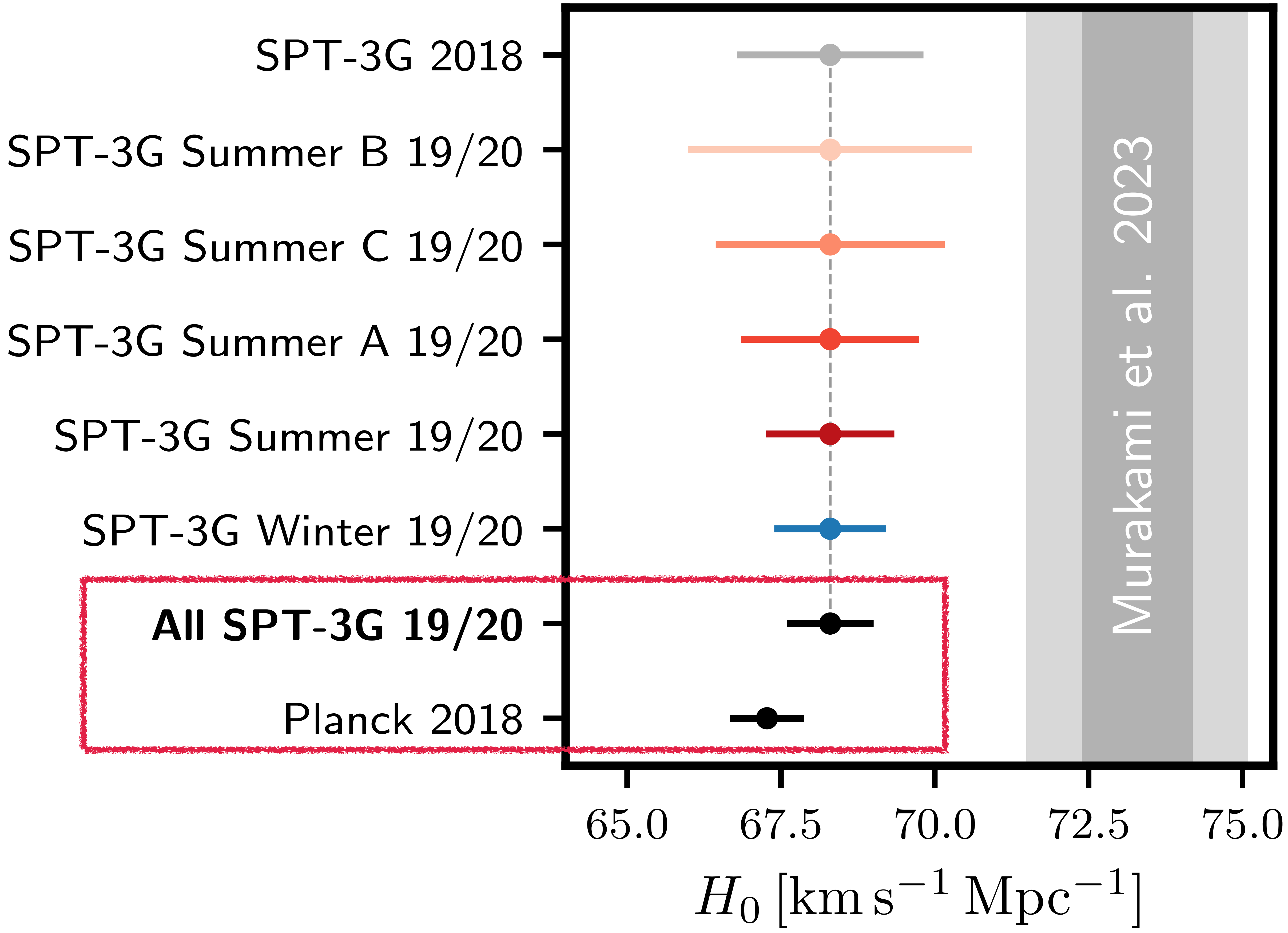
Focus on 19/20 primary



Forecasts

- Main TT/TE/EE alone will yield constraints 50% larger than *Planck*
- Summer TT/TE/EE will add additional constraining power
- **Combined TT/TE/EE constraints will be as good as *Planck* for H_0 without lensing**
- Results in upcoming months !

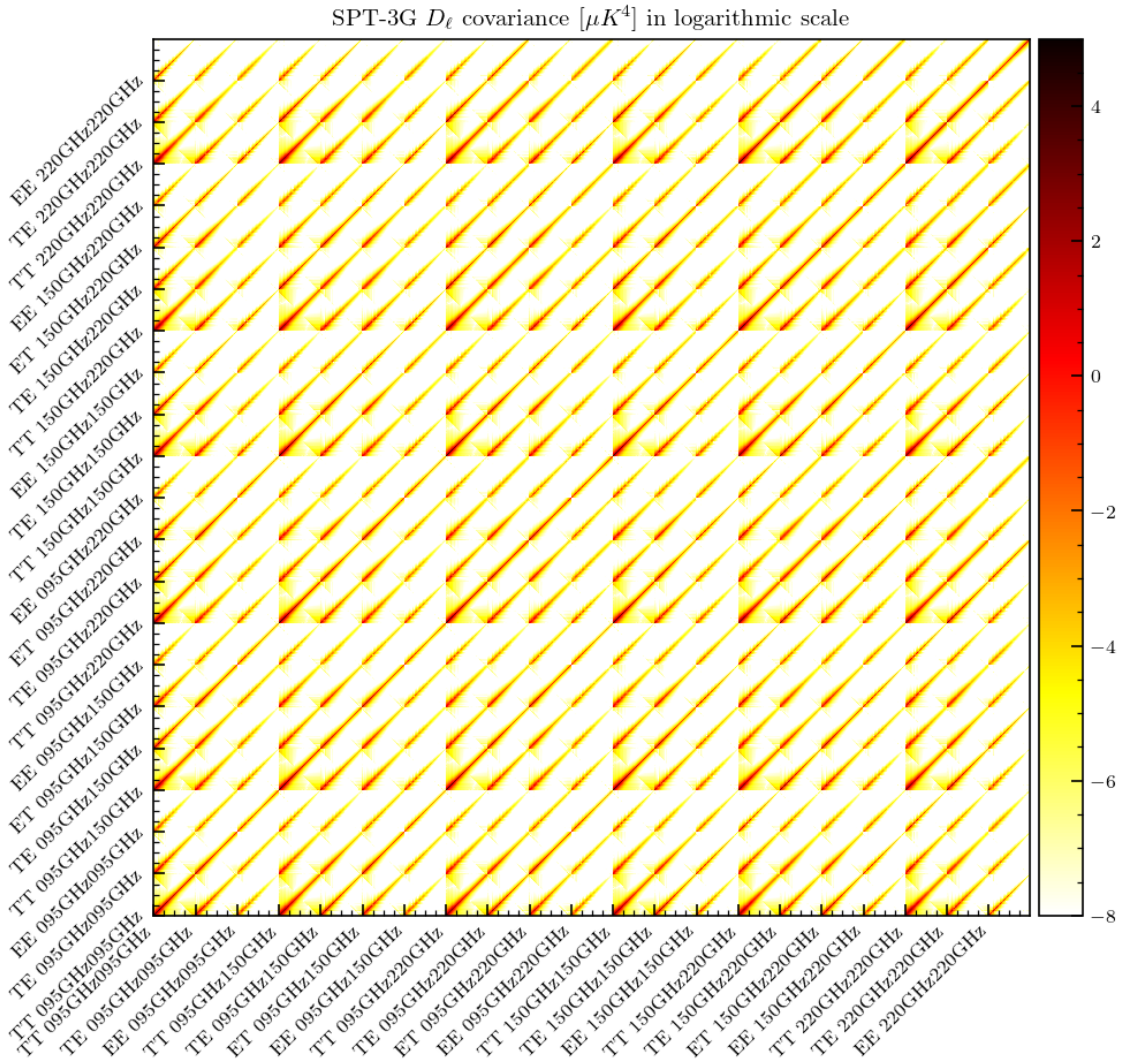
Plot by L. Balkenhol



Focus on 19/20 primary

Pipeline improvements

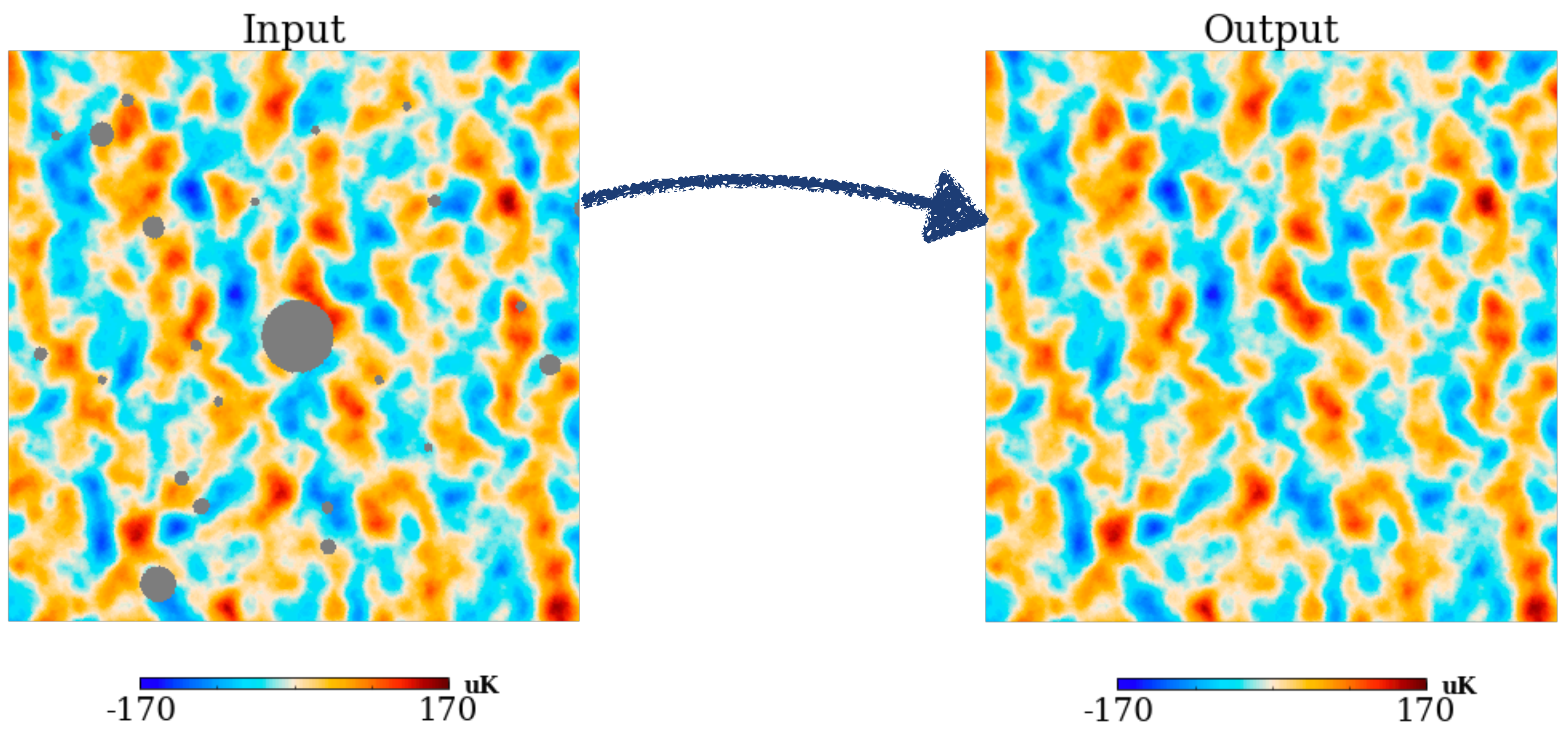
- **Semi-analytical framework based on EC et al., 2022**



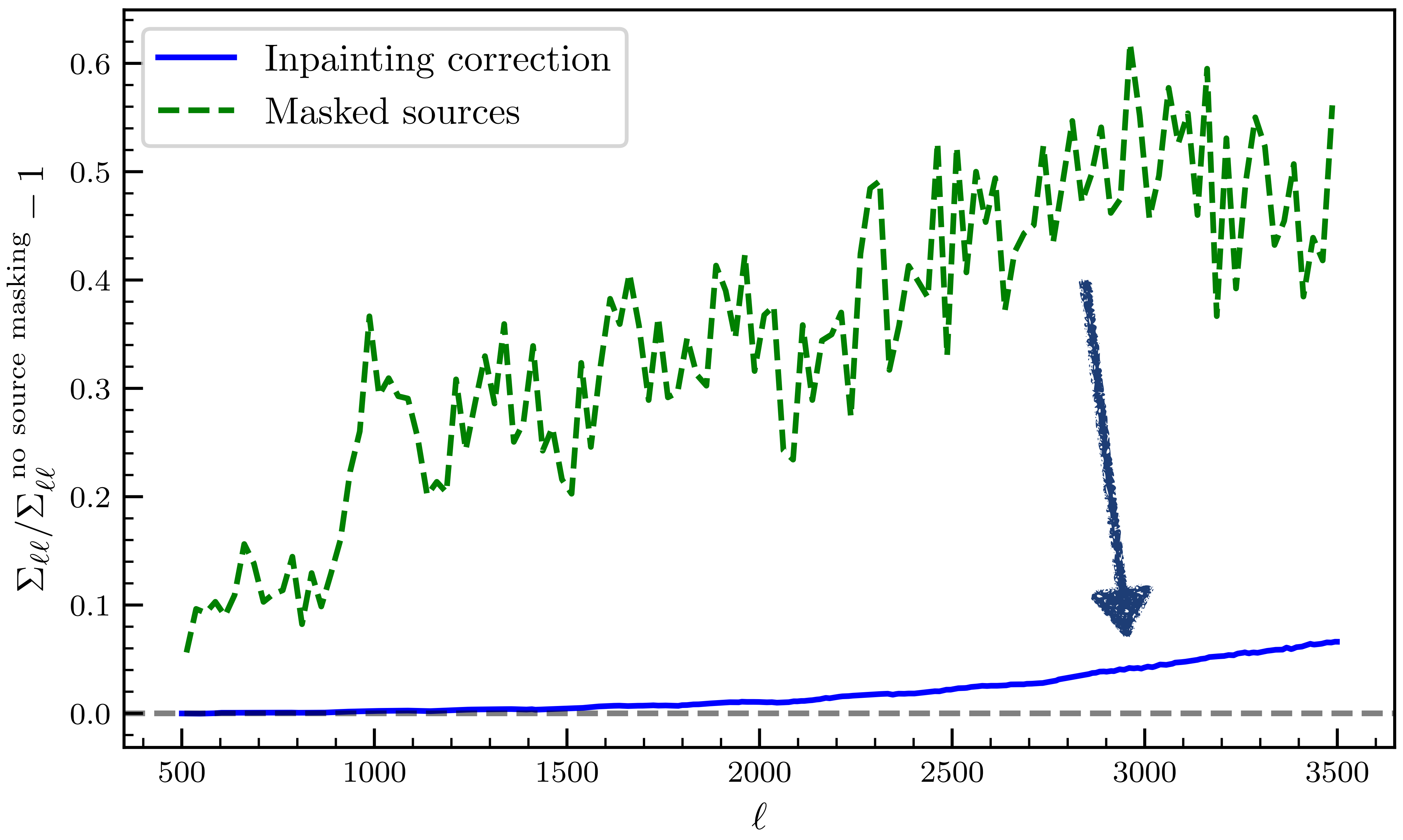
Focus on 19/20 primary

Pipeline improvements

- Semi-analytical framework based on EC et al., 2022
- **High-accuracy inpainting: pushing down geometric variance**



Impact on variance



Focus on 19/20 primary

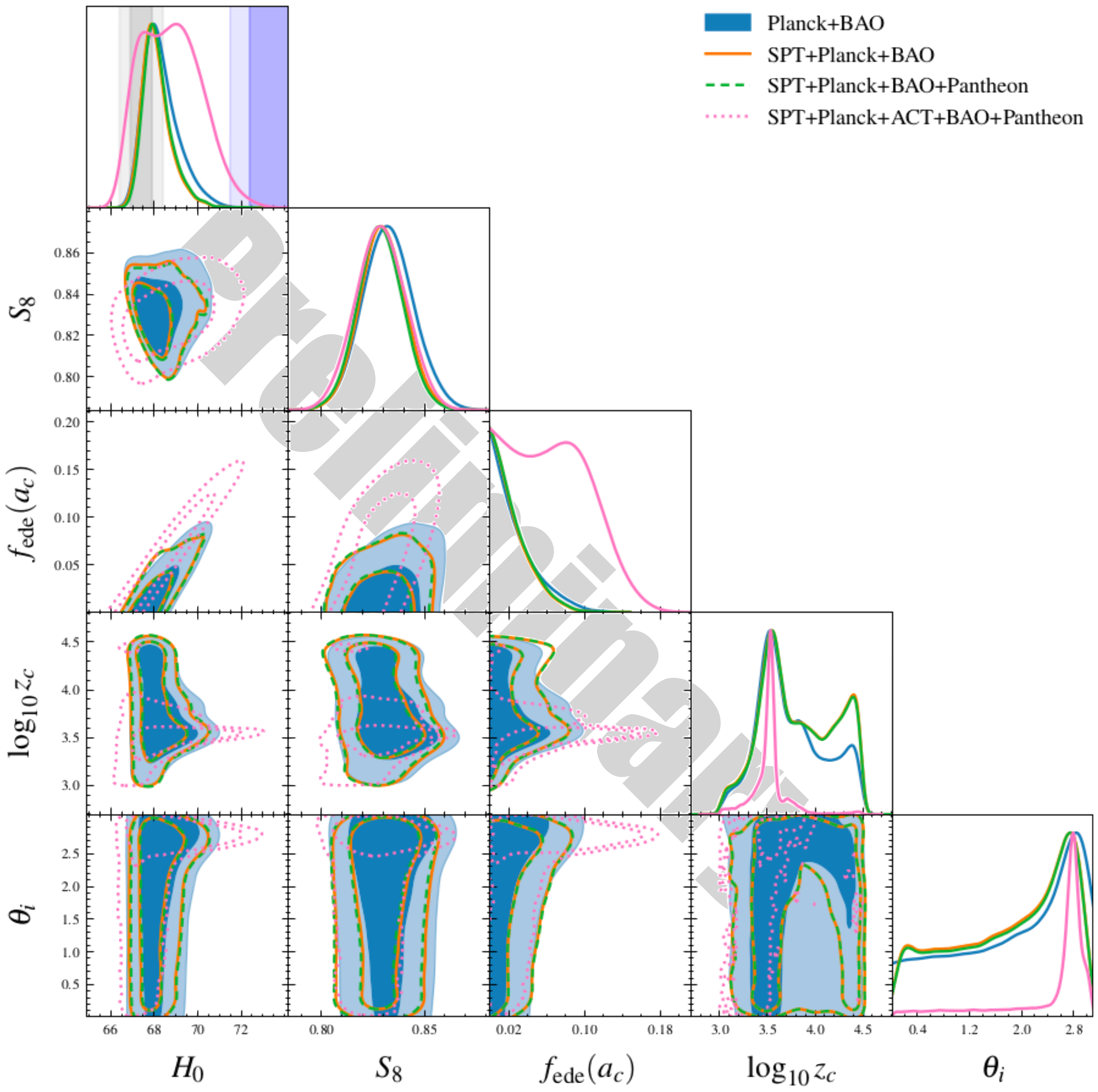
Pipeline improvements

- Semi-analytical framework based on EC et al., 2022
- High-accuracy inpainting: pushing down geometric variance
- **Differentiable likelihood: see Lennart's talk**

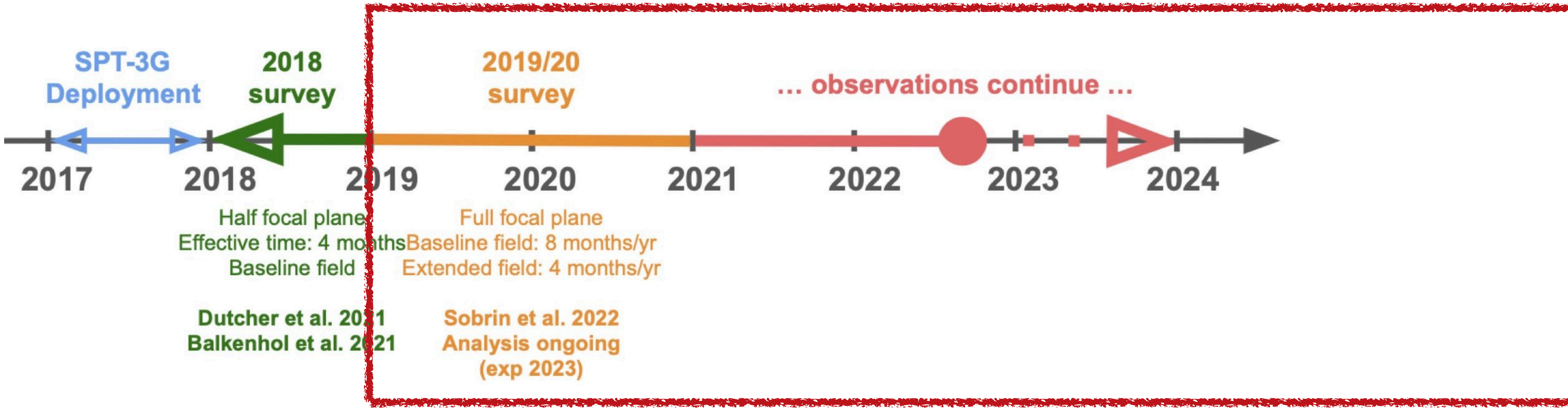
Focus on 19/20 primary

Pipeline improvements

- Semi-analytical framework based on EC et al., 2022
- High-accuracy inpainting: pushing down geometric variance
- Differentiable likelihood
- **Preparing for cosmological constraints: see Ali's talk**



Full survey prospects

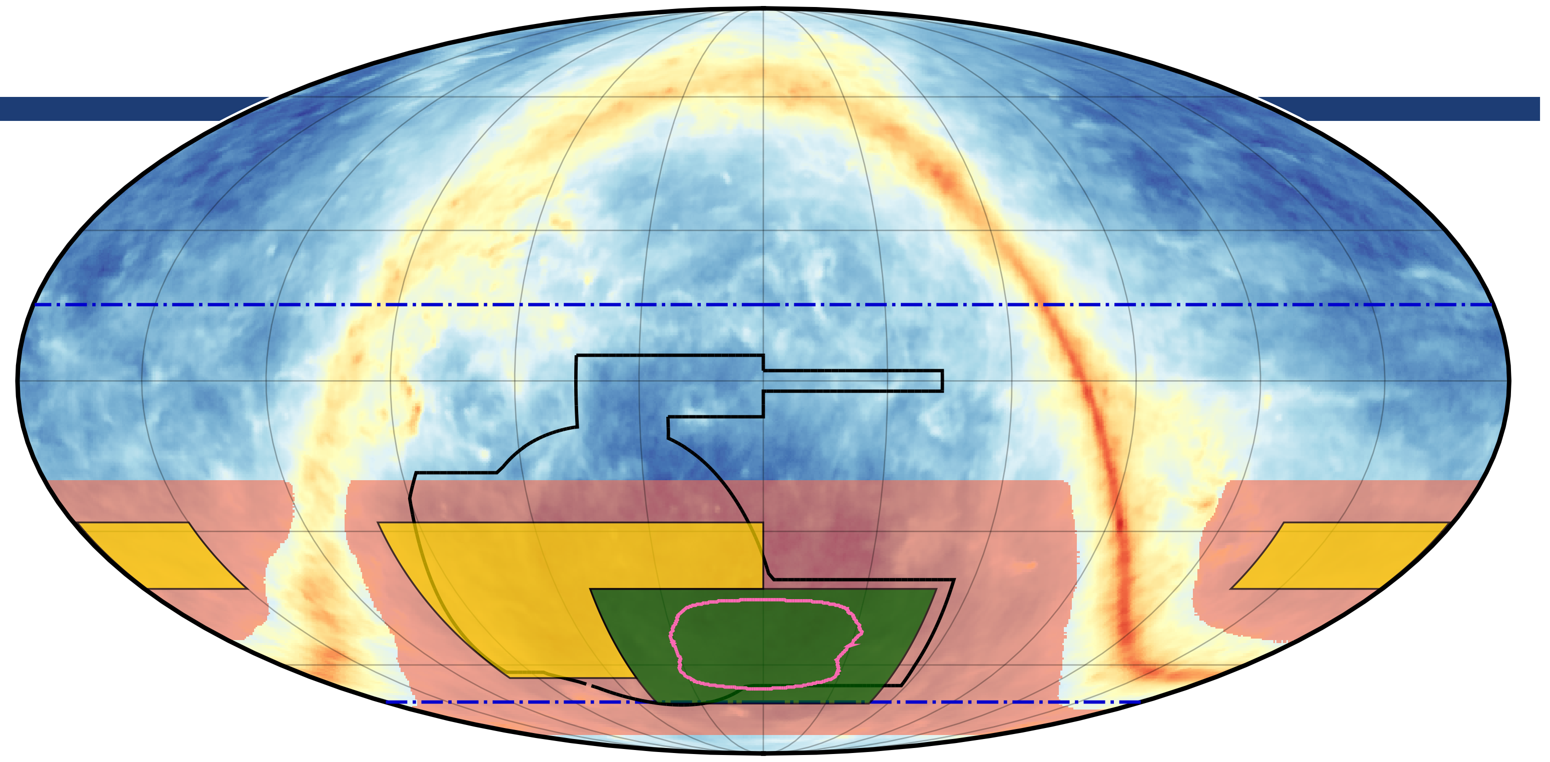


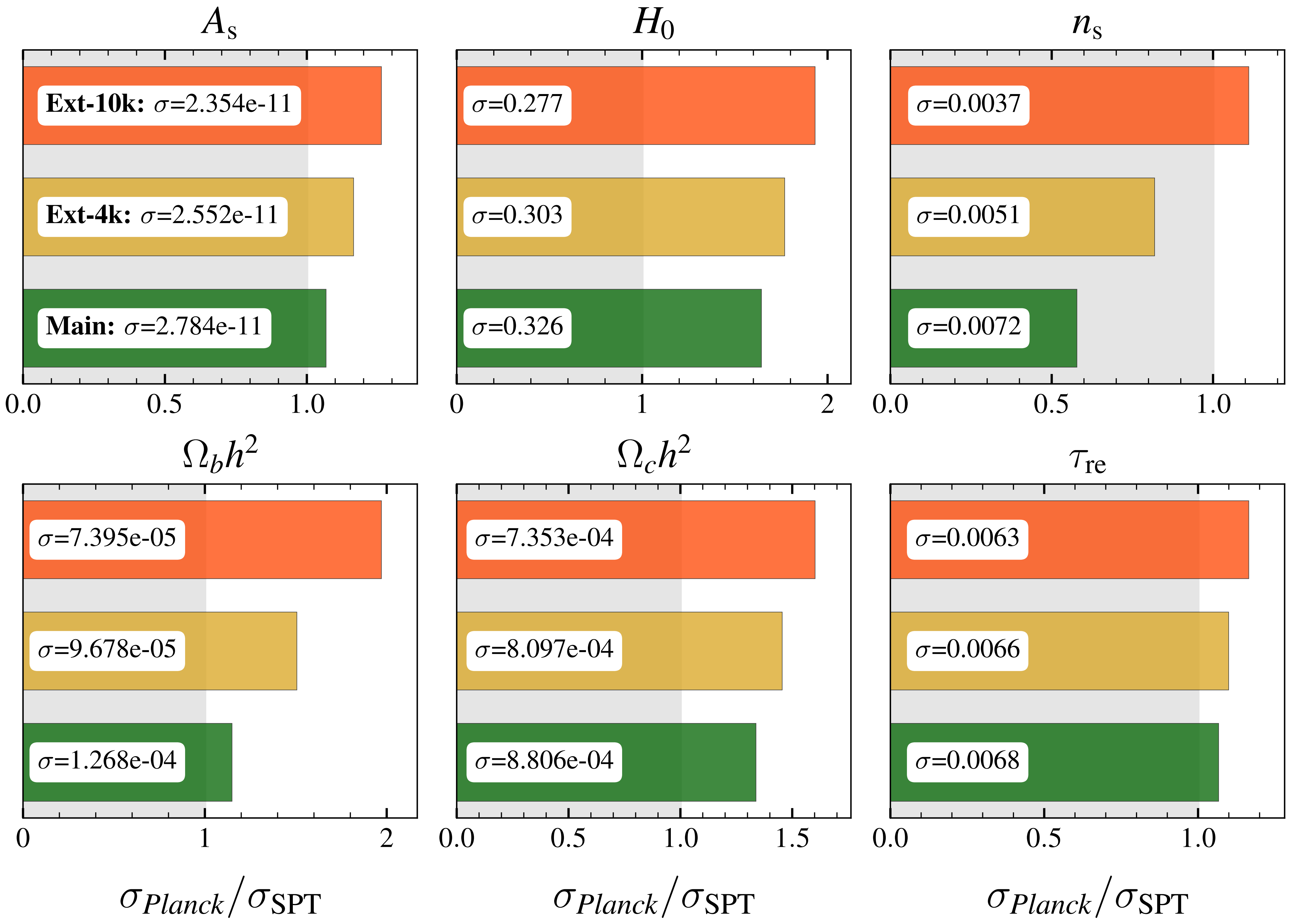
Final constraints

with TT/TE/EE + lensing

- **Main field alone will provide H_0 constraints 1.5x smaller than *Planck* $\sigma(\mathrm{H_0}) = 0.33\mathrm{Km/s/Mpc}$**

SPT-3G forecasting paper, Prabhu et al. *in prep.*





Final constraints

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- Main field alone will provide H_0 constraints 1.5x smaller than *Planck*
- **Summer fields will improve constraints by 20% due to reduced sample variance at low-ℓ**

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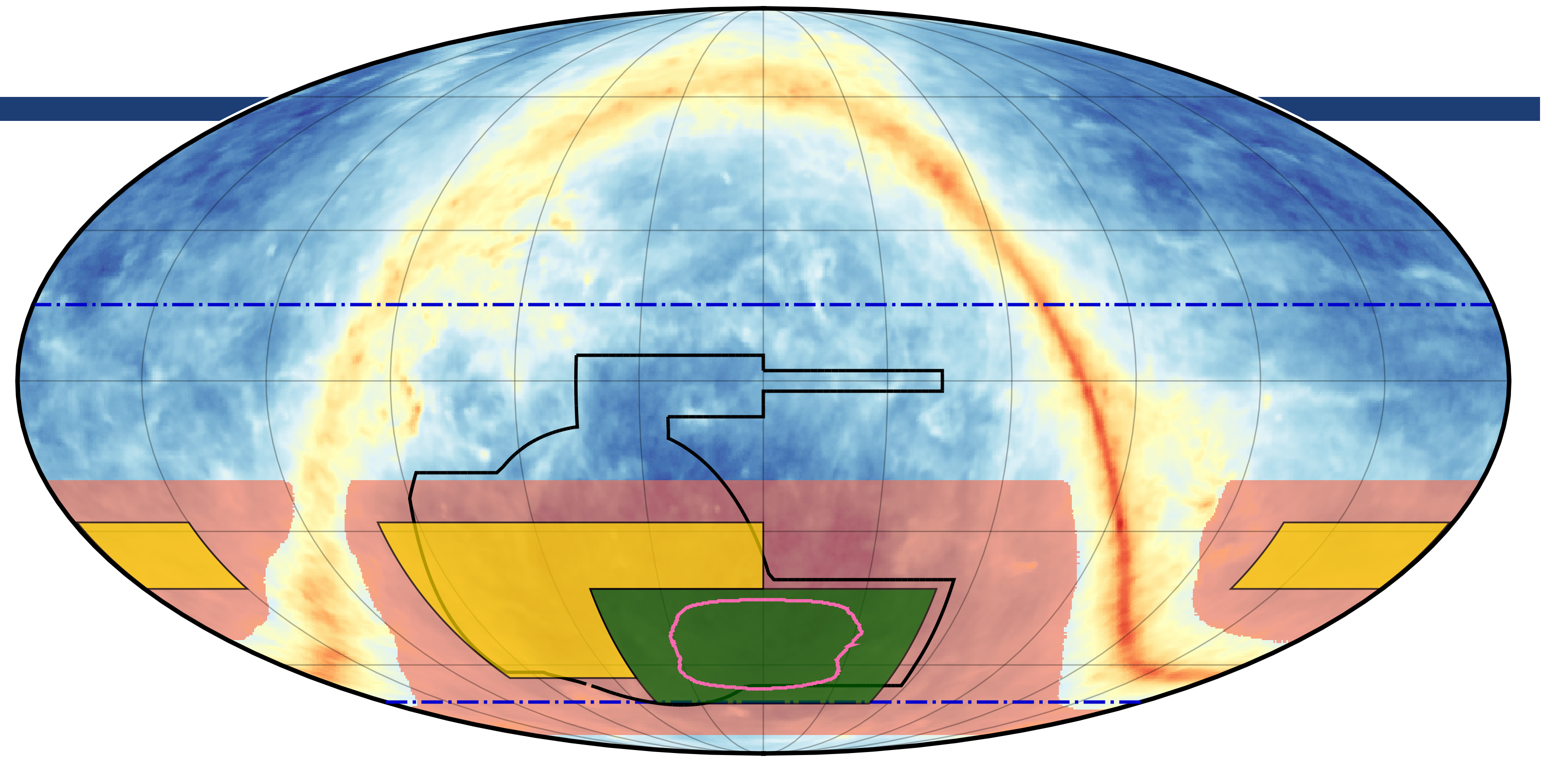

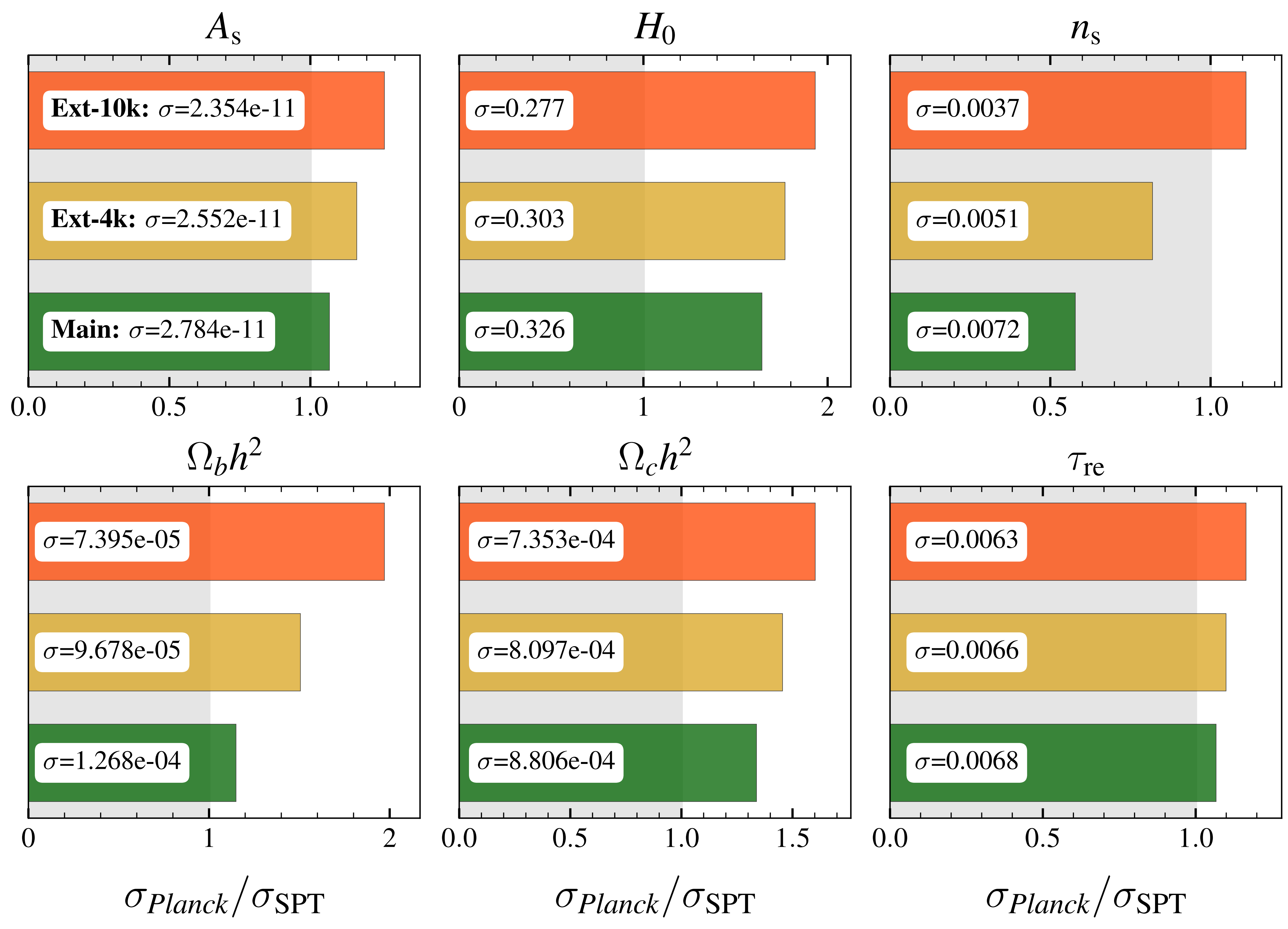

Final constraints

with TT/TE/EE + lensing

- Main field alone will provide H_0 constraints 1.5x smaller than *Planck* $\sigma(H_0) = 0.36$Km/s/Mpc
- Summer fields will improve the constraints by 20% due to reduced sample variance at low-ℓ
- **The all-including Extended-10k survey will yield independent constraints twice better than *Planck* on H_0**

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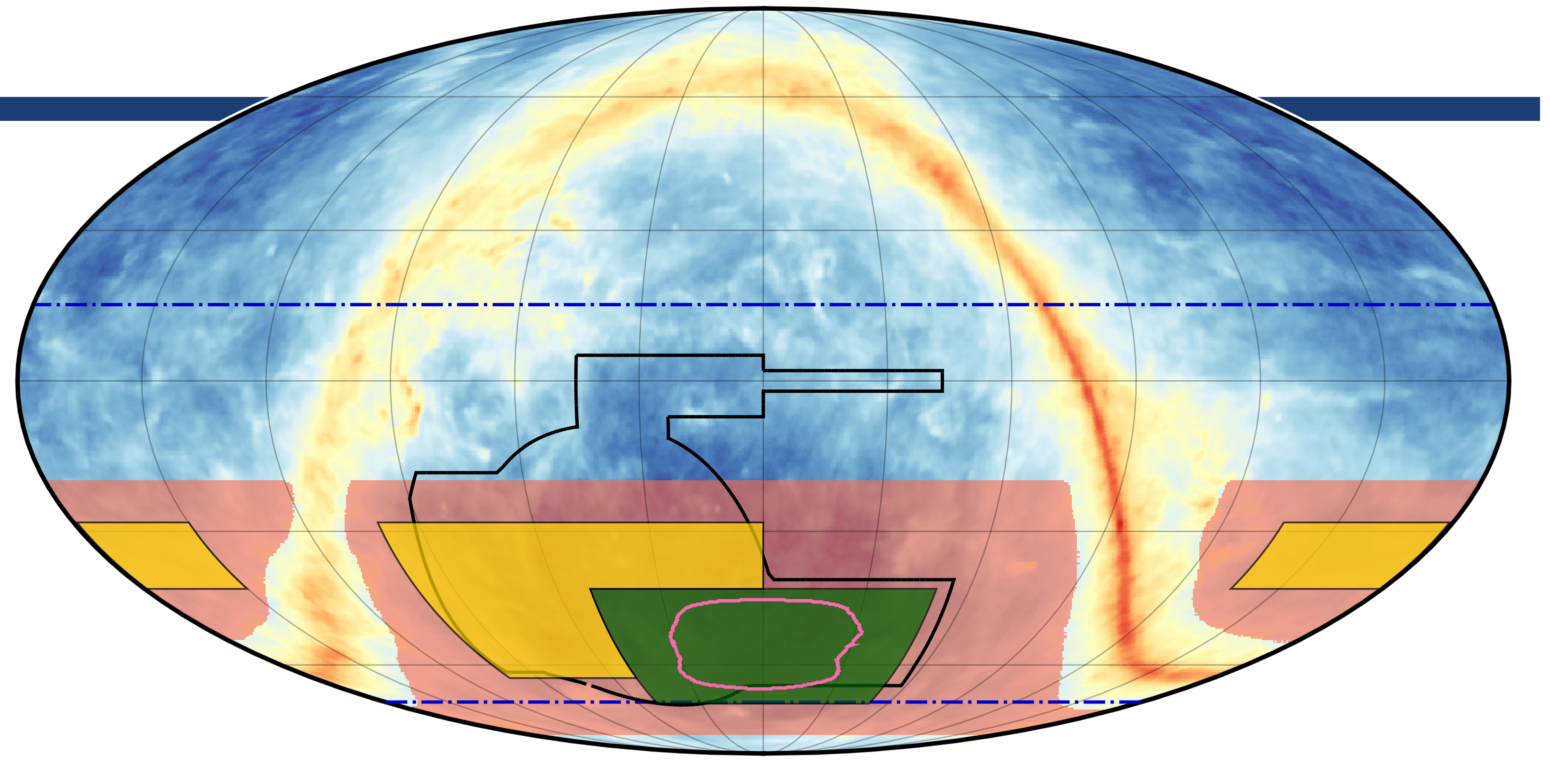

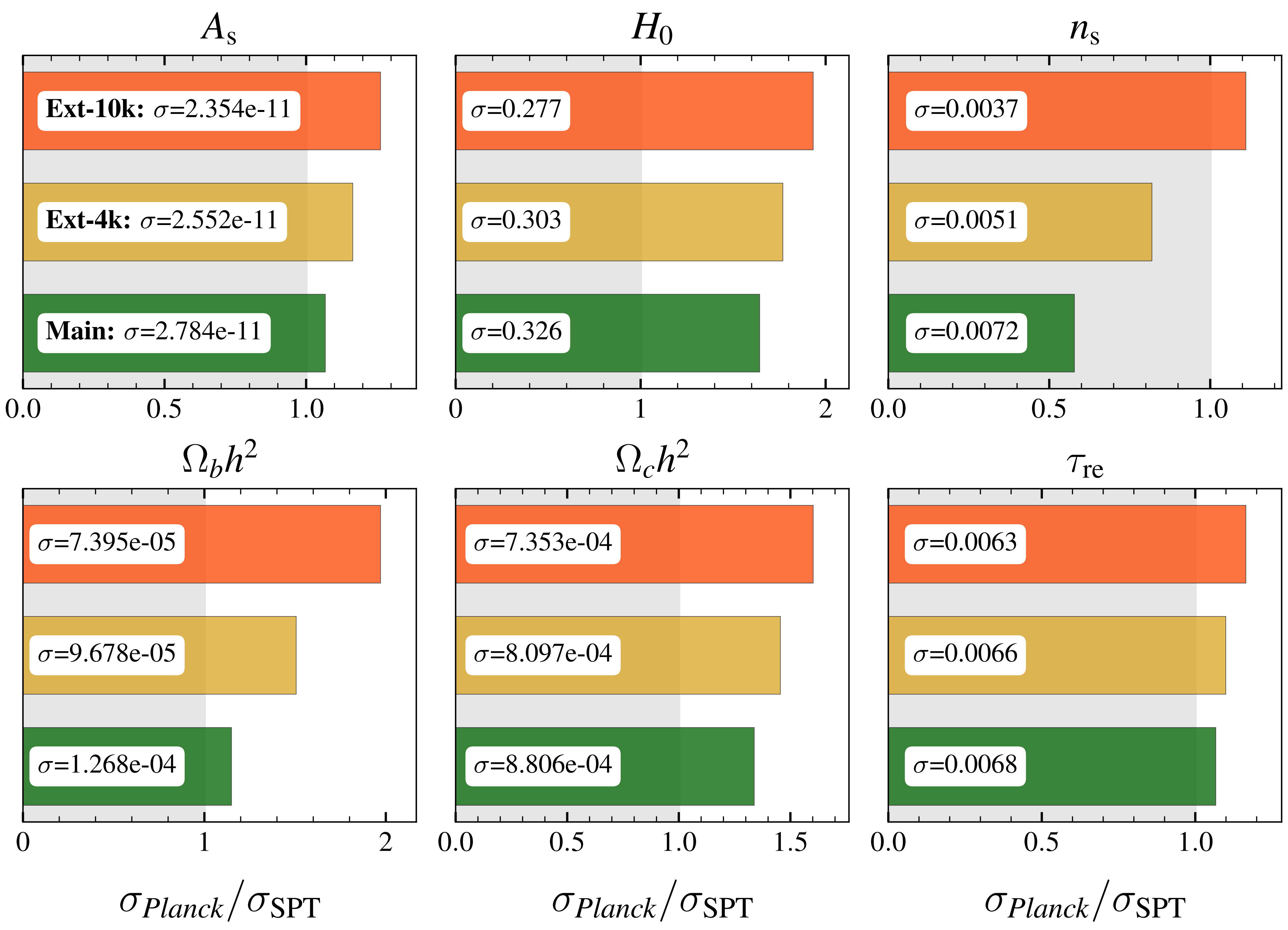

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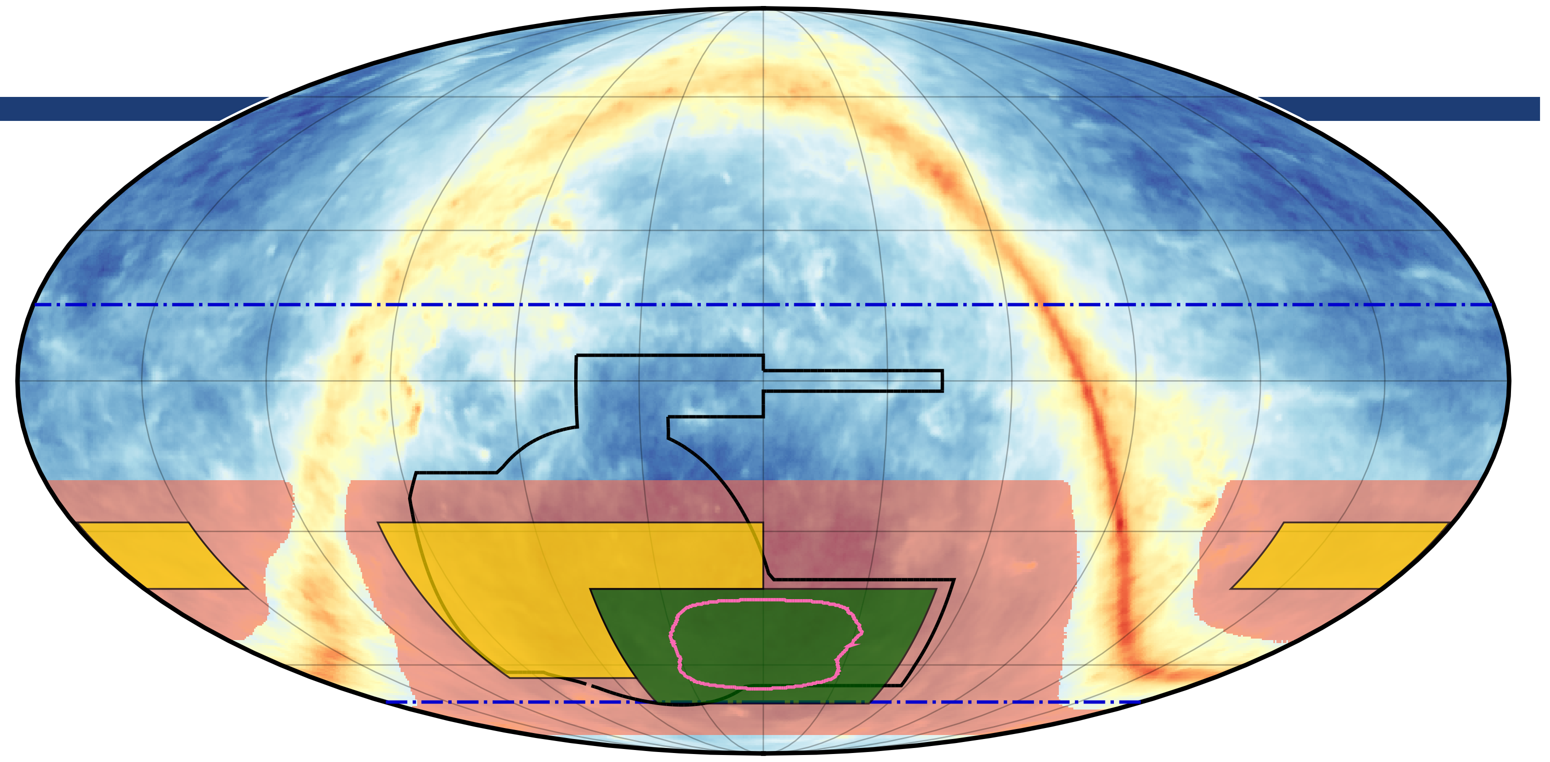

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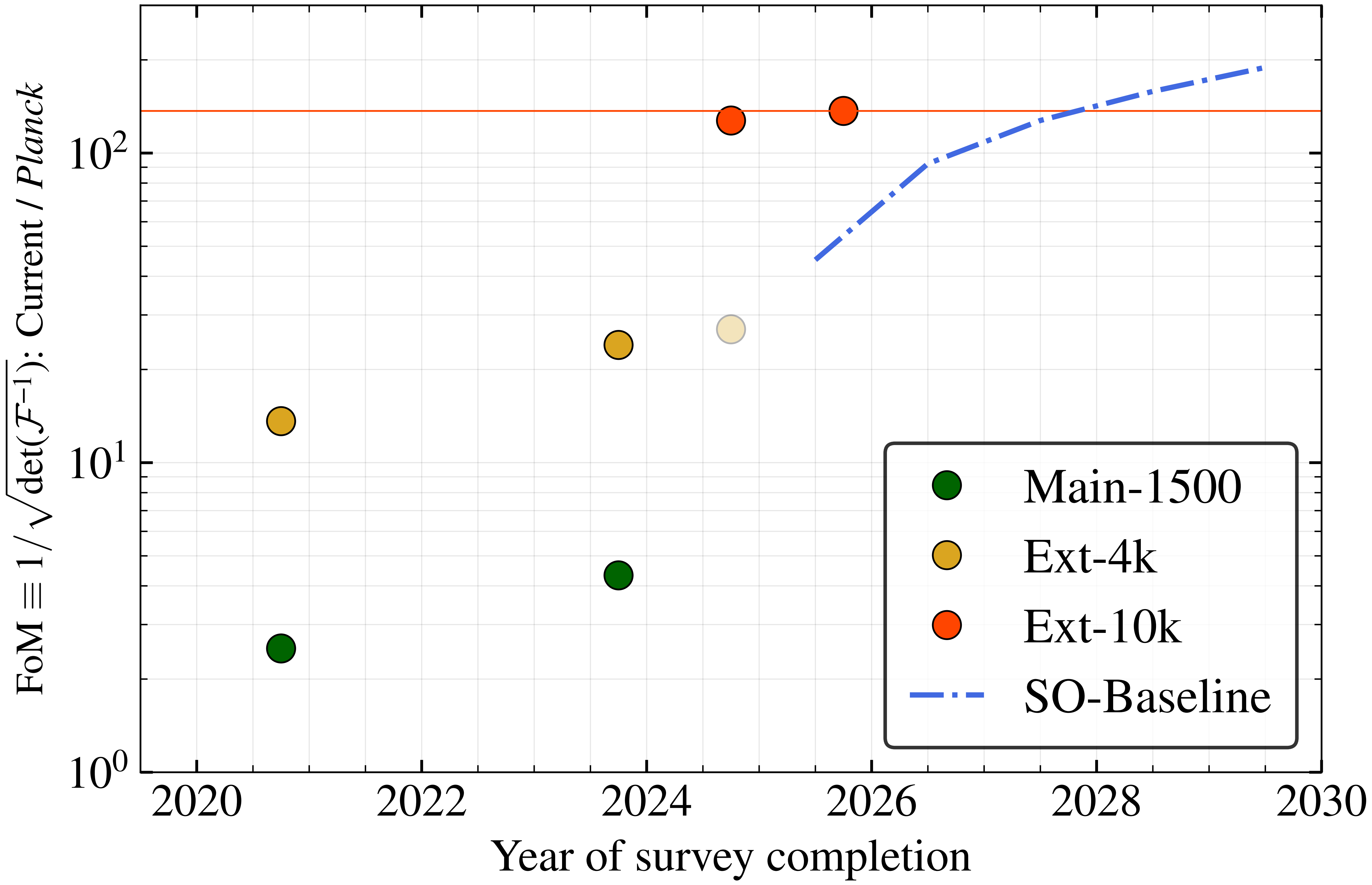

Final constraints

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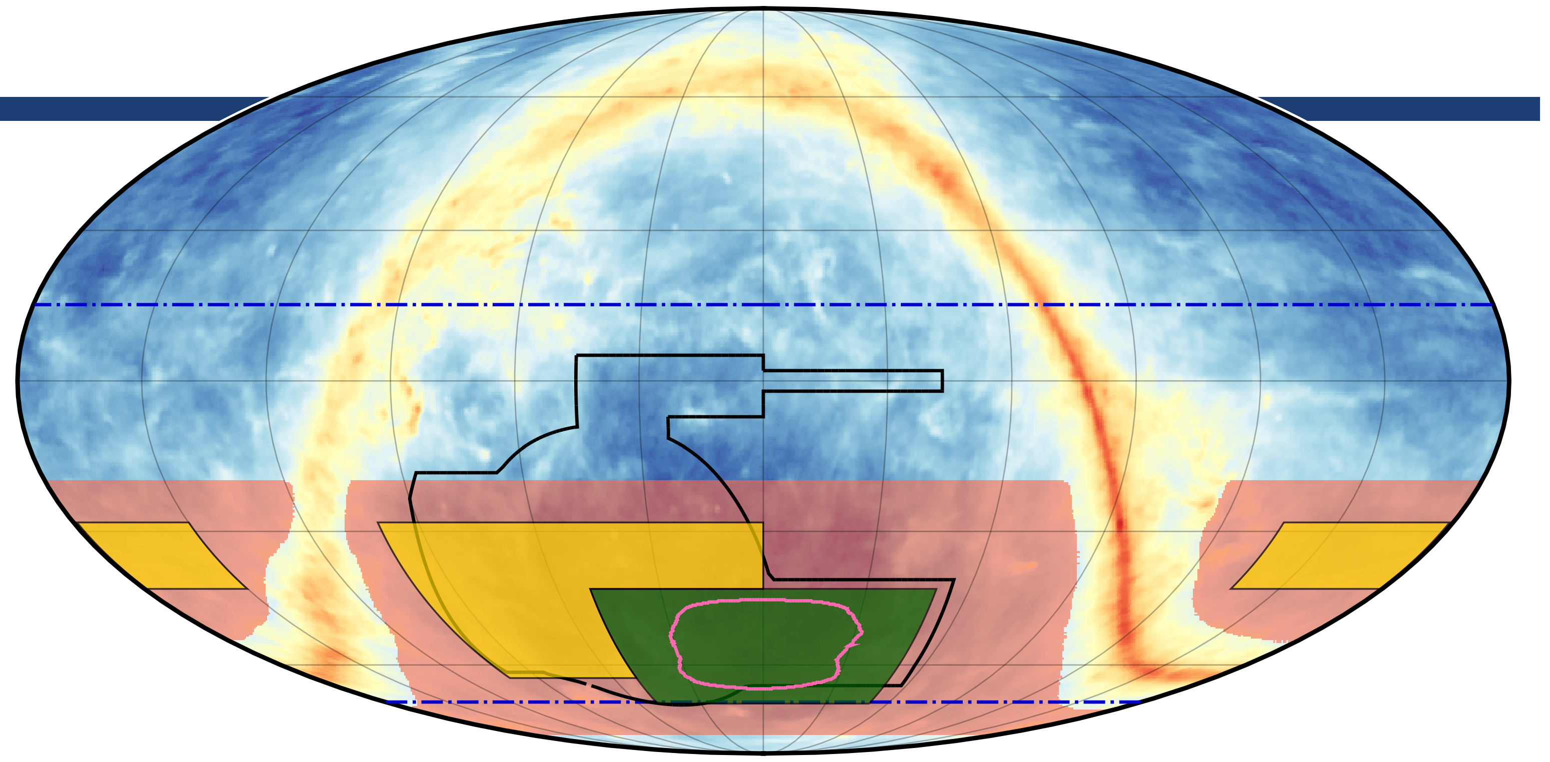

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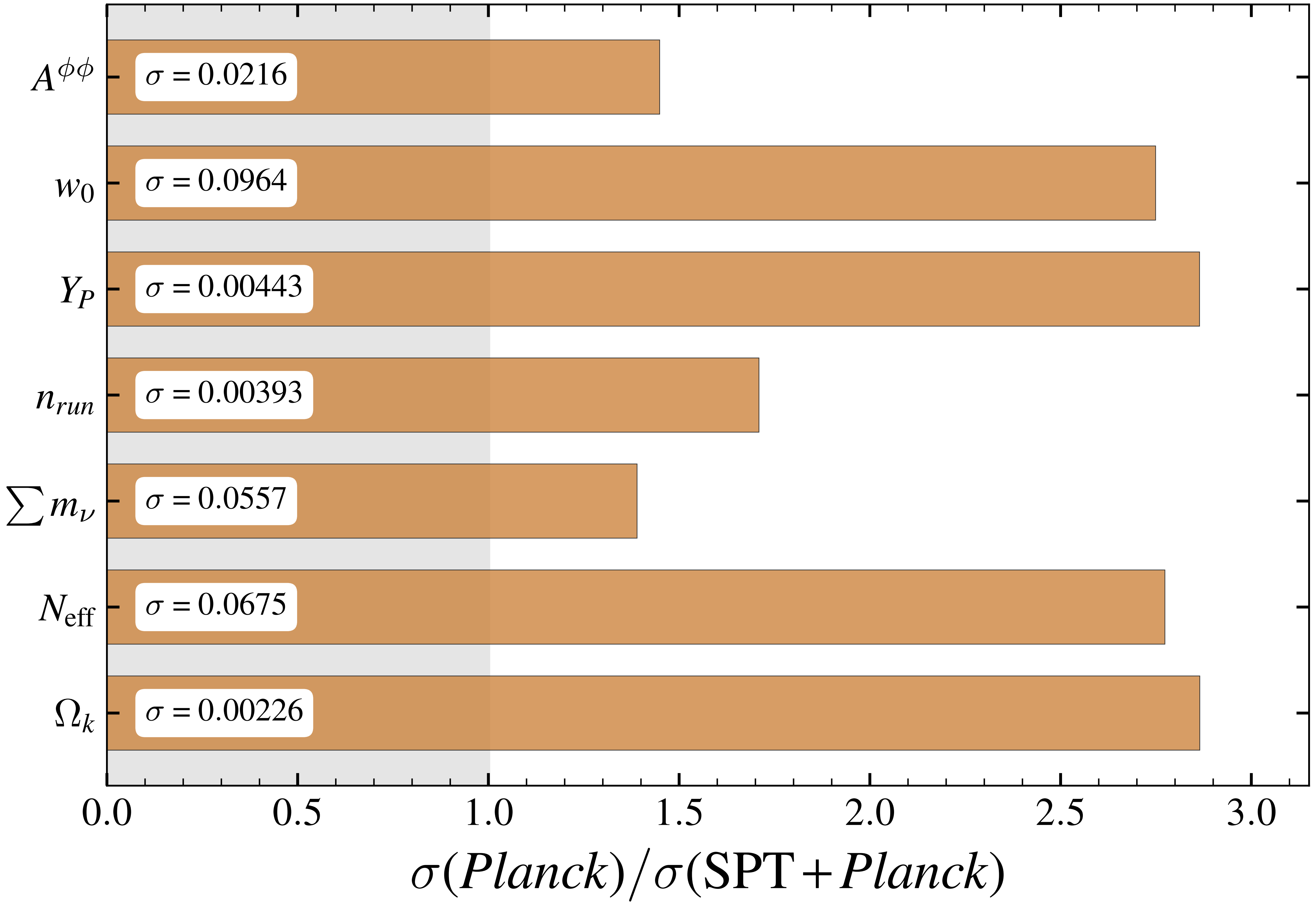
- Summer fields will improve the constraints by 20% due to reduced sample variance at low-ℓ
- The all-including Extended-10k survey will yield independent constraints twice better than *Planck* on H_0
- **Combined with *Planck***

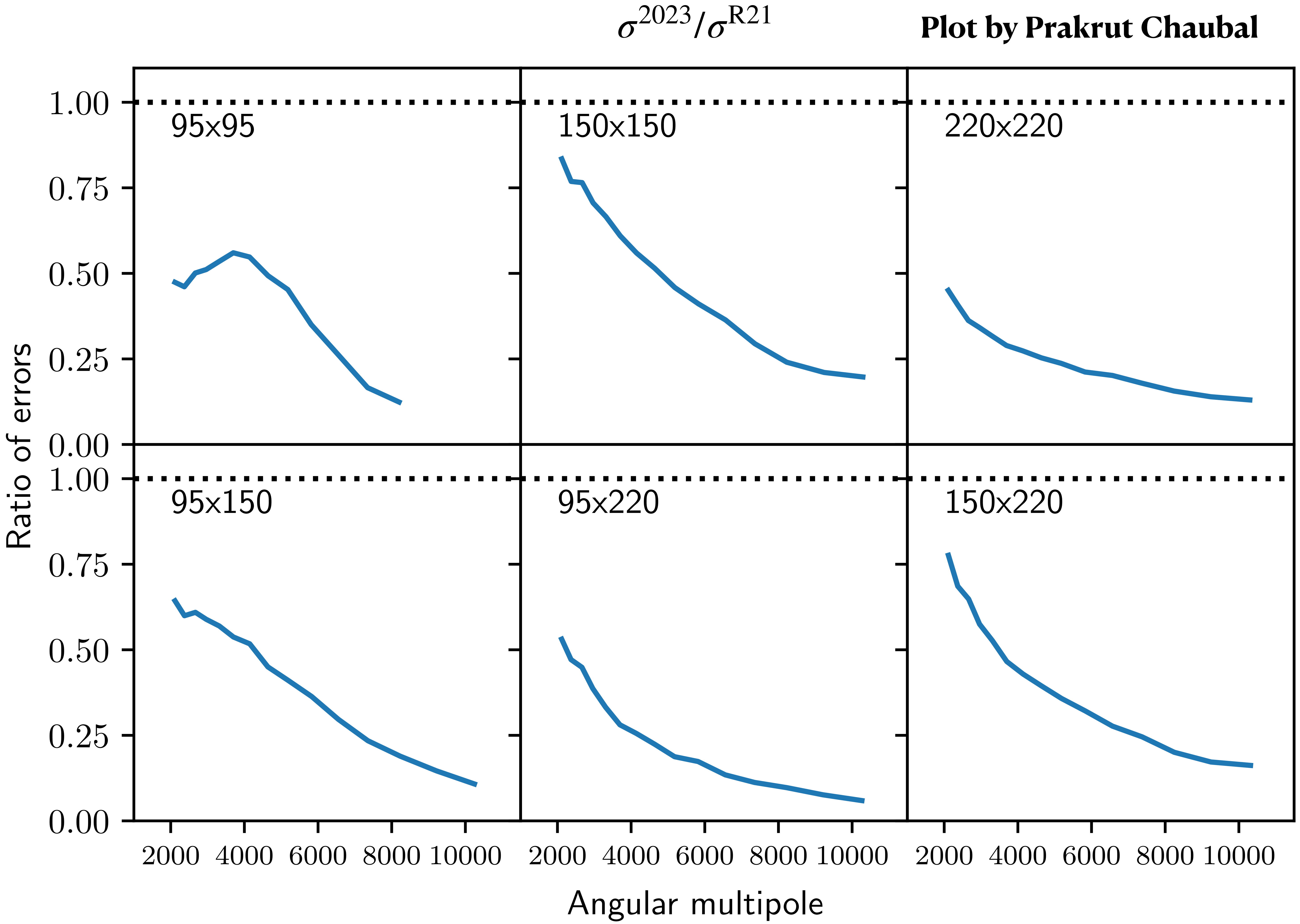


Highlighting other analyses

SPT-3G High-ell TT with 19/20 data

- Ongoing analysis by Prakrut Chaubal & Nicholas Huang
- Significant reduction in band power uncertainties at all angular multipoles and frequency combinations compared to SPT-SZ + SPTpol measurement in Reichardt21
- Smaller numbers indicate a greater reduction in bandpower uncertainty.

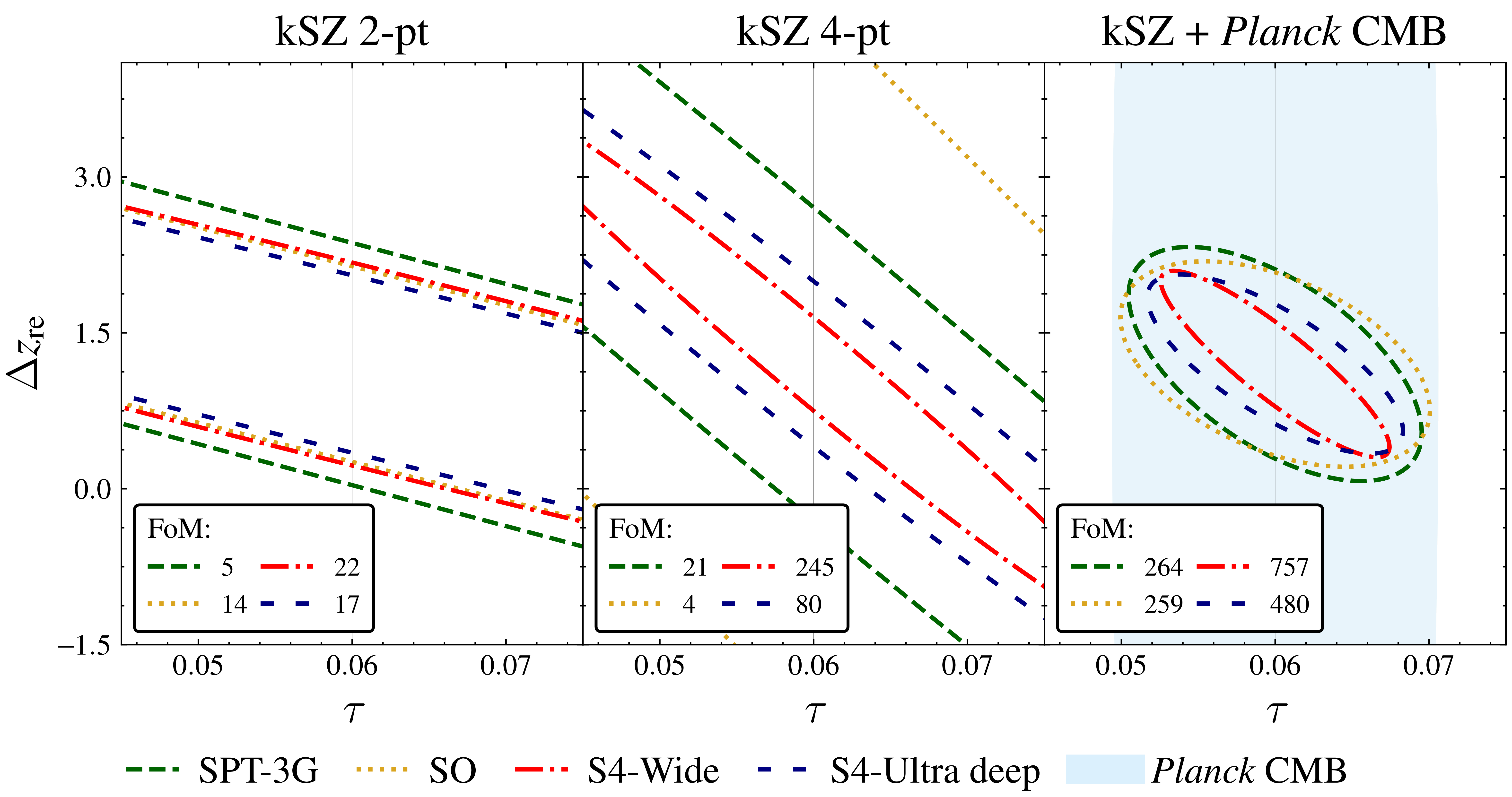
Plot by Prakrut Chaubal



SPT-3G constraints on EoR

Plot by Srini Raghunathan

- Using cross-ILC approach to characterize foregrounds [Raghunathan et Omori, 2023]
- Yields bias-free kSZ measurements, from which epoch of reionization can be constrained

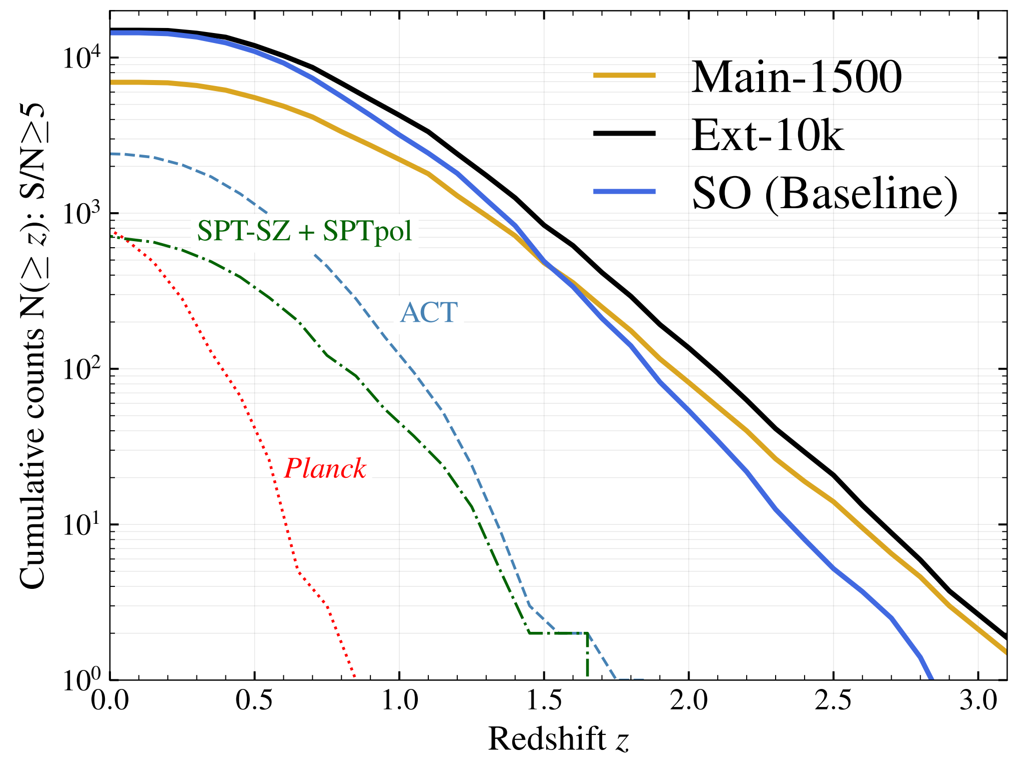


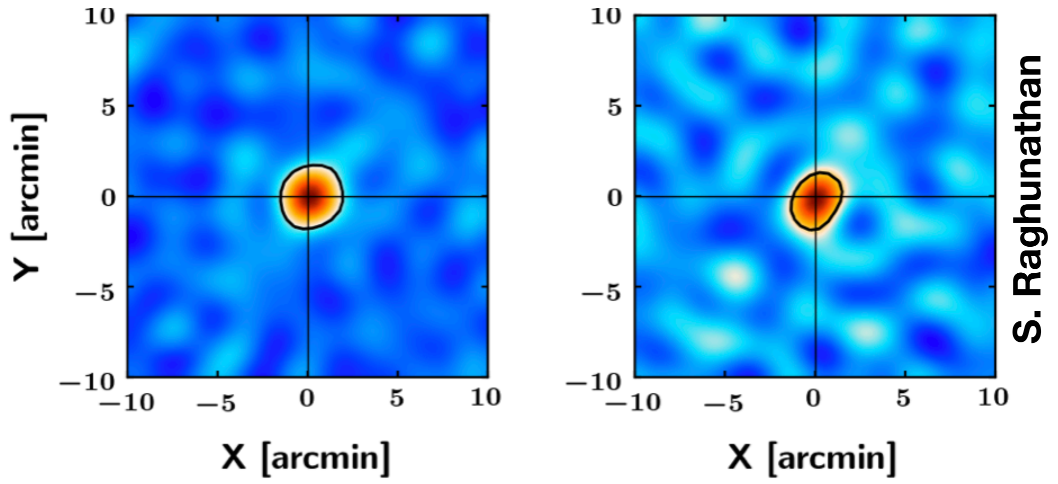
SPT-3G cluster science

Slides by L. Bleem

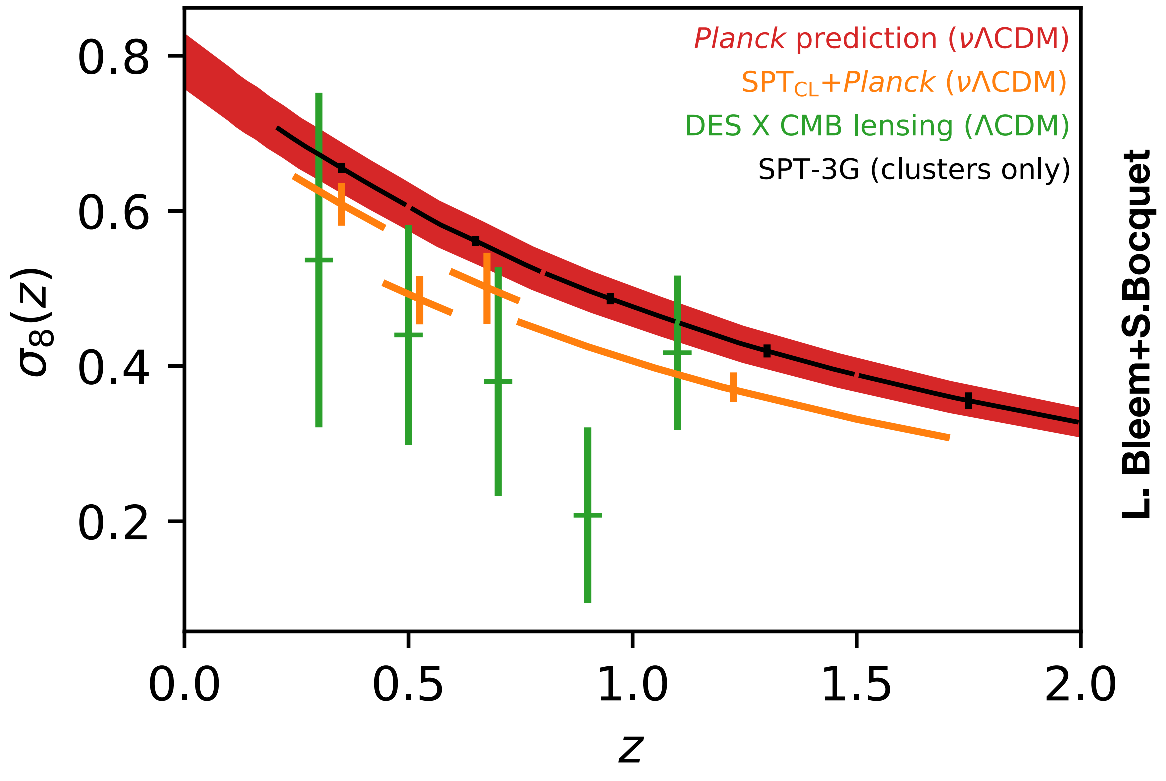
Cluster Forecasts

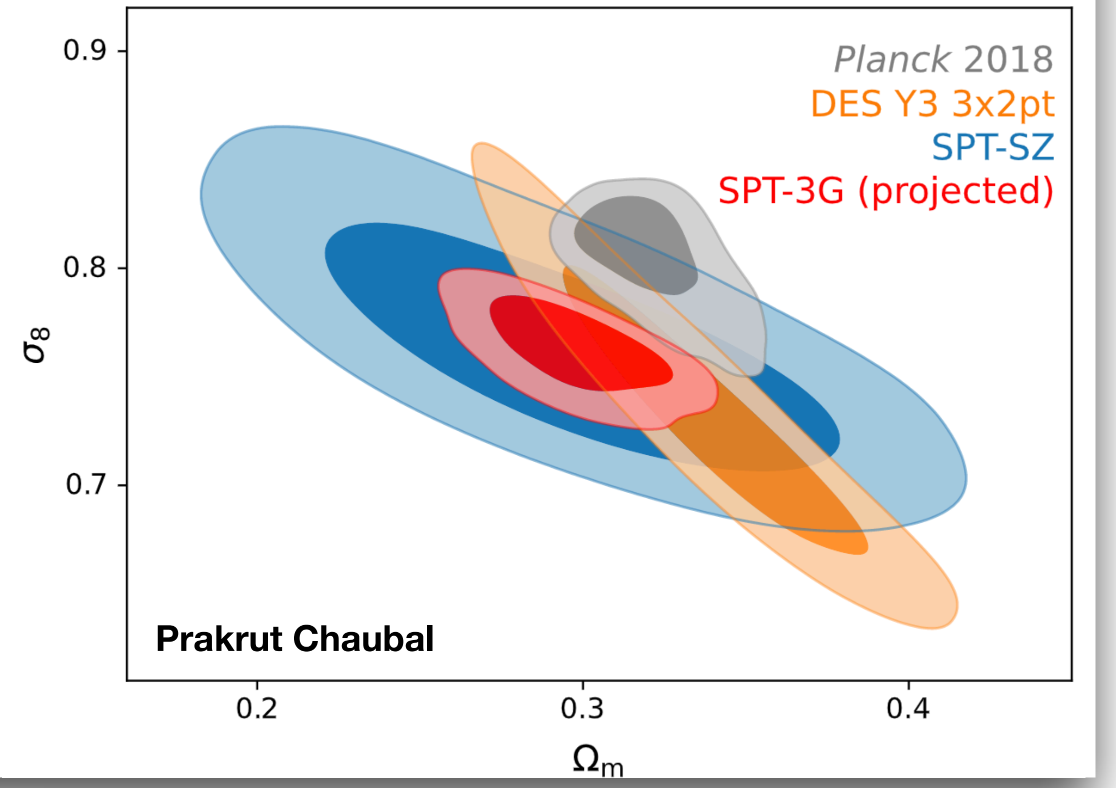
SPT-3G





High S/N (>30σ) detection of CMB cluster lensing!





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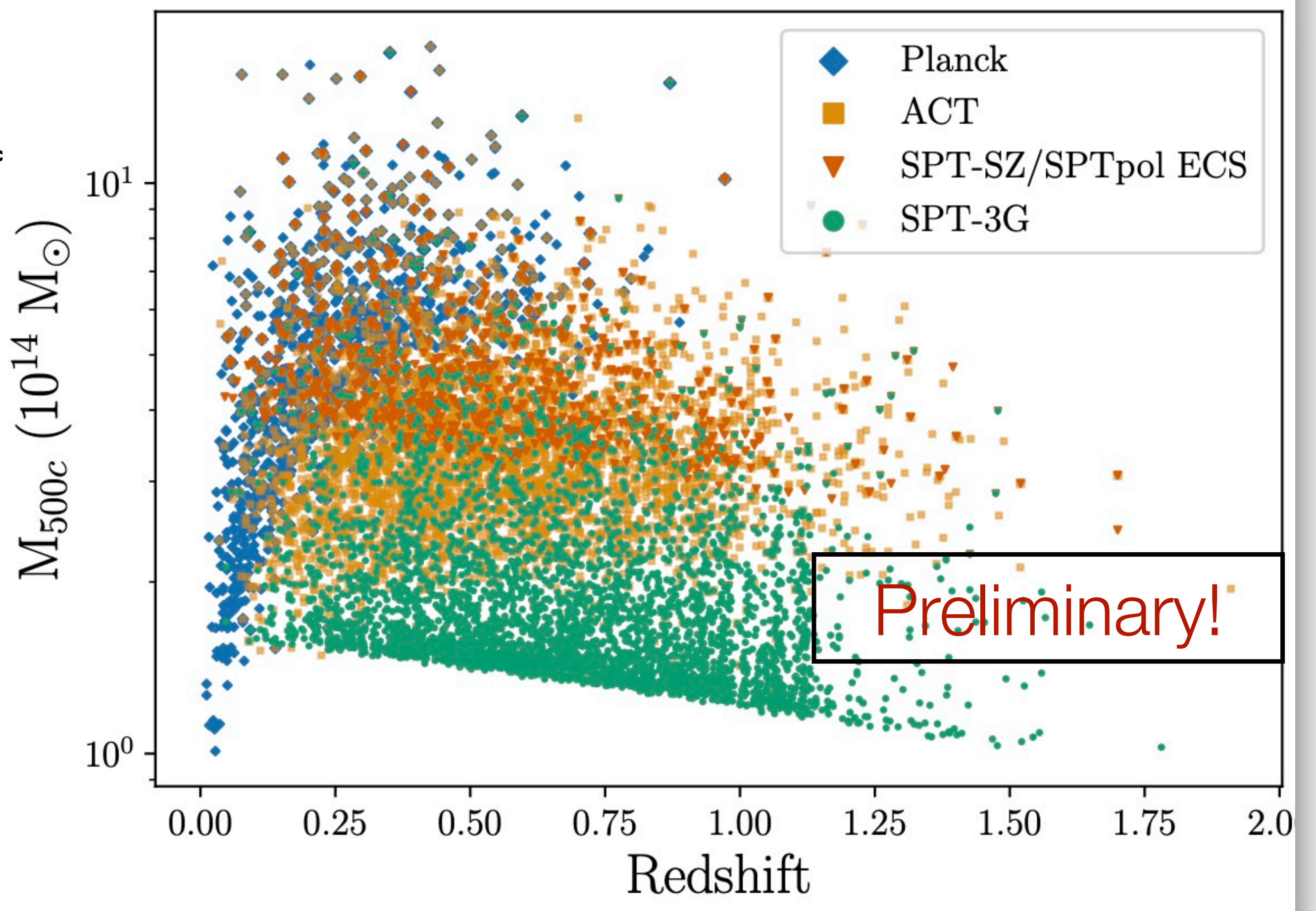
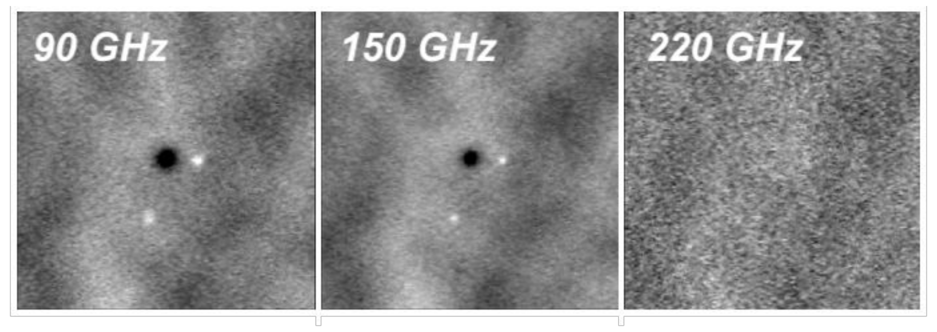
The SPT-3G SZ Catalog

- First full field catalog being produced from 2019-2020 data
- Preliminary cluster run has produced a catalog with 2457 cluster candidates at xi> (>99% purity)
- 5891 candidates at 3.85 < xi < **130.2**(!)
- Candidates screened through DES, promising high-z targets flagged for additional followup.





SPT-CL J2344-4243 (Phoenix Cluster, z=0.6) seen in SPT-3G data at S/N>120

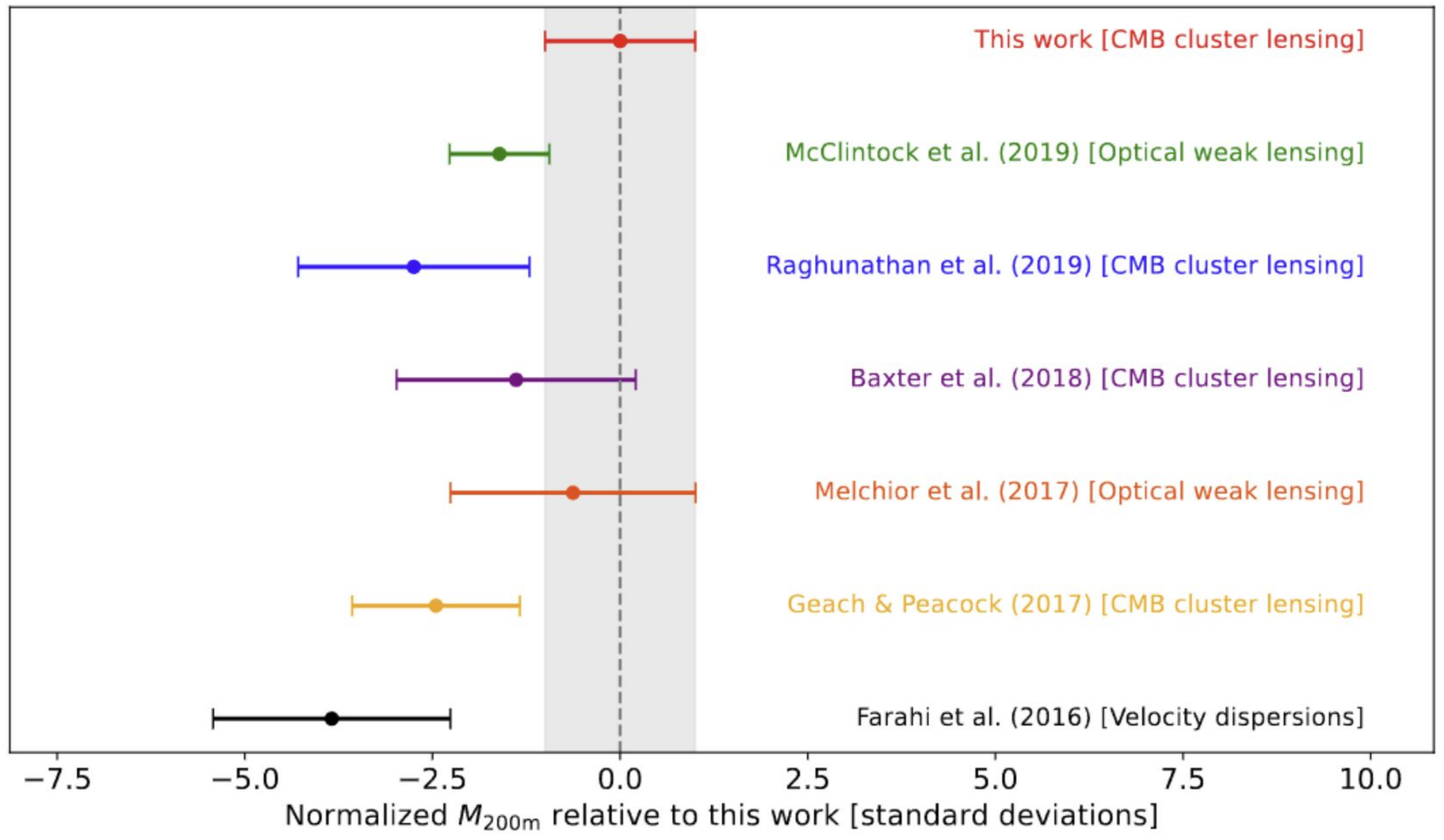
with L Bleem, F Kéruzoé, K. Kornoelje

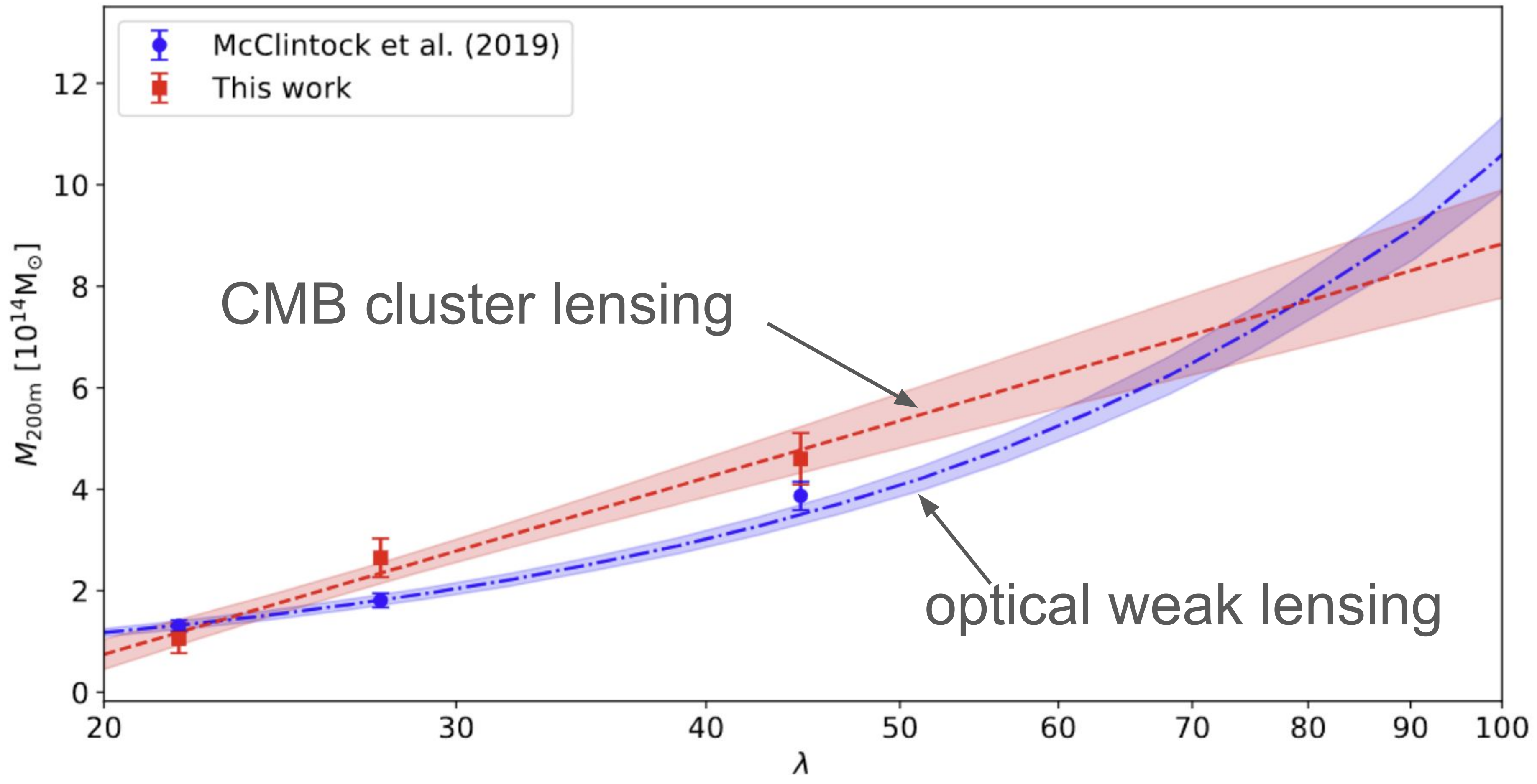
DES Y3 cluster mass calibration via SPT-3G CMB cluster lensing

- We obtain a **~9% constraint** on the mean cluster mass of the DES-Y3 sample. This is **2x more precise** compared to previous SPT measurements and in good agreement with masses from previous works (including optical weak lensing).

- Our measurements prefer a slightly different scaling relation to the optical weak lensing measurements, but currently not at a statistically significant level.

- Upon completion of the SPT-3G survey, we expect a **~5% constraint** on the mean sample mass, (using data from the 3G main & extended surveys.)





Behzad Ansarinjead, SPT & DES cluster working groups

Plots from: Ansarinejad et al. (in prep.)

SNO Labelization - by Karim Benabed

1. SNO labelization is an « INSU Thing »
    - Recognition that obtaining and distributing astrophysical data is a service to the whole community.
        - typically building/running a telescope/instrument/survey (in this case when data has more use than the survey main goal)
    - Recognition that this service is worthwhile enough to access extra resources: Astronomers
2. SPT-3G does not have the resources to deliver maps in a timely fashion…
    - includes description of the products, distribution and community support
3. We propose to take responsibility of the map distribution
    - We are already producing the summer fields maps, and will probably do the wide maps as well. This is a significant amount of sky which allow for a lot of ancillary science
    - Will include as well higher level products (likelihood, possibly lensing…)
4. Application presented at last call for new SNO
    - No success yet
    - Need to improve the application (wide was not part of it at the time)
    - Gather support from the CMB community

Conclusions

- Cosmology is constrained by SPT-3G 2018 TT/TE/EE + $\phi\phi$ [Balkenhol et al. 2023, Pan et al. 2023]
- 19/20 data will yield constraints comparable to *Planck*
  Primary anisotropies analyses (W. Quan, F. Guidi, E. Camphuis et al.)
- Extended-10k field TT/TE/EE + $\phi\phi$ (= all the data) constraints will be amazing
- Look out for our clusters and cross-correlation science!

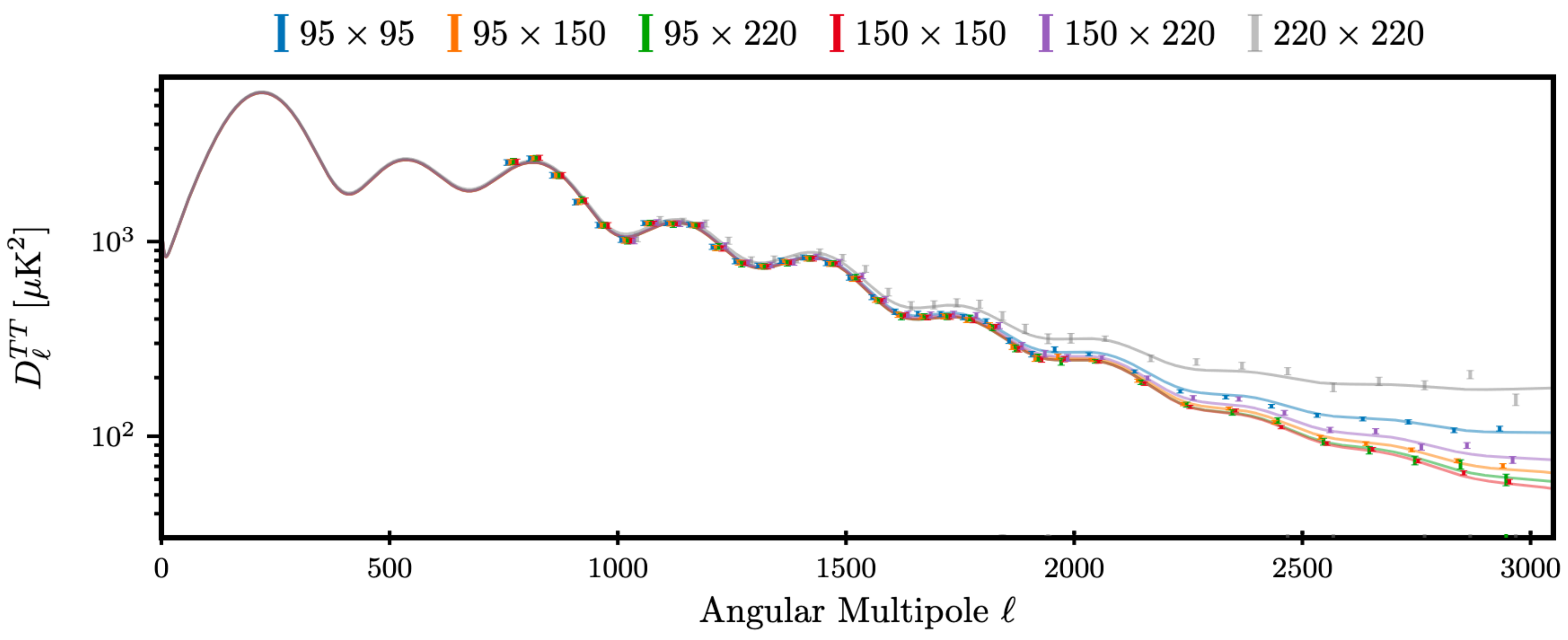

Aman Chokshi

Back-up slides

SPT-3G 2018 TT/TE/EE

Improvements from polarization-only analysis

- **Including TT from ell=750 to 3000**

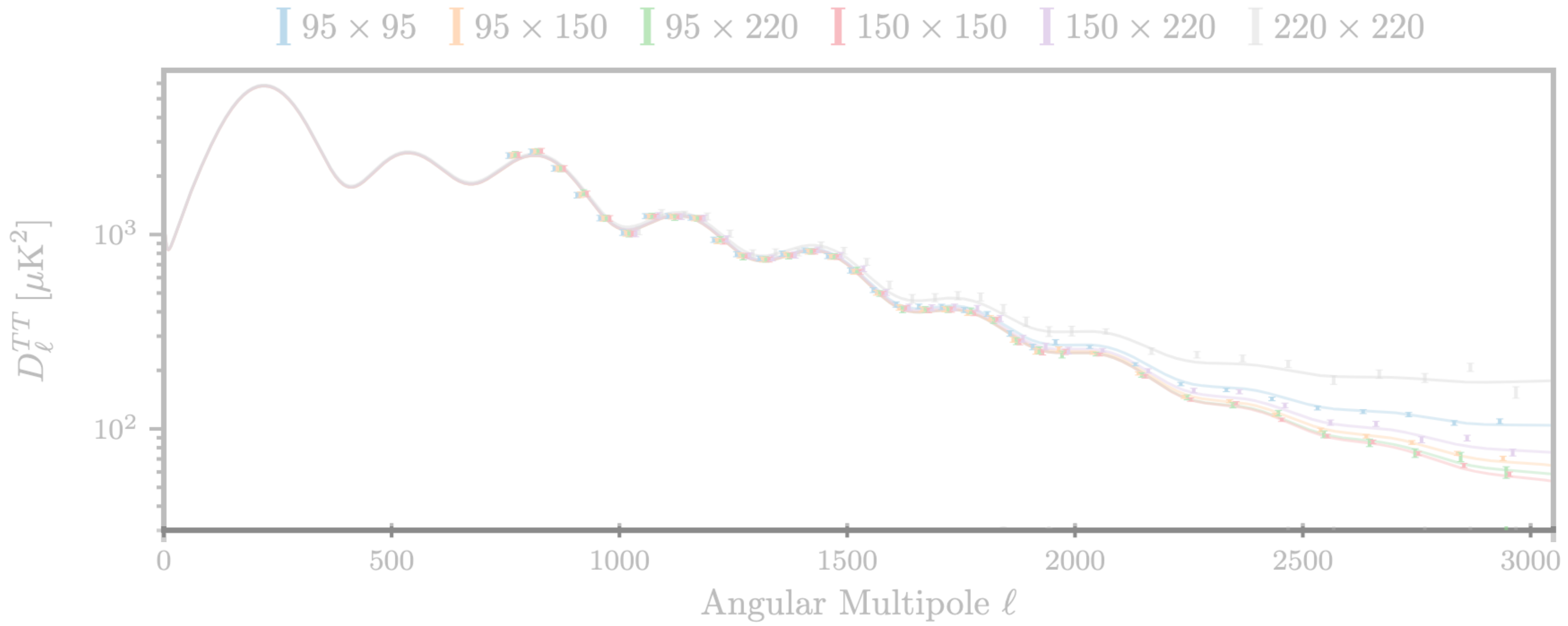


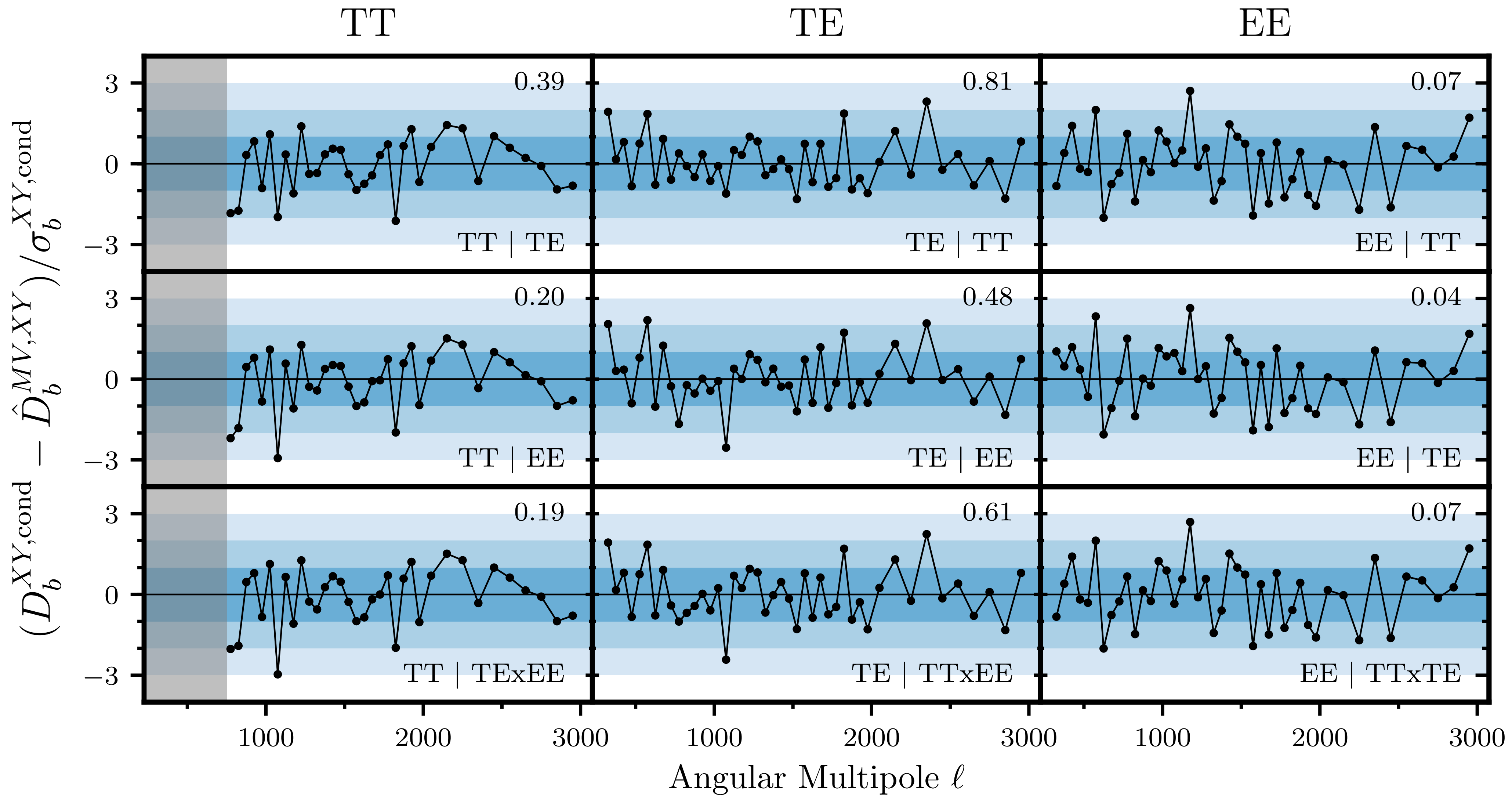
Balkenhol et al. 2023

SPT-3G 2018 TT/TE/EE

Improvements from polarization-only analysis

- Including TT from ell=750 to 3000
- **Internal consistency tests**
  - **Null tests**
  - **Difference spectra**
  - **Conditional spectra**



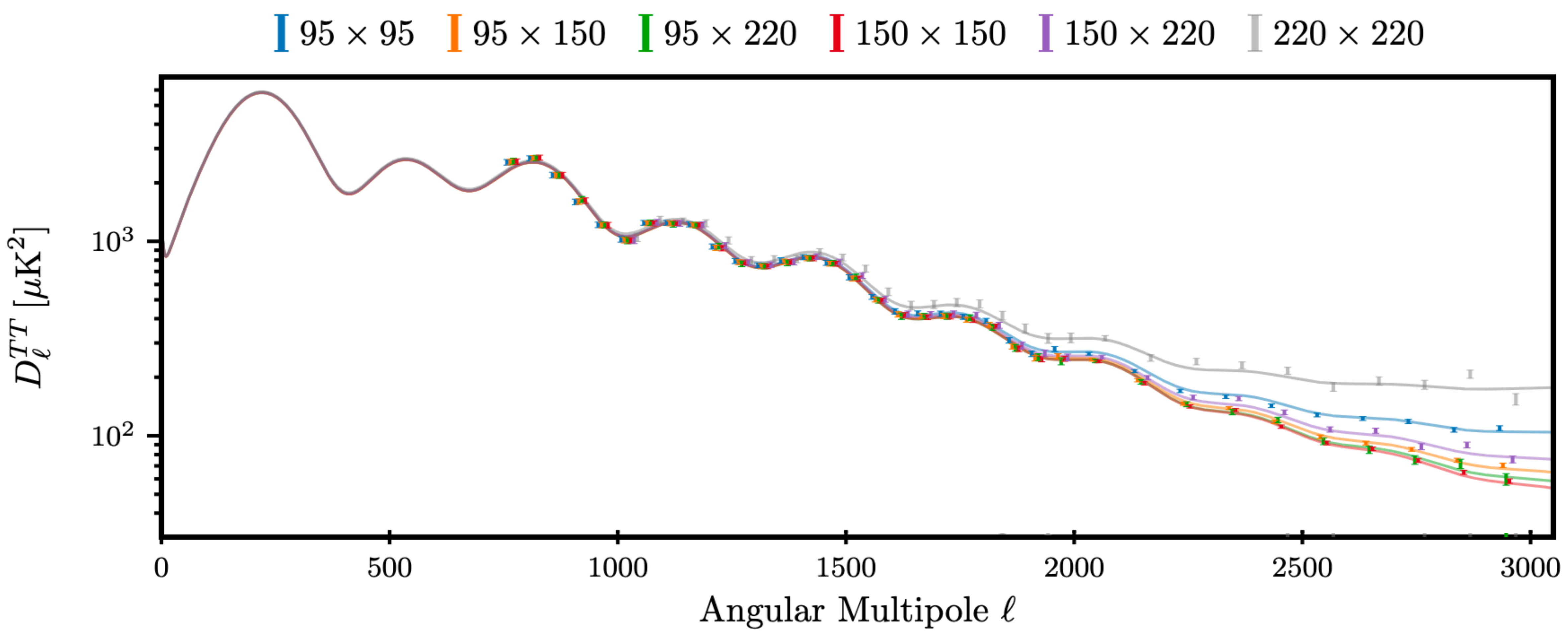


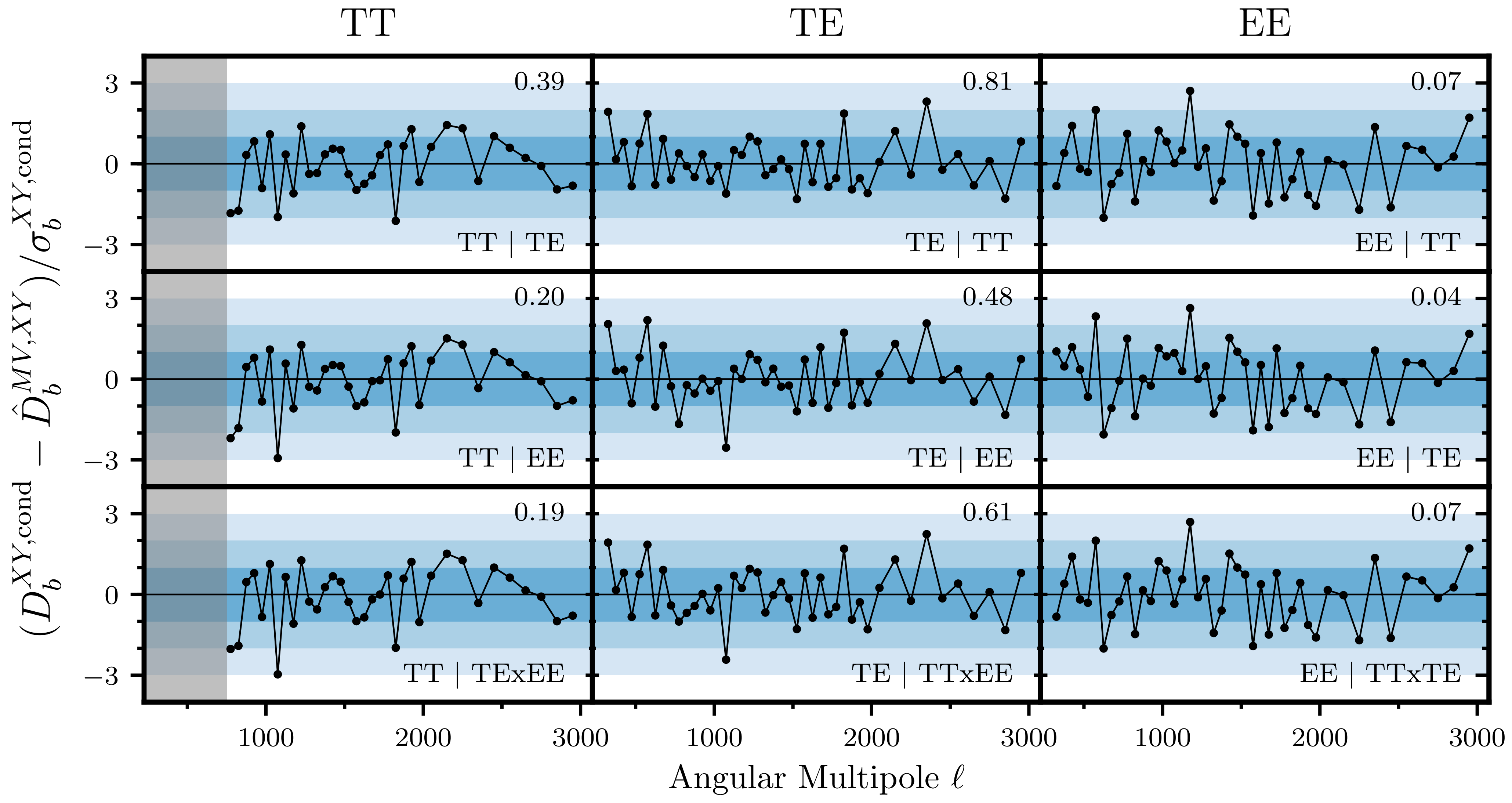
Balkenhol et al. 2023

SPT-3G 2018 TT/TE/EE

Improvements from polarization-only analysis

- Including TT from ell=750 to 3000
- Internal consistency tests
  - Null tests
  - Difference spectra
  - Conditional spectra
- **Improved parameter inference**
  - **High-accuracy CosmoPower models**
  - **Enabled large number of robustness tests for likelihood**



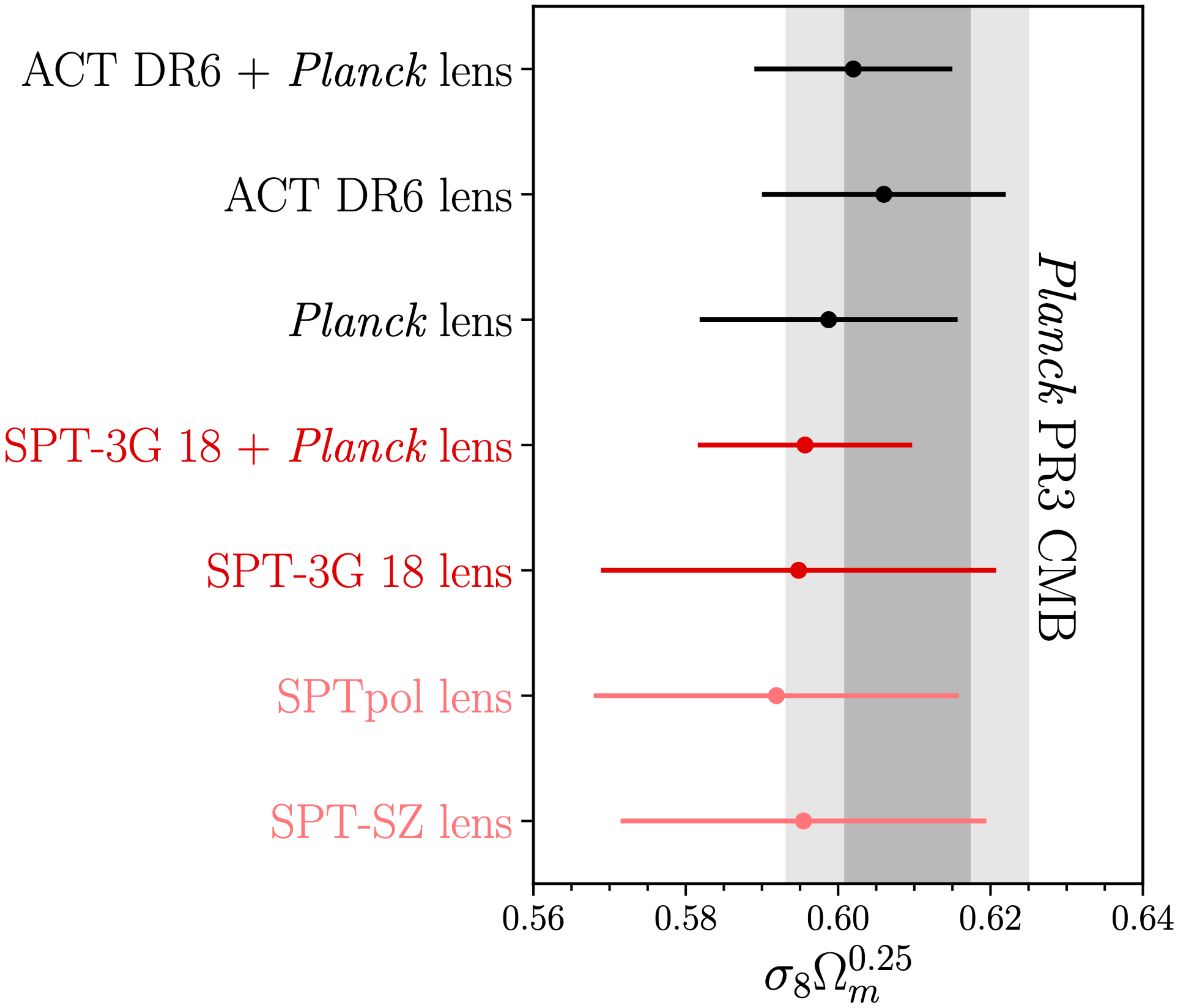


Balkenhol et al. 2023

SPT-3G 2018 Lensing

$\sigma_8\Omega_m^{0.25}$ measurement

Comparison with ACT DR6

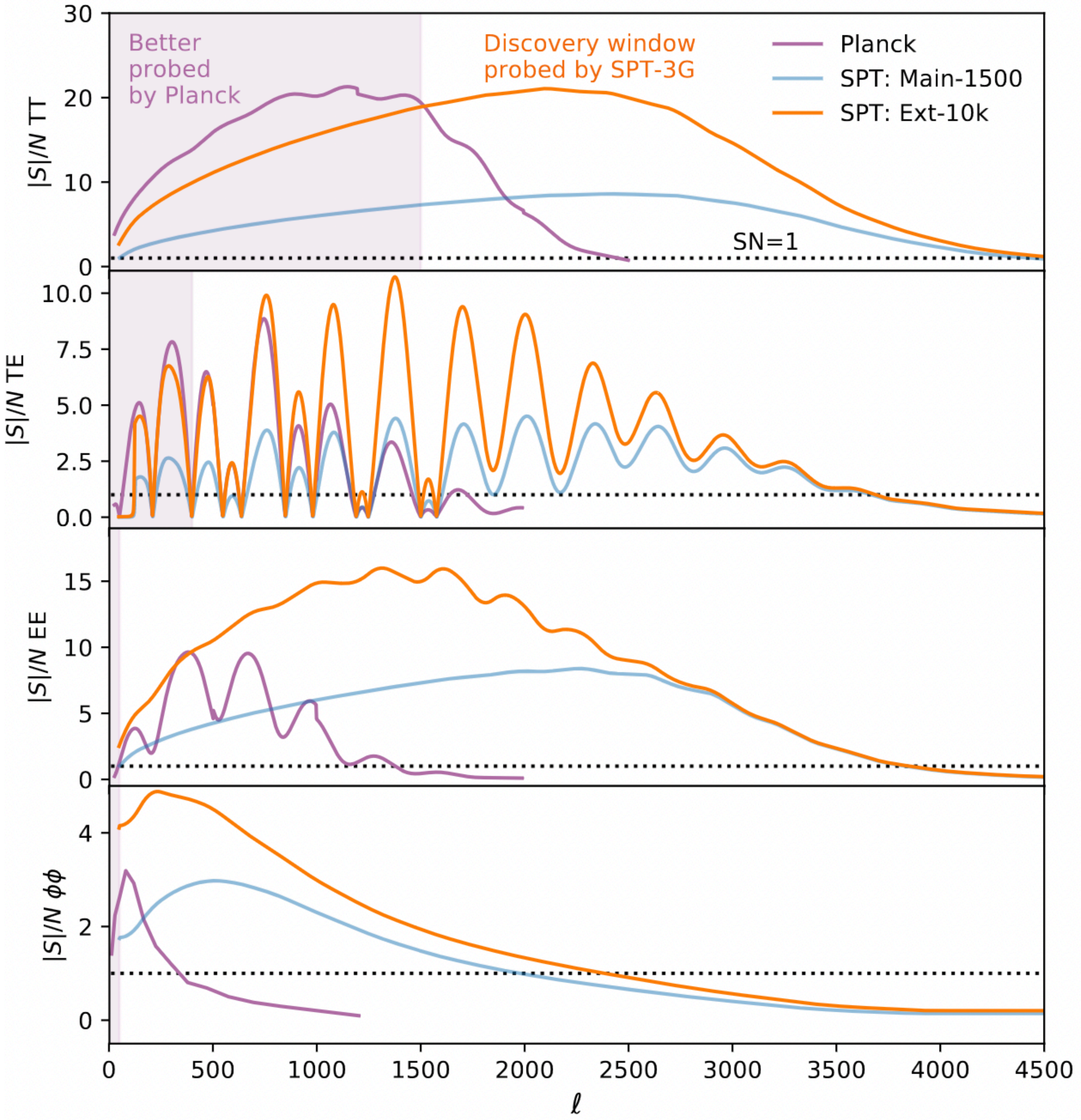


Final constraints

with TT/TE/EE + lensing

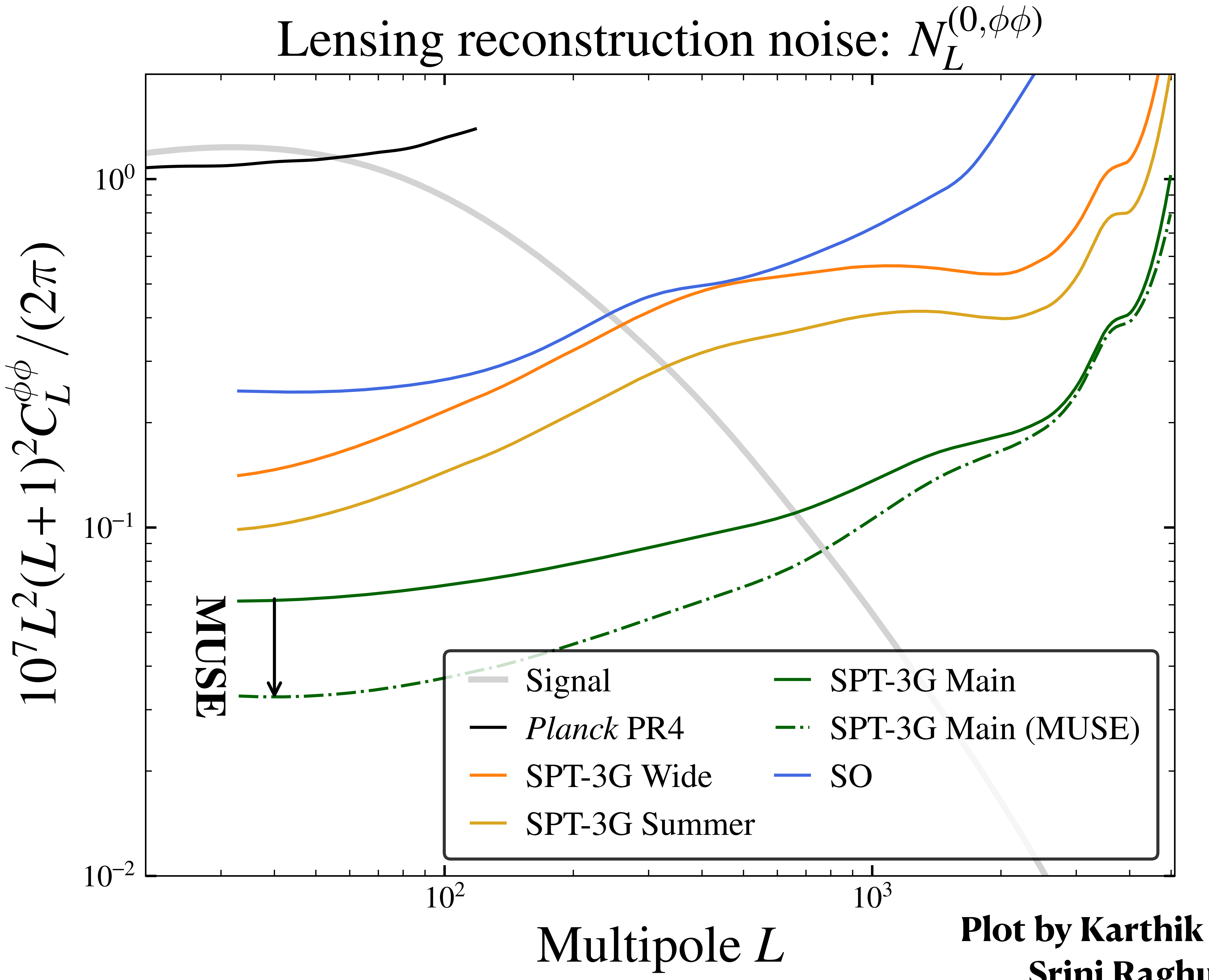
- Main field alone will provide H_0 constraints 1.5x smaller than *Planck* $\sigma(H_0) = 0.36$Km/s/Mpc
- Summer fields will improve the constraints by 20% due to reduced sample variance at low-ℓ
- **The all-including Extended-10k survey will yield independent constraints twice better than *Planck* on H_0**

Plot by S. Galli



Final constraints - lensing only

- 3 fields
- 3 lensing pipeline
  - Flat-sky with Gaussian likelihood
  - Curved-sky with Gaussian likelihood
  - MUSE: high-dimensional hierarchical Bayesian inference, see Millea&Seljak 2022



Plot by Karthik Prabhu and Srini Raghunathan

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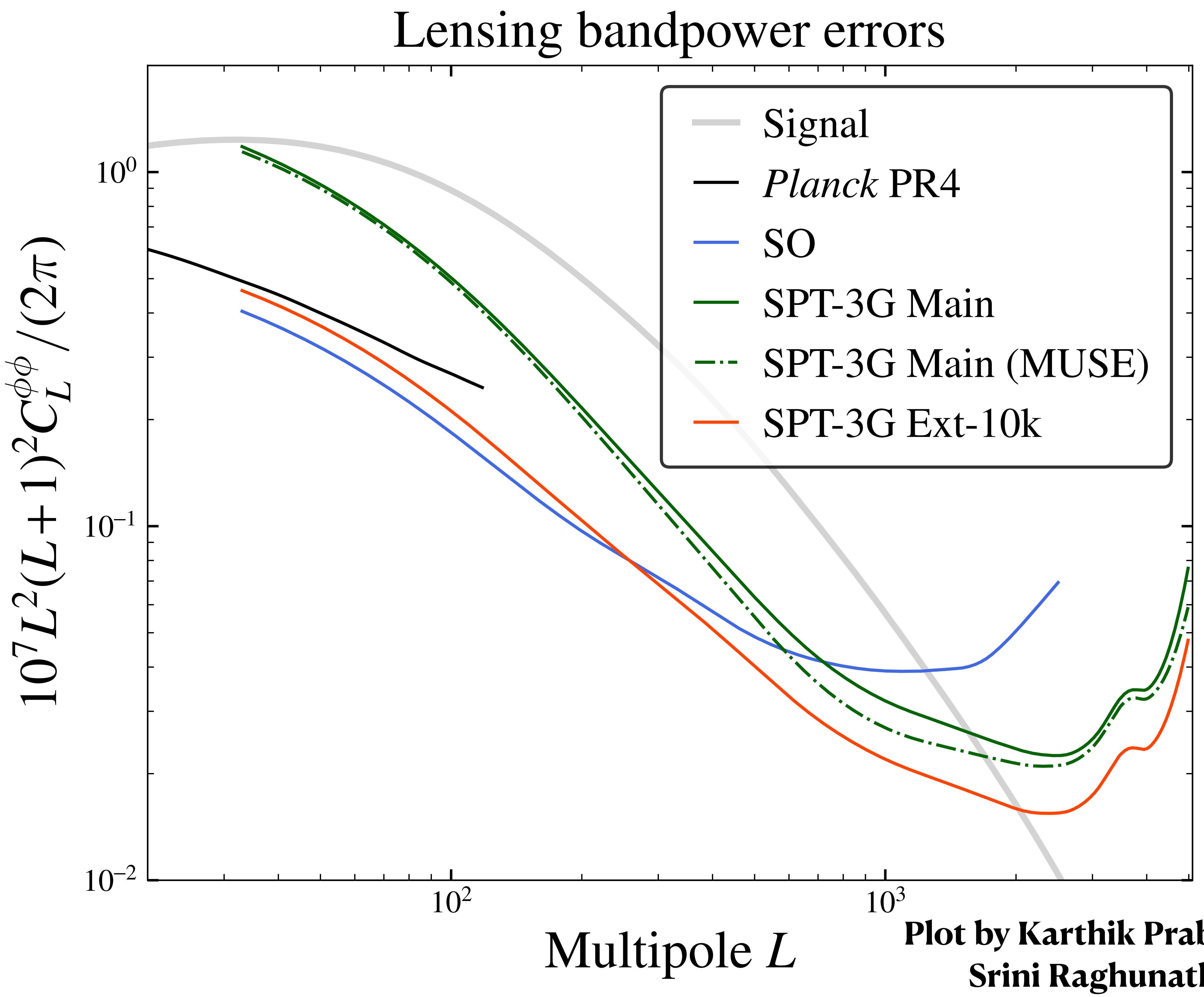

Plot by Karthik Prabhu and Srini Raghunathan