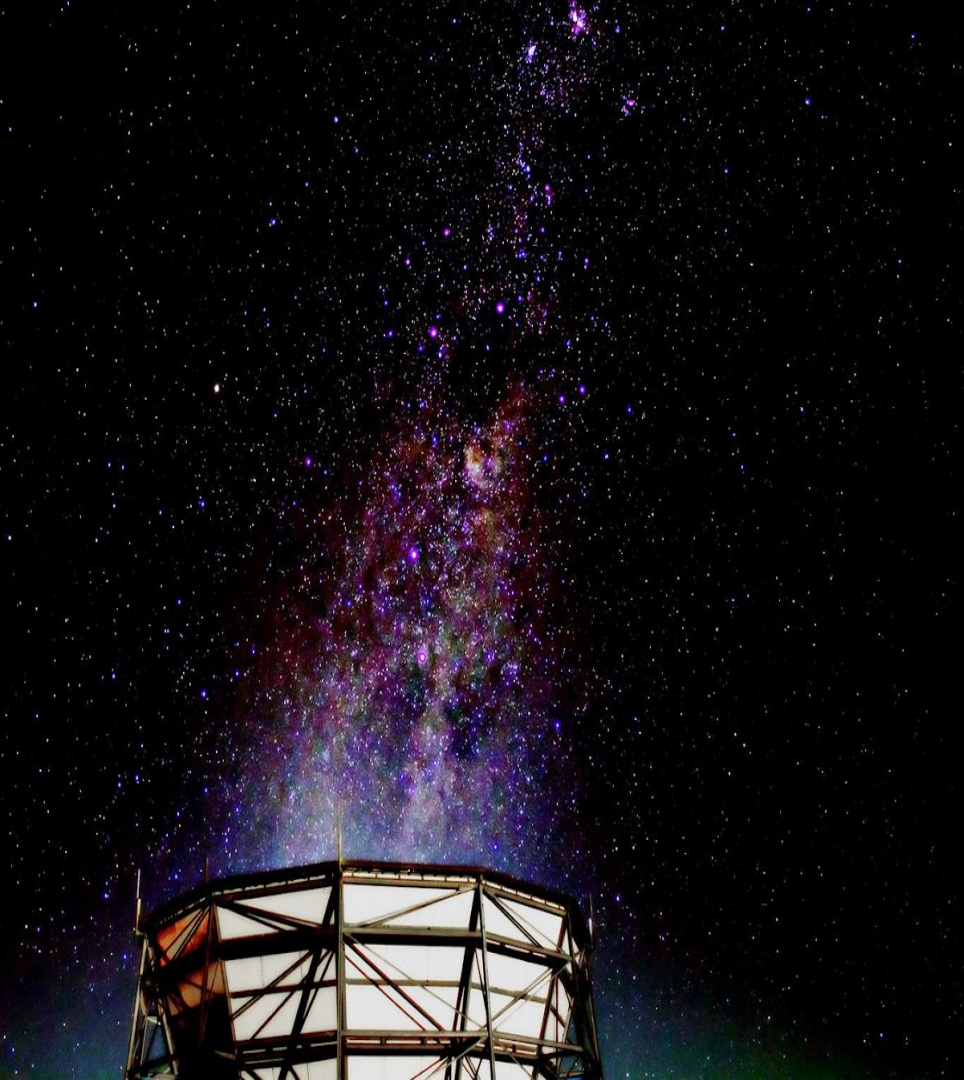


Cosmological constraints from ACT Data Release 6

Adrien La Posta (Oxford University)
and the ACT collaboration

EPS-HEP 2025, Marseille
Friday July 11th 2025

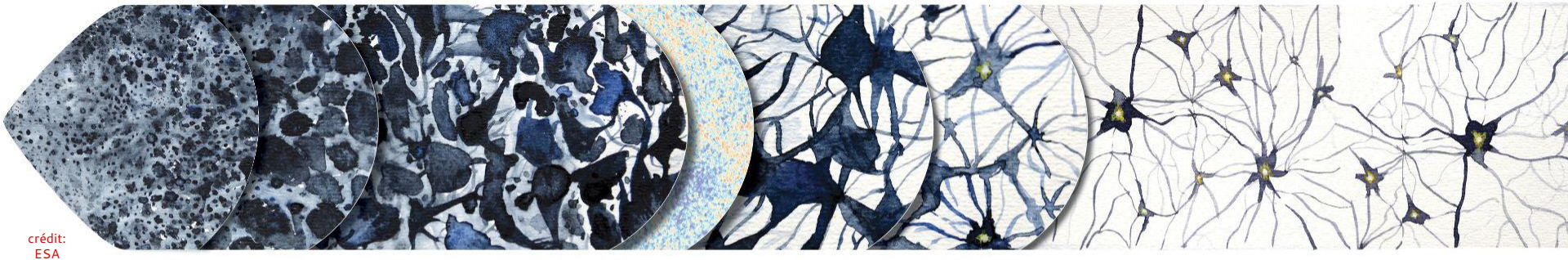
adrien.laposta@physics.ox.ac.uk

The ΛCDM description

ΛCDM is a very successful model to describe a wide range of cosmological observations

Some challenges to learn more about the Universe

- ➢ Inflation
- ➢ Nature of DM/DE
- ➢ Cosmological tensions ?



crédit: ESA

inflation 10^{-32} s

CMB emission 380.000 yr

growth of structures $> 10^{9}$ yr

The ΛCDM description: news from March 2025

ΛCDM is a very successful model to describe a wide range of cosmological observations

Some challenges to learn more about the Universe

- ➢ Inflation
- ➢ Nature of DM/DE
- ➢ Cosmological tensions ?

time-varying DE ?

March 2025 has been a busy month for Cosmology with **ACT DR6**, **DESI-Y3** and **KIDS-Legacy** analyses

no more S_8 “tension” ?

Outline

This talk is about the ACT DR6 cosmological results from primary CMB

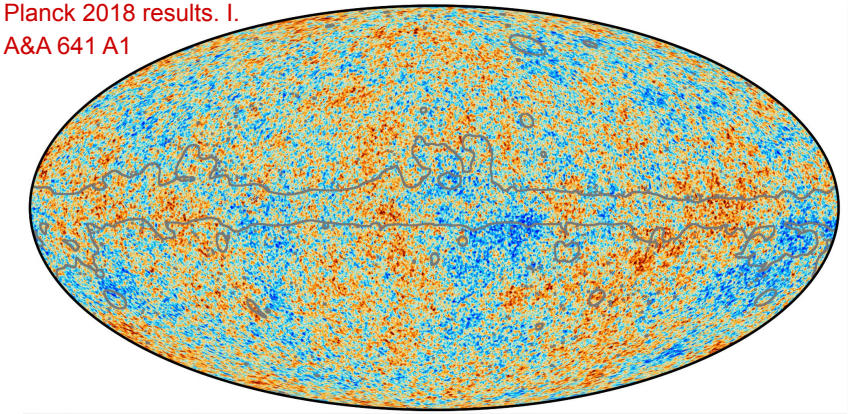
- *Naess, Guan, Duivenvoorden, Hasselfield, Wang et al. 2025*, **The Atacama Cosmology Telescope: DR6 maps**
- *Louis, **La Posta**, Atkins, Jense et al. 2025*, **The Atacama Cosmology Telescope: DR6 Power Spectra, Likelihoods and ΛCDM Parameters**
- *Calabrese, Hill, Jense, La Posta et al. 2025*, **The Atacama Cosmology Telescope: DR6 Constraints on Extended Cosmological Models**

more papers already out with this dataset

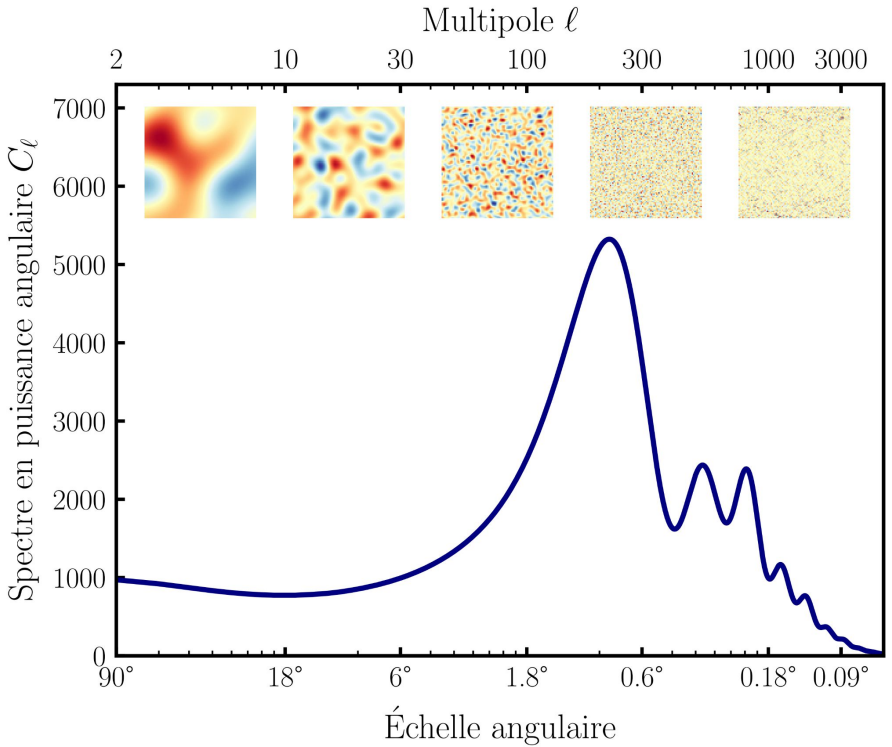
- ***Modelling and validation:*** *Atkins et al. (2412.07068) [covariances], Beringue et al. (2506.06274) [foregrounds]*
- ***CMB lensing:*** *Qu et al. 2023 (2304.05202), Madhavacheril et al. 2023 (2304.05203)*
- ***thermal SZ:*** *Coulton et al. 2023, (2307.01258)*
- ***CMB lensing x LSS:*** *Farren et al. 2023 (2309.05659), Kim et al. 2024 (2407.04606), Qu et al. 2024 (2410.10808), …*
- *+ many other papers and more to come soon (Duivenvoorden et al. [beams], Hasslefield et al. [passbands], Vargas et al. [sources]) [non exhaustive list]*

A little reminder about power spectra

Planck 2018 results. I.
A&A 641 A1



±300 µK

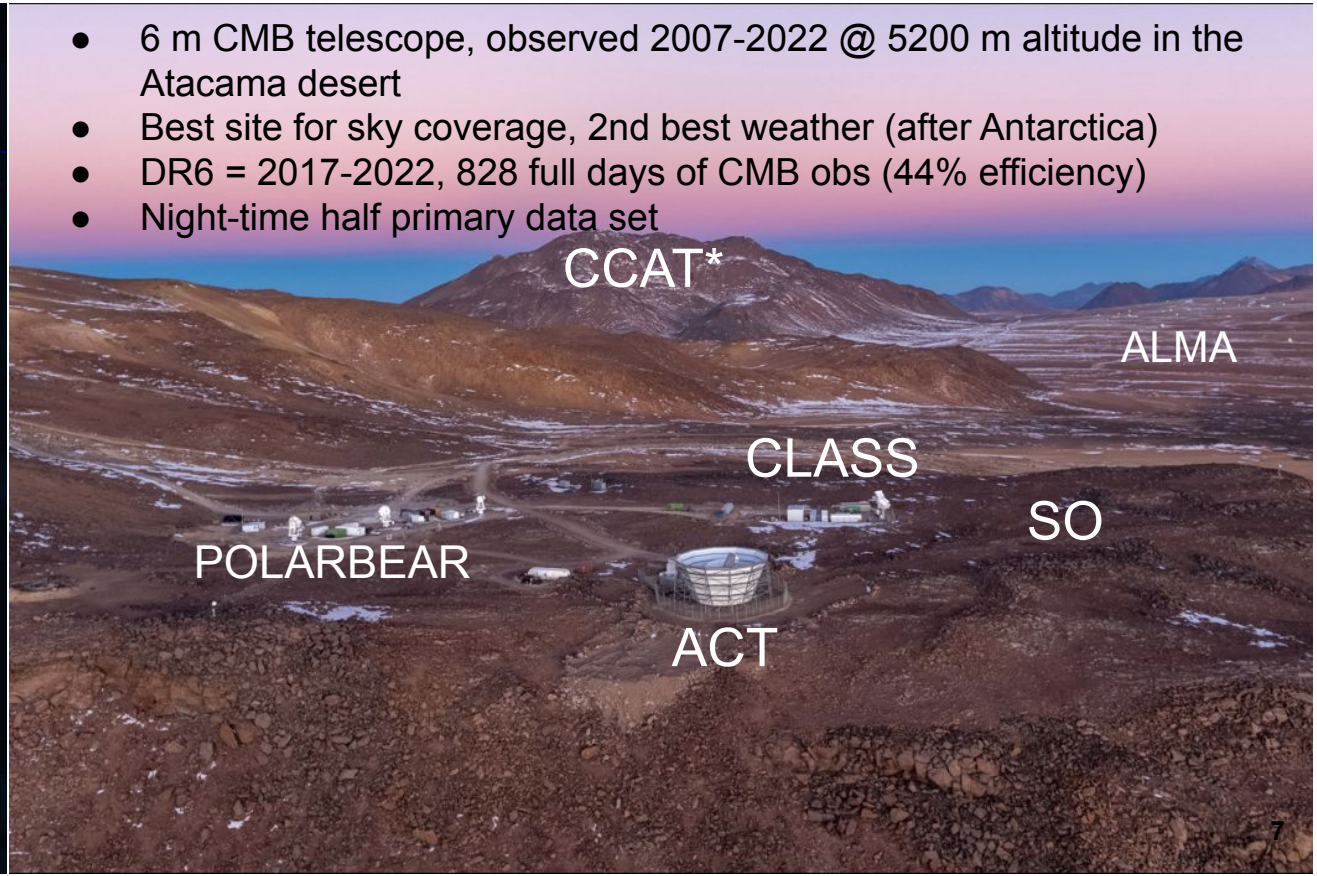


The ACT Collaboration

160 collaborators at 60 institutions

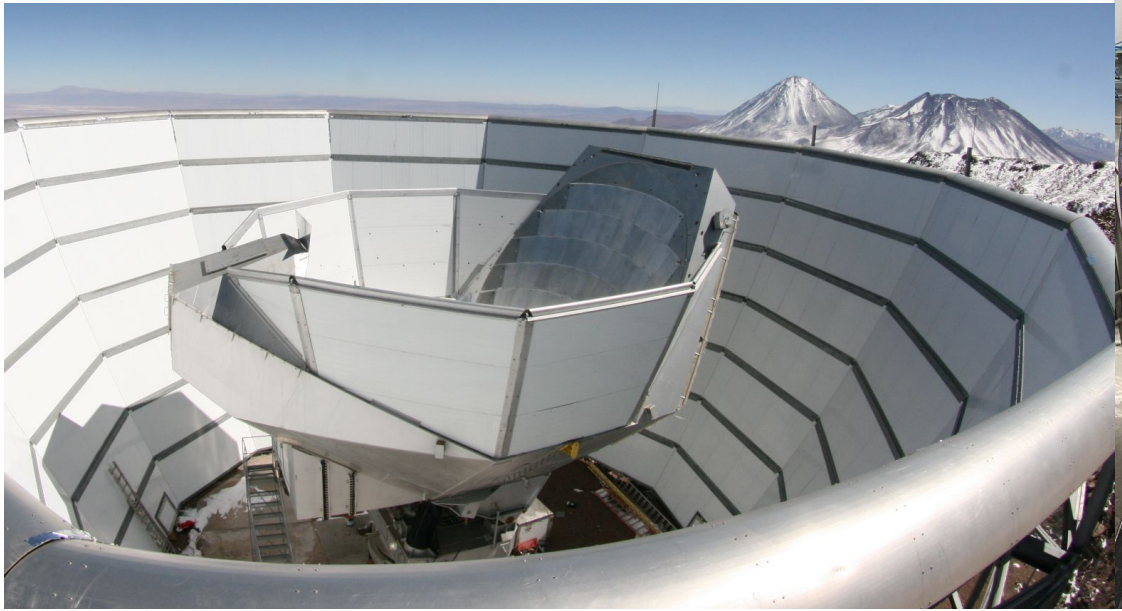
The Atacama Cosmology Telescope

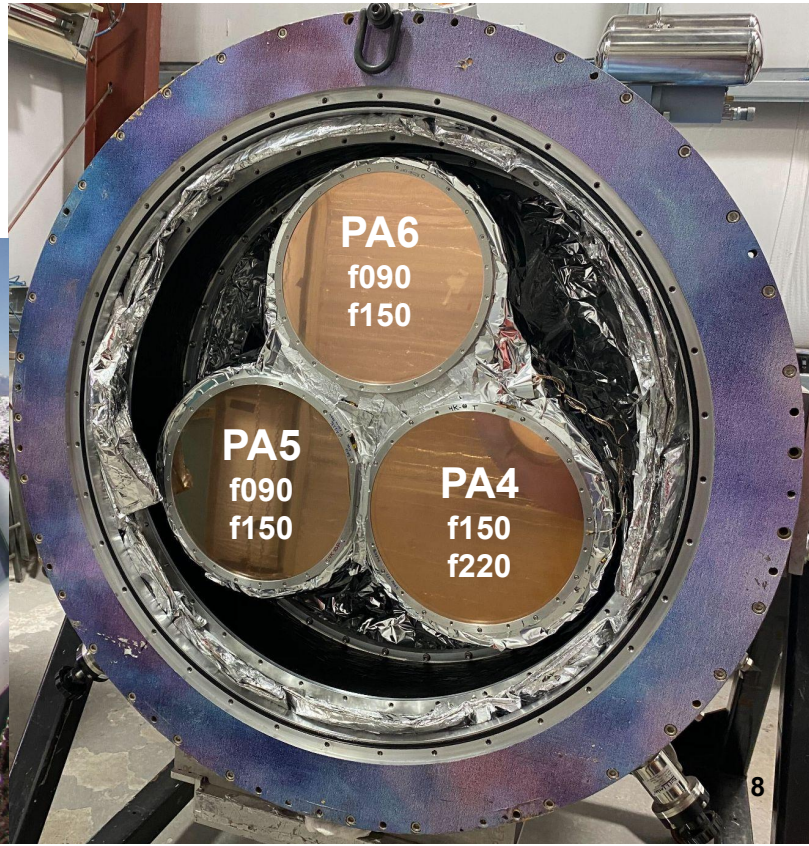
- 6 m CMB telescope, observed 2007-2022 @ 5200 m altitude in the Atacama desert
- Best site for sky coverage, 2nd best weather (after Antarctica)
- DR6 = 2017-2022, 828 full days of CMB obs (44% efficiency)
- Night-time half primary data set



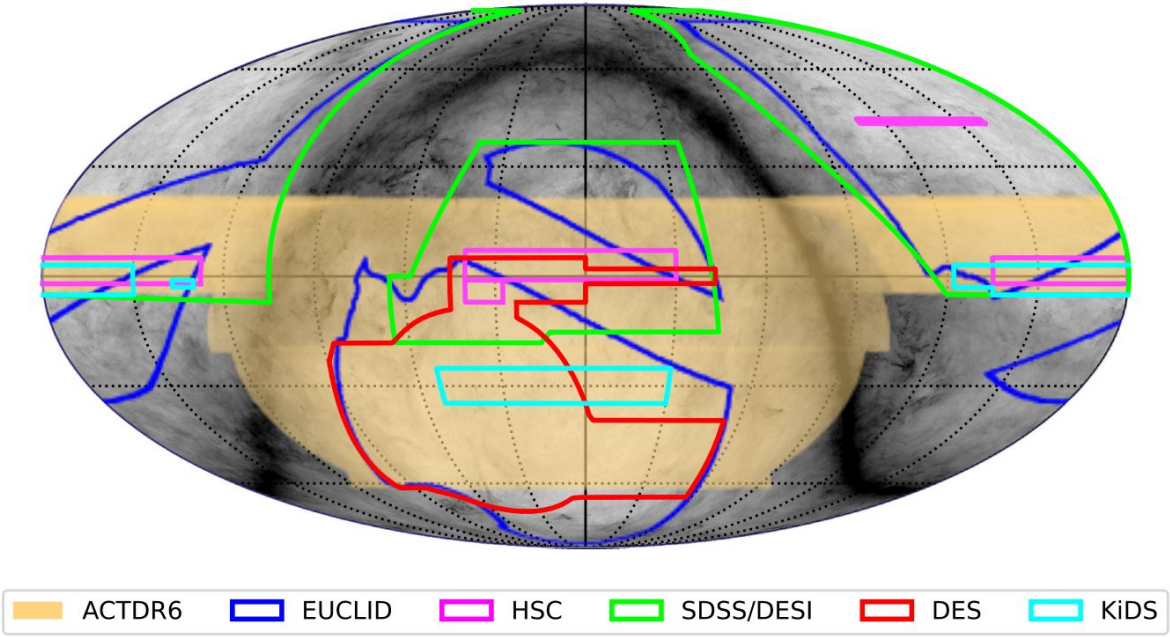
Closer look

- 3 dichroic detector arrays for DR6: PA4, PA5 and PA6
- 3750 working detectors (70% yield) at 100 mK
- 3 broad bands: f090 (77 – 112 GHz),
  f150 (124 – 172 GHz) and f220 (182 – 277 GHz)
- Combined sensitivity of 6.2 μK√s,
  and 1.4’ FWHM @ f150



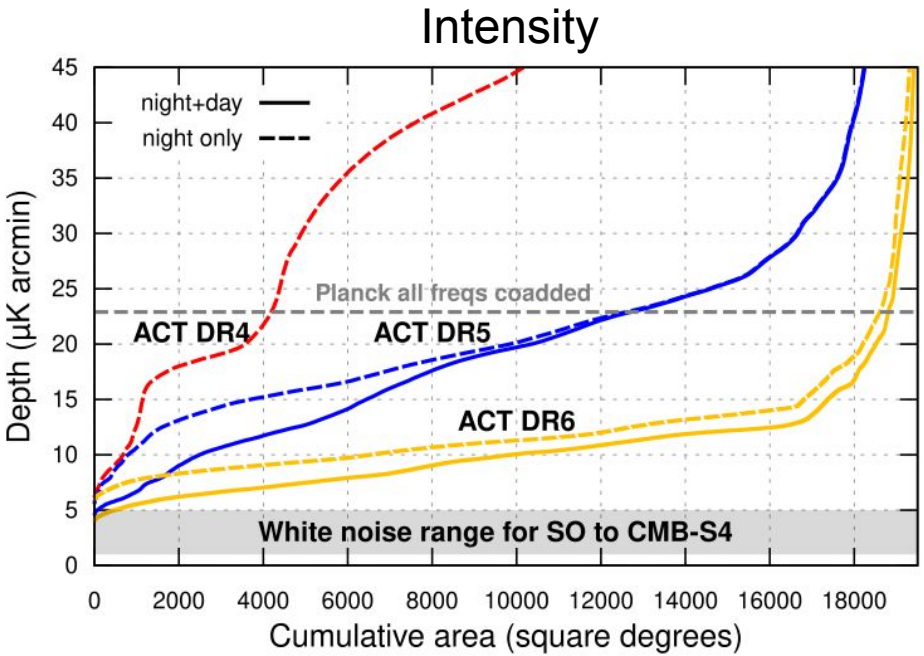


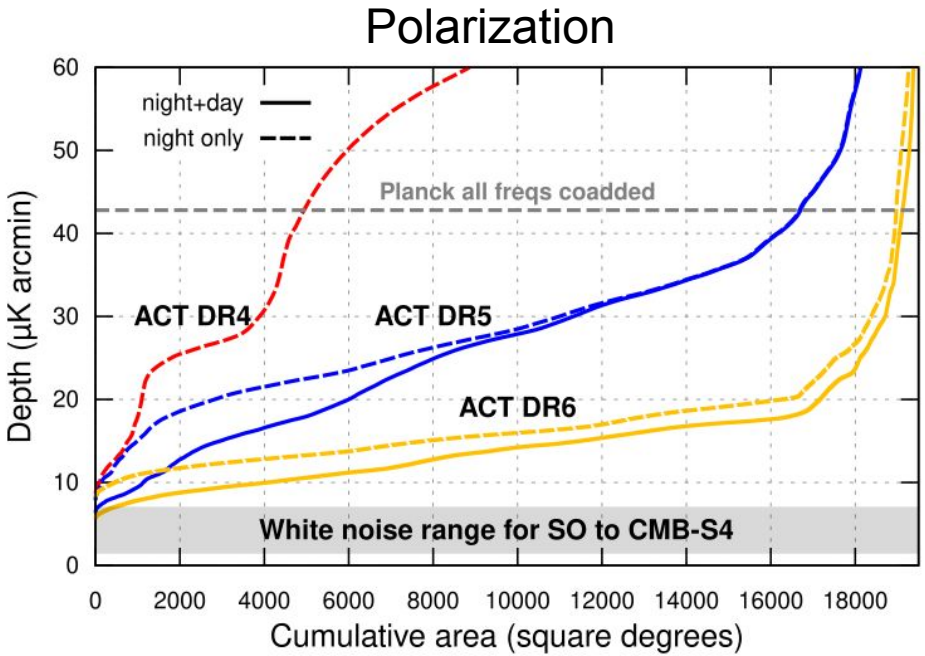
45% sky coverage and large overlap with other surveys

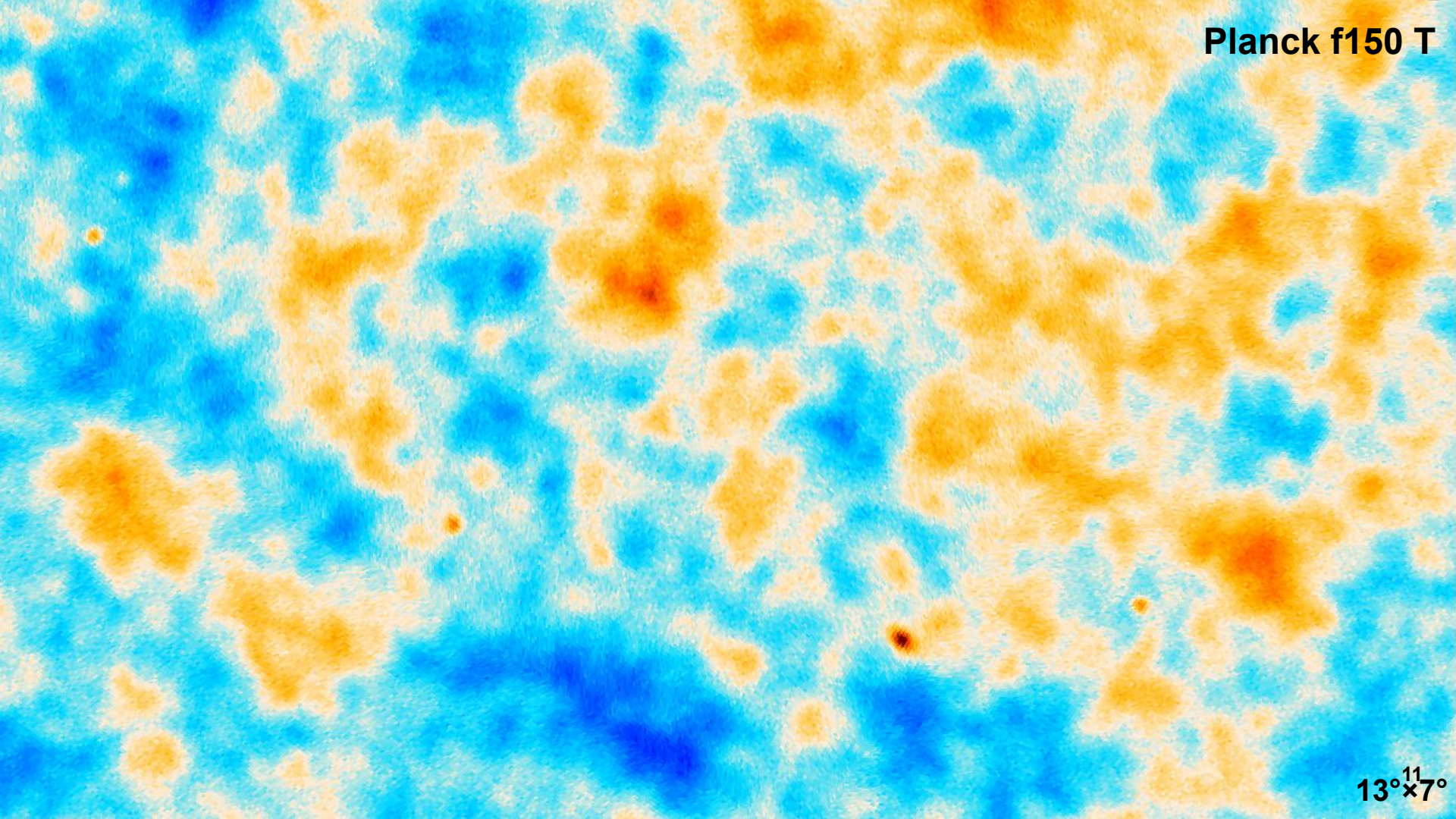


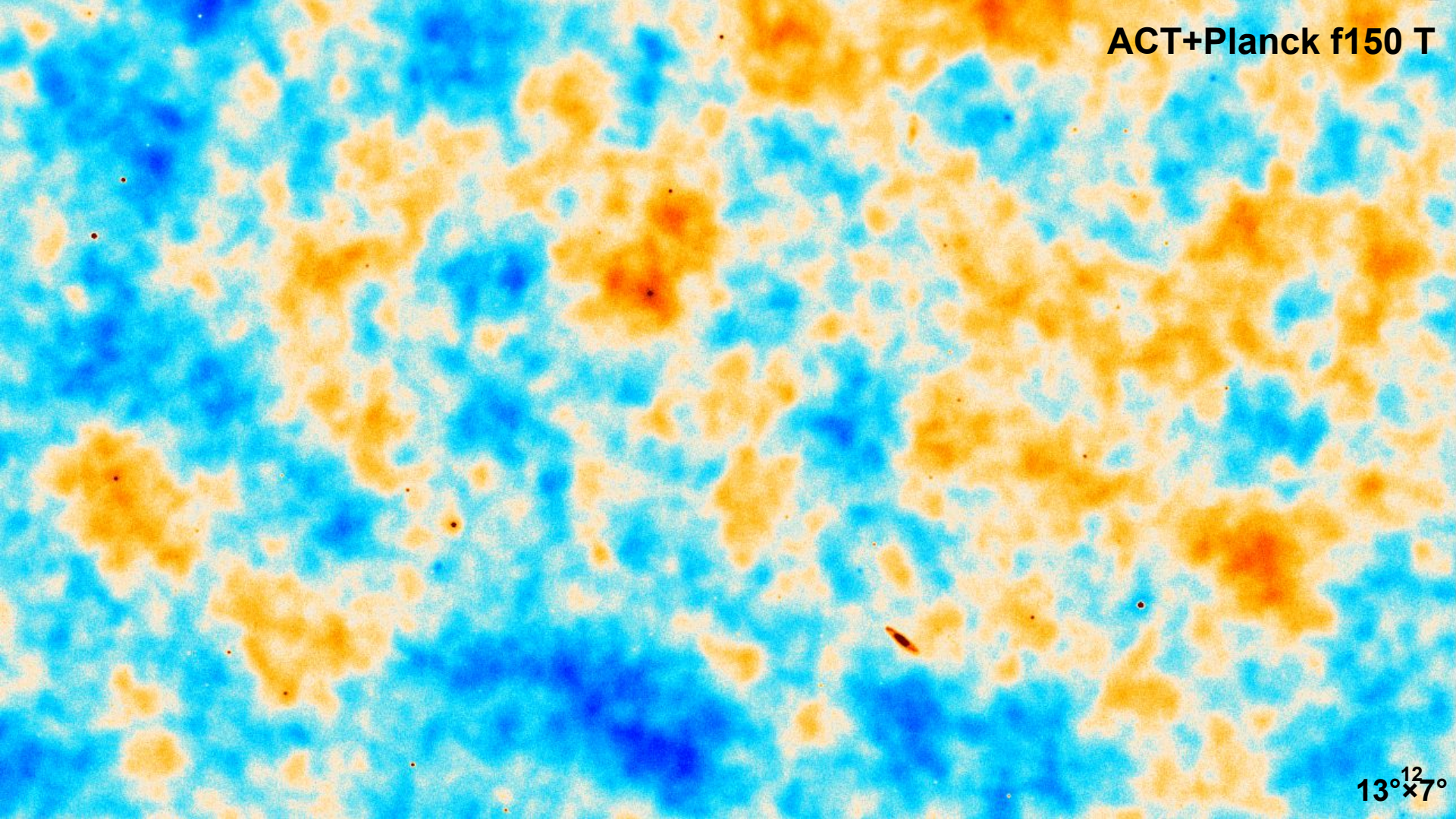
Sensitivity of DR6 data

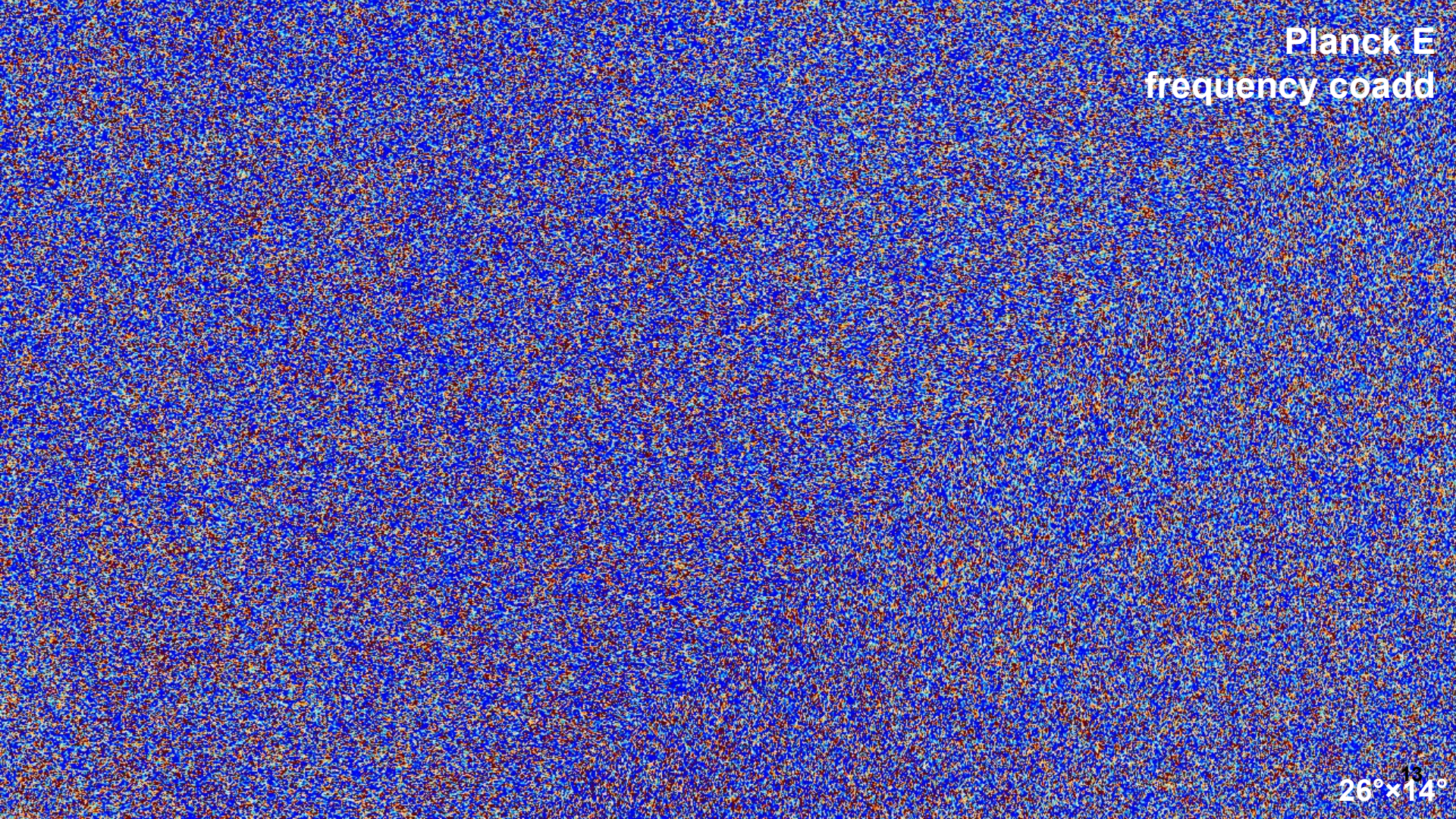
Deeper than Planck over 19000 square degrees (45% of the sky)

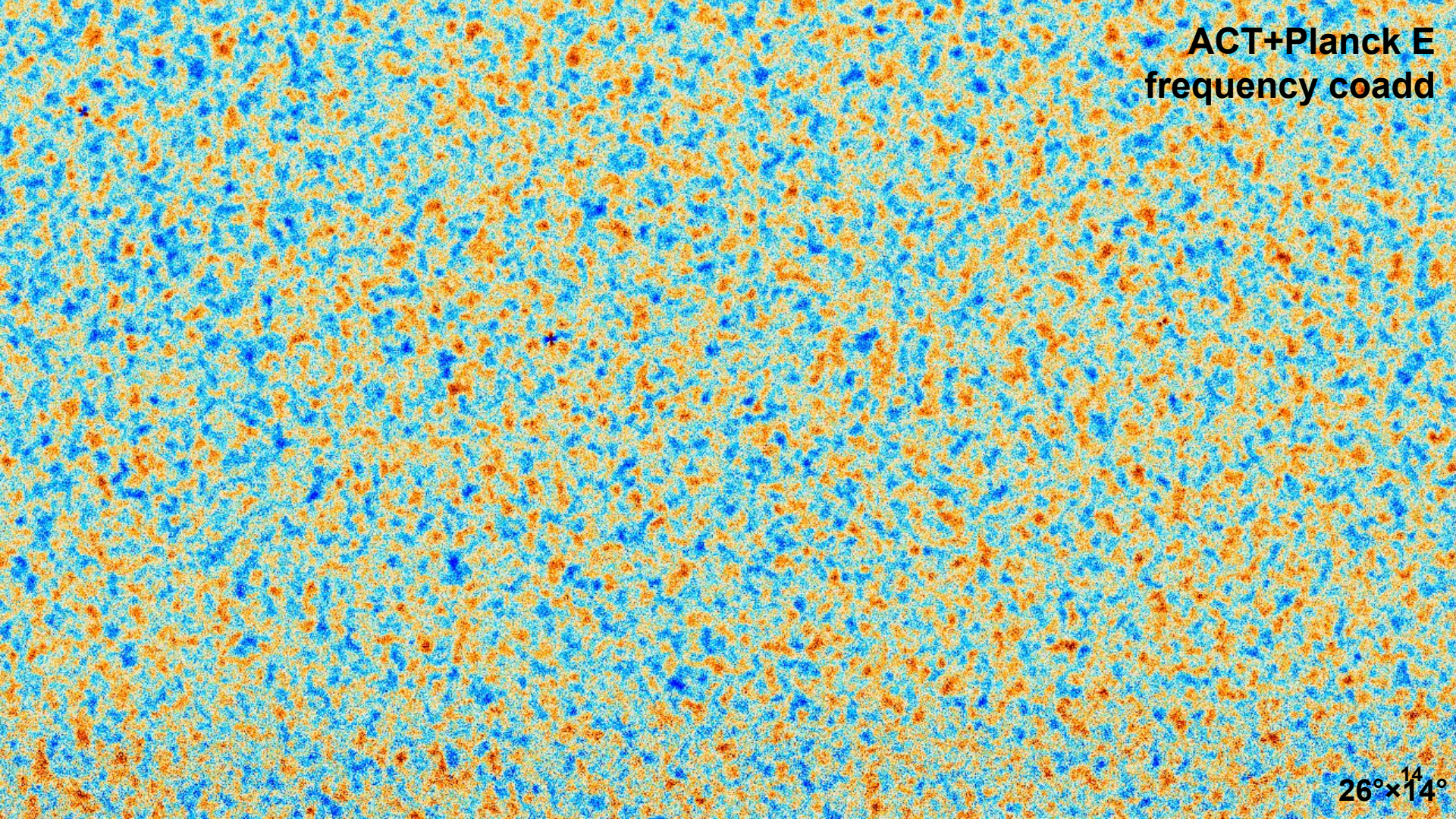


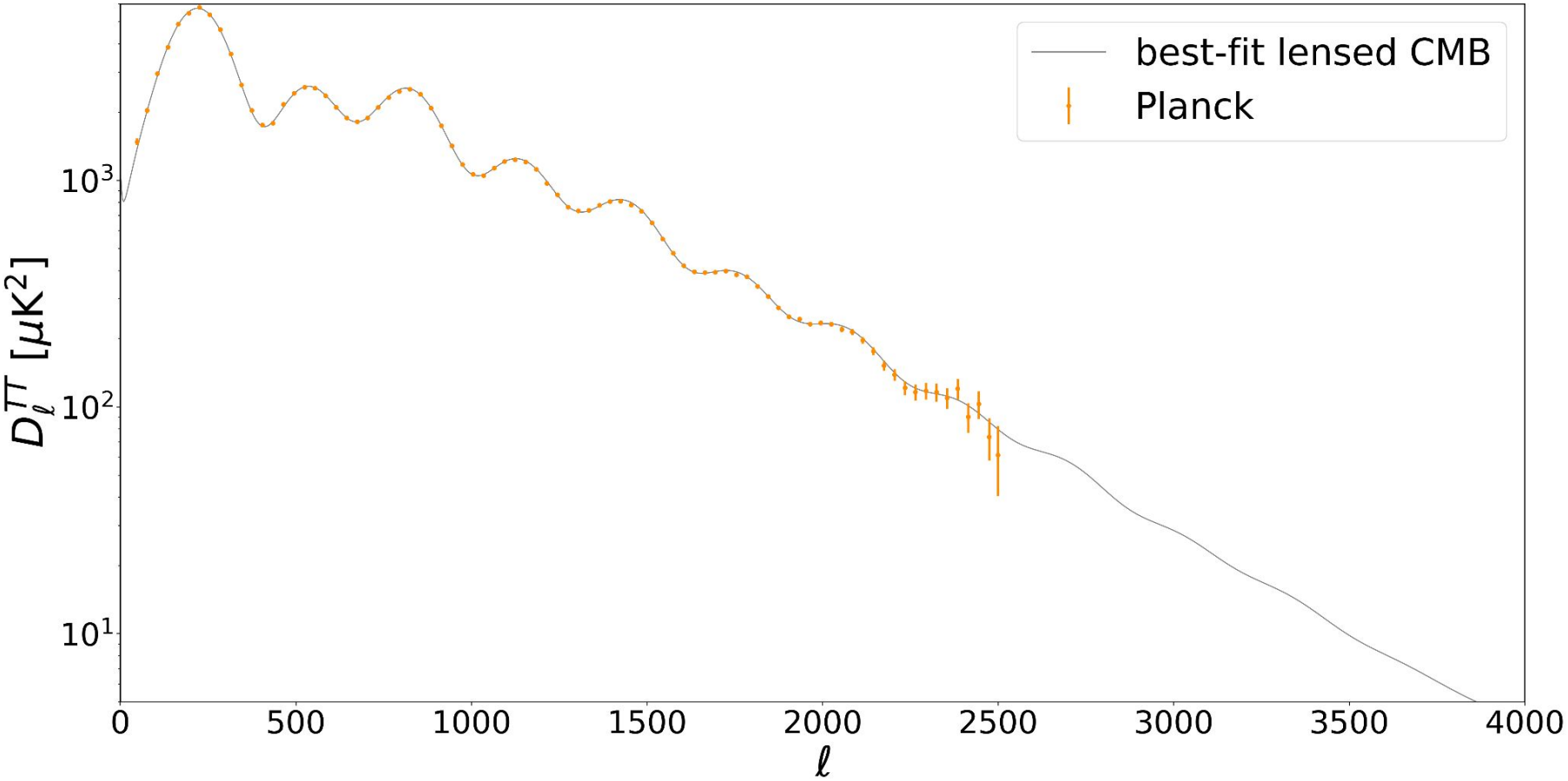


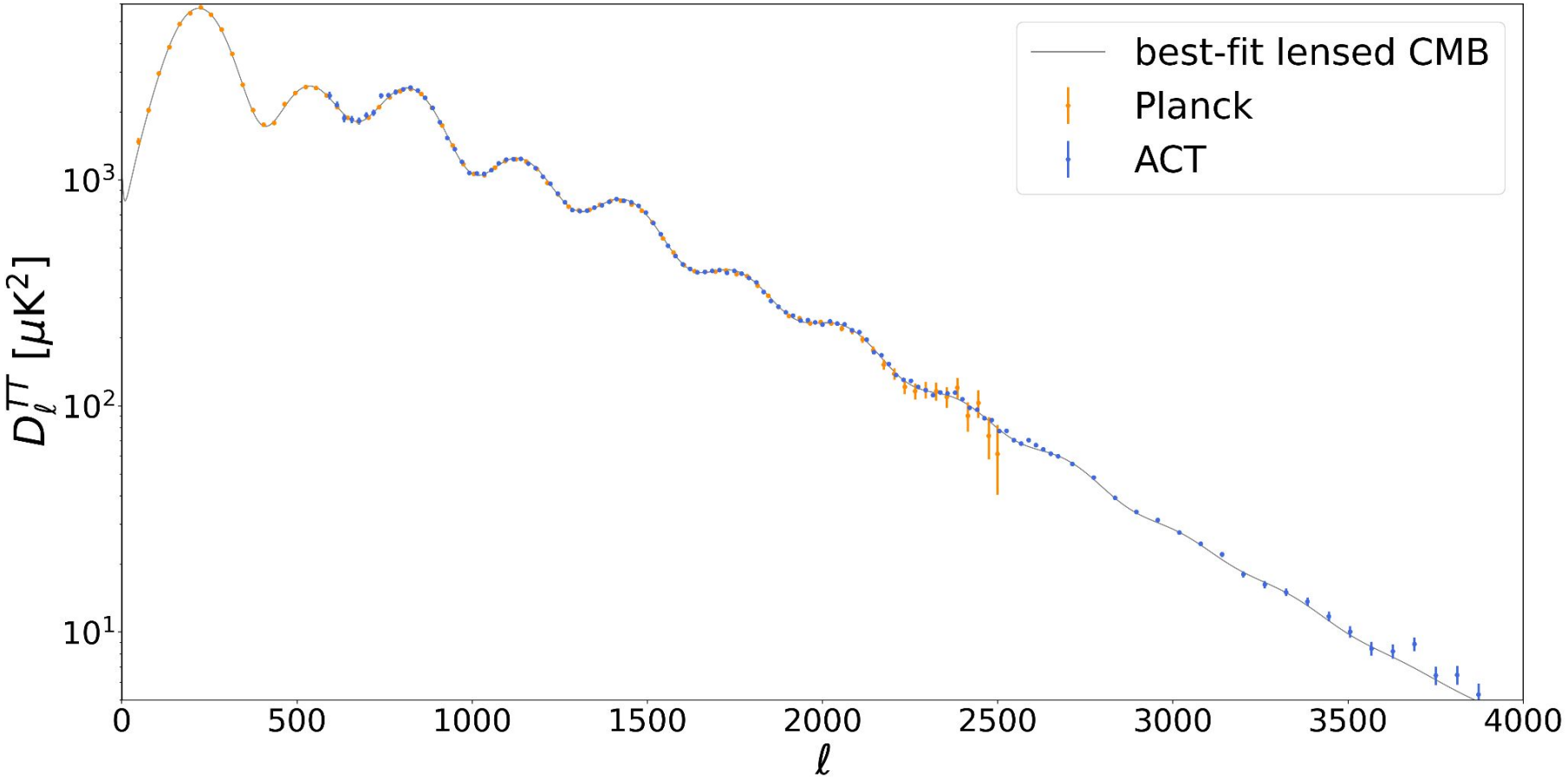

Planck f150 T
13°×7°


ACT+Planck f150 T
13°×7°


Planck E
frequency coadd
26°×14°


ACT+Planck E
frequency coadd
26°×14°


best-fit lensed CMB
Planck
D_ℓ^{TT} [μK^2]
10^3
10^2
10^1
0
500
1000
1500
2000
2500
3000
3500
4000
ℓ


best-fit lensed CMB
Planck
ACT
D_ℓ^{TT} [μK^2]
10^3
10^2
10^1
0
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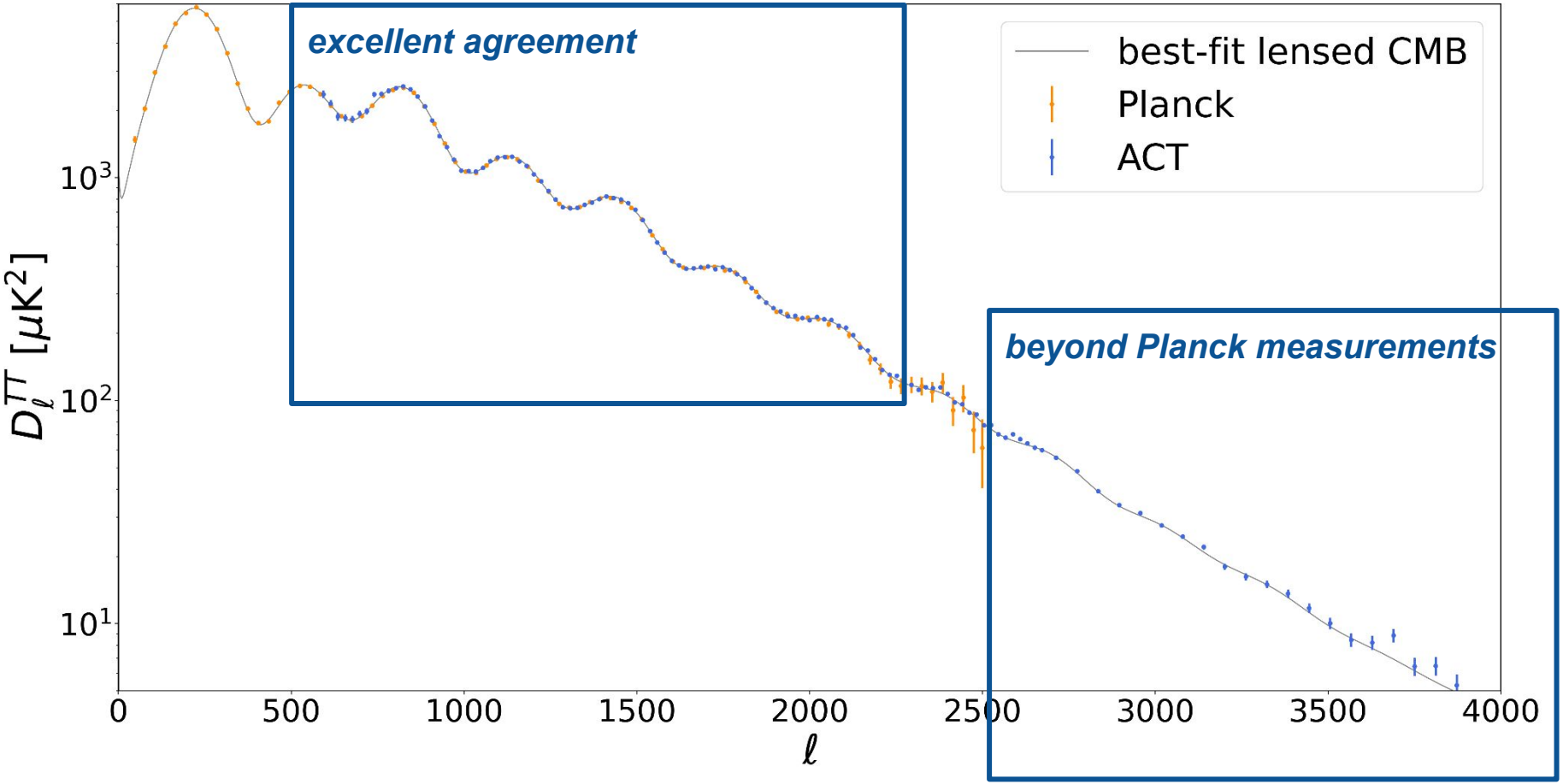
2000
2500
3000
3500
4000
ℓ


excellent agreement
beyond Planck measurements
best-fit lensed CMB
Planck
ACT
D_ℓ^{TT} [μK^2]
10^3
10^2
10^1
0
500
1000
1500
2000
2500
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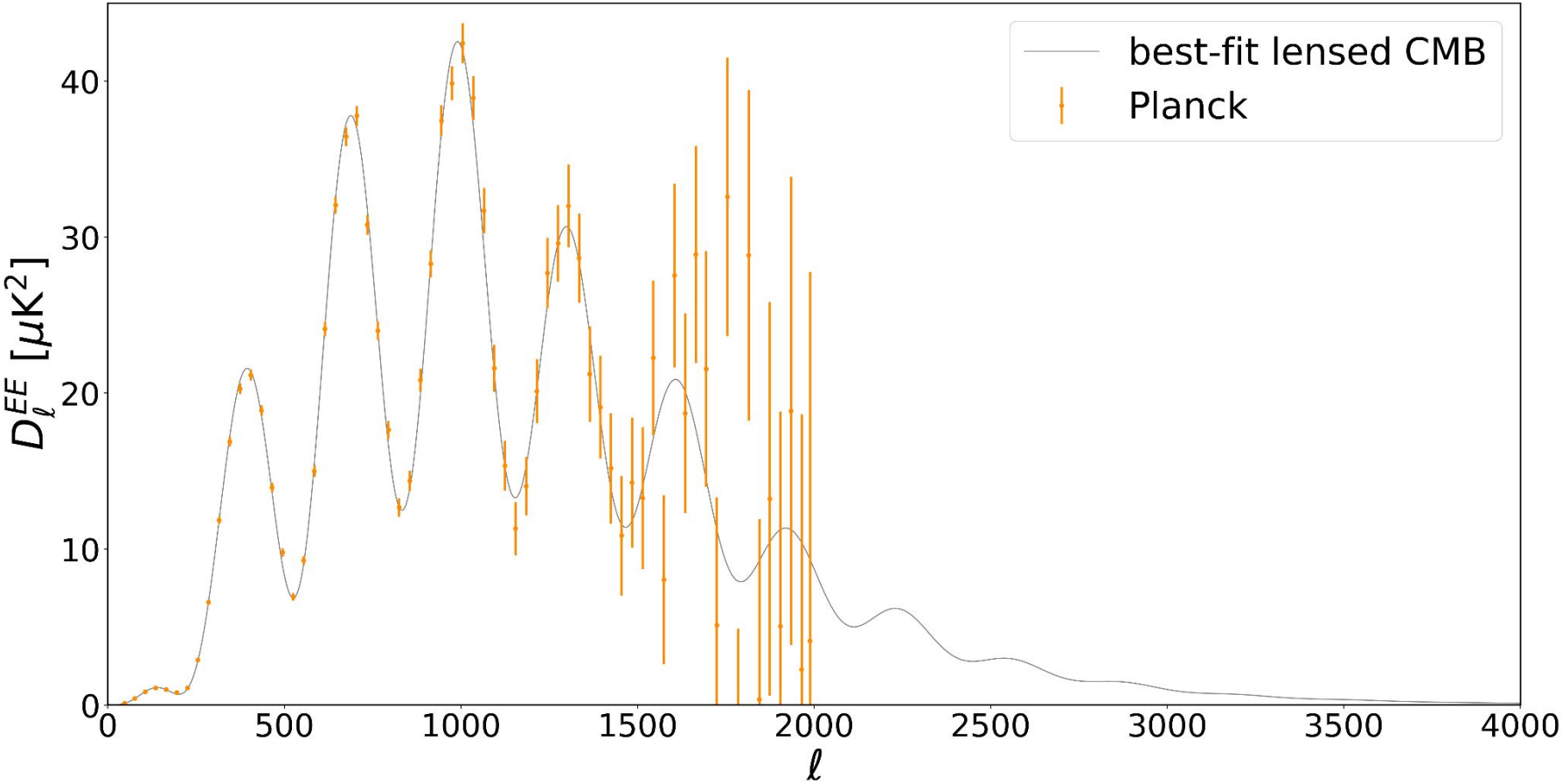
3500
4000
ℓ


best-fit lensed CMB
Planck
D_ℓ^{EE} [μK^2]
ℓ
0
10
20
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40
0
500
1000
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2500
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3500
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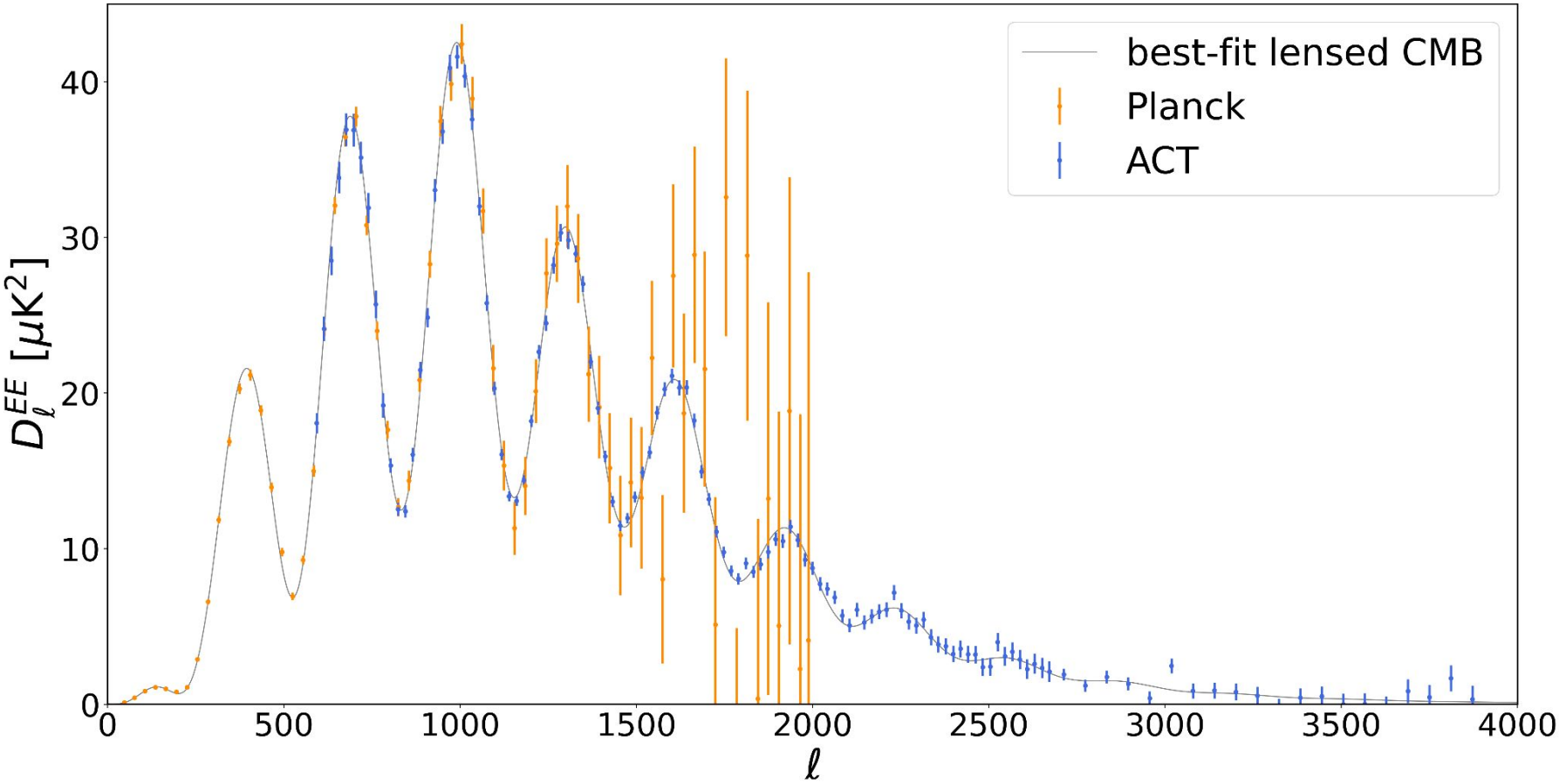
best-fit lensed CMB
Planck
ACT
D_ℓ^{EE} [μK^2]
ℓ
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0
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1000
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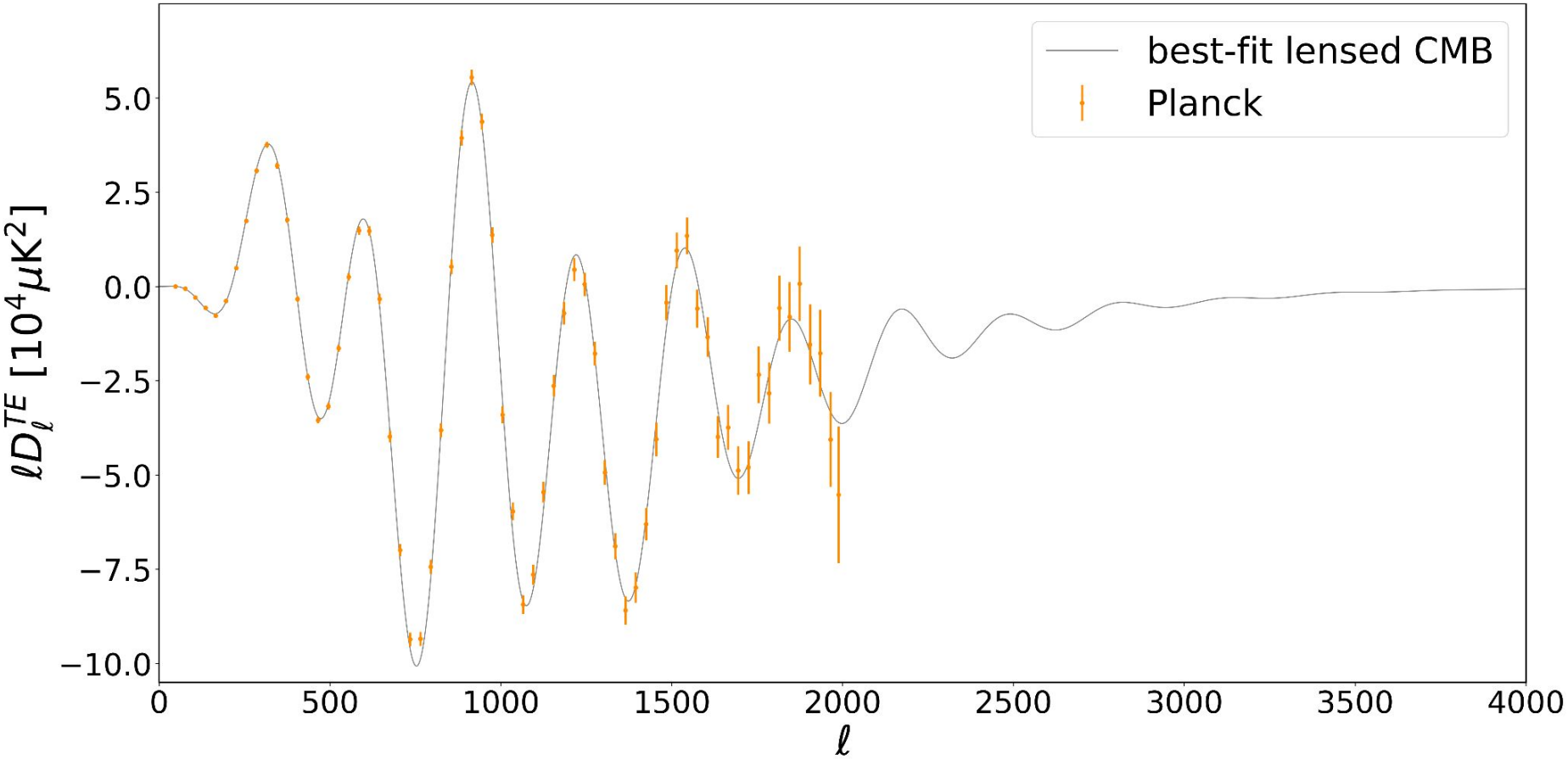
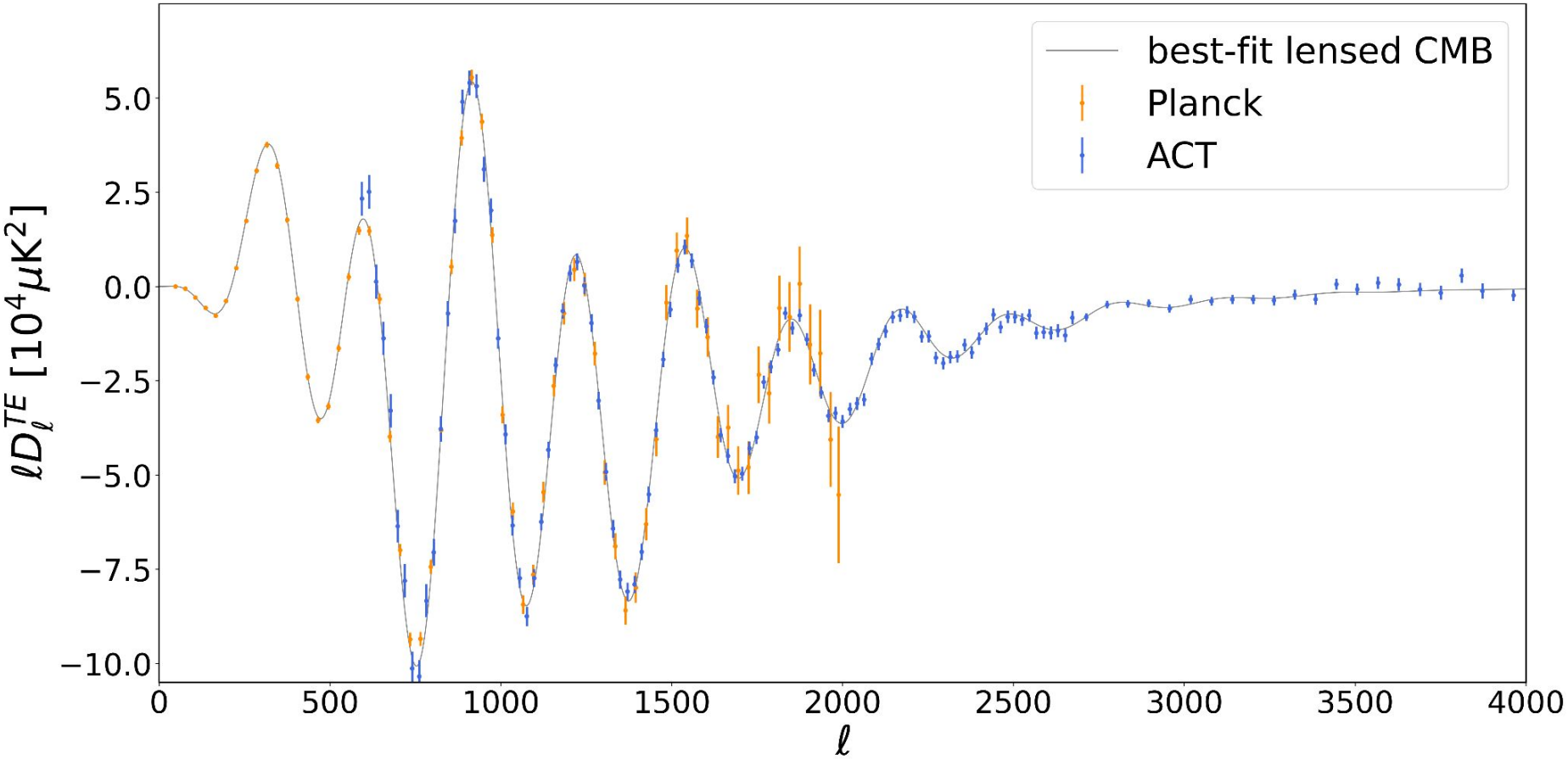
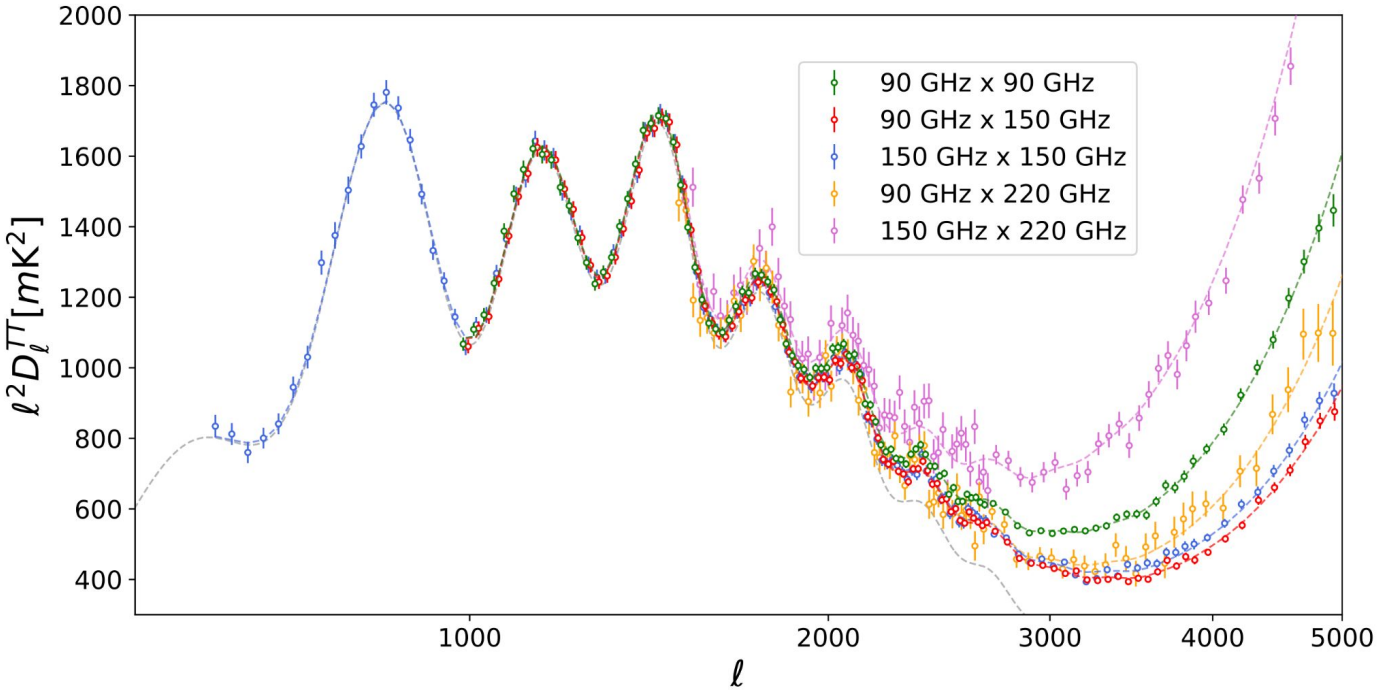
2000
2500
3000
3500
4000


best-fit lensed CMB
Planck
ℓD_ℓ^{TE} [$10^4 \mu K^2$]
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
0
500
1000
1500
2000
2500
3000
3500
4000
ℓ


best-fit lensed CMB
Planck
ACT
ℓD_ℓ^{TE} [$10^4 \mu K^2$]
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
0
500
1000
1500
2000
2500
3000
3500
4000
ℓ

ACT DR6 Cosmology results
-
Guided tour

Before we start, this is what the data look like

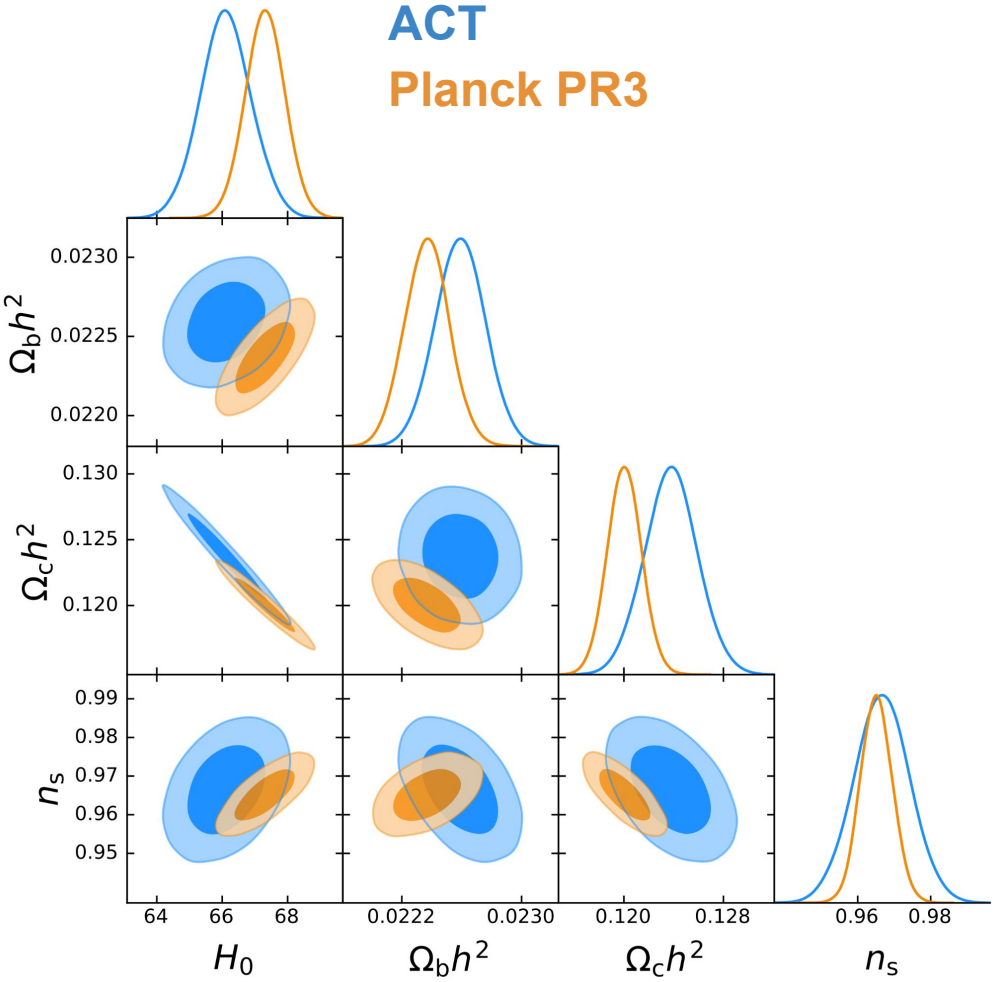


The Atacama Cosmology Telescope: DR6 Power Spectrum Foreground Model and Validation
Beringue et al. 2025 (2506.06274)

The ΛCDM model

- agrees very well with Planck PR3 constraints (**1.6σ**) with PTE=67% w.r.t. ΛCDM

Parameter	ACT
Sampled	
$\theta_{\rm MC}$	0.0104056 ± 0.0000031
$\Omega_{\rm b}h^2$	0.02259 ± 0.00017
$\Omega_{\rm c}h^2$	0.1238 ± 0.0021
$\log(10^{10}A_{\rm s})$	3.053 ± 0.013
$n_{\rm s}$	0.9666 ± 0.0077
τ	$0.0562^{+0.0053}_{-0.0063}$
Derived	
H_0	66.11 ± 0.79
$\Omega_{\rm m}$	0.337 ± 0.013
σ_8	0.8263 ± 0.0074

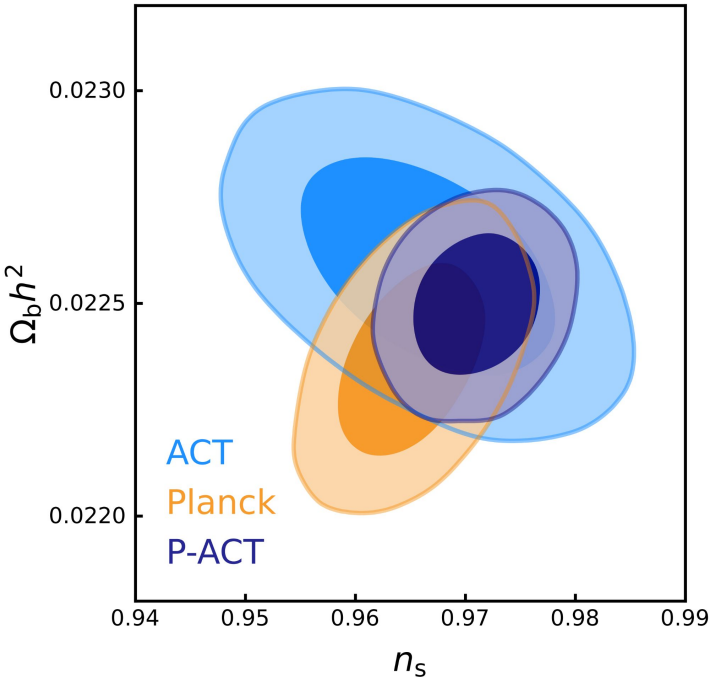


The ΛCDM model

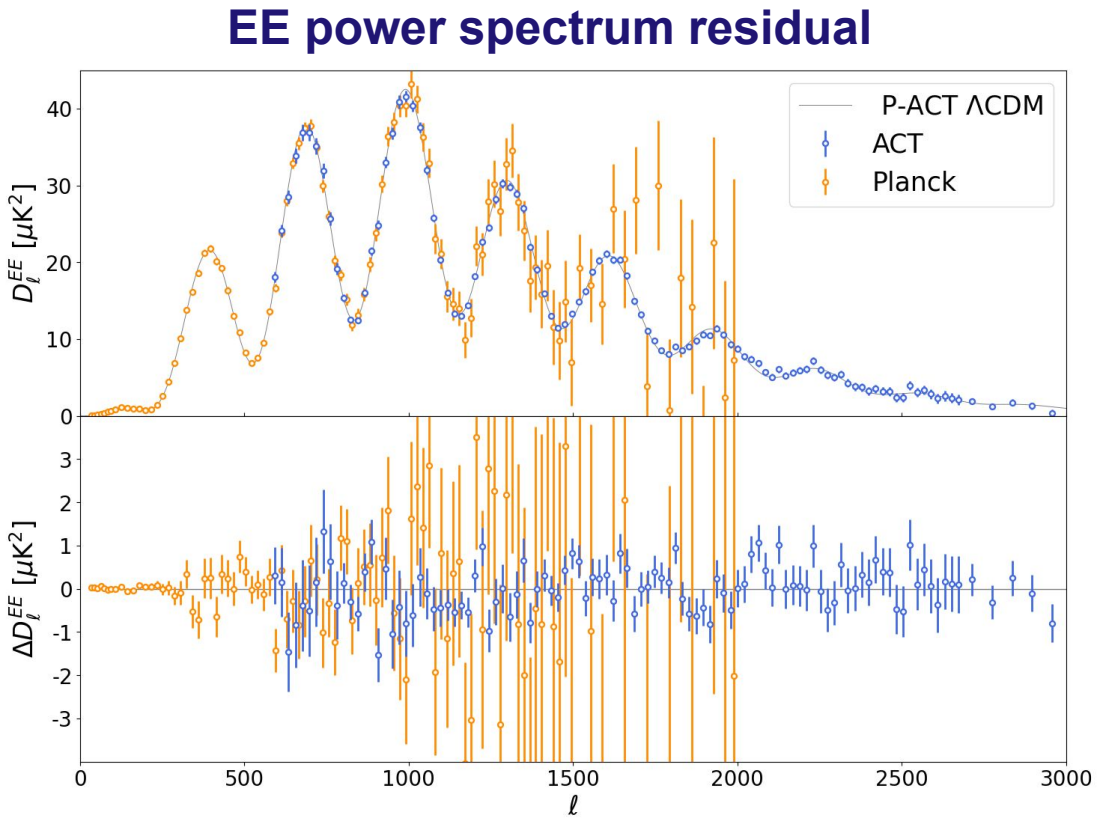
- agrees very well with Planck PR3 constraints (**1.6σ**) with PTE=67% w.r.t. ΛCDM

- can find a common model to fit both ACT and Planck data
  - □²(ACT) = 1598/1617 (63%)
  - □²(P-ACT) = 1842/1897 (81%)

ACT
Planck PR3
P-ACT (ACT + Planck)

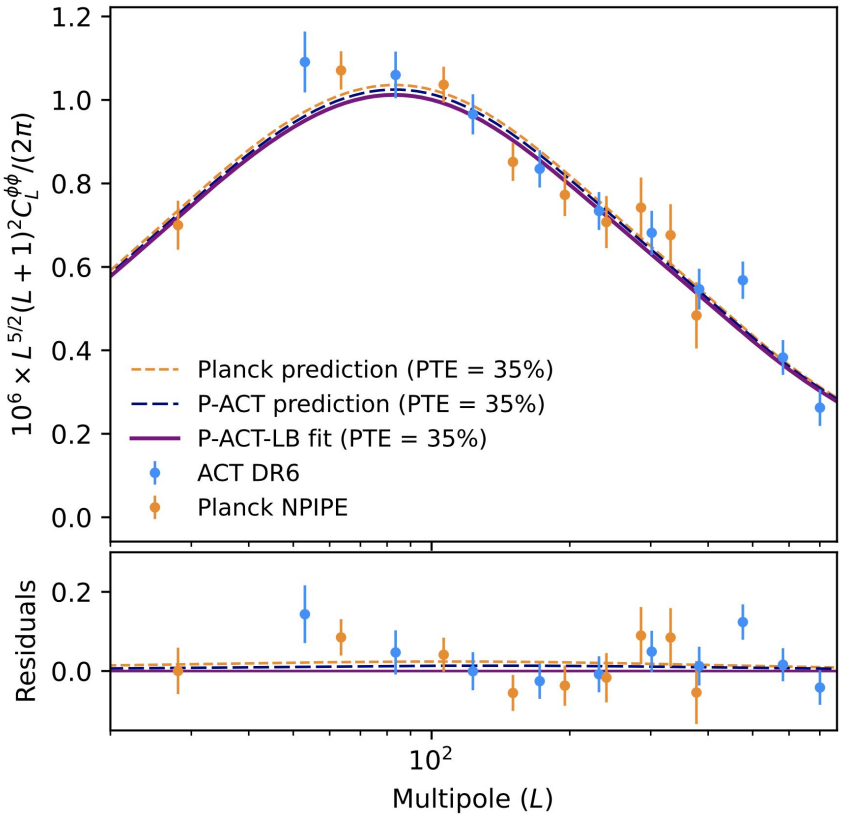


The ΛCDM model

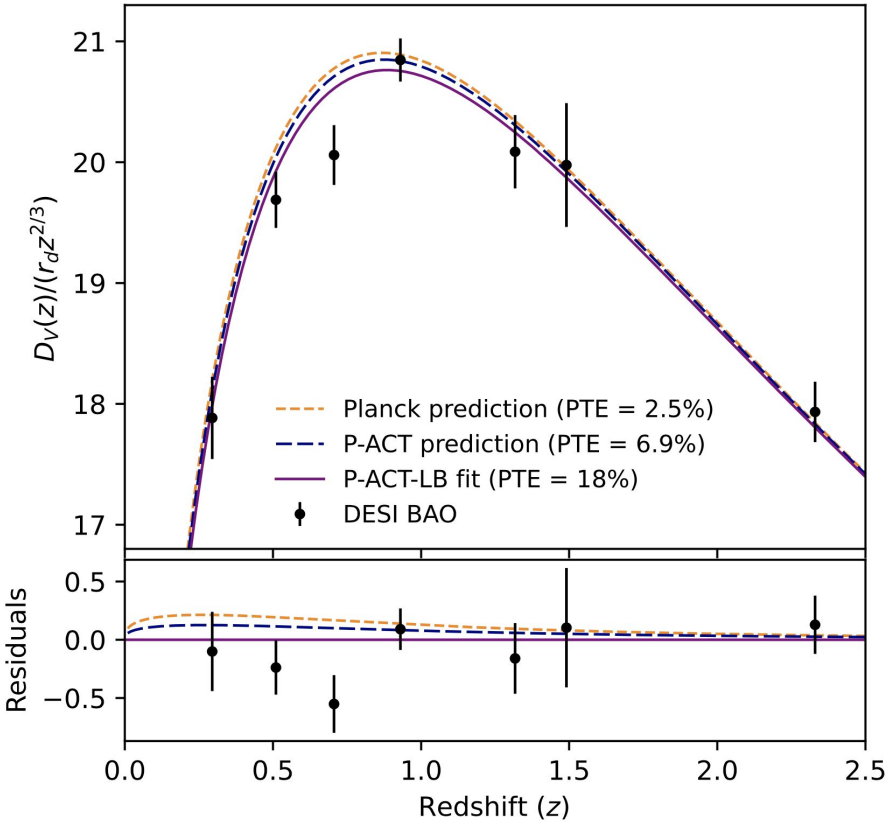


The ΛCDM model - Comparison with low-redshift data

CMB lensing



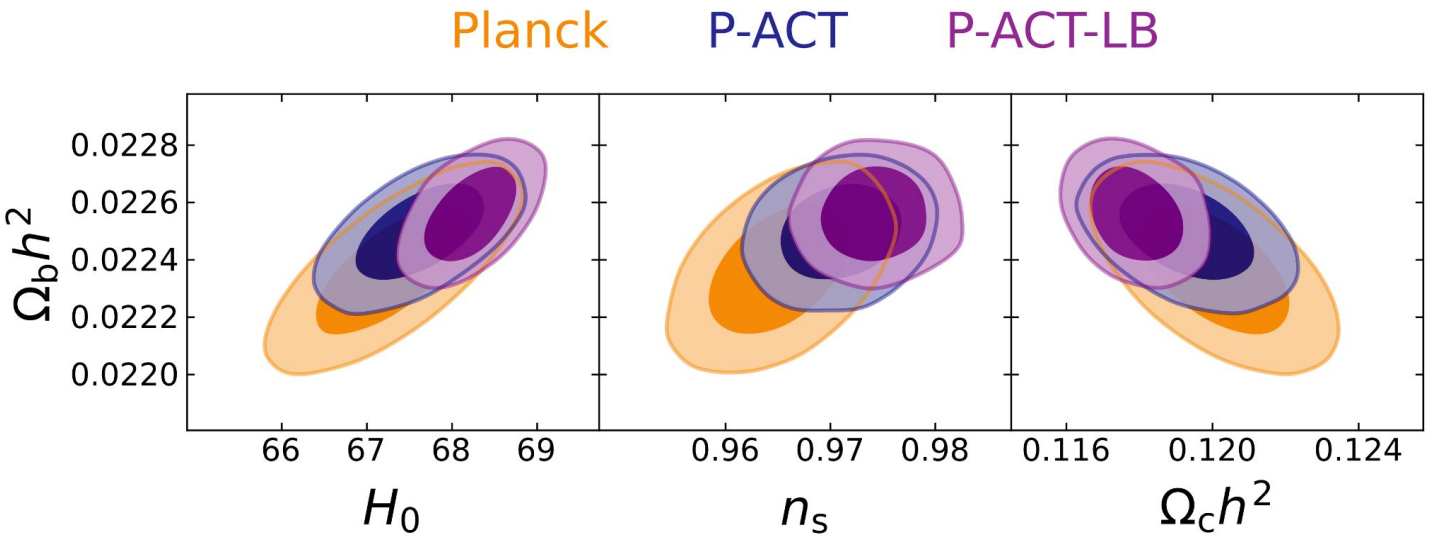
Baryonic Acoustic Oscillations



The ΛCDM model - Comparison with low-redshift data

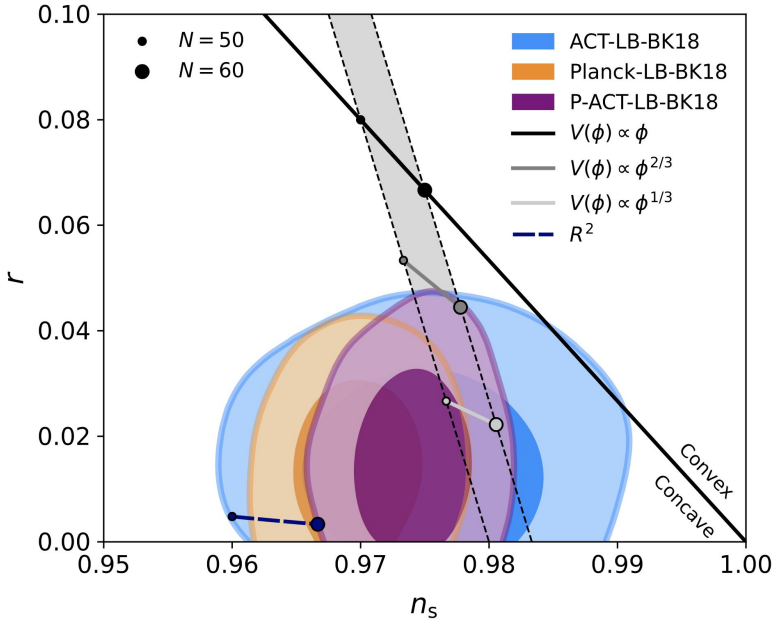
Combining with **CMB lensing** and **DESI-Y1 BAO** further improve constraints on the ΛCDM model parameters

0.5% measurement of the expansion rate $H_0 = 68.22 \pm 0.36$ *km/s/Mpc*

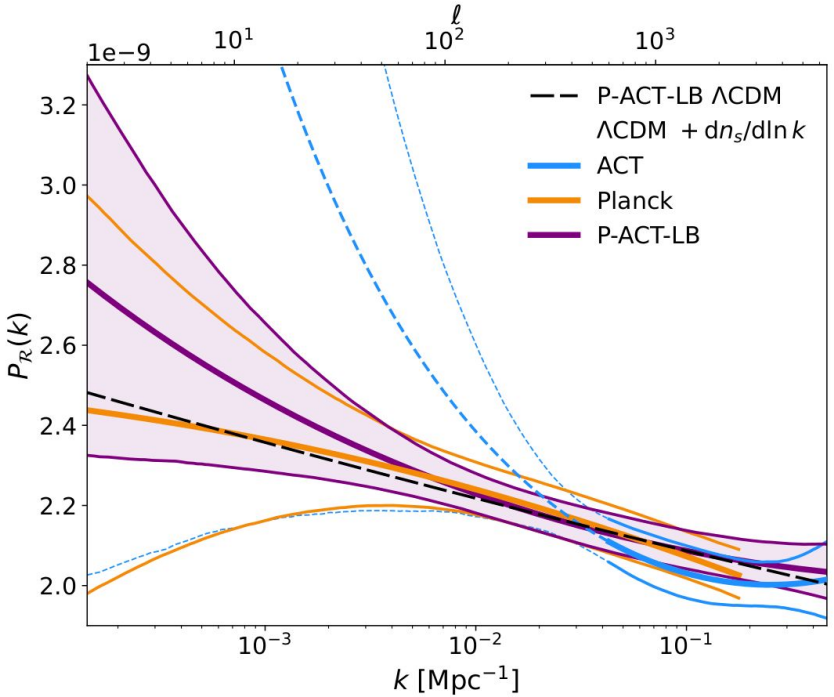


Primordial scalar perturbations

n_s = 0.9660 ± 0.0046 (WMAP + ACT)
n_s = 0.9651 ± 0.0044 (Planck PR3)



Deviation from a power law spectrum
$dn_s/d\ln k$ = 0.0062 ± 0.0052 (P-ACT-LB)



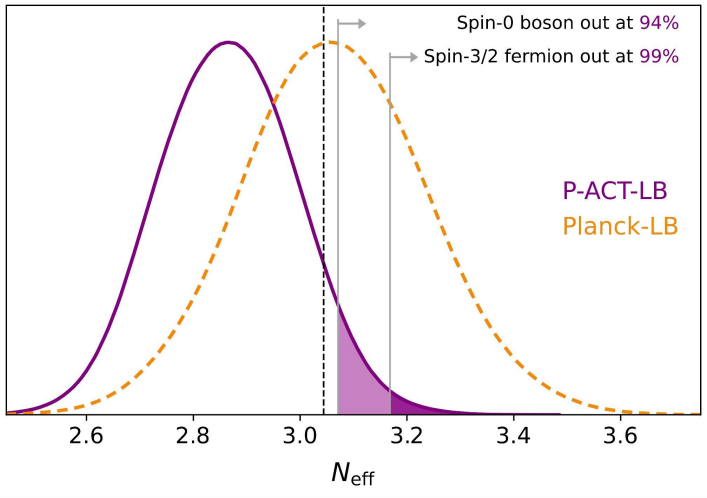
Additional light relativistic species

No evidence for new light, relativistic species

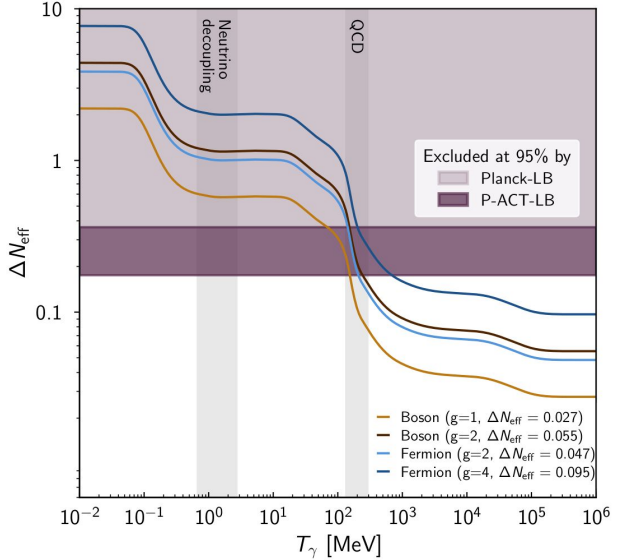
Free-streaming:

N_{eff} = 2.86 ± 0.13 (68%, P-ACT-LB) consistent with the standard model value (3.044)

Constraints on N_{eff}



Constraints on $\Delta N_{eff}>0$



Additional light relativistic species

No evidence for new light, relativistic species

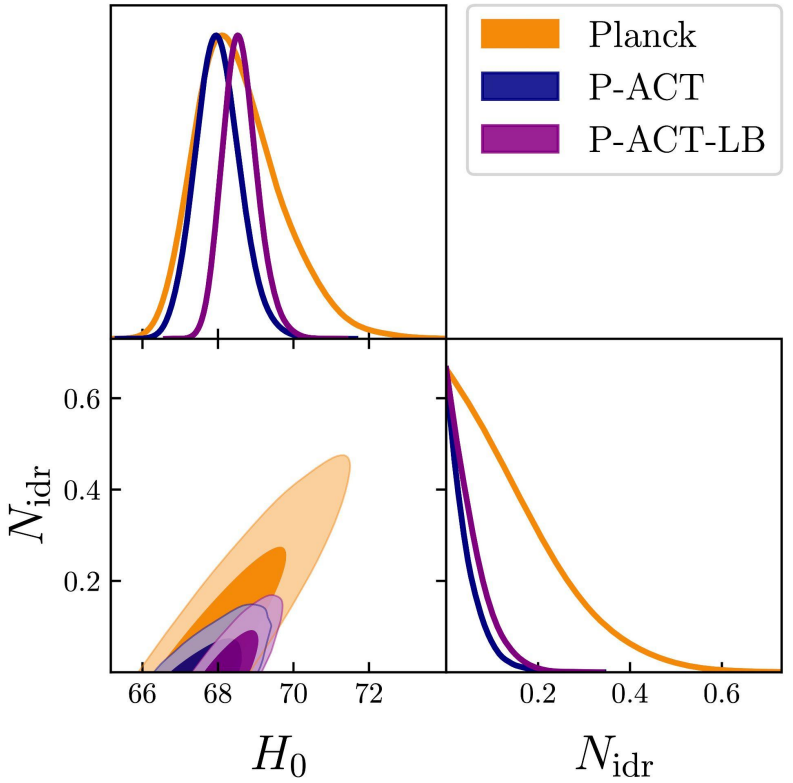
Free-streaming:

N_{eff} = 2.86 ± 0.13 (68%, P-ACT-LB)

Self-interacting:

N_{idr} < 0.134 (95%, P-ACT-LB)

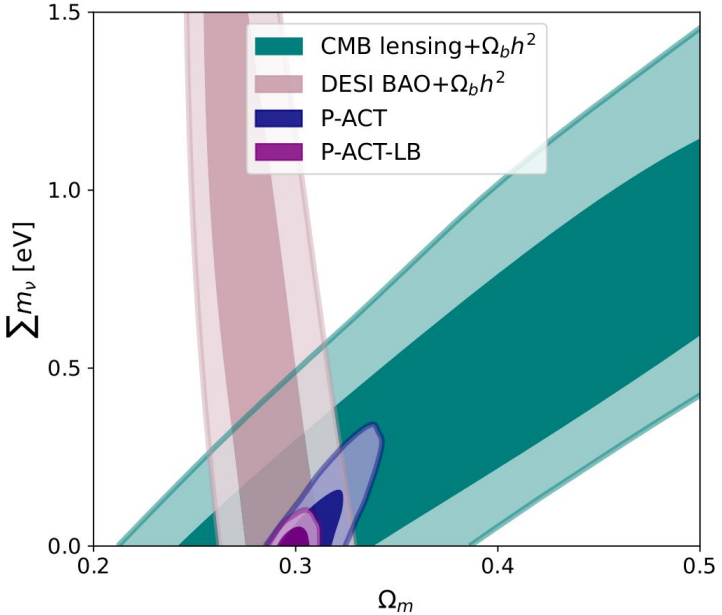
~3 times improvement from Planck to P-ACT

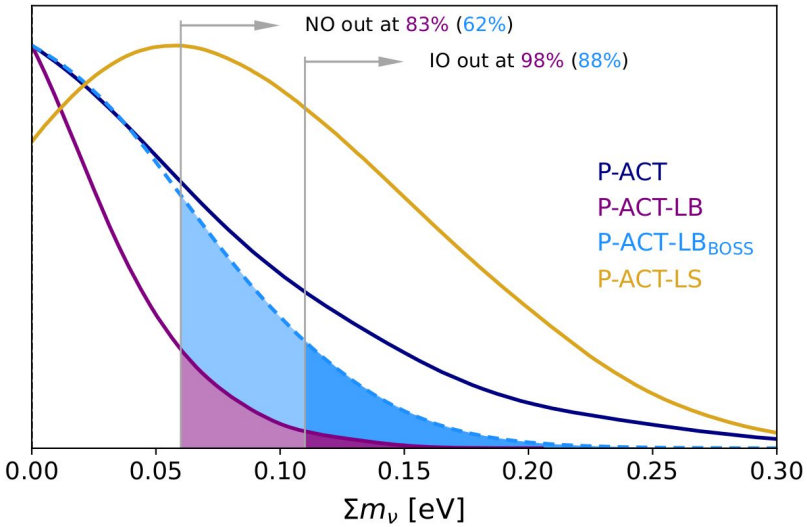


Neutrino mass constraints

Using DESI-Y1

$\Sigma m_\nu < 0.089$ eV (95%, P-ACT-LB)
$\Sigma m_\nu < 0.088$ eV (95%, WMAP + ACT-LB)





DR6 constraining power

Improved sensitivity from ACT DR6 data

Three types of models which would be still allowed by Planck data

Free-streaming dark radiation

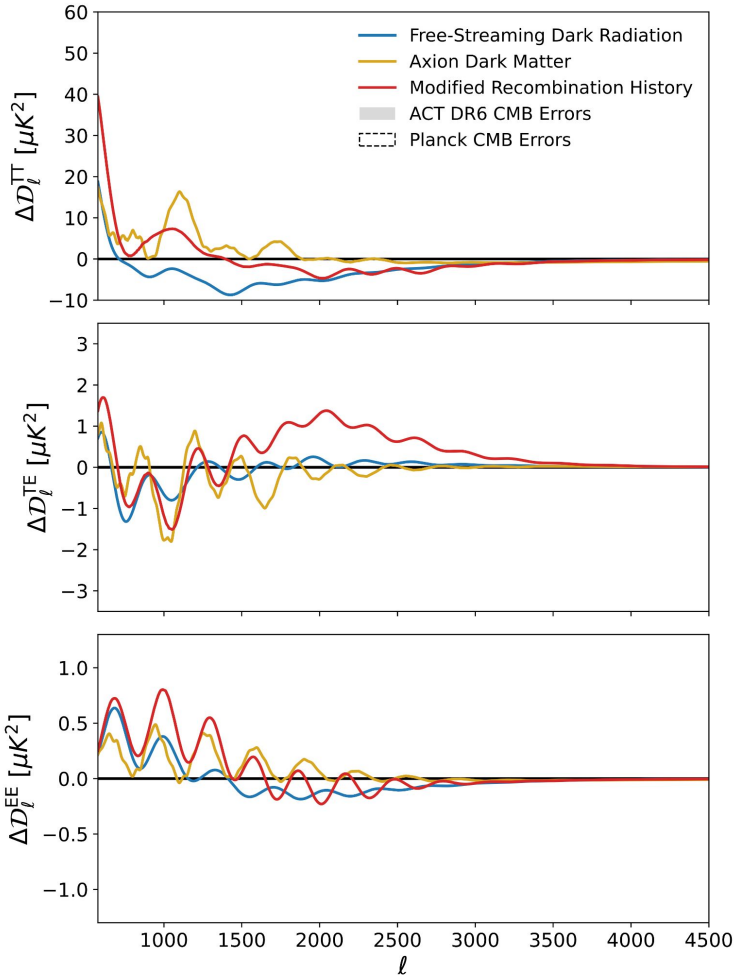
$N_{\rm eff} = 3.4$

Axion-like particles contributing to Dark Matter

$\Omega_{\rm ax}/(\Omega_{\rm ax} + \Omega_{\rm c}) = 5\% \quad (m_{\rm ax} = 10^{-26}\ {\rm eV})$

Modified recombination history

$\Delta X_e/X_e = -20\% \quad {\rm at} \quad z \sim 1470$



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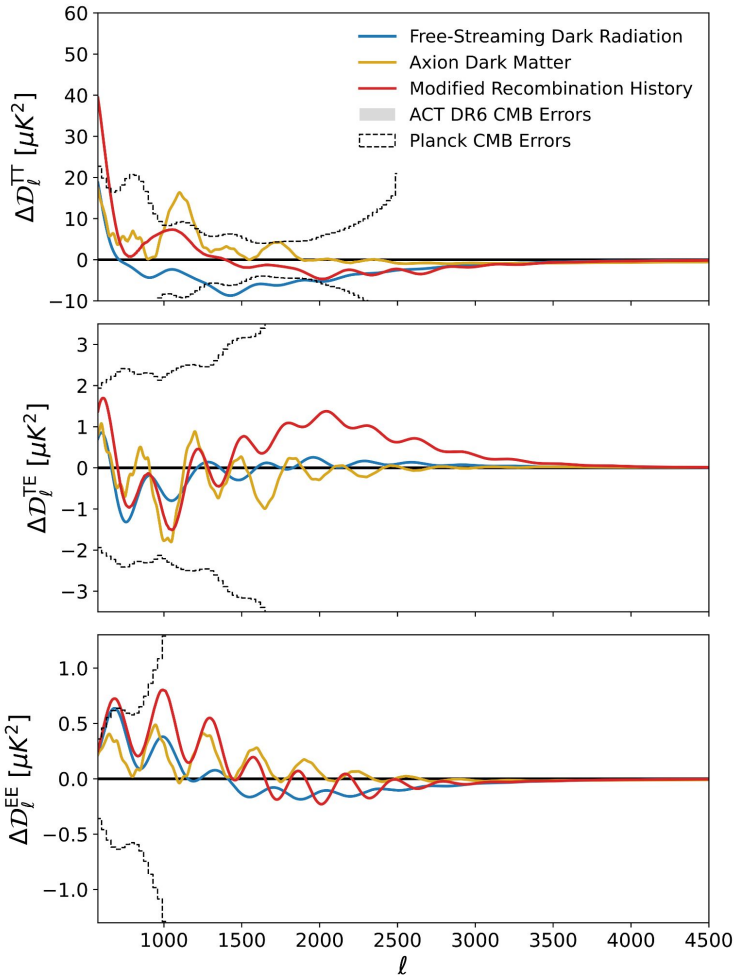

DR6 constraining power

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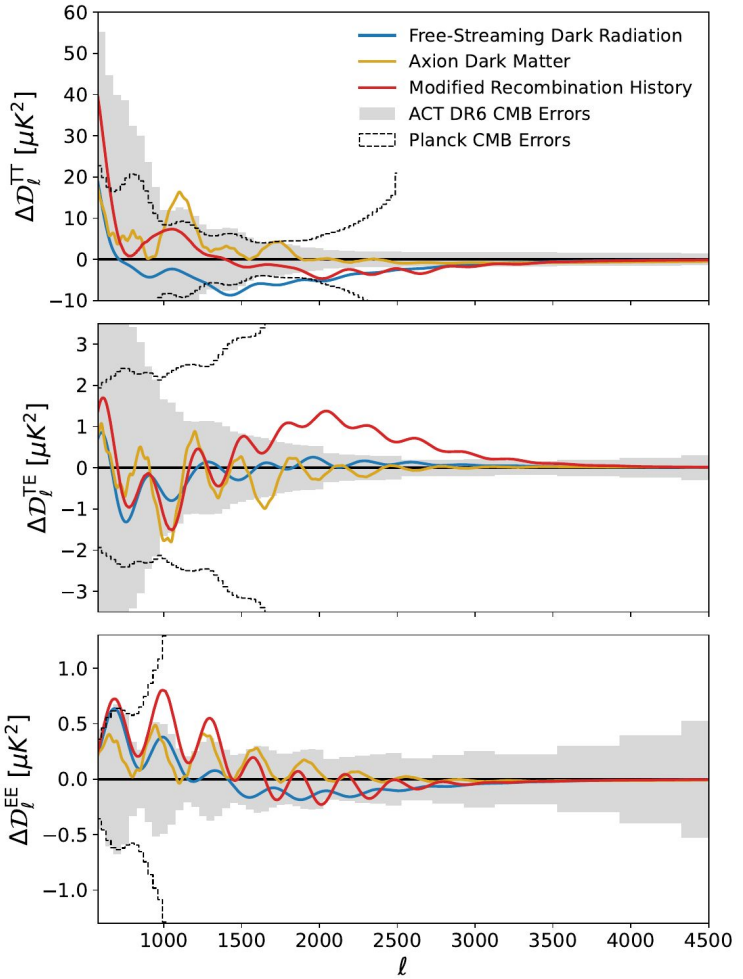
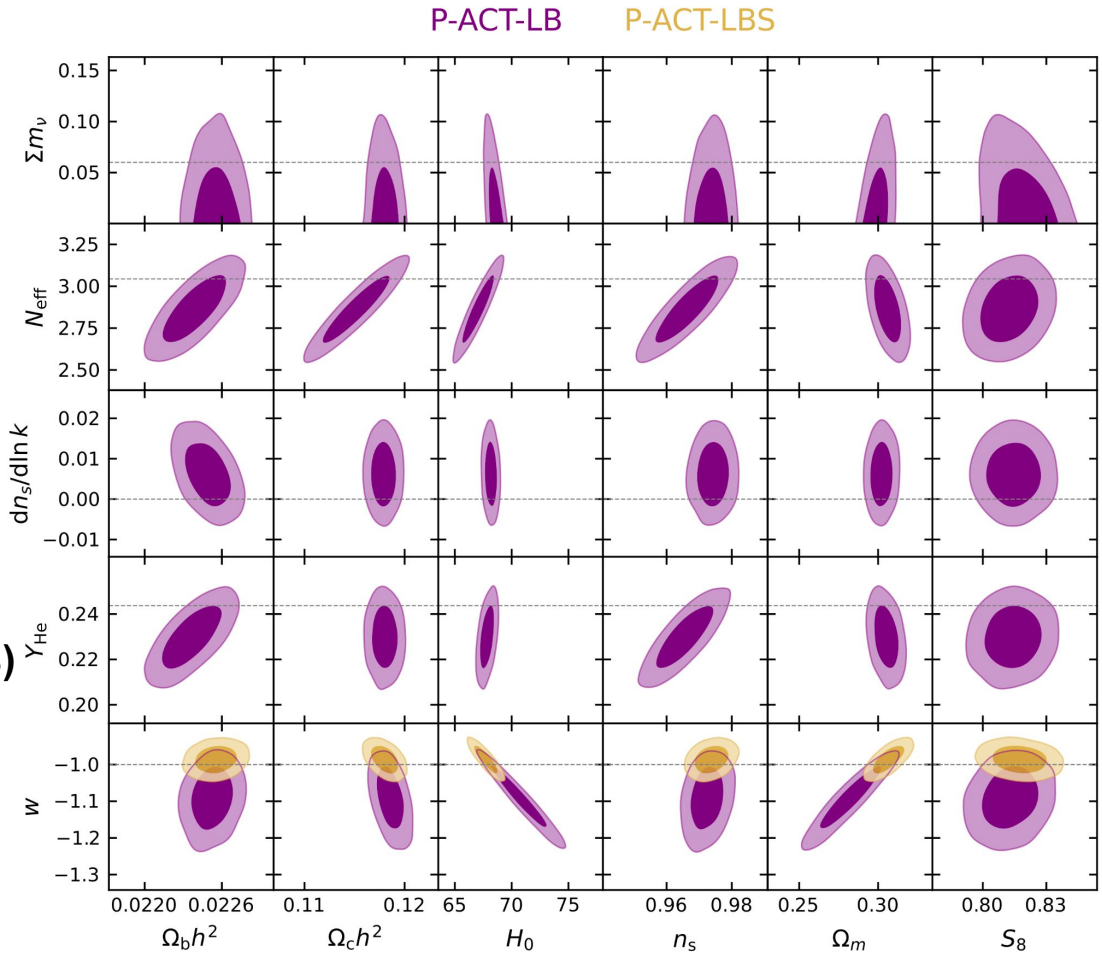


Extensions summary

Main takeaway

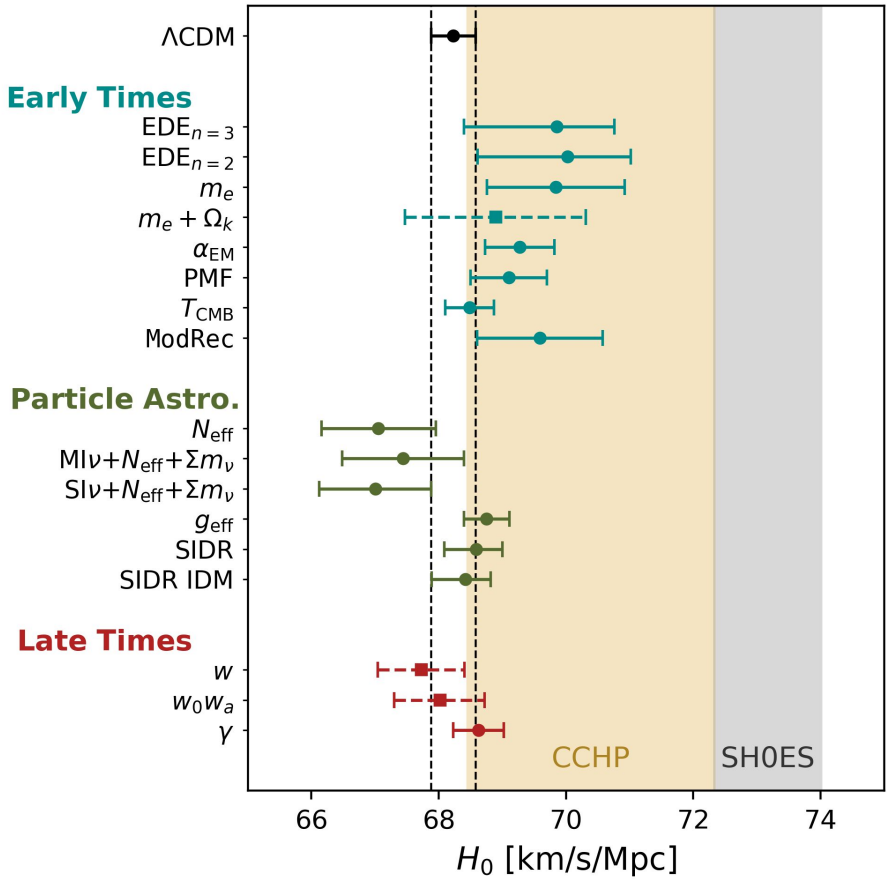
From ACT DR6 analysis, we find no statistically significant departure from LCDM

(not only on single parameter extensions)



The Hubble constant

None of the tested BSM scenario is able to rise up the value of the Hubble constant enough to agree with SH0ES supernovae



The end of the journey

- ACT DR6 provides a new consistent and complementary dataset to pre-existing CMB datasets. LCDM still provides an accurate description of CMB data

- It can substantially improve constraints on beyond standard model physics, providing best constraints from the P-ACT CMB dataset

- New measurements are on the way ! Simons Observatory started observing (first light from the LAT earlier this year)

ACT DR6 – Maps, Likelihoods, Code, Notebooks

LAMBDA legacy archive (lambda.gsfc.nasa.gov)

- Maps (frequency, coadd, ILC, null tests)
- MCMC chains, power spectra

NERSC (/global/cfs/cdirs/cmb/data/act_dr6/dr6.02)

In addition to all products on LAMBDA:

- Single-pass maps for time-domain studies
- Noise models and simulations
- Products to reproduce spectra and likelihood

PSpipe SIMONS OBSERVATORY

PSpipe repository (Simons Observatory) (https://github.com/simonsobs/PSpipe)

- Code to reproduce spectra and likelihood


DR6_Notebooks

ACT DR6 Jupyter Notebooks (https://github.com/ACTCollaboration/DR6_Notebooks)

- Explanatory tutorials for DR6 data products