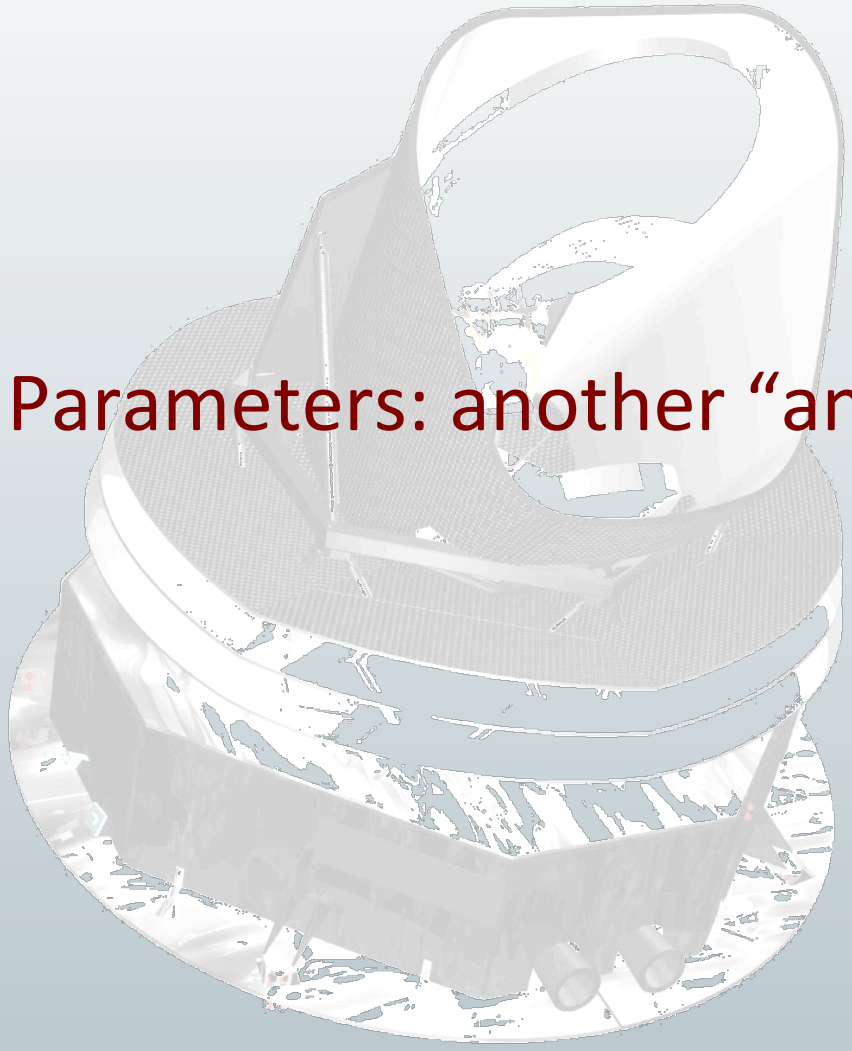
Parameters: another “angle”



Graça Rocha

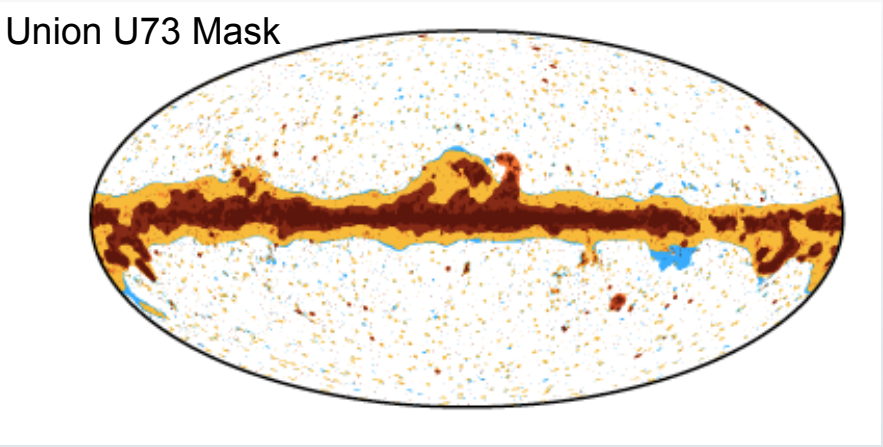
JPL/Caltech

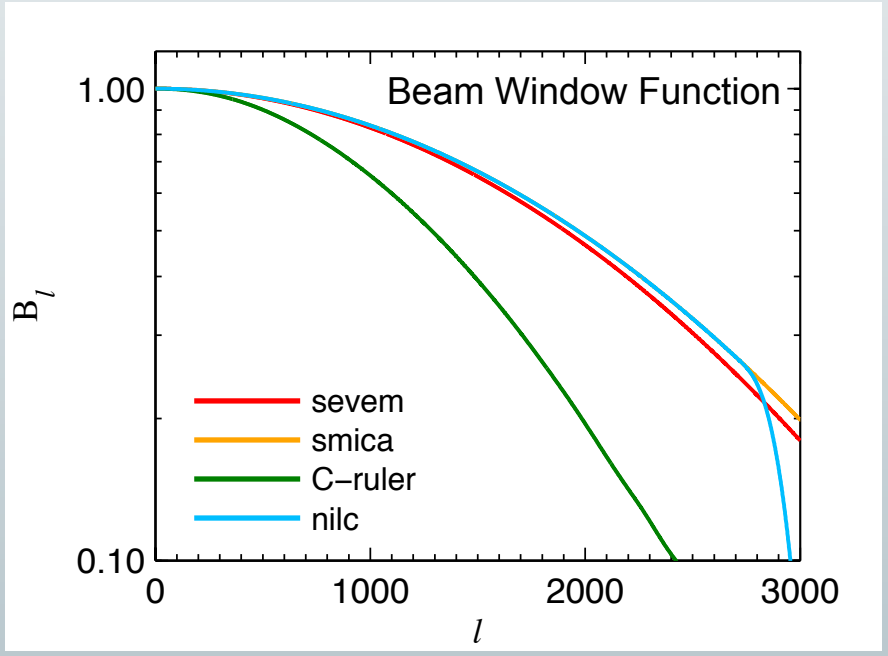
On behalf of the Planck collaboration

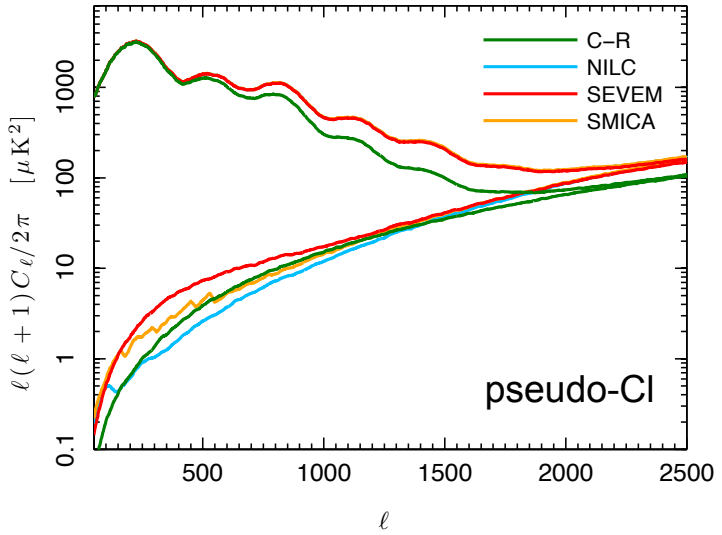
Power Spectrum and Parameters from CMB maps

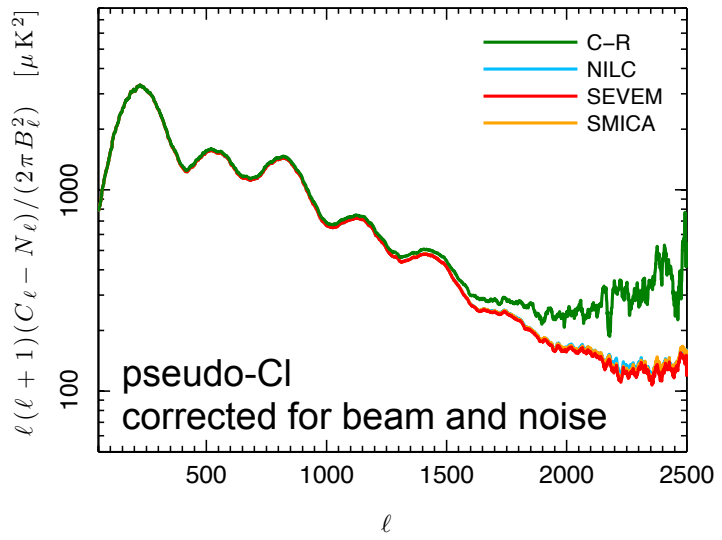
- Planck 2013 XII, Component Separation
- Planck 2013 XV, Likelihood
- Planck 2013 XVI Cosmological parameters

Power Spectrum from CMB maps



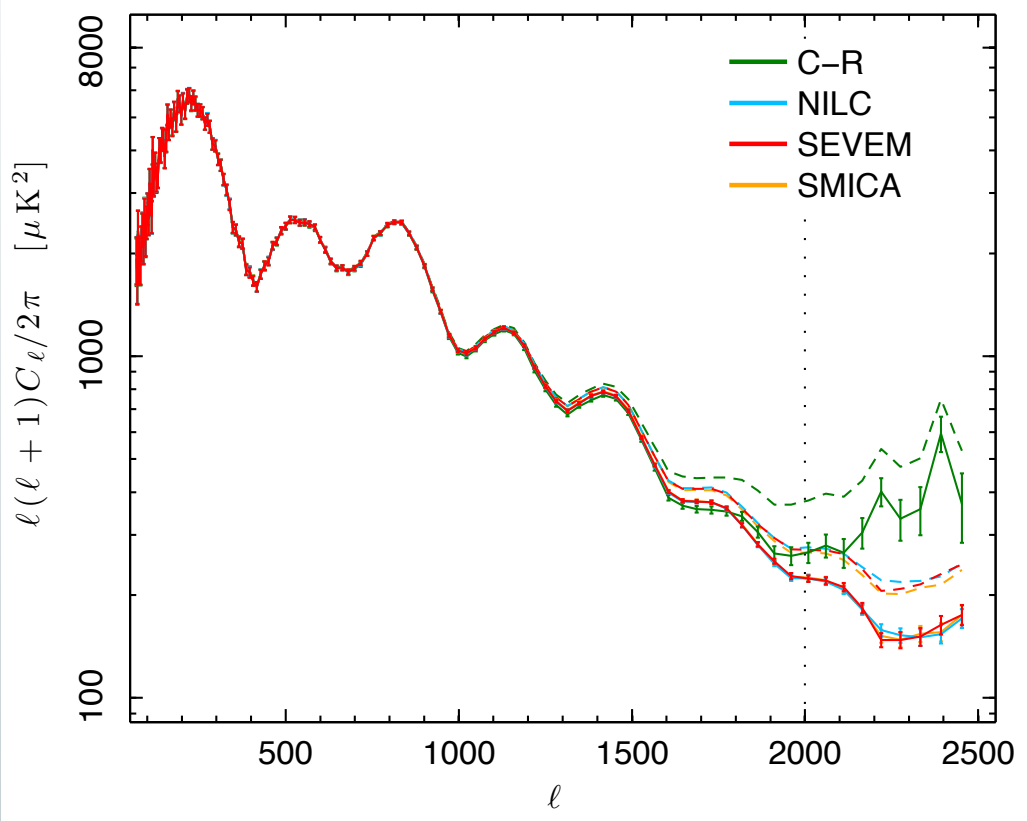






Power Spectrum from CMB maps

Full Sky Band Powers



The solid lines show the spectra after subtracting the best-fit model of residual foregrounds.

Band powers estimated with XFaster iterative scheme starting from a flat spectrum model. The result is a binned power spectrum and the associated Fisher matrix – dashed lines

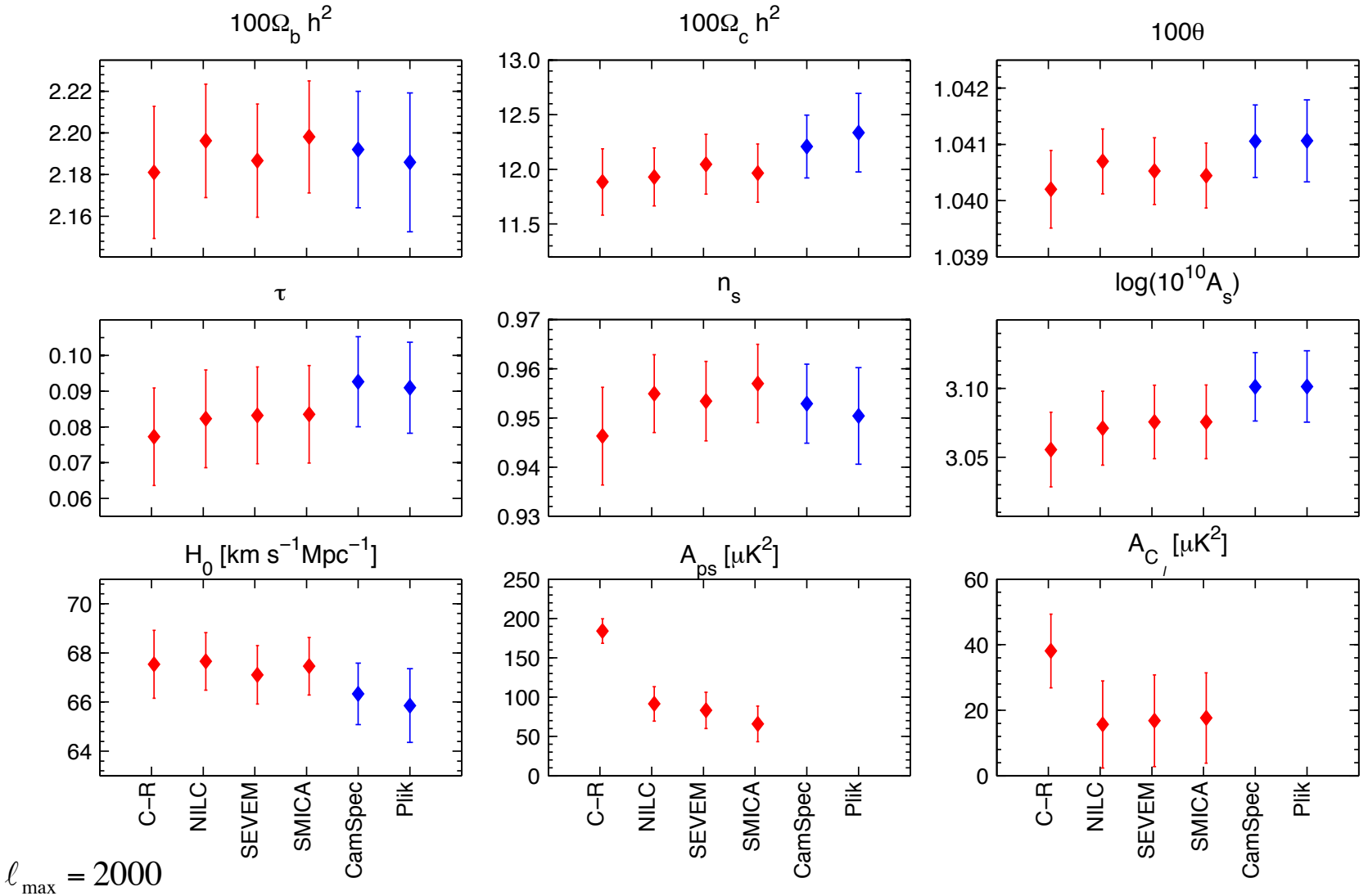
Estimate Cosmological Parameters with a Gaussian Correlated likelihood and a MCMC sampler and PICO for 70<l<2000

- 6 cosmological parameters
- **A_{ps}** - the amplitude of a Poisson component , $C_l=A_{ps}$=constant
- **A**cl - the amplitude of a clustered component with shape

$$D_\ell = \ell(\ell+1)C_\ell / 2\pi \propto \ell^{0.8}$$

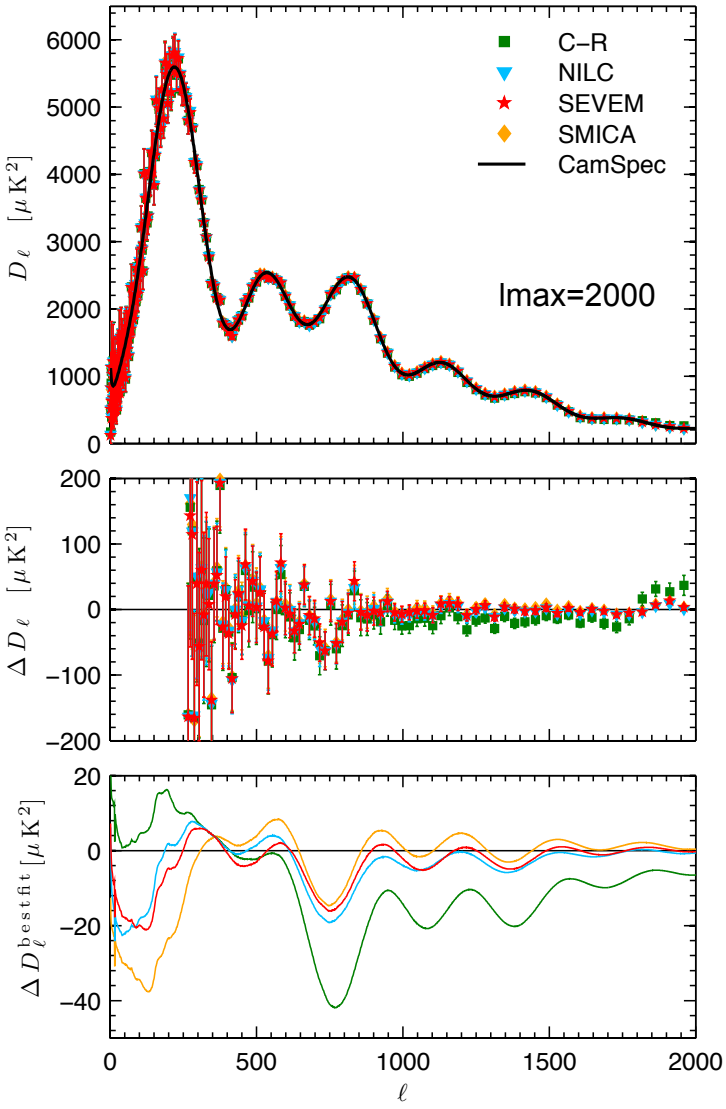
D_l at l = 3000 in units of μK^2.

Parameters from CMB maps vs multi-frequency cross-spectra



$\ell_{max} = 2000$

Best fit models from CMB maps vs multi-frequency cross-spectra



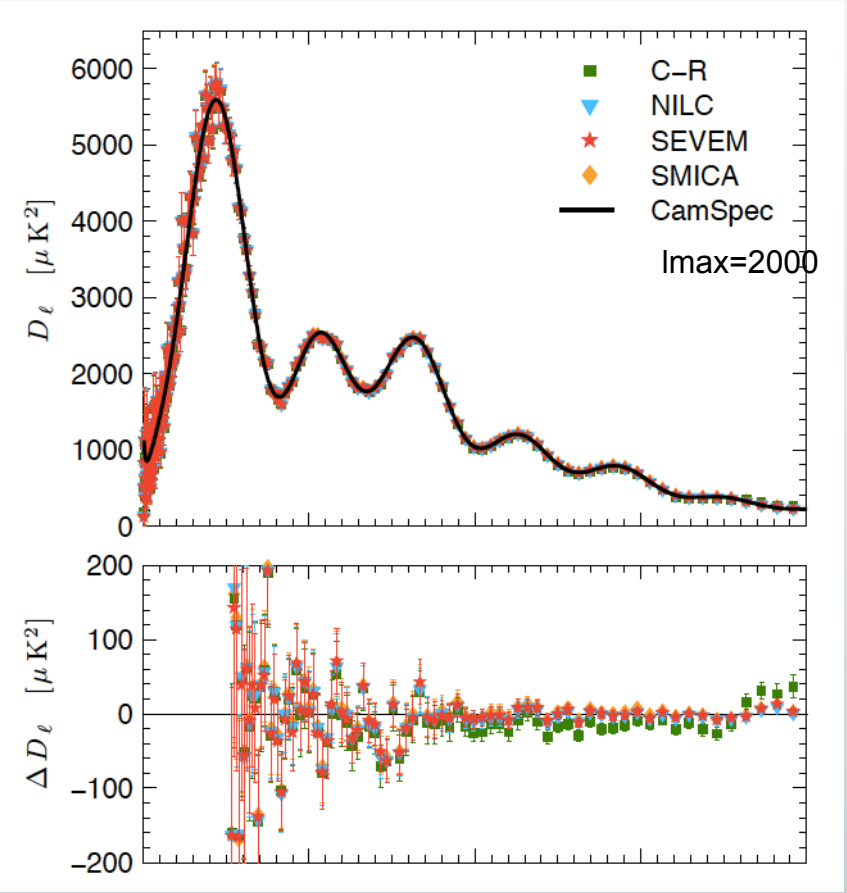
CMB power spectrum with best-fitting foreground model removed

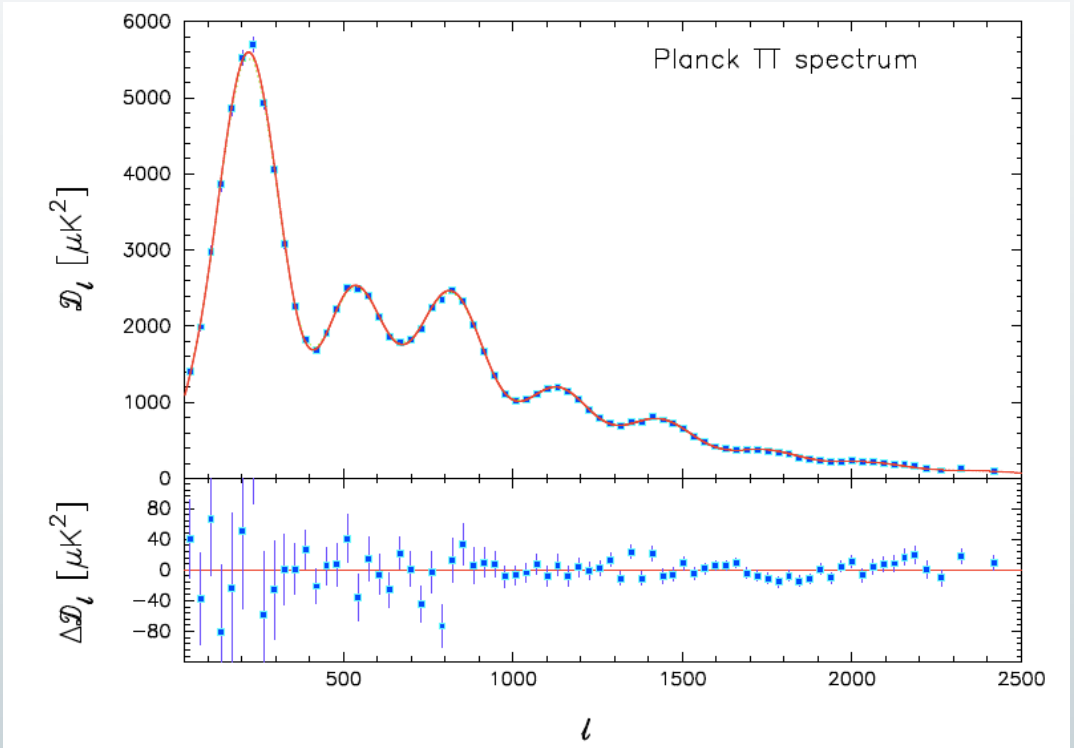
compared to multi-frequency cross-spectra (CamSpec) best fit model

Residuals wrt to CamSpec best fit model

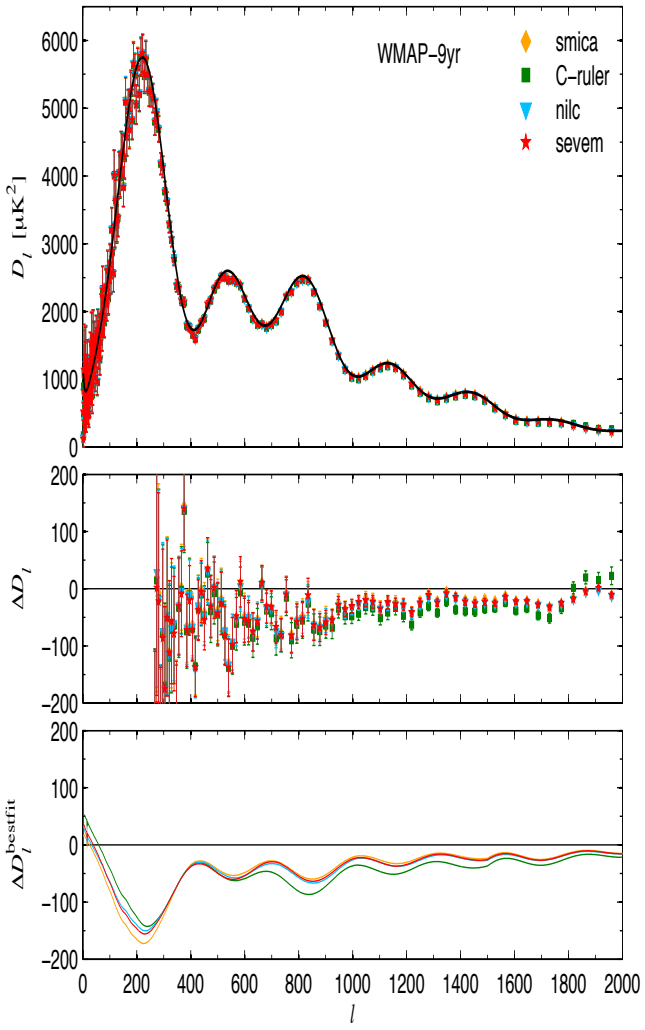
Residuals of best fit models from the map-based likelihoods with respect to the CamSpec best fit model

Power Spectra and best fit models from CMB maps vs multi-frequency cross-spectra





Best fit models from Planck CMB maps vs WMAP9



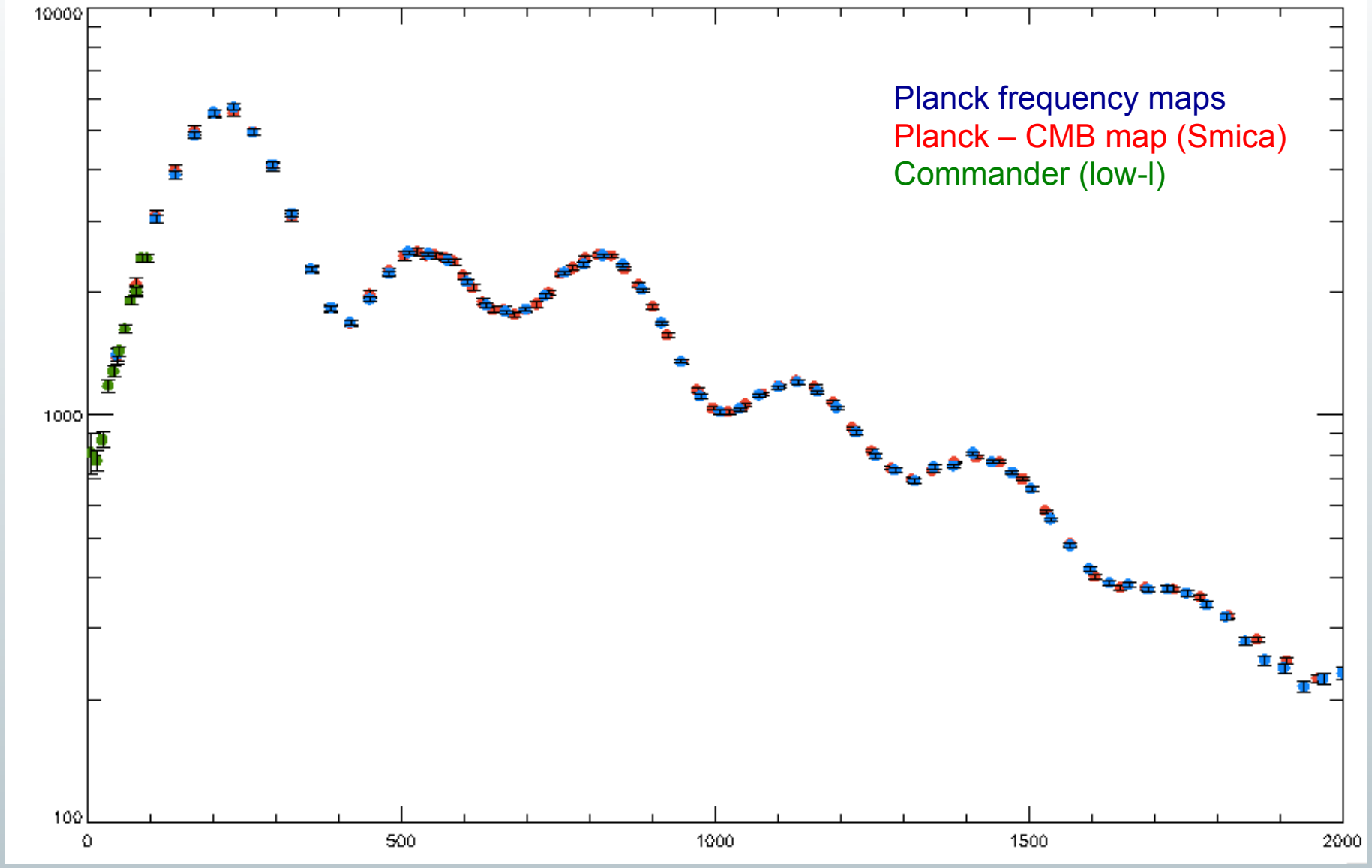
CMB power spectrum with best-fitting foreground model removed

compared to WMAP9 best fit model

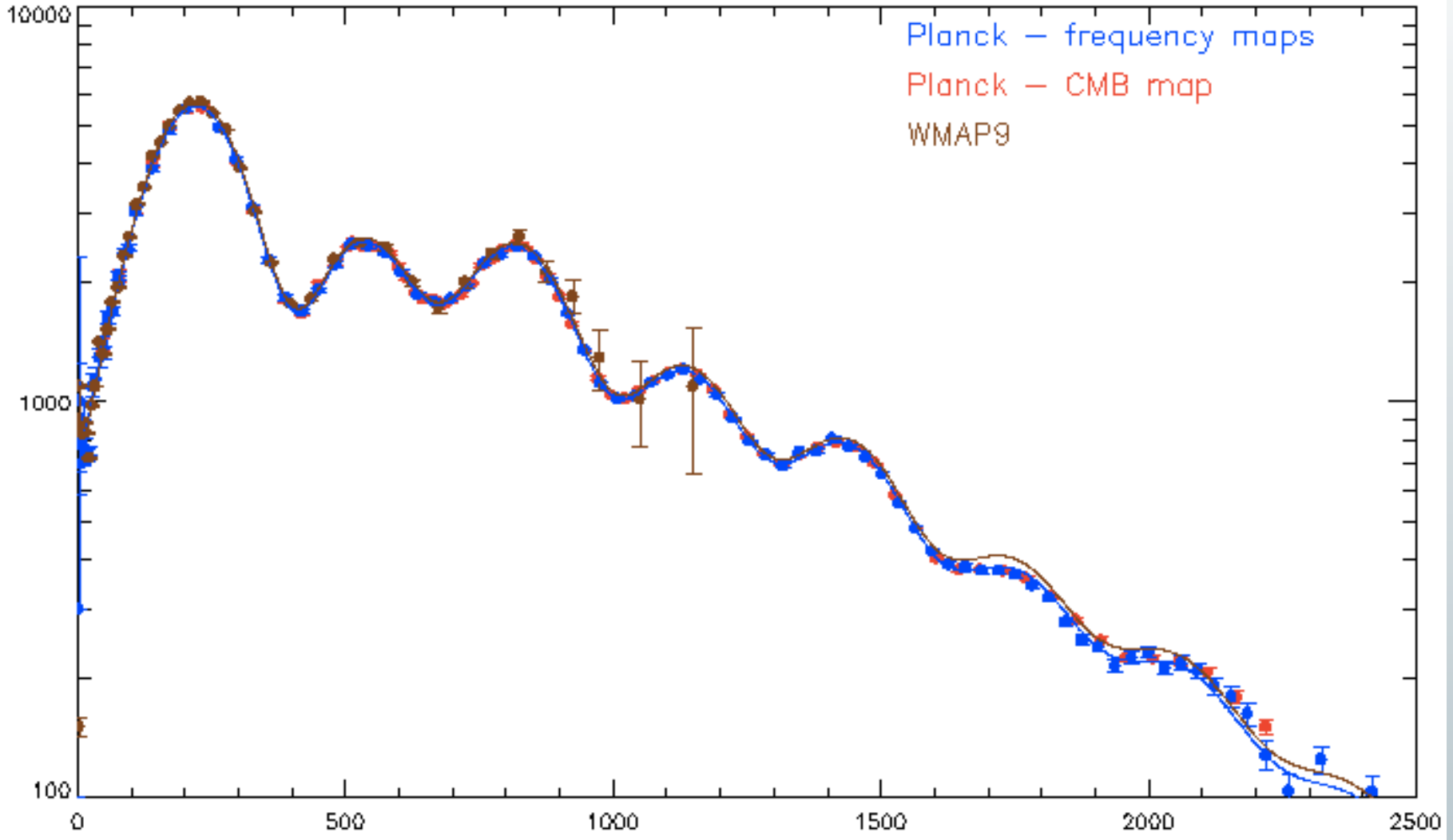
Residuals relative to WMAP9 best fit model

Residuals of best fit models from the map-based likelihoods with respect to the WMAP9 best fit model

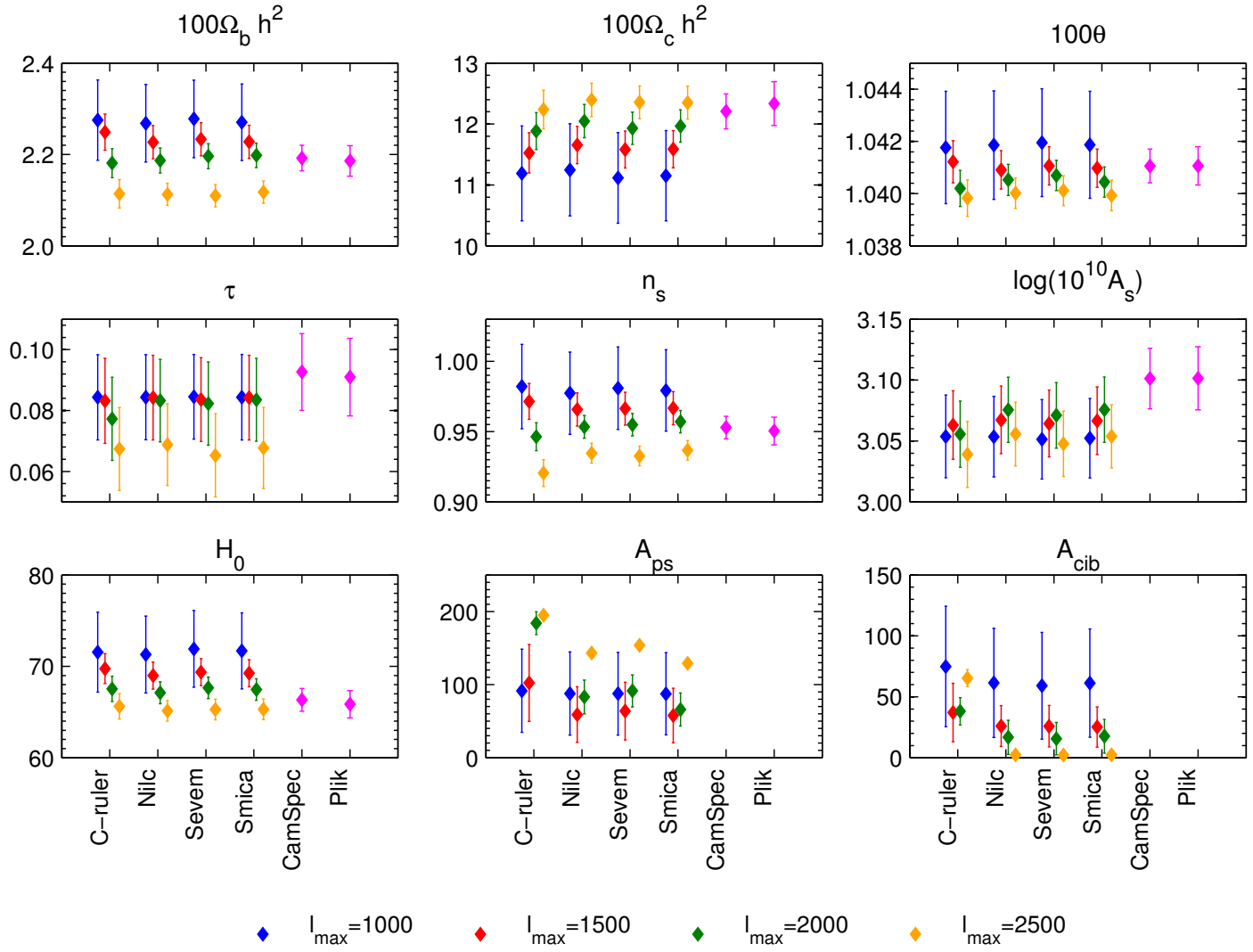
Planck Power Spectrum



Planck vs WMAP9



Parameters from CMB maps



l_{max} ↑

H_0 ↓

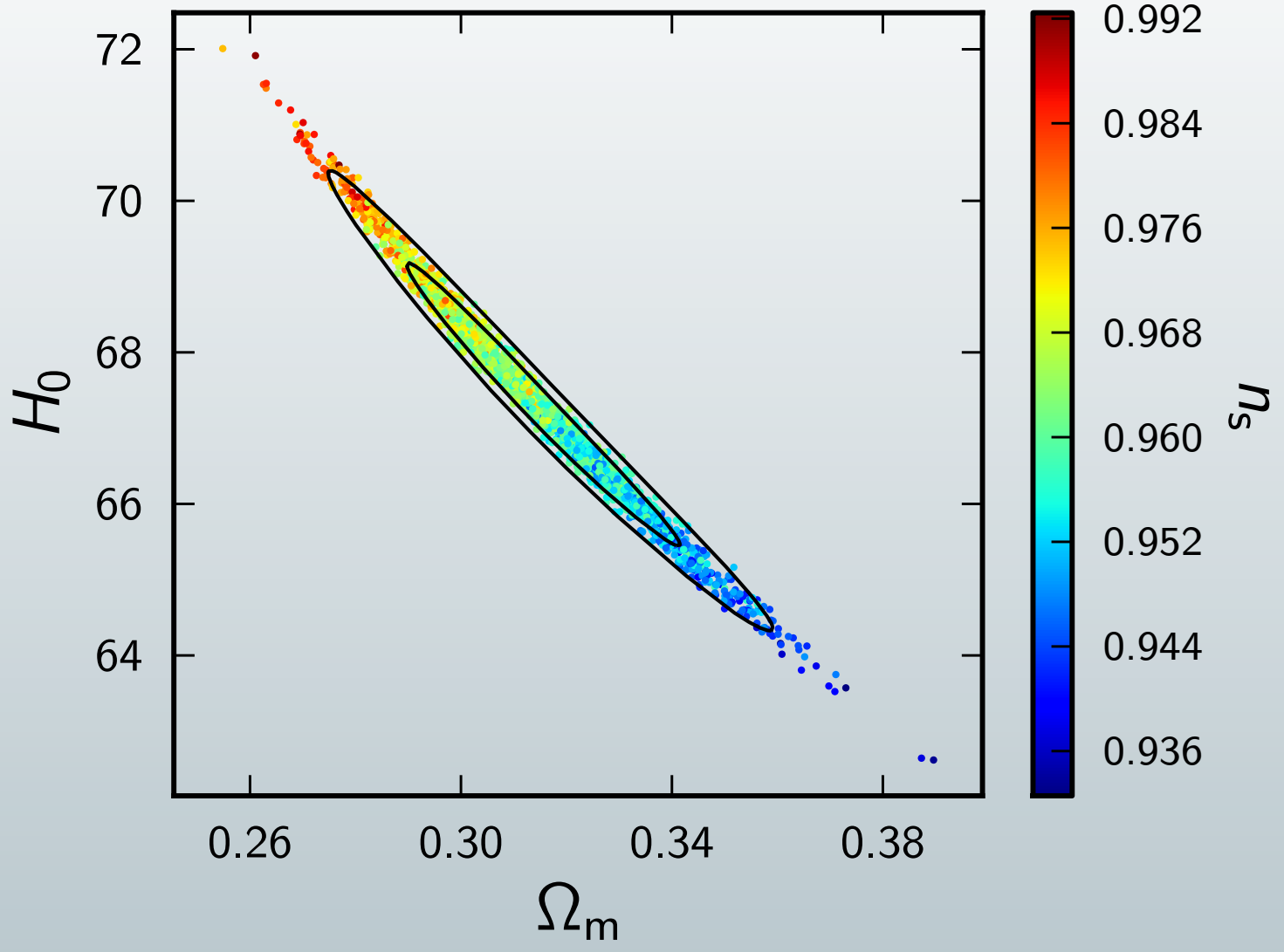
$\Omega_c h^2$ ↑

$\Omega_b h^2$ ↓

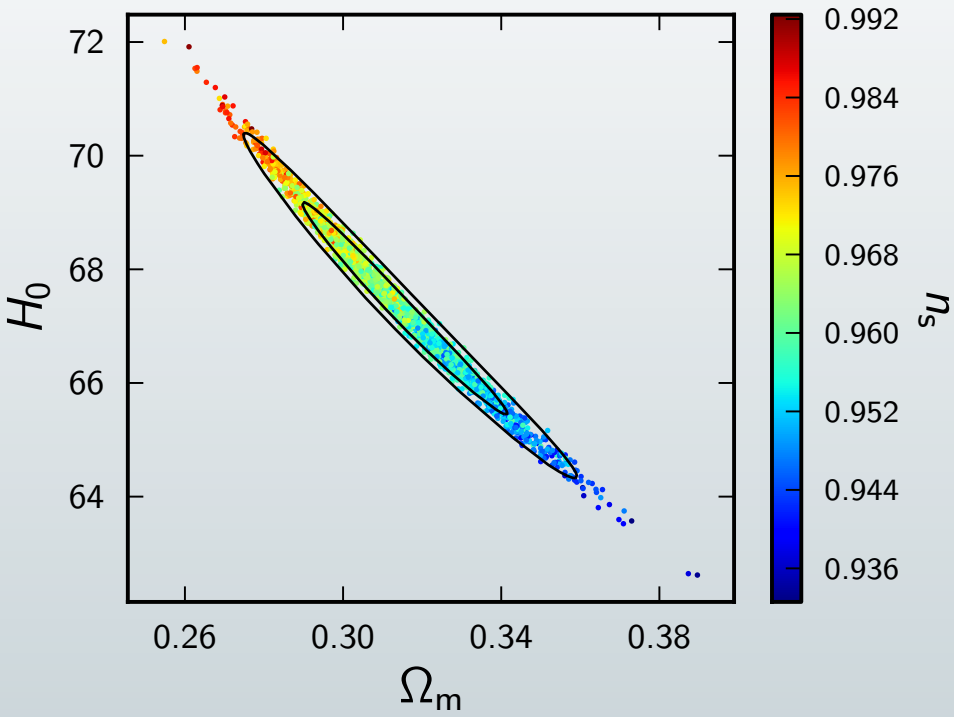
n_s ↓

Error bars ↓

Parameters from CMB maps



ΛCDM model parameters



- With accurate measurements of 7 acoustic peaks Planck determines the acoustic scale (angular size of the sound horizon at last scattering surface) better than 0.1% precision at 1σ
- parameter combinations can be constrained as well – 3d
  Ω_m- h - $\Omega_b h^2$, PCA -> ~ $\Omega_m h^3$
- H_0, Ω_m _ are only constrained by $\Omega_m h^3$ degeneracy limited by $\Omega_m h^2$ (rel heights of peaks)

The projection of the constant elipse onto the axes yields useful marginalised constraints on H_0 and Ω_m (or equivalently Ω_Λ) separately

$$H_0 = 67.3 \pm 1.2 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

ΛCDM model parameters

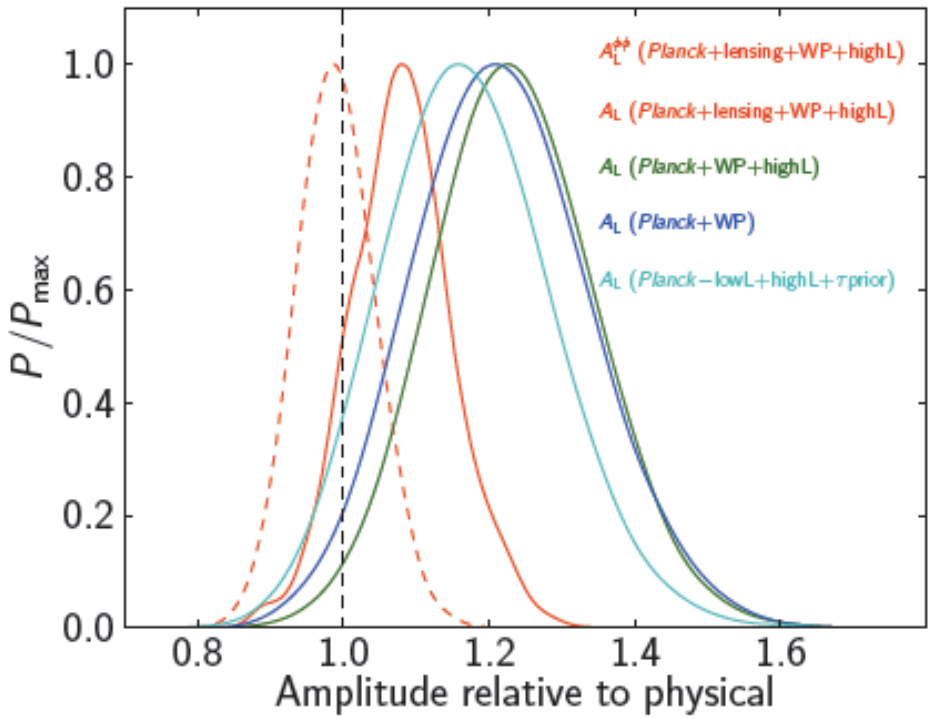
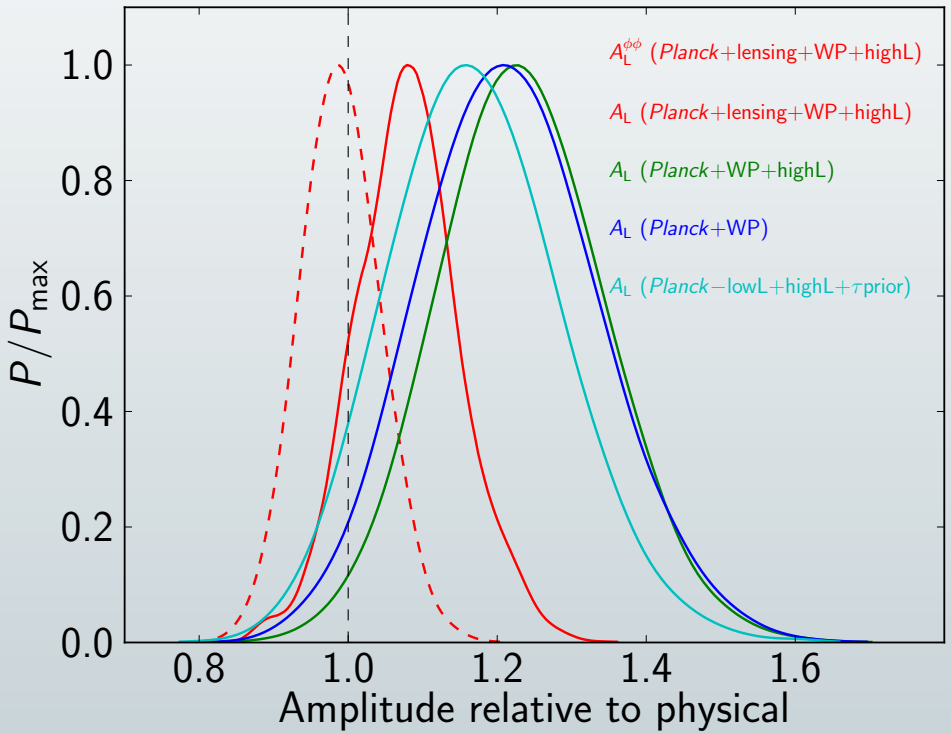
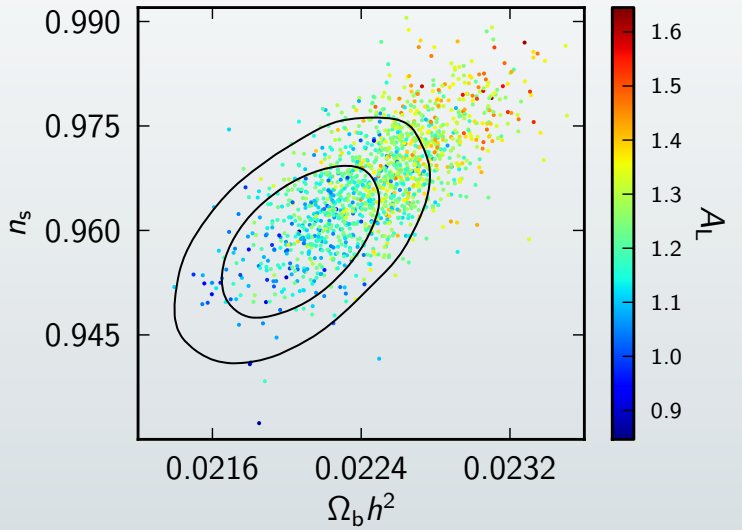


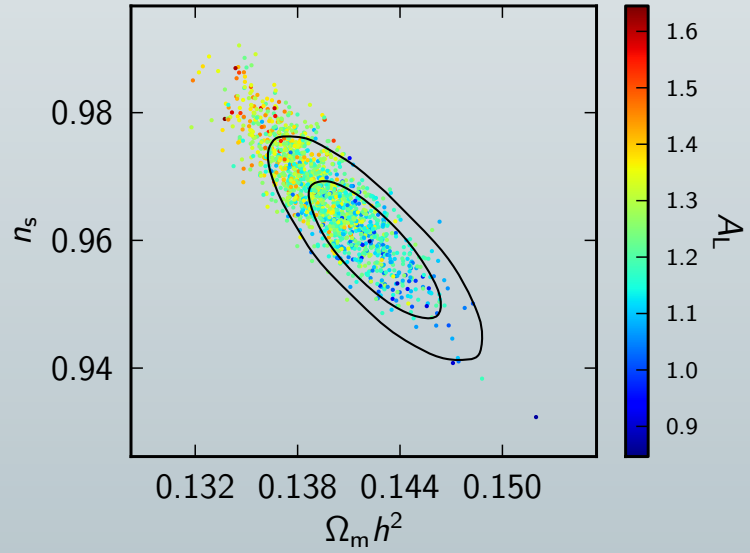
Fig. 13. Marginalized posterior distributions for $A_L^{\phi\phi}$ (dashed) and A_L (solid). For $A_L^{\phi\phi}$ we use the data combination *Planck*+lensing+WP+highL. For A_L we consider *Planck*+lensing+WP+highL (red), *Planck*+WP+highL (green), *Planck*+WP (blue) and *Planck*−lowL+highL+τprior (cyan; see text).

ΛCDM model parameters

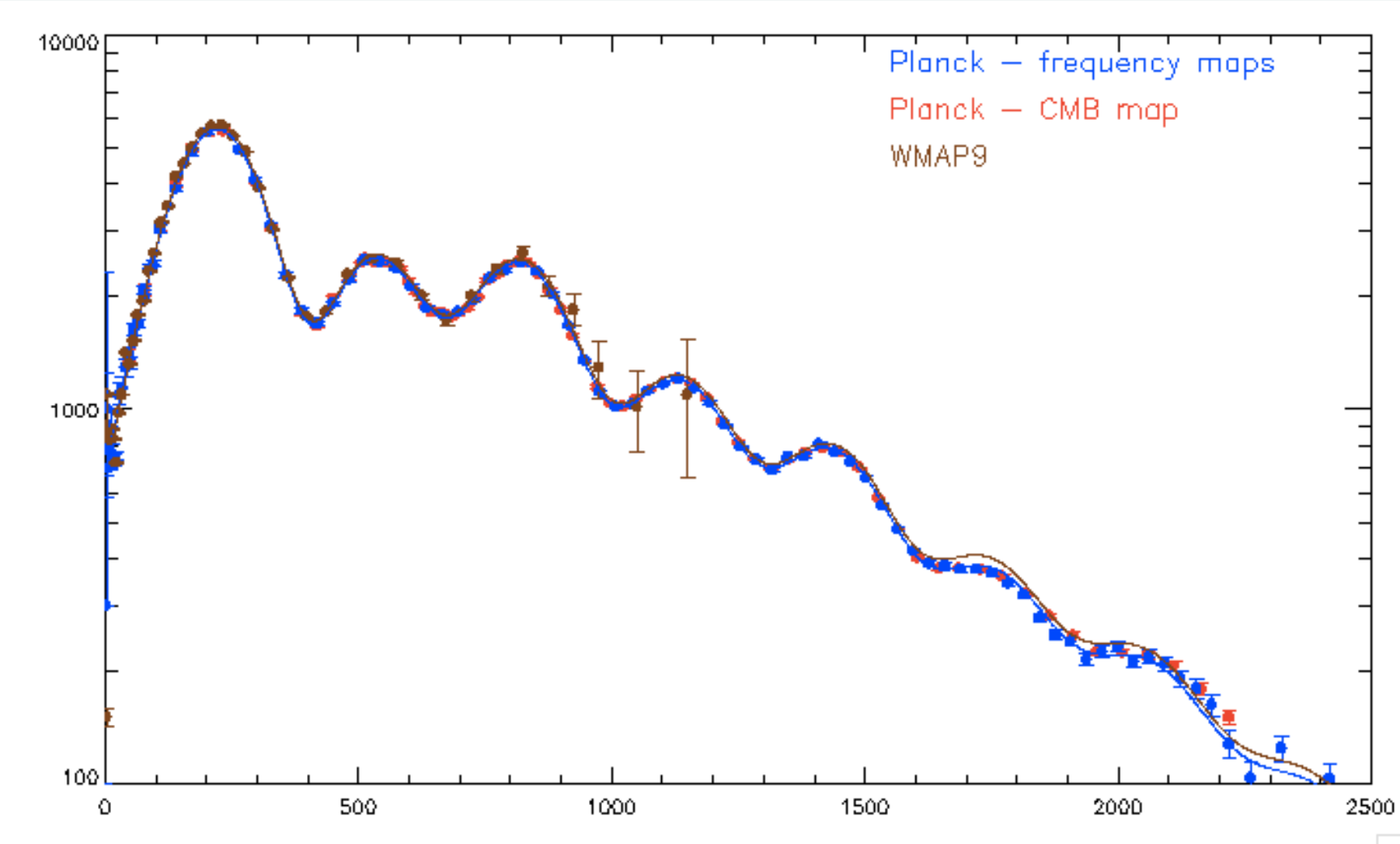


$A_L > 1$

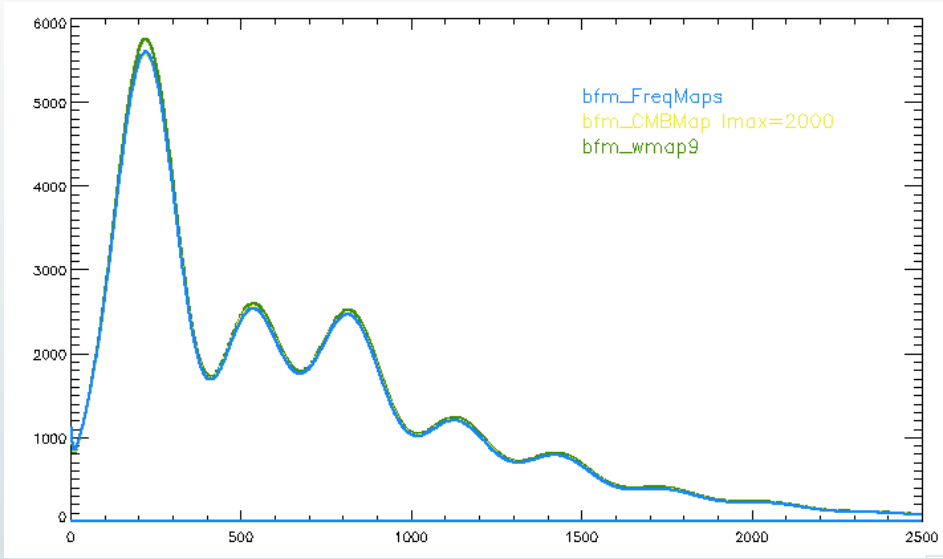


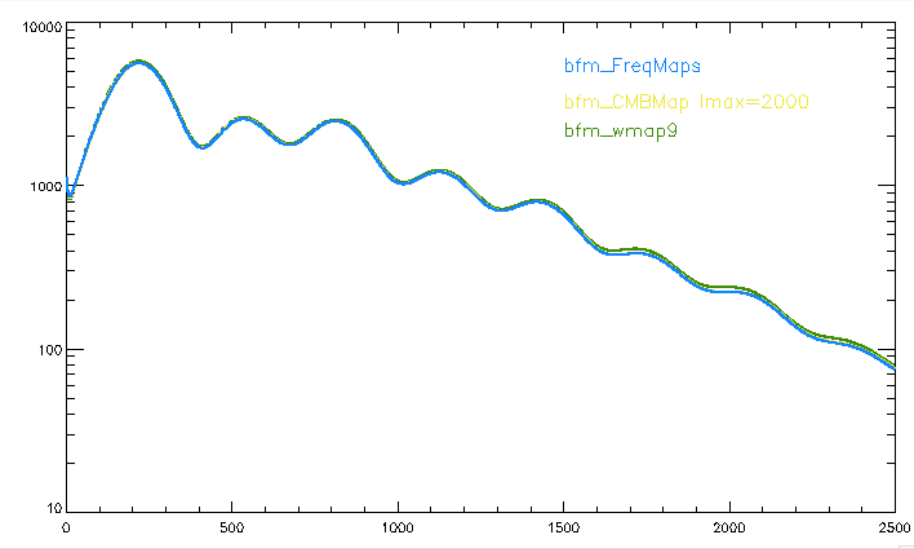


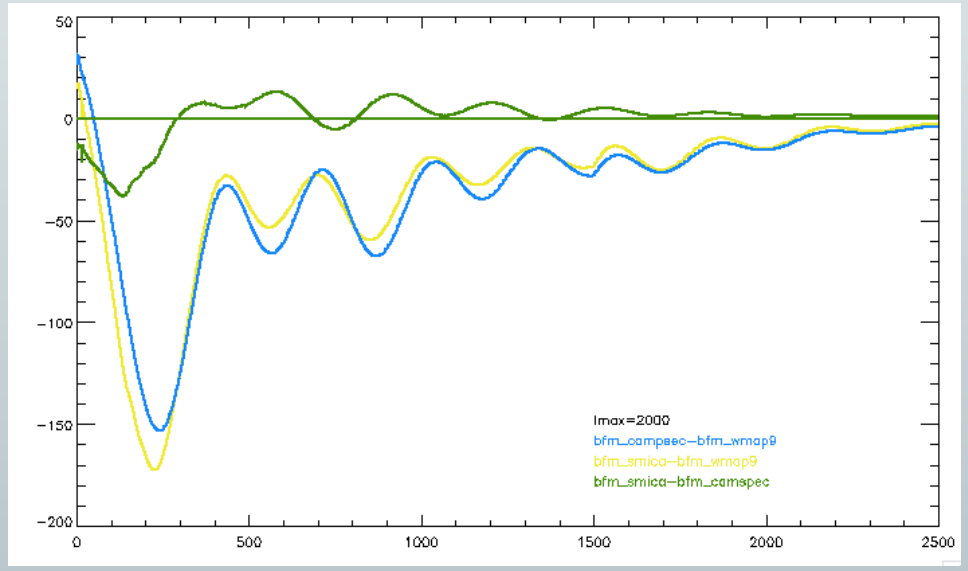
Planck vs WMAP9



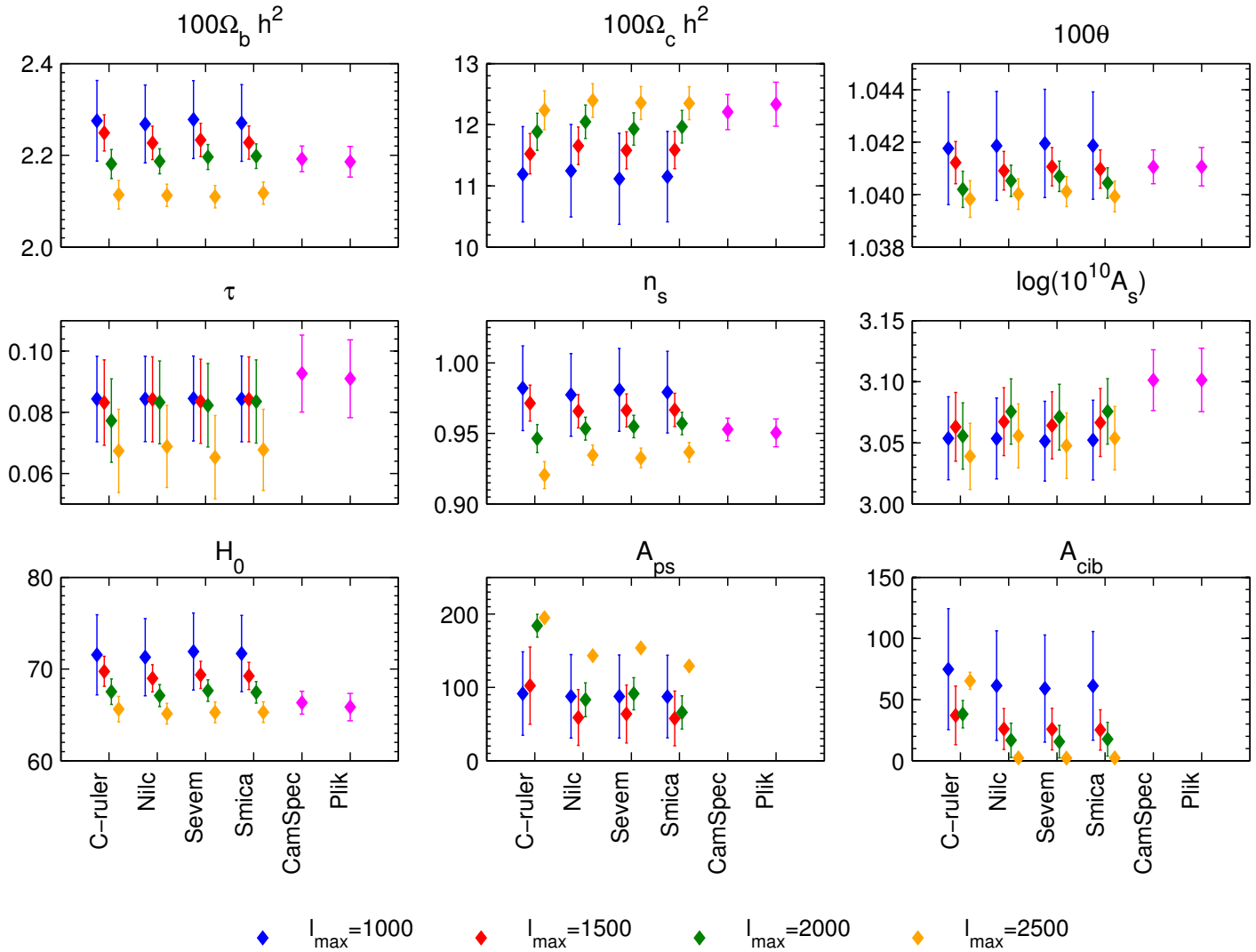
Planck vs WMAP9







Parameters from CMB maps



l_{max} ↑

H_0 ↓

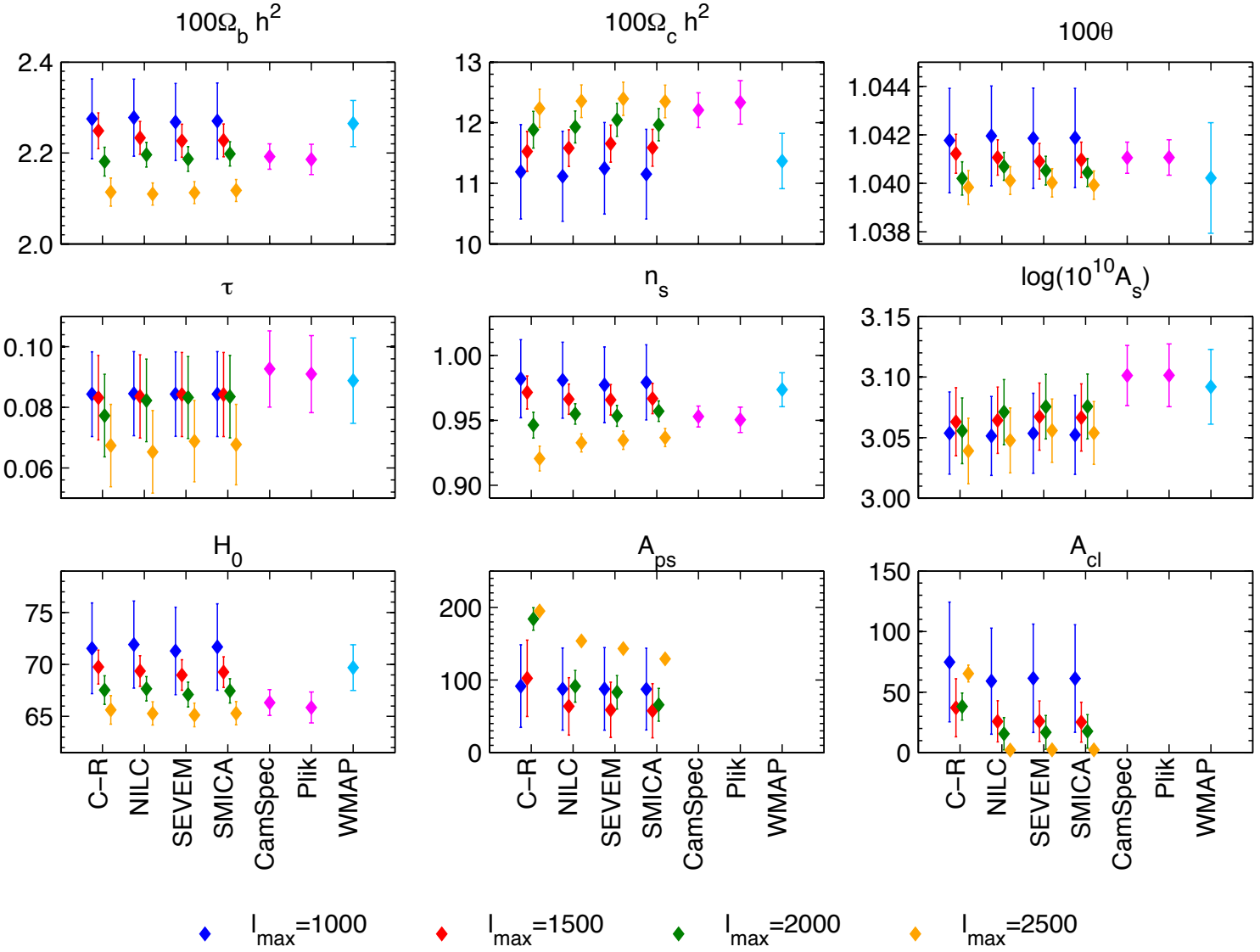
$\Omega_c h^2$ ↑

$\Omega_b h^2$ ↓

n_s ↓

Error bars ↓

Parameters from CMB maps



l_{max} ↑

H_0 ↓

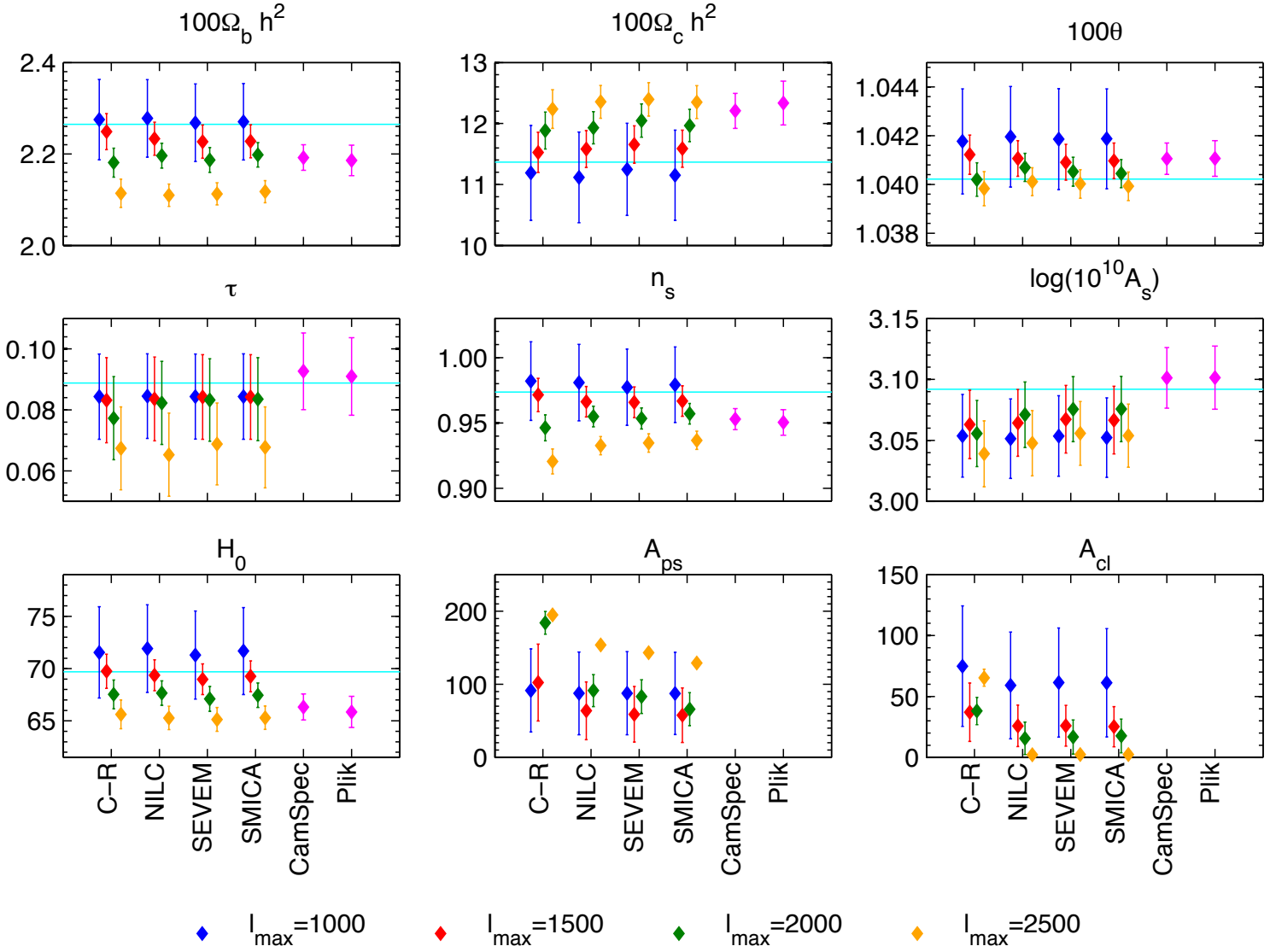
$\Omega_c h^2$ ↑

$\Omega_b h^2$ ↓

n_s ↓

Error bars ↓

Parameters from CMB maps



l_{max} ↑

H_0 ↓

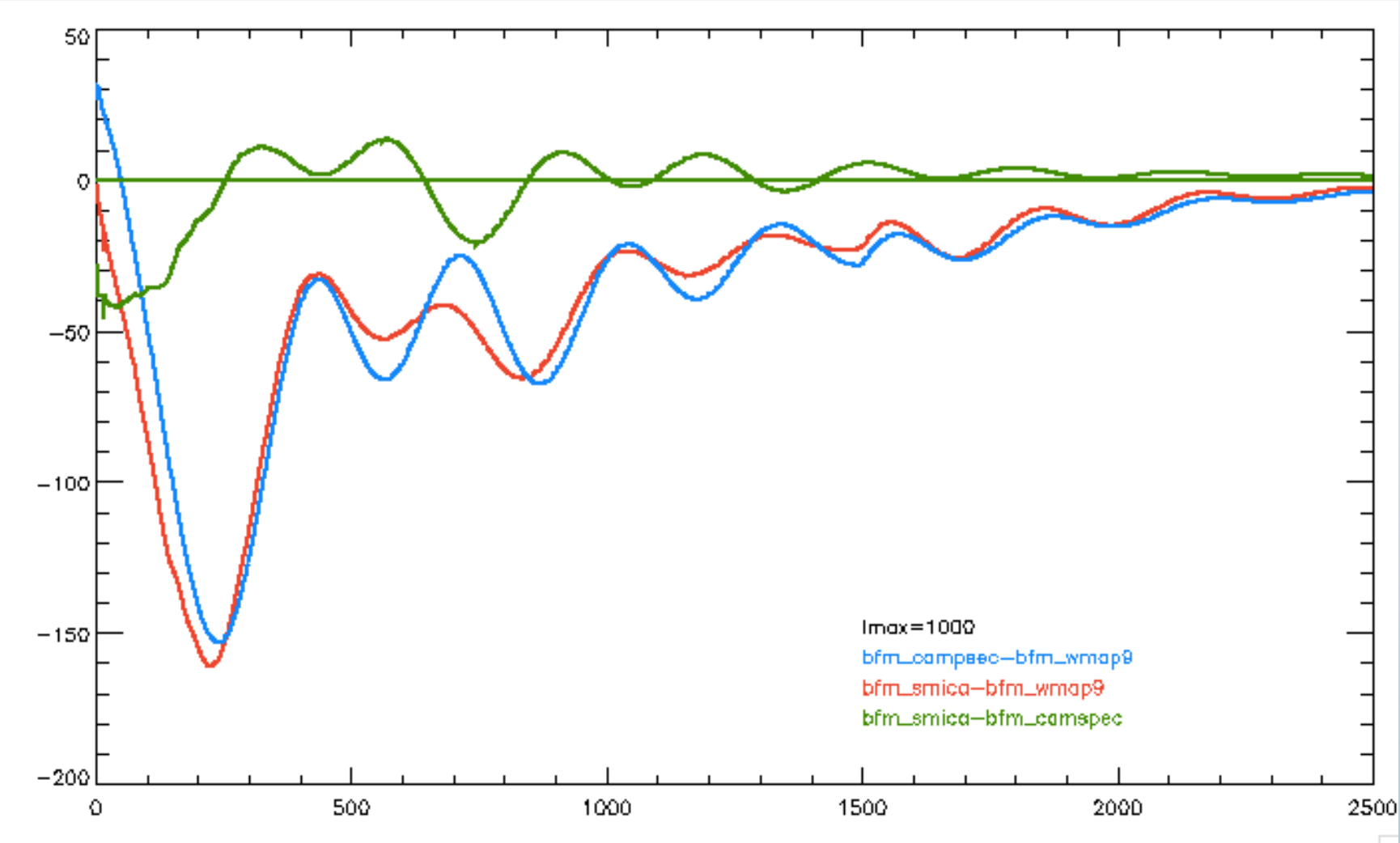
$\Omega_c h^2$ ↑

$\Omega_b h^2$ ↓

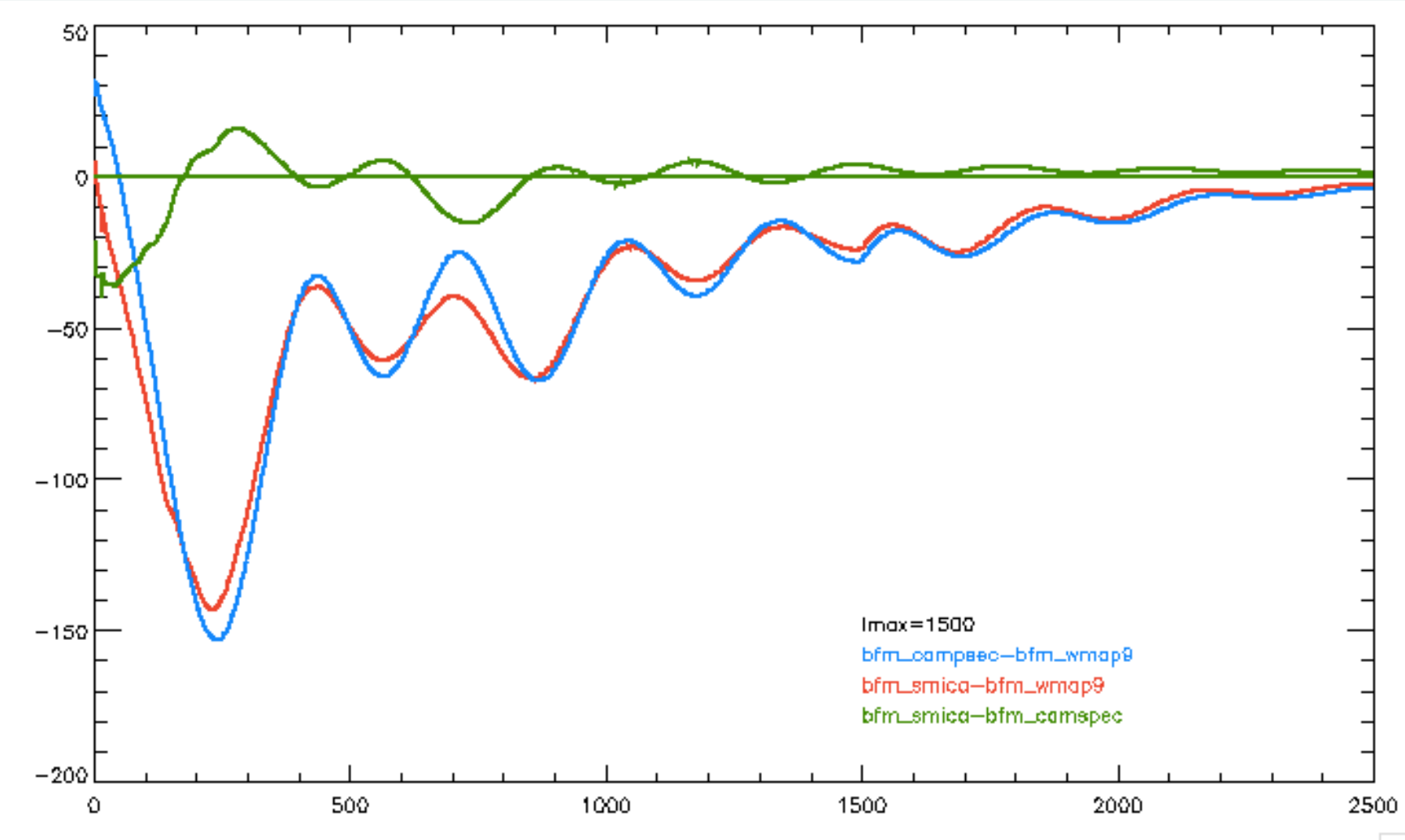
n_s ↓

Error bars ↓

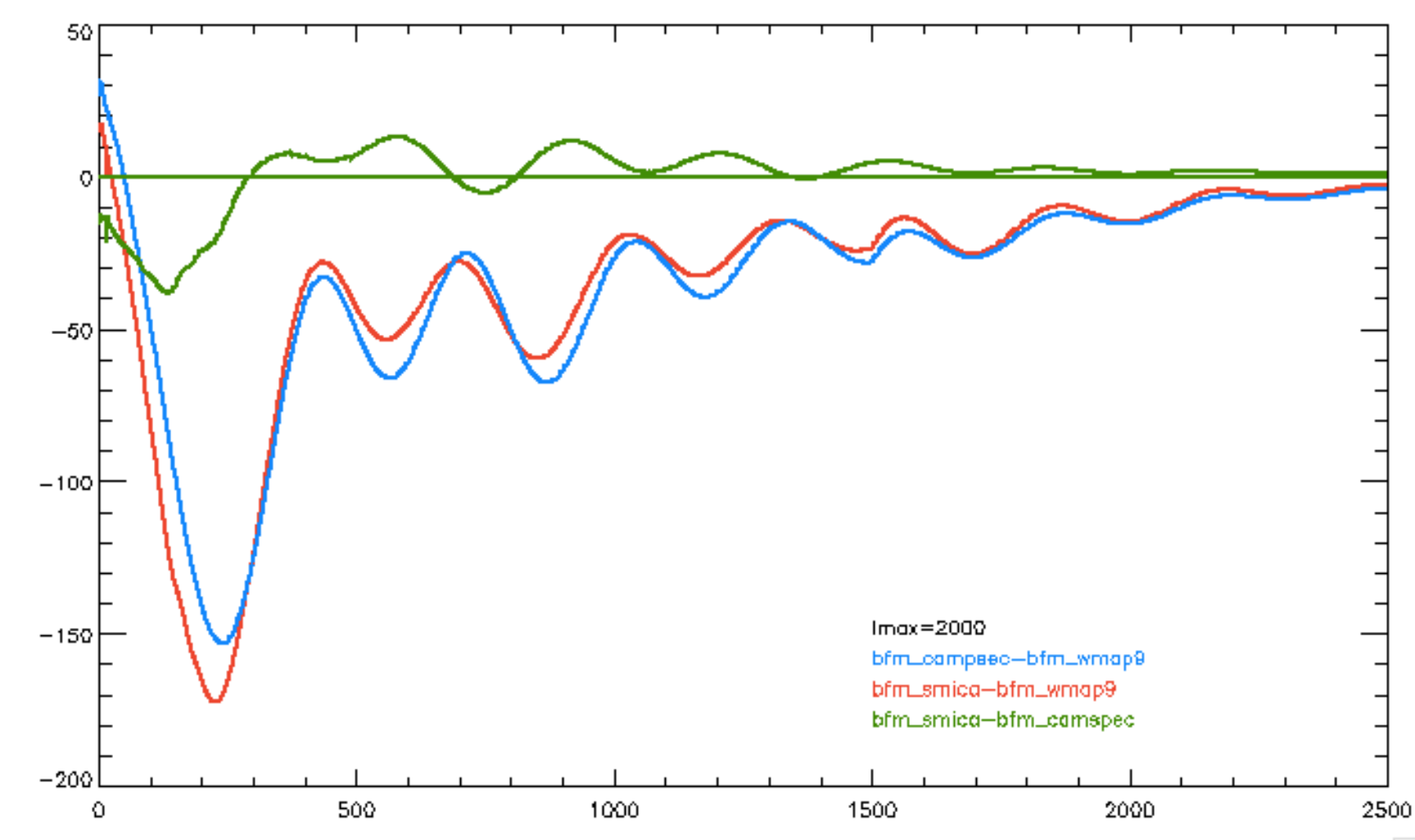
Planck vs WMAP9
lmax=1000



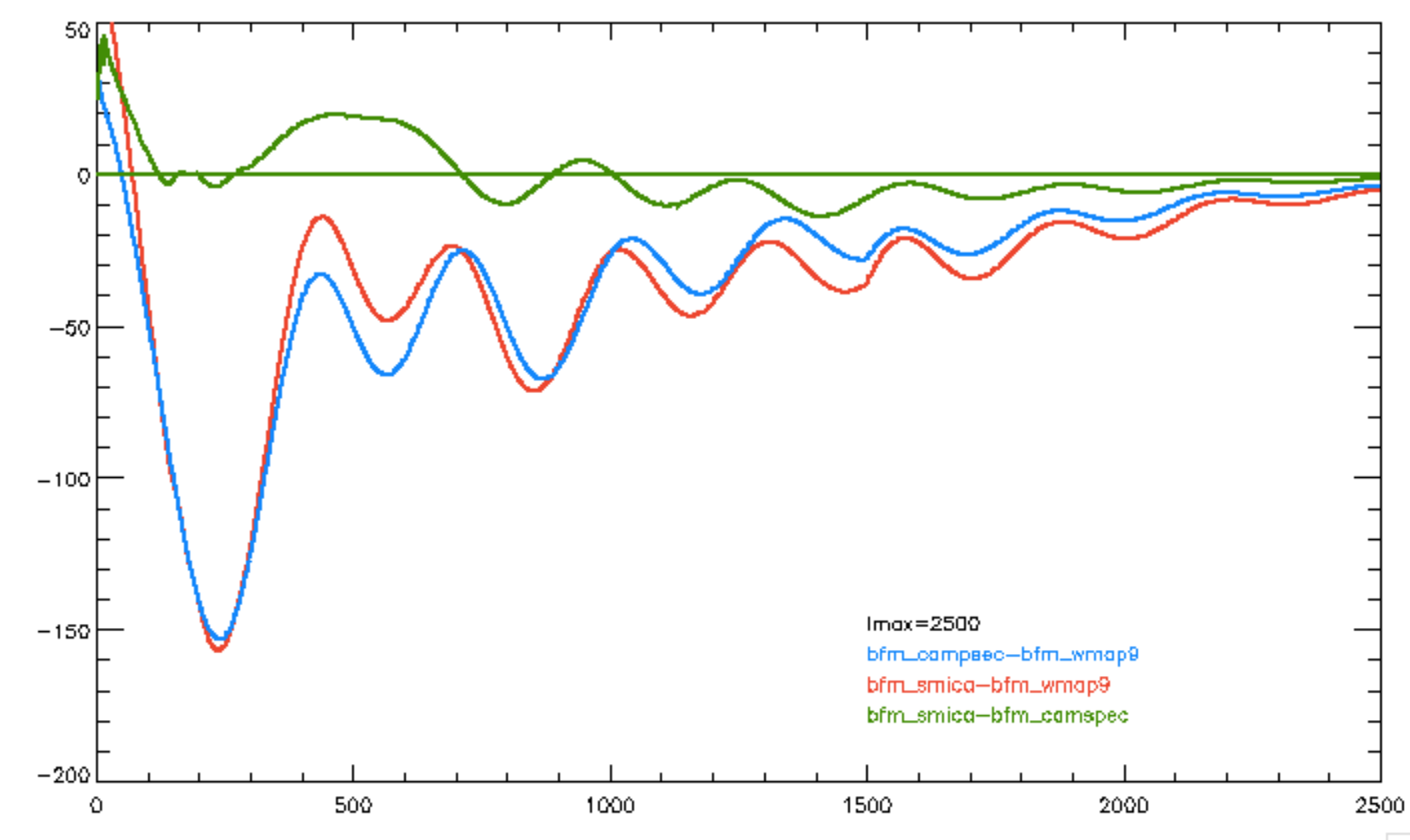
Planck vs WMAP9
lmax=1500



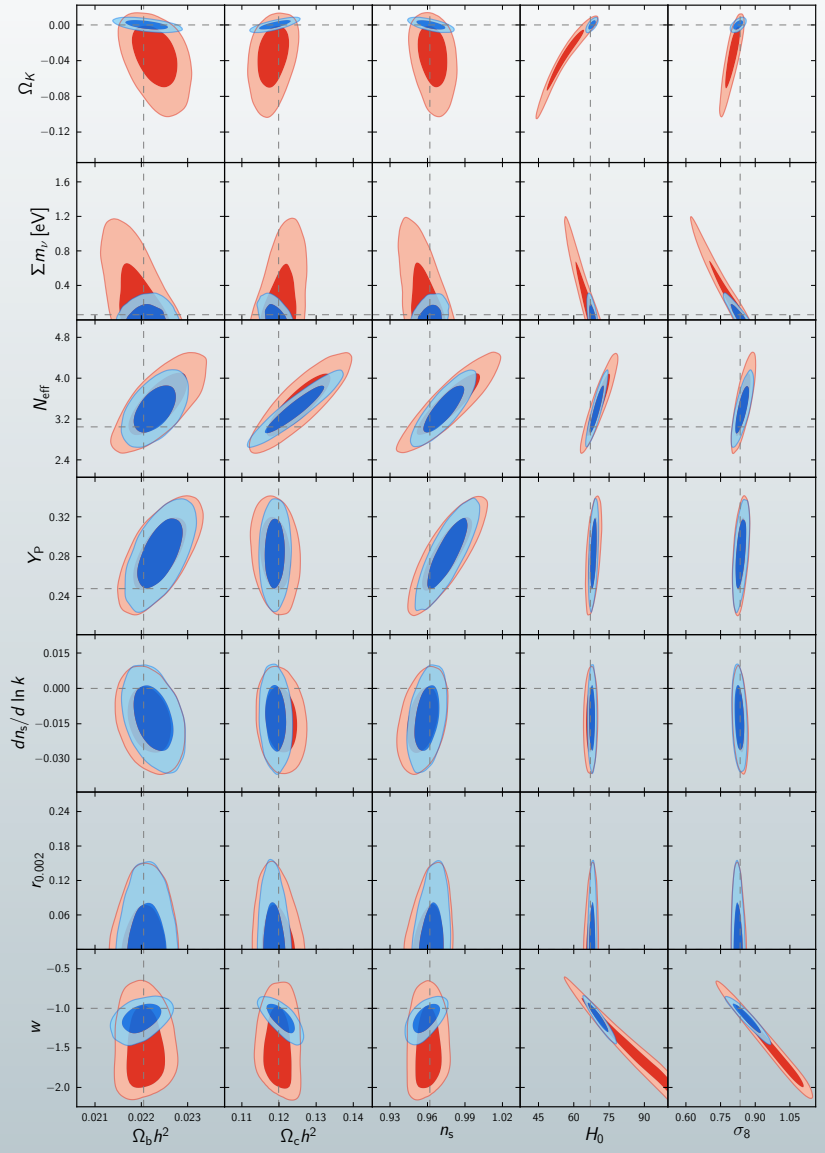
Planck vs WMAP9
lmax=2000



Planck vs WMAP9
lmax=2500



Extensions to ΛCDM model



Planck +WP (red)
Planck +WP+BAO (blue)

Posteriors of individual extra parameters
Generally overlaps the fiducial model within 1σ

The inclusion of BAO data shrinks further the allowed scope for deviation – the ΛCDM model is relatively robust to inclusion of additional parameters – but the error on some parameters broaden when additional degeneracies open-up

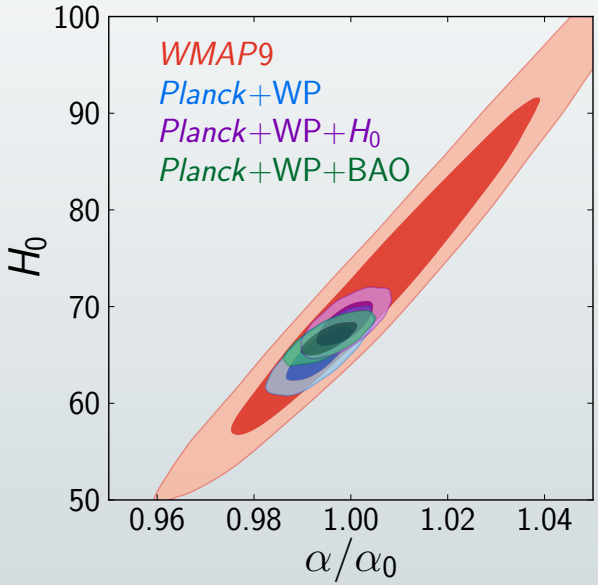
Vertical lines:
Mean posterior value in the base model
For Planck+WP

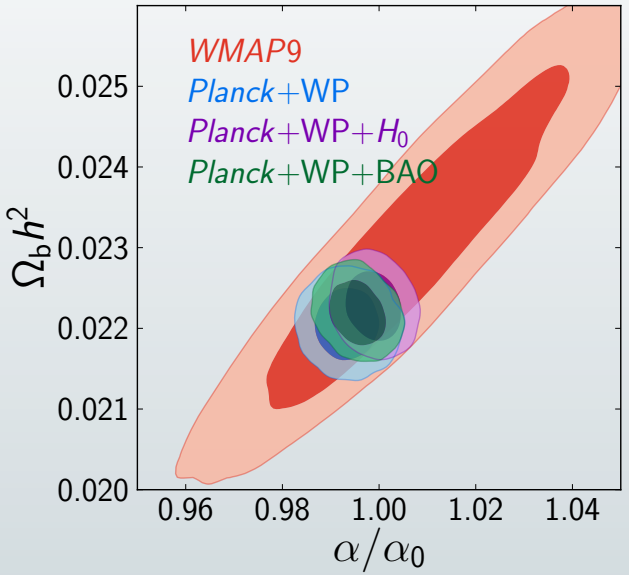
Horizontal lines:
Fixed base model parameter value

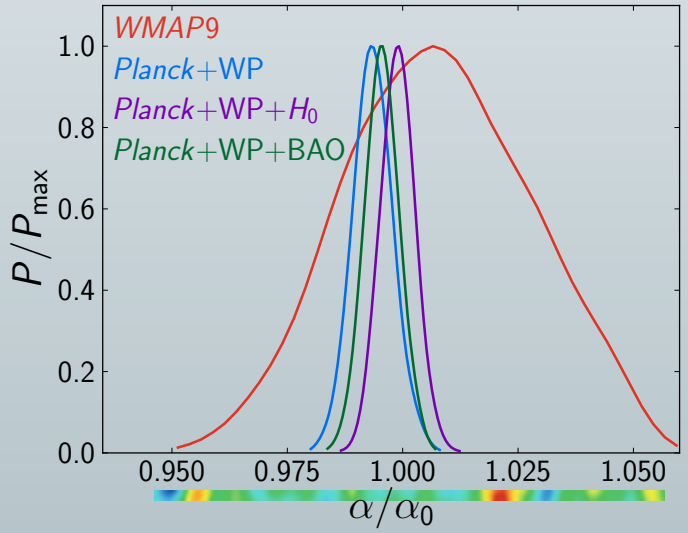
Extensions to ΛCDM model
Varying fundamental constants

Varying Fine Structure Constant

68%







$$\alpha / \alpha_0 = 0.9936 \pm 0.0043$$

A factor of 5 improvement compared to WMAP

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

esa

planck

cnes

agenzia spaziale italiana

NASA

cnrs

DTU Space
National Space Institute

Science & Technology Facilities Council

INAF ISTITUTO NAZIONALE DI ASTROFISICA

CSIC

National Research Council of Italy

GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA E INNOVACIÓN

CSA ASC

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

UK SPACE AGENCY

MAX-PLANCK-GESELLSCHAFT

HFI PLANCK
a look back to the birth of Universe

PLANCK LFI

IAS orsay

IAP

INAF - IASF BO
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ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA

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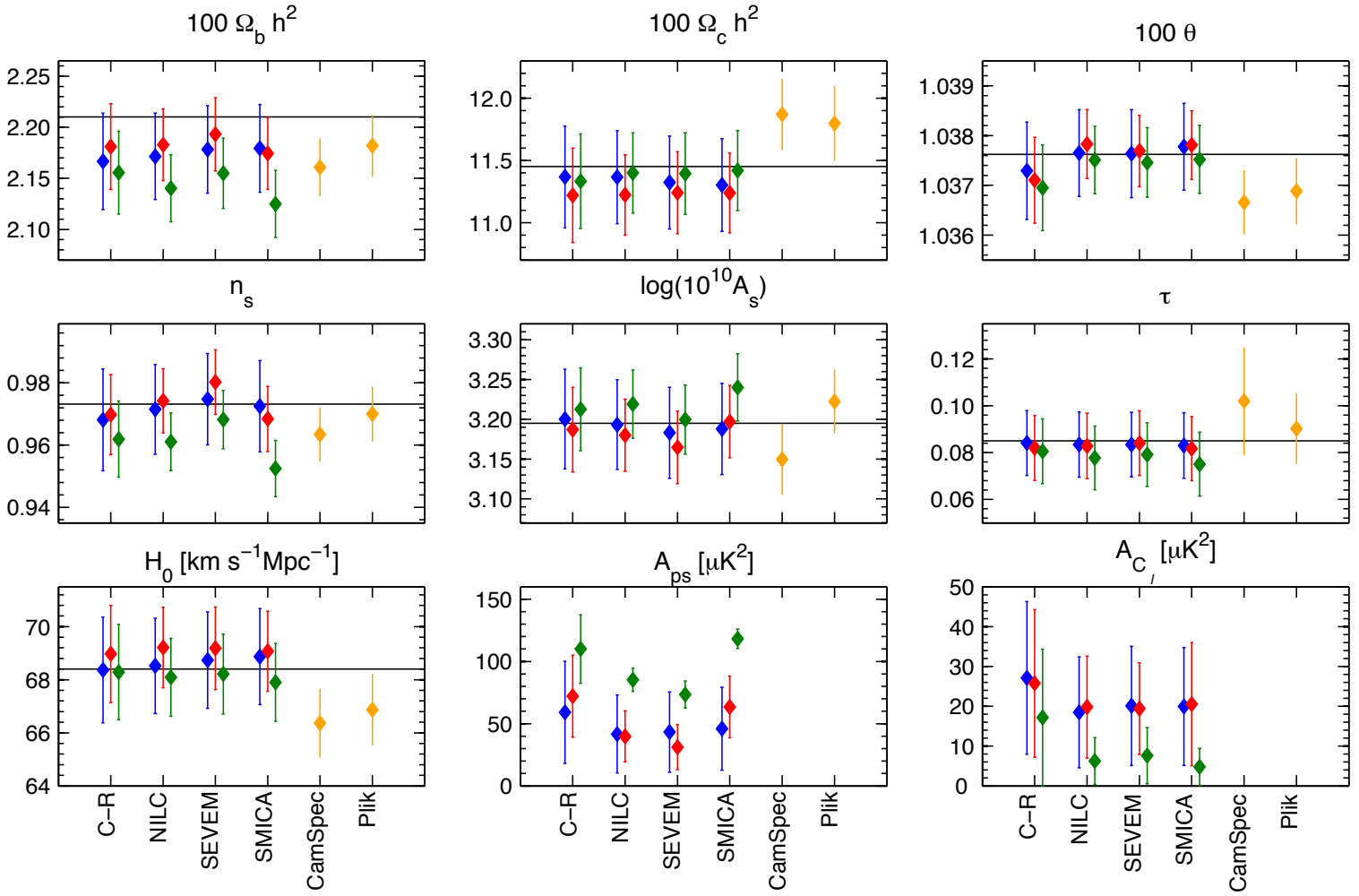
ALMA · ESO · University of Sussex · Haverford · esa · University of Helsinki · Université de Genève · University of Toronto · Université de Paris-Sud XI · asdc

X name "The talk"

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

Appendix

FFP6 simulations
Parameters from CMB maps

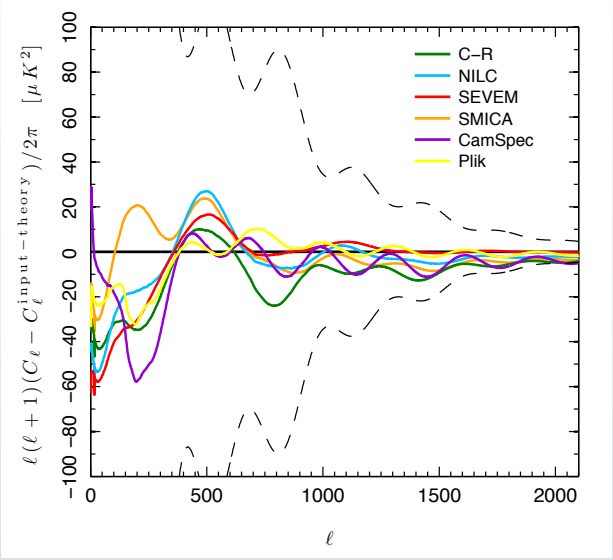


K_{pivot}=0.002
CamSpec: K_{pivot}=0.05

l_{max} = 1500 l_{max} = 2000 l_{max} = 2500

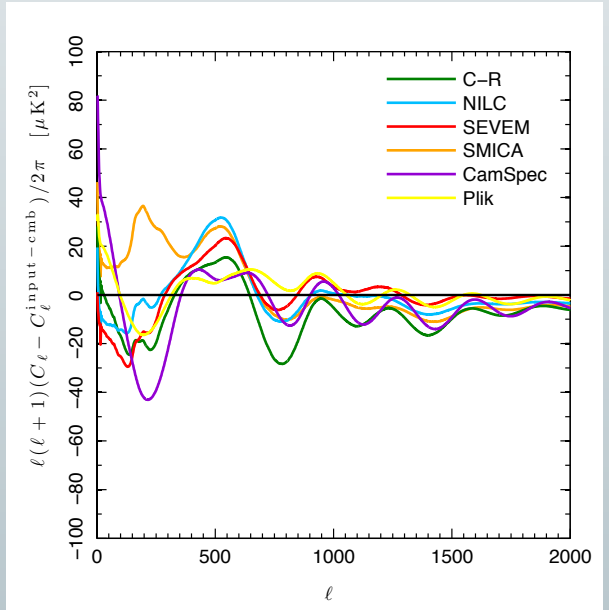
FFP6 simulations

Best Fit models: CMB maps, multi-frequency, and inputs



Residuals of map-based and spectrum-based best-fit models relative to the FFP6 simulation input CDM spectrum

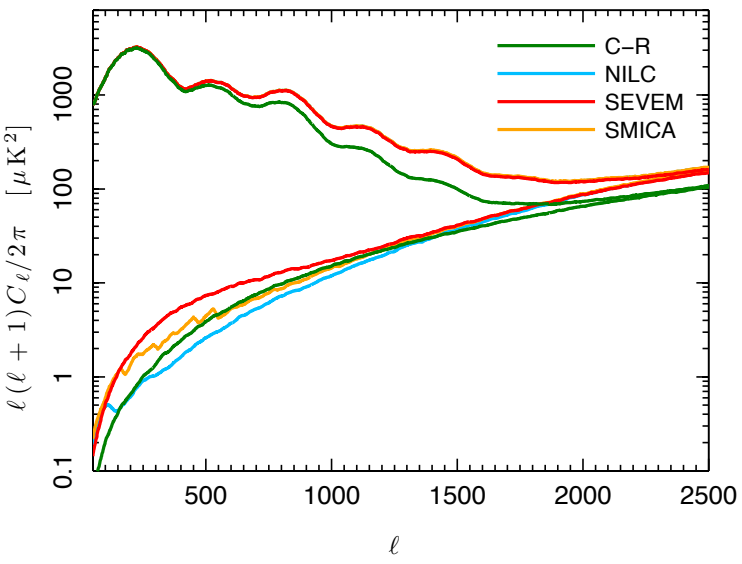
Cosmic variance is shown as the black dashed line.

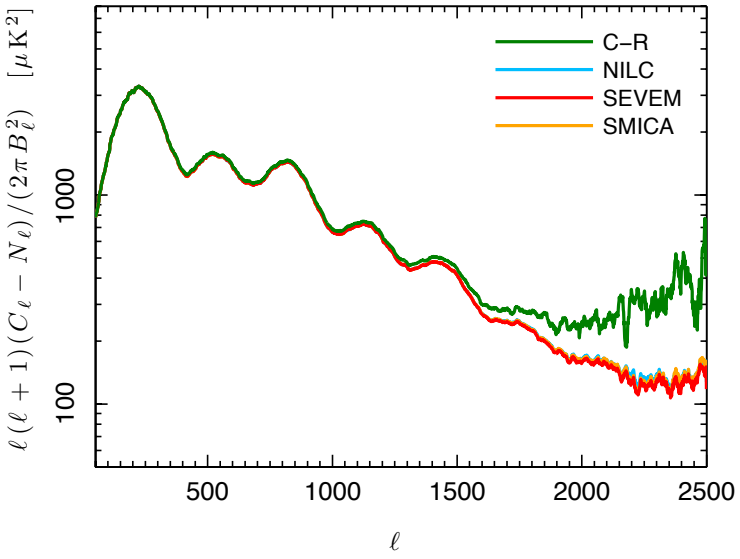


Residuals of CMB map based and spectrum-based best fit models relative to the best fit model of the CMB input realization

$\ell_{\rm max} = 2000$

Power Spectrum from CMB maps





Pseudo-Cl
of the foreground-cleaned CMB maps (half-ring half sum (HRHS) and
half-ring half-diference (HRHD) maps – gives an estimate of Instrumental noise in the CMB cleaned maps (inherits the correlations of the HFI half-ring frequency maps)
U73 mask

Pseudo-Cl
corrected for the effect of the beam transfer function and instrumental noise

Planck, WMAP9, SPT,ACT