Consistency study of Planck data using cosmological parameters

Gianluca Polenta
ASI Science Data Center
On behalf of the Planck collaboration

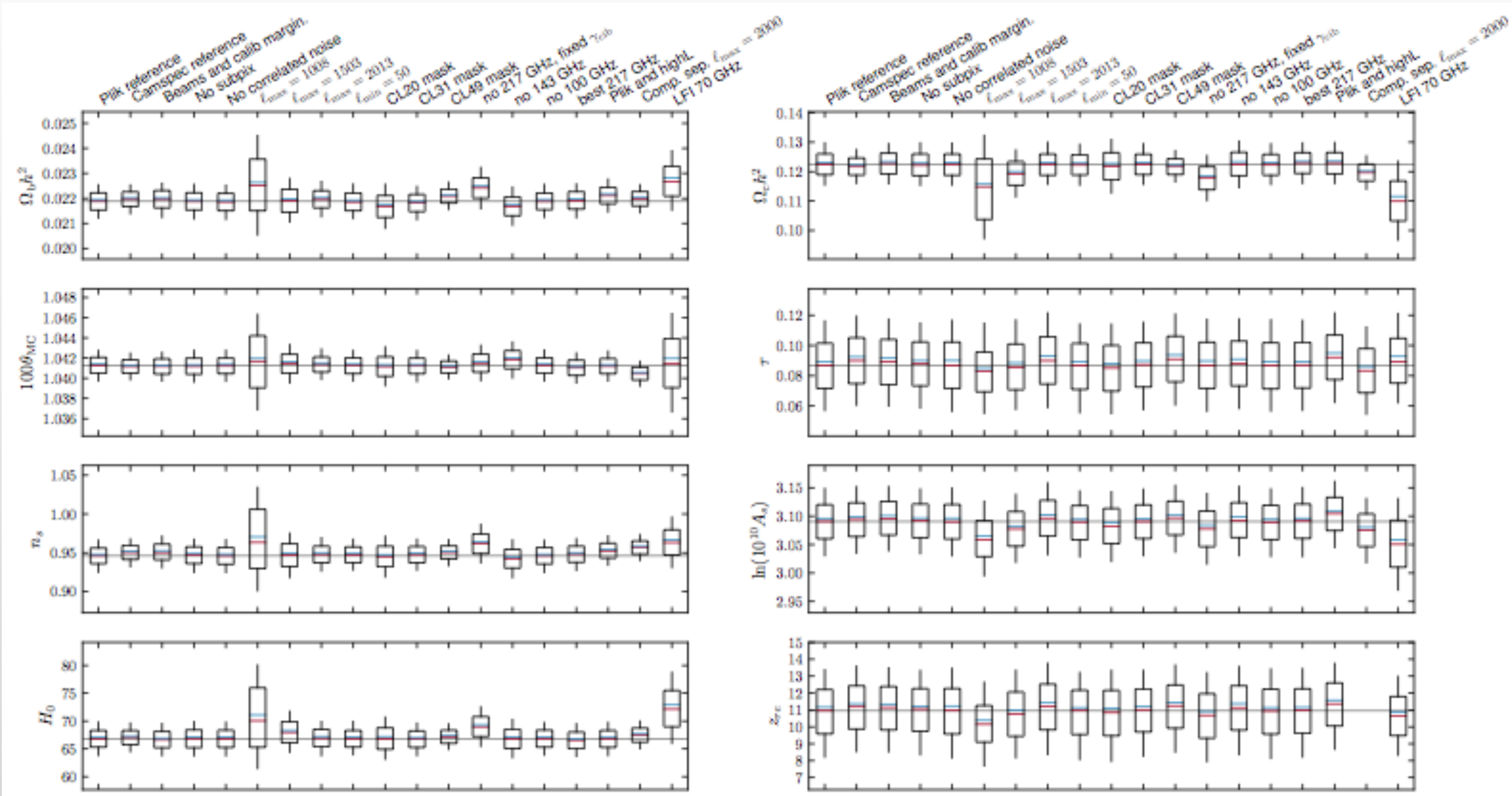
Consistency of Planck parameters: why

The exquisite sensitivity of Planck provides very tight constraints of cosmological parameters.

It is important to assess the impact of several choices made during data analysis, such as multipole range, frequency channels, mask, and modeling of foregrounds.

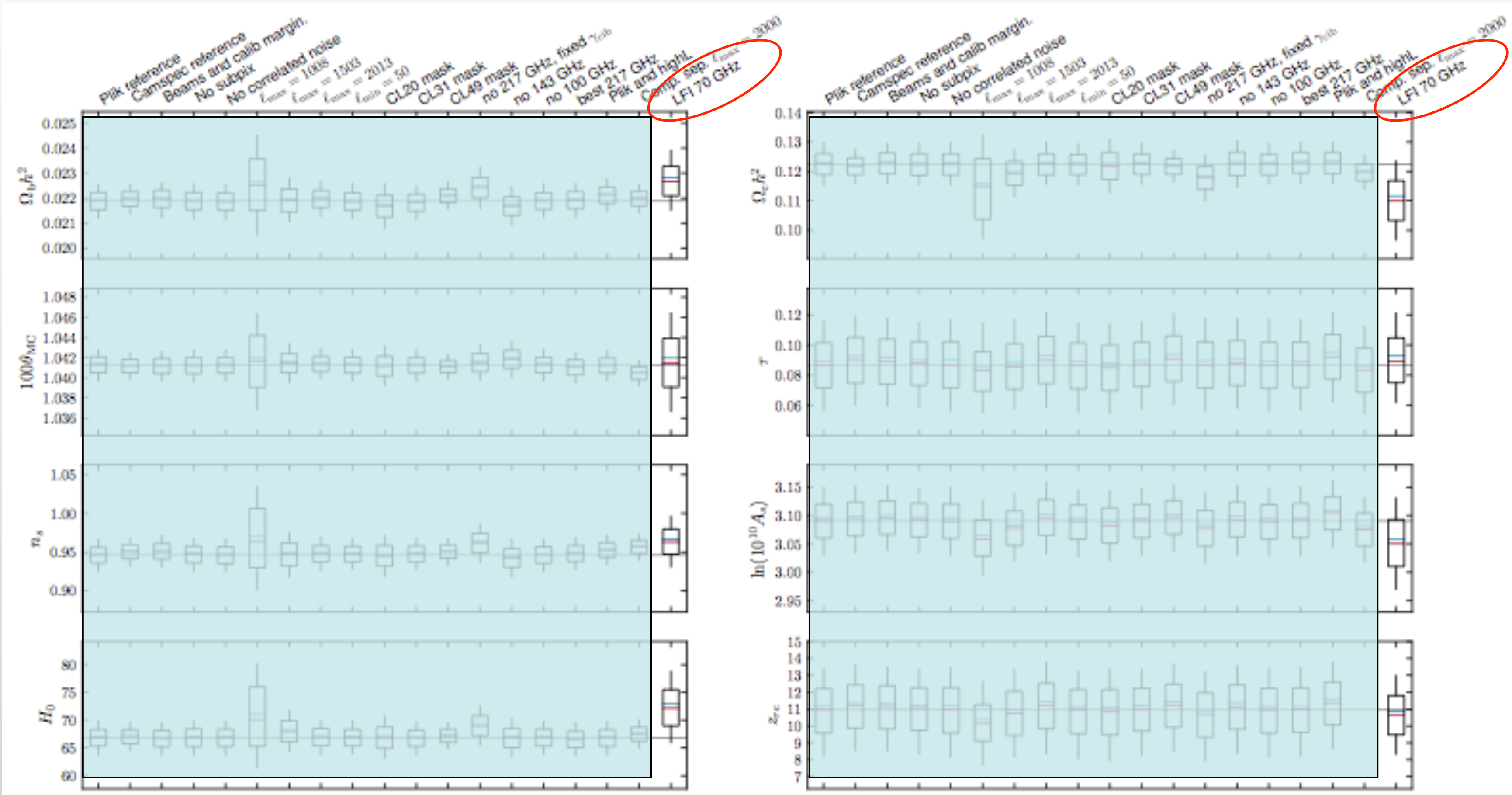
Several tests are reported in Planck Collaboration XV, 2013.

Consistency of Planck parameters: status



Planck Collaboration XV, 2013

Consistency of Planck parameters: status



This talk will focus on consistency test through the Planck 70 GHz channel

Consistency: why 70GHz

The Planck 70GHz channel is easy to characterize:

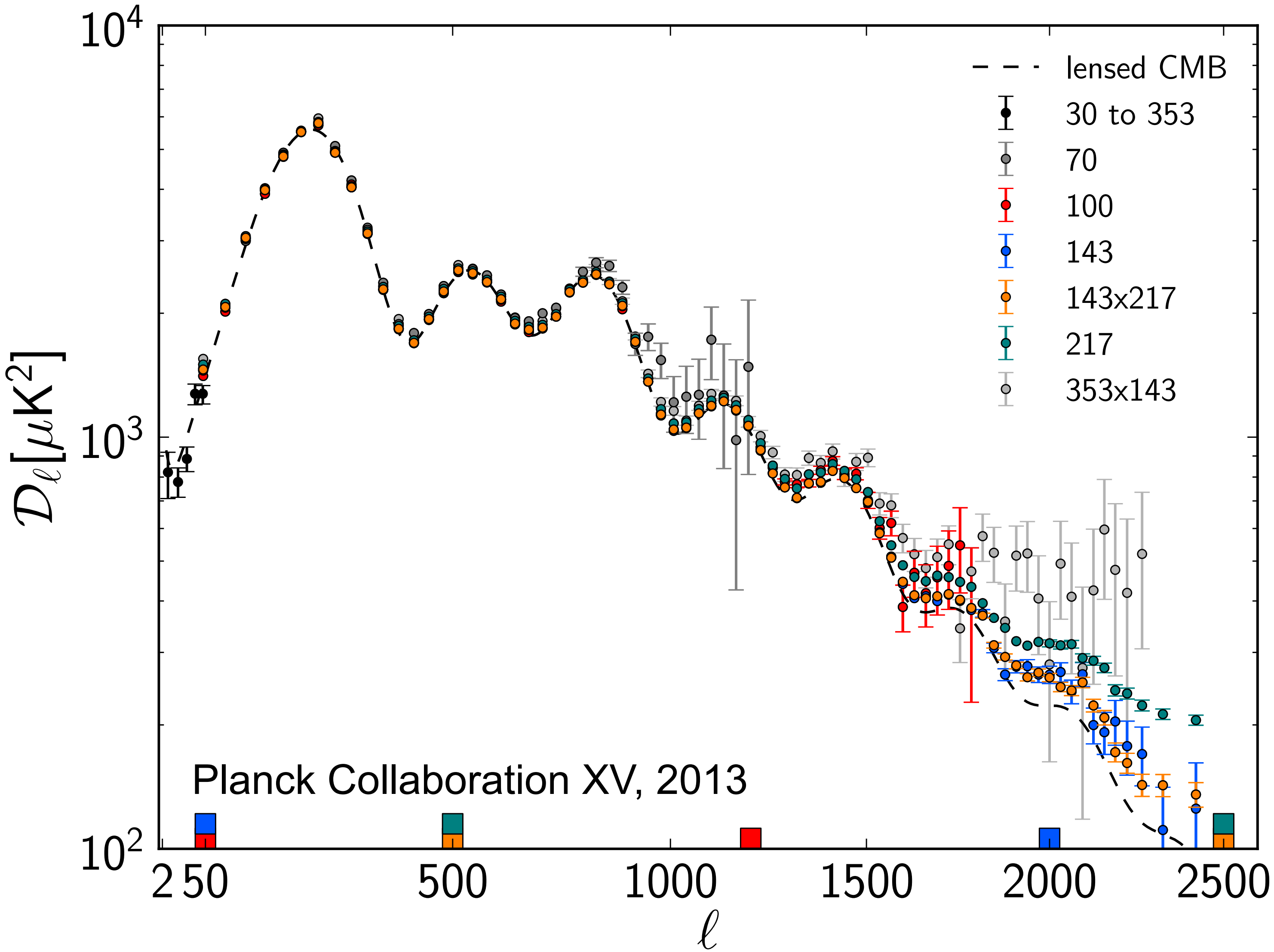
- *noise properties are well described by a simple 3 parameter model with only white noise and 1/f (Planck Collaboration II-III, 2013)*
- *Minimum of diffuse foreground contamination (Planck Collaboration XII, 2013)*
- *Point source component dominated by AGN (Planck Collaboration XXVIII, 2013)*

Planck 70GHz TT spectrum estimation

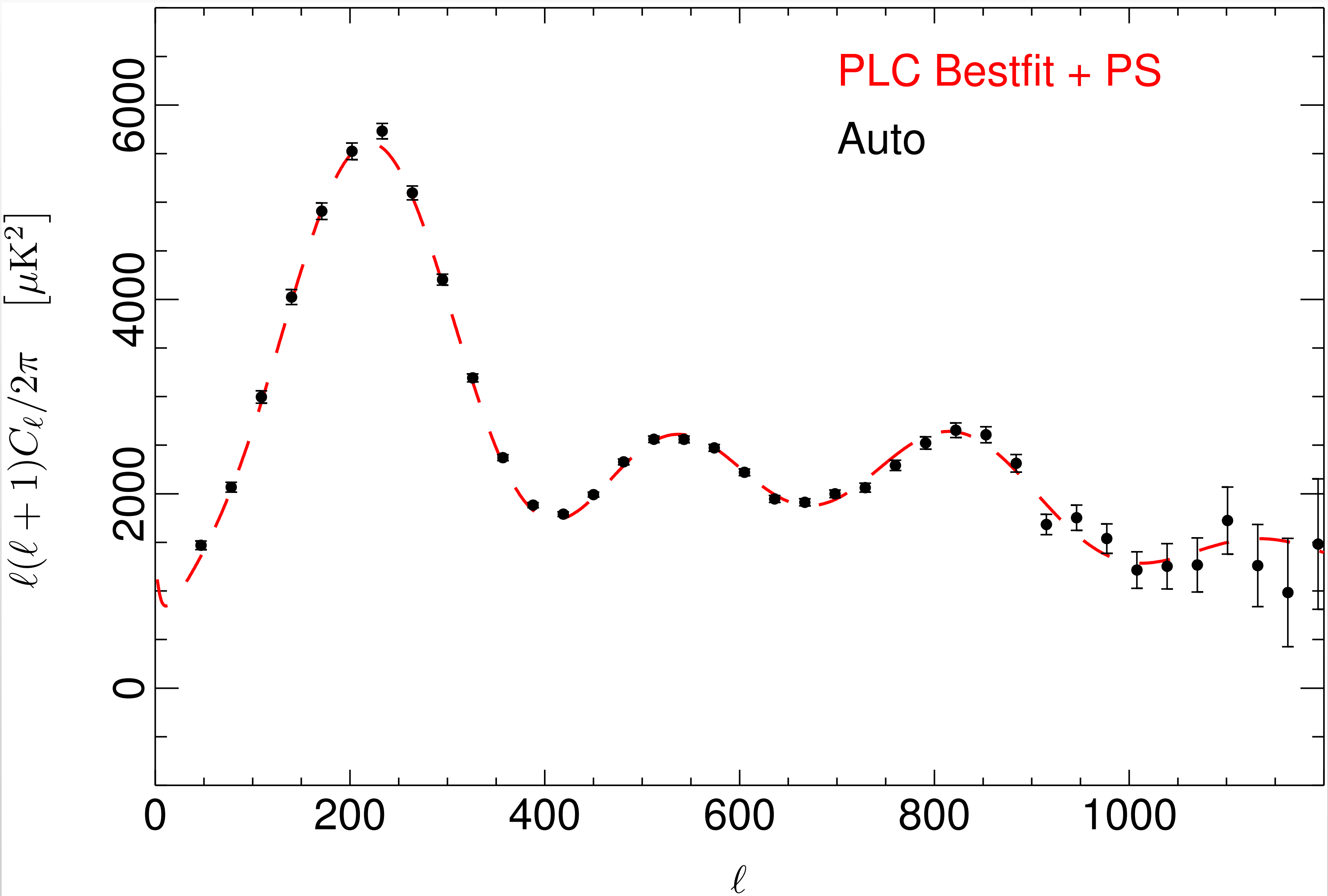
Power spectrum estimation pipeline at 70GHz is described in Planck Collaboration II, 2013.

- cROMAster, flexible Pseudo-Cl method allowing for both auto- and cross-power spectrum estimation
- Cut sky is accounted for by a coupling matrix
- Noise bias and error bars are obtained by realistic signal and noise Monte Carlo simulations (FFP6, 1000 sims)
- Beam window functions estimated with FEBECop as described in Planck Collaboration IV, 2013.

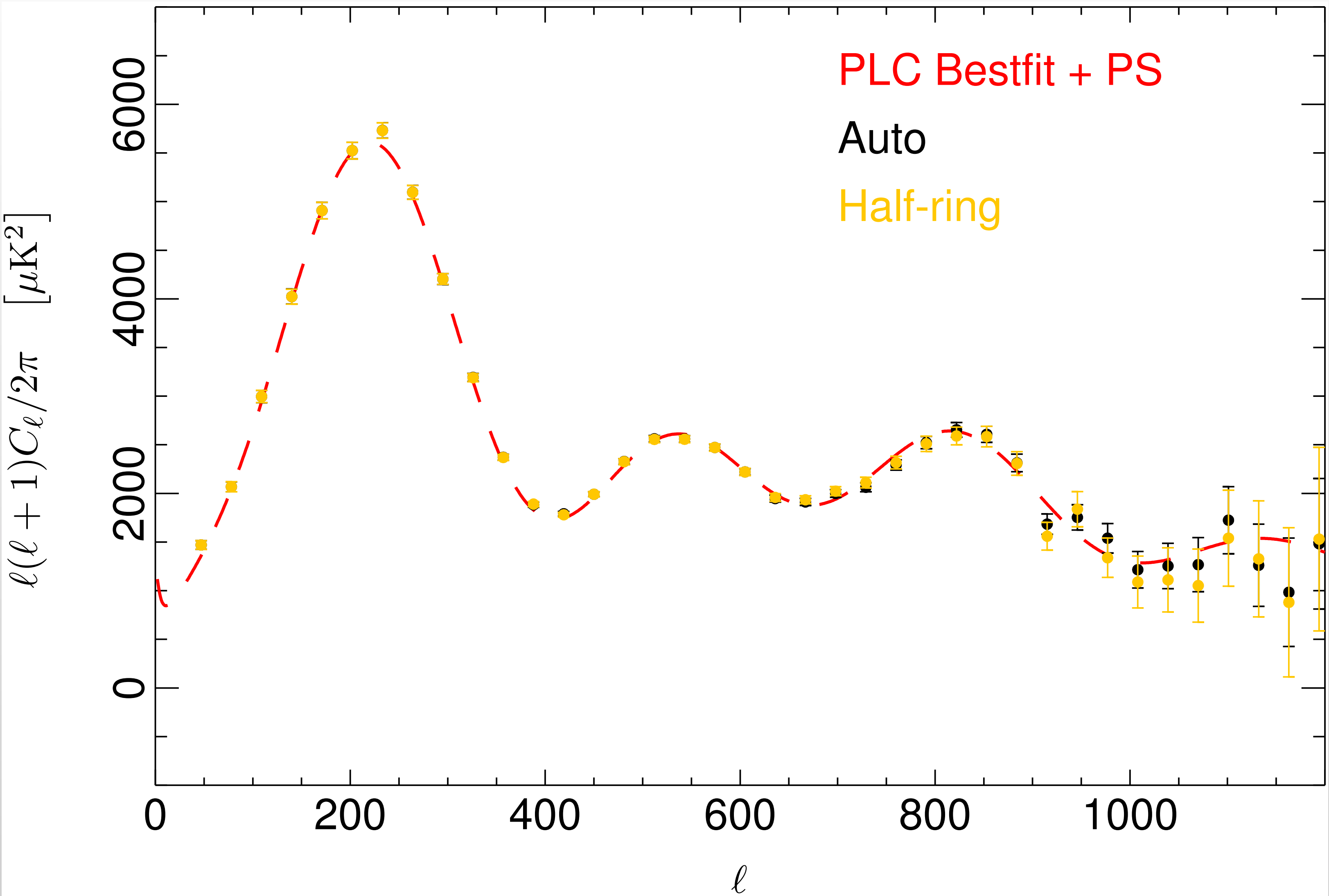
Consistency of Planck TT power spectra



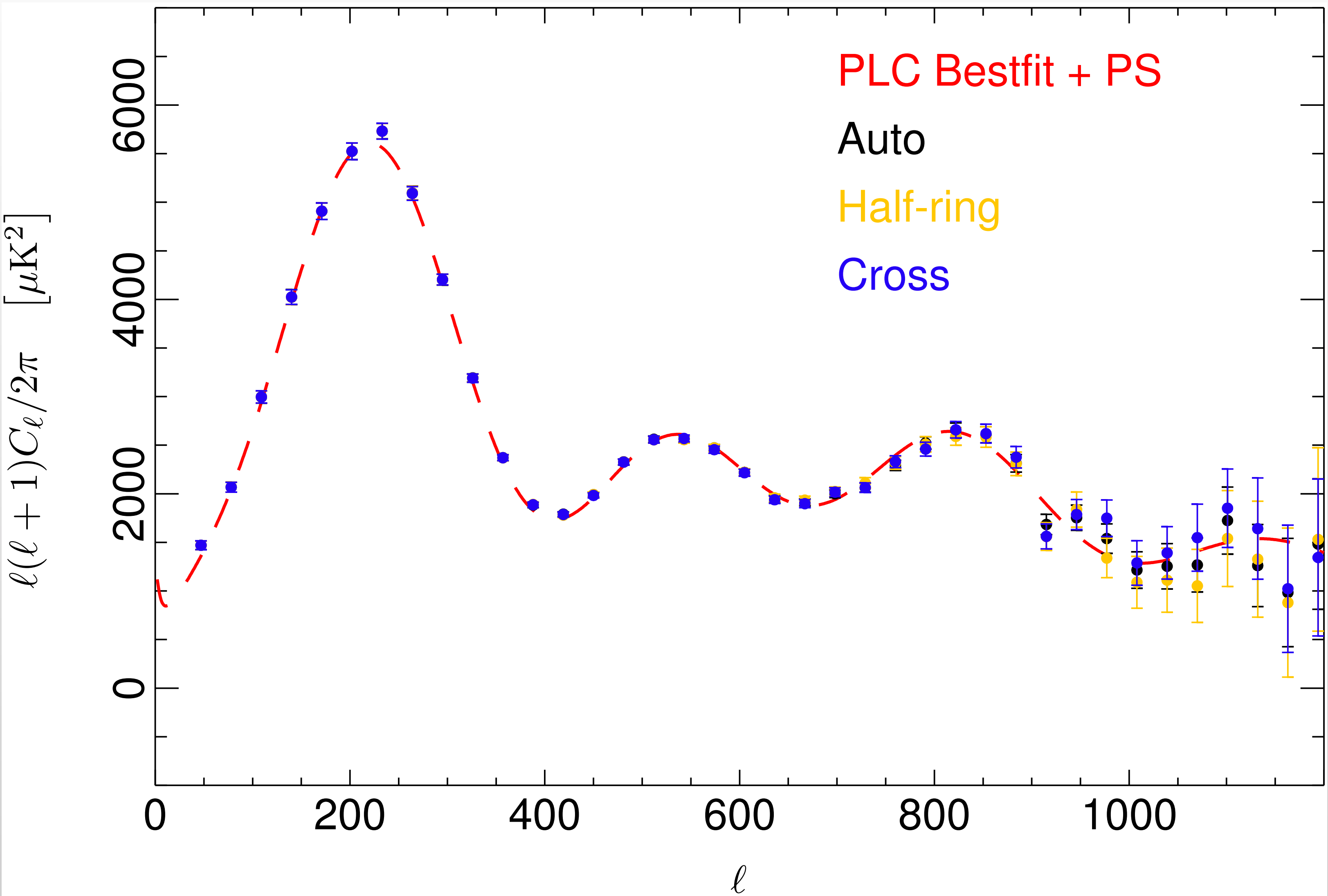
Consistency of 70GHz TT power spectra



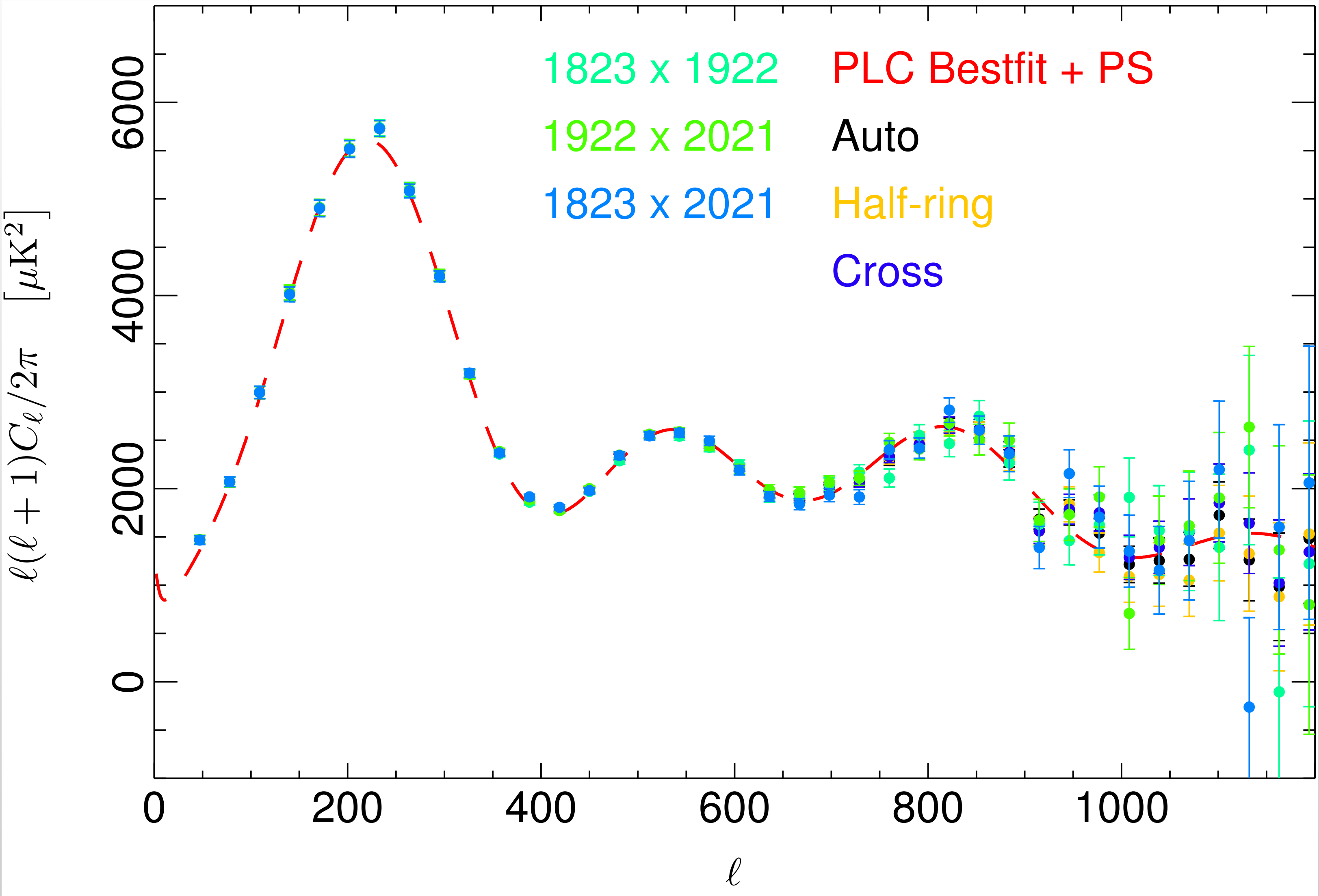
Consistency of 70GHz TT power spectra



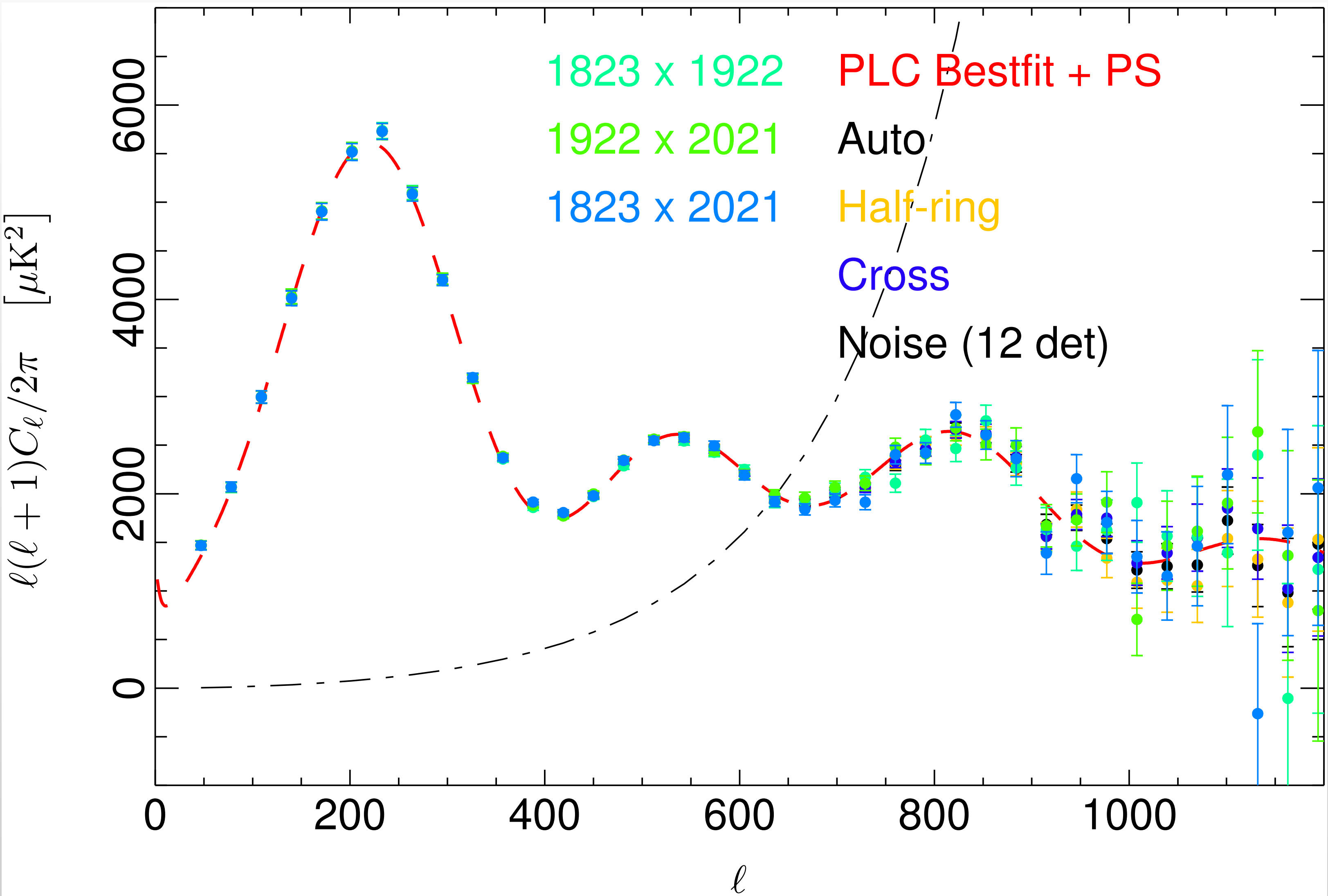
Consistency of 70GHz TT power spectra



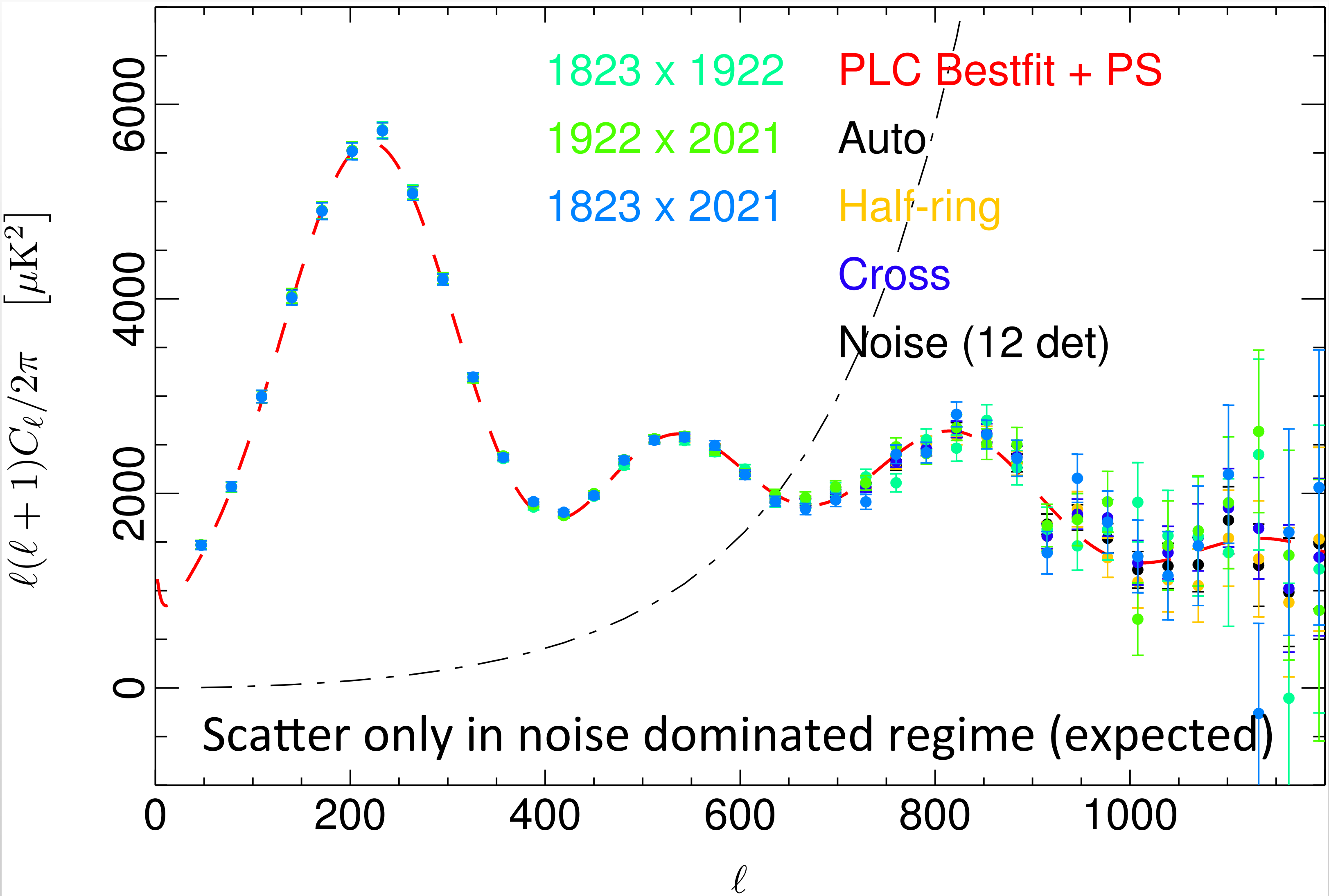
Consistency of 70GHz TT power spectra



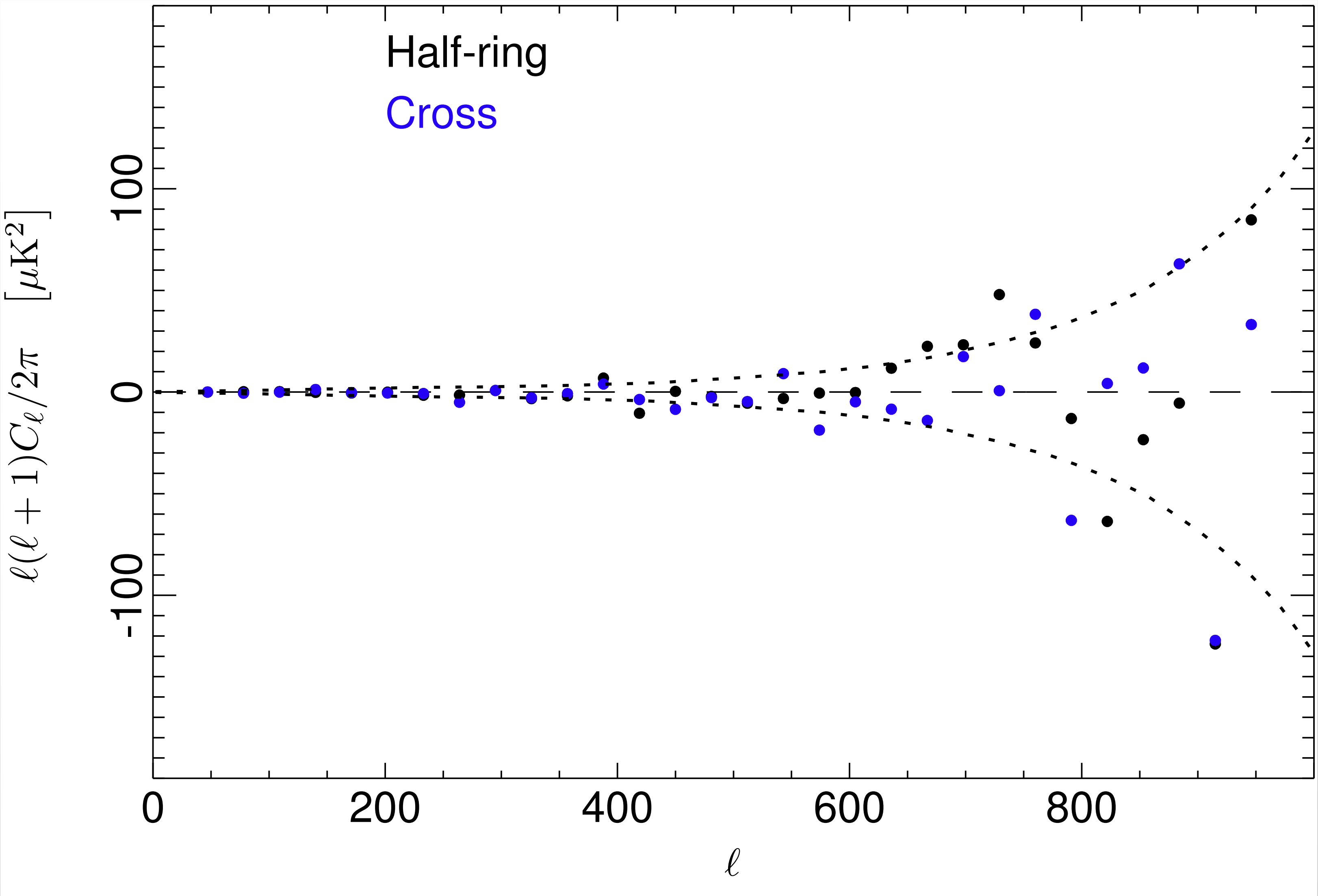
Consistency of 70GHz TT power spectra



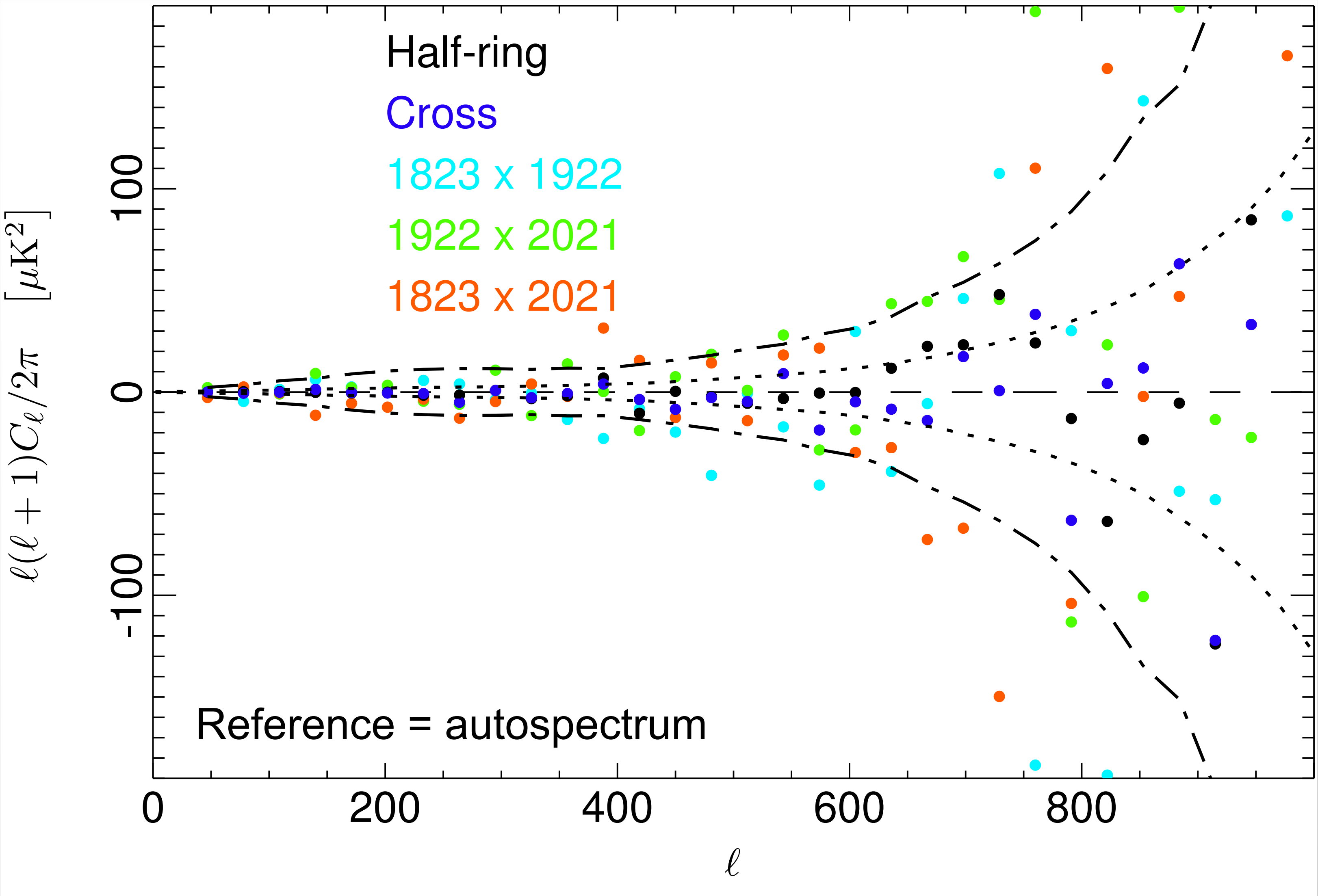
Consistency of 70GHz TT power spectra



Residuals of TT power spectra



Residuals of TT power spectra



Consistency of 70GHz TT power spectra

70 GHz power spectra computed within the same mask are very consistent:

- *Complete overlap in signal dominated regime.*
- *Some scatter appears, but only in noise dominated regime, as expected.*

A basic χ^2 analysis of residuals shows good consistency.

However, we need a dedicated test to look for a possible bias between different estimates.

The Hausman test

Quantitative assessment of consistency between two power spectrum estimates can be done using the Hausman test. We define:

$$H_\ell = \left(\tilde{C}_\ell - \hat{C}_\ell\right)/Var\{\tilde{C}_\ell - \hat{C}_\ell\}^{1/2}$$

Polenta et al 2005, JCAP

$$B_\ell = \frac{1}{\sqrt{L}} \sum_{\ell=0}^{rL} H_\ell, r \in [0,1]$$

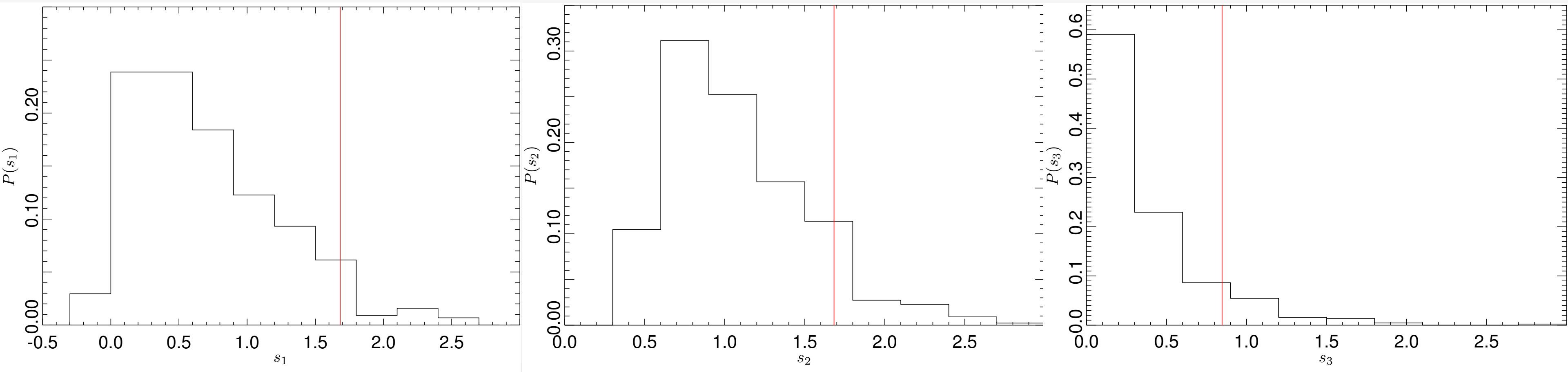
Where H_ℓ converges to a Normal distribution, and B_ℓ to a standard Brownian motion process. We then define 3 test statistics:

$$s_1 = sup_r B_\ell(r) \qquad s_2 = sup_r |B_\ell(r)| \qquad s_3 = \int_0^1 B_\ell^2(r) dr$$

and we compare results obtained for the 70 GHz channel against the empirical distribution of these statistics drawn through Monte Carlo simulations.

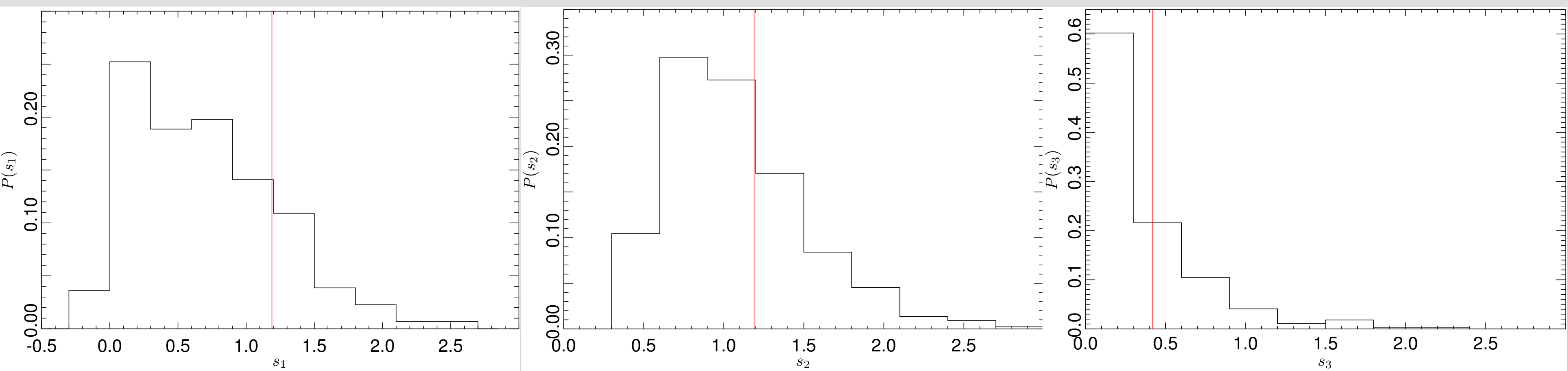
The Hausman test

70 GHz - Auto vs quadruplet cross-spectrum



Planck Collaboration II, 2013

70 GHz - quadruplet vs HR cross-spectrum



Consistency of 70GHz TT power spectra

The Hausman test shows significant consistency among different spectral estimates.

We have also tested various masks. However, these are not comparable point-by-point due to cosmic variance, and will be tested directly through cosmological parameters.

Cosmological parameters from 70GHz data

We have estimated the 6 ΛCDM cosmological parameters for the various 70 GHz power spectra as follows:

- 70GHz data are used at l>32 (high-l) assuming Gaussian likelihood
- Covariance matrix estimated from Monte Carlo simulations
- Planck low-ell likelihood at l<32, i.e. Planck data for temperature and WMAP polarisation.
- We added one foreground component to account for the unresolved point sources, parametrized by C_{900}.

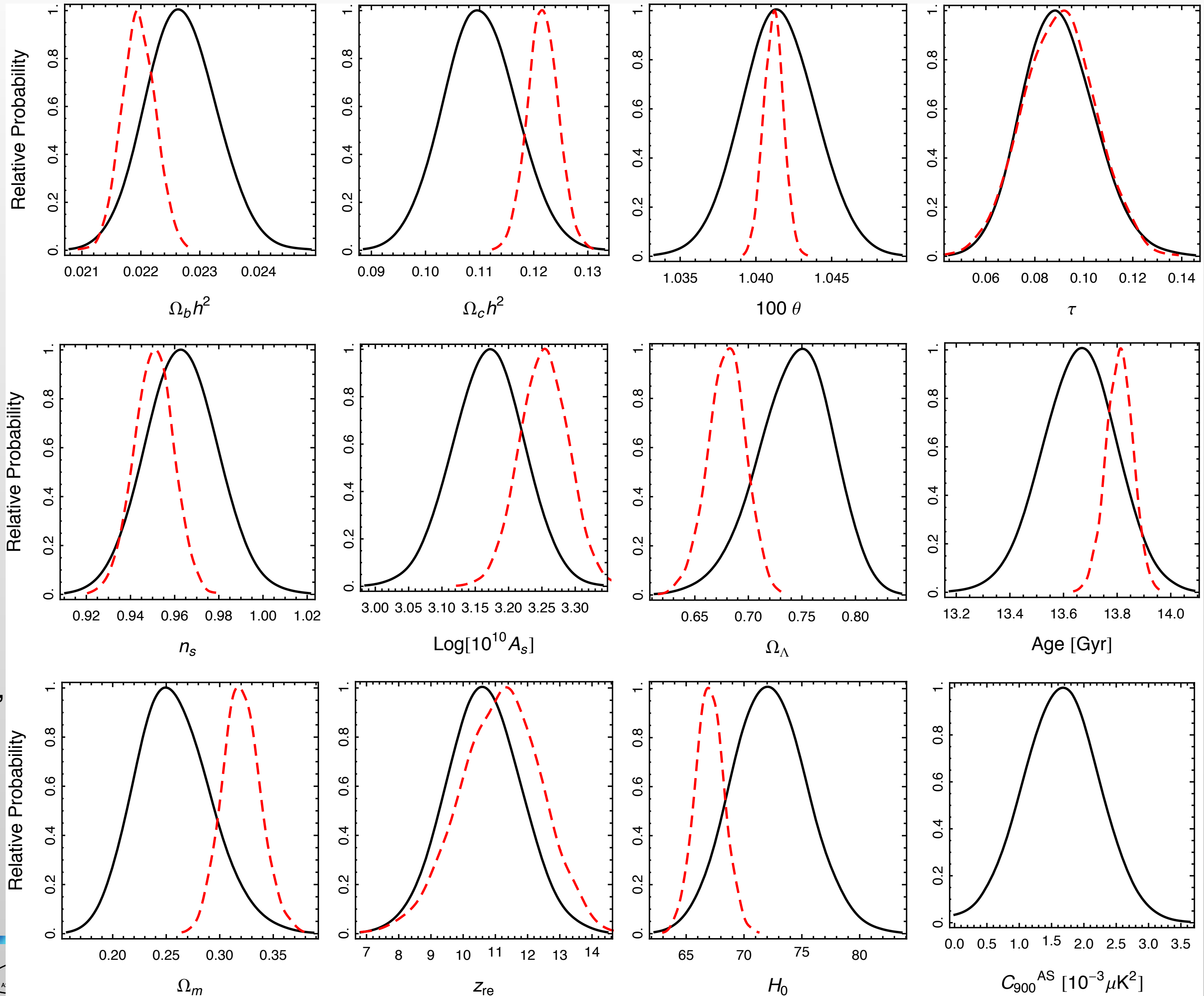
Cosmological parameters

Black: 70 GHz

Red: Planck Likelihood Code (PLC)

Good consistency, especially given the very different multipole range considered for the two cases.

Planck Collaboration XV, 2013



Cosmological parameters vs ℓ_{max}

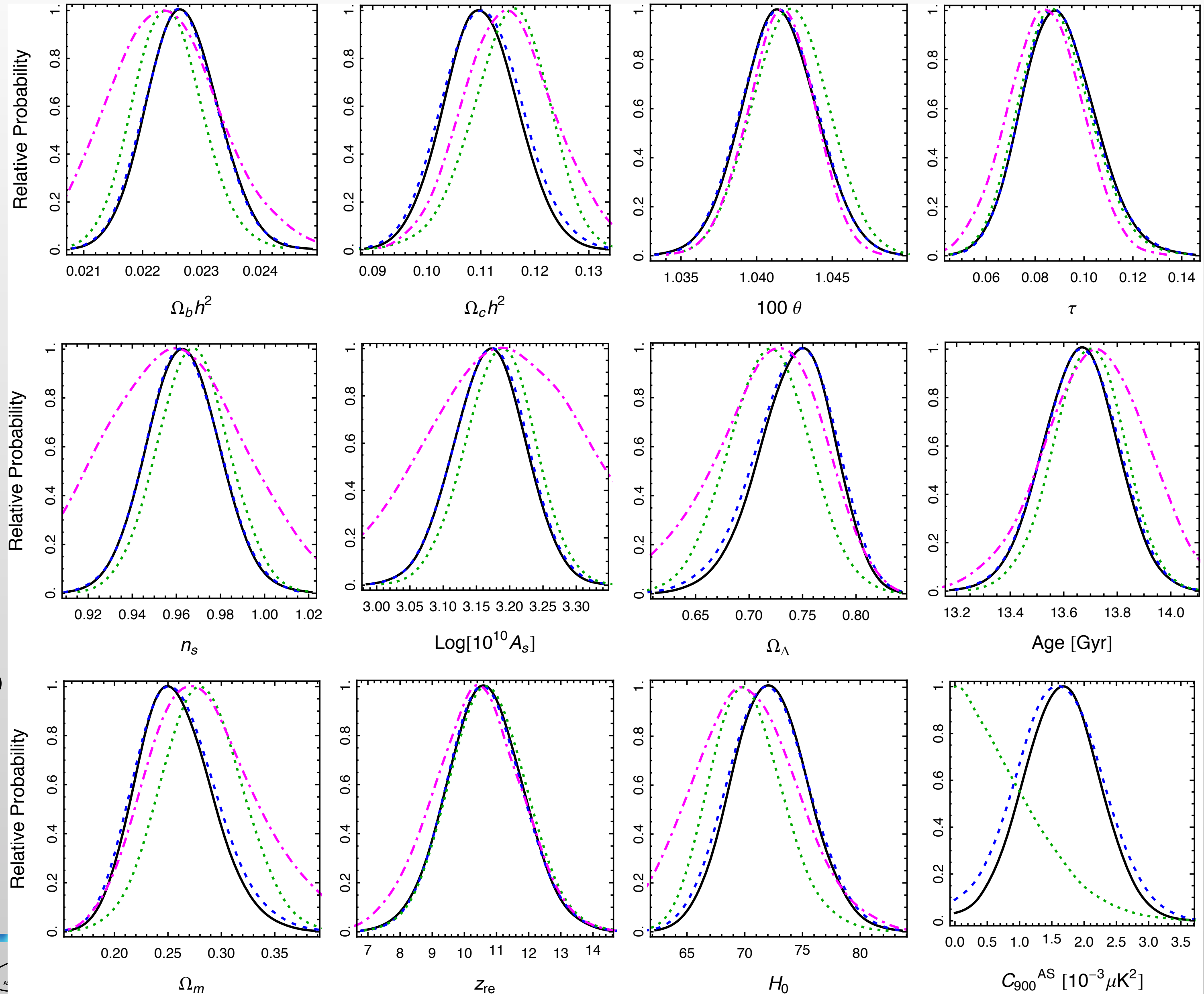
Black:
70GHz, ℓ_{max}=1200

Blue dashed:
70GHz, ℓ_{max}=1000

Green dotted:
70GHz, ℓ_{max}=800

Blue dot-dashed:
Plik, ℓ_{max}=1008

Great consistency, small differences for ℓ_{max}=800 due to poor PS fit. Plik is wider due to the large number of FG parameters.



G. Polenta

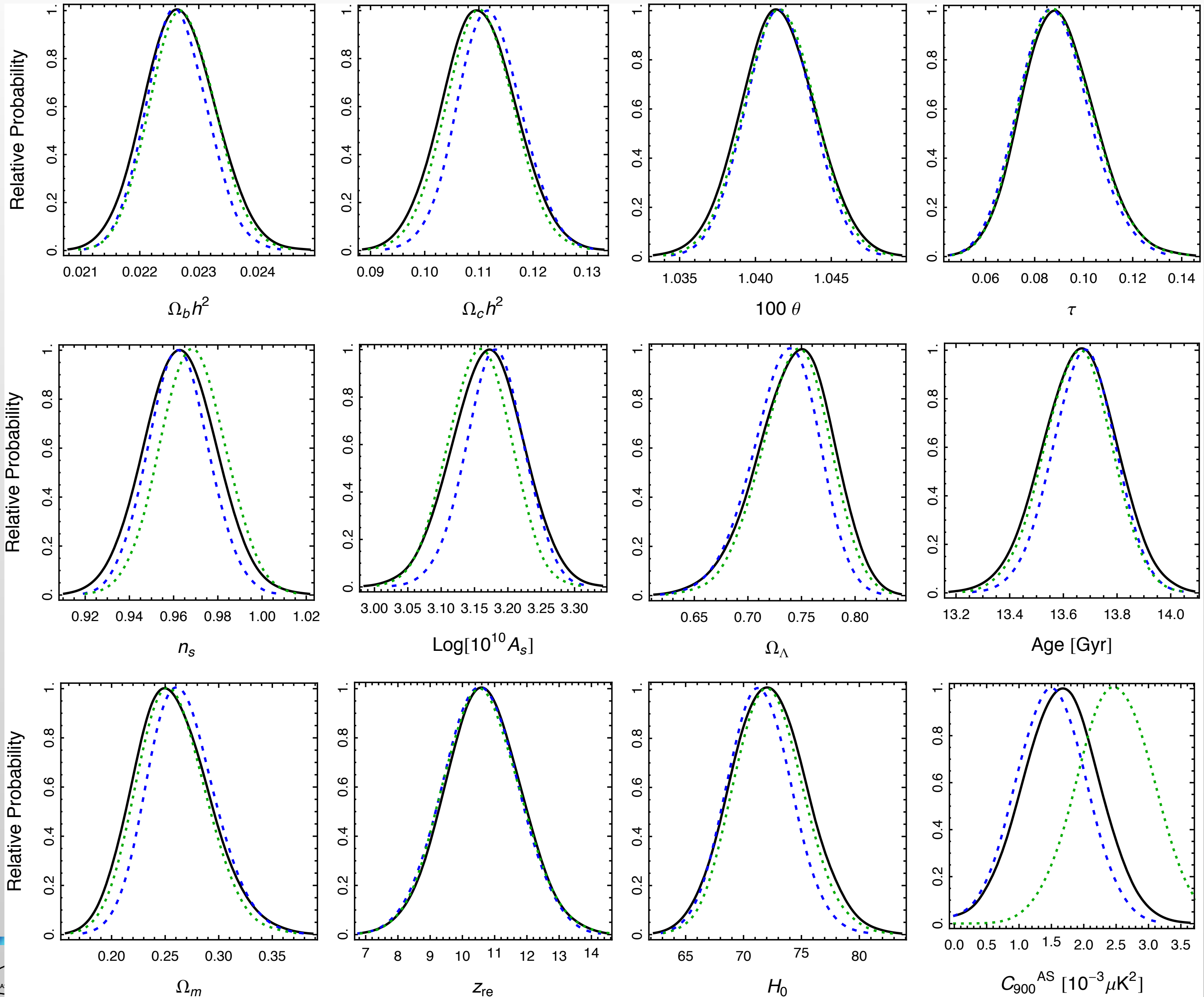
Cosmological parameters vs mask

Black:
70GHz, ℓ_{max}=1200

Blue dashed:
70GHz, mask 080

Green dotted:
70GHz, mask 070
with FL sources

Great consistency,
Note that the value
C_{PS}= 2.5x10^{-3} uK^2
is consistent within
the errors with
expectations from
De Zotti et al 2005
C_{PS}= 2.3x10^{-3} uK^2



Cosmological parameters + high-ℓ

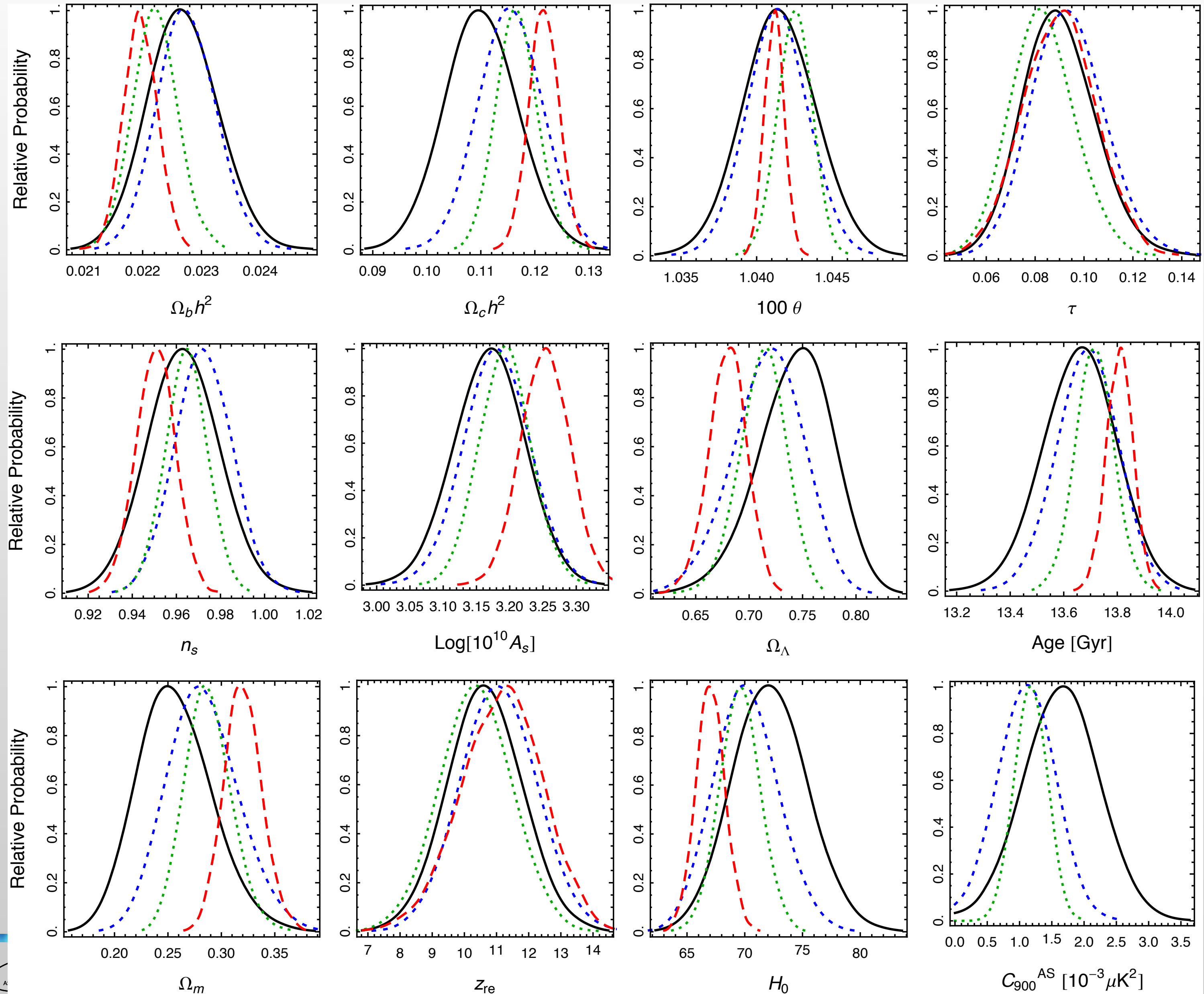
Black: 70GHz

Blue dashed: 70GHz+ACT

Green dotted: 70GHz+SPT

Red dashed: PLC

Adding external high-res dataset makes 70GHz results even closer to PLC, in terms of both the mean and the error.



G. Polenta

Conclusions

We have performed several consistency tests using data from Planck 70 GHz channel. This dataset is very solid:

- *It's at the minimum of diffuse foregrounds, so only a small Galactic mask is needed.*
- *Unresolved point sources can be modelled using only one Poisson component.*

Power spectra derived from different subsets of detectors are statistically very consistent.

Cosmological parameters are remarkably robust as well with respect to multipole range, sky-cut and foreground modelling.

70 GHz parameters are consistent with official PLC. Adding external dataset at small angular scales improves the agreement even further.

Significant noise reduction expected with full mission data.

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

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.