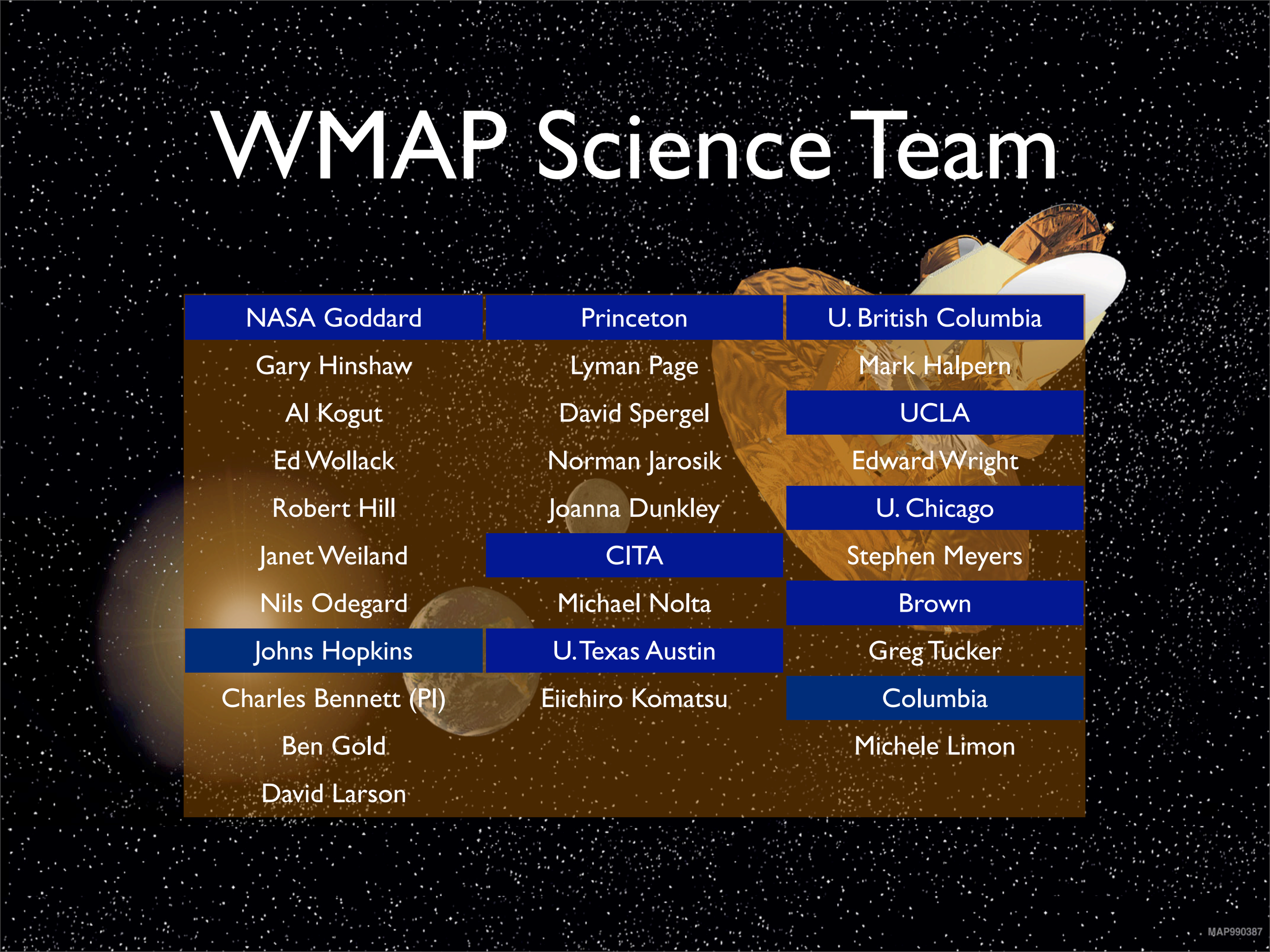
WMAP 5-year results

Mike Nolta

CITA–ICAT

WMAP Science Team



NASA Goddard

Gary Hinshaw

Al Kogut

Ed Wollack

Robert Hill

Janet Weiland

Nils Odegard

Johns Hopkins

Charles Bennett (PI)

Ben Gold

David Larson

Princeton

Lyman Page

David Spergel

Norman Jarosik

Joanna Dunkley

CITA

Michael Nolta

U. Texas Austin

Eiichiro Komatsu

U. British Columbia

Mark Halpern

UCLA

Edward Wright

U. Chicago

Stephen Meyers

Brown

Greg Tucker

Columbia

Michele Limon

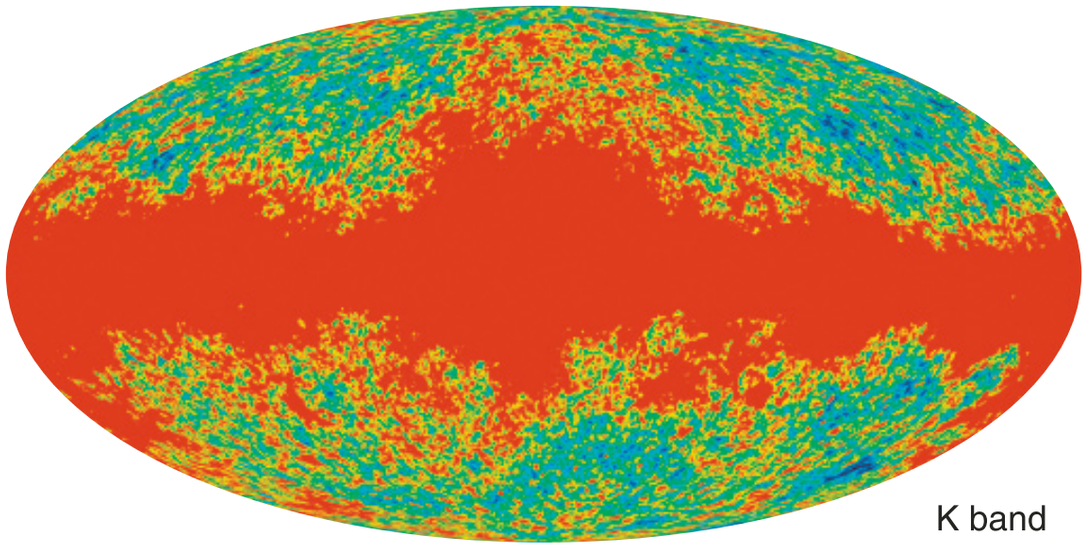
MAP990387

5yr papers

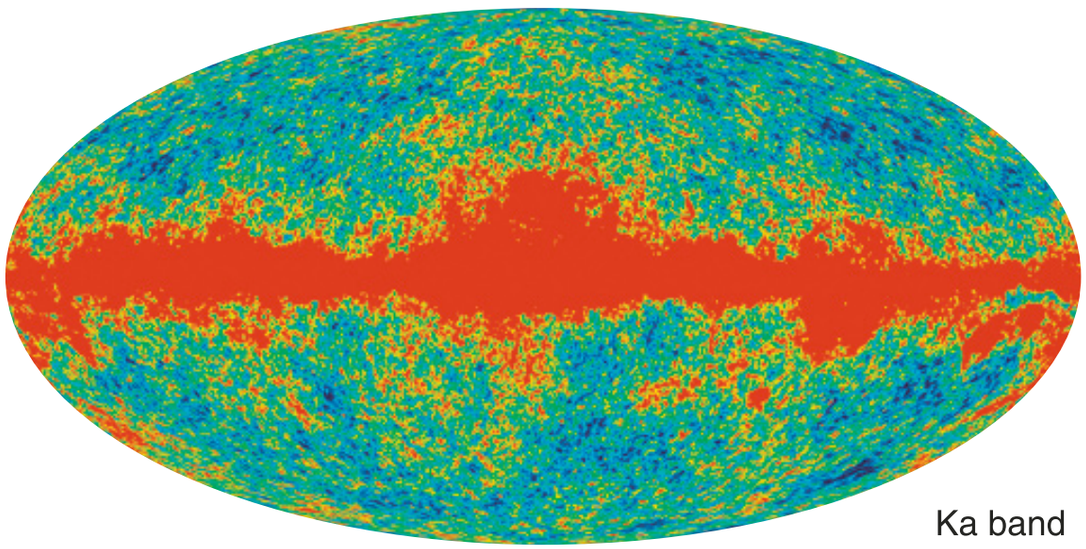
- Hinshaw et al. ,"Data processing, sky maps, and basic results"
- Hill et al., "Beam maps and window functions"
- Gold et al., "Galactic foreground emission"
- Wright et al., "Point sources"
- MN et al., "Angular power spectra"
- Dunkley et al., "Likelihoods and parameters"
- Komatsu et al., "Cosmological interpretation"

5yr/3yr analysis changes

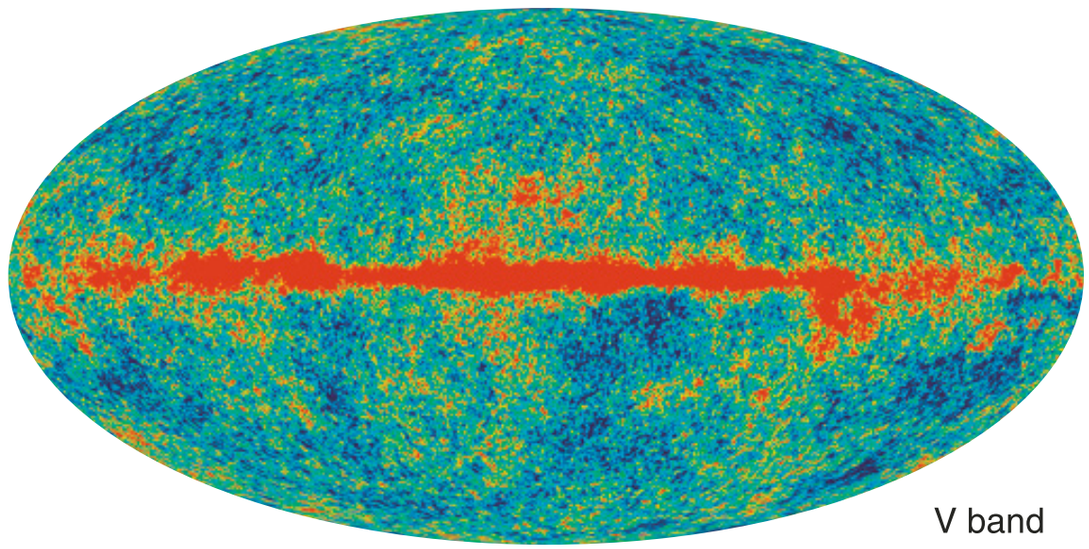
- Improved absolute gain recovery, calibration uncertainty reduced from 0.5% -> 0.2%.
- Improved determination of the beams, leading to an increase in solid angles by ~1%. Uncertainty cut by a factor of 2.
- Slightly enlarged T analysis mask, removing more free-free emission.
- Used Ka polarization data for cosmological analyses.



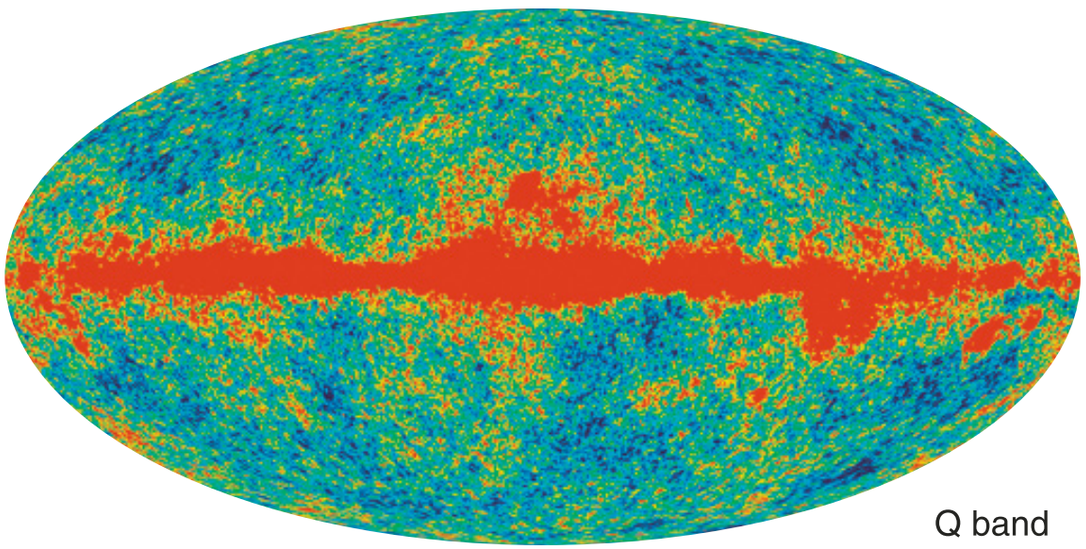
K band



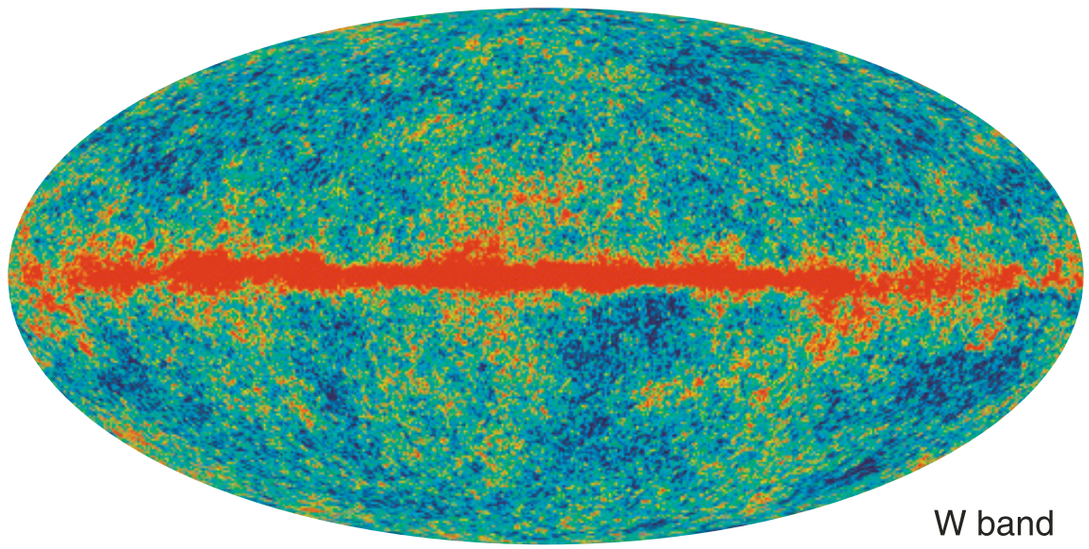
Ka band



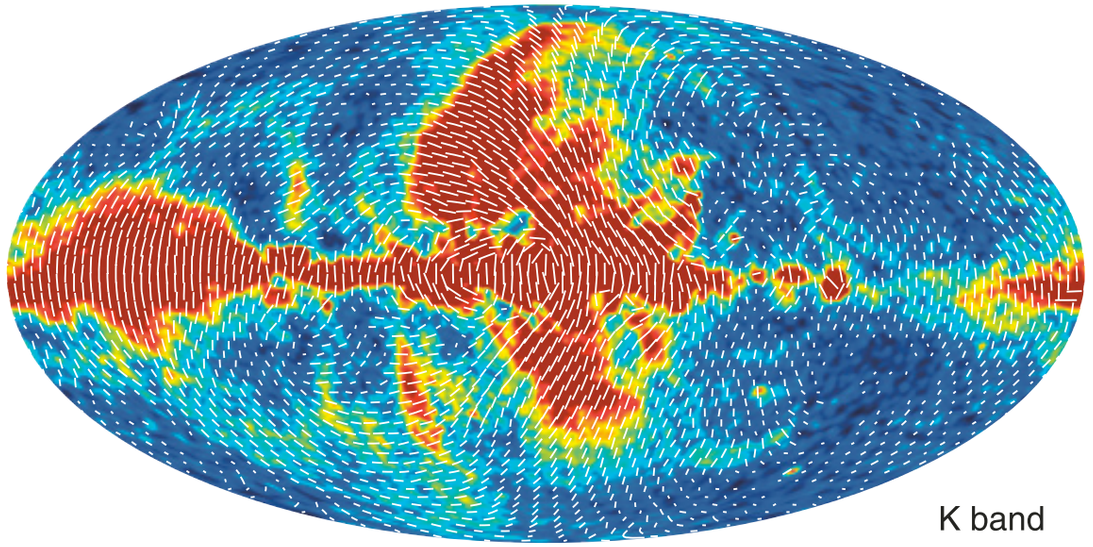
V band



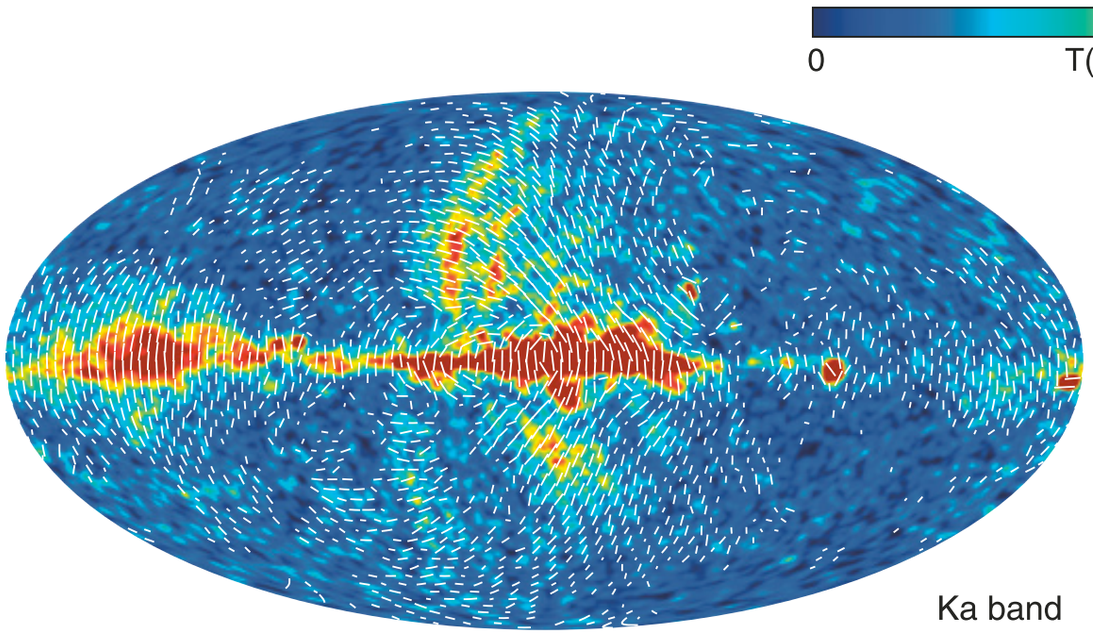
Q band



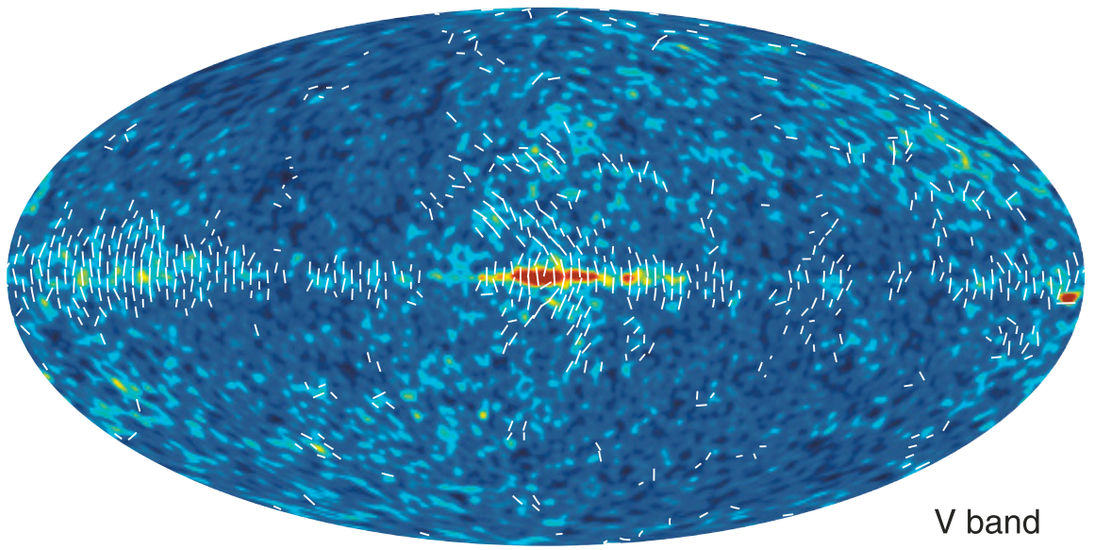
W band



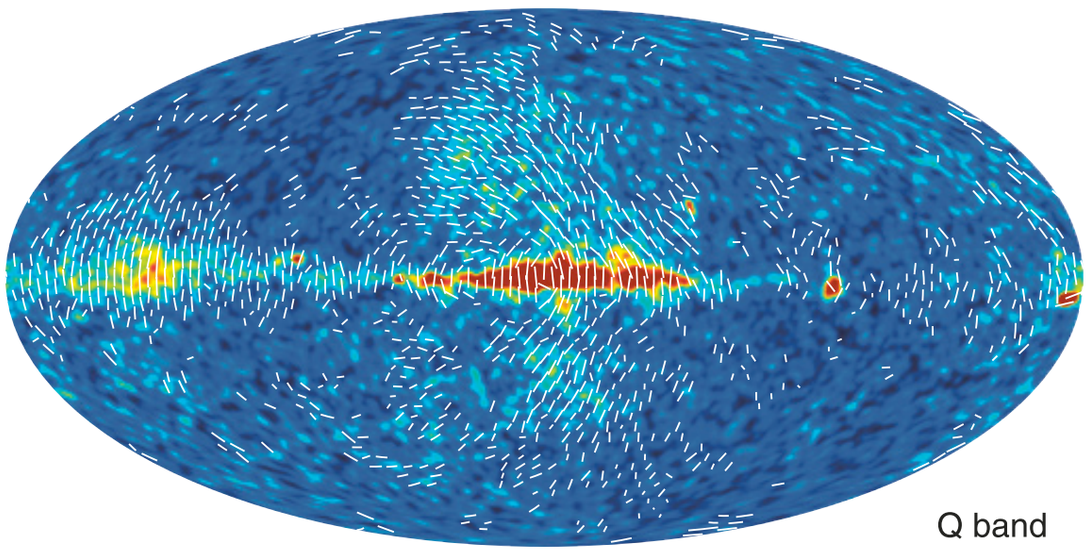
K band



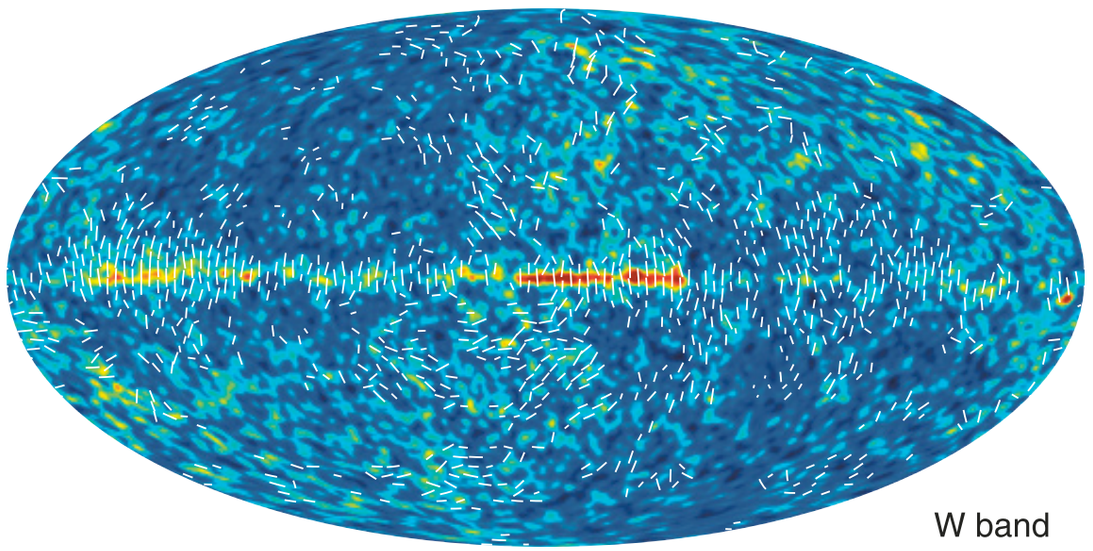
Ka band



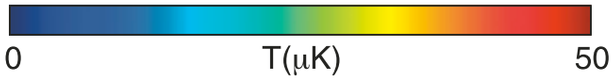
V band

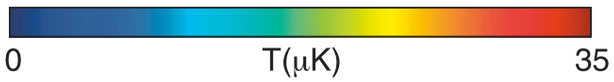


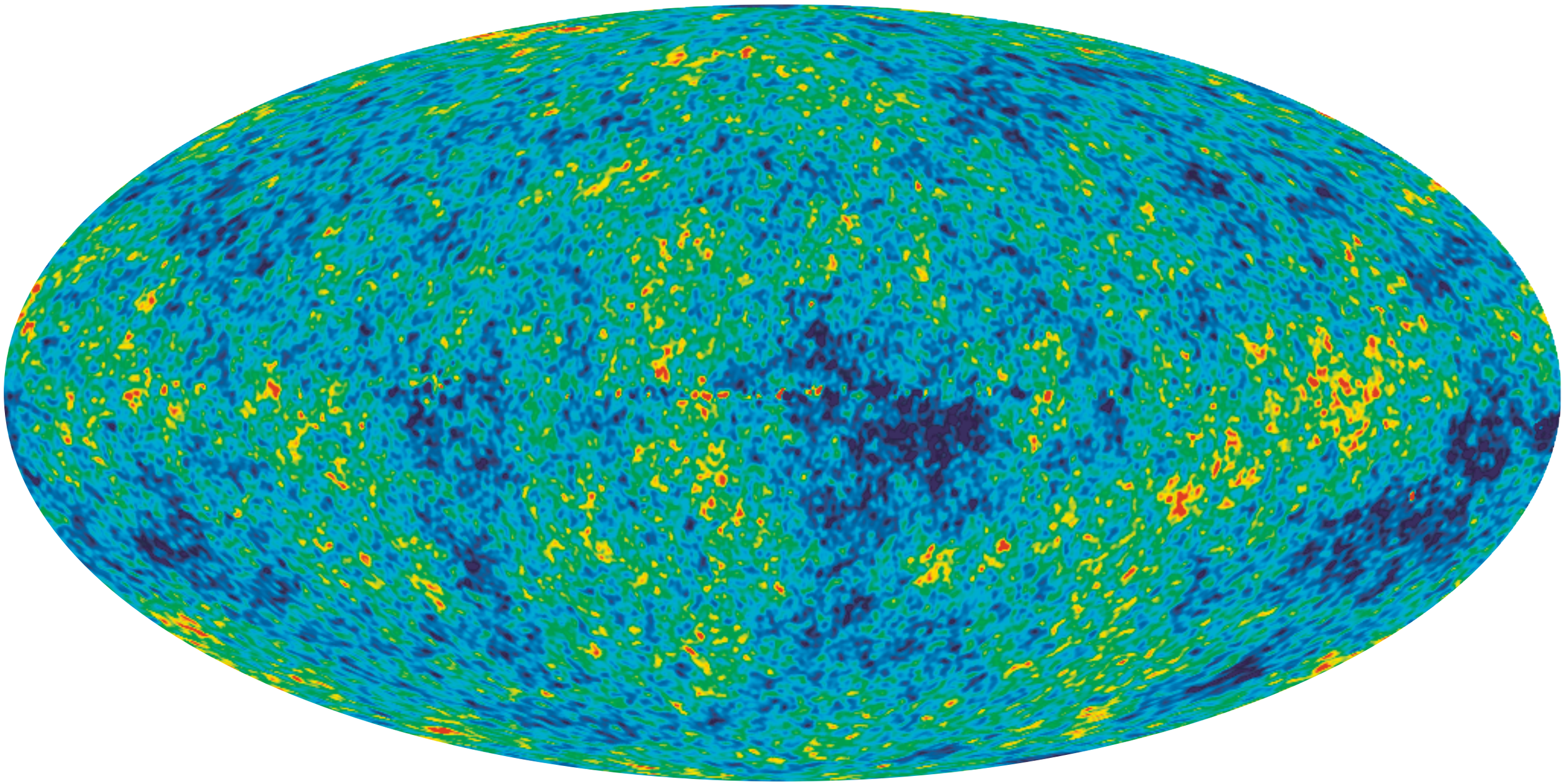
Q band



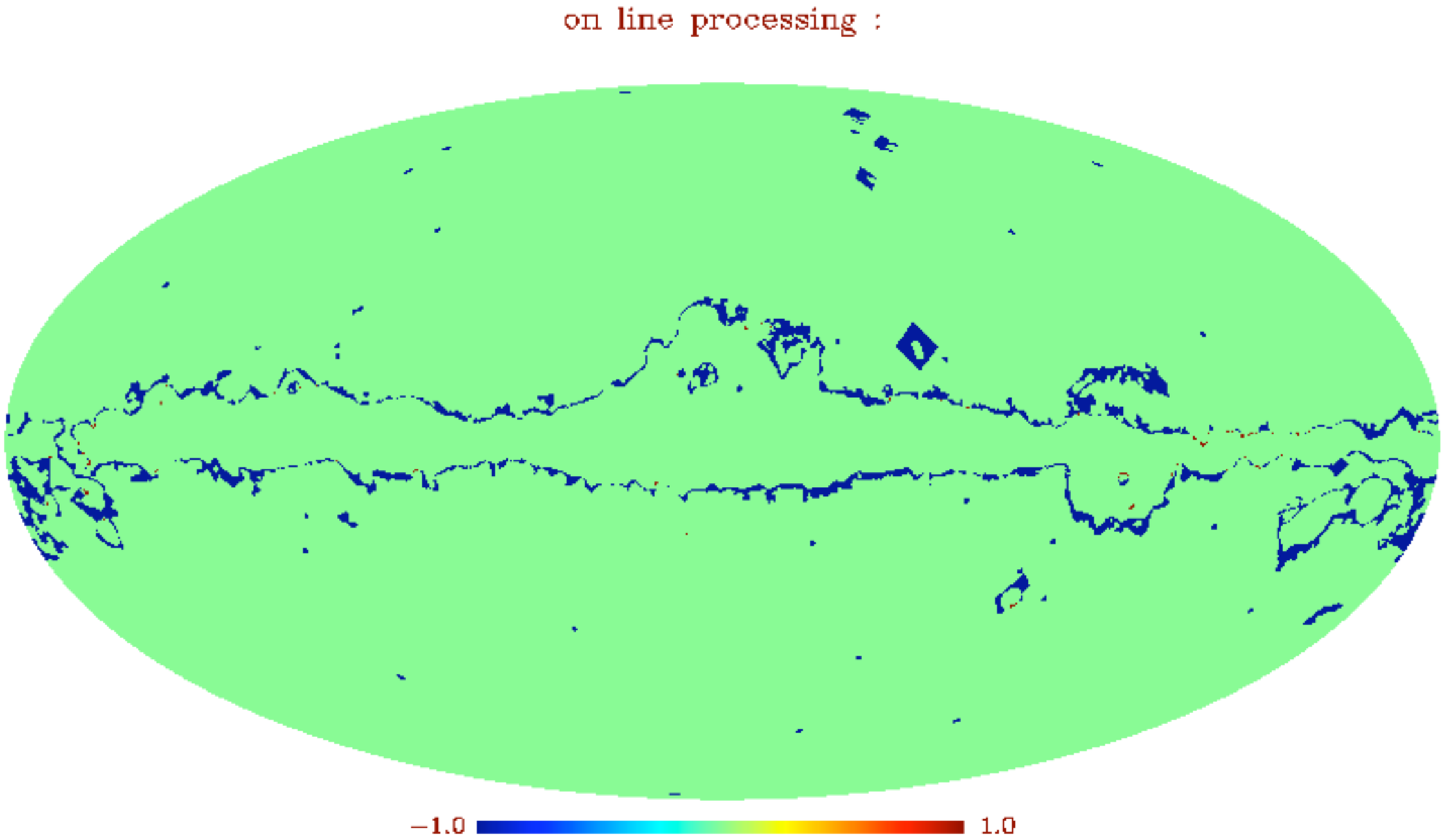
W band



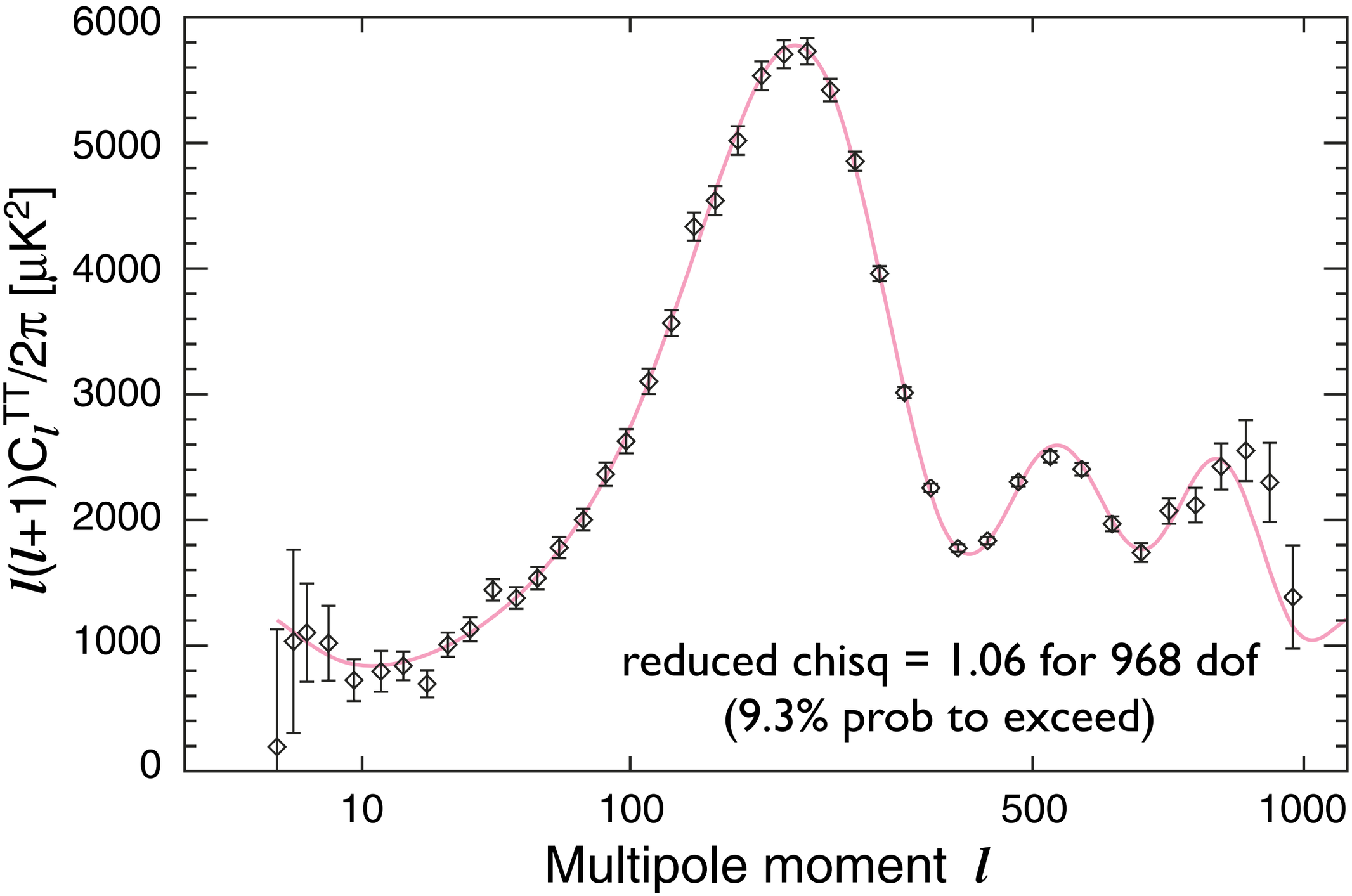



-200
T(μK)
+200
WMAP 5-year

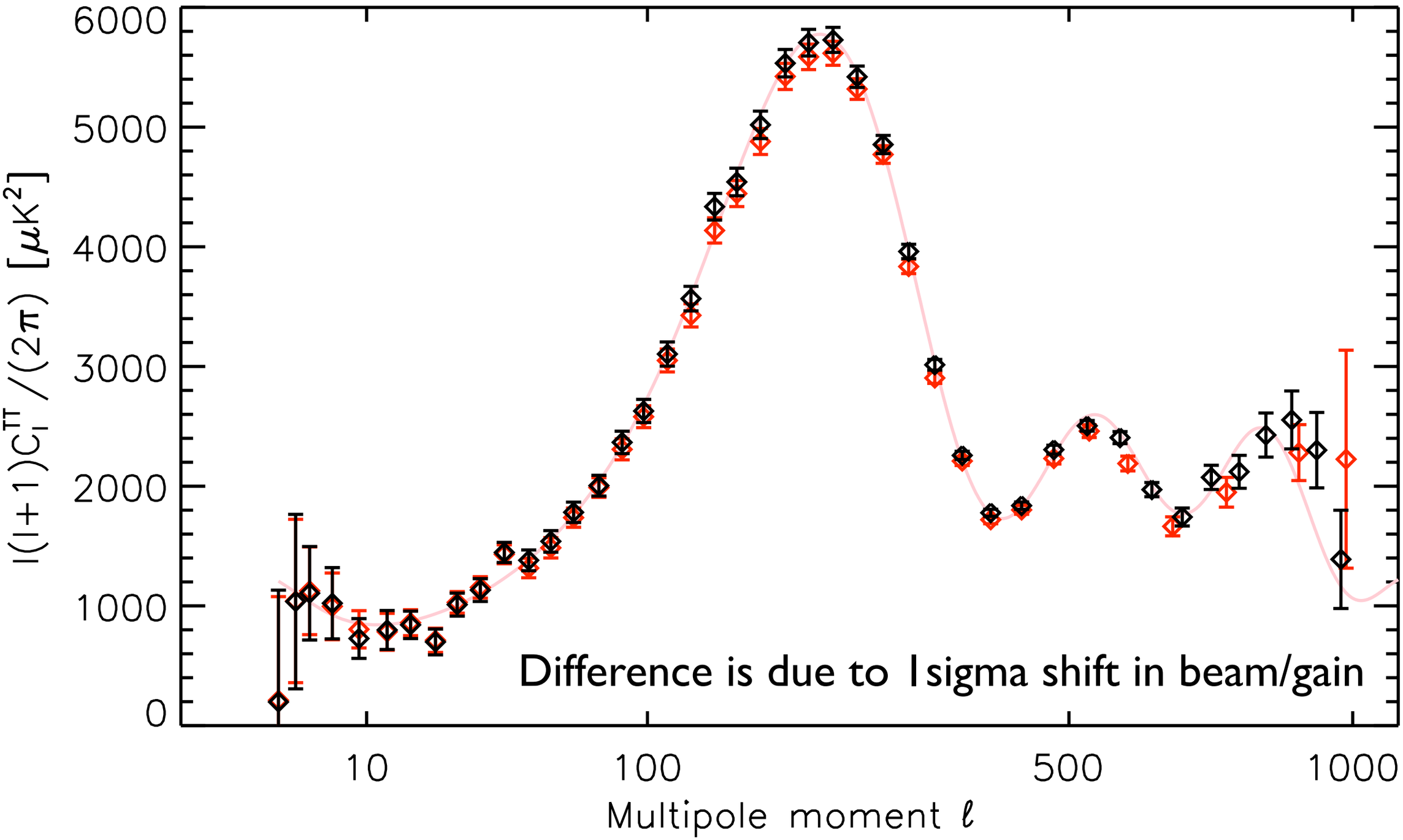
Slightly enlarged T mask



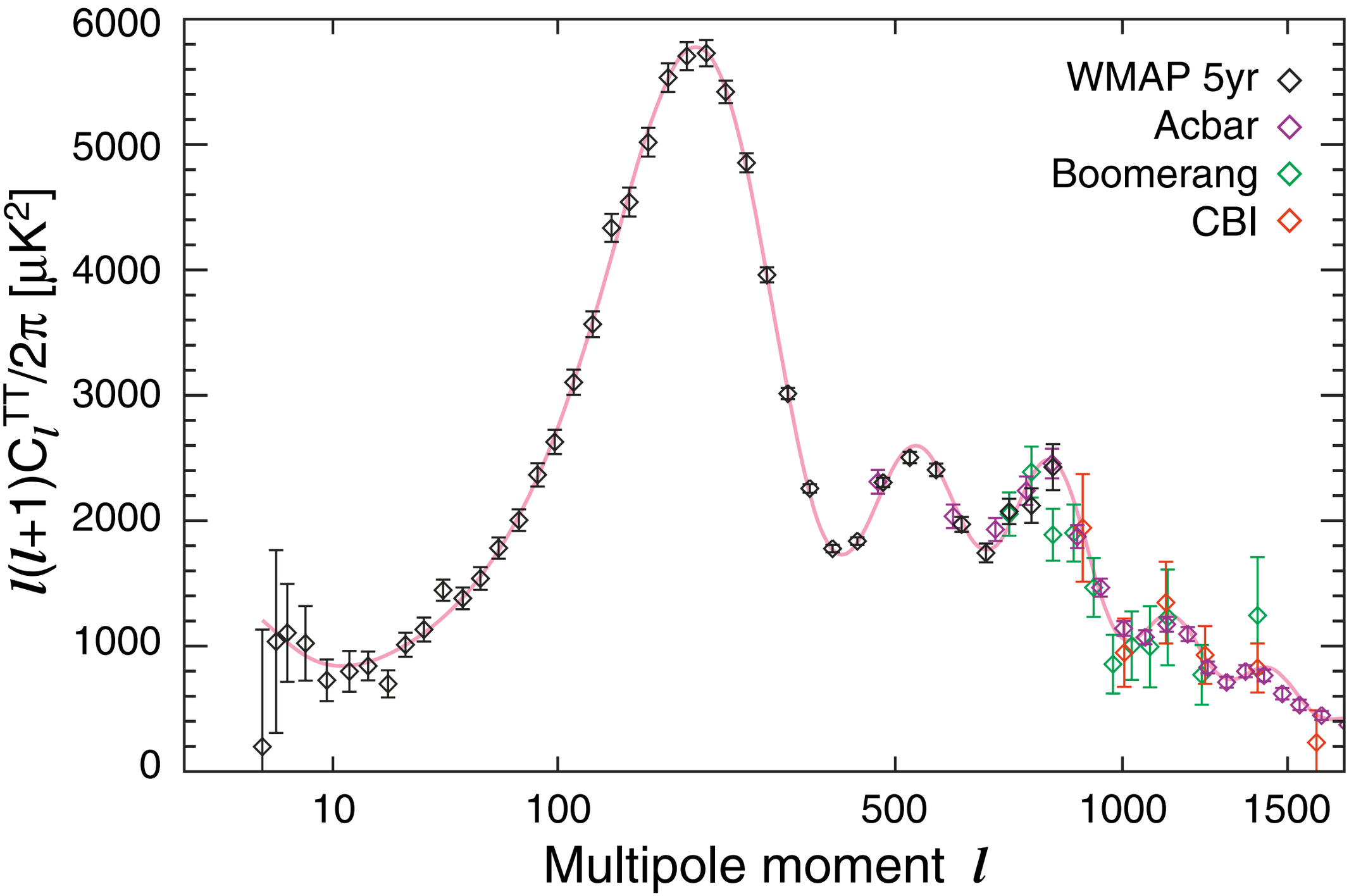
5yr TT spectrum



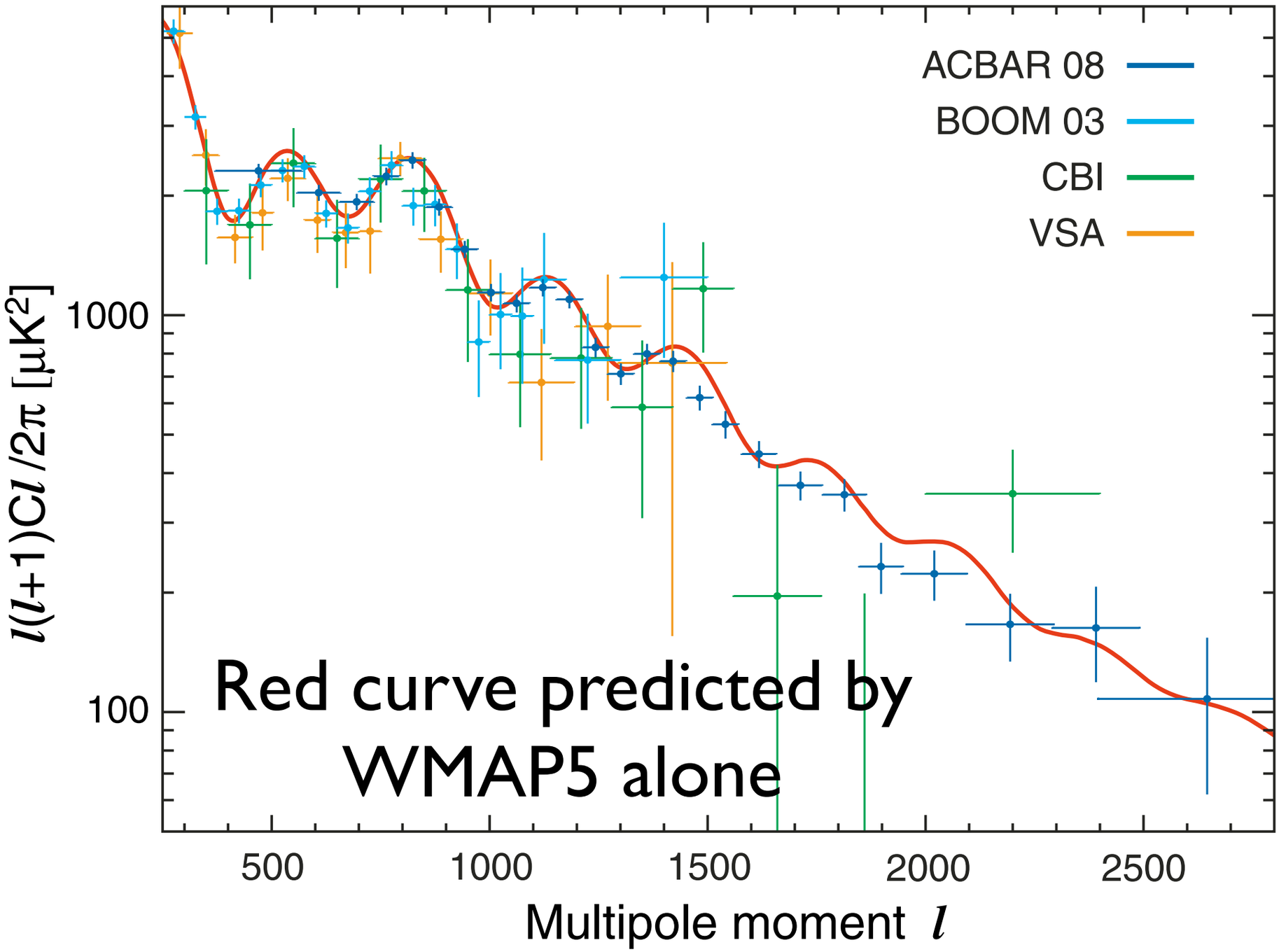
WMAP5 vs WMAP3



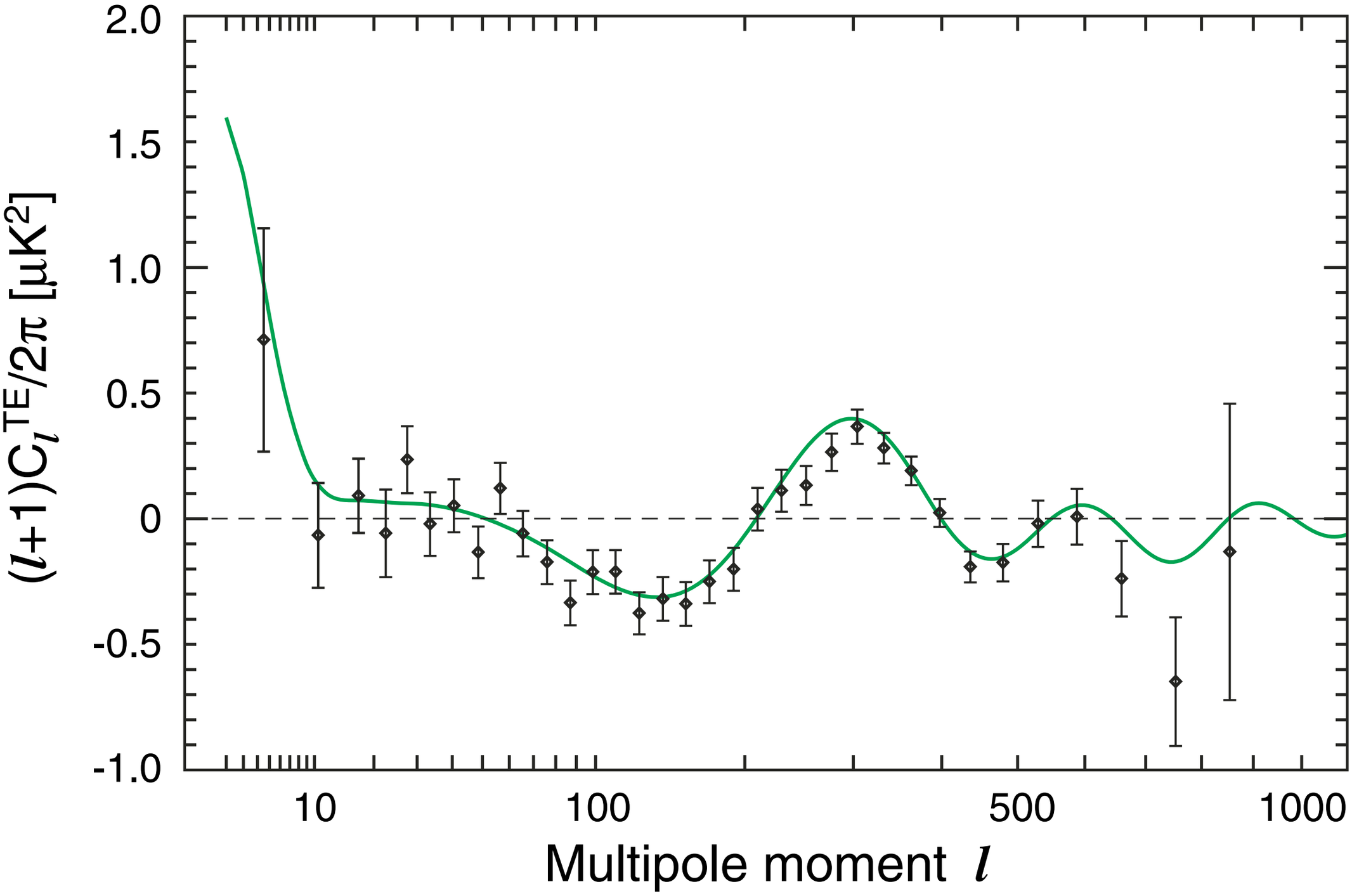
TT spectrum


6000
5000
4000
3000
2000
1000
0
$l(l+1)C_l^{TT}/2\pi$ [μK^2]
10
100
500
1000
1500
Multipole moment l
WMAP 5yr
Acbar
Boomerang
CBI

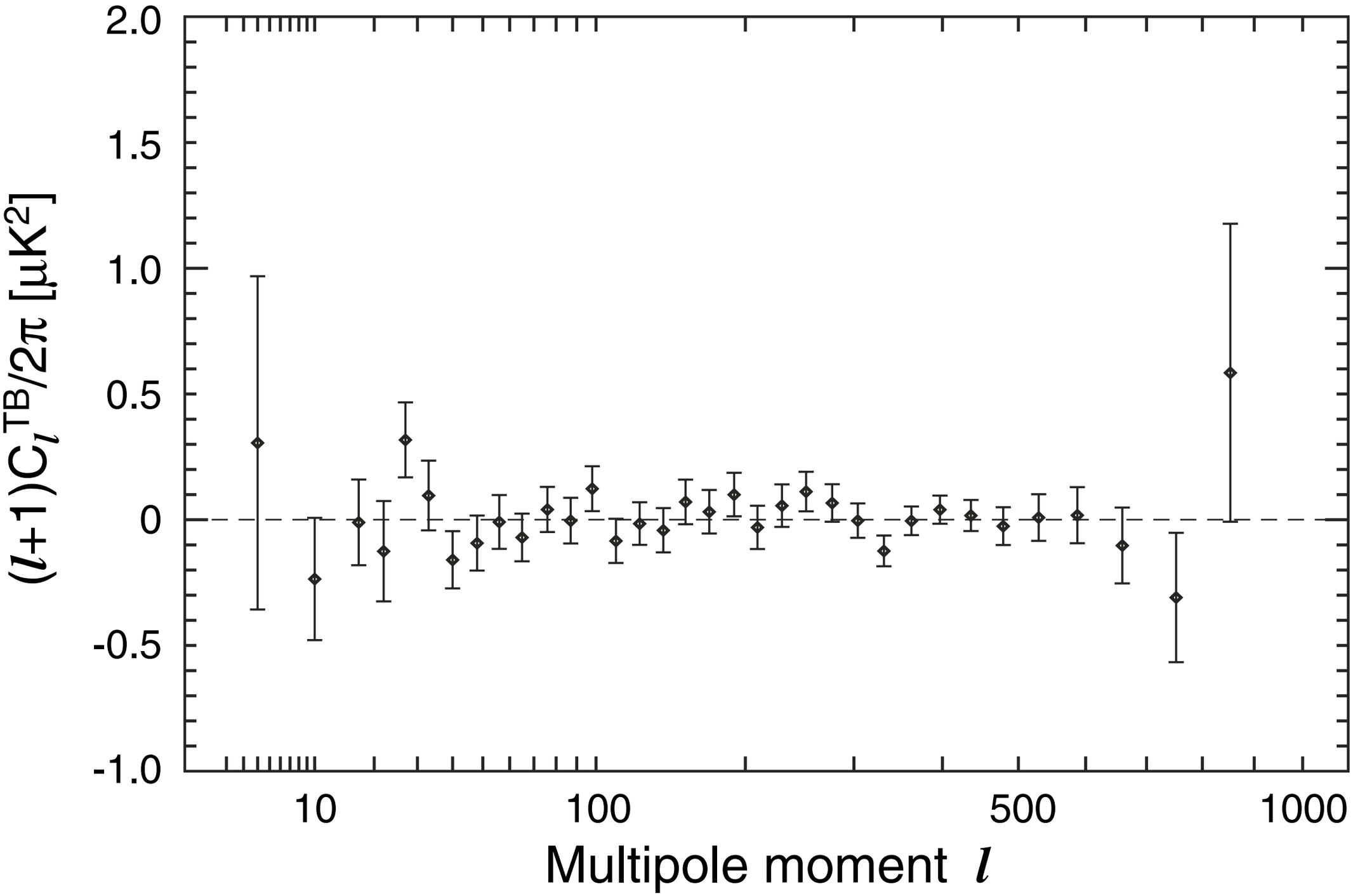
...consistent w/ other experiments



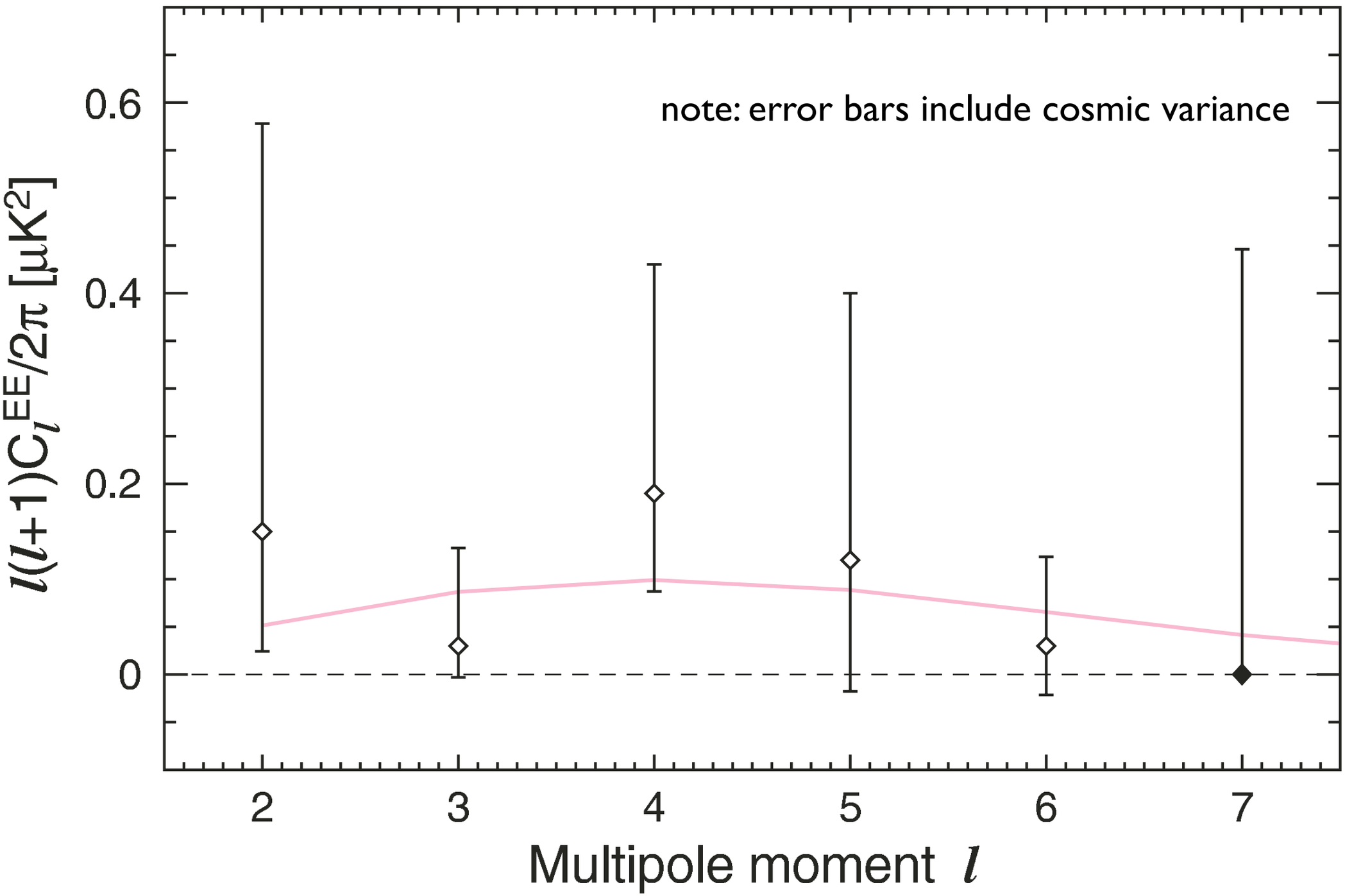
TE spectrum


2.0
1.5
1.0
0.5
0
-0.5
-1.0
$(l+1)C_l^{TE}/2\pi$ [μK^2]
10
100
500
1000
Multipole moment l

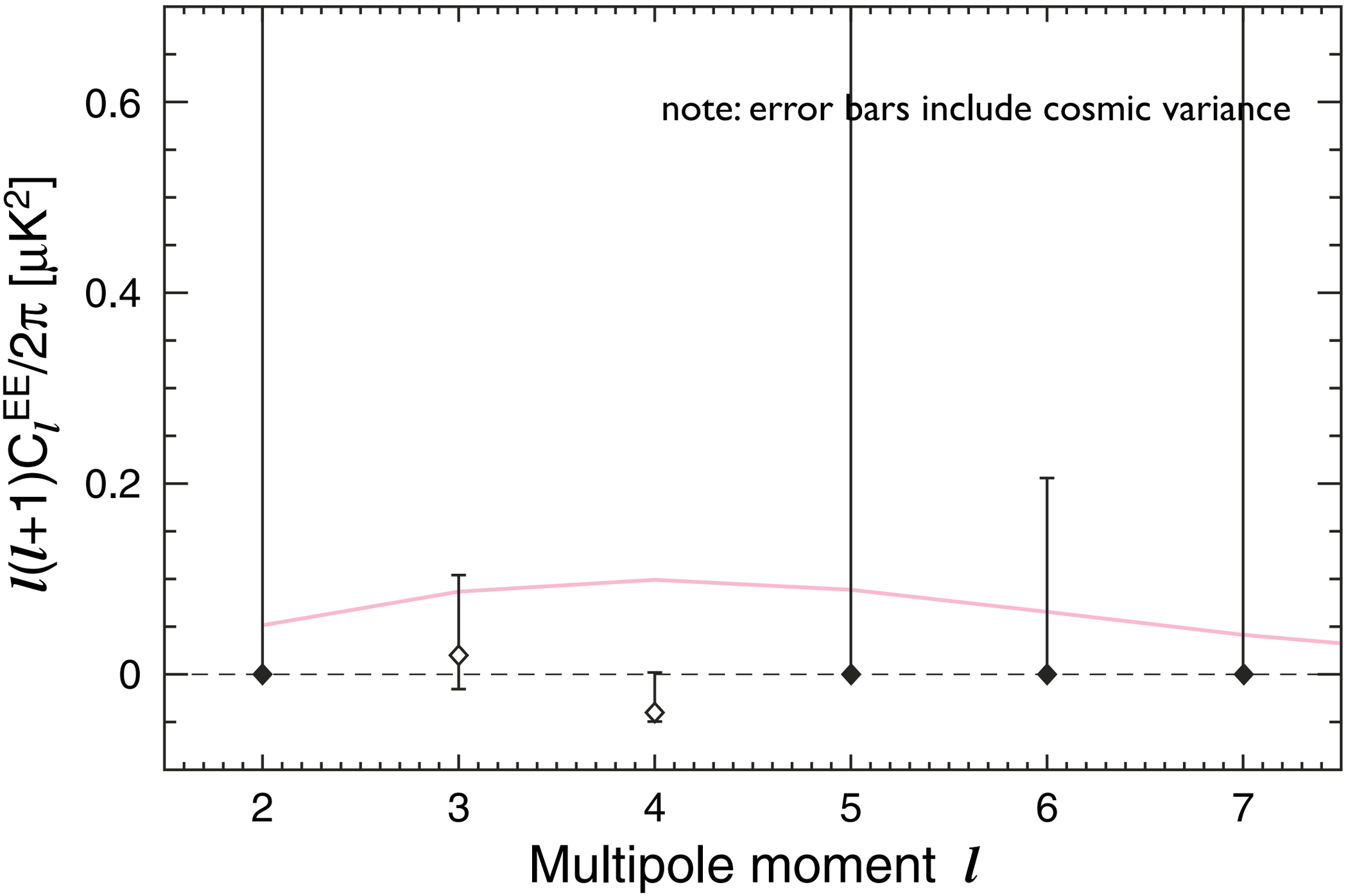
TB spectrum

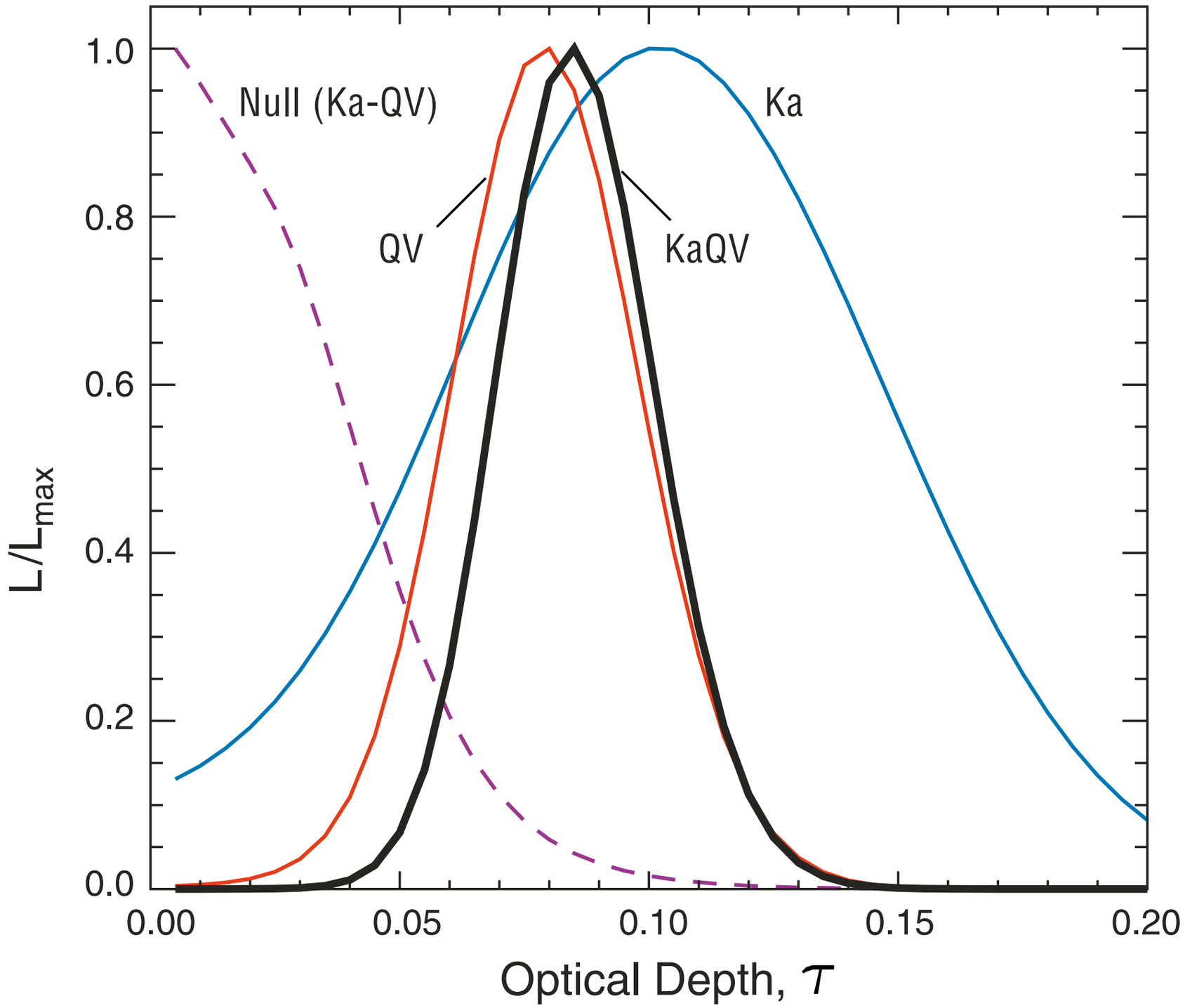

2.0
1.5
1.0
0.5
0
-0.5
-1.0
10
100
500
1000
$(l+1)C_l^{TB}/2\pi$ [μK^2]
Multipole moment l

EE spectrum (KaQV)

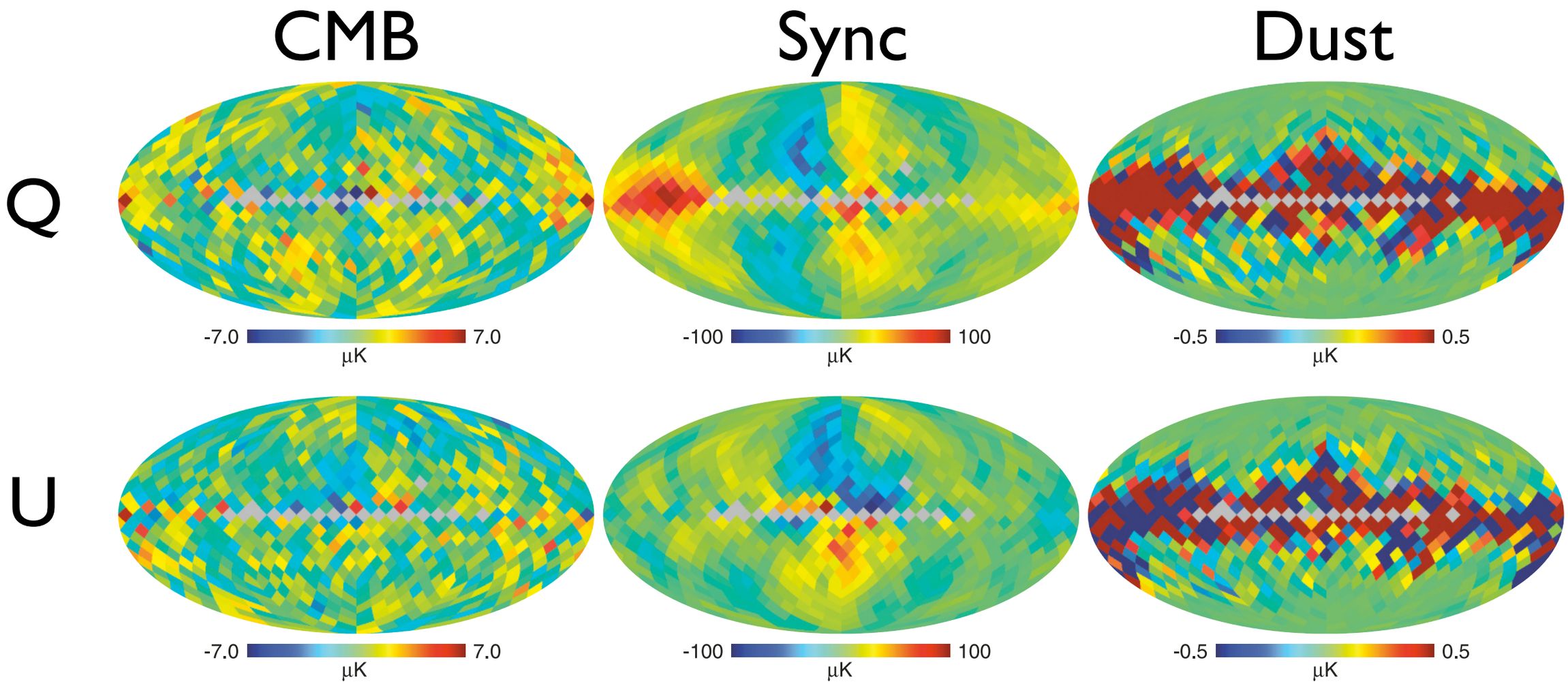


EE spectrum (Ka-QV)



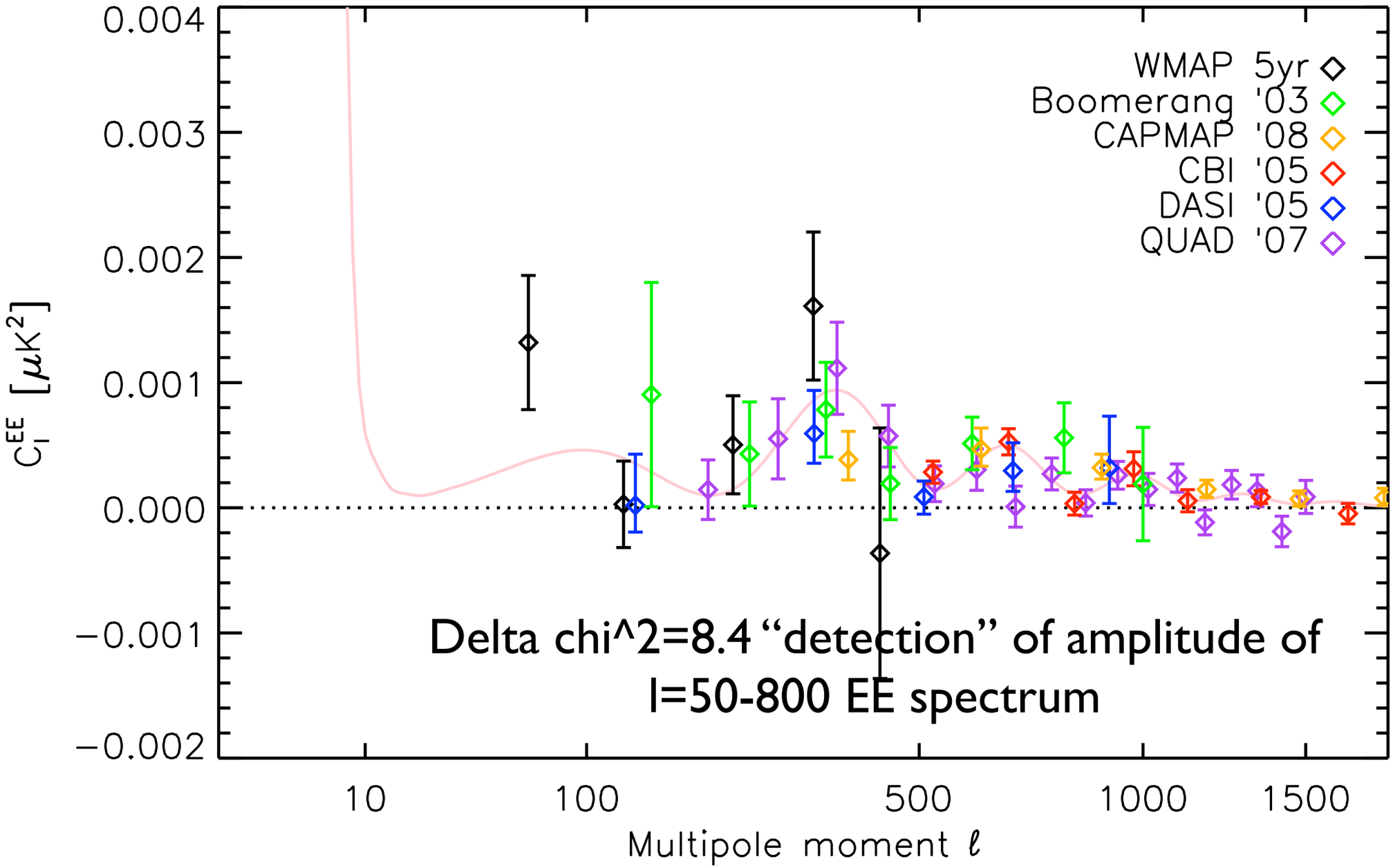

1.0
0.8
0.6
0.4
0.2
0.0
L/L_max
Null (Ka-QV)
Ka
QV
KaQV
0.00
0.05
0.10
0.15
0.20
Optical Depth, τ

Alternate pol cleaning



tau = 0.101+/-0.017

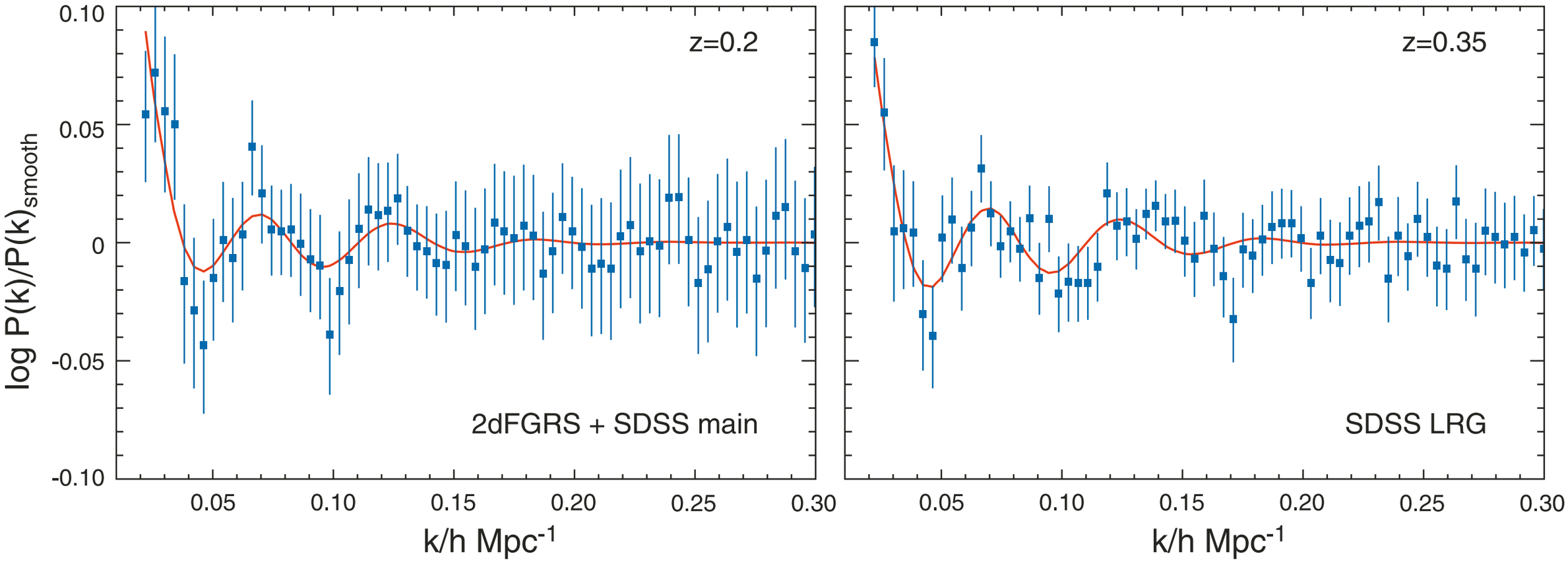
high-l EE spectrum



Cosmology

BAO in Galaxy Distribution

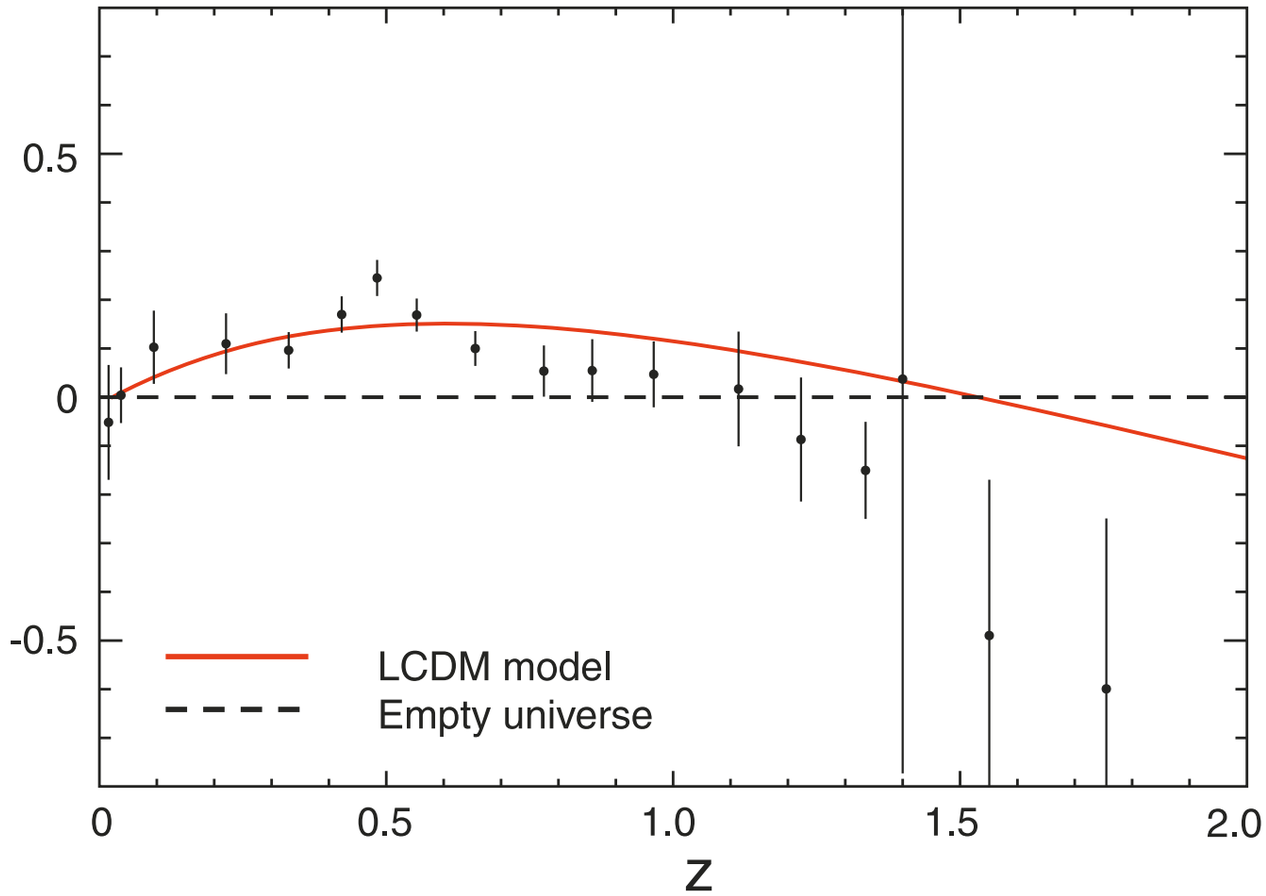
Dunkley et al.



- BAO measured from SDSS (main samples and LRGs) and 2dFGRS (Percival et al. 2007)
- Just like the acoustic oscillations in CMB, the galaxy BAOs can be used to measure the **absolute** distances

Dunkley et al.

Type Ia Supernova (SN) Data



From these measurements, we get the **relative** luminosity distances between Type Ia SNe. Since we marginalize over the absolute magnitude, the current SN data are insensitive to the absolute distances.

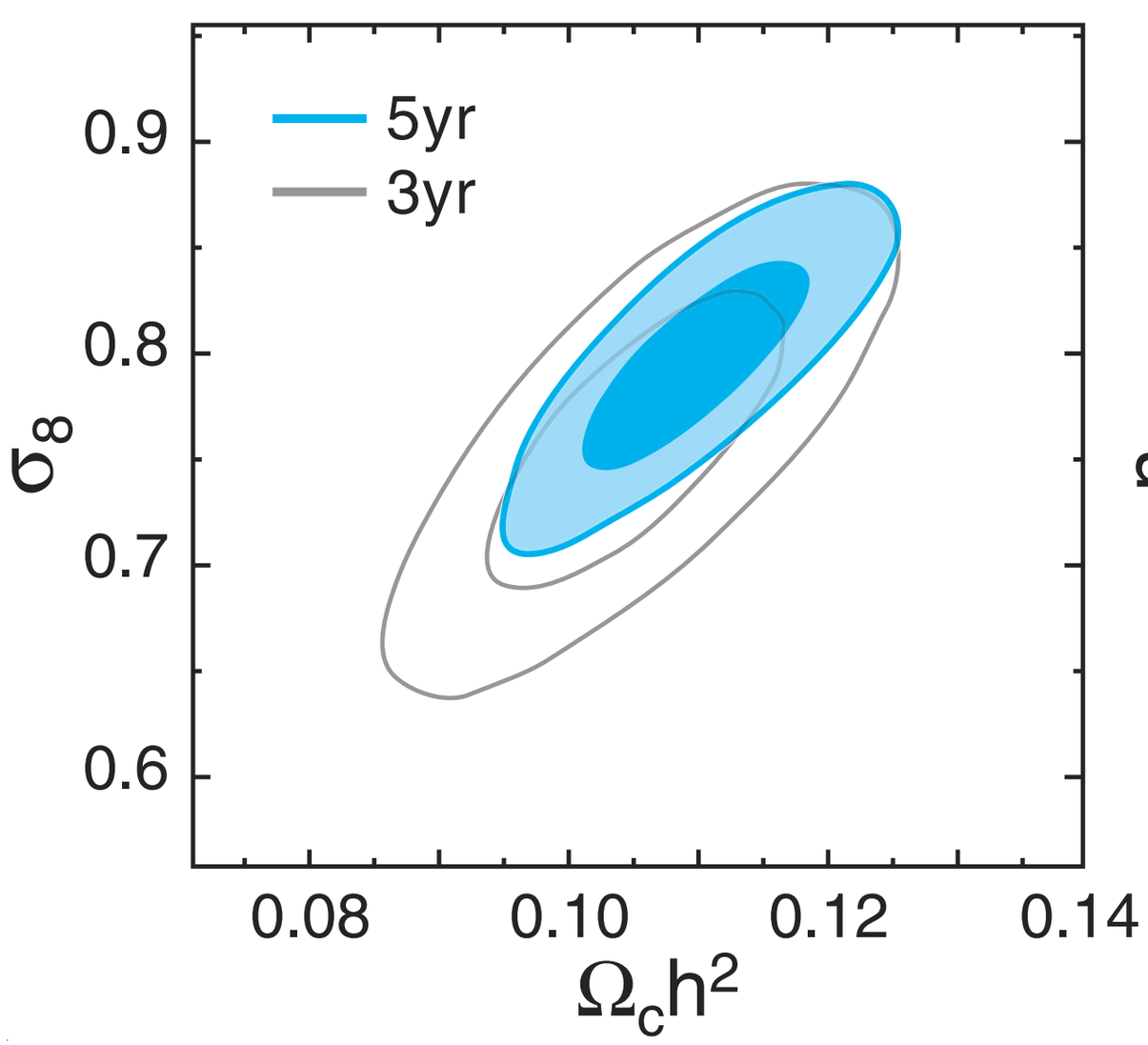
- Riess et al. (2004; 2006) HST data
- Astier et al. (2006) Supernova Legacy Survey (SNLS)
- Wood-Vasey et al. (2007) ESSENCE data

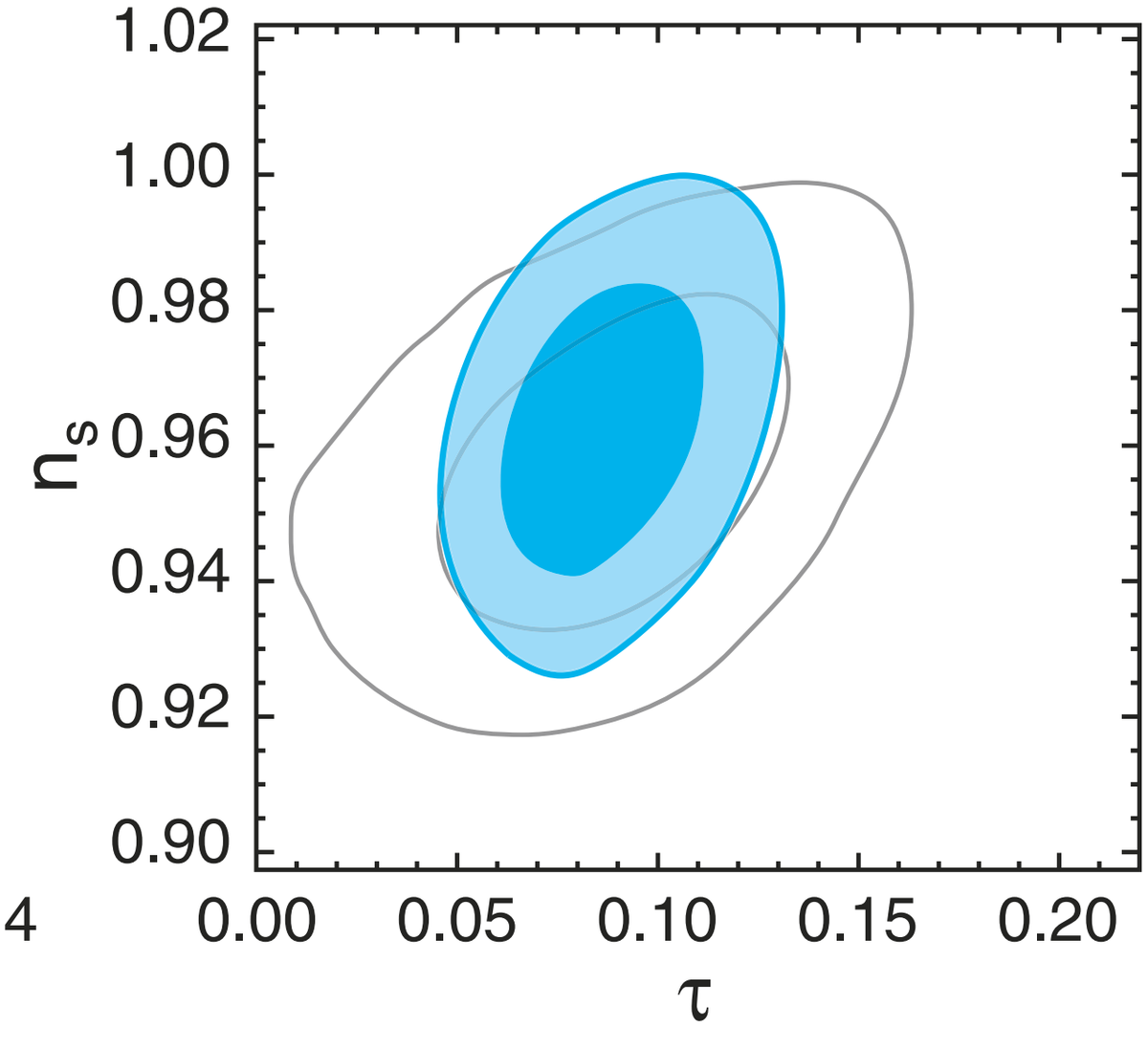
LCDM still a good fit

Parameter	3 Year Mean	5 Year Mean	5 Year Max Like
$100\Omega_b h^2$	2.229 ± 0.073	2.273 ± 0.062	2.27
$\Omega_c h^2$	0.1054 ± 0.0078	0.1099 ± 0.0062	0.108
Ω_Λ	0.759 ± 0.034	0.742 ± 0.030	0.751
n_s	0.958 ± 0.016	$0.963^{+0.014}_{-0.015}$	0.961
τ	0.089 ± 0.030	0.087 ± 0.017	0.089
$\Delta^2_{\mathcal{R}}$	$(2.35 \pm 0.13) \times 10^{-9}$	$(2.41 \pm 0.11) \times 10^{-9}$	2.41×10^{-9}
σ_8	0.761 ± 0.049	0.796 ± 0.036	0.787
Ω_m	0.241 ± 0.034	0.258 ± 0.030	0.249
$\Omega_m h^2$	0.128 ± 0.008	0.1326 ± 0.0063	0.131
H_0	$73.2^{+3.1}_{-3.2}$	$71.9^{+2.6}_{-2.7}$	72.4
$z_{\rm reion}$	11.0 ± 2.6	11.0 ± 1.4	11.2
t_0	13.73 ± 0.16	13.69 ± 0.13	13.7

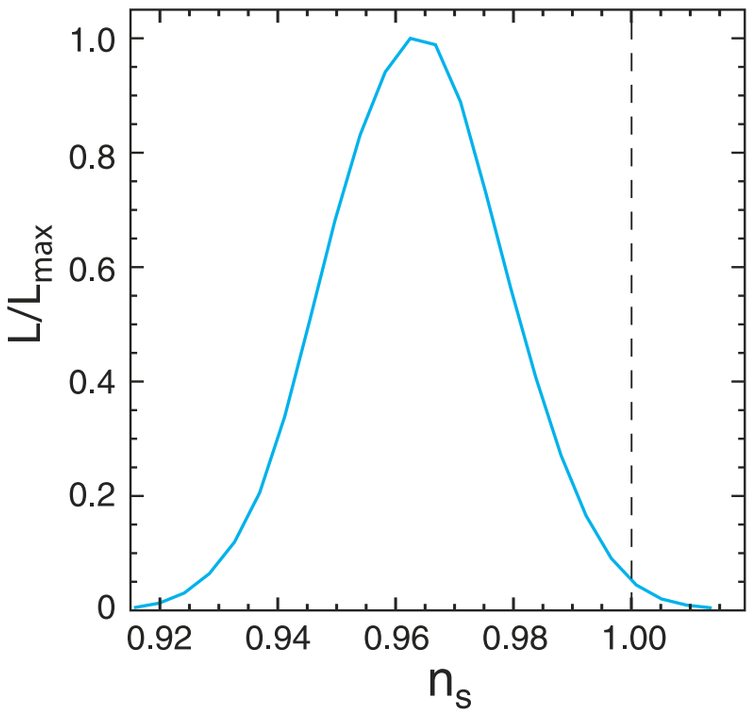
Table 2: ΛCDM model parameters and 68% confidence intervals from the five-year *WMAP* data alone. The three-year values are shown for comparison. For best estimates of parameters, the marginalized 'Mean' values should be used. The 'Max Like' values correspond to the single model giving the highest likelihood.

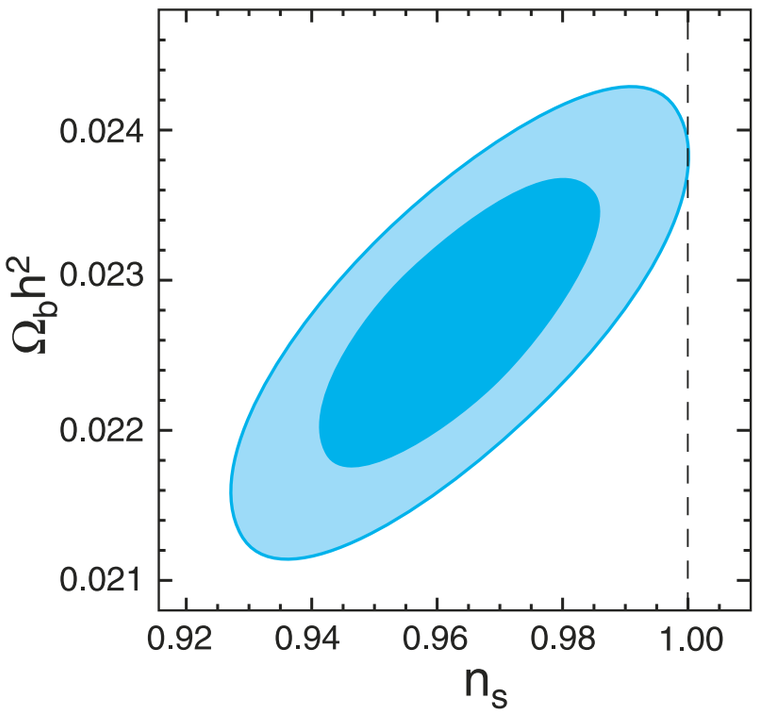
Parameters still improving...

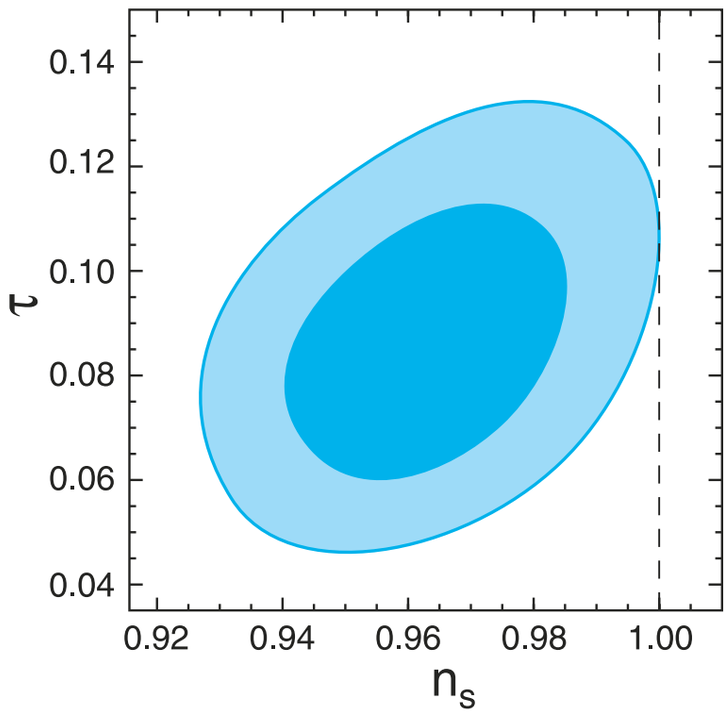




tau-ns degeneracy now largely broken...

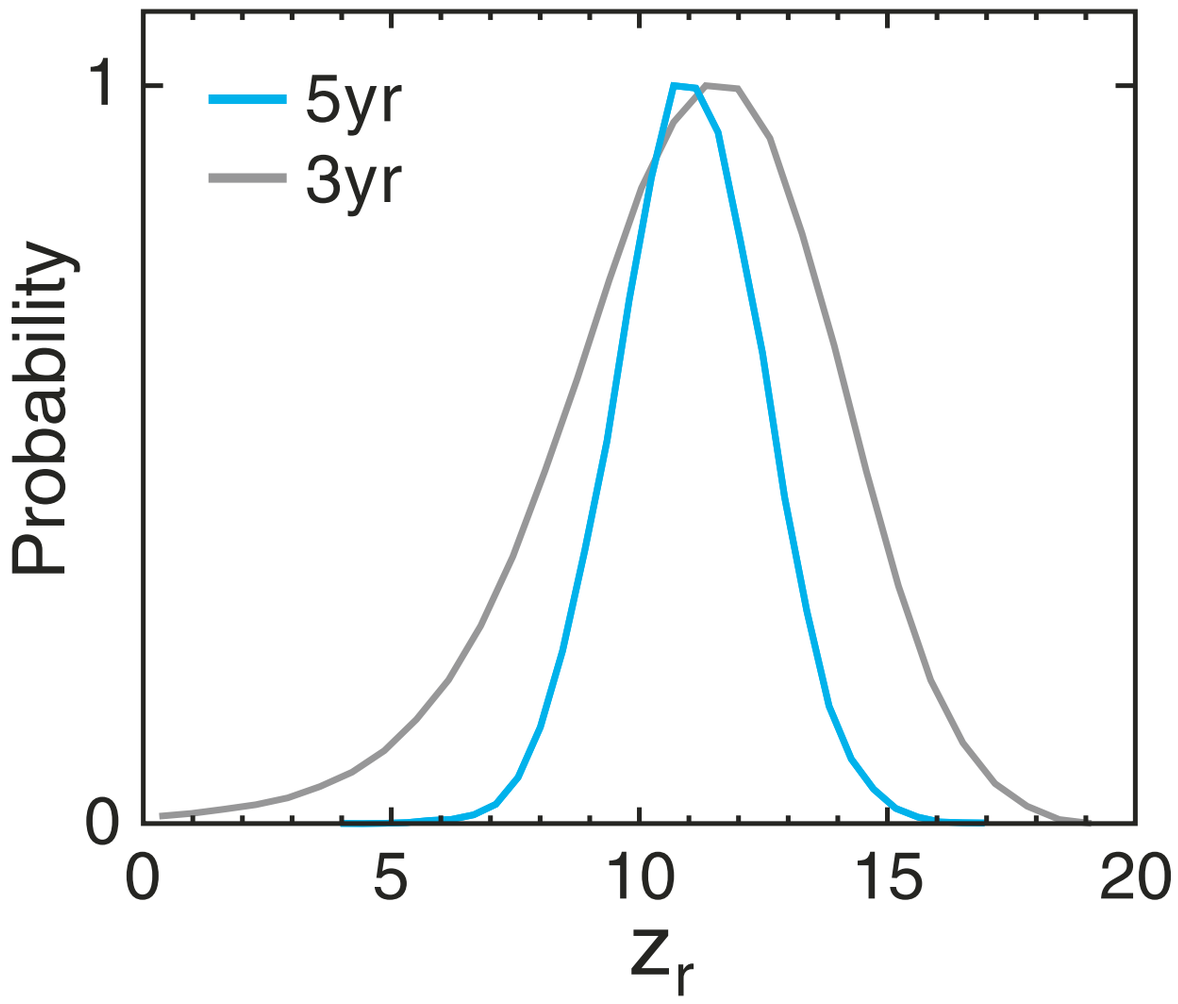


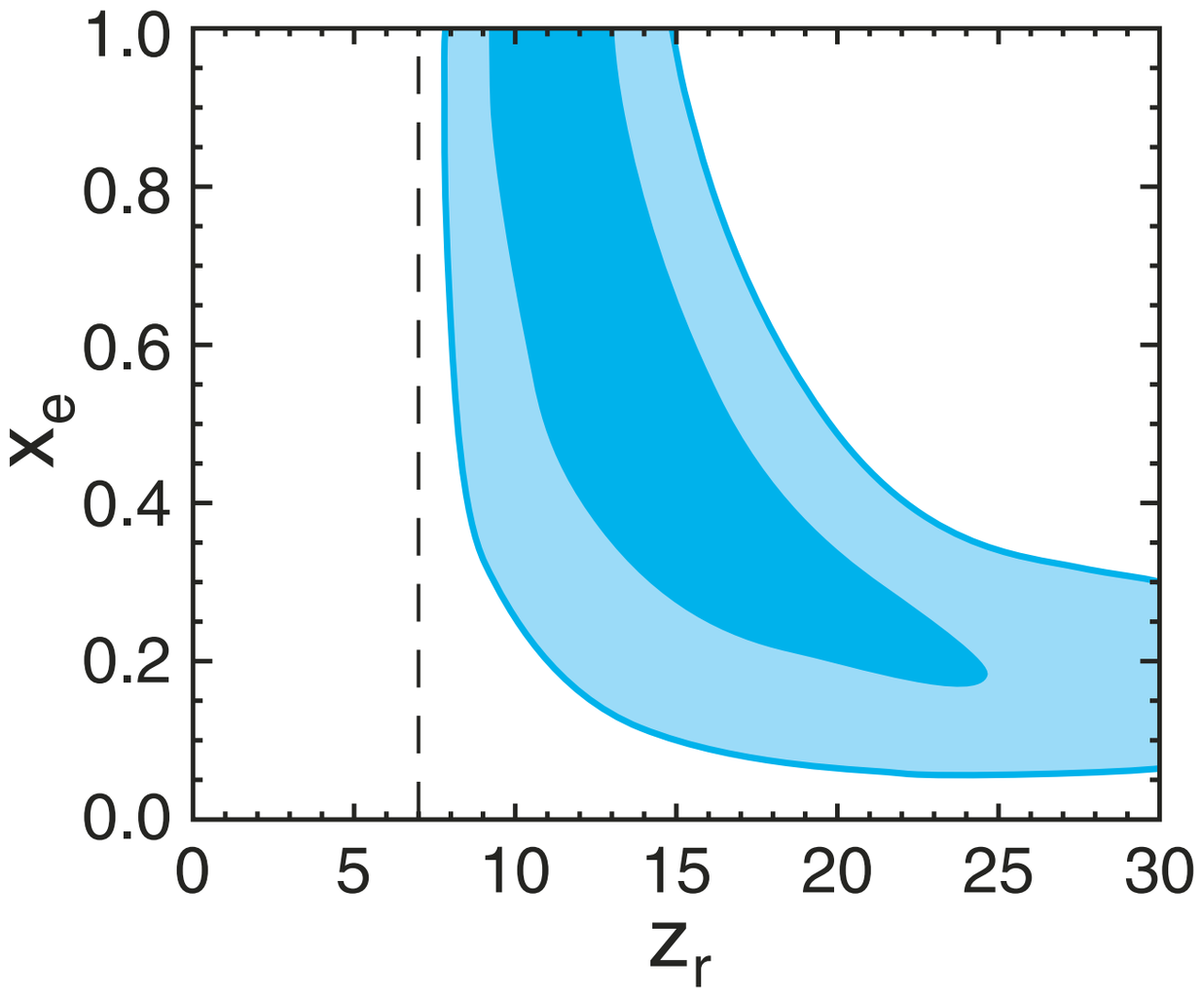




...while wb-ns is the primary degeneracy

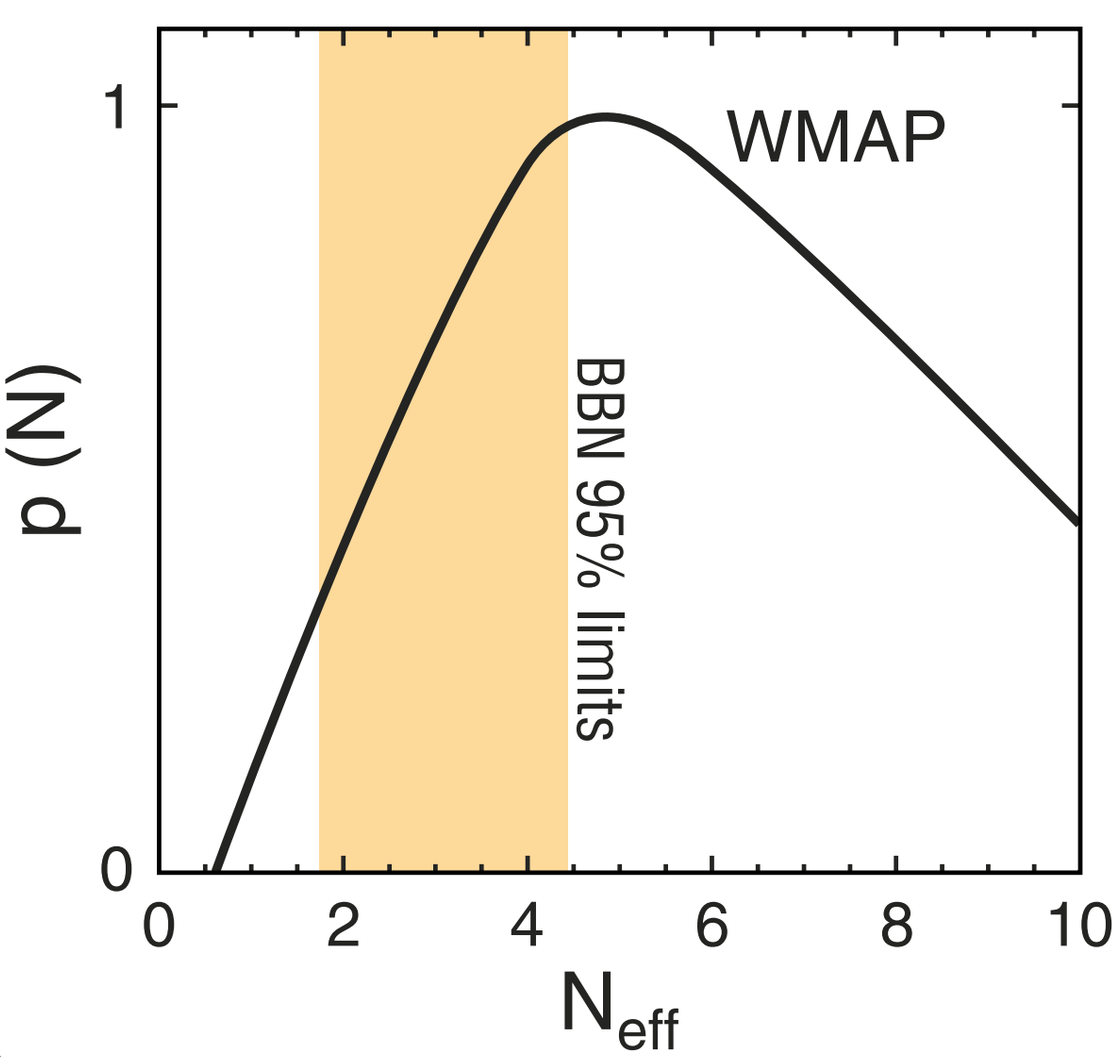
Reionization

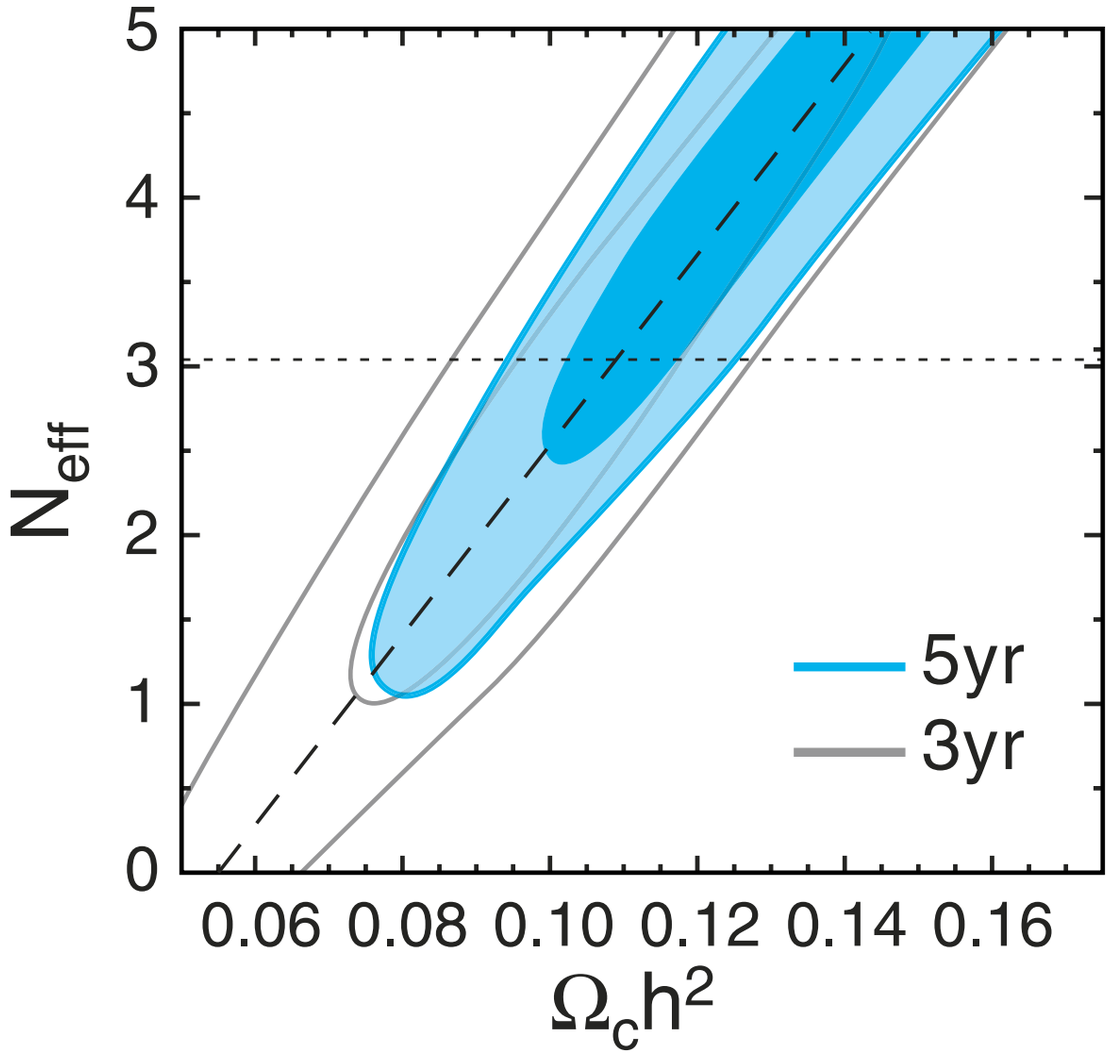




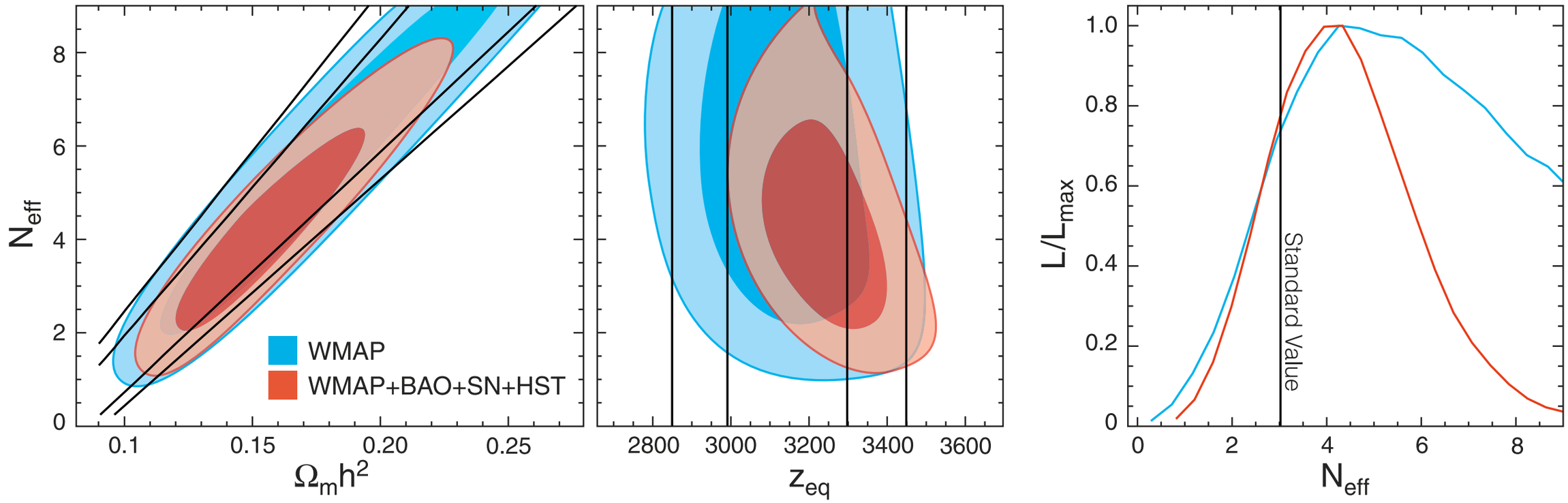
zreion > 8.2 (95%CL); >6 at 3.5sigma

Neutrino species



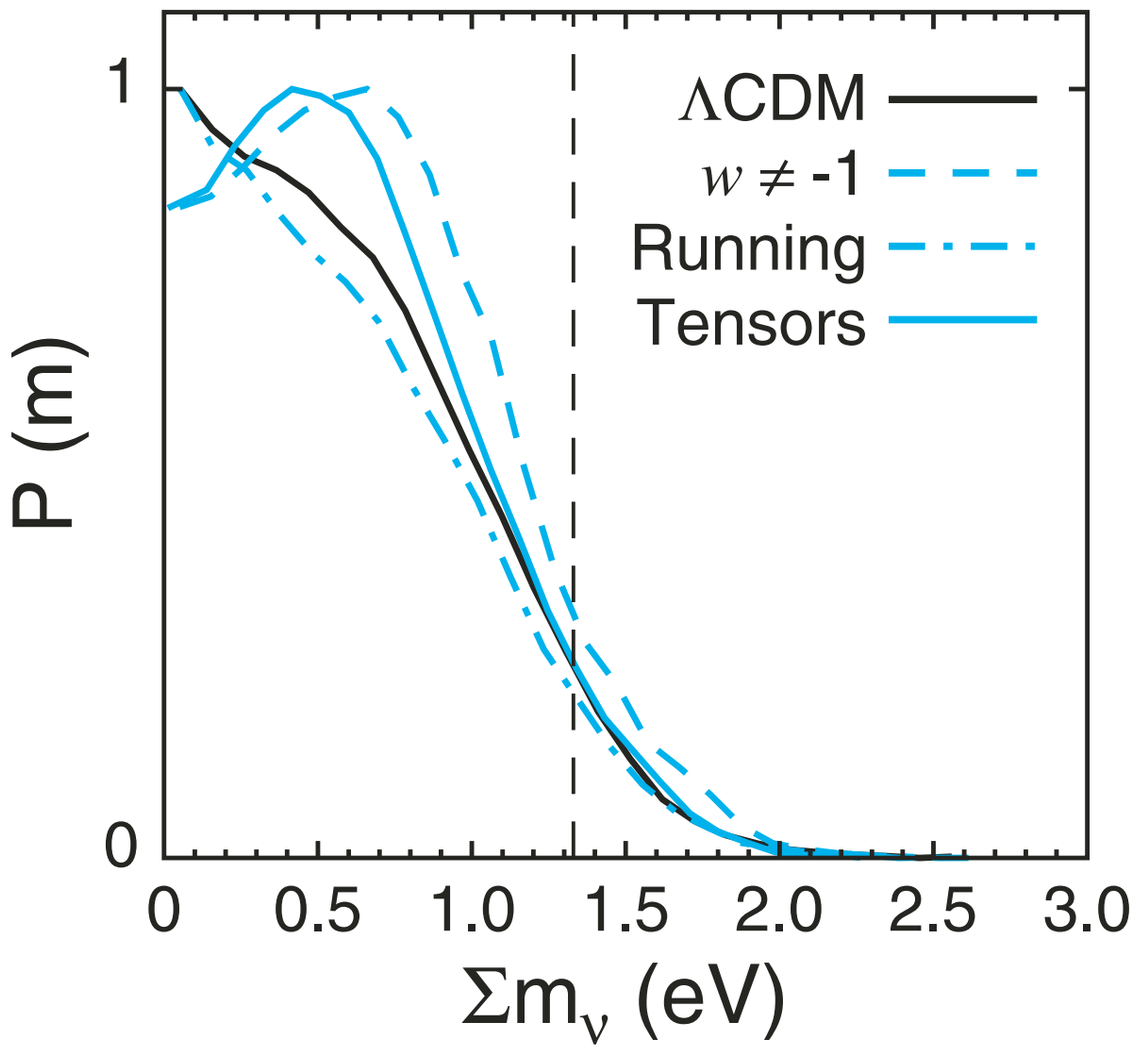


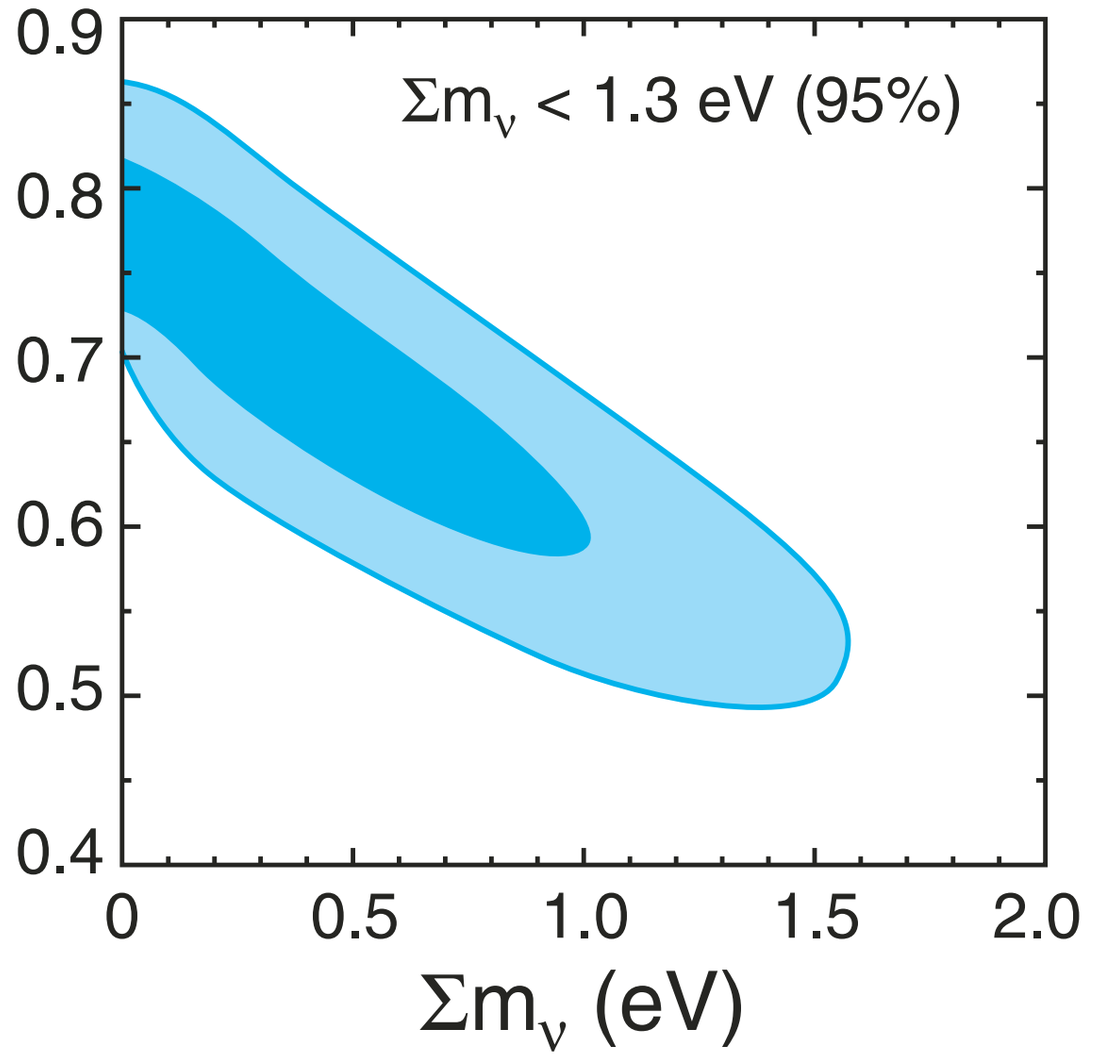
WMAP: Neff > 2.3 (95%CL), assuming prior Neff<10

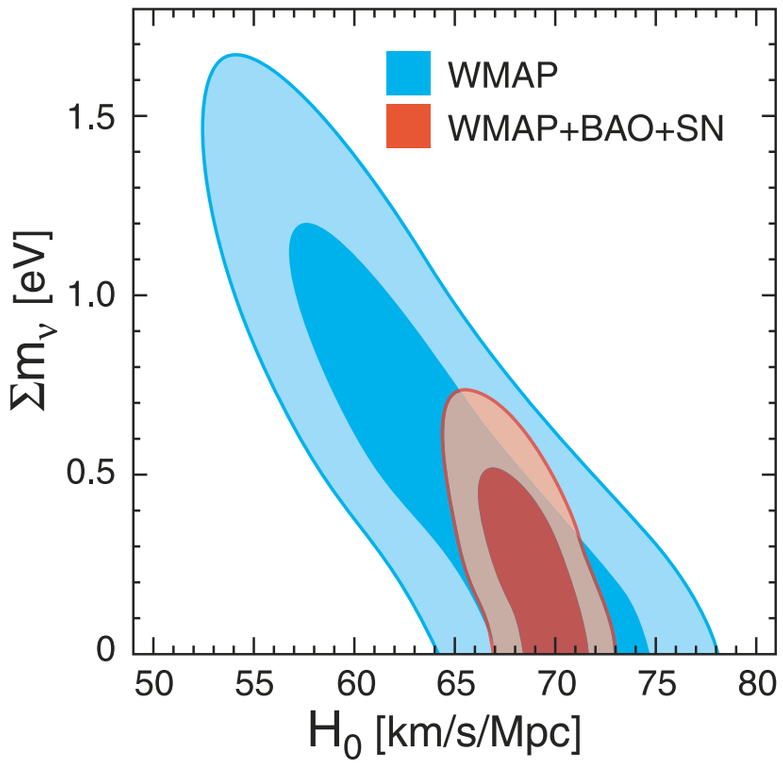


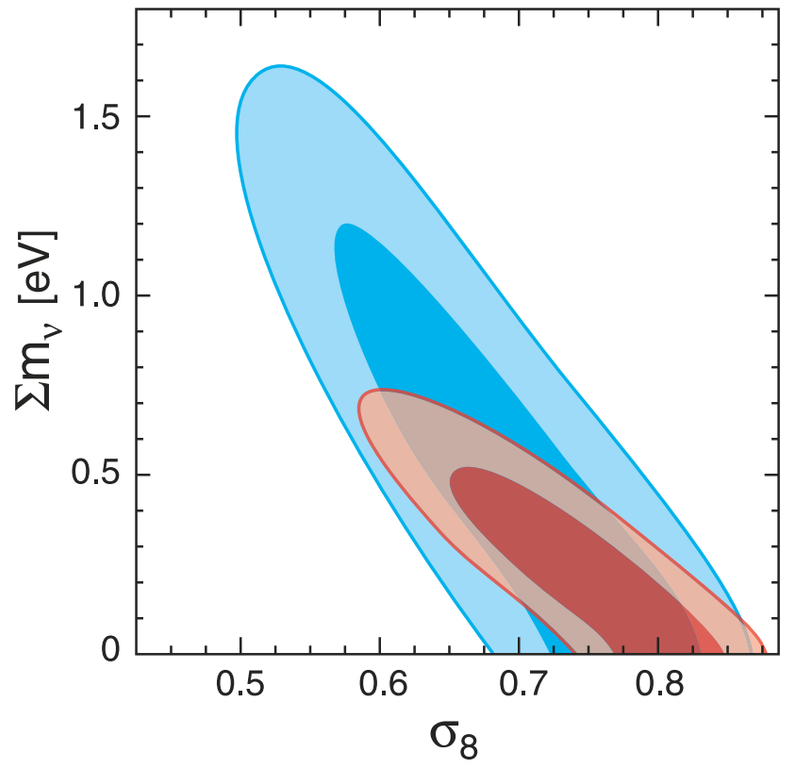
WMAP+BAO+SN: Neff = 4.4 +/- 1.5

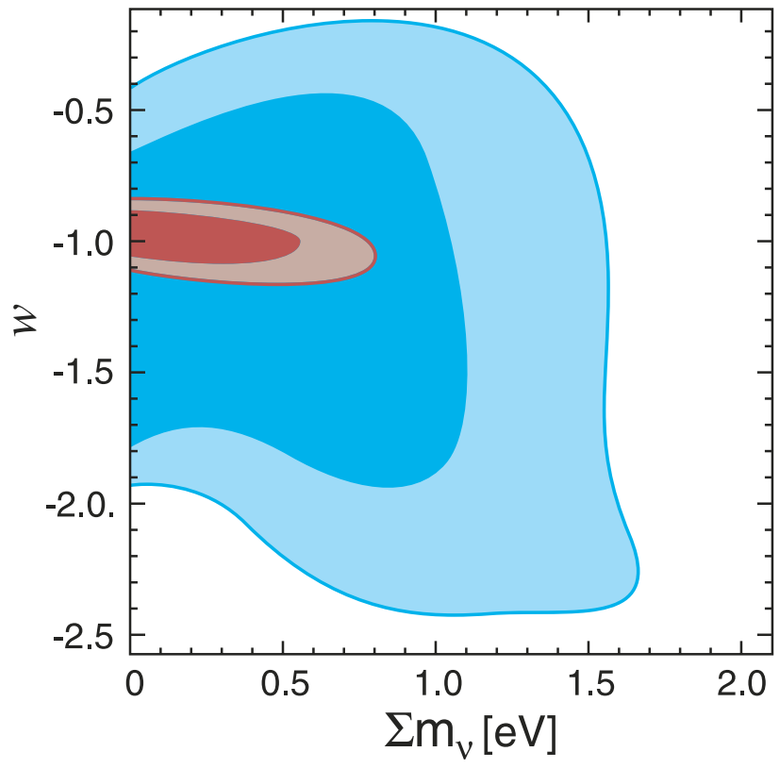
Massive neutrinos









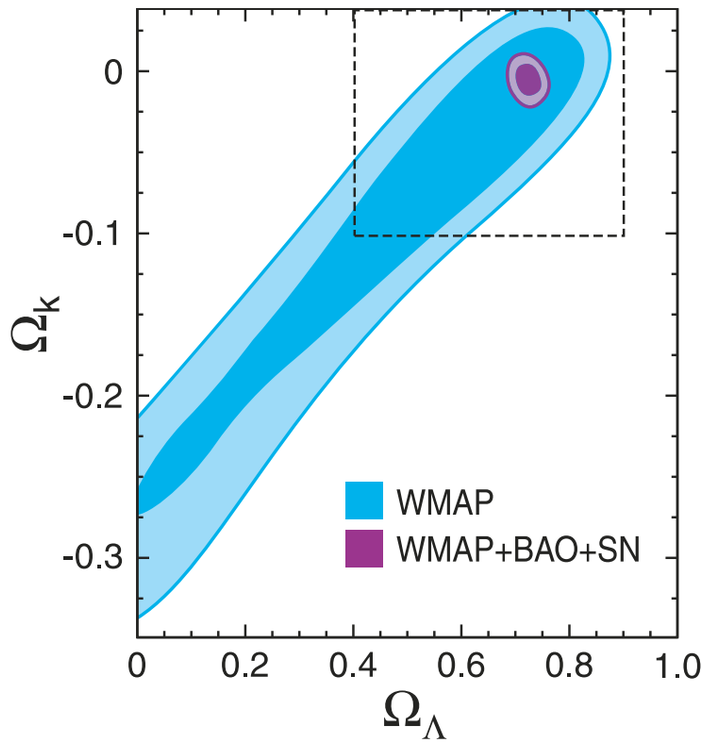


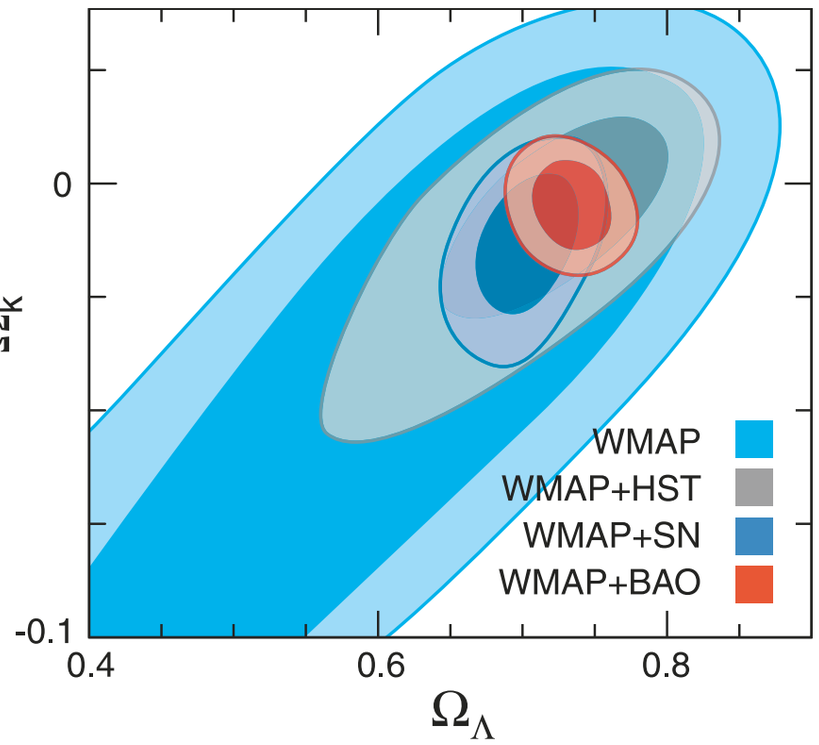
WMAP+BAO+SN: sum mnu < 0.61 eV

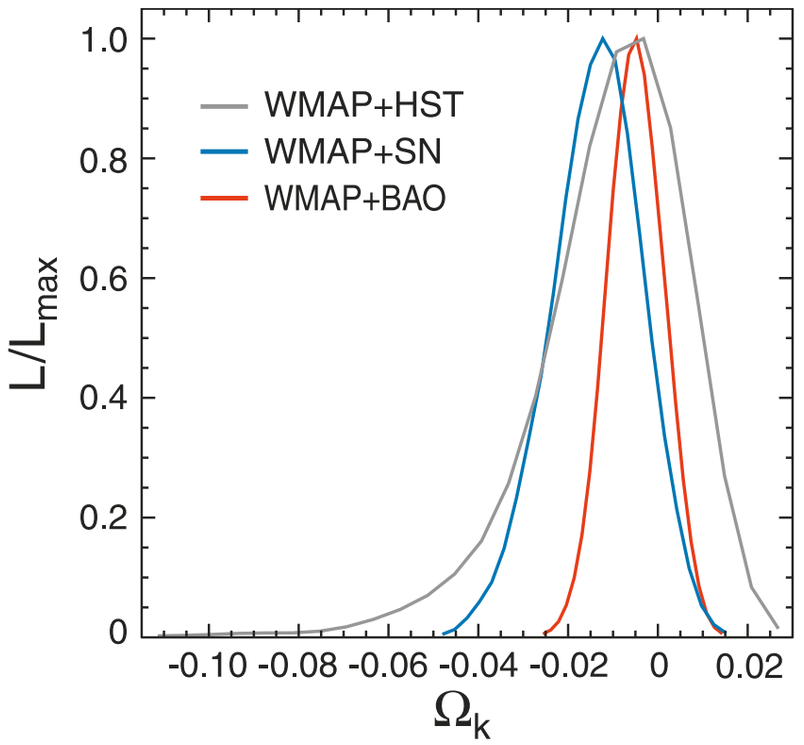
Inflation

As far as we can tell,
the universe...

is flat, ...



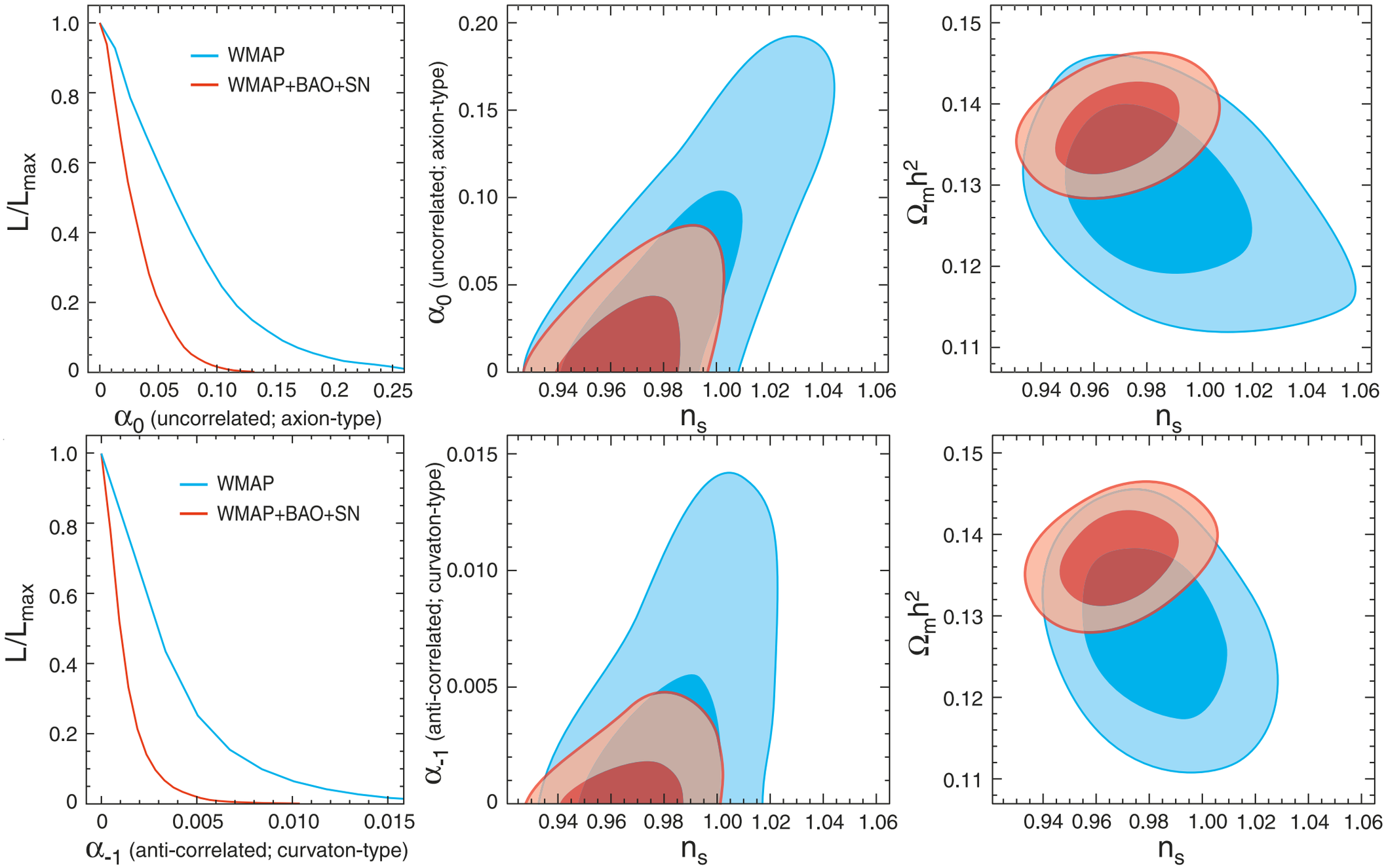




WMAP+BAO+SN:

-0.0181 < Omegak < 0.0071 (95%CL)

primordial fluctuations are adiabatic, ...

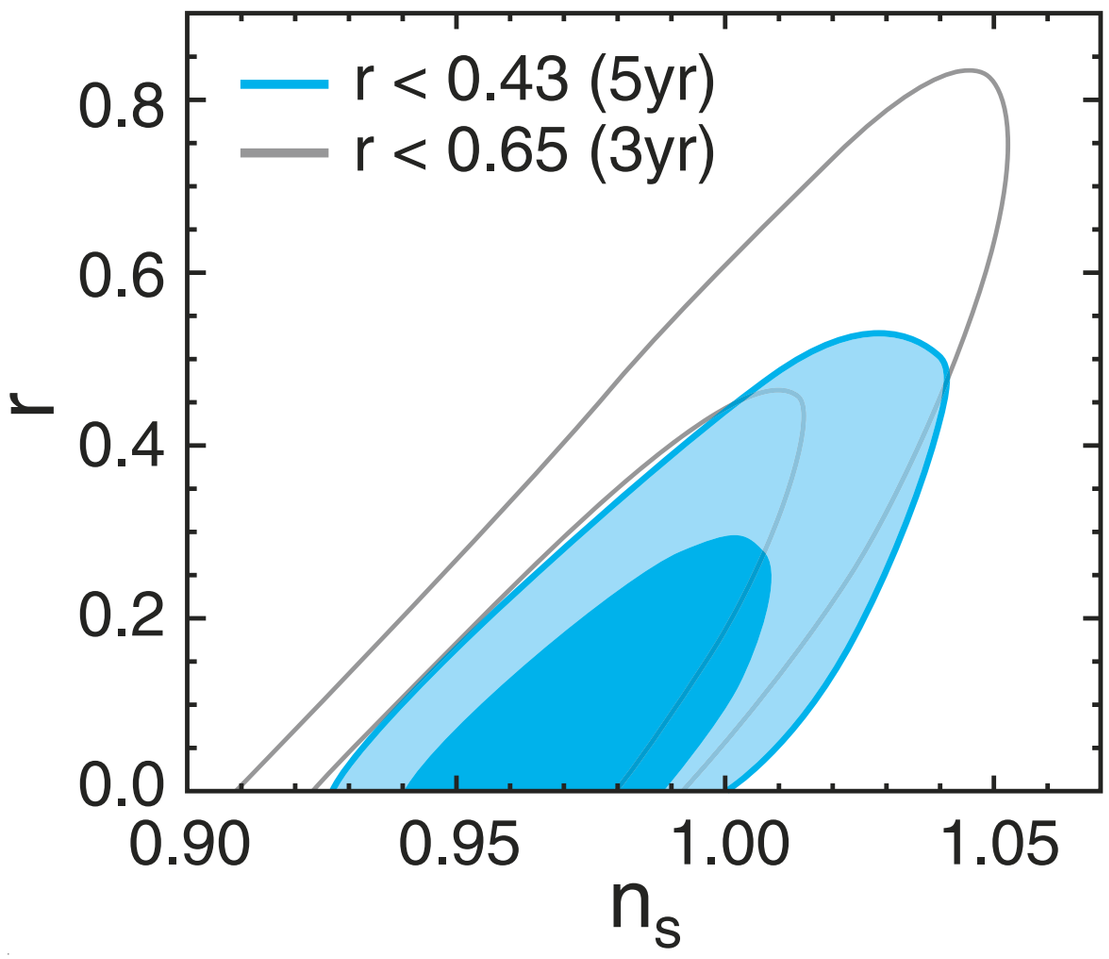


spectrum is nearly scale invariant, ...

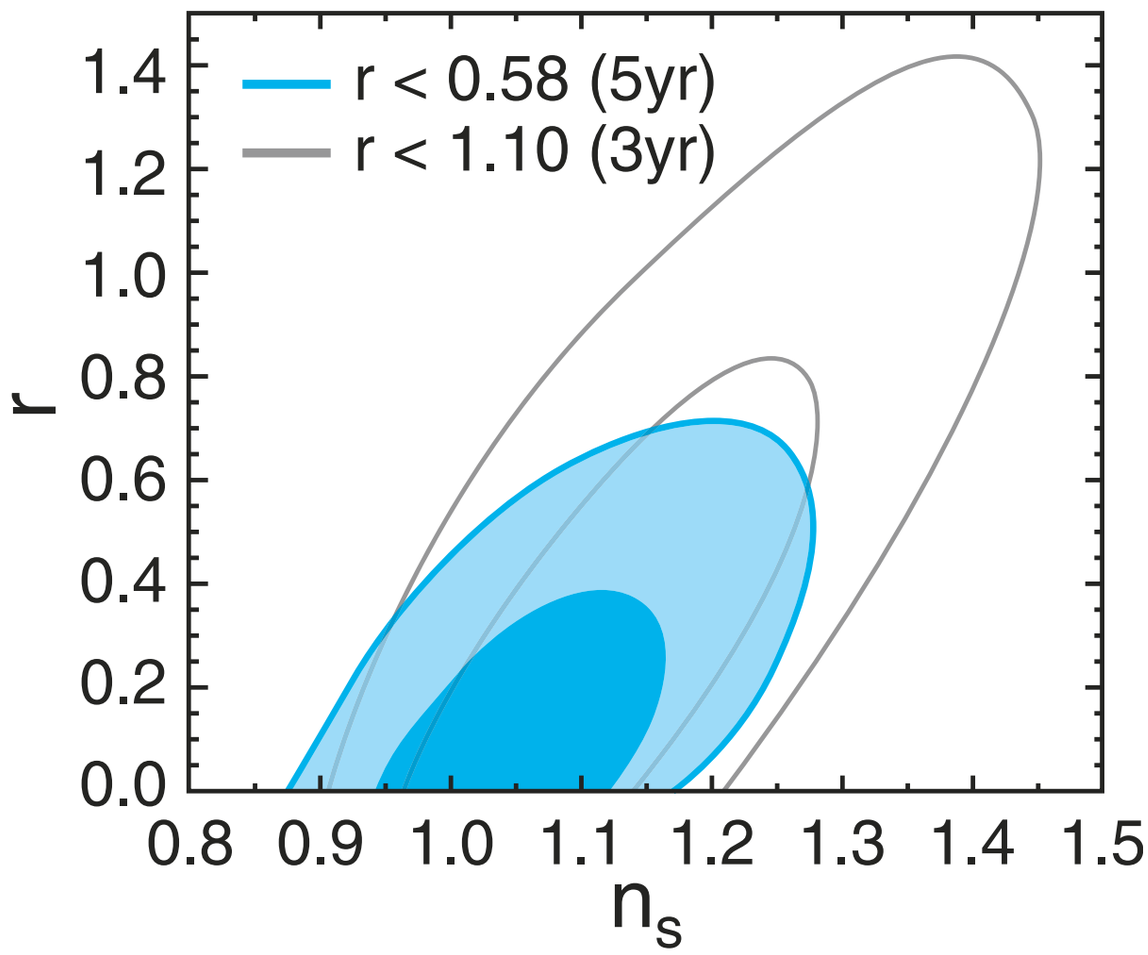
- WMAP: n_s = 0.963 +0.014 -0.015
- WMAP+BAO+SN: n_s = 0.960 +0.014 -0.013
- No evidence for running ($dn_s/d\ln k$):
  - WMAP: -0.037 +/- 0.028
  - WMAP+BAO+SN: -0.032 +0.021 -0.020

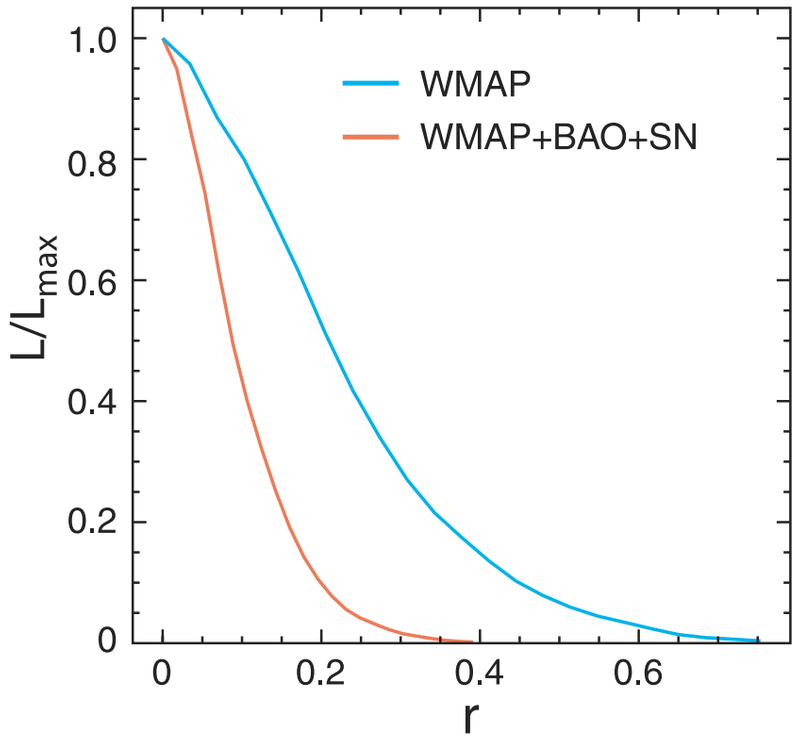
no evidence for tensor modes, ...

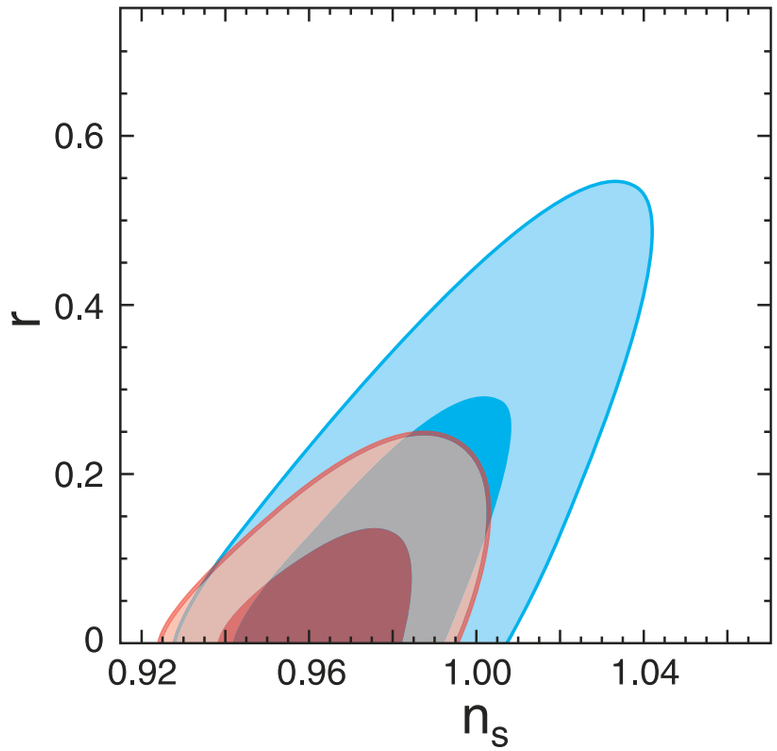
no running

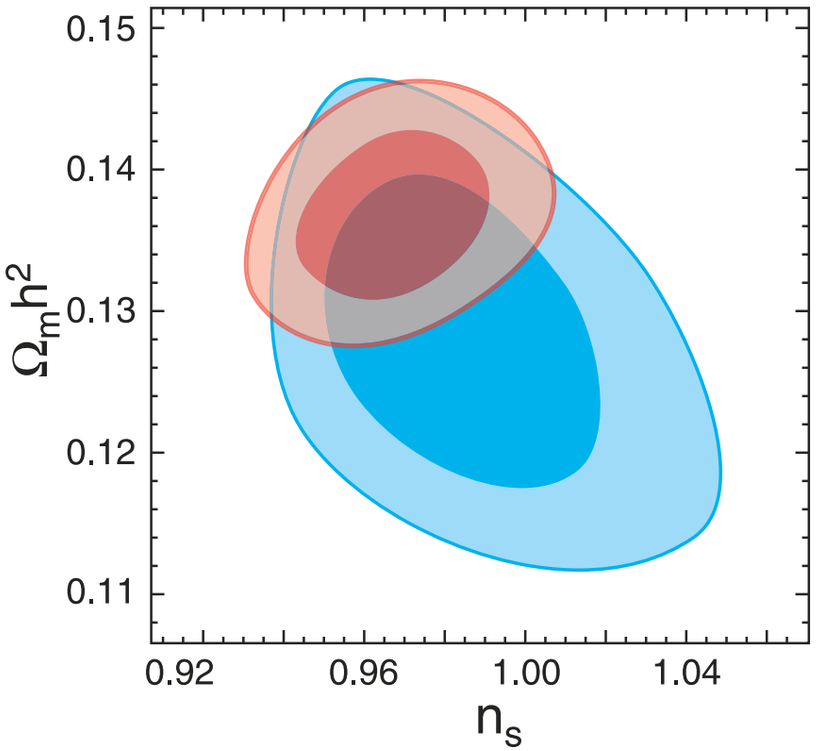


w/ running





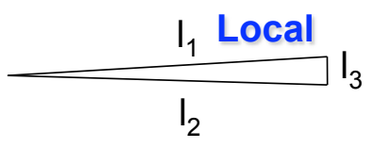


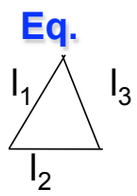


r < 0.2 for WMAP+BAO+SN

and fluctuations are Gaussian.

- Non-zero bispectrum means the detection of non-Gaussianity. It's always easy to look for deviations from zero!
- There are many triangles to look for, but...
  - Will focus on two classes
  - "Squeezed" parameterized by f_{NL}^{local}
  - "Equilateral" parameterized by f_{NL}^{equil}

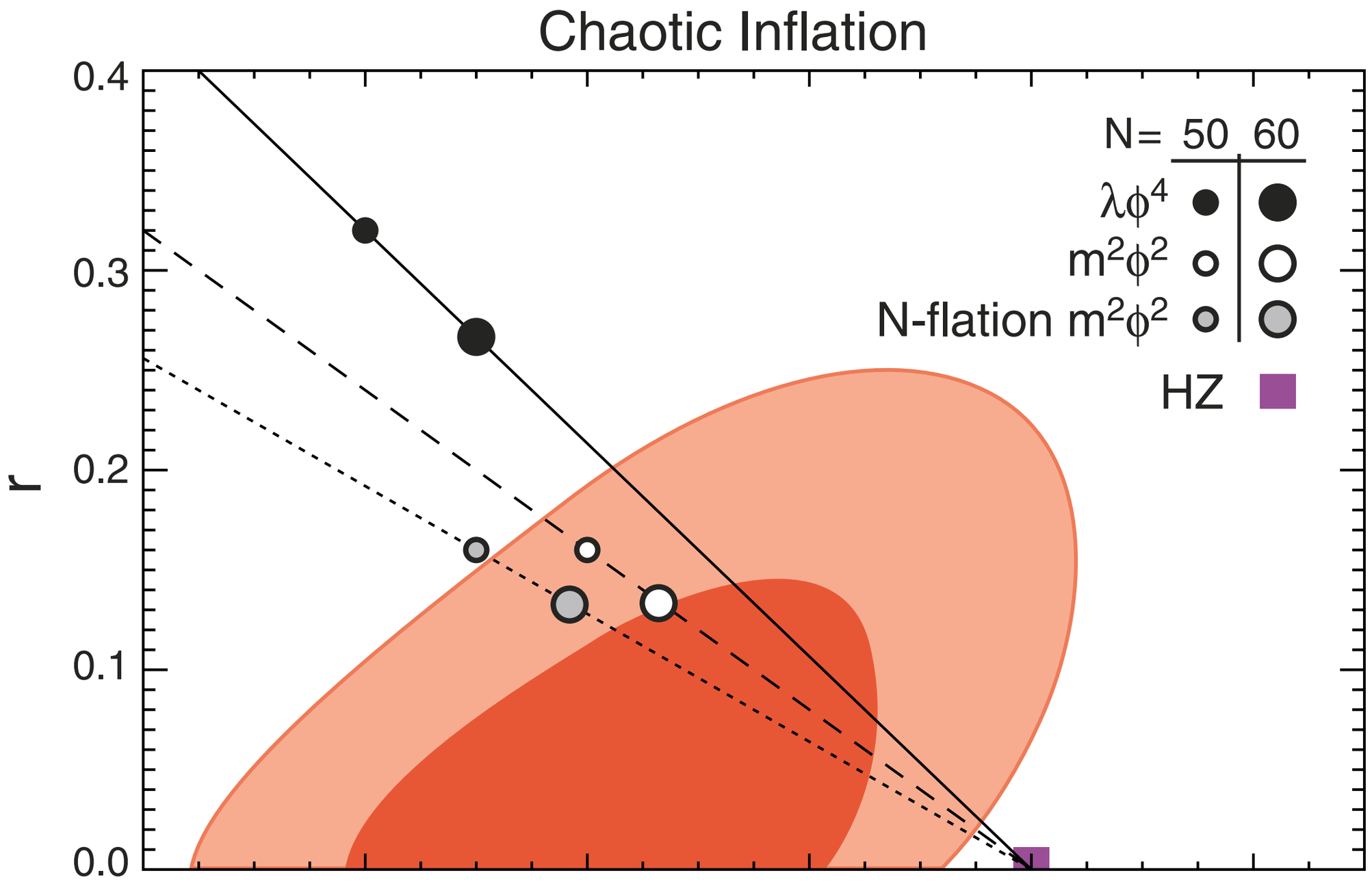


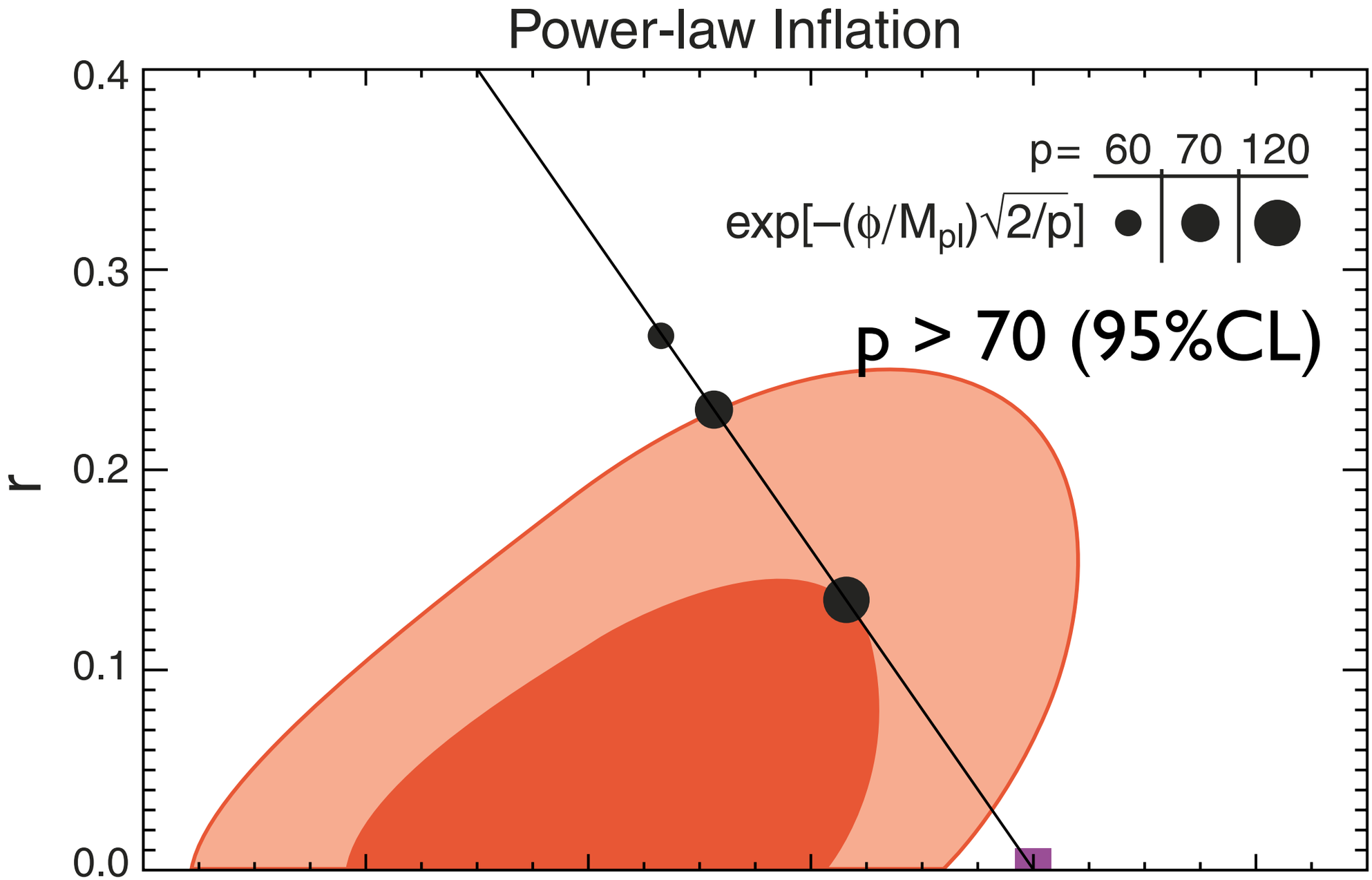


No detection of f_{NL}

- Yadav & Wandelt found $27 < f_{NL} < 147$ (95%CL) using the 3yr maps, Kp0 mask, and lmax = 750.
- With the Kp0 mask and the 5yr maps, we find $6.5 < f_{NL} < 110.5$ for lmax=500, even closer to zero when lmax=700.
- With the KQ75 mask, we find $-9 < f_{NL} < 111$

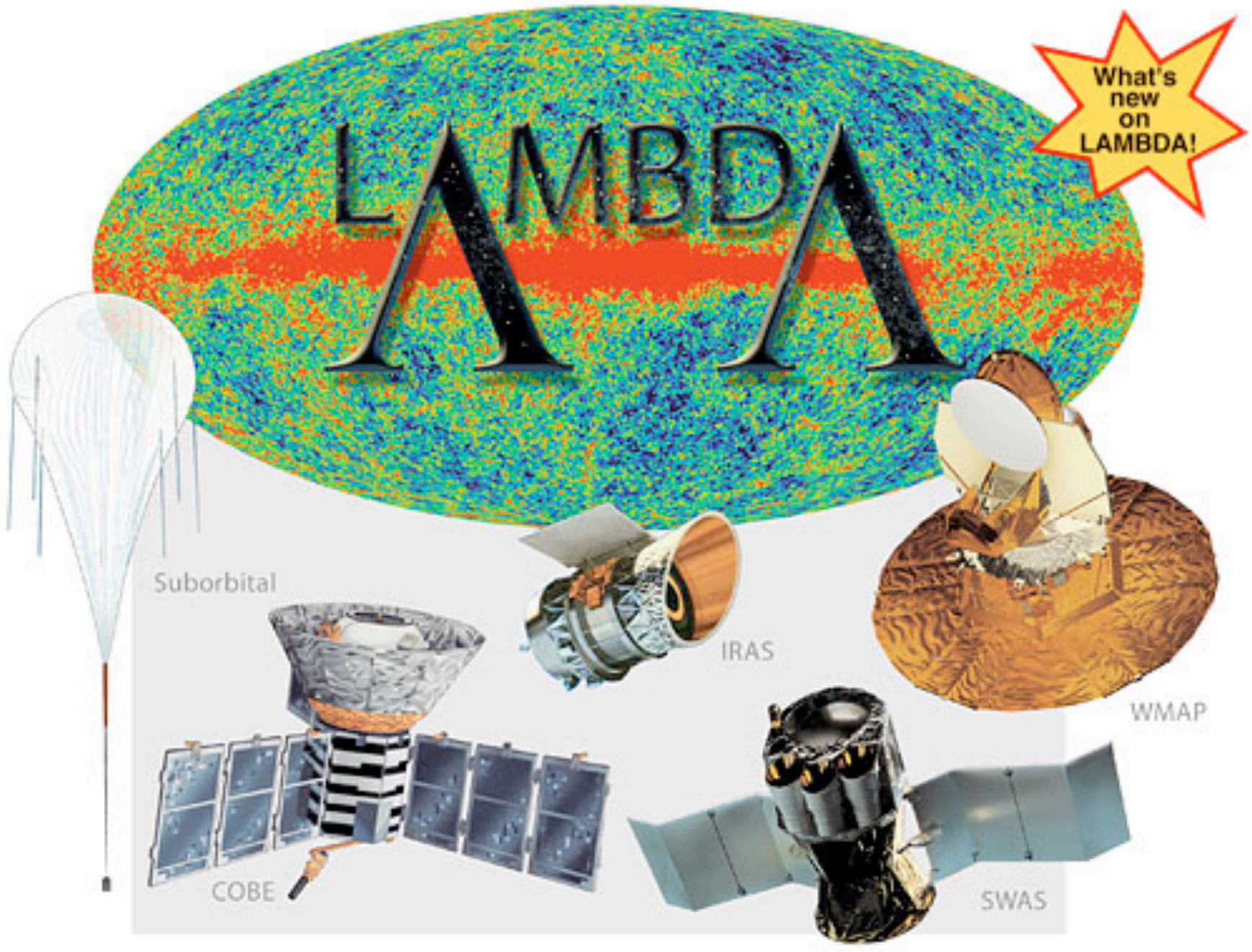
Inflationary models




Power-law Inflation
0.4
0.3
0.2
0.1
0.0
r
p= 60 70 120
exp[–(ϕ/M_pl)√2/p]
p > 70 (95%CL)

Summary

- Standard LCDM model still an excellent fit to the WMAP5 data. No evidence for exotic physics... yet.



http://lambda.gsfc.nasa.gov/