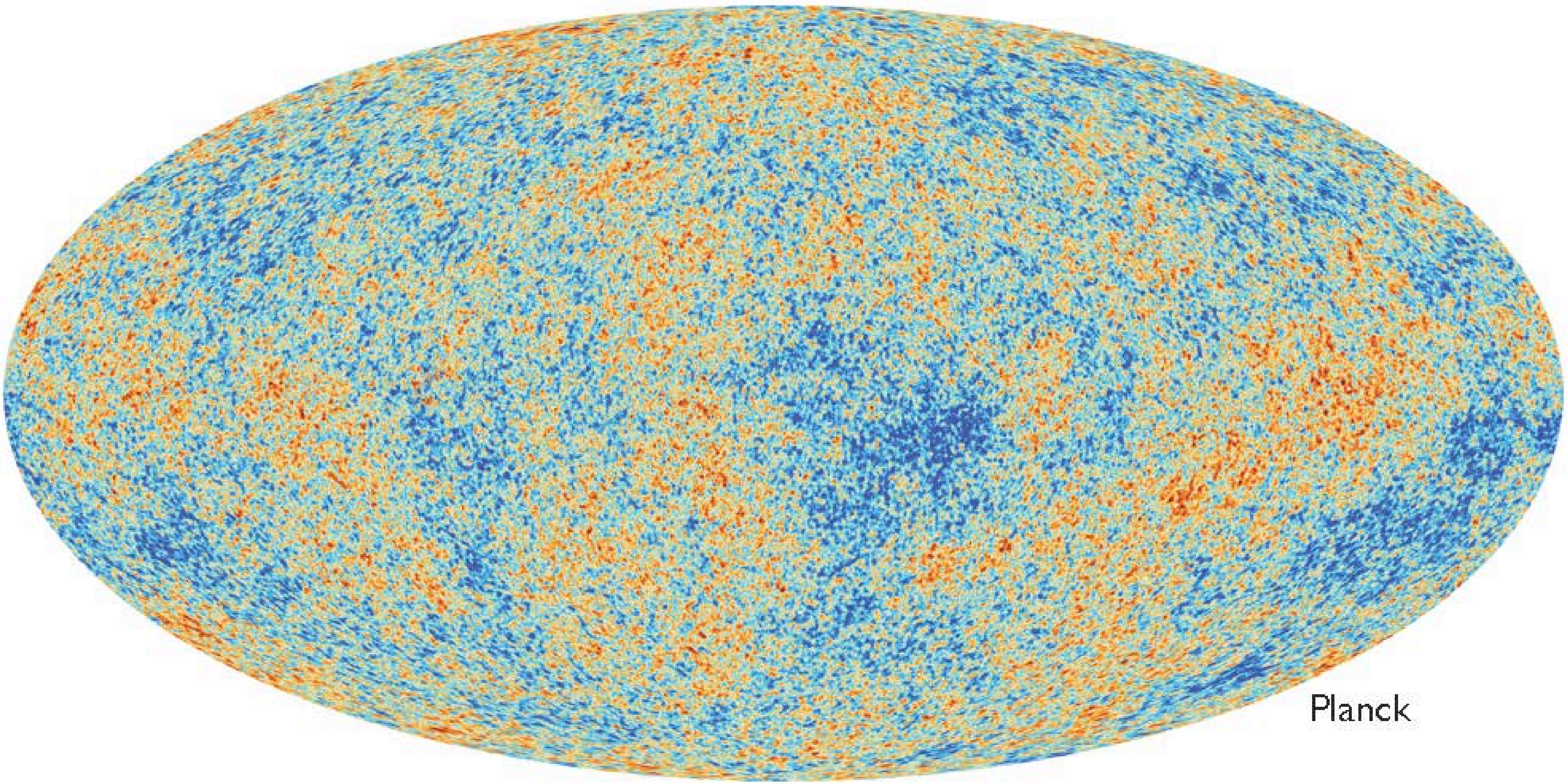
The CMB after 50 years



Planck

June 2014

Reaching a new threshold

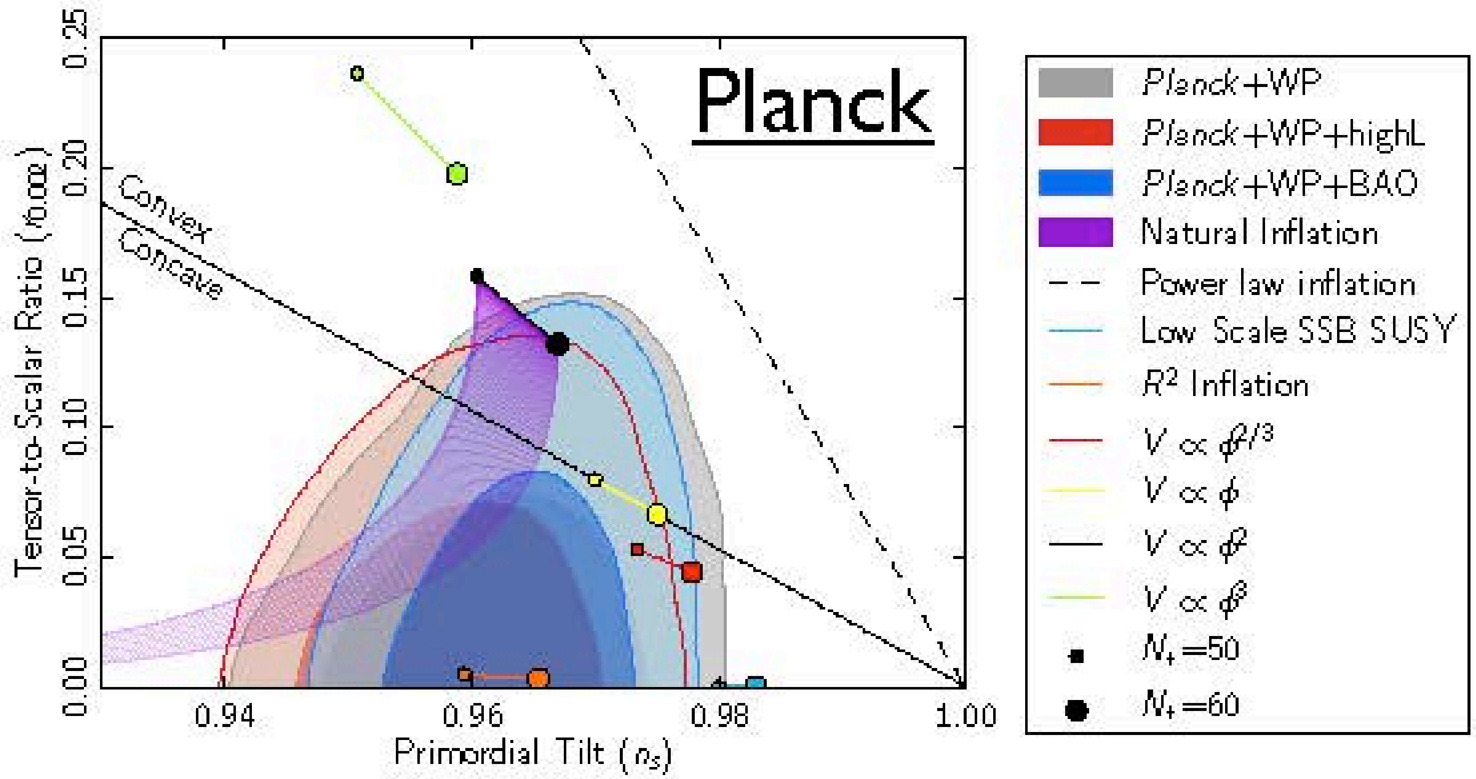
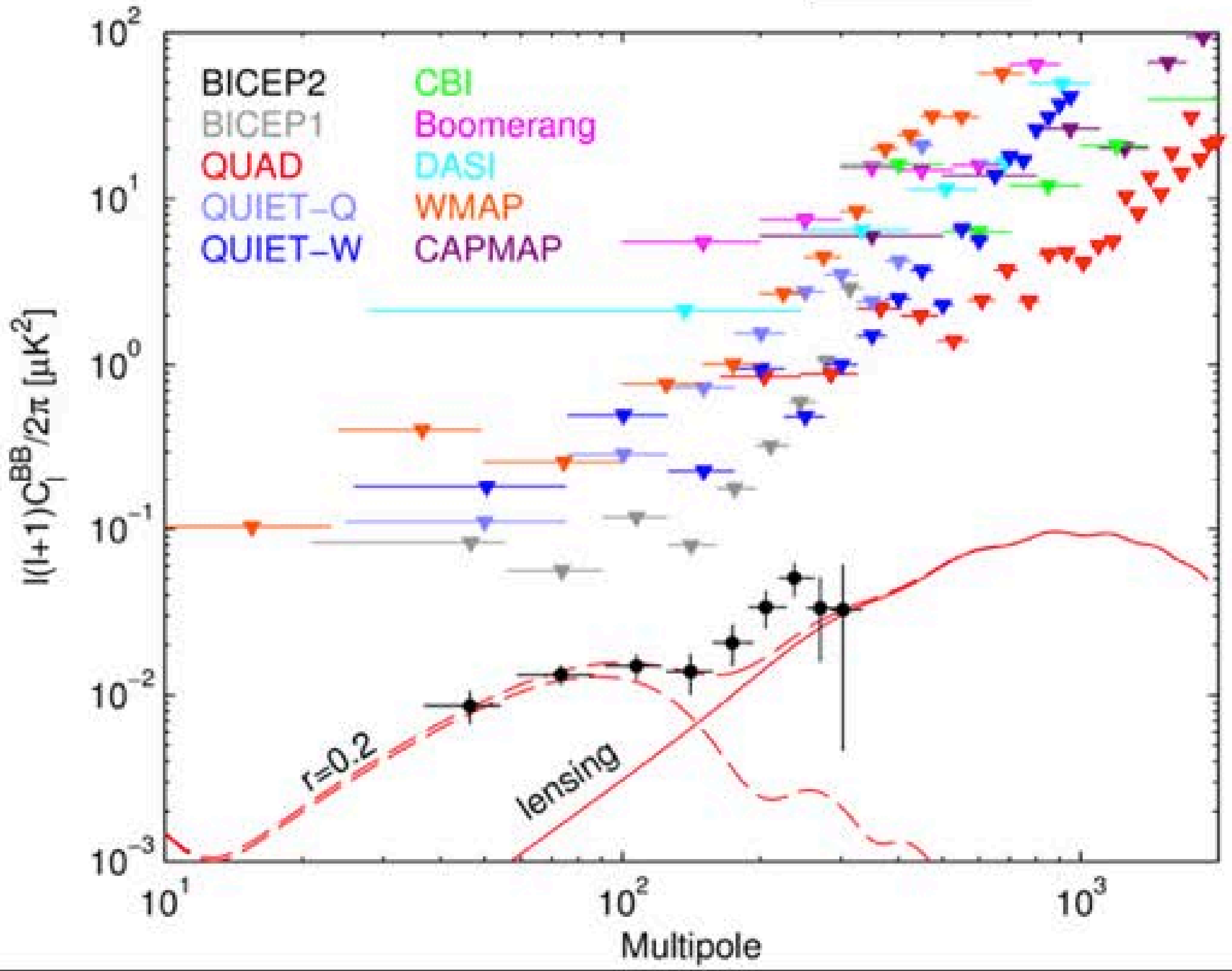


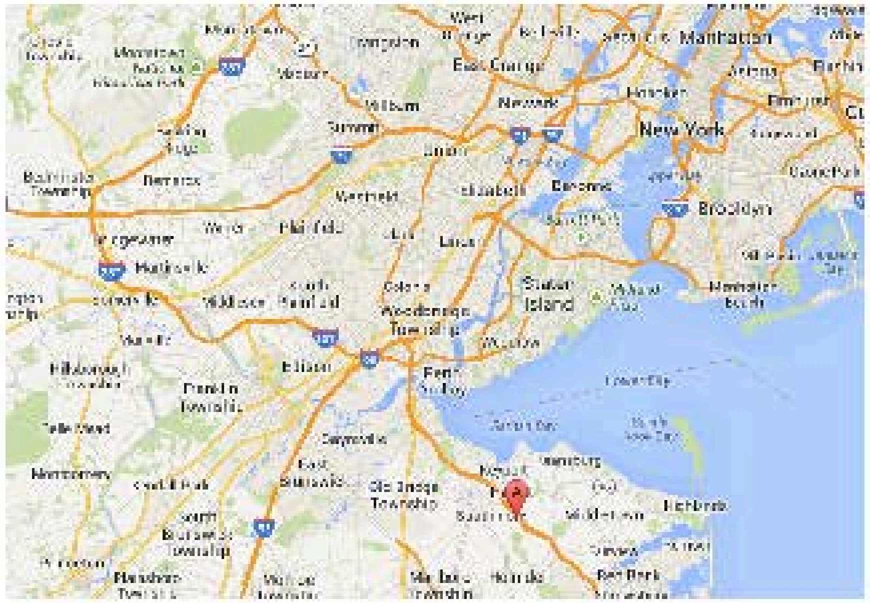
Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

BICEP



The Hot Big Bang

Penzias & Wilson 1965



The Spectrum of the CMB

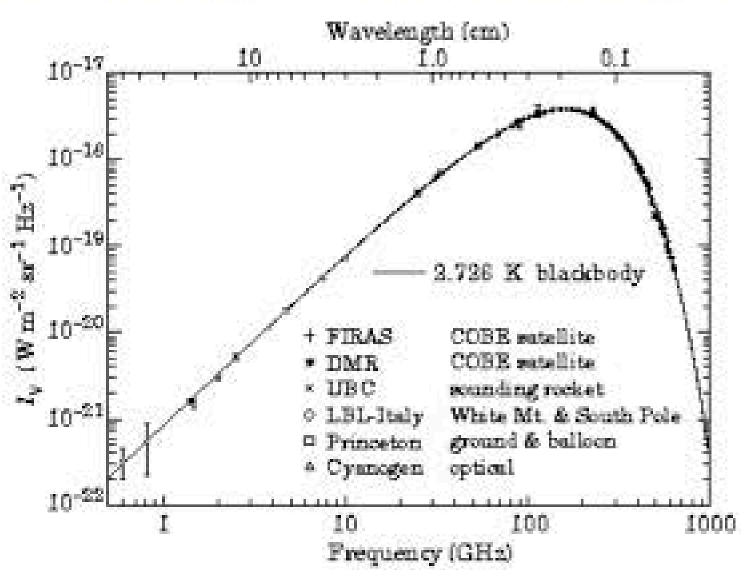
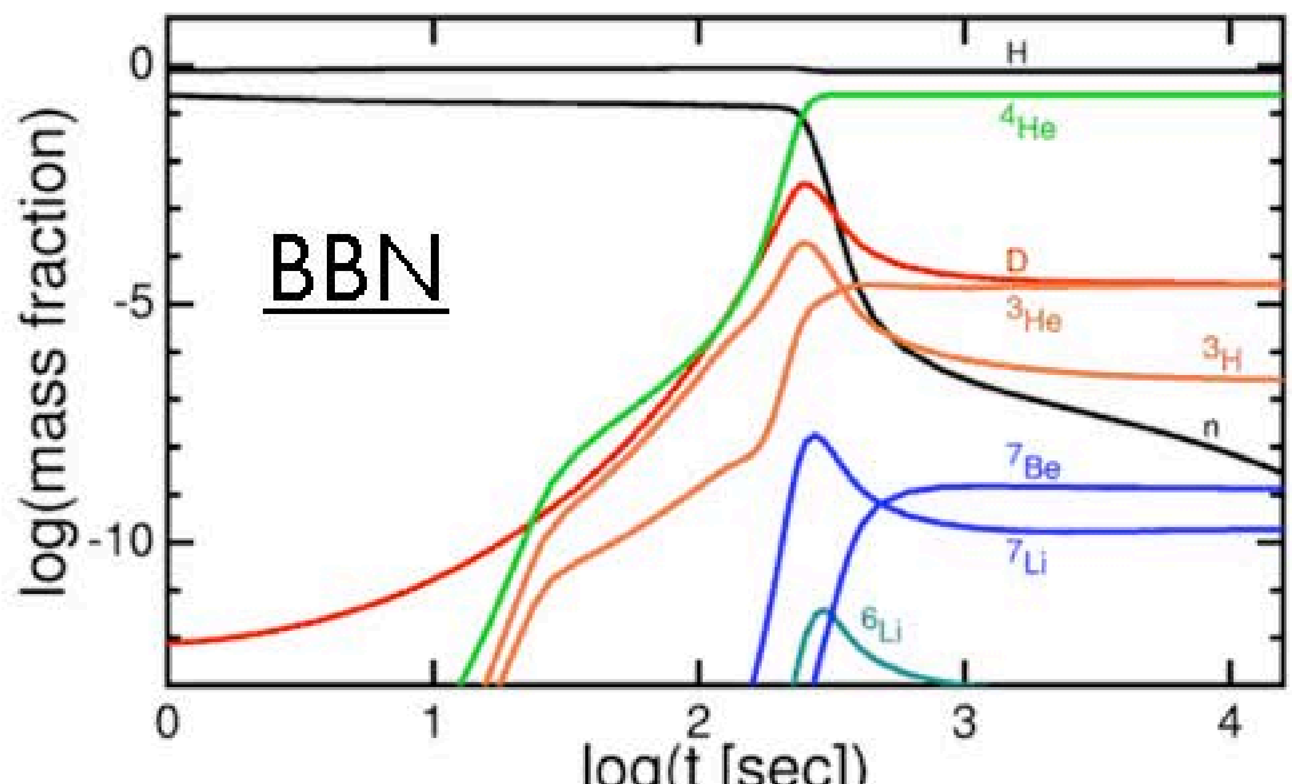
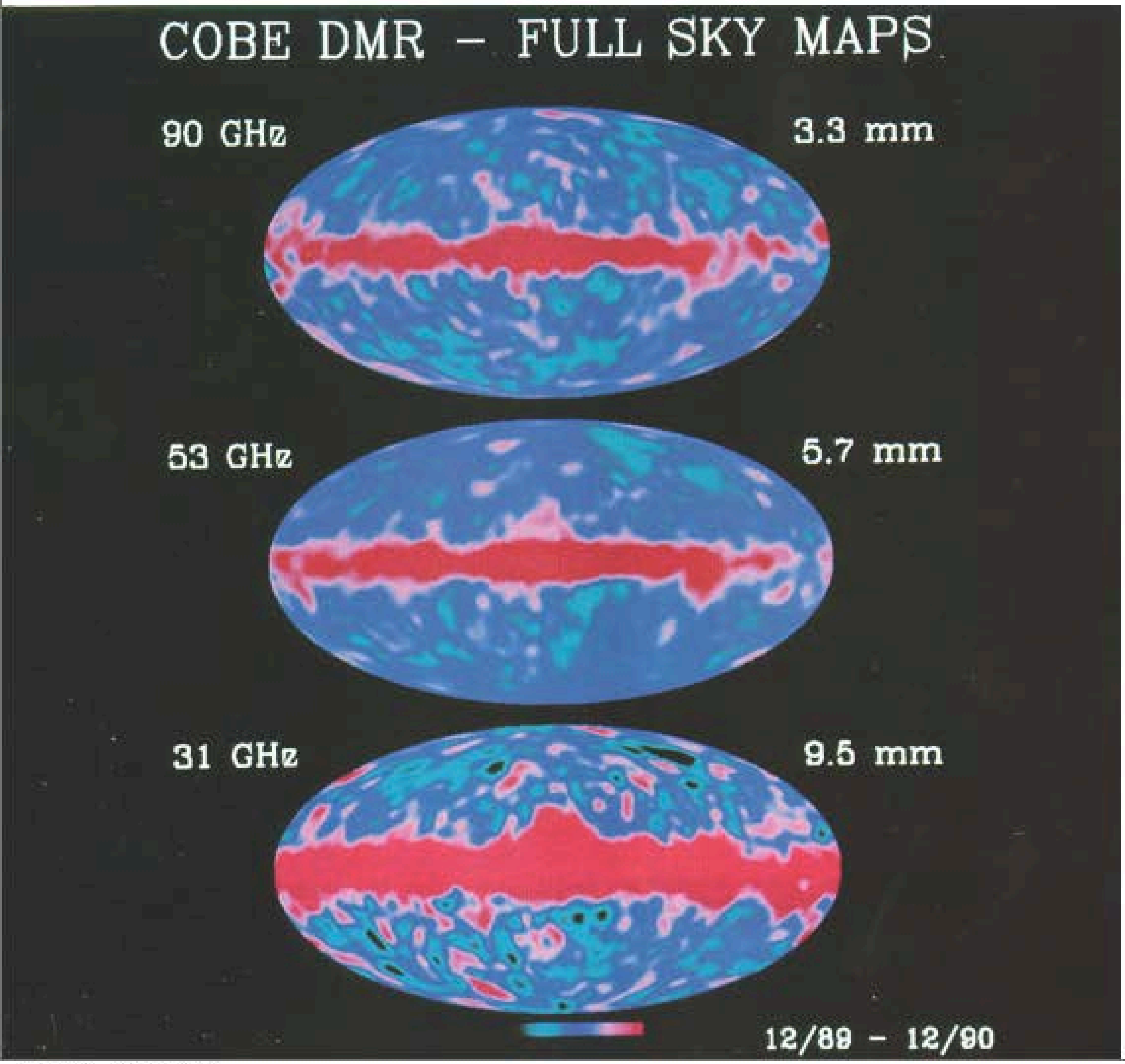


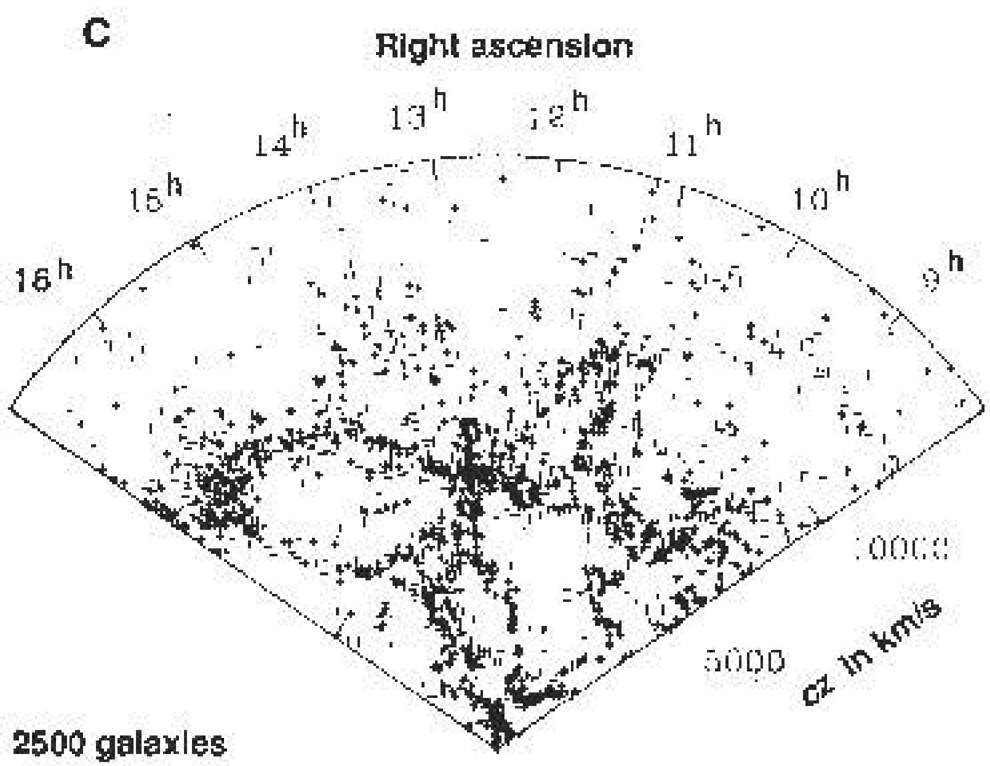
Figure 1. Precise measurements of the CMB spectrum. The line represents a 2.73 K blackbody, which describes the spectrum very well, especially around the peak of intensity. The spectrum is less well constrained at frequencies of 3 GHz and below (10 cm and longer wavelengths). (References for this figure are at the end of this section under "CMB Spectrum References.")



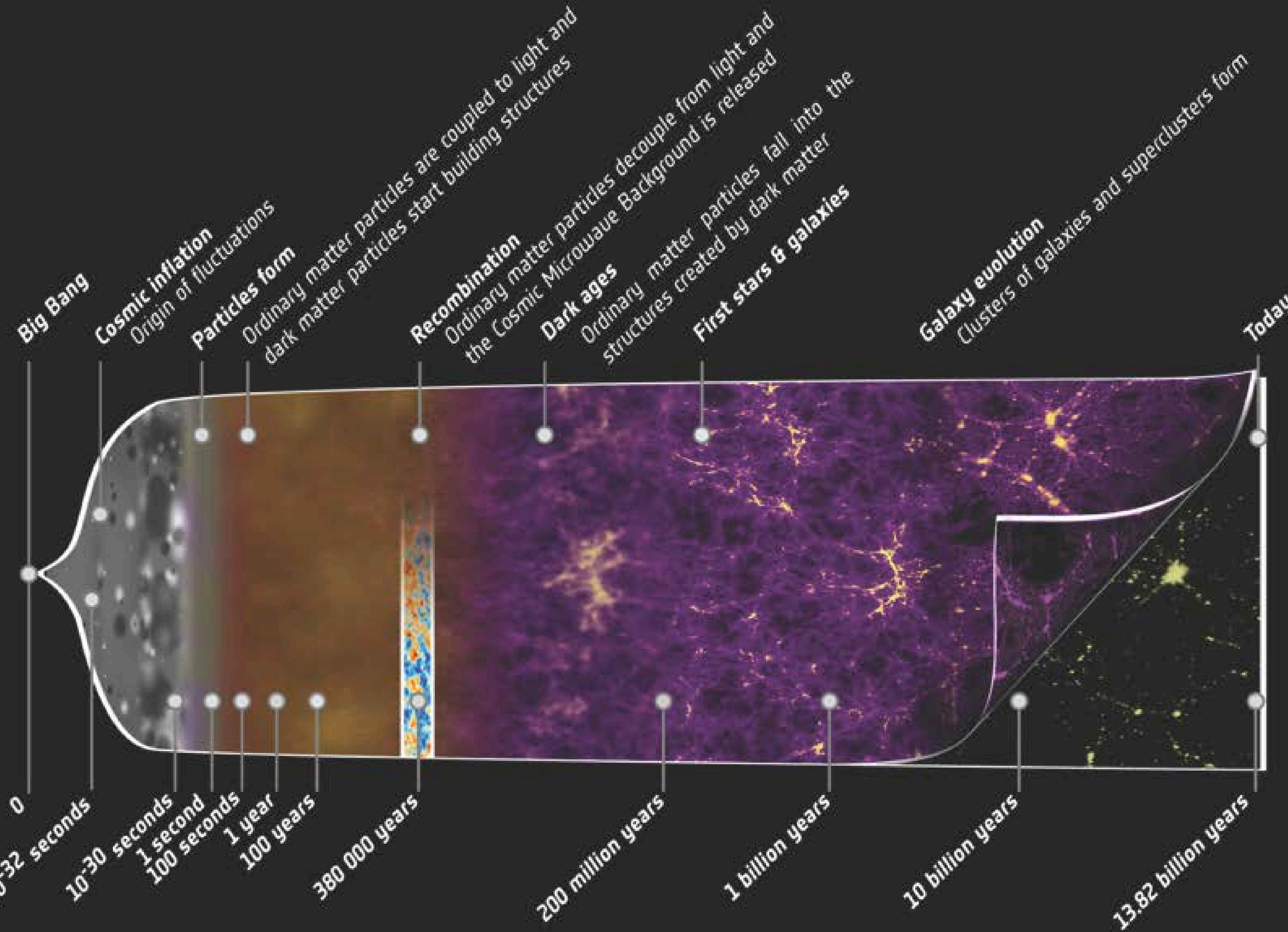
The study of fluctuations



CfA redshift survey



The initial conditions for the Hot Big Bang



Inflation

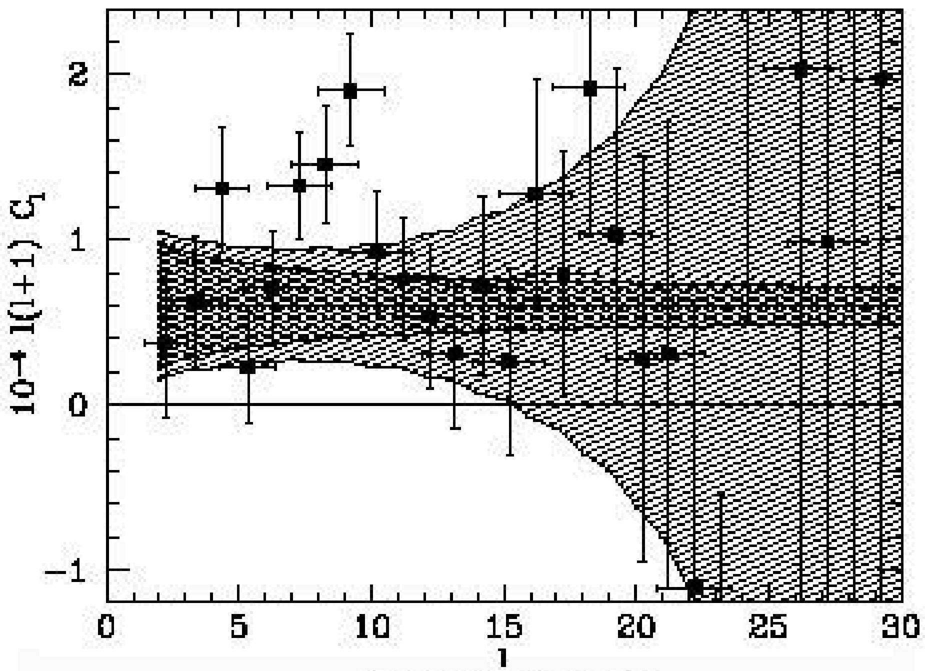
Flat Universe

Small departures from Scale invariance

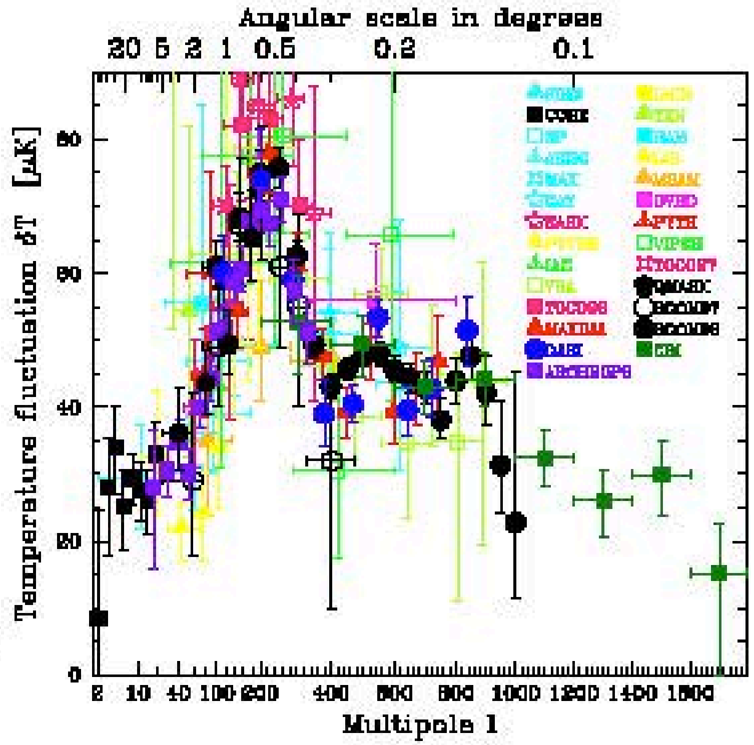
No fluctuations in composition

Gaussian statistics

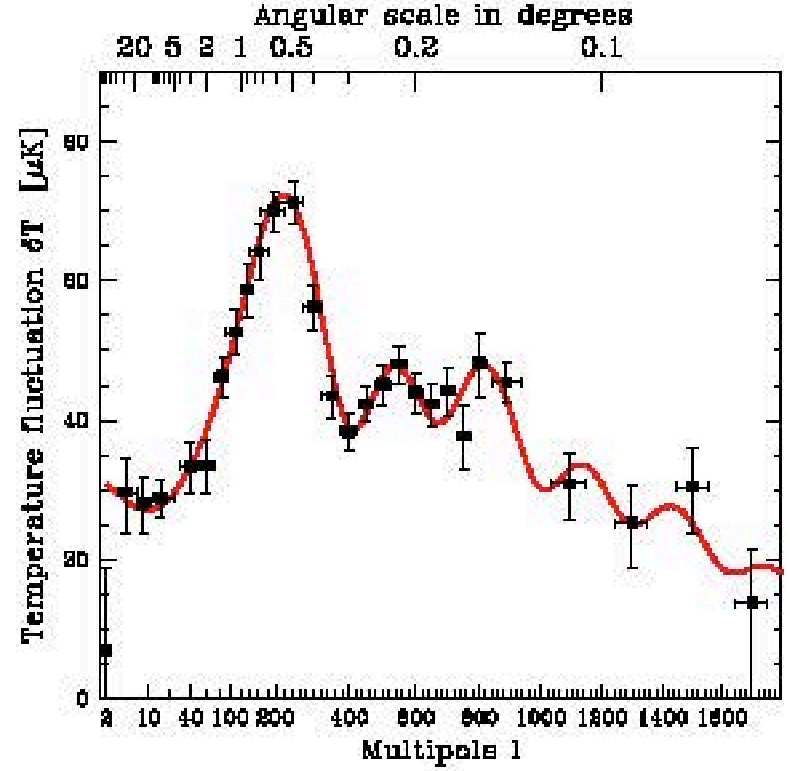
Stochastic Background of gravitational waves



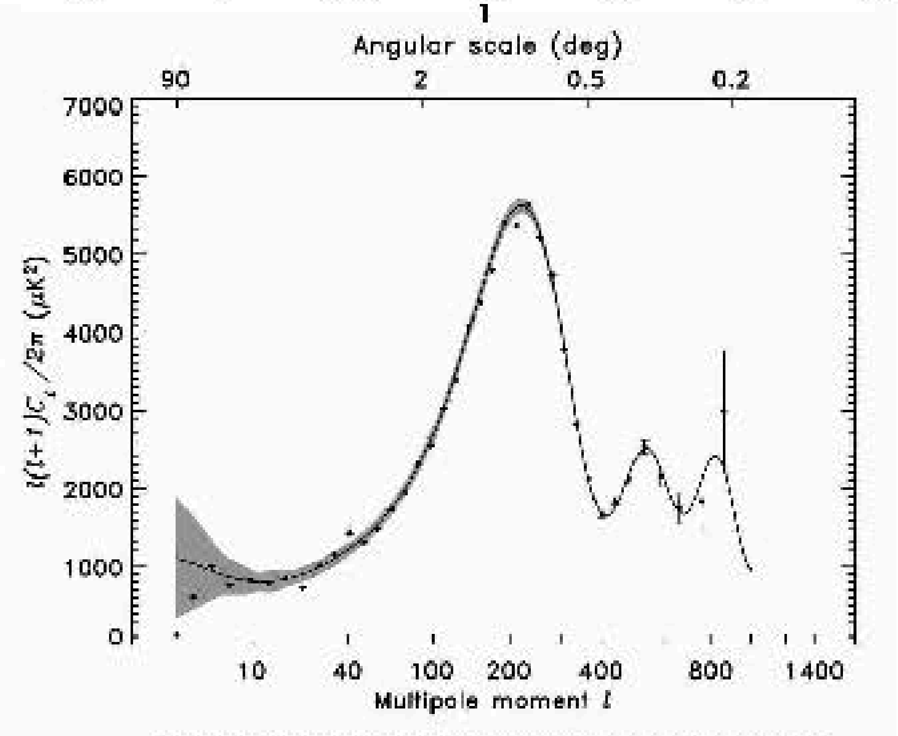
10^{-4} l(l+1) C_l
l



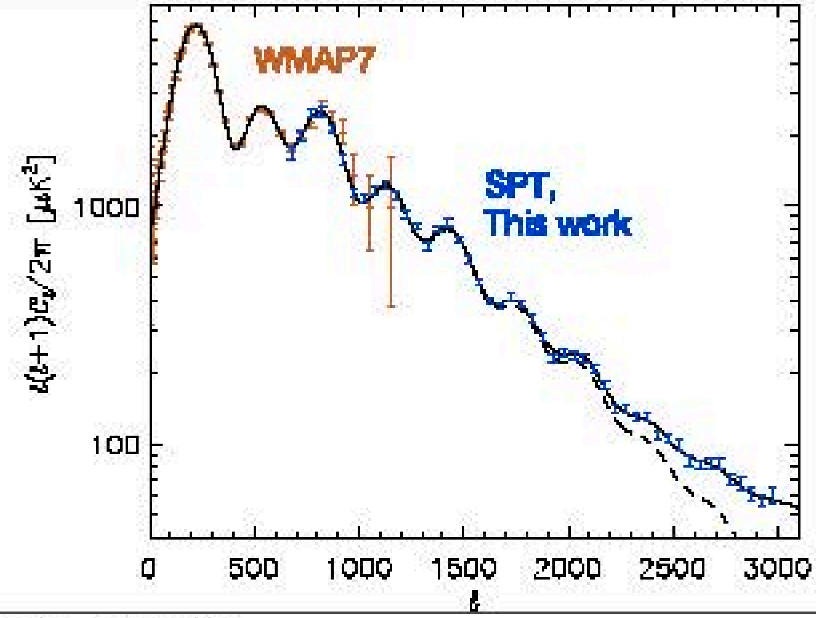
Angular scale in degrees
Temperature fluctuation δT [μK]
Multipole l



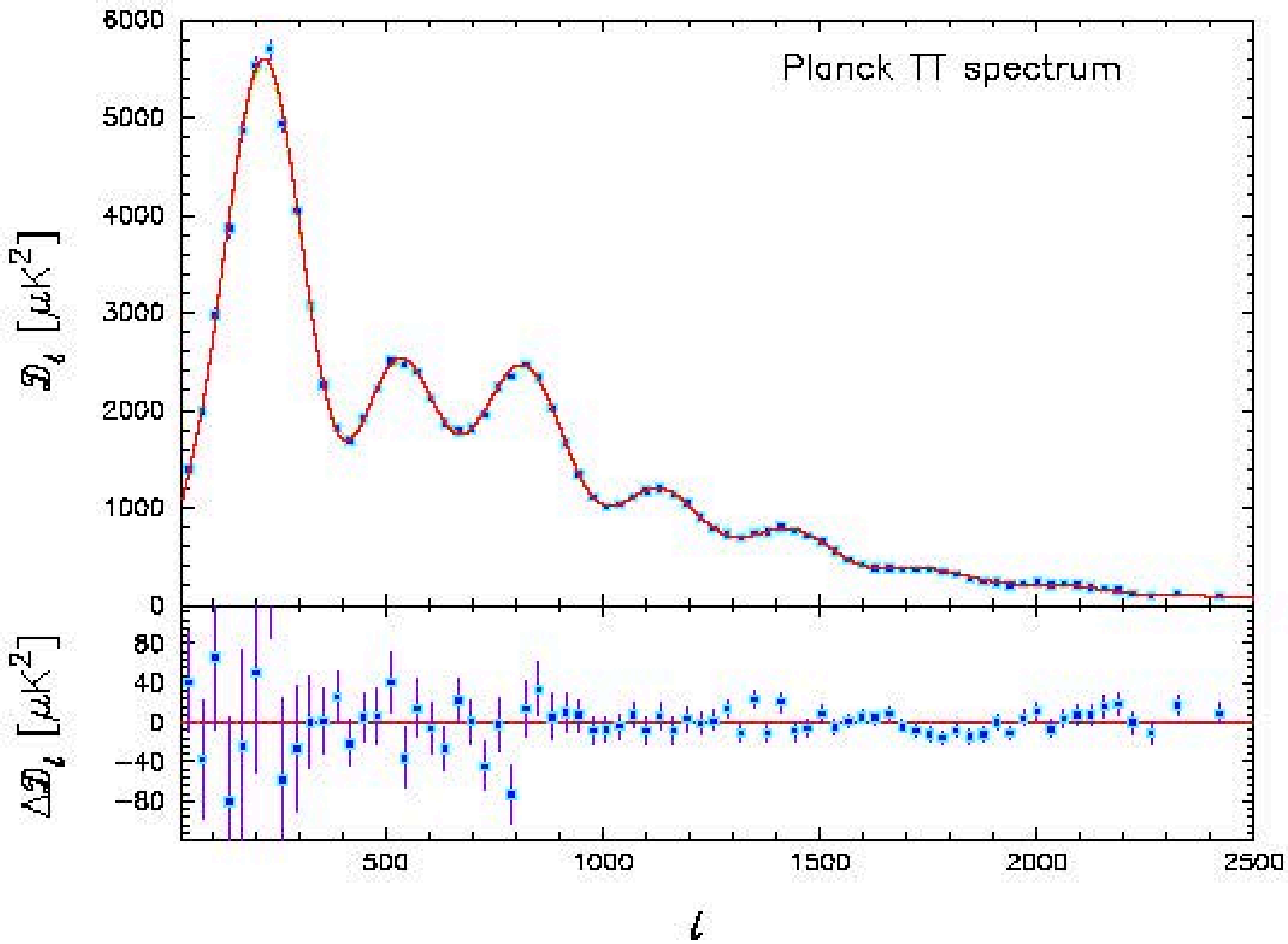
Angular scale in degrees
Temperature fluctuation δT [μK]
Multipole l



Angular scale (deg)
$l(l+1)C_l/2\pi$ (μK^2)
Multipole moment l

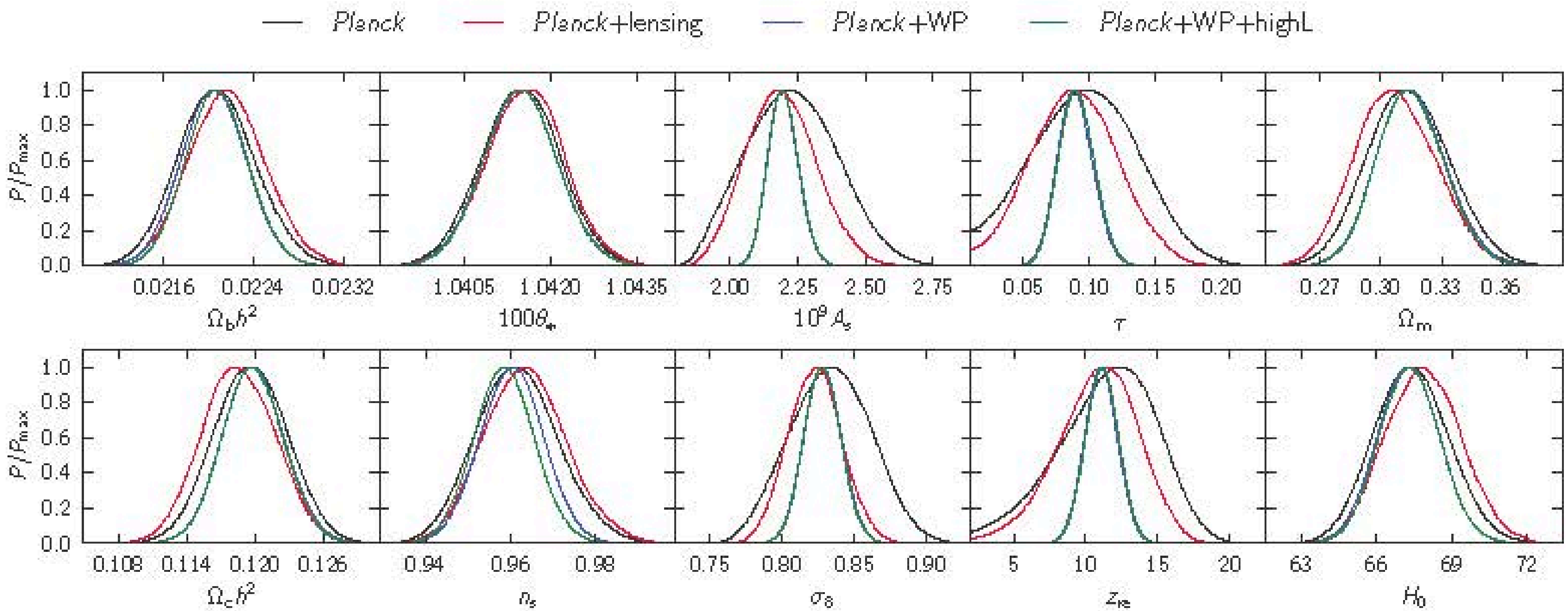


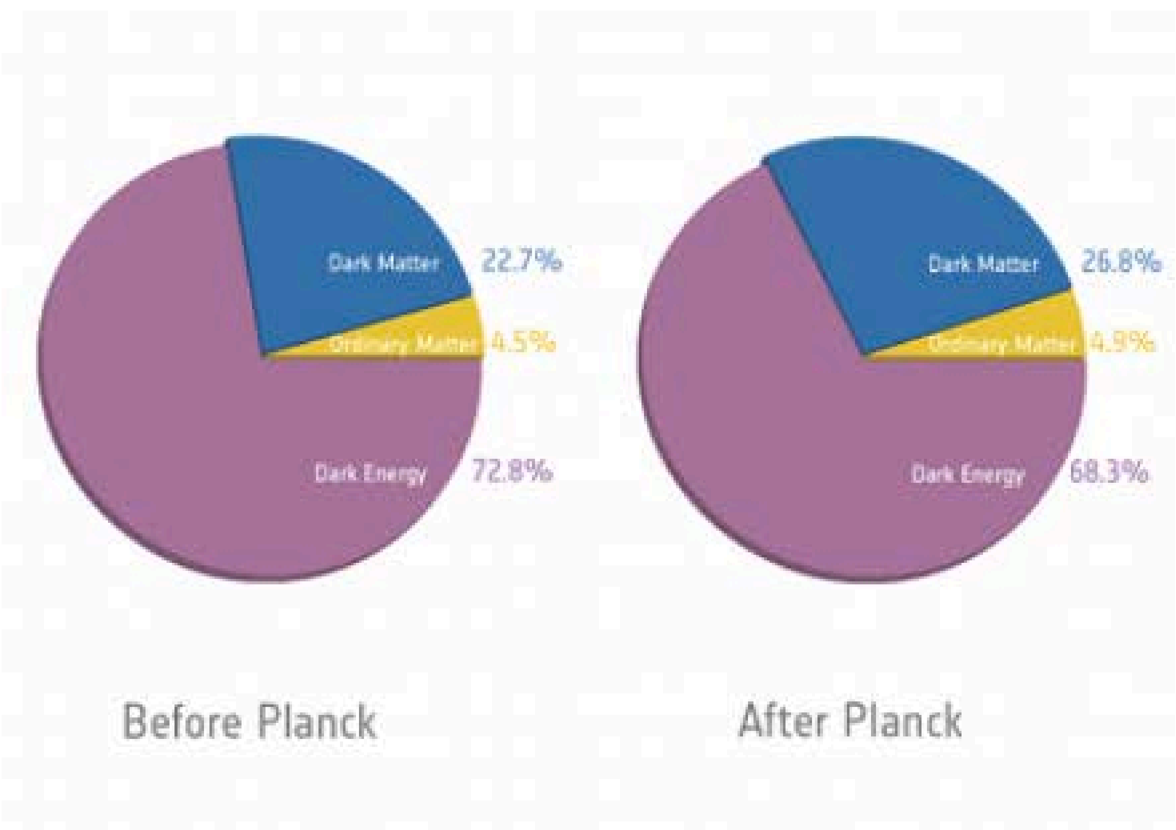
WMAP7
SPT,
This work
$\ell(\ell+1)C_\ell/2\pi$ [μK^2]
ℓ



Planck TT spectrum
$\mathcal{D}_\ell$ [μK^2]
$\Delta\mathcal{D}_\ell$ [μK^2]
ℓ

Our basic cosmological model

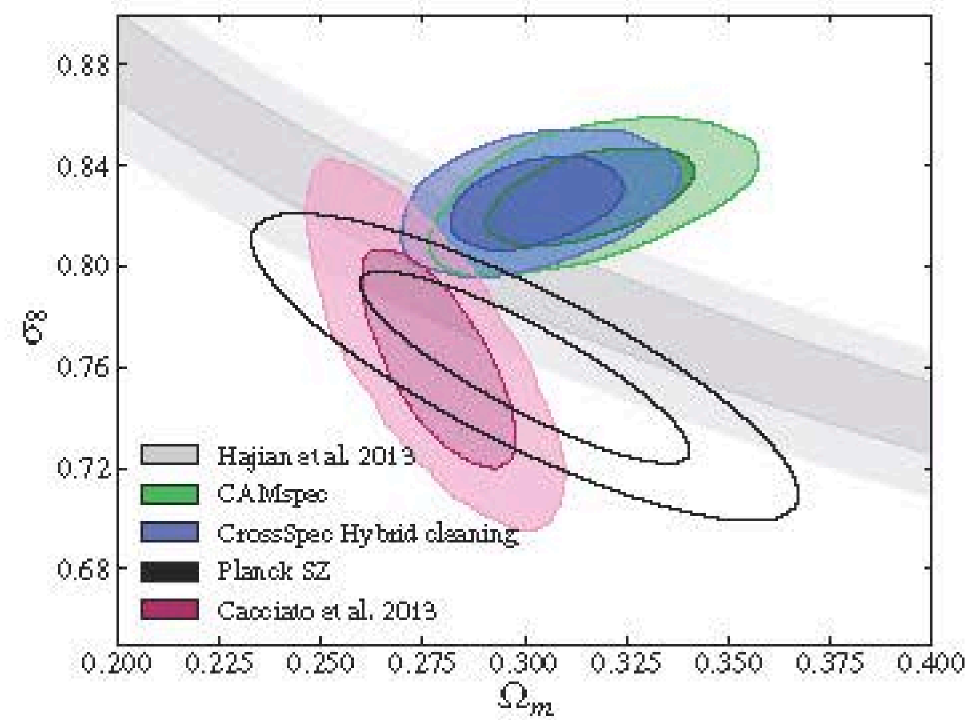




H_0 Revisited

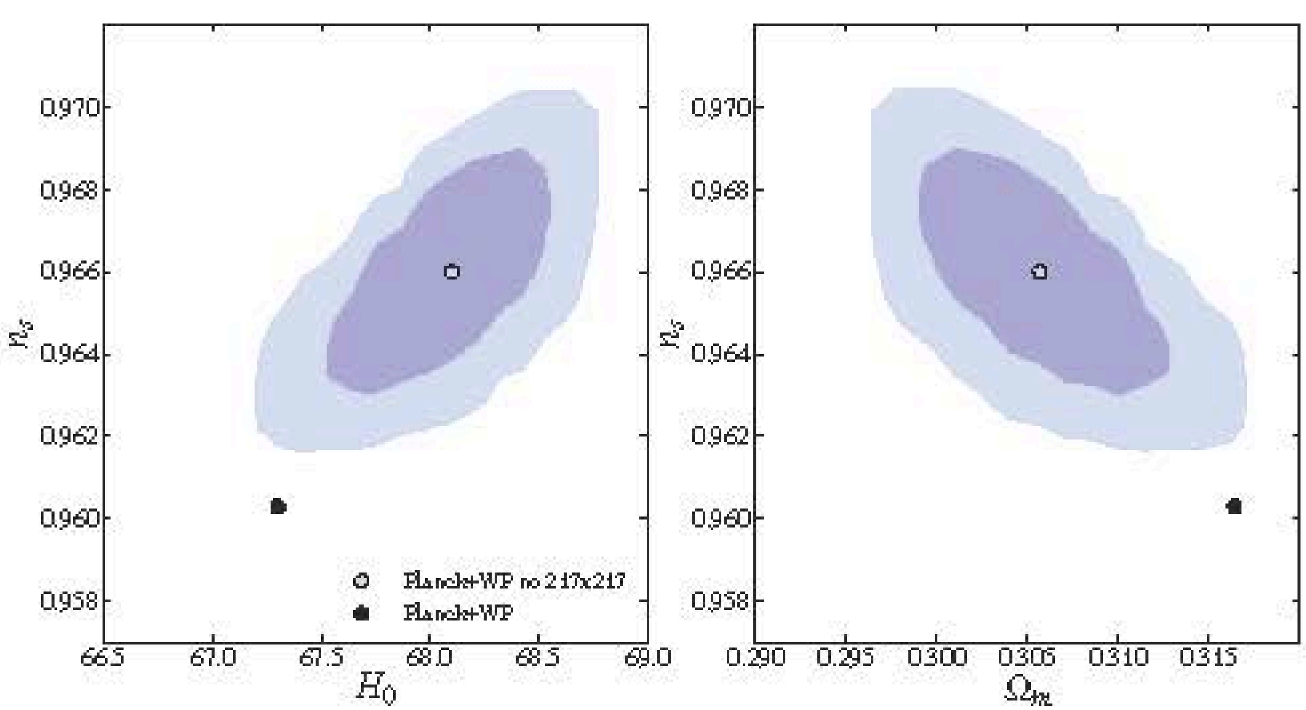
George Efstathiou
Kavli Institute for Cosmology and Institute of Astronomy, Madingley Road, Cambridge, CB3 OHA.

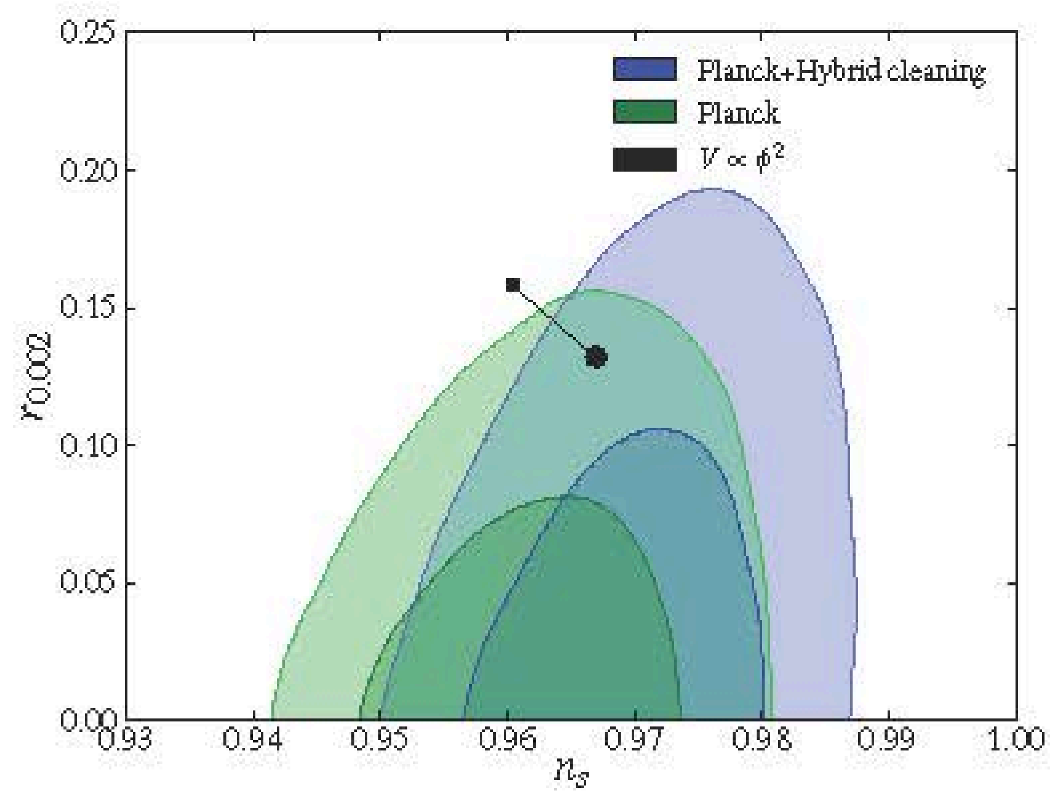
13 February 2014



PLANCK DATA RECONSIDERED

David N. Spergel[1], Raphael Flauger[2,3] & Renée Hložek[1]
[1]Department of Astronophysical Sciences, Princeton University, Princeton, NJ 08544, USA
[2]Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, USA
[3]CCPP, New York University, New York, NY 10003, USA





The initial seeds

	Independent KSW	ISW-lensing subtracted KSW
SMICA		
Local	9.8 ± 5.8	**2.7 ± 5.8**
Equilateral	−37 ± 75	**−42 ± 75**
Orthogonal	−46 ± 39	**−25 ± 39**

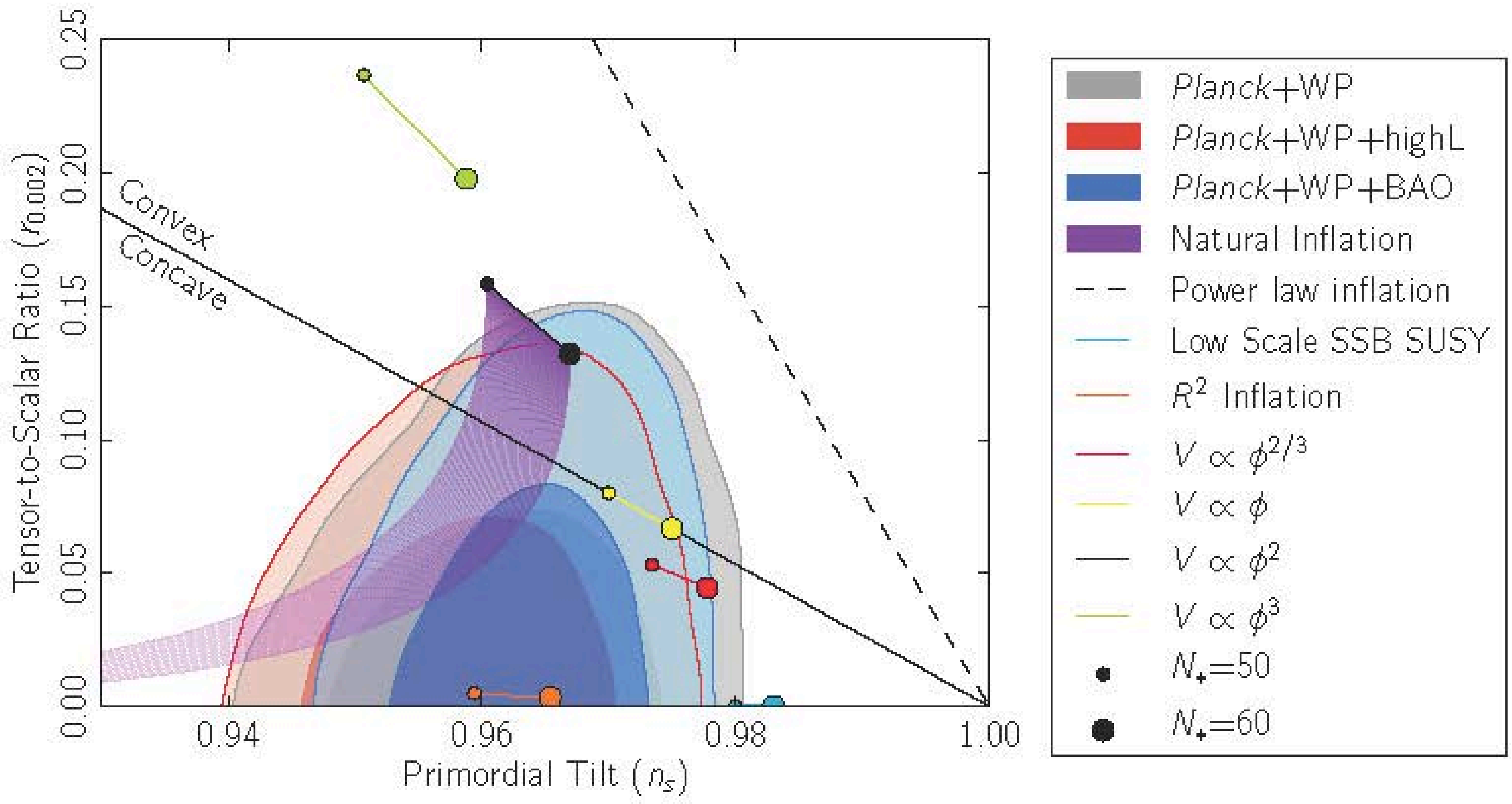
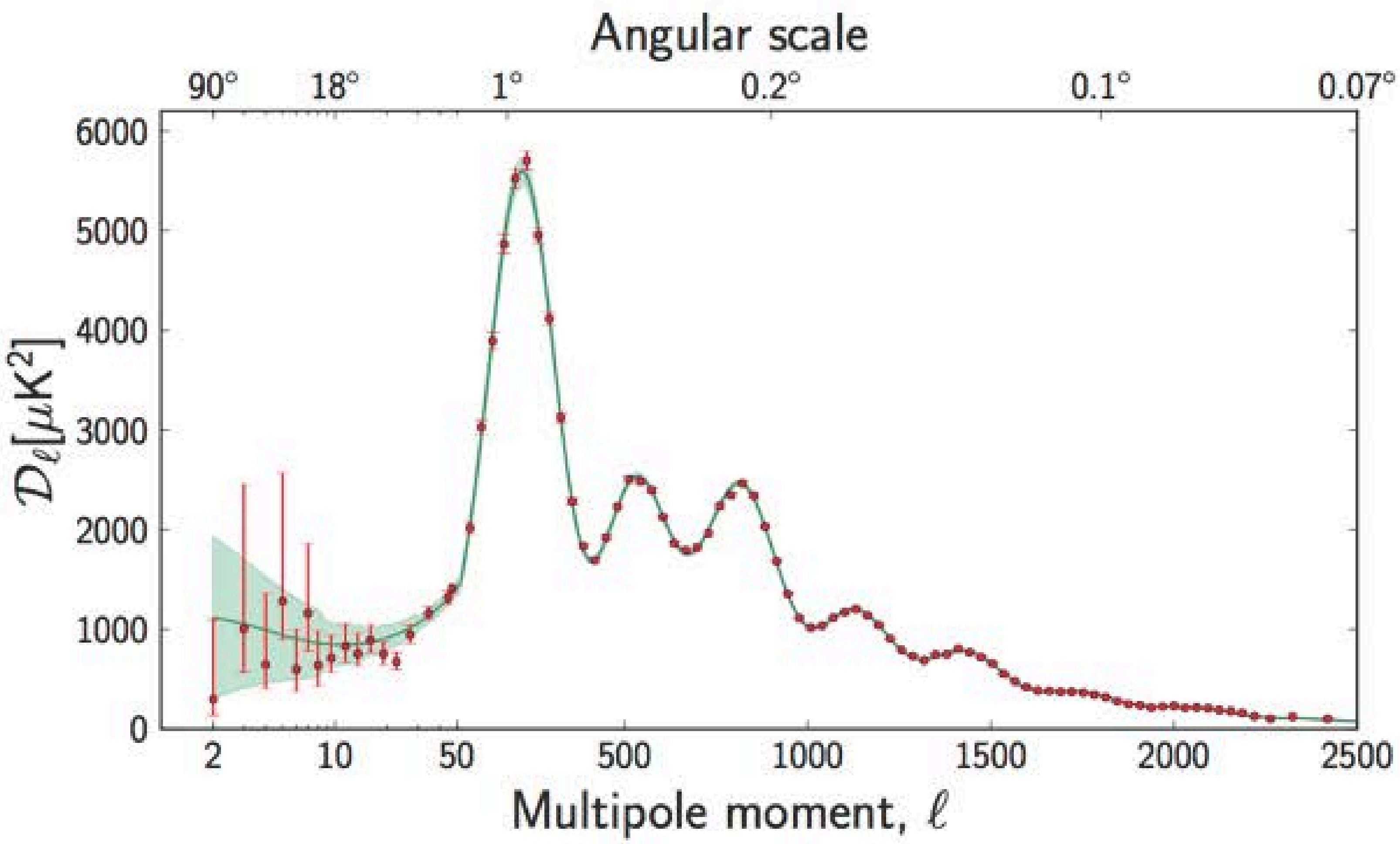


Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

Large angle anomaly



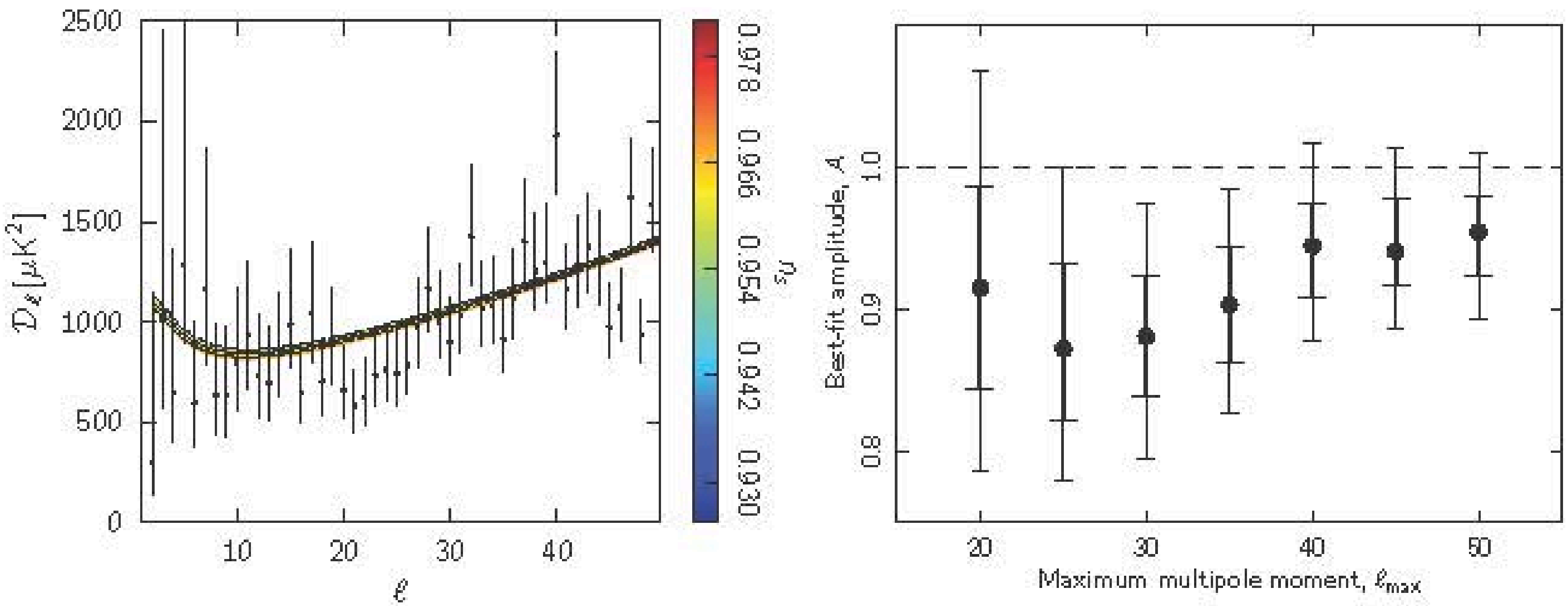
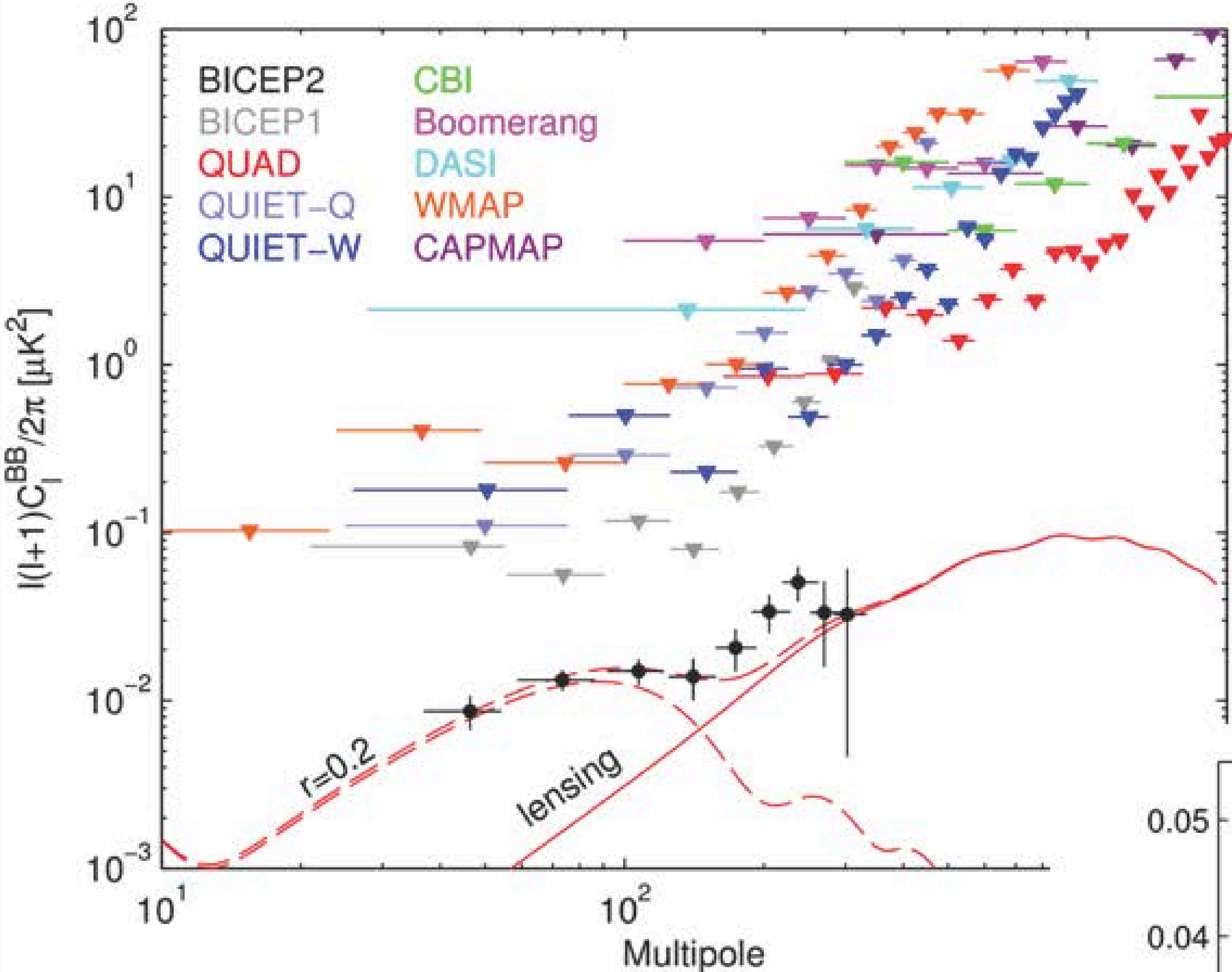
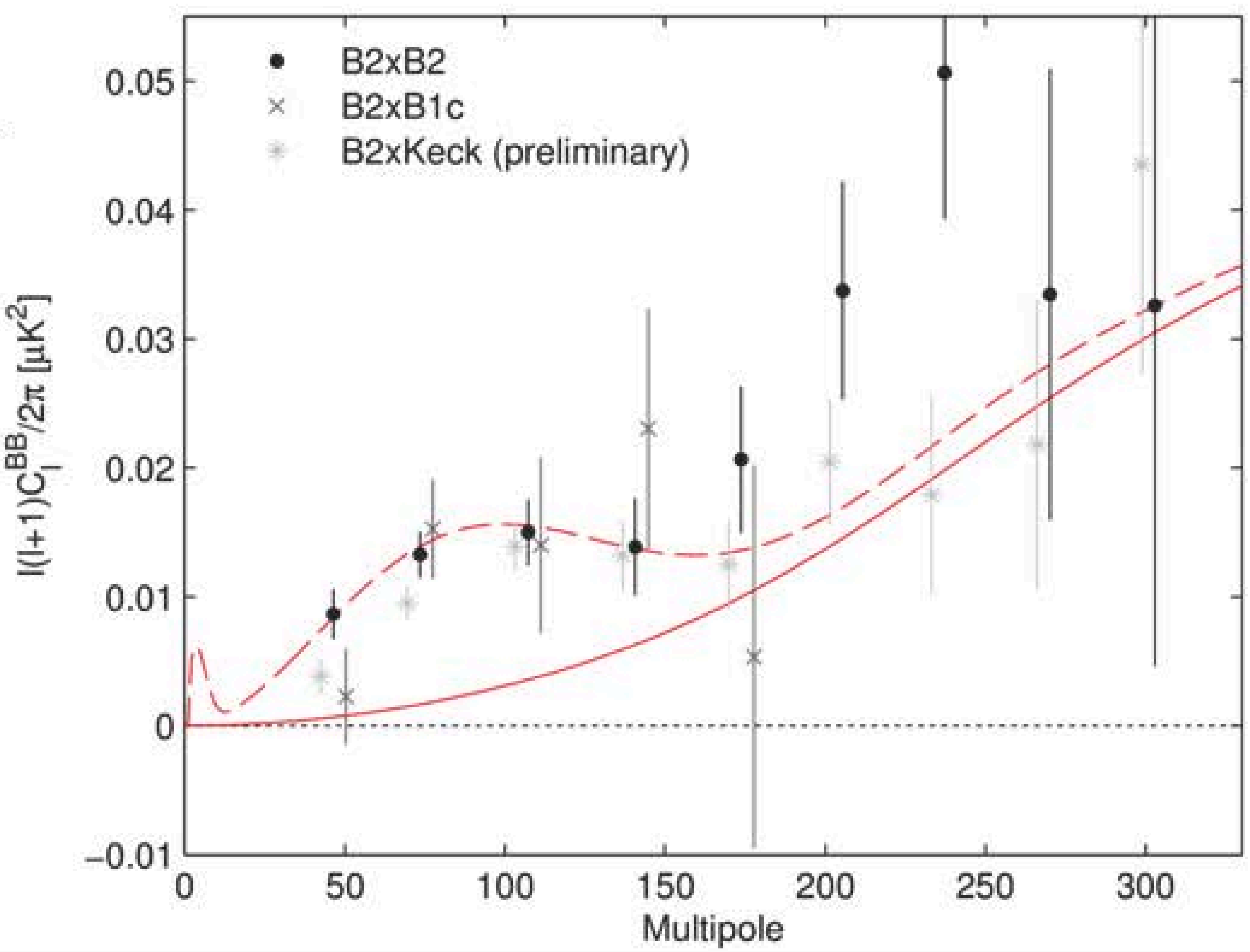


Fig. 39. *Left*: *Planck TT* spectrum at low multipoles with 68% ranges on the posteriors. The "rainbow" band show the best fits to the entire *Planck*+WP+highL likelihood for the base ΛCDM cosmology, colour-coded according to the value of the scalar spectral index n_s. *Right*: Limits (68% and 95%) on the relative amplitude of the base ΛCDM fits to the *Planck*+WP likelihood *fitted only to the Planck TT likelihood* over the multipole range $2 \leq \ell \leq \ell_{max}$.

Bicep 2:



An amazing improvement in sensitivity.
An extremely exciting claim of discovery of primordial B-modes.



“The tension”

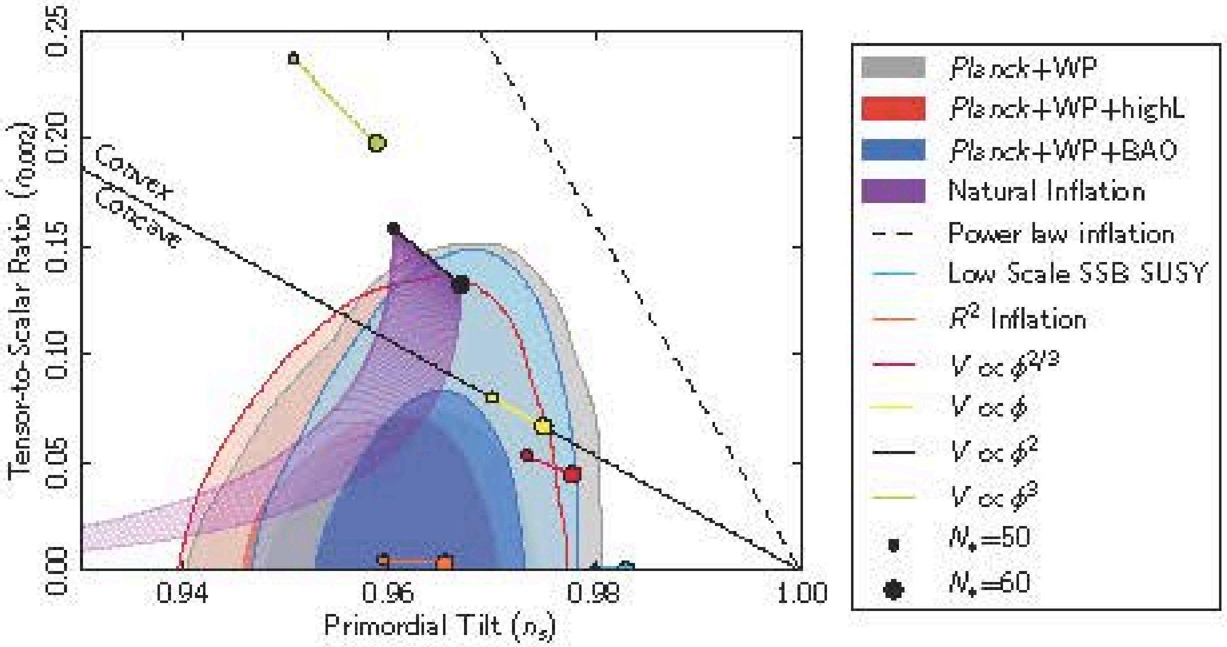


Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

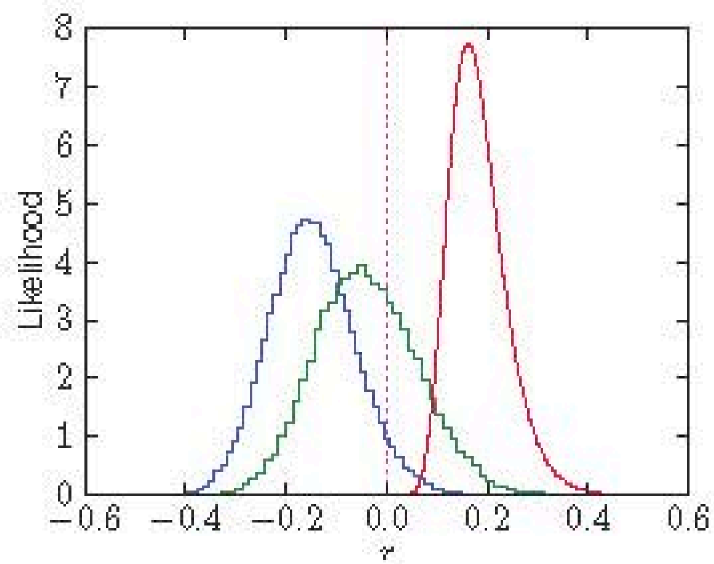


FIG. 2: 1D probability distribution functions for the tensor-to-scalar ratio r using Planck+WP data (blue/left), WMAP+SPT+BAO+H_0 data (green/middle), and BICEP2 data (red/right). We use the CosmoMC [5] code with the six cosmological parameters $\{\Omega_b h^2,\ \Omega_m h^2,\ \Omega_\Lambda,\ A_\xi,\ \tau,\ n_s\}$ marginalized. As discussed in the text, we allow r to be negative in order to parameterize a possible power deficit on large angular scales.

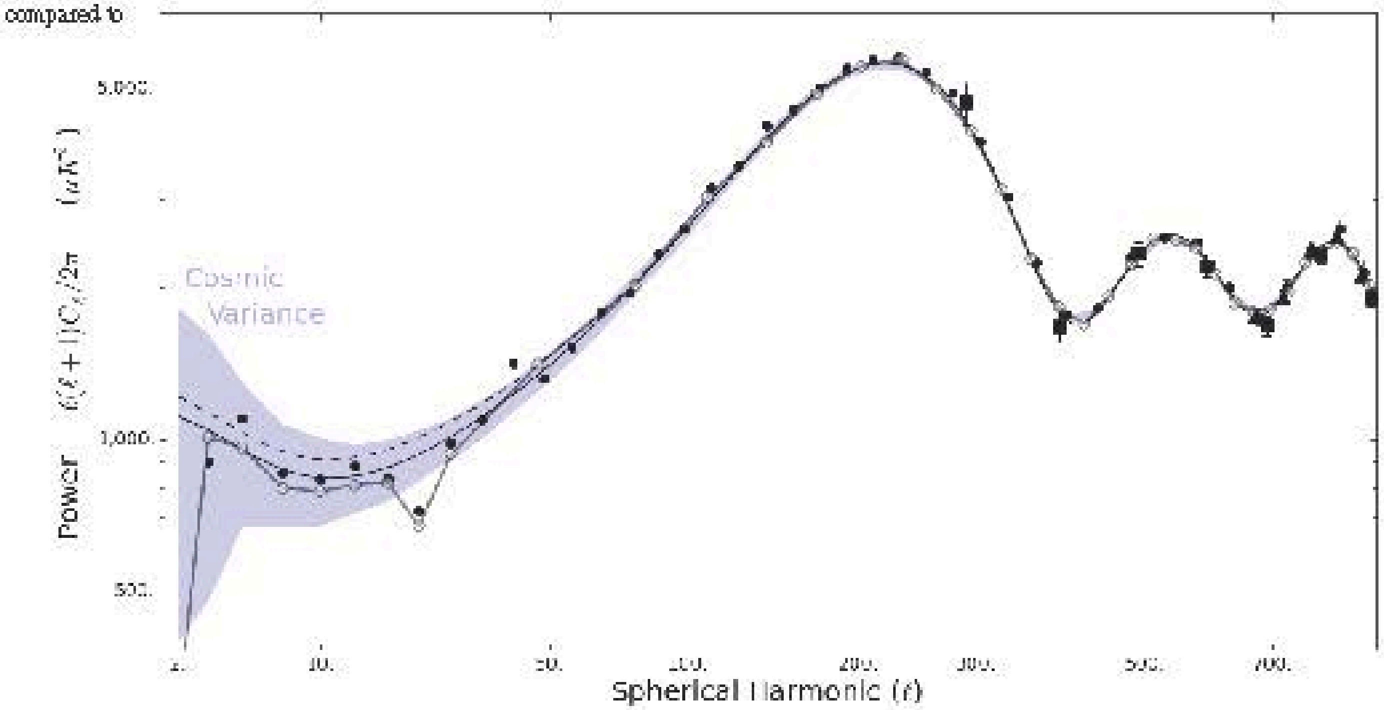
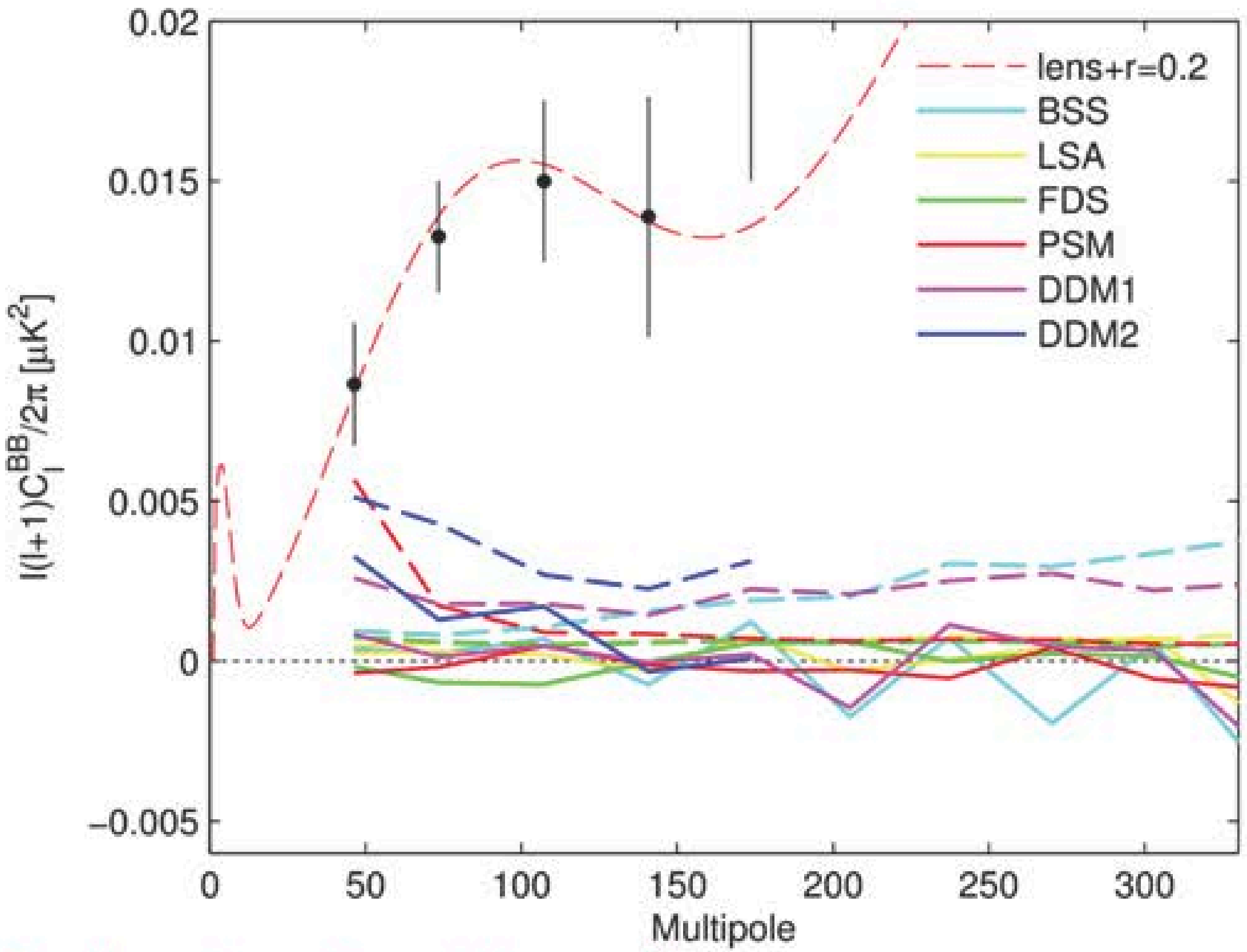


FIG. 1: Current measurements of the CMB temperature power spectrum, from Planck (open circles), WMAP (closed circles), ACT (squares) and SPT (triangles). Error bars include noise variance only; the shaded region represents cosmic variance. There is a small deficit of power on large angular scales relative to an $r = 0$ model (solid curve) which becomes more statistically significant if $r = 0.2$ as BICEP2 suggests (dashed curve).

Fun speculation

- Running (unacceptably large, "rules out slow-roll inflation")
- A brake in the spectrum (Evidence for Bubble-nucleation event)
- Additional relativistic species (does not really look like the signal)

At face value the BICEP results require a modification of the baseline model in addition to adding tensor modes.



Foregrounds

The four lines of argument

Having demonstrated that the signal is real and "on the sky" we proceeded to investigate if it may be due to foreground contamination. Polarized synchrotron emission from our galaxy is easily ruled out using low frequency polarized maps from WMAP. For polarized dust emission public maps are not yet available. We therefore investigate a range of models including new ones which use all of the information which is currently available from *Planck*. These models all predict auto spectrum power well below our observed level. In addition none of them show any significant cross correlation with our maps.

Taking cross spectra against 100 GHz maps from BICEP1 we find significant correlation and set a constraint on the spectral index of the signal consistent with CMB, and disfavoring synchrotron and dust by 2.3σ and 2.2σ respectively. The fact that the BICEP1 and *Keck Array* maps cross correlate is powerful further evidence against systematics.

The simplest and most economical remaining interpretation of the *B*-mode signal which we have detected is that it is due to tensor modes — the IGW template is an excellent fit to the observed excess. We therefore proceed to set a constraint on the tensor-to-scalar ratio and find $r = 0.20^{+0.07}_{-0.05}$ with $r = 0$ ruled out at a significance of 7.0σ. Multiple lines of evidence have been presented that foregrounds are a subdominant contribution: i) direct projection of the best available foreground models, ii) lack of strong cross correlation of those models against the observed sky pattern (Figure 6), iii) the frequency spectral index of the signal as constrained using BICEP1 data at 100 GHz (Figure 8), and iv) the spatial and power spectral form of the signal (Figures 3 and 10).

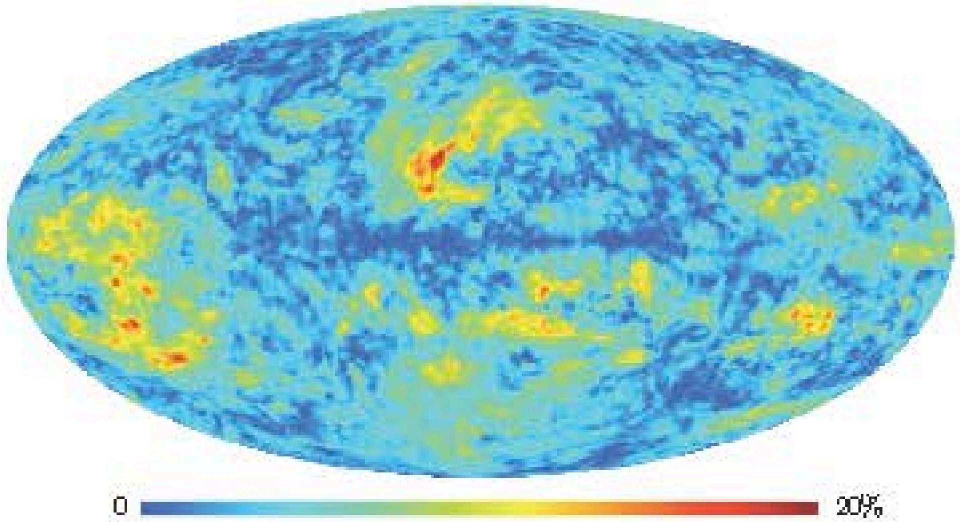
Explanation of models used.
Given the importance of the results it is rather short.

DDM1: "Data Driven Model 1" (DDM1) constructed from publicly available *Planck* data products. The *Planck* dust model map at 353 GHz is scaled to 150 GHz assuming a constant emissivity value of 1.6 and a constant temperature of 19.6 K. In our field these values agree both with the mean values shown by the *Planck* Collaboration in dust polarization[32], and with the median values of the recently delivered *Planck* dust model (Planck Collaboration et al. 2013a). A uniform 5% sky polarization fraction is assumed in agreement with the first all-sky images of dust polarization shown by the *Planck* Collaboration[33]. The polarization angles are taken from the PSM.

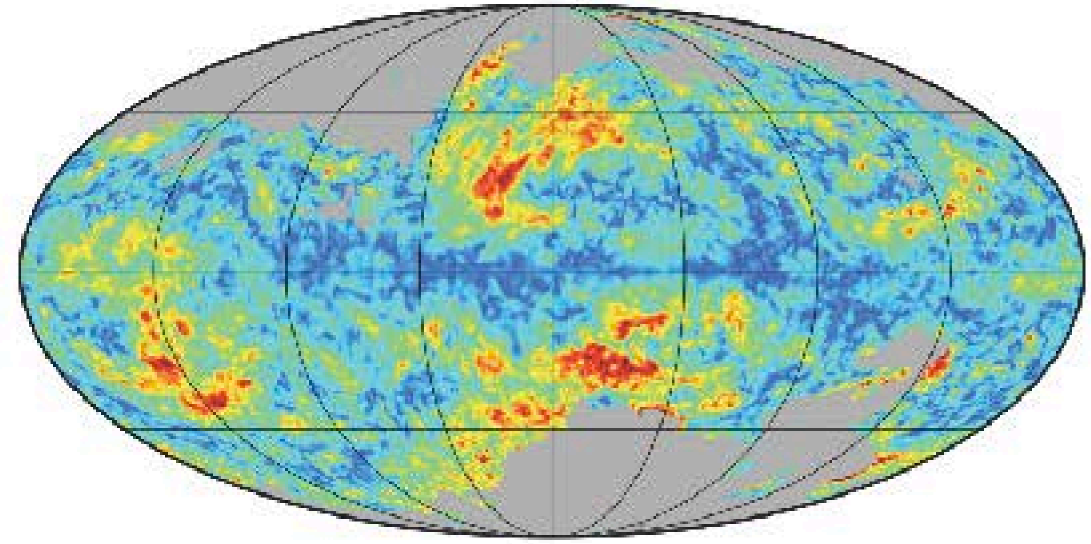
DDM2: "Data Driven Model 2" (DDM2) constructed using all publicly available information from *Planck*. Uses the same dust model temperature map as DDM1, with polarization fractions and angles matching those shown by the *Planck* Collaboration[33].

Errors enter squared in the Cl plot. <u>An underestimate of less than a factor of two relative to DDM2 auto is enough to explain away the signal.</u>

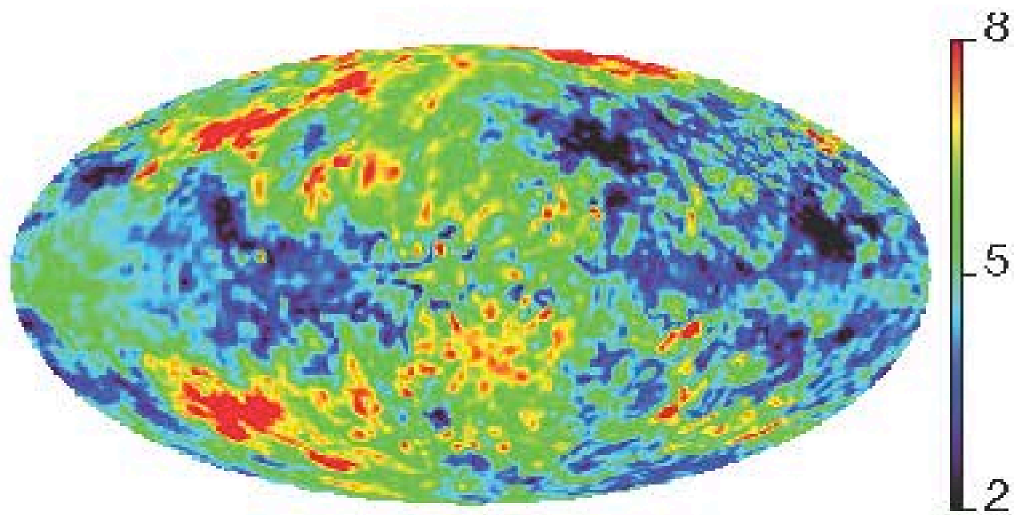
map used by bicep



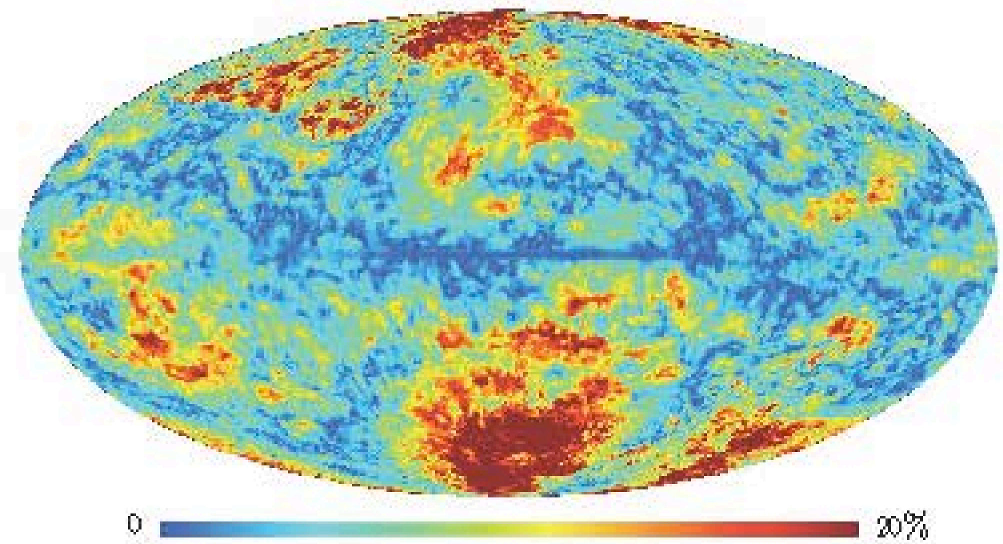
New official map from Planck



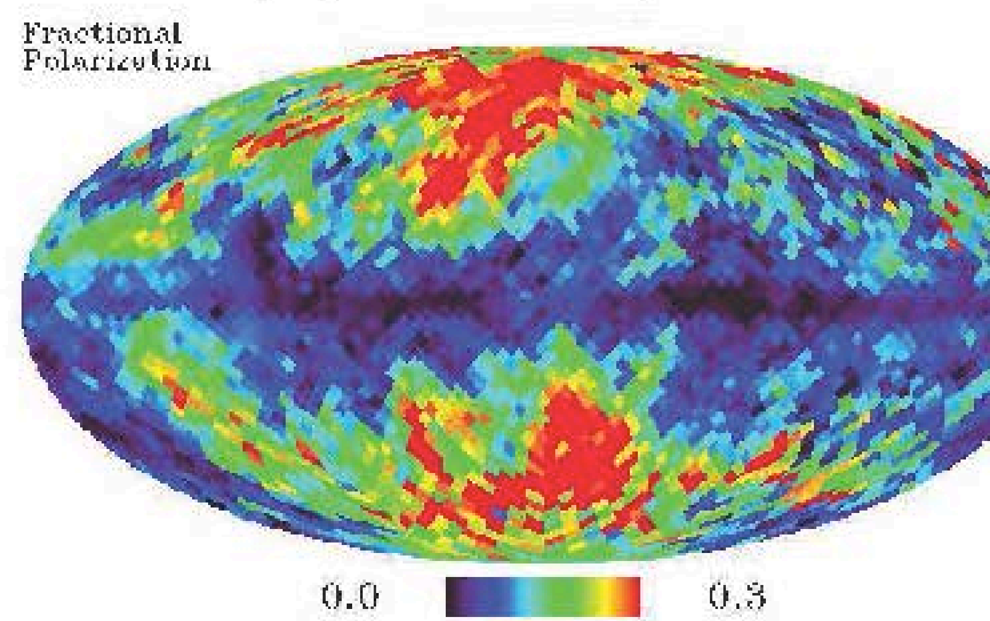
pre-launch Planck Sky model



CIB corrected From Hauger



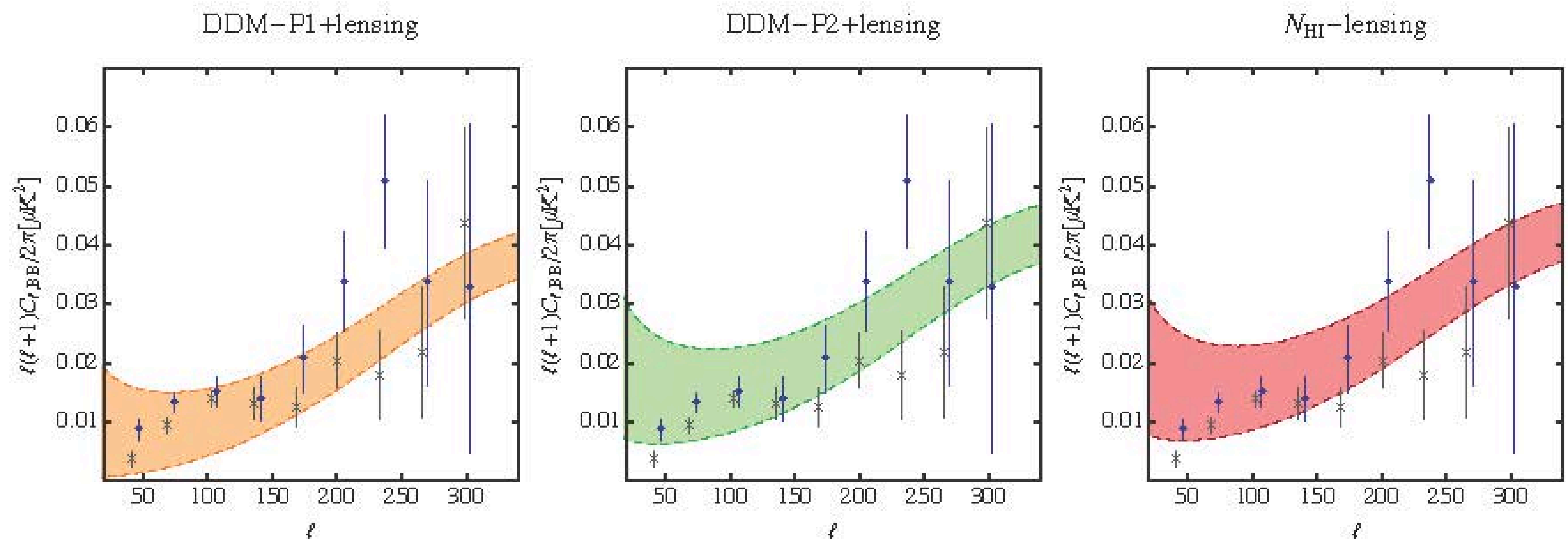
wmap synchrotron pol fraction

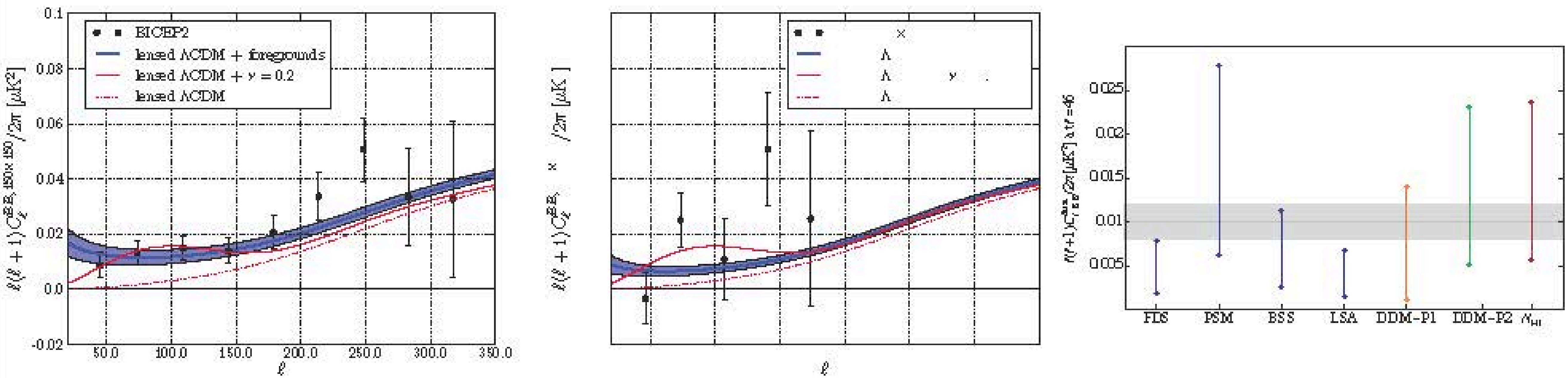


Region	ℓ_{II} [°]	b_{II} [°]	$\Delta\ell_{II}$ [°]	Δb_{II} [°]	min(p) [%]	mean(p) [%]	med(p) [%]	max(p) [%]	stdev(p) [%]	med(ψ) [°]	stdev(ψ) [°]
Polaris Flare	120.0	27.0	12.0	12.0	0.10	3.11	2.94	7.40	1.30	176.72	46.23
Orion	211.0	−16.0	12.0	12.0	0.08	3.22	2.97	10.23	1.73	177.17	42.87
Pipe	0.0	4.5	5.5	5.5	0.31	3.85	3.33	8.43	1.90	143.13	16.85
Ophiuchus	−6.0	15.0	12.0	12.0	0.11	5.11	4.39	12.22	2.60	0.84	20.69
Taurus	173.0	−15.0	12.0	12.0	0.16	5.08	4.83	11.62	2.19	129.00	60.11
RCrA	10.0	−22.0	15.0	17.0	0.30	6.80	6.71	13.97	2.94	11.62	15.42
Cham-fil	315.0	−22.0	12.0	12.0	1.40	6.95	6.78	15.29	2.22	14.32	8.56
Pyxis	−120.0	12.0	25.0	15.0	0.34	7.09	6.96	16.71	3.03	171.04	15.33
Aquila	42.0	−15.0	10.0	10.0	0.88	7.71	7.10	14.63	3.00	38.61	12.94
Auriga	145.0	0.0	30.0	30.0	0.12	7.55	7.38	18.64	2.76	1.69	12.20
RCrA-Tail	25.0	−22.0	15.0	17.0	1.66	8.63	8.40	15.33	3.16	170.71	14.63
Hercules	40.0	45.0	15.0	50.0	0.37	8.67	8.39	37.49	3.69	65.26	38.68
Libra	−10.0	40.0	30.0	30.0	0.34	9.35	9.90	21.39	3.42	20.03	23.72
Chamaeleon-Musca	300.0	−13.0	12.0	12.0	0.89	9.29	9.98	15.08	3.15	15.06	10.80
Aquila Rift	18.0	24.0	25.0	30.0	0.12	10.25	10.21	20.15	3.55	30.91	15.09
Ara	336.0	−14.0	12.0	12.0	3.15	11.18	10.85	21.09	2.99	177.49	8.90
Pisces	133.0	−37.0	12.0	12.0	4.32	12.10	11.72	20.81	3.22	15.60	4.99
Microscopium	15.0	−40.0	12.0	12.0	6.20	11.78	11.76	18.63	2.27	24.66	10.80
Triangulum	−35.0	−14.0	10.0	7.0	5.21	12.12	12.12	17.14	2.82	6.66	4.95
Perseus	143.0	−25.0	12.0	12.0	5.66	12.68	12.68	21.10	3.20	9.68	5.96
Pavo	336.0	−28.0	12.0	12.0	3.60	14.13	14.33	21.77	3.61	14.29	7.99

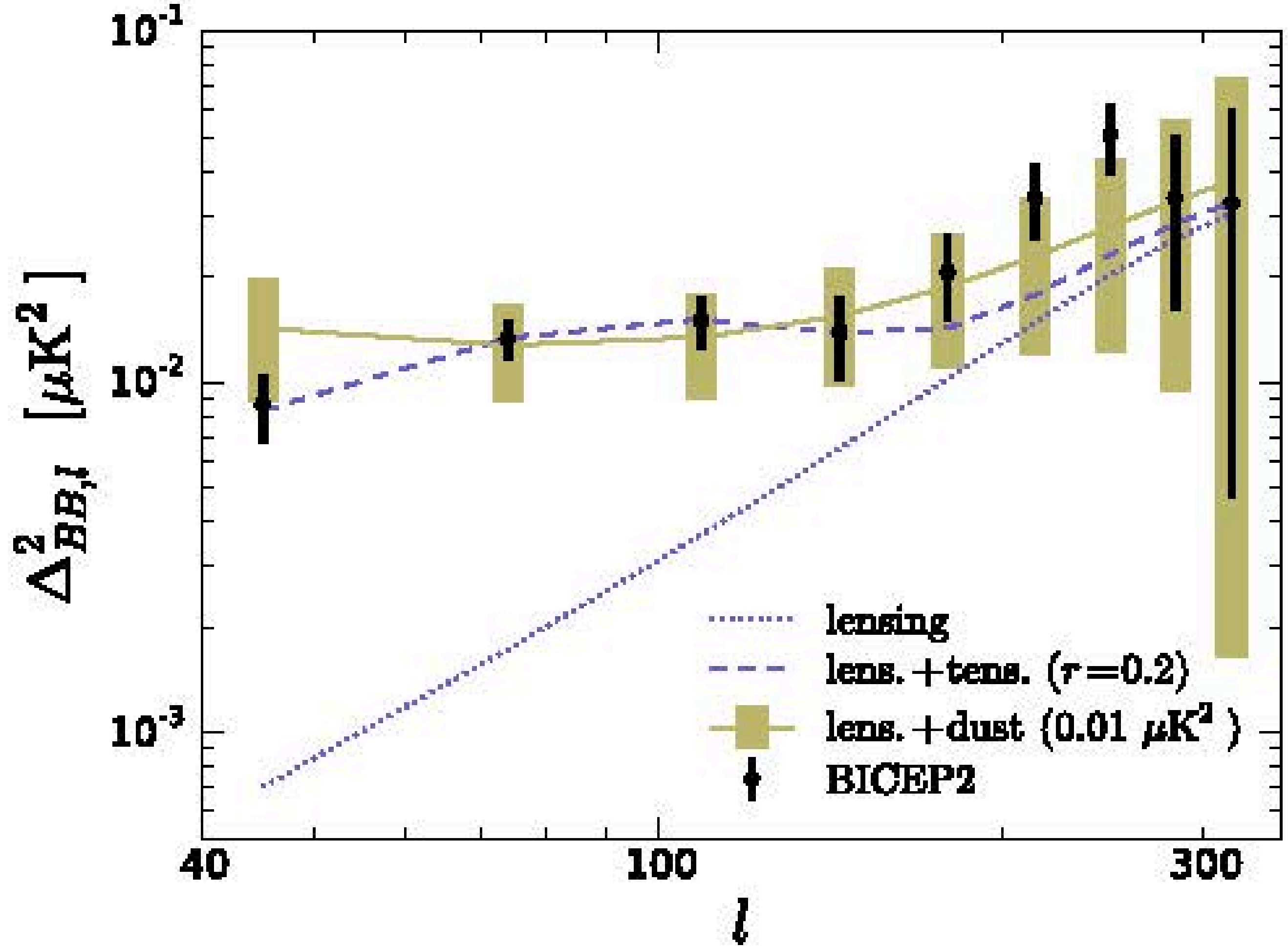
Many regions have more than 15 % polarization. The assumed maximum in the default PSM.

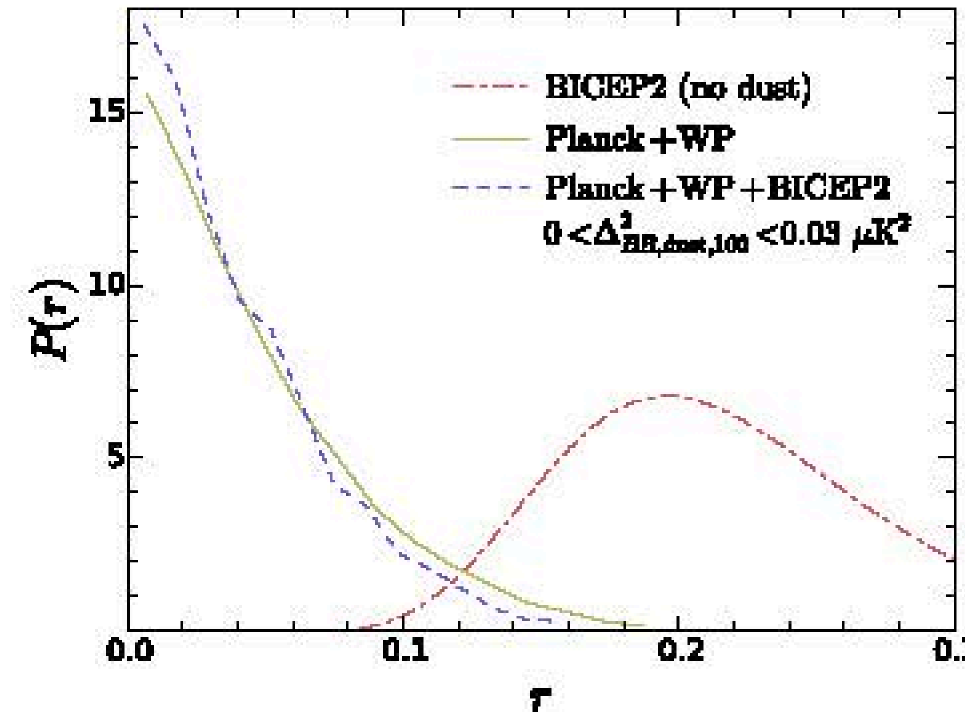
Flauger, Hill & Spergel: Revised Estimates of the level of dust in the BICEP patch

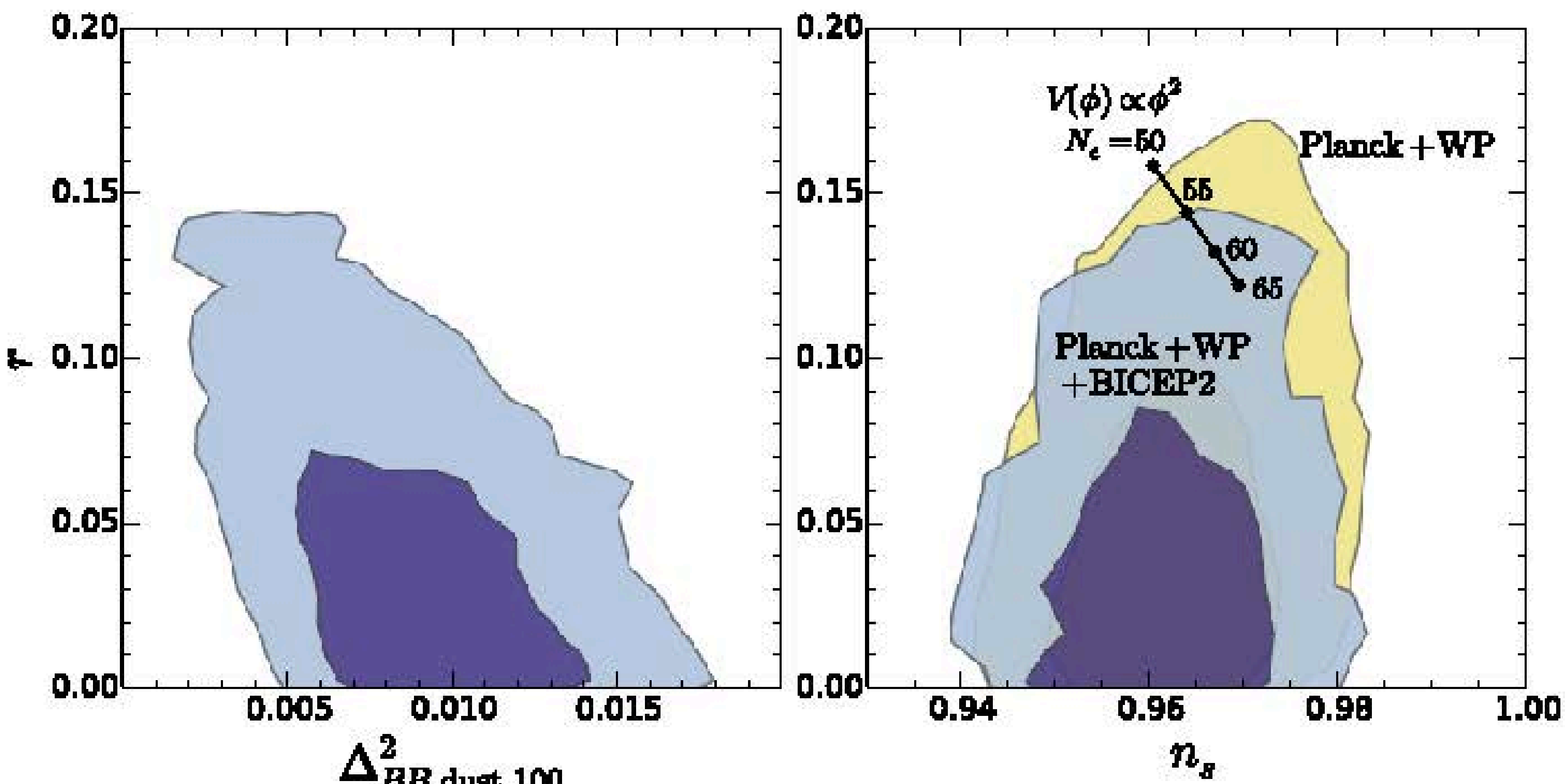




Our current state of knowledge?

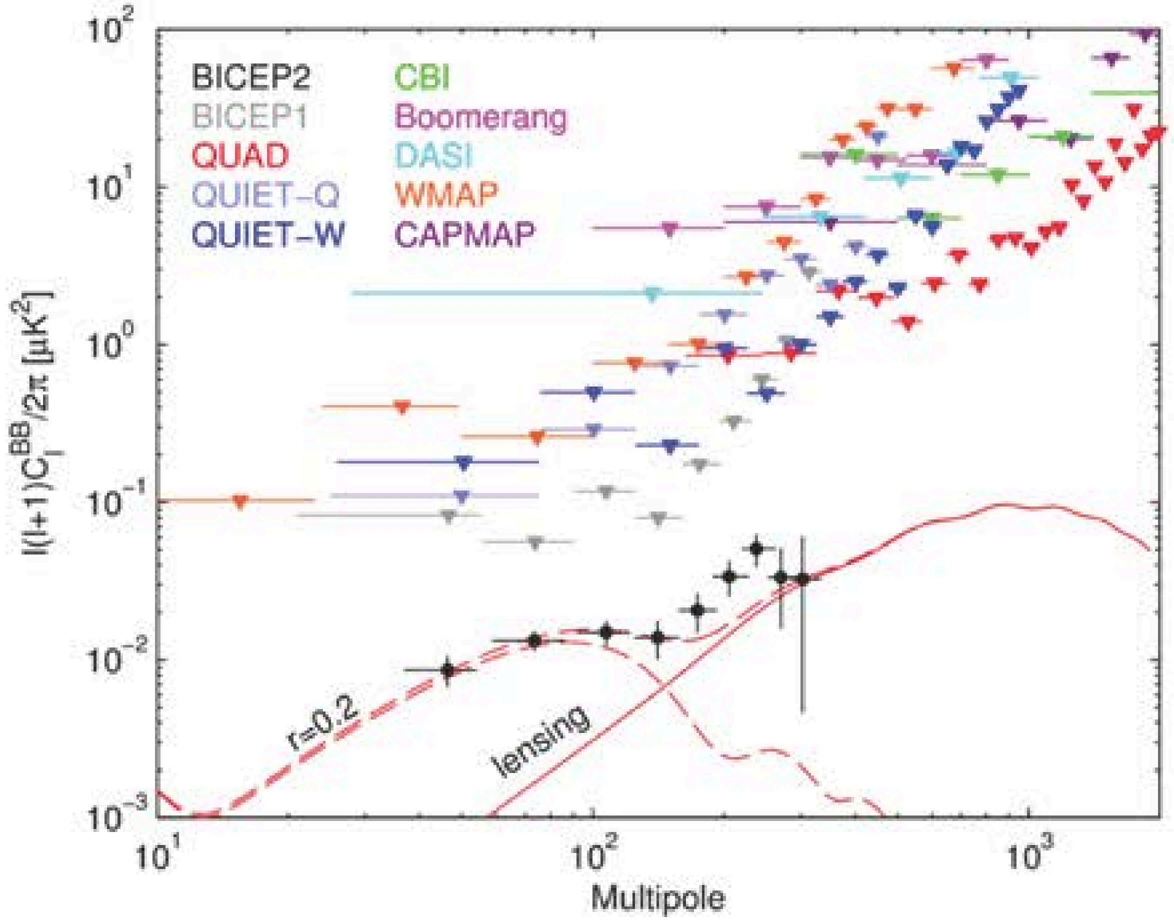


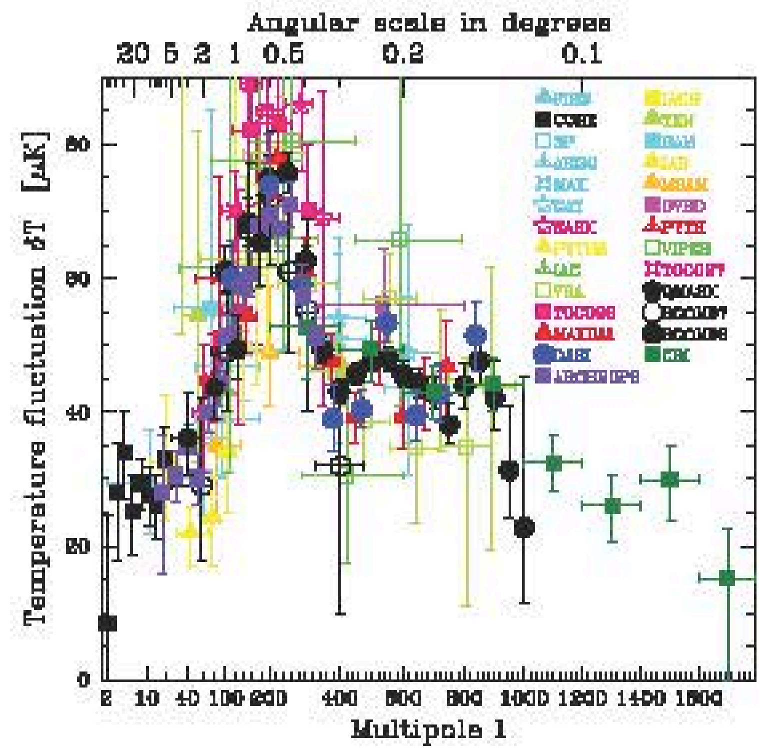




Mortonson & Seljak

... a new era of B-mode cosmology has begun.





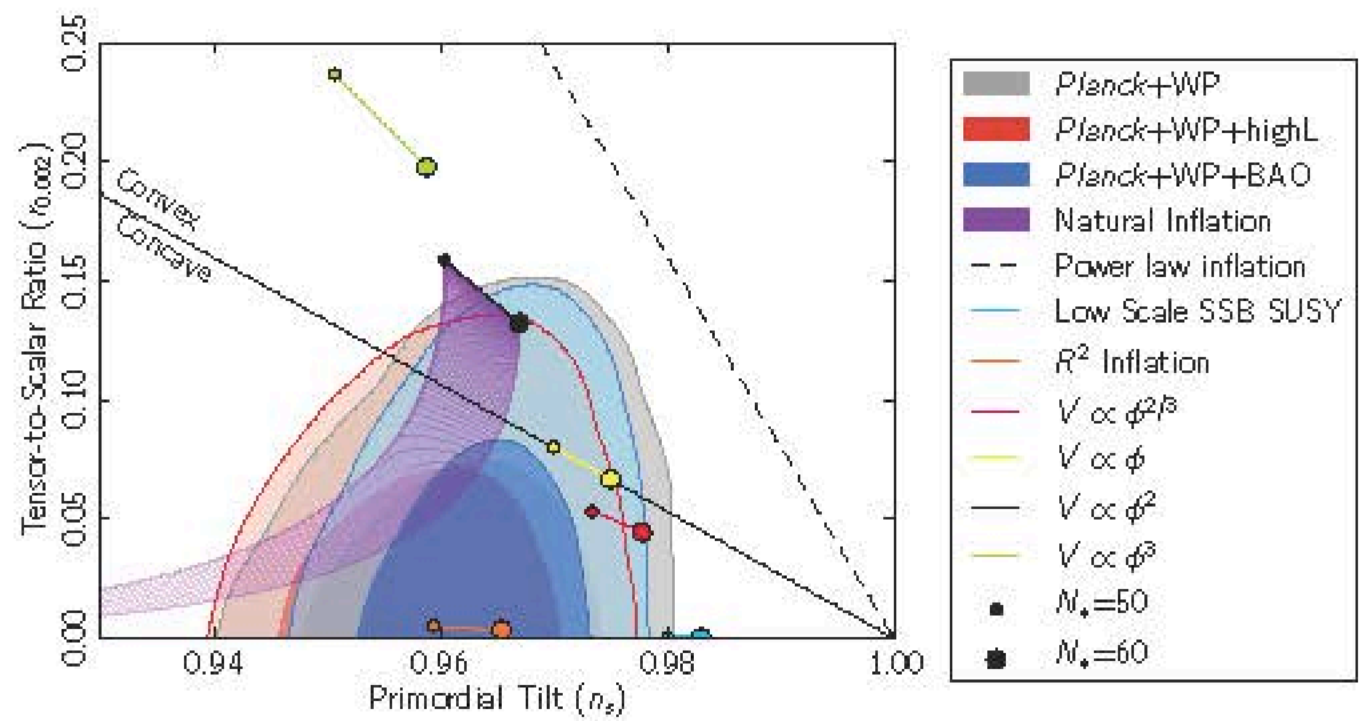


Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

The origin of the seeds of structure

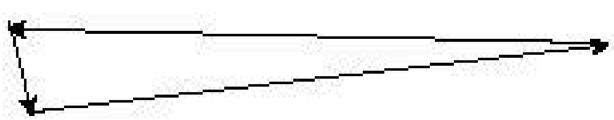
The fact that the seeds for structure formation are primordial in well established. After such impressive data, the idea that the fluctuations were generated during a period of de-Sitter like expansion has survived impressive tests. The firm detection of a non-zero slope for the power spectrum is a stunning success of both the idea and the experiments.

The idea that the source of fluctuations are vacuum fluctuations of a slowly rolling scalar field which served as the clock that determined when inflation ends (ie slow-roll inflation) is much less well established. It is **only** tested through our study of non-Gaussianities. In this area Planck has made tremendous progress. After Planck we can say that this idea has survived non-trivial tests. However a significant fraction of parameter space is still unexplored.

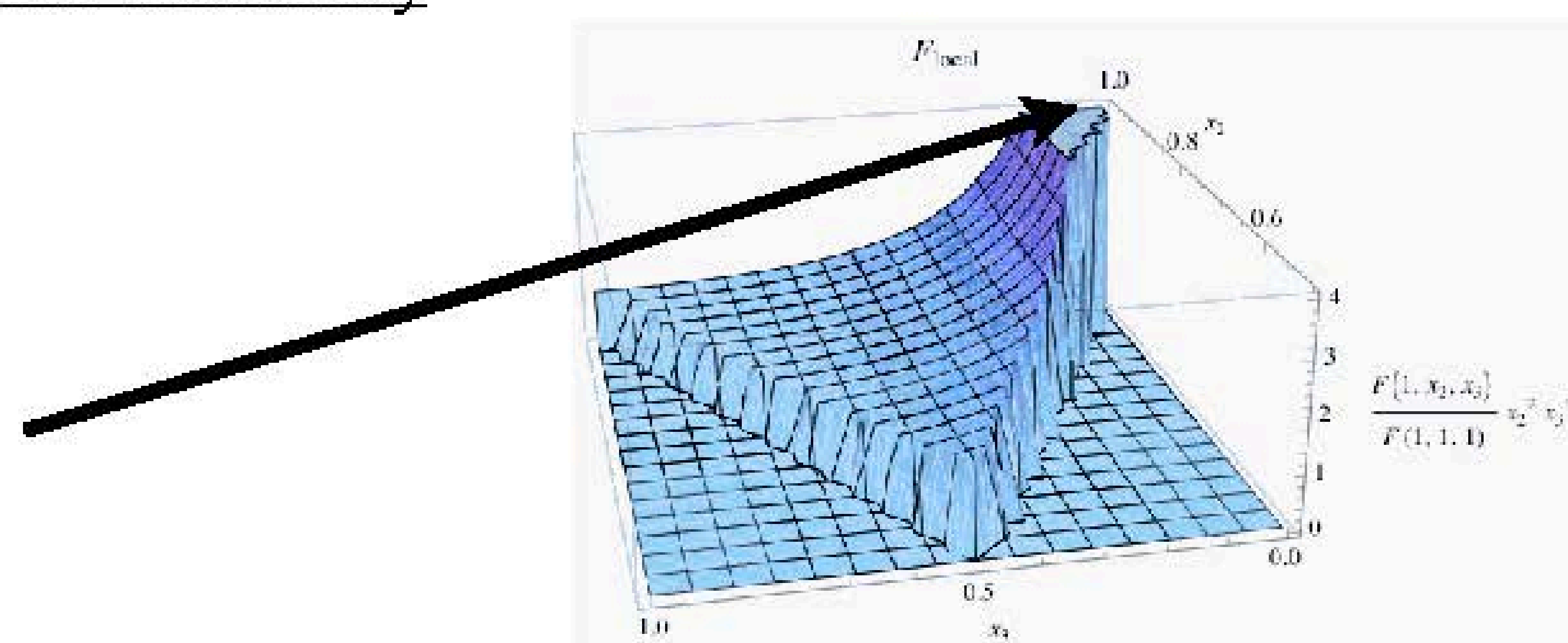
Were fluctuations converted into curvature fluctuations at the beginning/during the hot big bang?

Did super-horizon modes ever produce locally observable differences that modulate the equation of state?

<u>Robust signature: Primordial non-Gaussiniaty</u>



$$k_3 \ll k_2, k_1$$



Dynamics of the adiabatic mode

What is the velocity of propagation of the adiabatic modes during inflation?

Were there other light degrees of freedom interacting with the adiabatic mode during inflation?

The connection between sound speed and non-Gaussianity

In the decoupling limit:

$$S = \int d^4x \sqrt{-g} \left[-\frac{M_{\rm Pl}^2 \dot{H}}{c_s^2} \left(\dot{\pi}^2 - c_s^2 \frac{(\partial_i \pi)^2}{a^2} \right) + (M_{\rm Pl}^2 \dot{H}) \frac{1 - c_s^2}{c_s^2} \left(\frac{\dot{\pi} (\partial_i \pi)^2}{a^2} + \frac{A}{c_s^2} \dot{\pi}^3 \right) + \cdots \right]$$

$$A = -(c_s^2 + (2/3)\tilde{c}_3),$$

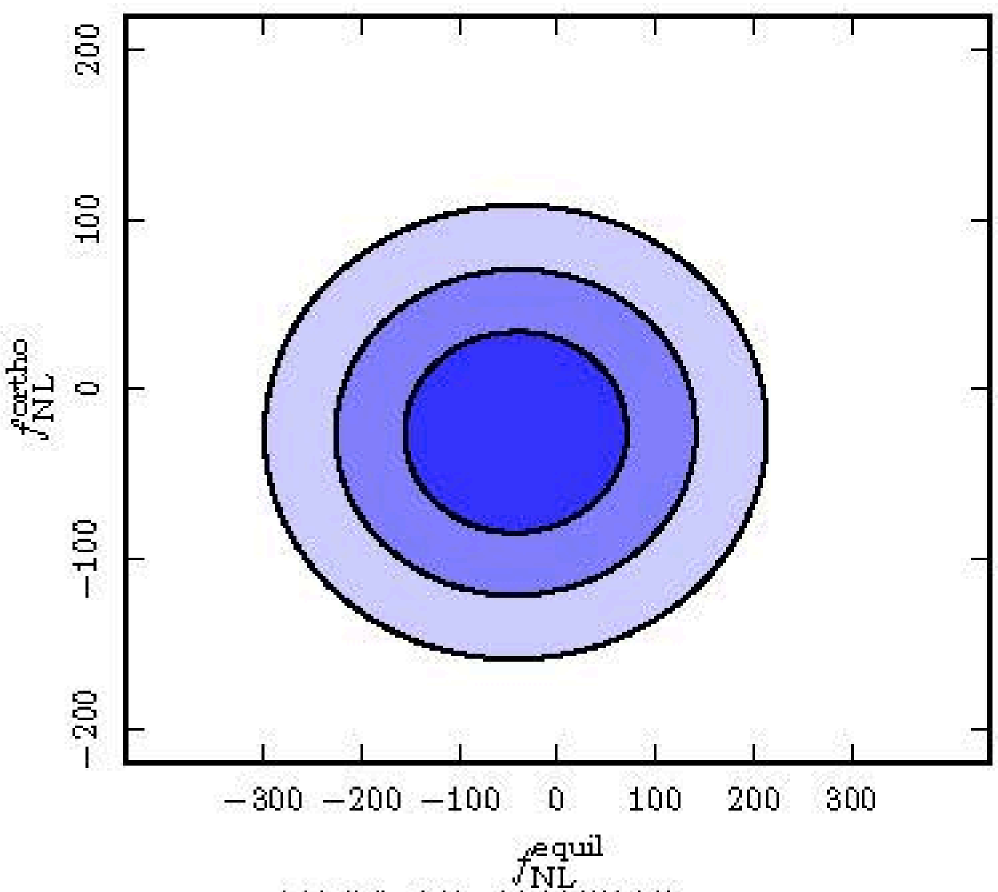
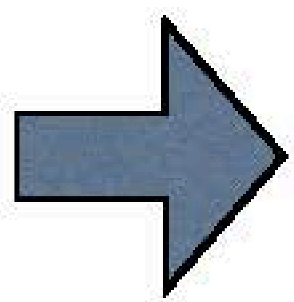


Fig. 22. 68%, 95%, and 99.7% confidence regions in the parameter space ($f_{\rm NL}^{\rm equil}$, $f_{\rm NL}^{\rm ortho}$), defined by thresholding χ^2 as described



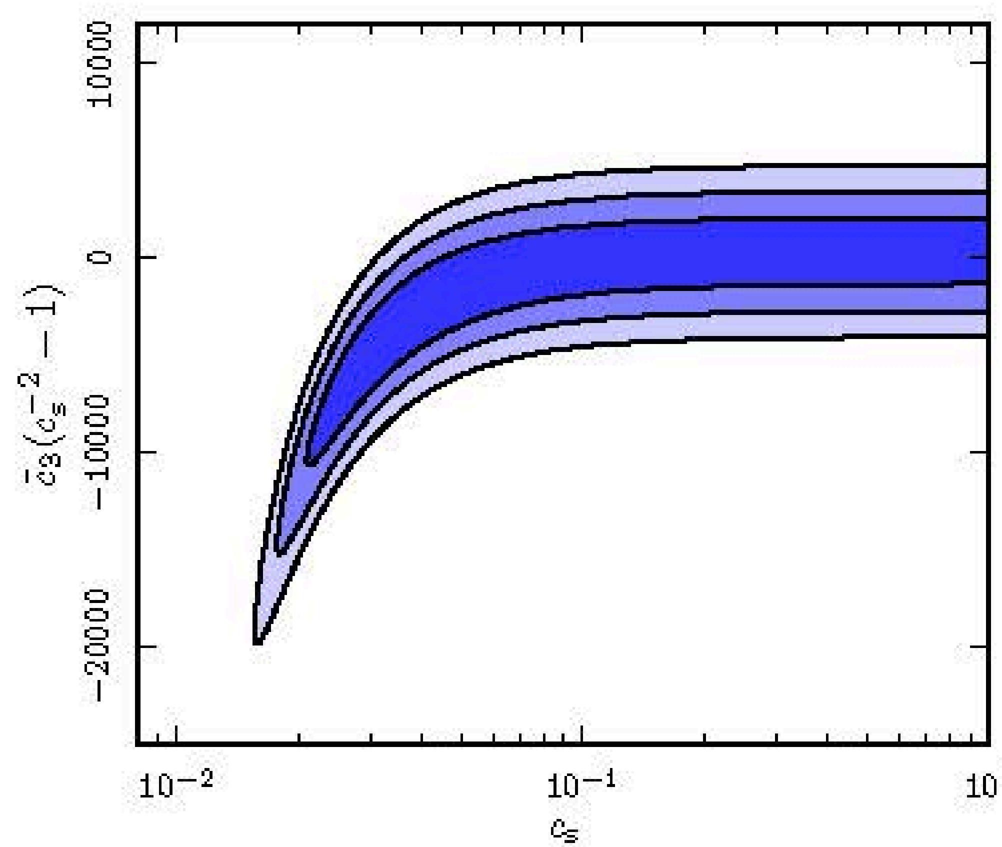


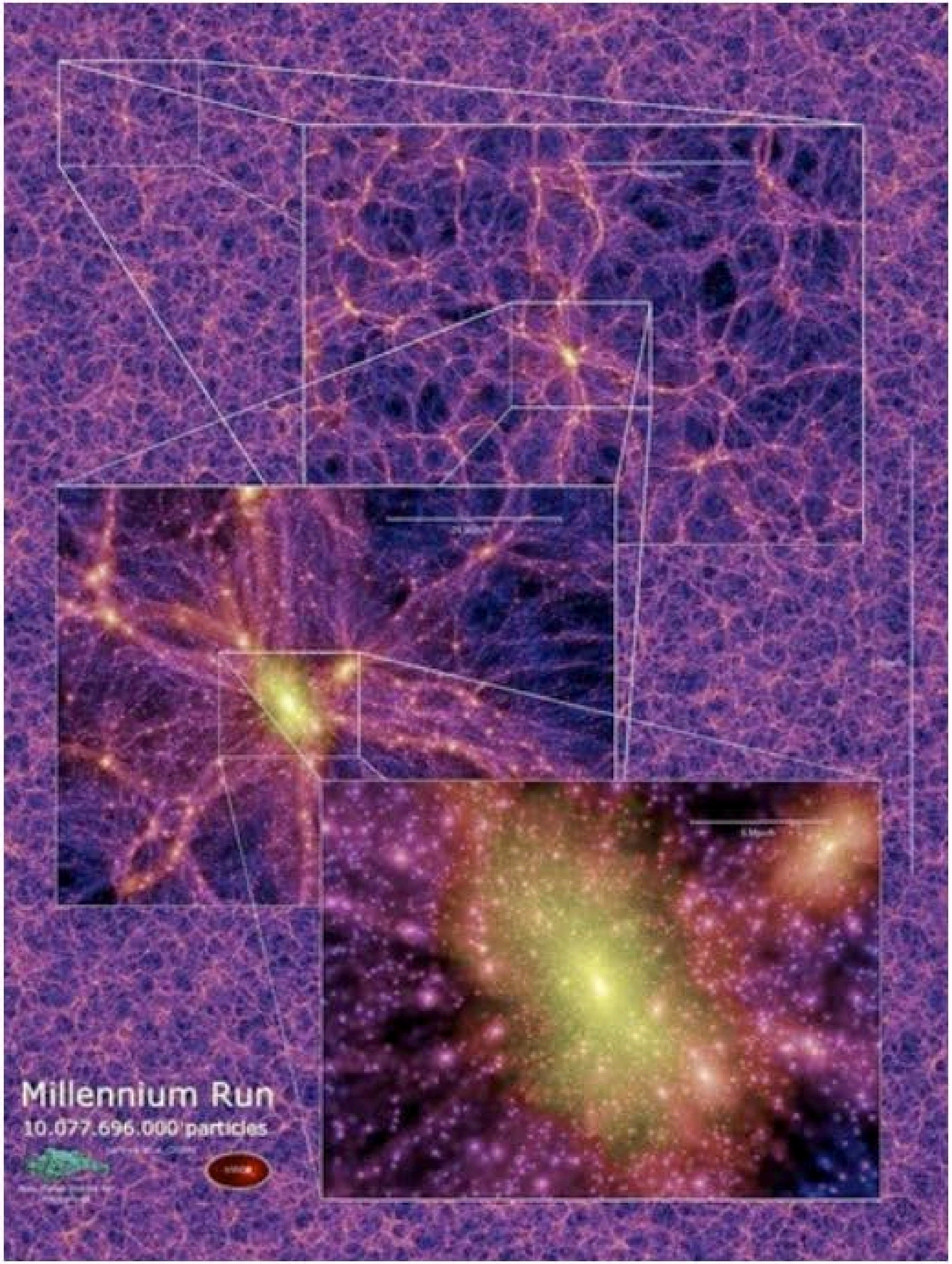
Fig. 23. 68%, 95%, and 99.7% confidence regions in the single-field inflation parameter space (c_s, $\tilde{c}_3$), obtained from Fig. 22 via the change of variables in Eq. (98).

Where do we stand?

	Independent KSW	ISW-lensing subtracted KSW
SMICA		
Local	9.8 ± 5.8	$\mathbf{2.7 \pm 5.8}$
Equilateral	-37 ± 75	$\mathbf{-42 \pm 75}$
Orthogonal	-46 ± 39	$\mathbf{-25 \pm 39}$

The CMB has left us short of the theoretical threshold.

Large Scale Structure



In search for more modes

Mapping larger regions

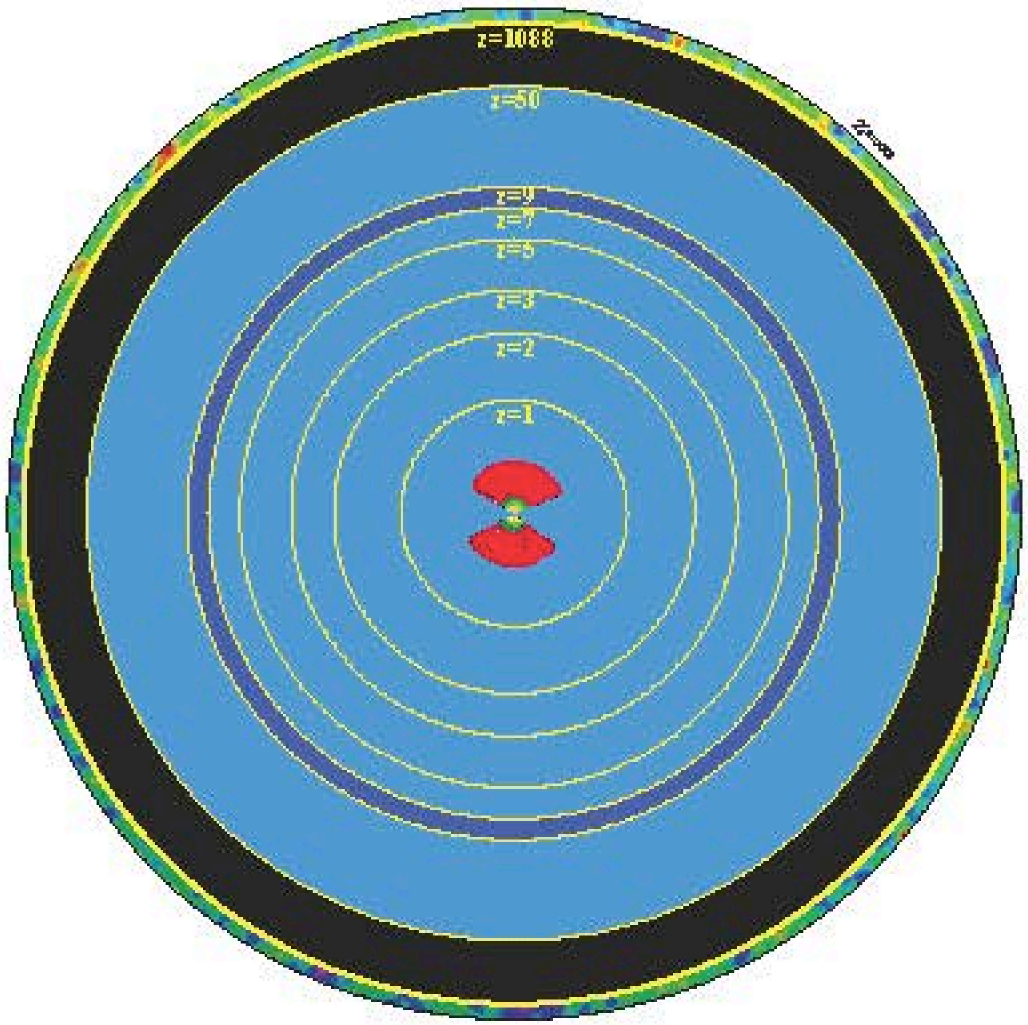
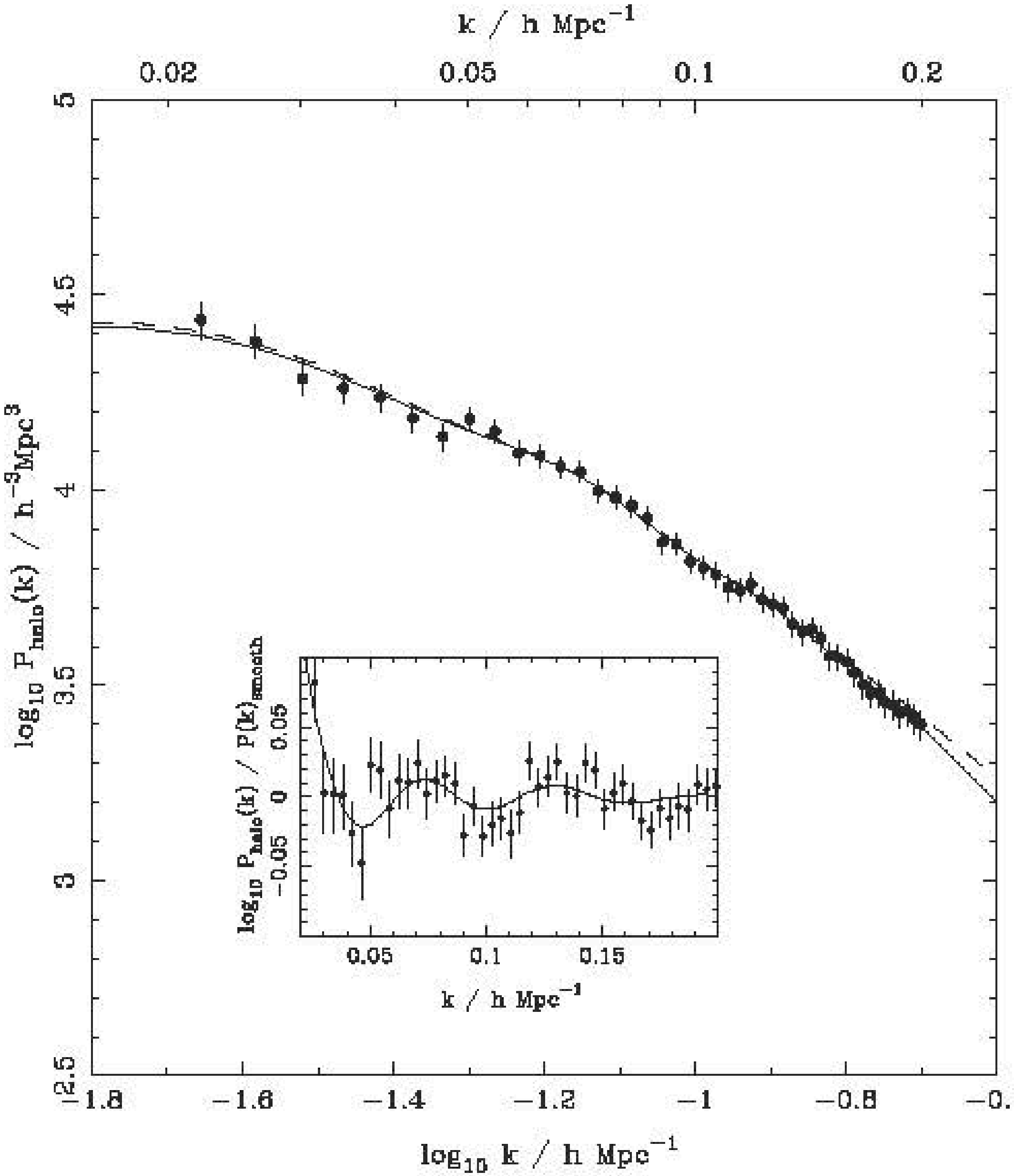


FIG. 1: 21 cm tomography can potentially map most of our observable universe (light blue/grey), whereas the CMB probes mainly a thin shell at $z \approx 1100$ and current large-scale structure maps (here exemplified by the Sloan Digital Sky Survey and its luminous red galaxies) map only small volumes near the center. Half of the comoving volume lies at $z > 29$. Even the convenient $7 \lesssim z \lesssim 9$ region (dark blue/grey) can eclipse the CMB in cosmological precision [1], probing the nature of neutrinos, dark energy, dark matter, reionization and early universe.

Extending our understanding to smaller scales



The EFT of Large Scale Structure: Motivation

From what scales can we still extract information about the initial conditions?

What information is preserved? 2 pt, 3 pt amplitudes/shapes

In what statistic is that information encoded?

The further we can push to smaller scales the more we have. $N \sim k_{max}^3 V$

Summary

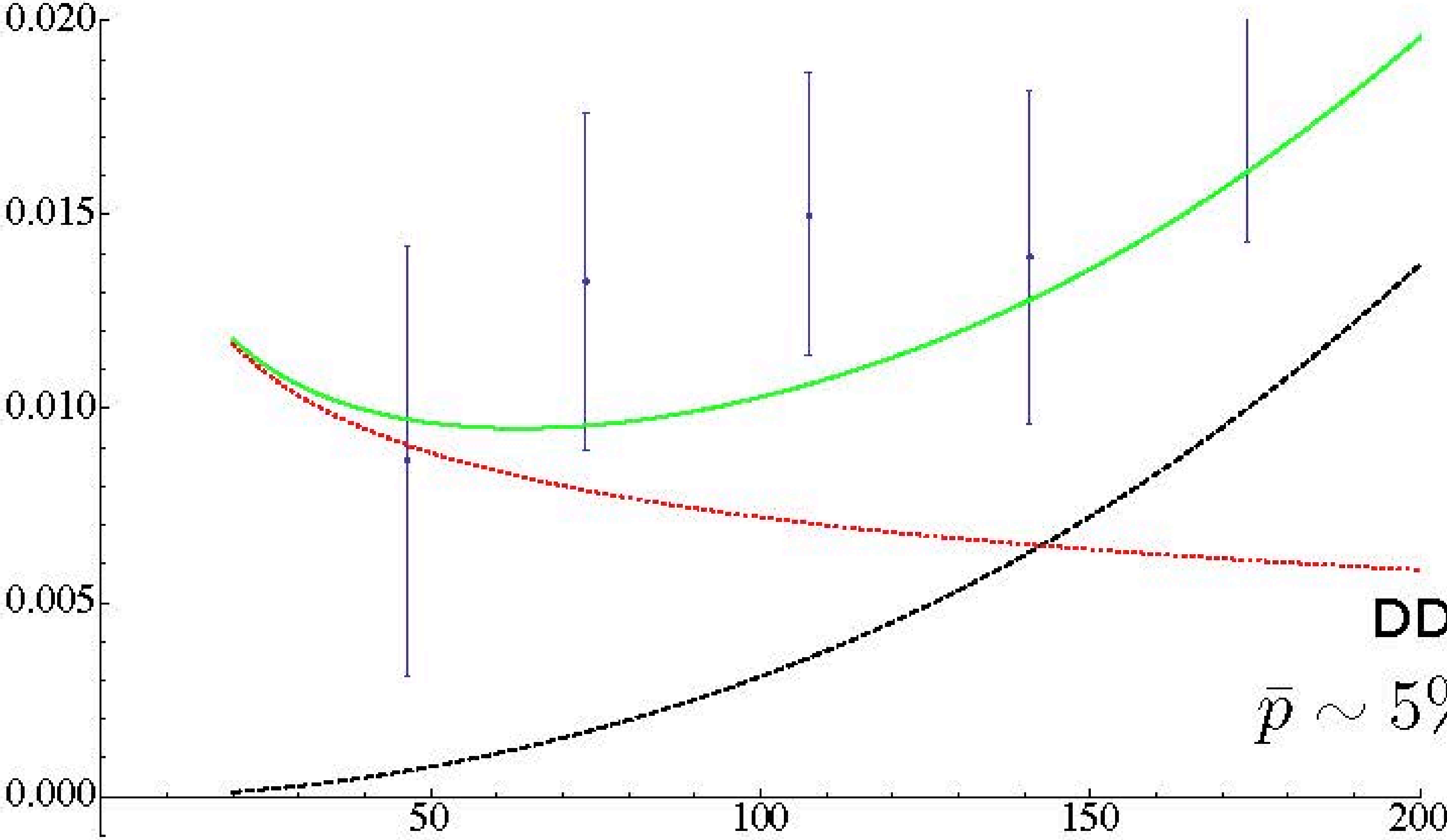
There are several interesting thresholds we want to cross observationally to improve our understanding of the epoch during which the seeds of structure were created.

Our experimental colleagues have arrived to the "gravity wave" threshold.

The non-Gaussianity threshold is further out but is hopefully achievable.

There is reason to hope the coming decades will be as interesting as the previous ones.

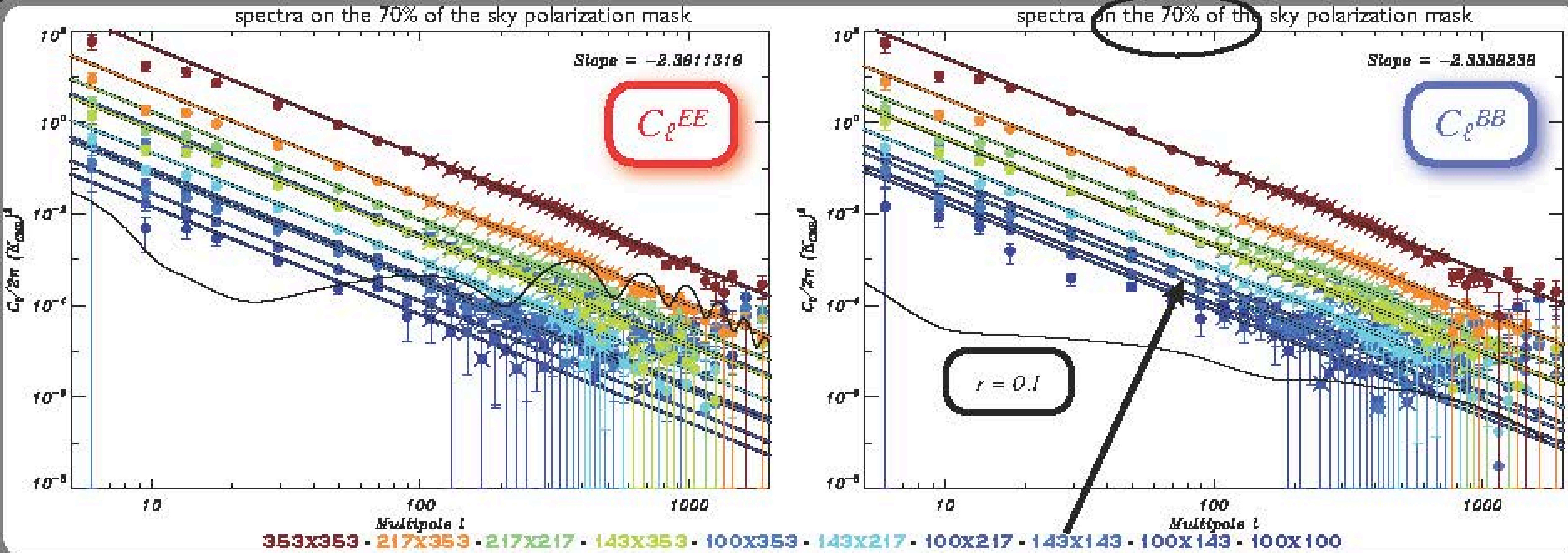
DDM2 rescaled using estimate of bias from CIB monopole

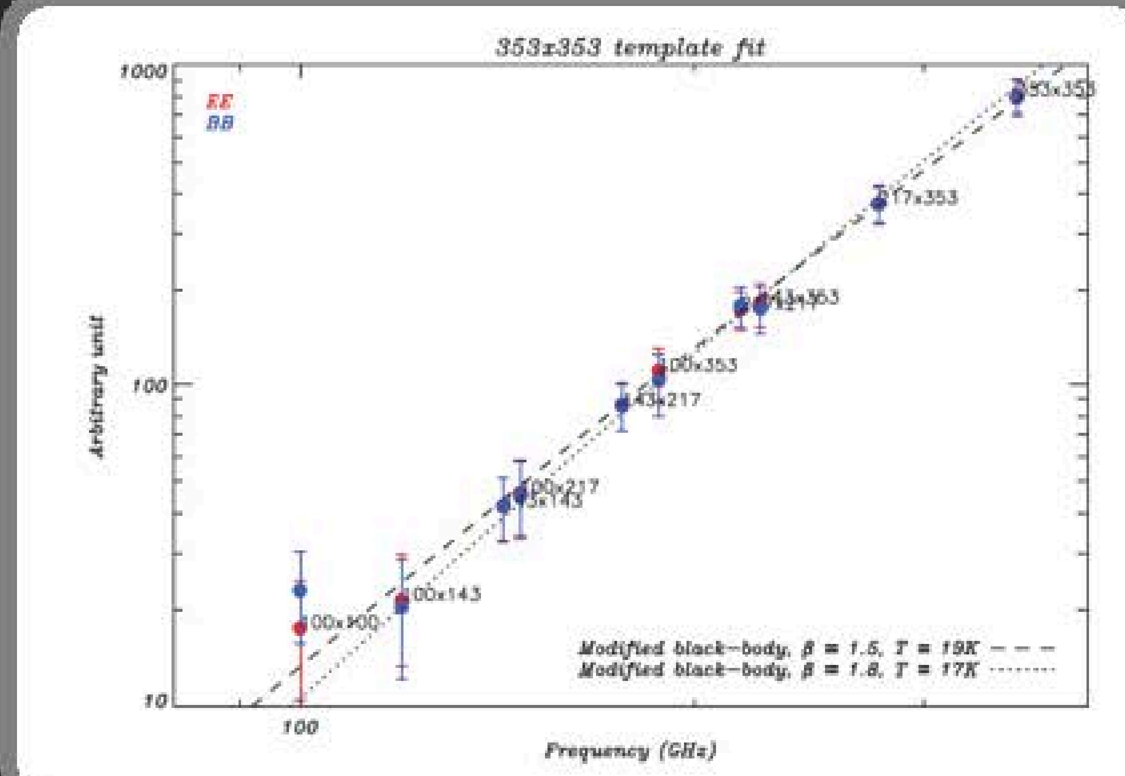


Consistent with "Aumont" scaling.

Without detailed Planck one cannot be confident about a difference between 5% and 8%. Significance much reduced. Need actual maps.

Consistency across HFI frequency bands



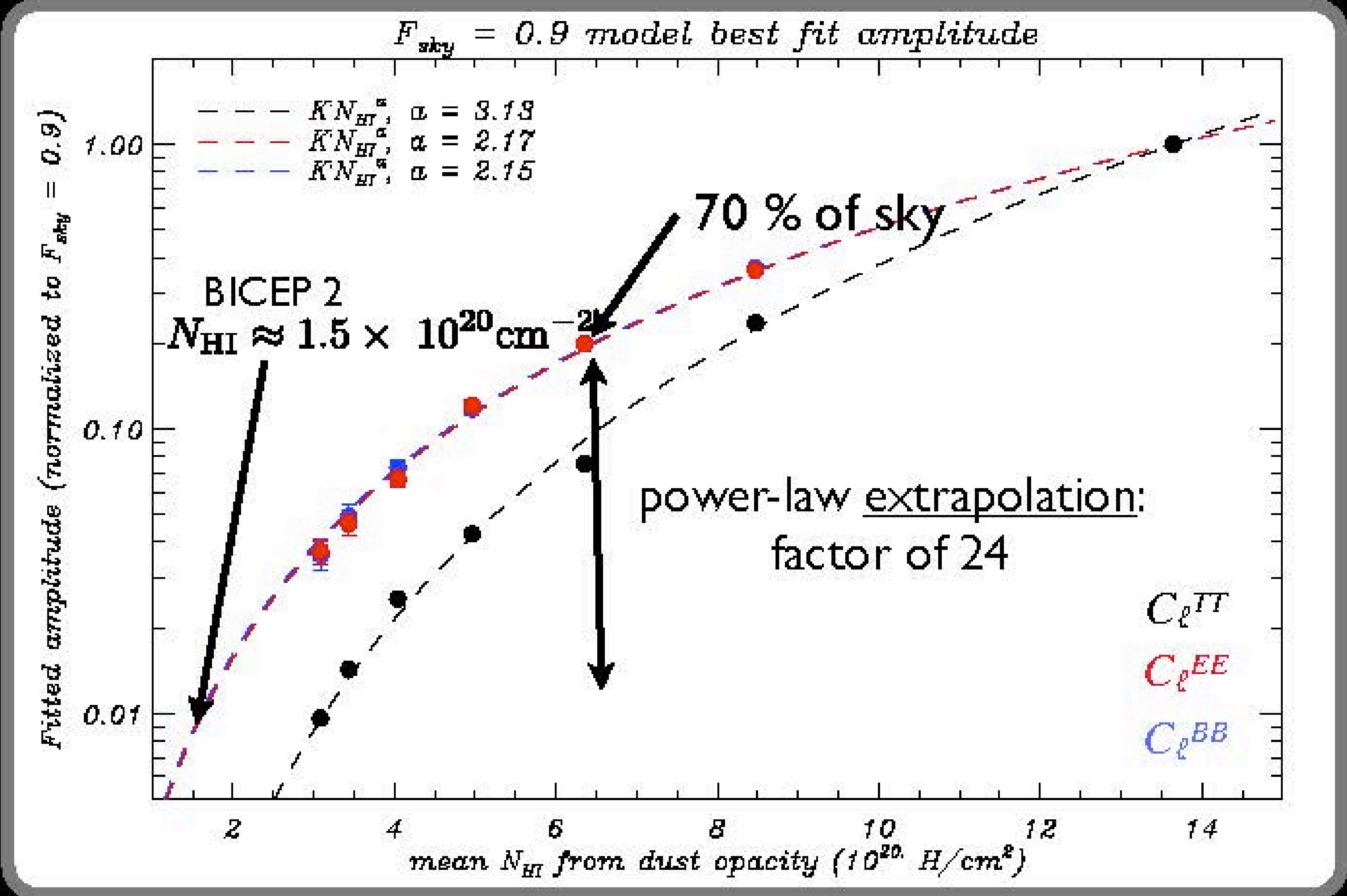


★Spectra among the HFI frequencies are very coherent in *EE* and *BB*

★The SED computed from the effective frequencies are compatible with the other Planck polarization results, i.e. dust polarization is well modeled by a modified blackbody with $\beta = 1.6$ and $T = 19.6$ K

[see Ghosh's poster @ ESLAB, Planck Intermediate Paper 37, to be published]

Proposition for a mask dependence law



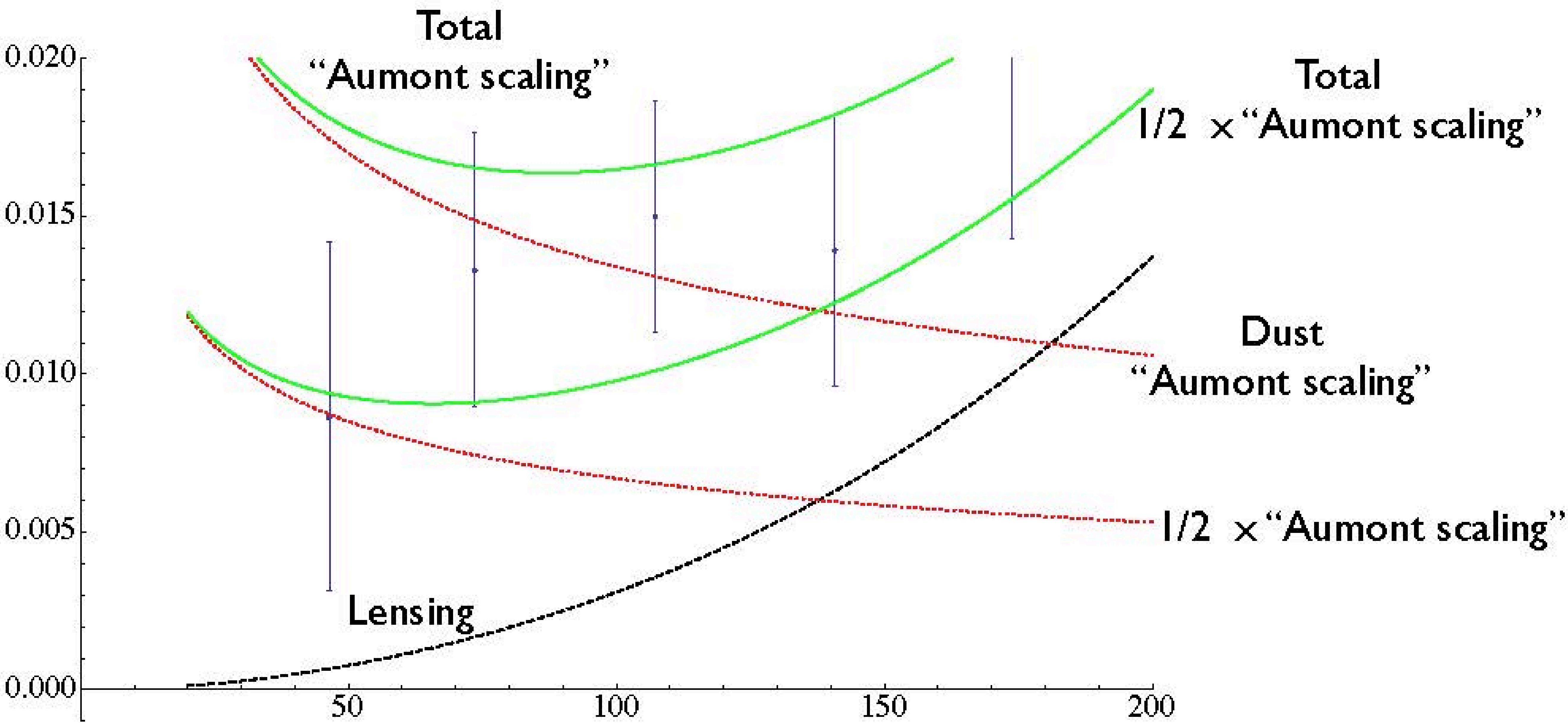
★We fit the amplitudes of the spectra on the intensity and polarization masks with respect to the amplitude of the spectra on 90% of the sky

★We plot the amplitudes as a function of the mean column density of the masks inferred from the opacity of the Planck Sub-millimeter Dust Model [Planck Collab., Planck 2013 results, Explanatory supplement]

★We find that the amplitudes of the spectra follow nicely a power-law of the mean column density

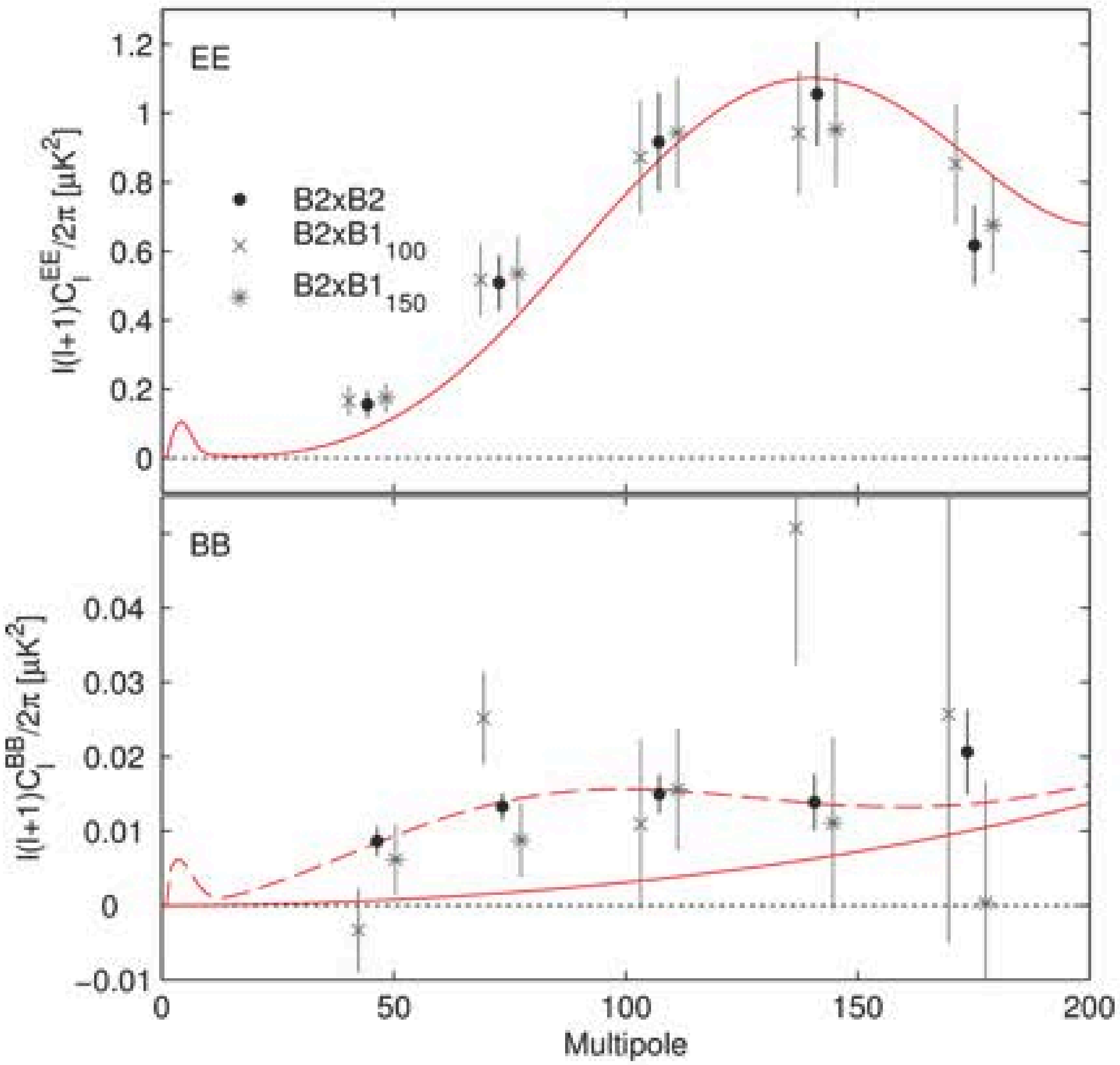
★The dependence law is steeper for intensity than for polarization

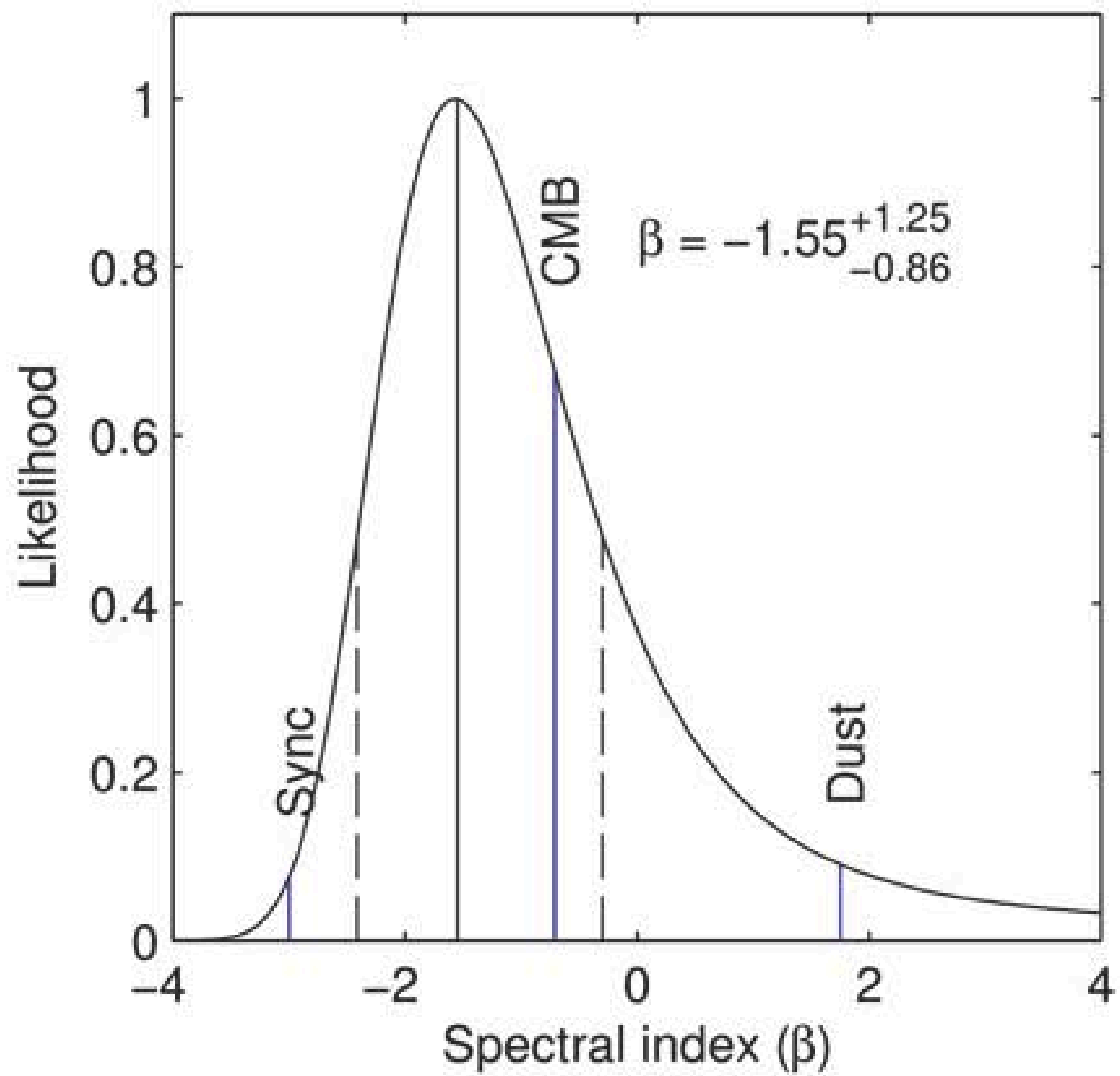
Level of dust contamination from rescaling the Aumont plots



BICEP data seems consistent with "Aumont" scaling for a patch that clean.
Is the BICEP patch much cleaner in BB that the "Aumont" scaling implies?
Impossible to know without Planck maps.
At this point we should quit and wait for Planck, but who can handle the wait?.

Frequency dependence



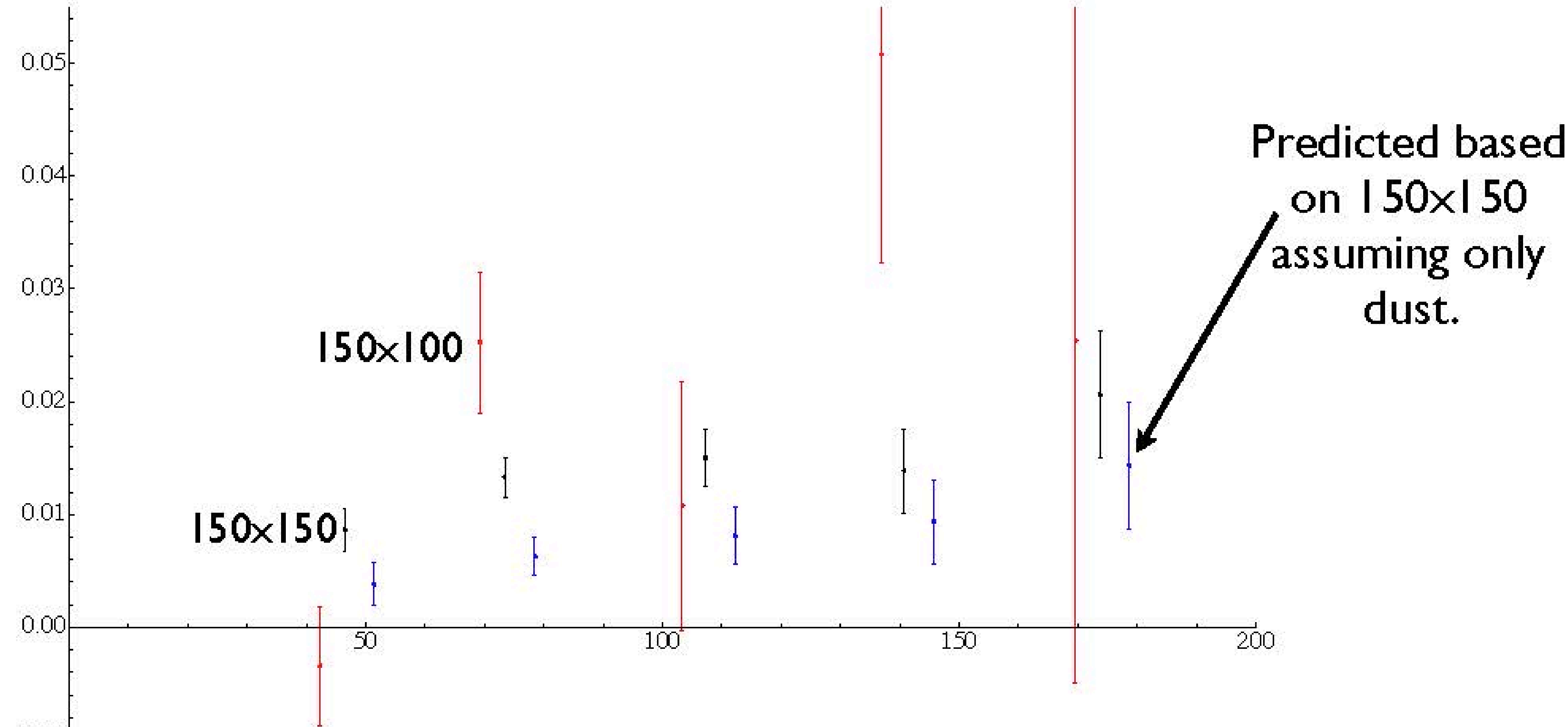


$$f_{\mathrm{dust}} \approx (\frac{100}{150})^{1.65+0.7} \approx 0.4$$

$$f_{\mathrm{sync}} = (\frac{100}{150})^{-3+0.7} \approx 2.5$$

Assumes one single spectral slope for all 5 band powers

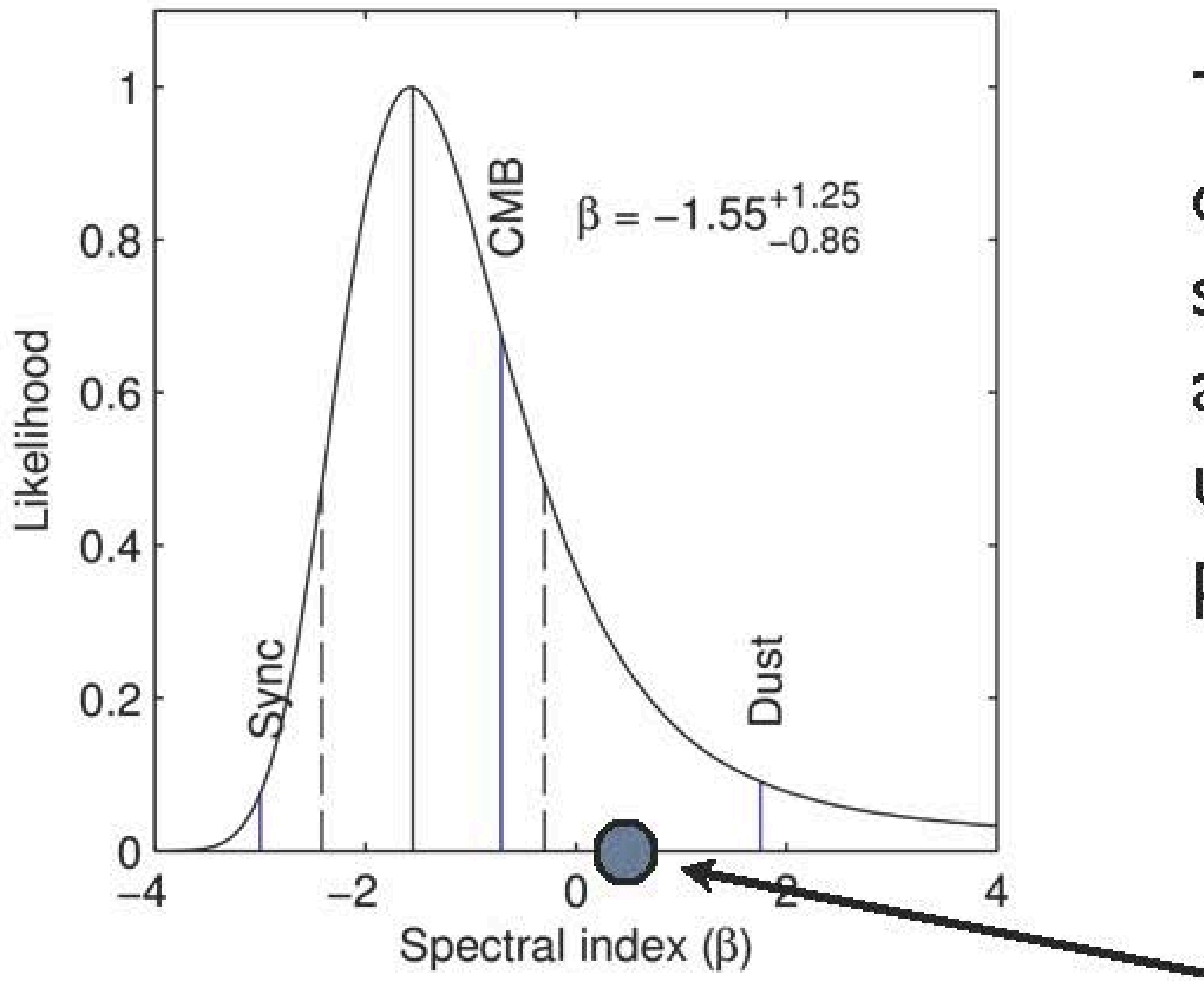
Cross 100-150 vs null hypothesis



Are the blue or the black points a better match to the red 150×100 data points ?

First and second points make most of the difference. They argue in opposite directions. Tensors slightly more likely. However chi squared is very large so there probably is an important covariance, possibly including sample variance (it was not given). Should be done better.

Frequency dependence



The alternative is not pure dust or pure synchrotron, it should include lensing, dust and synchrotron with the uncertainties properly propagated.

Dust + Synch + CMB Lensing
Most important effect is Lensing

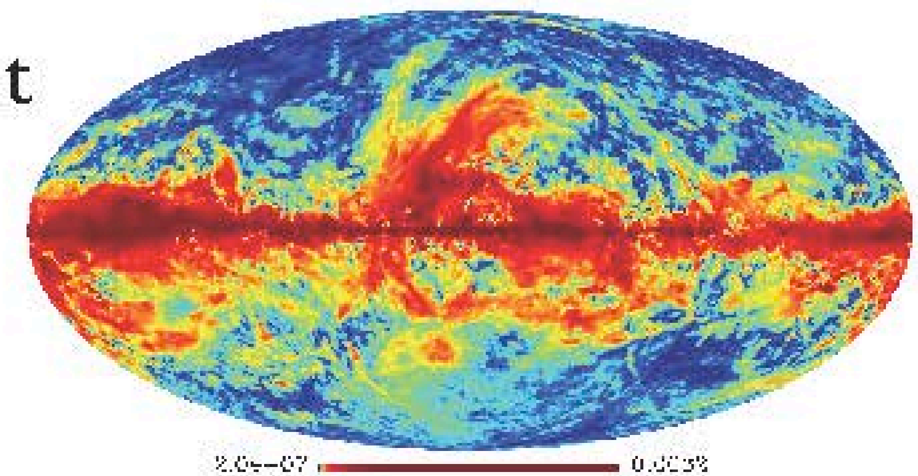
Less than 2 sigma.

Synchrotron and dust are present at the same time and are correlated.

Planck Polarization maps in context

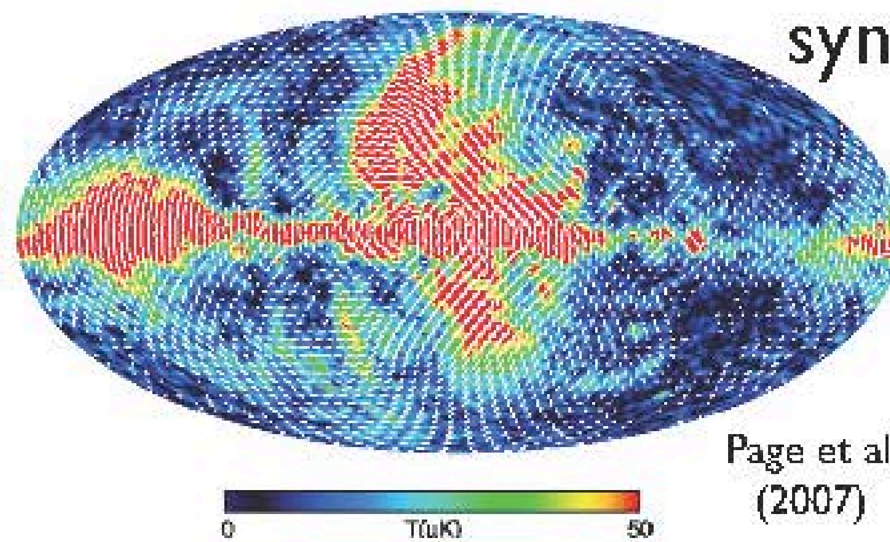
P from Planck 353 GHz at 1° resolution

dust



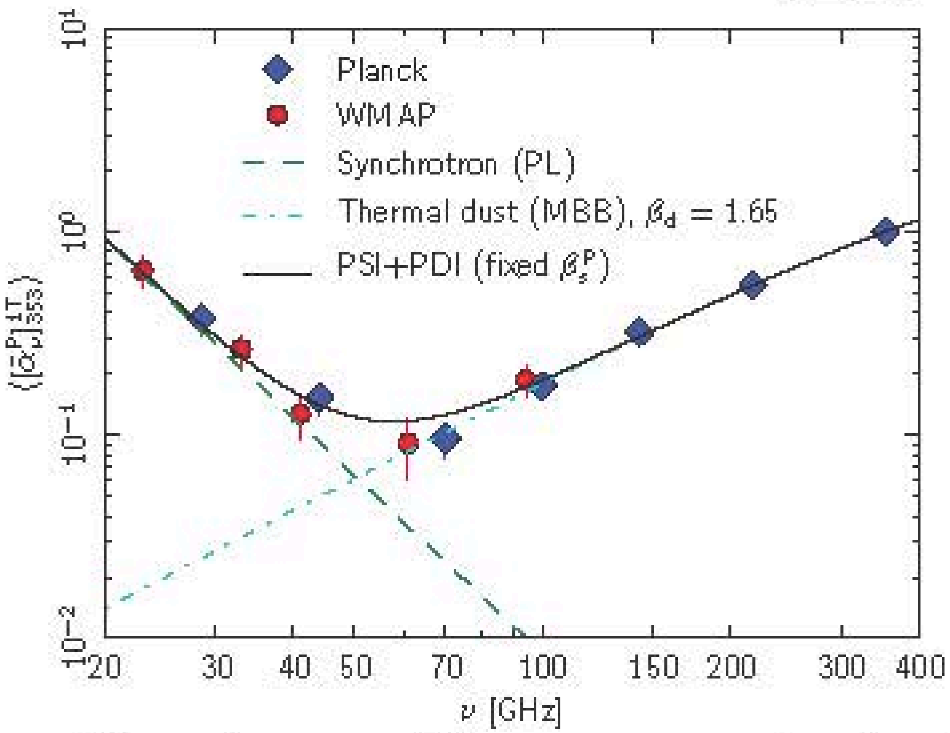
P from WMAP 23 GHz

synchrotron

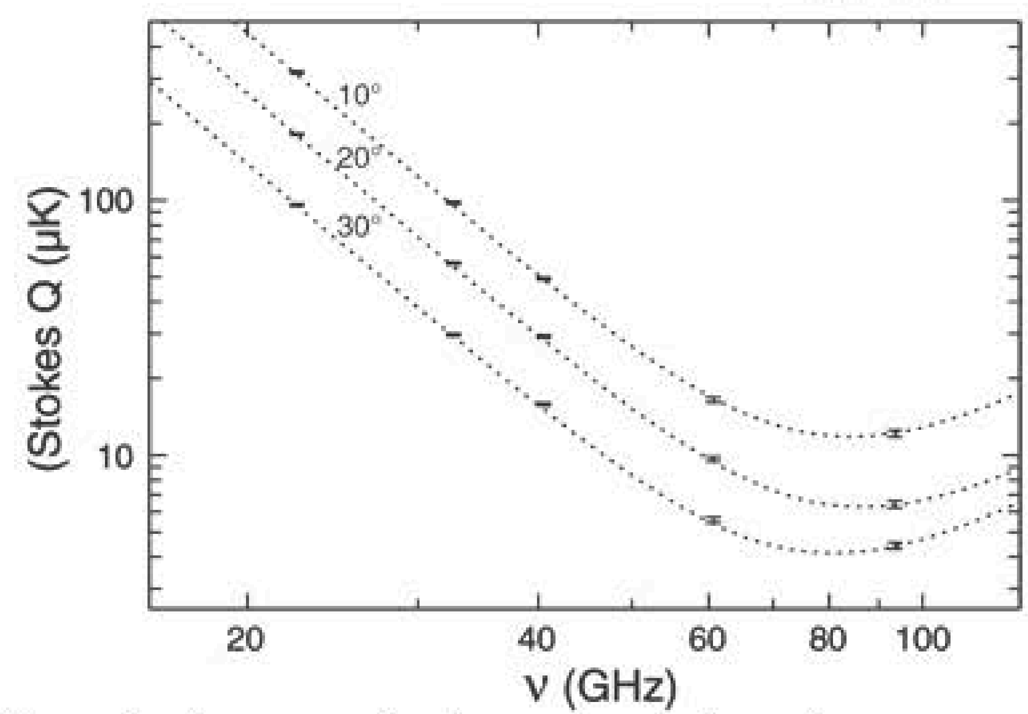


Page et al. (2007)

Planck



WMAP



The shape of these curves is due to the correlation between dust and synchrotron

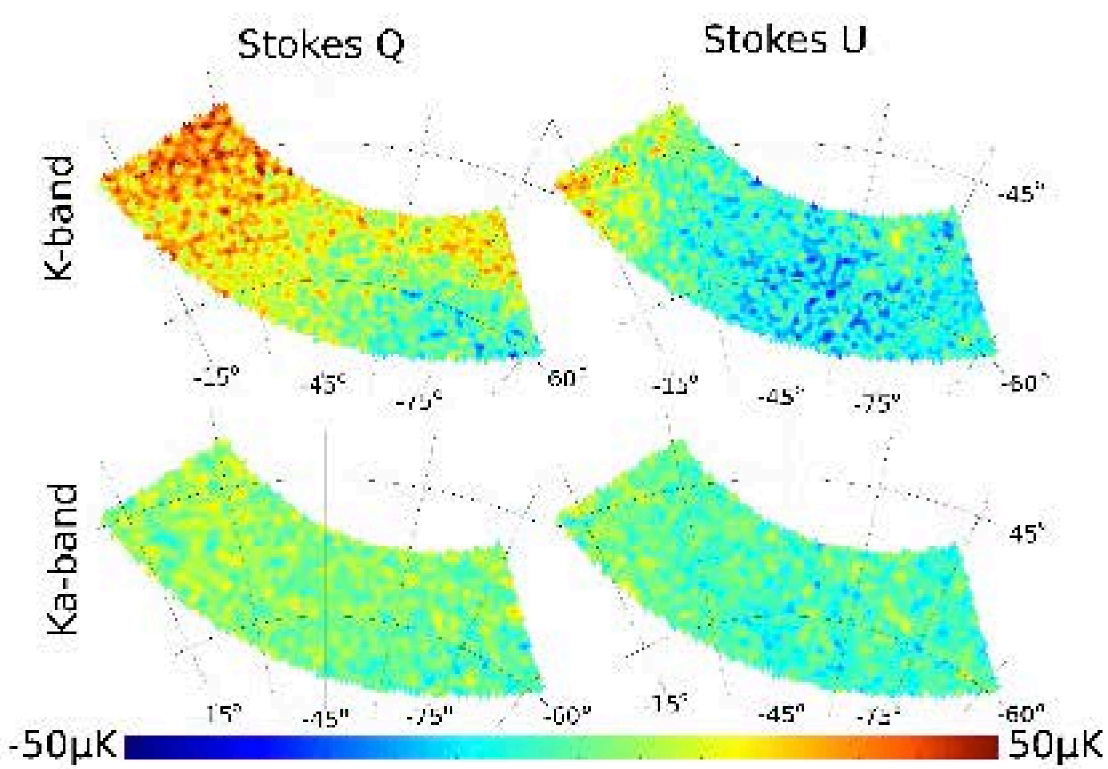
What is the level of synchrotron?

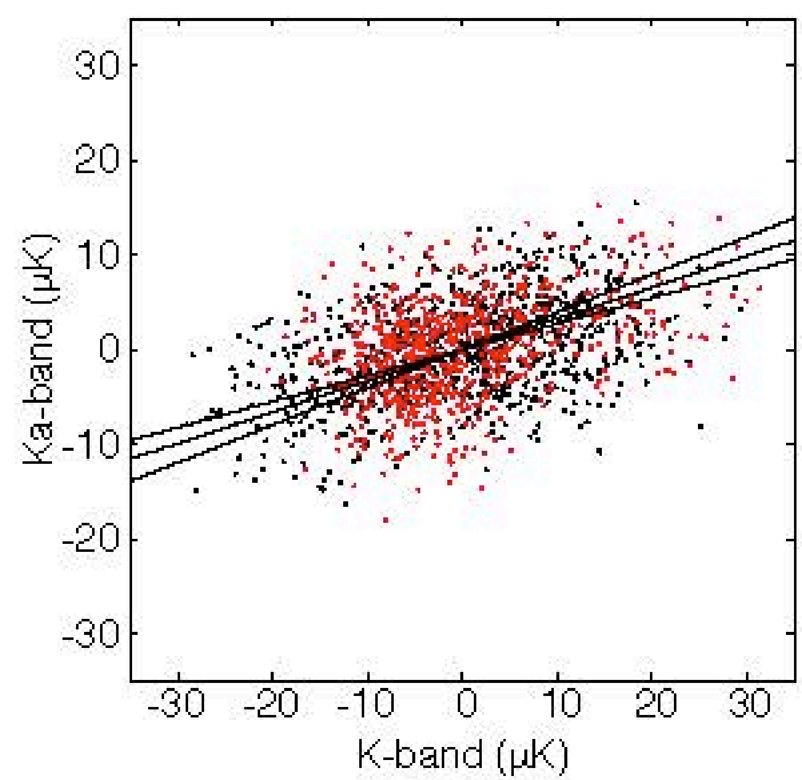
Example: SPATIAL VARIATIONS IN THE SPECTRAL INDEX OF POLARIZED SYNCHROTRON EMISSION IN THE 9-YEAR WMAP SKY MAPS

U. Fuskeland[1], I. K. Wehus[2,3], H. K. Eriksen[1], and S. K. Næss[1,3]

Draft version April 23, 2014

Finally, we study synchrotron emission in the BICEP2 field, in an attempt to understand whether the recently claimed detection of large-scale B-mode polarization could be explained in terms of synchrotron contamination. We estimate that the standard deviation of synchrotron emission in this field is 2.4 μK at K-band on the angular scales of interest. Adopting a spectral index of $\beta = -3.12$, typical for high Galactic latitudes, this corresponds to a synchrotron amplitude of 0.011μK at 150 GHz, equivalent to a primordial B-mode signal of $r = 0.003$. The flattest index allowed by the data in this very low signal to noise region is $\beta = -2.5$, for which the projected amplitude is 0.036 μK. Thus, under the assumption of a straight power-law frequency spectrum, we find that synchrotron emission can in the absolutely worst-case scenario account for at most 20% of the reported BICEP2 signal.





Likely r = 0.003 but could be as large as 0.04. Probably r = 0.01 is a more reasonable "pessimistic scenario". One could probably do a bit better using more WMAP frequencies.

- The level seen in the BICEP patch is what was expected from dust contamination for a typical patch of that characteristics.

- Making more definitive statements require knowing if the BICEP patch is additionally clean and thus require access to dust polarization maps. Unfortunately no such publicly available map exists, thus one is left having to be creative.

- The p map shown at ESLAB seems unreliable in regions of low emission such as the BICEP patch. The mean polarization fraction is likely to have been underestimated due to CIB. Error bars due to zero mode subtraction are probably large, probably also affects the polarization directions.

- Q & U maps not used by BICEP were also shown at ESLAB. Making an argument based on those would require believing they are free of systematics (contrary to what a naive reading of the published Planck papers seems to indicate) and reliably estimating the artifacts from the procedure, including uncertainties related to powerpoint/keynote. In any case results from such exercise seem consistent with estimates based on the "Aumont scaling".

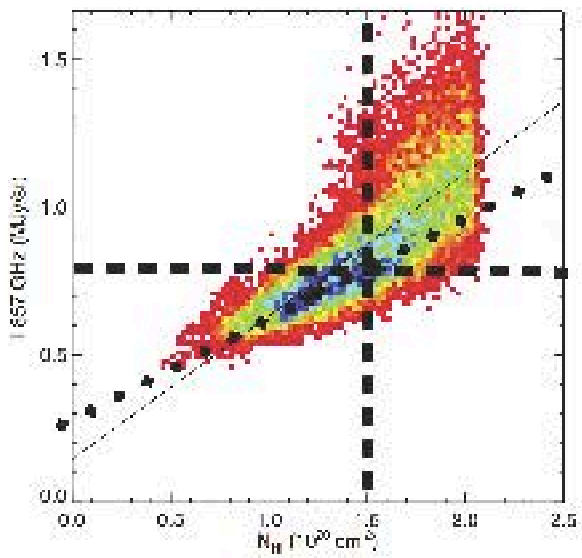
- The constraints from 100x150 are weak, especially once CMB lensing and synchrotron are included.

- I believe the case in favor of a detection of primordial B modes is not convincing (hopefully just temporarily).

Example 2: Zero mode in the intensity maps

$$I = \bar{I} + \delta I$$

Correlation used to set zero level of 857 intensity



20-30 % errors?

Figure 11. 857 GHz-HI correlation over 11.5 % of the sky ($N_{HI} < 2 \times 10^{20}$ cm^{-2} – smoothed to 1° – and excluding intermediate velocity clouds).

The zero modes in the Planck maps are set using a correlation of 857 GHz intensity with NHI which seem uncertain and probably induces tens of percent uncertainties in clean regions such as the BICEP2 one.
This uncertainties propagate to both the degree of polarization and the polarization angle. This uncertainty in not estimated in the BICEP2 paper.
The CIB monopole is added using an empirical model of galaxy evolution.

Correlations used for other channels

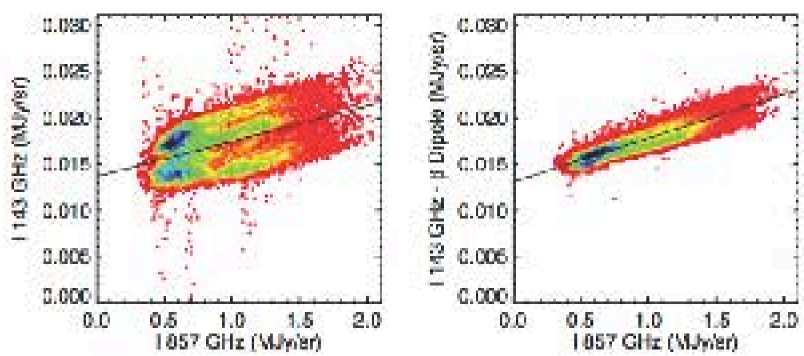


Figure 12. Correlation between the 143 and 857 GHz frequency maps on 28 % of the sky (HI column density smoothed at 1° lower than 3×10^{20} cm^{-2}). CMB anisotropies have been removed at 143 GHz. *Left:* Raw correlation. *Right:* Correlation after a residual solar dipole has been removed at 143 GHz. The offset of this correlation sets the Galactic zero level of the 143 GHz map.

Table 4. CIB monopole that has to be added to the maps.

Frequencies [GHz]	CIB [MJy sr^{-1}] (νI_ν = constant)
100	3.0×10^{-3}
143	7.9×10^{-3}
217	3.3×10^{-2}
353	1.3×10^{-1}
545	3.5×10^{-1}
857	6.4×10^{-1}

Table 5. Table giving the offsets that have to be removed at each frequency to set the Galactic zero level. These offsets have been computed assuming zero Galactic dust emission for zero gas column density.

Frequencies [GHz]	Total maps [MJy sr^{-1}] (νI_ν = constant)	Zodi-removed maps [MJy sr^{-1}] (νI_ν = constant)
100	0.0047 ± 0.0008	0.0044 ± 0.0009
143	0.0136 ± 0.0010	0.0139 ± 0.0010
217	0.0384 ± 0.0024	0.0392 ± 0.0023
353	0.0885 ± 0.0067	0.0851 ± 0.0058
545	0.1065 ± 0.0165	0.0947 ± 0.0140
857	0.1470 ± 0.0147	0.0929 ± 0.0093

How were the equivalent levels for Q and U set? If they have similar size errors it would lead to a factor of 2 error in the predicted CIBB. Going through p seems very unreliable.

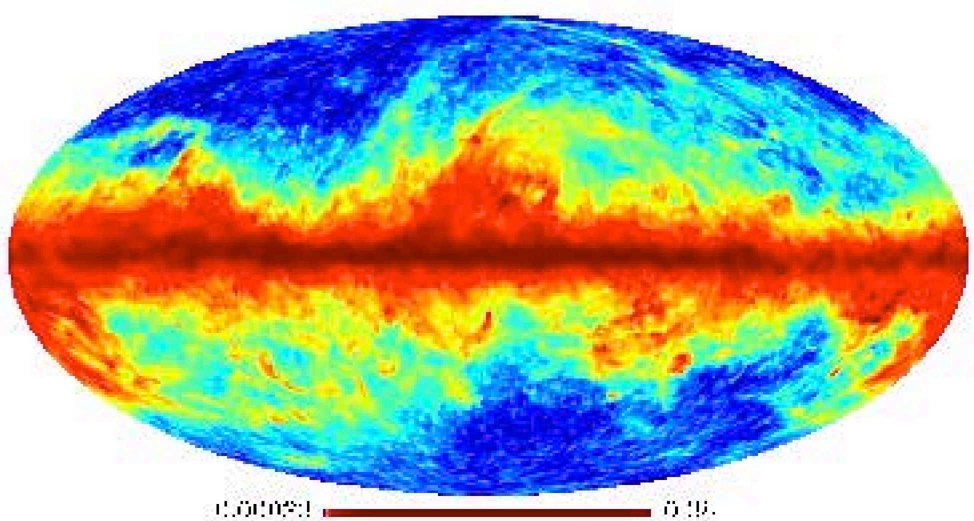
Q & U maps not used in the BICEP analysis were also presented at ESLAB. Using those would side track a lot of the issues related to the p map.

Of course just as with the p map, one should not use them to claim a discovery.

planck

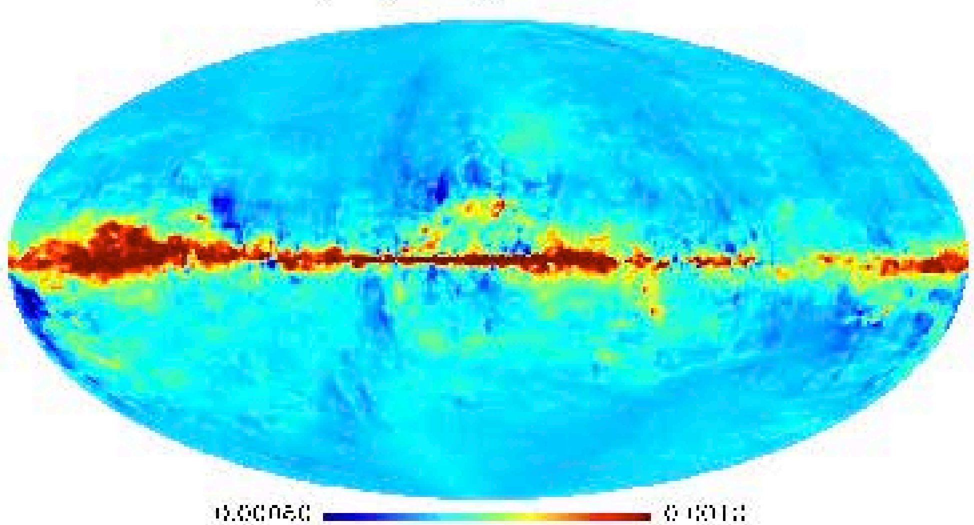
The dust polarization sky at 353 GHz

I map 1deg resolution

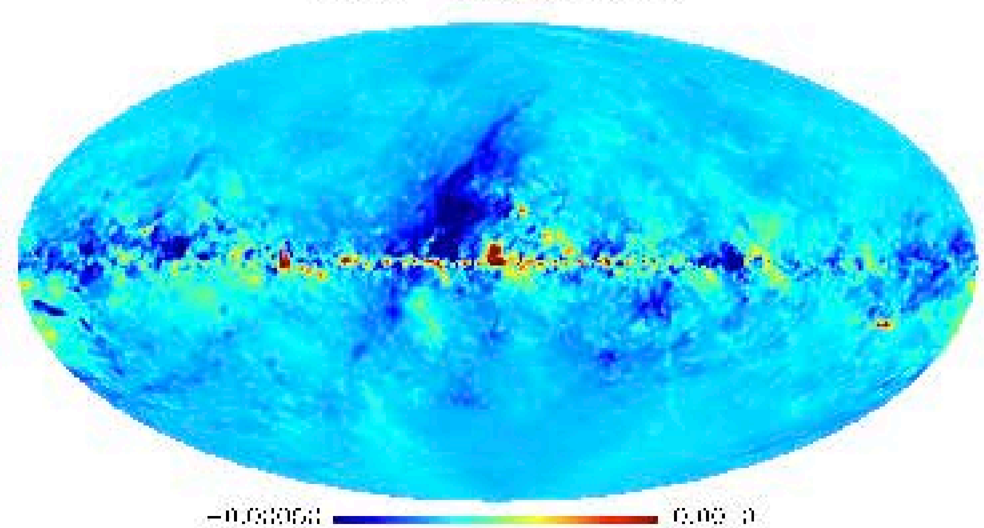


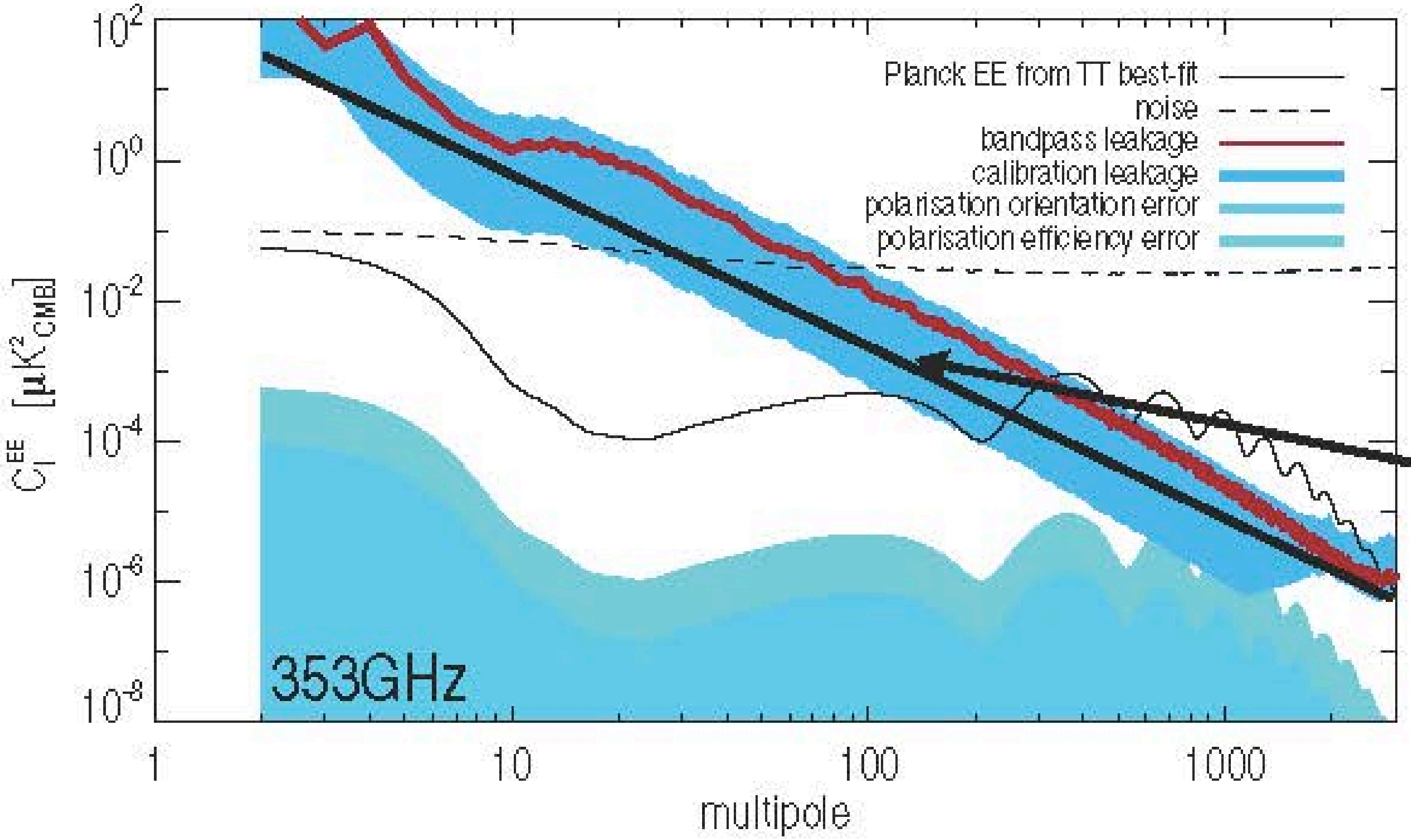
- First all sky maps of dust polarization.
- The data provides the sensitivity to image the polarization of dust emission over the whole sky
- Complementary to observations of stellar polarization which provide detailed information on smaller angular scales

Q map 1deg resolution



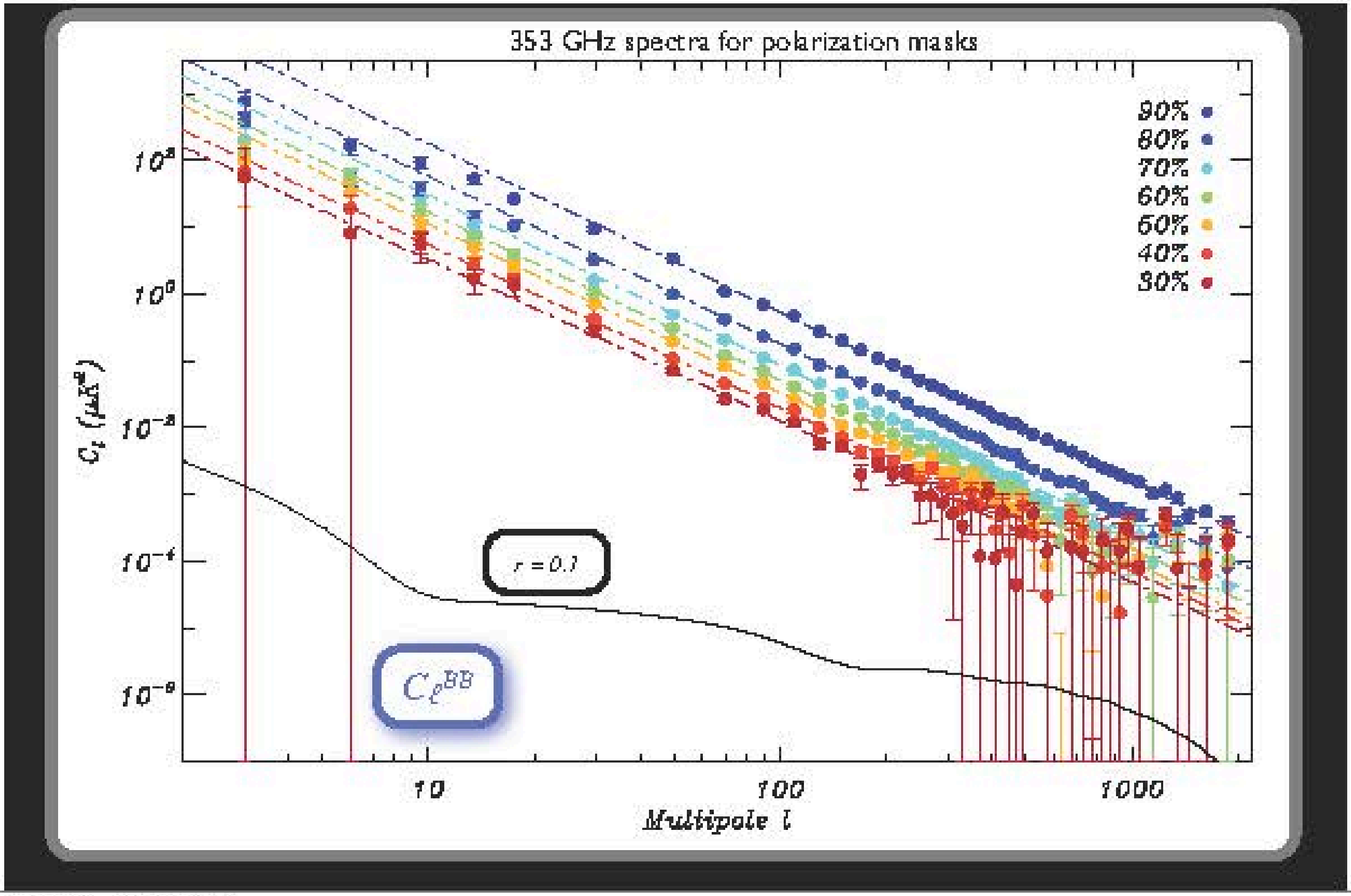
U map 1deg resolution





Are the ESLAB maps reliable enough?

Expected level in BICEP patch from Aumont scaling.



Spectra for regions cleaner than the 30 % presented by Aumont could be affected by systematics in the maps presented at ESLAB.

Let us go on a little bit:

Digitization of the ESLAB Q and U maps

Results from Raphael Flauger:

- Measurement of E and B spectra agree with Aumont estimates.

- Can reproduce the original ESLAB polarization fraction map and the one presented in 1405.0871 after CIB and monopole corrections. Monopole corrections seem to in introduce significant uncertainty into this map in regions as clean as the BICEP one.

- BB power spectra in BICEP patch consistent with Aumont scaling.

- Healpix -> powerpoint -> Healpix can introduce significant artifacts that need calibration.

- Strong correlation between dust and synchrotron.

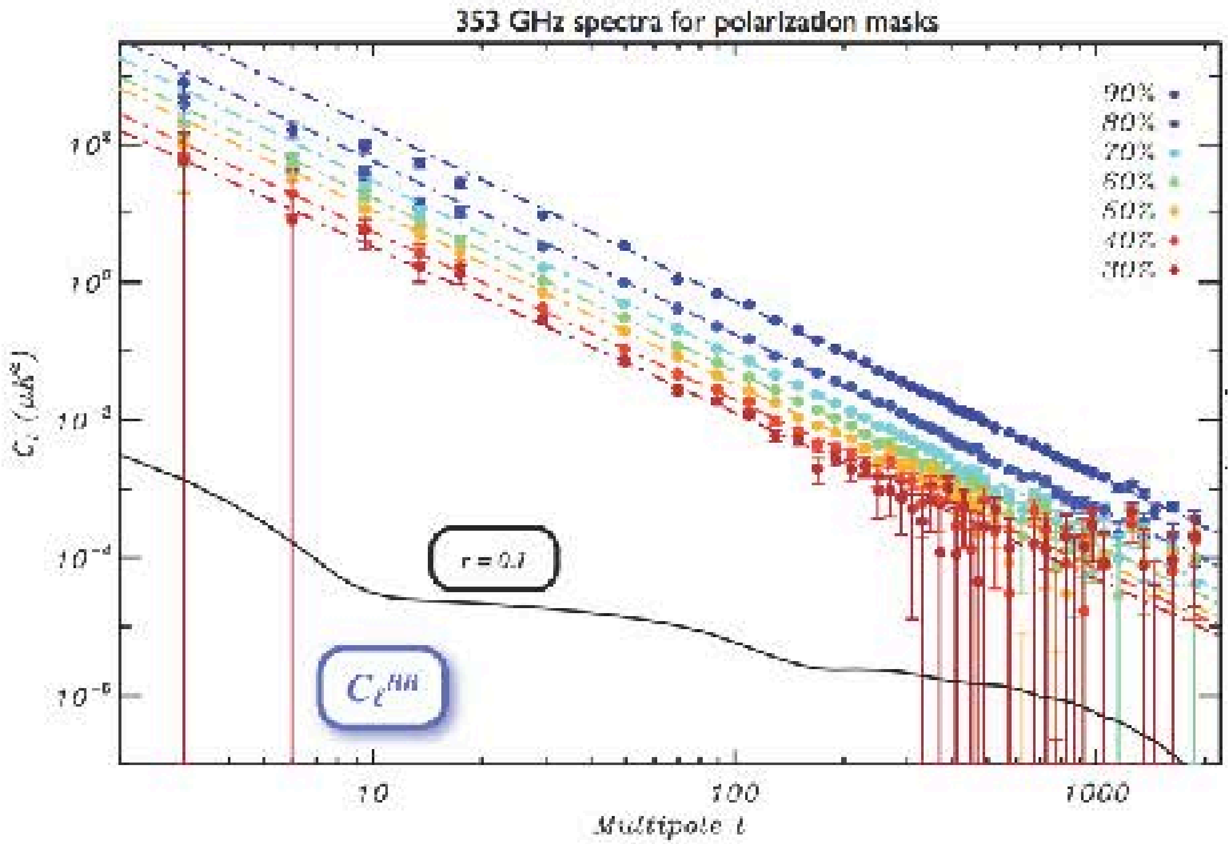
The Aumont extrapolation seems reasonable, suggesting again that BICEP could be significantly contaminated. More definite statements will have to wait until Planck releases its data.

Estimate from HI column density

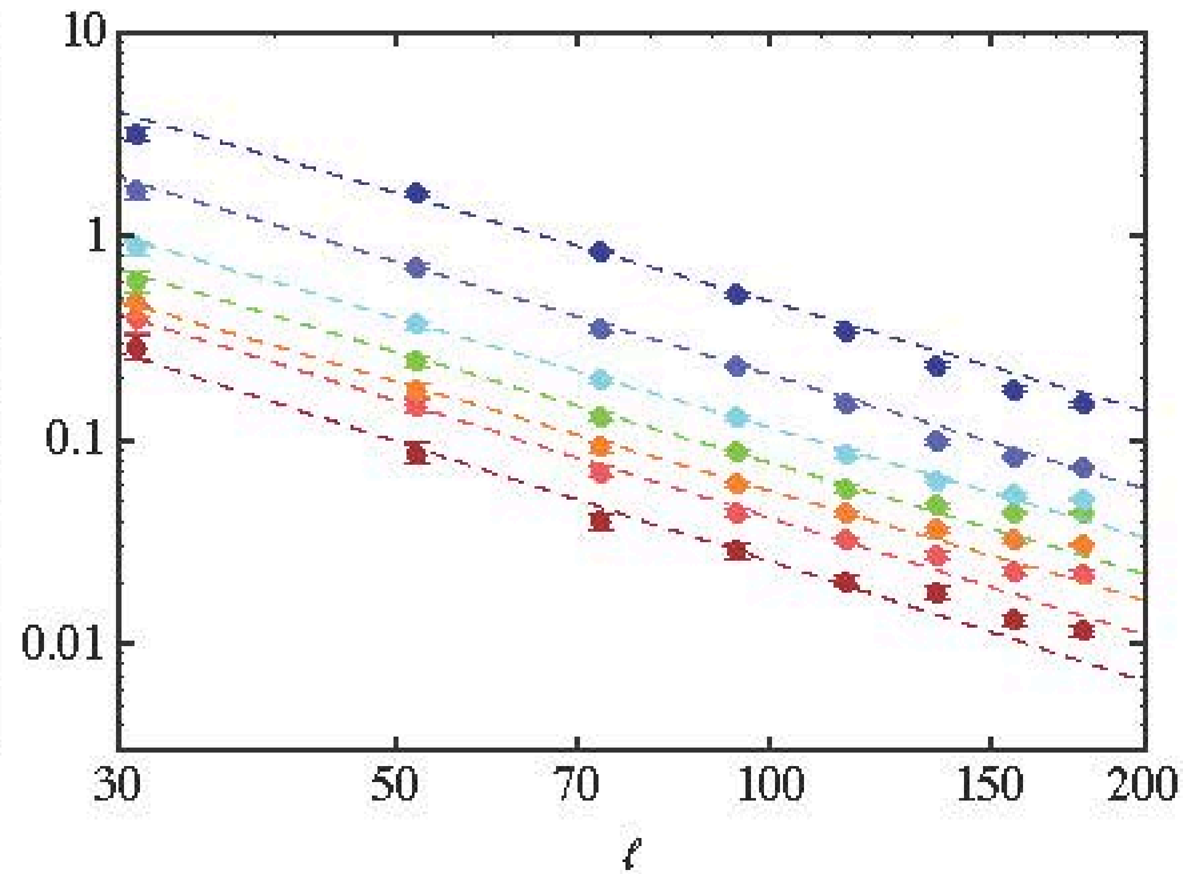
353 GHz

$f_{\rm sky}$ 90% - 80% - 70% - 60% - 50% - 40% - 30%

Aumont ESLAB presentation



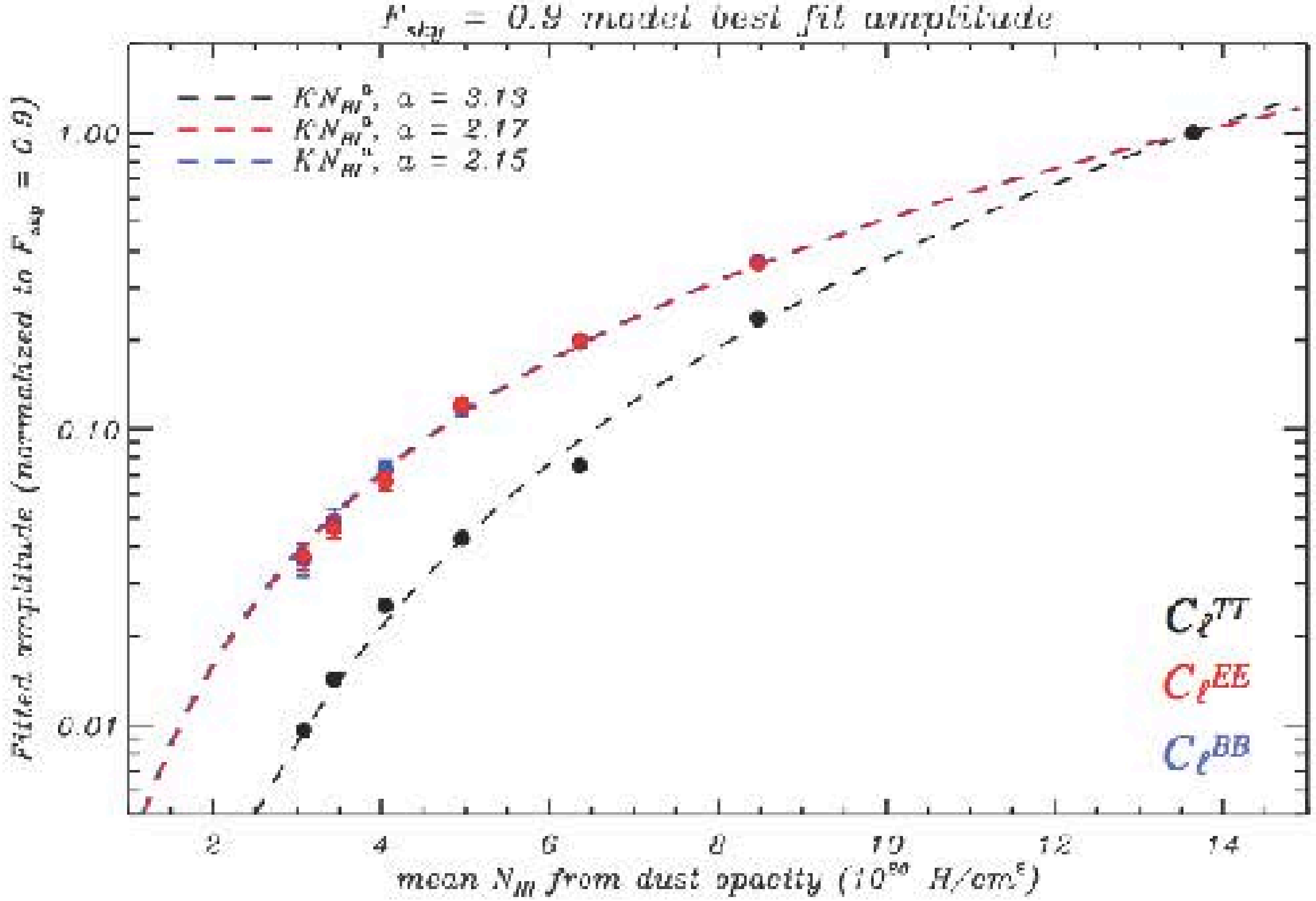
Digitized Q and U maps



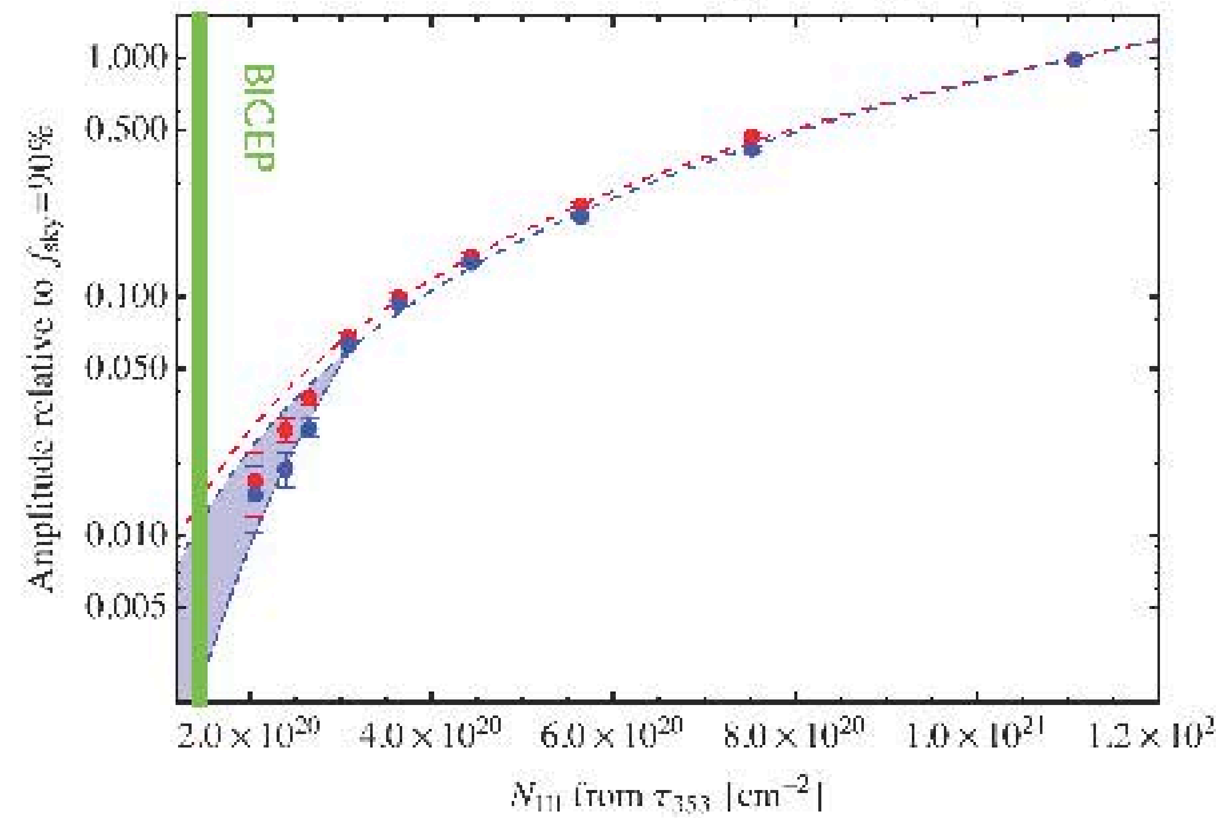
not corrected for instrumental noise
or effects of digitization

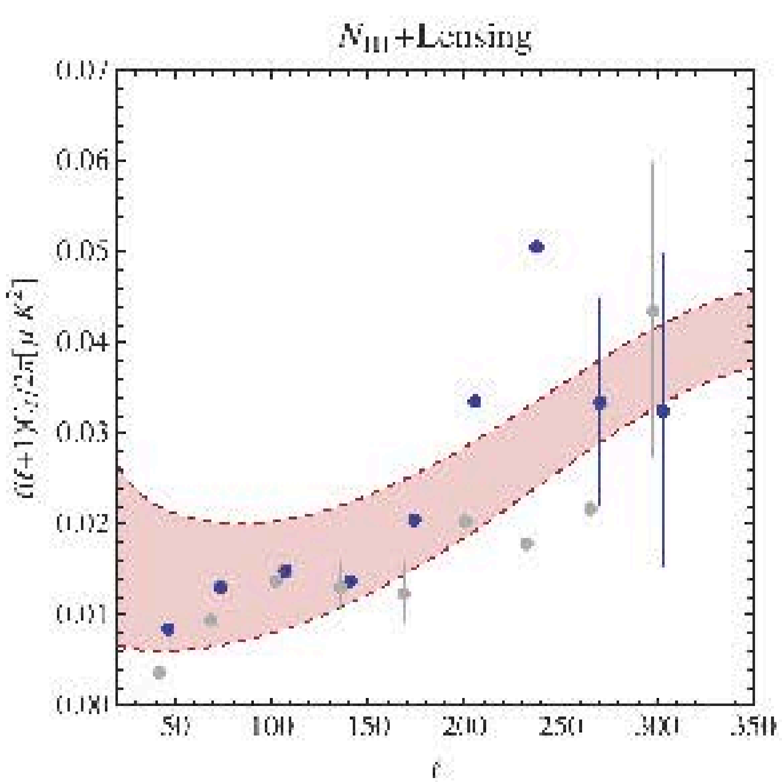
From R. Flauger

Aumont ESLAB presentation



Digitized Q and U maps



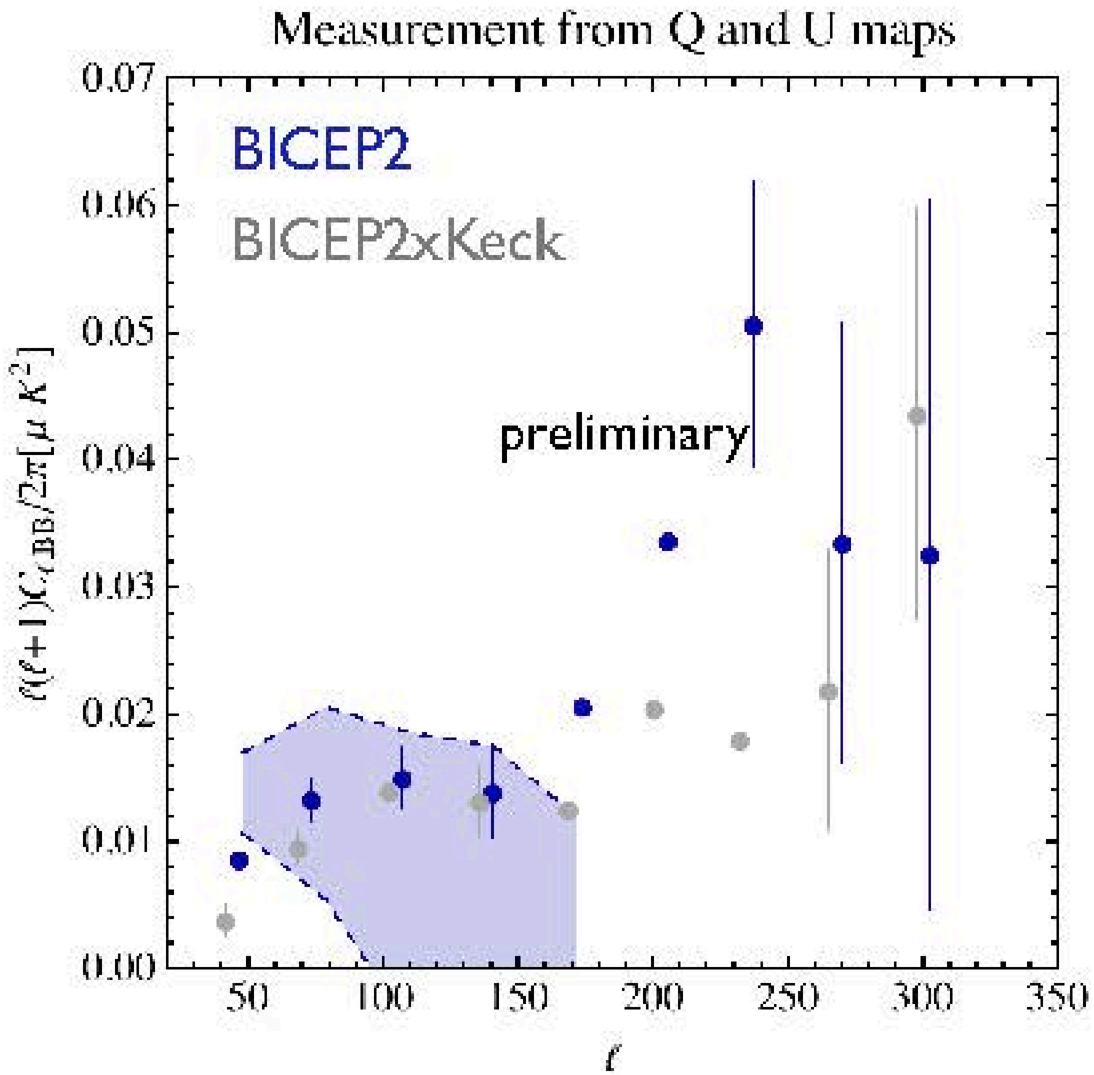


From R. Flauger

Measurement from Boulanger maps

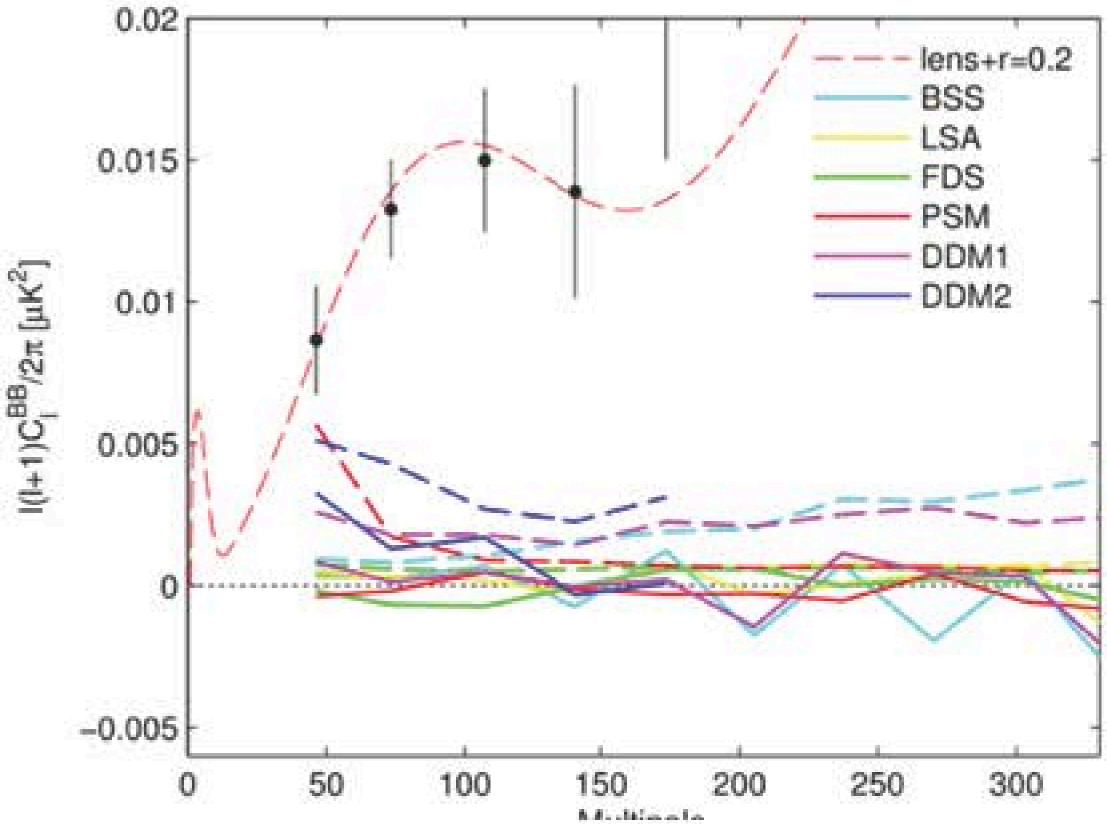
Effect of HEALPix→gif→pdf→gif→HEALPix

Measured dust power spectrum scaled to 150 GHz

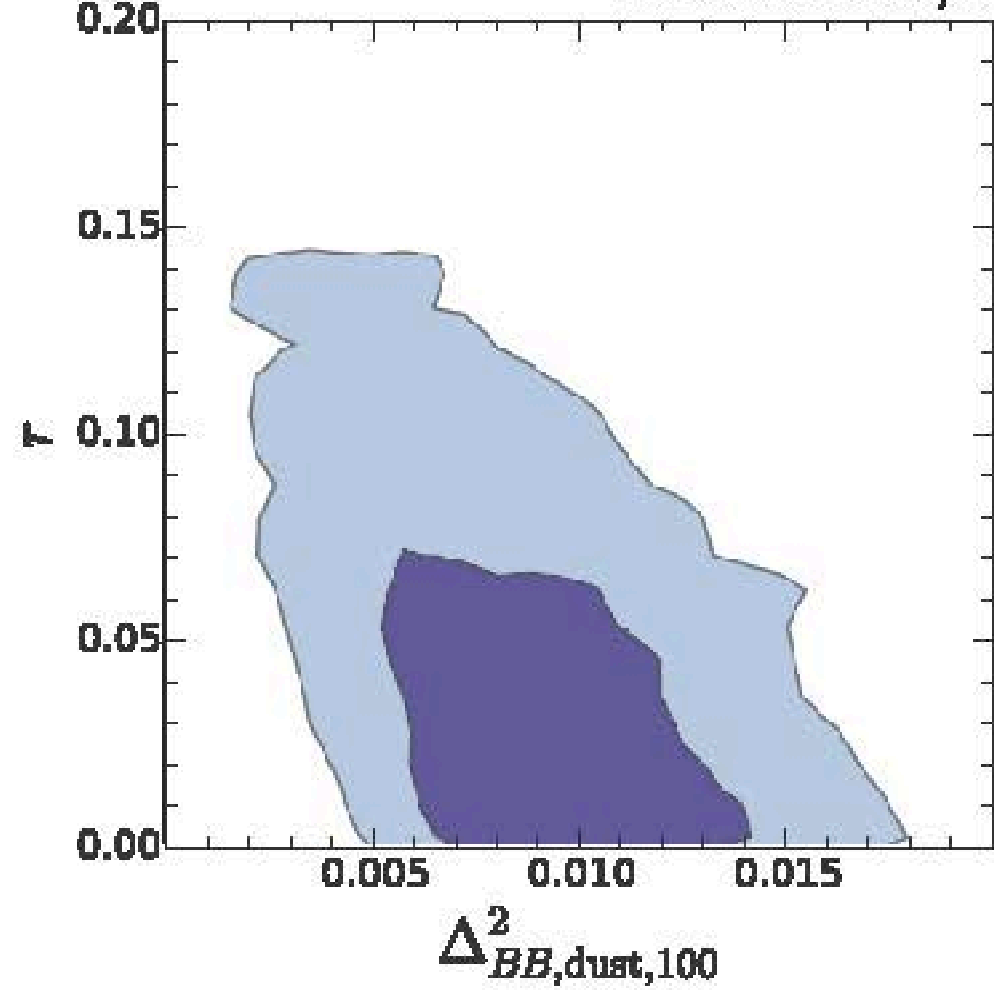


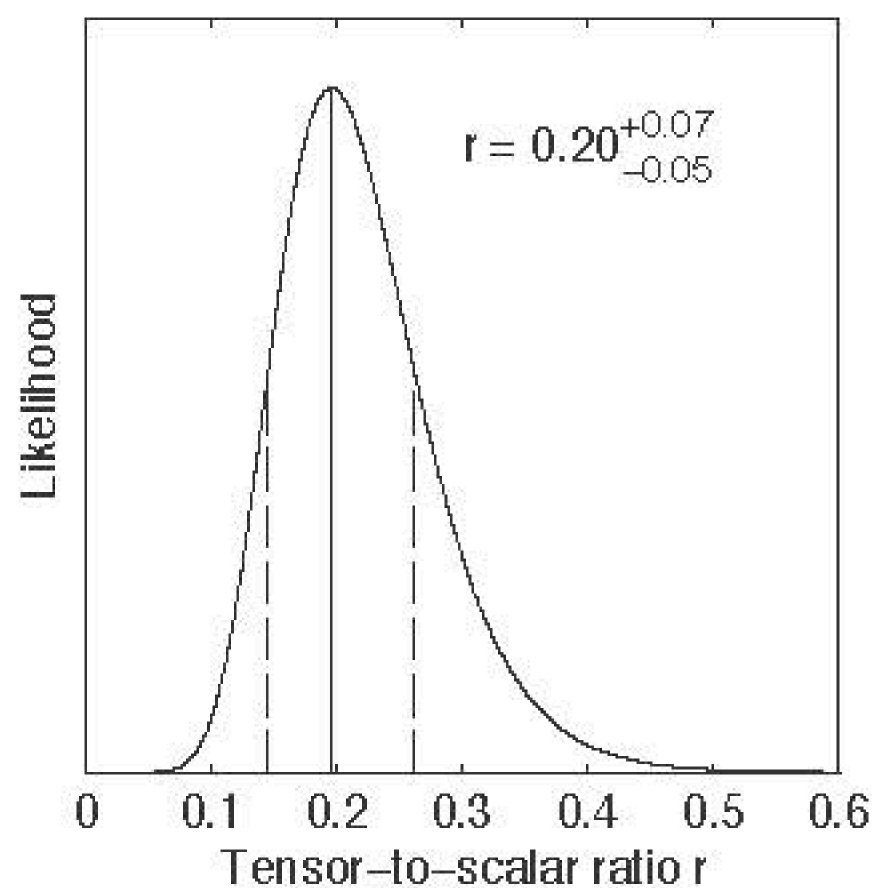
From R. Flauger

Interpreting BICEP

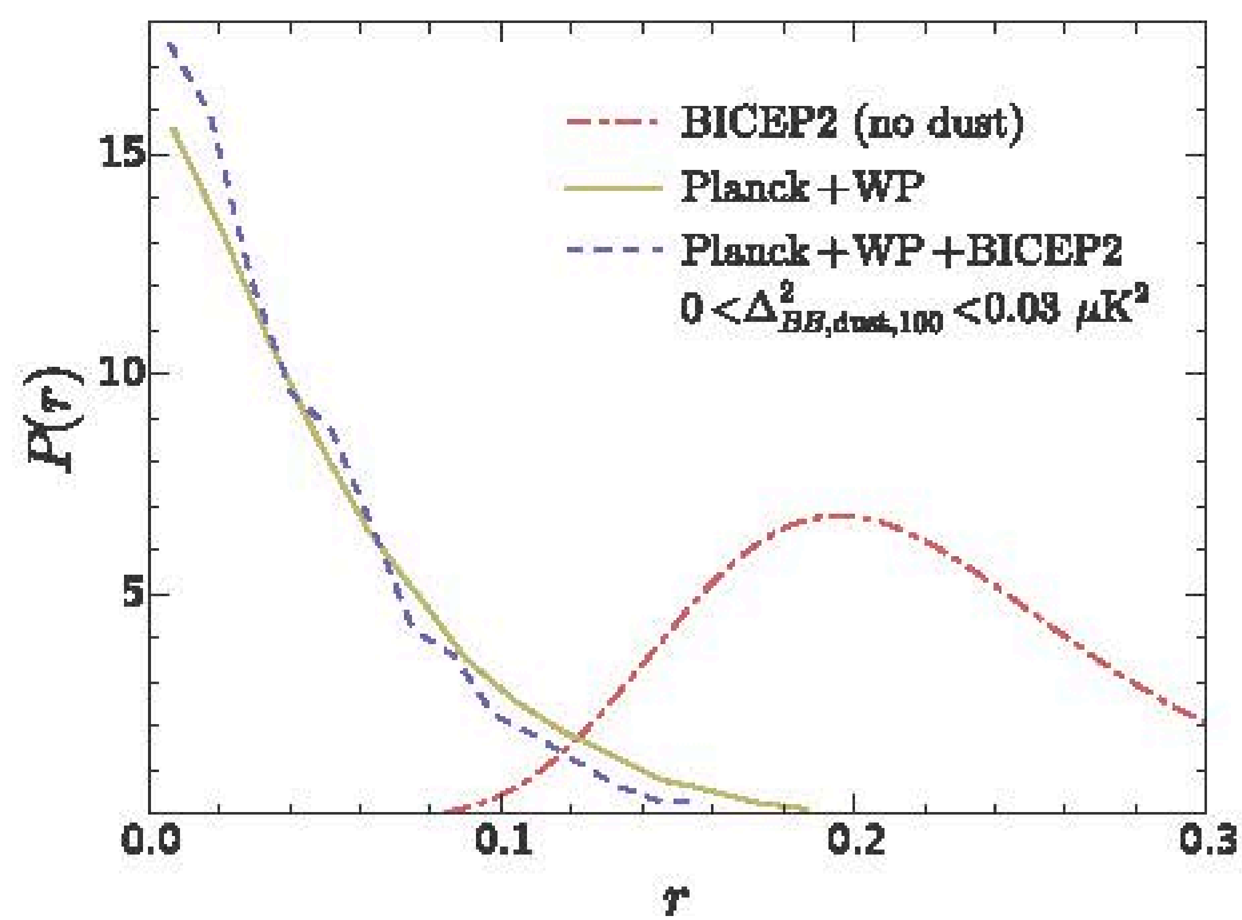


Mortonson & Seljak





Mortonson & Seljak

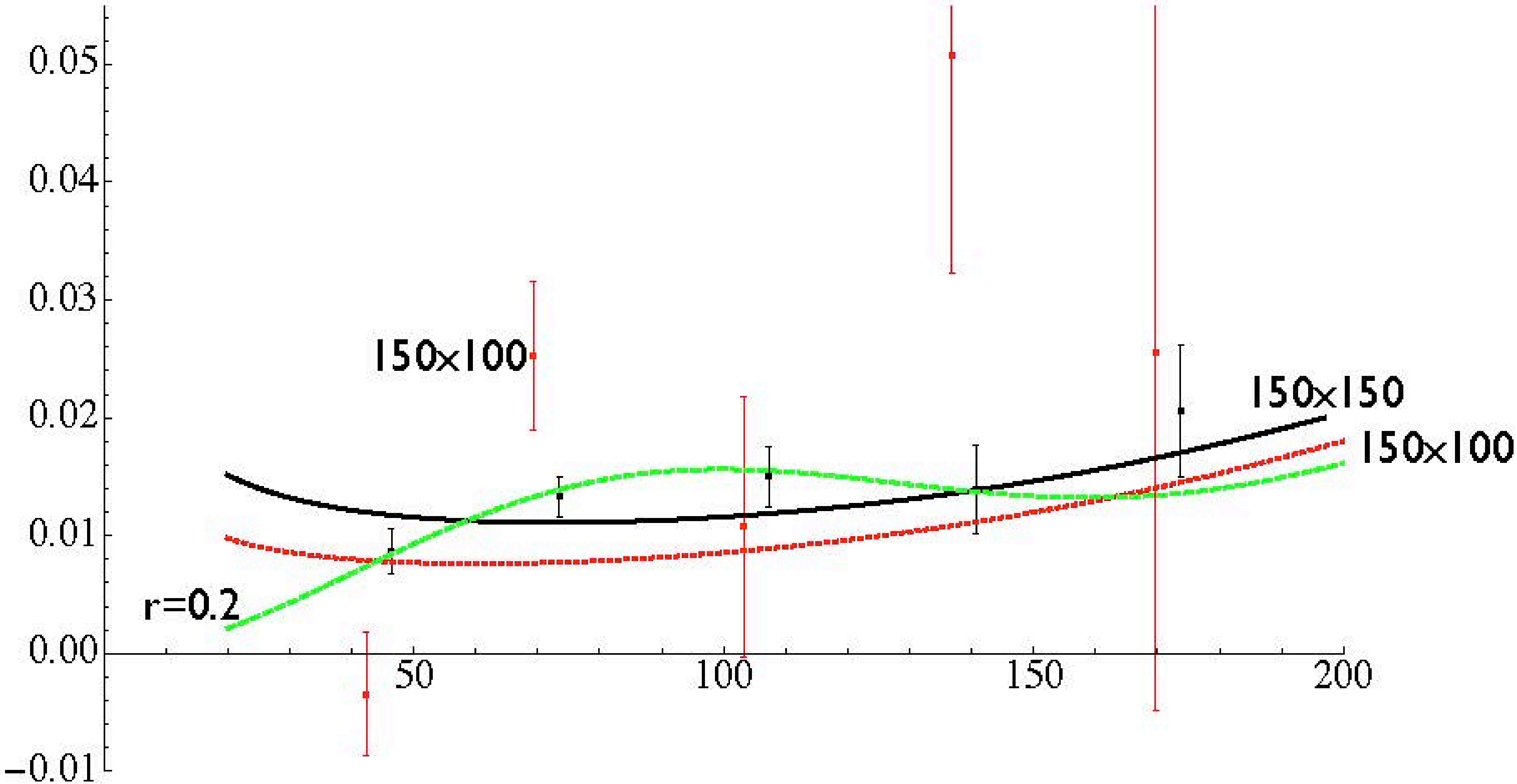


Cross 100-150 vs null hypothesis

1/2 Aumont scaling

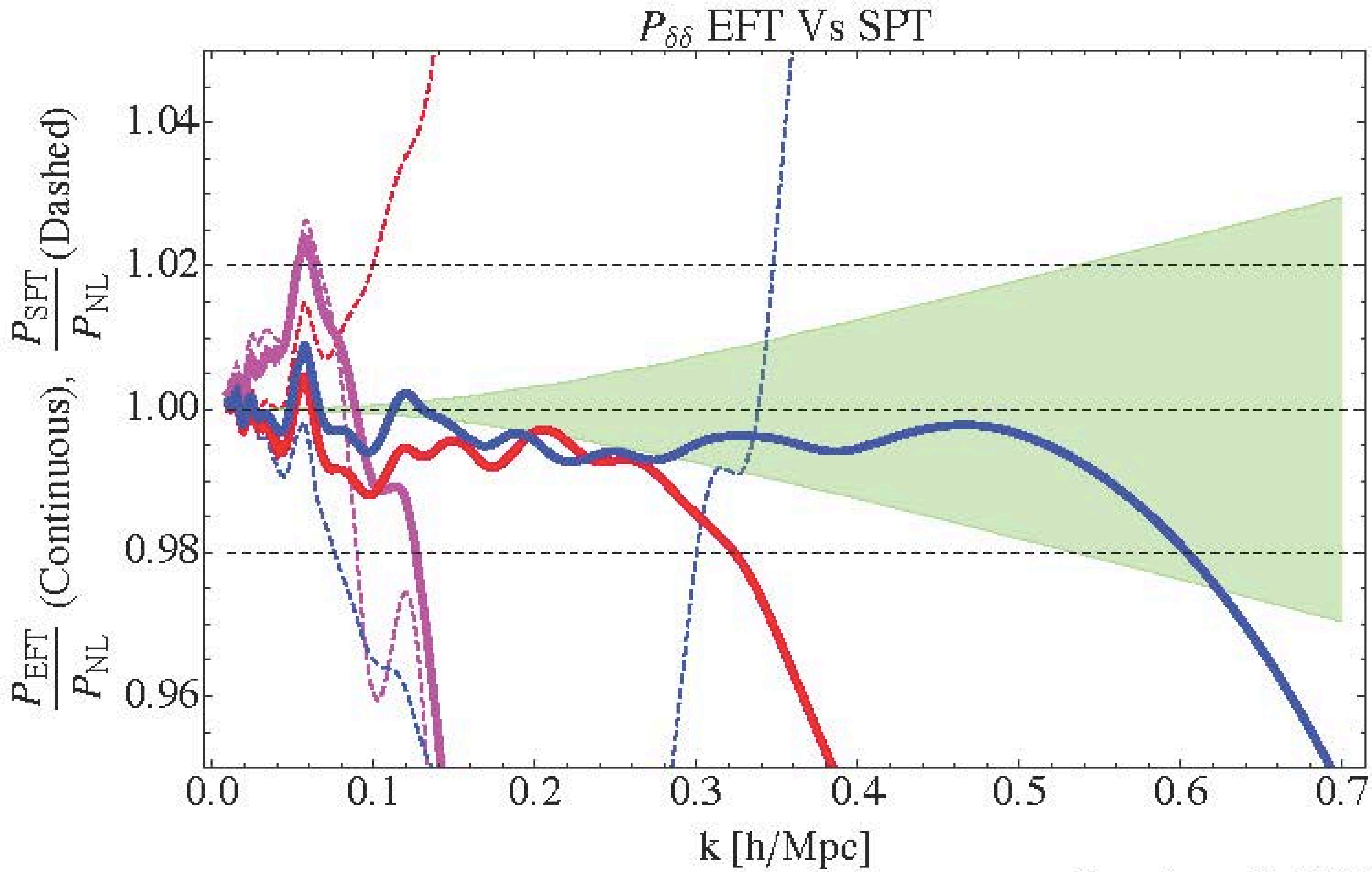
$r_{\text{synch}} = 0.01$

correlation coefficient $= 0.5$



Most important effect is keeping Lensing.

Is the Green dashed curve significantly better at explaining the red points than the red dashed curve?


$P_{\delta\delta}$ EFT Vs SPT
$\frac{P_{\rm EFT}}{P_{\rm NL}}$ (Continuous), $\frac{P_{\rm SPT}}{P_{\rm NL}}$ (Dashed)
1.04
1.02
1.00
0.98
0.96
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
k [h/Mpc]

Senatore & MZ