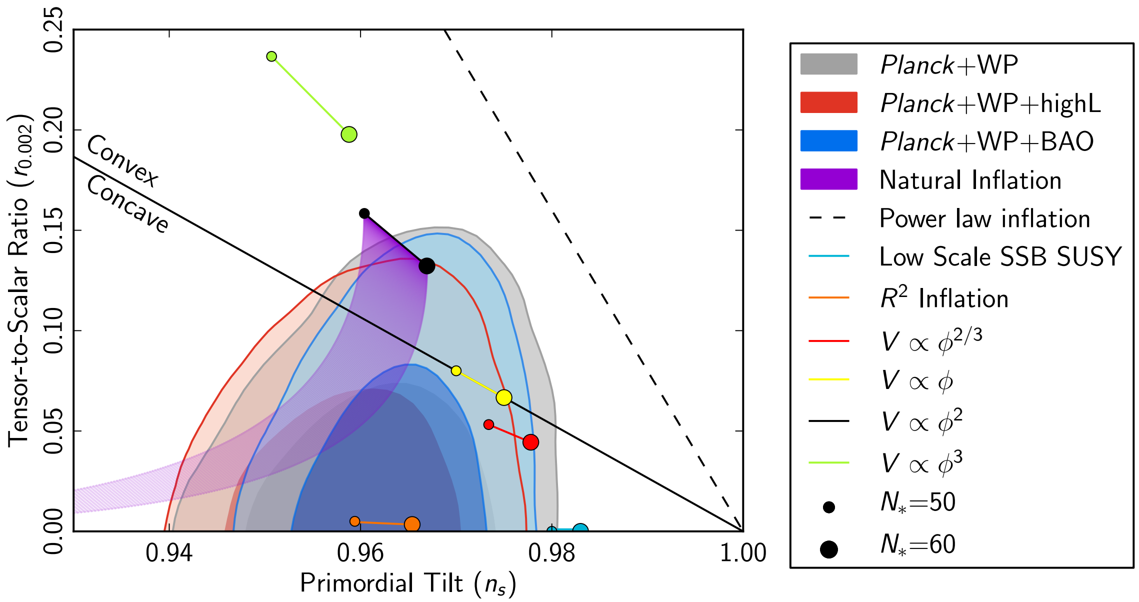
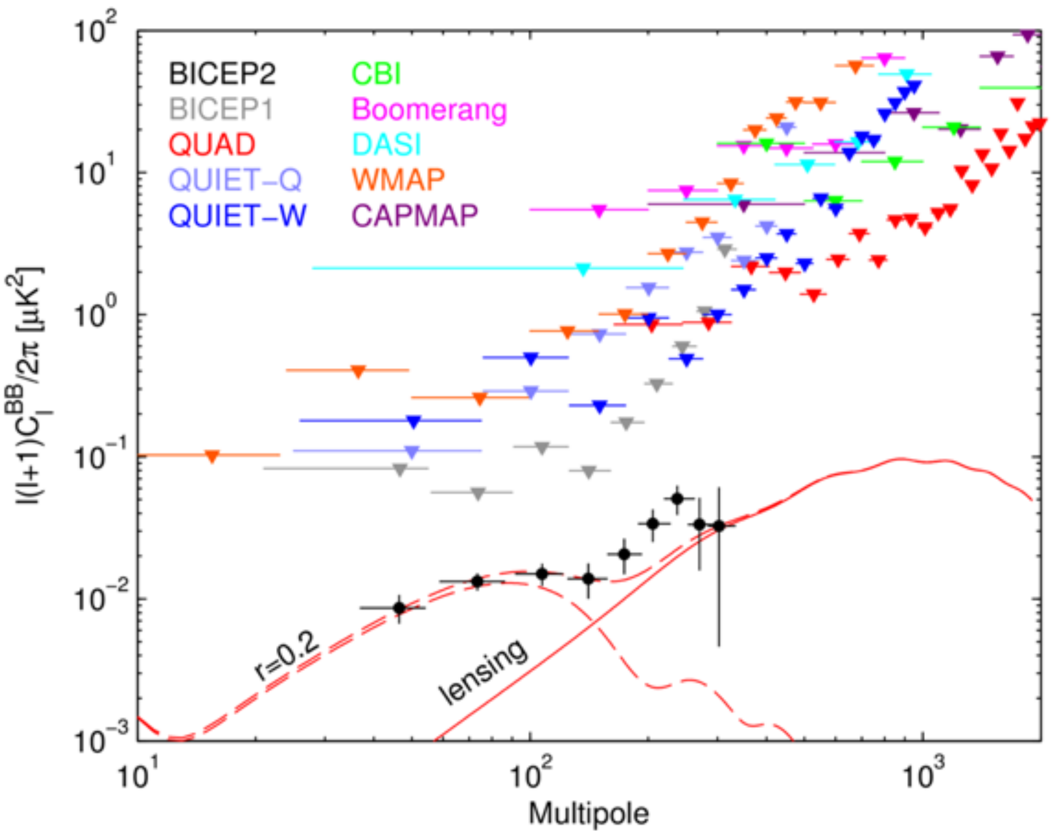
The dawn of B mode cosmology

Strings 2014



Planck

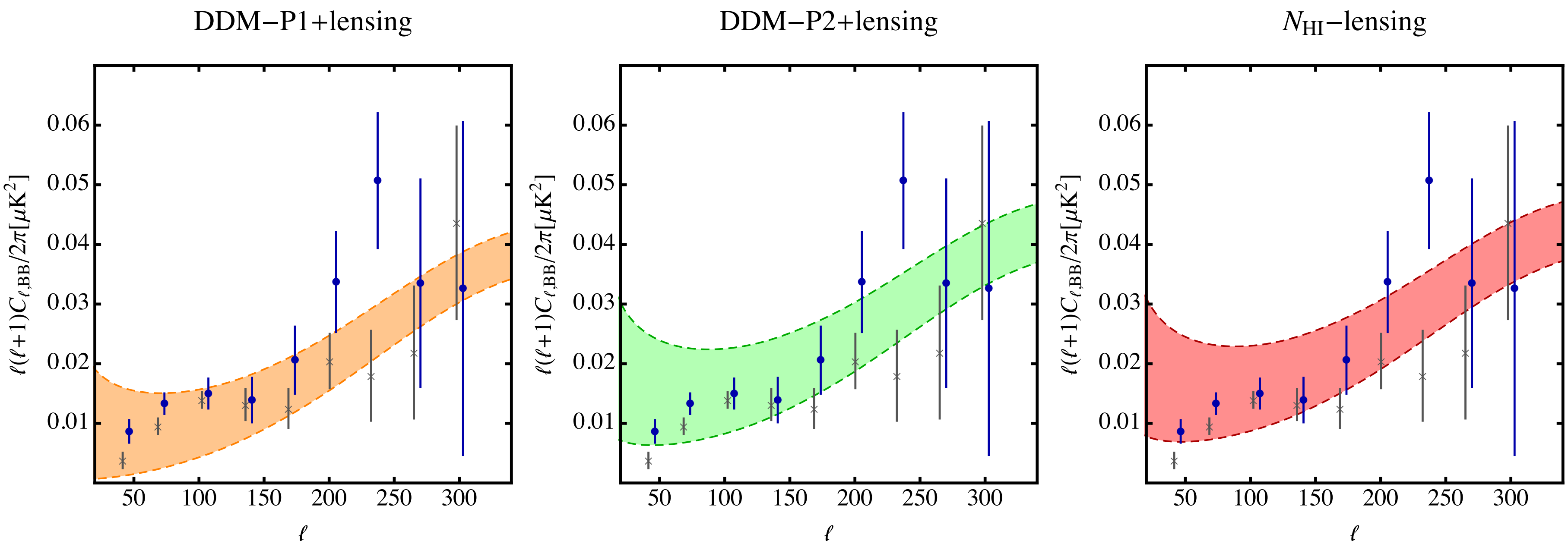
Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.



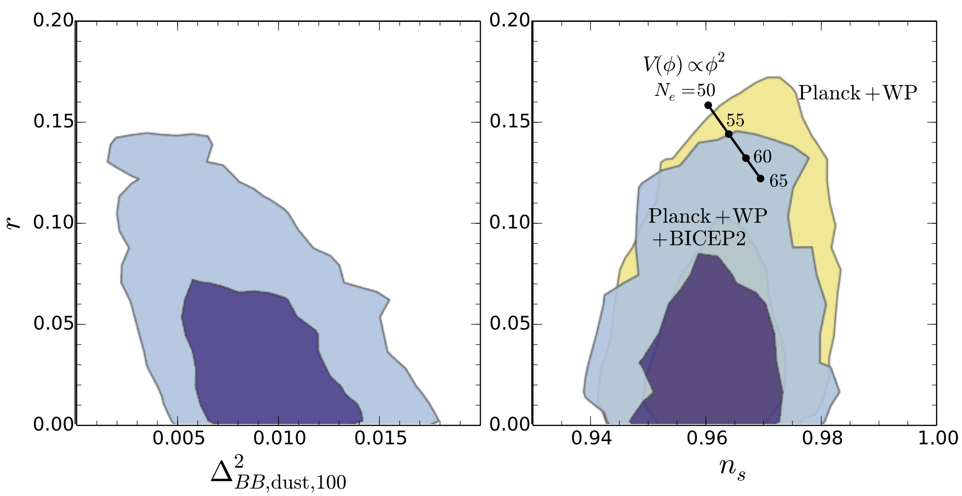
BICEP

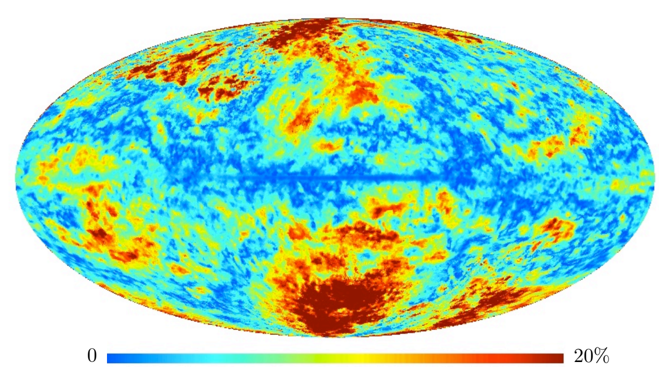
The interpretation of the BICEP2 results

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

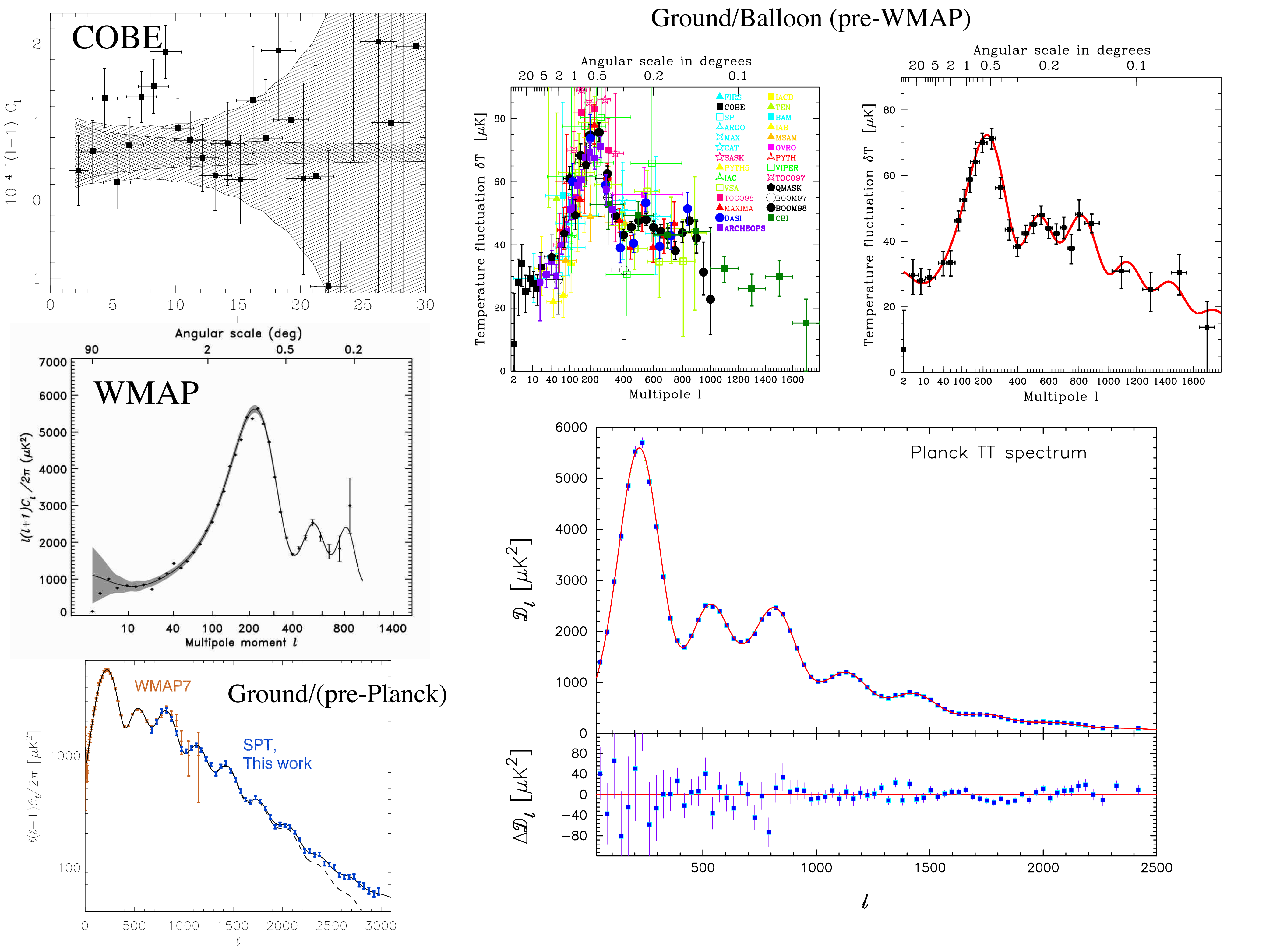


Mortonson & Seljak: Constraints after marginalizing over foregrounds



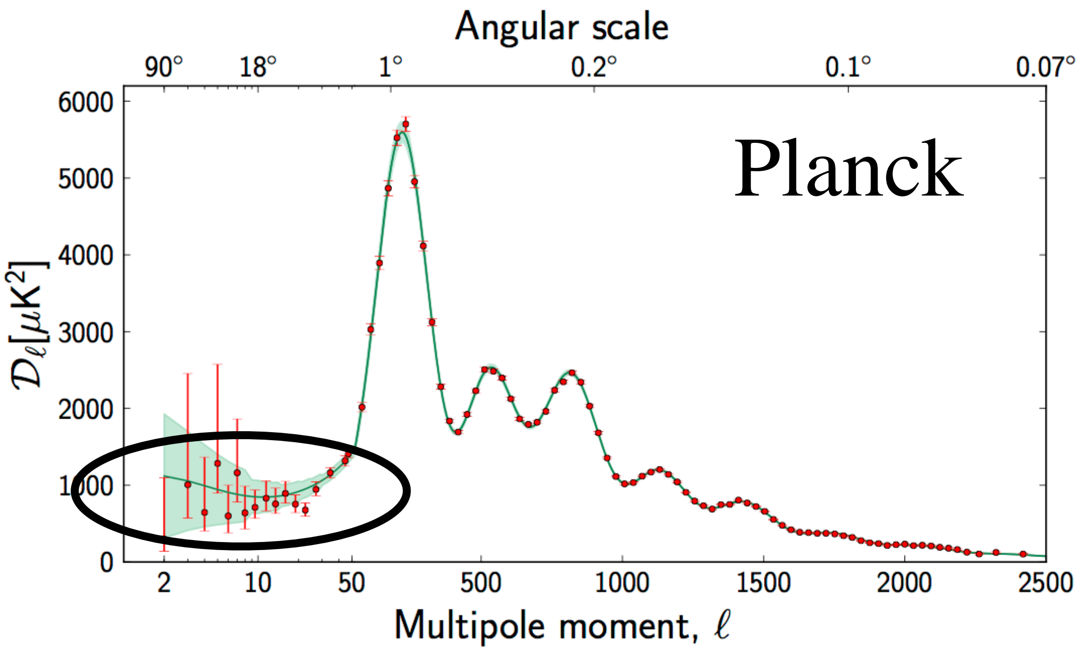


Flauger: CIB corrected polarization fraction

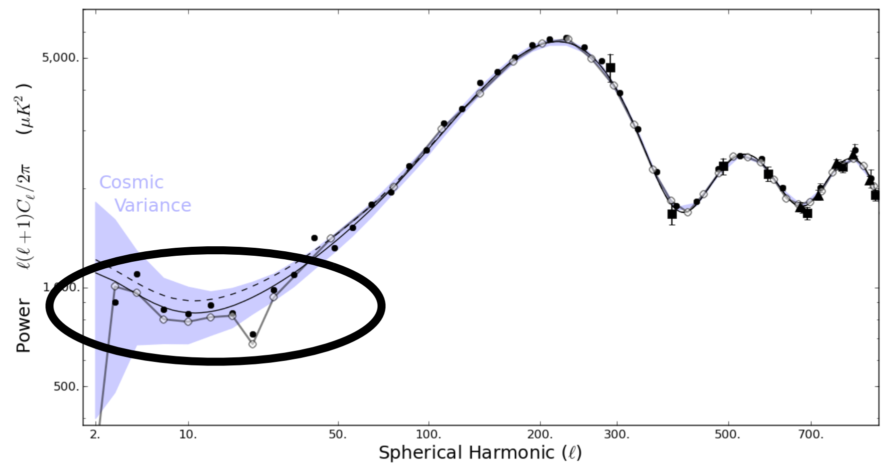


COBE
Ground/Balloon (pre-WMAP)
Angular scale in degrees
Temperature fluctuation δT [μK]
Multipole l
FIRS
COBE
SP
ARGO
MAX
CAT
SASK
PYTHS
IAC
VSA
TOCO98
MAXIMA
DASI
ARCHEOPS
IACB
TEN
BAM
IAB
MSAM
OVRO
PYTH
VIPER
TOCO97
QMASK
BOOM97
BOOM98
CBI
WMAP
Angular scale (deg)
Multipole moment l
Planck TT spectrum
WMAP7
Ground/(pre-Planck)
SPT,
This work

Large angle power deficit



Adding tensors makes it worse



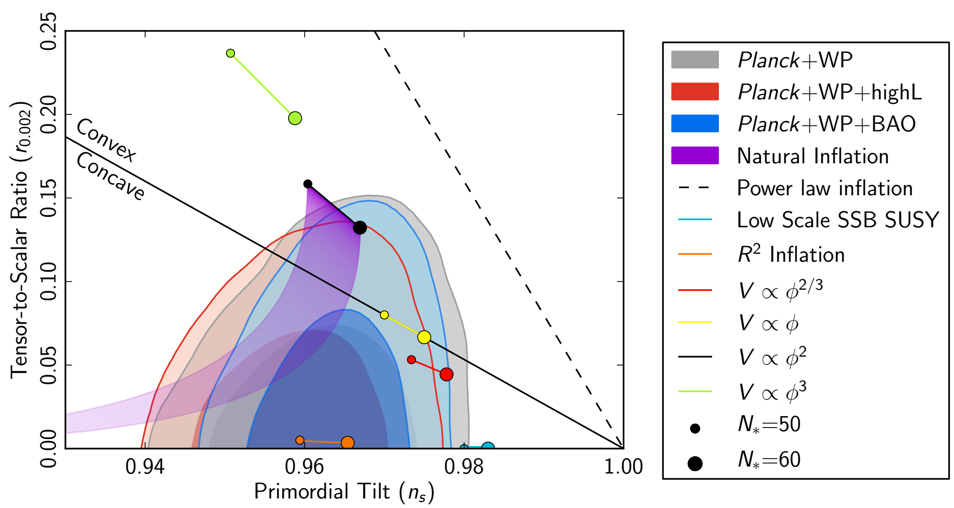


Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

FIG. 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).

From the bottom up: The simplest models

- Inflationary background: scale invariant
- Fluctuations of the clock: no fluctuations in the composition, or "local" non-Gaussianities
- Simple history: Large tensors
- Theory of the fluctuations valid all the way to the symmetry braking scale: cs = 1, no "equilateral" non-Gaussianities

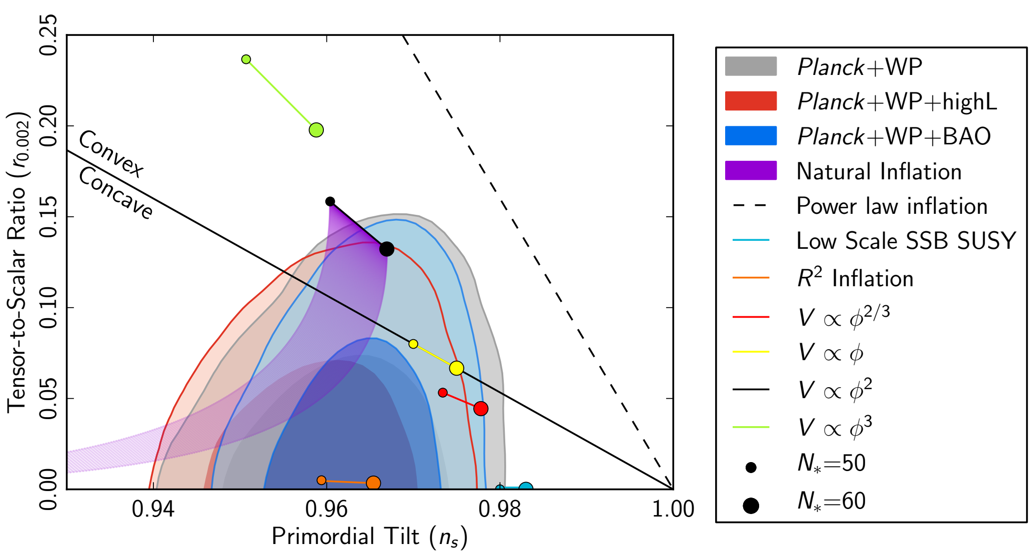


Fig. 1. Marginalized joint 68% and 95% CL regions for n_s and $r_{0.002}$ from *Planck* in combination with other data sets compared to the theoretical predictions of selected inflationary models.

	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**

Single time scale histories

Changes over one e-fold

$$\epsilon_X = |\frac{\dot{X}}{HX}|$$

$$\epsilon_H = |\frac{\dot{H}}{HH}|$$

If both are of the same size then the gravitational wave contribution is substantial.

$$\epsilon_{\dot{H}} = |\frac{\ddot{H}}{H\dot{H}}|$$

$$r = 16\epsilon_H$$

Of course it is easy to open a hierarchy between these two parameters.

$$H(t) = H_\star + \Delta H(t/t_\star)$$

$$\frac{\epsilon_H}{\epsilon_{\dot{H}}} \sim \frac{\Delta H}{H_\star}$$

$$\Delta H \sim 1/t_\star \to \epsilon_H \sim \epsilon_{\dot{H}}^2$$

UV sensitivity

$$\frac{\Delta\phi}{M_{\rm pl}} \approx \frac{1}{\sqrt{8}} \int_0^N \mathrm{d}N \sqrt{r}$$

$$\boxed{\frac{\Delta\phi}{M_{\rm pl}} = \mathcal{O}(1) \times \left(\frac{r}{0.01}\right)^{1/2}}$$

$$\boxed{\mathcal{L}_{\rm eff}(\phi) = -\frac{1}{2}(\partial\phi)^2 - \frac{1}{2}m^2\phi^2 - \frac{1}{4}\lambda\phi^4 - \sum_{p=1}^{\infty}\left[\lambda_p\phi^4 + \nu_p(\partial\phi)^2\right]\left(\frac{\phi}{M_{\rm pl}}\right)^{2p} + \cdots}$$

Shift symmetry forbids these terms $\phi \to \phi + const.$

Symmetry needs to be respected by quantum gravity.

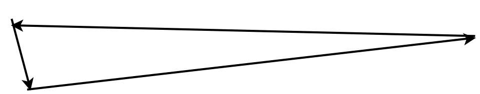
The origin of the seeds of structure

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 **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.

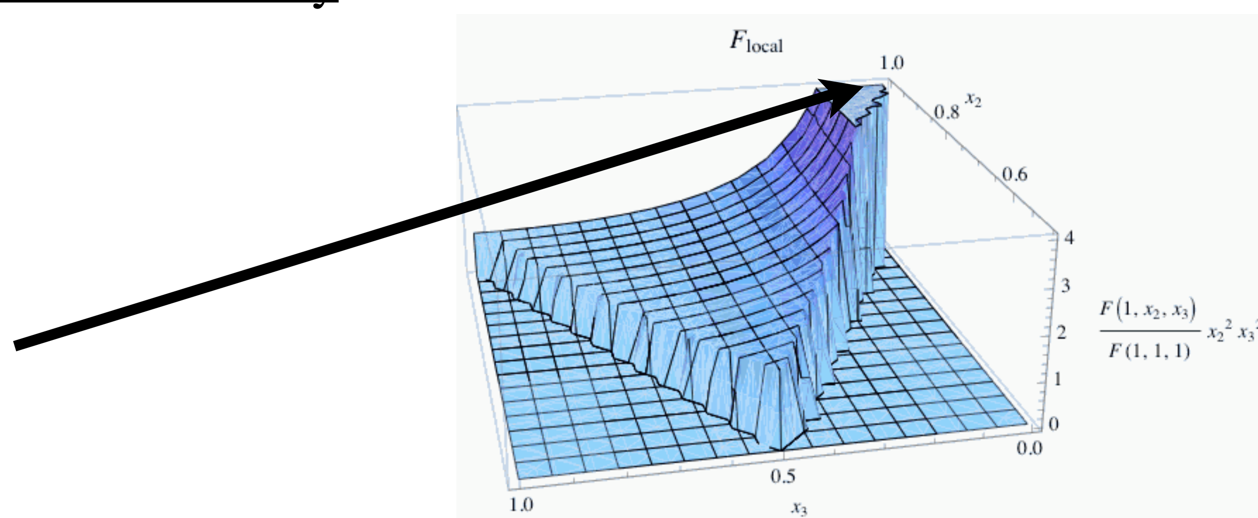
Were fluctuations converted into curvature fluctuations at the beginning/during the hot big bang?

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

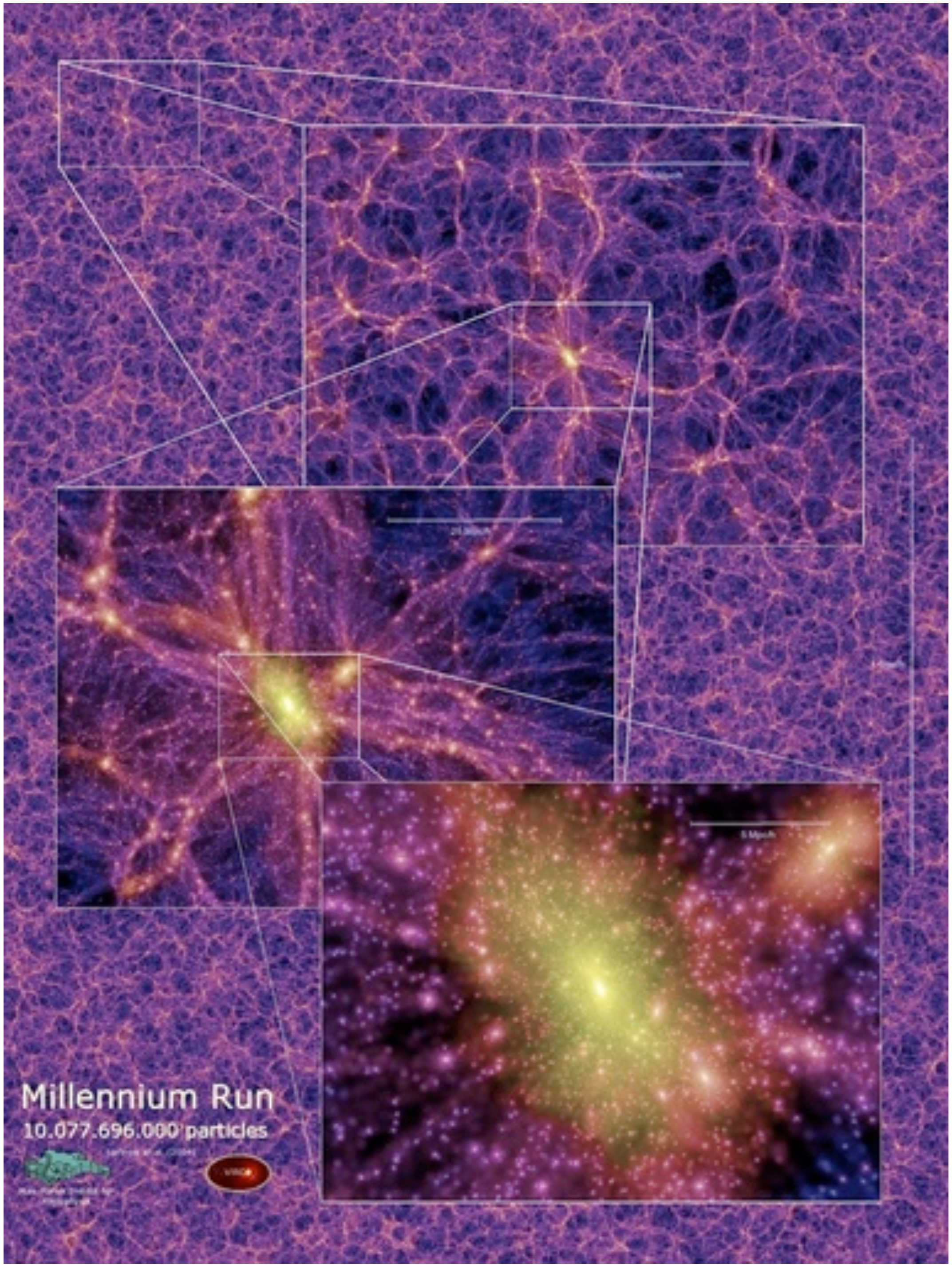
<u>Robust signature: Primordial non-Gaussiniaty</u>



$$k_3 \ll k_2, k_1$$



Large Scale Structure



In search for more modes

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.