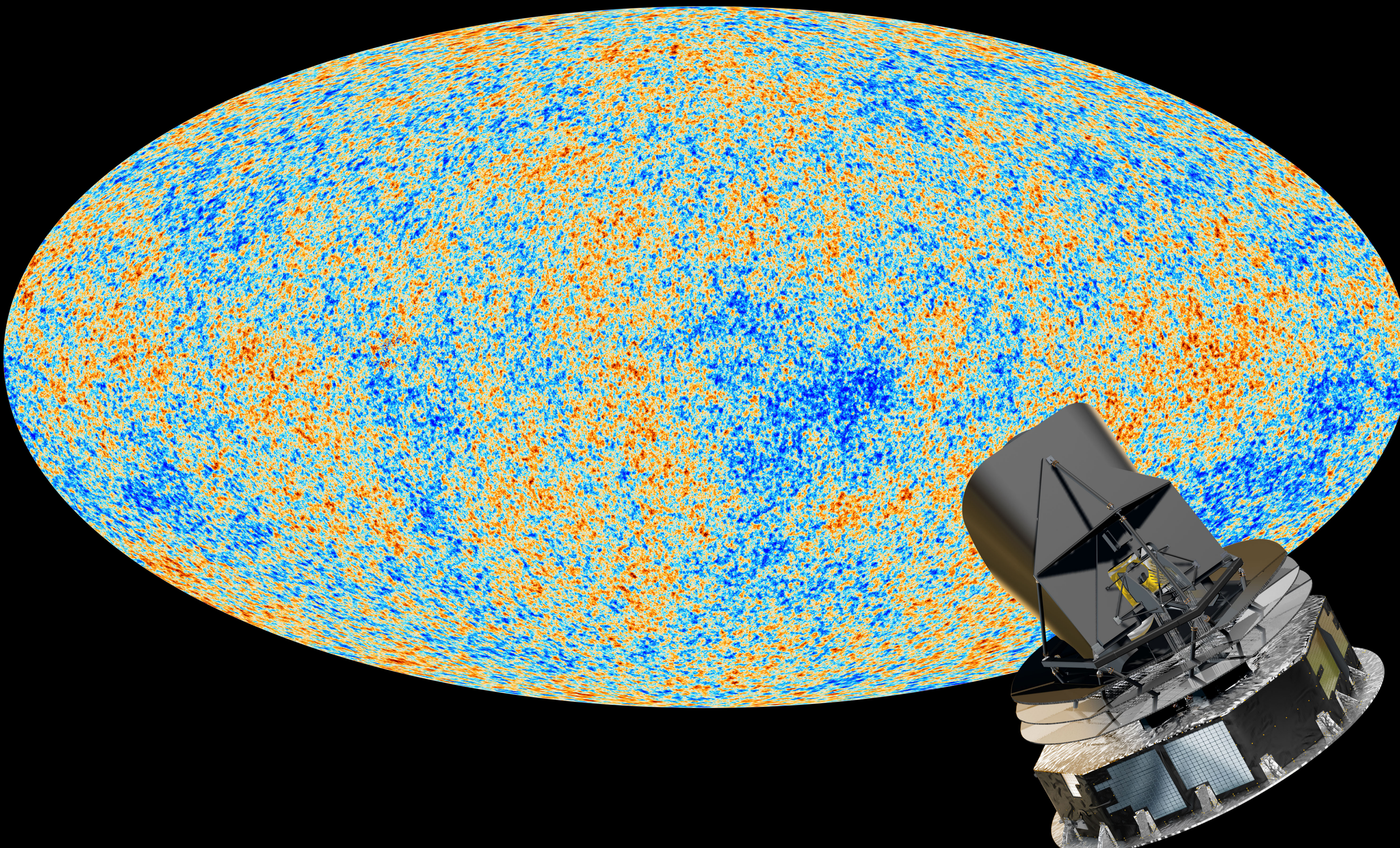
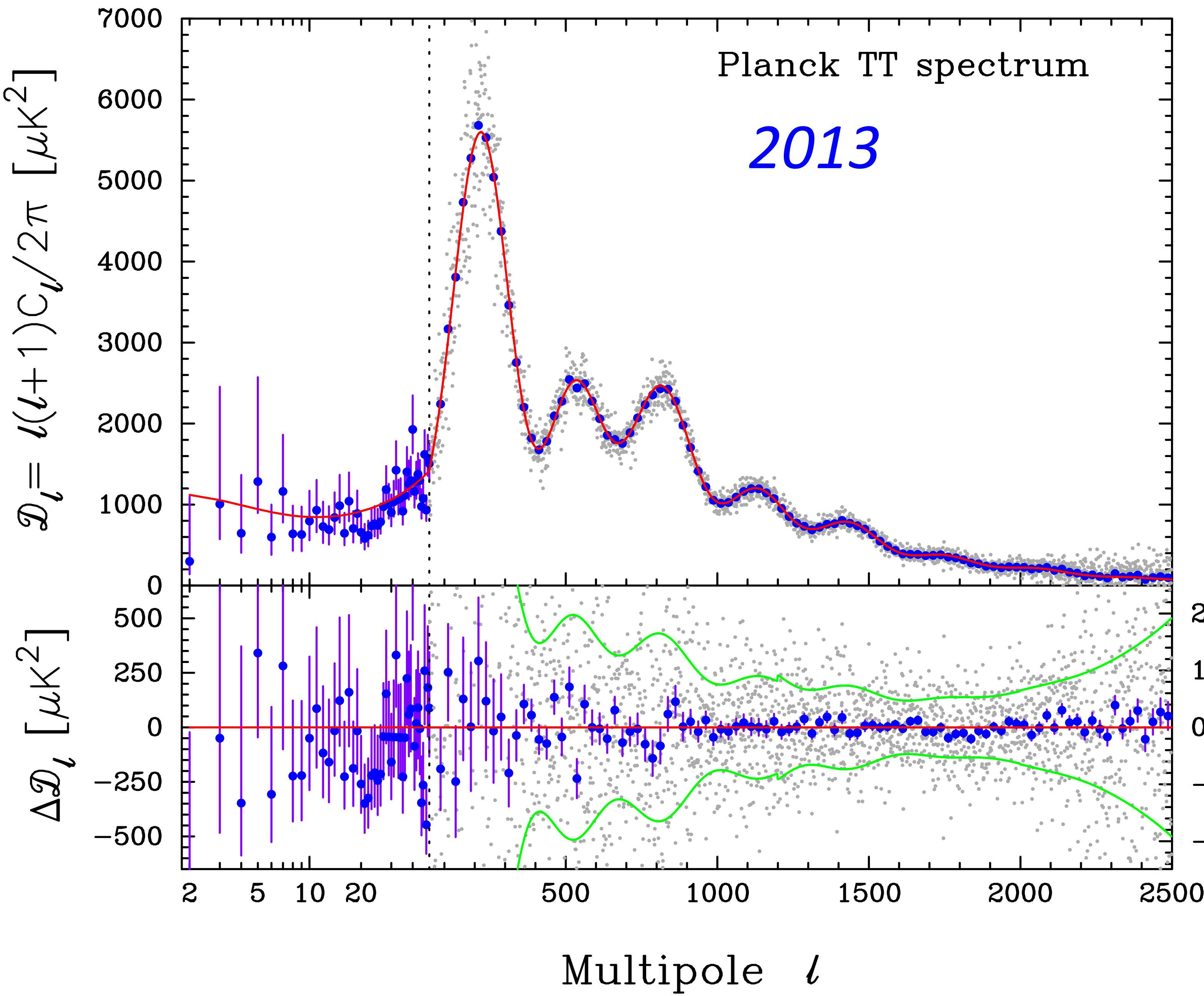
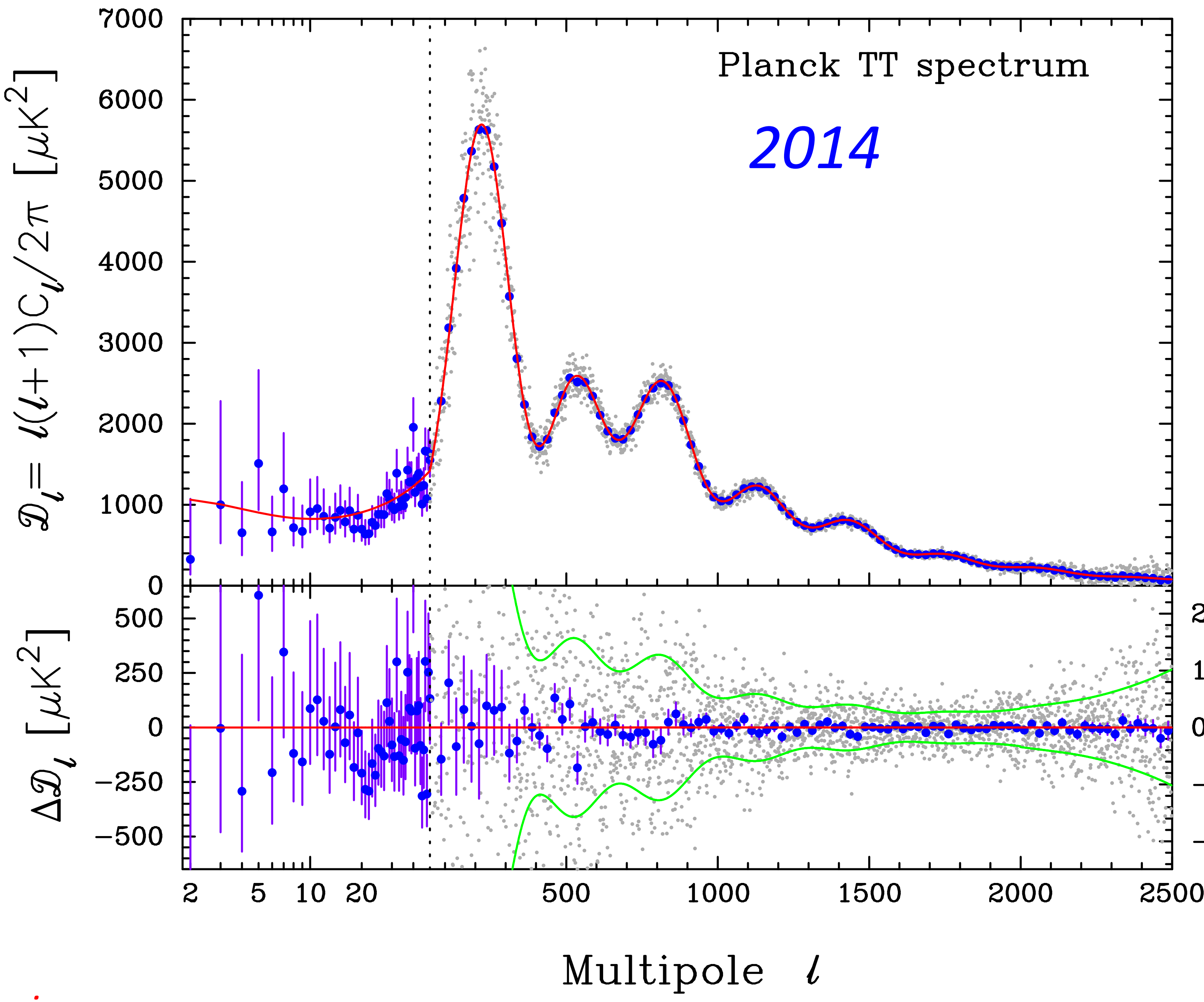
Preliminary 2014 results from Planck

George Efstathiou on behalf of the Planck collaboration





Planck TT spectrum
2013
$\mathcal{D}_\ell = \ell(\ell+1)C_\ell/2\pi\ [\mu K^2]$
$\Delta\mathcal{D}_\ell\ [\mu K^2]$
Multipole ℓ
7000
6000
5000
4000
3000
2000
1000
0
500
250
0
−250
−500
200
100
0
−100
−200
2
5
10
20
500
1000
1500
2000
2500



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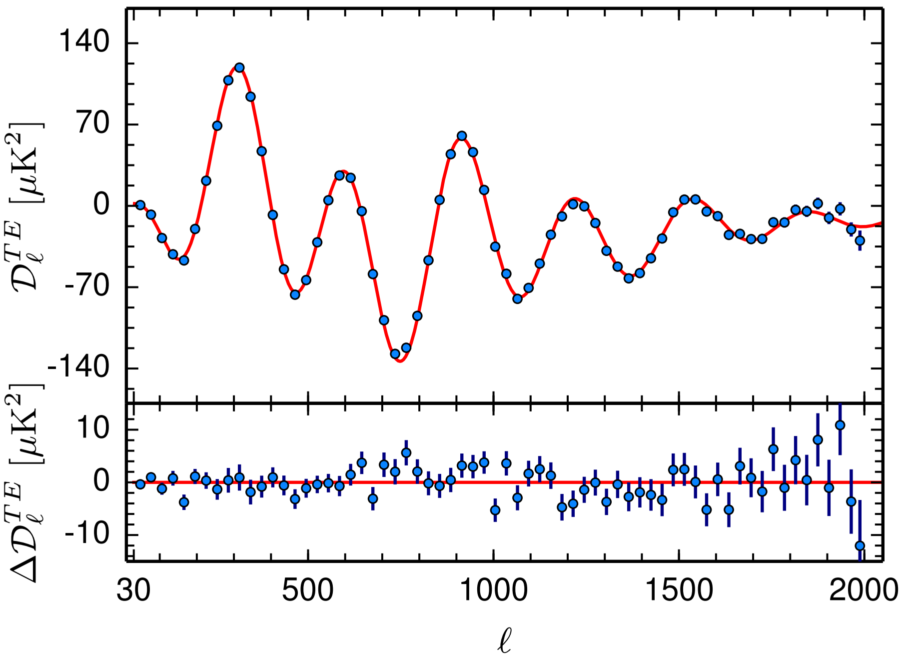
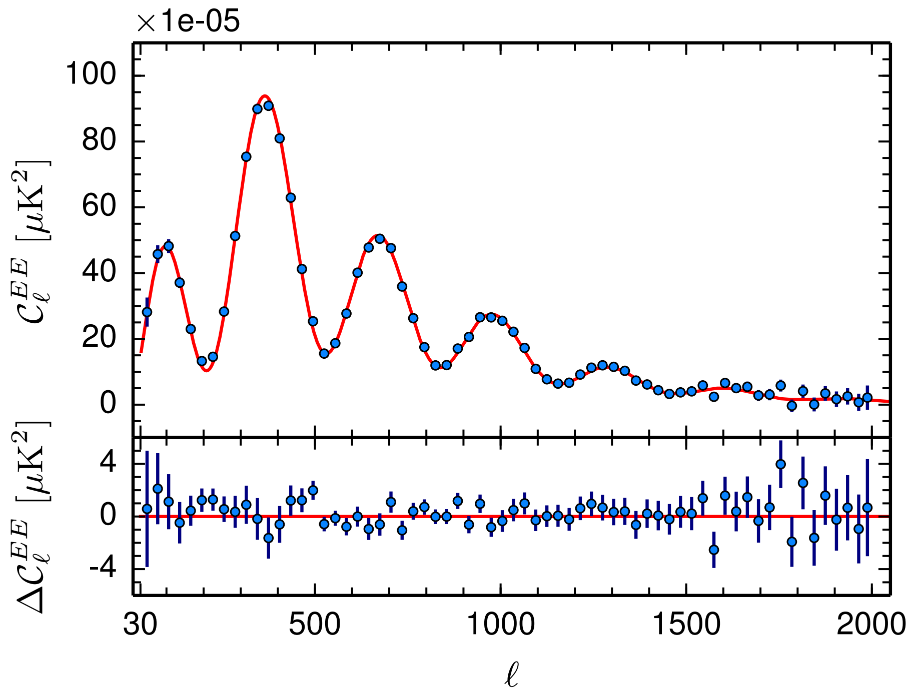
… and beautiful polarization spectra

TE



EE



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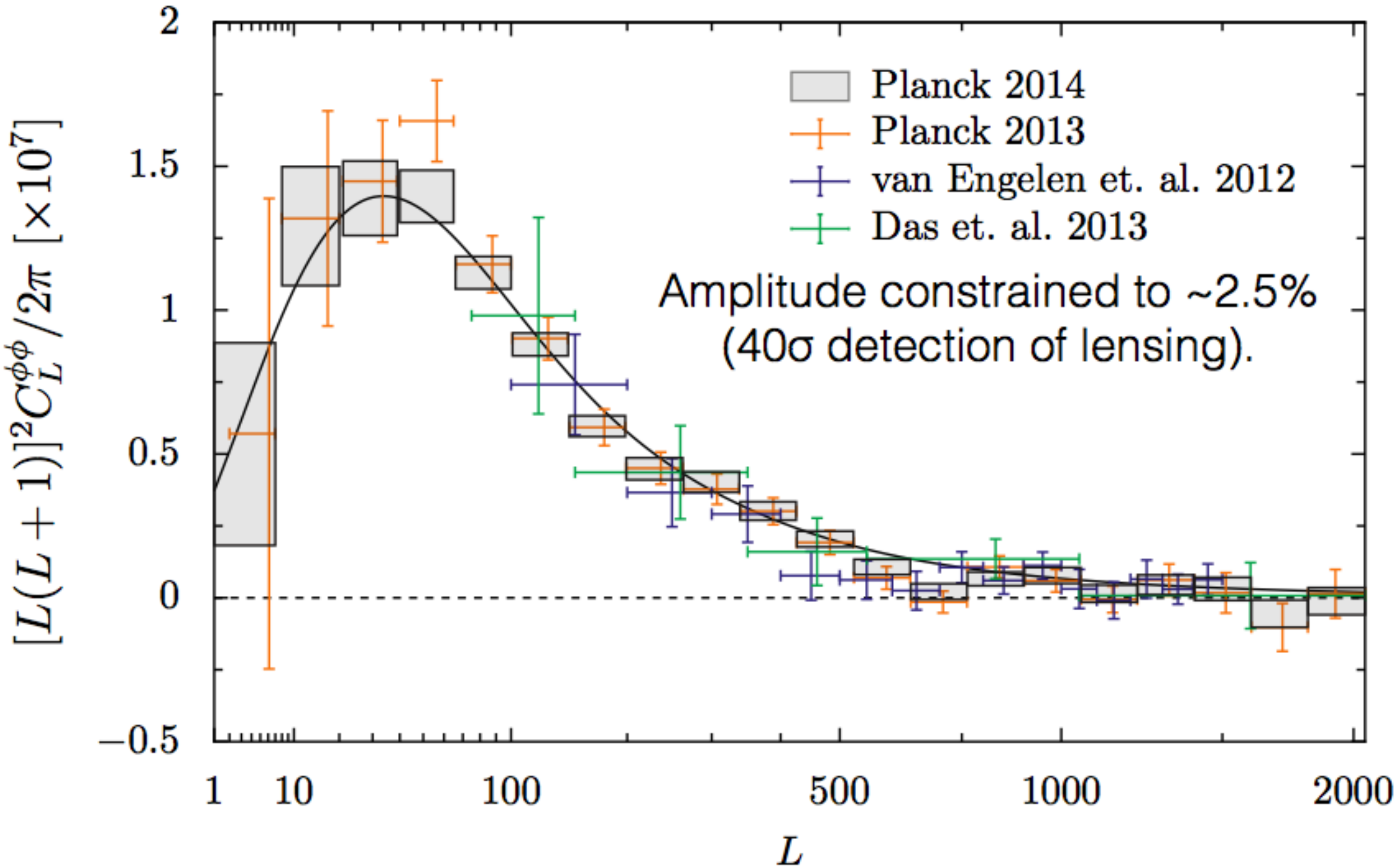
… and beautiful lensing spectra



TT, TE, EE, EB, TB spectra (see talk by Antony Lewis)

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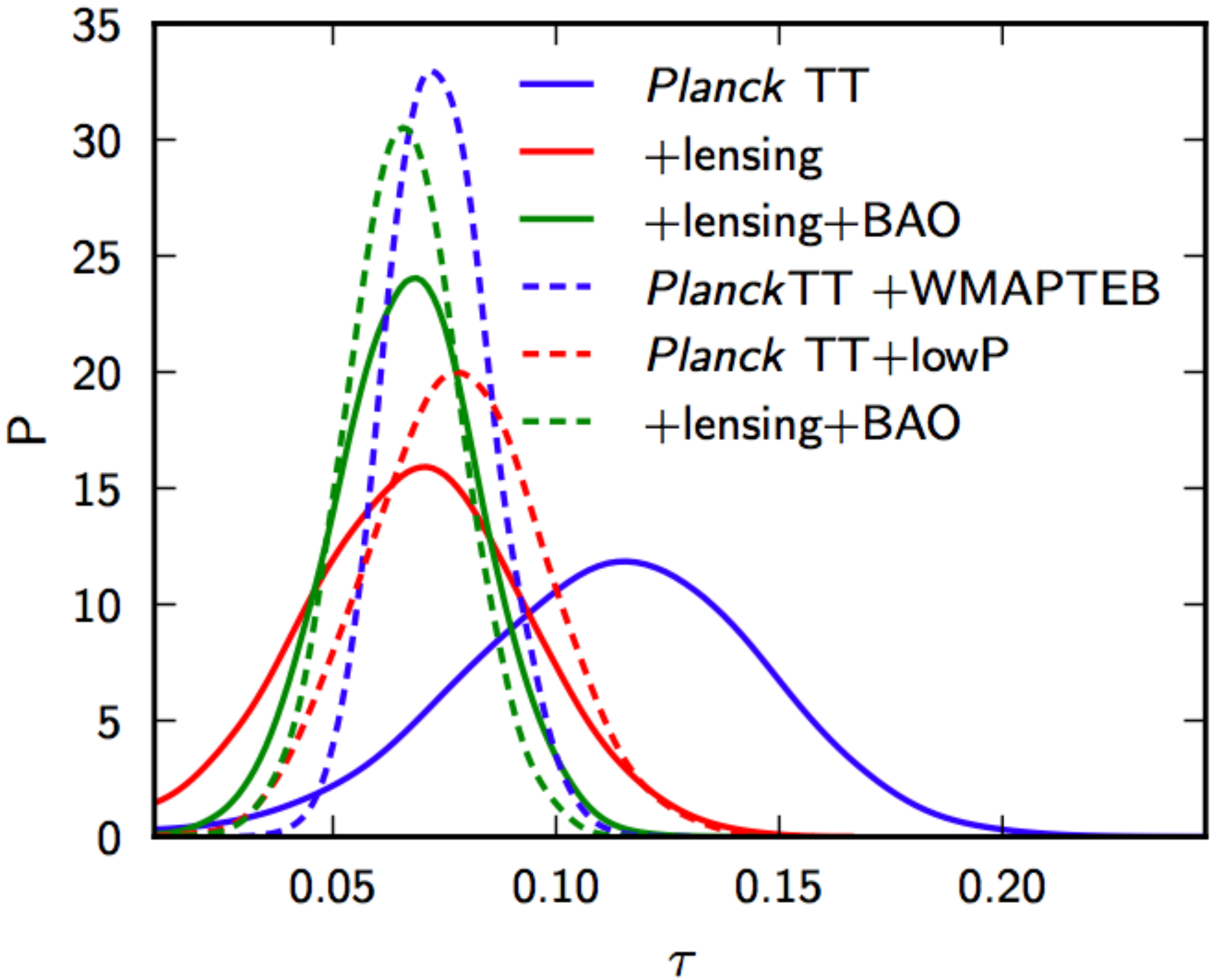
Constraints on reionization optical depth τ



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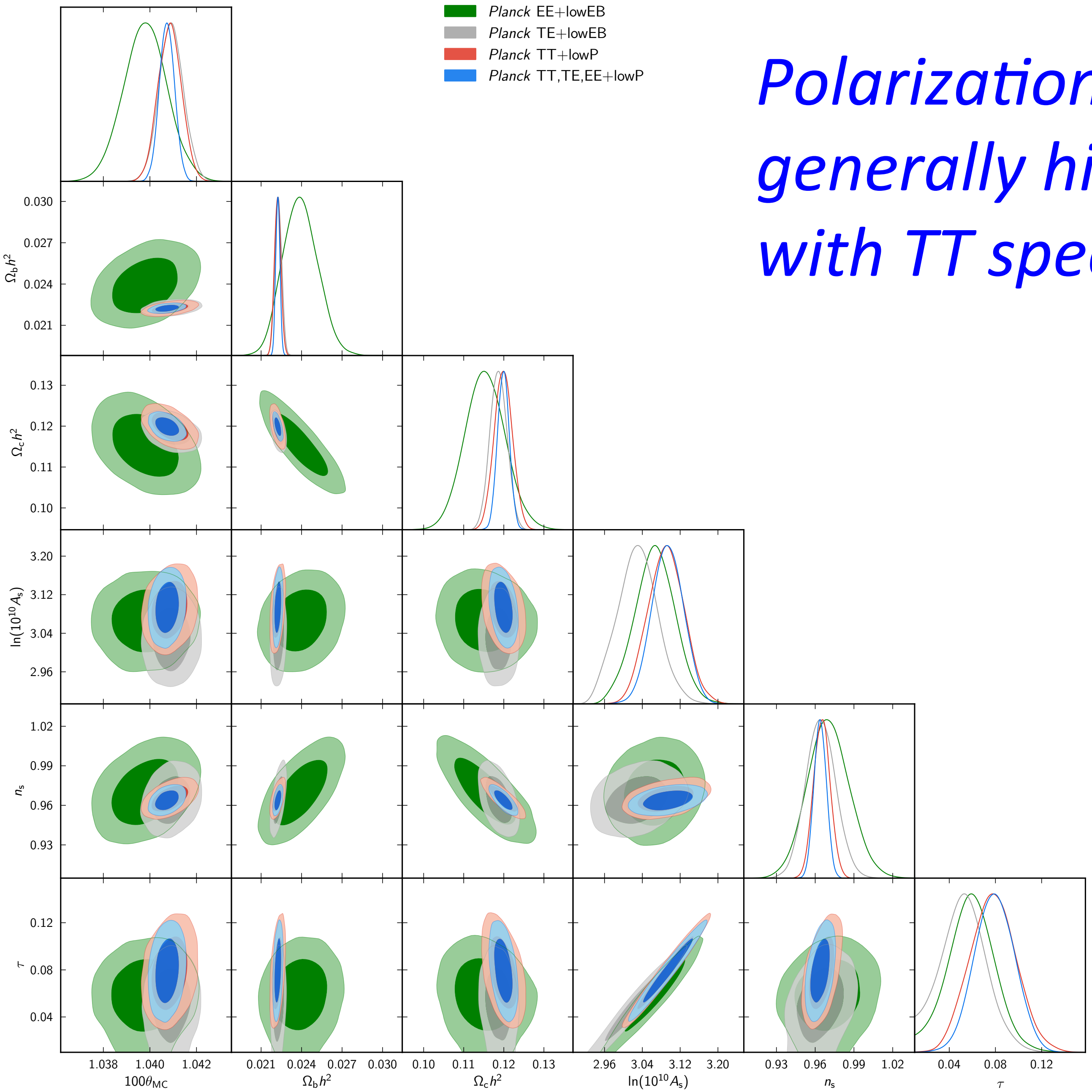

Polarization spectra are generally highly consistent with TT spectra.

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BASE ΛCDM MODEL

Parameter	TT	TT,TE,EE
$\Omega_b h^2$	0.02222±0.00023	0.02224±0.00015
$\Omega_c h^2$	0.1199±0.0022	0.1199±0.0014
$100\theta_*$	1.04086±0.00048	1.04073±0.00032
τ	0.078±0.019	0.079±0.017
n_s	0.9652±0.0062	0.9639±0.0047
H_0	67.3±1.0	67.6 ± 0.6 (+BAO)
Ω_m	0.316±0.014	0.316±0.009
σ_8	0.830±0.015	0.831±0.013
z_{re}	9.9±1.9	10.7±1.7

…but beware there are still low level systematics in the polarization spectra

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Planck 2013:

- good agreement with Planck lensing ✔
- consistent with BAO ✔
- ~2σ tension with Ia SNe ✔
- ~2.5σ tension with H_0 ✔ GPE ✗ AGR
- tension with measures of σ_8 including:
    - weak lensing ✗
    - cluster counts ✗
    - redshift space distortions ?

Some skeptics even doubted the fidelity of the Planck data! ✗

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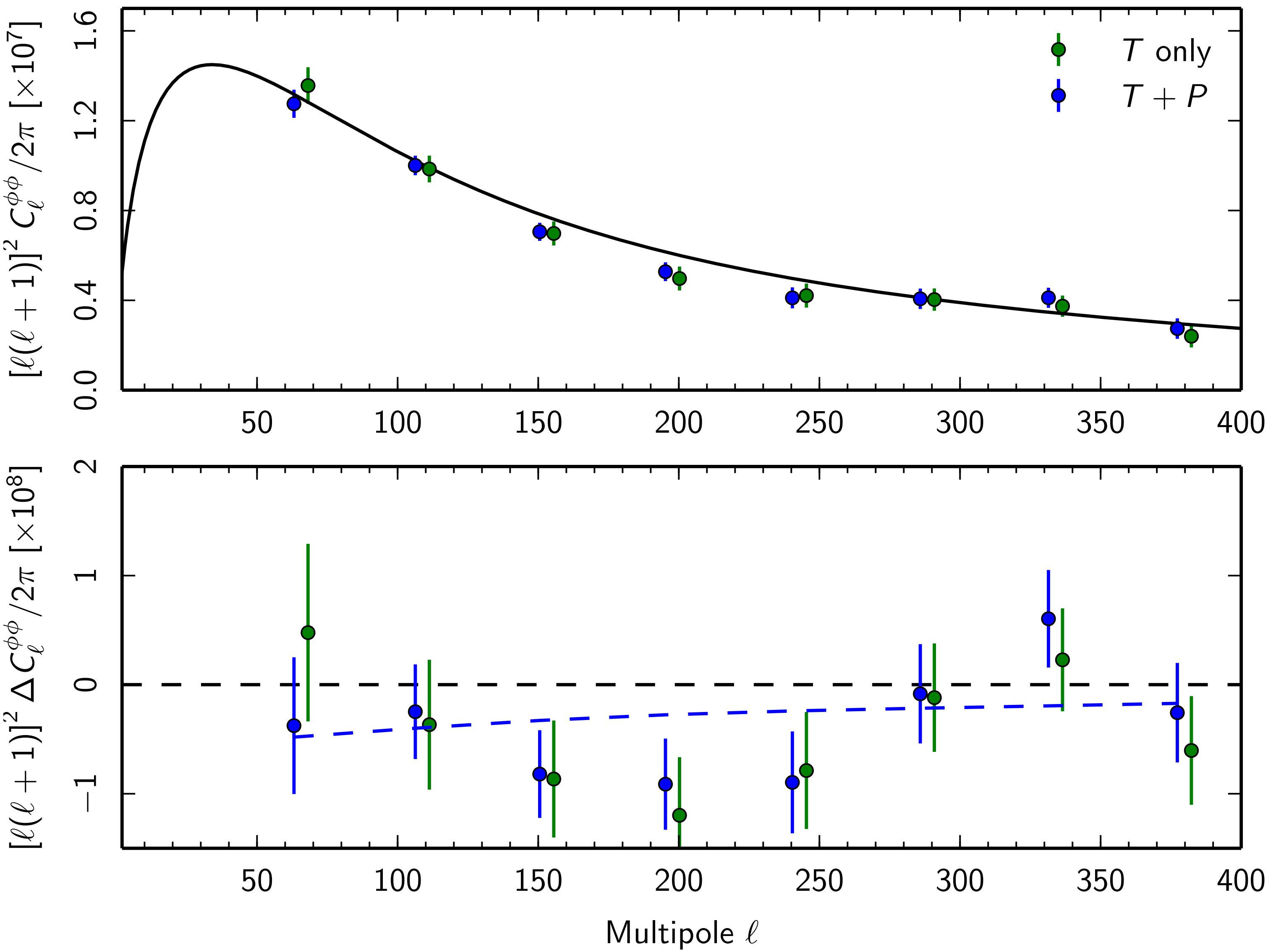
2014 Planck lensing $\chi^2 = 15.4$ (8 bins)



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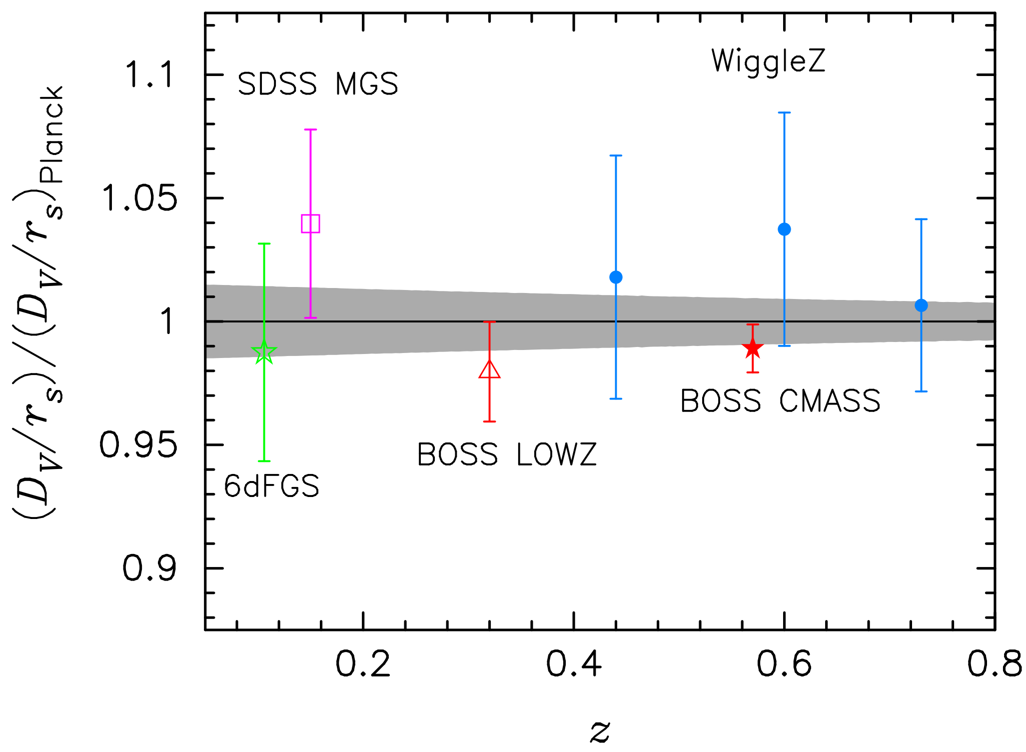
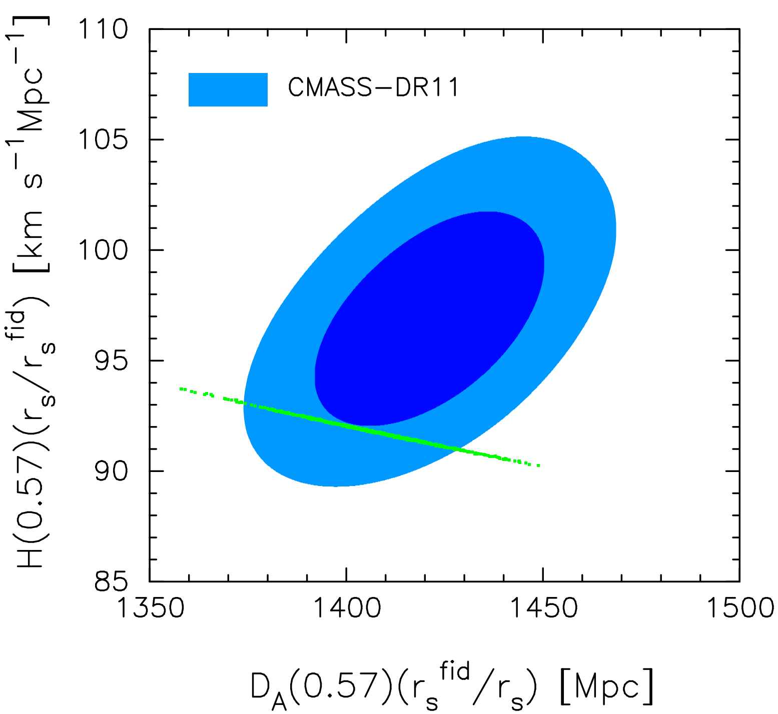
Baryon Acoustic Oscillations (BAO)





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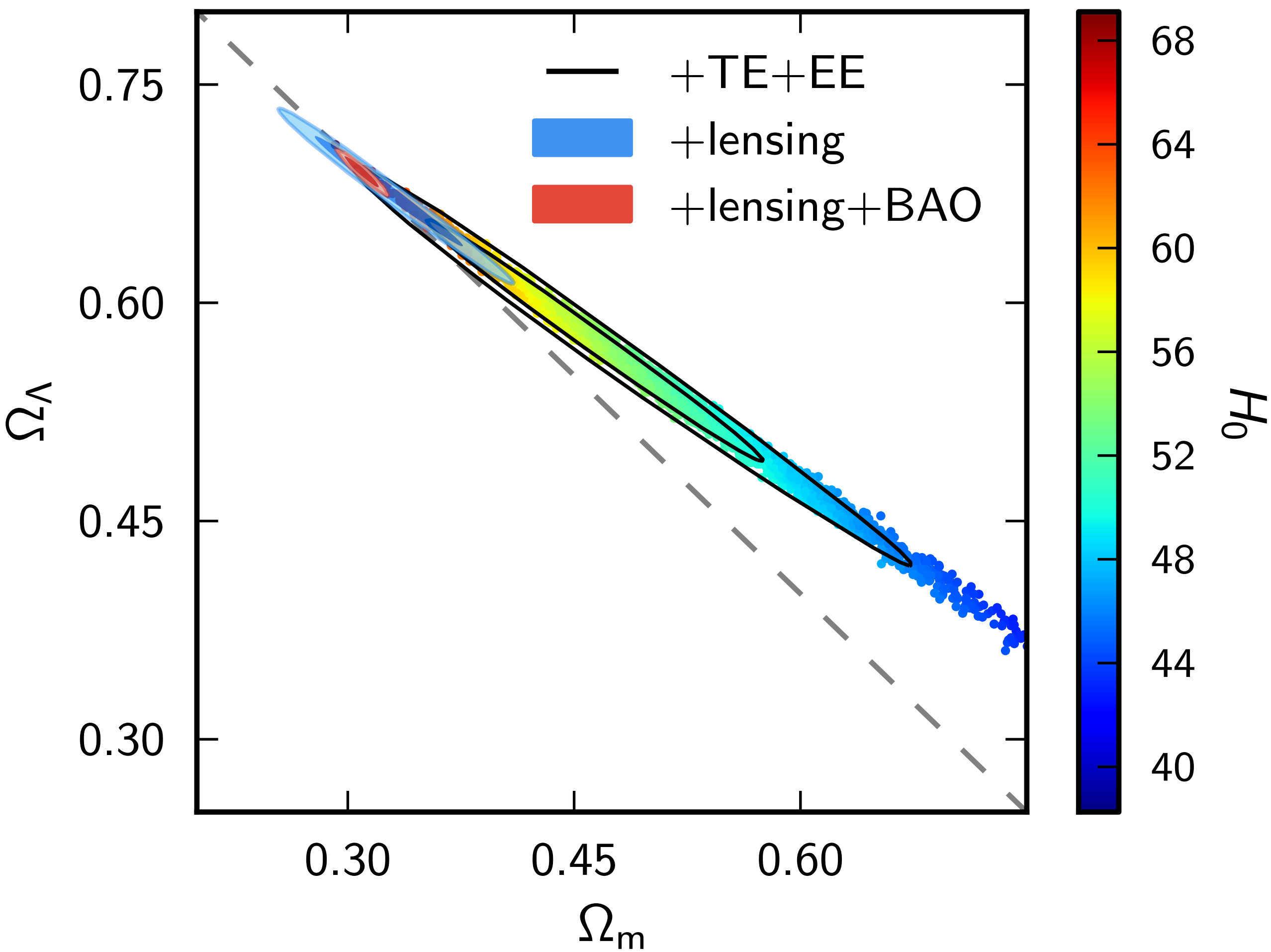
…. leading to remarkable constraints on spatial curvature Ω_k=0.000±0.005 (95%)



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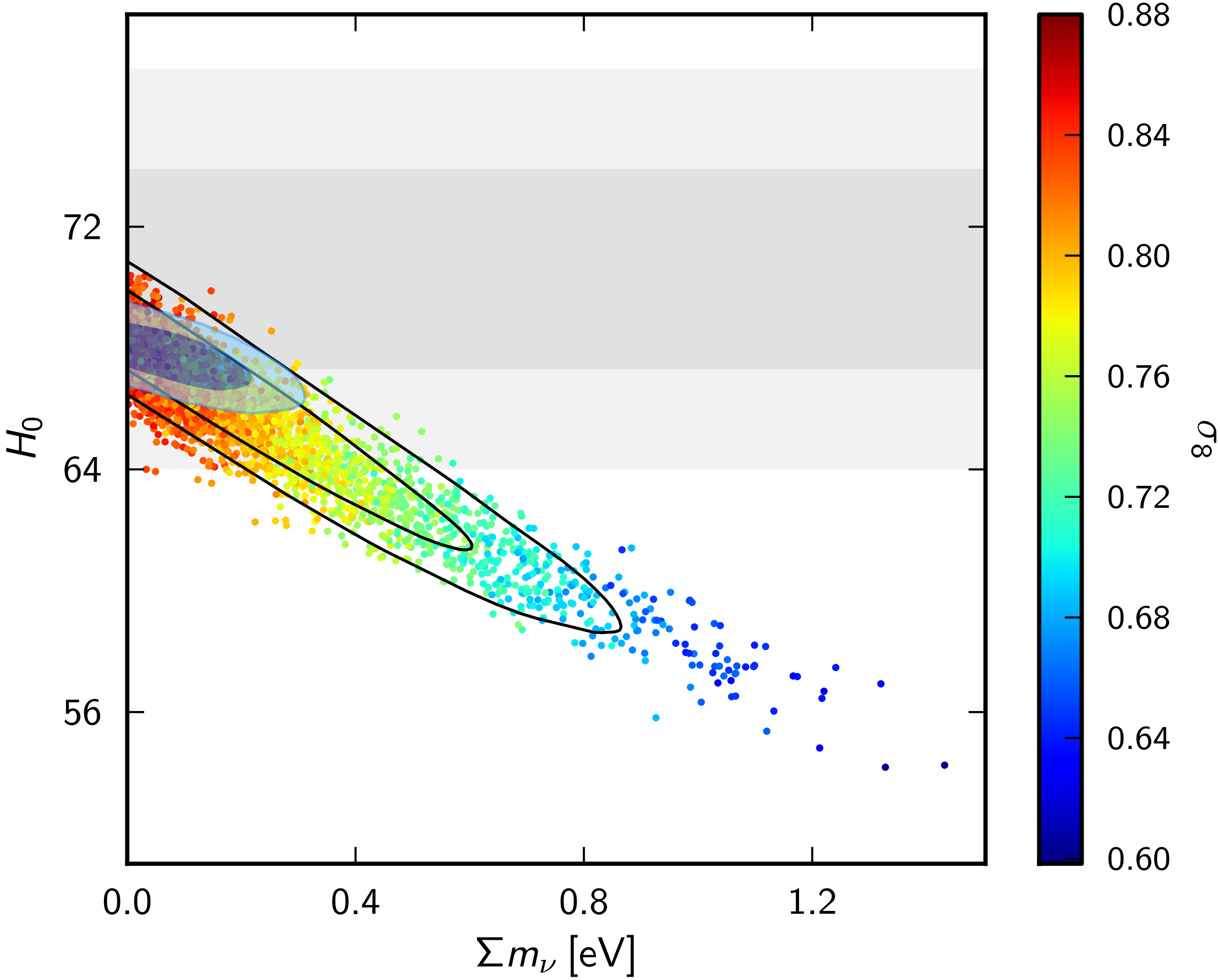
…. and to neutrino masses $\Sigma m_\nu < 0.21$ eV (95%)



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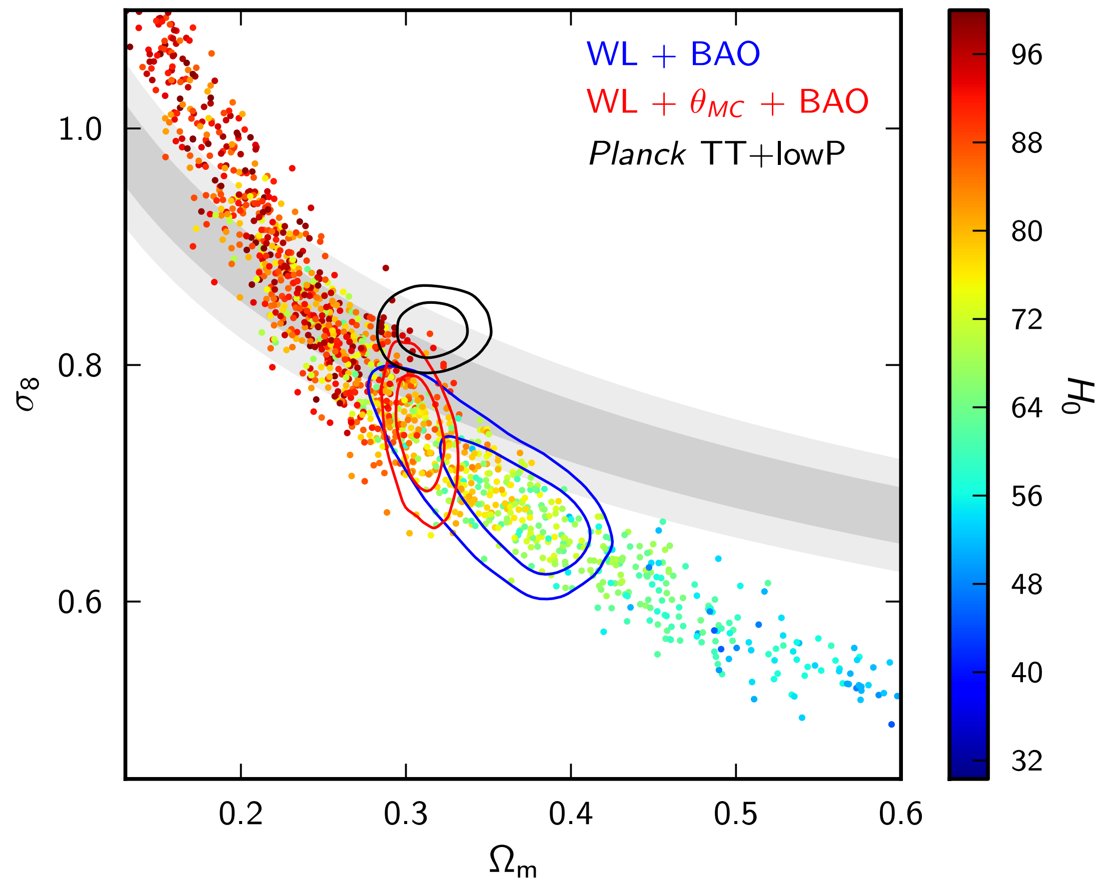
Possible tensions: Weak gravitational lensing (CFHTlens)



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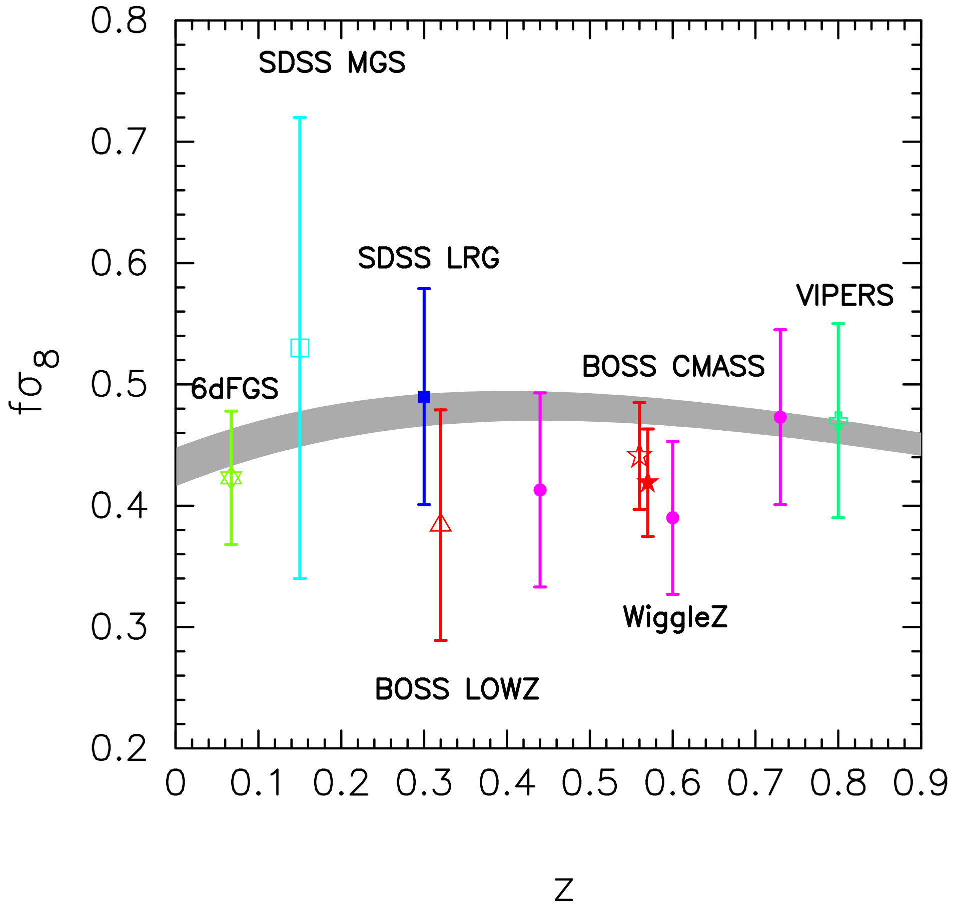
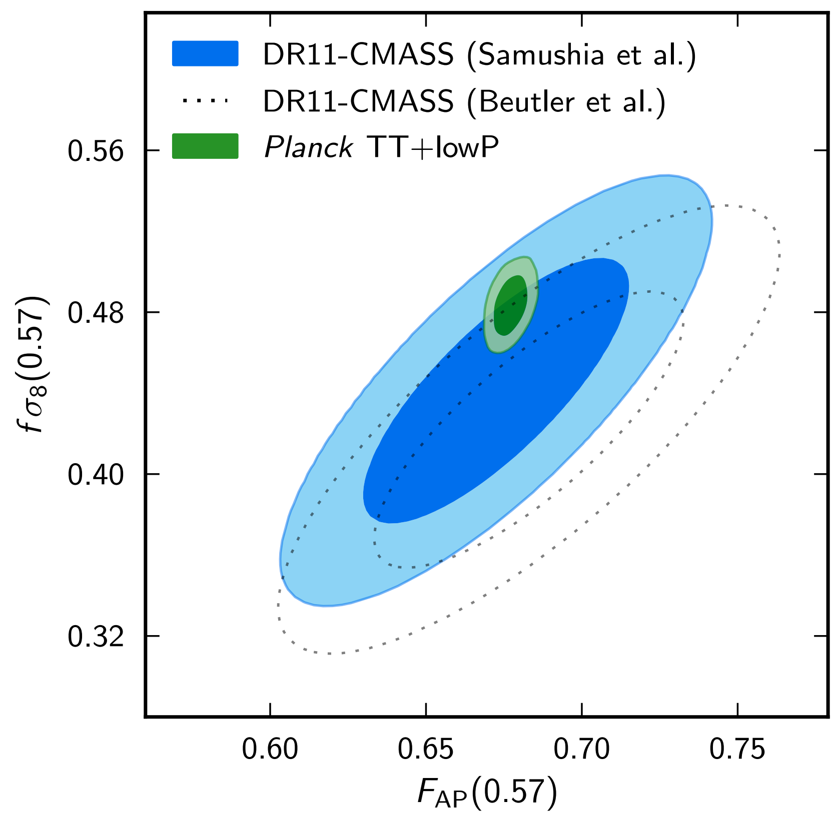
..... and redshift space distortions......





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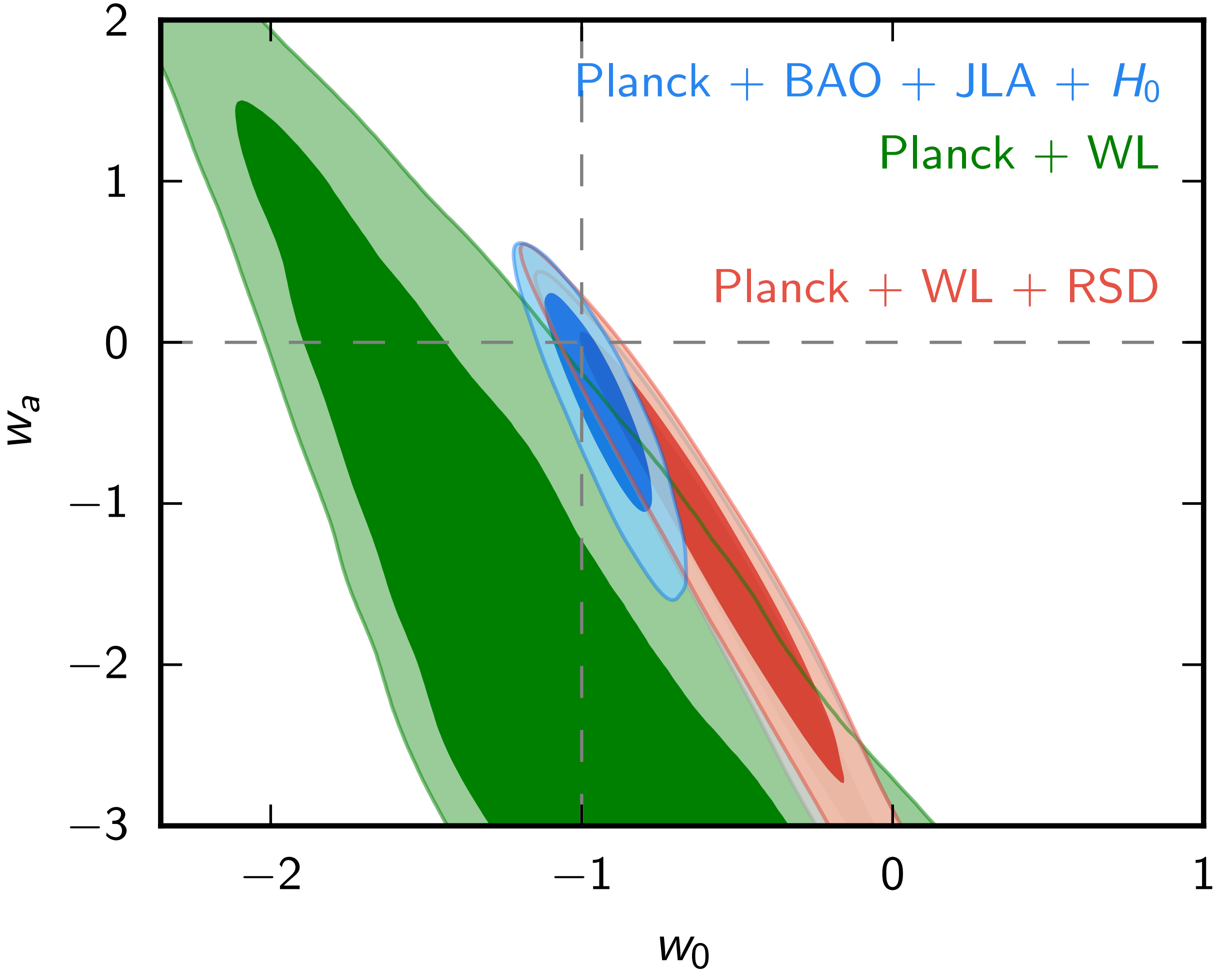
….. and one example of what these tensions can do…….

$$w(a) = w_0 + (1\text{-}a)w_a$$



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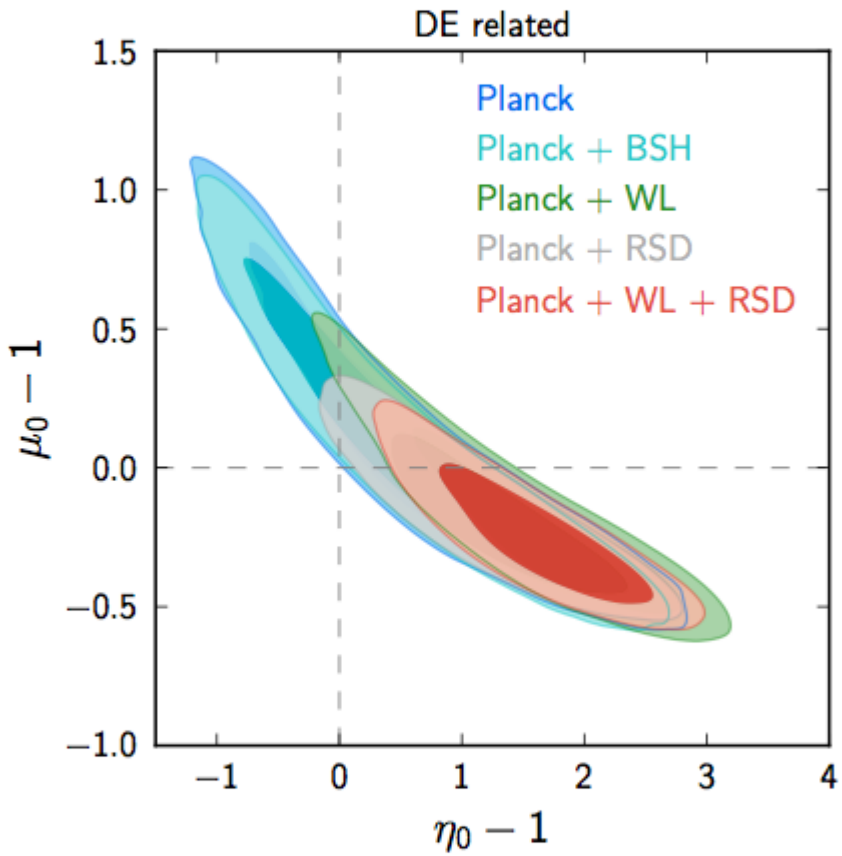
..... and another ....

Modified gravity: μ modifies gravitational potential, η is the ratio of the potentials Φ and Ψ.



(see talk by Valeria Pettorino)

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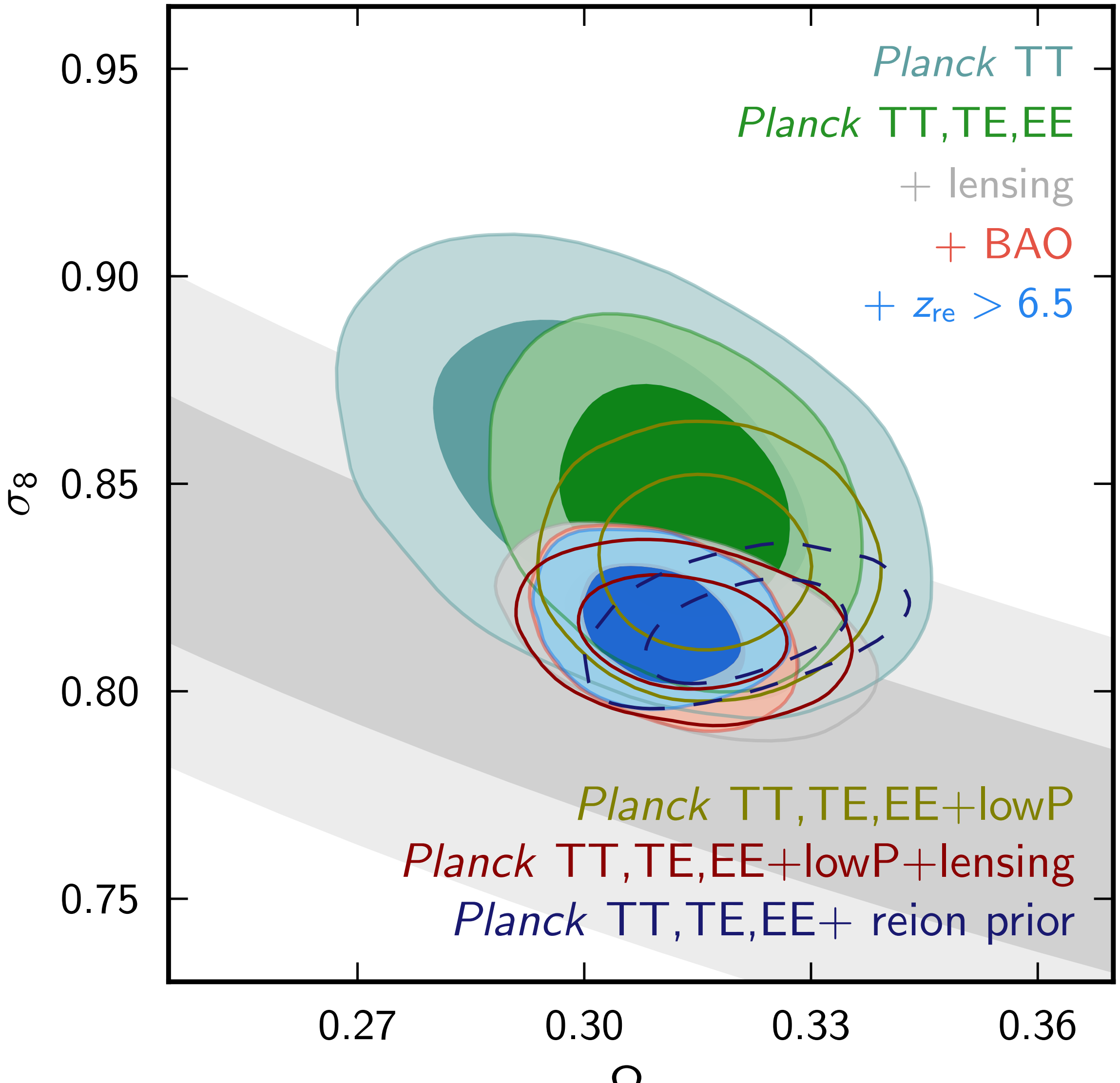
There is no doubt that in base ΛCDM Planck wants high σ_8:



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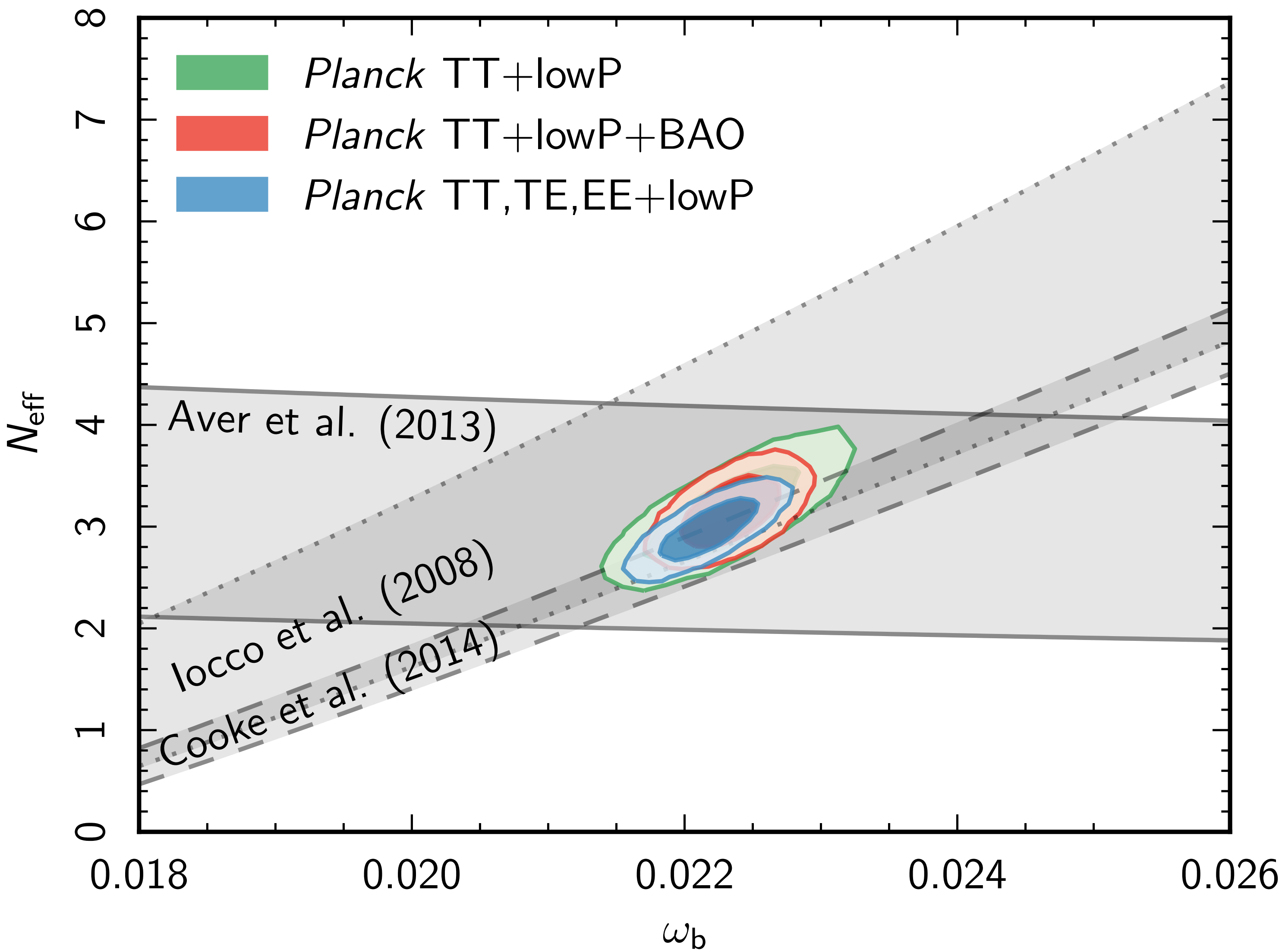
Primordial nucleosynthesis (deuterium abundance) and N_{eff}



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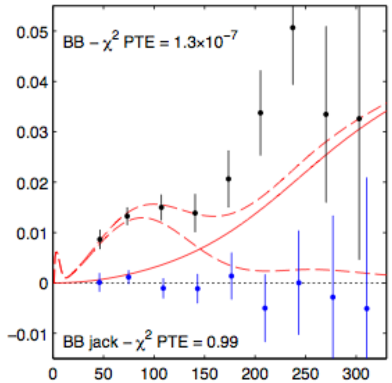
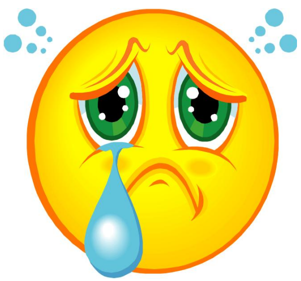
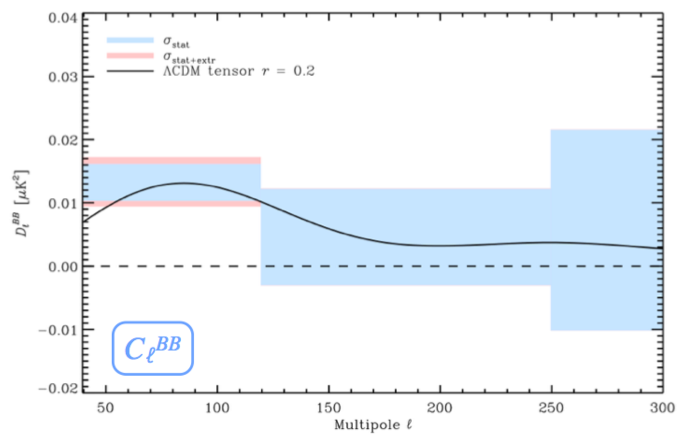
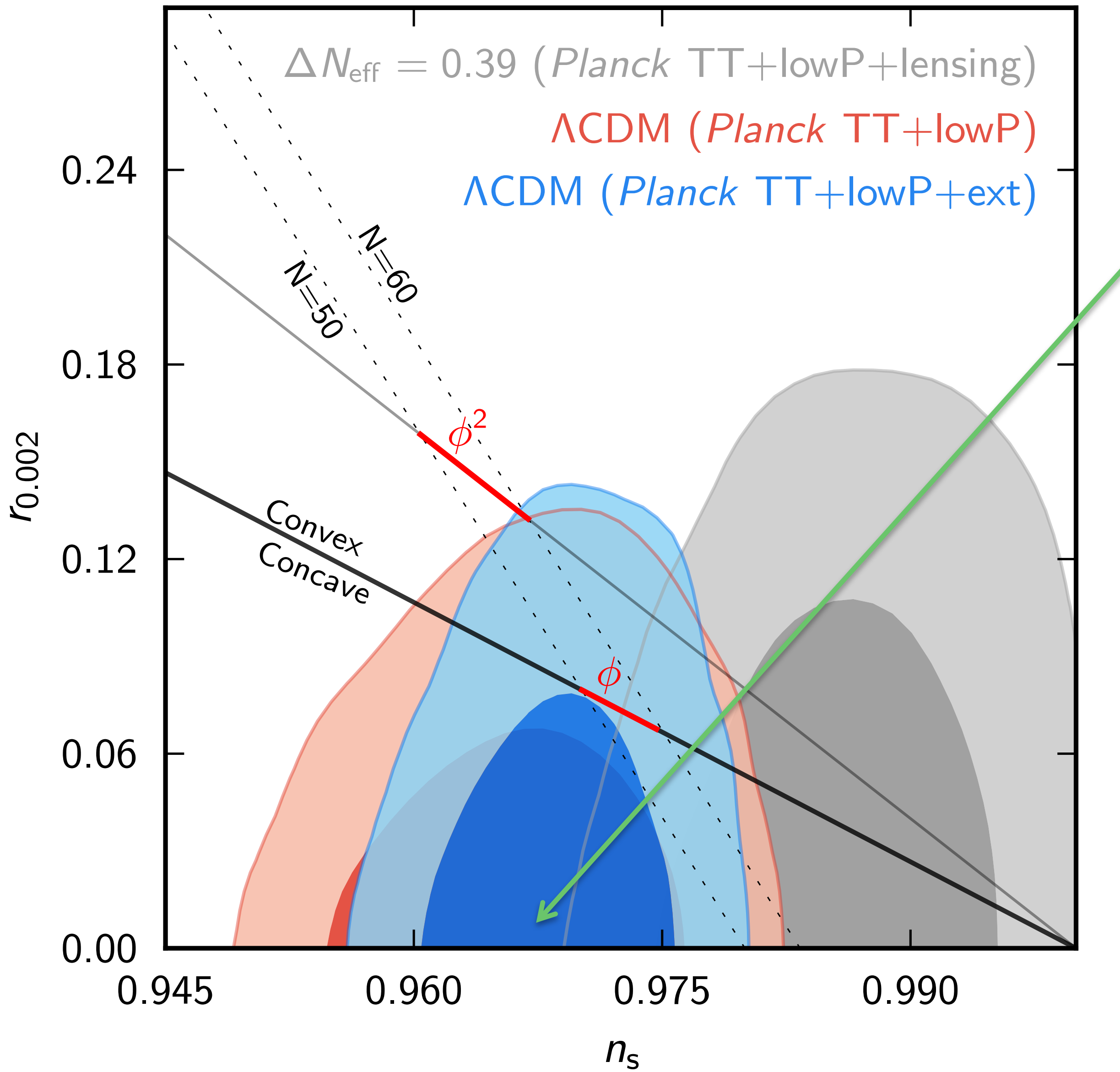
The three faces of BICEP







WAIT!



Starobinsky (R^2) inflation

$n_s \approx 1 - 2/N \approx 0.967$

$r \approx 12/N^2 \approx 0.0033$

$dn_s/d\ln k \approx -2/N^2 \approx -0.0006$

…… but, there is plenty of room at the top

(and to the side!)

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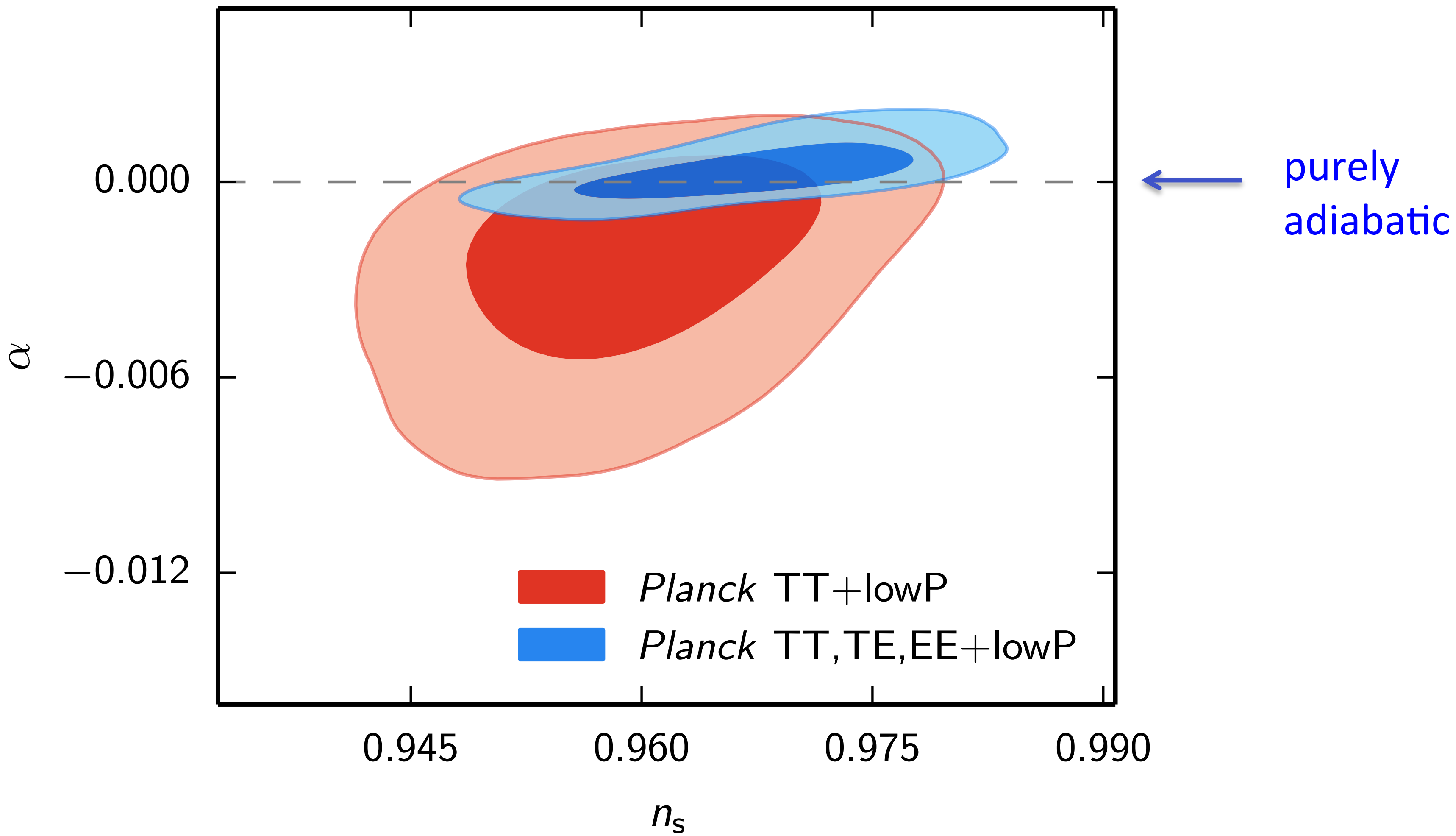
Isocurvature modes
(simple case of fully correlated matter isocurvature modes)



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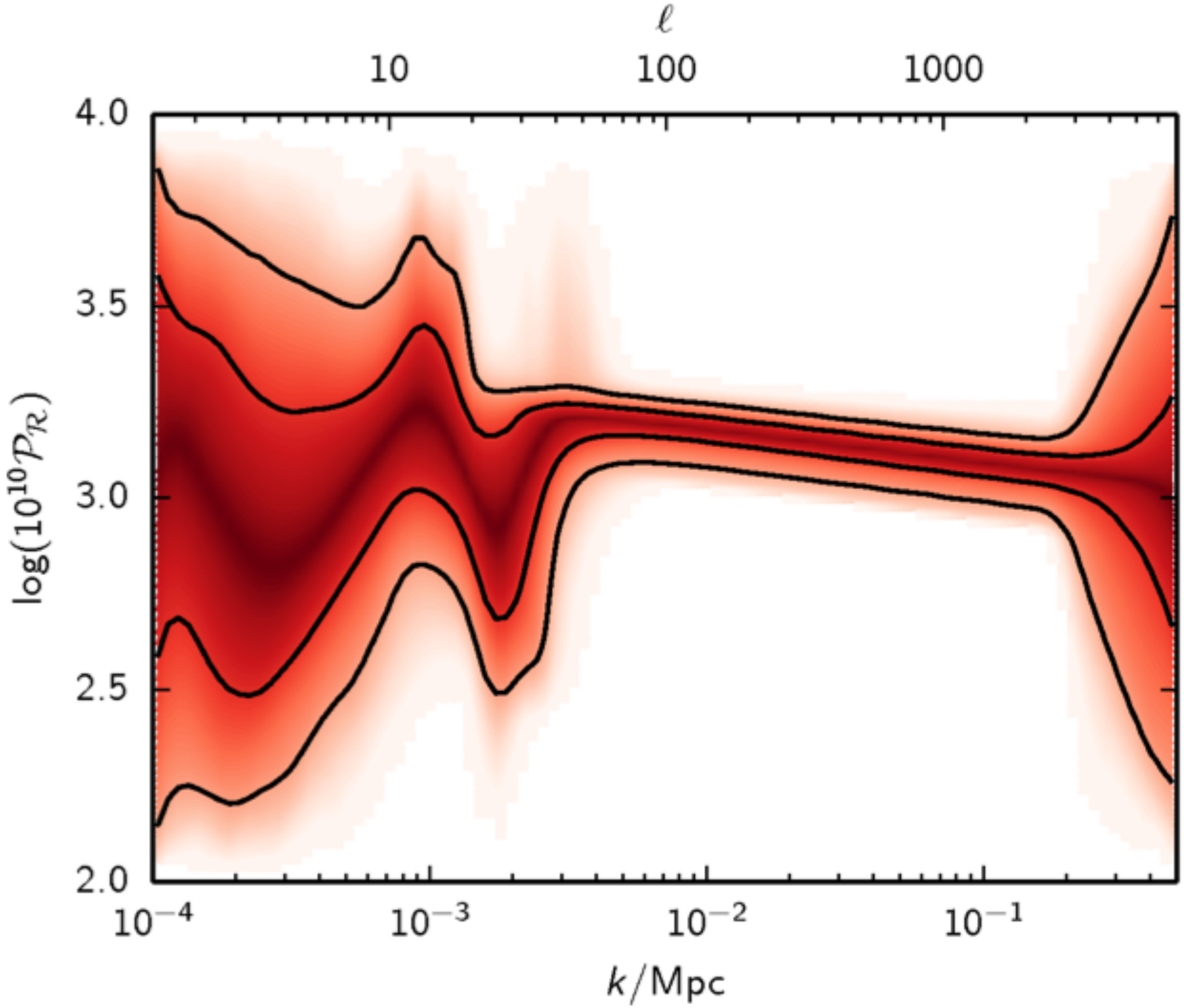
Power spectrum reconstruction (typical example)



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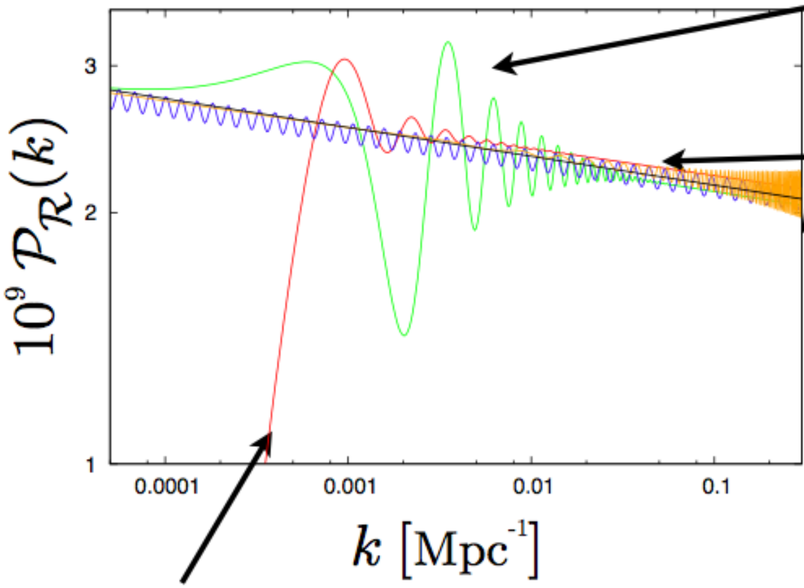
Searches for features:



Feature in the potential:

$$V(\phi) = \frac{m^2}{2}\phi^2 \left[1 + c\tanh\left(\frac{\phi - \phi_c}{d}\right)\right]$$

Non vacuum initial conditions/instanton effects in axion monodromy

$$V(\phi) = \mu^3\phi + \Lambda^4 \cos\left(\frac{\phi}{f}\right)$$

$$\mathcal{P}_{\mathcal{R}}^{\log}(k) = \mathcal{P}_{\mathcal{R}}^{0}(k)\left[1 + \mathcal{A}_{\log}\cos\left(\omega_{\log}\ln\left(\frac{k}{k_*}\right) + \varphi_{\log}\right)\right].$$

Linear oscillations as from Boundary EFT

$$\mathcal{P}_{\mathcal{R}}^{\mathrm{lin}}(k) = \mathcal{P}_{\mathcal{R}}^{0}(k)\left[1 + \mathcal{A}_{\mathrm{lin}}\left(\frac{k}{k_*}\right)^{n_{\mathrm{lin}}}\cos\left(\omega_{\mathrm{lin}}\frac{k}{k_*} + \varphi_{\mathrm{lin}}\right)\right]$$

Just enough e-folds, i.e. inflation preceded by a kinetic stage

see talk by Fabio Finelli on Thurday for more details.

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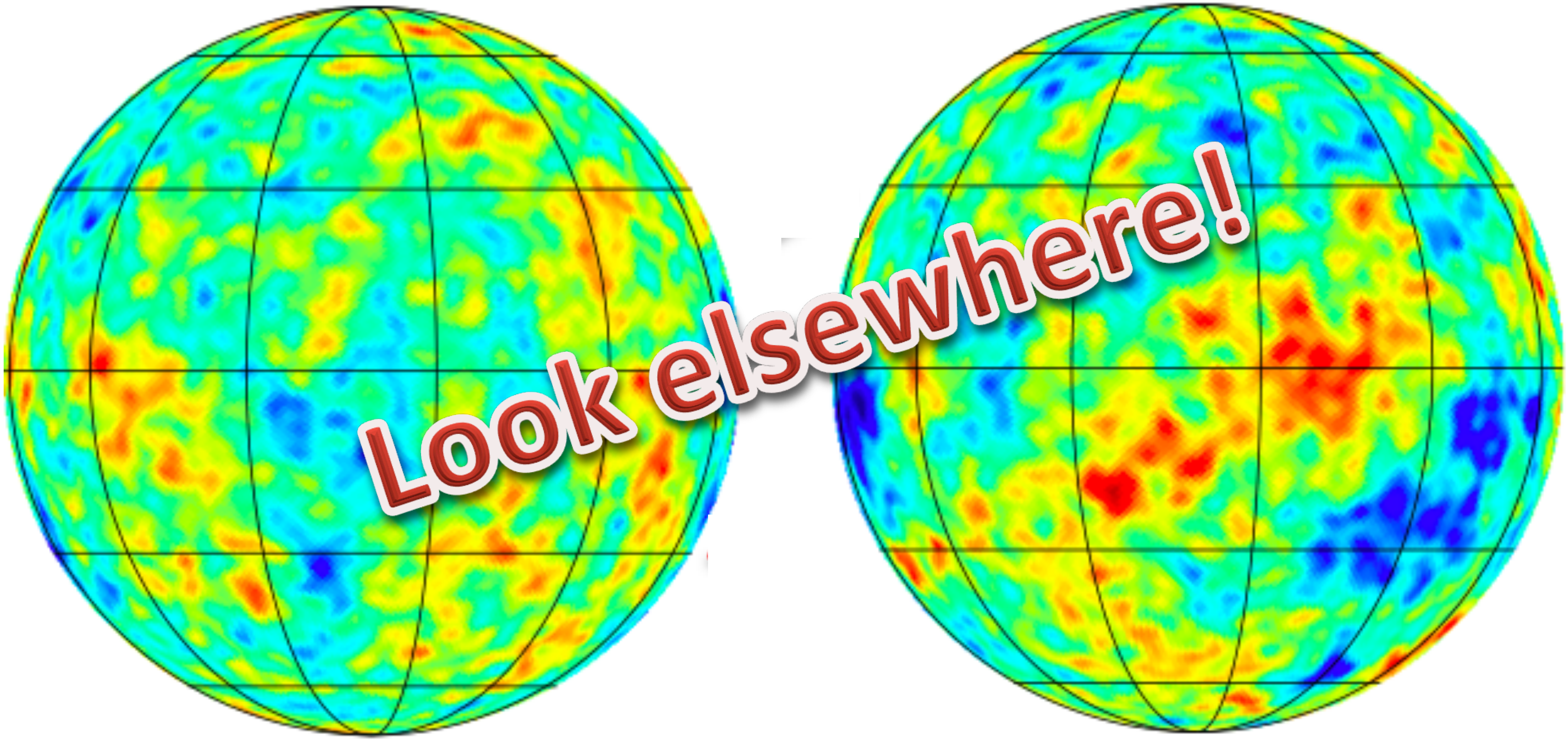
Large Angle Anomalies



- As in 2013 base ΛCDM continues to be a good fit to the Planck data, *including polarization*.
- No convincing evidence for any simple extensions.
- Some tensions with astrophysical data that measure the amplitude of matter fluctuations.
- Planck constraints on r as in 2013

  $r<0.11$ (95%)

  (but this constraint is model dependent).
- Scalar fluctuations consistent with pure adiabatic modes with a featureless tilted spectrum.

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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.