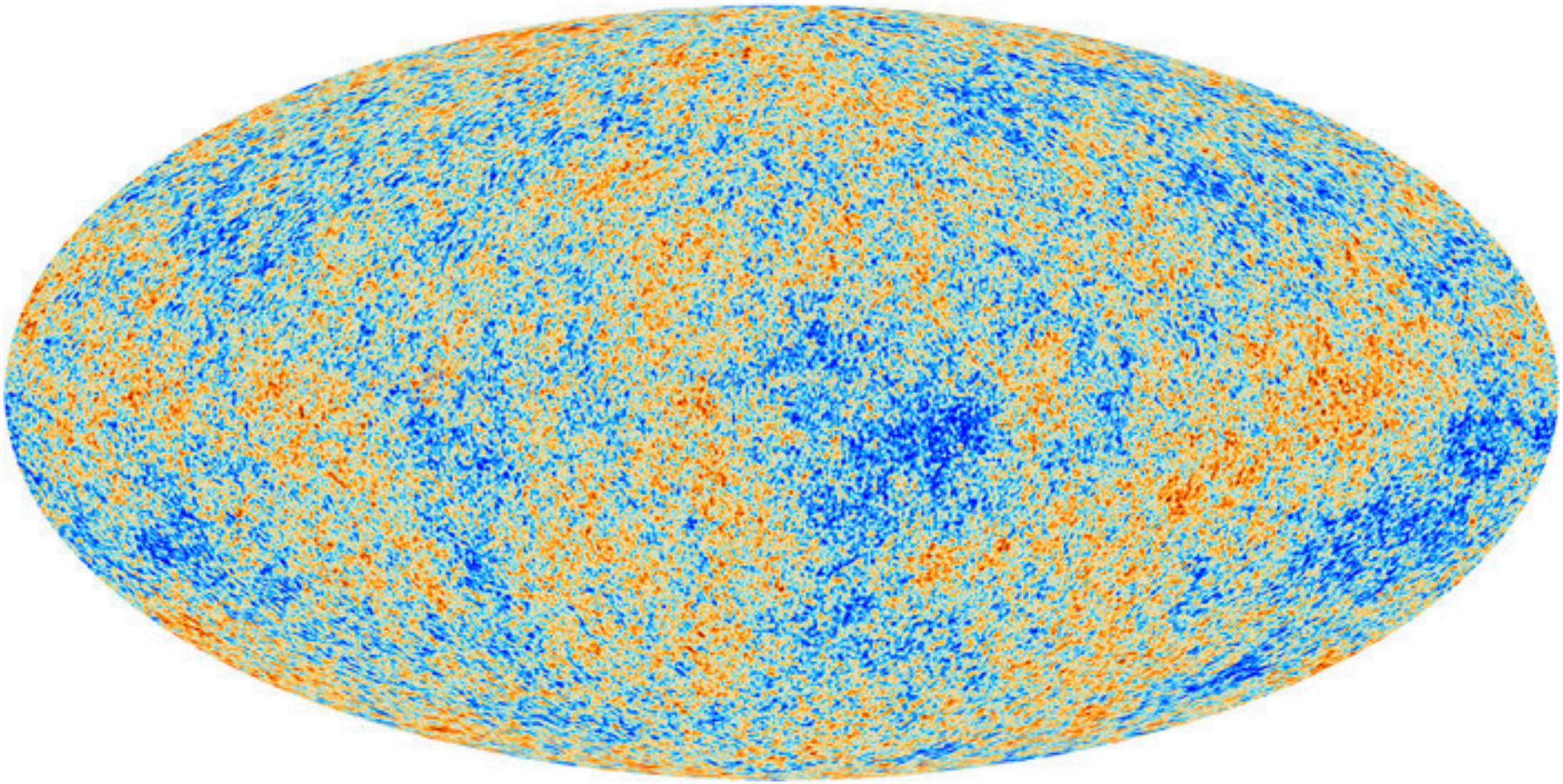
Inflationary Features and Shifts in Cosmological Parameters from Planck 2015 Data

Cora Dvorkin
Harvard University

"Advances in Theoretical Cosmology in Light of Data"
July 2017, Stockholm

Based on:
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

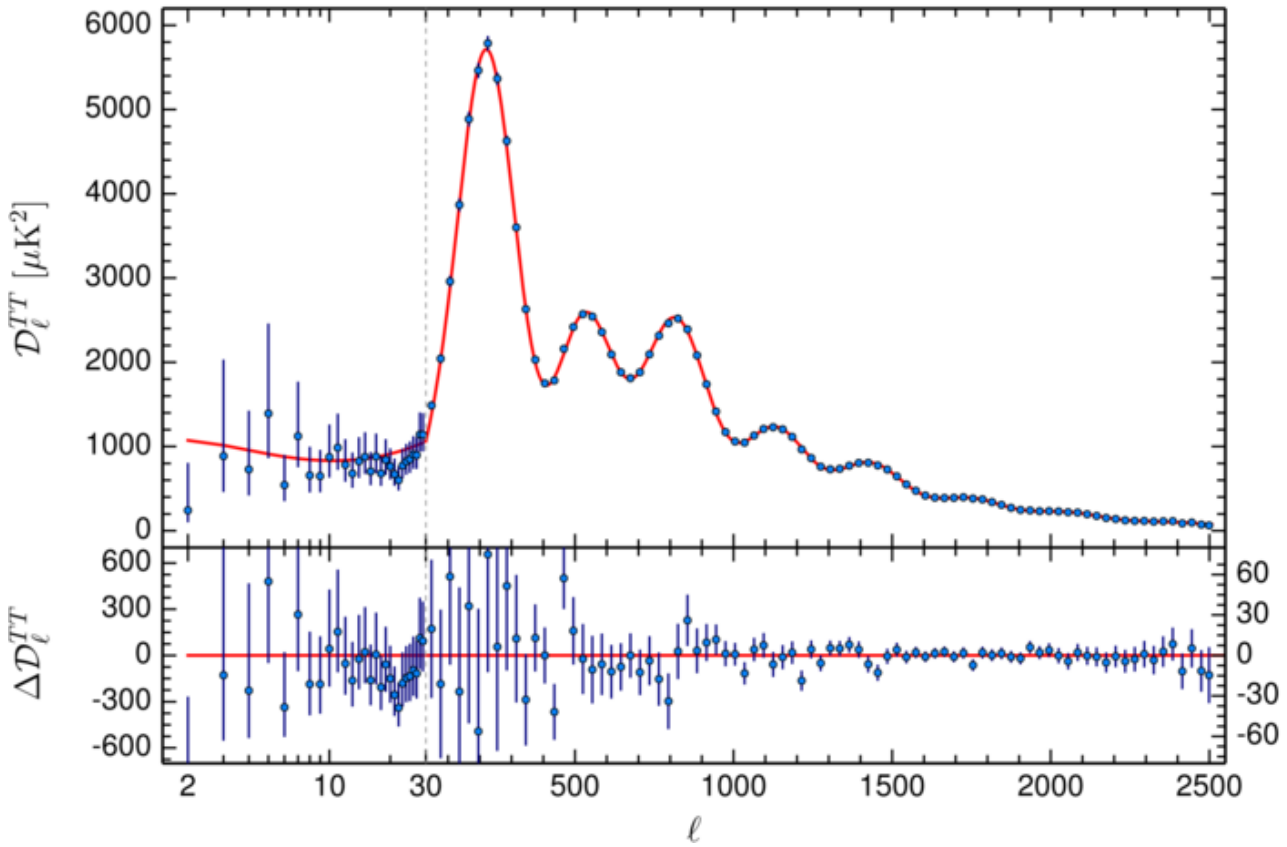
Cosmic Microwave Background



Planck collaboration

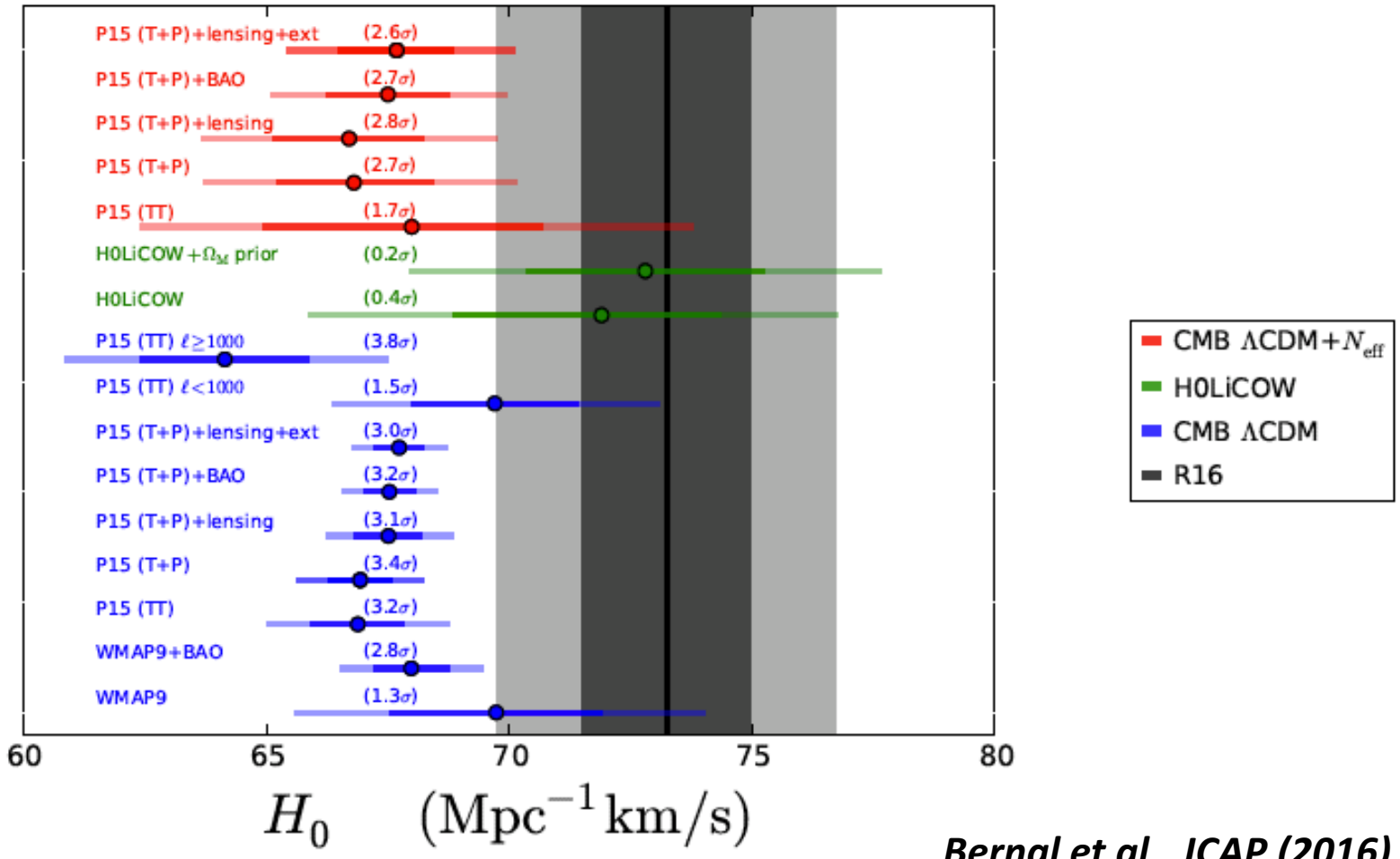
CMB Power Spectrum

Power spectrum: **predicted** and **measured** with great precision.



Planck collaboration

H_0 tension



Bernal et al., JCAP (2016)

Data sets and models used in this analysis

We study the relationship between:

- **features in the Planck 2015 temperature and polarization data.**
- **shifts in cosmological parameters.**
- **features from inflation.**

Combinations of Planck 2015 data sets:

Dataset	Likelihood
TT	binned TT + low TEB
TTEE	binned TTTEEE + low TEB
$\phi\phi$	lens reconstruction

Models and parametrizations of the inflationary power spectrum:

Model	Parameters $\{\tau, \theta_{\rm MC}, \Omega_b h^2, \Omega_c h^2\}$
ΛCDM	$+\{A_s, n_s\}$
rΛCDM	$+\{A_s, n_s, n_{\rm run}, n_{\rm run,run}\}$
SB	$+\{A_s, n_s, p_i\}$
rSB	$+\{A_s, n_s, n_{\rm run}, n_{\rm run,run}, p_i\}$

Going Beyond Slow Roll

Slow roll is a commonly used approximation for inflationary models where the scalar field potential is sufficiently flat and slowly varying.
It leads to curvature power spectra that are featureless and nearly scale invariant.

Generalized Slow-Roll approximation: allows for features in the inflationary potential. Here, the curvature power spectrum depends on a single source function (responsible for the observable features):

$$\ln \Delta^2_{\mathcal{R}}(k) = G(\ln \eta_{\rm min}) + \int_{\eta_{\rm min}}^{\eta_{\rm max}} \frac{d\eta}{\eta} W(k\eta) G'(\ln \eta) + \ln \left[1 + \frac{1}{2} \left(\int_{\eta_{\rm min}}^{\eta_{\rm max}} \frac{d\eta}{\eta} X(k\eta) G'(\ln \eta) \right)^2 \right]$$

C.Dvorkin, W.Hu, PRD (2009)

Simple to relate to the inflaton potential: $G' \approx 3 \left(\frac{V_{,\phi}}{V} \right)^2 - 2 \left(\frac{V_{,\phi\phi}}{V} \right)$

Inflationary Parameters

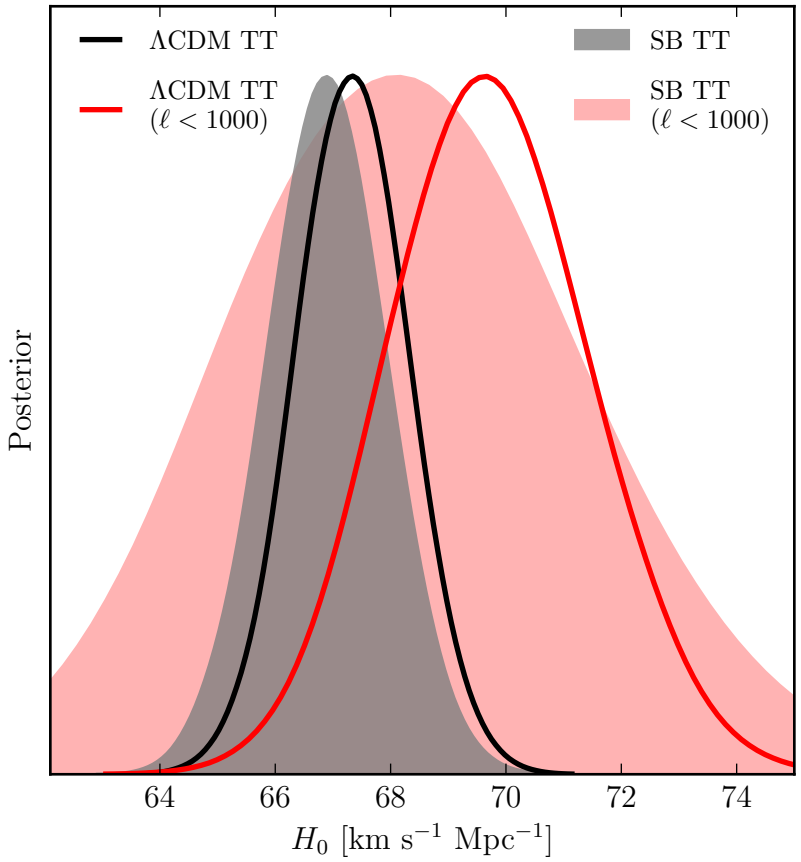
Models considered in our analysis:

- $\Lambda CDM: \quad \dfrac{d\ln\Delta^2_{\mathcal{R}}}{d\ln k} = n_s - 1$
- $r\Lambda CDM: \quad \dfrac{d\ln\Delta^2_{\mathcal{R}}}{d\ln k} = n_s - 1 + n_{\rm run}\ln\left(\dfrac{k}{k_0}\right) + \dfrac{n_{\rm run,run}}{2}\ln^2\left(\dfrac{k}{k_0}\right)$
- $SB: \quad G'(\ln s) = (1-n_s) + \sum_i p_i B_i(\ln s)$
- $rSB: \quad G'(\ln s) = (1-n_s) - n_{\rm run}\ln\left(\dfrac{k}{k_0}\right) - \dfrac{n_{\rm run,run}}{2}\ln^2\left(\dfrac{k}{k_0}\right) + \sum_i p_i B_i(\ln s)$

H_0 for full TT data vs. TT l<1000

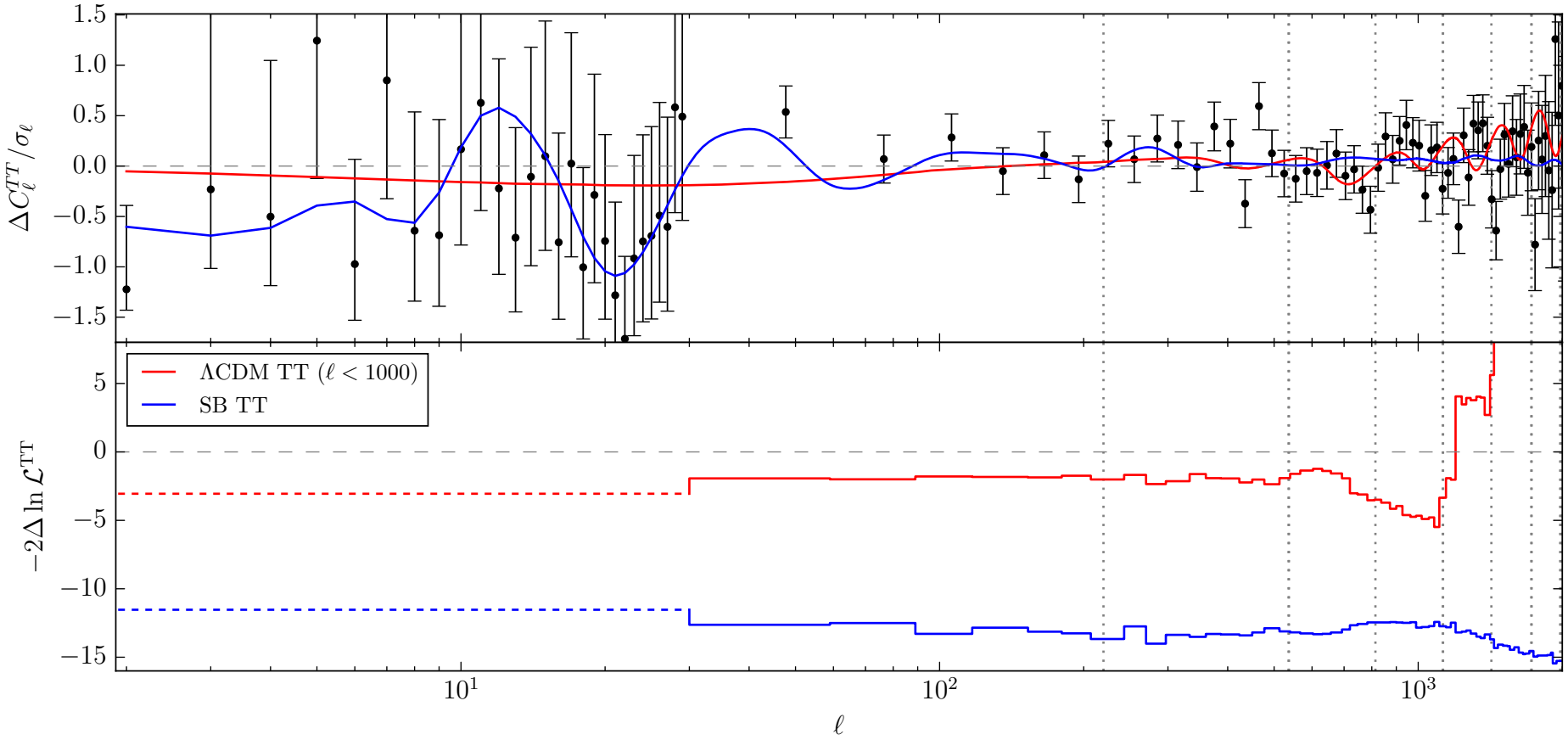
ΛCDM TT vs. ΛCDM TT l<1000 is in agreement with previous studies:

- Aghanim et al. (Planck, 2016)
- Addison et al. (2016)



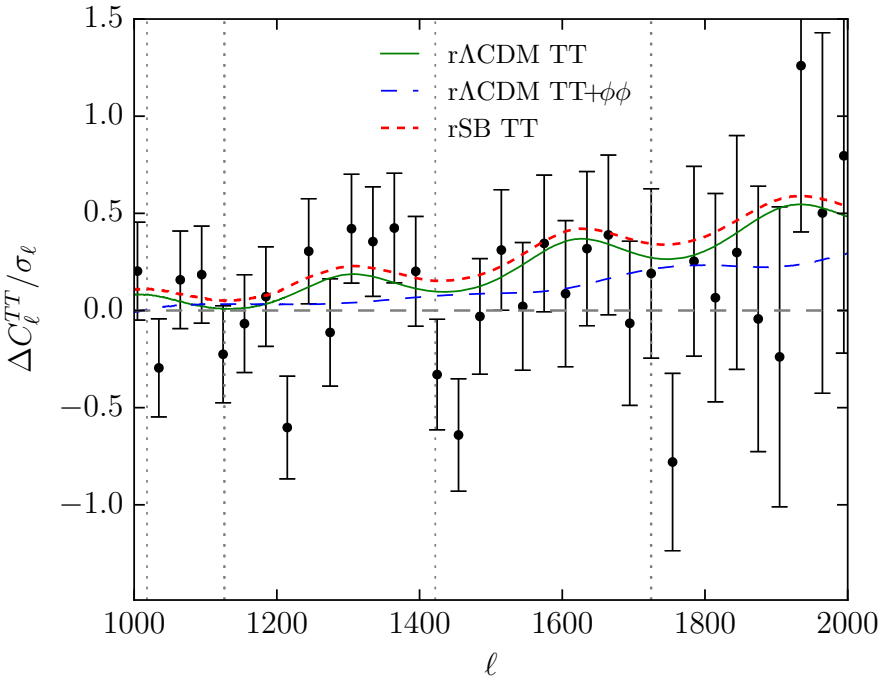
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

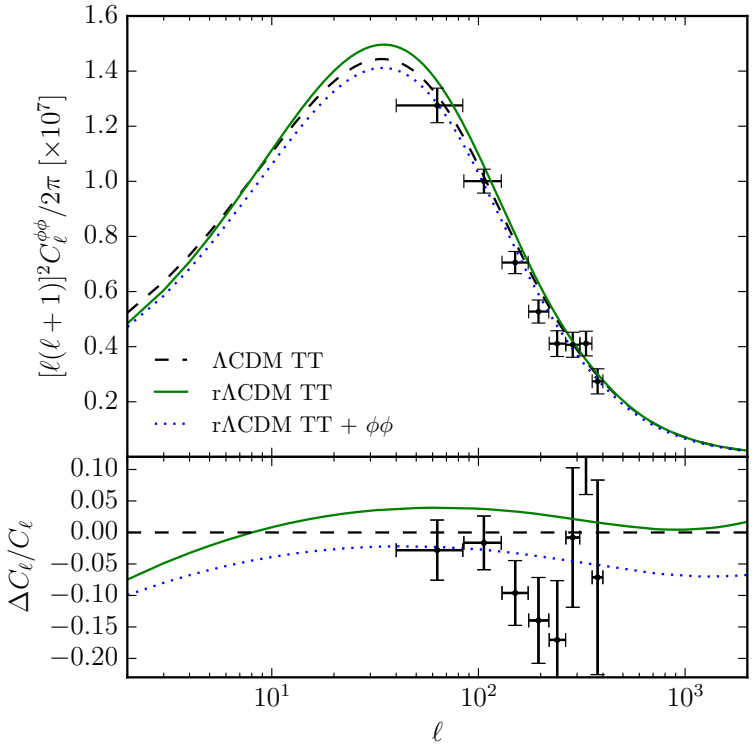
Residuals in the TT data



G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

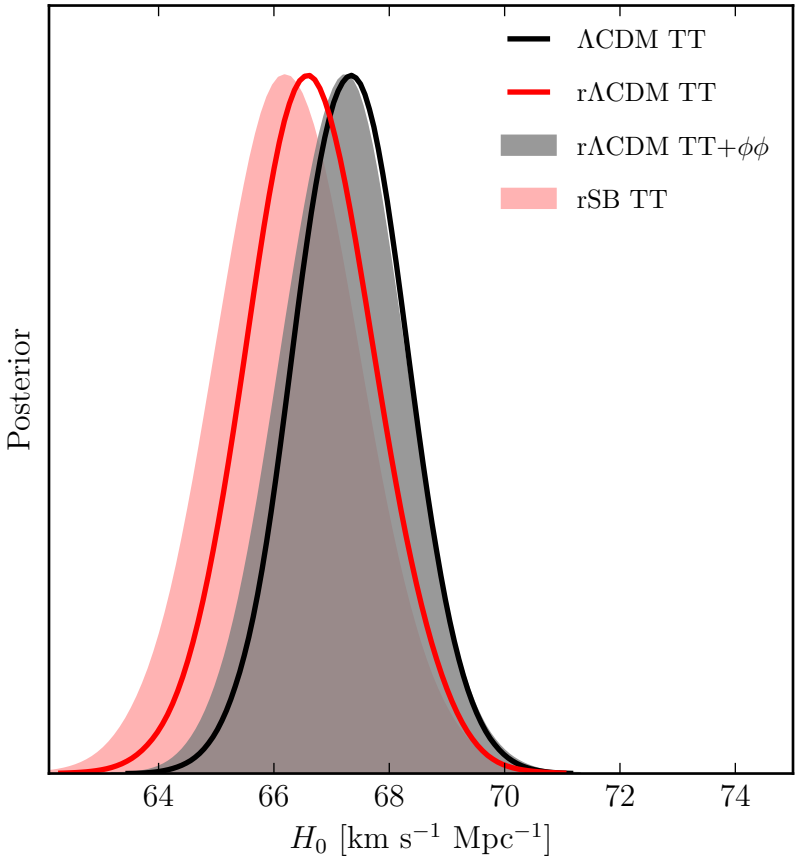
High-l TT residuals, lensing power spectrum, and running models





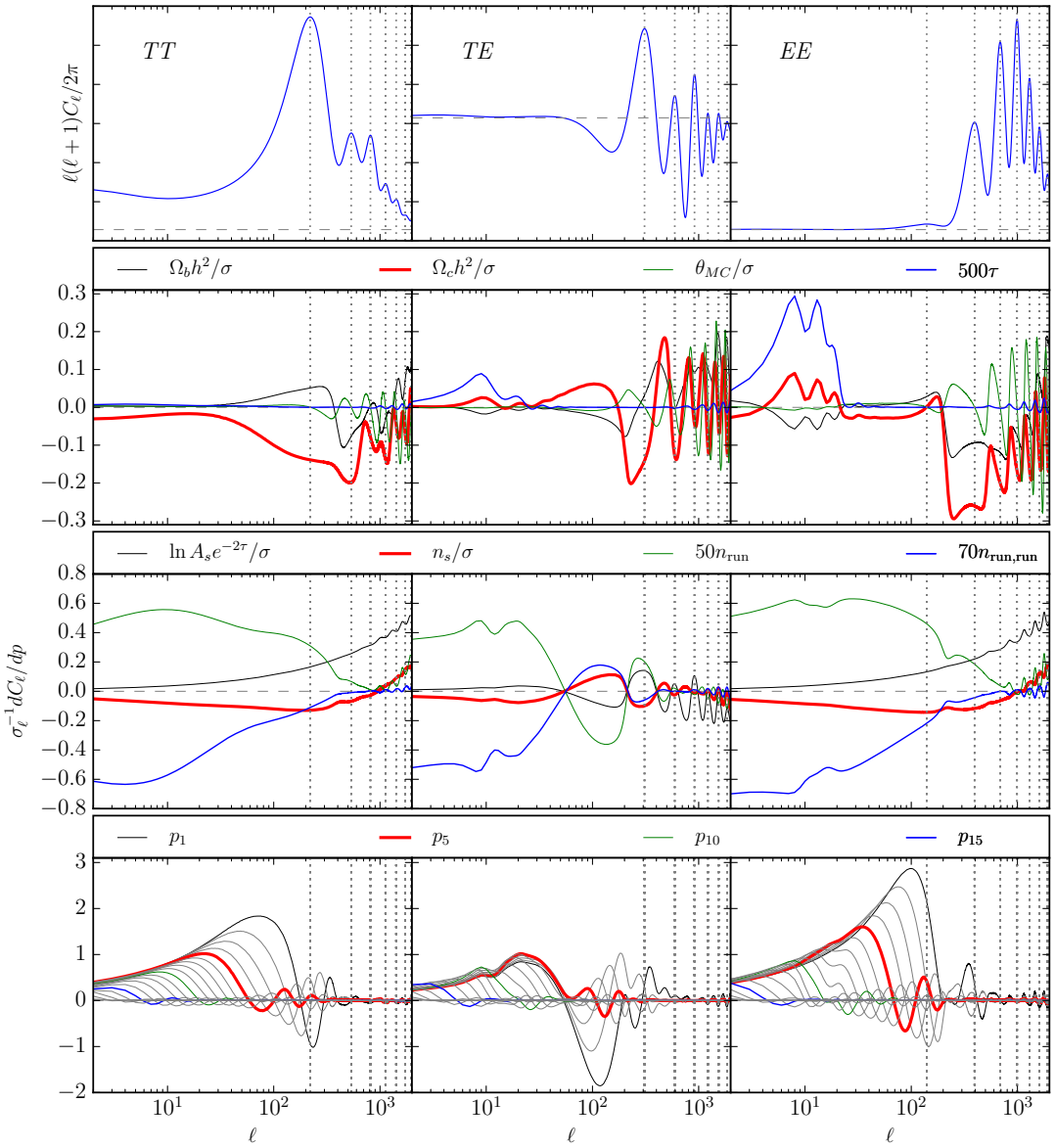
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

H_0 and inflationary parameters

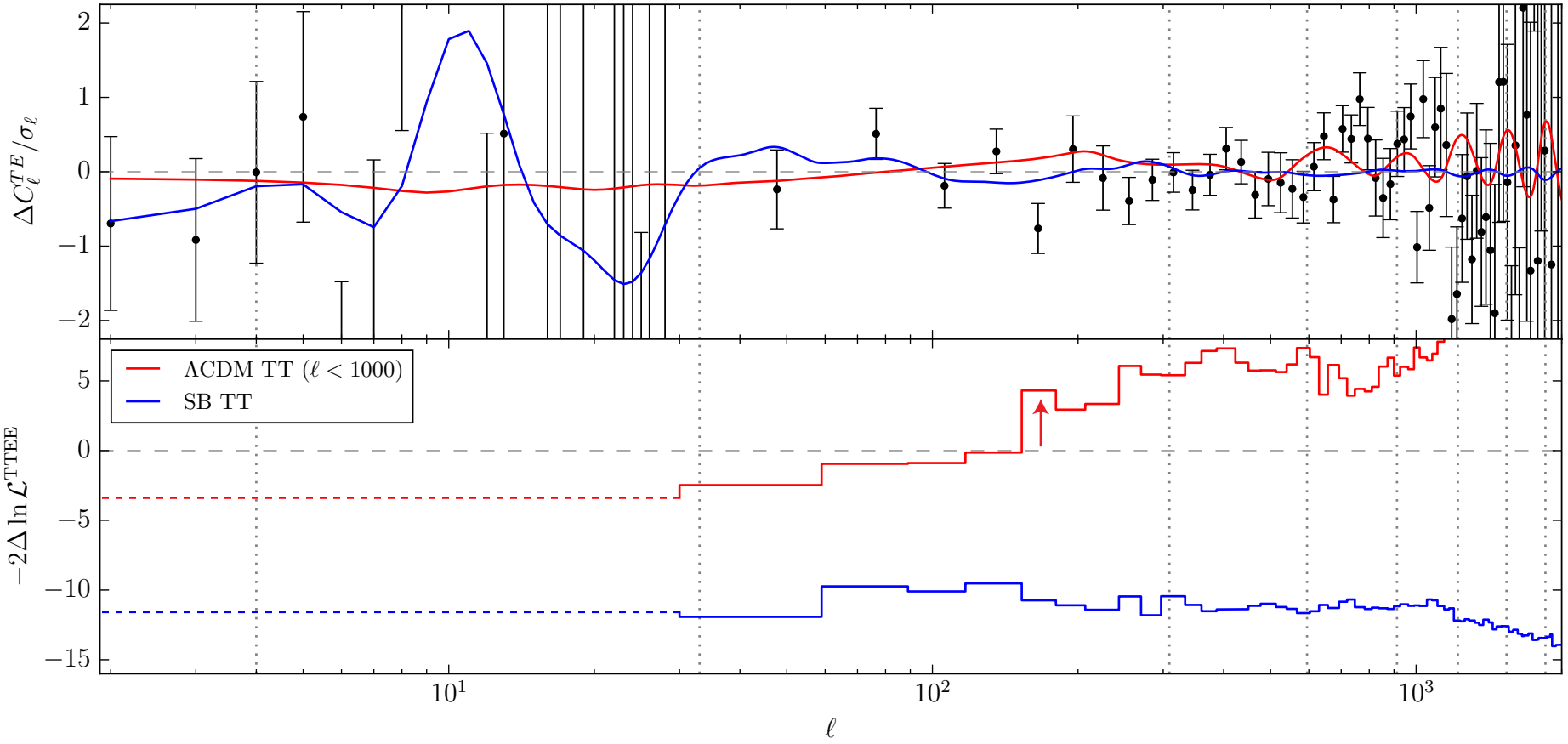


G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

Response functions

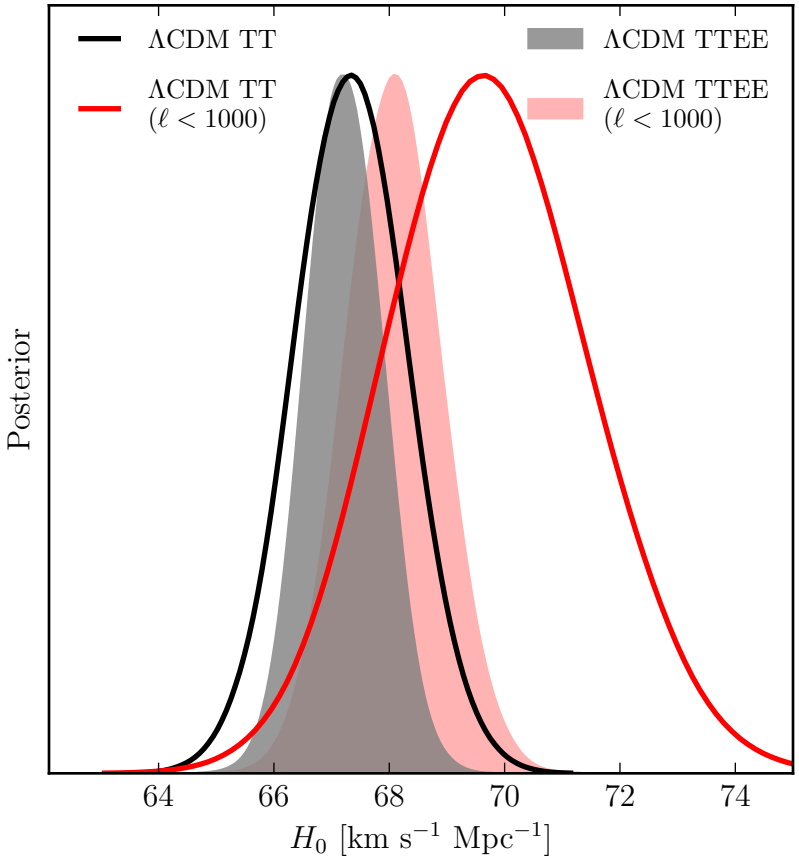


Residuals in the TE data



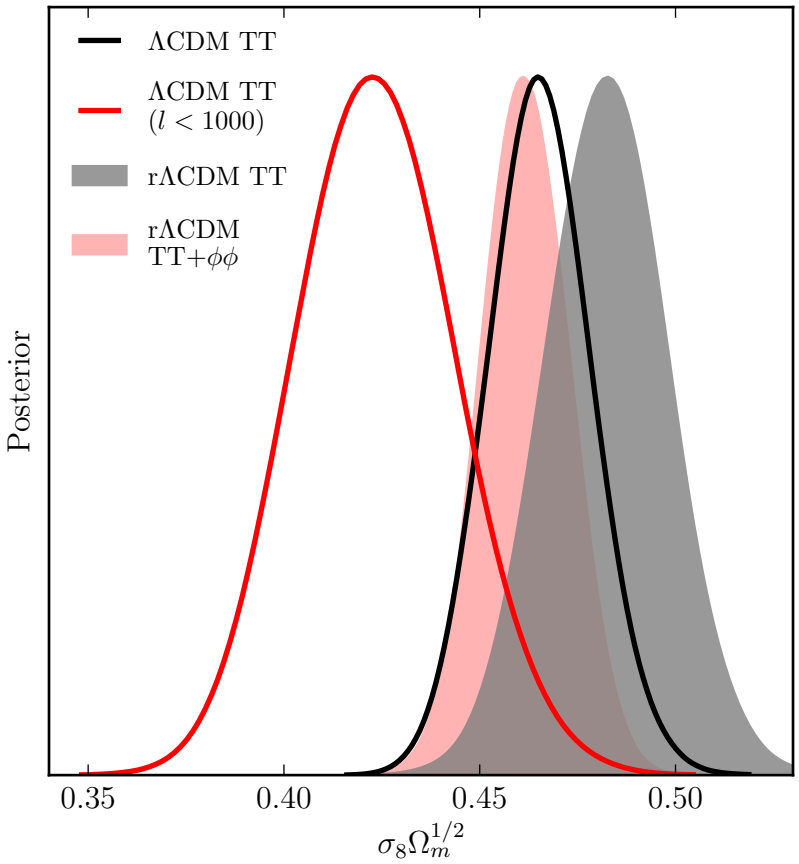
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

H_0 and polarization data



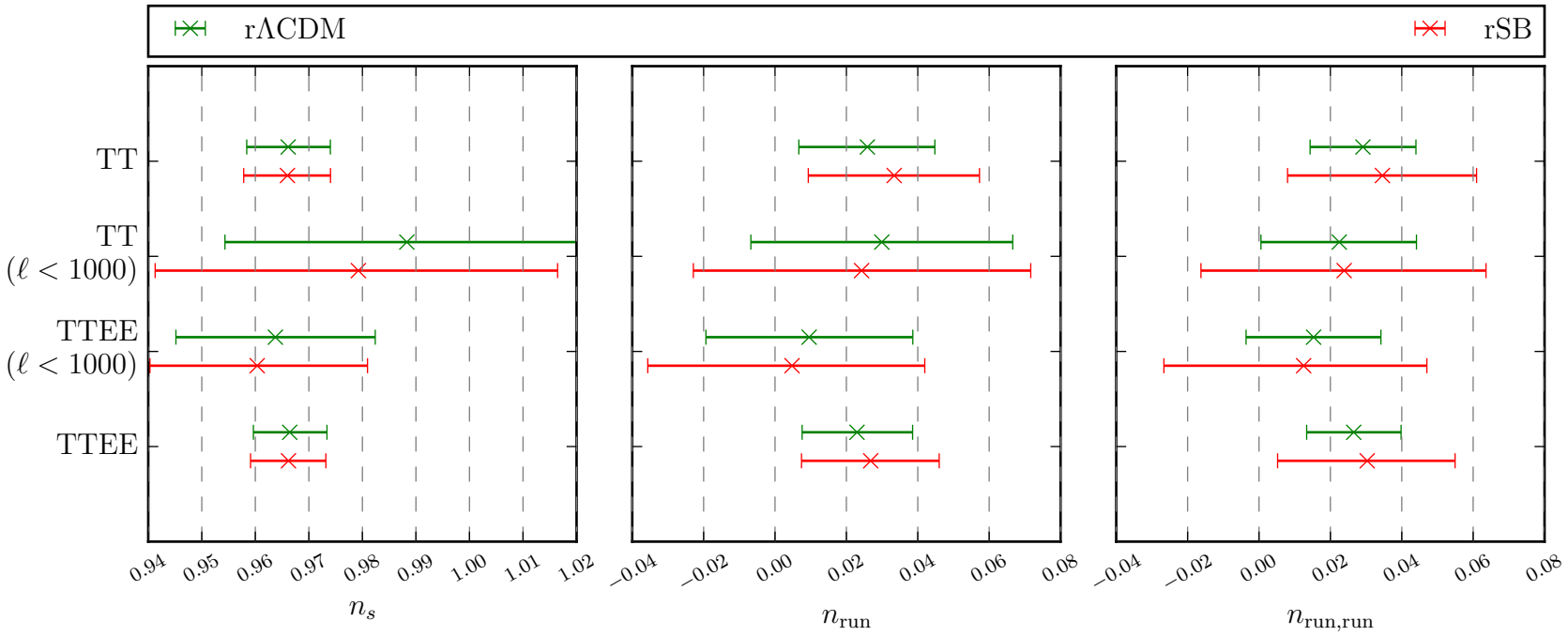
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

Amplitude of structure



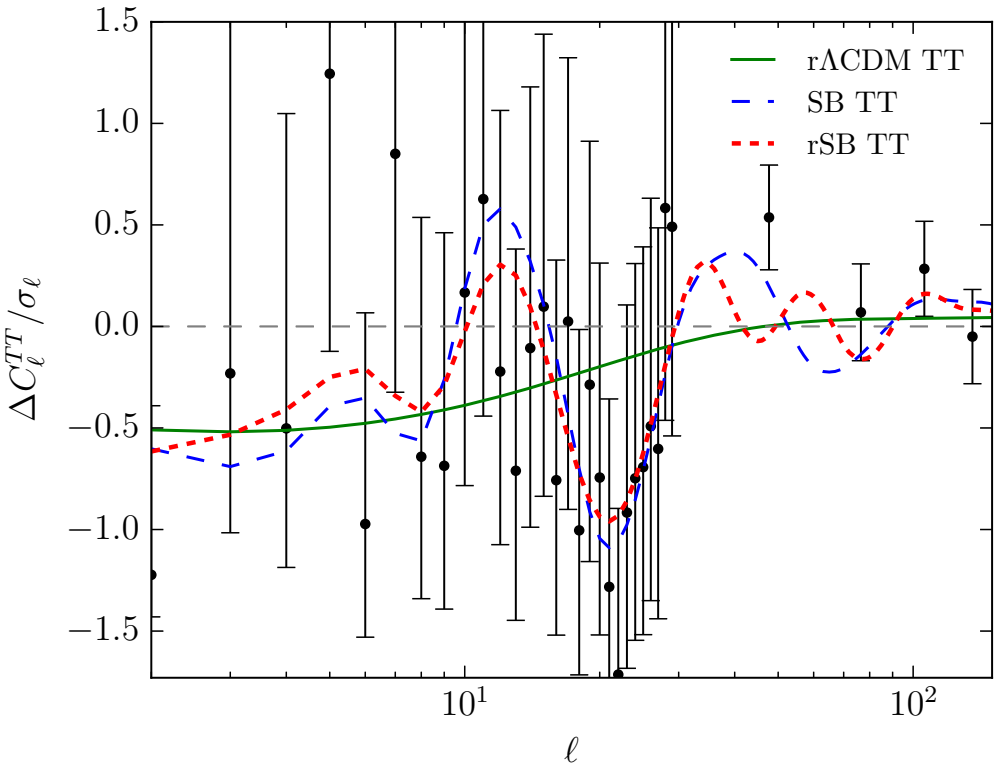
G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

Constraints on inflationary parameters



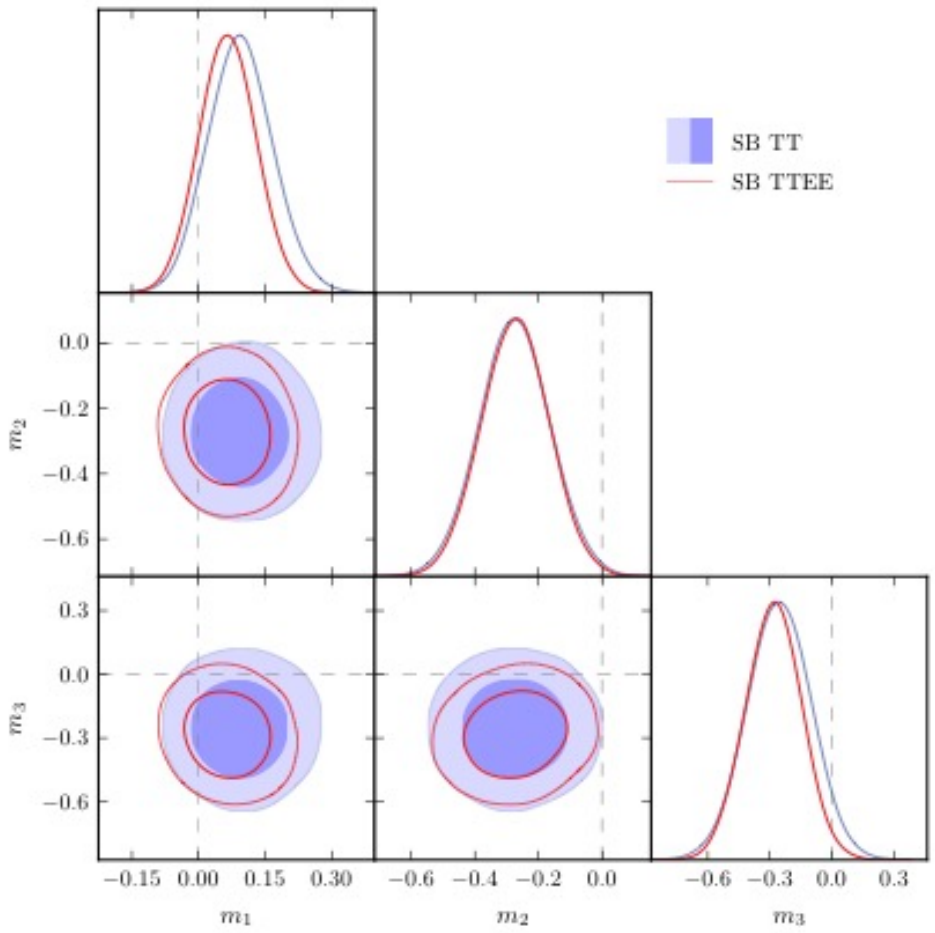
- $n_{run,run}$ shows a 1.9σ preference for violation of slow-roll in the rΛCDM model.

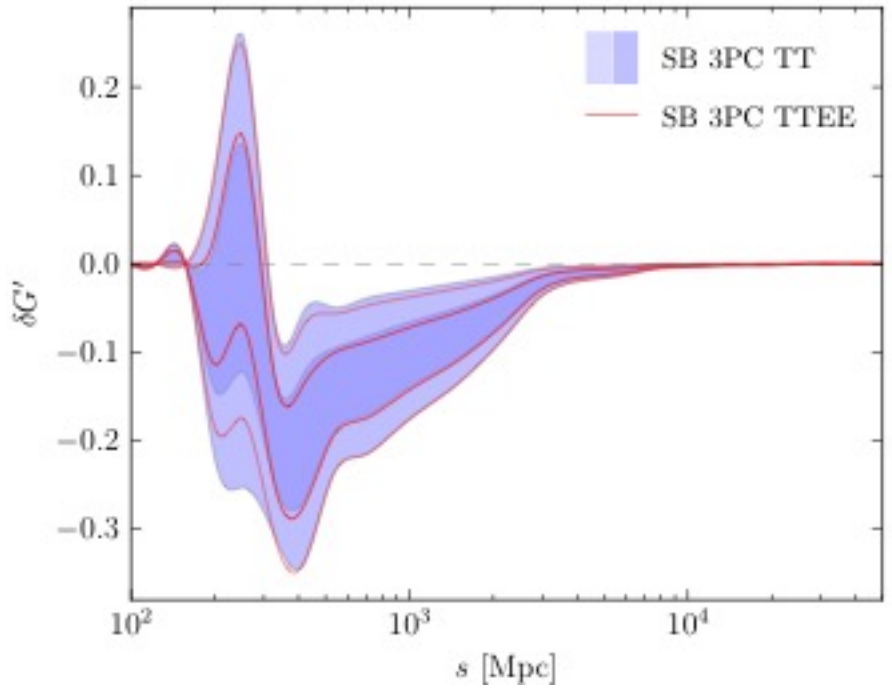
Low-l TT residuals



G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

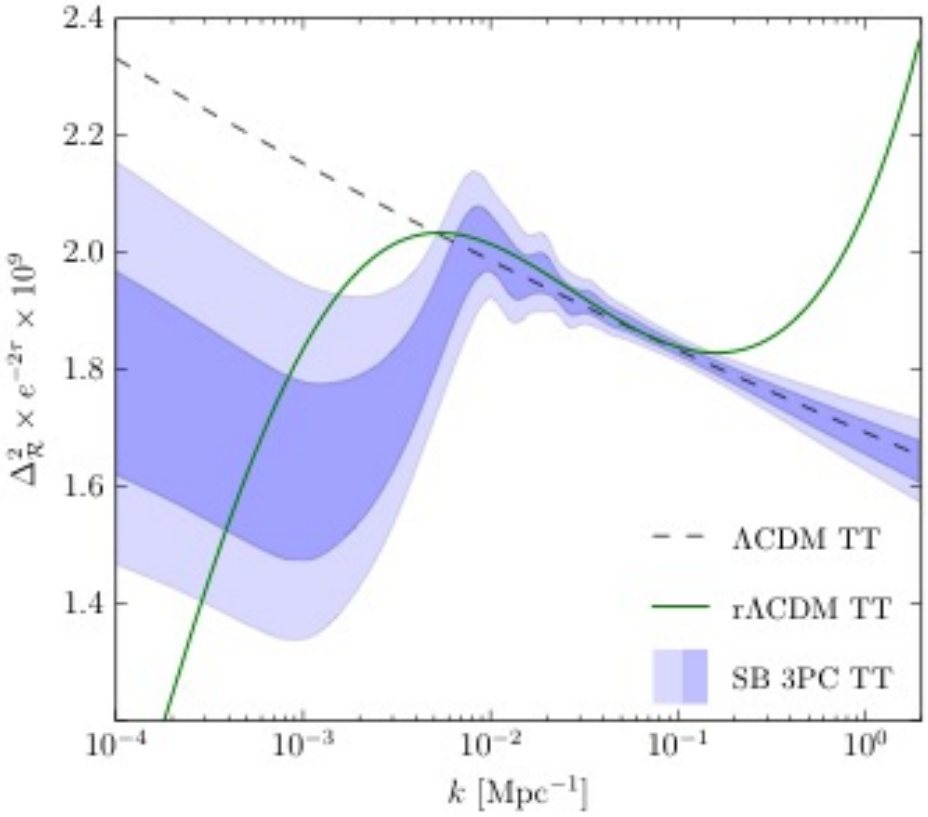
Functional reconstruction of Generalized tilt





G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

Functional reconstruction of Inflationary Power spectrum



G. Obied, C. Dvorkin, C. Heinrich, W. Hu, and V. Miranda, arXiv:1706.09412 (2017)

Conclusions

- We explored the relationship between features in the Planck 2015 data, features from inflation, and shifts in the cosmological parameters.
- Preference for high H_0 and low $\sigma_8\Omega_m^{1/2}$ values in ΛCDM from the TT data at ℓ<1000 is driven by low ℓ<40 residuals in the data.
- However, ΛCDM TT, ℓ <1000 does not match the residuals particularly well. Fitting for inflationary features, the low H_0 values favored by the full TT data are compatible with TT, ℓ <1000 data.
- The SB parameters show 2 PCs that deviate from zero at > 95% CL. These deviations prefer a sharp suppression in power at k=0.004 Mpc^{-1}.
- The combination of low-ℓ and high-ℓ anomalies makes running of the running preferred at the 1.9 sigma level in the TT data. Once the sharp feature is marginalized over with SB parameters, this significance drops to 1.3 sigma. With lensing reconstruction, preference for fitting oscillatory residuals disappears.
- Planck TE data prefers low H_0 values (due to an outlier at the l=165 bin, region particularly sensitive to changes in $\Omega_c h^2$).
- HFI data should provide insight into low-ℓ TT residuals. Features from reionization will have to be disentangled from features from inflation.