The Planck view of $Λ$CDM

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That's Fake News!!!

ΛCDM?

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The Assertions:

- There are no internal inconsistencies in the Planck data
- Planck polarization tells the same story as Planck temperature
- Temperature and polarization restricted to \( l < 800 \) gives same \( \Lambda \)CDM parameters as full Planck.
- If your experiment (CMB, LSS, \( H_0 \) .......) disagrees with Planck, then either you are wrong, or there is new physics beyond \( \Lambda \)CDM.
PLANCK FREQUENCY MAPS
Planck TT spectrum

2013
Planck TT spectrum

$\Delta P_l [\mu K^2]$

$P_l = \ell (\ell+1) C_\ell / 2\pi$ [\mu K^2]

Multipole $\ell$
Slow roll parameters

\[ \epsilon = \frac{m_{\text{pl}}^2}{16\pi} \left( \frac{V'}{V} \right)^2, \quad \eta = \frac{m_{\text{pl}}^2}{8\pi} \left( \frac{V''}{V} \right) \]

\[ n_s = 1 - 6\epsilon + 2\eta, \quad r = 16\epsilon, \quad n_t = -2\epsilon/N \]

If \( V(\phi) = \lambda \phi^\alpha \) then

\[ 1 - n_s = (\alpha + 2)/N, \quad r = 4\alpha/N, \]

For \( n_s = 0.965, \; N \approx 60, \; \alpha \approx 2.2, \; r \approx 0.15. \)

so we have a hierarchy, \( \epsilon \ll \eta. \)
Planck TT+BAO+JLA

phantom at $z=0$

phantom in past

Standard dark energy!

$w(a) = w_0 + w_a(1-a)$
‘Odd’ aspects of Planck spectra?

- Planck temperature spectra want more lensing ($A_L > 1$).
- Planck data favour closed universes.
- High multipoles ($l > 800$) give different parameters to lower multipoles (e.g. Addison et al. 2016, ApJ, 818, 132).
- Outliers in TT spectrum and in TE spectrum (e.g. $l > 165$ in TE, Obied et al. 2017, PRD, 083526).

based on work done with Steven Gratton
Planck TT spectrum
12.5HMcI

$D_l \, [\mu K^2]$ vs. $l$

$\Delta D_l \, [\mu K^2]$ vs. $l$
Lensing amplitude
best fit $A_l = 1.08$
Curvature
The graph shows the angular power spectrum for TE 12.5HM, represented by the red line. The y-axis is labeled as $\mathcal{D}^T_E$ [\(\mu K^2\)] and $\Delta \mathcal{D}^T_E$ [\(\mu K^2\)], while the x-axis represents $l$, ranging from 100 to 400. The data points are indicated by blue squares with error bars.
\[ S_8 = \sigma_8 \left( \Omega_m / 0.3 \right)^{0.5} \]
The Conclusions:

- $\Lambda$CDM fits the Planck data perfectly within acceptable statistical errors.
- If your experiment (CMB, LSS, $H_0$ ........) disagrees with Planck, then either you are wrong, or there is new physics beyond $\Lambda$CDM.
- Any new physics must produce temperature and polarization spectra that are degenerate with base $\Lambda$CDM over the multipole range $2 \leq l \leq 2500$. Any such evidence is strongly dependent on the fidelity of other data.
Non-Gaussianity

\[
\begin{align*}
    f_{\text{local}}^{NL} &= -0.9 \pm 5 \\
    f_{\text{equil}}^{NL} &= -26 \pm 47 \\
    f_{\text{orth}}^{NL} &= -34 \pm 24
\end{align*}
\]
$H^2(z) = H^2_f \left[ A(1+z)^3 + B + Cz + D(1+z)\varepsilon \right]$