Planck constraints on Deuterium and comparison with direct observations

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Abstract. The baryon abundance is now strongly constrained by the Planck temperature and polarization datasets. Assuming standard Big Bang Nucleosynthesis, it is possible to derive primordial abundances of light elements.
Focusing in particular on D, we compare the primordial abundance inferred with the PArthENoPE code for the Planck model with the observations. We consider different contributions to the uncertainty including extensions to the LCDM model and the d(p,y)^{3}He reaction rate. Results are preliminary.

PArthENoPE code [1]: primordial abundances as a function of baryon abundance $\Omega_b h^2$ and relativistic degrees of freedom $N_{\rm eff}$. Comparison between D abundance evaluated from Planck and direct measurements in metal poor damped Lyman alpha system (DLA) [2].

Analysis method: Monte Carlo Markov Chain package *cosmomc,* using Planck data:
TT,TE,EE = spectrum based temperature-polarization likelihood (including cross correlation) from *l*=30 up to *l*=2500.
TT = spectrum based temperature likelihood from *l*=30 up to *l*=2500.
lowP = temperature-polarization likelihood at low multipoles from *l*=2 up to *l*=29.

We have to consider also the uncertainty coming from the PArthENoPE code. On the plots we report the total error, obtained summing in quadrature error from PArthENoPE with the experimental one.

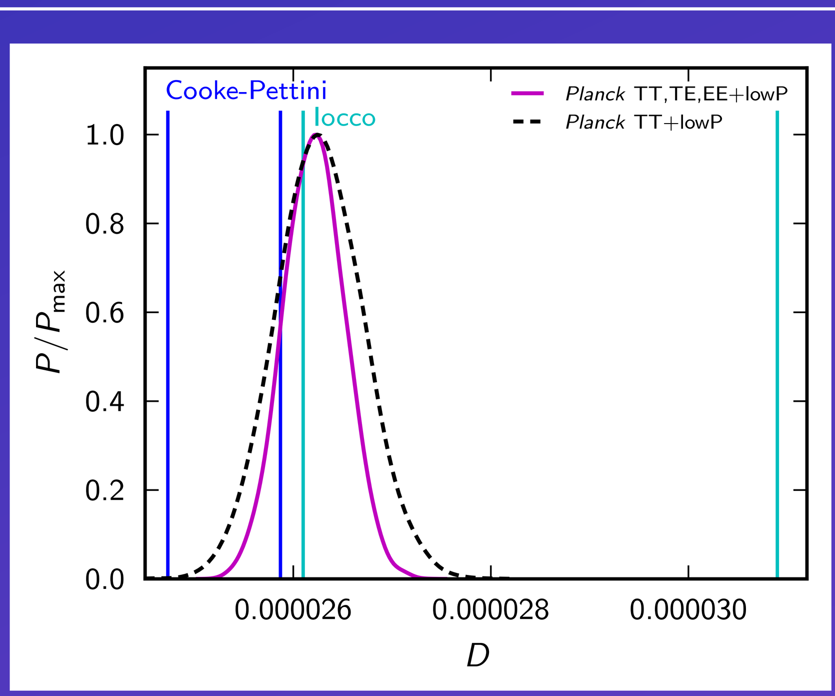


Fig.1 Posterior distributions for Deuterium, LCDM model.

$\sigma_{\rm PC} = 0.04 \quad \sigma_{\rm PAr} = 0.04$

$\Omega_b h^2$	$(0.2225 \pm 0.0016) \cdot 10^{-1}$	$N_{\rm eff}$	3.046

Dataset	Planck TT,TE,EE	Planck TT	Cooke&Pettini	Iocco
D	$2.621^{+0.031}_{-0.030} \cdot 10^{-5}$	$(2.627 \pm 0.043) \cdot 10^{-5}$	$(2.53 \pm 0.057) \cdot 10^{-5}$	$(2.87^{+0.22}_{-0.21}) \cdot 10^{-5}$

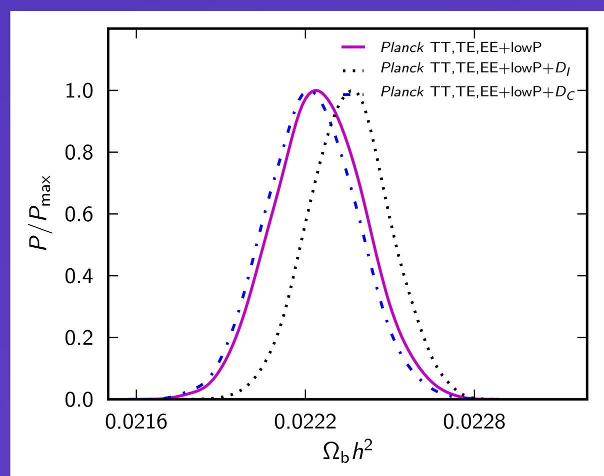


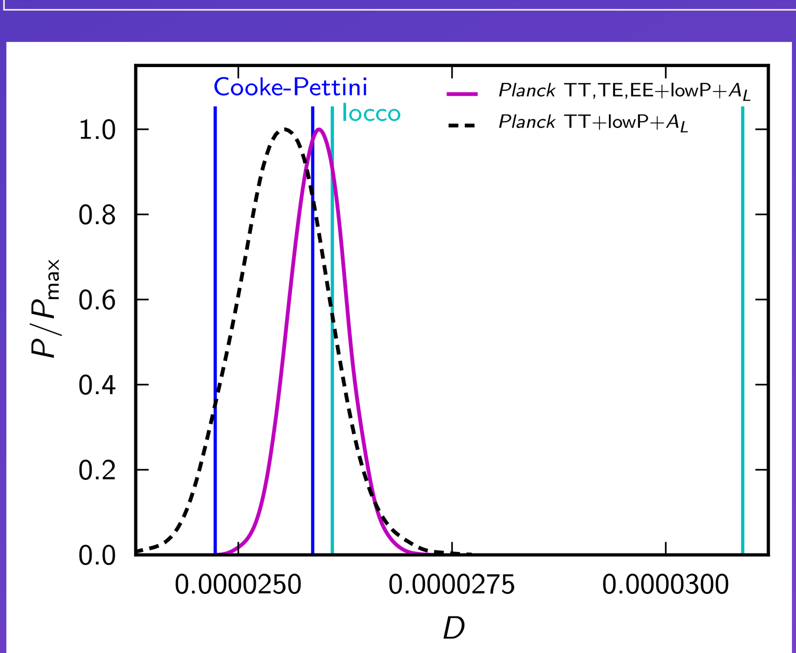
Fig.2 Posterior distributions for baryon abundance.

We consider initially two different experimental measures, [2] and [3] for the abundance of D. Adding the experimental priors on *TT,TE,EE* we see that for $\Omega_b h^2$ there is a very good agreement with data from [3] and a moderate shift for data from [2]. To understand this shift, we will concentrate on these results. For *TT* we have the same behavior.

Constraints in extended models

1. Extensions to LCDM model

To see how model-dependent our inferences are, we consider two different models adding alternatively to LCDM the amplitude of lensing power (A_L) [4] or the curvature parameter (Ω_k) as free parameters.
Then we add a prior with the experimental value of D from [2], considering also the error due to the PArthENoPE code, to see how the parameters would shift. Adopting the prior from [3] results from Planck remain unchanged.



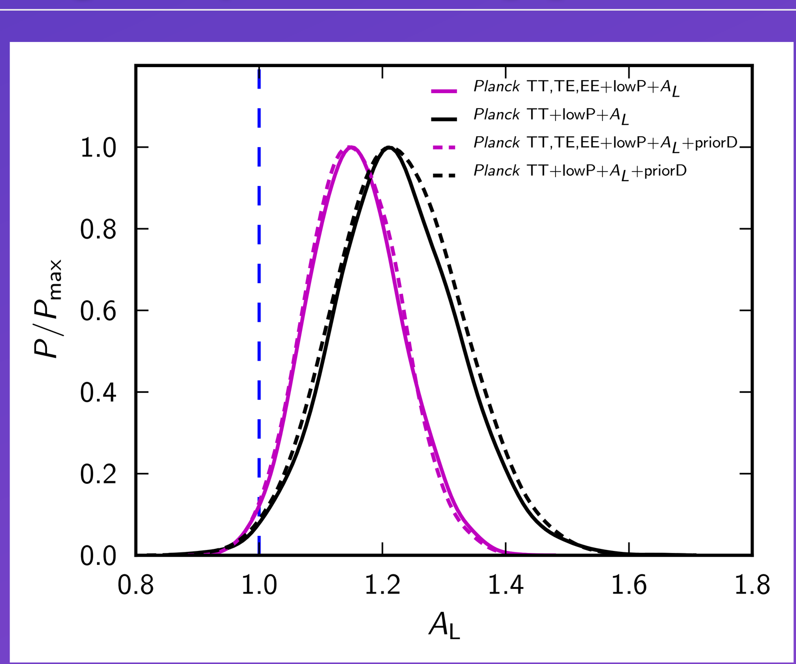
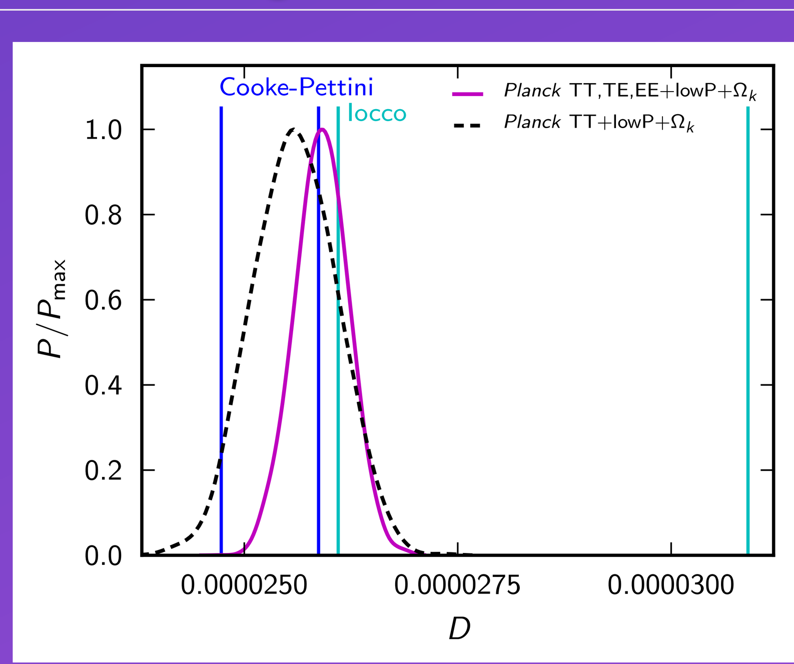


Fig.3-4 Posterior distributions for Deuterium and lensing amplitude. PriorD is from [2]

Model	ΛCDM+A_L (TT,TE,EE)	ΛCDM+A_L (TT)
D	$(2.594^{+0.031}_{-0.032}) \cdot 10^{-5}$	$(2.552^{+0.051}_{-0.052}) \cdot 10^{-5}$

Dataset	Planck TT,TE,EE	Planck TT	Planck TT,TE,EE+Dprior	Planck TT+Dprior
A_L	$1.156^{+0.072}_{-0.083}$	1.22 ± 0.10	$1.150^{+0.073}_{-0.074}$	$1.23^{+0.08}_{-0.11}$



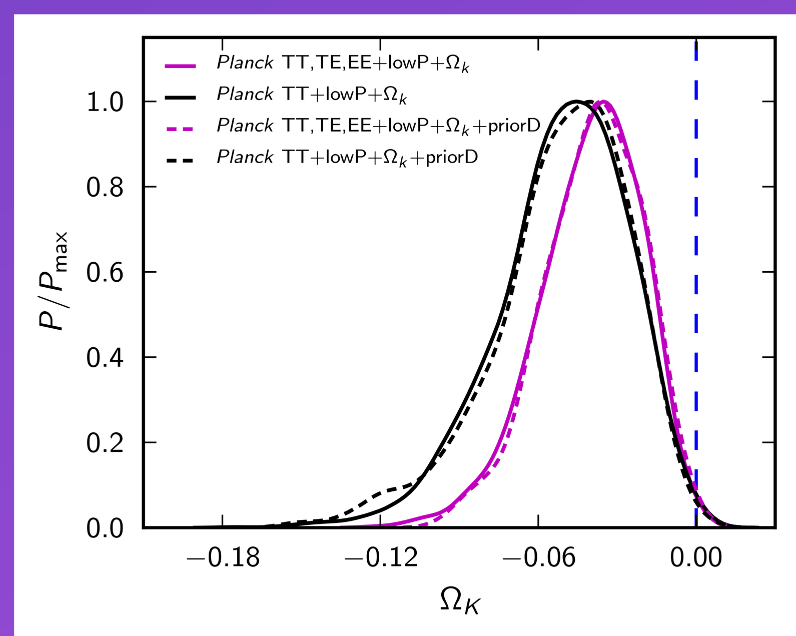


Fig.5-6 Posterior distributions for Deuterium and curvature parameter. PriorD is from [2]

Model	ΛCDM+Ω_k (TT,TE,EE)	ΛCDM+Ω_k (TT)
D	$(2.591 \pm 0.031) \cdot 10^{-5}$	$(2.559^{+0.049}_{-0.050}) \cdot 10^{-5}$

Dataset	Planck TT,TE,EE	Planck TT	Planck TT,TE,EE+Dprior	PLanck TT+Dprior
Ω_k	$-0.040^{+0.024}_{-0.015}$	$-0.051^{+0.030}_{-0.019}$	$-0.039^{+0.023}_{-0.016}$	$-0.051^{+0.030}_{-0.017}$

Allowing for spatial curvature or the amplitude of lensing to be free, we obtain agreement with D experimental value using *TT* or *TT,TE,EE*.
From Planck power spectra we see an increase of the amplitude of lensing signal that drives also Ω_k to negative values and this trend remanis the same also adding the experimental prior.

2. Parameterization of d(p,y)^{3}He cross section

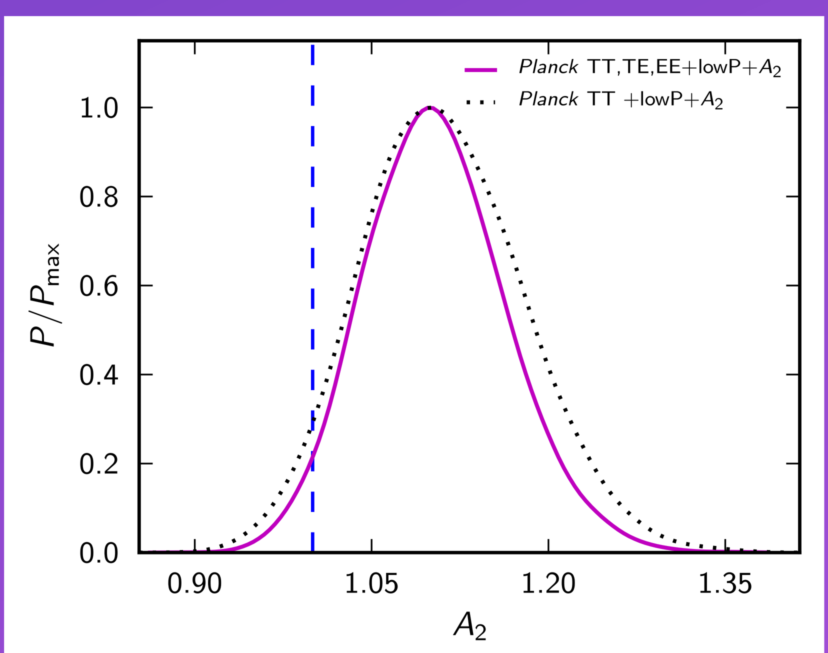


Fig.7 Posterior distributions for A_2.

$$A_2 = \frac{R^{\rm th}}{R^{\rm exp}}; \quad R = \text{rate}$$

Dataset	Planck TT,TE,EE+$D_{\rm prior}$	Planck TT+$D_{\rm prior}$
A_2	$1.104^{+0.054}_{-0.065}$	$1.110^{+0.064}_{-0.074}$

The main uncertainty on D is due to the knowledge of the reaction rate of d(p,y)^{3}He. Infact the theoretical expectation differs significantly from the experimental value.
To account for this, we parametrize this rate with the scaling factor A_2 as defined in [5], such that if A_2=1 the rate coincides with the one from current experimental data.

Adding a prior on D from [2] we get constraints on A_2, obtaining informations also on the rate of the reaction d(p,y)^{3}He.

References: [1] O. Pisanti et al, Comput. Phys. Commun., 178, 956 (2008), [arXiv:0705.0290 [astro-ph]]. [2] R. Cooke, M. Pettini, R. A. Jorgenson, M. T.Murphy and C. C. Steidel, arXiv:1308.3240 [astro-ph.CO]. [3] Iocco, F., Mangano, G., Miele, G., Pisanti, O., & Serpico, P. D. 2009, Phys.Rept., arXiv:0809.0631. [4] Calabrese, E., Slosar, A., Melchiorri, A., Smoot, G. F., & Zahn, O. 2008, Phys. Rev. D, 77, 123531. [5] E. Di Valentino et al, arXiv:1404.7848, Phys.Rev. D90 (2014) 023543.

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