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Cornering the *Planck* A_{lens} tension with future CMB data

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The precise measurements of cosmic microwave background (CMB) anisotropy angular power spectra made by the Planck satellite show an anomalous value for the lensing amplitude, defined by the parameter A_{lens}, at about 2 standard deviations (2.6 standard deviations when cosmic shear data are included). Moreover, considering A_{lens} brings the values of the cosmological parameters determined by Planck in better agreement with those found by pre-Planck data sets. In this paper, after discussing the current status of the anomaly, we quantify the potential of future CMB measurements in confirming/falsifying the A_{lens} tension. We find that a space-based experiment such as LiteBIRD could falsify the current A_{lens} tension at the level of 5 standard deviations. Similar constraints can be achieved by a stage-III experiment assuming an external prior on the reionization optical depth of $\tau = 0.055 \pm 0.010$ as already provided by the Planck satellite. A stage-IV experiment could further test the A_{lens} tension at the level of 10 standard deviations. A comparison between temperature and polarization measurements made at different frequencies could further identify possible systematics responsible for $A_{\mathrm{lens}} > 1$. We show that, in the case of the CMB-S4 experiment, polarization data alone have the potential of falsifying the current A_{lens} anomaly at more than 5 standard deviations and to strongly bound its frequency dependence. We also evaluate the future constraints on a possible scale dependence for A_{lens}.

I. INTRODUCTION

The precise measurements of cosmic microwave background (CMB) anisotropies made by the Planck satellite [1] have provided a wonderful confirmation of the standard cosmological model of structure formation based on inflation, dark matter and a cosmological constant. The predictions of acoustic oscillations in the CMB anisotropy angular power spectra have been fully confirmed with unprecedented accuracy.

Nonetheless a few interesting tensions are emerging hinting to systematics and/or possible extensions to the standard scenario (see e.g., [2–5]).

The most relevant anomaly, at least from the statistical point of view, concerns the amount of lensing in the CMB angular power spectra. Gravitational lensing slightly redistributes the photon paths from the last scattering surface, smoothing the acoustic oscillations in the CMB anisotropy and polarization power spectra (see [6]).

The amount of smearing due to CMB lensing, once the cosmological parameters are fixed, can be computed with great accuracy (see e.g., [7]) and the effect is included in all

current parameter analyses. In [8] a phenomenological parameter, A_{lens}, was introduced that essentially rescales the lensing amplitude in the CMB spectra. This parameter has, in principle, no physical meaning and is mainly used as an effective parameter for testing theoretical assumptions and systematics. However, the value of this parameter from the latest Planck analysis of [9] is $A_{\mathrm{lens}} = 1.15^{+0.13}_{-0.12}$ at 95% C.L., i.e., about 2.3σ larger than the expected value with a significant impact on parameter extraction.

Indeed, the inclusion of A_{lens} in the analysis shifts the constraints derived from Planck data on several cosmological parameters. Interestingly, some tension exists between the cosmological parameters derived from a combination of pre-Planck data sets and those obtained by the Planck satellite (see Table I in [10] and discussion in [3,4]). As noted in [3,4] and as we report in Appendix I of this paper, the inclusion of A_{lens} significantly reduces this tension.

Moreover, lensing in the CMB spectra is crucial in constraining neutrino masses. A larger value for A_{lens}, if not accounted for, could produce biased bounds on neutrino masses, stronger than those that realistically could be reached with the Planck specifications and experimental noise. Indeed, from simulated Planck angular spectra (assuming a neutrino mass of $\Sigma m_\nu \leq 0.06$ eV), one would expect a limit on the sum of neutrino masses of $\Sigma m_\nu \leq 0.59$ eV at 95% C.L., while the current limit from real

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Planck data is much stronger, at the level of $\Sigma m_\nu \leq 0.34$ eV at 95% C.L. (see [9]). These stronger than expected neutrino mass bounds from Planck are connected to the 2.3σ $A_{\rm lens}$ tension and should be treated with great care.

Finally, $A_{\rm lens}$ anticorrelates with the amplitude of r.m.s. matter density fluctuations on $8h^{-1}$ Mpc scales, the so-called σ_8 parameter. Allowing $A_{\rm lens}$ to vary brings indeed the constraints on the $S_8 = \sigma_8(\Omega_m/0.3)^{0.5}$ parameter from $S_8 = 0.852 \pm 0.018$ at 68% C.L. to $S_8 = 0.808 \pm 0.034$, in better agreement with the constraints derived from cosmic shear data from the KiDS-450 [11] and DES [12,13] surveys.

While $A_{\rm lens}$ seems to solve several current tensions, there are at least two puzzling aspects of the $A_{\rm lens}$ anomaly that should suggest some caution. First of all, there is no easy theoretical way to accommodate a value of $A_{\rm lens}$ *larger* than expected, even in an extended parameter space (see e.g., [14–16]). Proposals that can give a theoretical explanation to the $A_{\rm lens}$ anomaly include, for example, modified gravity [17], the running of the spectral index [18], closed universes [19], and compensated baryon isocurvature perturbations [20,21]. These explanations are certainly all rather exotic and hint at a significant change in the standard scenario. The second point is that an anomalous $A_{\rm lens}$ value, if related to lensing, must show up also in the CMB lensing measurements based on the trispectrum analysis of the Planck temperature and polarization maps. However Planck CMB lensing is in perfect agreement with the standard expectations. Combining the Planck angular power spectra with the CMB lensing yields $A_{\rm lens} = 1.025^{+0.051}_{-0.058}$ [1], in agreement with the standard value even if at the price of a higher χ^2 value due to the relative inconsistency between the two data sets. This fact in practice, even if based on the assumption of ΛCDM, disfavors the hypothesis of $A_{\rm lens} > 1$ due to gravitational lensing.

These two aspects could suggest that the $A_{\rm lens}$ anomaly is related to some systematics in the data. However, the anomaly survived the scrutiny of two Planck data releases and hints at its presence have already been reported, albeit at small statistical level, in pre-Planck data (see e.g., [22]).

It is therefore timely to investigate the potential of future CMB experiments to confirm and/or rule out the $A_{\rm lens}$ anomaly. Several ground and space-based experiments are indeed proposed or expected in the next years that will sample the small scale region of the CMB angular spectrum. At the same time it is important to scrutinize the ability of these experiments to detect a possible scale dependence of the effect.

This is indeed the goal of the present paper. While this kind of analysis is straightforward, none of the several recent papers that forecasted the ability of future experiments in constraining cosmological parameters (see e.g., [23–25]), as far as we know, considered the $A_{\rm lens}$ parameter.

In the next section we briefly discuss the current status of the $A_{\rm lens}$ tension. In Sec. III we describe the data analysis method adopted for our forecasts. In Sec. IV we show the obtained results and in Sec. V we present our conclusions.

II. CURRENT STATUS OF THE $A_{\rm lens}$ ANOMALY

In this section we discuss the current status of the $A_{\rm lens}$ anomaly and its impact on current cosmological parameter estimation. In Table I we compare the constraints presented in [10] with those derived from Planck 2015 temperature and polarization data assuming ΛCDM (third column) and a variation in $A_{\rm lens}$ (see fourth column of the table). We also show the effects of including cosmic shear data from CFHTLenS (named WL) as in [1] (fifth column). In the square brackets, on the right side of the constraint, we also report the shift S between the cosmological constraints from Planck and pre-Planck measurements defined as

TABLE I. Constraints at 68% C.L. on cosmological parameters from pre-Planck data sets (second column, see [10]), Planck TTTEEE in the case of ΛCDM (third column), and Planck TTTEEE and Planck TTTEEE + WL varying $A_{\rm lens}$ (fourth and fifth column, respectively). In the square brackets we report the shift S, defined via Eq. (1), that quantifies the discrepancy in the constraint on the parameter Π between pre-Planck and Planck measurements. As we can see, when $A_{\rm lens}$ is included, the tensions on the value of the Hubble constant, the matter and cosmological constant densities and the value of σ_8 are significantly reduced, especially when including cosmic shear data (WL).

Parameter	WMAP9 + ACT + SPT	Planck TTTEEE	Planck TTTEEE ($A_{\rm lens}$)	Planck TTTEEE + WL ($A_{\rm lens}$)
$100\Omega_b h^2$	2.242 ± 0.032	2.222 ± 0.015 [0.56]	2.239 ± 0.017 [0.08]	2.245 ± 0.017 [0.08]
$100\Omega_c h^2$	11.34 ± 0.36	12.03 ± 0.14 [1.79]	11.87 ± 0.16 [1.34]	11.78 ± 0.15 [1.13]
$10^4\theta_{MC}$	104.24 ± 0.10	104.069 ± 0.032 [1.63]	104.09 ± 0.033 [1.42]	104.10 ± 0.033 [1.32]
n_s	0.9638 ± 0.0087	0.9626 ± 0.0044 [0.12]	0.9675 ± 0.0049 [0.37]	0.9697 ± 0.0047 [0.59]
Ω_Λ	0.723 ± 0.019	0.6812 ± 0.0086 [2.00]	0.6920 ± 0.0096 [1.46]	0.6974 ± 0.0089 [1.22]
Ω_m	0.277 ± 0.019	0.3188 ± 0.0086 [2.00]	0.3080 ± 0.0096 [1.46]	0.3026 ± 0.0089 [1.22]
σ_8	0.780 ± 0.017	0.8212 ± 0.0086 [2.16]	0.806 ± 0.017 [1.08]	0.797 ± 0.016 [0.73]
t_0 [Gyrs]	13.787 ± 0.057	13.822 ± 0.025 [0.56]	13.790 ± 0.029 [0.05]	13.777 ± 0.028 [−0.20]
H_0 [km/s/Mpc]	70.3 ± 1.6	67.03 ± 0.61 [1.91]	67.84 ± 0.72 [1.4]	68.25 ± 0.69 [1.18]
$A_{\rm lens}$	1	1	1.154 ± 0.076	1.194 ± 0.076

$$S = \frac{|\Pi_{\text{pre-Planck}} - \Pi_{\text{Planck}}|}{\sqrt{\sigma_{\text{pre-Planck}}^2 + \sigma_{\text{Planck}}^2}}, \tag{1}$$

where Π and σ are the parameter mean value and uncertainty reported for the pre-Planck and Planck data sets. As we can see, the most relevant (at about $\sim 2\sigma$) shifts on the values of Ω_m, σ_8 and H_0 are relieved when a variation in A_{lens} is considered, especially when also the WL data set is included. As we can see, we obtain a value for $A_{\text{lens}} > 1$ at about 2 sigma level from Planck TTTEEE and at about 2.6 sigma from Planck TTTEEE + WL. The inclusion of cosmic shear data therefore not only improves the agreement with the WMAP constraints but also the statistical significance for A_{lens}.

III. METHOD

The goal of this paper is to investigate to what extent future CMB experiments will be able to constrain the value of A_{lens} and falsify/confirm the current anomaly. We have therefore simulated CMB anisotropy and polarization angular spectra data with a noise given by

$$N_\ell = w^{-1} \exp(\ell(\ell+1)\theta^2 / 8 \ln 2), \tag{2}$$

where w^{-1} is the experimental power noise expressed in μK-arcmin and θ is the experimental FWHM angular resolution. We have considered several future experiments with technical specifications listed in Table II. In particular, we have considered three possible CMB satellite experiments, CORE [23,26], LiteBIRD [27] and PIXIE [28]. A stage-III experiment in two possible configurations as in [24], i.e., a wide experiment similar to AdvACT and a deep experiment similar to SPT-3G. Finally we consider the possibility of a stage-IV experiment as in [24] (but see also [25,29]).

We have computed the theoretical CMB angular power spectra C_ℓ^{TT}, C_ℓ^{TE}, C_ℓ^{EE}, C_ℓ^{BB} for temperature, cross temperature polarization and E and B modes polarization using the CAMB Boltzmann code [30]. The angular spectra are generated assuming a fiducial flat ΛCDM model with parameters compatible with the recent Planck 2015 constraints [9] as listed in Table III.

TABLE II. Experimental specifications for the several configurations considered in the forecasts.

Experiment	Beam	Power noise w^{-1} [μK-arcmin]	ℓ_{max}	ℓ_{min}	f_{sky}
Pixie	96′	4.2	500	2	0.7
LiteBIRD	30′	4.5	3000	2	0.7
CORE	6′	2.5	3000	2	0.7
CORE-ext	4′	1.5	3000	2	0.7
Stage III (Deep)	1′	4	3000	50	0.06
Stage III (Wide)	1.4′	8	3000	50	0.4
Stage IV	3′	1	3000	5,50	0.4

TABLE III. Cosmological parameters assumed for the fiducial model.

Parameter	Value
$\Omega_b h^2$	0.02225
$\Omega_c h^2$	0.1198
τ	0.055
n_s	0.9645
$100\theta_{MC}$	1.04077
$\ln(10^{10} A_s)$	3.094
A_{lens}	1.00

The theoretical C_ℓ's are then compared with the simulations using the Monte Carlo Markow chain code CosmoMC[1] [32] based on the Metropolis-Hastings algorithm. The convergence of the chains is verified by the Gelman and Rubin method. Given a simulated data set, for each theoretical model we evaluate a likelihood $\mathcal{L}$ given by

$$-2 \ln \mathcal{L} = \sum_l (2l+1) f_{\text{sky}} \left(\frac{D}{|\bar{C}|} + \ln \frac{|\bar{C}|}{|\hat{C}|} - 3 \right), \tag{3}$$

where $\bar{C}_l$ are the fiducial spectra plus noise (i.e., our simulated data set) while $\hat{C}_l$ are the theory spectra plus noise. $|\bar{C}|$, $|\hat{C}|$ are given by

$$|\bar{C}| = \bar{C}_\ell^{TT} \bar{C}_\ell^{EE} \bar{C}_\ell^{BB} - (\bar{C}_\ell^{TE})^2 \bar{C}_\ell^{BB}, \tag{4}$$

$$|\hat{C}| = \hat{C}_\ell^{TT} \hat{C}_\ell^{EE} \hat{C}_\ell^{BB} - (\hat{C}_\ell^{TE})^2 \hat{C}_\ell^{BB}, \tag{5}$$

with D defined as

$$D = \hat{C}_\ell^{TT} \bar{C}_\ell^{EE} \bar{C}_\ell^{BB} + \bar{C}_\ell^{TT} \hat{C}_\ell^{EE} \bar{C}_\ell^{BB} + \bar{C}_\ell^{TT} \bar{C}_\ell^{EE} \hat{C}_\ell^{BB} - \bar{C}_\ell^{TE}(\bar{C}_\ell^{TE} \hat{C}_\ell^{BB} + 2\hat{C}_\ell^{TE} \bar{C}_\ell^{BB}). \tag{6}$$

In what follows we also test the possibility of an angular dependence for A_{lens}. Such scale dependence could arise from beyond standard model physics such as modified gravity, cold dark energy, or massive neutrinos. We therefore consider the following parametrization (see [33]),

$$A_{\text{lens}}(\ell) = A_{\text{lens},0}(1 + B_{\text{lens}} * \log(\ell/\ell_*)) \tag{7}$$

considering also the parameters $A_{\text{lens},0}$ and B_{lens} as free parameters and different values of the pivot scale ℓ_*.

IV. RESULTS

A. Future constraints on A_{lens}

The expected constraints on A_{lens} for several future CMB experiments are reported in Table IV. As we can see a

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[1]Reference [31].

TABLE IV. Expected constraints on A_{lens}. The fiducial model assumes $A_{\text{lens}} = 1.000$. For stage-III wide, deep and stage IV with $l_{\min} = 50$ we have further imposed a Gaussian prior on the reionization optical depth corresponding to Planck 2015 results: $\tau = 0.055 \pm 0.010$.

Experiment	A_{lens}
Pixie	$1.016^{+0.09}_{-0.11}$
LiteBIRD	1.001 ± 0.025
CORE	1.001 ± 0.013
CORE-ext	1.002 ± 0.011
Stage III (deep)	$0.92^{+0.13}_{-0.11}$
Stage III (wide)	$0.97^{+0.11}_{-0.07}$
Stage III (deep) + τ-prior	$1.004^{+0.044}_{-0.048}$
Stage III (wide) + τ-prior	$1.001^{+0.026}_{-0.028}$
Stage IV ($l_{\min} = 50$)	0.998 ± 0.025
Stage IV ($l_{\min} = 5$)	0.999 ± 0.015

satellite experiment such as PIXIE, devoted mainly to the measurement of CMB spectral distortions, will not have enough angular resolution to constrain A_{lens}; conversely a satellite such as LiteBIRD, despite the poorer angular resolution with respect to Planck, thanks to the precise measurement of CMB polarization, could reach an accuracy of $\Delta A_{\text{lens}} \sim 0.026$, enough to falsify the current value of $A_{\text{lens}} \sim 0.15$ at more than 5 standard deviations. A more ambitious space-based experiment such as CORE, on the other hand, could test the A_{lens} anomaly at more than 10 standard deviations. Near future ground-based experiments such as stage III will not have enough sensitivity on A_{lens} unless the optical depth can be complementary measured by a different experiment. As we can see, considering an external prior on the optical depth such as $\tau = 0.055 \pm 0.010$ (in agreement with the recent Planck constraint [9]) can improve the stage-III (deep) constraint to a level comparable with LiteBIRD, while stage-III (wide) can also
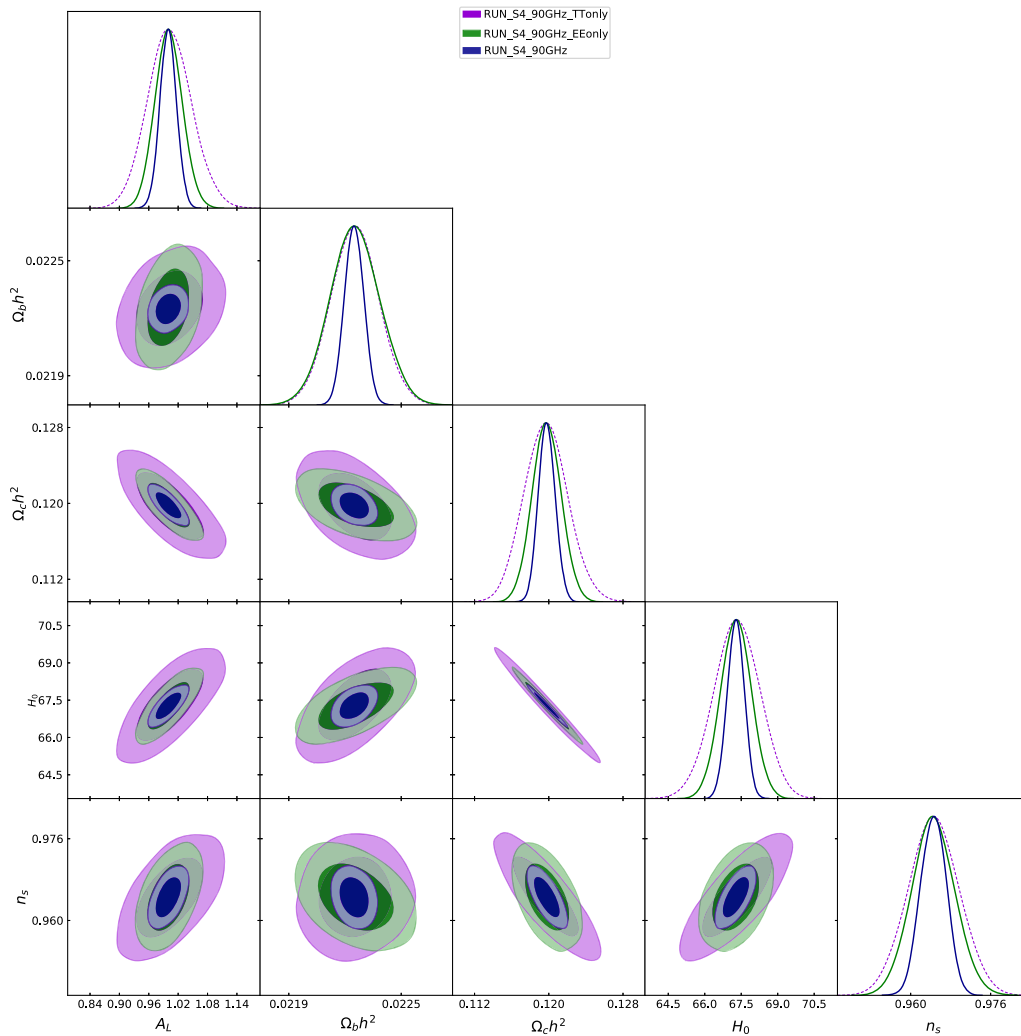

FIG. 1. Forecasted constraints at 68% and 95% C.L. for A_{lens} and other cosmological parameters from a future CMB-S4 mission considering only the frequency channel at 90 GHz.
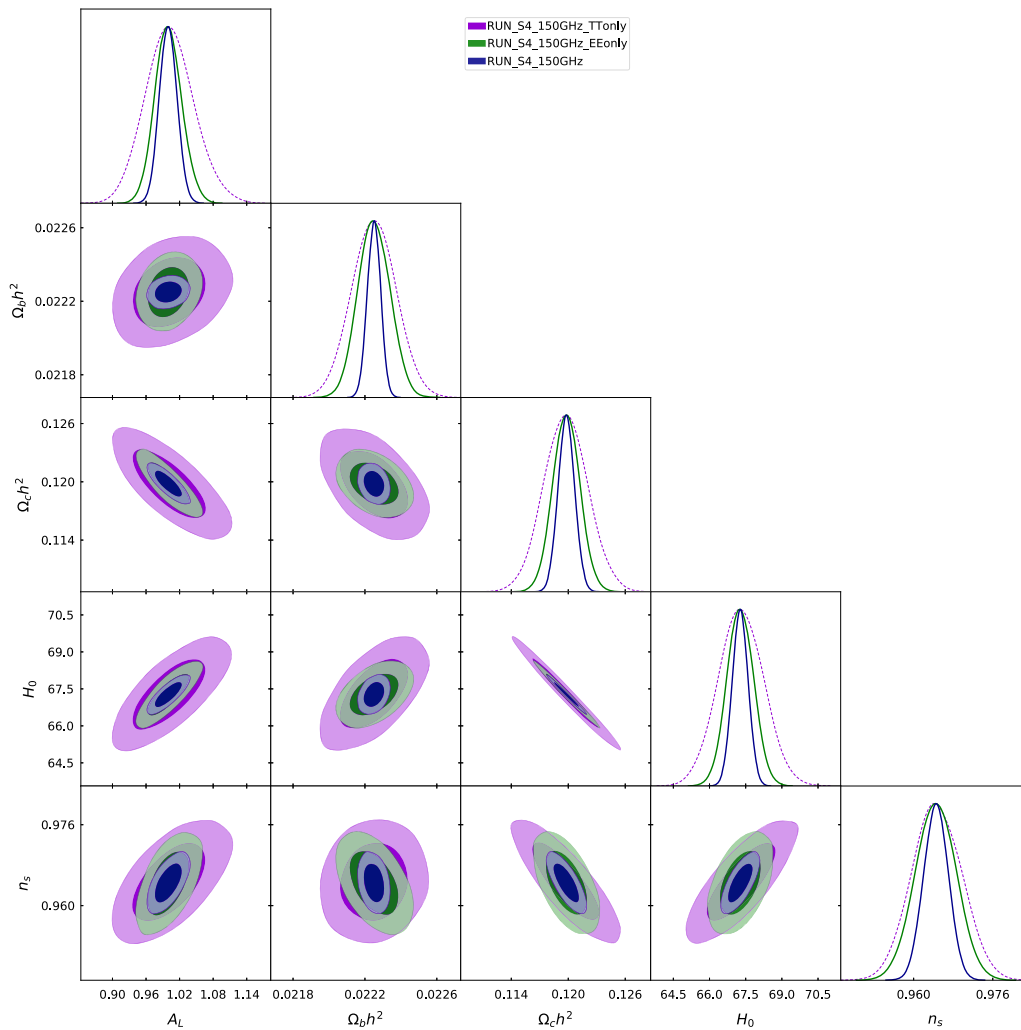
FIG. 2. Forecasted constraints at 68% and 95% C.L. for A_{lens} and other cosmological parameters from a future CMB-S4 mission considering only the frequency channel at 150 GHz.

improve but with an accuracy smaller by about a factor 2. A stage-IV experiment can measure A_{lens} with an accuracy about a factor ~4.5 better than the current Planck constraint, providing a large angular scale sensitivity from $l_{\text{min}} = 5$. In this case, the current indication for $A_{\text{lens}} \sim 1.15$ can be tested by a stage-IV experiment at the level of ~10 standard deviations. In the less optimistic case of a smaller sensitivity from $l_{\text{min}} = 50$, the stage-IV experiment is expected to constrain the A_{lens} parameter with a precision comparable with the one achievable by LiteBIRD.

B. Testing A_{lens} in different spectra and frequency channels

There are two, straightforward, ways for testing if the A_{lens} anomaly is due to a systematic in the data: checking for its presence in the temperature and polarization spectra separately and considering also the frequency dependence. Of course, if the A_{lens} anomaly is not simultaneously present in all the spectra and at all the frequencies this

could better support the hypothesis of a systematic or unresolved foreground. However when analyzing just one C_ℓ spectrum or just one frequency at a time, the experimental noise is clearly larger and it is therefore interesting to investigate what kind of accuracy could be reached in this case.

As an example, we have considered the optimistic CMB-S4 configuration and considered the constraints on A_{lens} achievable when using just the TT and EE channels. We have found the following constraints at 68% C.L.: $A_{\text{lens}} = 1.000 \pm 0.044$ (TT) and $A_{\text{lens}} = 1.000 \pm 0.024$ (from EE). So, in practice, E polarization data alone from CMB-S4 could test the current $A_{\text{lens}} \sim 1.15$ anomaly at the level of 5 standard deviations.

A complete configuration for the CMB-S4 experiment is clearly not yet finalized. In order to study the frequency sensitivity to A_{lens} we have however assumed three channels at 90, 150 and 220 GHz with angular resolutions of 5, 3, and 2 arcminutes and detector sensitivities of 2.2, 1.3 and 2.2 μK arcmin, respectively. We have found from TT
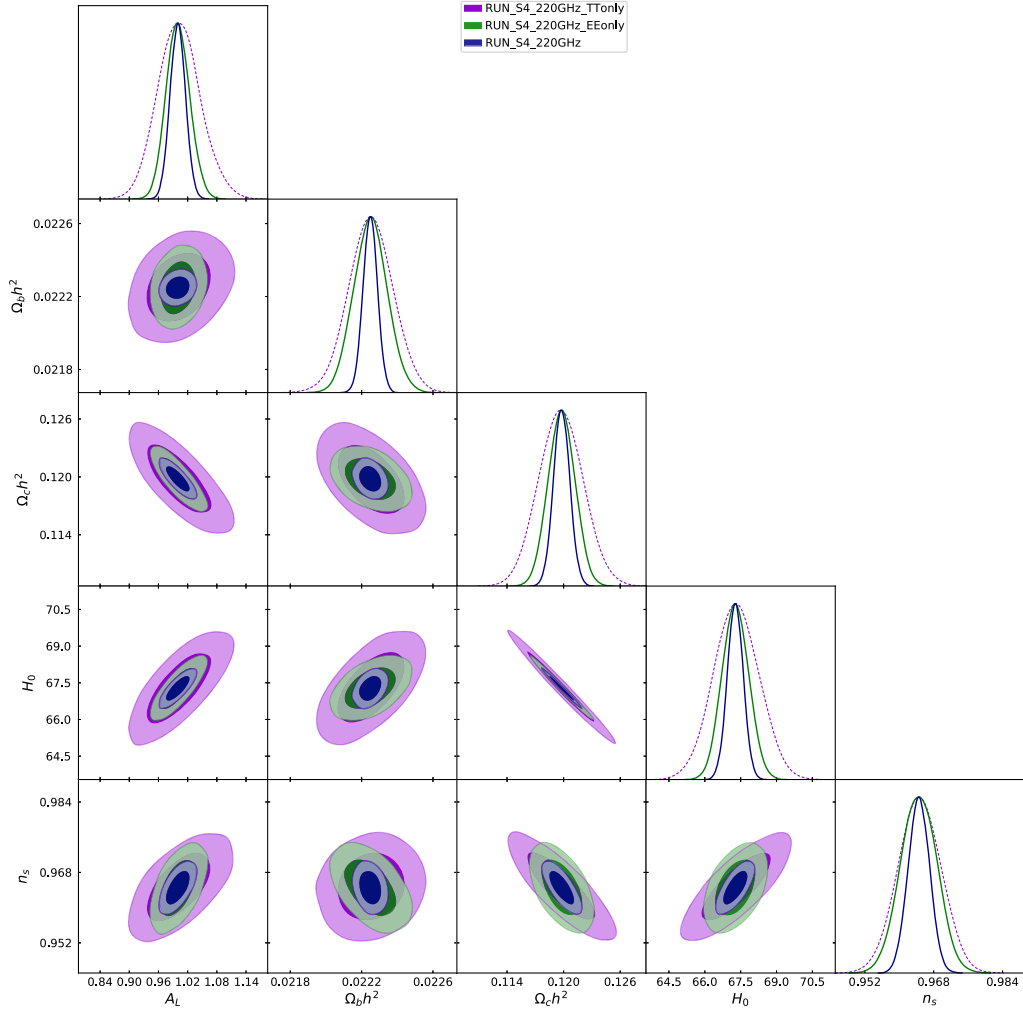
FIG. 3.   Forecasted constraints at 68% and 95% C.L. for A_{lens} and other cosmological parameters from a future CMB-S4 mission considering only the frequency channel at 220 GHz.

data the constraints $A_{\text{lens}} = 1.003^{+0.044}_{-0.045}, A_{\text{lens}} = 1.002^{+0.041}_{-0.045}$, and $A_{\text{lens}} = 1.003^{+0.041}_{-0.046}$ for the 90, 150 and 220 GHz channels, respectively. Using the EE data we have $A_{\text{lens}} = 1.003^{+0.028}_{-0.028}$, $A_{\text{lens}} = 1.002^{+0.023}_{-0.025}$, and $A_{\text{lens}} = 1.003^{+0.023}_{-0.025}$ again for the 90, 150 and 220 GHz channels, respectively.

In Figs. 1–3 we report the two-dimensional forecasted constraints at 68% and 95% C.L. for A_{lens} and other cosmological parameters from a future CMB-S4 mission considering the frequency channels at 90, 150, and 220 GHz.

As we can see from the figures, polarization measurements will be crucial in improving the constraint on A_{lens}. In particular, polarization will somewhat reduce the degeneracy between A_{lens} and the baryon density parameter present in TT data. However, A_{lens} still strongly correlates with parameters as n_S, $\Omega_{cdm}h^2$, and H_0 even when the combined polarization + temperature measurements are considered.

As we can see, therefore, with the assumed experimental configuration, the sensitivity to A_{lens} in each frequency

channel will be essentially the same as the one achievable when all channels are combined. A frequency dependence of the A_{lens} anomaly as a power law $\sim \nu^n$ could be tested with spectral indices of $n \sim 0.09$ at the level of 3 standard deviations.

C. Using B modes to test the A_{lens} anomaly

Future experiments such as stage IV will measure with great accuracy the CMB polarization B mode that arises from lensing. The B mode spectra could therefore be in principle extremely useful for placing independent constraints on A_{lens}. In particular, an indication for an anomaly present in the TT, TE and EE angular spectra but not in the BB lensing spectrum would clearly confirm (once systematics or foregrounds are excluded) that the real physical nature of the anomaly is not connected to lensing but more to systematics or to new and unknowns processes possibly related to recombination or inflation that leave the small scale B mode
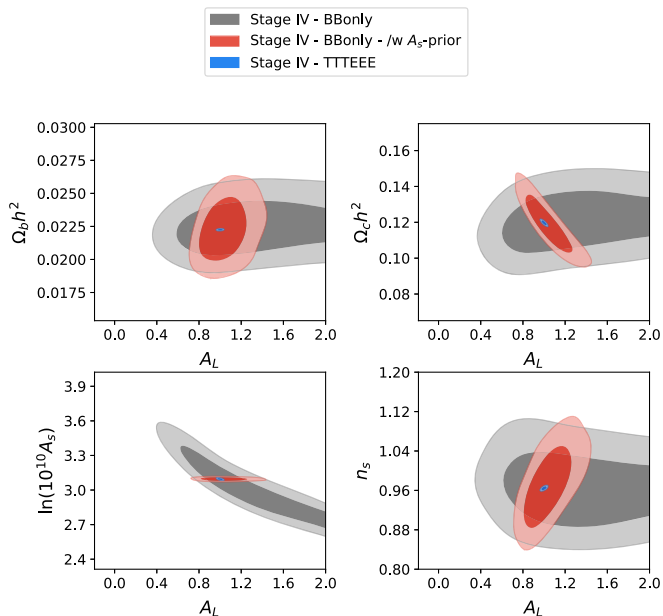
FIG. 4. Future constraints at 68% and 95% C.L. from the stage-IV experiment (with $l_{\min} = 5$) in the A_{lens} vs $\Omega_b h^2$, $\Omega_c h^2$, n_s, and $\ln[10^{10}A_s]$ planes (clockwise from top left panel). The constraints from BB modes only (grey) leave A_{lens} practically unbounded. Including a prior on the primordial amplitude improves the constraints on A_{lens} from B modes only (red) but they are still far weaker than the constraints from TTTEEE (blue).

TABLE V. Expected constraints on A_{lens} and B_{lens} from Planck real data and stage-IV simulated data. The fiducial model for the simulated stage-IV data has $A_{\text{lens}} = 1.00$ and $B_{\text{lens}} = 0.00$. We choose a hard flat prior $-0.4 < B_{\text{lens}} < 0.4$.

Parameter	Planck TTTEEE	Stage IV
$\ell_* = 50$		
$A_{\text{lens},0}$	$1.157^{+0.116}_{-0.144}$	1.000 ± 0.016
B_{lens}	Unconstrained	0.0002 ± 0.0147
$\ell_* = 300$		
$A_{\text{lens},0}$	$1.150^{+0.111}_{-0.139}$	0.999 ± 0.016
B_{lens}	Unconstrained	$0.0002^{+0.0145}_{-0.0144}$
$\ell_* = 900$		
$A_{\text{lens},0}$	$1.220^{+0.181}_{-0.356}$	0.999 ± 0.019
B_{lens}	Unconstrained	-0.0004 ± 0.0144
$\ell_* = 1500$		
$A_{\text{lens},0}$	$1.269^{+0.209}_{-0.462}$	0.999 ± 0.021
B_{lens}	Unconstrained	-0.0005 ± 0.0150
$\ell_* = 2100$		
$A_{\text{lens},0}$	$1.313^{+0.223}_{-0.551}$	$0.999^{+0.022}_{-0.023}$
B_{lens}	Unconstrained	-0.0004 ± 0.0143

signal as unaffected. Unfortunately the polarization B mode signal does not only depend on A_{lens}. Degeneracies are indeed present between cosmological parameters and we have found that even with the stage-IV experiment A_{lens} will be practically unbounded from just the B mode spectra, with a major degeneracy with the amplitude of primordial perturbations A_s.

Including an external Gaussian prior of $\log(10^{10}A_s) = 3.094 \pm 0.005$ for the primordial inflationary density perturbation amplitude and of $\tau = 0.055 \pm 0.010$ for the reionization optical depth, we found that stage IV could reach the constraint $A_{\text{lens}} = 1.04^{+0.13}_{-0.19}$ at 68% C.L. This would only marginally test the current anomaly and other complementary constraints will be needed to further test A_{lens}. In Fig. 4, we plot the future constraints at 68% and 95% C.L. from the stage-IV experiment (with $l_{\min} = 5$) in the A_{lens} vs $\Omega_b h^2$, $\Omega_c h^2$, n_s, and $\ln[10^{10}A_s]$ planes. As we can see, the B modes are unable to bound A_{lens} due mainly to a degeneracy with the primordial amplitude A_s. However, when a prior on A_s is included, degeneracies are still present between A_{lens} and $\Omega_b h^2$, $\Omega_c h^2$, and n_s that prevent a precise determination of A_{lens}.

In conclusion, the measurement of primordial B modes from lensing will not let one significantly improve the constraints on A_{lens} given the degeneracies between cosmological parameters.

D. Future constraints on angular scale dependence of A_{lens}

In Table V we report the constraints on the parameters of the angular scale dependency A_{lens} in the form of Eq. (7) for the stage-IV configuration. For comparison, we also report the constraints using temperature and anisotropy spectra from the Planck 2015 release [1].

As we can see, while the current bounds from Planck are rather weak and there is no indication for a scale dependency of the A_{lens} anomaly (see also [33]), the stage-IV experiment can provide constraints at $\sim 1\%$ level on B_{lens}, providing useful information on a possible scale dependence. As discussed in the previous section, we have considered different pivot scales ℓ_*. As we see from the results in Table V, while the choice of the pivot can change significantly current constraints, the effect on the accuracy stage-IV constraints is less significant.

V. CONCLUSIONS

While the agreement with the predictions of the ΛCDM model is impressive, the Planck data show indications for a tension in the value of the lensing amplitude A_{lens} that clearly deserve further investigations. If future analyses of Planck data confirm this tension then it will be the duty of new experiments to clarify the issue. In this brief paper we have shown that future proposed satellite experiments such as LiteBIRD can confirm/rule out the A_{lens} tension at the level of 5 standard deviations. The same accuracy can be reached by near future ground-based experiments such as stage III providing an accurate measurement of the

reionization optical depth τ as already reported by Planck. Future, more optimistic, experiments such as stage IV can falsify the A_{lens} tension at the level of 10 standard deviations. The stage-IV experiment will also give significant information on the possible scale dependence of A_{lens}, clearly shedding more light on its physical nature. A comparison between temperature and polarization measurements made at different frequencies could further identify possible systematics responsible for $A_{\text{lens}} > 1$. We have shown that, in the case of the CMB-S4 experiment, polarization data alone will have the potential of falsifying the current A_{lens} anomaly at more than 5 standard deviations and to strongly bound its frequency dependence.

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