The lensing amplitude $A_L = 1$ is not a good cosmological parameter for the LCDM model *

Observatório Nacional

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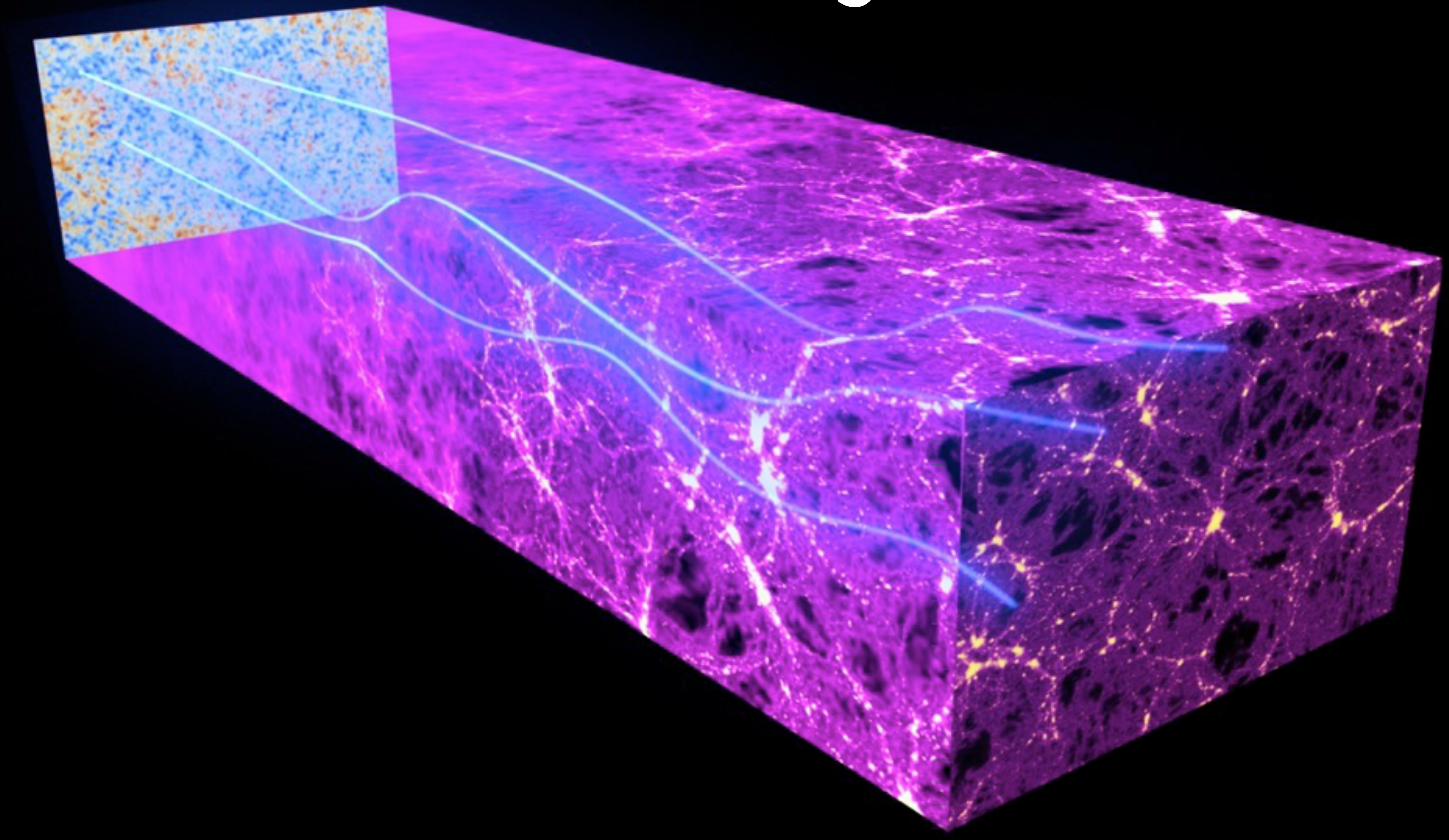
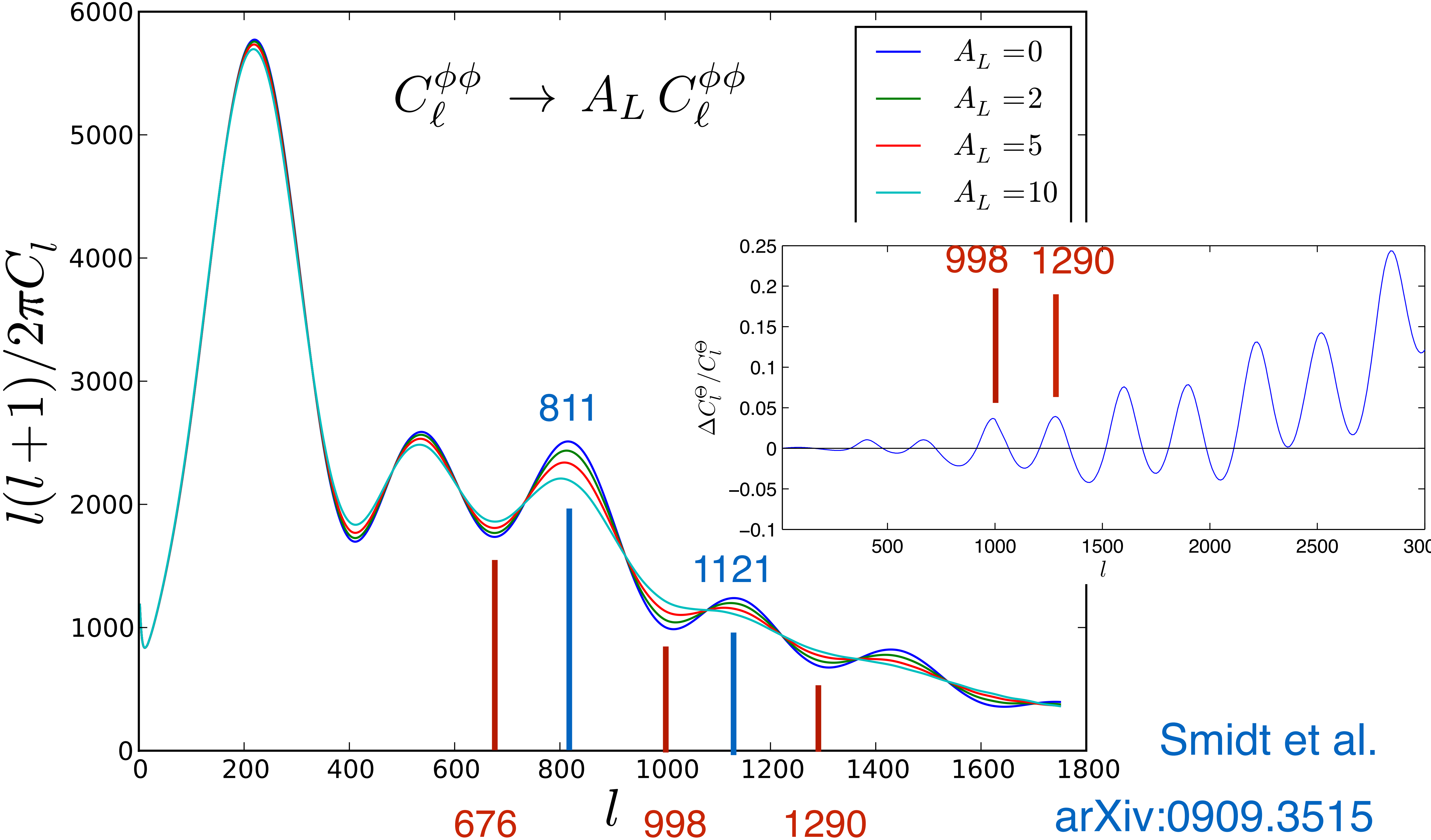
Weak Grav. Lensing of the CMB



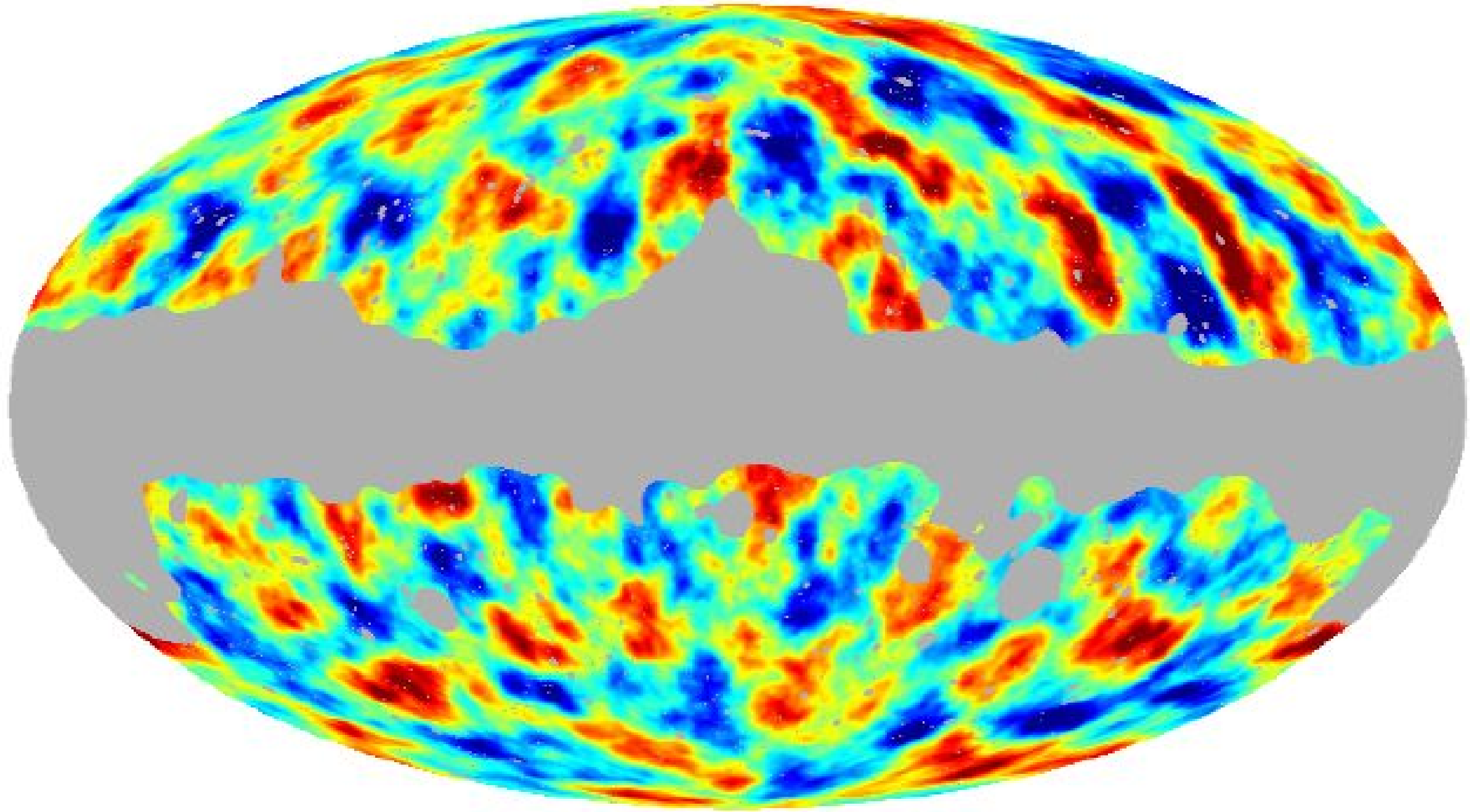
Effect of weak lensing on CMB power spectrum



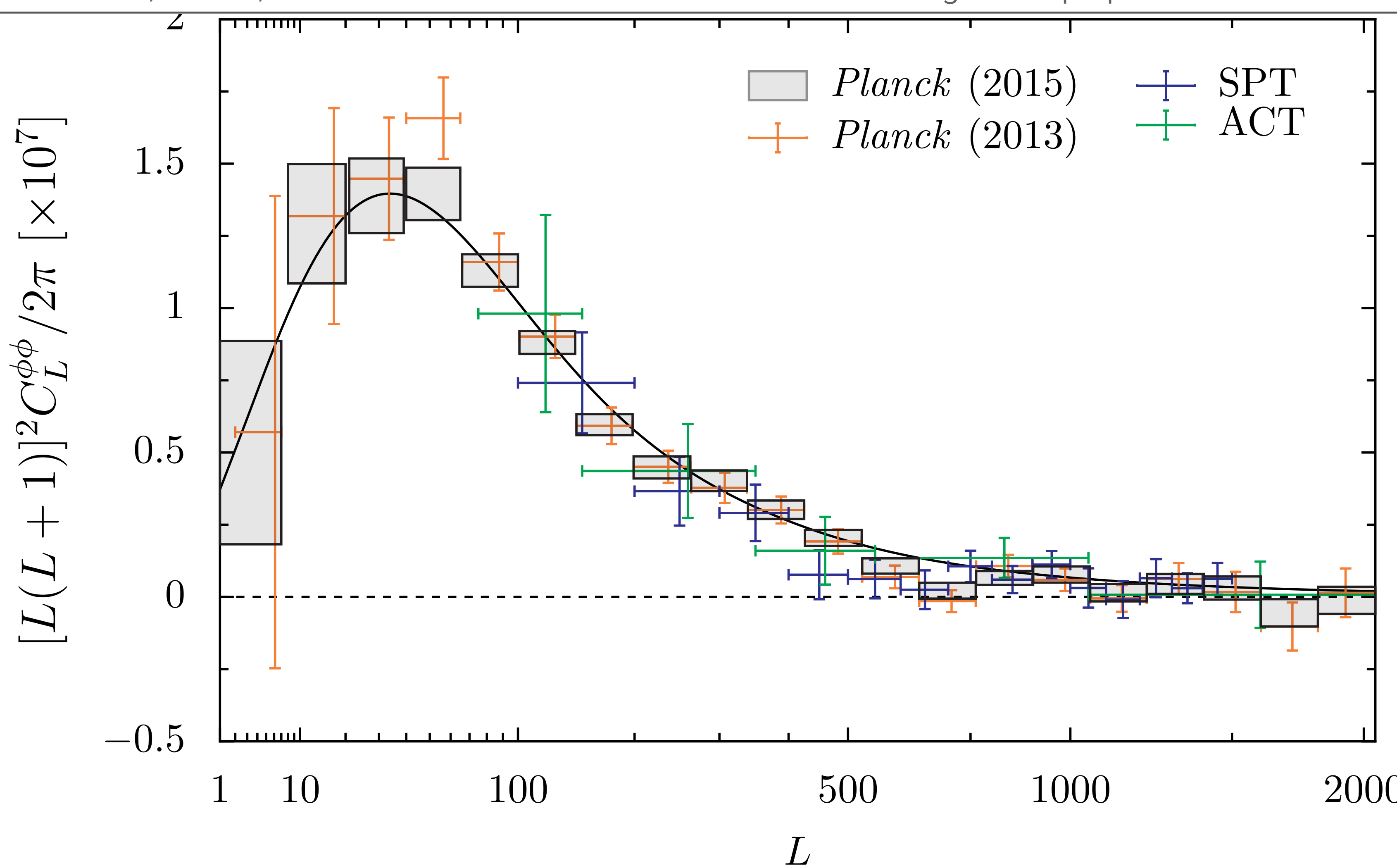
Smidt et al.

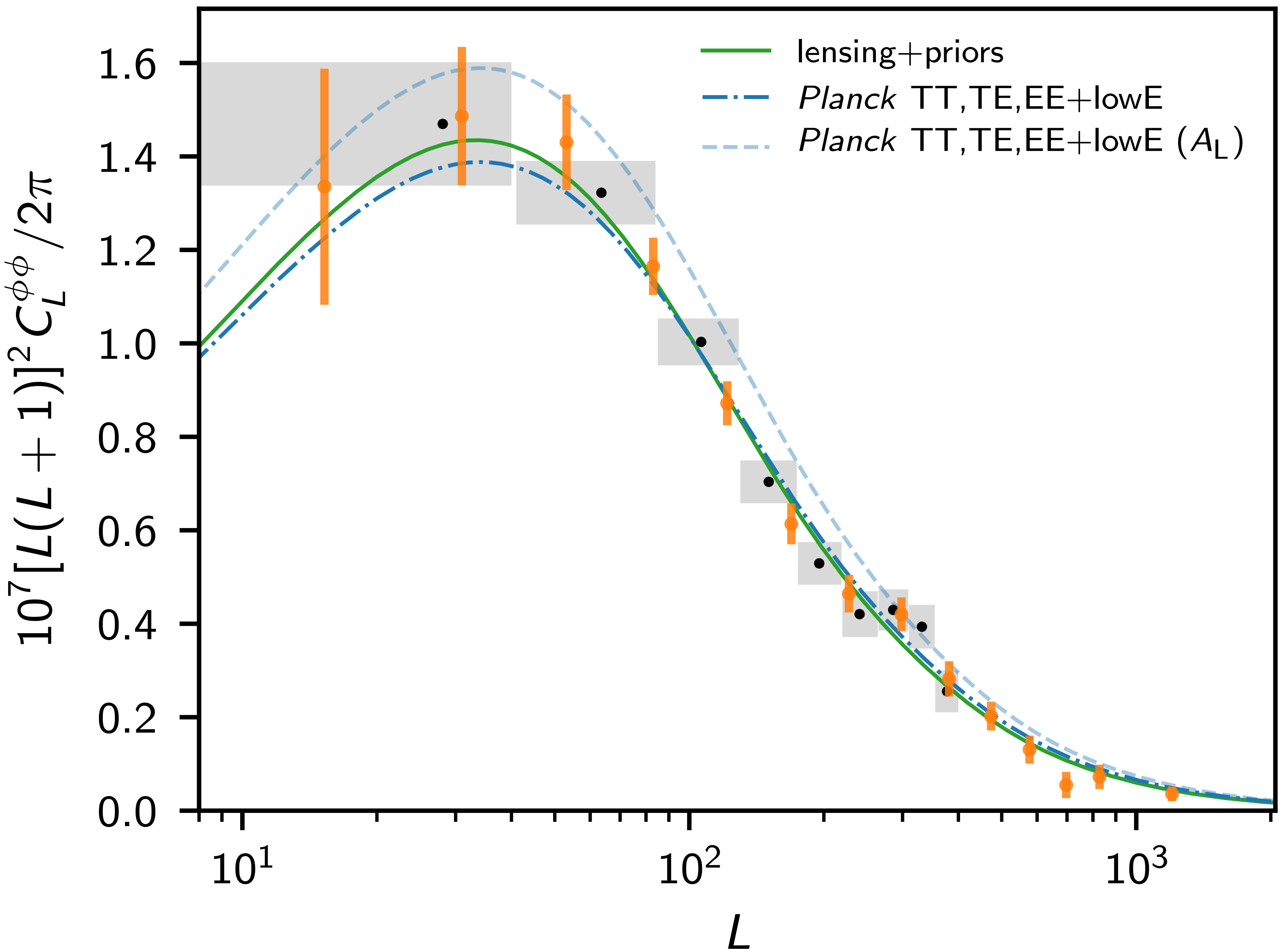
arXiv:0909.3515

LENSING POTENTIAL MAP



Source: Ade, P. A. R., et al. "Planck 2015 results. XV. Gravitational lensing." arXiv preprint arXiv:1502.01591 (2015).



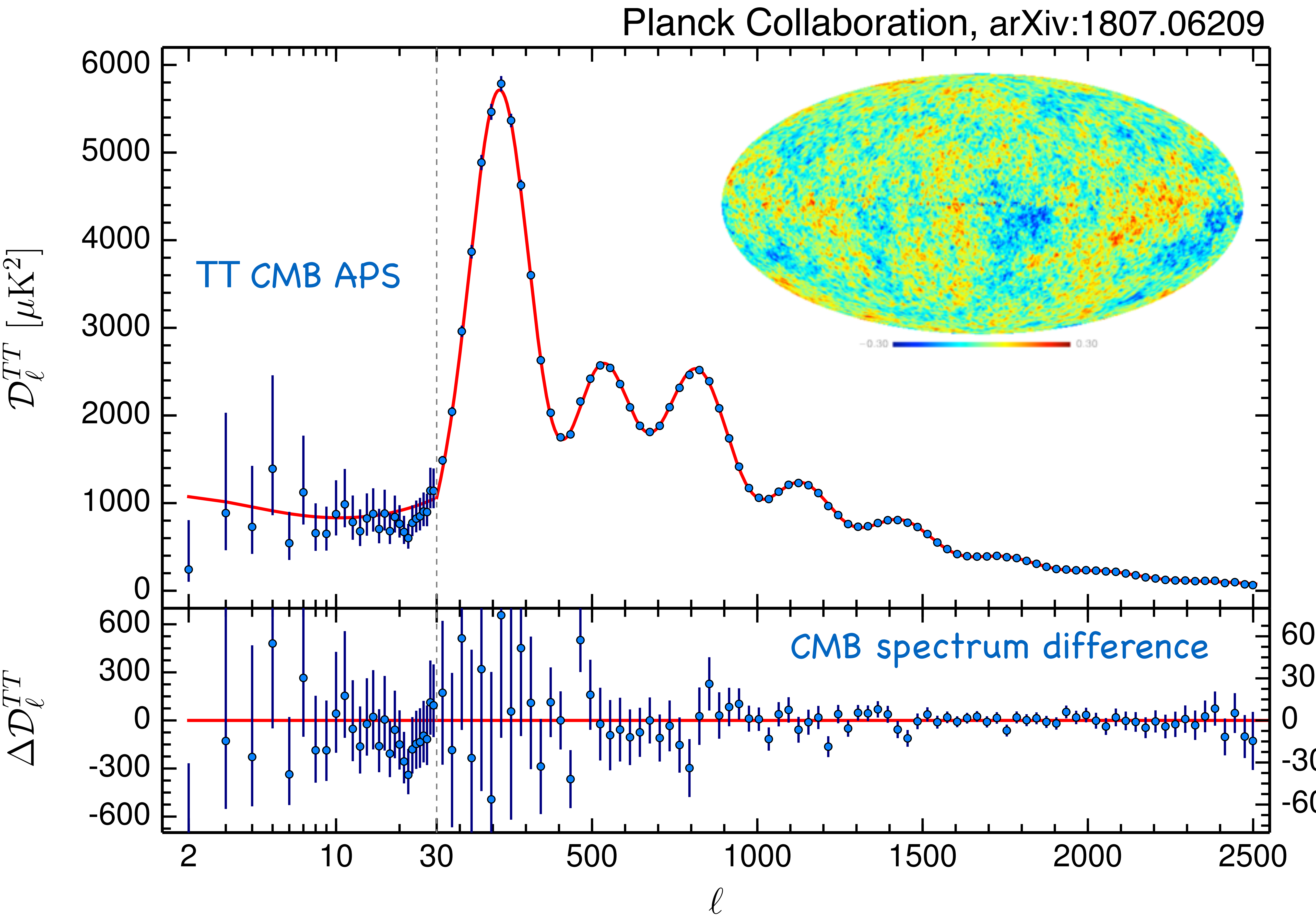


Planck Collaboration, arXiv:1807.06209

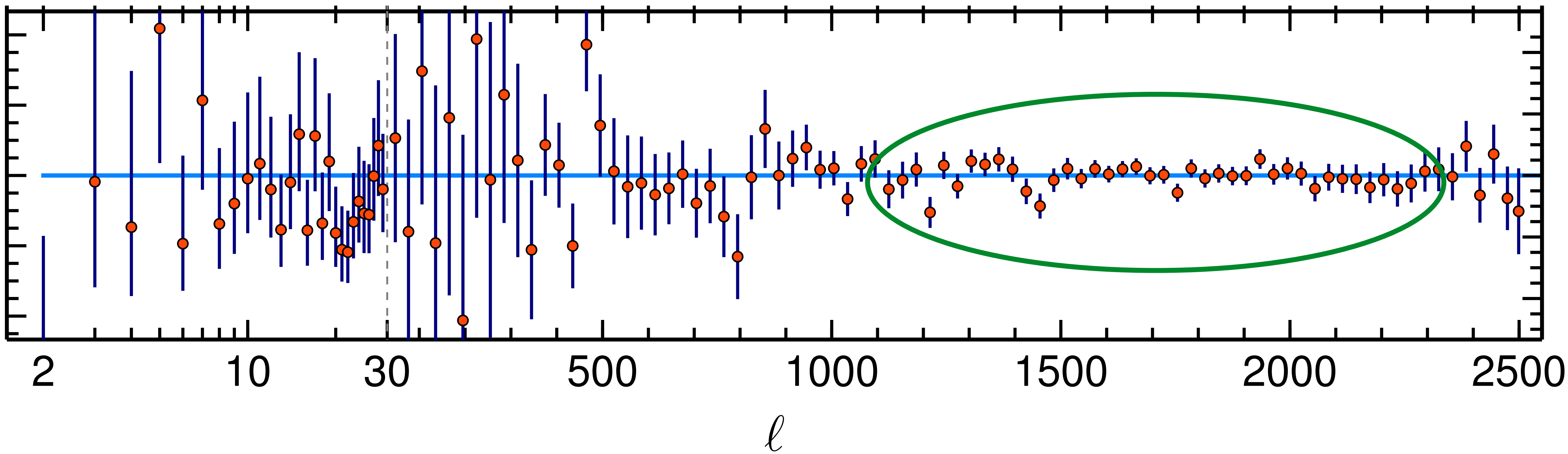
The dashed line shows the prediction from the best fit to the CMB power spectra when the lensing amplitude A_L is also varied ($A_\mathrm{L} = 1.19$ for the best-fit model; see Sect. 6.2 for a detailed discussion of A_L).

$$A_\mathrm{L} = 1.243 \pm 0.096 \quad (68\,\%, \ \textit{Planck}\ \mathrm{TT{+}lowE}), \tag{36a}$$

$$A_\mathrm{L} = 1.180 \pm 0.065 \quad (68\,\%, \ \textit{Planck}\ \mathrm{TT,TE,EE{+}lowE}), \tag{36b}$$


Planck Collaboration, arXiv:1807.06209
TT CMB APS
CMB spectrum difference
$\mathcal{D}_\ell^{TT}$ [μK^2]
$\Delta\mathcal{D}_\ell^{TT}$
ℓ
6000
5000
4000
3000
2000
1000
0
600
300
0
-300
-600
2
10
30
500
1000
1500
2000
2500

CMB spectrum difference:
Planck APS data minus LCDM best-fit model



Two features of this spectrum difference are crucial in our analyses:

1) The data "show" some signature at the angular scales of the acoustic peaks where grav. lensing is important ($\ell > 1000$)
2) At these scales the data show the lowest errors

Are these data white noise?

Are these spectrum difference data white noise?

Ljung-Box test

The Ljung-Box criterium test the null hypothesis:

H0: The data are independently distributed (i.e. the correlations in the population from which the sample is taken are 0, so that any observed correlations in the data result from randomness of the sampling process).

Null hypothesis analyses ← Ljung-Box test

H_0: The spectrum difference, $\{\delta_\ell^{obs}\}$, corresponds to a residual statistical (or white) noise.

Multipole intervals	p-value	Reject H_0	% of repetition
$\ell = [2, 2500]$	0	Yes	100%
$\ell = [2, 100]$	6.0346×10^{-1}	No	95%
$\ell = [2, 800]$	1.1739×10^{-1}	No	56%
$\ell = [2, 1200]$	1.709739×10^{-2}	No	20%
$\ell = [1100, 2500]$	1.043610×10^{-14}	Yes	100%
$\ell = [1600, 2500]$	3.70592×10^{-8}	Yes	94%
$\ell = [2000, 2500]$	1.567727×10^{-3}	Yes	59%
$\ell = [1100, 2000]$	2.9949×10^{-5}	Yes	77%
$\ell = [1100, 2100]$	1.3562×10^{-7}	Yes	89%
$\ell = [1100, 2200]$	2.6334×10^{-13}	Yes	100%

Regarding the first comment:
"the data show some signature at the angular scales of the acoustic peaks where grav. lensing is important ($\ell > 1000$)"

we performed some best-fit tests using synthetic APS to get:

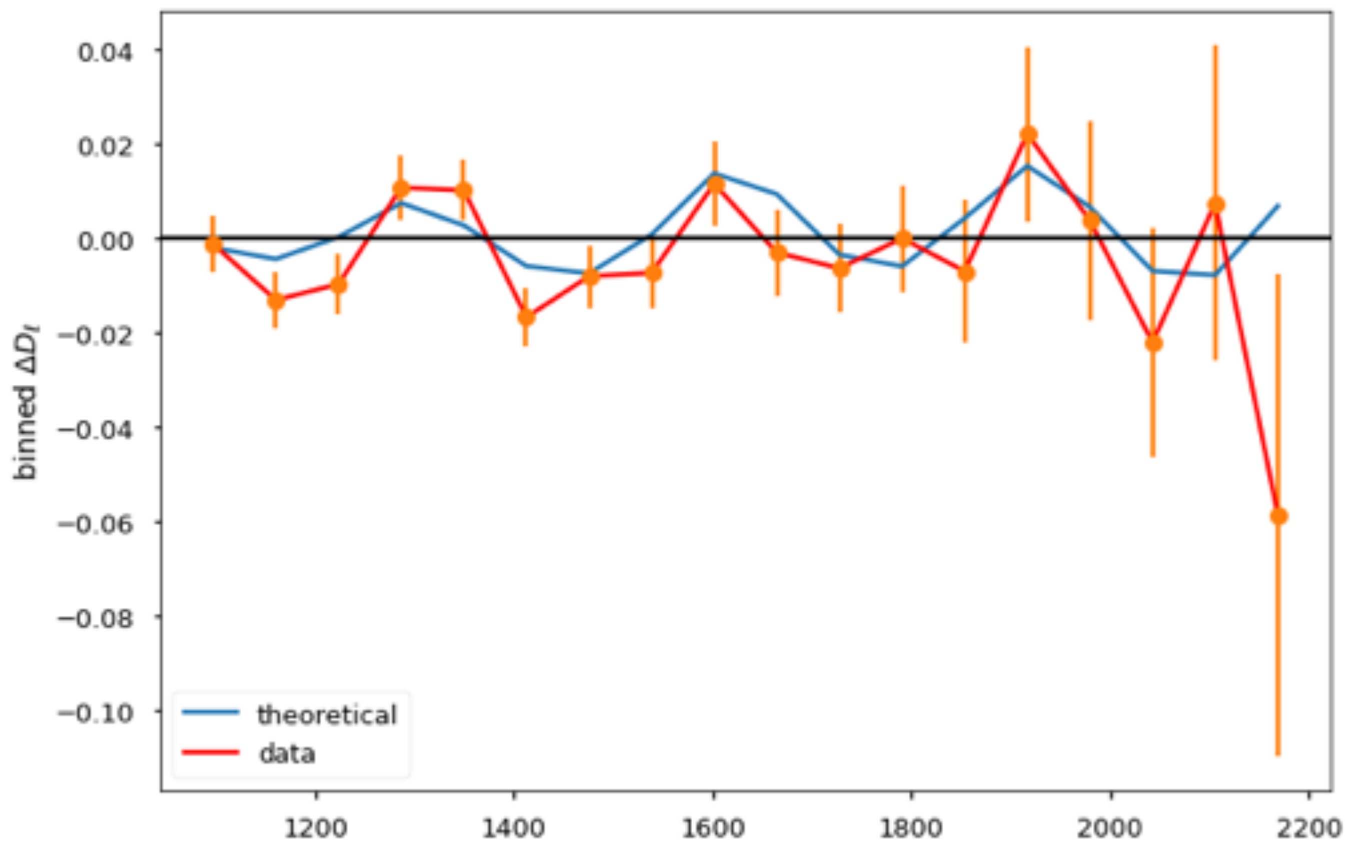
$$\delta_\ell^{exc}(A_{lens}) \equiv \frac{C_\ell^{syn,L}(A_{lens}) - C_\ell^{syn,uL}}{C_\ell^{syn,uL}}$$

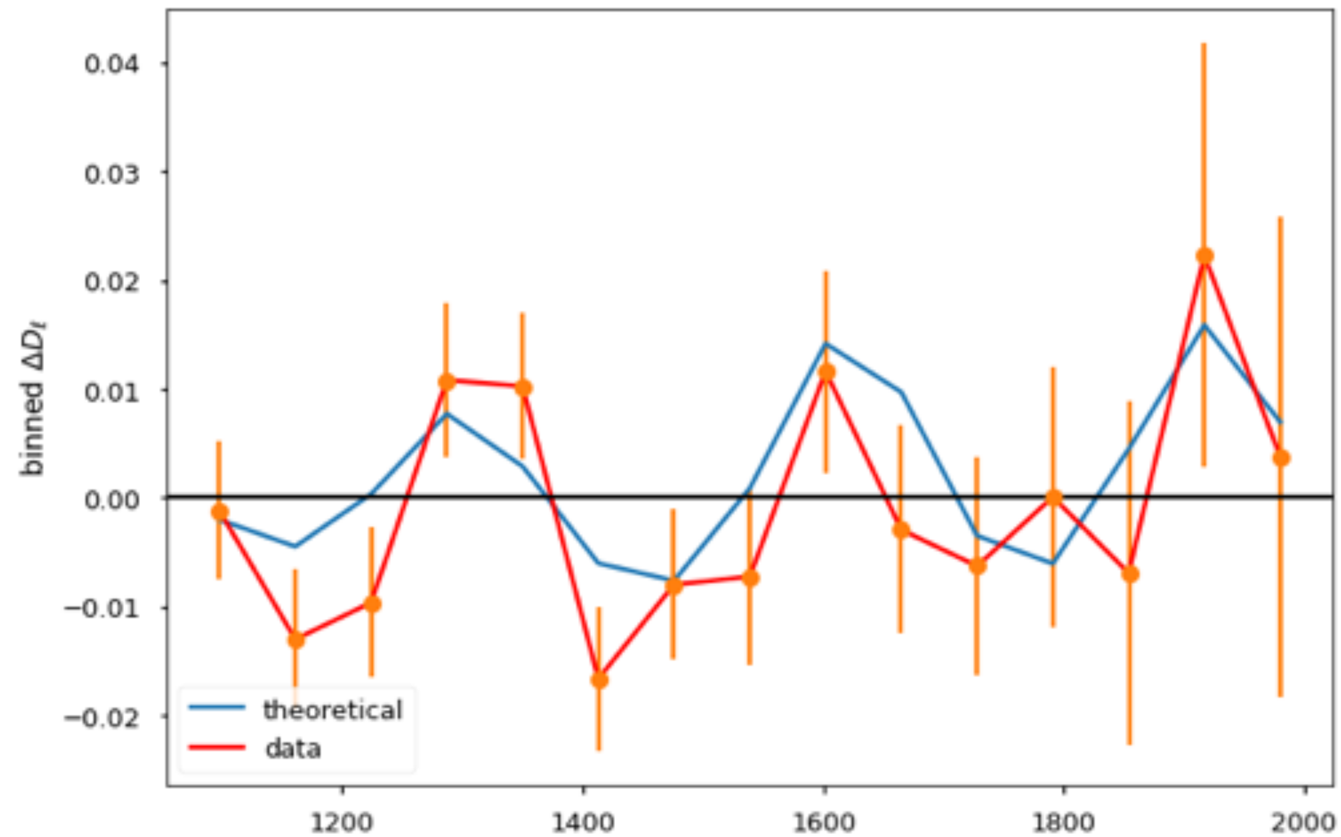
with the aim to best-fit the data:

$$\delta_\ell^{obs} \equiv \frac{C_\ell^{\rm Planck} - C_\ell^{\Lambda\rm CDM}}{C_\ell^{\Lambda\rm CDM}}$$

Notice: $A_{lens} \equiv A_L - 1,$ where A_L is the Planck's lensing amplitude parameter

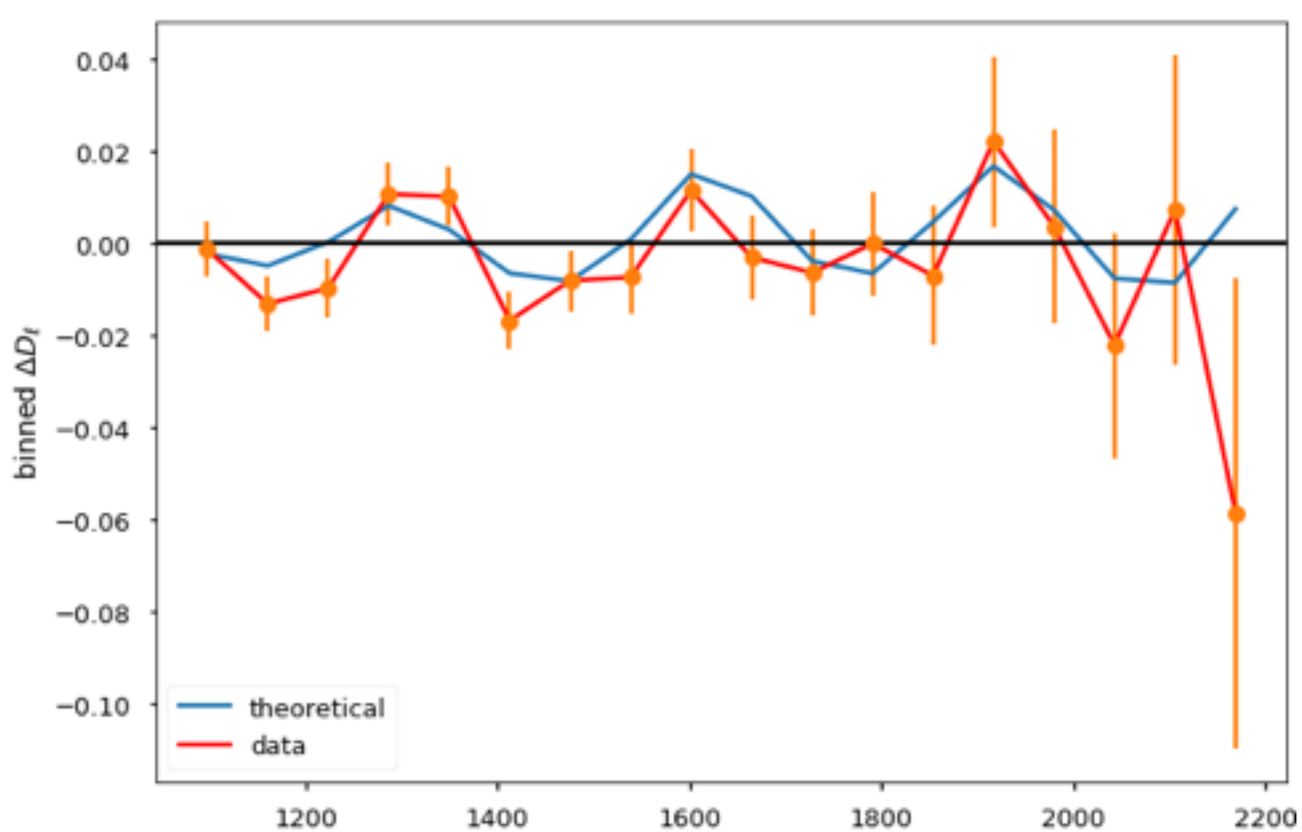
$\Longrightarrow$ in flat-ΛCDM model: $A_L = 1$

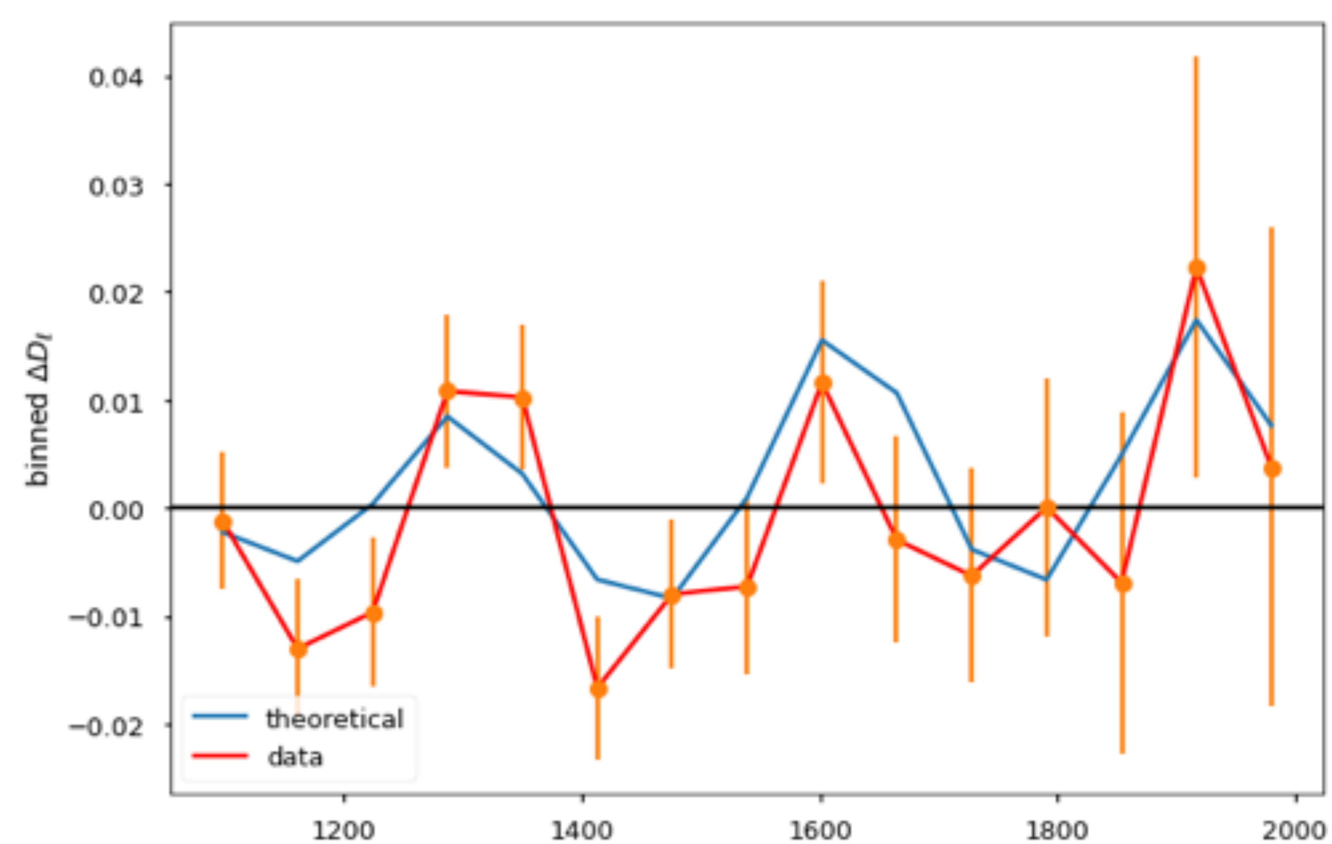


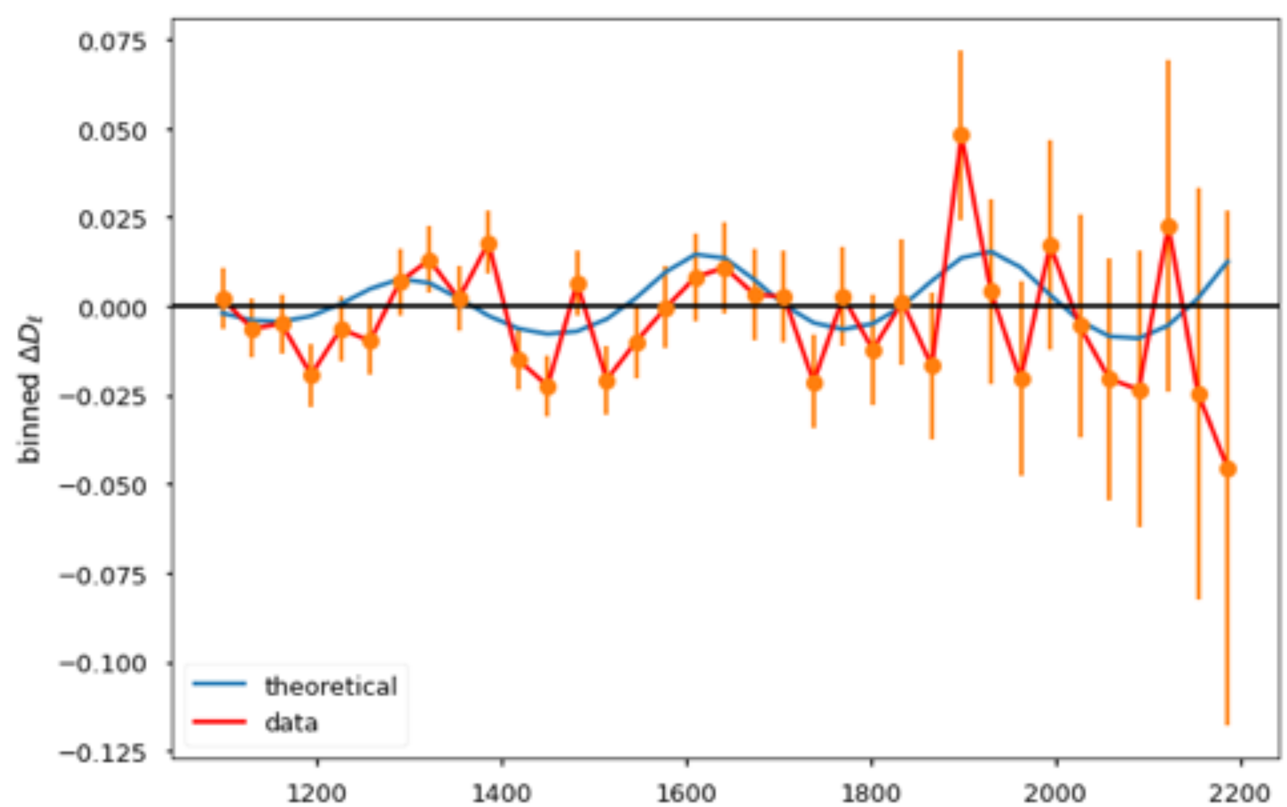


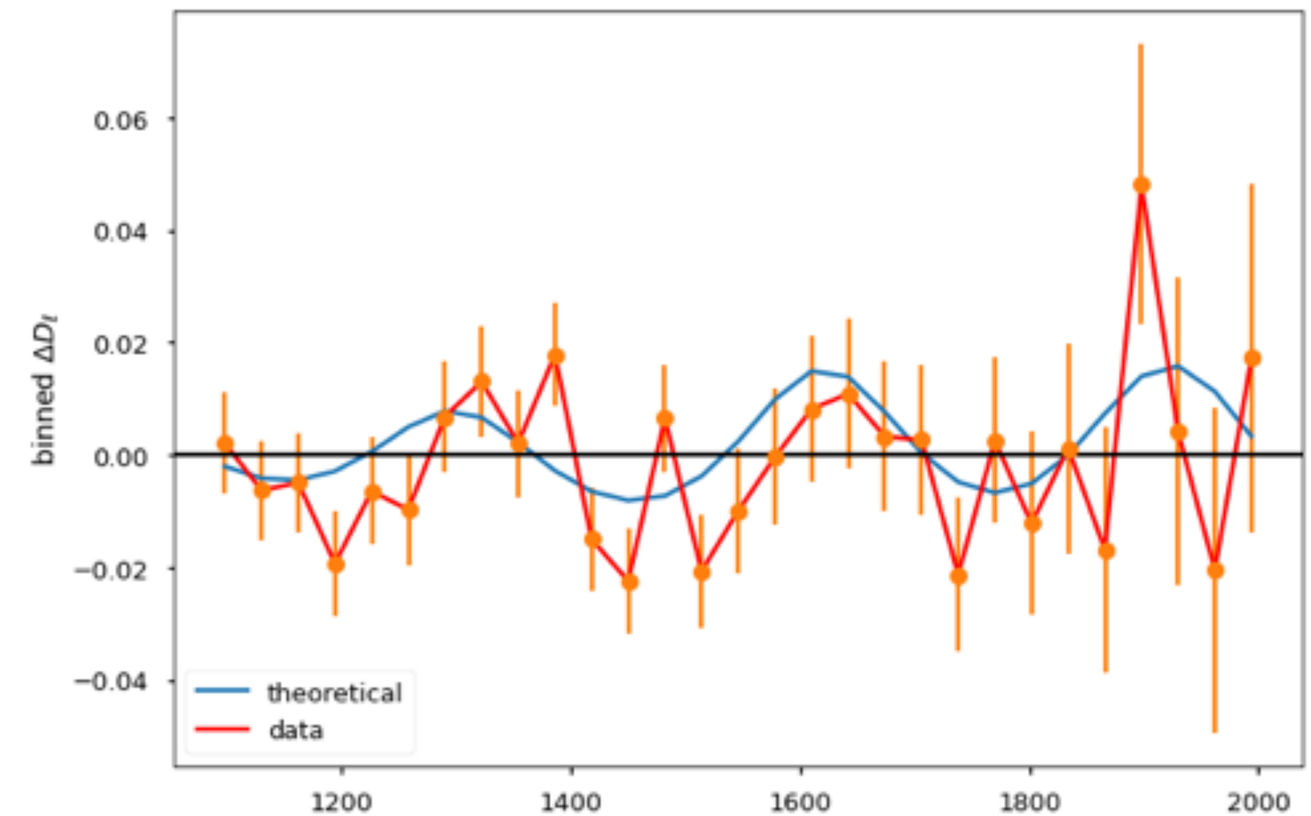
$$\boxed{\delta_\ell^{obs} \equiv \frac{C_\ell^{\mathrm{Planck}} - C_\ell^{\Lambda\mathrm{CDM}}}{C_\ell^{\Lambda\mathrm{CDM}}}}$$

$$\boxed{\delta_\ell^{exc}(A_{lens}) \equiv \frac{C_\ell^{syn,L}(A_{lens}) - C_\ell^{syn,uL}}{C_\ell^{syn,uL}}}$$



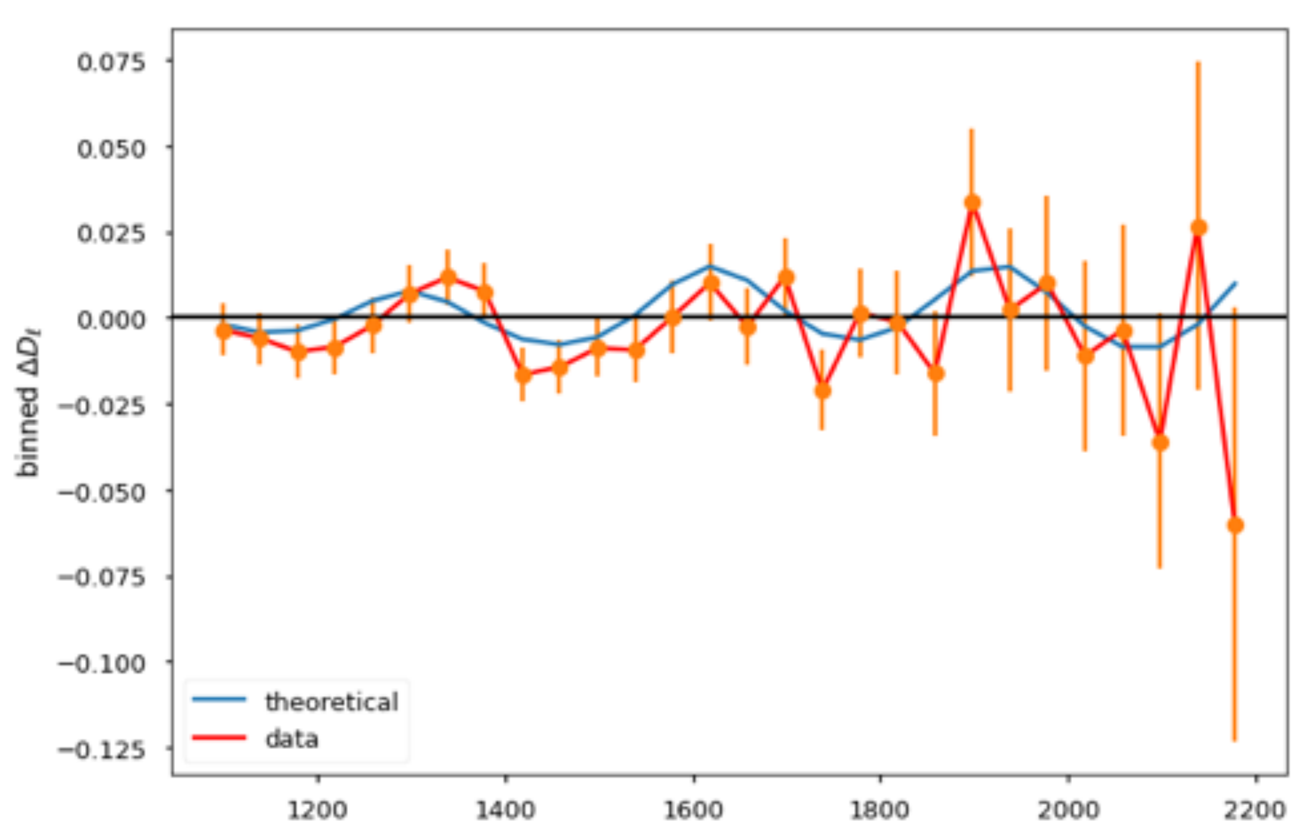


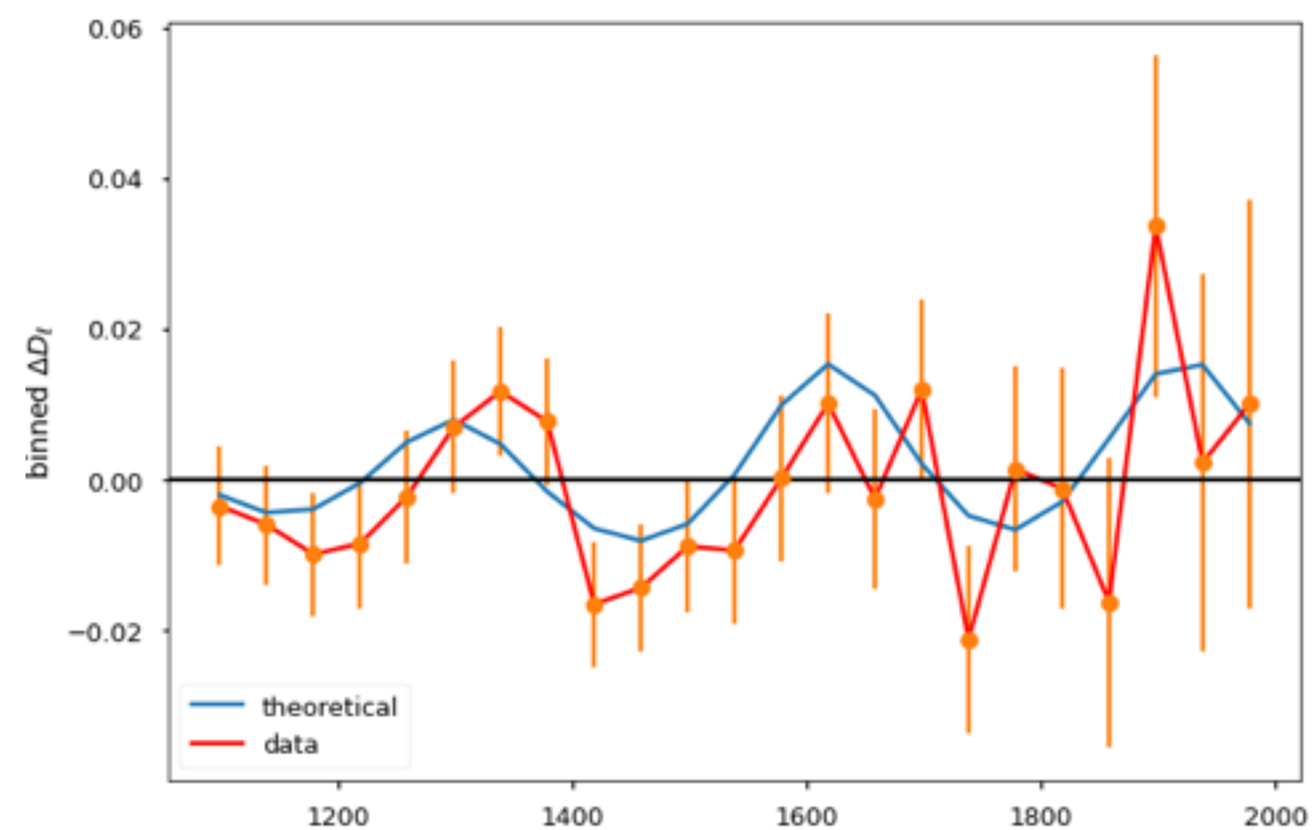




$$\boxed{\delta_\ell^{obs} \equiv \frac{C_\ell^{\mathrm{Planck}} - C_\ell^{\Lambda\mathrm{CDM}}}{C_\ell^{\Lambda\mathrm{CDM}}}}$$

$$\boxed{\delta_\ell^{exc}(A_{lens}) \equiv \frac{C_\ell^{syn,L}(A_{lens}) - C_\ell^{syn,uL}}{C_\ell^{syn,uL}}}$$





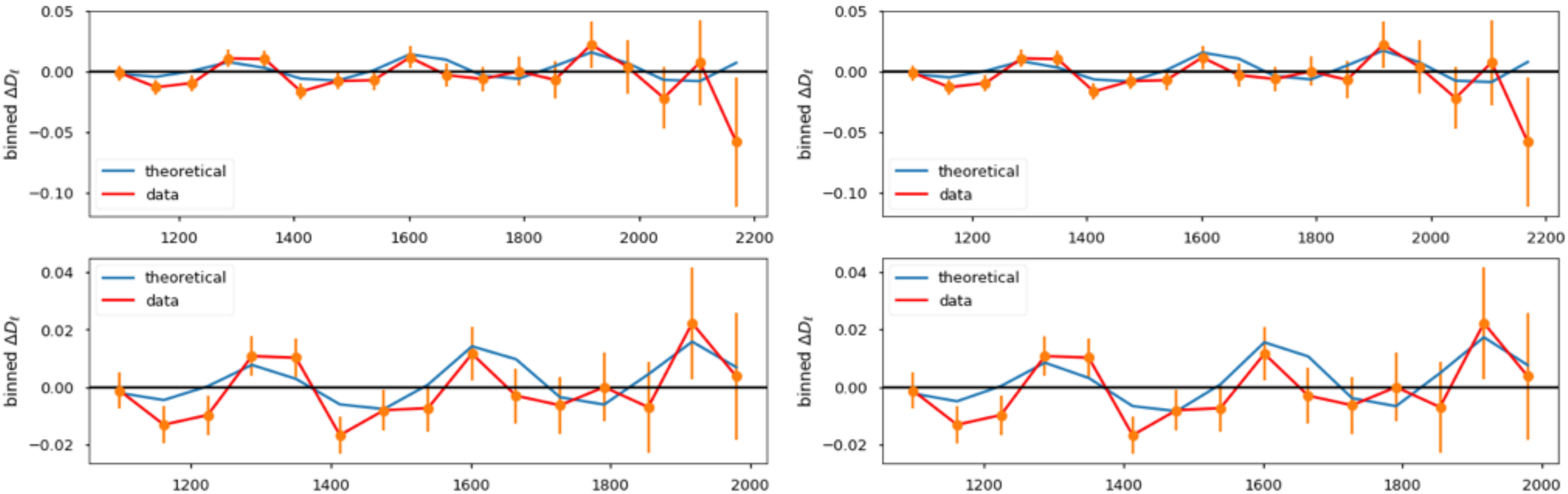


Table 3. Illustrative examples of χ^2 calculations for different values of A_{lens} and several binnation choices $\Delta\ell$. Some of these cases can be seen in figures 1, 2, and 3.

A_{lens}	$\Delta\ell = 17$	$\Delta\ell = 32$	$\Delta\ell = 41$	$\Delta\ell = 51$	$\Delta\ell = 63$
0.00	1.0363	1.2809	1.02590	0.95802	1.63446
0.10	0.9414	1.0747	0.7610	0.6416	1.0798
0.20	0.9329	1.0305	0.7094	0.5851	0.8395
0.24	0.9525	1.0561	0.7459	0.6319	0.8274
0.34	1.0565	1.2238	0.9734	0.9150	0.9980

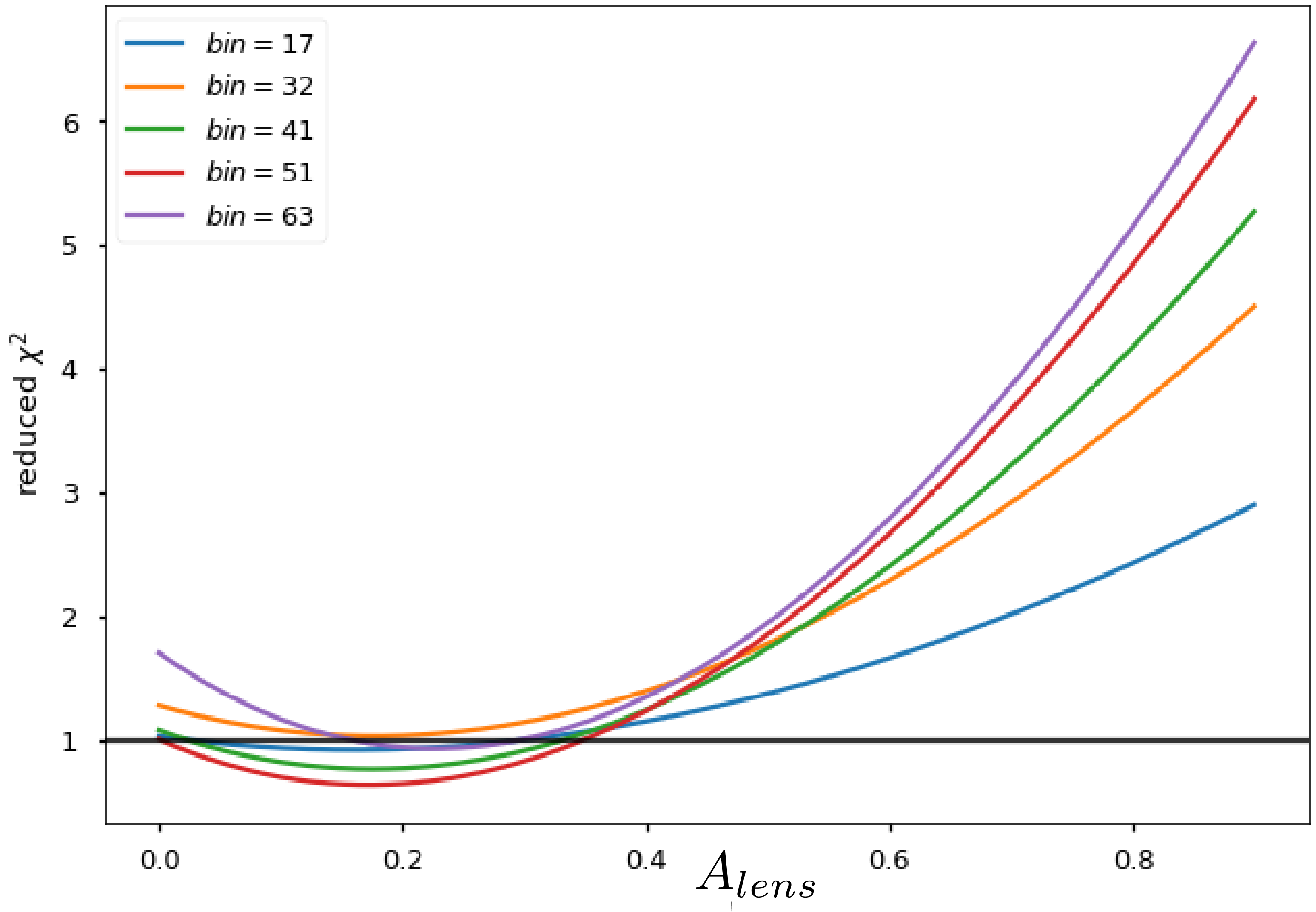
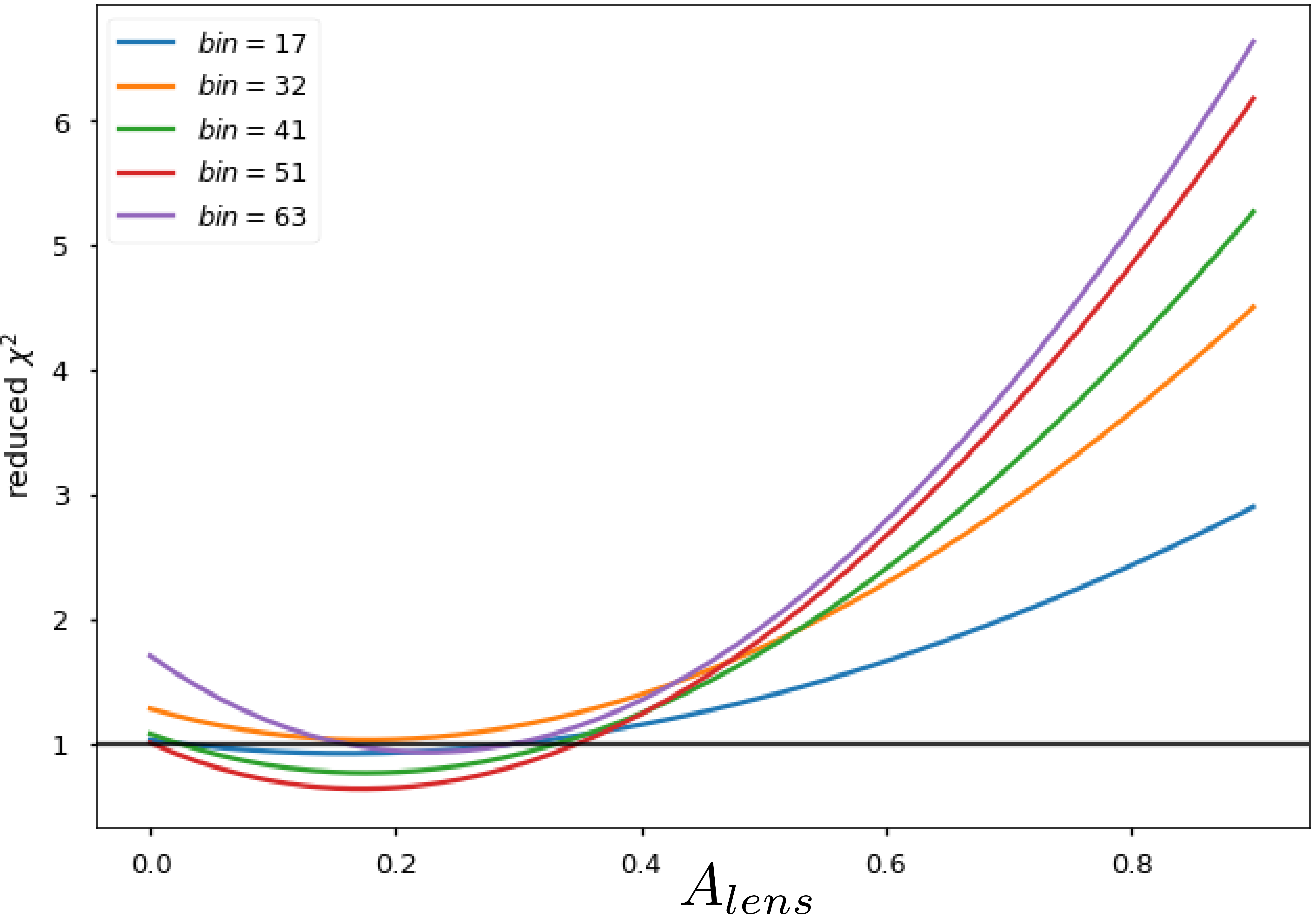


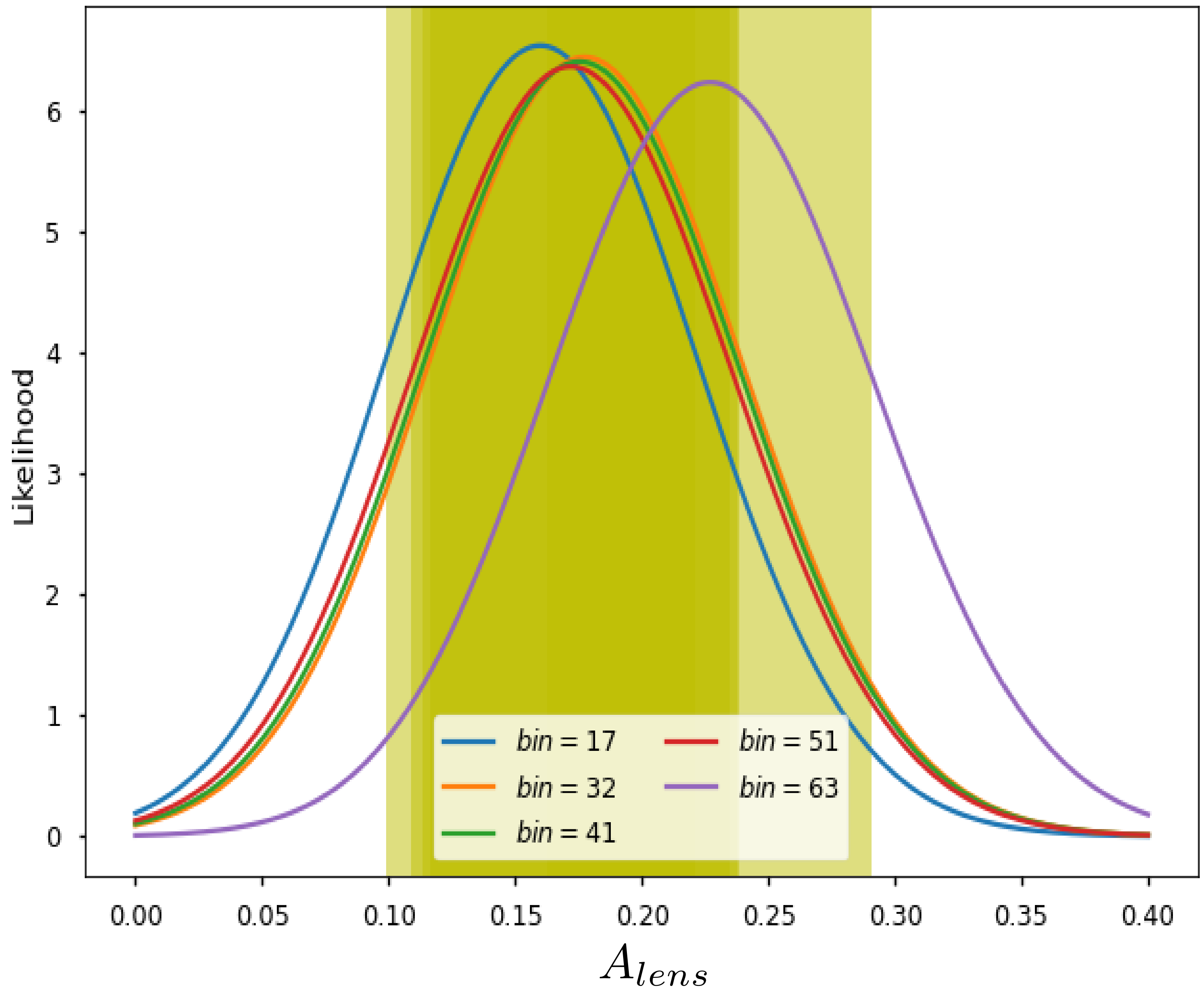
Figure 4. χ^2 as a function of A_L and for different number of bins. This plot shows that, independent of the bin size Δ_ℓ, the χ^2 function exhibits solutions for the case $\chi^2 = 1$ for $A_L \neq 0$, which justify our search for the value A_L that best-fits the observed data δ_ℓ^{obs}.

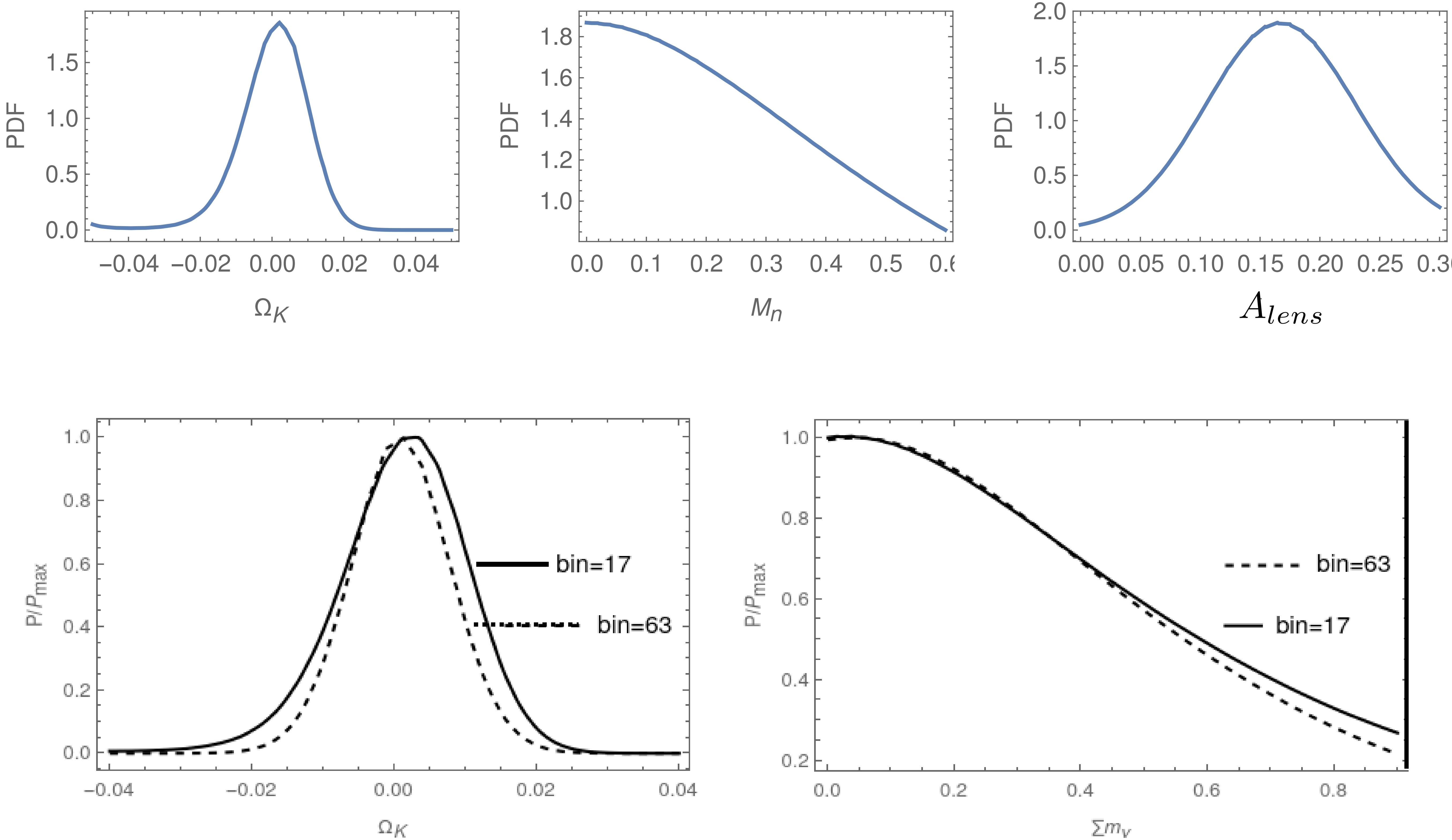
bin length	first point	second point
$\Delta\ell = 17$	0.028675	0.29479
$\Delta\ell = 32$	–	–
$\Delta\ell = 41$	0.02495	0.3305
$\Delta\ell = 51$	0.0023	0.3477
$\Delta\ell = 63$	0.16053	0.29425

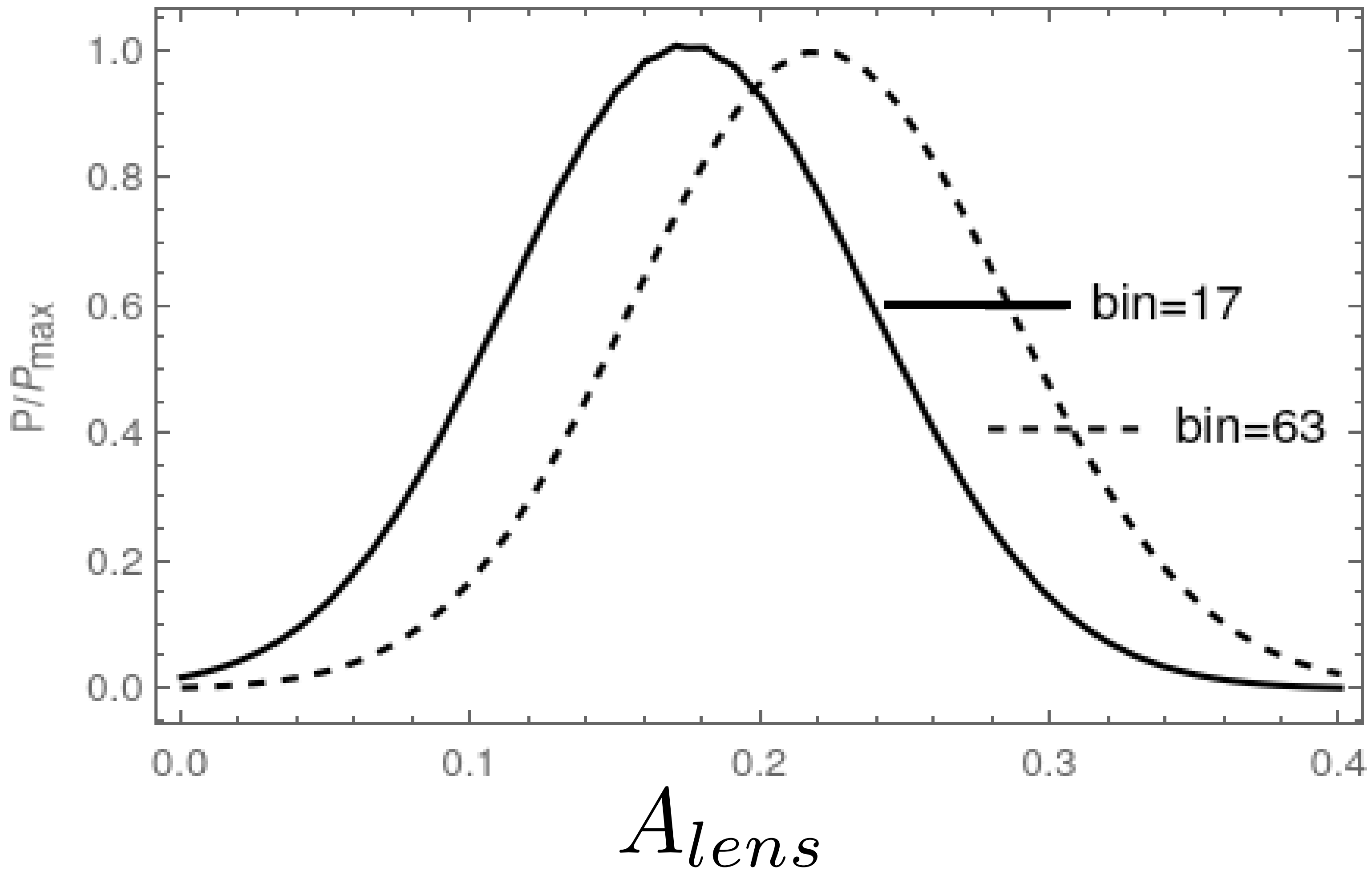


$bin = 17$
$bin = 32$
$bin = 41$
$bin = 51$
$bin = 63$
reduced χ^2
1
2
3
4
5
6
0.0
0.2
0.4
0.6
0.8
A_{lens}

bin length	A_{lens} at max. likelihood	1σ interval	CL for $A_{lens} > 0$
$\Delta\ell = 17$	0.16036	$[0.0883, 0.2326]$	2.6σ
$\Delta\ell = 32$	0.177477	$[0.1049, 0.2509]$	2.8σ
$\Delta\ell = 41$	0.17567	$[0.1025, 0.2494]$	2.8σ
$\Delta\ell = 51$	0.172072	$[0.0986, 0.2466]$	2.7σ
$\Delta\ell = 63$	0.22702	$[0.1521, 0.3028]$	3.5σ




PDF
Ω_K
PDF
M_n
PDF
A_{lens}
P/P_{max}
bin=17
bin=63
Ω_K
P/P_{max}
bin=63
bin=17
Σm_ν



bin length	A_{lens}	$\sum m_\nu$	Ω_K	CL for $A_{lens} > 0$
$\Delta\ell = 17$	$0.18^{+0.063}_{-0.063}$	< 0.47 eV	$0.0029^{+0.009}_{-0.009}$	3σ
$\Delta\ell = 63$	$0.22^{+0.065}_{-0.065}$	< 0.45 eV	$0.0013^{+0.0071}_{-0.0071}$	2.9σ

Conclusions (and final remarks)

- We have proved that the residual data [between Planck TT APS and LCDM best-fit APS] correspond to an oscillatory signature

- The smallest errors of the CMB temperature fluctuations, at $1000 \lesssim \ell \lesssim 2000$, where crucial to prove that the spectrum difference is not white noise!

- We find that the CMB spectrum difference can be explained by a higher lensing amplitude $A_{lens} \in [0.10, 0.30]$ at 68% CL, and $A_{lens} \neq 0$ at $\sim 3\sigma$

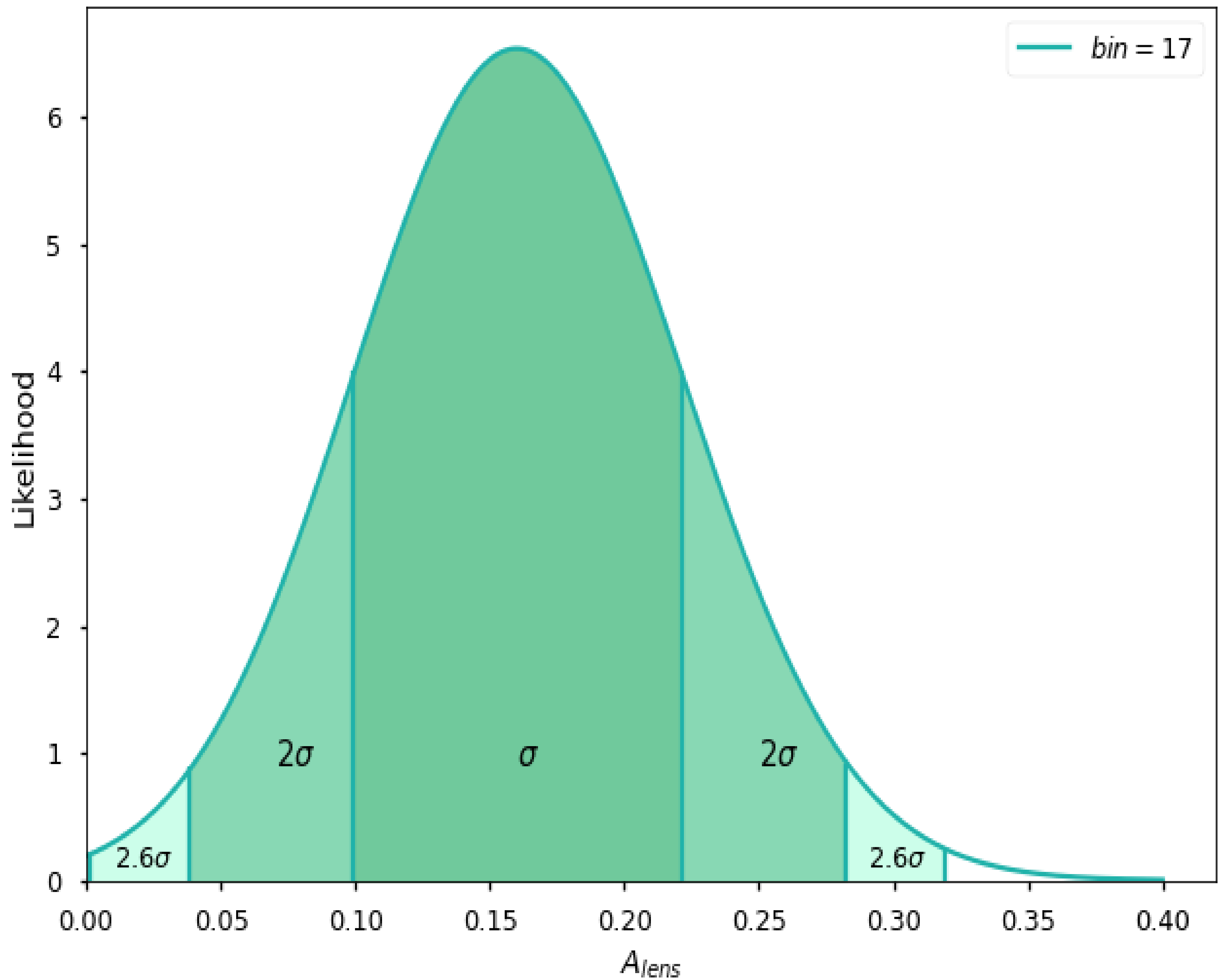


Figure 7. Illustrative example of σ intervals for the $\Delta\ell = 17$ case. As observed, for this binnation case the value $A_{lens} = 0$ (equivalently $A_L > 1$) is excluded with 2.6σ (i.e., at 99% CL).