Constraints on cosmological parameters from future missions

17-20 May 2016
Towards a next space probe for CMB observations and cosmic origins exploration
CERN

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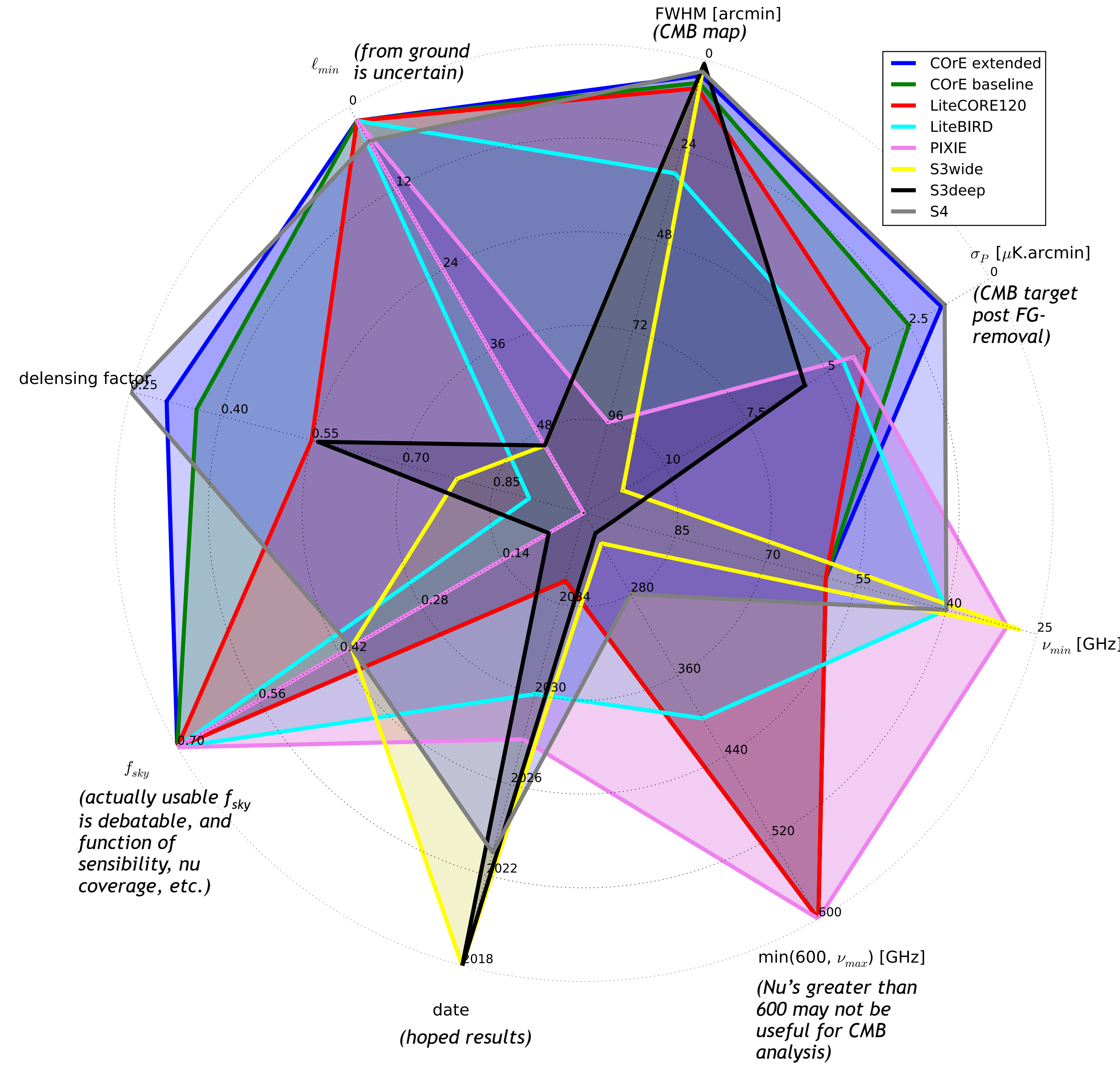
Institut d'Astrophysique de Paris

Experiments considered

	σ_P [μK.arcmin]	FWHM [arcmin]	delensing factor	f_{sky}
PIXIE	4.2	96	1	0.7
LiteBIRD	4.5	30	0.91	0.7
LiteCORE120	3.75	7.5	0.55	0.7
COrE+ baseline	2.5	6	0.41	0.7
COrE+ extended	1.5	4	0.31	0.7

	σ_P [μK.arcmin]	FWHM [arcmin]	delensing factor	ℓ_{min}	f_{sky}
S3 wide (Adv-ACT)	11.3	1.4	0.79	50	0.4
S3 deep (SPT-3G)	5.7	1	0.56	50	0.06
S4	1.4	3	0.25	5	0.4



EDV, F.R.Bouchet, in prep.

LCDM

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$\Omega_b h^2$	0.02225 ± 0.00016	0.0223 ± 0.0012	0.02226 ± 0.00013	0.022249 ± 0.000048	0.022249 ± 0.000037	0.022251 ± 0.000028
$\Omega_c h^2$	0.1198 ± 0.0015	0.1200 ± 0.0033	0.11978 ± 0.00060	0.11978 ± 0.00030	0.11978 ± 0.00025	0.11978 ± 0.00023
$ln(10^{10} A_S)$	3.094 ± 0.034	3.095 ± 0.017	3.0946 ± 0.0043	3.0941 ± 0.0033	3.0942 ± 0.0029	3.0943 ± 0.0031
n_S	0.9645 ± 0.0049	0.965 ± 0.014	0.9648 ± 0.0036	0.9646 ± 0.0016	0.9646 ± 0.0014	0.9646 ± 0.0013
$H_0 [km\, s^{-1}\, Mpc^{-1}]$	67.27 ± 0.66	67.5 ± 2.1	67.29 ± 0.33	67.28 ± 0.12	67.28 ± 0.10	67.284 ± 0.088
σ_8	0.831 ± 0.013	0.832 ± 0.021	0.8314 ± 0.0028	0.8312 ± 0.0011	0.83123 ± 0.00094	$0.83120^{+0.00081}_{-0.00092}$

TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM model.

By considering COrE+ we gain, on most of the cosmological parameters, about an order of magnitude with respect to the Planck experiment, and a factor 3 in average with respect to the LiteBIRD satellite.
In particular, it is impressive the accuracy with which we could constrain H_0.

EDV, F.R.Bouchet, in prep.

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.188	< 0.305	$0.107^{+0.038}_{-0.099}$	$0.083^{+0.041}_{-0.056}$	$0.078^{+0.039}_{-0.054}$	0.079 ± 0.041
$N_{\rm eff}$	2.99 ± 0.20	$3.9^{+1.0}_{-1.9}$	3.06 ± 0.20	3.048 ± 0.055	3.047 ± 0.043	3.047 ± 0.035
$\frac{dln n_S}{dln k}$	-0.0057 ± 0.0071	-0.001 ± 0.024	0.0003 ± 0.0080	-0.0001 ± 0.0028	0.0001 ± 0.0024	0.0001 ± 0.0022
r	< 0.0463	< 0.000304	< 0.000300	< 0.000243	< 0.000192	< 0.000173
w	$-1.19^{+0.54}_{-0.42}$	$-1.10^{+0.25}_{-0.14}$	$-1.18^{+0.40}_{-0.24}$	$-1.09^{+0.23}_{-0.11}$	$-1.05^{+0.17}_{-0.11}$	$-1.03^{+0.14}_{-0.09}$
Y_P	0.250 ± 0.014	$0.237^{+0.057}_{-0.048}$	0.245 ± 0.012	0.2453 ± 0.0037	0.2454 ± 0.0029	0.2454 ± 0.0023

TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

Extensions to LCDM..

	S3wide + tau05	S3deep +tau05	S4 +tau05
Σm_ν [eV]	< 0.151	< 0.211	$0.085^{+0.035}_{-0.073}$
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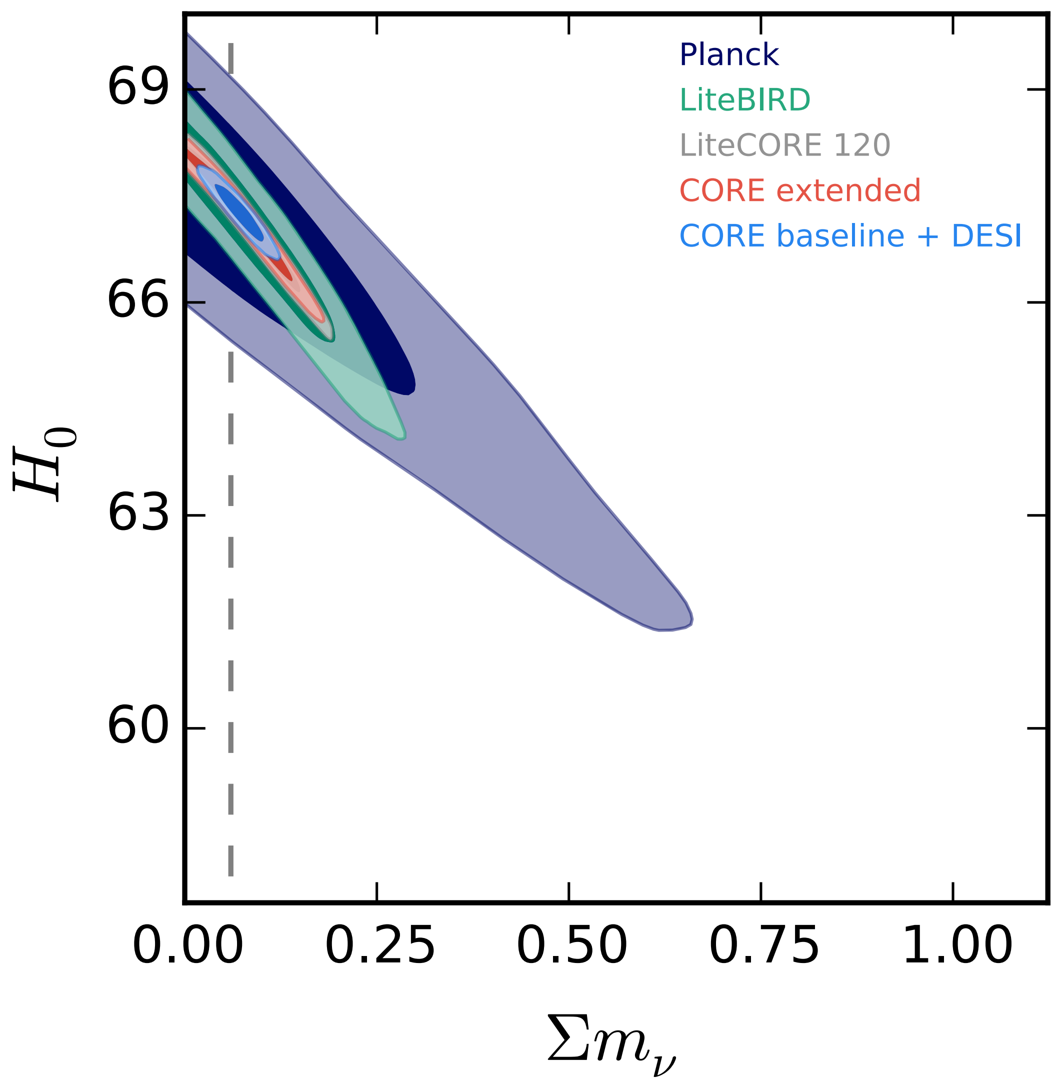
TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

By considering COrE we can reach the accuracy to have an indication of the total neutrino mass at 1sigma level.



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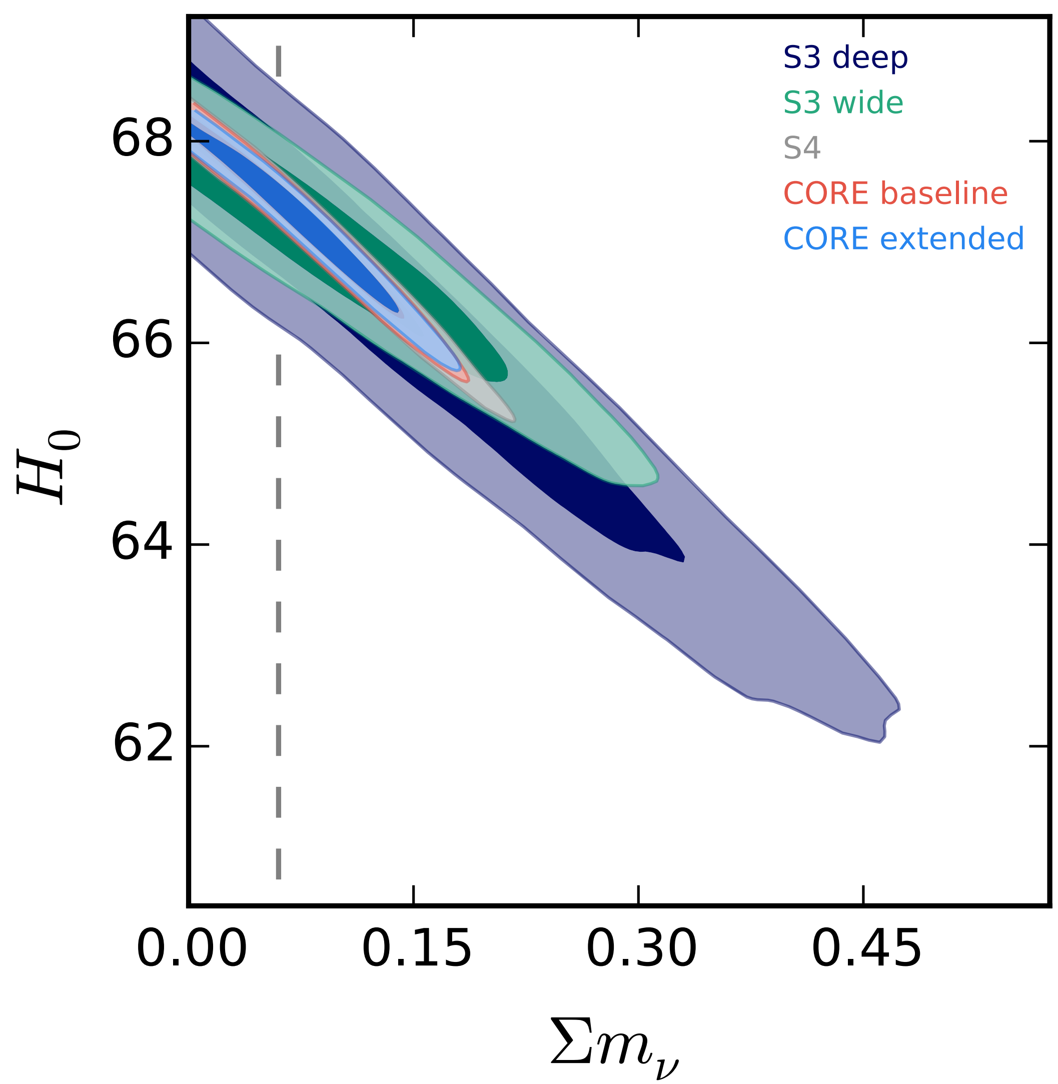
Ground based telescopes with a tau prior as provided by Planck HFI at low ell cannot be competitive with COrE.



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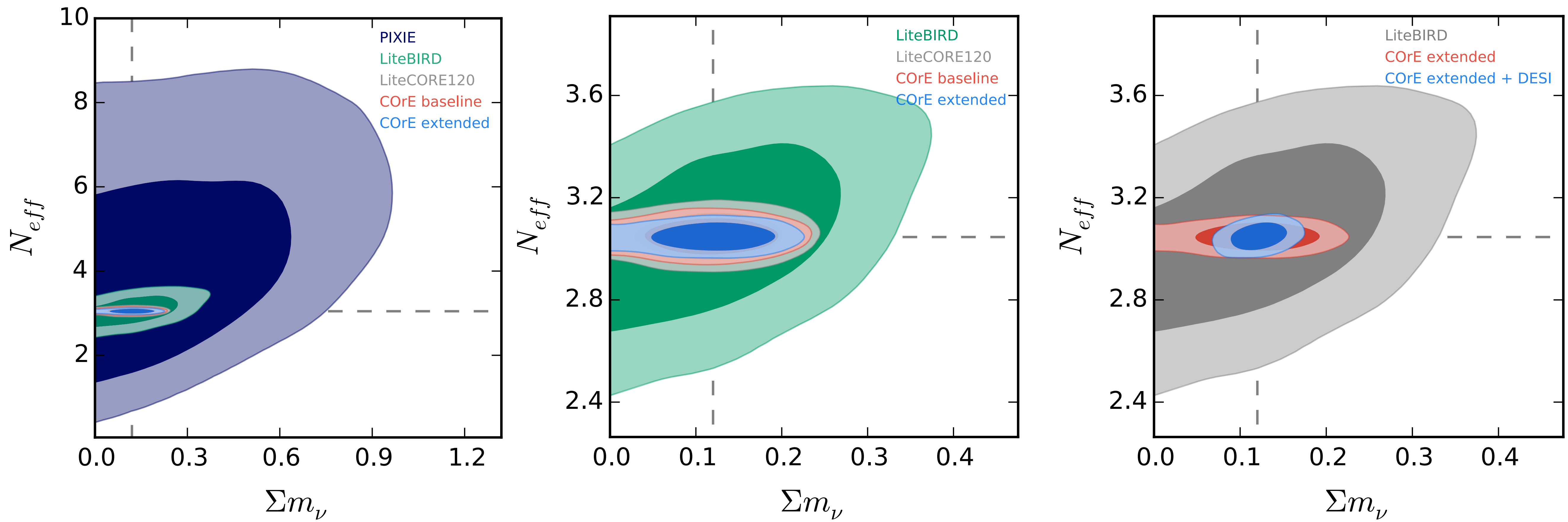
By considering a different fiducial value: mnu=0.12eV (IH?)



	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.417	$0.144^{+0.058}_{-0.12}$	0.118 ± 0.051	0.117 ± 0.048	$0.118^{+0.051}_{-0.042}$
$N_{\rm eff}$	$4.5^{+1.2}_{-2.1}$	3.09 ± 0.23	3.050 ± 0.056	3.049 ± 0.043	3.047 ± 0.034

In this case we have more than 2 sigma detection for COrE+.

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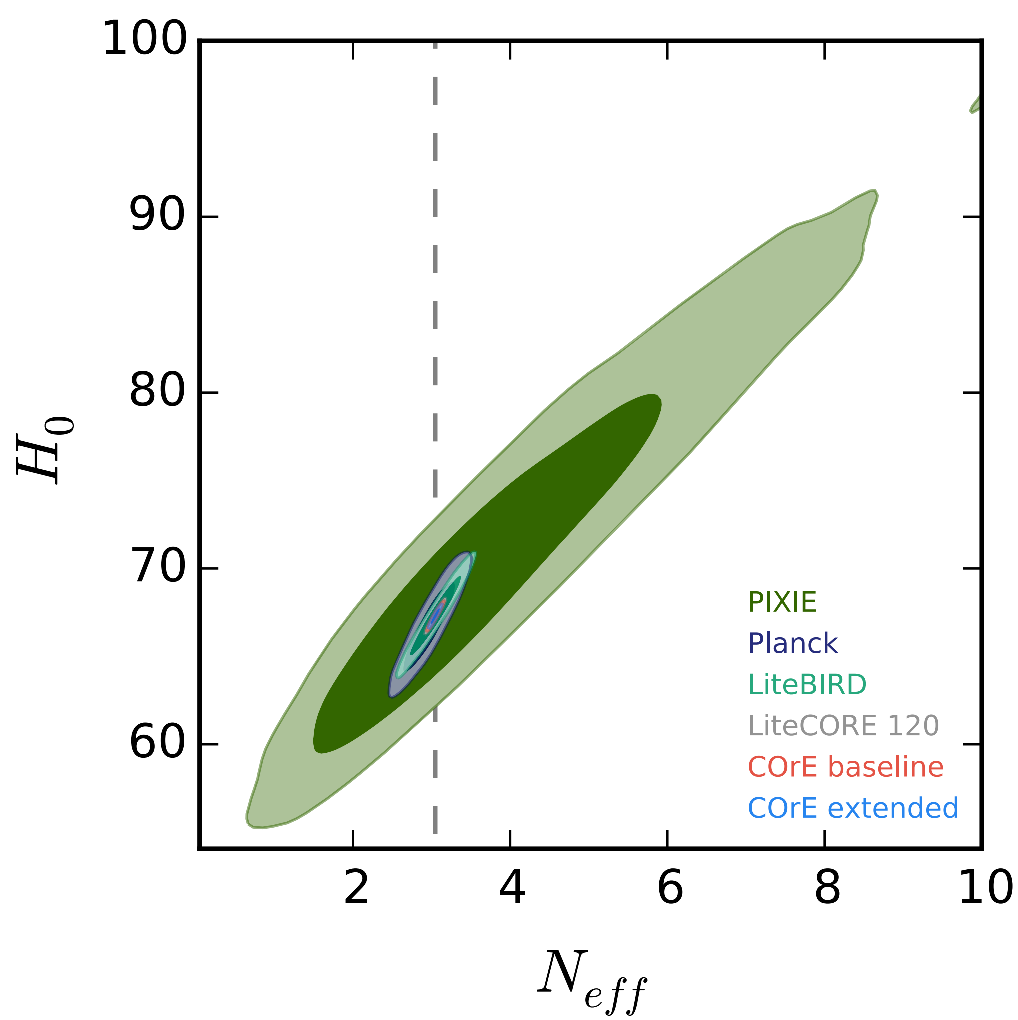
With COrE+ we can constrain the neutrino effective number better than all the other experiments..



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..we gain about a factor 4(7) with respect to the Planck polarization..

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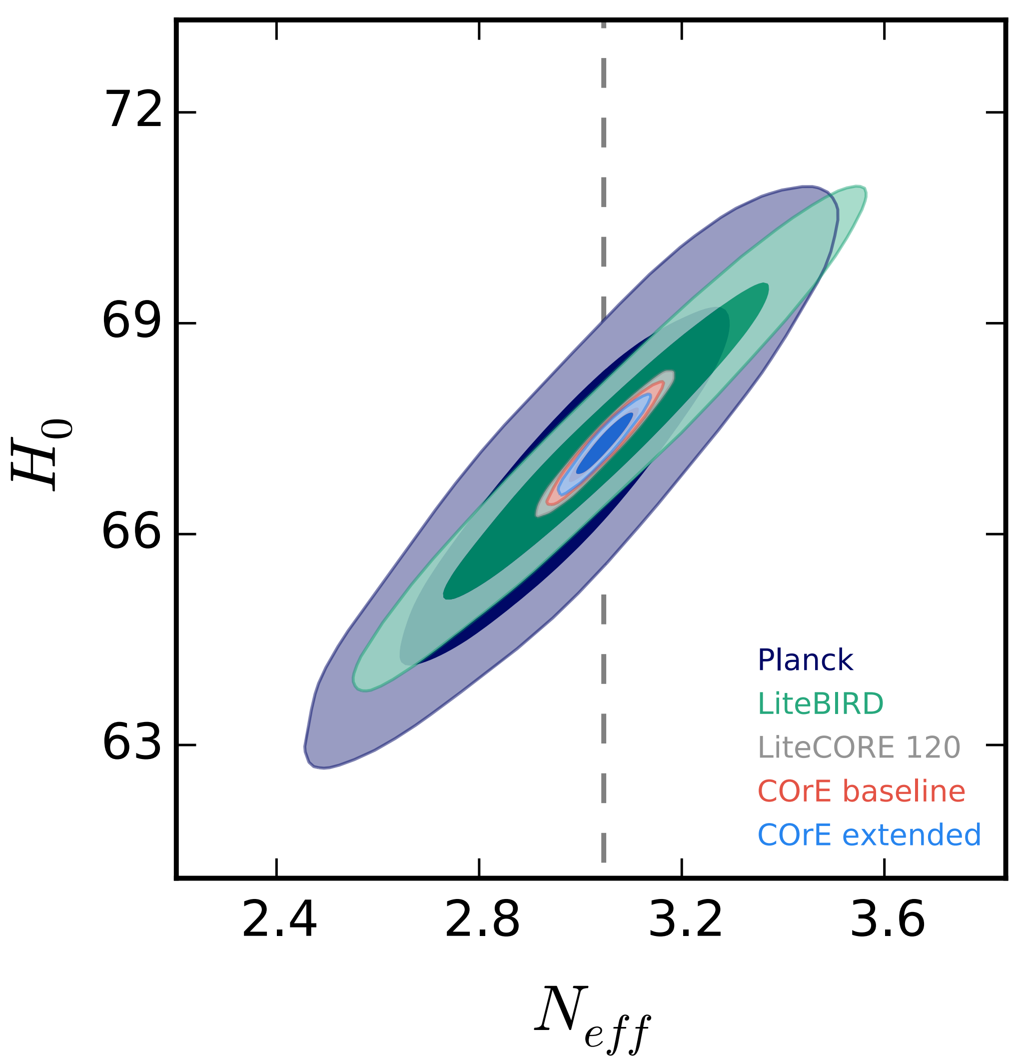

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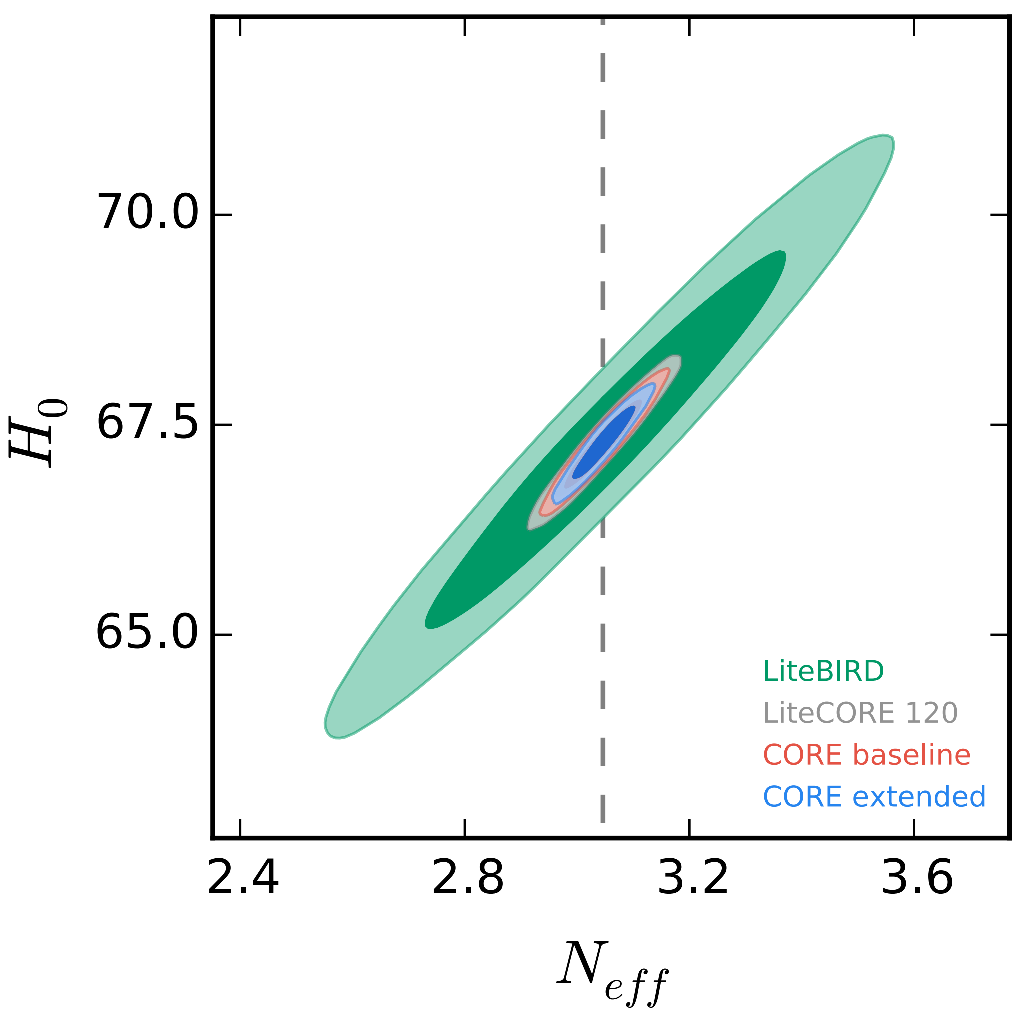

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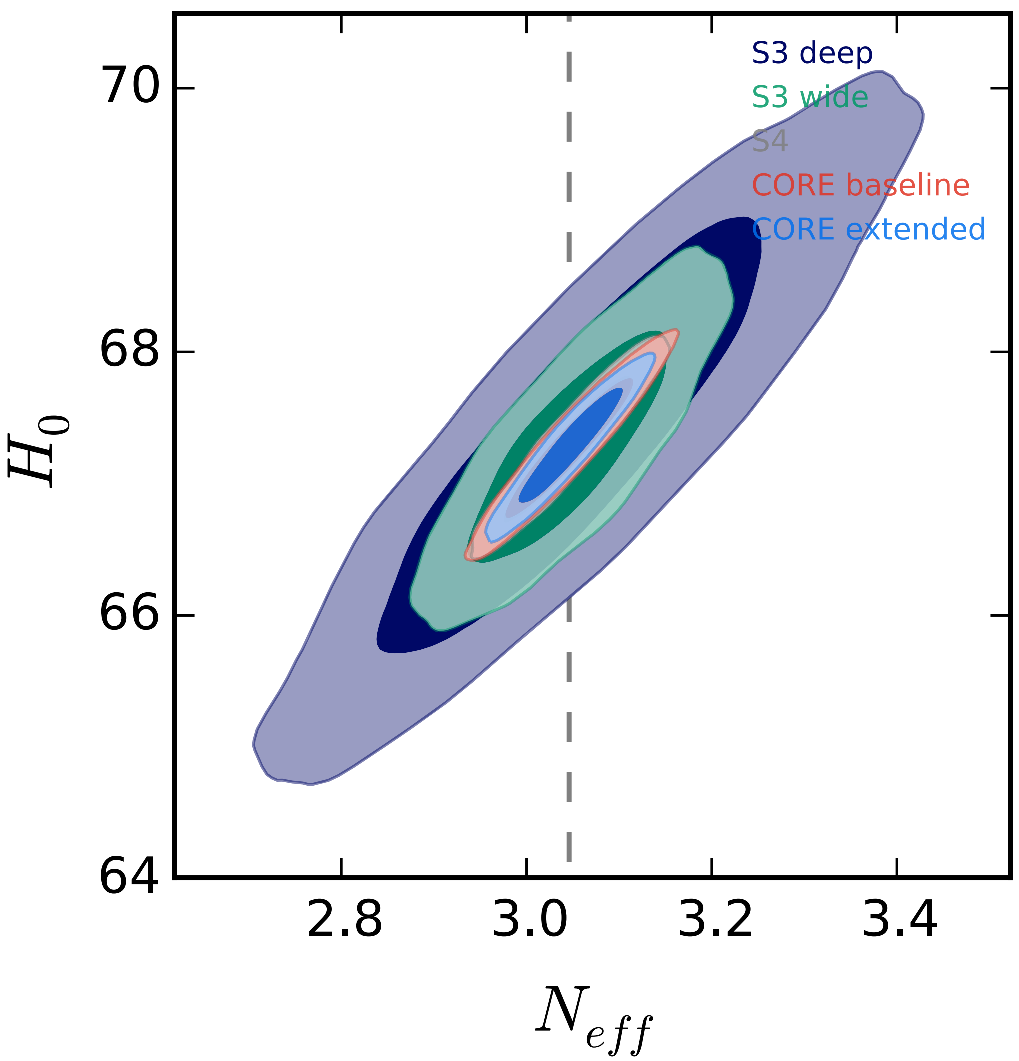
The only ground based telescope competitive with COrE is Stage-IV considering a tau prior as Planck HFI at low ell.



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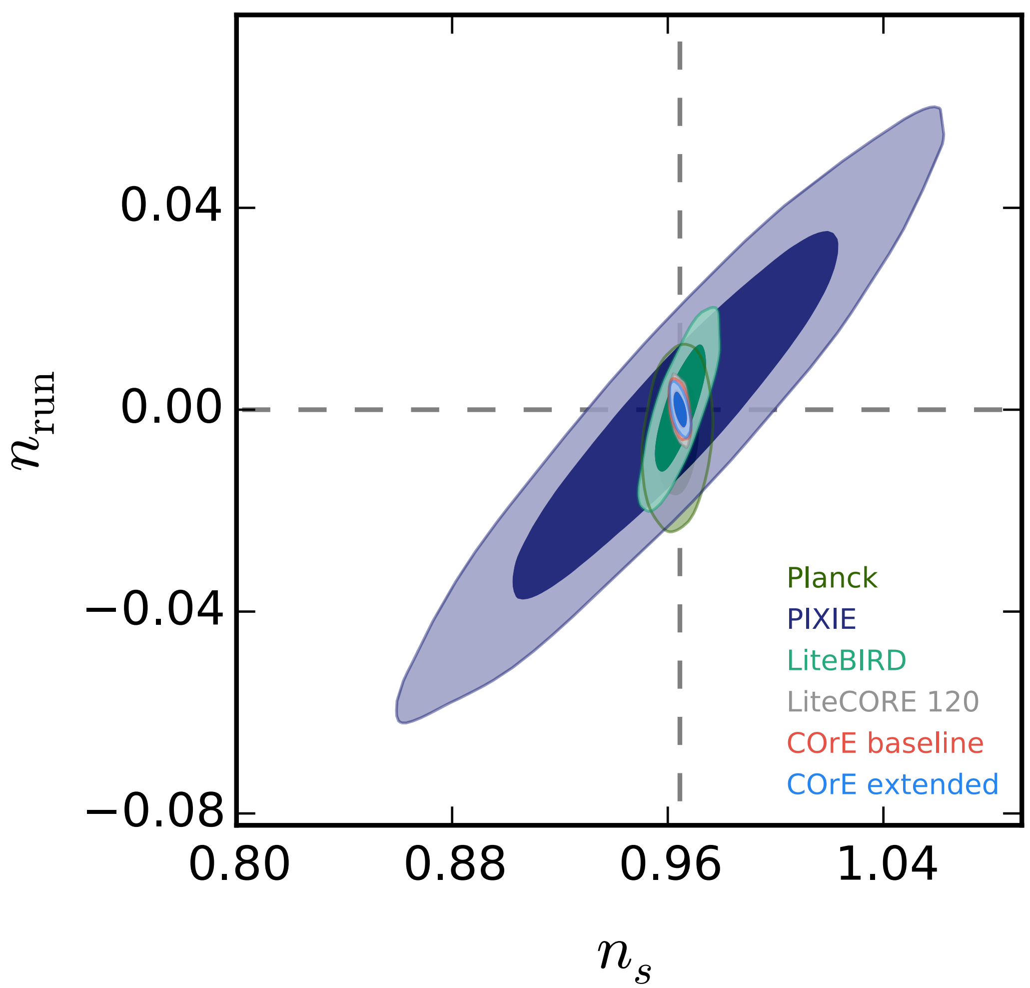

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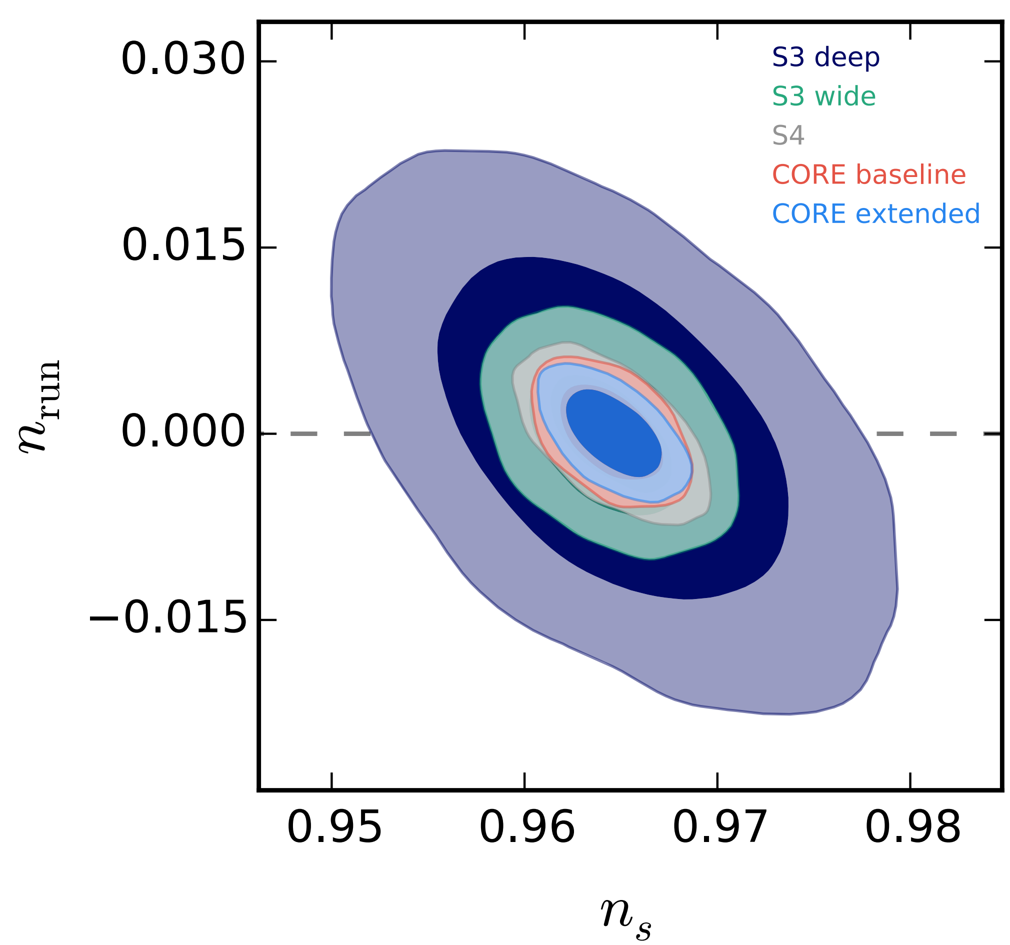
The ground based experiments cannot constrain the running with the same accuracy, but Stage-IV can give very close results.



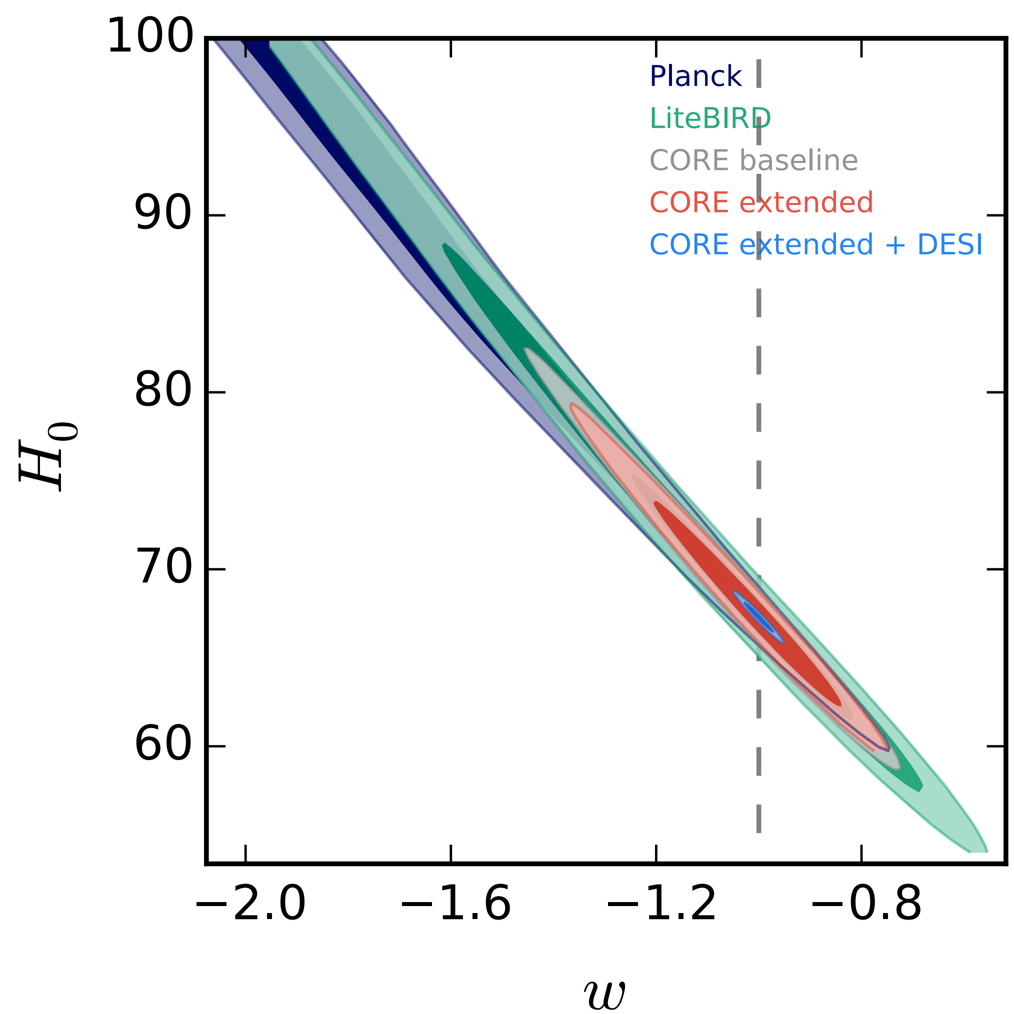
	S3wide + tau05	S3deep +tau05	S4 +tau05
Σm_ν [eV]	< 0.151	< 0.211	$0.085^{+0.035}_{-0.073}$
$N_{\rm eff}$	3.048 ± 0.068	3.06 ± 0.14	3.046 ± 0.043
$\frac{dln n_S}{dln k}$	-0.0001 ± 0.0040	0.0002 ± 0.0089	0.0000 ± 0.0029
r	< 0.00420	< 0.00439	< 0.000492
w	$-1.23^{+0.44}_{-0.24}$	$-1.25^{+0.46}_{-0.39}$	$-1.06^{+0.19}_{-0.12}$
Y_P	0.2454 ± 0.0041	0.2446 ± 0.0089	0.2452 ± 0.0029

EDV, F.R.Bouchet, in prep.

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.188	< 0.305	$0.107^{+0.038}_{-0.099}$	$0.083^{+0.041}_{-0.056}$	$0.078^{+0.039}_{-0.054}$	0.079 ± 0.041
$N_{\rm eff}$	2.99 ± 0.20	$3.9^{+1.0}_{-1.9}$	3.06 ± 0.20	3.048 ± 0.055	3.047 ± 0.043	3.047 ± 0.035
$\frac{dln n_S}{dln k}$	-0.0057 ± 0.0071	-0.001 ± 0.024	0.0003 ± 0.0080	-0.0001 ± 0.0028	0.0001 ± 0.0024	0.0001 ± 0.0022
r	< 0.0463	< 0.000304	< 0.000300	< 0.000243	< 0.000192	< 0.000173
w	$-1.19^{+0.54}_{-0.42}$	$-1.10^{+0.25}_{-0.14}$	$-1.18^{+0.40}_{-0.24}$	$-1.09^{+0.23}_{-0.11}$	$-1.05^{+0.17}_{-0.11}$	$-1.03^{+0.14}_{-0.09}$
Y_P	0.250 ± 0.014	$0.237^{+0.057}_{-0.048}$	0.245 ± 0.012	0.2453 ± 0.0037	0.2454 ± 0.0029	0.2454 ± 0.0023

TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

CorE in all the configurations can constrain dark energy better than all the other experiments.



	S3wide + tau05	S3deep +tau05	S4 +tau05
Σm_ν [eV]	< 0.151	< 0.211	$0.085^{+0.035}_{-0.073}$
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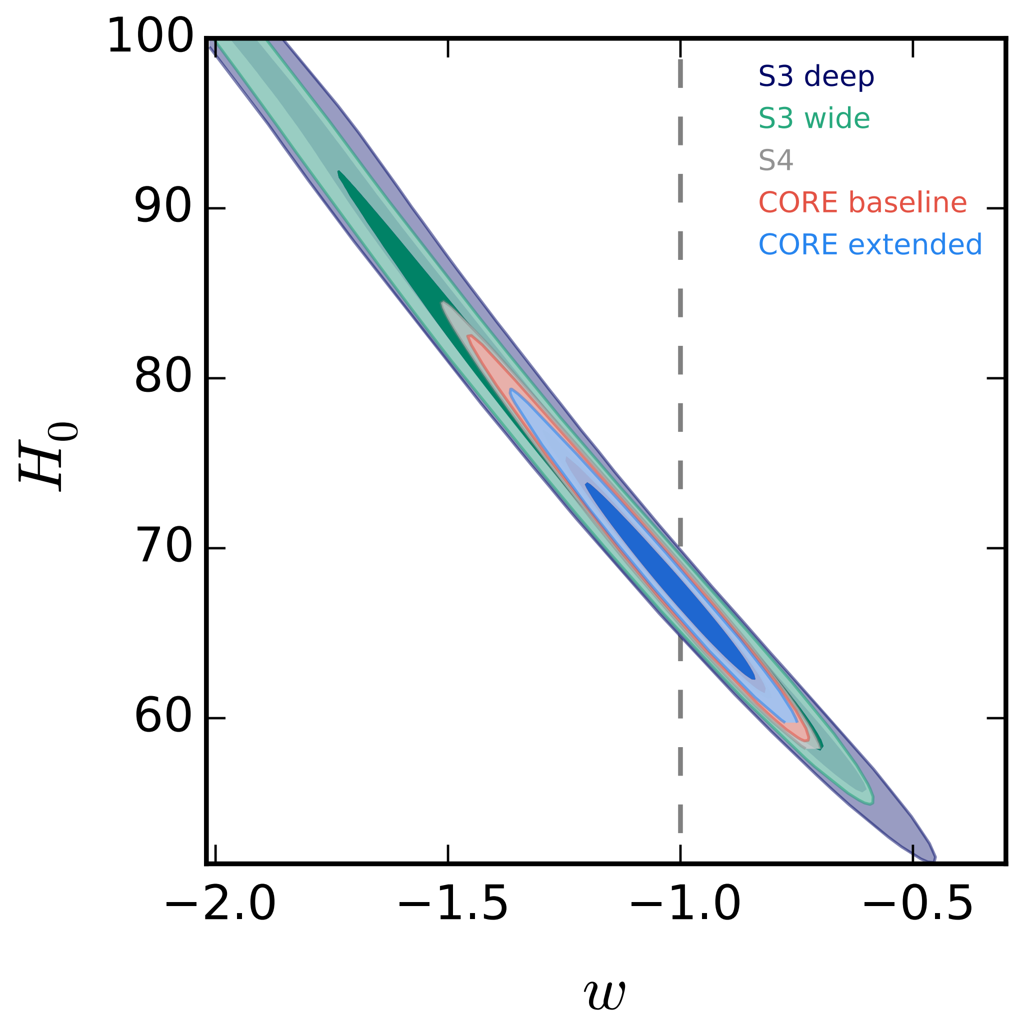
TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

..and also with respect to all the ground based telescopes.



	S3wide + tau05	S3deep +tau05	S4 +tau05
Σm_ν [eV]	< 0.151	< 0.211	$0.085^{+0.035}_{-0.073}$
$N_{\rm eff}$	3.048 ± 0.068	3.06 ± 0.14	3.046 ± 0.043
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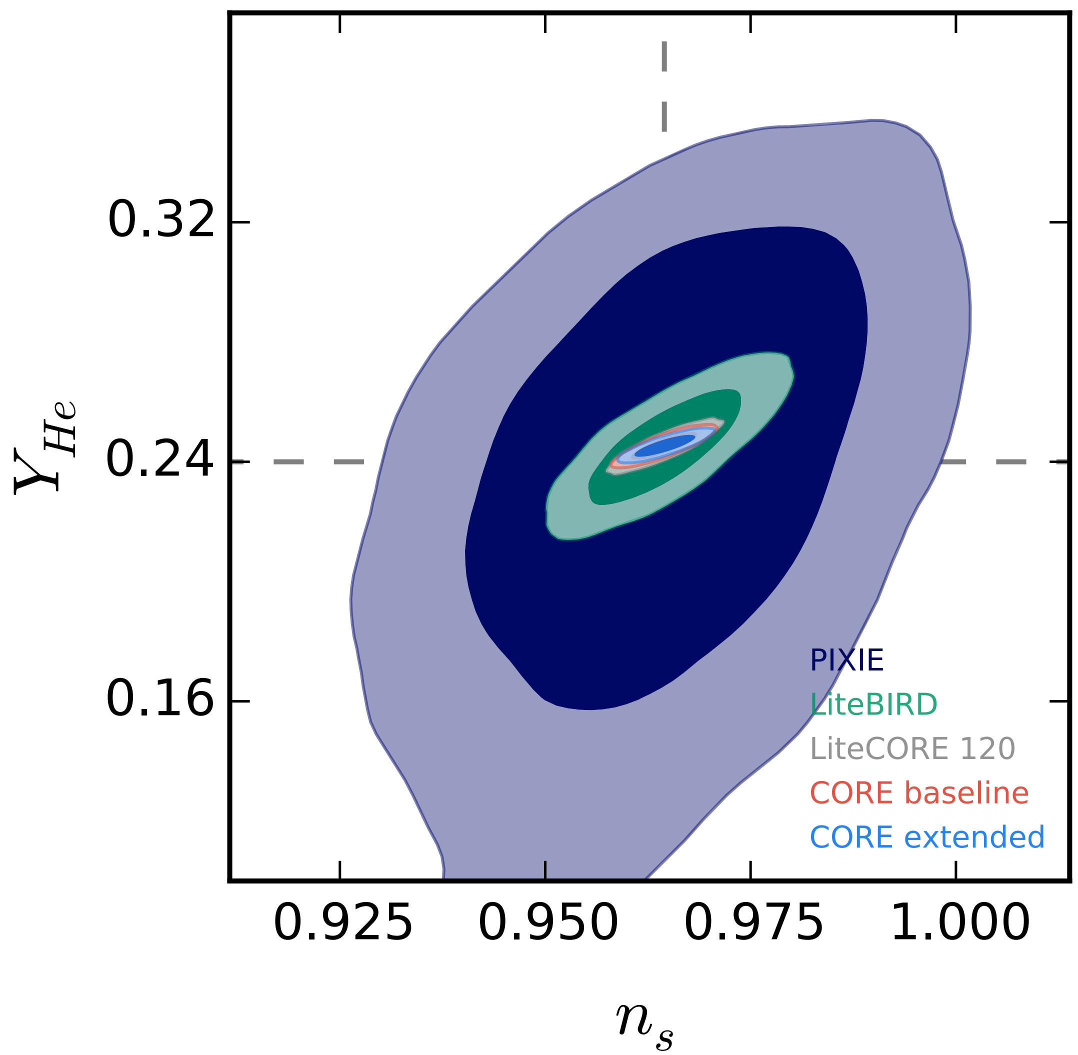
TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

Also in the BBN sector we can improve Planck constraints on the primordial helium abundance by a factor 6.



	S3wide + tau05	S3deep +tau05	S4 +tau05
Σm_ν [eV]	< 0.151	< 0.211	$0.085^{+0.035}_{-0.073}$
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EDV, F.R.Bouchet, in prep.

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.188	< 0.305	$0.107^{+0.038}_{-0.099}$	$0.083^{+0.041}_{-0.056}$	$0.078^{+0.039}_{-0.054}$	0.079 ± 0.041
$N_{\rm eff}$	2.99 ± 0.20	$3.9^{+1.0}_{-1.9}$	3.06 ± 0.20	3.048 ± 0.055	3.047 ± 0.043	3.047 ± 0.035
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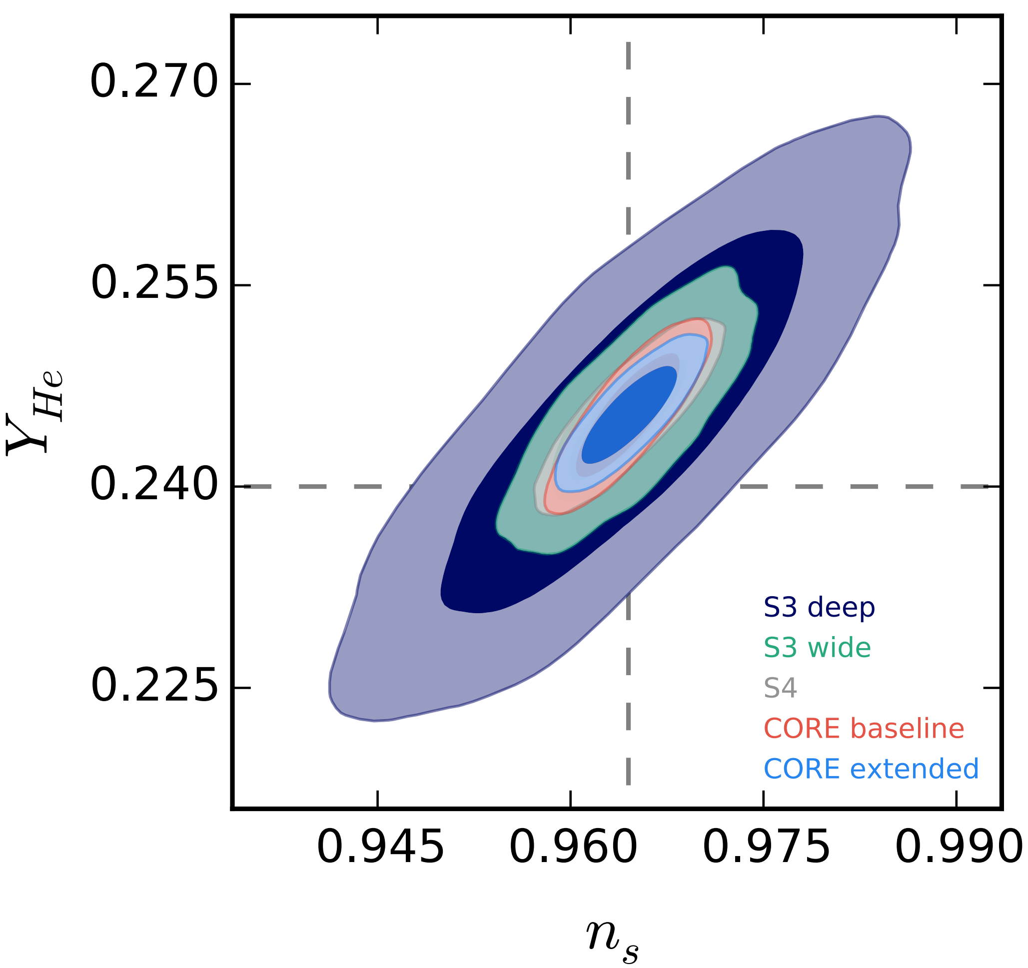
TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

Stage-IV is competitive with COrE+ baseline in constraining the primordial helium abundance.



	S3wide + tau05	S3deep +tau05	S4 +tau05
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$\frac{dln n_S}{dln k}$	-0.0001 ± 0.0040	0.0002 ± 0.0089	0.0000 ± 0.0029
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w	$-1.23^{+0.44}_{-0.24}$	$-1.25^{+0.46}_{-0.39}$	$-1.06^{+0.19}_{-0.12}$
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EDV, F.R.Bouchet, in prep.

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.188	< 0.305	$0.107^{+0.038}_{-0.099}$	$0.083^{+0.041}_{-0.056}$	$0.078^{+0.039}_{-0.054}$	0.079 ± 0.041
$N_{\rm eff}$	2.99 ± 0.20	$3.9^{+1.0}_{-1.9}$	3.06 ± 0.20	3.048 ± 0.055	3.047 ± 0.043	3.047 ± 0.035
$\frac{dln n_S}{dln k}$	-0.0057 ± 0.0071	-0.001 ± 0.024	0.0003 ± 0.0080	-0.0001 ± 0.0028	0.0001 ± 0.0024	0.0001 ± 0.0022
r	< 0.0463	< 0.000304	< 0.000300	< 0.000243	< 0.000192	< 0.000173
w	$-1.19^{+0.54}_{-0.42}$	$-1.10^{+0.25}_{-0.14}$	$-1.18^{+0.40}_{-0.24}$	$-1.09^{+0.23}_{-0.11}$	$-1.05^{+0.17}_{-0.11}$	$-1.03^{+0.14}_{-0.09}$
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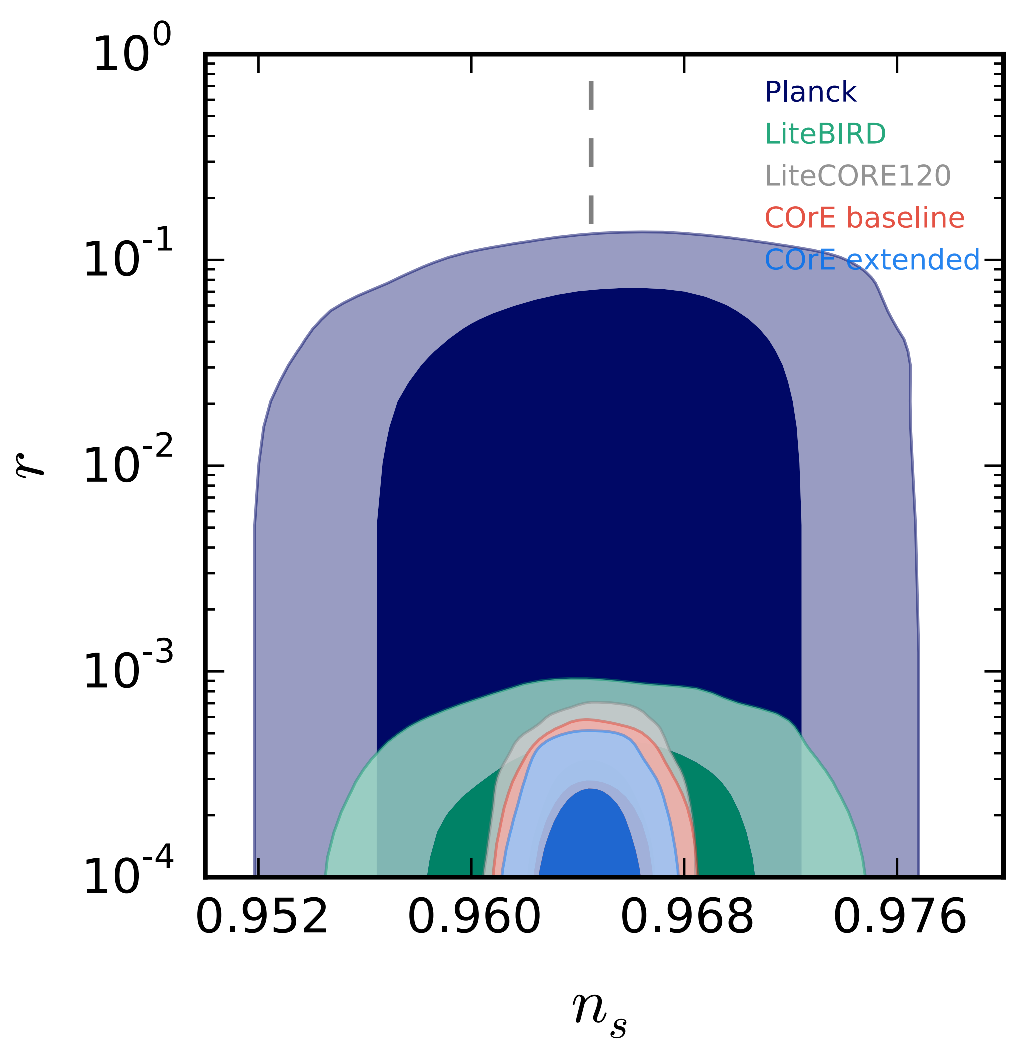
TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

With new satellite experiments we gain more than 2 order of magnitude with respect to the Planck polarization.



EDV, F.R.Bouchet, in prep.

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$N_{\rm eff}$	3.048 ± 0.068	3.06 ± 0.14	3.046 ± 0.043
$\frac{dln n_S}{dln k}$	-0.0001 ± 0.0040	0.0002 ± 0.0089	0.0000 ± 0.0029
r	< 0.00420	< 0.00439	< 0.000492
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Y_P	0.2454 ± 0.0041	0.2446 ± 0.0089	0.2452 ± 0.0029

These results are without considering delensing.

	Planck TTTEEE + lowTEB	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
Σm_ν [eV]	< 0.188	< 0.305	$0.107^{+0.038}_{-0.099}$	$0.083^{+0.041}_{-0.056}$	$0.078^{+0.039}_{-0.054}$	0.079 ± 0.041
$N_{\rm eff}$	2.99 ± 0.20	$3.9^{+1.0}_{-1.9}$	3.06 ± 0.20	3.048 ± 0.055	3.047 ± 0.043	3.047 ± 0.035
$\frac{dln n_S}{dln k}$	-0.0057 ± 0.0071	-0.001 ± 0.024	0.0003 ± 0.0080	-0.0001 ± 0.0028	0.0001 ± 0.0024	0.0001 ± 0.0022
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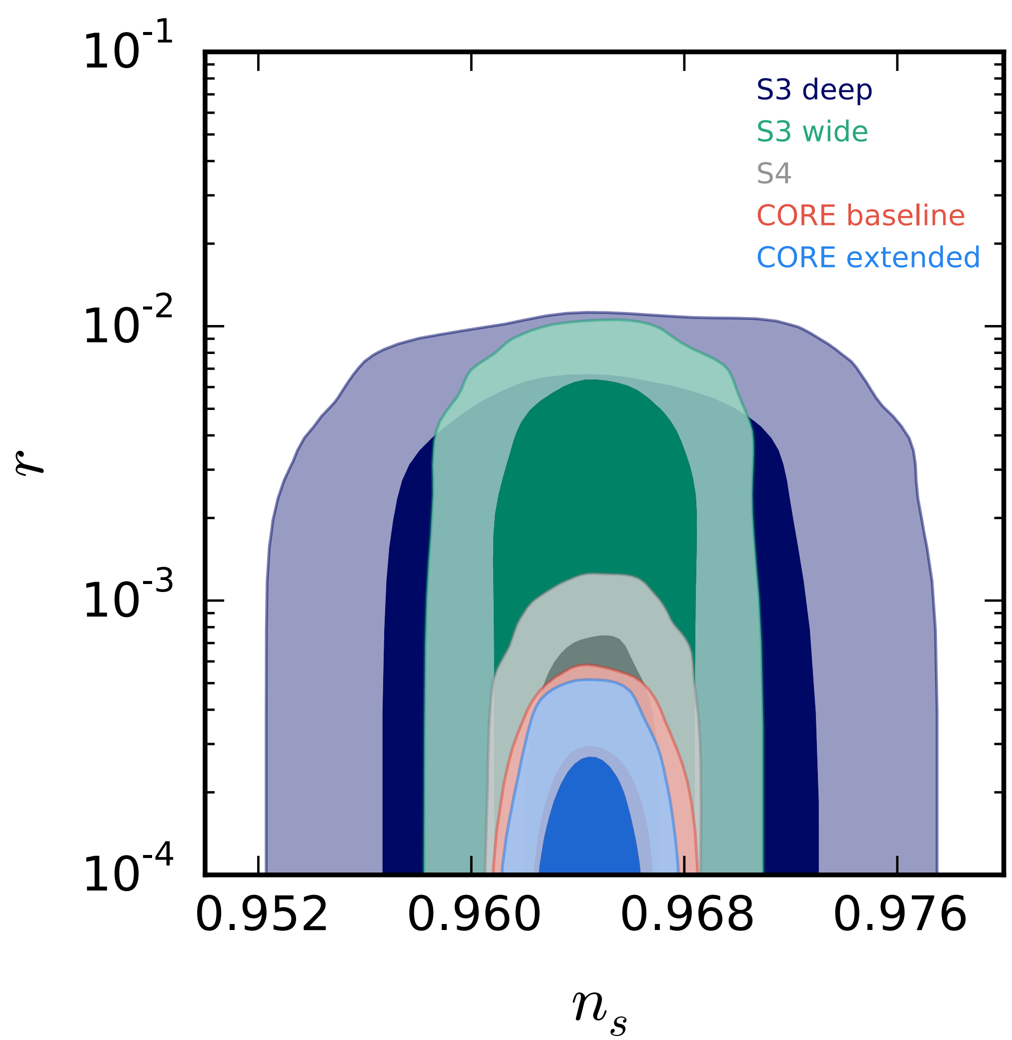
Y_P	0.250 ± 0.014	$0.237^{+0.057}_{-0.048}$	0.245 ± 0.012	0.2453 ± 0.0037	0.2454 ± 0.0029	0.2454 ± 0.0023

TABLE I: 68% CL constraints on cosmological parameters in the ΛCDM + one parameter extension model.

..and COrE+ can do more than a factor 2 better than Stage-IV, without considering delensing.



	S3wide + tau05	S3deep +tau05	S4 +tau05
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Y_P	0.2454 ± 0.0041	0.2446 ± 0.0089	0.2452 ± 0.0029

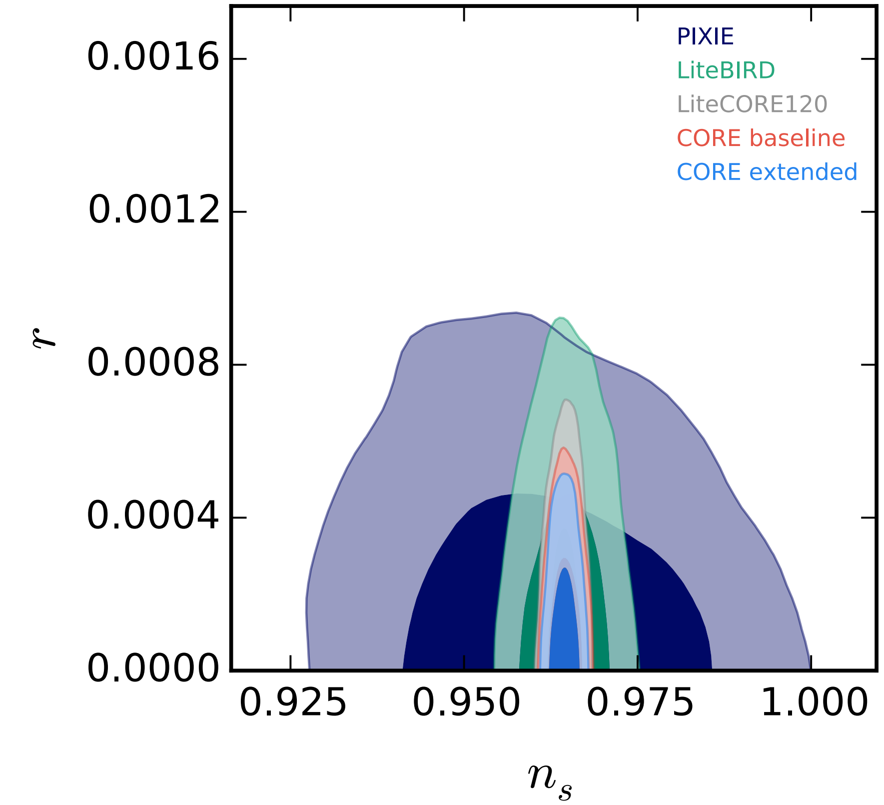
EDV, F.R.Bouchet, in prep.

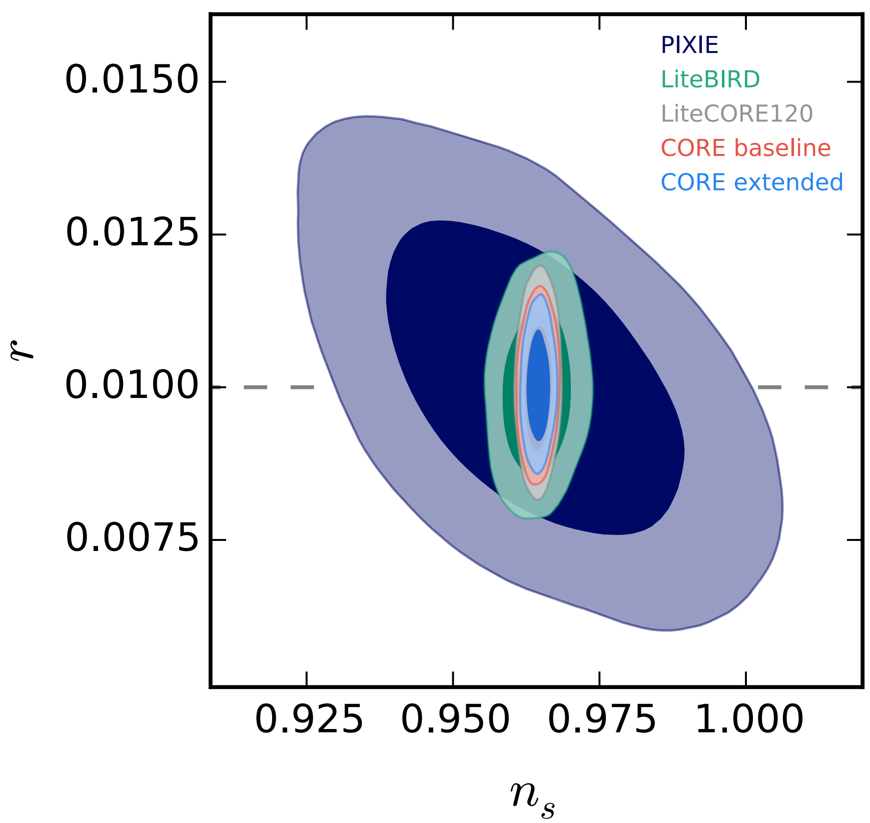
w/o delensing

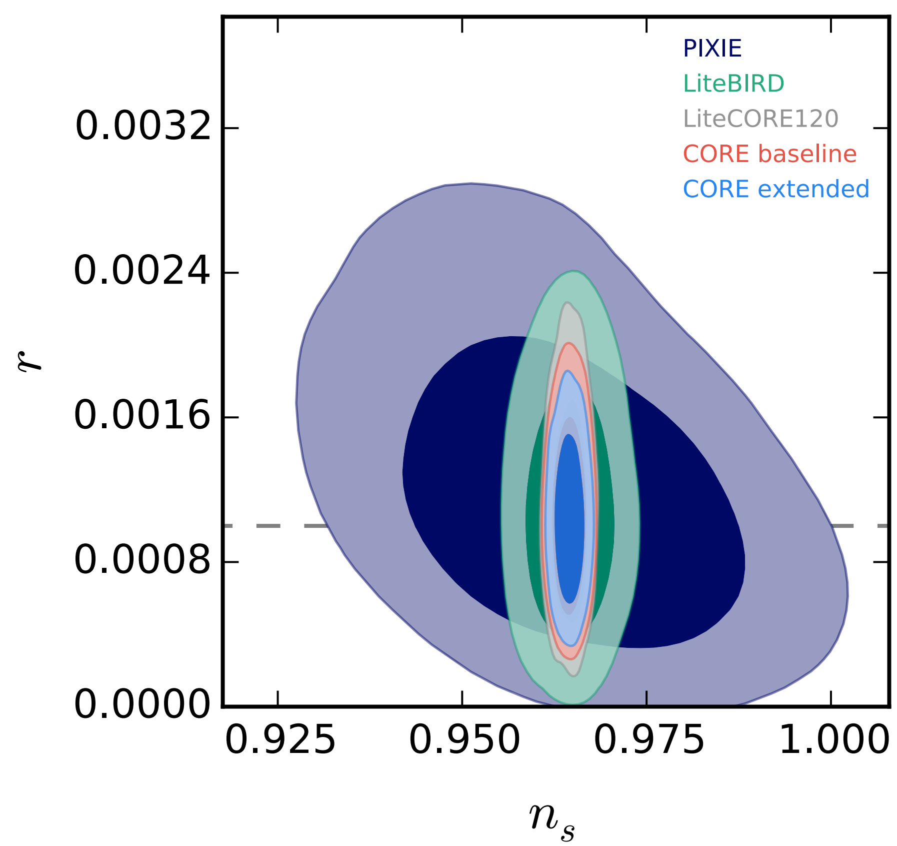
	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0]$	< 0.000304	< 0.000300	< 0.000243	< 0.000192	< 0.000173
$r[0.01]$	0.0101 ± 0.0016	$0.00996^{+0.00082}_{-0.00094}$	0.01006 ± 0.00073	0.01000 ± 0.00062	0.01002 ± 0.00056
$r[0.001]$	$0.00125^{+0.00036}_{-0.00070}$	$0.00112^{+0.00035}_{-0.00054}$	$0.00110^{+0.00031}_{-0.00046}$	$0.00108^{+0.00030}_{-0.00039}$	$0.00105^{+0.00026}_{-0.00034}$
$r[0.0001]$	< 0.000420	< 0.000378	< 0.000344	< 0.000284	< 0.000253

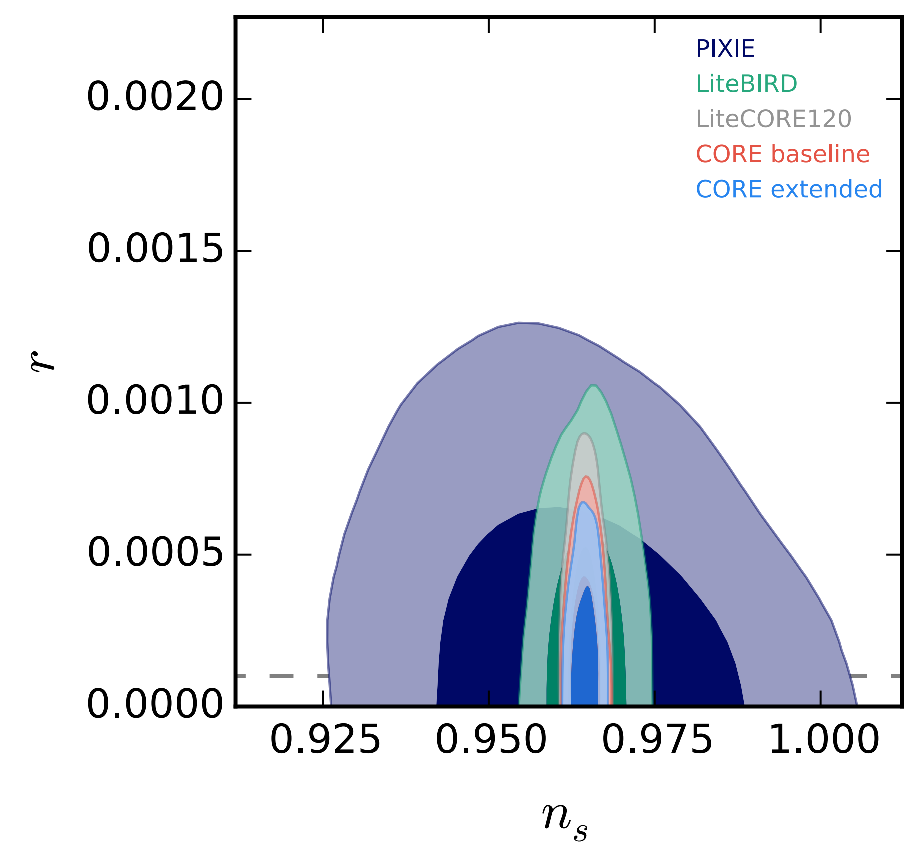
TABLE I: 68% CL constraints on r in the $LCDM + r$ model, for different fiducial values.

EDV, F.R.Bouchet, in prep.







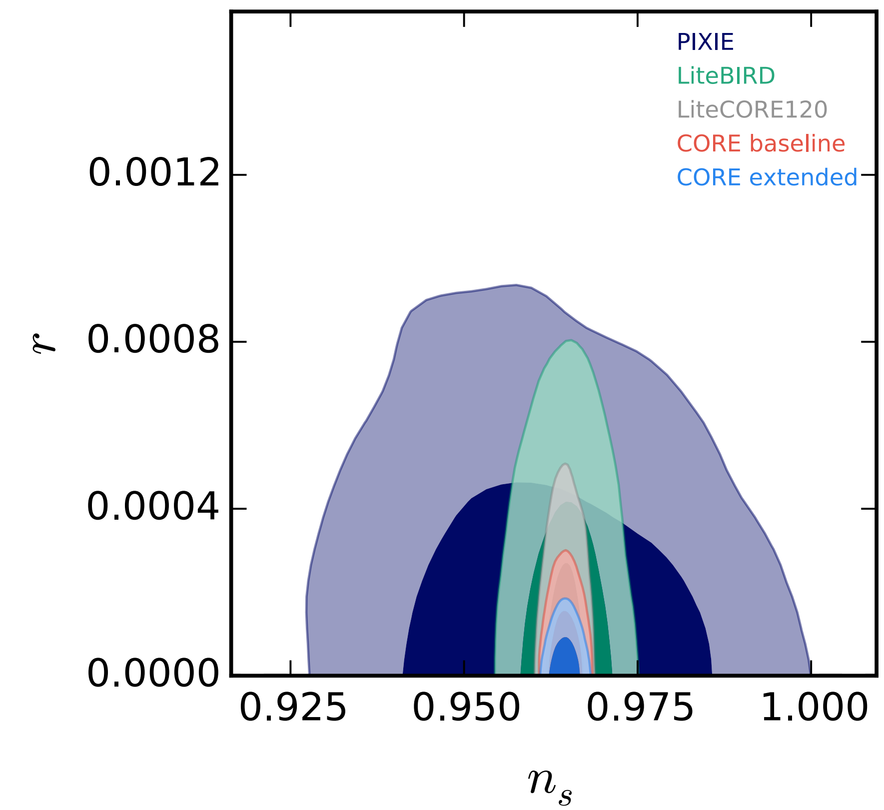


We can constrain at about 3 sigma r until 10^-3 without delensing.
We have no significant difference between the different experiments.

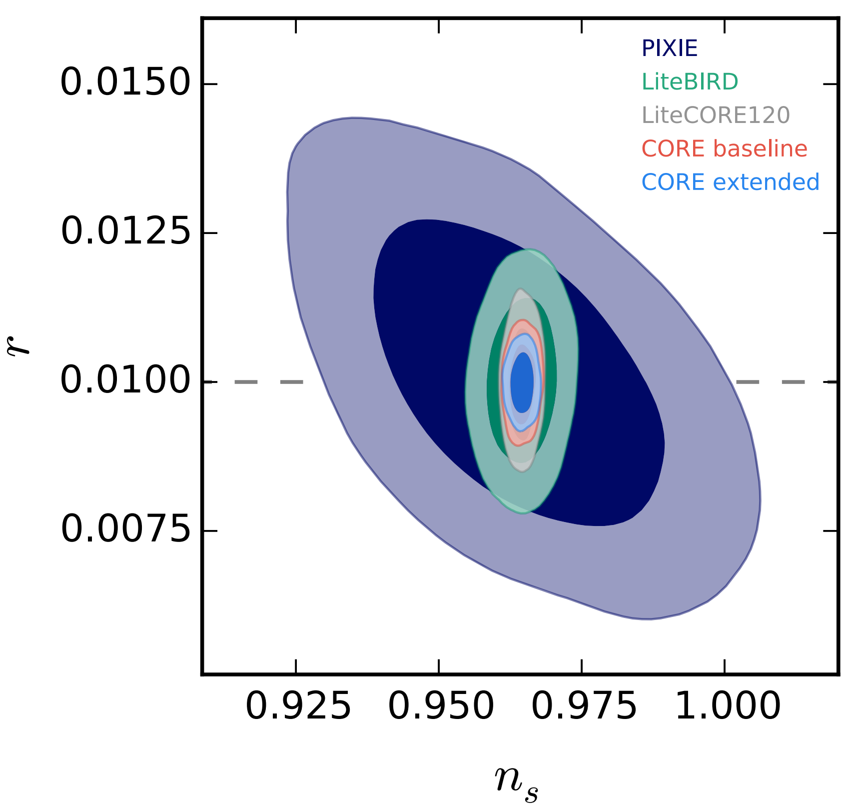
with delensing

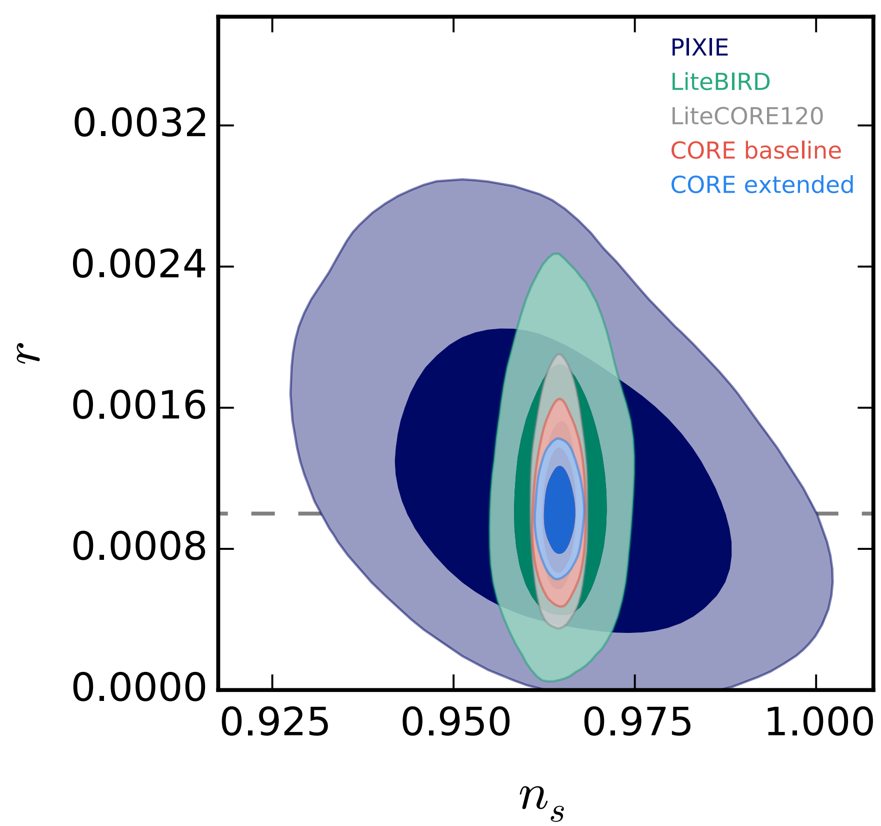
	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0]$	< 0.000304	< 0.000269	< 0.000170	< 0.0000990	< 0.0000596
$r[0.01]$	0.0101 ± 0.0016	0.01002 ± 0.00085	0.00999 ± 0.00058	0.00998 ± 0.00042	$0.00998^{+0.00030}_{-0.00034}$
$r[0.001]$	$0.00125^{+0.00036}_{-0.00070}$	$0.00115^{+0.00035}_{-0.00053}$	$0.00106^{+0.00028}_{-0.00034}$	$0.00103^{+0.00020}_{-0.00025}$	0.00102 ± 0.00015
$r[0.0001]$	< 0.000420	< 0.000364	< 0.000264	$0.00016^{+0.00005}_{-0.00014}$	$0.000132^{+0.000047}_{-0.000093}$

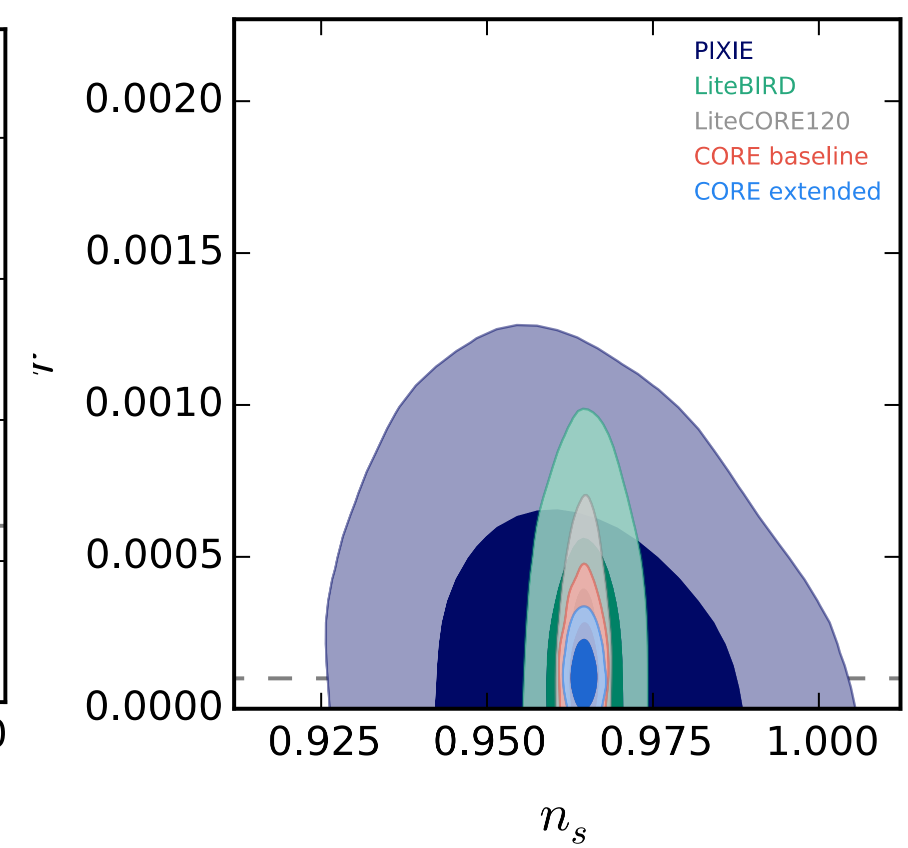
TABLE I: 68% CL constraints on r in the $LCDM + r$ model, for different fiducial values.



EDV, F.R.Bouchet, in prep.







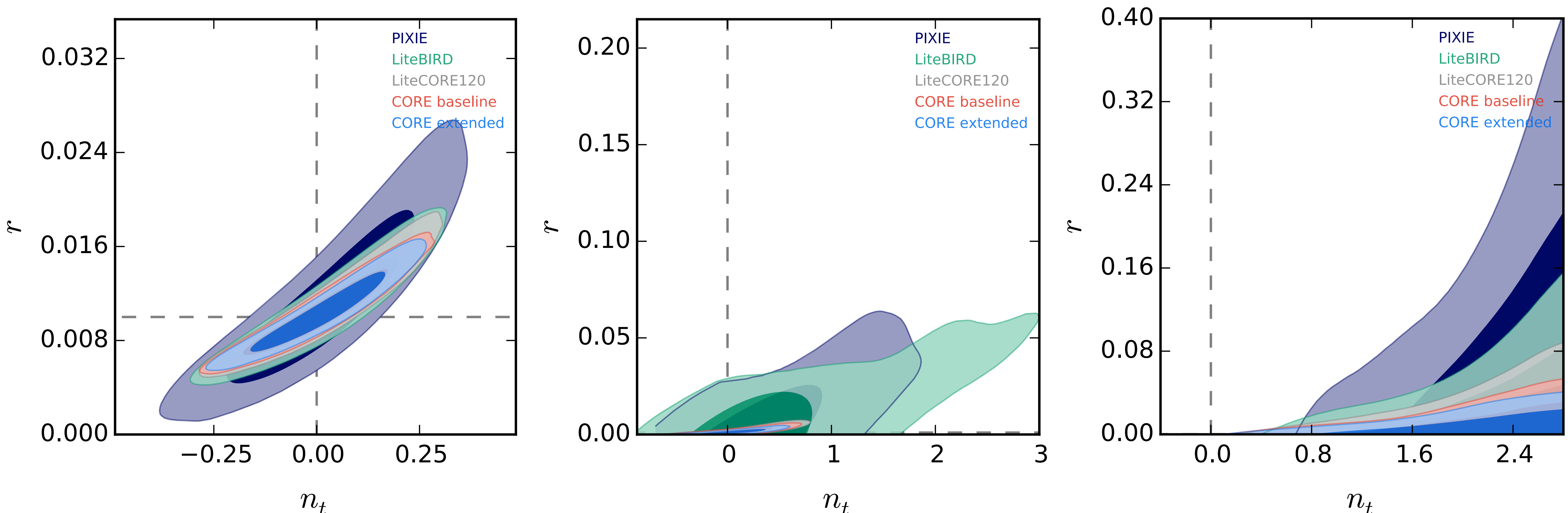
Considering the internal delensing, we gain a factor 2 between COrE+ and LiteBIRD, constraining a possible r=10^-3 at about 5 sigma level.
An indication at 1 sigma for r=10^-4 starts to appear with COrE.

w/o delensing

	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0.01]$	$0.0118^{+0.0031}_{-0.0058}$	$0.0109^{+0.0022}_{-0.0035}$	$0.0109^{+0.0022}_{-0.0032}$	$0.0105^{+0.0019}_{-0.0028}$	$0.0105^{+0.0018}_{-0.0025}$
n_T	0.03 ± 0.14	0.02 ± 0.12	$0.03^{+0.13}_{-0.11}$	0.01 ± 0.11	0.02 ± 0.10
$r[0.001]$	< 0.00864	< 0.00395	$0.0022^{+0.0005}_{-0.0021}$	$0.0019^{+0.0005}_{-0.0016}$	$0.0016^{+0.0005}_{-0.0013}$
n_T	$0.50^{+0.28}_{-0.47}$	$0.41^{+0.21}_{-0.56}$	0.16 ± 0.28	0.12 ± 0.26	$0.08^{+0.24}_{-0.22}$
$r[0.0001]$	< 0.122	< 0.0455	< 0.0270	< 0.0180	< 0.0145
n_T	> 2.24	> 2.19	> 2.12	> 2.06	> 2.00

TABLE II: 68% CL constraints on r and n_T in a $LCDM + r + n_T$ model, for different fiducial values.

EDV, F.R.Bouchet, in prep.



When varying also n_T, while we have no difference with a fiducial r=10^-2, COrE+ starts to have an indication at 1 sigma for a fiducial r=10^-3..

w/o delensing

	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0.01]$	$0.0118^{+0.0031}_{-0.0058}$	$0.0109^{+0.0022}_{-0.0035}$	$0.0109^{+0.0022}_{-0.0032}$	$0.0105^{+0.0019}_{-0.0028}$	$0.0105^{+0.0018}_{-0.0025}$
n_T	0.03 ± 0.14	0.02 ± 0.12	$0.03^{+0.13}_{-0.11}$	0.01 ± 0.11	0.02 ± 0.10
$r[0.001]$	< 0.00864	< 0.00395	$0.0022^{+0.0005}_{-0.0021}$	$0.0019^{+0.0005}_{-0.0016}$	$0.0016^{+0.0005}_{-0.0013}$
n_T	$0.50^{+0.28}_{-0.47}$	$0.41^{+0.21}_{-0.56}$	0.16 ± 0.28	0.12 ± 0.26	$0.08^{+0.24}_{-0.22}$
$r[0.0001]$	< 0.122	< 0.0455	< 0.0270	< 0.0180	< 0.0145
n_T	> 2.24	> 2.19	> 2.12	> 2.06	> 2.00

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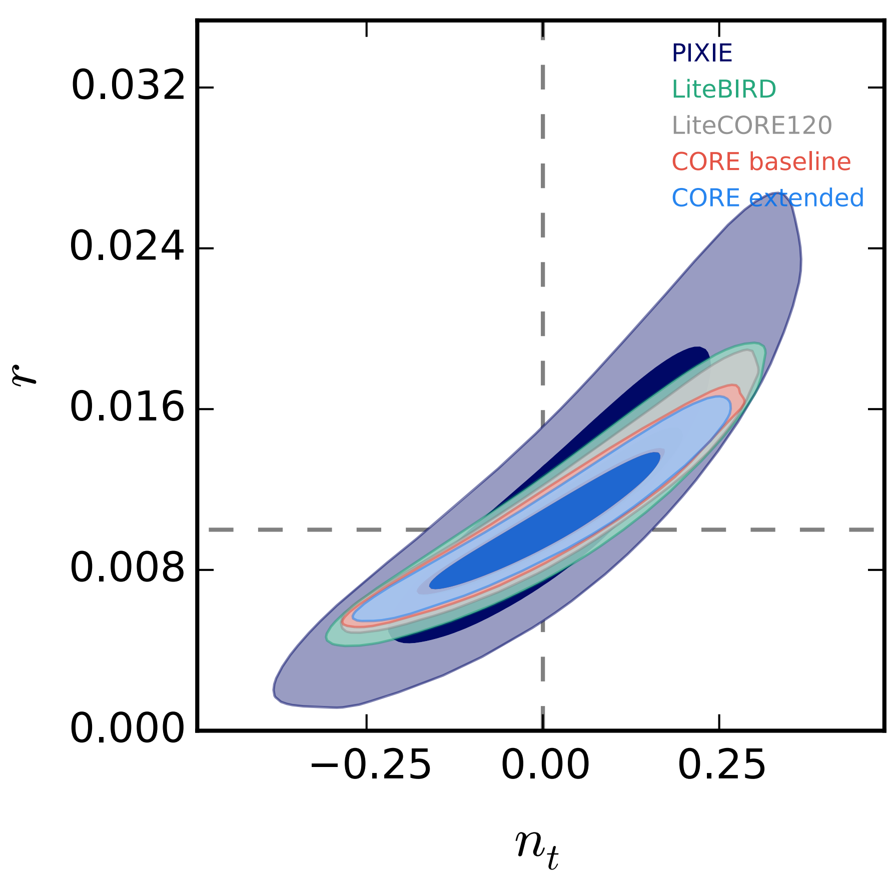
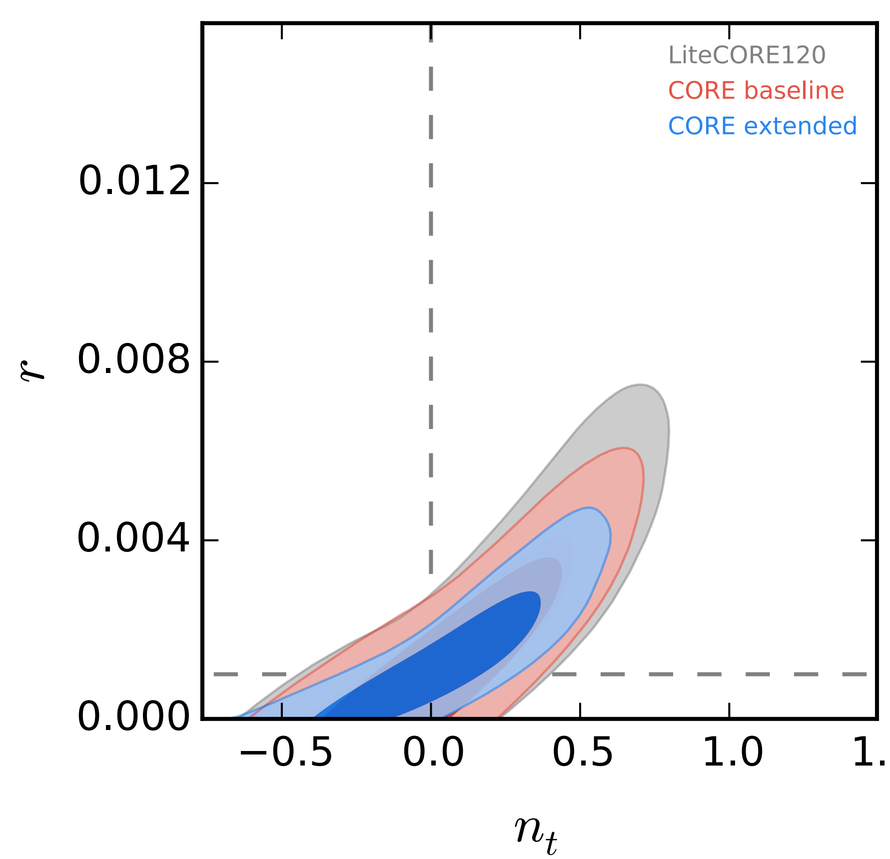
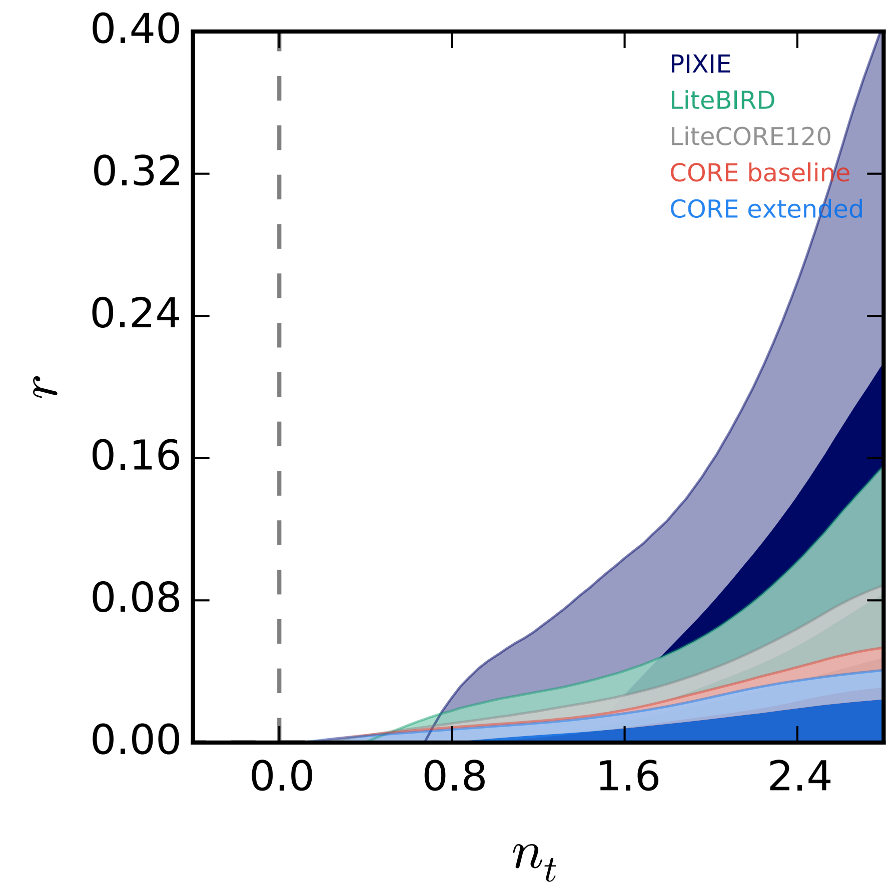
EDV, F.R.Bouchet, in prep.







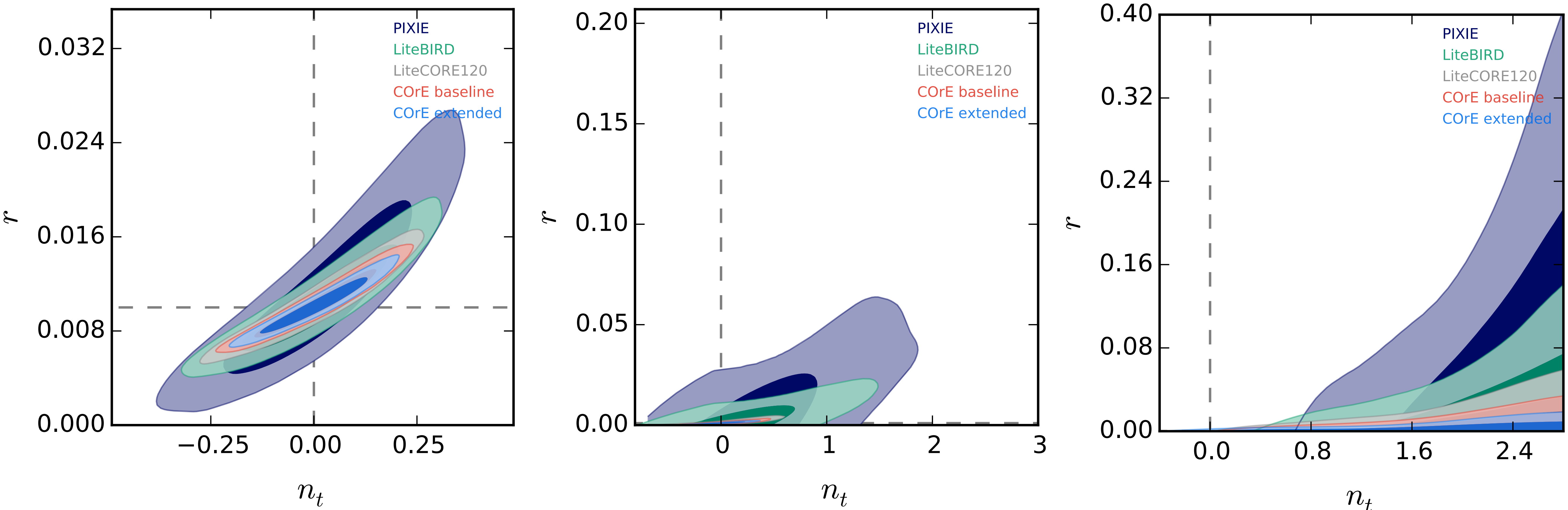
We have a factor 2 between COrE+ and LiteBIRD when r=10^-4.

with delensing

	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0.01]$	$0.0118^{+0.0031}_{-0.0058}$	$0.0109^{+0.0023}_{-0.0034}$	$0.0106^{+0.0020}_{-0.0026}$	$0.0104^{+0.0016}_{-0.0021}$	$0.0103^{+0.0014}_{-0.0017}$
n_T	0.03 ± 0.14	0.02 ± 0.12	0.02 ± 0.10	0.014 ± 0.091	0.010 ± 0.080
$r[0.001]$	< 0.00864	< 0.00327	$0.0016^{+0.0005}_{-0.0013}$	$0.00132^{+0.00038}_{-0.00081}$	$0.00112^{+0.00029}_{-0.00049}$
n_T	$0.50^{+0.28}_{-0.47}$	$0.30^{+0.24}_{-0.43}$	$0.09^{+0.24}_{-0.21}$	0.06 ± 0.18	0.02 ± 0.14
$r[0.0001]$	< 0.122	< 0.0418	< 0.0184	< 0.0107	< 0.00584
n_T	> 2.24	> 2.16	> 2.06	> 2.01	> 1.61

TABLE II: 68% CL constraints on r and n_T in a $LCDM + r + n_T$ model, for different fiducial values.

EDV, F.R.Bouchet, in prep.



By considering the internal delensing, we gain a lot of sensitivity with COrE+..

with delensing

	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0.01]$	$0.0118^{+0.0031}_{-0.0058}$	$0.0109^{+0.0023}_{-0.0034}$	$0.0106^{+0.0020}_{-0.0026}$	$0.0104^{+0.0016}_{-0.0021}$	$0.0103^{+0.0014}_{-0.0017}$
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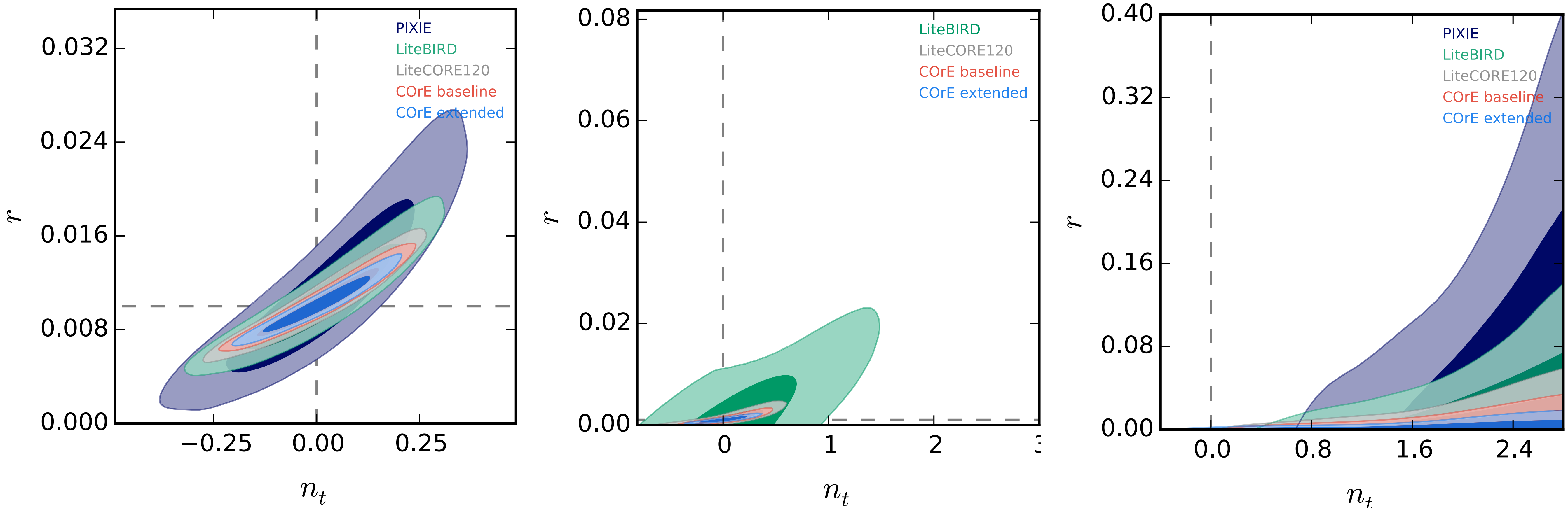

In fact it is the only experiment to can constrain r=10^-3 at more than 2 sigma level..

with delensing

	PIXIE	LiteBIRD	LiteCORE120	COrE+ baseline	COrE+ extended
$r[0.01]$	$0.0118^{+0.0031}_{-0.0058}$	$0.0109^{+0.0023}_{-0.0034}$	$0.0106^{+0.0020}_{-0.0026}$	$0.0104^{+0.0016}_{-0.0021}$	$0.0103^{+0.0014}_{-0.0017}$
n_T	0.03 ± 0.14	0.02 ± 0.12	0.02 ± 0.10	0.014 ± 0.091	0.010 ± 0.080
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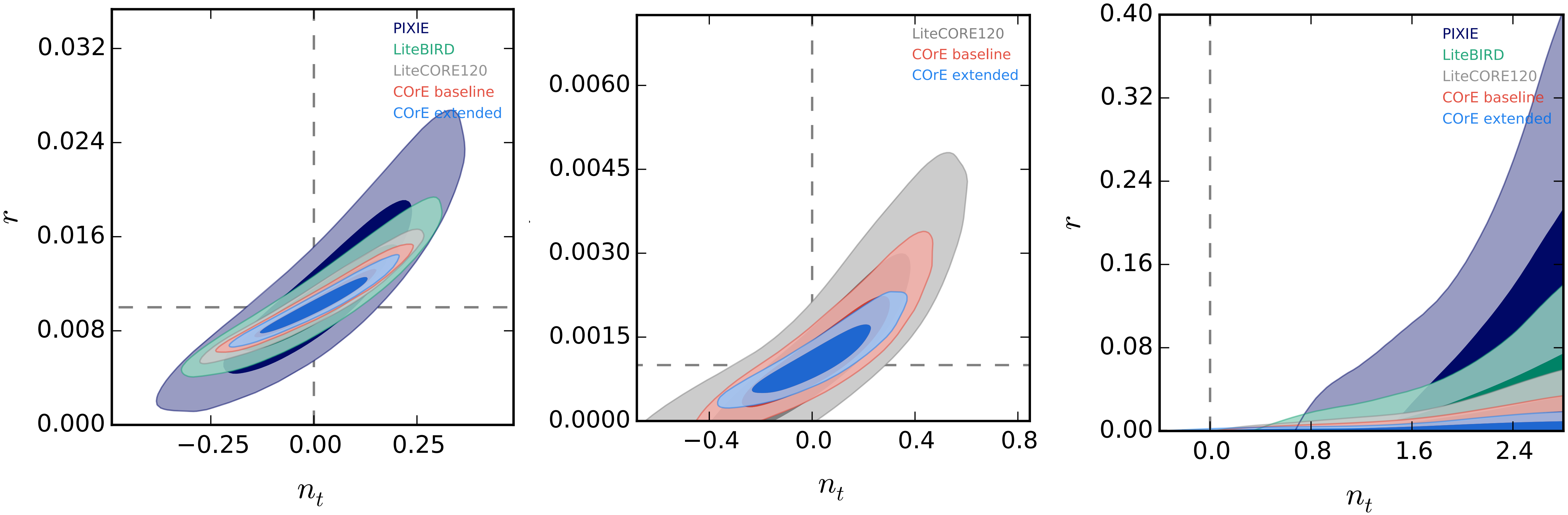
EDV, F.R.Bouchet, in prep.



Also when n_T is varying.

Conclusions

- In a LCDM model COrE+ can do a factor 3 better than LiteBIRD on cosmological parameters. In particular $\sigma(H_0)$=0.088 km/s/Mpc.
- With COrE+ $\sigma(\Sigma m_\nu)$=0.04eV vs $\sigma(\Sigma m_\nu)$=0.06eV of LiteBIRD or Stage-IV.
- With COrE+ $\sigma(N_{eff})$=0.04 vs $\sigma(N_{eff})$=0.20 of LiteBIRD.
- With COrE+ $\sigma(w)$=0.11 vs $\sigma(w)$=0.30 of LiteBIRD or $\sigma(w)$=0.15 of Stage-IV.
- Considering the CMBxCMB delensing, COrE+ can do a factor 2 better than LiteBIRD for the tensor-to-scalar ratio, constraining a possible r=10^-3 at 5 sigma level.
- Considering the CMBxCMB delensing, COrE+ extended can constrain r=10^-3 at more than 2 sigma level, also when n_T is varying at the same time, while with LiteBIRD there is only an upper limit.

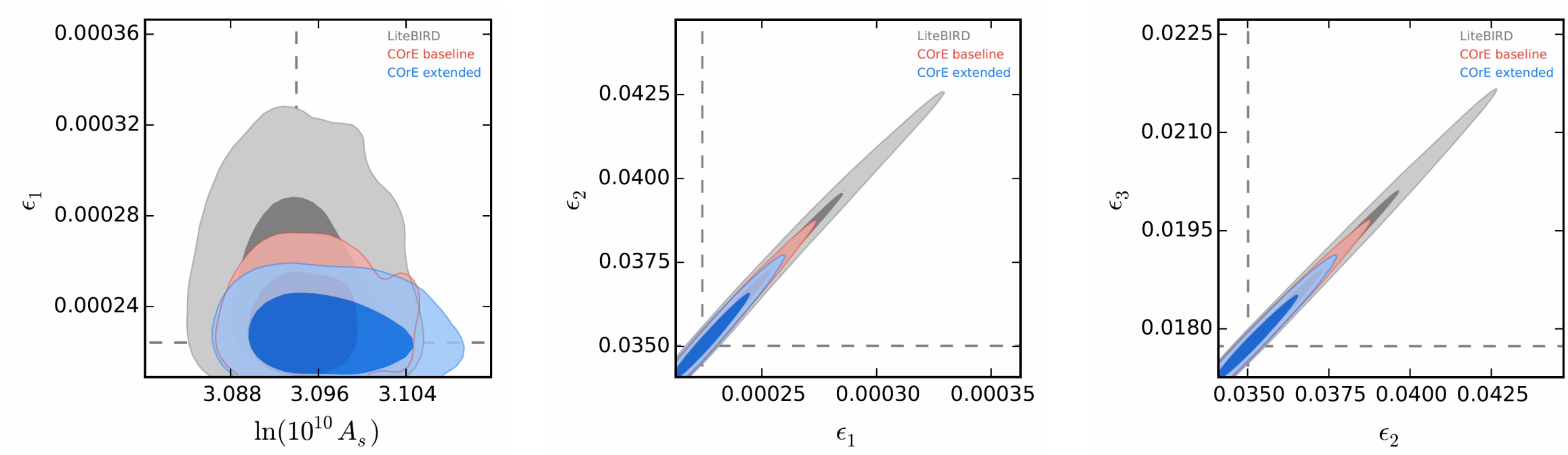
with delensing

Higgs Inflation

Constraints on slow roll parameters for a Higgs Inflation model with fiducial r_{fid}=3.58 x 10^{-3} (n_s= 0.9645)

$$\epsilon_1 \simeq \frac{M_{\rm Pl}^2}{2}\left(\frac{V_\phi}{V}\right)^2,$$
$$\epsilon_2 \simeq 2M_{\rm Pl}^2\left[\left(\frac{V_\phi}{V}\right)^2 - \frac{V_{\phi\phi}}{V}\right],$$
$$\epsilon_2\epsilon_3 \simeq 2M_{\rm Pl}^4\left[\frac{V_{\phi\phi\phi}V_\phi}{V^2} - 3\frac{V_{\phi\phi}}{V}\left(\frac{V_\phi}{V}\right)^2 + 2\left(\frac{V_\phi}{V}\right)^4\right]$$

$$V(\phi) = M^4\left(1 - e^{-\sqrt{2/3}\phi/M_{\rm Pl}}\right)^2$$



$$\epsilon_1 = \frac{4}{3}\left(1 - e^{\sqrt{2/3}x}\right)^{-2}, \qquad \epsilon_2 = \frac{2}{3}\left[\sinh\left(\frac{x}{\sqrt{6}}\right)\right]^{-2}$$
$$\epsilon_3 = \frac{2}{3}\left[\coth\left(\frac{x}{\sqrt{6}}\right) - 1\right]\coth\left(\frac{x}{\sqrt{6}}\right).$$

Delensing methods

We compare 2 CMBxCMB delensing methods:

- Lensing reconstruction with quadratic estimator (A. Lewis and A. Challinor, arXiv:astro-ph/0601594v4), provided by A. Challinor.

- The iterative delensing estimator using the CMB polarization, given by (K. M. Smith et al., arXiv:1010.0048v2)

$$B^{\rm del}_{\ell_1 m_1} = B^{\rm obs}_{\ell_1 m_1} - \sum_{\ell_2 m_2 \ell m} f^{EB}_{\ell_1 \ell_2 \ell} \begin{pmatrix} \ell_1 & \ell_2 & \ell \\ m_1 & m_2 & m \end{pmatrix} \left(\frac{C^{EE}_{\ell_2} E^{\rm obs *}_{\ell_2 m_2}}{C^{EE}_{\ell_2} + N^{EE}_{\ell_2}} \right) \left(\frac{C^{\phi\phi}_{\ell} \phi^{\rm obs *}_{\ell m}}{C^{\phi\phi}_{\ell} + N^{\phi\phi}_{\ell}} \right)$$

where

$$N^{EE}_{\ell} = N^{BB}_{\ell} = \Delta_P^2 \exp\left(\frac{\theta^2_{\rm FWHM} \ell^2}{8 \log 2} \right)$$

$$N^{\phi\phi}_{\ell} = \left[\frac{1}{2\ell + 1} \sum_{\ell_1 \ell_2} |f^{EB}_{\ell_1 \ell_2 \ell}|^2 \left(\frac{1}{C^{BB}_{\ell_1} + N^{BB}_{\ell_1}} \right) \left(\frac{(C^{EE}_{\ell_2})^2}{C^{EE}_{\ell_2} + N^{EE}_{\ell_2}} \right) \right]^{-1}$$

Delensing methods

$$N_\ell^{\phi\phi} = \left[\frac{1}{2\ell+1} \sum_{\ell_1 \ell_2} |f_{\ell_1 \ell_2 \ell}^{EB}|^2 \left(\frac{1}{C_{\ell_1}^{BB} + N_{\ell_1}^{BB}} \right) \left(\frac{(C_{\ell_2}^{EE})^2}{C_{\ell_2}^{EE} + N_{\ell_2}^{EE}} \right) \right]^{-1}$$

We compare the gain we have by using one single iteration with respect to several iterations, where to replace each time the obtained delensed B modes, until to reach (J. Errard et al., arXiv:1509.06770v3):

$$\left| \sum_\ell \frac{N_\ell^{\phi\phi,i} - N_\ell^{\phi\phi,i-1}}{N_\ell^{\phi\phi,i}} \right| \leq 1\%.$$

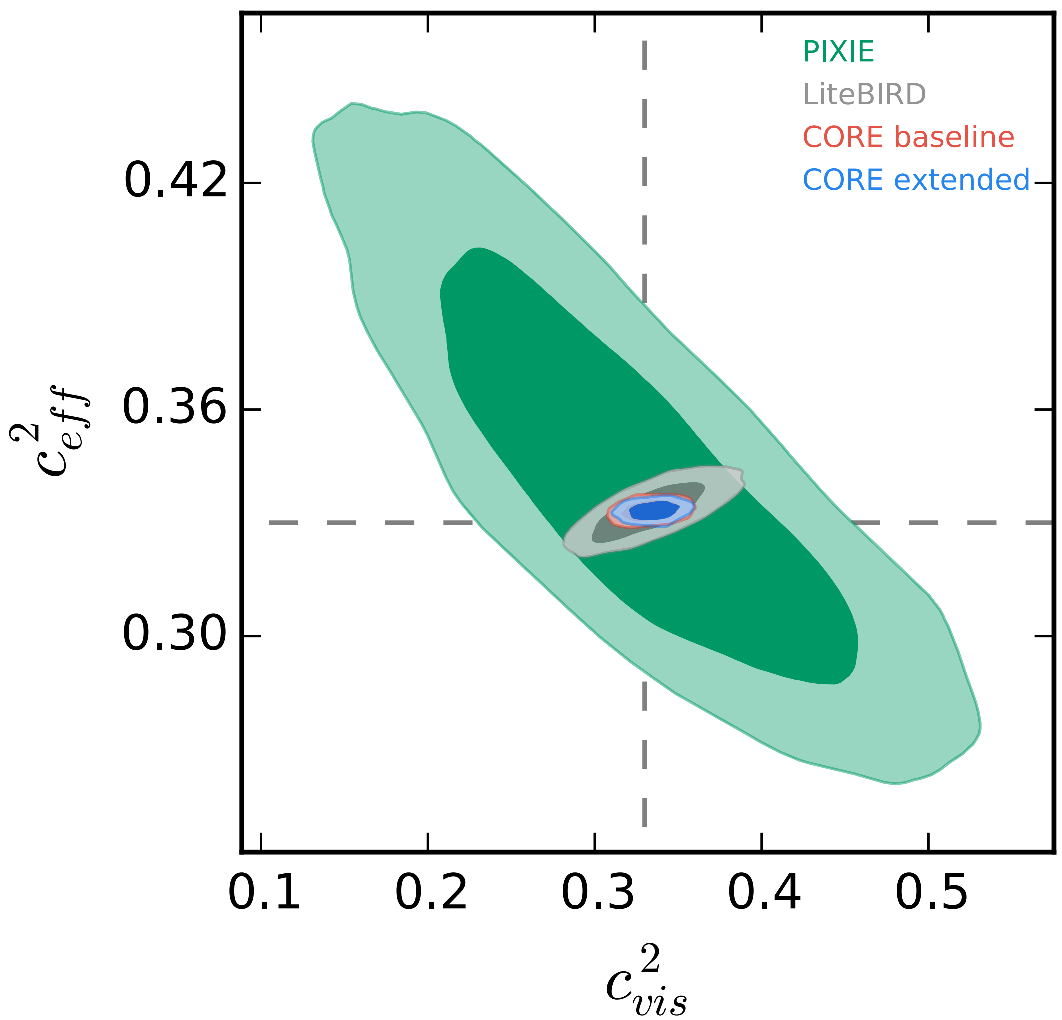
Finally, we define the delensing factor to evaluate the performance of the experiments:

$$\alpha = \frac{\sum_{\ell=\ell_{min}}^{\ell=500} C_\ell^{BB,del}}{\sum_{\ell=\ell_{min}}^{\ell=500} C_\ell^{BB,lens}}$$

Delensing methods

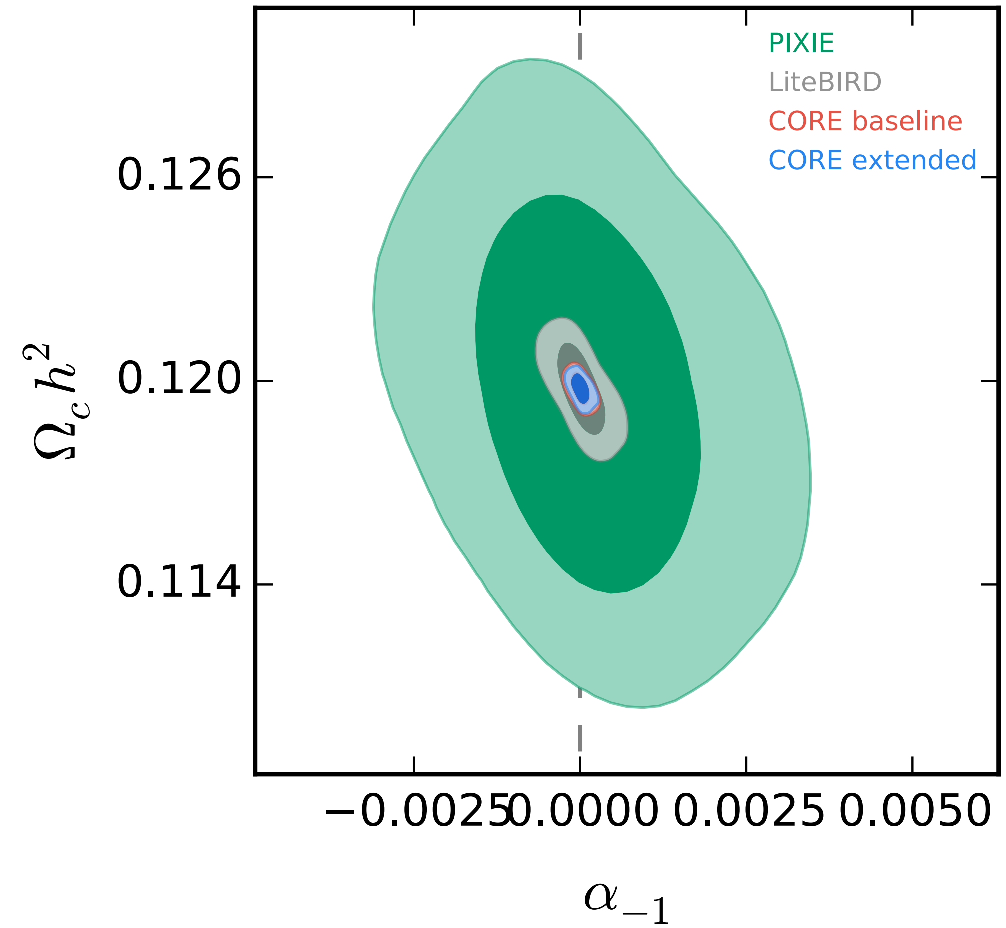
```
core extended 4arcmin 1.5uK QE=0.3070762  1iter=0.4039403   moreiter=0.3312646
core baseline 6arcmin 2.5uK QE=0.4136011  1iter=0.5225181   moreiter=0.4968156
litebird     30arcmin 4.5uK QE=0.9126866  1iter=0.9449672   moreiter=0.9402915
pixie        96arcmin 4.2uK QE=1


LiteCORE120  7.5armin 3.75uK              1iter=0.5699989   moreiter=0.5518946

S3wide      1.4arcmin 11.3uK              1iter=0.7800362   moreiter=0.7851662
S3deep        1arcmin  5.7uK              1iter=0.5674735   moreiter=0.5577870
S4            3arcmin  1.4uK              1iter=0.3218611   moreiter=0.2506848
```

$$\alpha = \frac{\sum_{\ell=\ell_{min}}^{\ell=500} C_\ell^{BB,del}}{\sum_{\ell=\ell_{min}}^{\ell=500} C_\ell^{BB,lens}}$$



Generalized Dark Matter for Neutrinos

Cold Dark Matter Isocurvature Perturbation



	PIXIE +DESI	LiteBIRD +DESI	LiteCORE120 +DESI	COrE+ baseline+DESI	COrE+ extended+DESI
Σm_ν [eV]	< 0.158	0.071 ± 0.031	0.072 ± 0.021	$0.071^{+0.022}_{-0.020}$	0.073 ± 0.020
$N_{\rm eff}$	$3.5^{+0.8}_{-1.4}$	3.05 ± 0.15	3.048 ± 0.051	3.046 ± 0.041	3.046 ± 0.033
$\frac{dlnn_S}{dlnk}$	-0.003 ± 0.022	0.0002 ± 0.0023	0.0003 ± 0.0080	0.0001 ± 0.0024	0.0000 ± 0.0022
r	< 0.000303	< 0.000300	< 0.000241	< 0.000188	< 0.000172
w	$-1.005^{+0.065}_{-0.050}$	-1.003 ± 0.027	-1.001 ± 0.020	-1.001 ± 0.019	-1.000 ± 0.018
Y_P	$0.237^{+0.047}_{-0.039}$	$0.245^{+0.010}_{-0.012}$	0.2452 ± 0.0037	0.2453 ± 0.0029	0.2454 ± 0.0023

	S3wide + tau05+DESI	S3deep +tau05+DESI	S4 +tau05+DESI
Σm_ν [eV]	$0.073^{+0.035}_{-0.043}$	$0.073^{+0.034}_{-0.058}$	0.072 ± 0.022
$N_{\rm eff}$	3.046 ± 0.065	3.06 ± 0.12	3.046 ± 0.040
$\frac{dlnn_S}{dlnk}$	-0.0001 ± 0.0040	0.0003 ± 0.0089	0.0000 ± 0.0029
r	< 0.00416	< 0.00428	< 0.000488
w	$-1.004^{+0.034}_{-0.029}$	$-1.006^{+0.040}_{-0.029}$	-0.999 ± 0.019
Y_P	0.2454 ± 0.0042	0.2446 ± 0.0090	0.2452 ± 0.0029