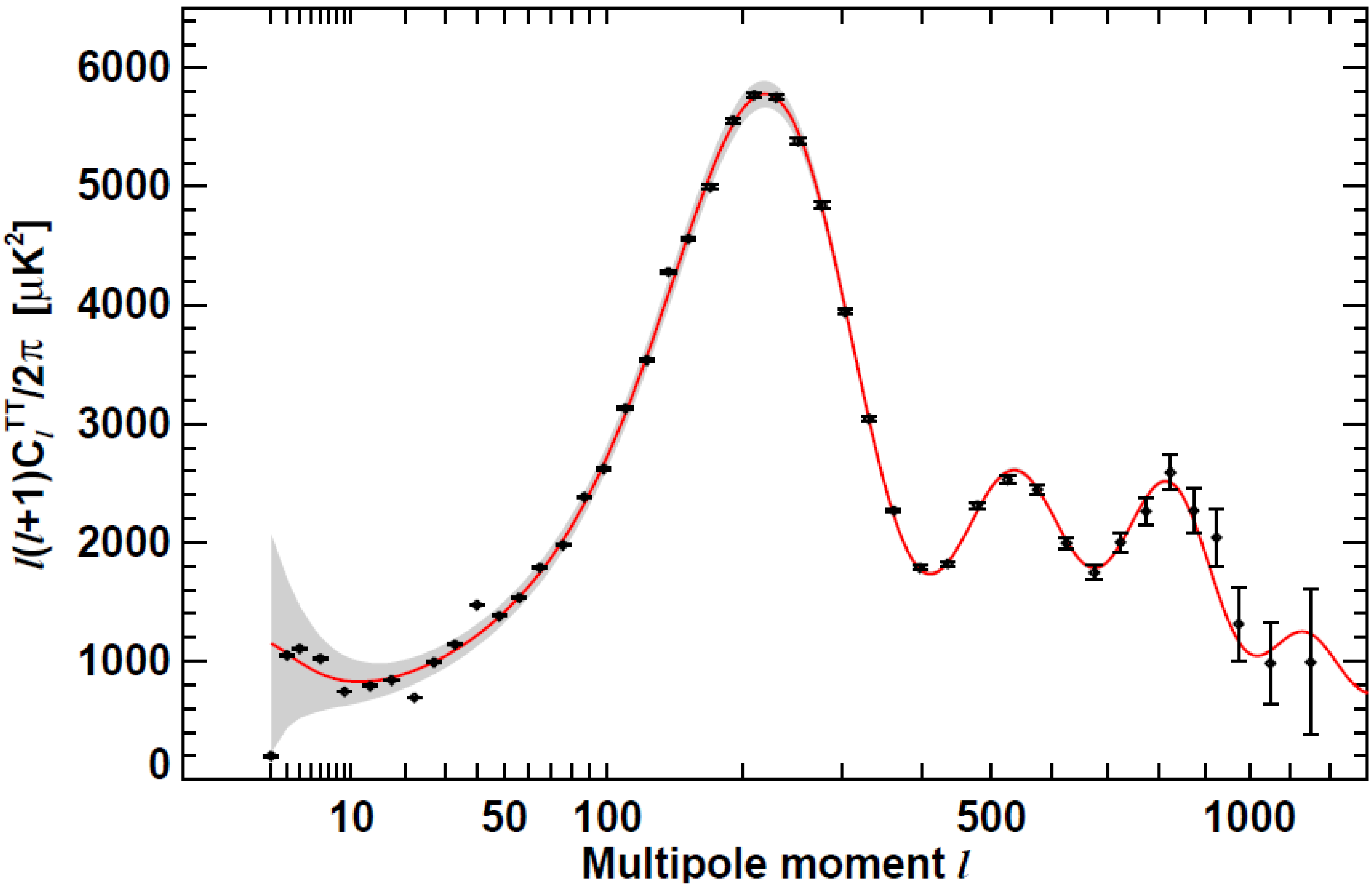
Neutrinos and Cosmology

NOW 2010, Conca-Specchiulla September 7th 2010

Alessandro Melchiorri
Universita’ di Roma, “La Sapienza”

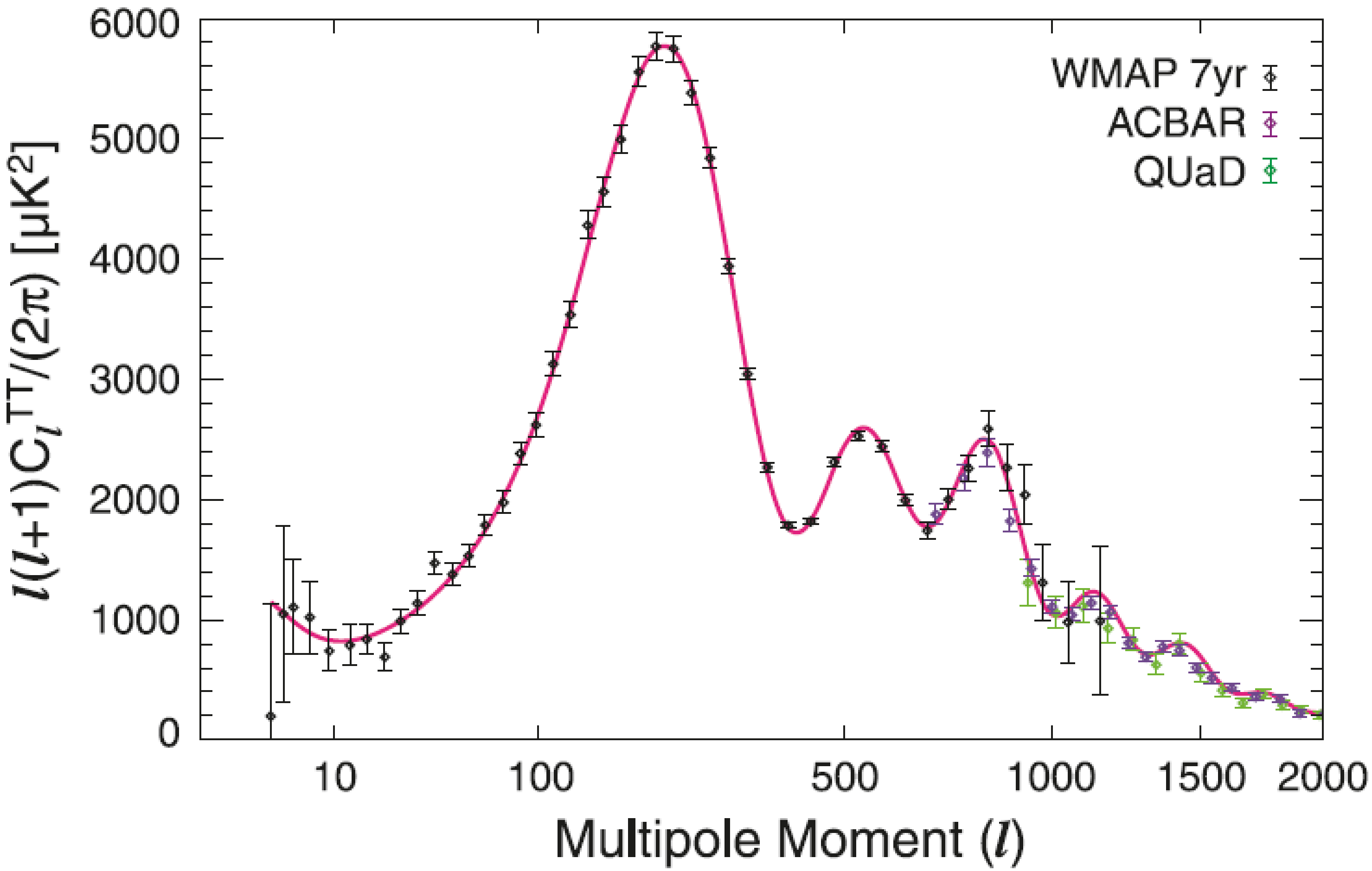
New WMAP results from 7 years of observations



Komatsu et al, 2010, 1001.4538

Table 3
Six-Parameter ΛCDM Fit [a]

Parameter	7-year Fit	5-year Fit
Fit parameters		
$10^2\Omega_b h^2$	$2.258^{+0.057}_{-0.056}$	2.273 ± 0.062
$\Omega_c h^2$	0.1109 ± 0.0056	0.1099 ± 0.0062
Ω_Λ	0.734 ± 0.029	0.742 ± 0.030
$\Delta^2_{\mathcal{R}}$	$(2.43 \pm 0.11) \times 10^{-9}$	$(2.41 \pm 0.11) \times 10^{-9}$
n_s	0.963 ± 0.014	$0.963^{+0.014}_{-0.015}$
τ	0.088 ± 0.015	0.087 ± 0.017
Derived parameters		
t_0	13.75 ± 0.13 Gyr	13.69 ± 0.13 Gyr
H_0	71.0 ± 2.5 km/s/Mpc	$71.9^{+2.6}_{-2.7}$ km/s/Mpc
σ_8	0.801 ± 0.030	0.796 ± 0.036
Ω_b	0.0449 ± 0.0028	0.0441 ± 0.0030
Ω_c	0.222 ± 0.026	0.214 ± 0.027
$z_{\rm eq}$	3196^{+134}_{-133}	3176^{+151}_{-150}
$z_{\rm reion}$	10.5 ± 1.2	11.0 ± 1.4

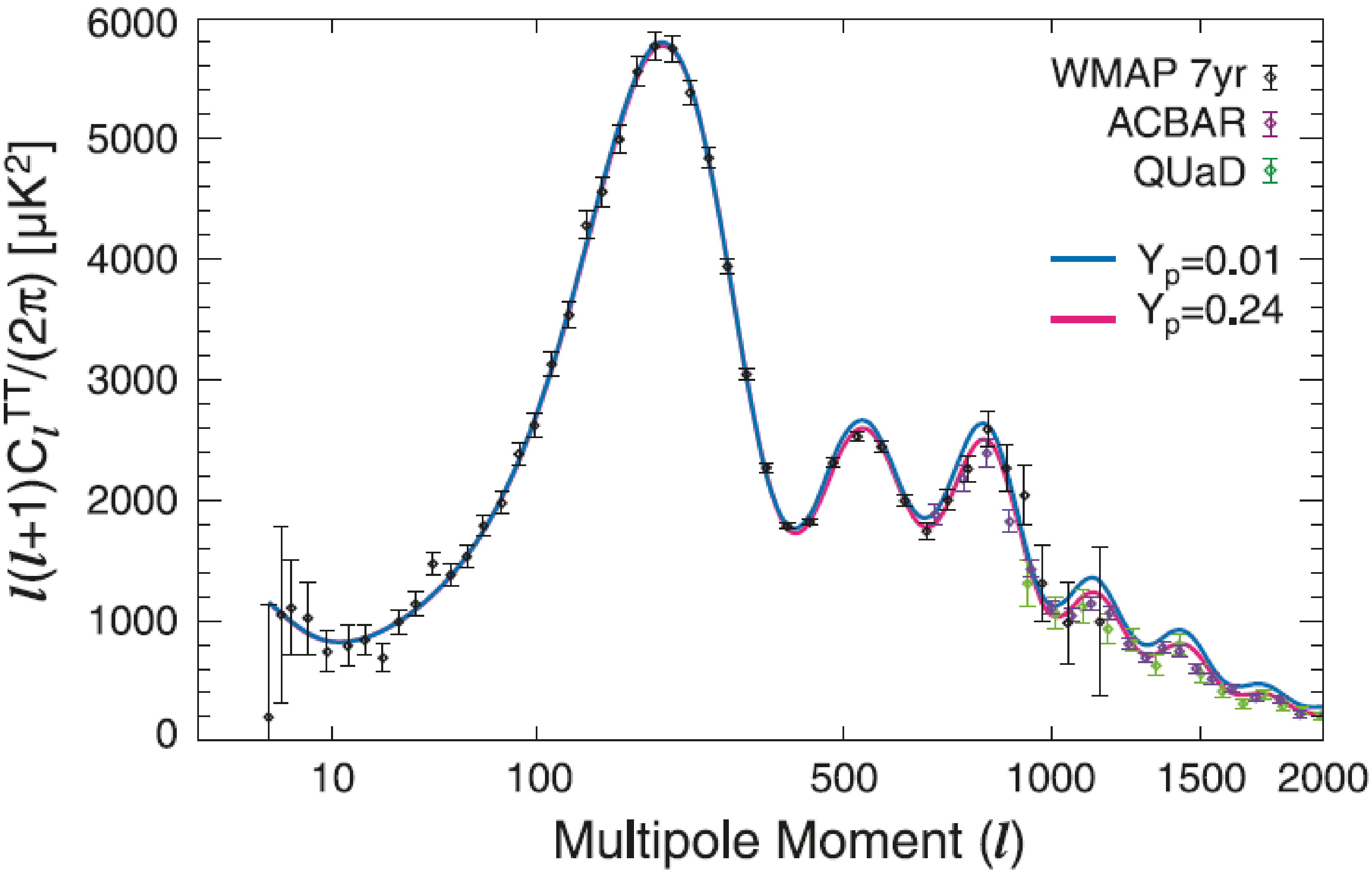


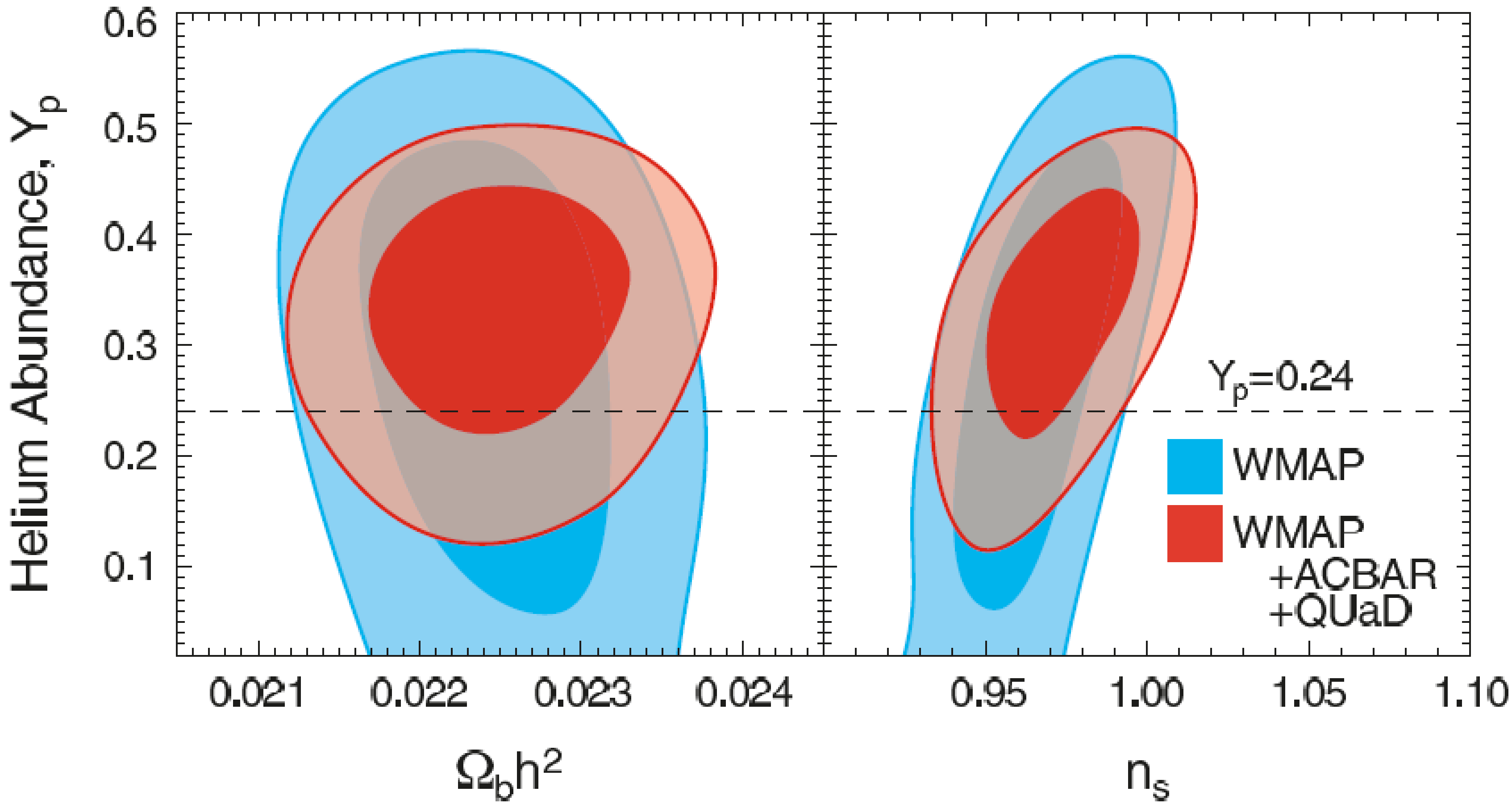
Komatsu et al, 2010, 1001.4538

New Measurements, More Parameters !

- Neutrino masses Σm_{ν}
- Neutrino effective number N_{ν}^{eff}
- Primordial Helium Y_{P}

Small scale CMB can probe Helium abundance at recombination.



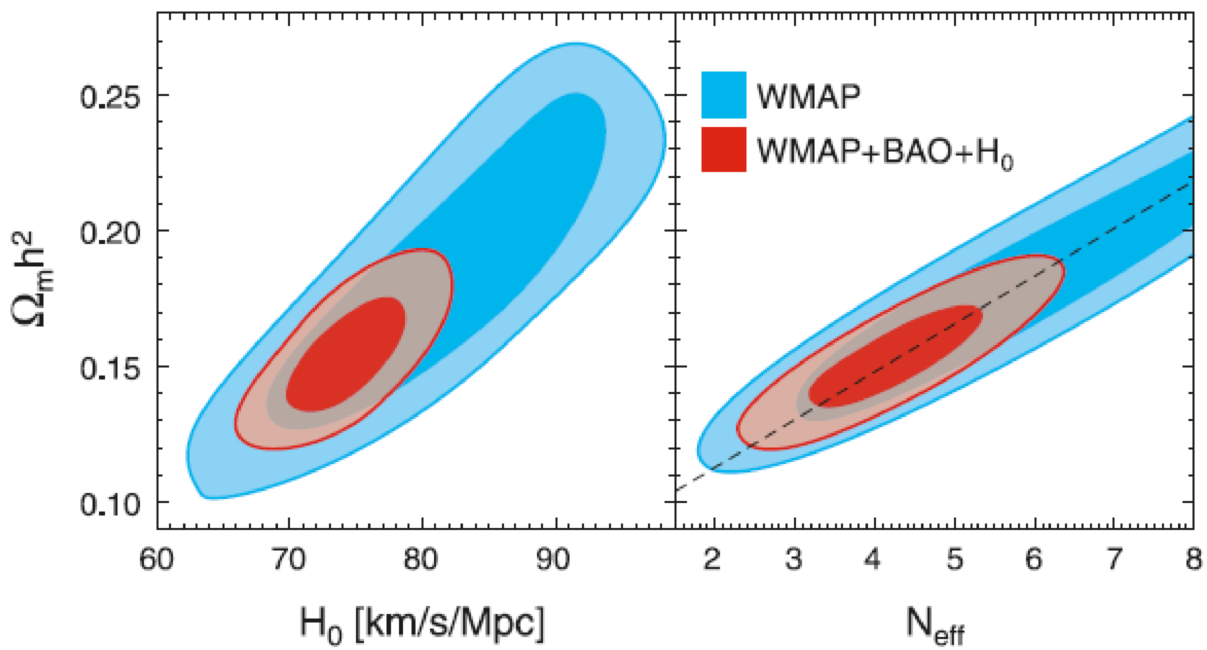


	WMAP only	*WMAP*+ACBAR+QUaD
Y_p	< 0.51 (95% CL)	$Y_p = 0.326 \pm 0.075$ (68% CL)[b]

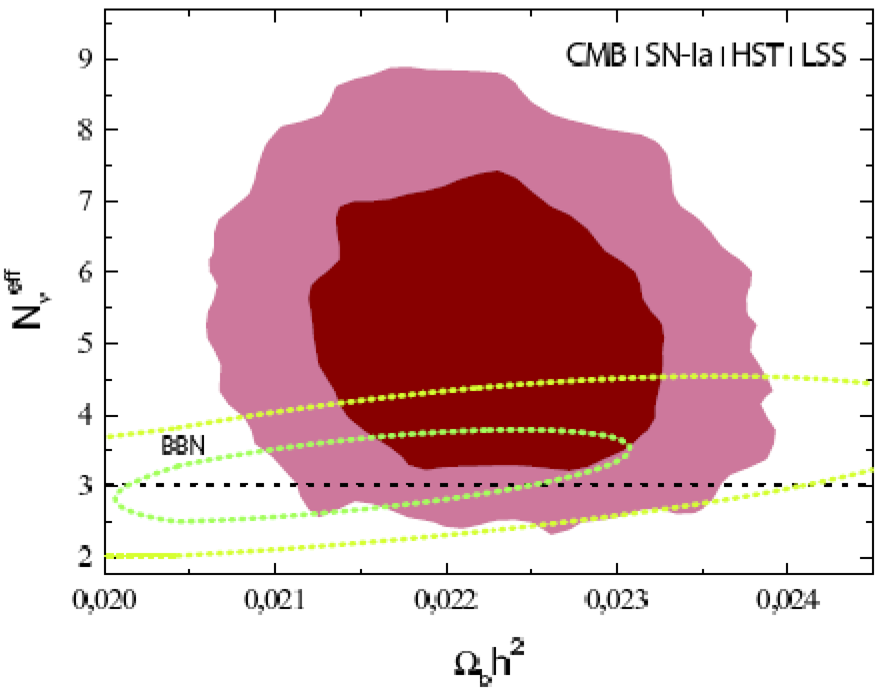
Komatsu et al, 2010, 1001.4538

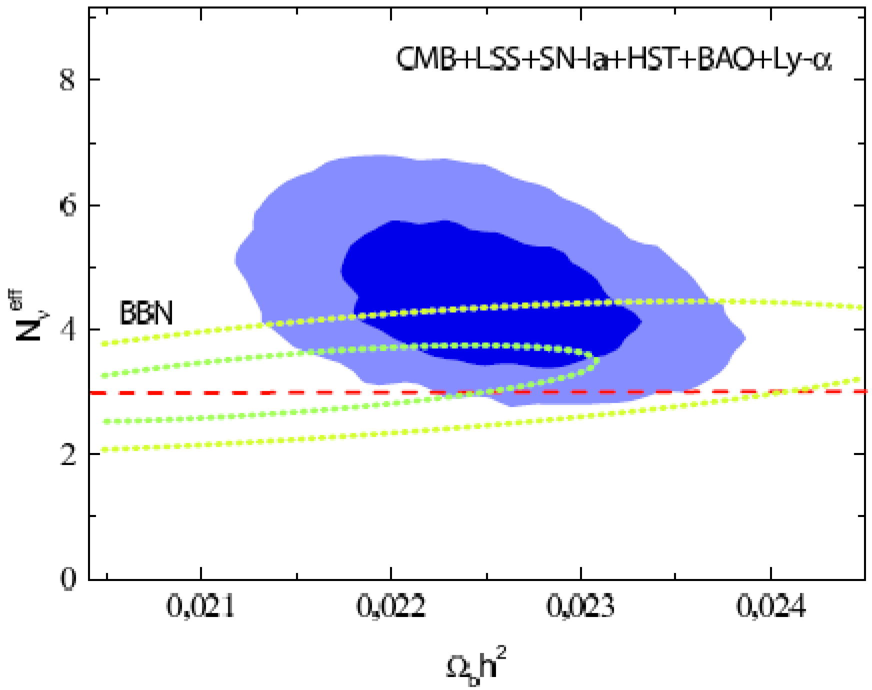
Komatsu et al, 2010, 1001.4538

Neutrino background.
Changes early ISW.
Hint for N>3 ?



Parameter	Year	*WMAP* only	*WMAP*+BAO+SN+*HST*	*WMAP*+BAO+H_0	*WMAP*+LRG+H_0
$z_{\rm eq}$	5-year	3141^{+154}_{-157}	3240^{+99}_{-97}		
	7-year	3145^{+140}_{-139}		3209^{+85}_{-89}	3240 ± 90
$\Omega_m h^2$	5-year	$0.178^{+0.044}_{-0.041}$	0.160 ± 0.025		
	7-year	$0.184^{+0.041}_{-0.038}$		0.157 ± 0.016	$0.157^{+0.013}_{-0.014}$
$N_{\rm eff}$	5-year	> 2.3 (95% CL)	4.4 ± 1.5		
	7-year	> 2.7 (95% CL)		$4.34^{+0.86}_{-0.88}$	$4.25^{+0.76}_{-0.80}$

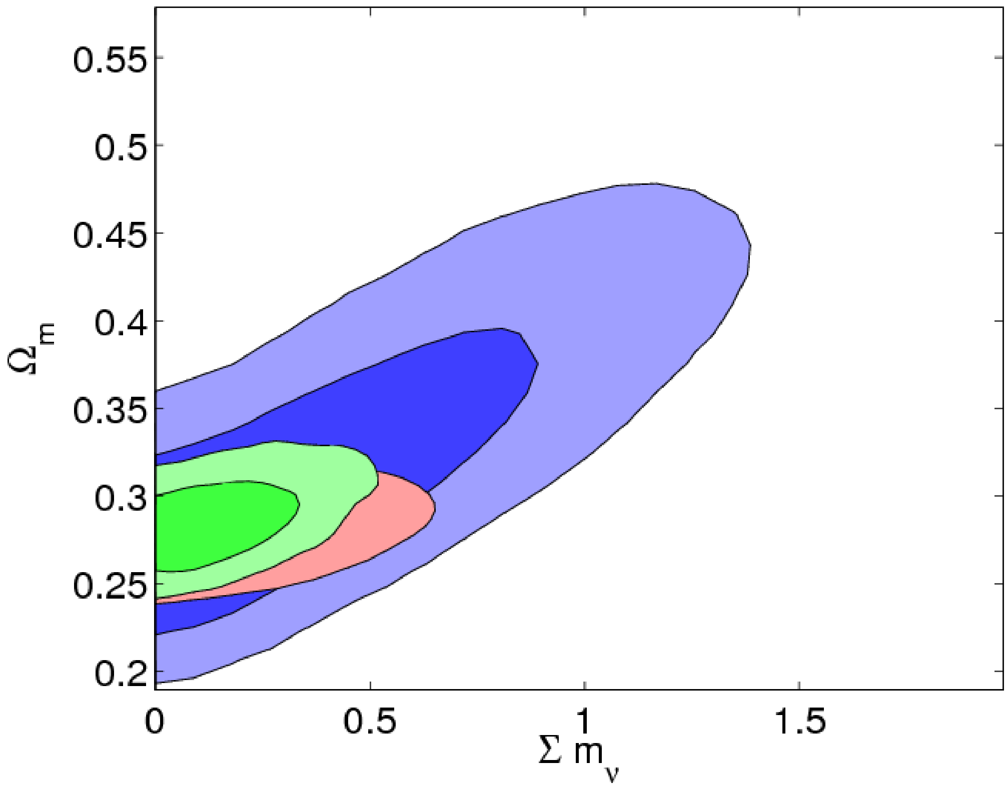




Gianpiero Mangano, Alessandro Melchiorri, Olga Mena, Gennaro Miele, Anze Slosar

Journal-ref: JCAP0703:006,2007

Current constraints on neutrino mass from Cosmology (Fogli et al, 2010 in preparation).



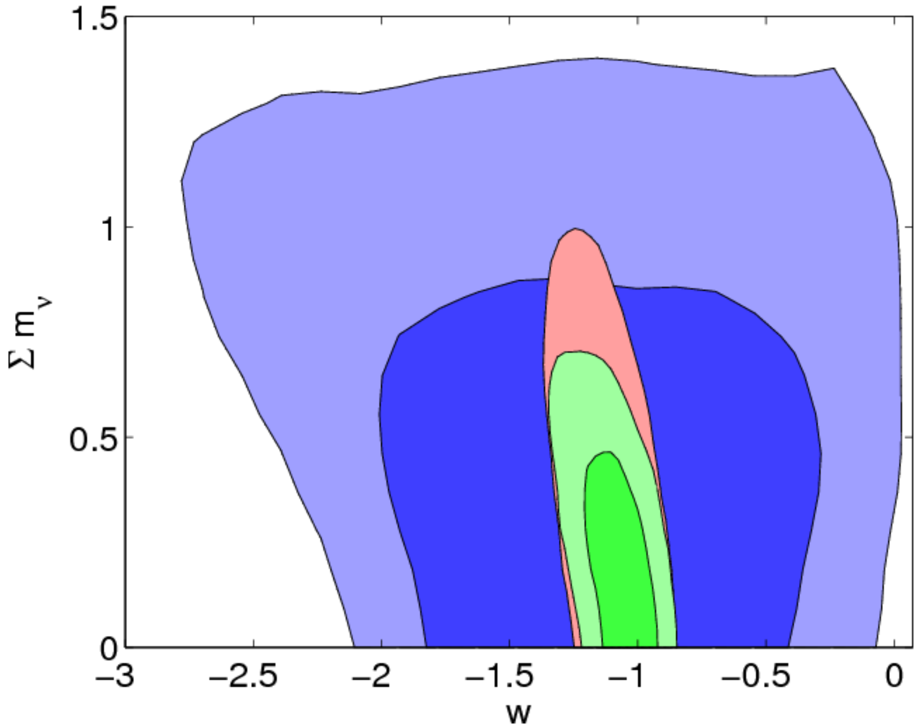
Blue: WMAP-7

Red: w7+SN+Bao+H0

Green: w7+CMBsuborb+SN+LRG+H0

(Plot made by Luca Pagano)

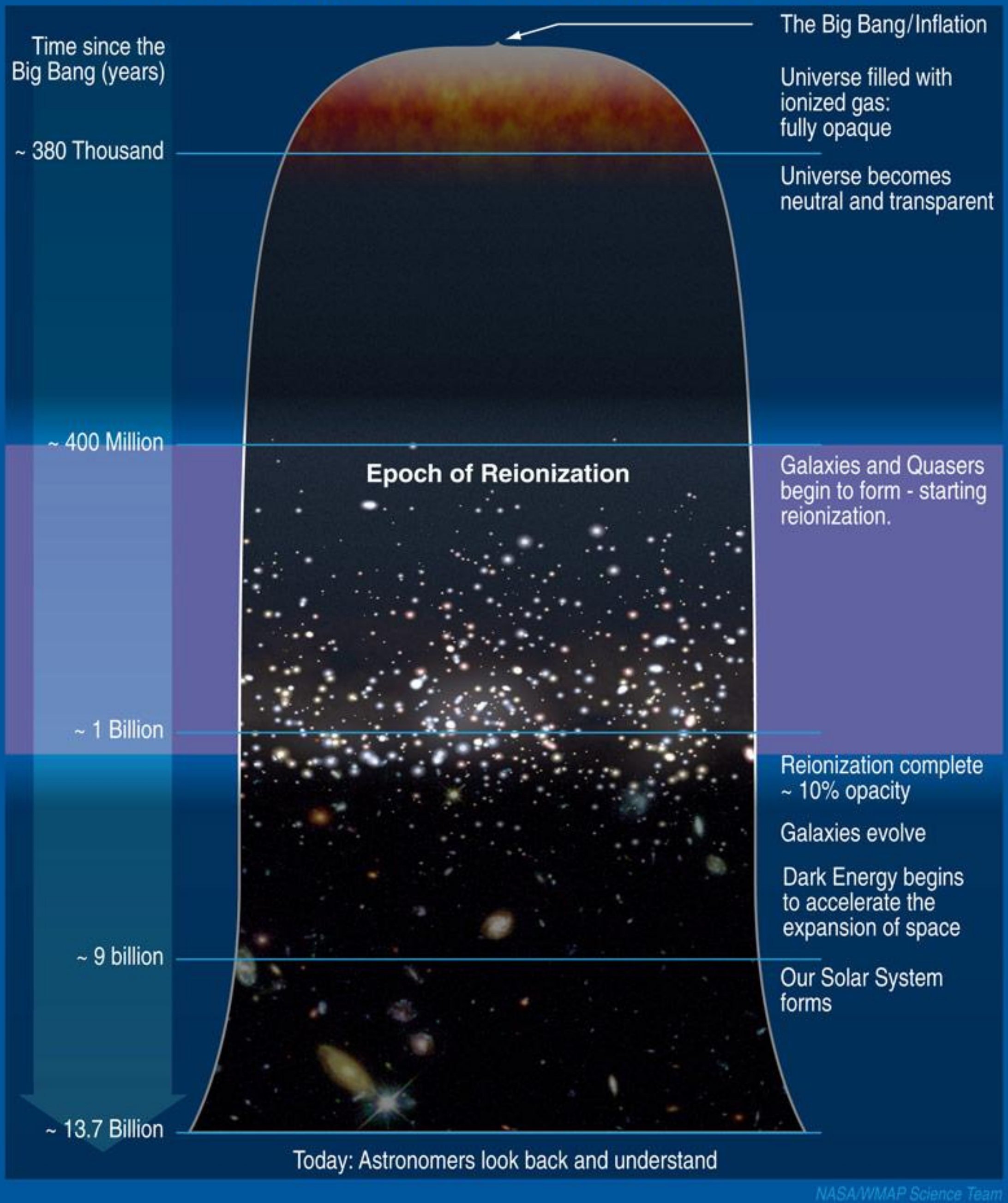
Current constraints on neutrino mass from Cosmology (Fogli et al, 2010 in preparation).



Blue: WMAP-7
Red: w7+SN+Bao+H0
Green: w7+CMBsuborb+SN+LRG+H0

(Plot made by Luca Pagano)

First Stars and Reionization Era

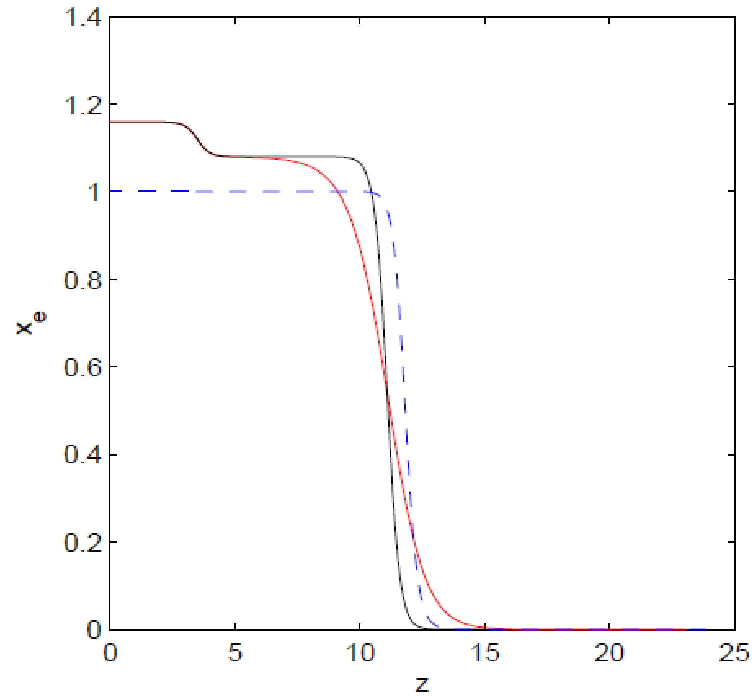


Sudden Reionization

$$y(z_{re}) = (1 + z_{re})^{3/2}$$

$$x_e(y) = \frac{f}{2}\left[1 + \tanh\left(\frac{y - y(z_{re})}{\Delta_y}\right)\right]$$

CAMB Notes, Antony Lewis



As we don't know precisely the details of the reionization history we should consider more general reionization scenarios

MH's Reionization

Following Mortonson & Hu we can parametrize the reionization history as a free function of the redshift by decomposing the free electron fraction as

$$x_e(z) = x_e^f(z) + \sum_\mu m_\mu S_\mu(z)$$

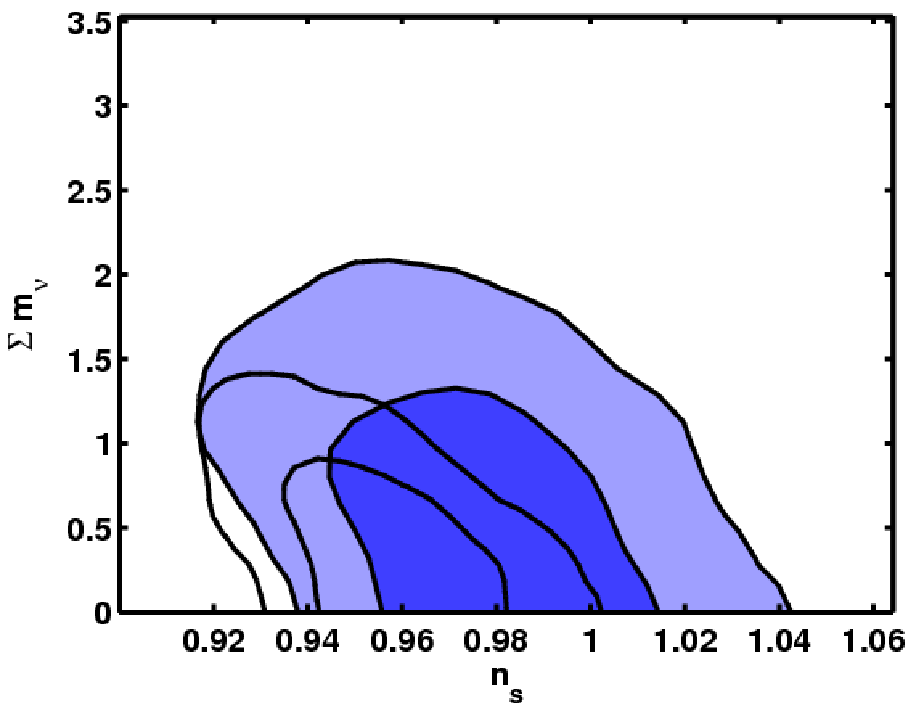
- The principal components $S_\mu(z)$ are the eigenfunctions of the Fisher matrix of an ideal, cosmic variance limited, experiment.

$$F_{ij} = \sum_{\ell=2}^{\ell_{\max}} \left(\ell + \frac{1}{2}\right) \frac{\partial \ln C_\ell^{EE}}{\partial x_e(z_i)} \frac{\partial \ln C_\ell^{EE}}{\partial x_e(z_j)} \qquad F_{ij} = (N_z + 1)^{-2} \sum_{\mu=1}^{N_z} S_\mu(z_i) \sigma_\mu^{-2} S_\mu(z_j)$$

- m_μ are the amplitudes of the $S_\mu(z)$
- $x^{fid}(z)$ is the WMAP fiducial model at which the FM is computed

M. J. Mortonson and W. Hu ApJ 686, L53 (2008)

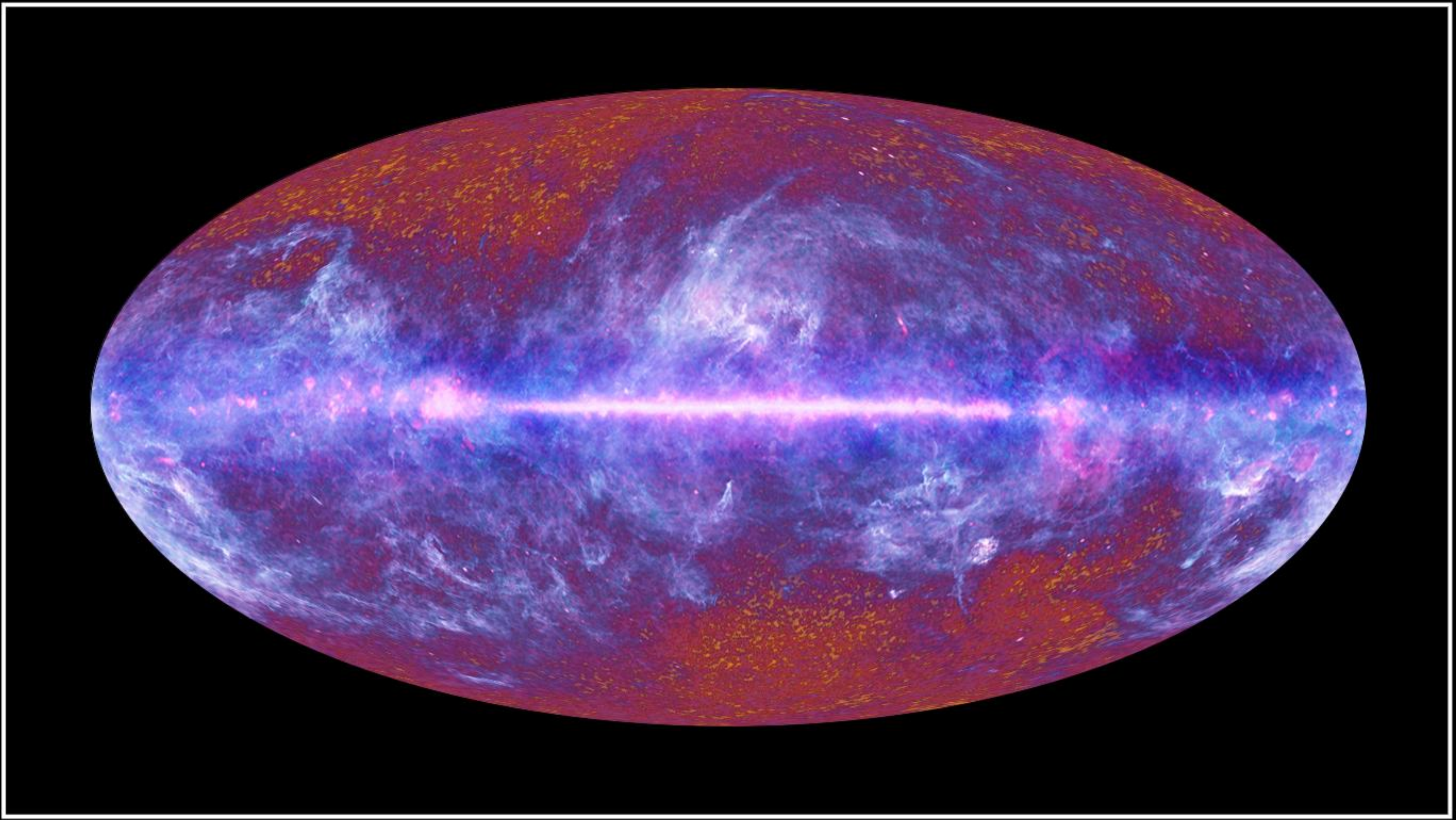
Impact of generalized reionization on CMB constraints on Neutrino Mass



Parameter	WMAP7 (Sudden Reionization)	WMAP7 (MH Reionization)
$\Omega_b h^2$	$0.0221^{+0.0012}_{-0.0012}$	$0.0226^{+0.0015}_{-0.0014}$
$\Omega_c h^2$	$0.117^{+0.013}_{-0.013}$	$0.115^{+0.017}_{-0.017}$
θ_s	$1.038^{+0.005}_{-0.005}$	$1.039^{+0.006}_{-0.005}$
n	$0.955^{+0.032}_{-0.033}$	$0.975^{+0.0448}_{-0.0434}$
H_0	$65.7^{+7.6}_{-8.2}$	$66.0^{+10.2}_{-9.0}$
Ω_Λ	$0.674^{+0.091}_{-0.134}$	$0.675^{+0.112}_{-0.148}$
Σm_ν	< 1.15eV	< 1.66eV

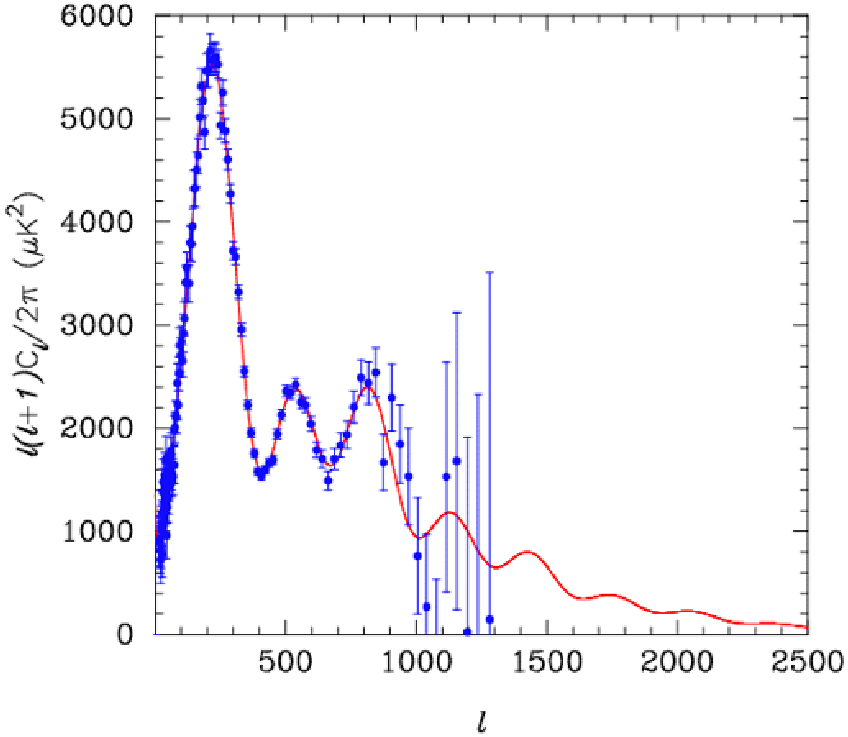
Archidiacono, Cooray, Melchiorri, Pandolfi, 2010, PRD

Planck
Satellite launch
14/5/2009



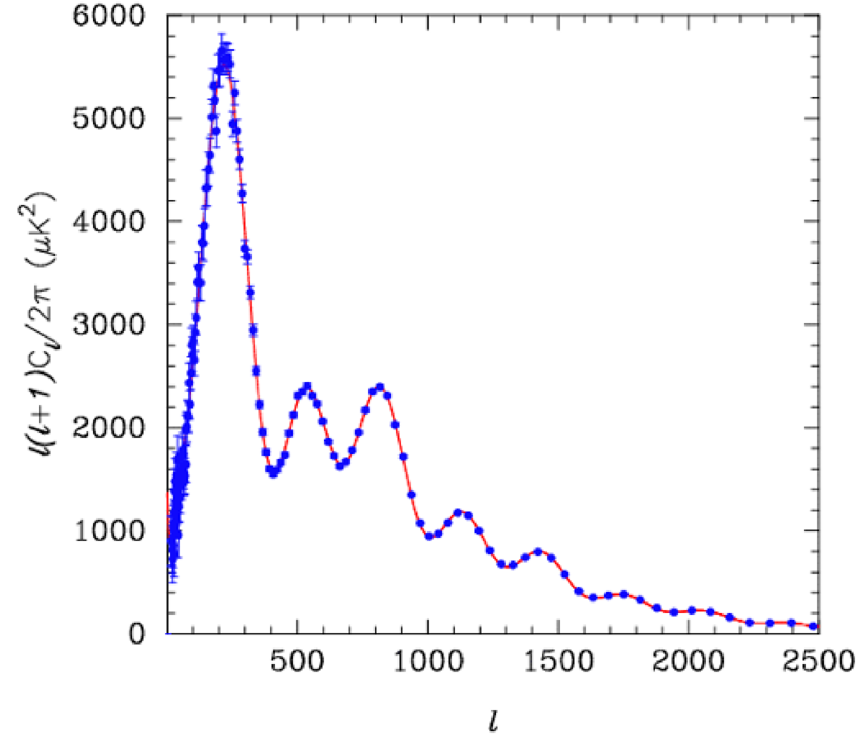
The Planck one-year all-sky survey

WMAP

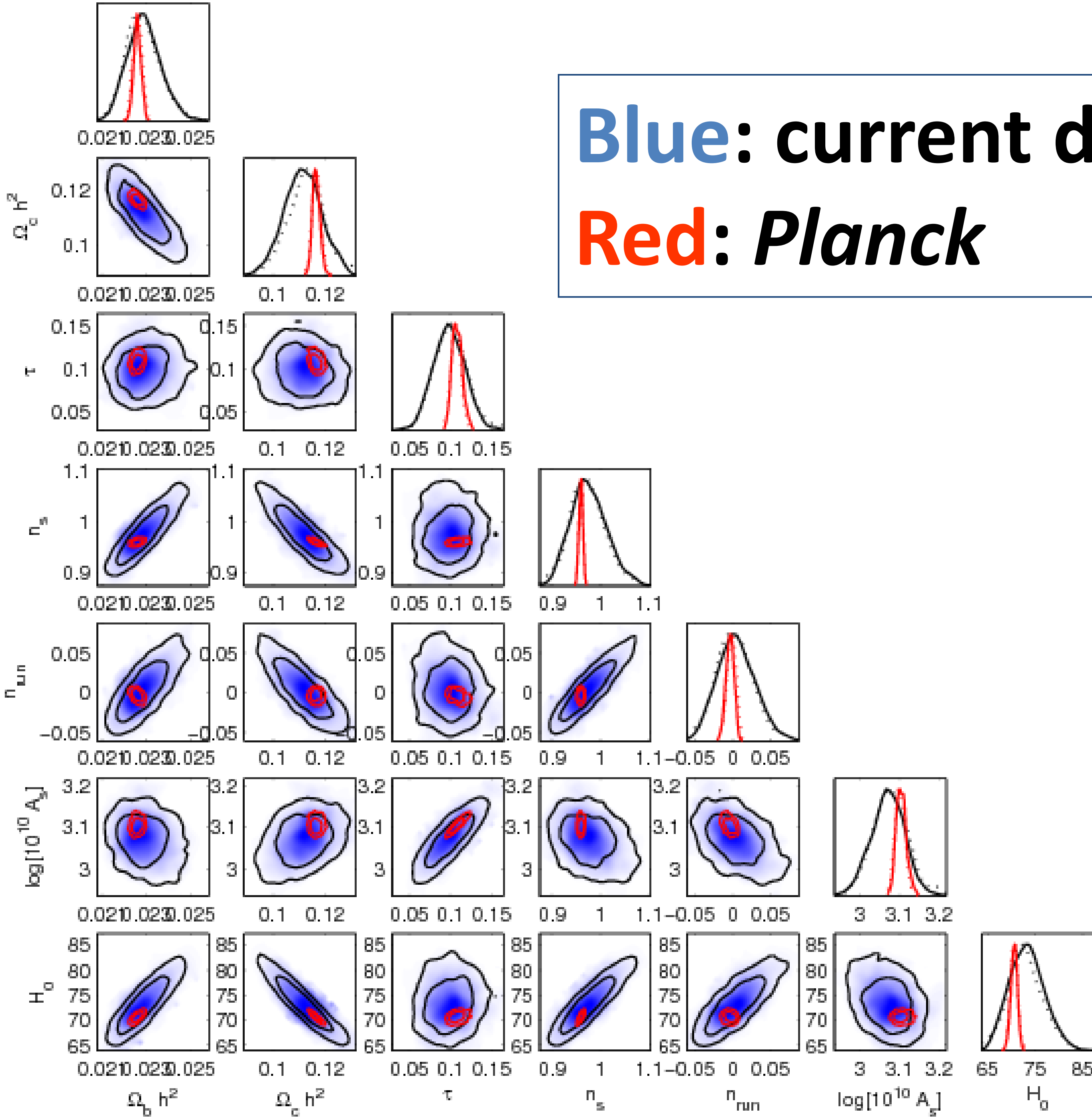


6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
$\ell(\ell+1)C_\ell/2\pi$ (μK^2)
l

PLANCK



6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
$\ell(\ell+1)C_\ell/2\pi$ (μK^2)
l



Blue: current data

Red: ***Planck***

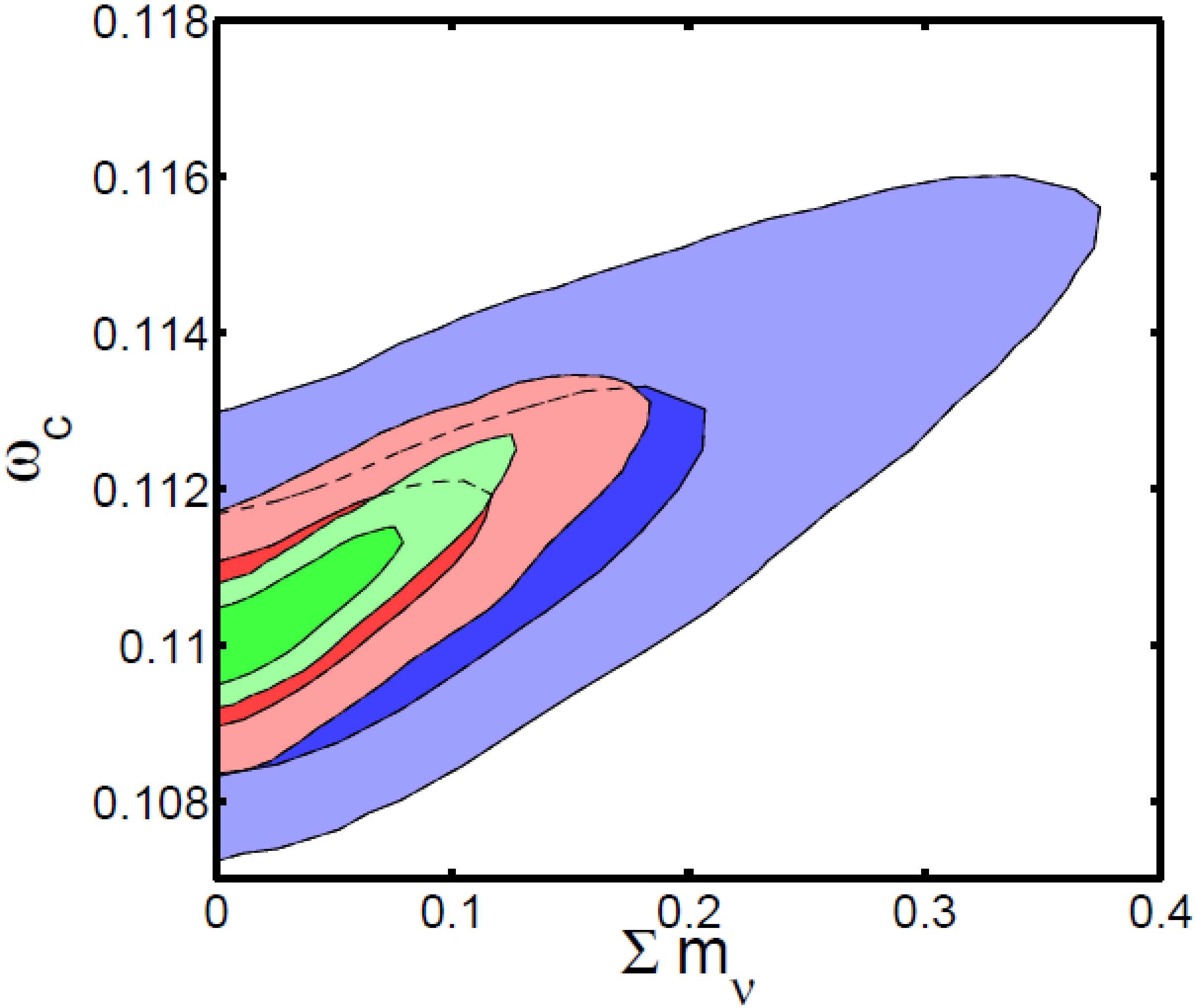
Let's consider not only Planck but also
ACTpol (From Atacama Cosmology Telescope, Ground based, results expected by 2013)
CMBpol (Next CMB satellite, 2020 ?)

Experiment	Channel	FWHM	$\Delta T/T$	$\Delta P/T$
Planck	70	14'	4.7	6.7
$f_{sky} = 0.85$	100	10'	2.5	4.0
	143	7.1'	2.2	4.2
ACTPol	150	1.4'	14.6	20.4
$f_{sky} = 0.19$				
CMBPol	150	5.6'	0.037	0.052
$f_{sky} = 0.72$				

Parameter uncertainty	Planck	Planck+ACTPol		CMBPol	
$\sigma(\Omega_b h^2)$	0.00013	0.000078	(1.7)	0.000034	(3.8)
$\sigma(\Omega_c h^2)$	0.0010	0.00064	(1.6)	0.00027	(3.7)
$\sigma(\theta_s)$	0.00026	0.00016	(1.6)	0.000052	(5.0)
$\sigma(\tau)$	0.0042	0.0034	(1.2)	0.0022	(1.9)
$\sigma(n_s)$	0.0031	0.0021	(1.5)	0.0014	(2.2)
$\sigma(\log[10^{10} As])$	0.013	0.0086	(1.5)	0.0055	(2.4)
$\sigma(H_0)$	0.53	0.30	(1.8)	0.12	(4.4)

Galli, Martinelli, Melchiorri, Pagano, Sherwin, Spergel, PRD submitted, **arXiv:1005.3808** 2010

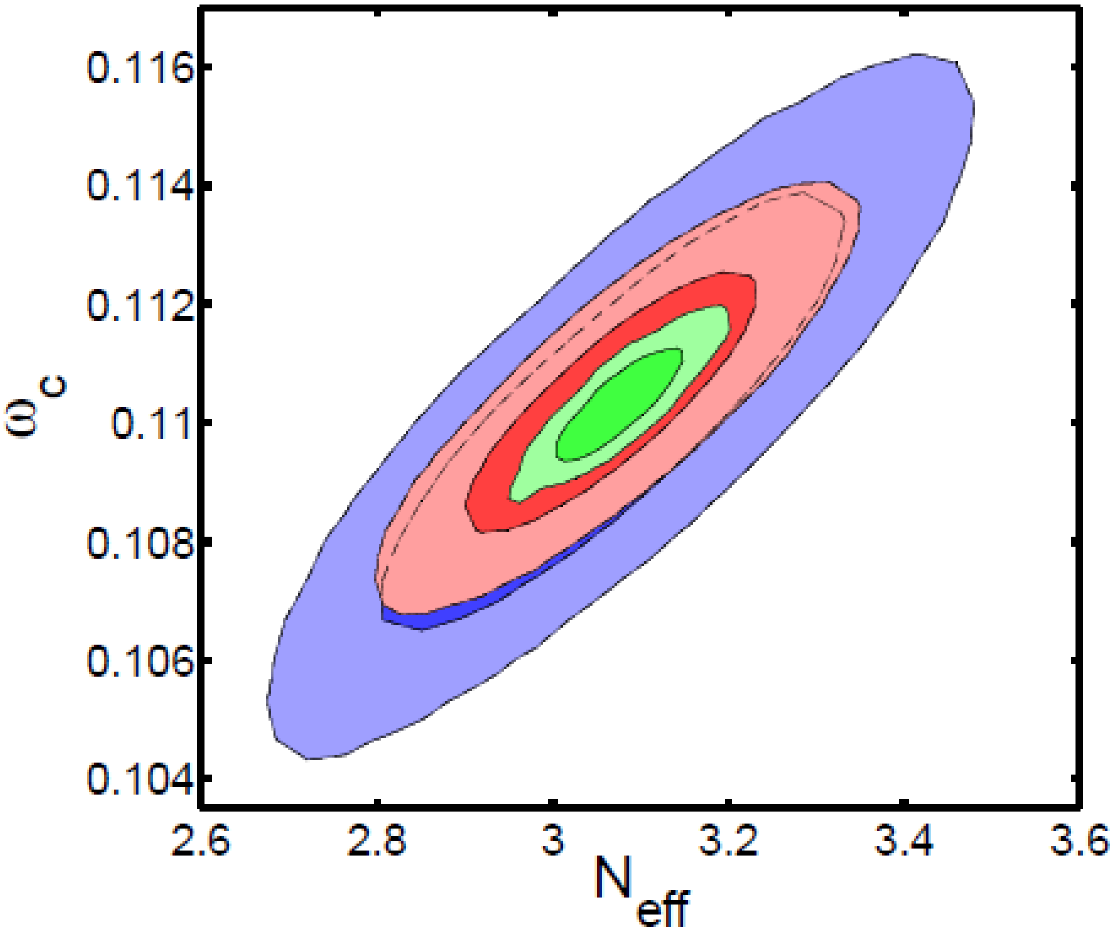
Constraints on Neutrino Mass



Blue: Planck
Red: Planck+ACTpol
Green: CMBPol

Galli, Martinelli, Melchiorri, Pagano, Sherwin, Spergel, PRD submitted, **arXiv:1005.3808** 2010

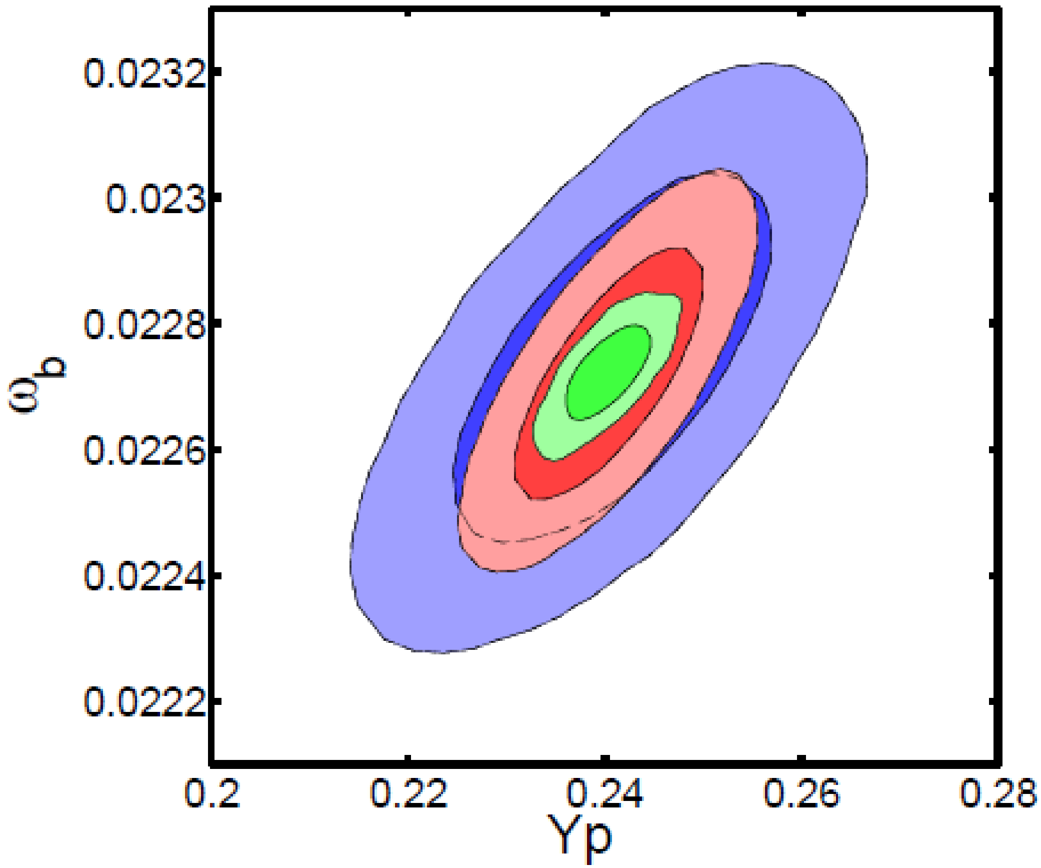
Constraints on Neutrino Number



Blue: Planck
Red: Planck+ACTpol
Green: CMBPol

Galli, Martinelli, Melchiorri, Pagano, Sherwin, Spergel, PRD submitted, **arXiv:1005.3808** 2010

Constraints on Helium Abundance



Blue: Planck
Red: Planck+ACTpol
Green: CMBPol

Galli, Martinelli, Melchiorri, Pagano, Sherwin, Spergel, PRD submitted, **arXiv:1005.3808** 2010

CONCLUSIONS

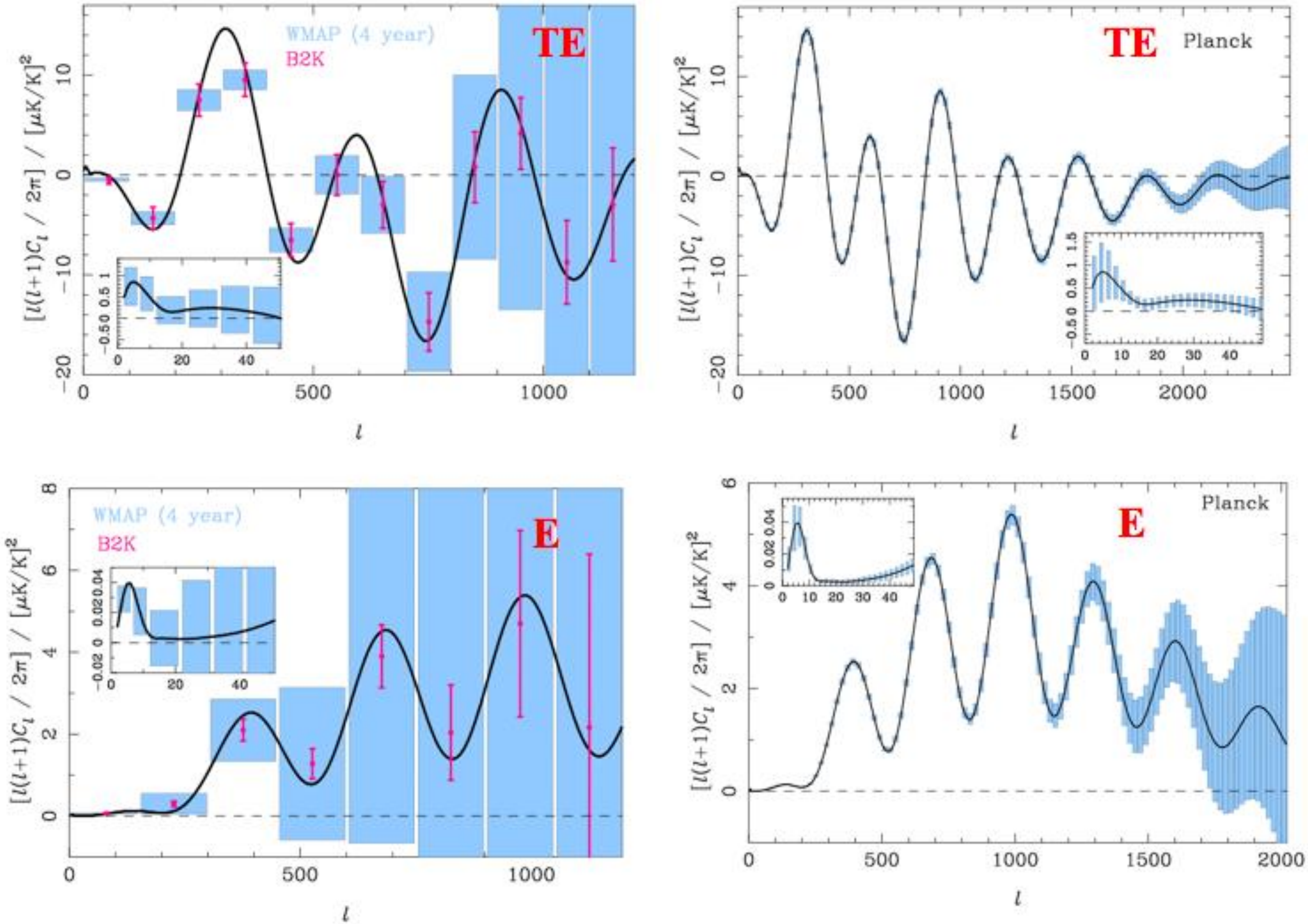
• Recent CMB measurements fully confirm Λ-CDM. Improved constraints on inflation

• With future measurements constraints on new parameters related to laboratory Physics could be achieved.

In 2012 from Planck we will know:

- If the total neutrino mass is less than 0.5eV.
- If there is an extra background of relativistic particles.
- Helium abundance with 0.01 accuracy.

We Want NOW 2012 !


WMAP (4 year)
B2K
TE
TE
Planck
E
E
Planck
[l(l+1)C_l / 2π] / [μK/K]^2
l