Inflation in a general reionization scenario

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"Harrison-Z'eldovich primordial spectrum is consistent with observations"

SP, A. Cooray, E. Giusarma, E. W. Kolb, A. Melchiorri, O. Mena, P.Serra
arXiv:1003.4763v1 [astro-ph.CO]

Ibericos 2010 Porto, 30/03/2010

For inflation produced by a single scalar field, during the slow-roll phase, the kinetic energy of the field is negligible and the potential is nearly constant:

$$\rho_\phi = V(\phi) + \frac{\dot{\phi}^2}{2} \approx V(\phi) \approx \text{const.}$$

This gives rise to a (quasi-) de Sitter phase: $H^2 = \frac{8\pi G}{3} V(\phi)$

The perturbations in the field are proportional to the value of the Hubble parameter *at the time of horizon crossing:*

$$(\Delta\phi)_k = \left(\frac{H_{hc}}{2\pi}\right)^2 = \frac{2G}{3\pi} V(\phi)^2$$

Since V(ϕ) is not actually constant, but slowly-varying, we expect a weak dependence of the amplitude of the perturbations on the wavenumber

➡ If the perturbations were originated from the dynamics of a scalar field the spectrum should not be *exactly* scale invariant

HZ spectrum

- Inflation predicts $n \approx 1$ but $n \neq 1$
- A major point to clarify is if HZ's **n=1** is ruled out from currrent observations or not.
- If $n \neq 1$ this would provide an indication for the dynamical evolution as perturbation are being produced

WMAP7

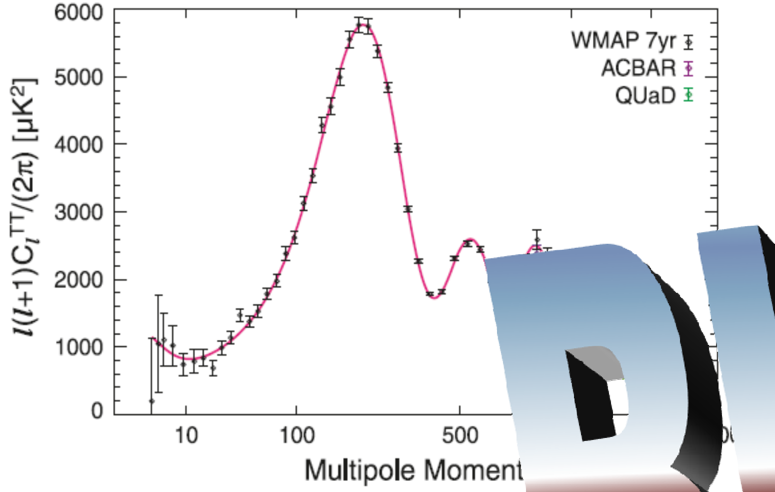


FIG. 7.— The *WMAP* 7-year temperature power spectrum (Larson et al. 2010), along with ... from ACBAR (Reichardt et al. 2009) and QUaD (Brown et al. 2009) experiments. We show the ACBA... the errors in the *WMAP* power spectrum are dominated by noise. We do not use the power spe... contribution from the SZ effect and point sources. The solid line shows the best-fitting 6-paramet... alone (see the 3rd column of Table 1 for the maximum likelihood parameters).

Class	Parameter	*WMAP* 7-year Mean[b]	*WMAP*+BAO+H_0 Mean
Primary	$100\Omega_b h^2$	$2.258^{+0.057}_{-0.056}$	2.260 ± 0.053
	$\Omega_c h^2$	0.1109 ± 0.0056	0.1123 ± 0.0035
	Ω_Λ	0.734 ± 0.029	$0.728^{+0.015}_{-0.016}$
	n_s	0.963 ± 0.014	0.963 ± 0.012
		0.088 ± 0.015	0.087 ± 0.014
		$(2.43 \pm 0.11) \times 10^{-9}$	$(2.441^{+0.088}_{-0.092}) \times 10^{-9}$

...del	...ameter[a]	7-year *WMAP*[b]	*WMAP*+ACBAR+QUaD[c]
P... law	n_s	0.963 ± 0.014	$0.962^{+0.014}_{-0.013}$

BUT...

... *Pri...ial Spectr... I... c and Gravitational Waves*

...e 7-y... W... P... a... mbined with BAO and H_0 ...de th... ale... a... t s... ctrum by more than 3σ, if ...nore ... or... le... gravitational waves). ...r a power-law power spectrum of primordial curvature perturbations $\mathcal{R}_k$, i.e.,

$$\Delta^2_{\mathcal{R}}(k) = \frac{k^3\langle|\mathcal{R}_k|^2\rangle}{2\pi^2} = \Delta^2_{\mathcal{R}}(k_0)\left(\frac{k}{k_0}\right)^{n_s-1}, \quad (29)$$

where $k_0 = 0.002$ Mpc^{-1}, we find

$$n_s = 0.963 \pm 0.012 \ (68\% \ \text{CL}).$$

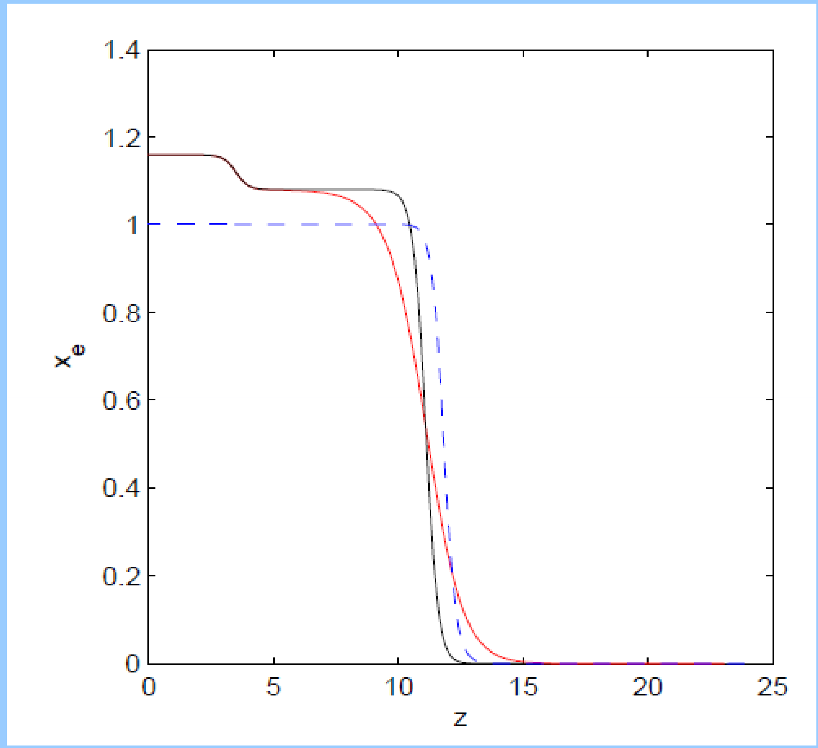
Komatsu, E., et.al (2010)

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

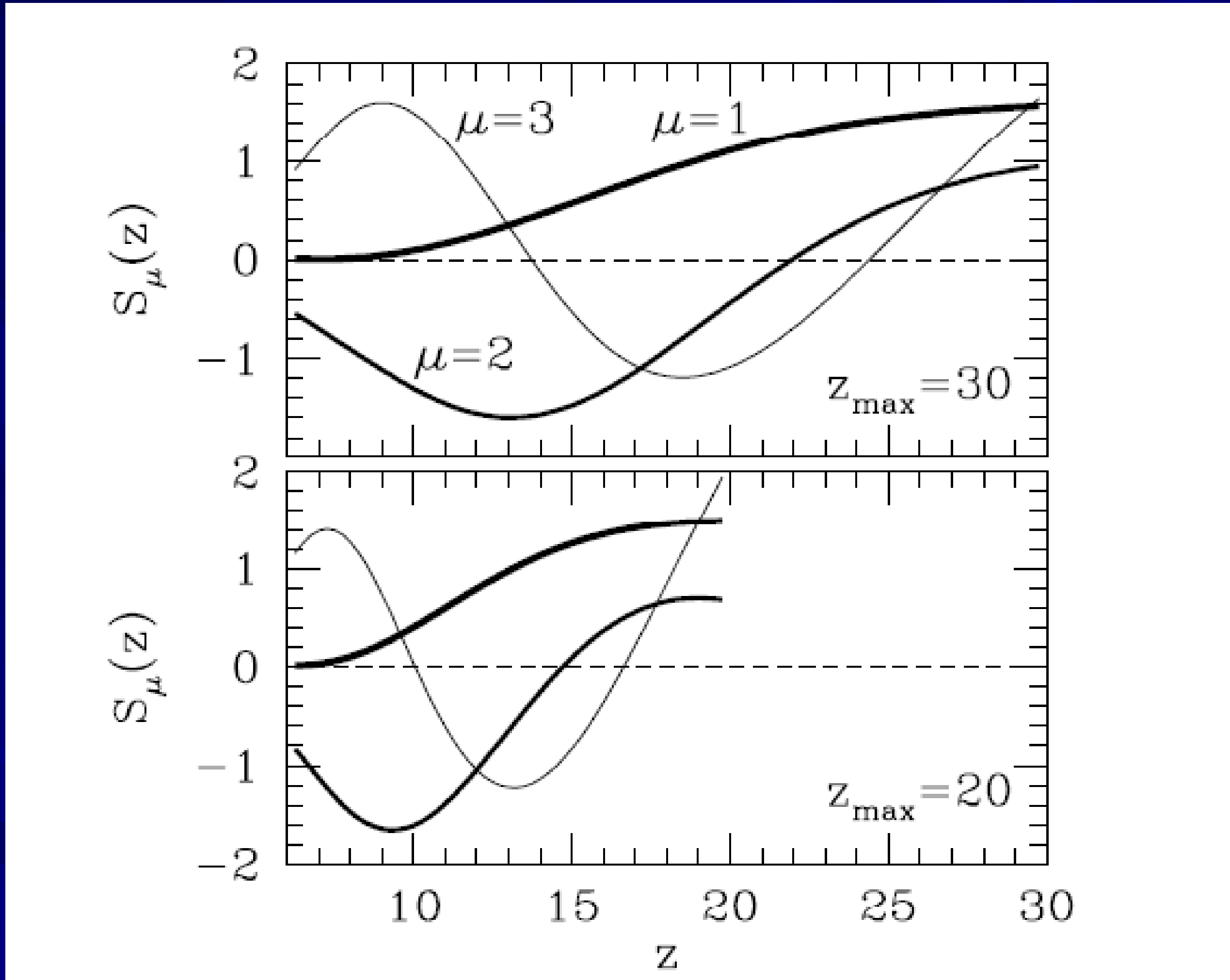
Following Mortonson & Hu we can parametrize the reionization history as a free function of the redshift by decomposing the free electron fraction as

$$x_e(z) = x_e^{fid}(z) + \sum_\mu m_\mu S_\mu(z)$$

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

MH's Reionization

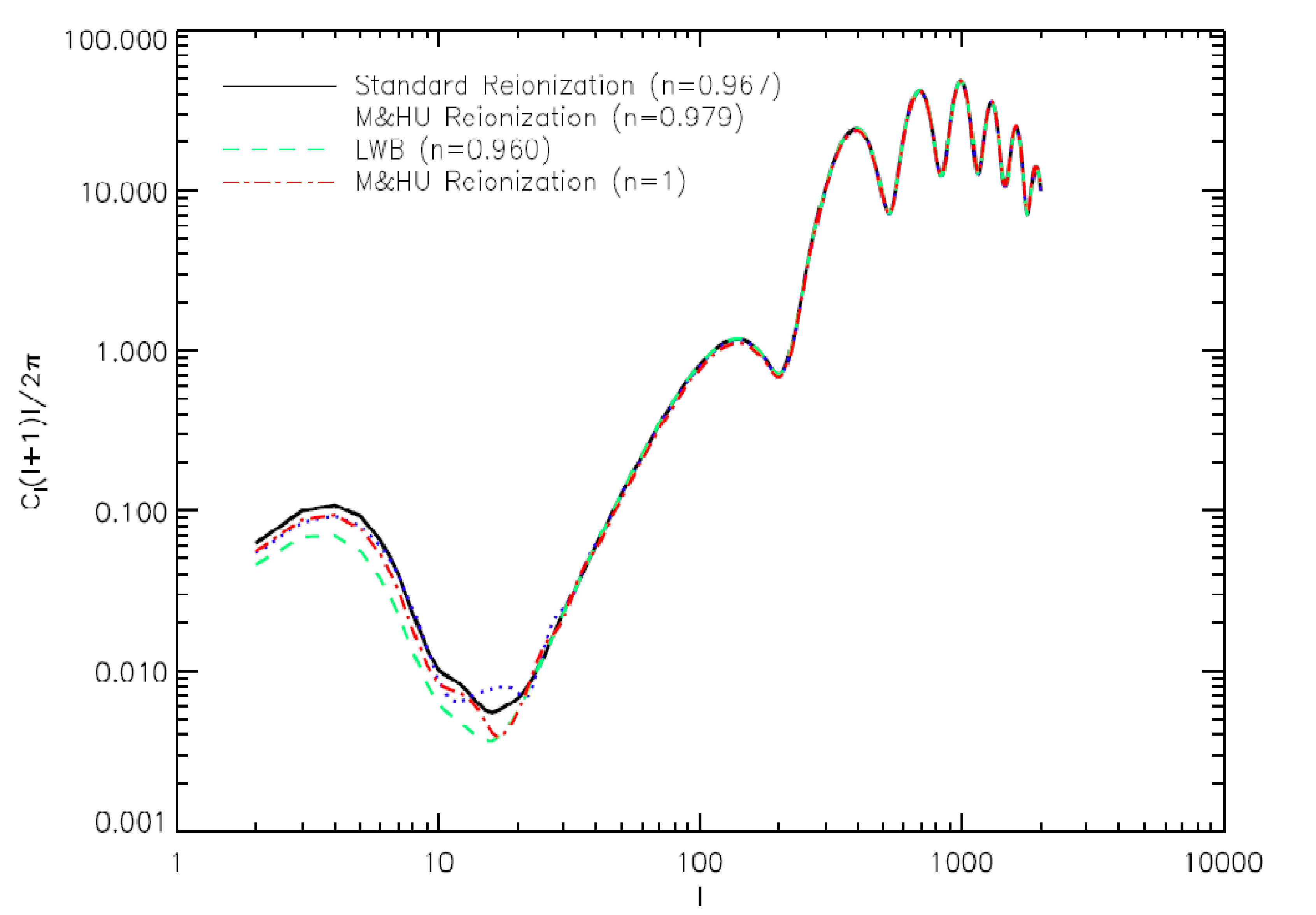


Results

Dataset	Ionization	n (68% c.l.)	95% c.l.
WMAP7	sudden	0.965 ± 0.014	$n \leq 0.993$
CMB All	sudden	0.959 ± 0.013	$n \leq 0.984$
WMAP7	MH	0.993 ± 0.023	$n \leq 1.042$
CMB All	MH	0.975 ± 0.017	$n \leq 1.011$
CMB All+LRG-7	MH	0.966 ± 0.014	$n \leq 0.994$
CMB All+BAO	MH	0.965 ± 0.014	$n \leq 0.995$
CMB All+BAO	MH+$w(z)$	0.985 ± 0.018	$n \leq 1.025$

CMB All = WMAP7+ BICEP+QUAD+ACBAR

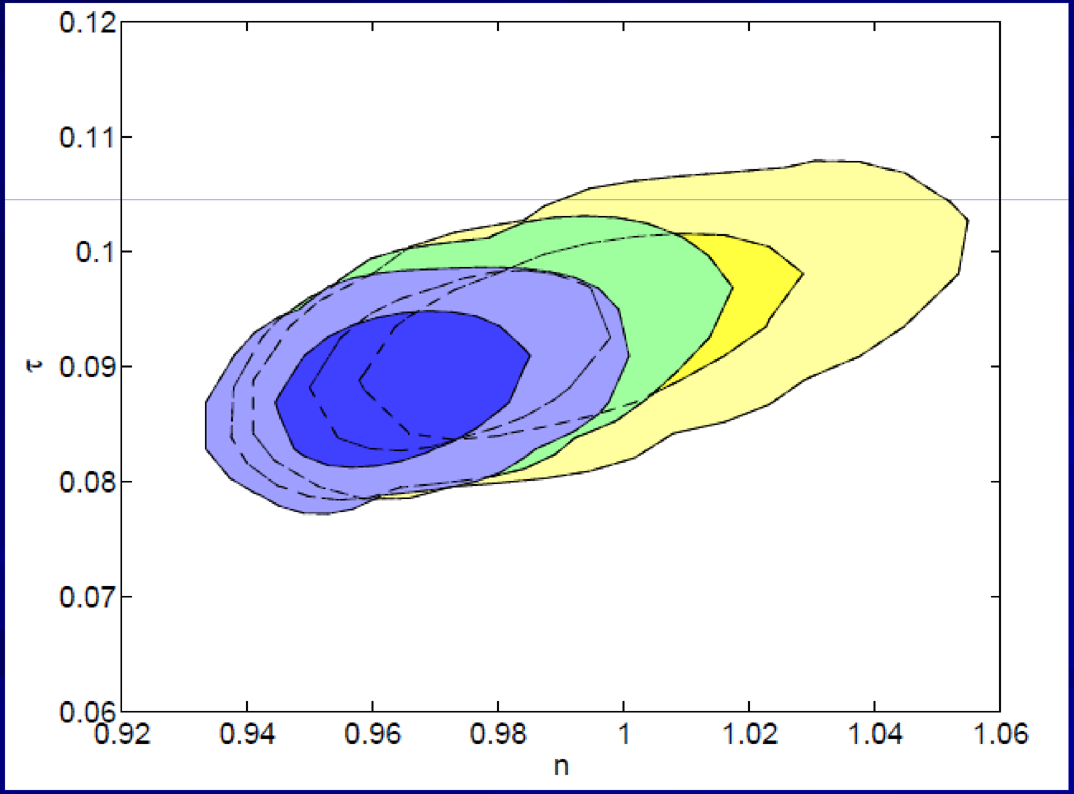
$$w(z) = w_0 + w_a \frac{z}{1+z}$$



Standard Reionization (n=0.967)
M&HU Reionization (n=0.979)
LWB (n=0.960)
M&HU Reionization (n=1)
100.000
10.000
1.000
0.100
0.010
0.001
1
10
100
1000
10000
l
$C_l(l+1)l/2\pi$

Optical Depth

It is interesting to consider the constraints on the optical depth, derived by integrating xe(z)



WMAP7 alone

CMB all

CMB all + BAO

Cosmology with HZ's n=1?

Parameter	Constraint (68% c.l.)
$\Omega_b h^2$	0.0234 ± 0.0004
$\Omega_c h^2$	0.106 ± 0.005
H_0 (km s^{-1}Mpc^{-1})	74.2 ± 2.1
Age (Gyr)	13.6 ± 0.1
Ω_Λ	0.765 ± 0.022

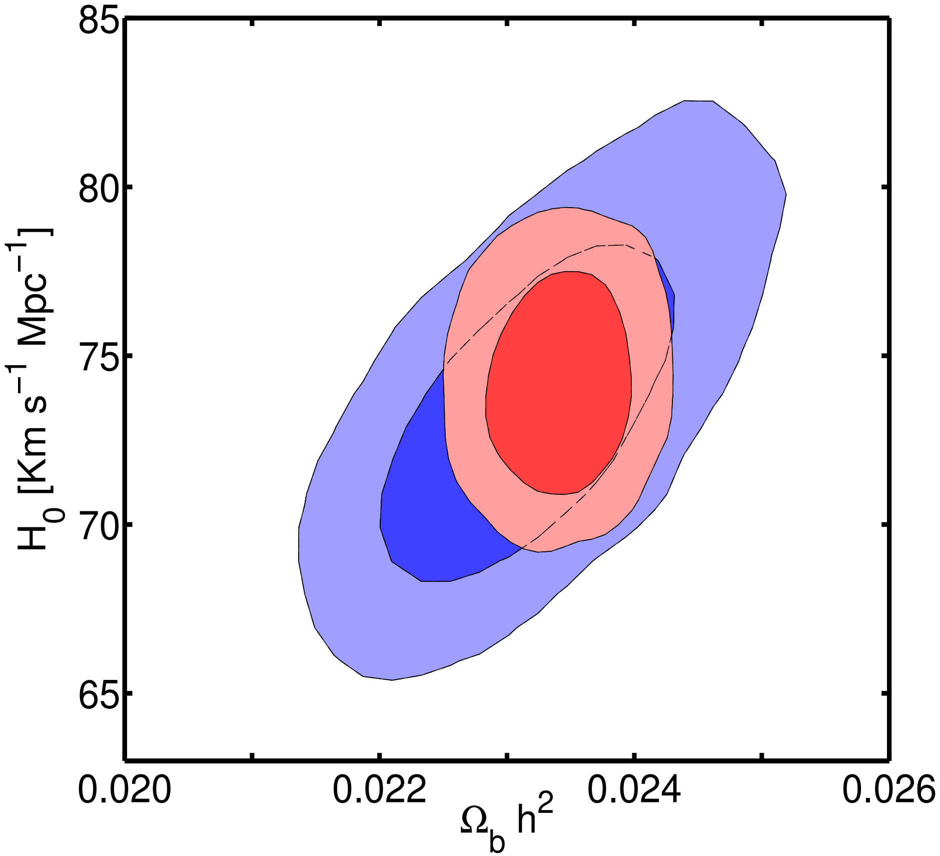
Sudden Reionization

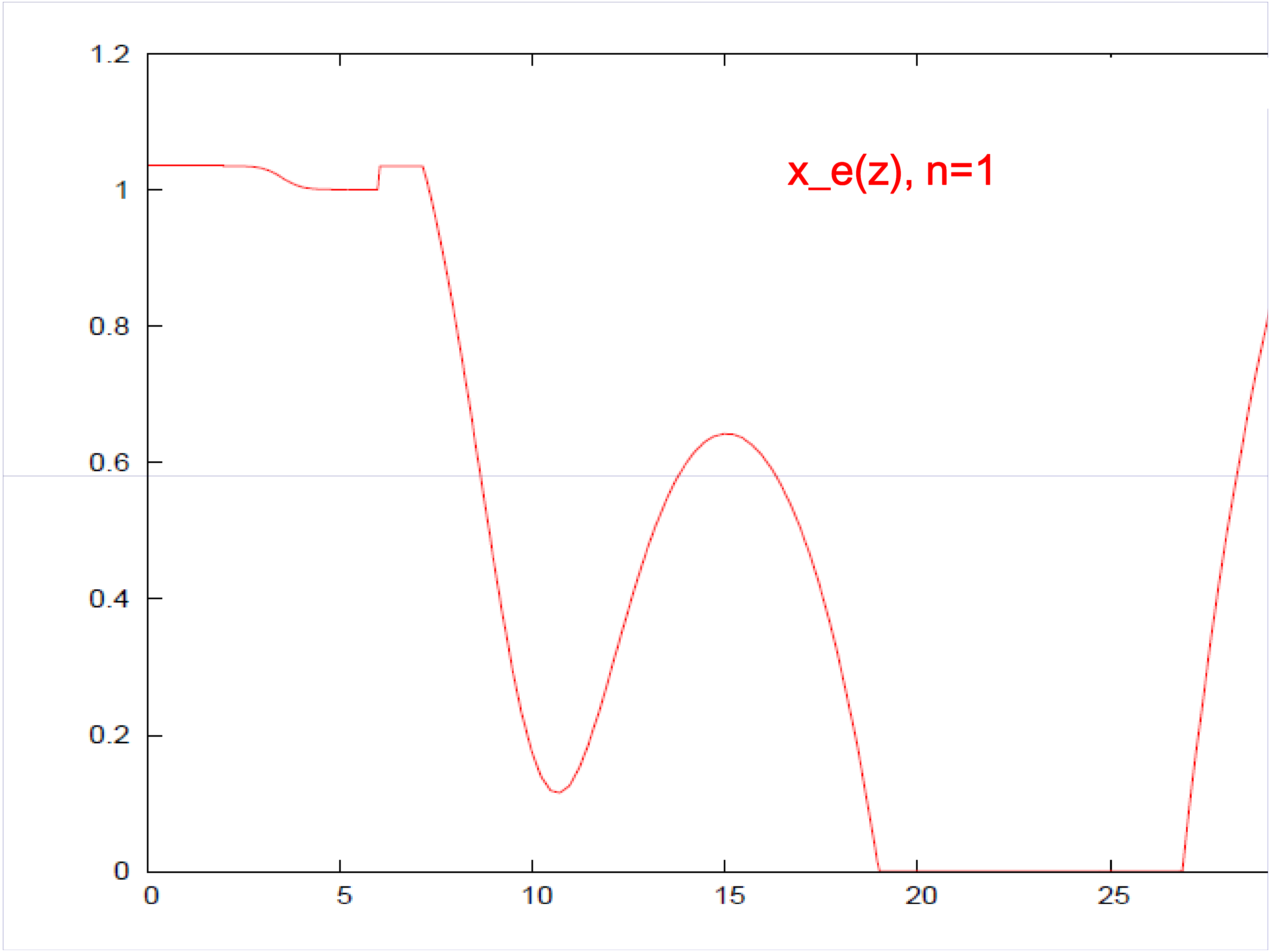
	HZ
ω_b	0.0239 ± 0.0007
ω_c	0.114 ± 0.007
h	$0.728^{+0.027}_{-0.026}$
τ	$0.108^{+0.036}_{-0.034}$
$\log[10^{10} A_S]$	3.14 ± 0.07
n_S	—

F. Finelli, J. Hamann, S. M. Leach, and J. Lesgourgues, arXiv:0912.0522 [astro-ph.CO].

MH reionization

WMAP7, n parameter
WMAP7, n=1





x_e(z), n=1
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25

Conclusion

- Inflation predicts $n \cong 1$ but $n \neq 1$

- WMAP7 data $n = 0.963 \pm 0.014 \ (68\% \ CL)$
  but assuming Sudden Reionization

- A modified Reionization history weakens the bound on the spectral index

- Assuming an HZ primordial spectrum and a modified Reionization lead a viable cosmology