Implications of absolute neutrino mass on cosmological parameter estimation

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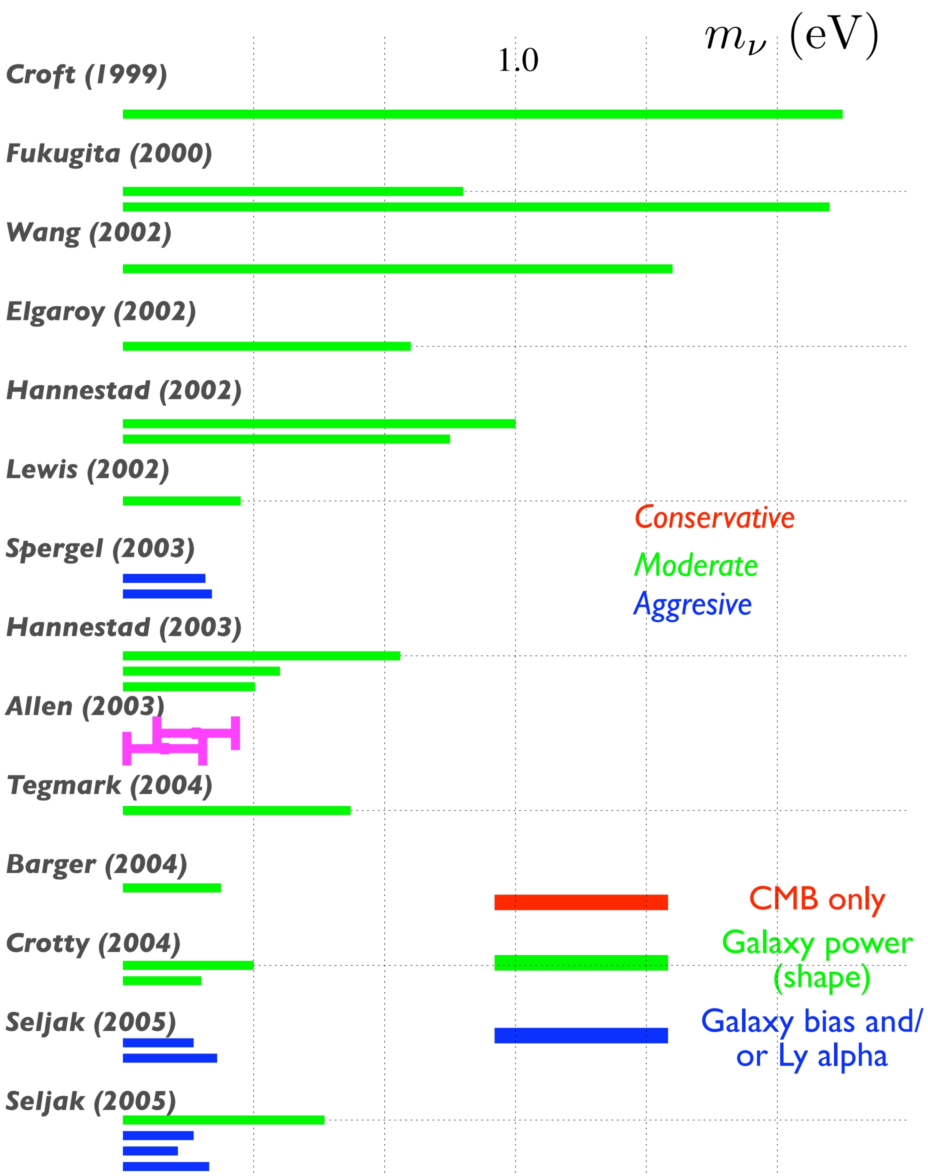
KI, M. Fukugita & M. Kawasaki, PRD71 043001 (2005)

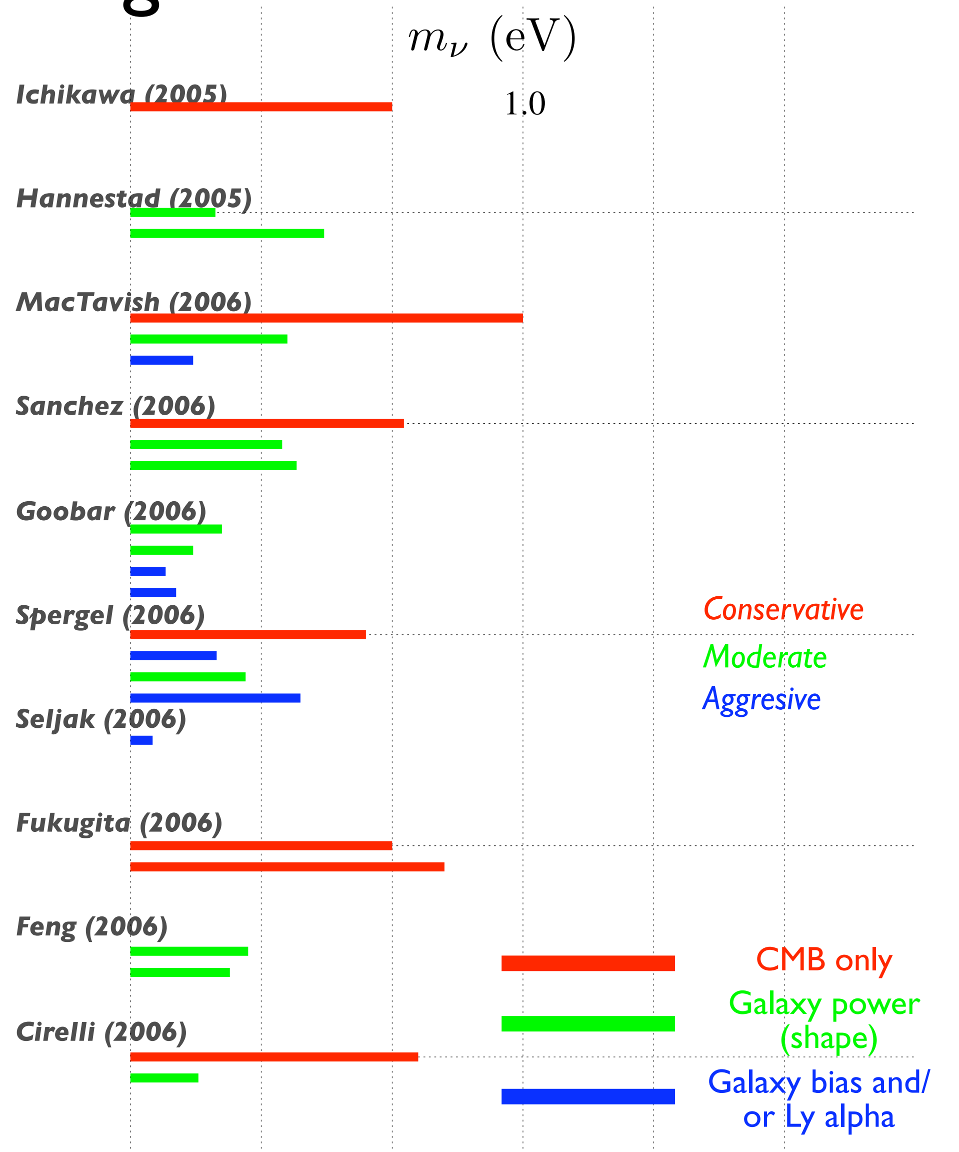
M. Fukugita, KI, M. Kawasaki & O. Lahav, PRD74 027302 (2006)

KI & M. Fukugita , in preparation

International Workshop on Double Beta Decay and Neutrinos,
Osaka, June 2007

There are many works to derive constraint on neutrino masses from cosmological data.



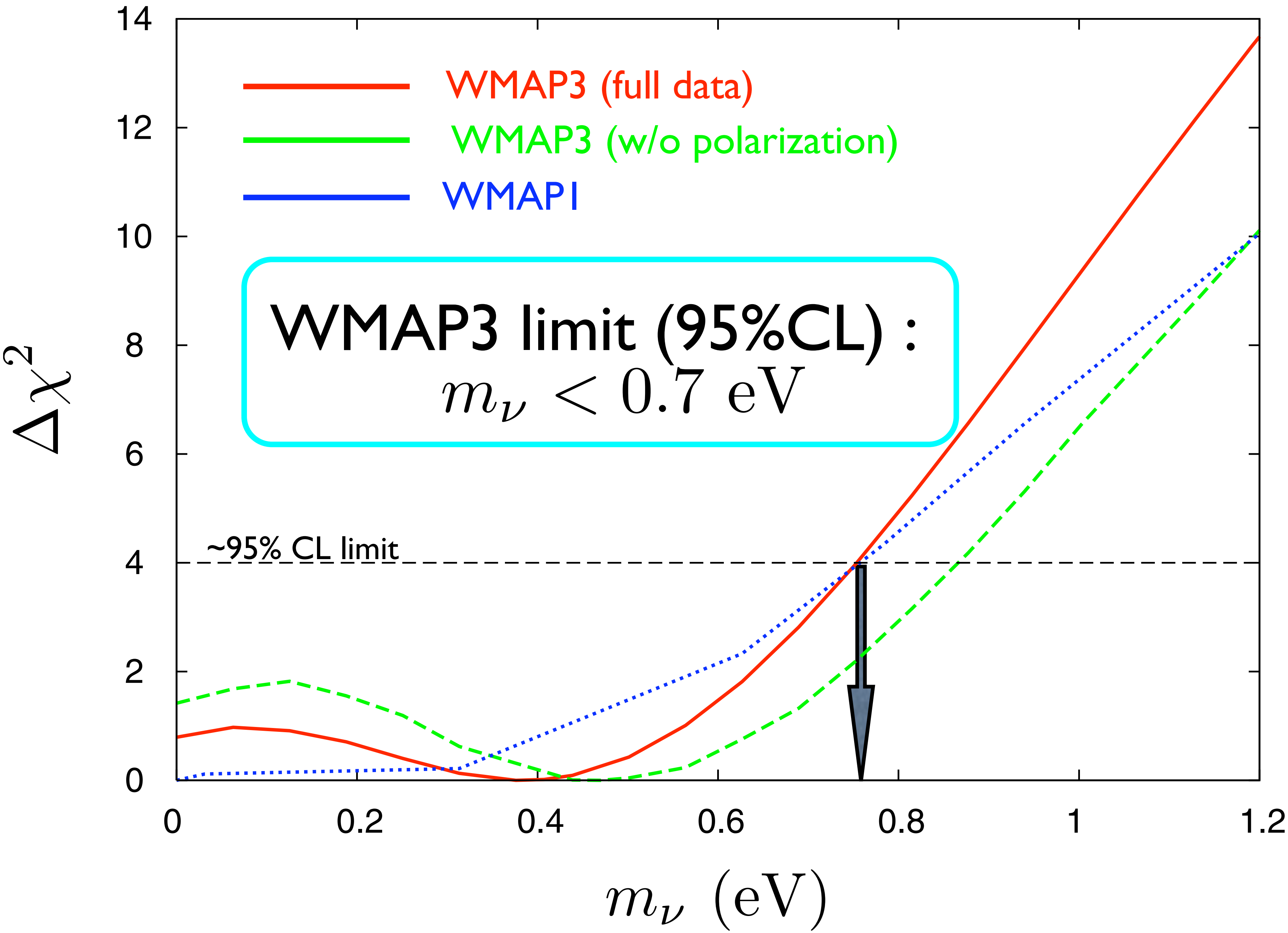


χ^2 analysis

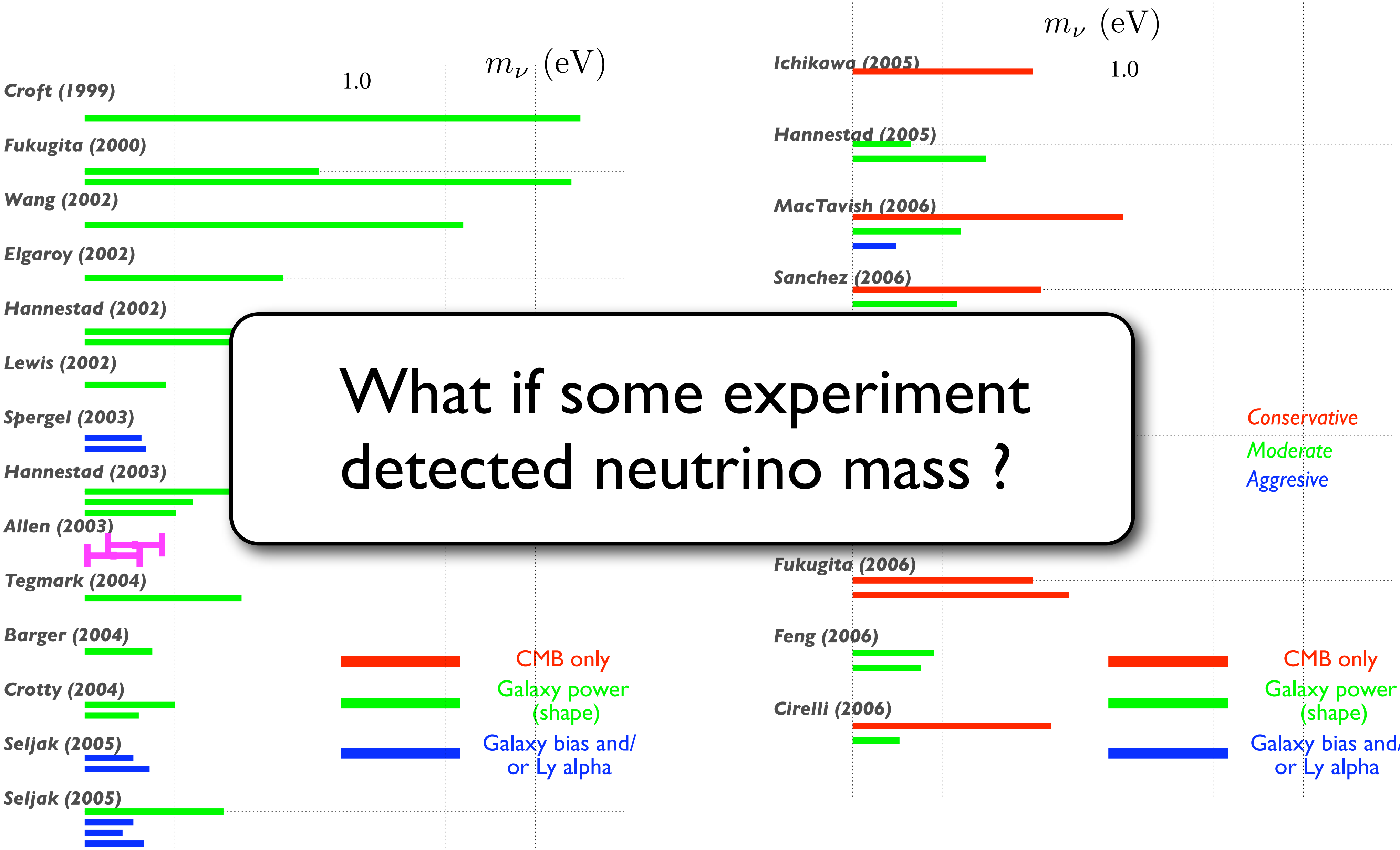
(We marginalized over 6 other LCDM cosmological parameters)

KI, Fukugita & Kawasaki, PRD71 043001 (2005)

Fukugita, KI, Kawasaki & Lahav, PRD74 027302 (2006)



There are many works on cosmological constraint on neutrino masses.



What if some experiment detected neutrino mass ?

We need cosmological parameter estimation fixing neutrino mass to some finite value.

WMAP Cosmological Parameters Model: lcdm Data: wmap	
$10^2\Omega_b h^2$	2.229 ± 0.073
$\Delta^2_{\mathcal{R}}(k = 0.002/\mathrm{Mpc})$	$(23.5 \pm 1.3) \times 10^{-10}$
h	$0.732^{+0.031}_{-0.032}$
H_0	$73.2^{+3.1}_{-3.2}$ km/s/Mpc
$\log(10^{10} A_s)$	3.156 ± 0.056
$n_s(0.002)$	0.958 ± 0.016
$\Omega_b h^2$	0.02229 ± 0.00073
$\Omega_c h^2$	$0.1054^{+0.0078}_{-0.0077}$
Ω_Λ	0.759 ± 0.034
Ω_m	0.241 ± 0.034
$\Omega_m h^2$	$0.1277^{+0.0080}_{-0.0079}$
σ_8	$0.761^{+0.049}_{-0.048}$
τ	0.089 ± 0.030
θ_A	0.5952 ± 0.0021 °
z_r	$11.0^{+2.6}_{-2.5}$

Assuming massless neutrinos.

http://lambda.gsfc.nasa.gov/

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The Hubble constant decreases significantly by the finite neutrino mass.

$$m_\nu \sim 0.5 \text{ eV}$$

$$\rightarrow H_0 \sim 60$$

($H_0 = 73.2 \pm 3.1$ for massless case.)

http://lambda.gsfc.nasa.gov/

We assume flat Lambda CDM model (6 parameters) + neutrino mass

baryon density
CDM density
Hubble constant
epoch of reionization
amplitude of fluctuation
a slope for the scalar perturbation

Hubble constant (expansion rate at present): H_0

$$H_0 = 100 h \,\mathrm{km/s/Mpc}$$

neutrino mass (for one generation): m_ν

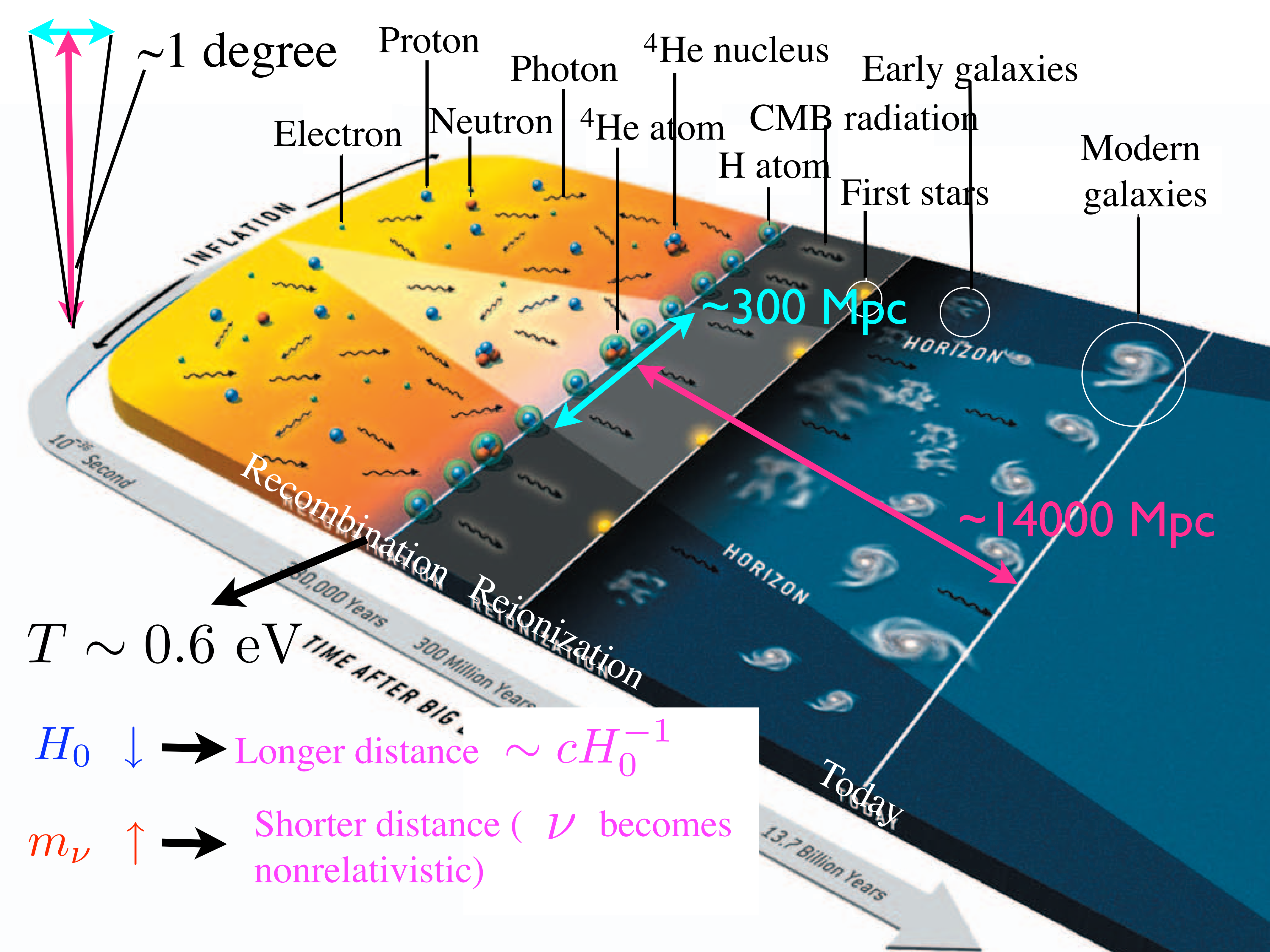
We assume three generations and the masses are degenerate.

neutrino mass density (relative to the critical density)

$$\omega_\nu = \frac{3\, m_\nu}{94\, \mathrm{eV}}$$

1 eV corresponds to $\omega_\nu \sim 0.03$

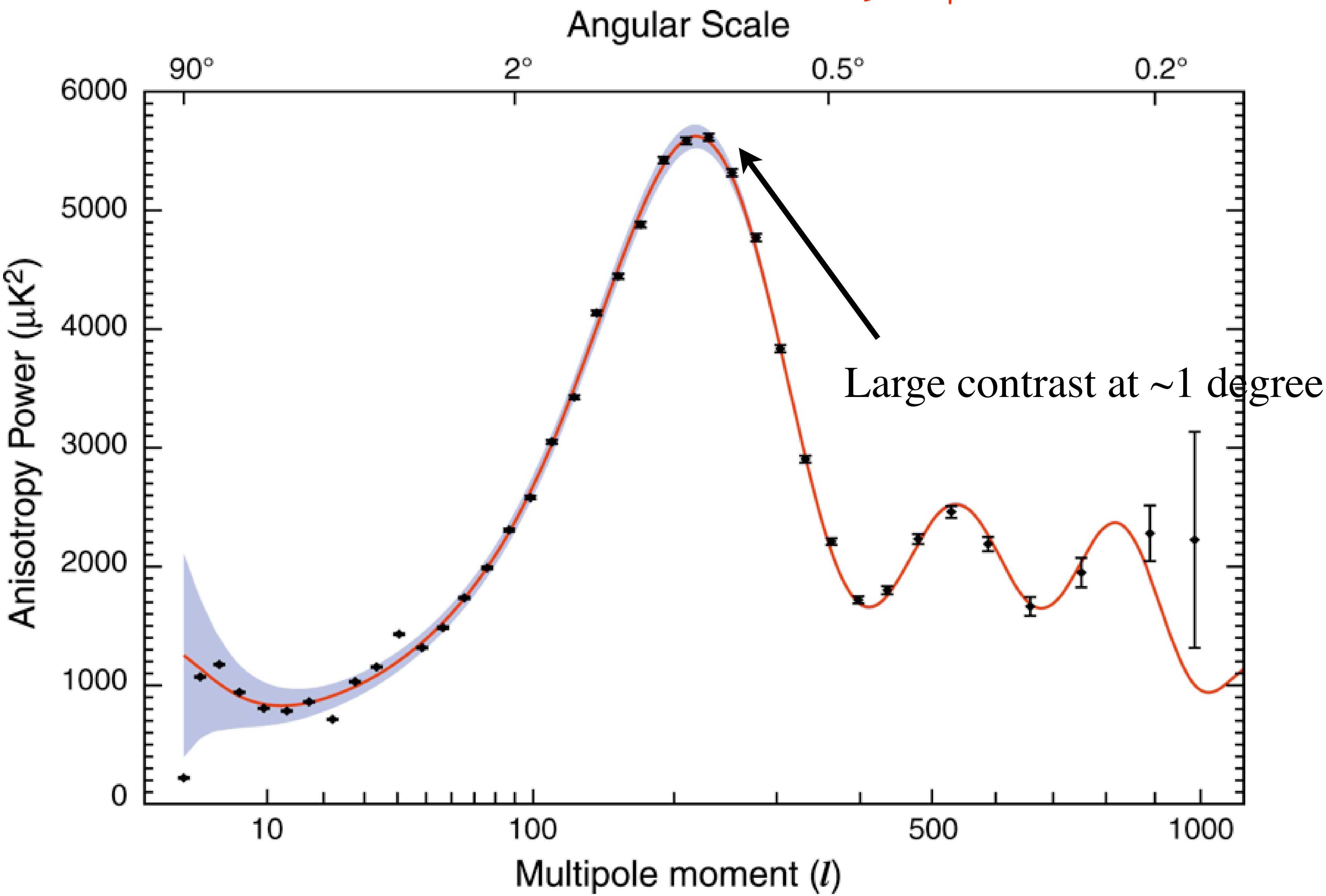
(cf. $\omega_{\mathrm{CDM}} \sim 0.105$)

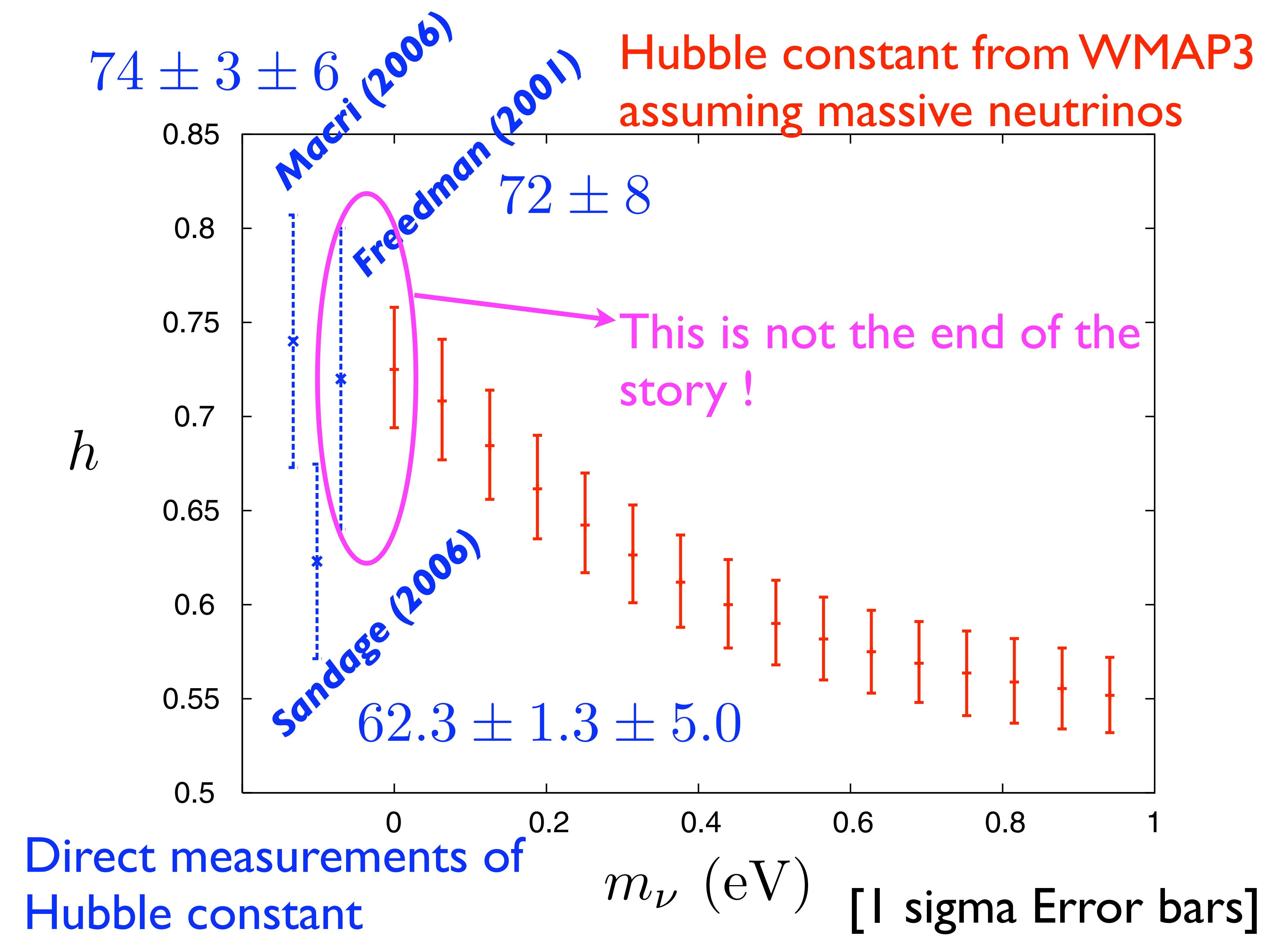

~1 degree
Proton
Photon
^{4}He nucleus
Early galaxies
Electron
Neutron
^{4}He atom
CMB radiation
H atom
First stars
Modern galaxies
INFLATION
~300 Mpc
HORIZON
Second
Recombination
Reionization
~14000 Mpc
HORIZON
300 Million Years
Today
13.7 Billion Years
$T \sim 0.6$ eV
H_0 $\downarrow$ → Longer distance $\sim cH_0^{-1}$
m_ν $\uparrow$ → Shorter distance (ν becomes nonrelativistic)

CMB angular spectrum

$\longrightarrow H_0 \downarrow$

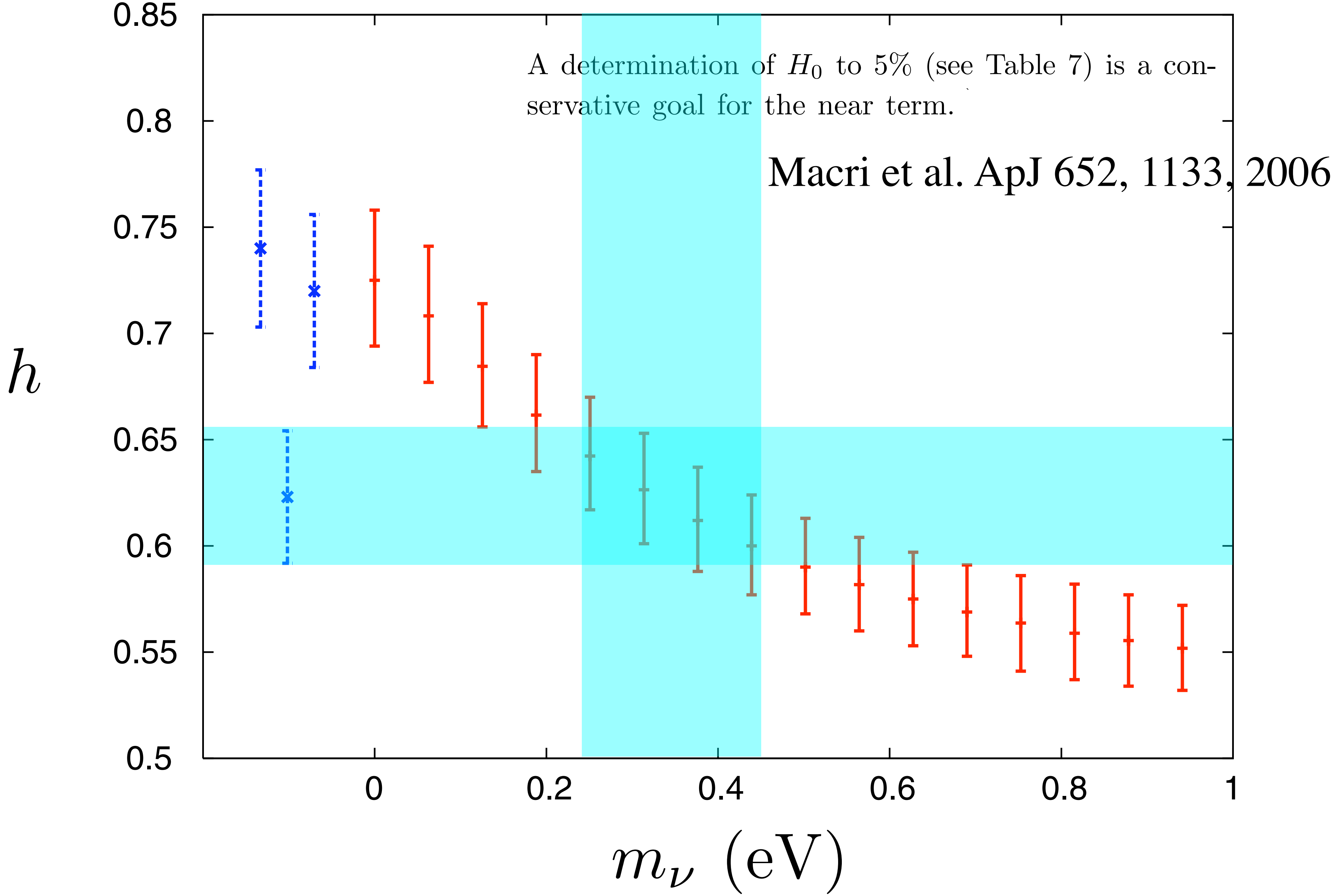
$\longleftarrow m_\nu \uparrow$





Hubble constant from WMAP3
assuming massive neutrinos
$74 \pm 3 \pm 6$
Macri (2006)
Freedman (2001)
72 ± 8
Sandage (2006)
$62.3 \pm 1.3 \pm 5.0$
This is not the end of the story !
h
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
0.2
0.4
0.6
0.8
1
m_ν (eV)
Direct measurements of Hubble constant
[1 sigma Error bars]

Assume h is measured with a total uncertainty of 5%



Conclusion

- If neutrino mass is detected to be $m_\nu \gtrsim 0.3$ eV, it is consistent with people claiming small Hubble constant.

- If not detected, upper bound of $\lesssim 0.3$ eV is very useful because uncertainty of m_ν is one of the largest systematic errors for estimating cosmological parameters from CMB (most notably for Hubble constant).

- These correlation between m_ν and H_0 holds if we combine CMB data with Supernova and galaxy clustering data.
  It is also expected to hold in the Planck era.