Title: Sloan Digital Sky Survey

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URL: http://pirsa.org/07080029

Abstract:

Surveys: An Outsider's Perspective

Mark Wyman
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Surveys: An Outsider's Perspective

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Overview

- What are Surveys?
  - 3D catalogs of galaxies and quasars
  - Data archives
- How can we use them?
  - Cosmology: primordial power spectrum
  - Astrophysics and rare phenomena

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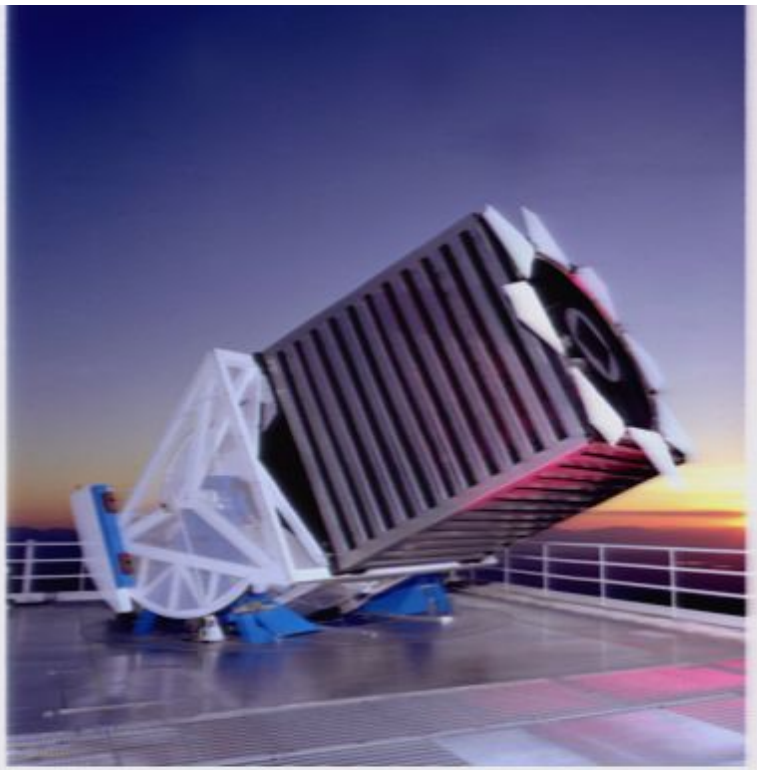
Surveys



Get a telescope; record the sky.

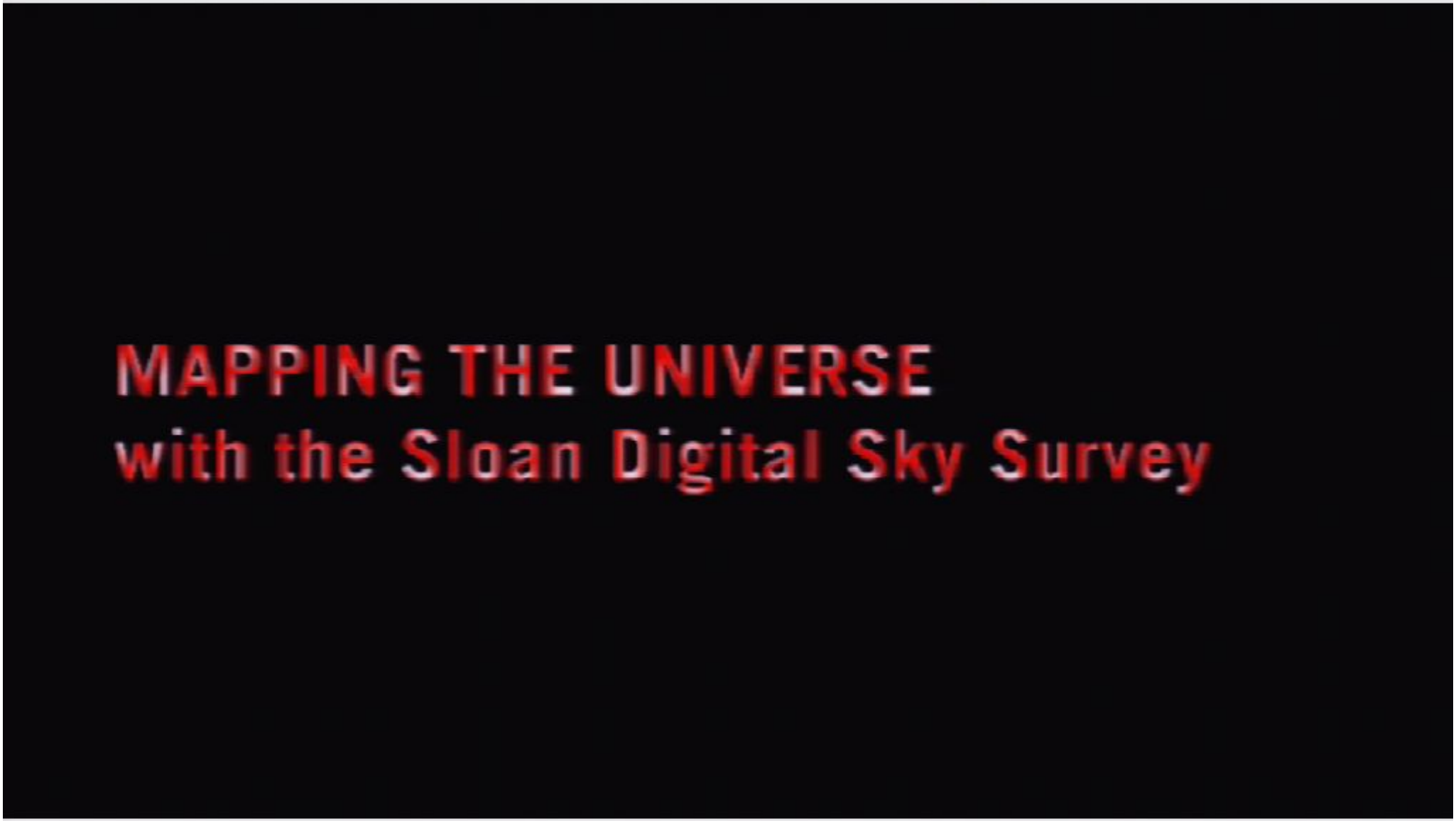
Qualities:

- Depth - how faint an object can you see?
- Breadth - how much of the sky do you see?
- Resolution - can you resolve objects?
- Spectroscopy - can you get 3d or 2d data?

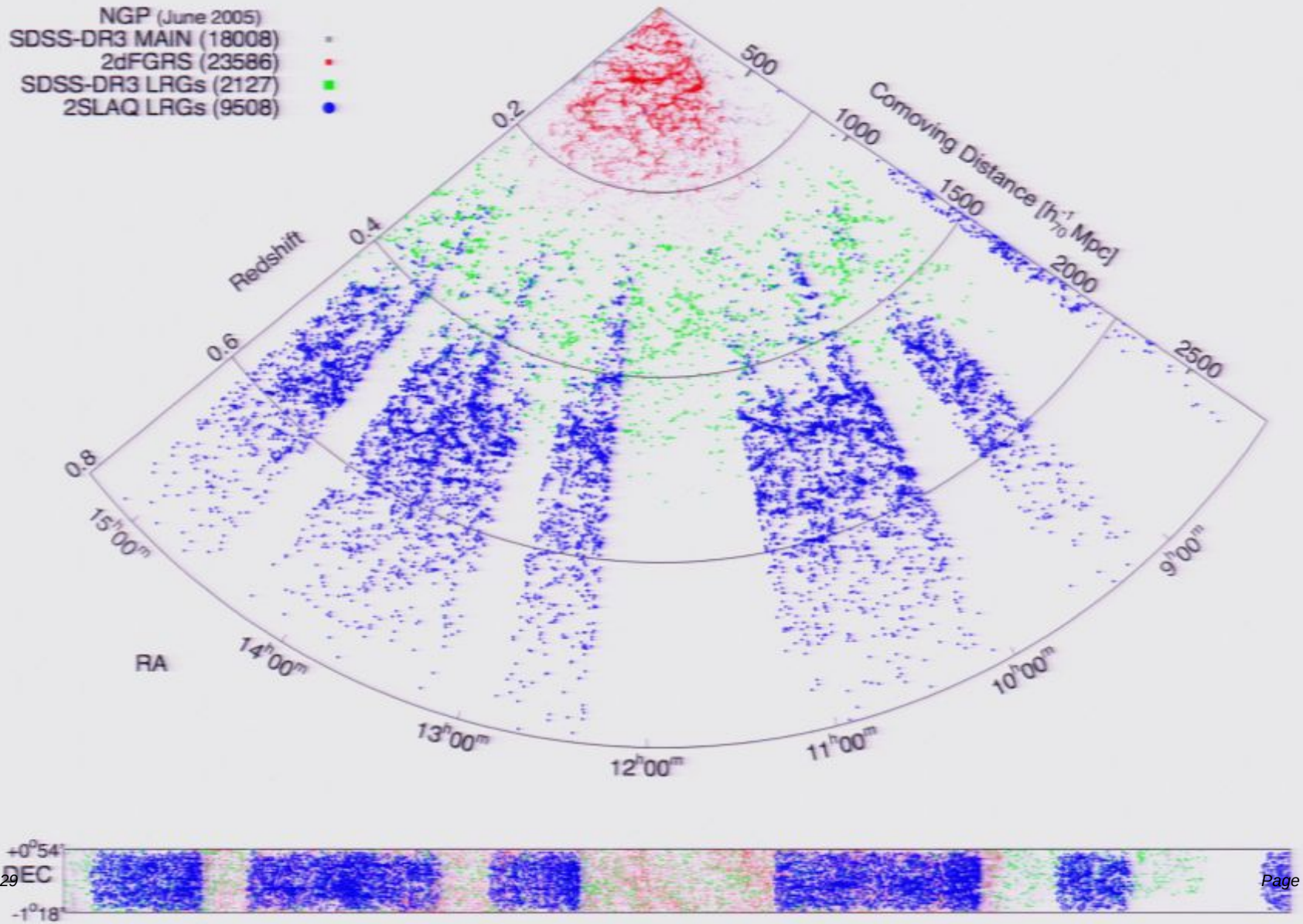
(SDSS 100” telescope in corner)

The SDSS Sky

The SDSS Sky



SDSS-2dF LRG Wedge Plot



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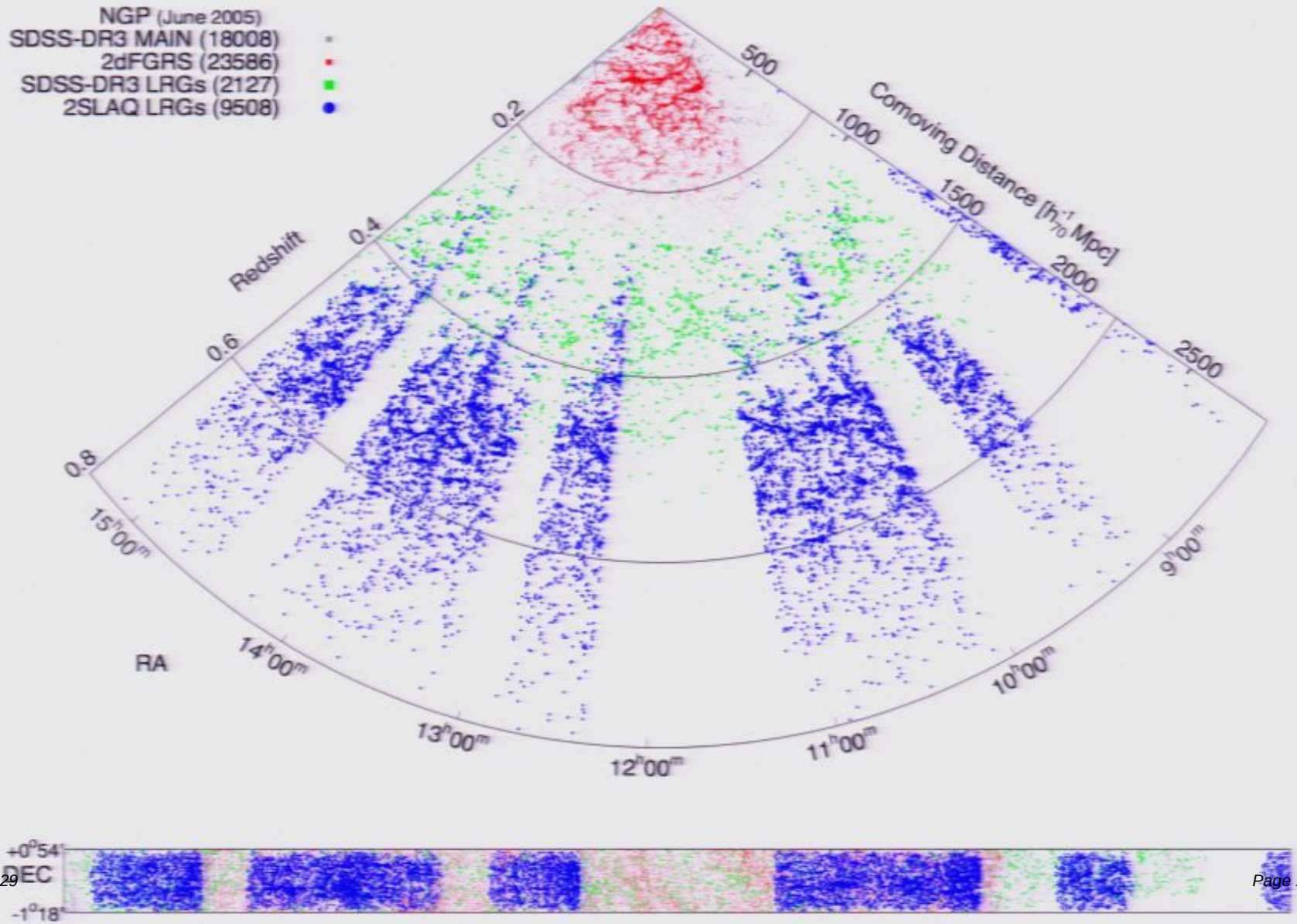

Quasars and Galaxies: Why?

- Quasars are *distant* and *old* (up to z=6!)
  - *distance* implies they are behind other objects (LyA talk!)
  - *age* implies they lived in another epoch
- Galaxies are *big*, *bright,* and *trace DM*
  - We can *see* and *resolve* them far away
  - They are our *primary tracers* of where matter is (in the form of ***Clusters***)

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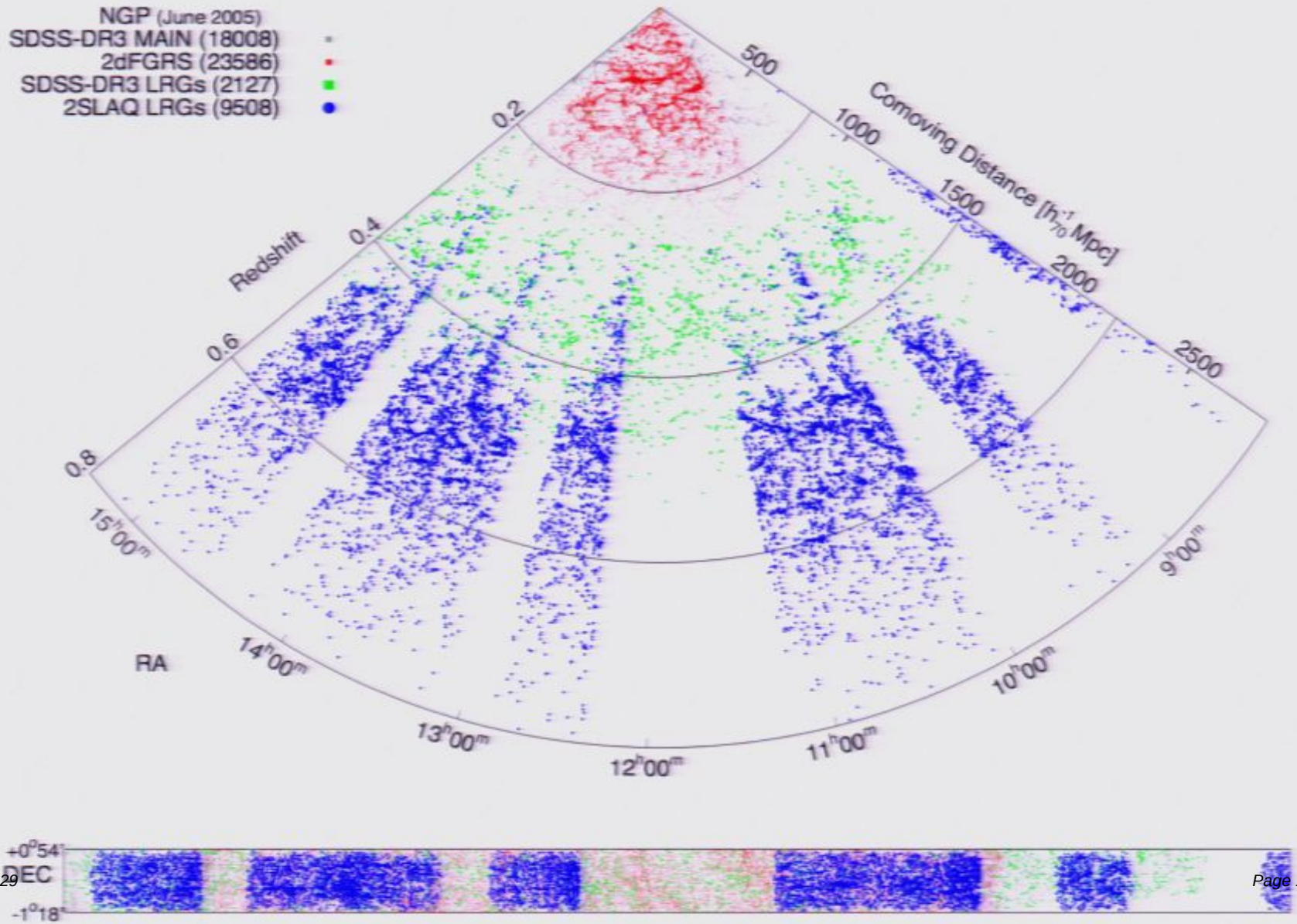

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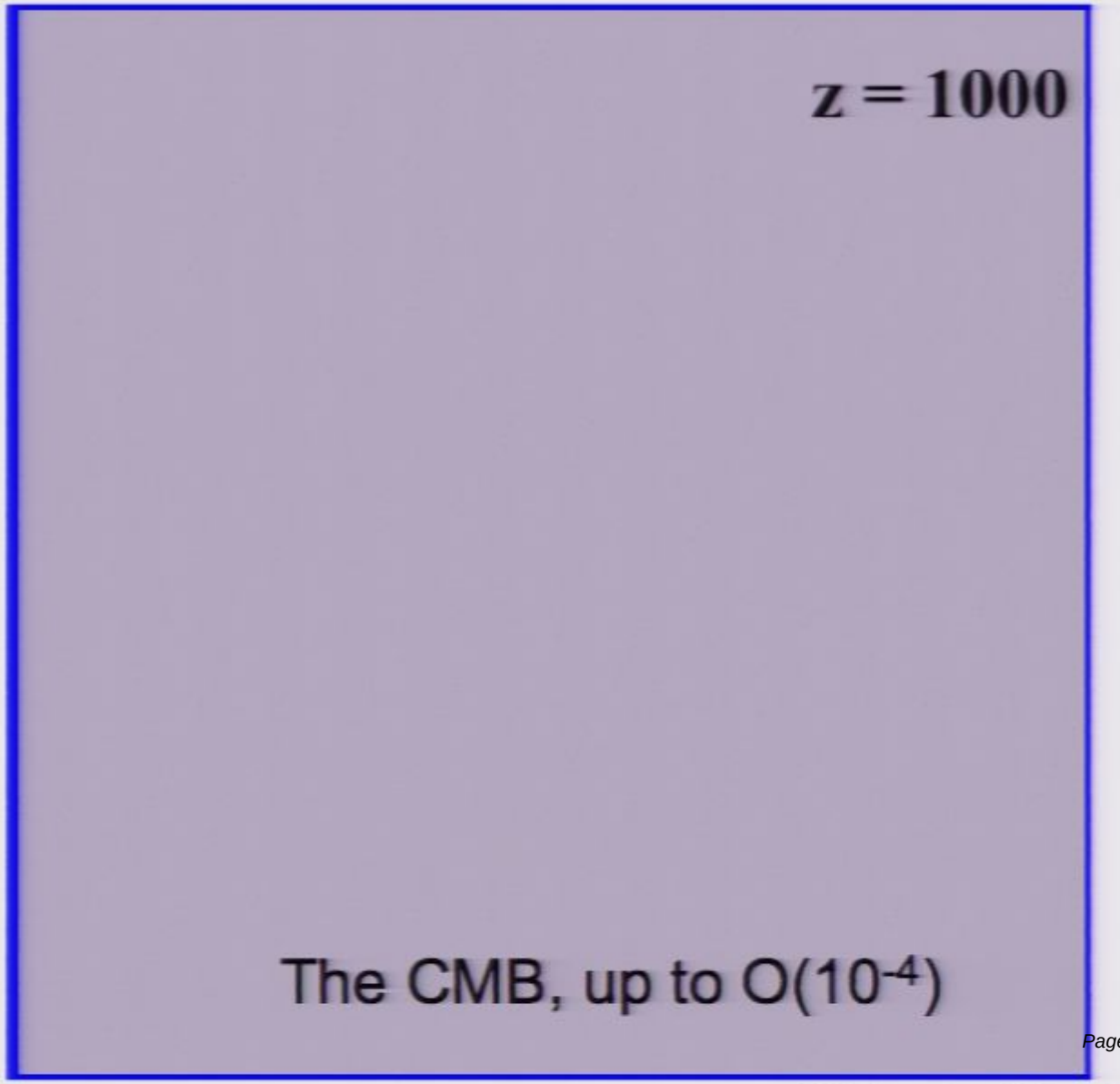
Galaxies are NOT the CMB



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tegmark@mit.edu
Hunt for Dark Matter
May 11, 2007

Slides by Max Tegmark

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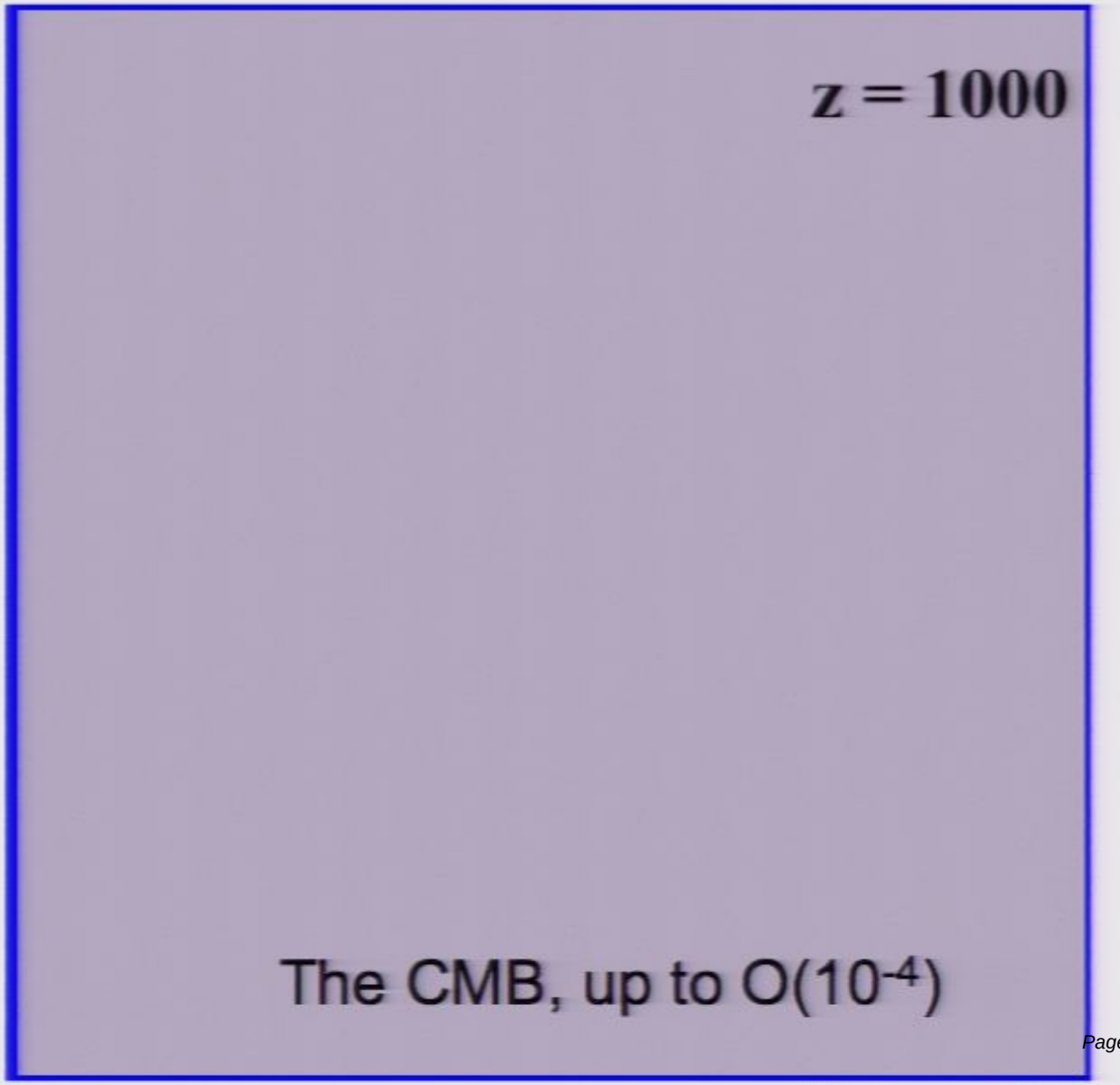

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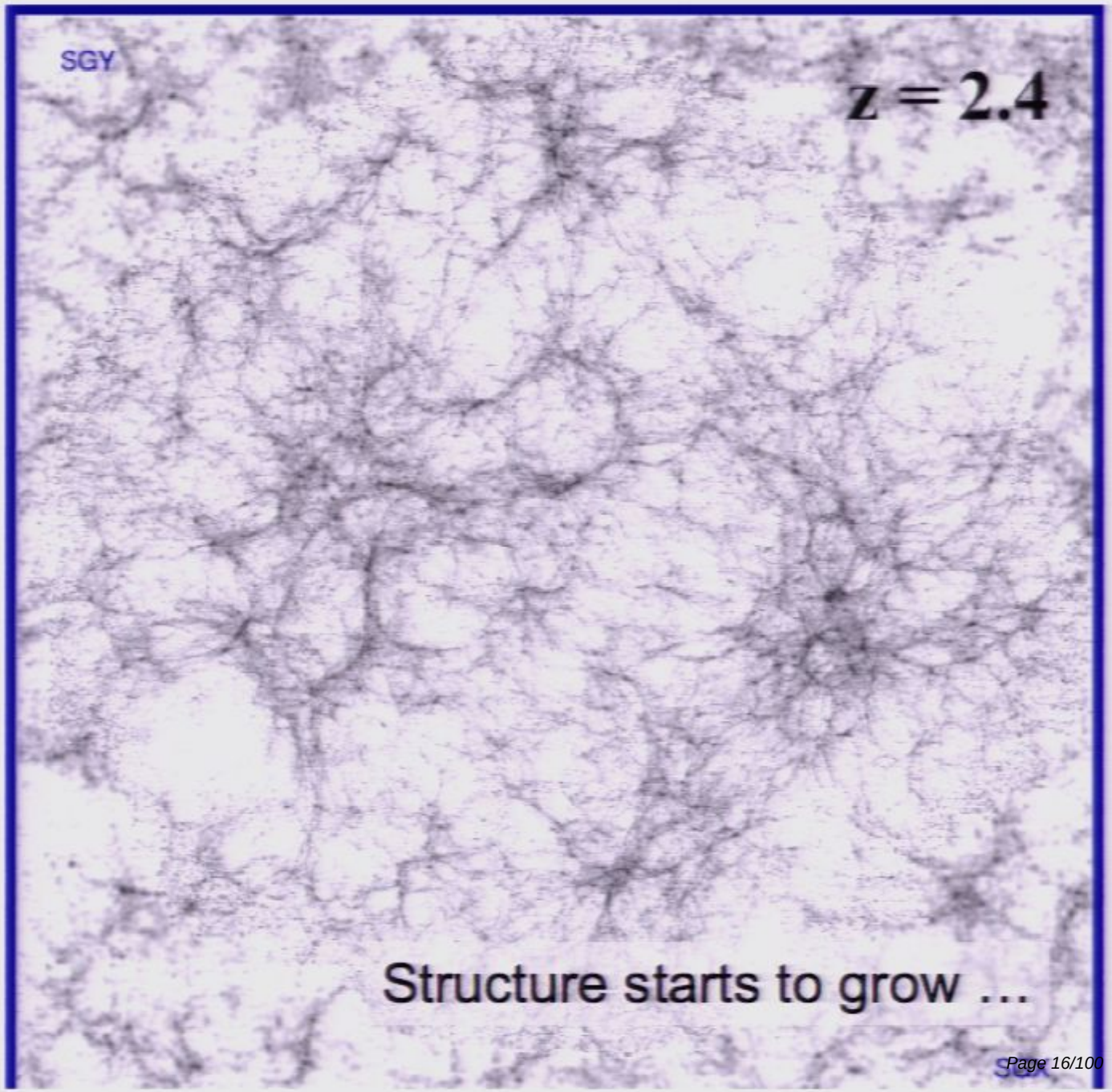

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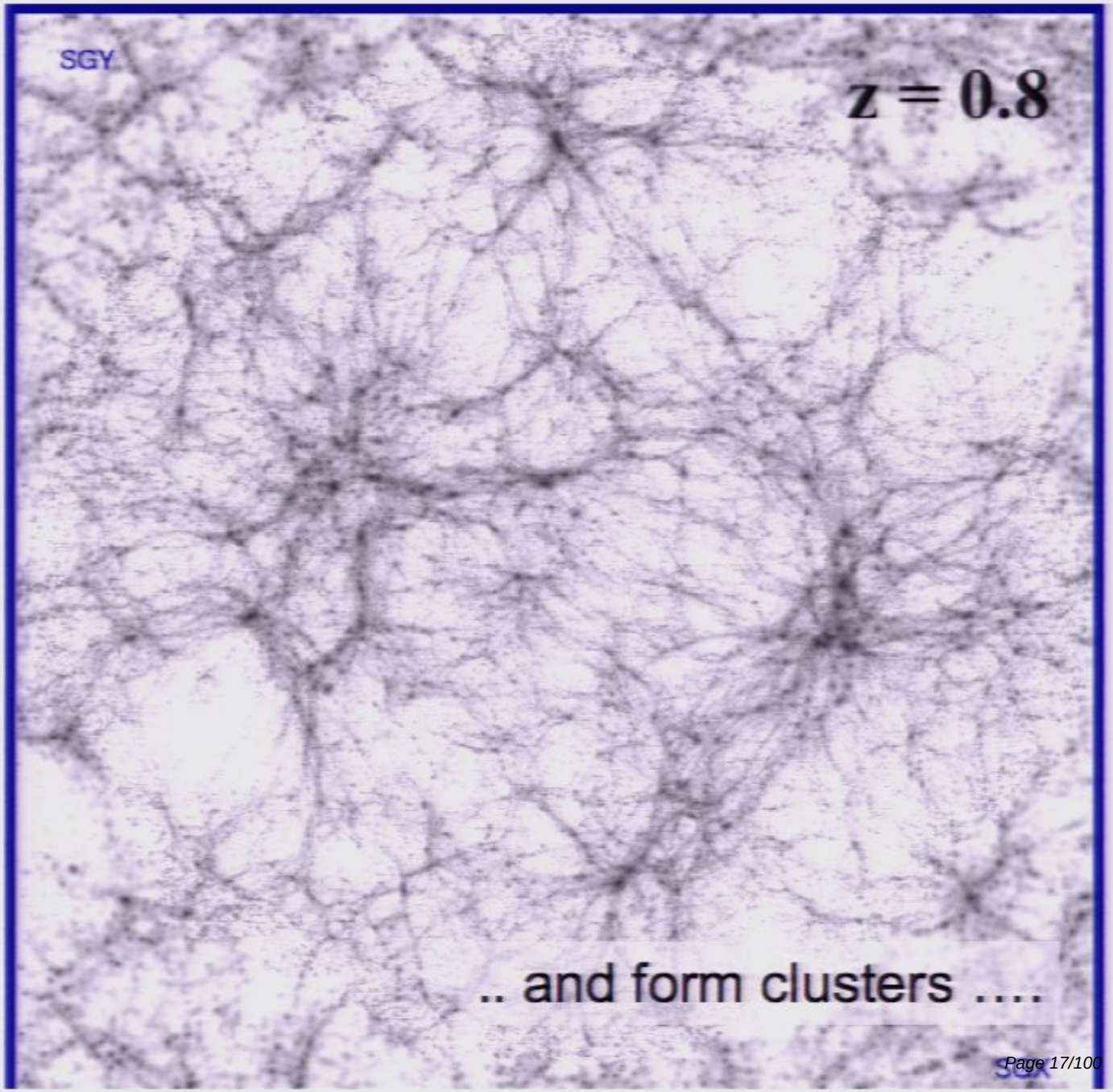

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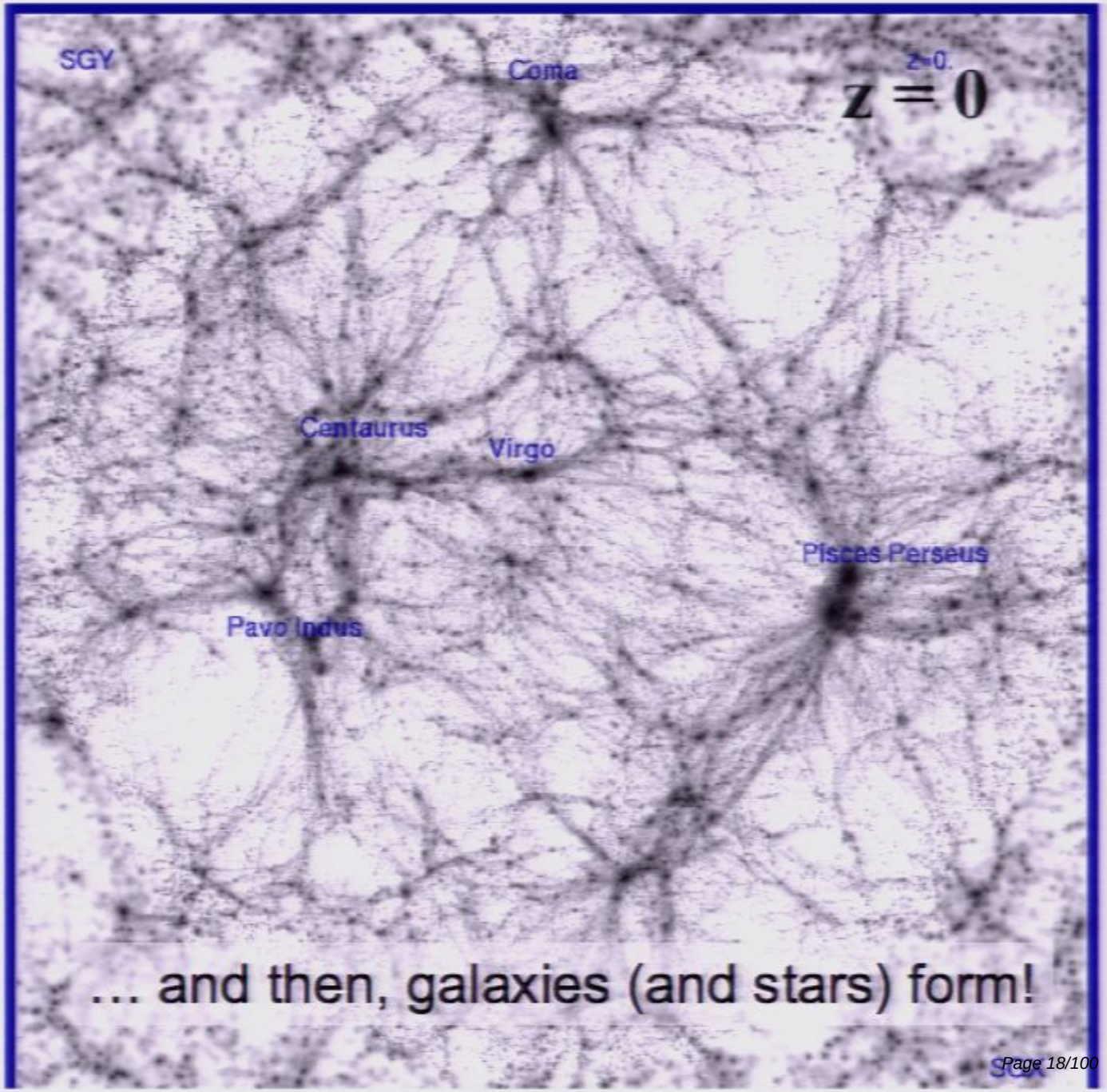

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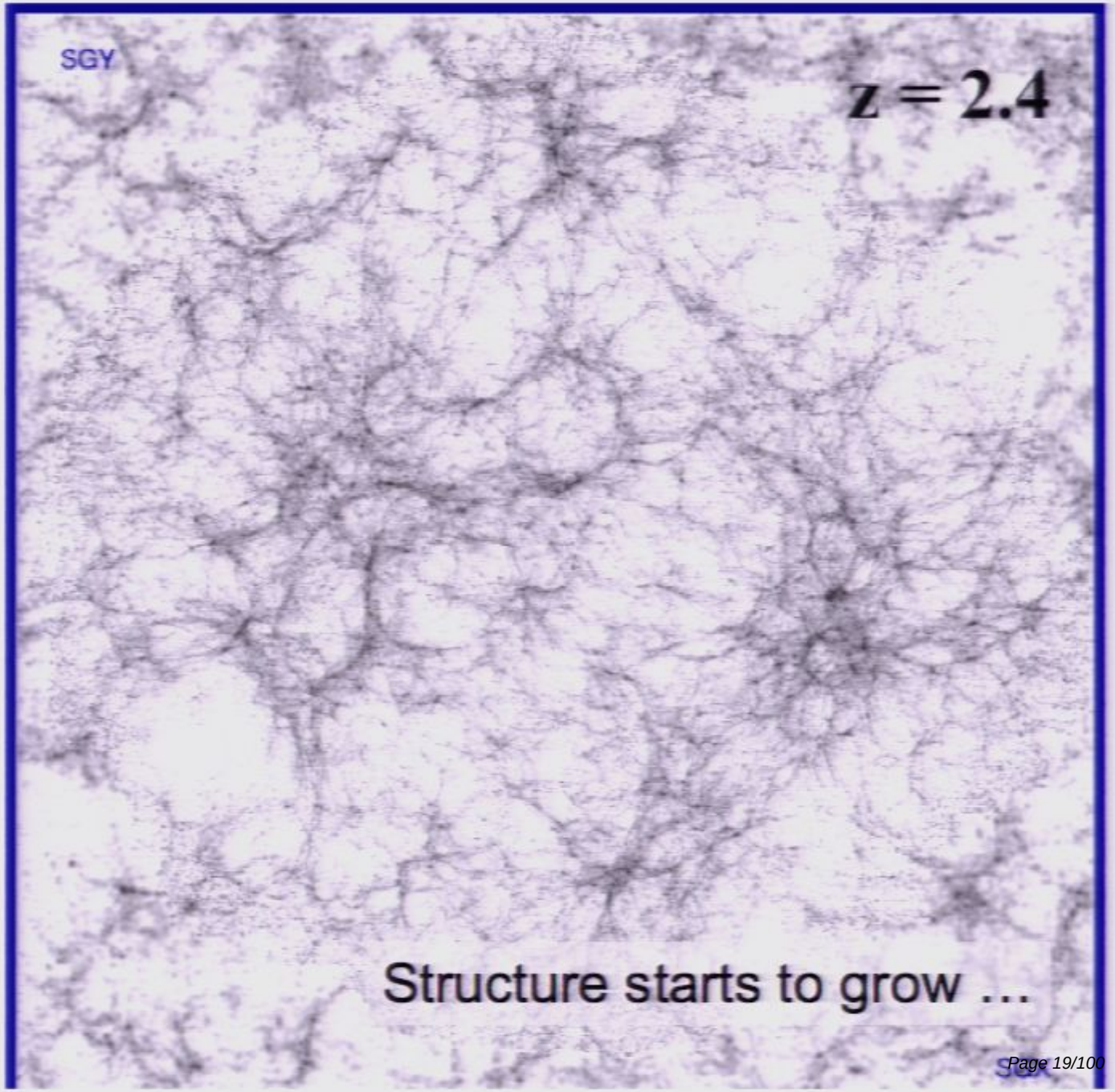

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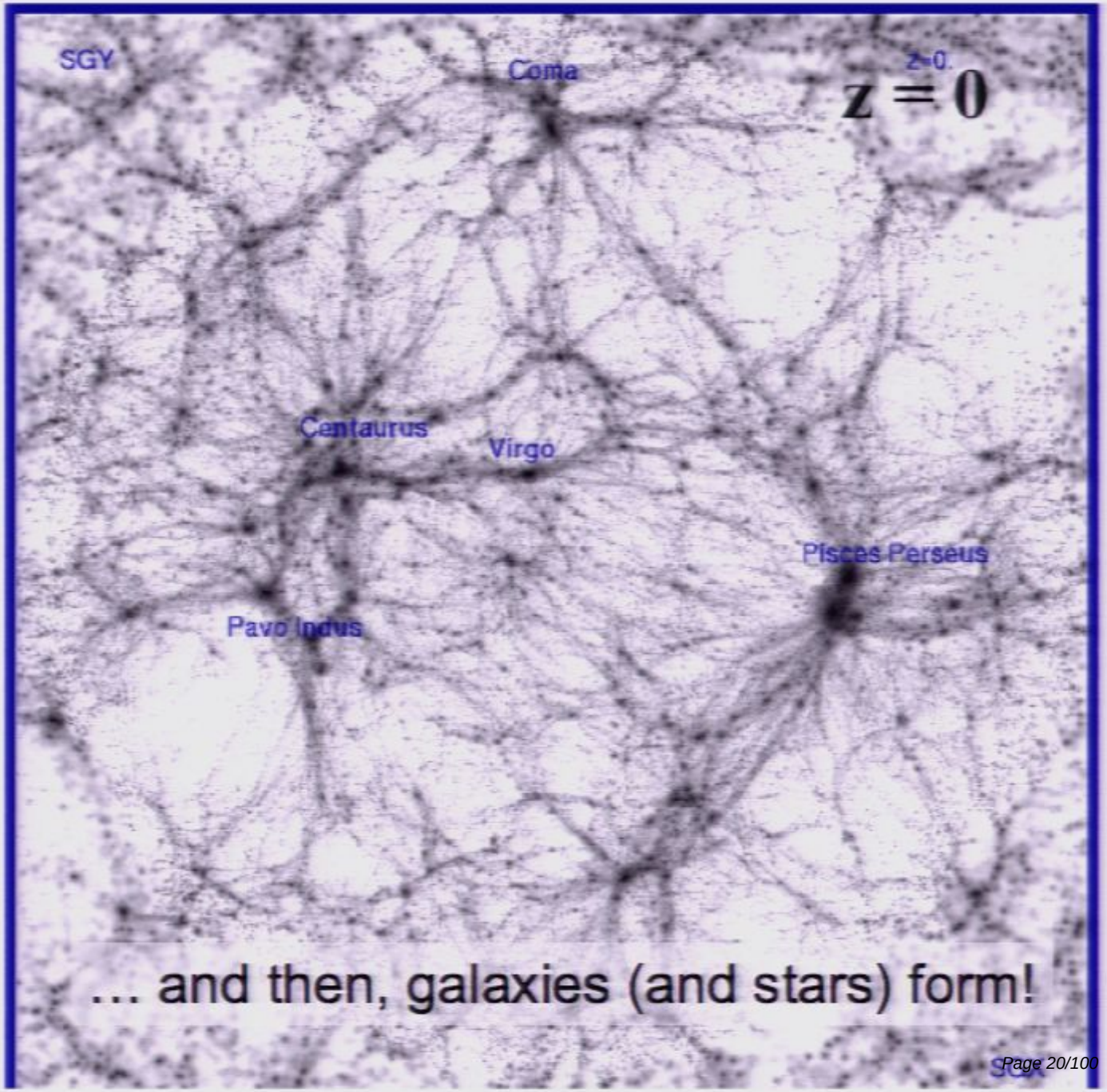

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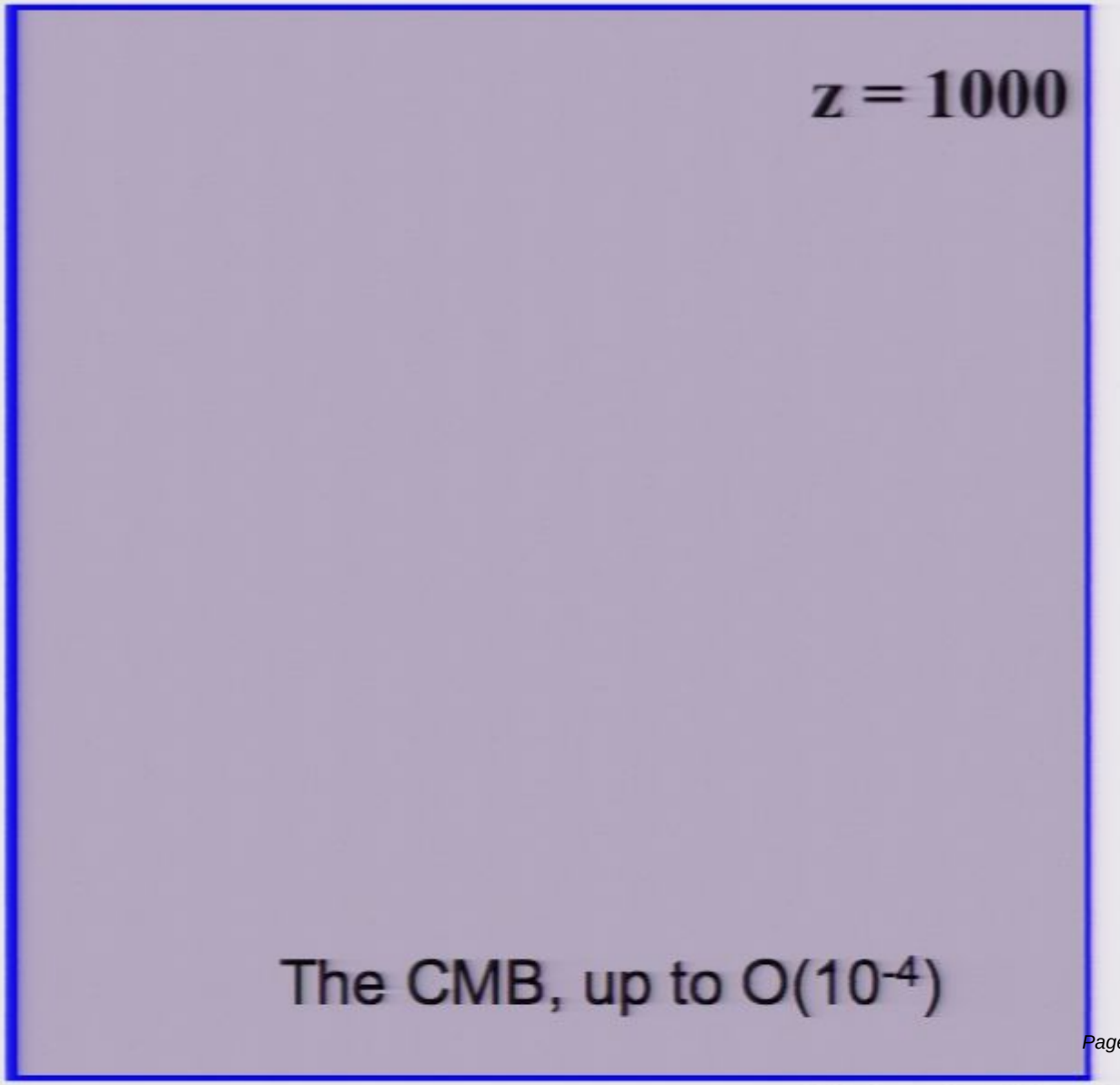

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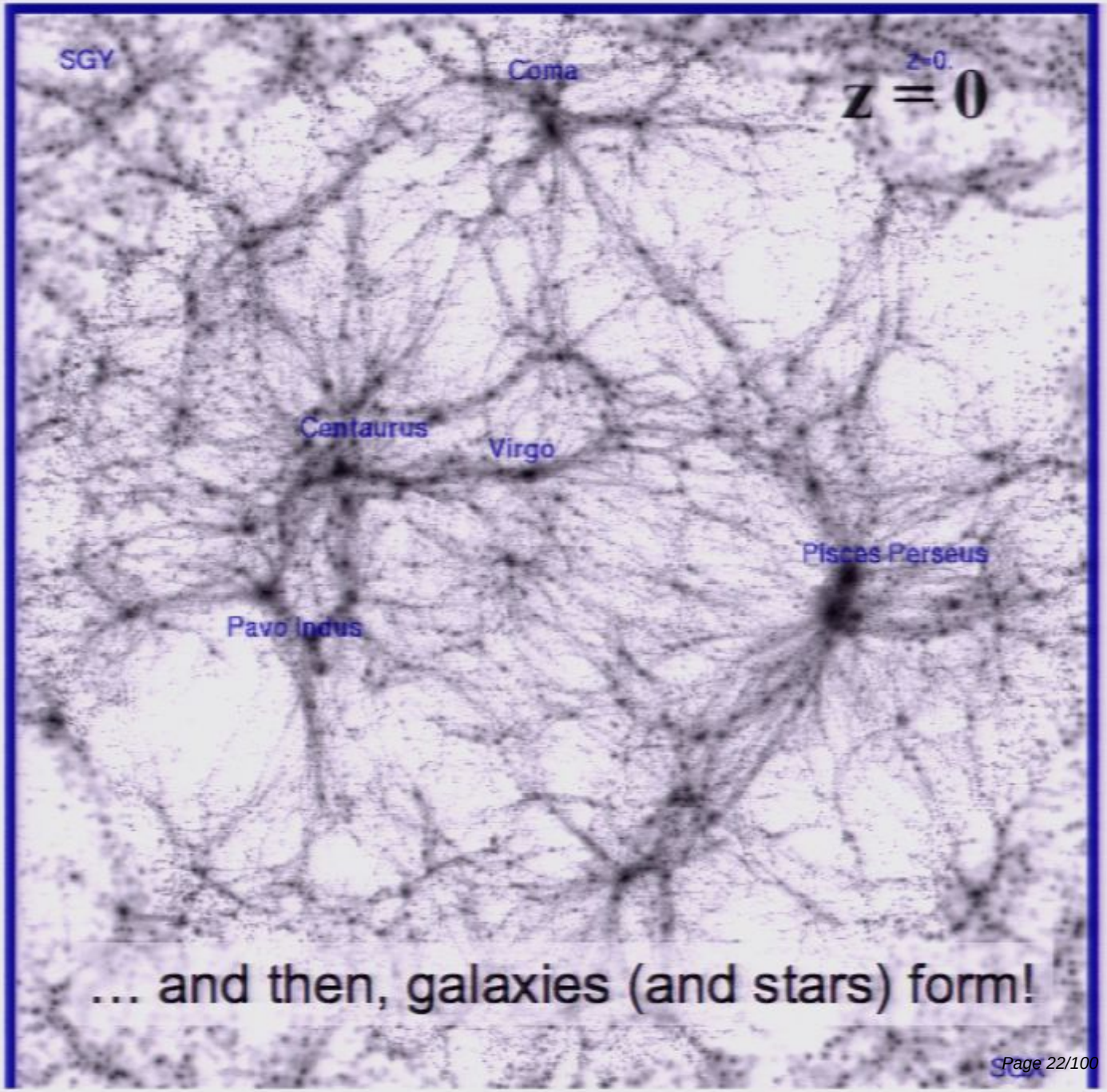

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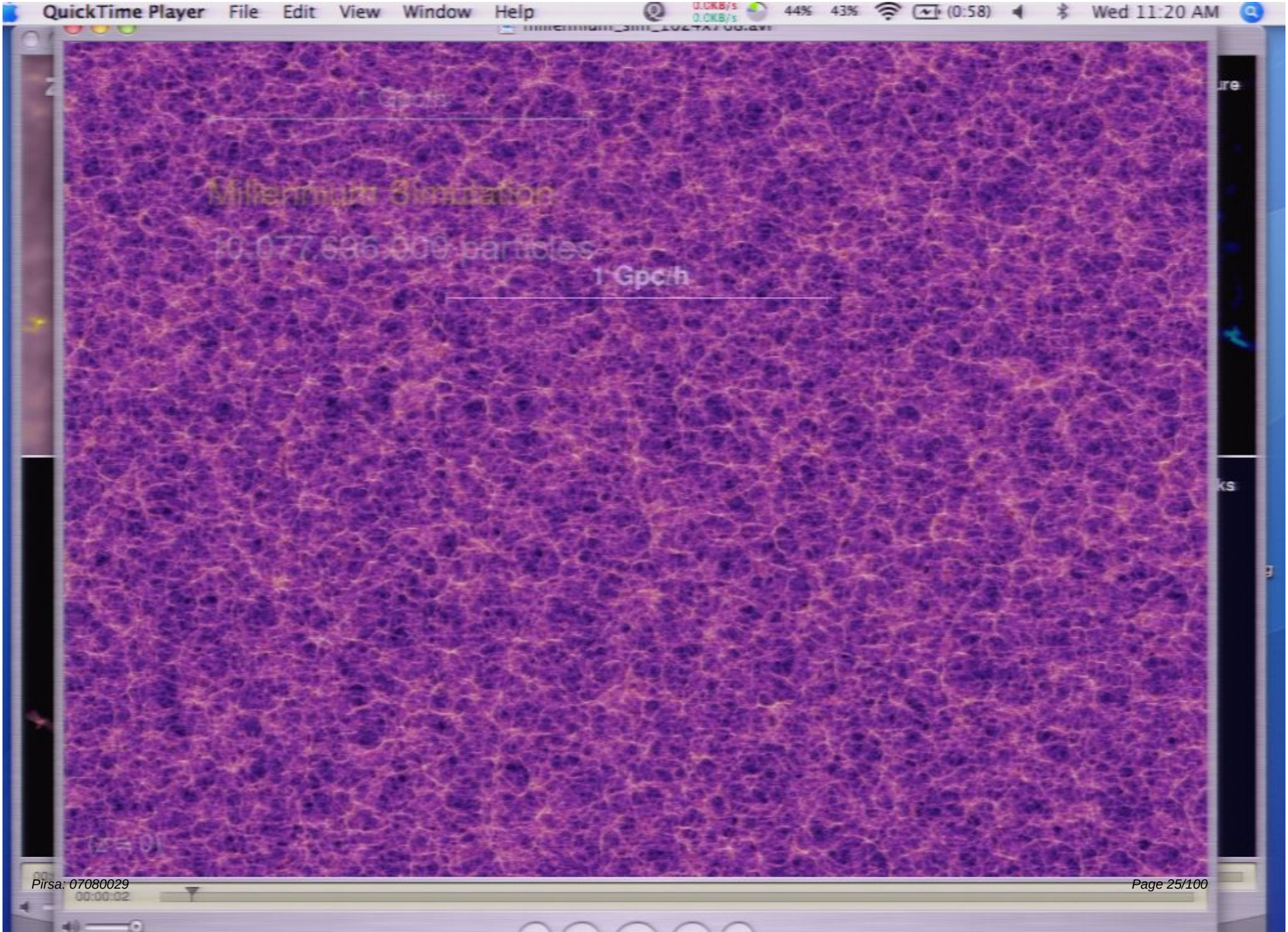
see movie ...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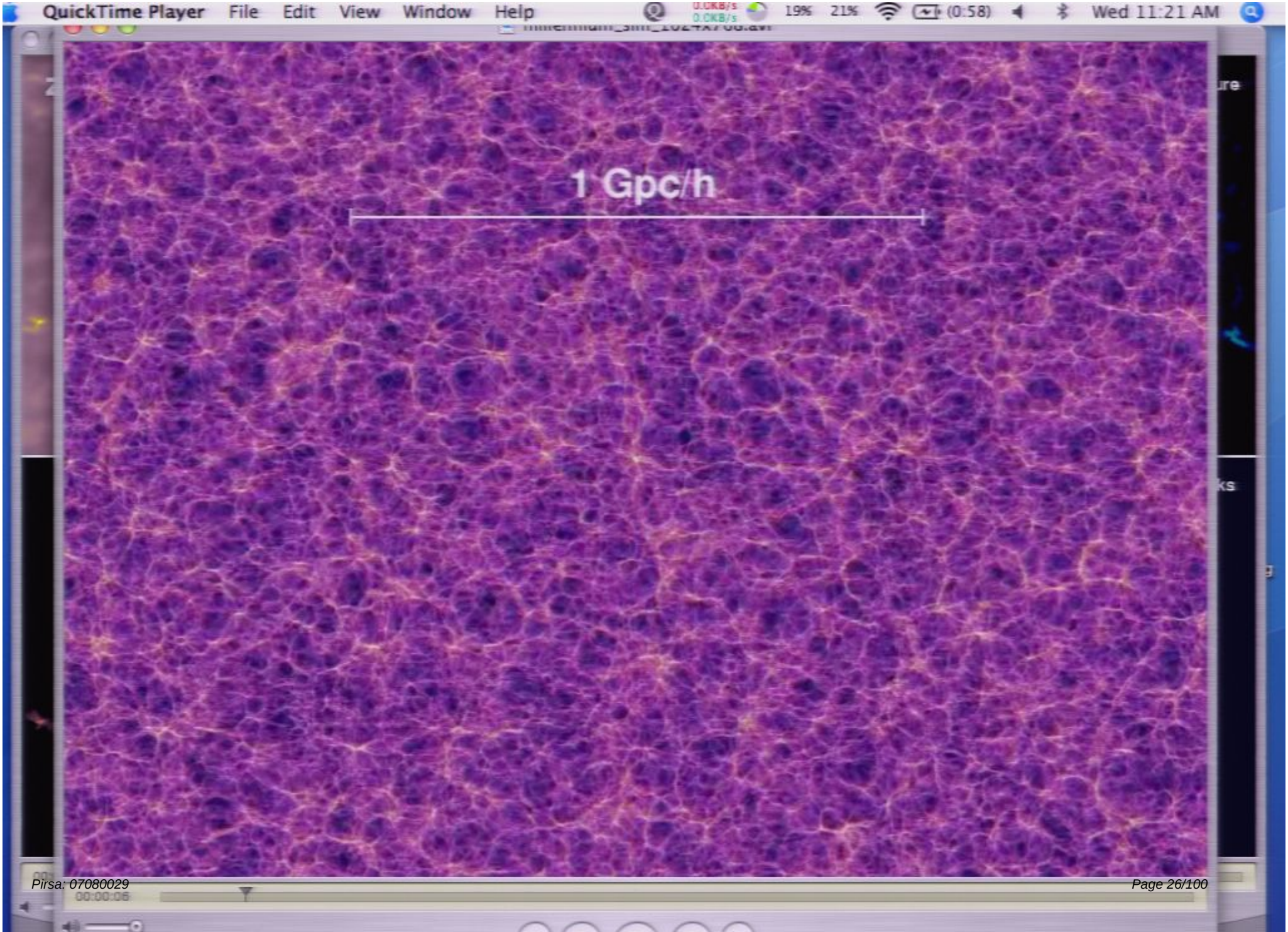
1 Gpc/h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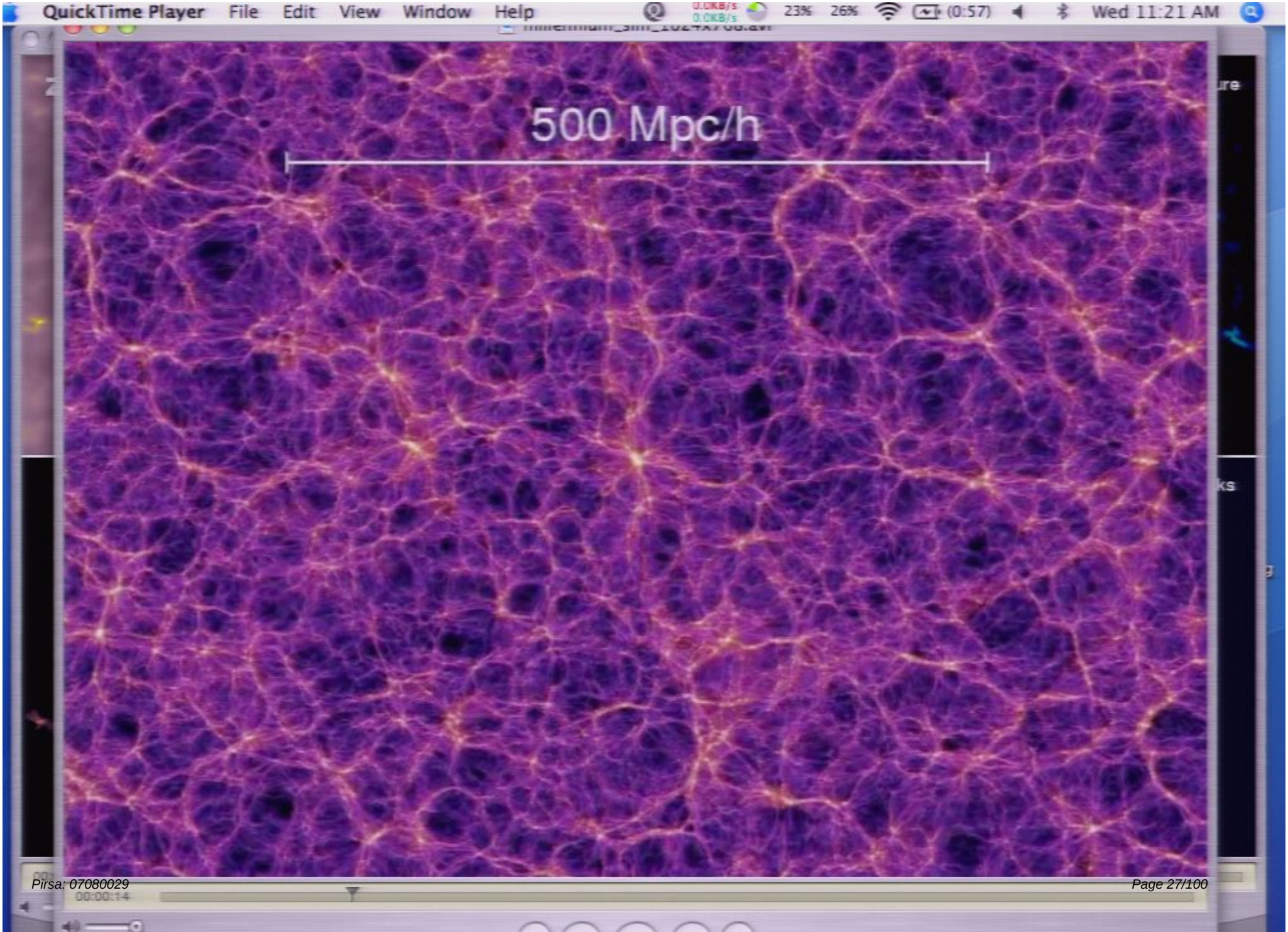
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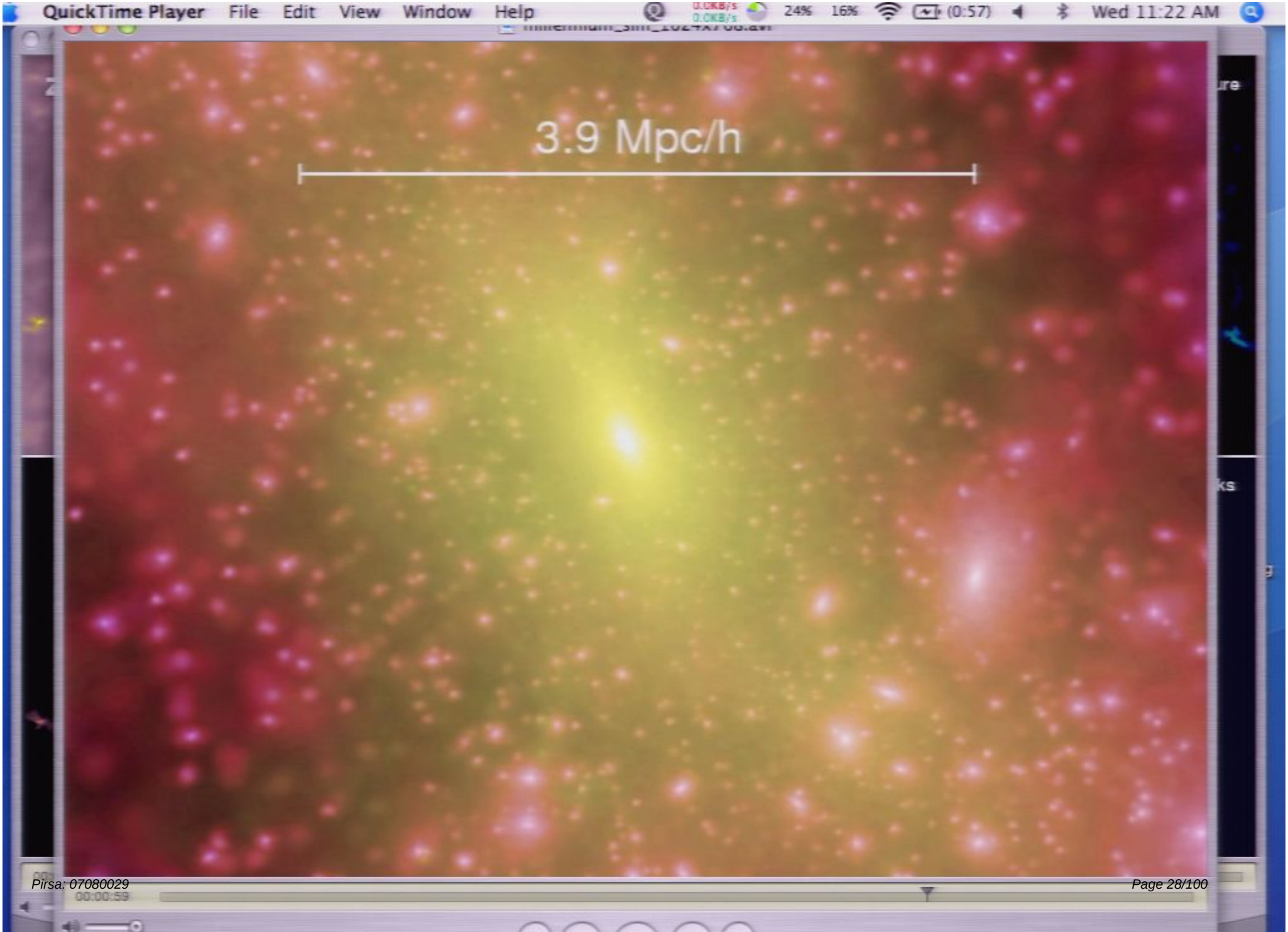
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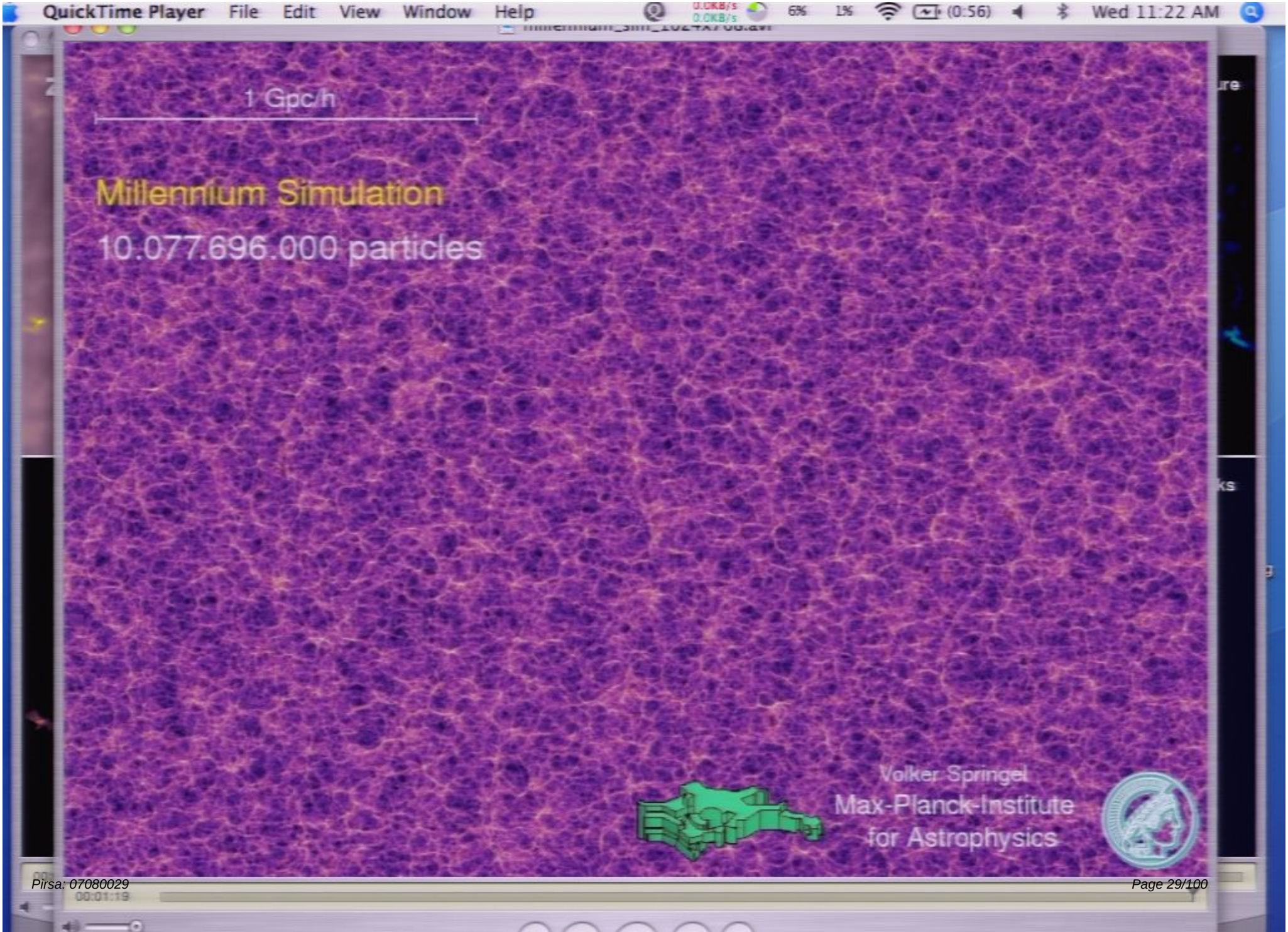
QuickTime Player File Edit View Window Help
Wed 11:22 AM
1 Gpc/h
Millennium Simulation
10.077.696.000 particles
Volker Springel
Max-Planck-Institute
for Astrophysics

What Does Structure Teach Us?

- About the power spectrum, whence:
  - *Dark Matter* -- more matter, more clumps
  - *Baryons* -- no baryons, no light, no bumps
  - *Neutrinos* -- massive neutrinos ERASE structure
  - *Dark Energy* -- DE epoch stops structure's growth, gives alt. measure of when DE dominates

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- *Inflation* -- n_s from slope of P(k)
  - More data, longer lever arm = better constraint
- *Hubble Parameter* H -- indirectly

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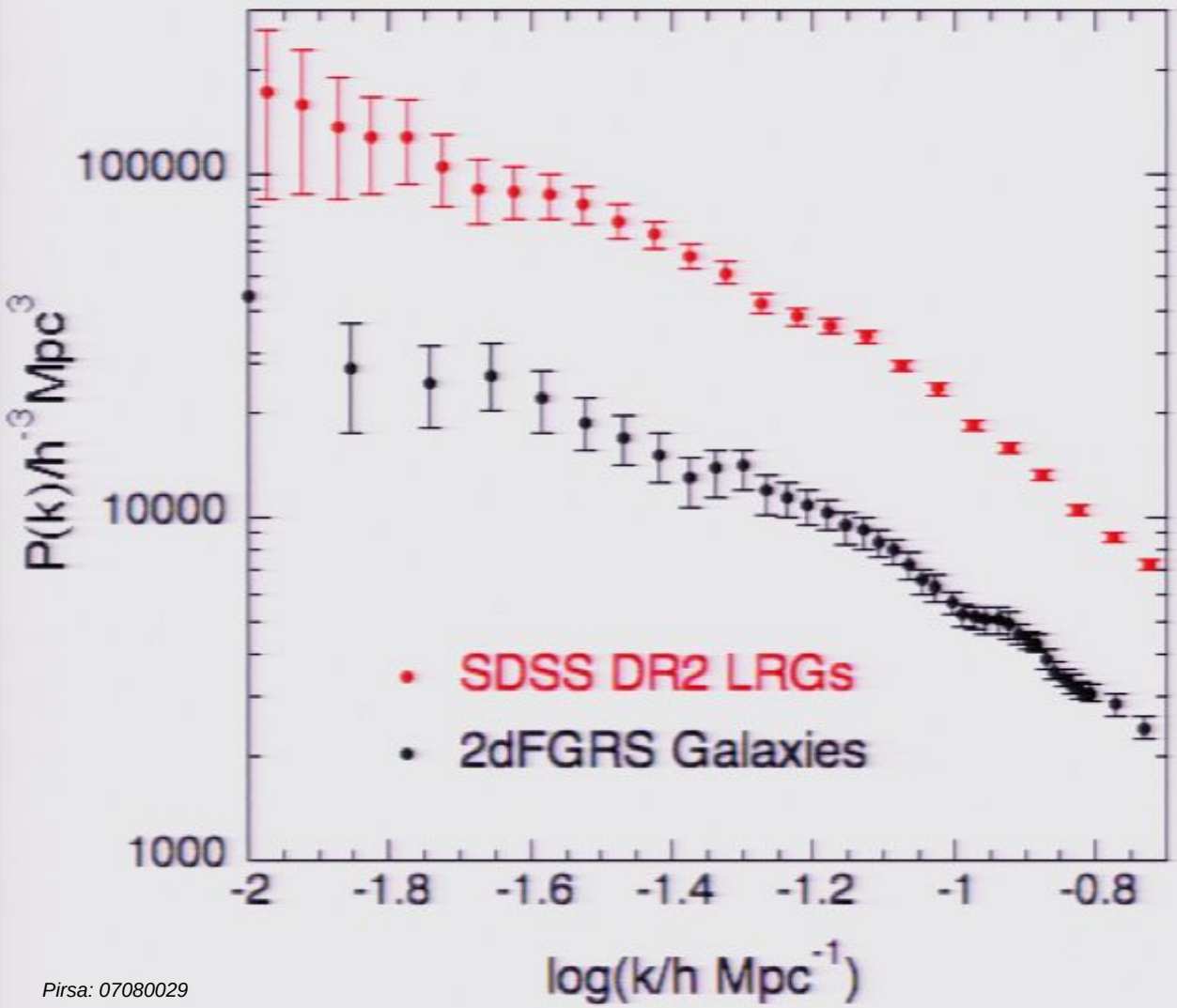
2dFGRS vs DR2 LRG P(k)



- P(k) from 230000 2dF galaxies (Cole et al 2005) +
- P(k) from 24500 DR2 LRGs (Ross et al in prep.)
- z~0.5 LRGs have 3.5x higher P(k) amplitude than z~0.1 2dF galaxies

Slides by Tom Shanks

2dF, for comparison

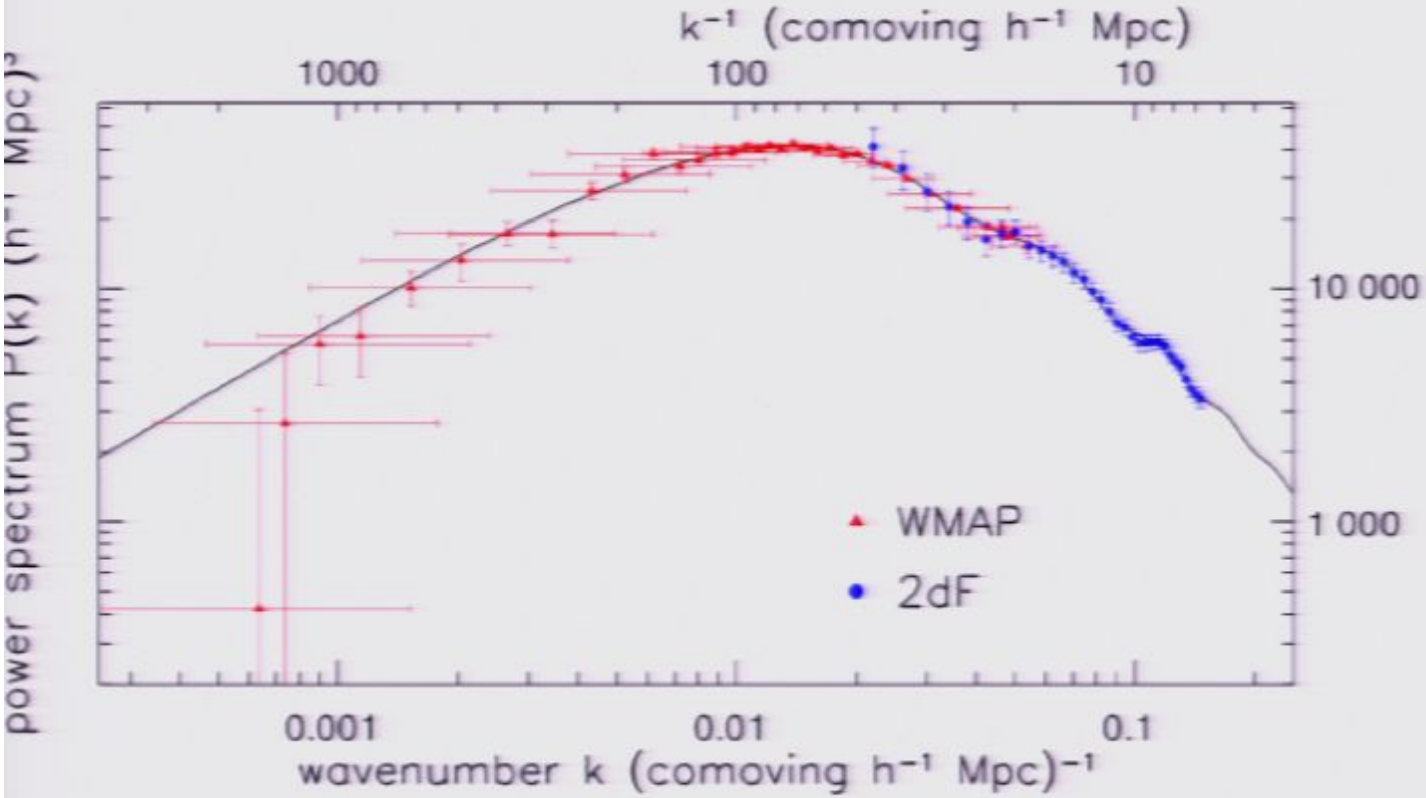


Fig 8.17 (A. Sanchez) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Focus on longer scales than SDSS

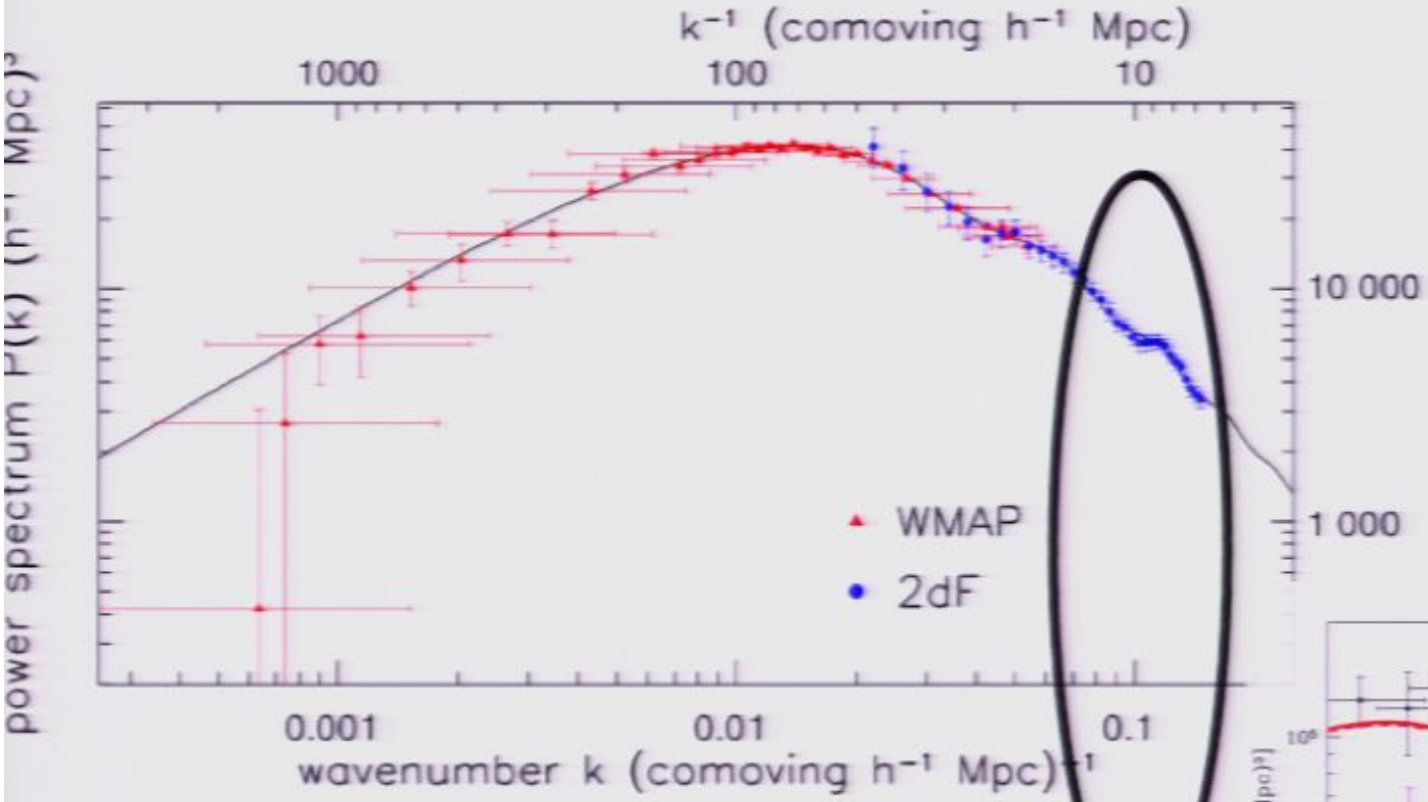
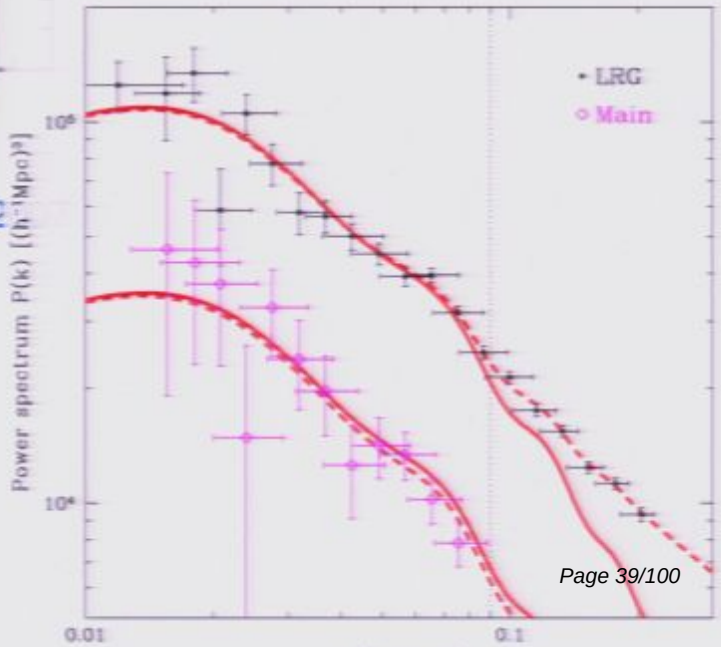
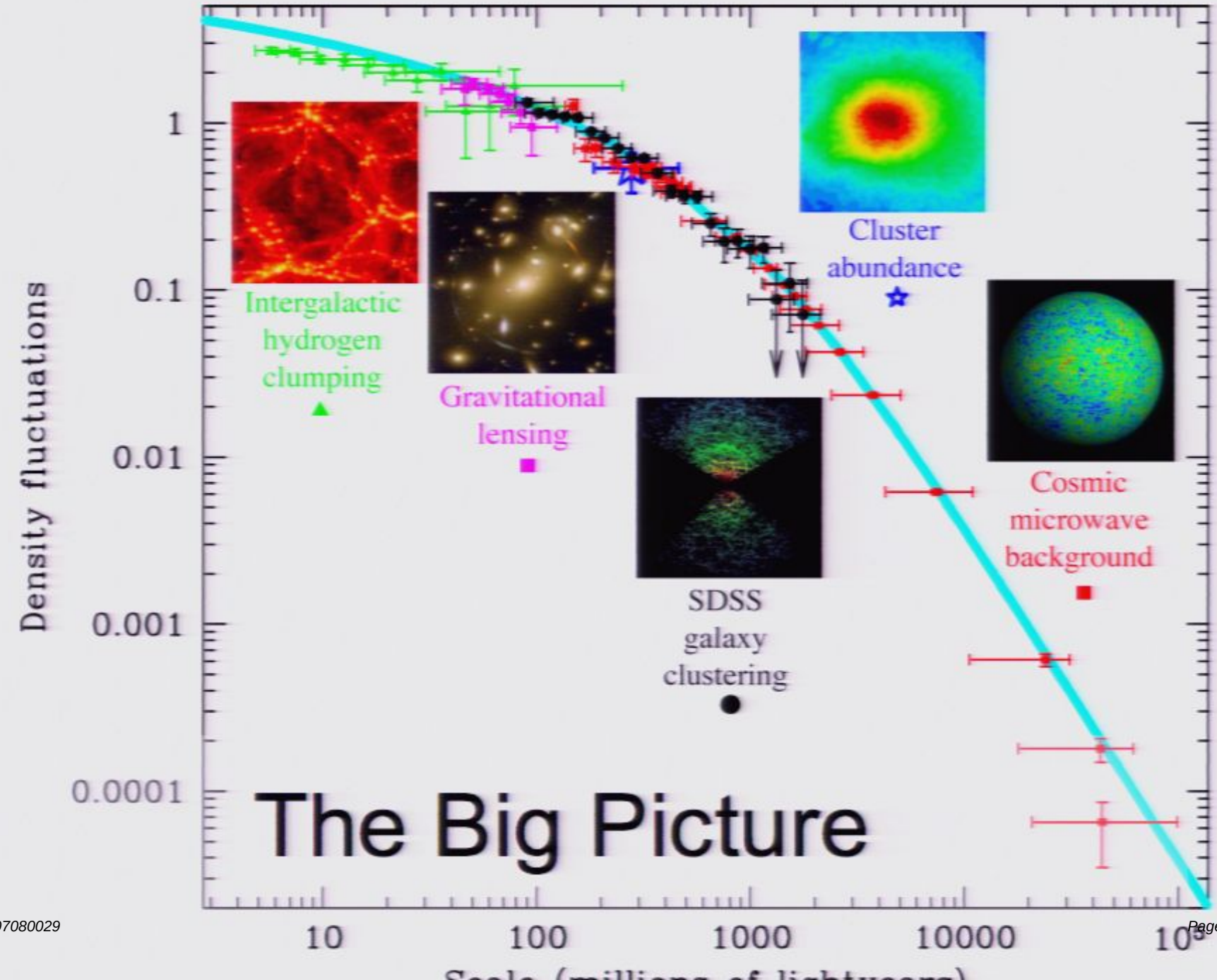


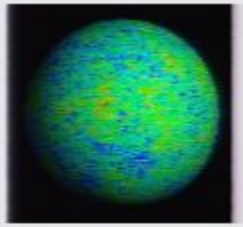
Fig 8.17 (A. Sanchez) 'Galaxies in the Universe' Sparke/Gallagher CUP 2




The Big Picture
Density fluctuations
1
0.1
0.01
0.001
0.0001
10
100
1000
10000
10^5
Intergalactic hydrogen clumping
Gravitational lensing
SDSS galaxy clustering
Cluster abundance
Cosmic microwave background

Guide to Cosmological Parameters and SDSS

Next 45 slides by Max Tegmark and the SDSS team



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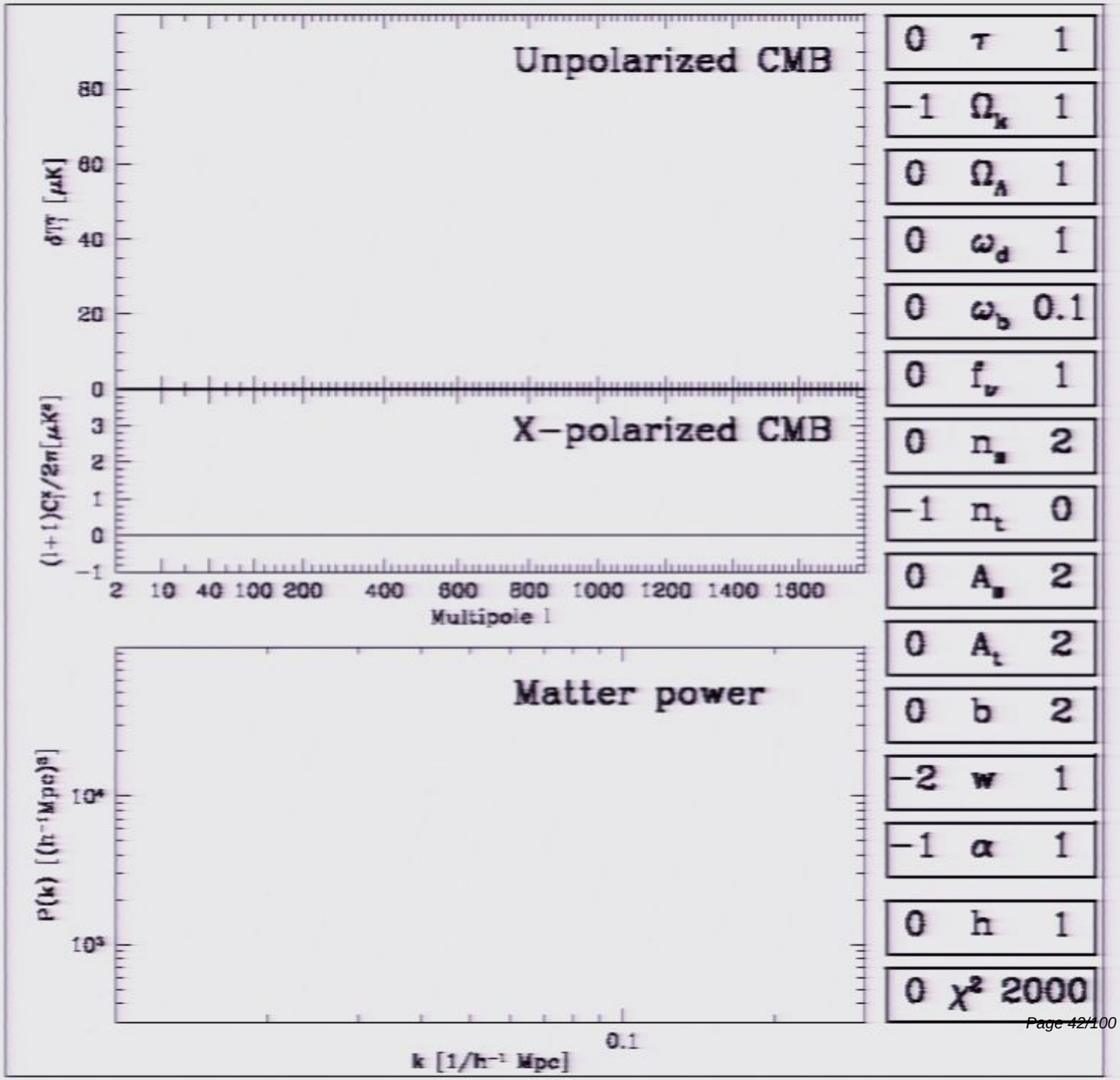
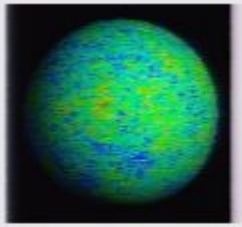

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
P(k) [(h⁻¹Mpc)³]
0 τ 1
−1 Ω_k 1
0 Ω_Λ 1
0 ω_d 1
0 ω_b 0.1
0 f_ν 1
0 n_s 2
−1 n_t 0
0 A_s 2
0 A_t 2
0 b 2
−2 w 1
−1 α 1
0 h 1
0 χ² 2000



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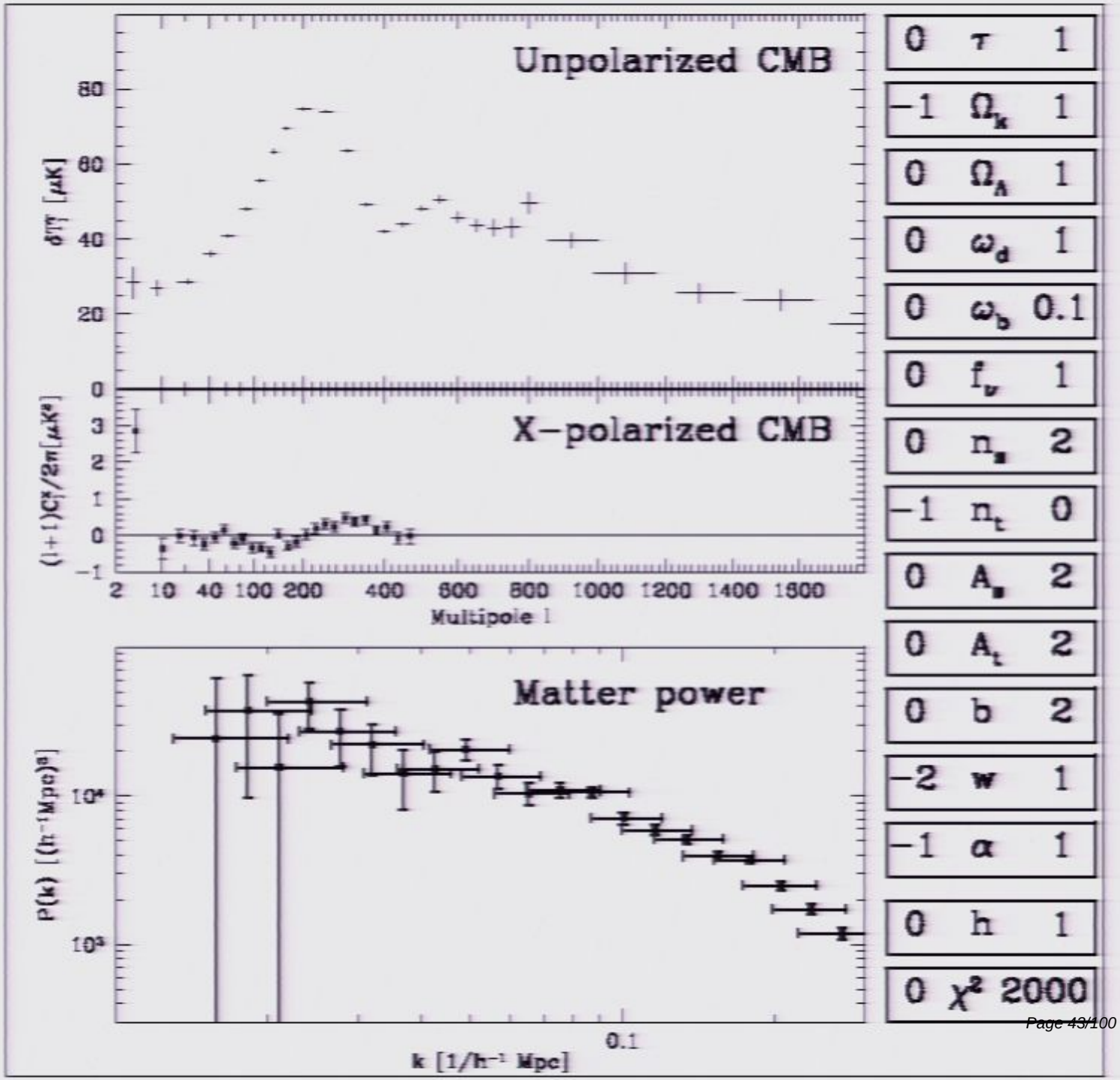
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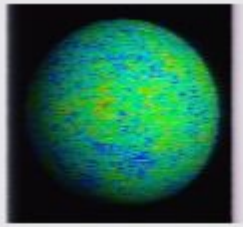

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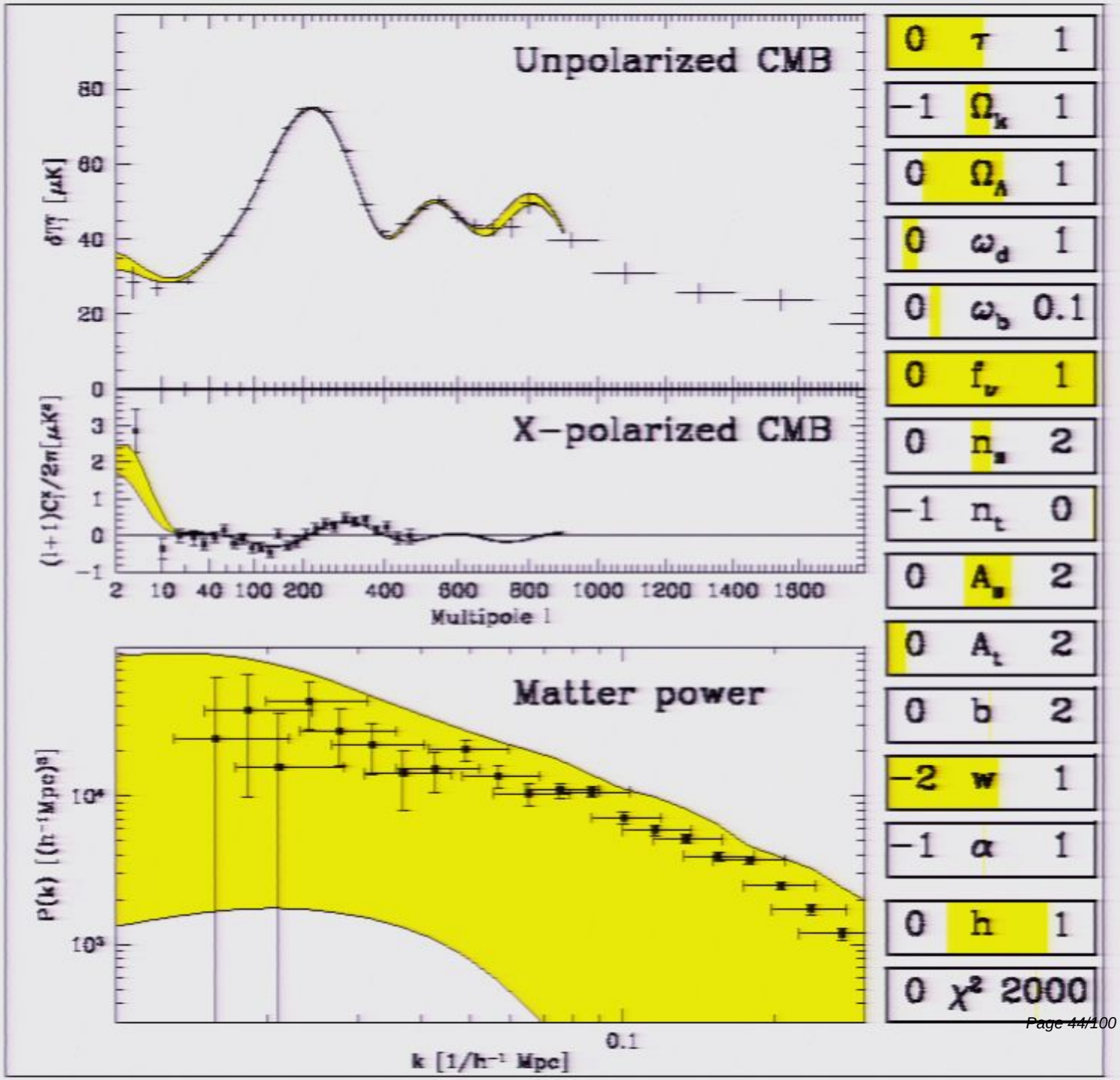
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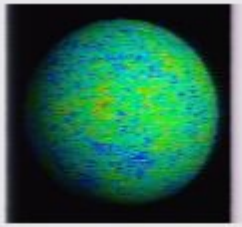

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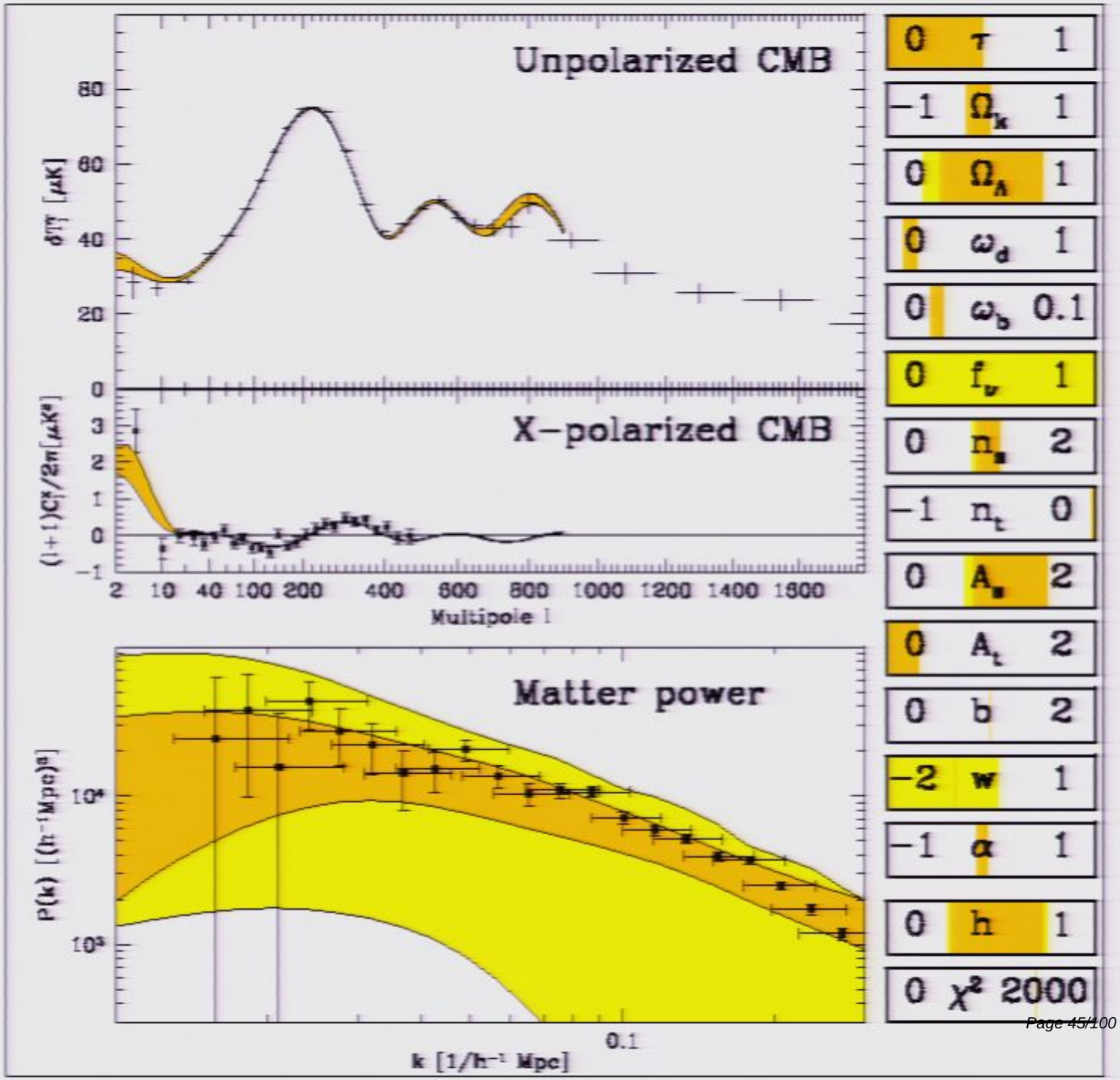
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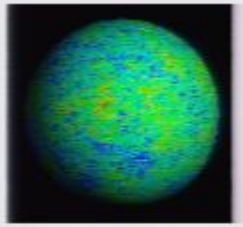

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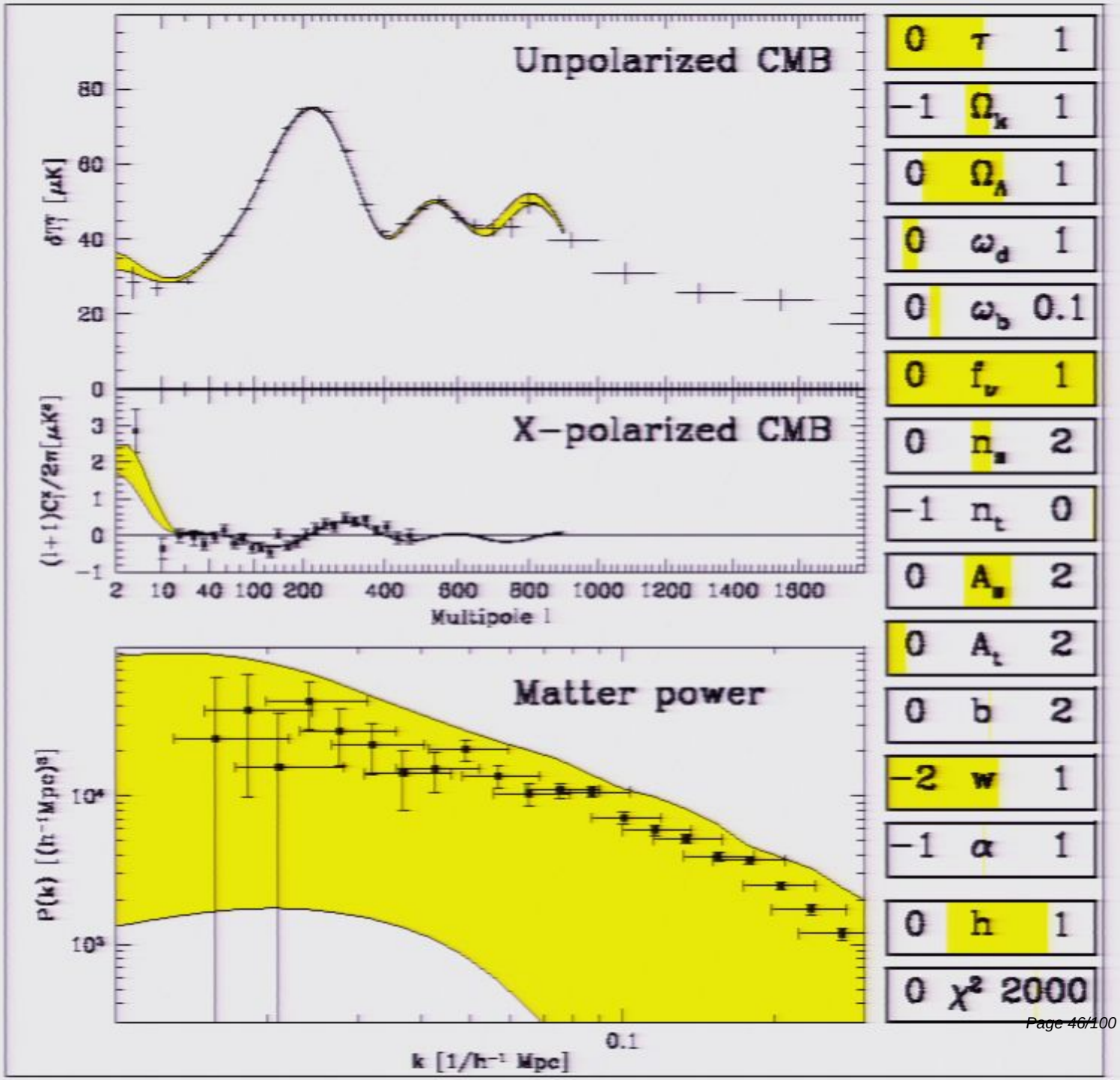
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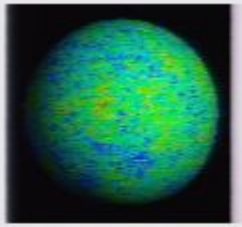

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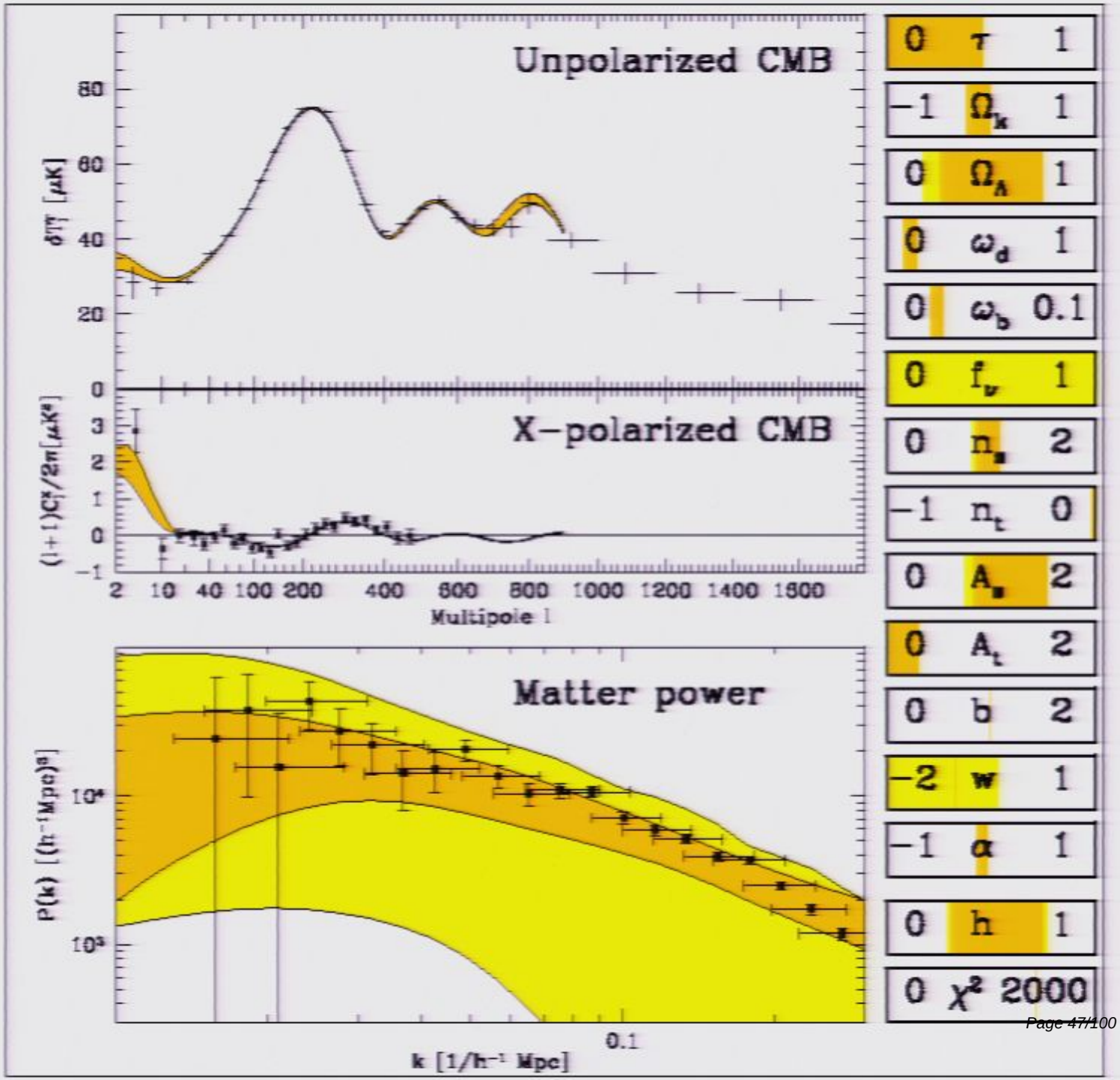
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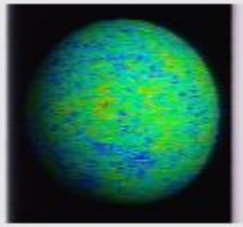
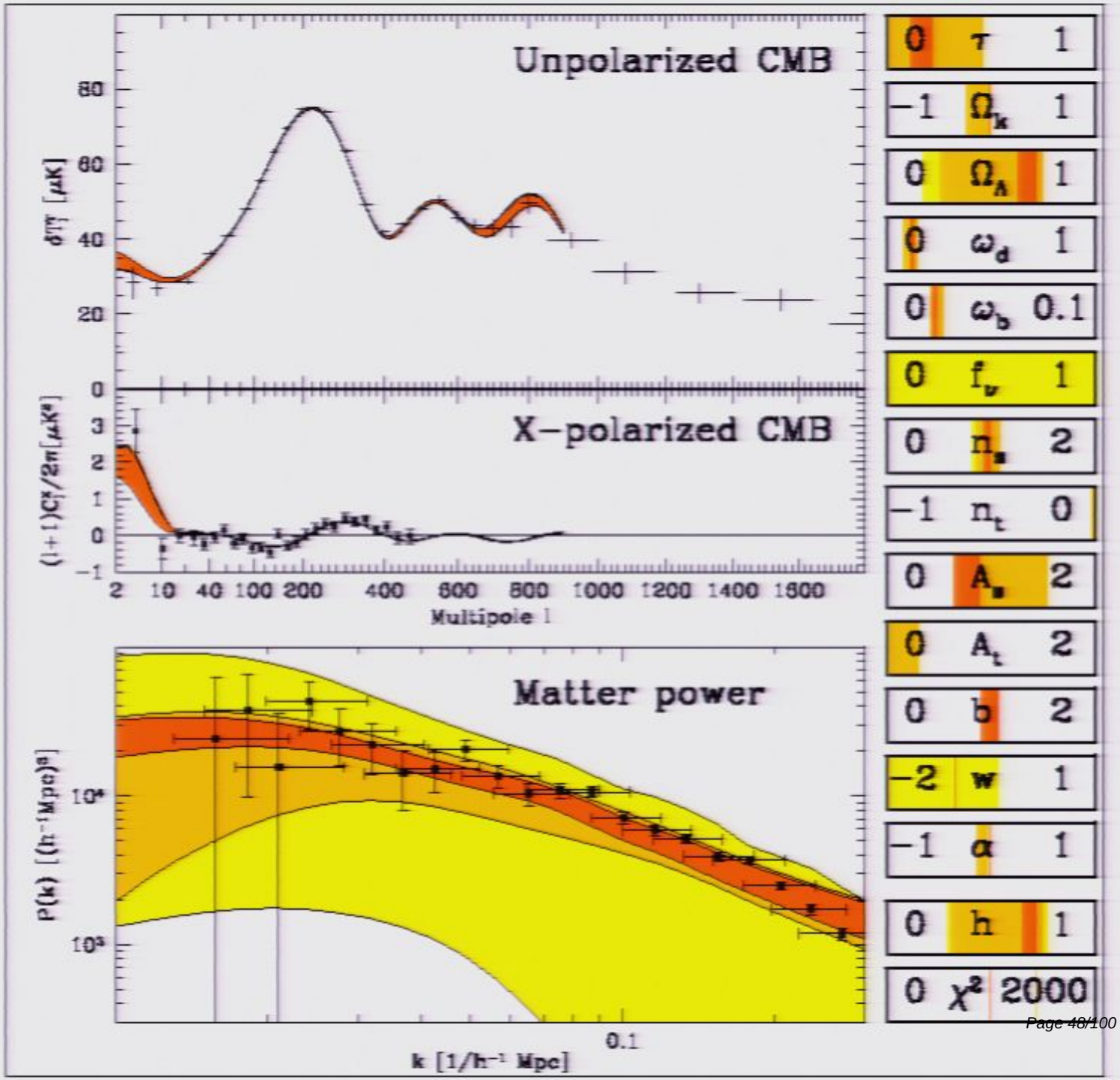
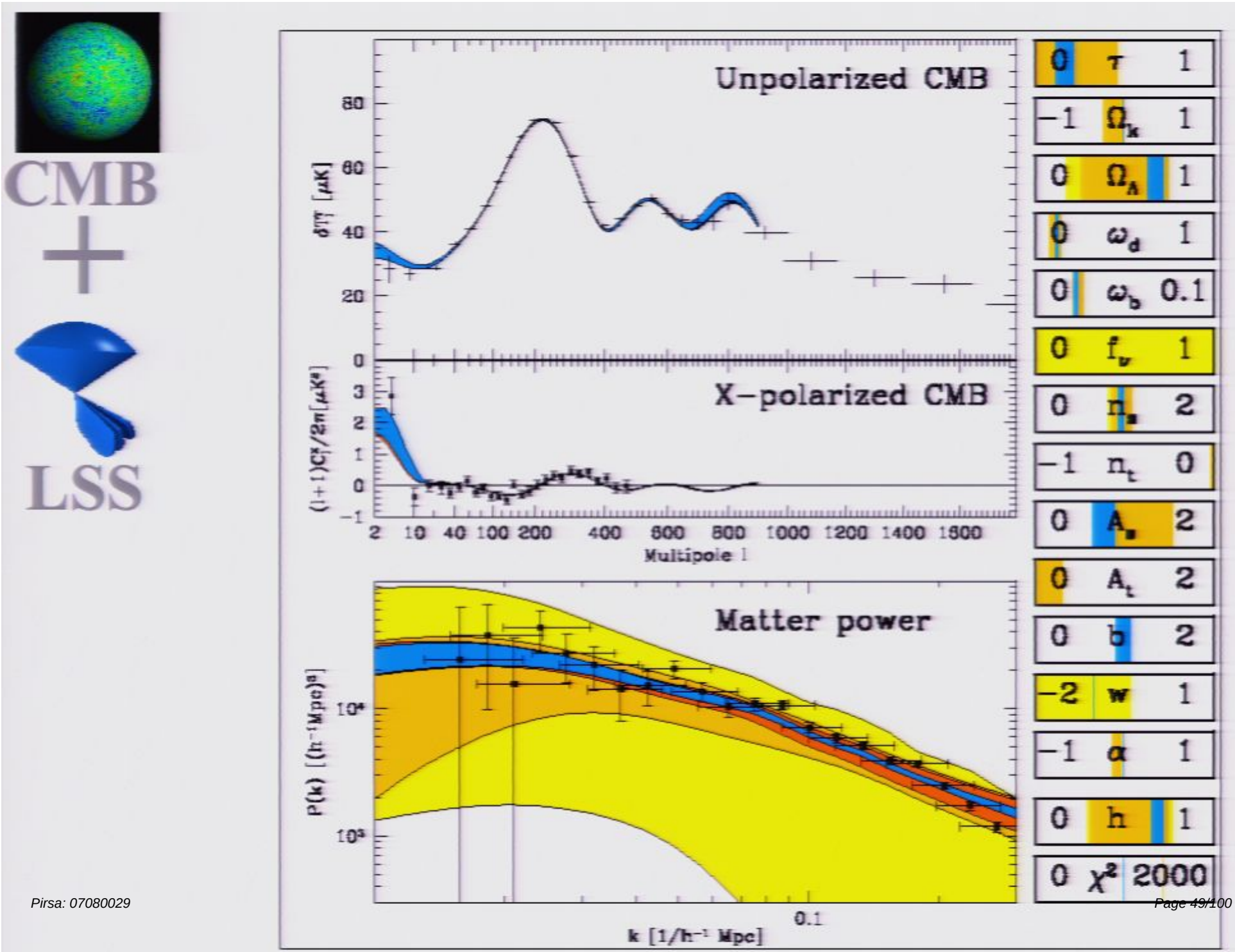
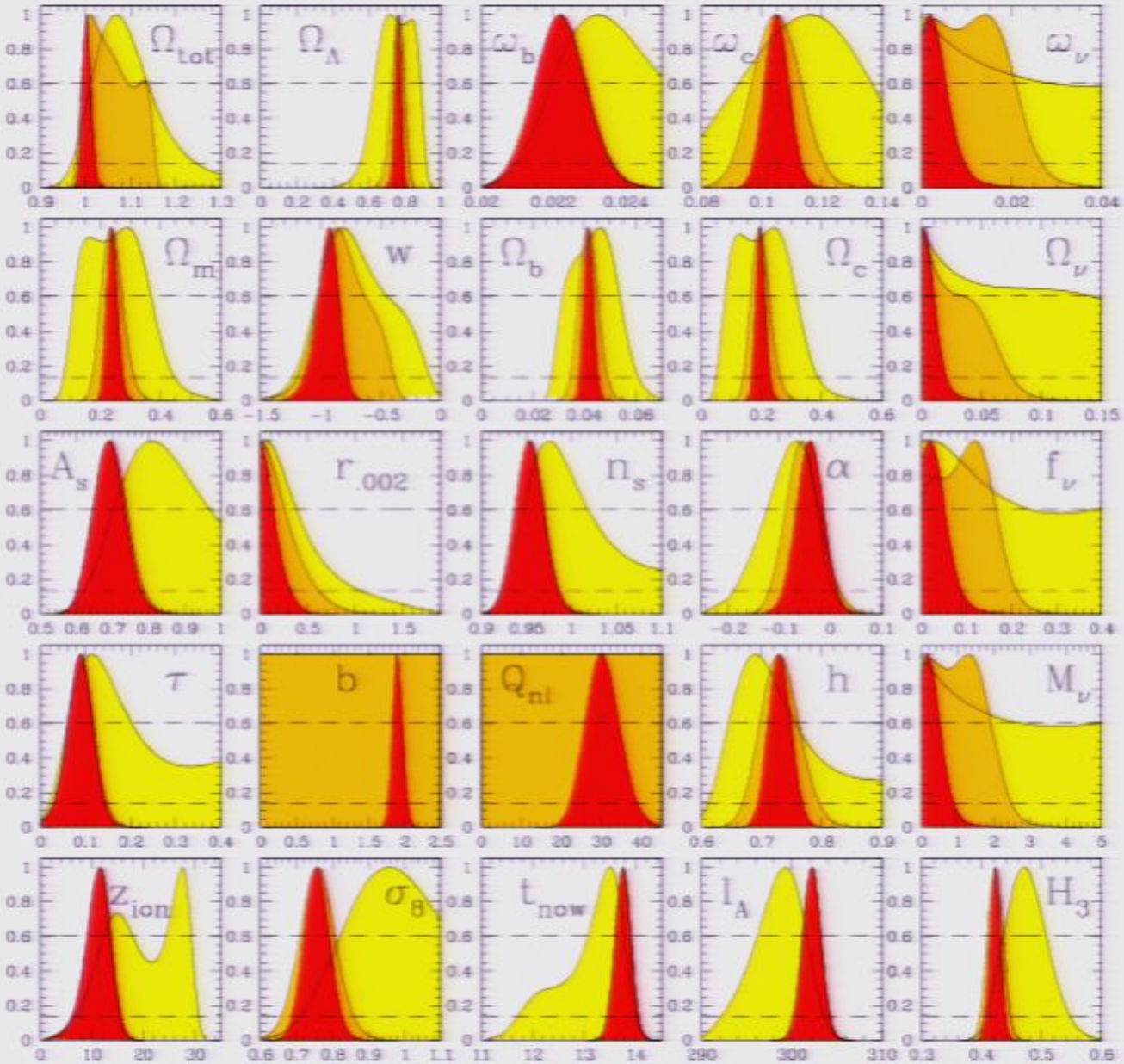
0 h 1
0 χ² 2000



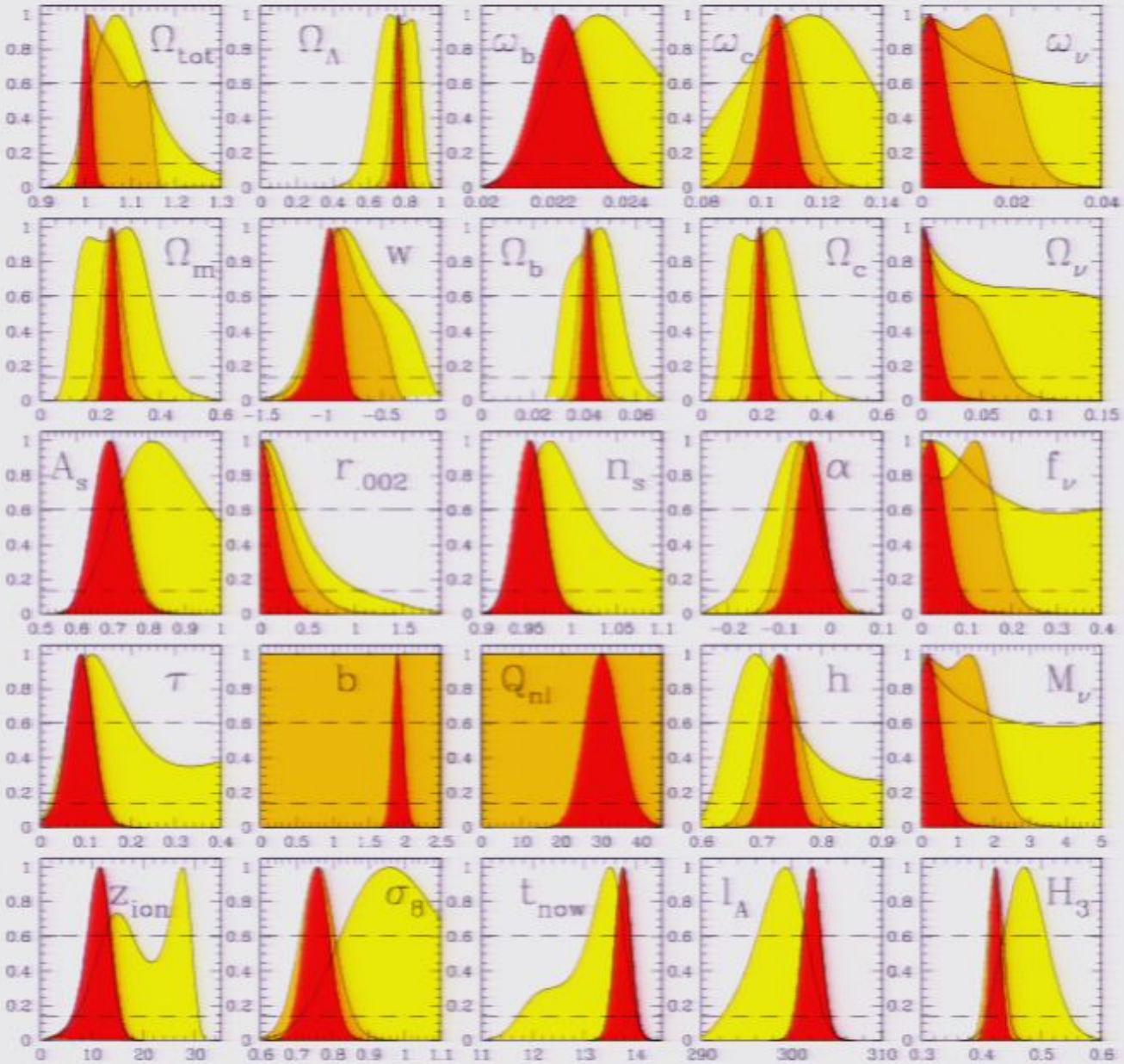
CMB

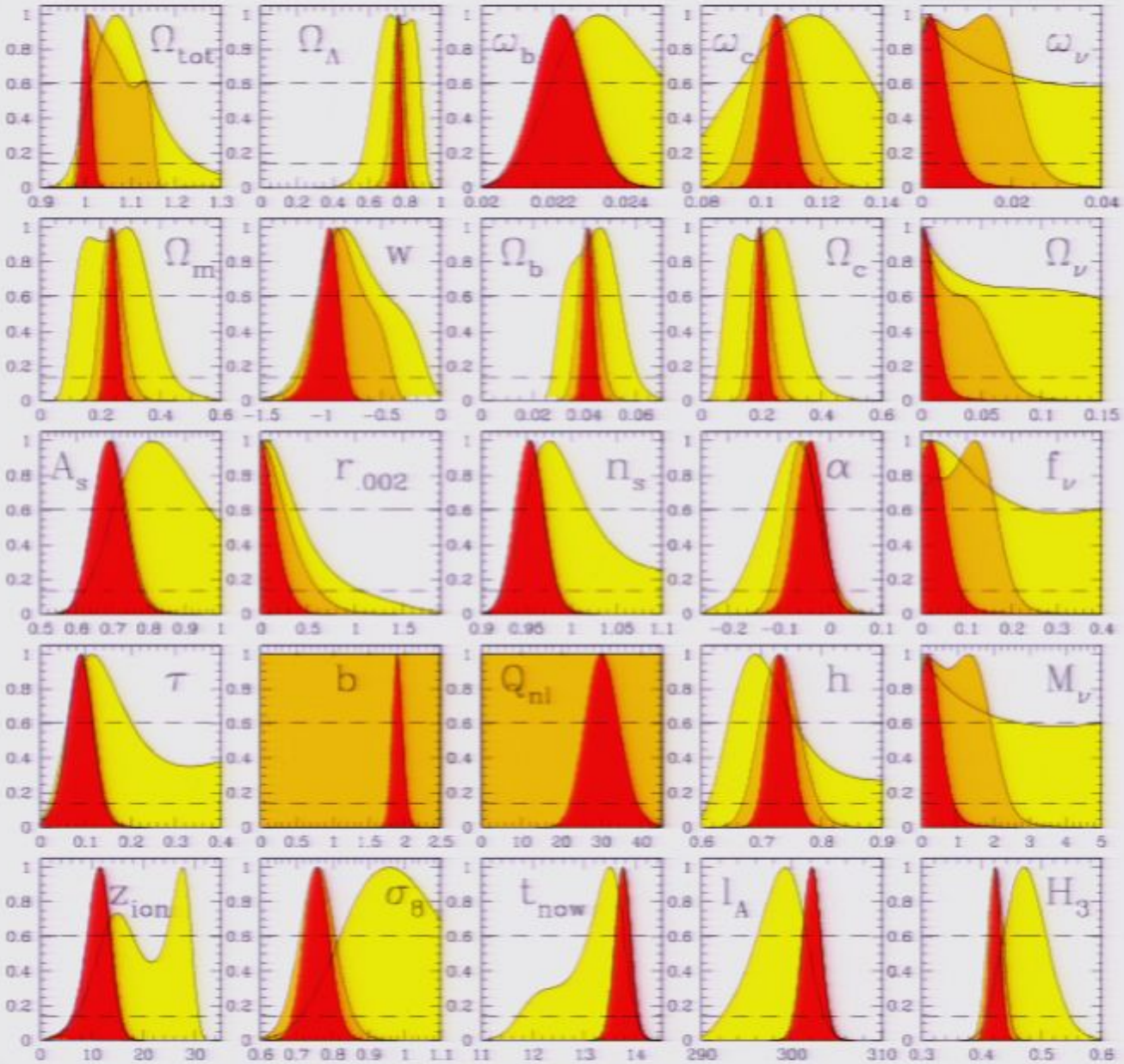

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
0 τ 1
−1 Ω_k 1
0 Ω_Λ 1
0 ω_d 1
0 ω_b 0.1
0 f_ν 1
0 n_s 2
−1 n_t 0
0 A_s 2
0 A_t 2
0 b 2
−2 w 1
−1 α 1
0 h 1
0 χ² 2000


CMB
+
LSS
Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
P(k) [(h⁻¹Mpc)³]
0 τ 1
−1 Ω_k 1
0 Ω_Λ 1
0 ω_d 1
0 ω_b 0.1
0 f_ν 1
0 n_s 2
−1 n_t 0
0 A_s 2
0 A_t 2
0 b 2
−2 w 1
−1 α 1
0 h 1
0 χ² 2000

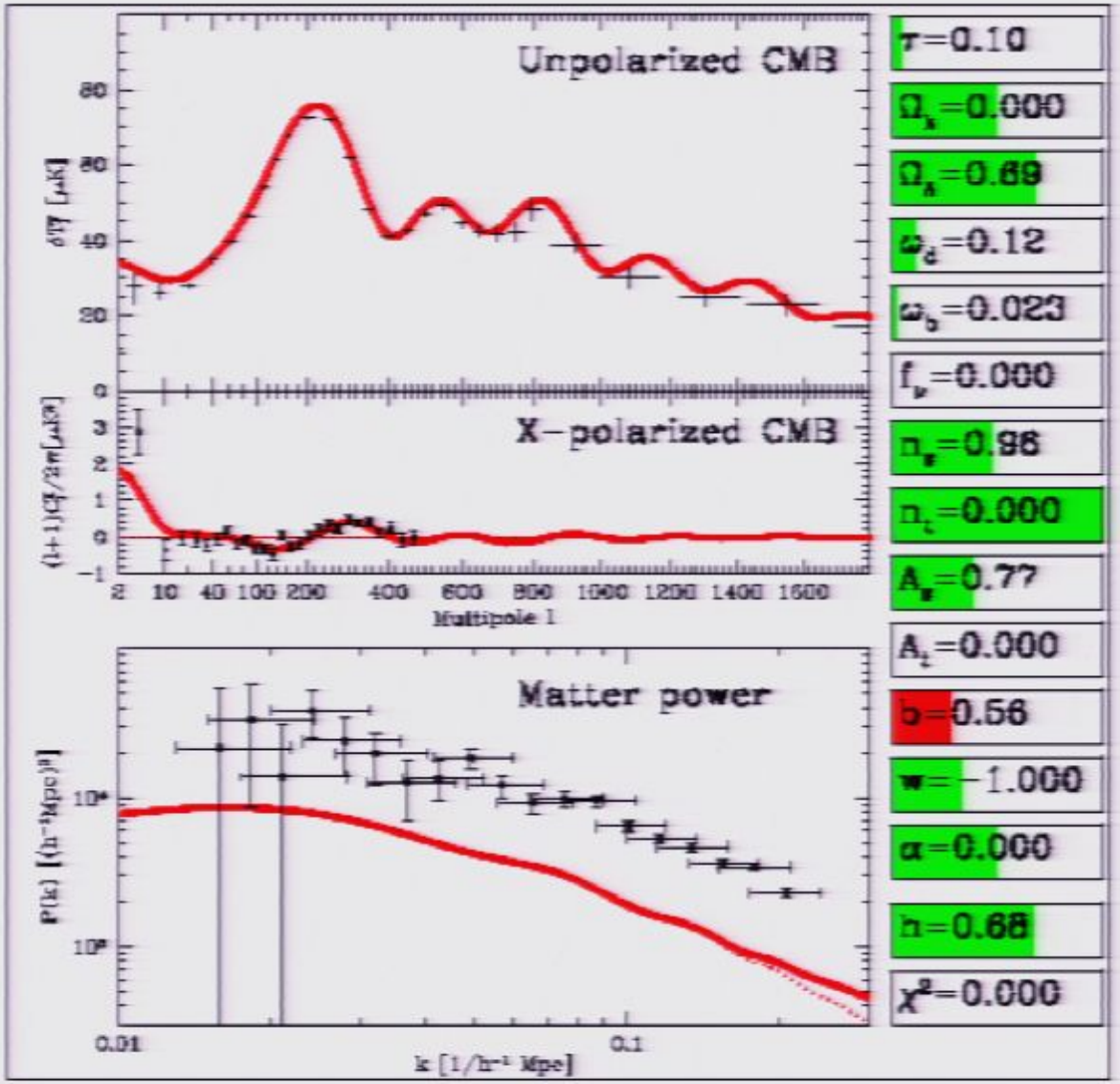

Ω_{tot}
Ω_Λ
ω_b
ω_c
ω_ν
Ω_m
w
Ω_b
Ω_c
Ω_ν
A_s
$r_{.002}$
n_s
α
f_ν
τ
b
Q_{nl}
h
M_ν
z_{ion}
σ_8
t_{now}
l_A
H_3

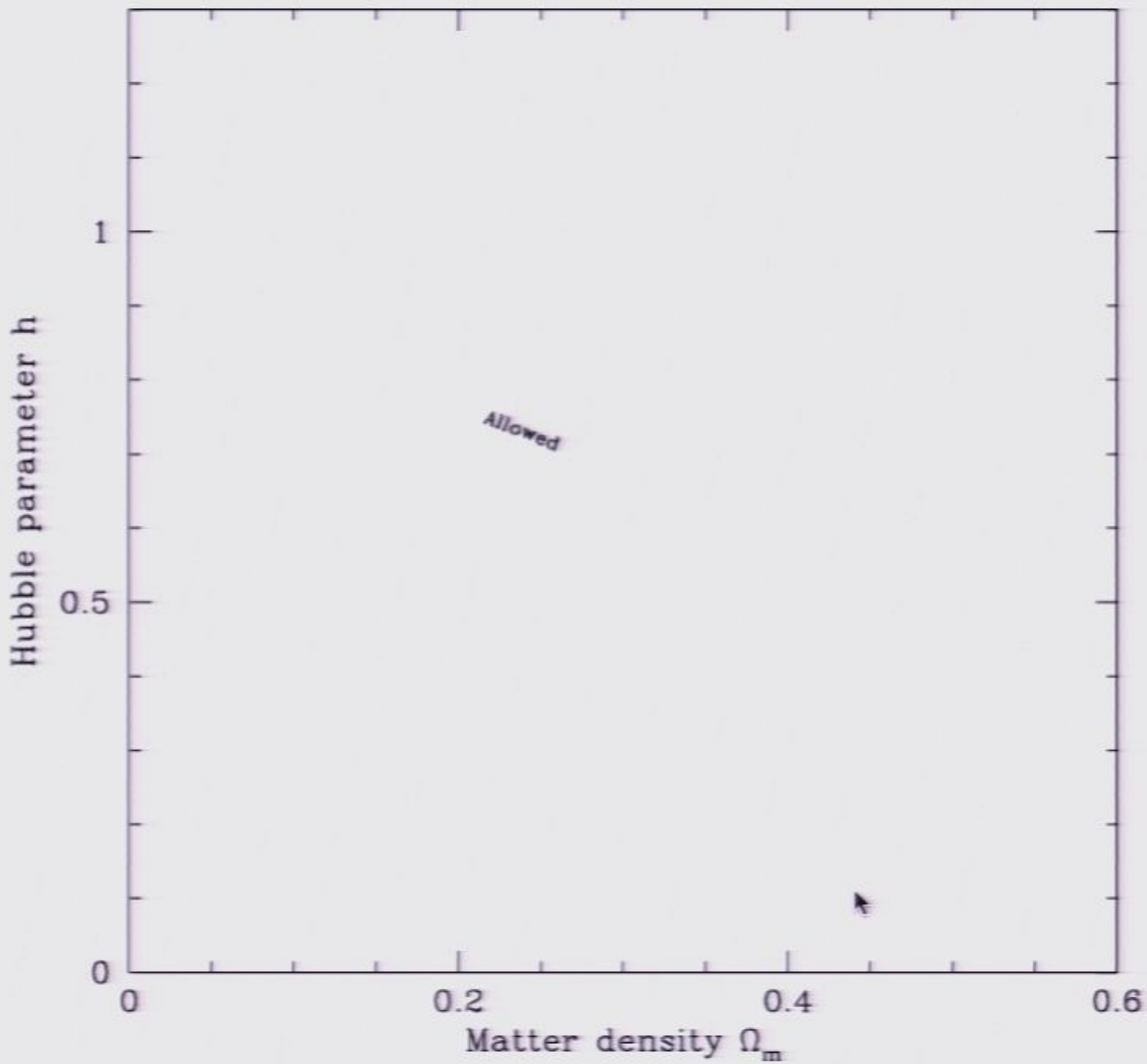
$$\left(\frac{k}{k_0}\right)^{n_s-1}$$

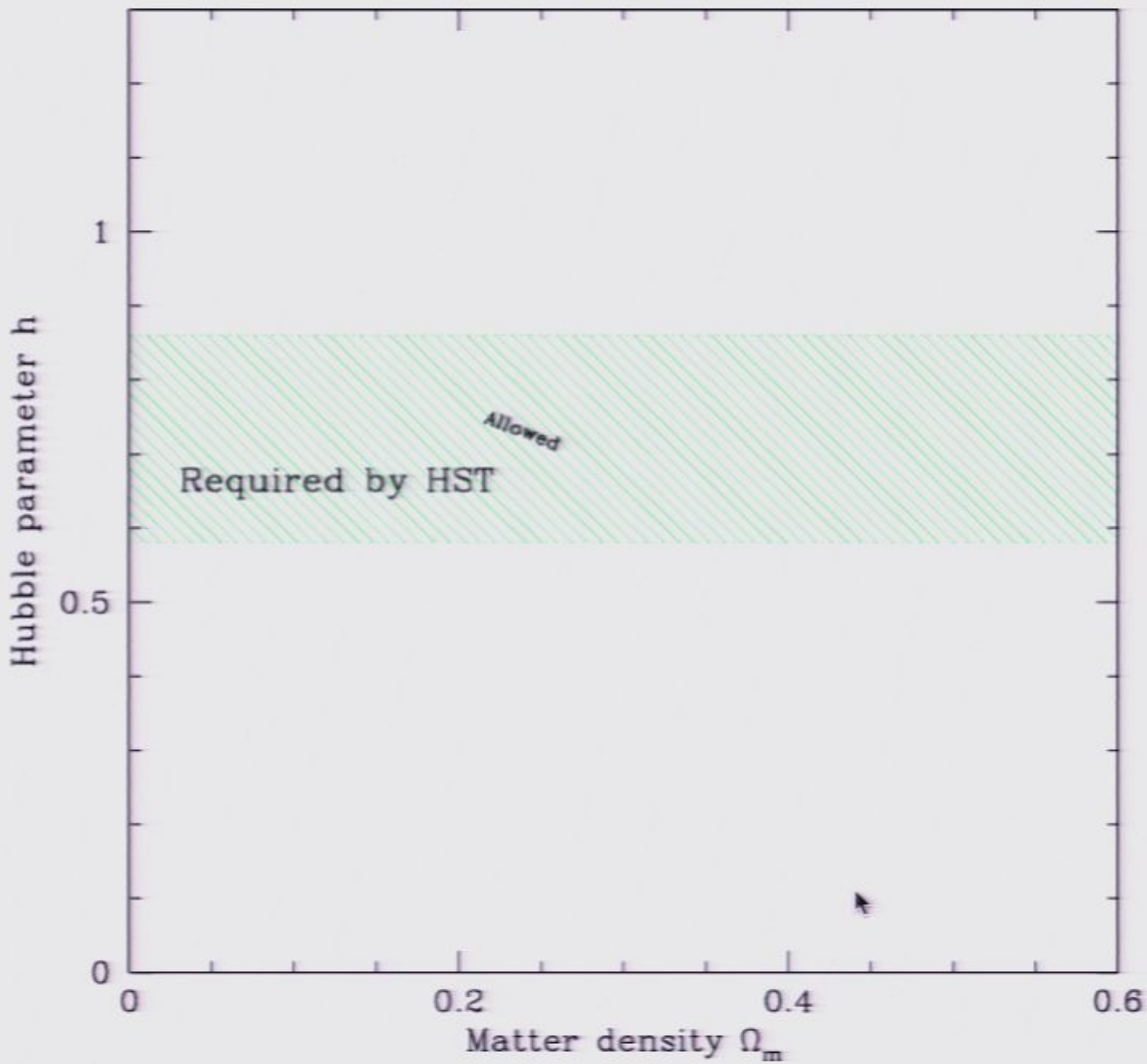

Ω_{tot}
Ω_Λ
ω_b
ω_c
ω_ν
Ω_m
w
Ω_b
Ω_c
Ω_ν
A_s
$r_{.002}$
n_s
α
f_ν
τ
b
Q_{nl}
h
M_ν
z_{ion}
σ_8
t_{now}
l_A
H_3

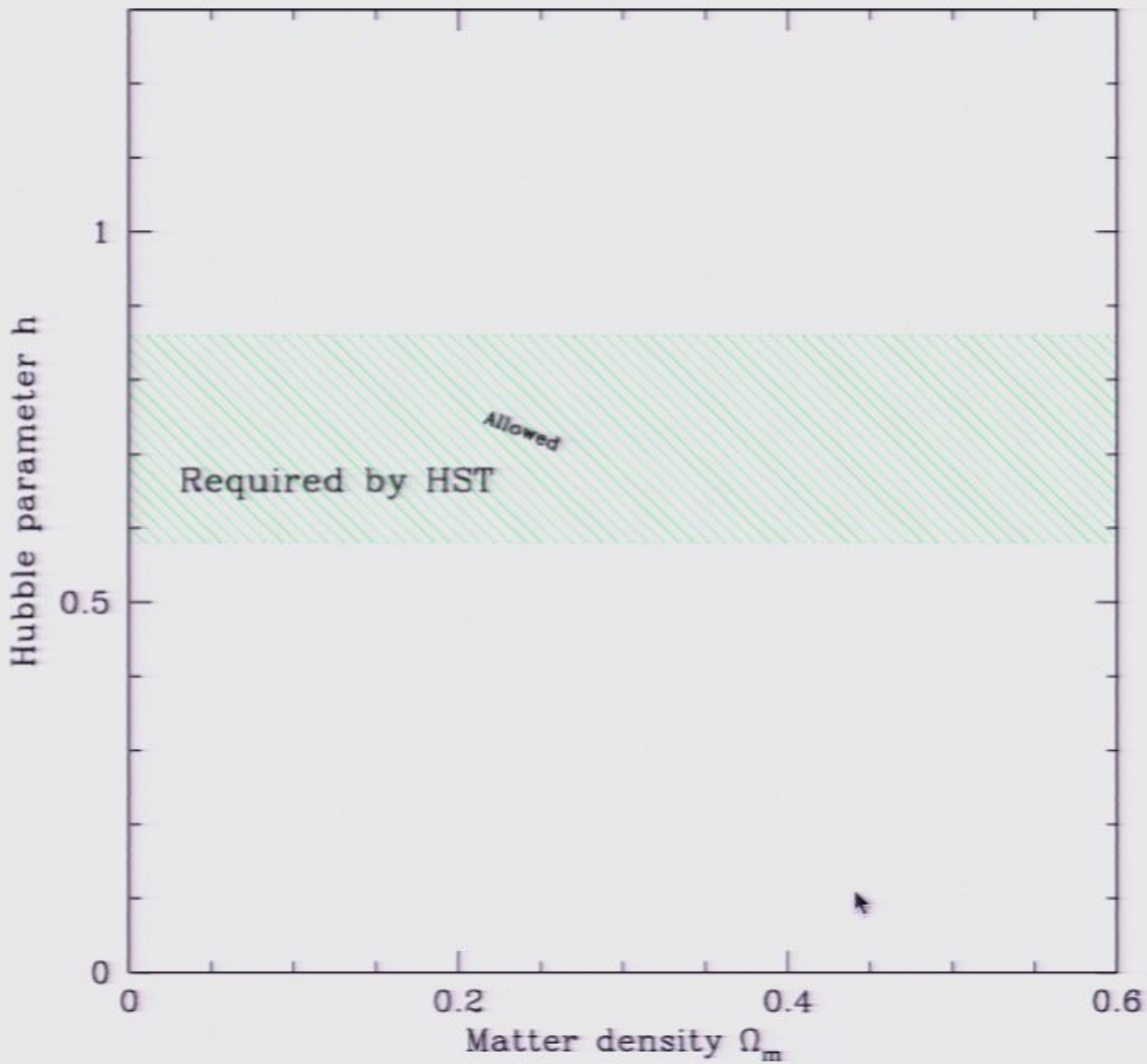

Ω_{tot}
Ω_Λ
ω_b
ω_c
ω_ν
Ω_m
w
Ω_b
Ω_c
Ω_ν
A_s
$r_{.002}$
n_s
α
f_ν
τ
b
Q_{nl}
h
M_ν
z_{ion}
σ_8
t_{now}
l_A
H_3

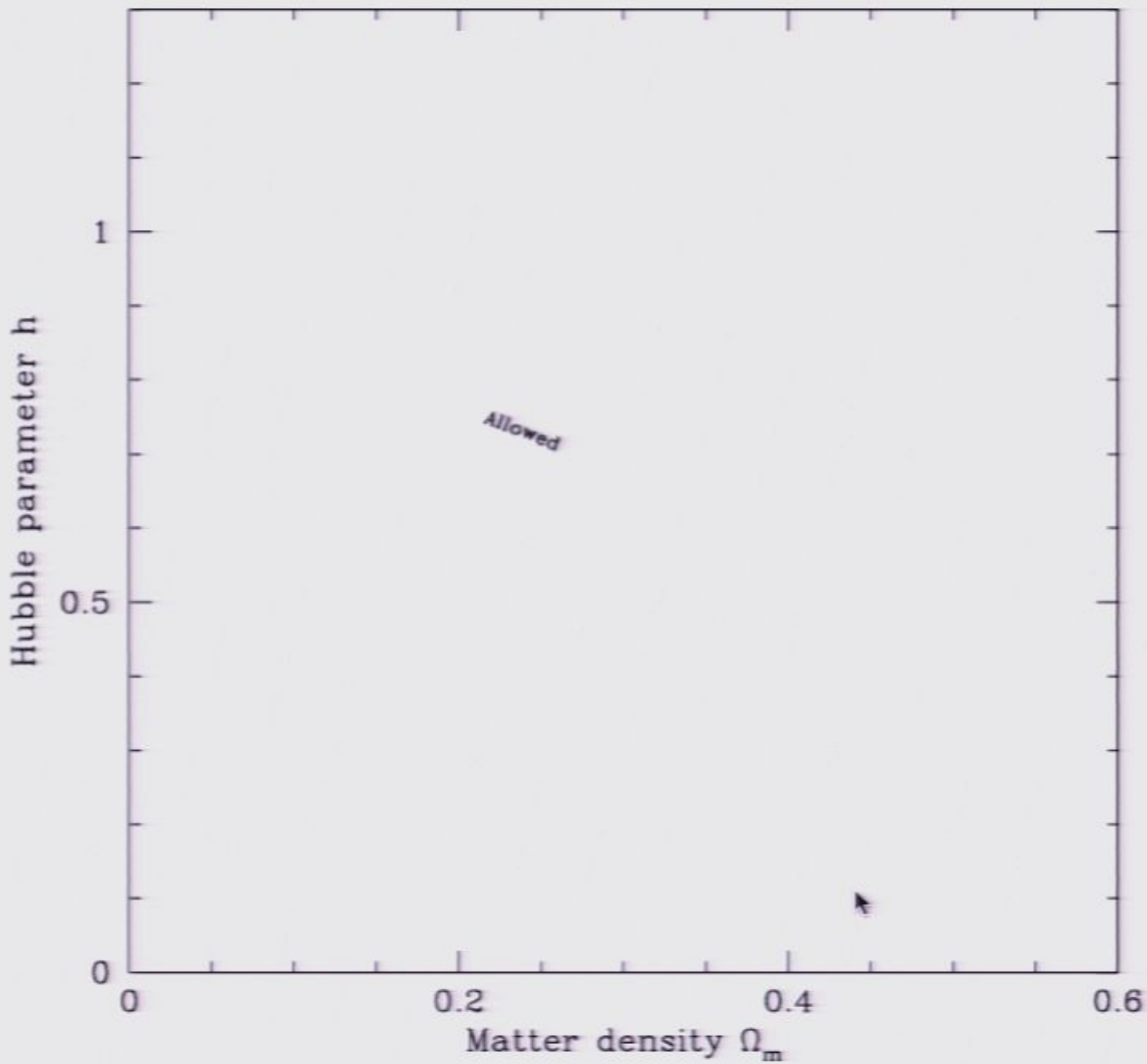
What's Bias?

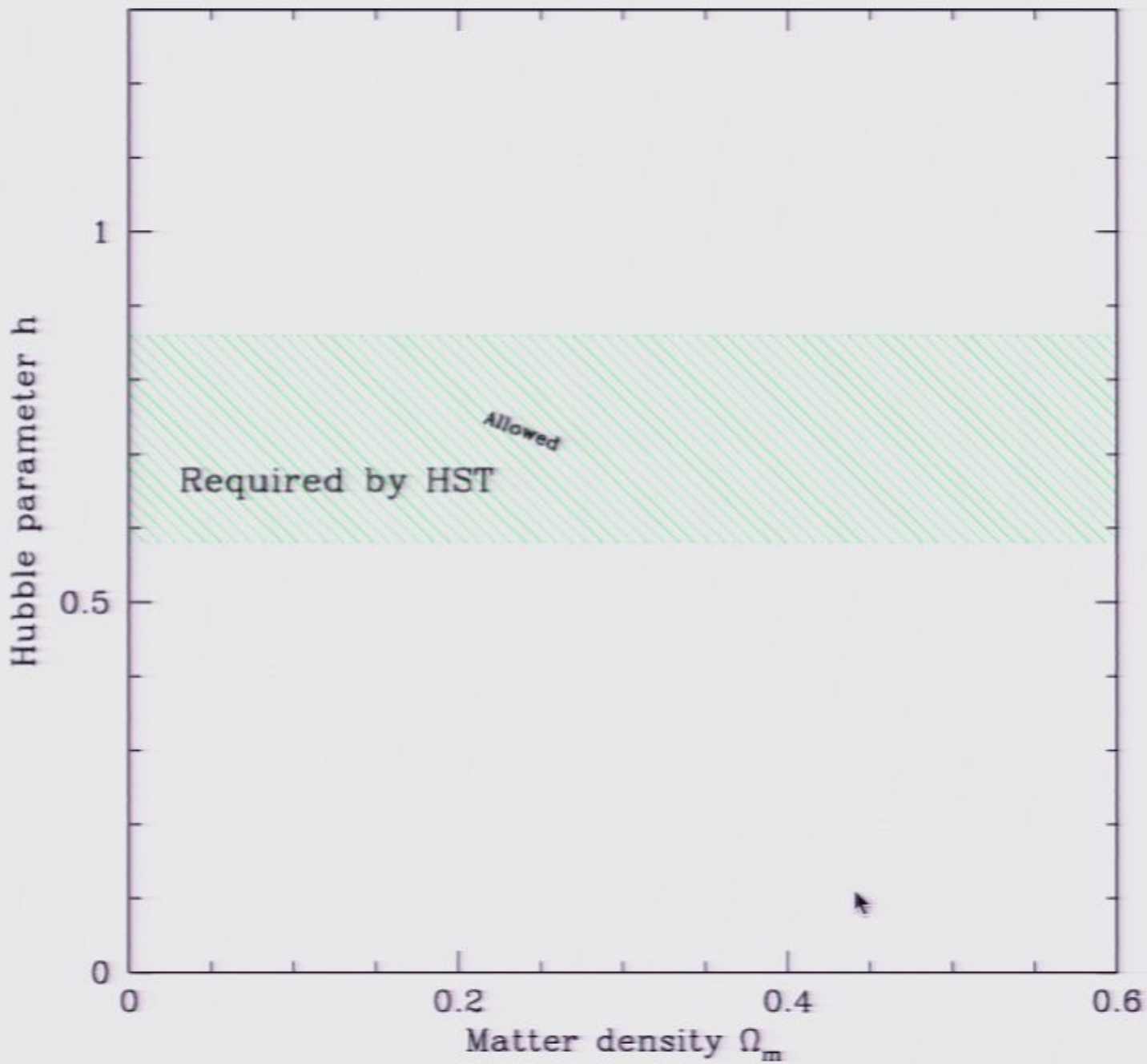

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=0.56
w=−1.000
α=0.000
h=0.68
χ²=0.000

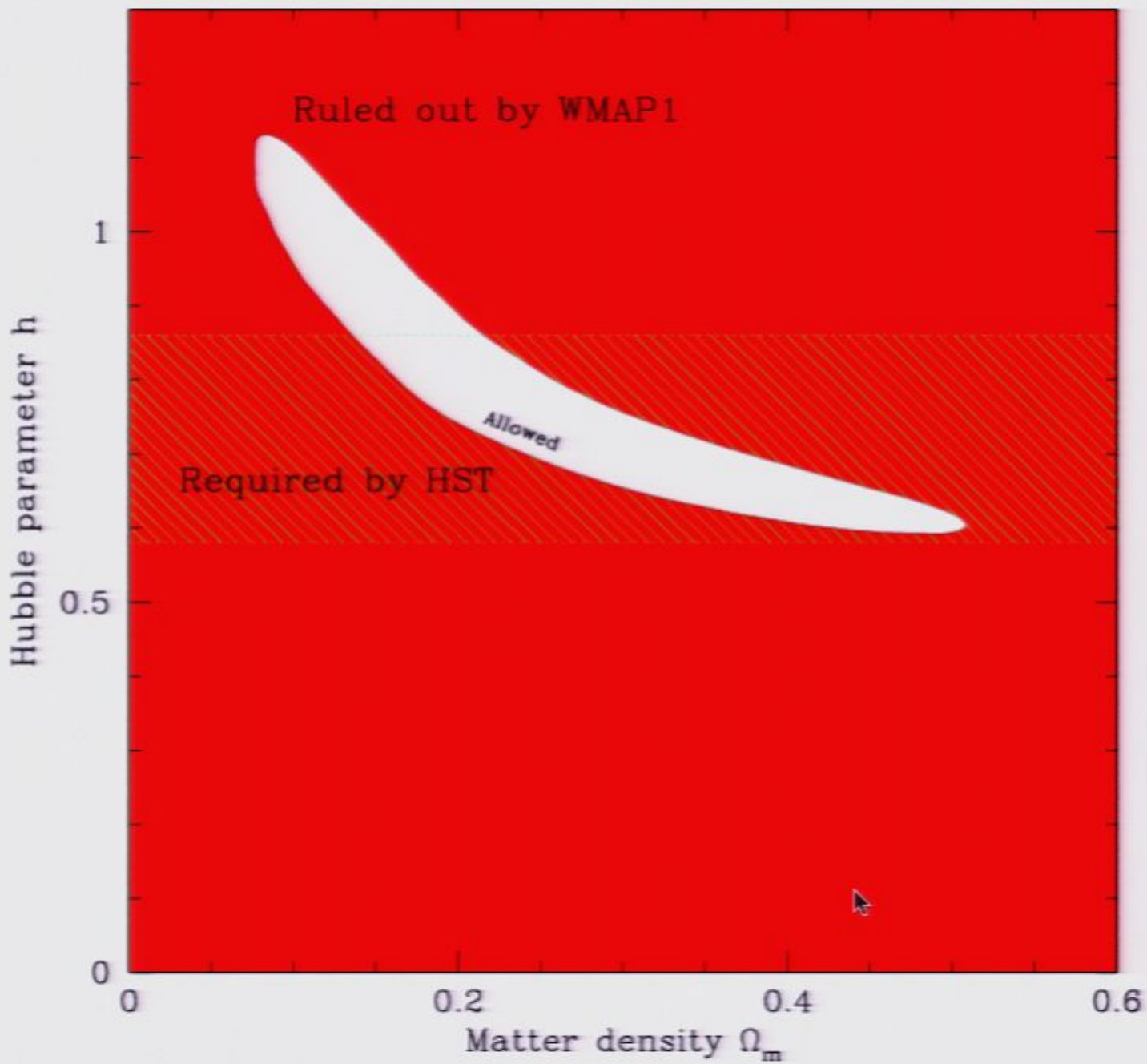

Allowed
Hubble parameter h
1
0.5
0
0
0.2
0.4
0.6
Matter density Ω_m

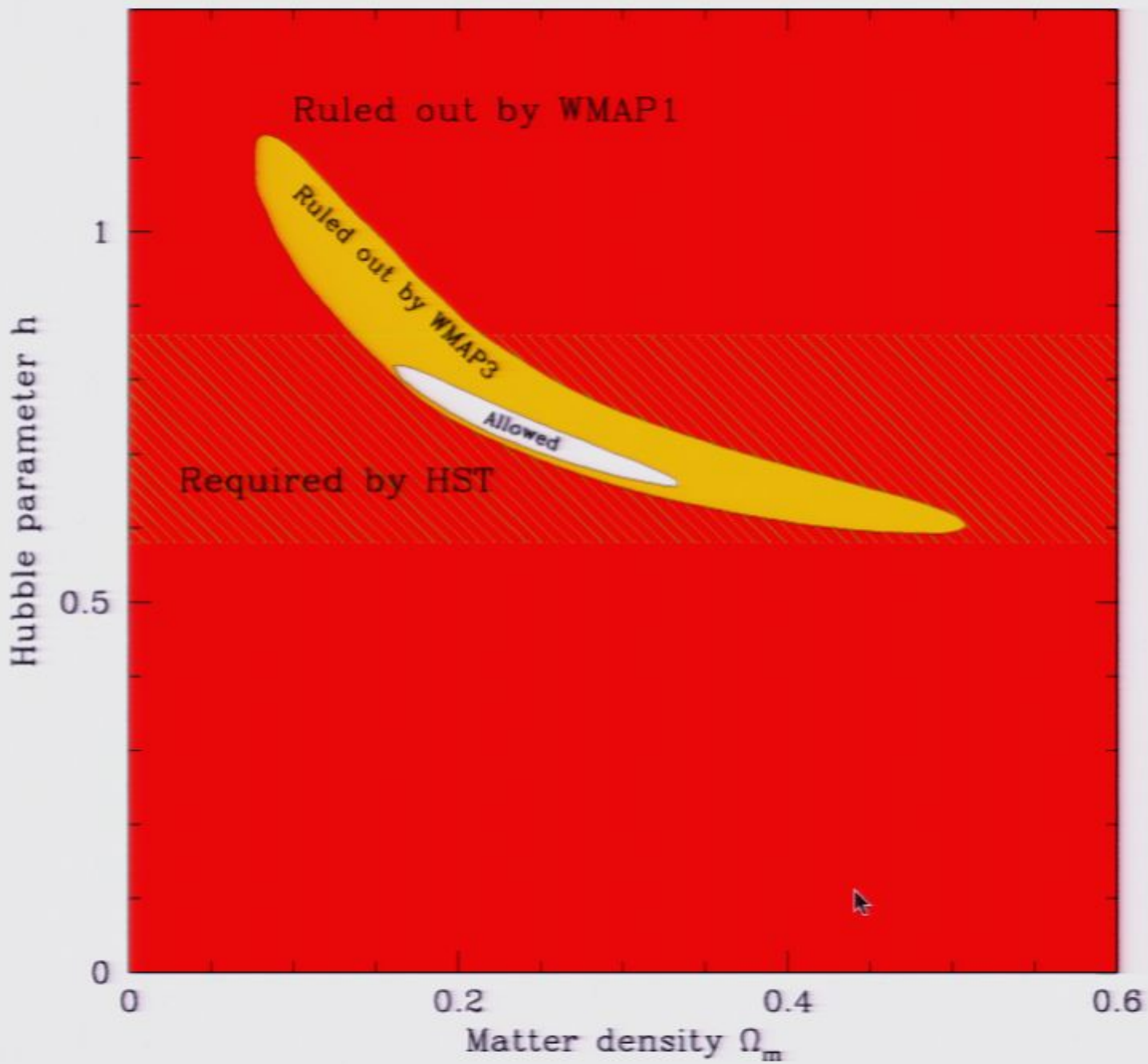

Hubble parameter h
1
0.5
0
Allowed
Required by HST
0
0.2
0.4
0.6
Matter density Ω_m

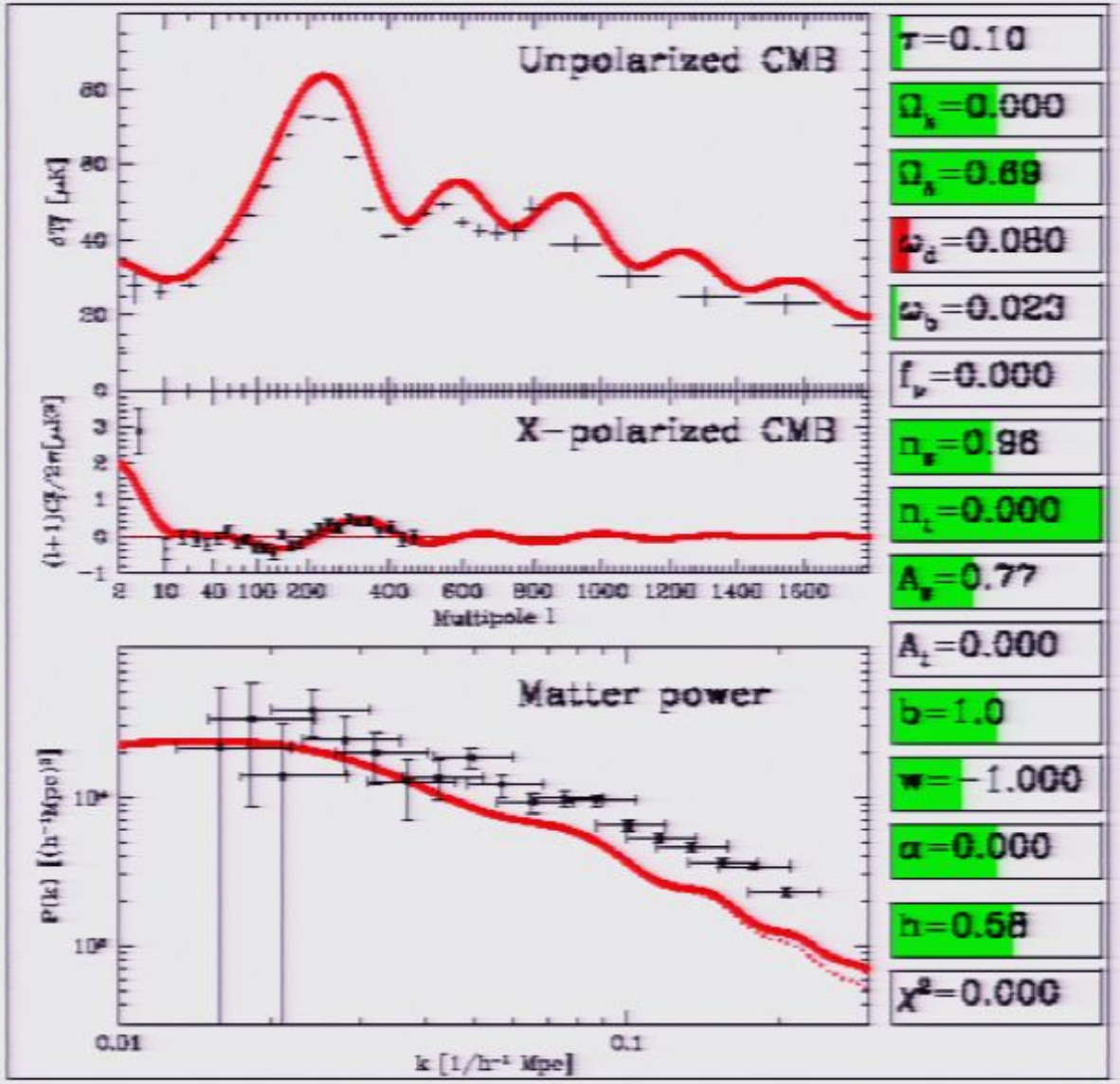

Hubble parameter h
1
0.5
0
Allowed
Required by HST
0
0.2
0.4
0.6
Matter density Ω_m

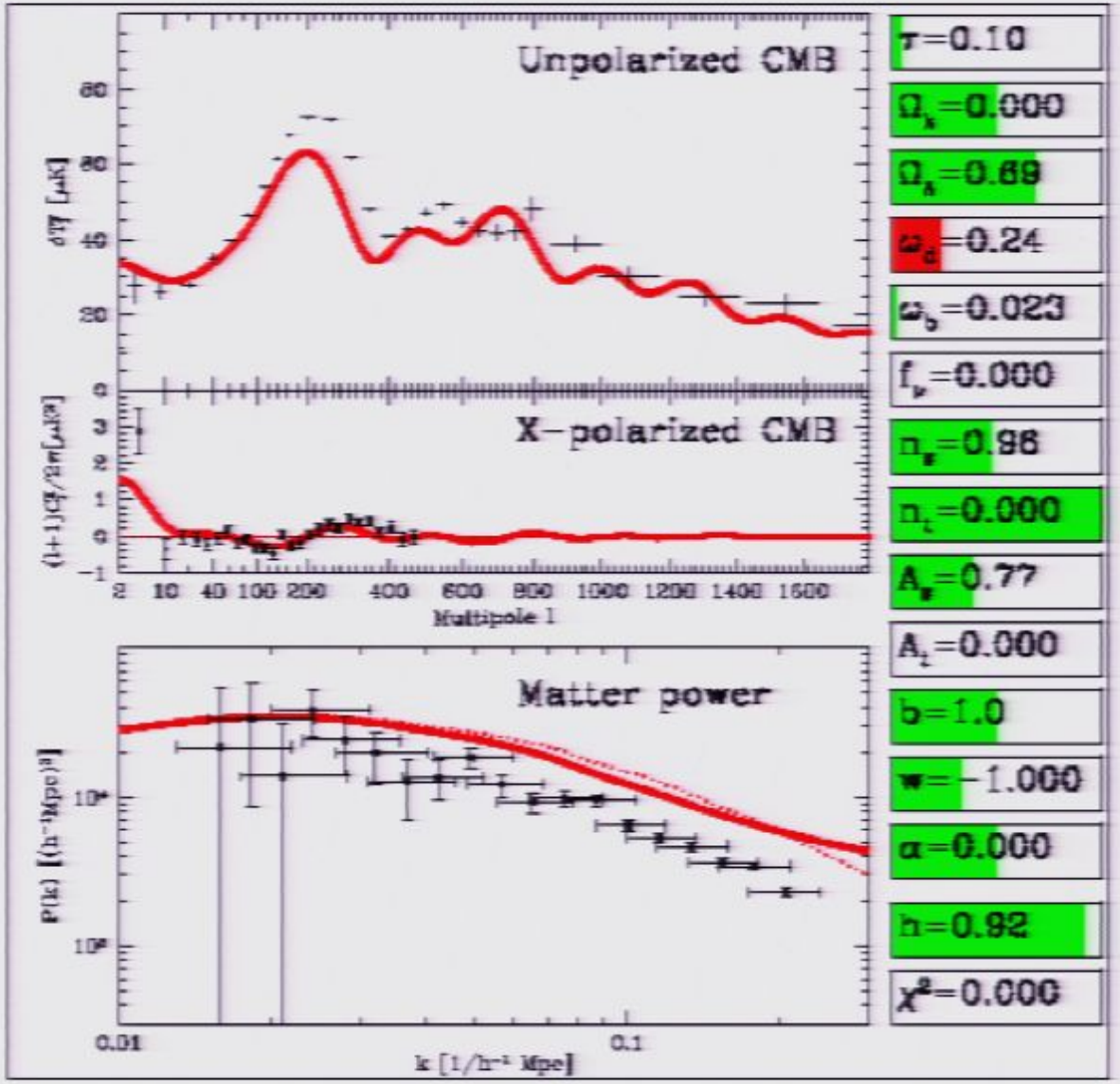

Allowed
Hubble parameter h
1
0.5
0
0
0.2
0.4
0.6
Matter density Ω_m

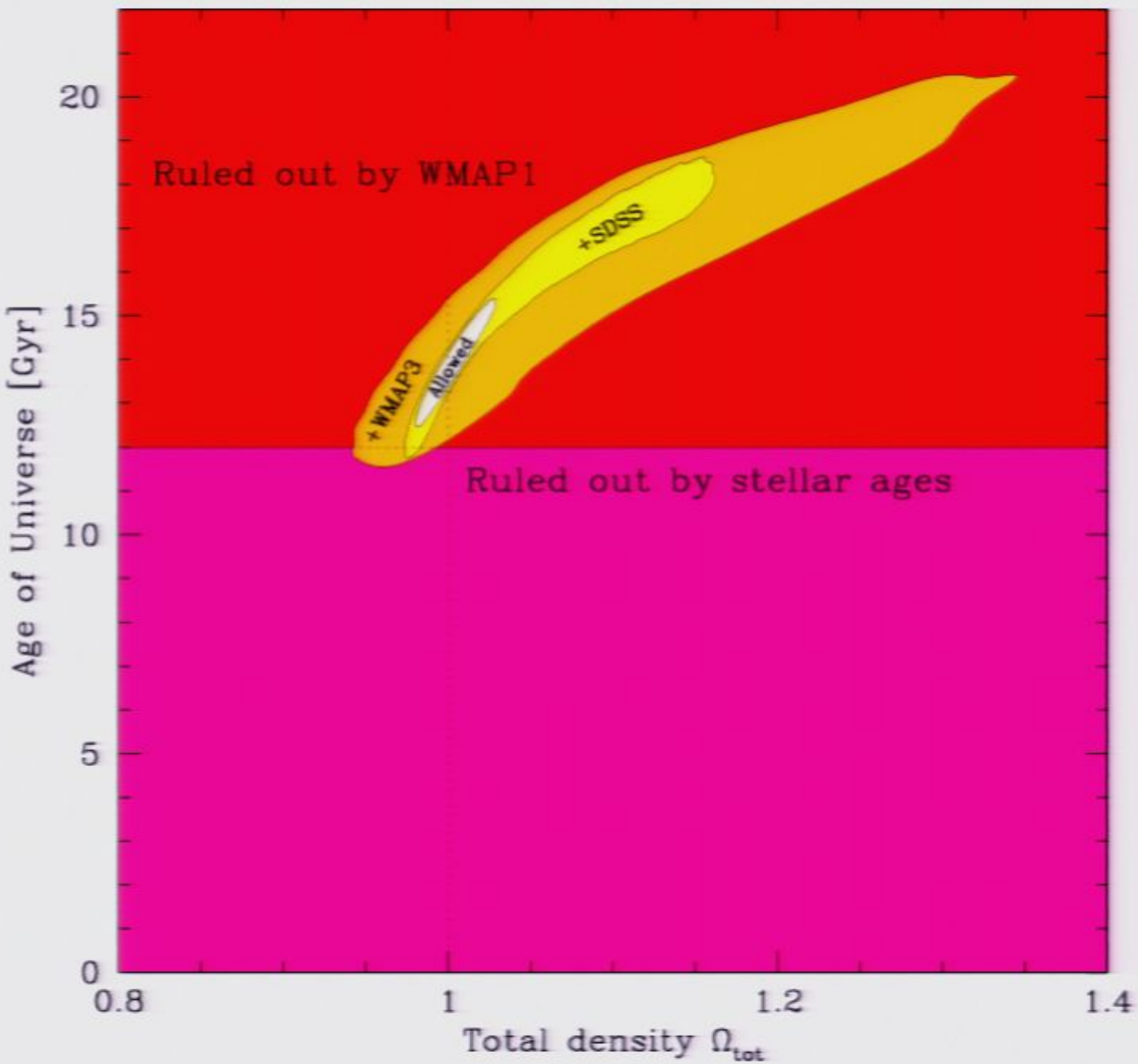

Hubble parameter h
1
0.5
0
Allowed
Required by HST
0
0.2
0.4
0.6
Matter density Ω_m

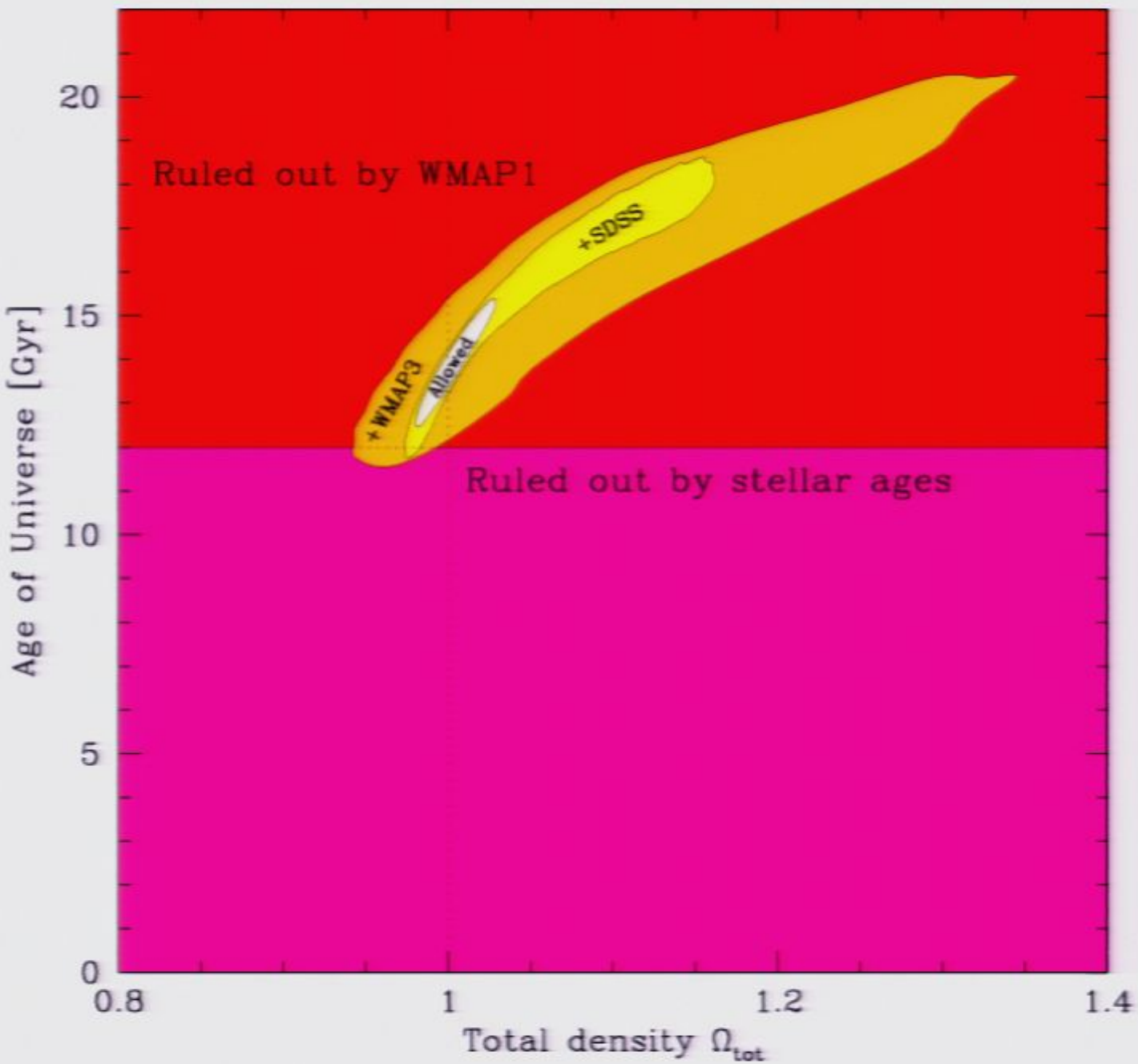

Ruled out by WMAP1
Allowed
Required by HST
Hubble parameter h
1
0.5
0
0
0.2
0.4
0.6
Matter density Ω_m

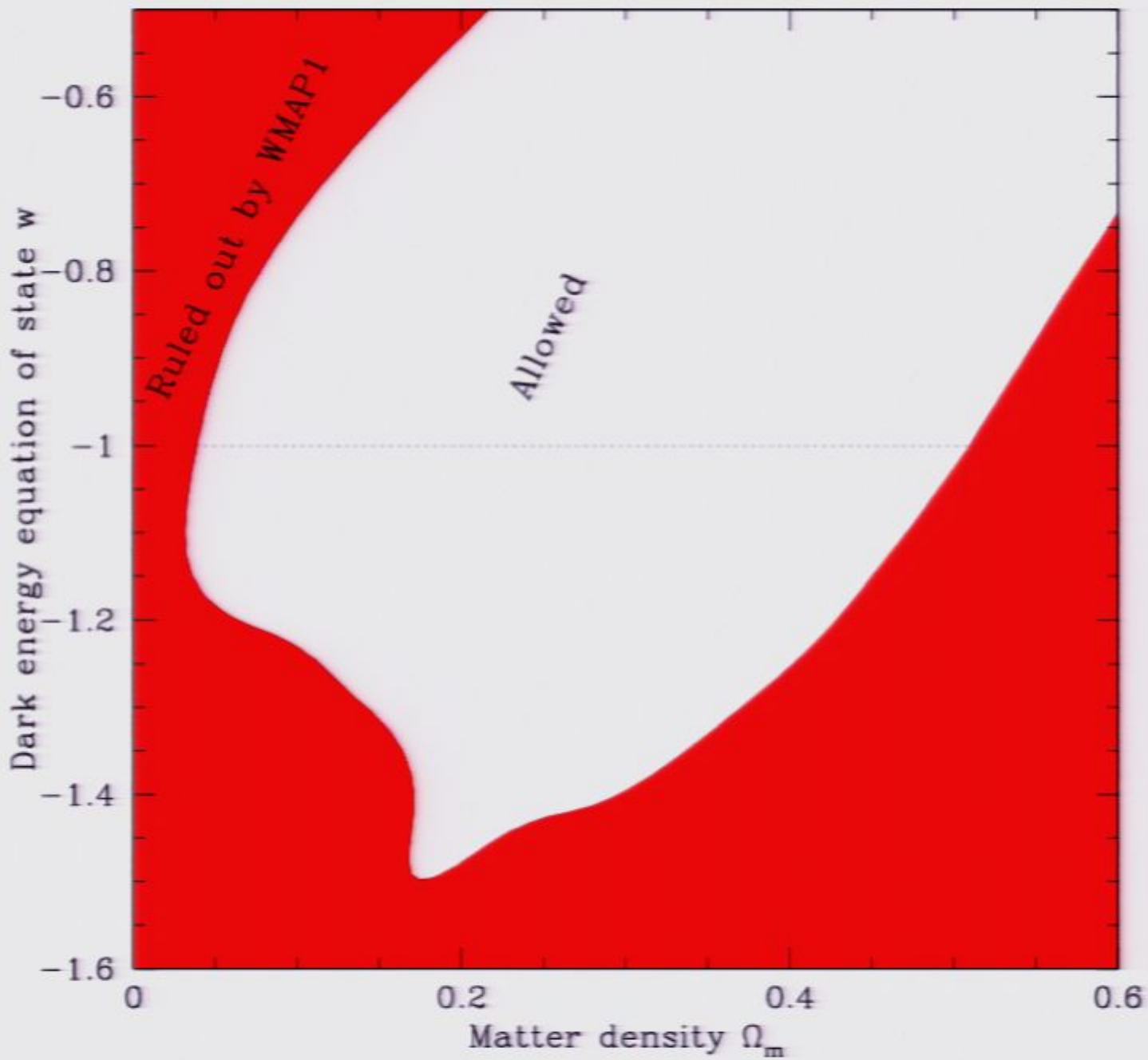

Ruled out by WMAP1
Ruled out by WMAP3
Allowed
Required by HST
Hubble parameter h
1
0.5
0
0
0.2
0.4
0.6
Matter density Ω_m

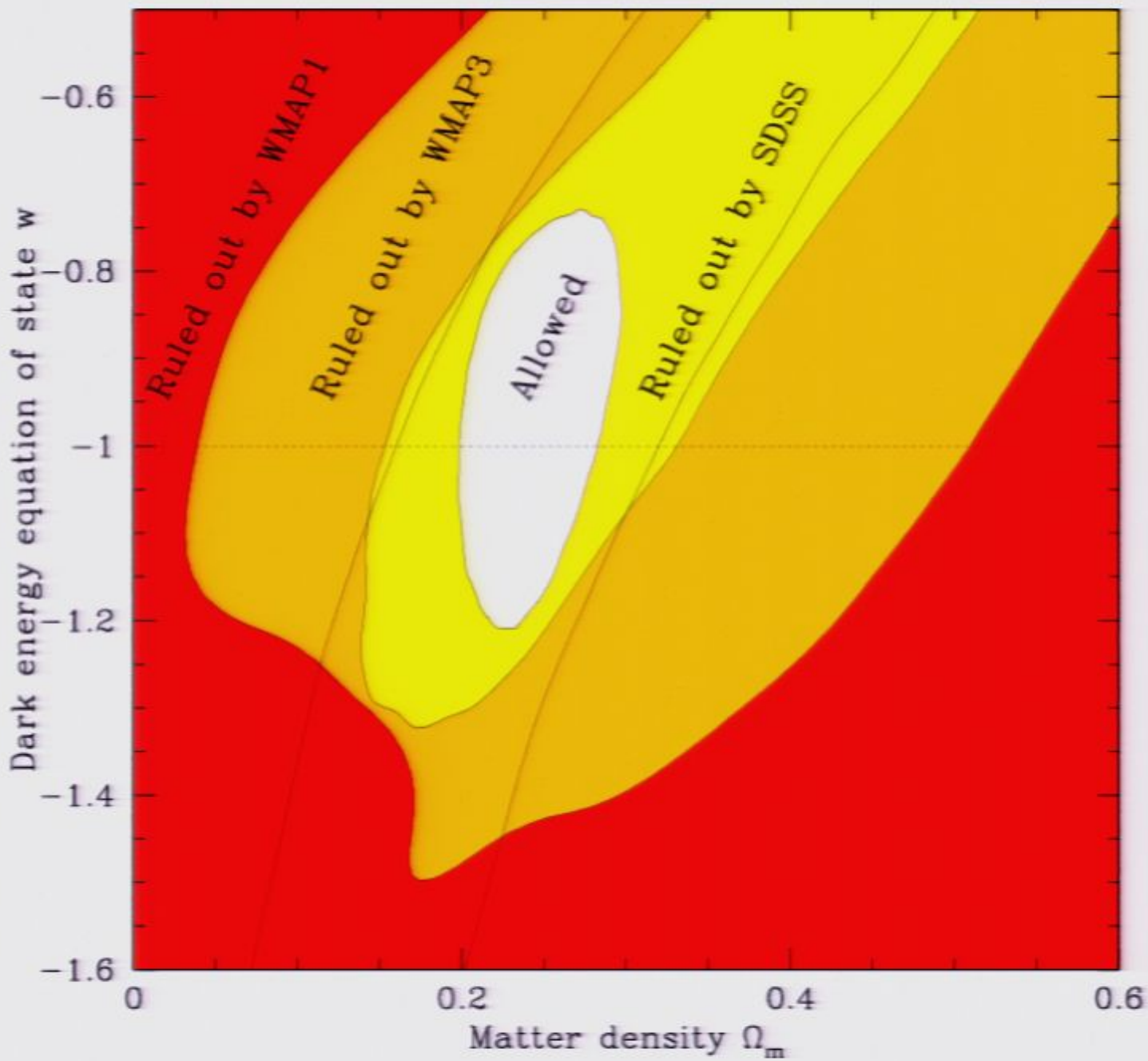

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.080
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.58
χ²=0.000

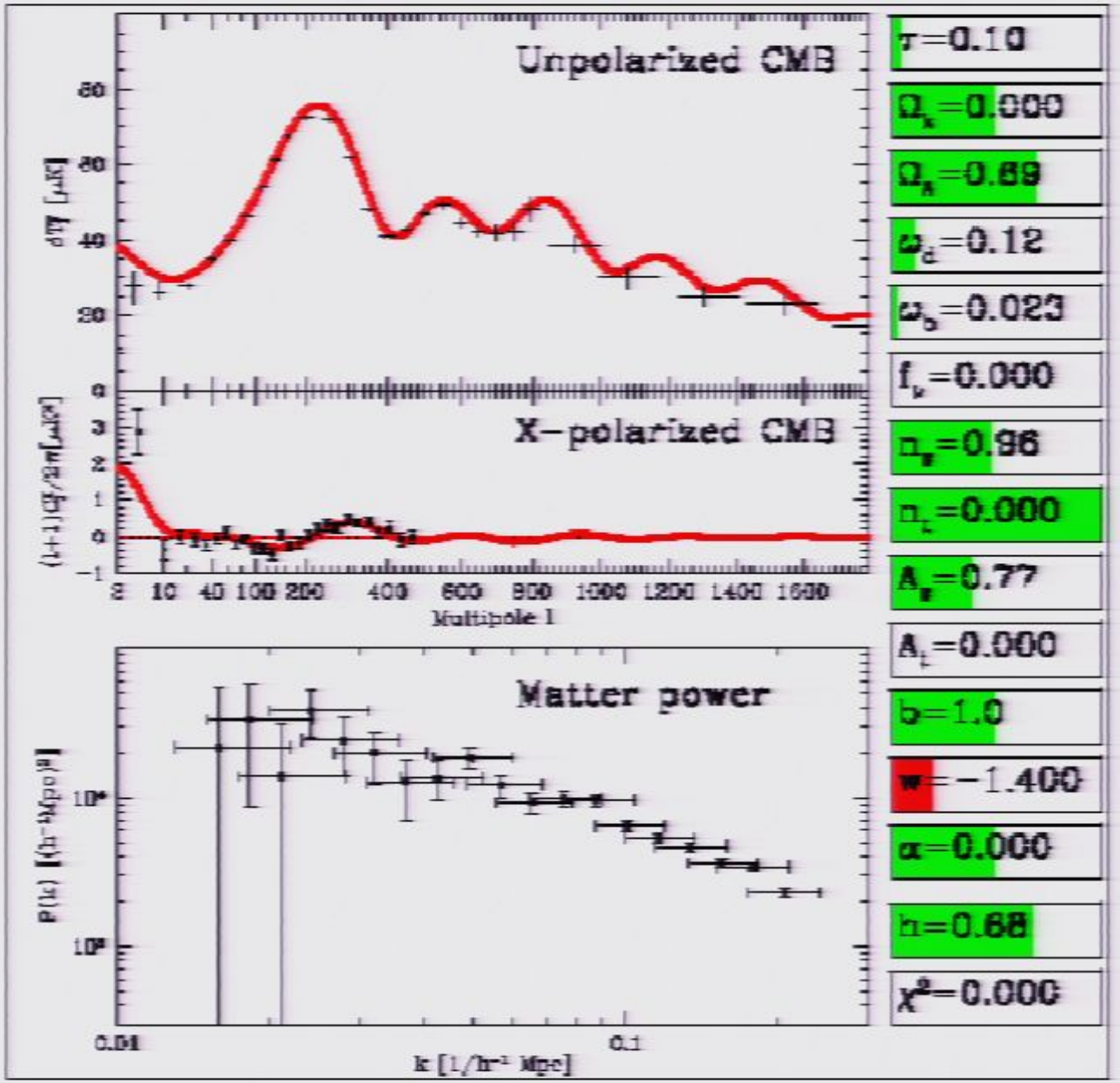

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.24
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.92
χ²=0.000

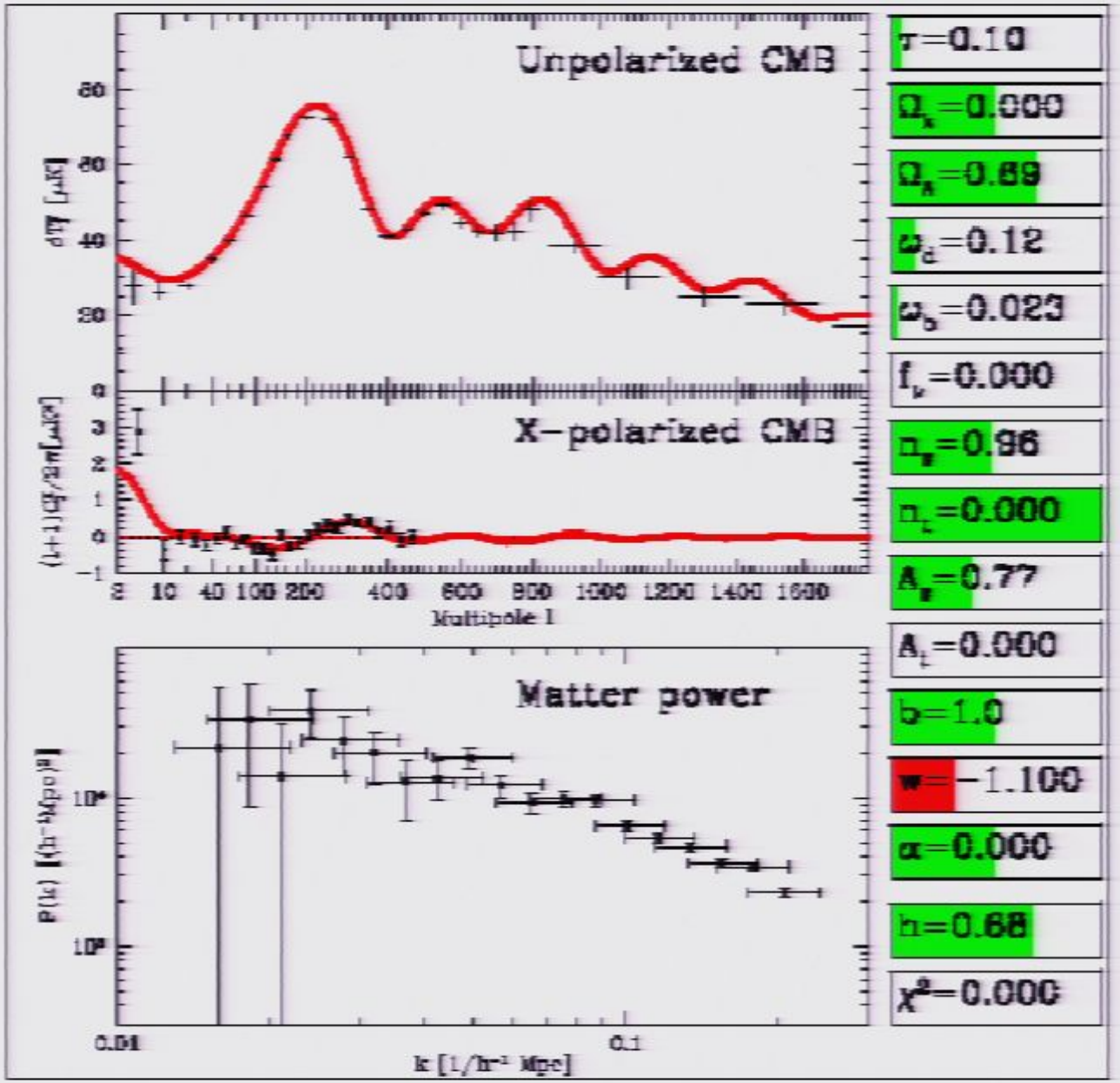

Ruled out by WMAP1
+SDSS
+WMAP3
Allowed
Ruled out by stellar ages
Age of Universe [Gyr]
Total density Ω_{tot}
0
5
10
15
20
0.8
1
1.2
1.4

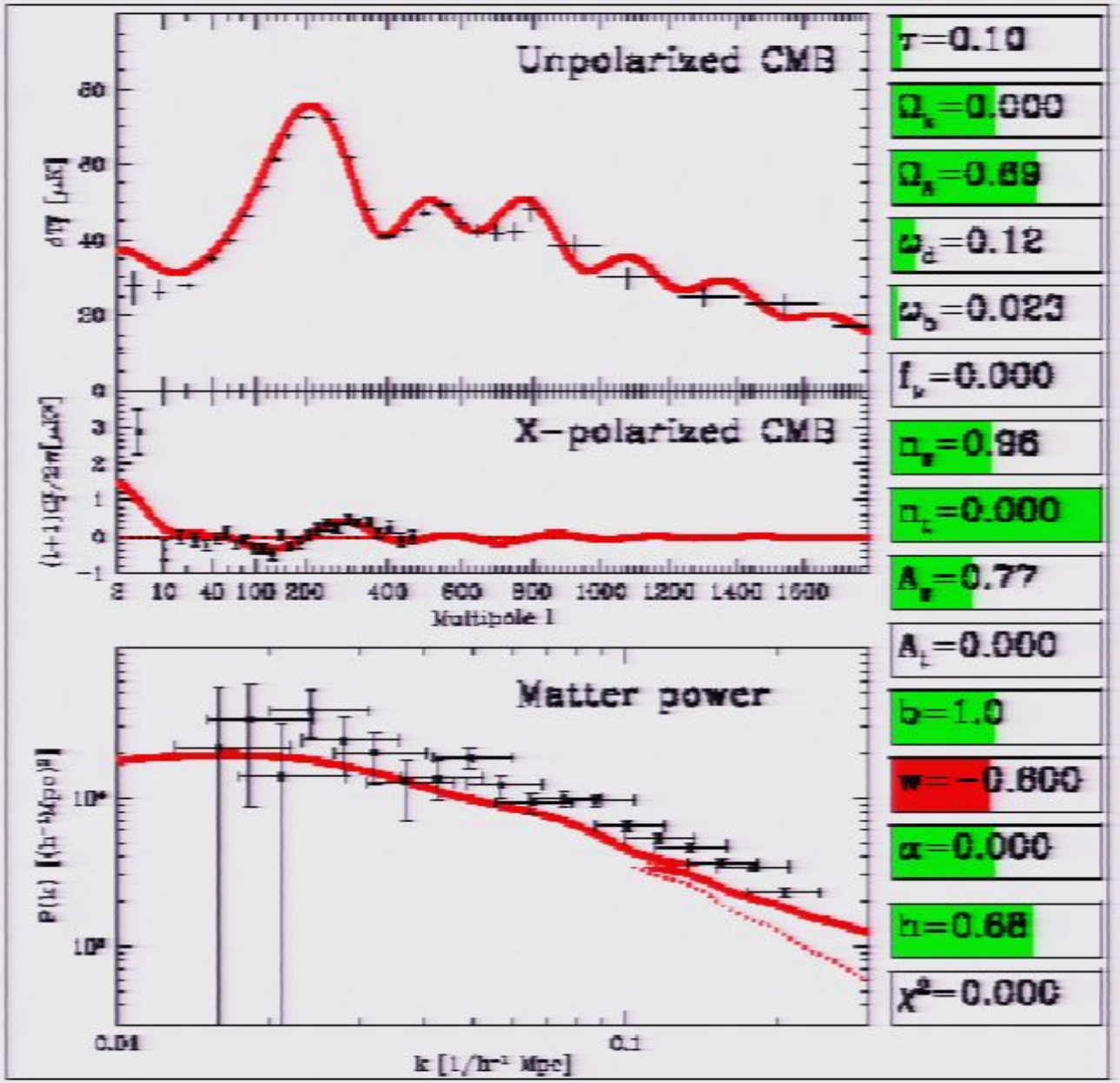

Ruled out by WMAP1
+SDSS
+WMAP3
Allowed
Ruled out by stellar ages
Age of Universe [Gyr]
Total density Ω_{tot}
0
5
10
15
20
0.8
1
1.2
1.4

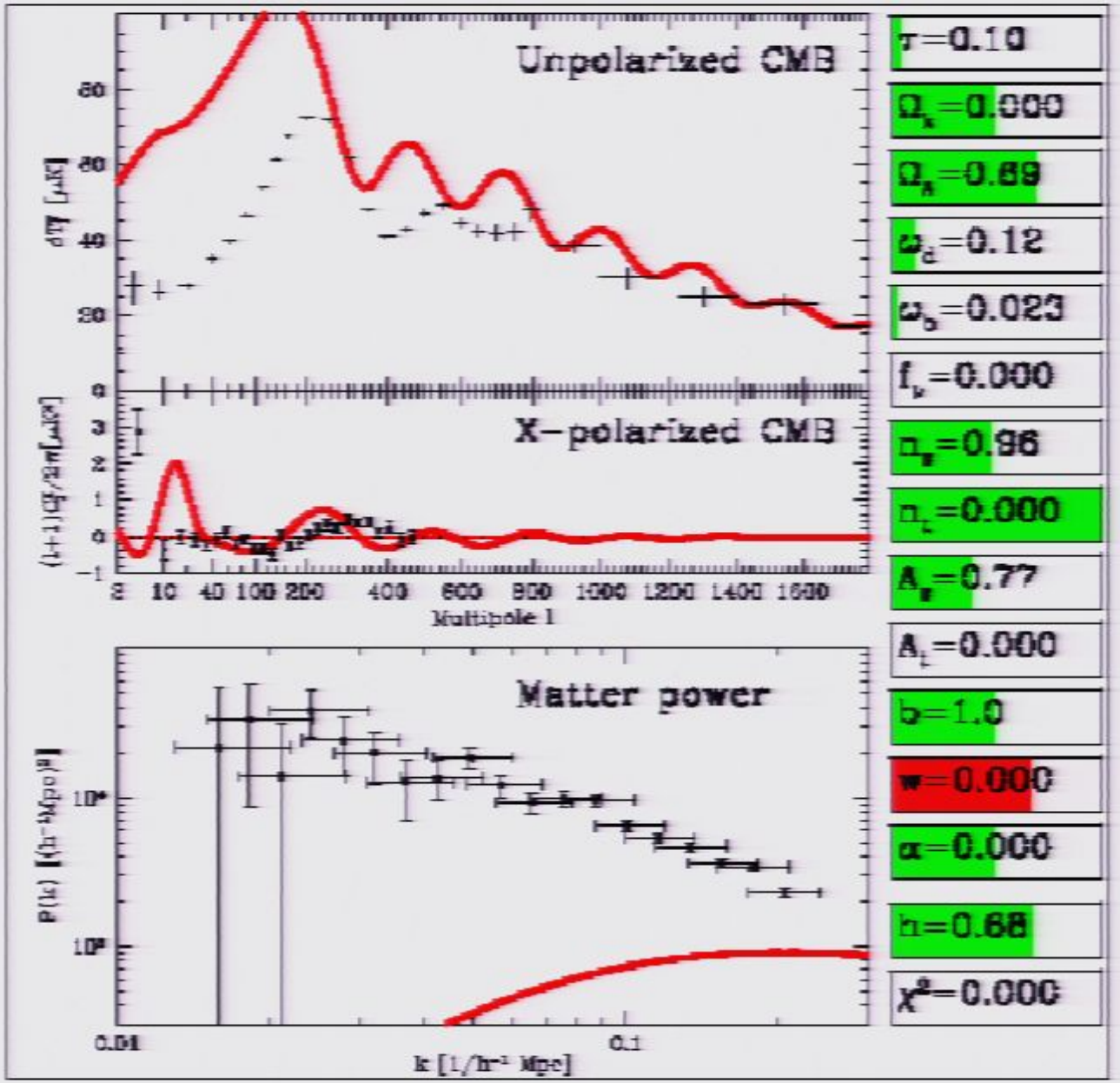

Ruled out by WMAP1
Allowed
Dark energy equation of state w
−0.6
−0.8
−1
−1.2
−1.4
−1.6
0
0.2
0.4
0.6
Matter density Ω_m

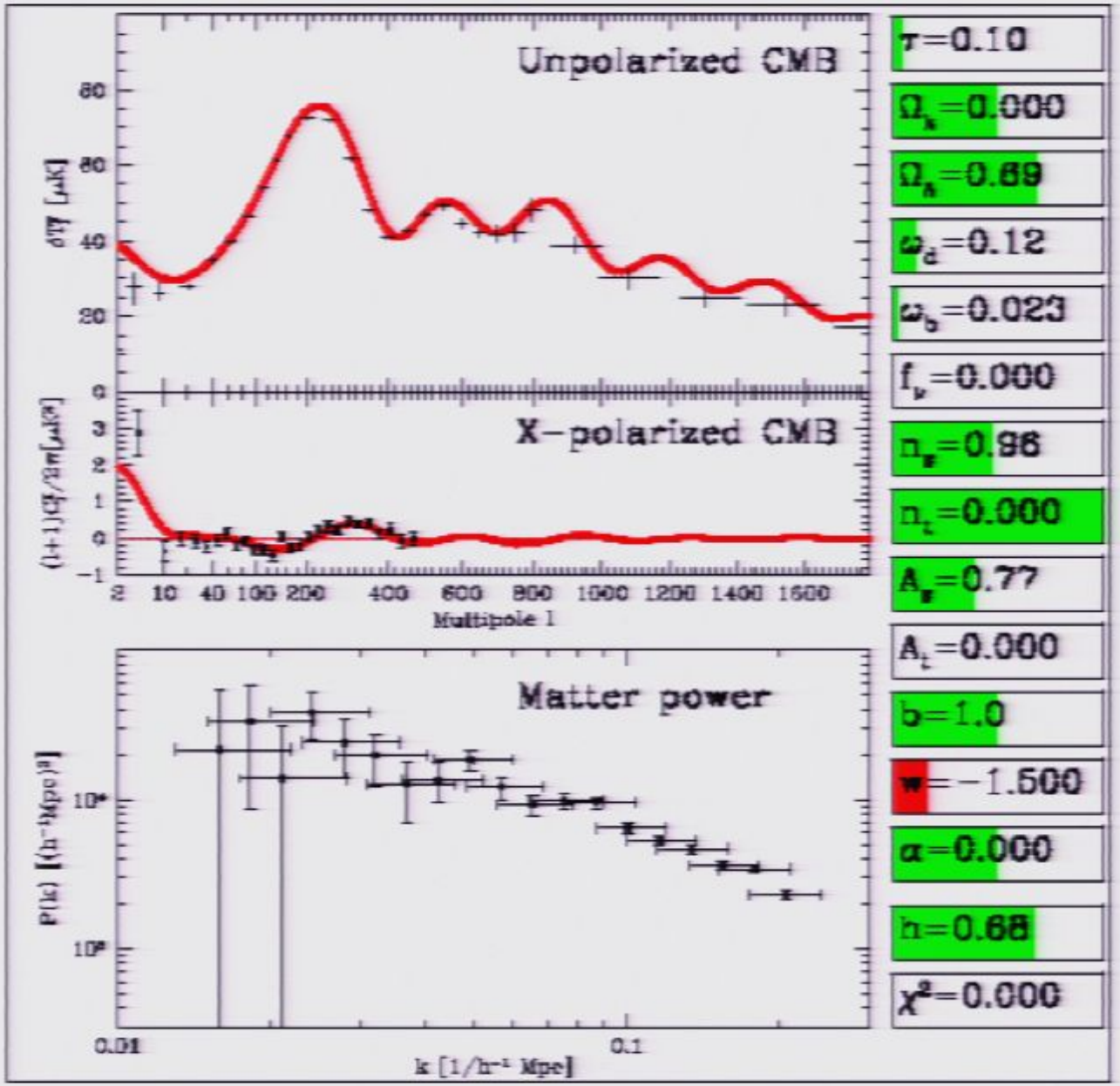

Ruled out by WMAP1
Ruled out by WMAP3
Allowed
Ruled out by SDSS
−0.6
−0.8
−1
−1.2
−1.4
−1.6
0
0.2
0.4
0.6
Dark energy equation of state w
Matter density Ω_m

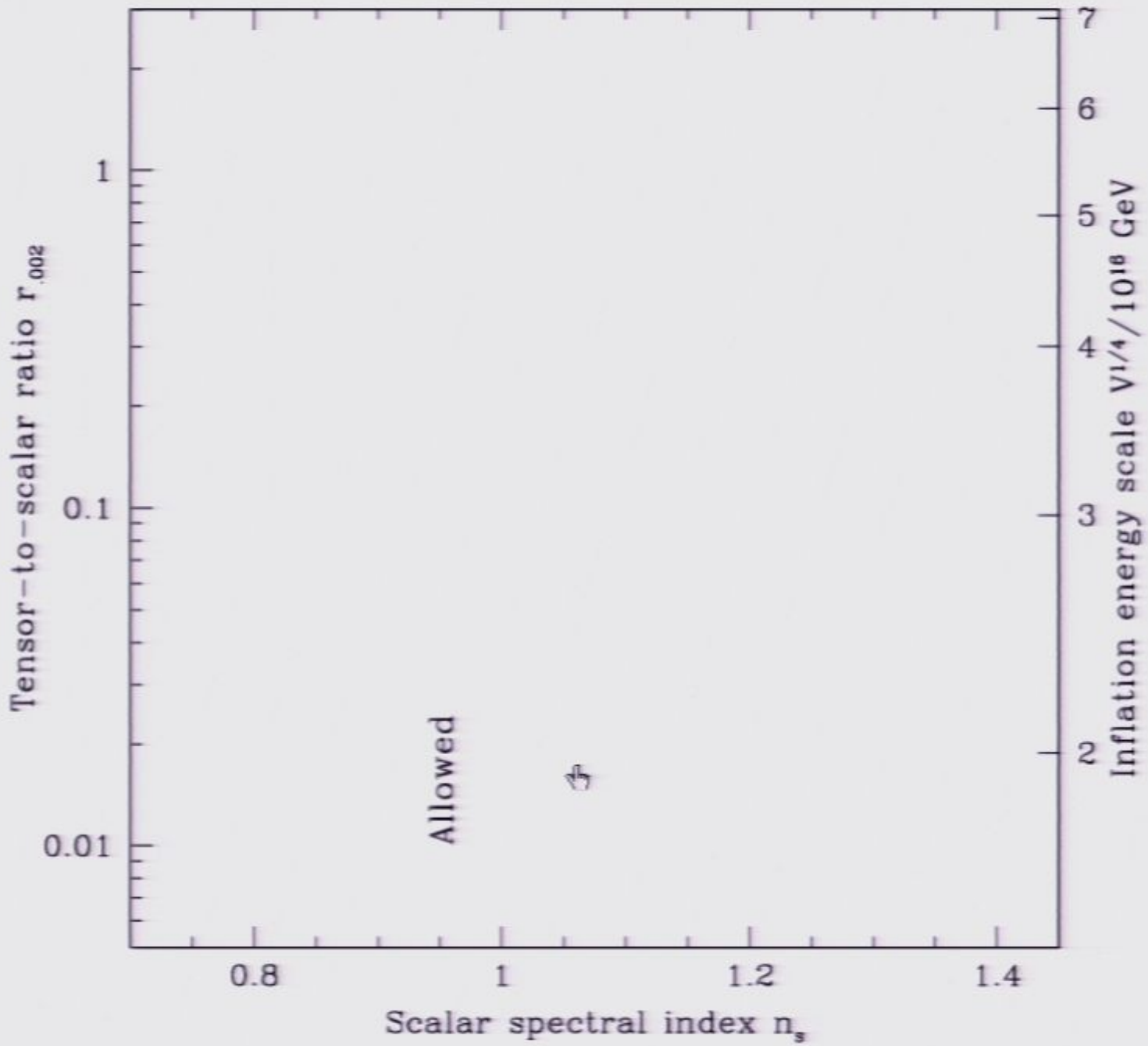

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h² Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.400
α=0.000
h=0.68
χ²=0.000

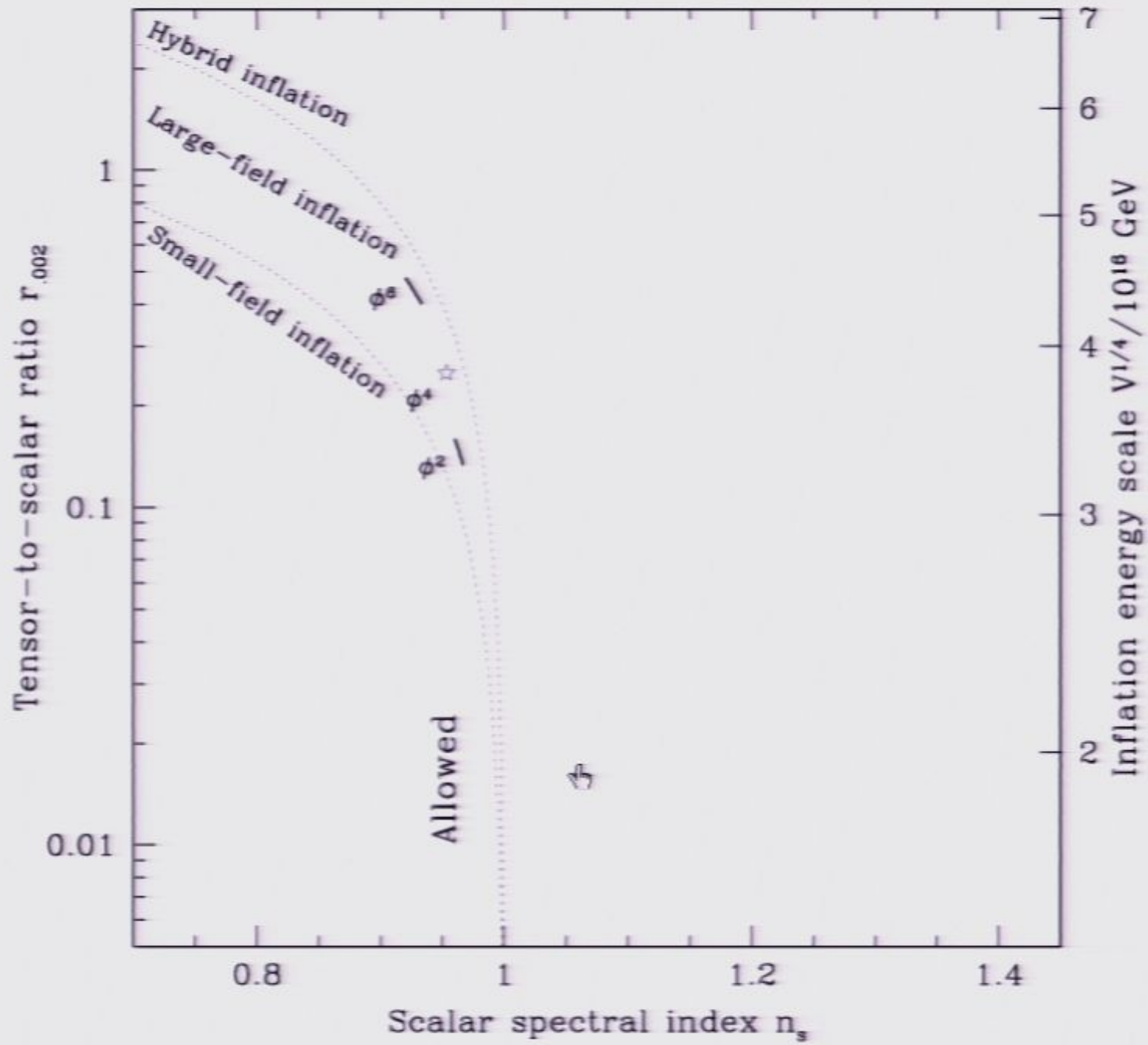

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h² Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.100
α=0.000
h=0.68
χ²=0.000

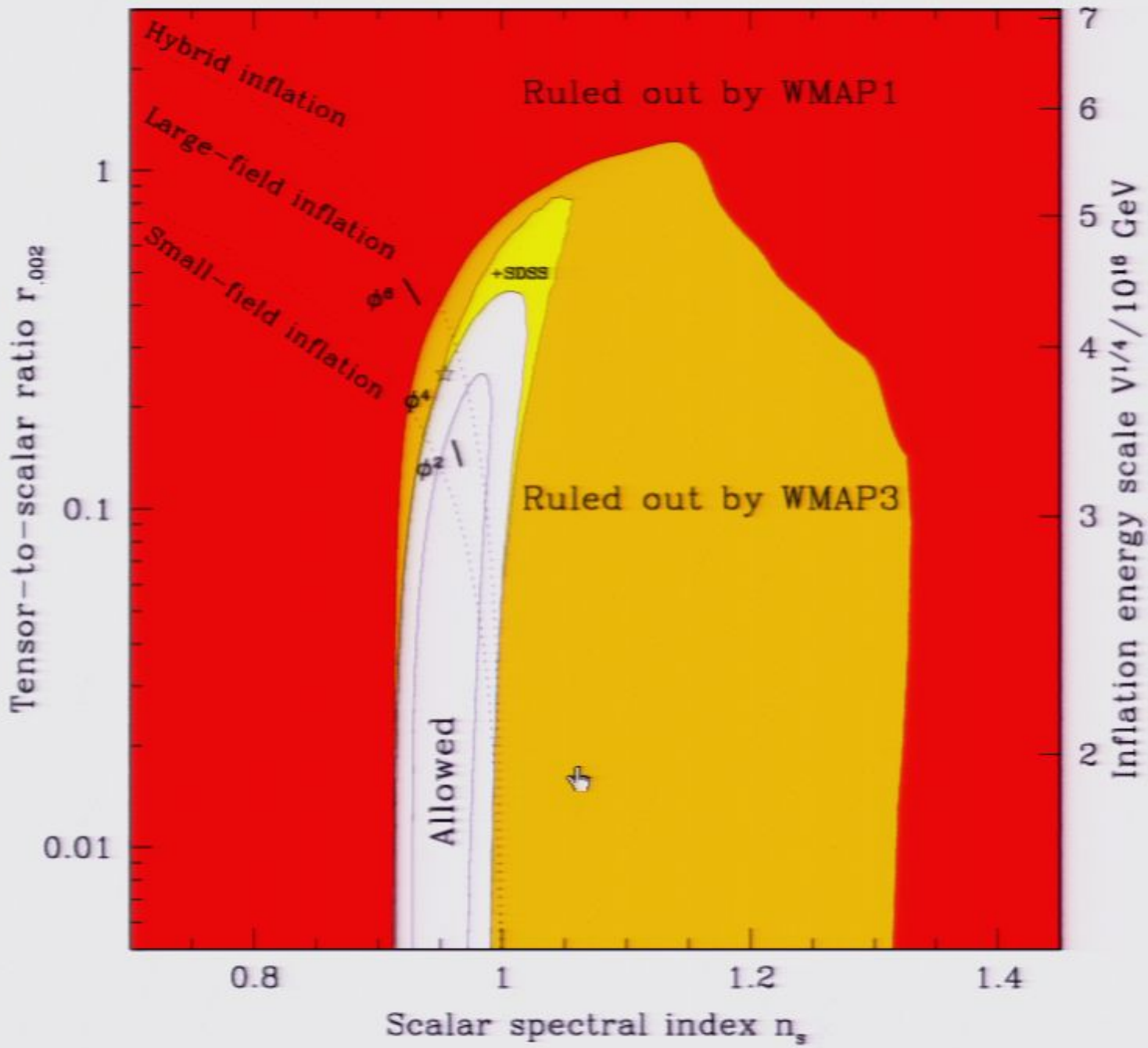

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h² Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−0.800
α=0.000
h=0.68
χ²=0.000

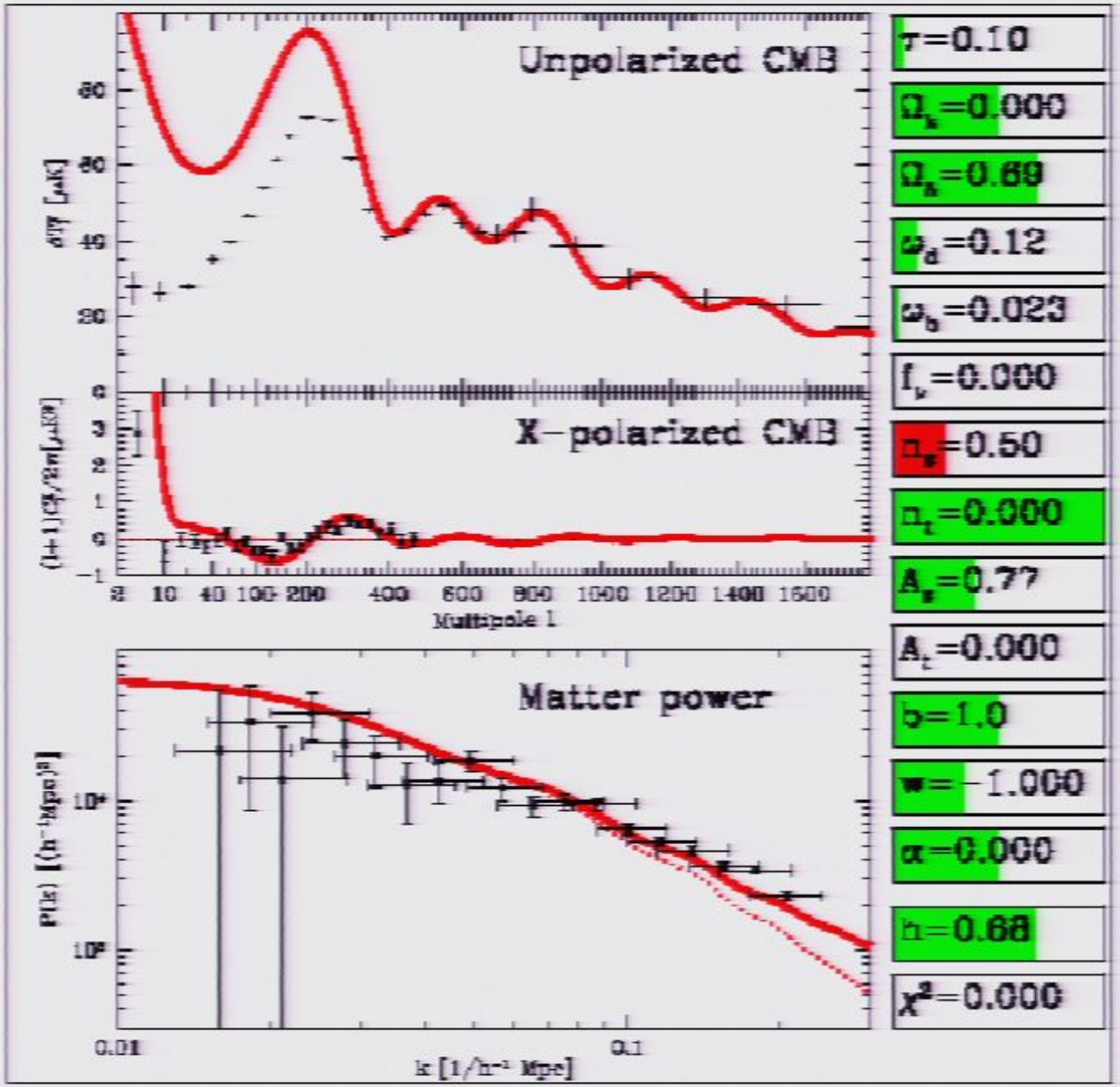

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h² Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=0.000
α=0.000
h=0.68
χ²=0.000

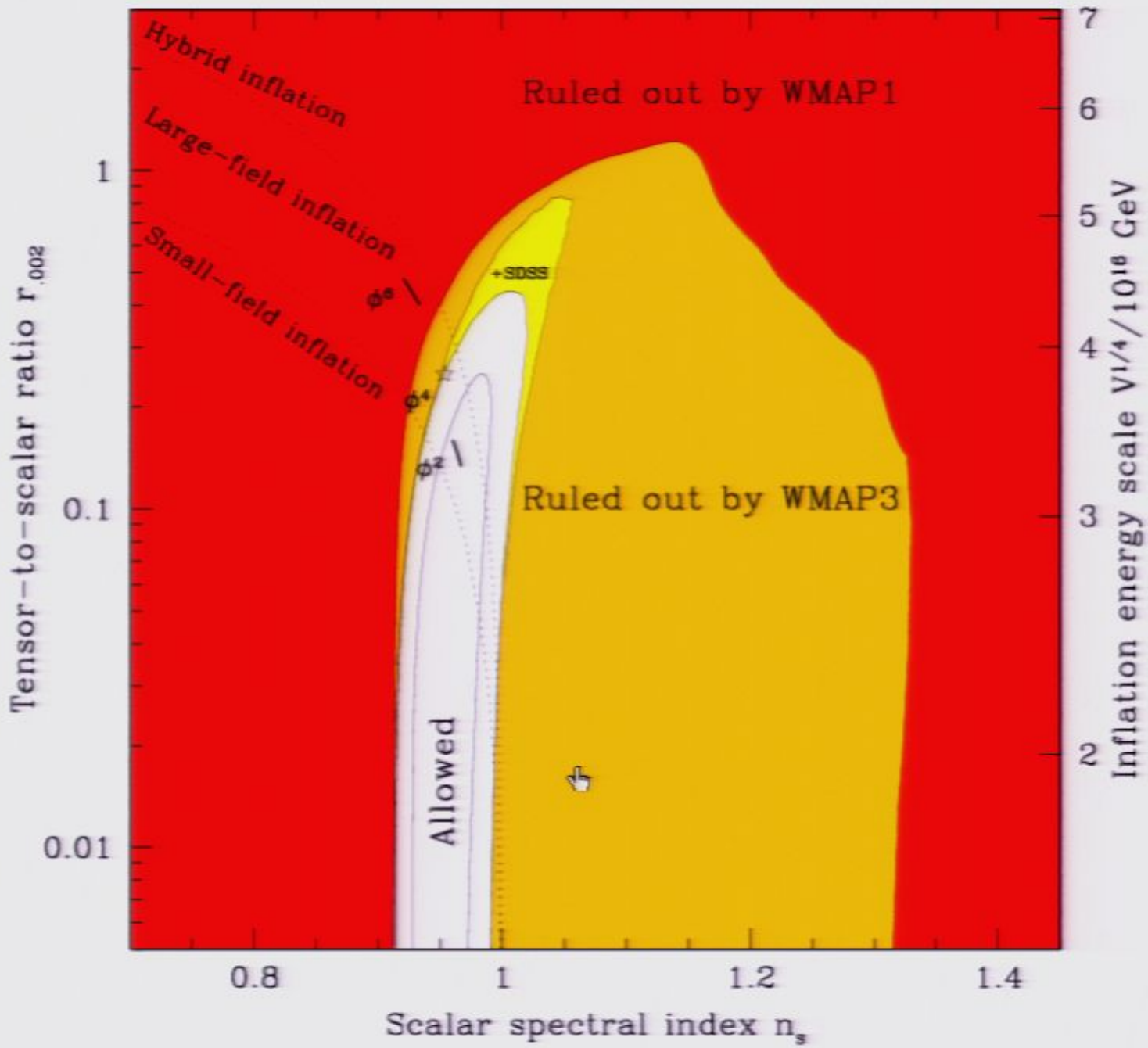

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
P(k) [(h⁻¹Mpc)³]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.500
α=0.000
h=0.68
χ²=0.000

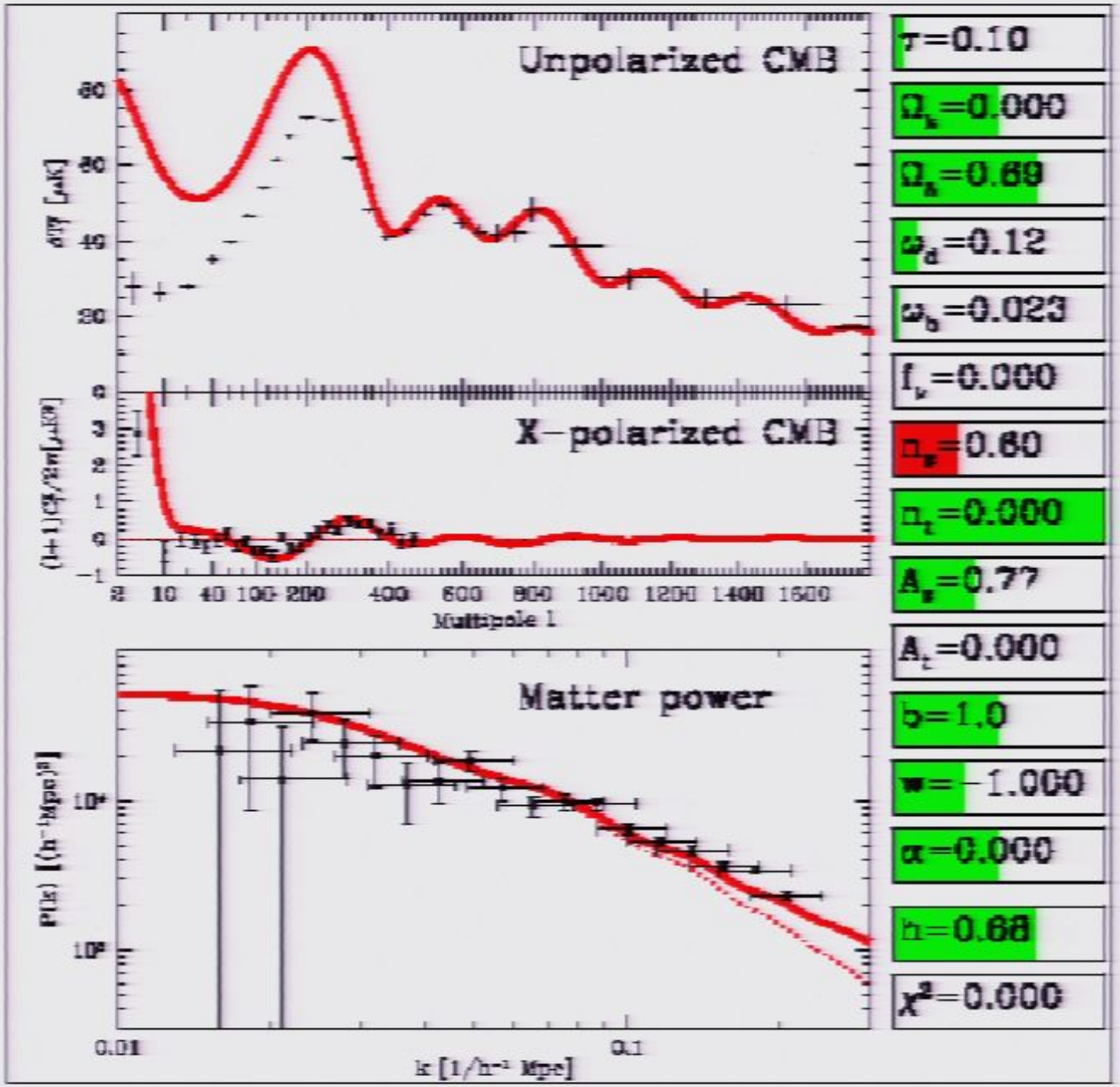

Tensor-to-scalar ratio $r_{.002}$
1
0.1
0.01
Allowed
0.8
1
1.2
1.4
Scalar spectral index n_s
7
6
5
4
3
2
Inflation energy scale $V^{1/4}/10^{16}$ GeV

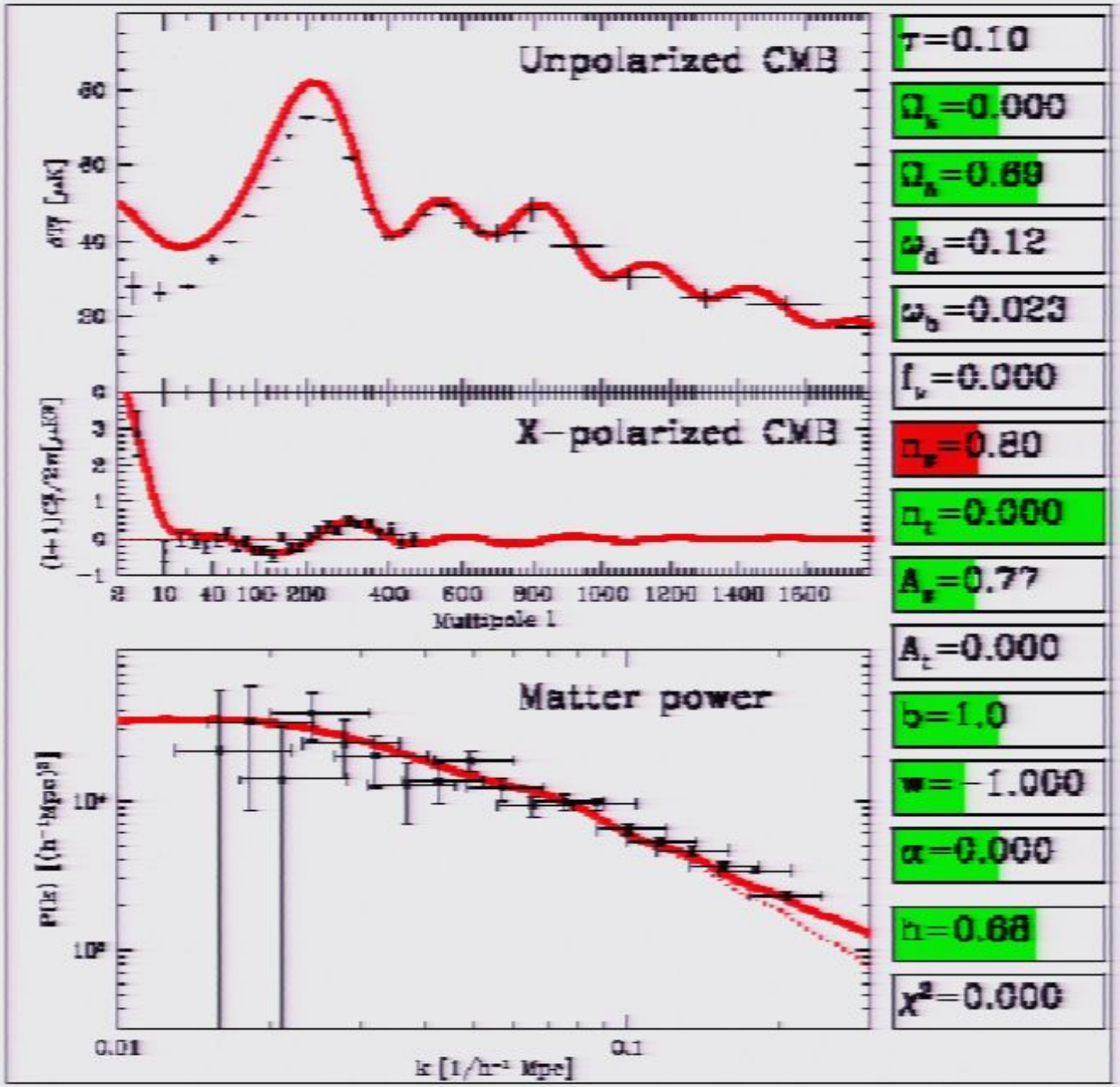

Hybrid inflation
Large-field inflation
Small-field inflation
ϕ^6
ϕ^4
ϕ^2
Allowed
Tensor-to-scalar ratio $r_{.002}$
Inflation energy scale $V^{1/4}/10^{16}$ GeV
Scalar spectral index n_s
1
0.1
0.01
0.8
1
1.2
1.4
7
6
5
4
3
2

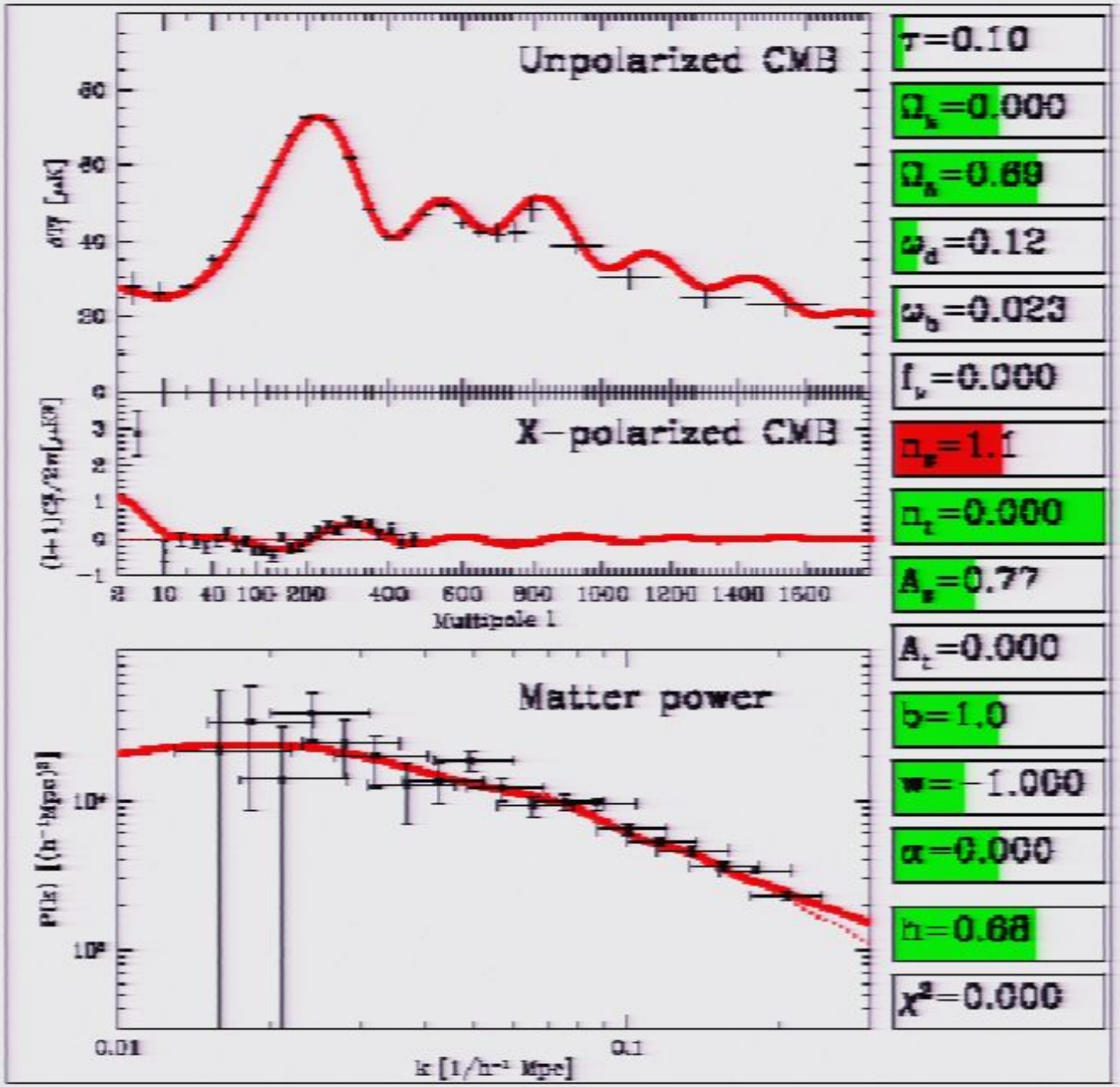

Hybrid inflation
Large-field inflation
Small-field inflation
Ruled out by WMAP1
Ruled out by WMAP3
+SDSS
ϕ^6
ϕ^4
ϕ^2
Allowed
Tensor-to-scalar ratio $r_{.002}$
Inflation energy scale $V^{1/4}/10^{16}$ GeV
Scalar spectral index n_s
1
0.1
0.01
0.8
1
1.2
1.4
7
6
5
4
3
2

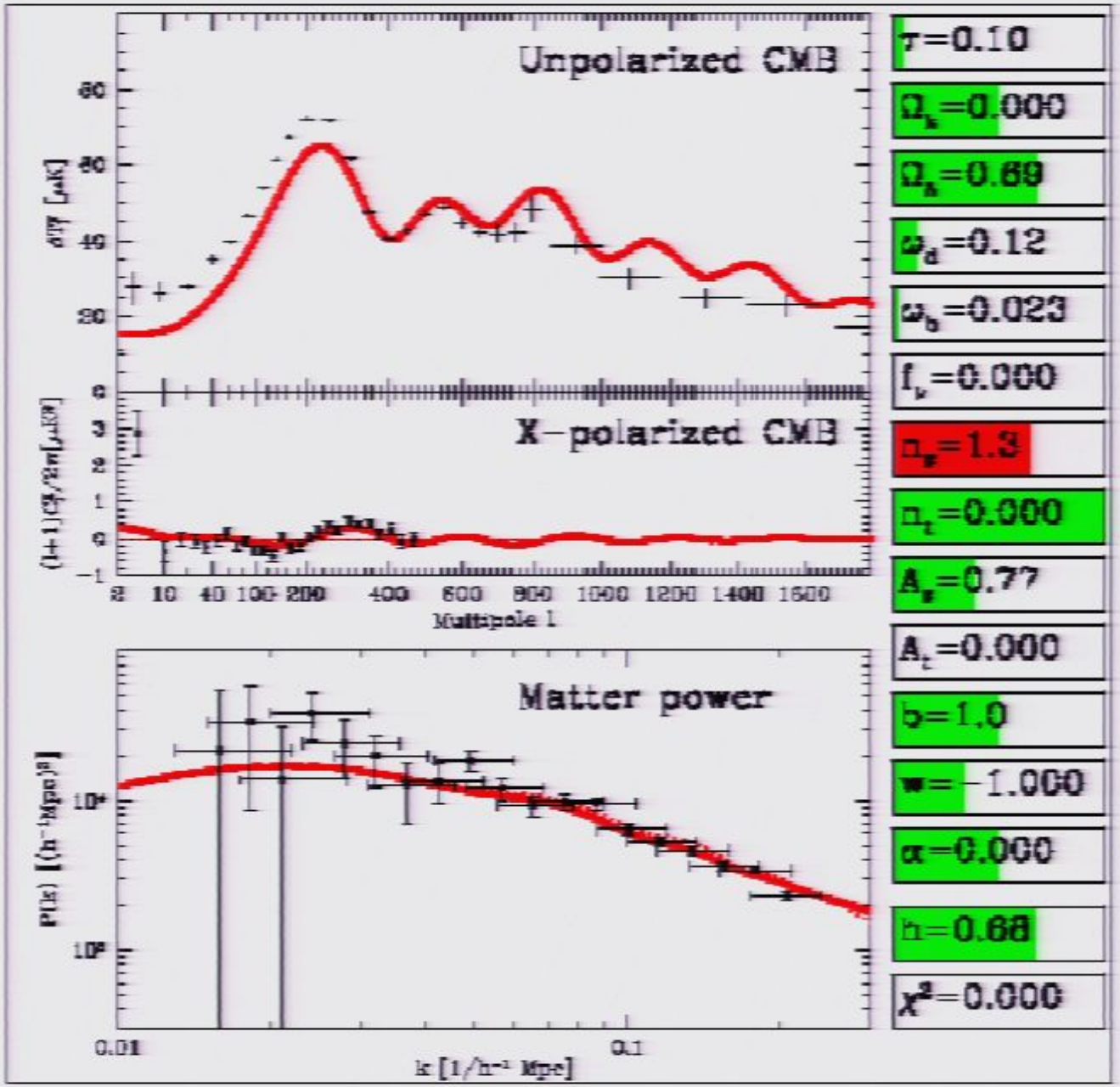

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.50
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

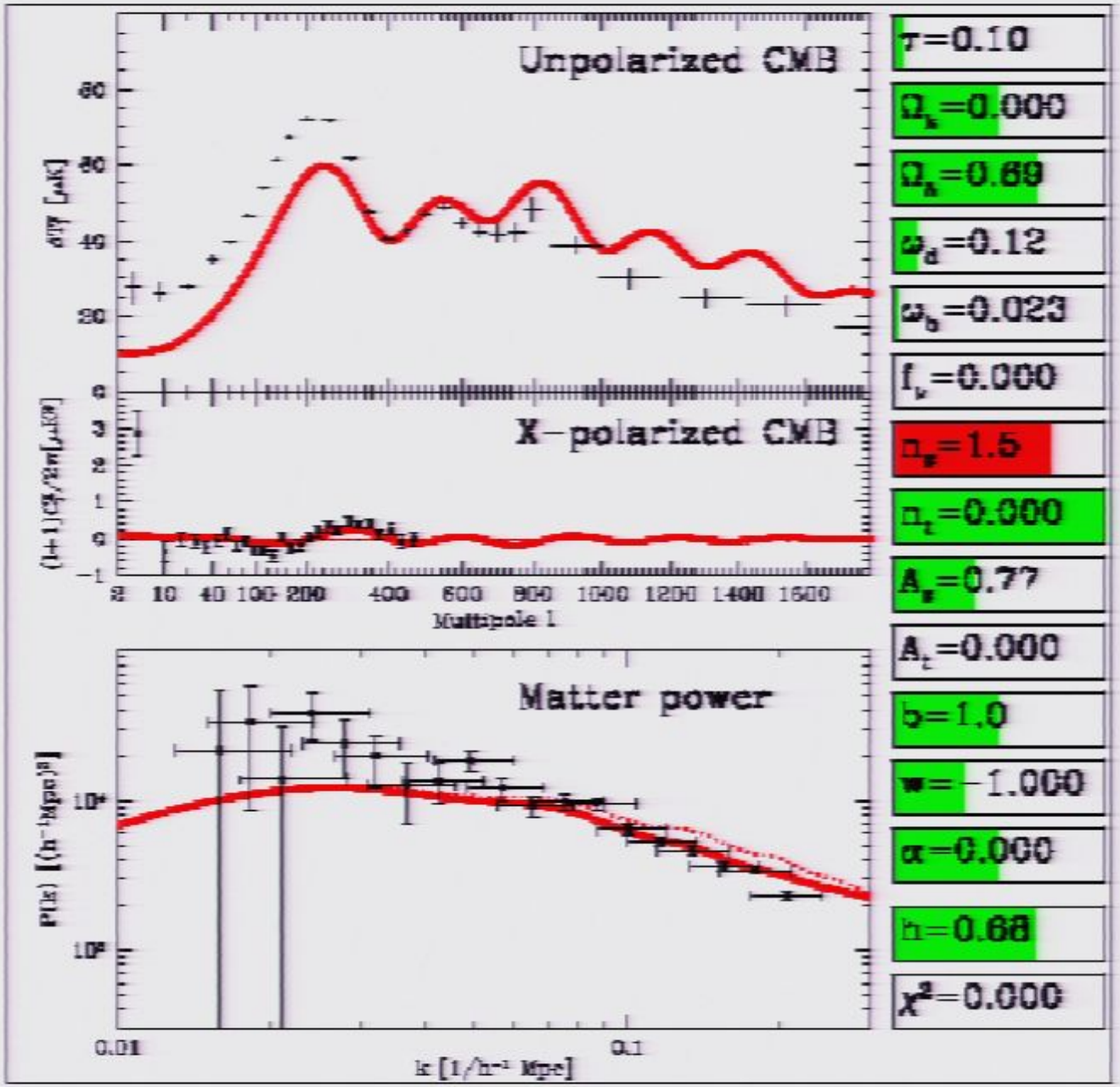

Hybrid inflation
Large-field inflation
Small-field inflation
Ruled out by WMAP1
Ruled out by WMAP3
+SDSS
ϕ^6
ϕ^4
ϕ^2
Allowed
Tensor-to-scalar ratio $r_{.002}$
1
0.1
0.01
Scalar spectral index n_s
0.8
1
1.2
1.4
Inflation energy scale $V^{1/4}/10^{16}$ GeV
7
6
5
4
3
2

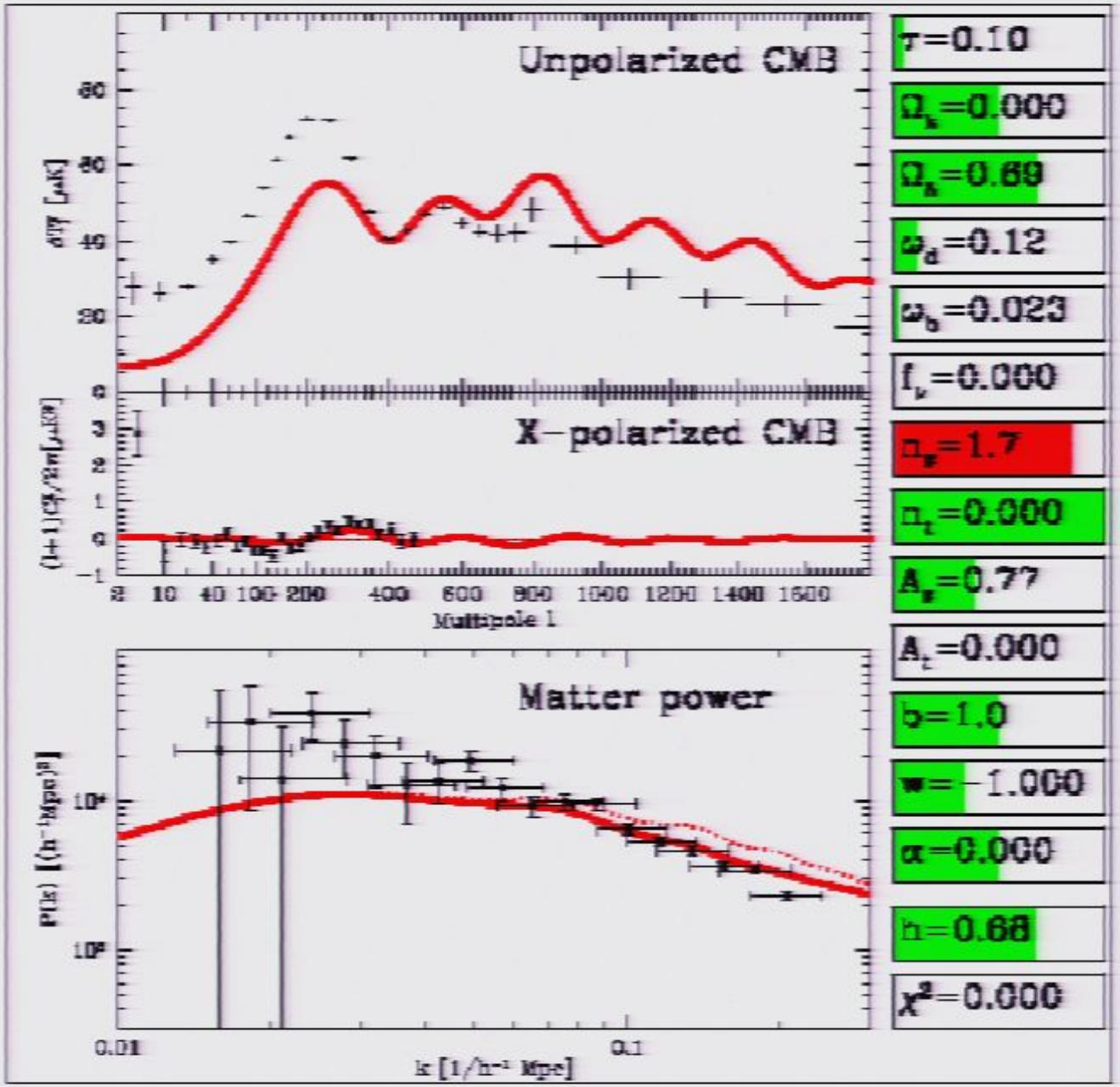

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.60
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

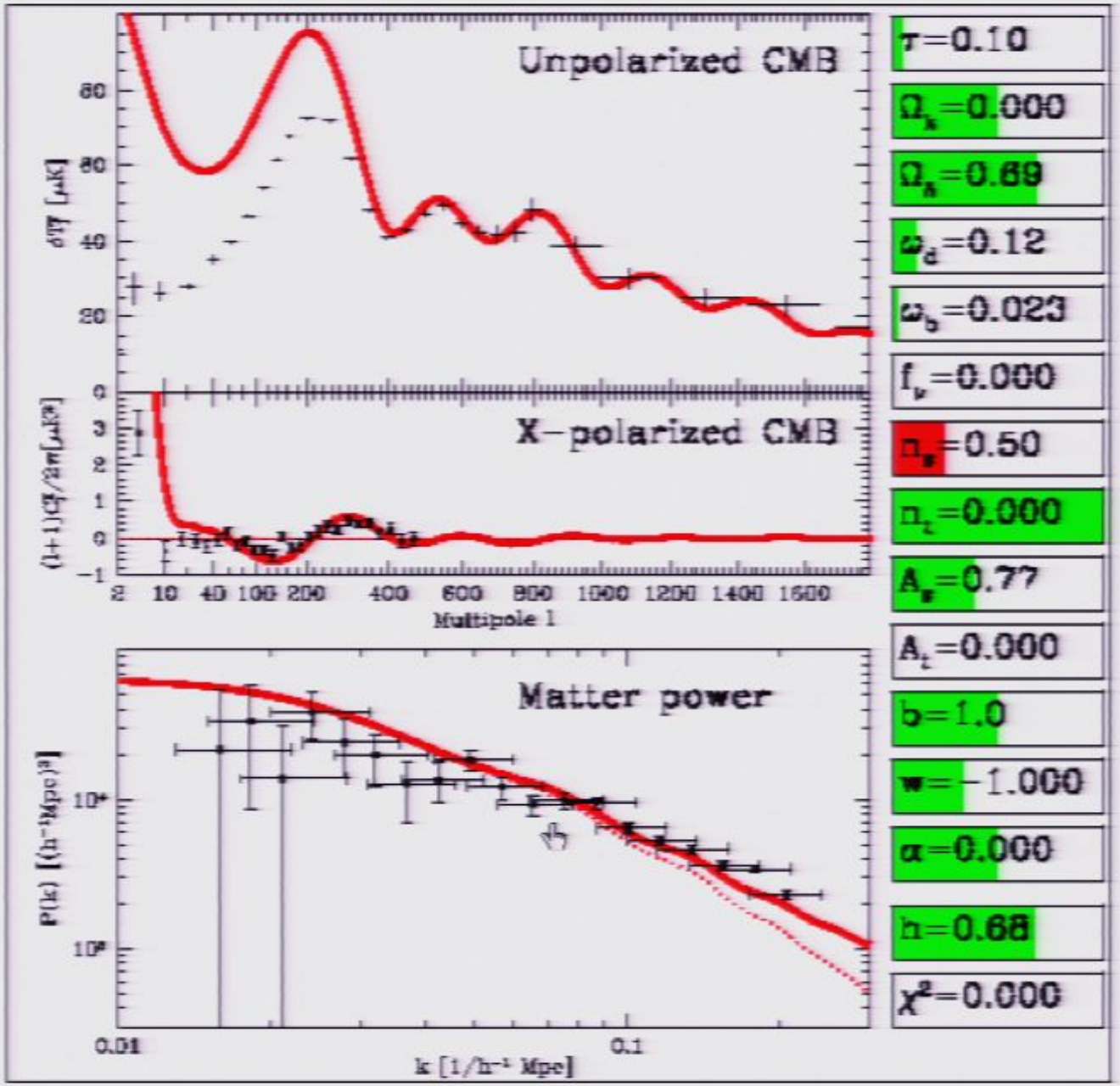

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.80
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

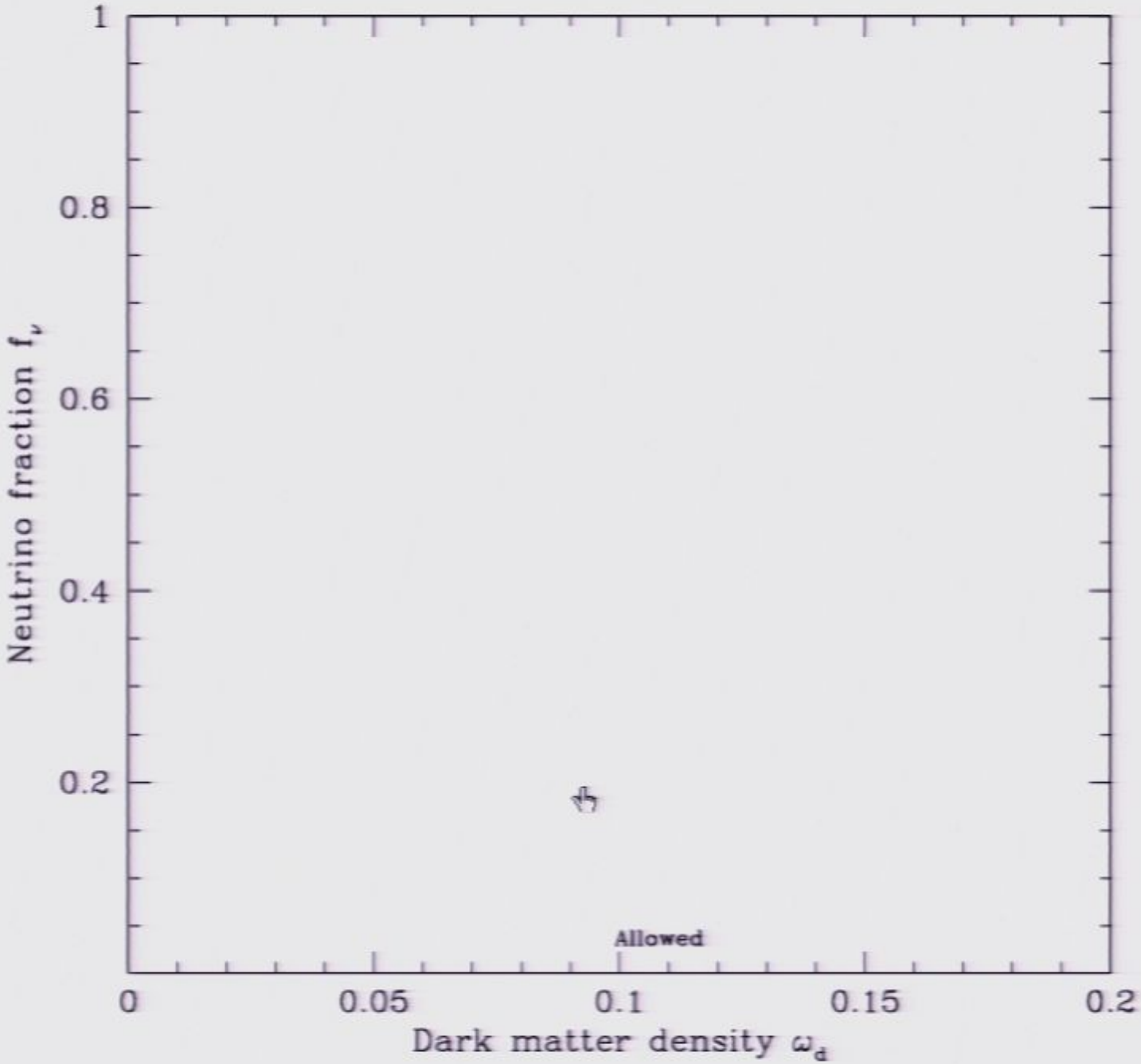

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=1.1
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000


Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=1.3
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

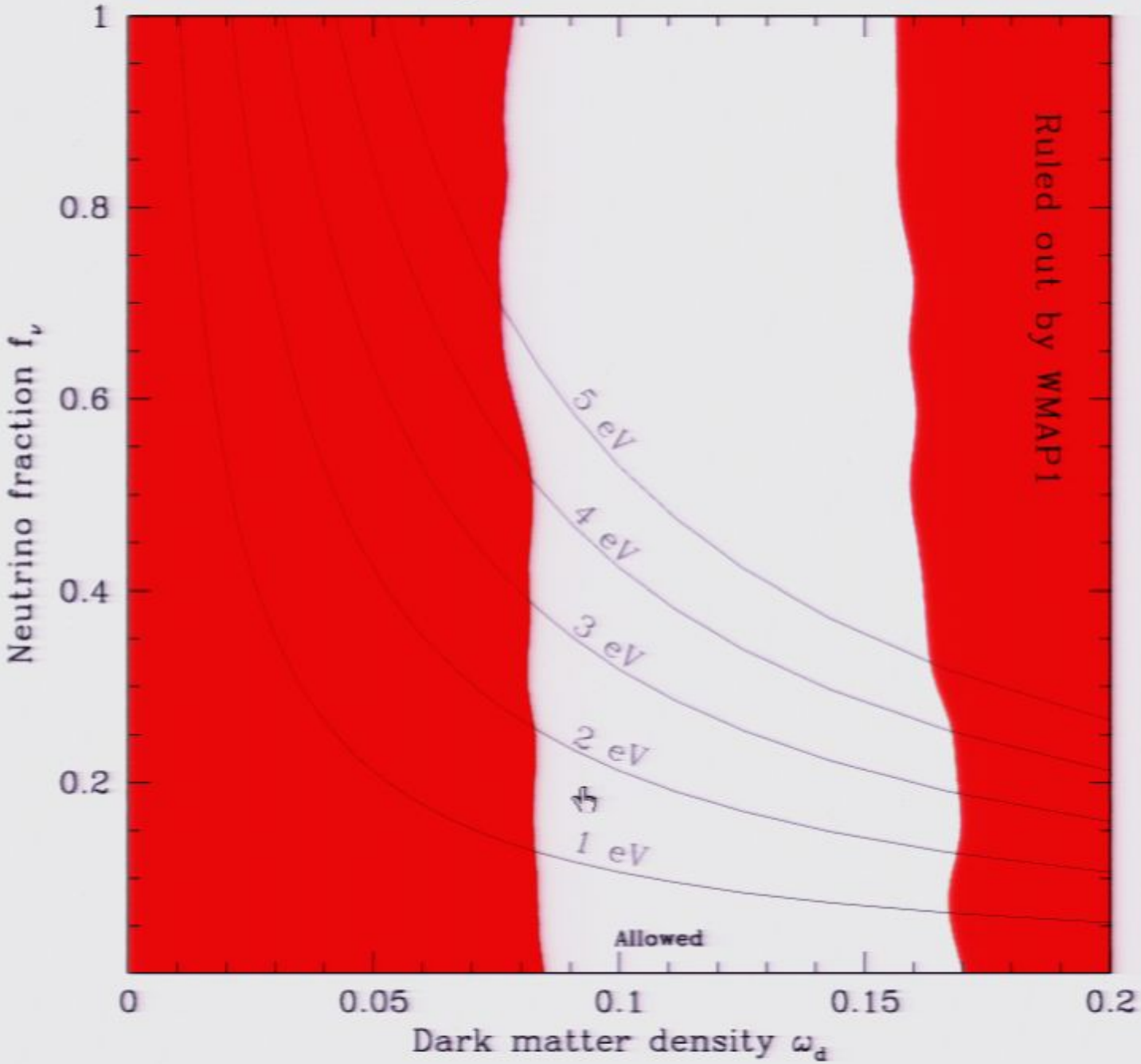

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=1.5
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000


Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=1.7
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

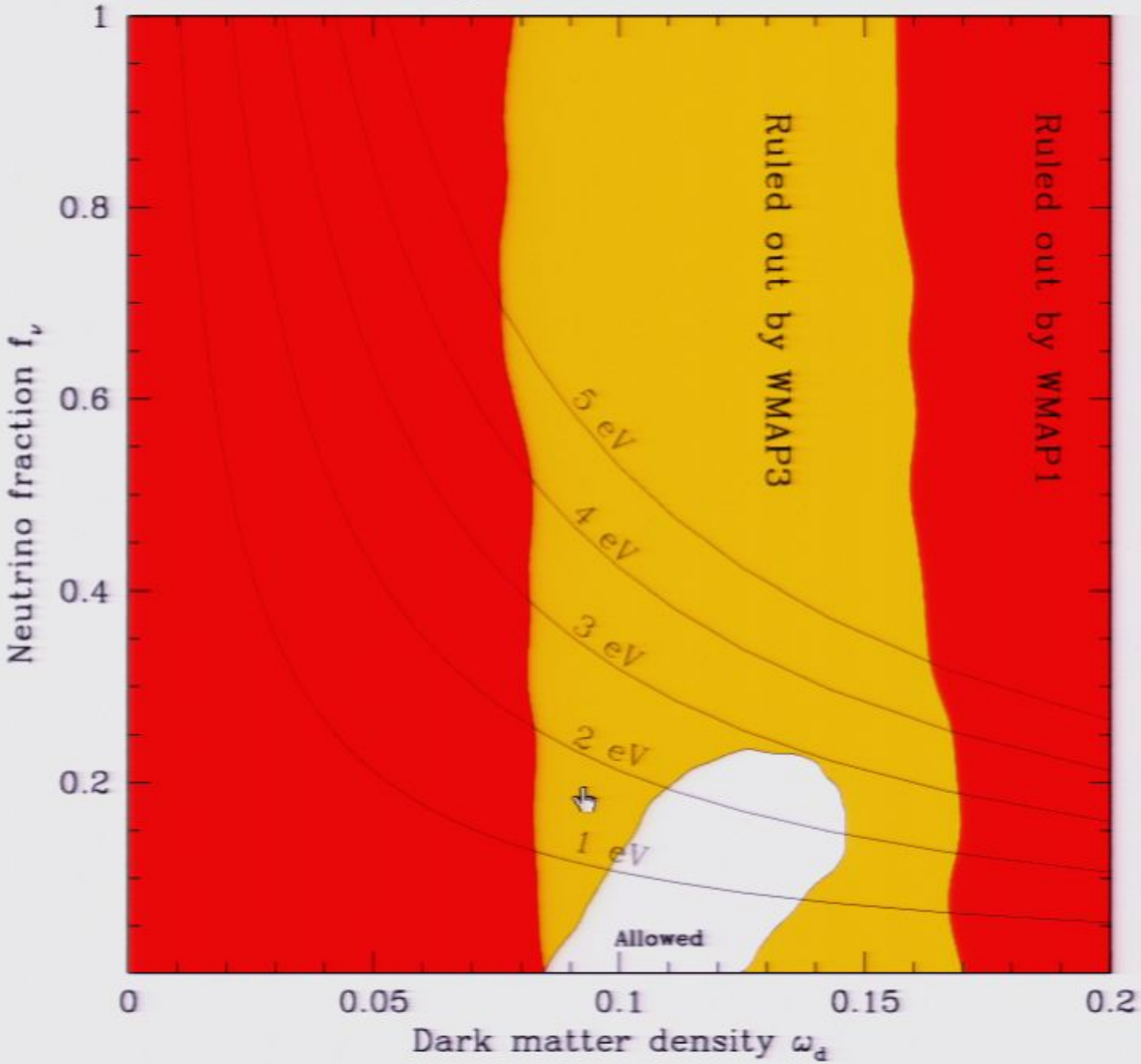

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.50
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000


1
0.8
0.6
0.4
0.2
Neutrino fraction f_ν
Allowed
0
0.05
0.1
0.15
0.2
Dark matter density ω_d

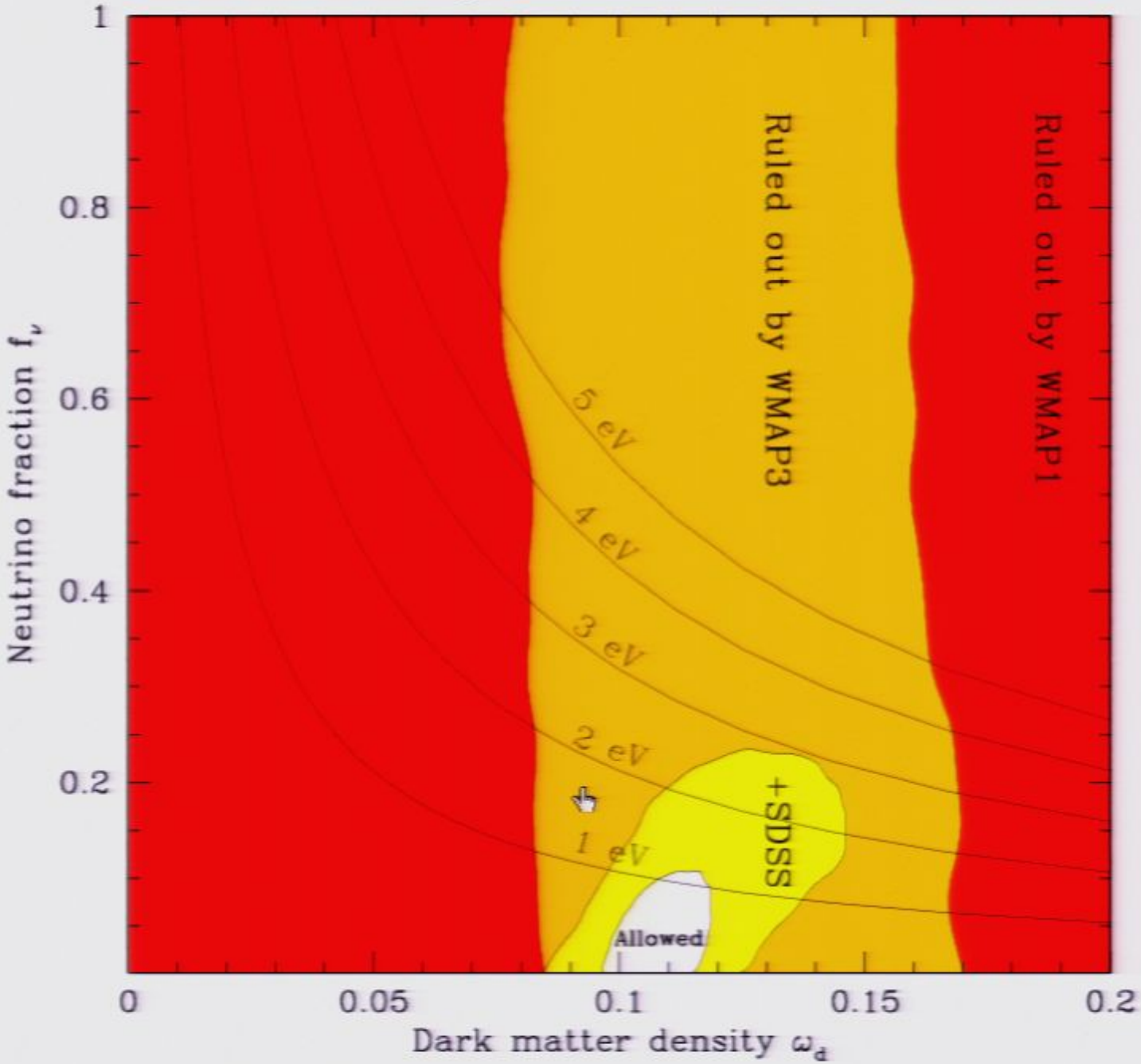
Cosmological neutrino bounds

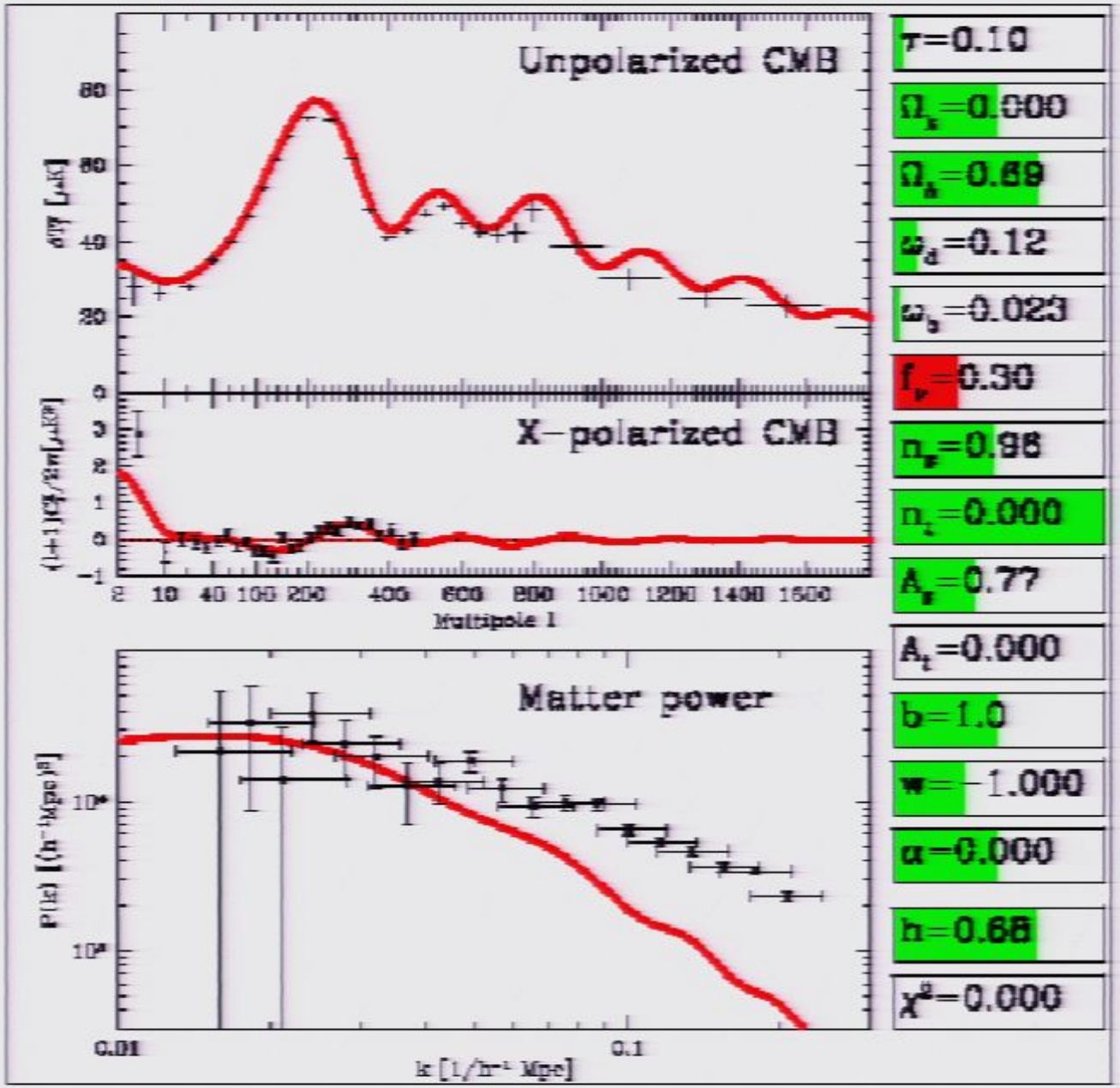


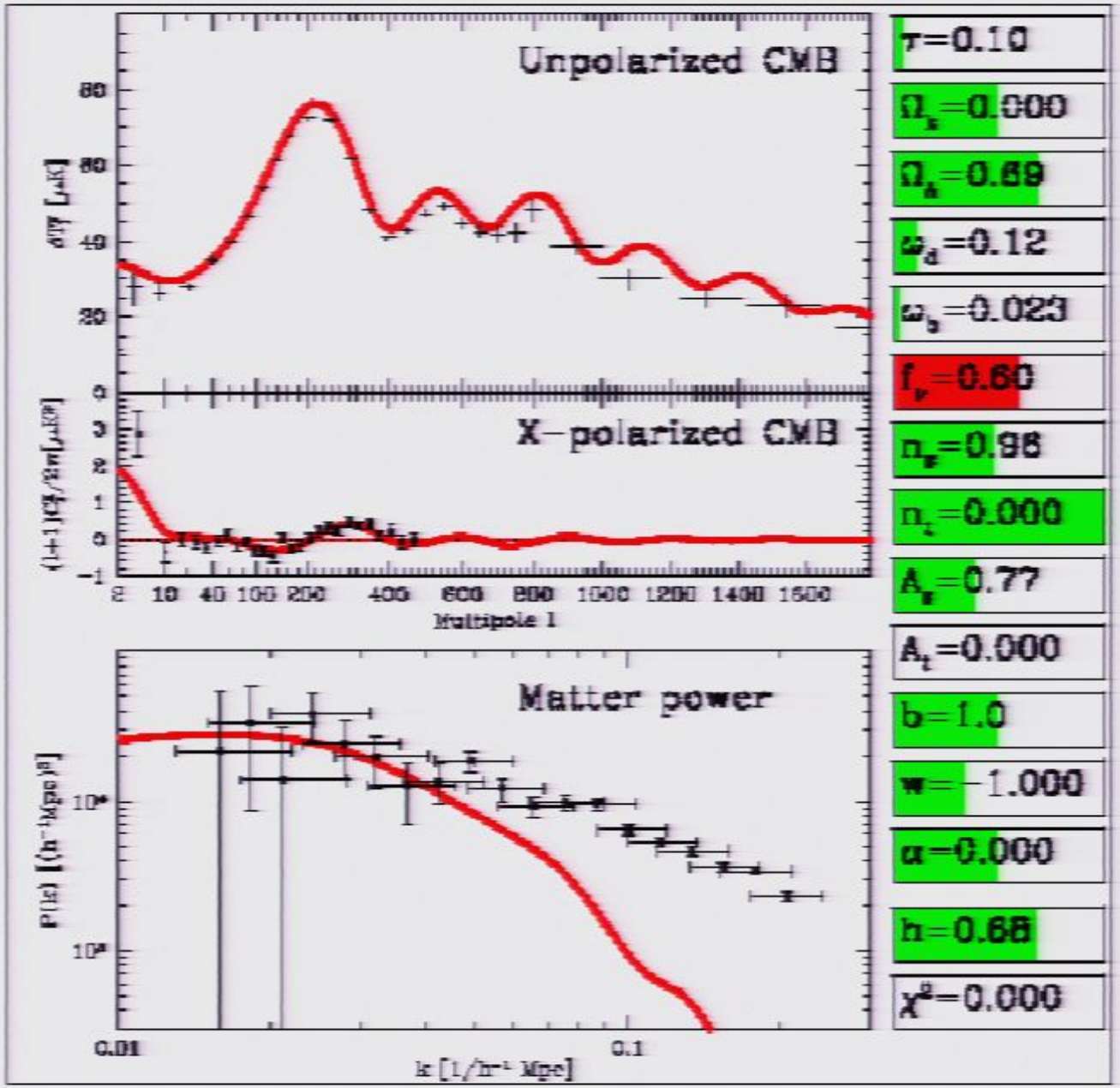
Cosmological neutrino bounds

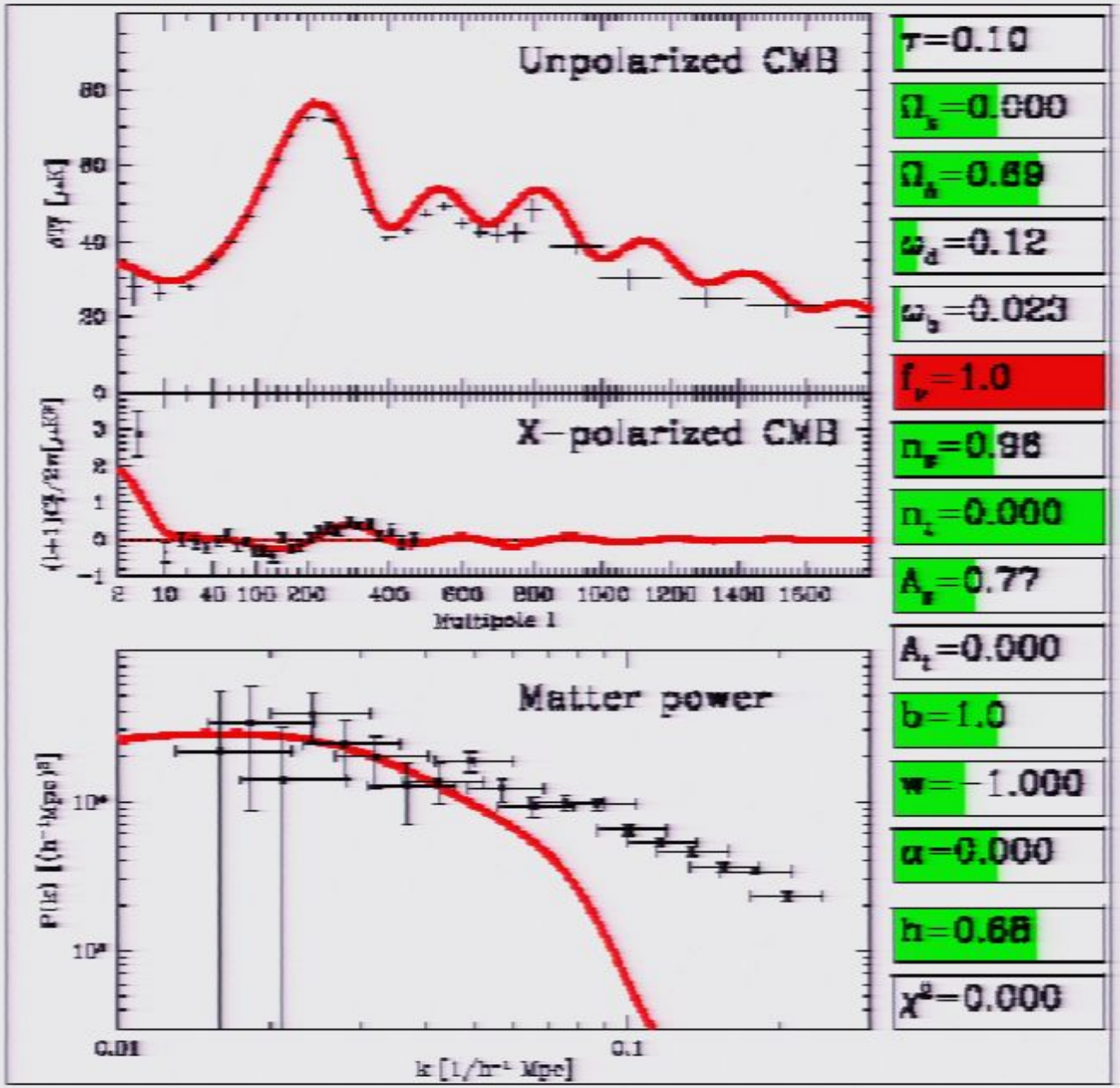


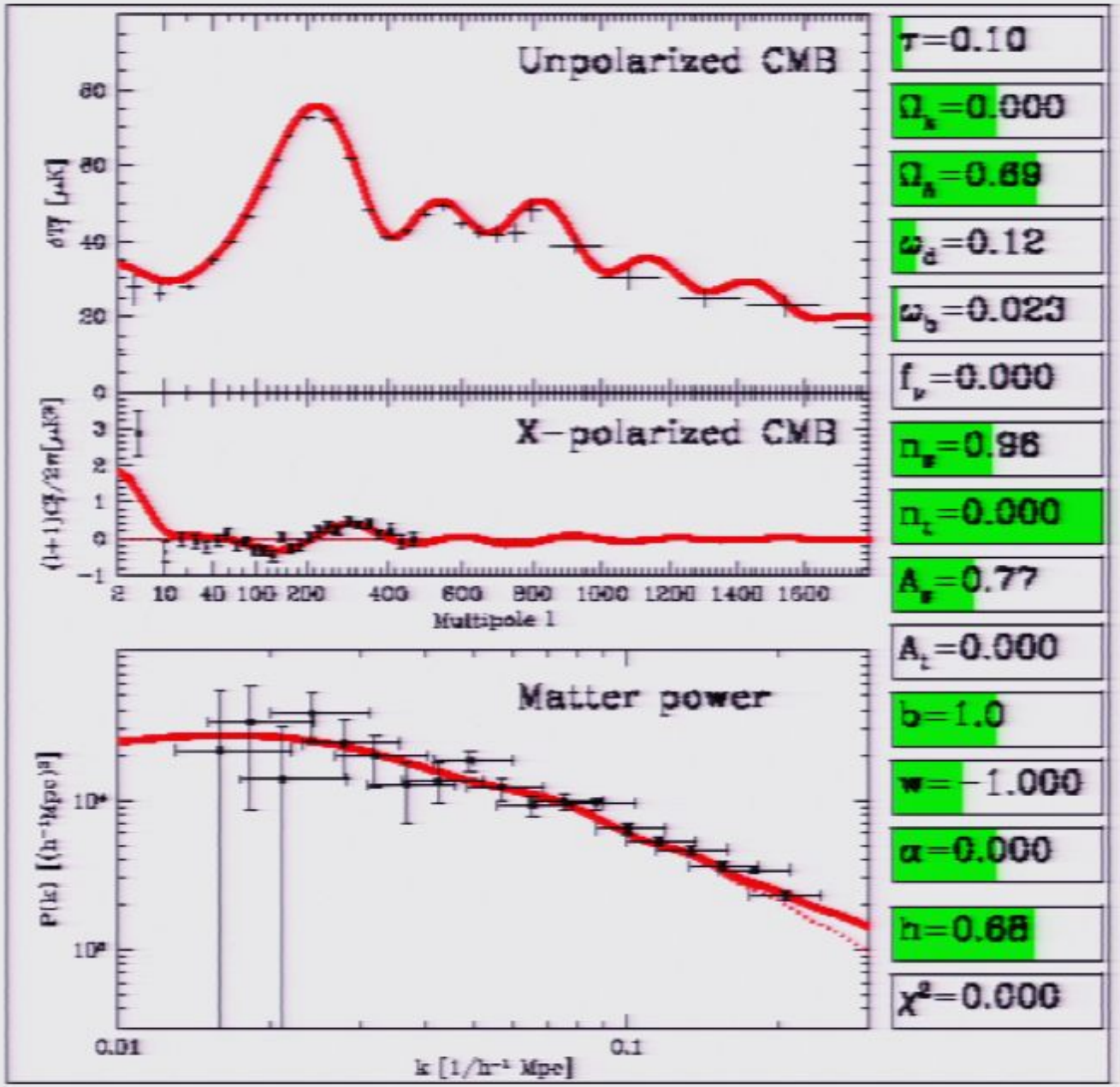
Cosmological neutrino bounds

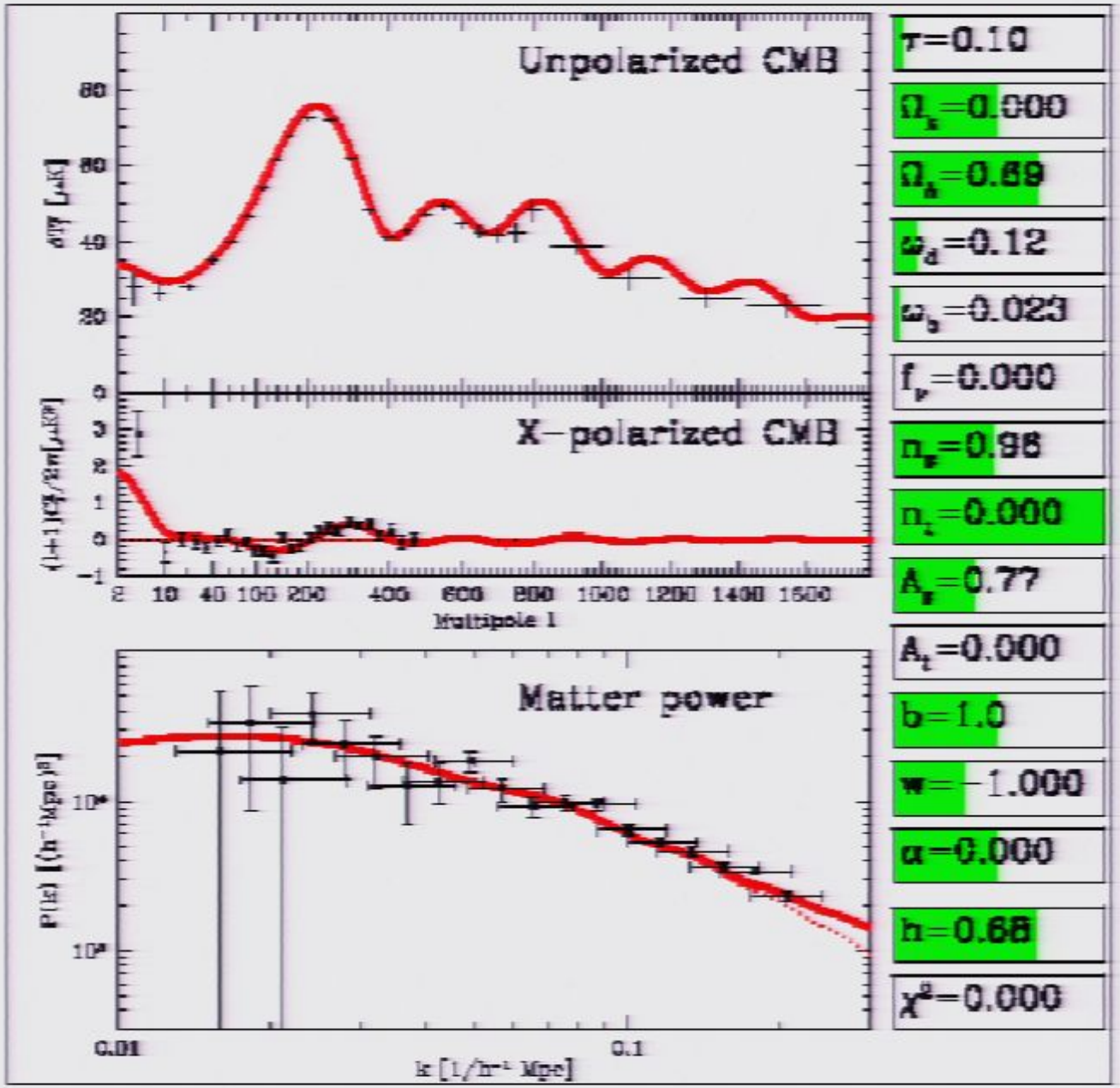


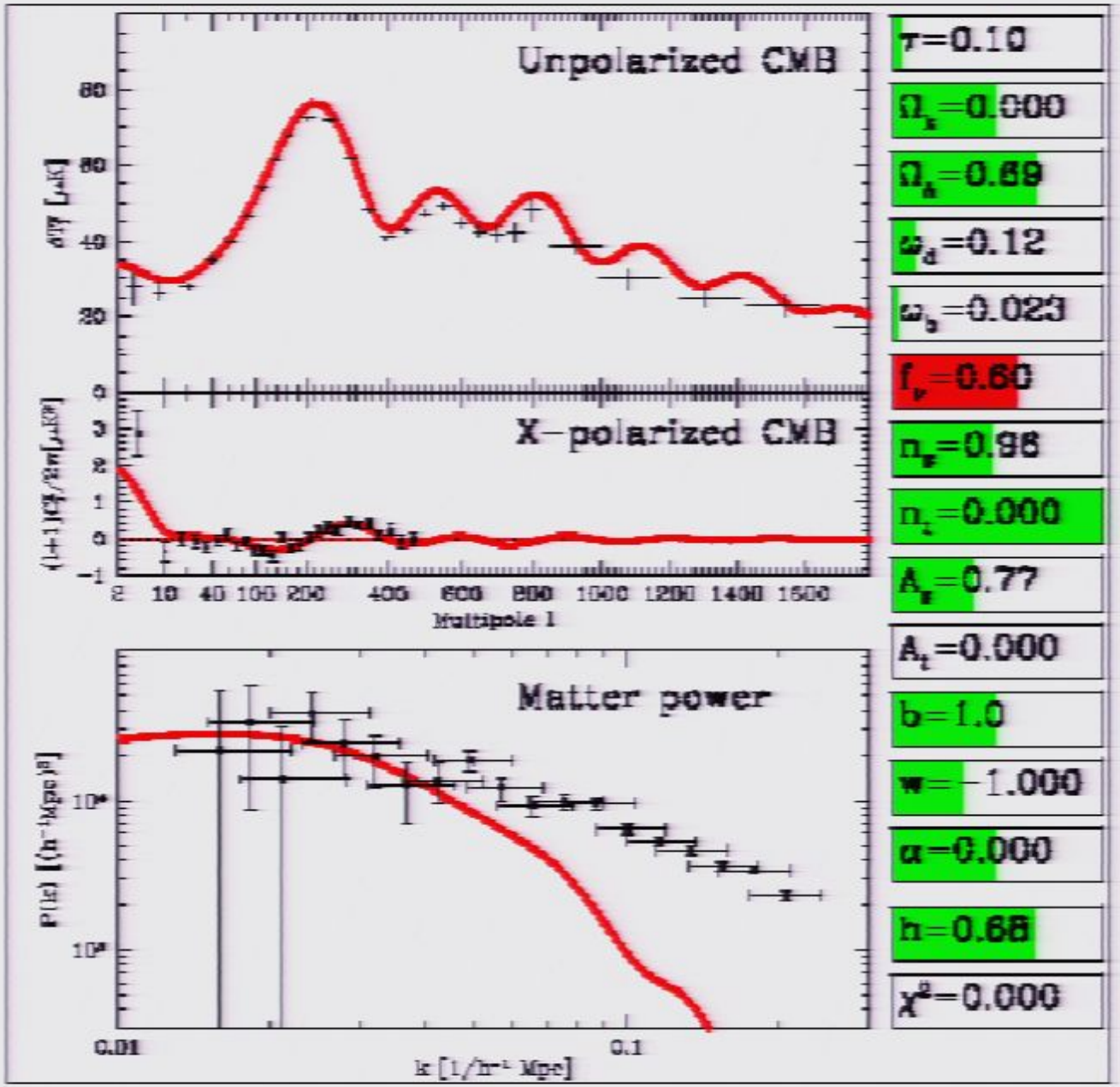

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.30
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

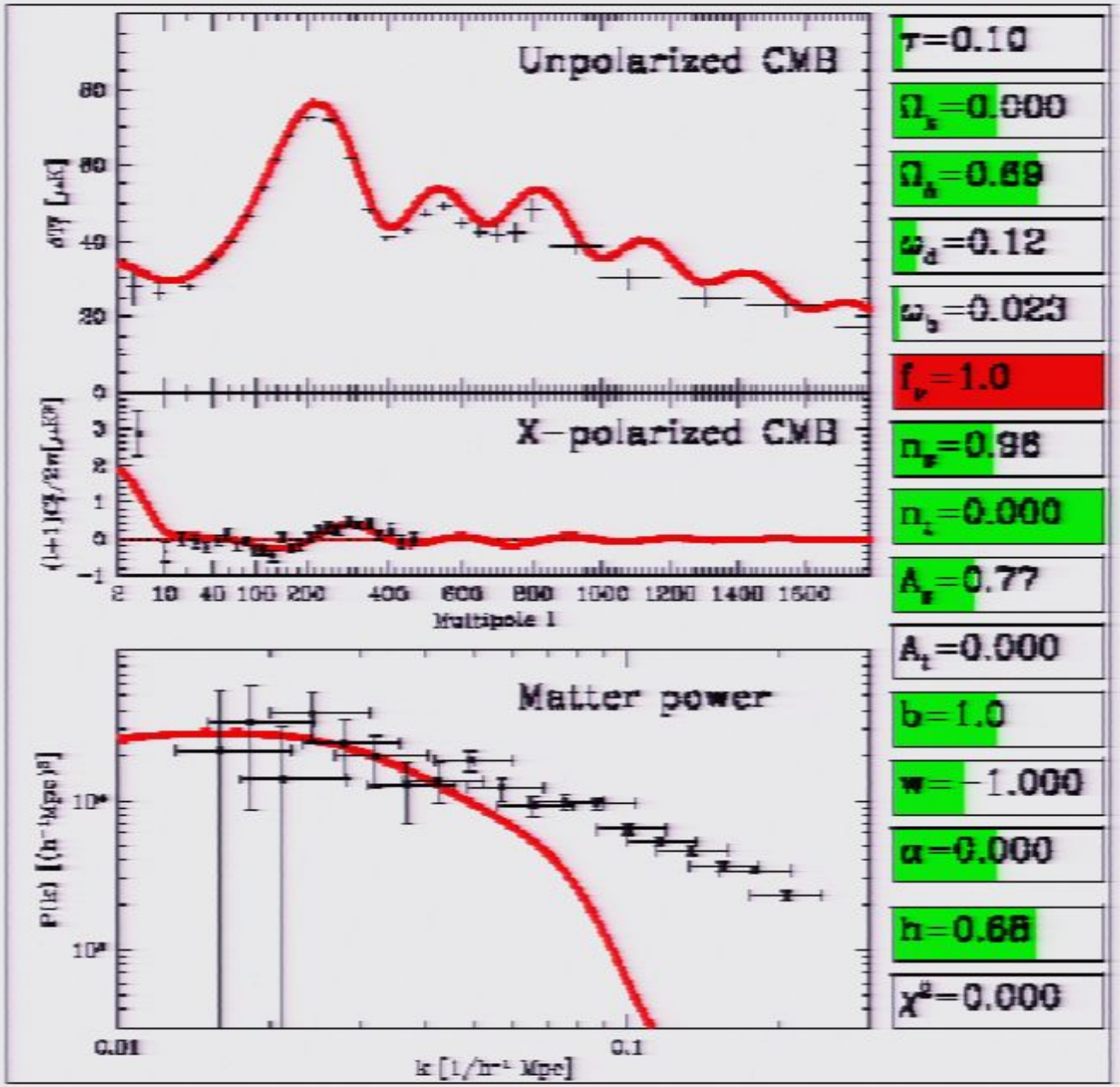

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.60
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.66
χ²=0.000

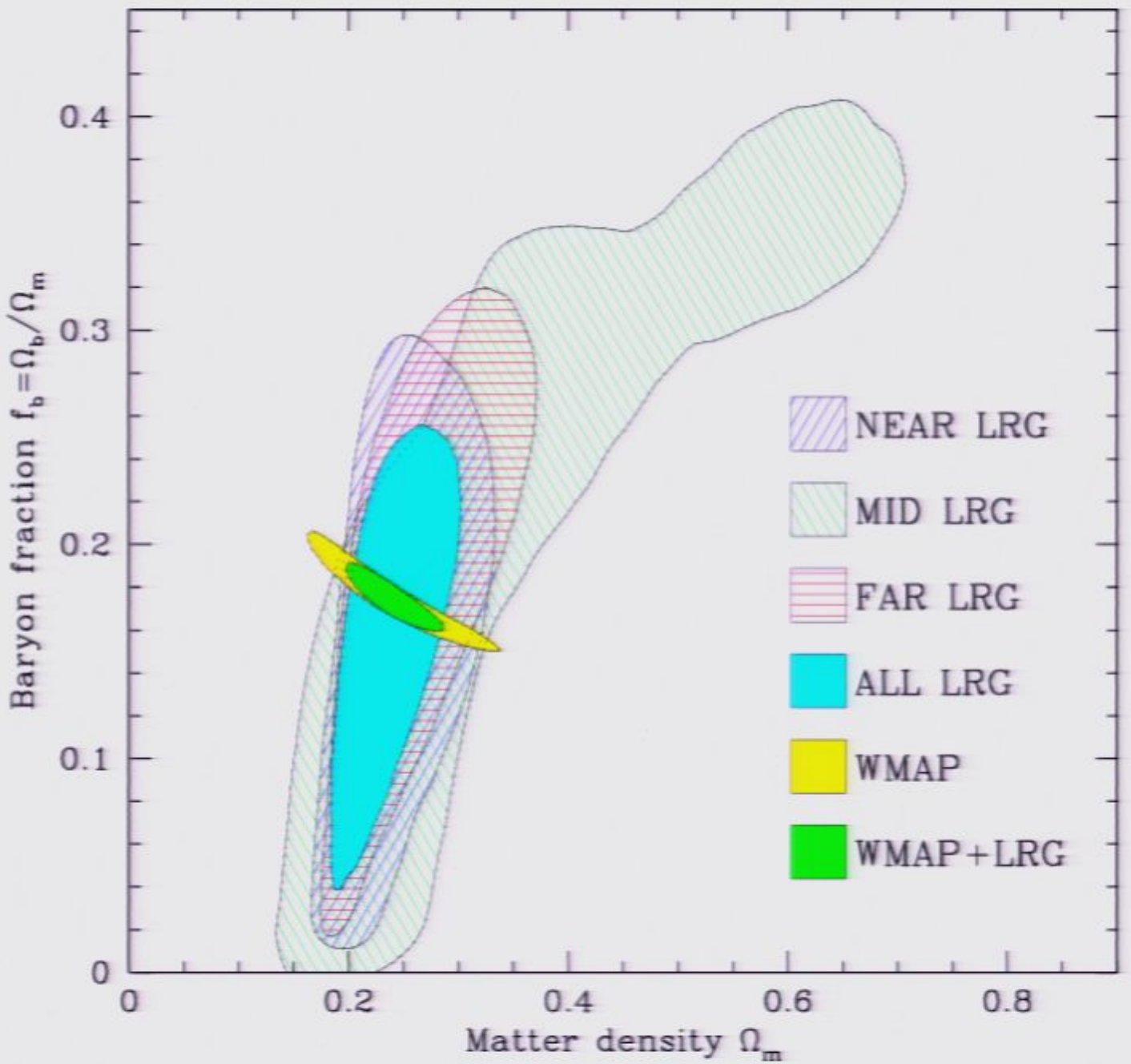

Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_Λ=0.000
Ω_b=0.69
ω_d=0.12
ω_b=0.023
f_ν=1.0
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.66
χ²=0.000


Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000


Unpolarized CMB
X-polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.000
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000


Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_Λ=0.69
ω_d=0.12
ω_b=0.023
f_ν=0.60
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.68
χ²=0.000

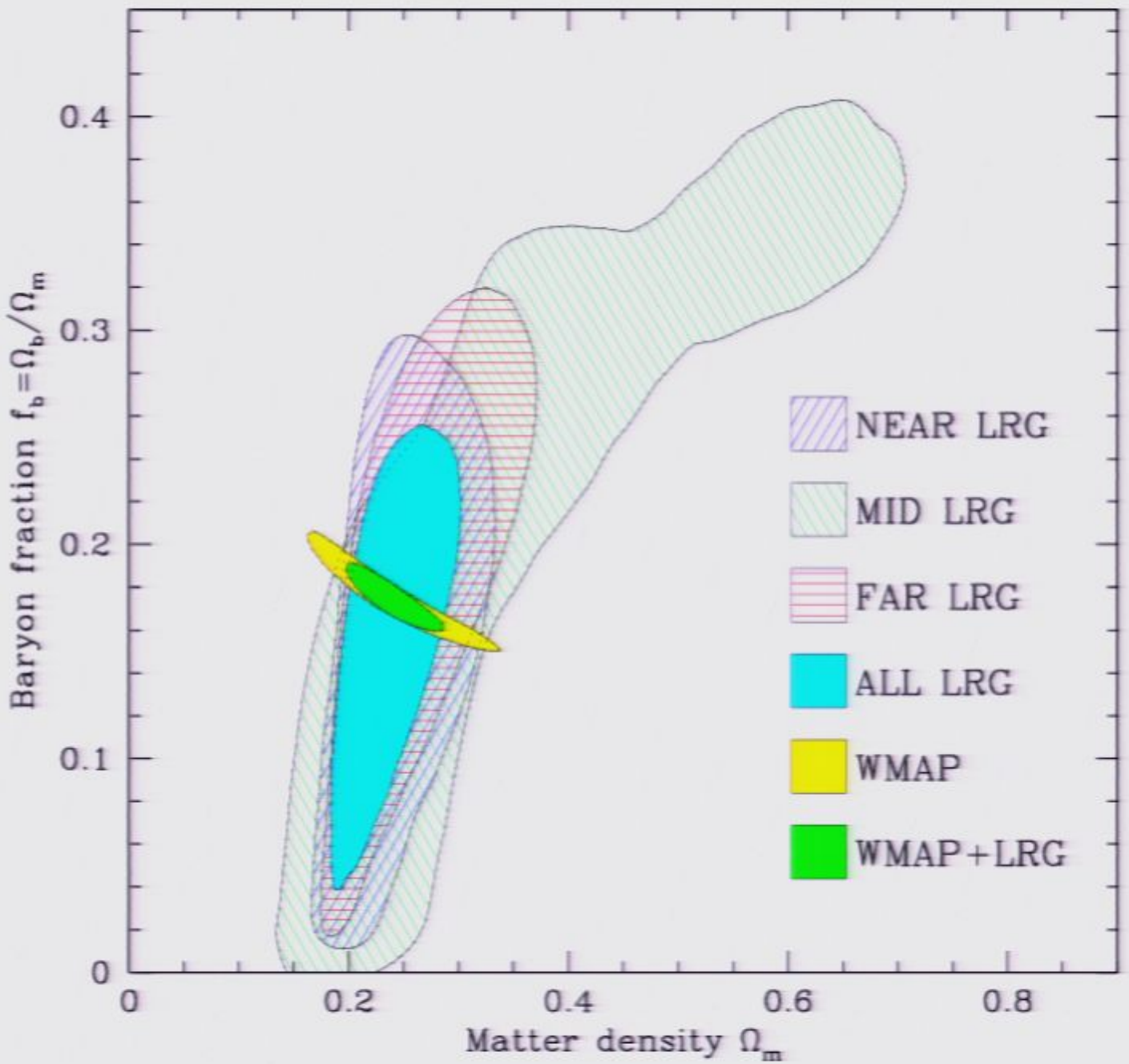

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
τ=0.10
Ω_k=0.000
Ω_b=0.69
ω_d=0.12
ω_b=0.023
f_ν=1.0
n_s=0.96
n_t=0.000
A_s=0.77
A_t=0.000
b=1.0
w=−1.000
α=0.000
h=0.66
χ²=0.000


Baryon fraction $f_b=\Omega_b/\Omega_m$
Matter density Ω_m
0
0.1
0.2
0.3
0.4
0
0.2
0.4
0.6
0.8
NEAR LRG
MID LRG
FAR LRG
ALL LRG
WMAP
WMAP+LRG

Movies from …

http://space.mit.edu/home/tegmark/movies_60dpi/fb_movie_slow.html

Matter density Ω_m


Baryon fraction $f_b=\Omega_b/\Omega_m$
Matter density Ω_m
0
0.1
0.2
0.3
0.4
0
0.2
0.4
0.6
0.8
NEAR LRG
MID LRG
FAR LRG
ALL LRG
WMAP
WMAP+LRG

Movies from …

http://space.mit.edu/home/tegmark/movies_60dpi/fb_movie_slow.html