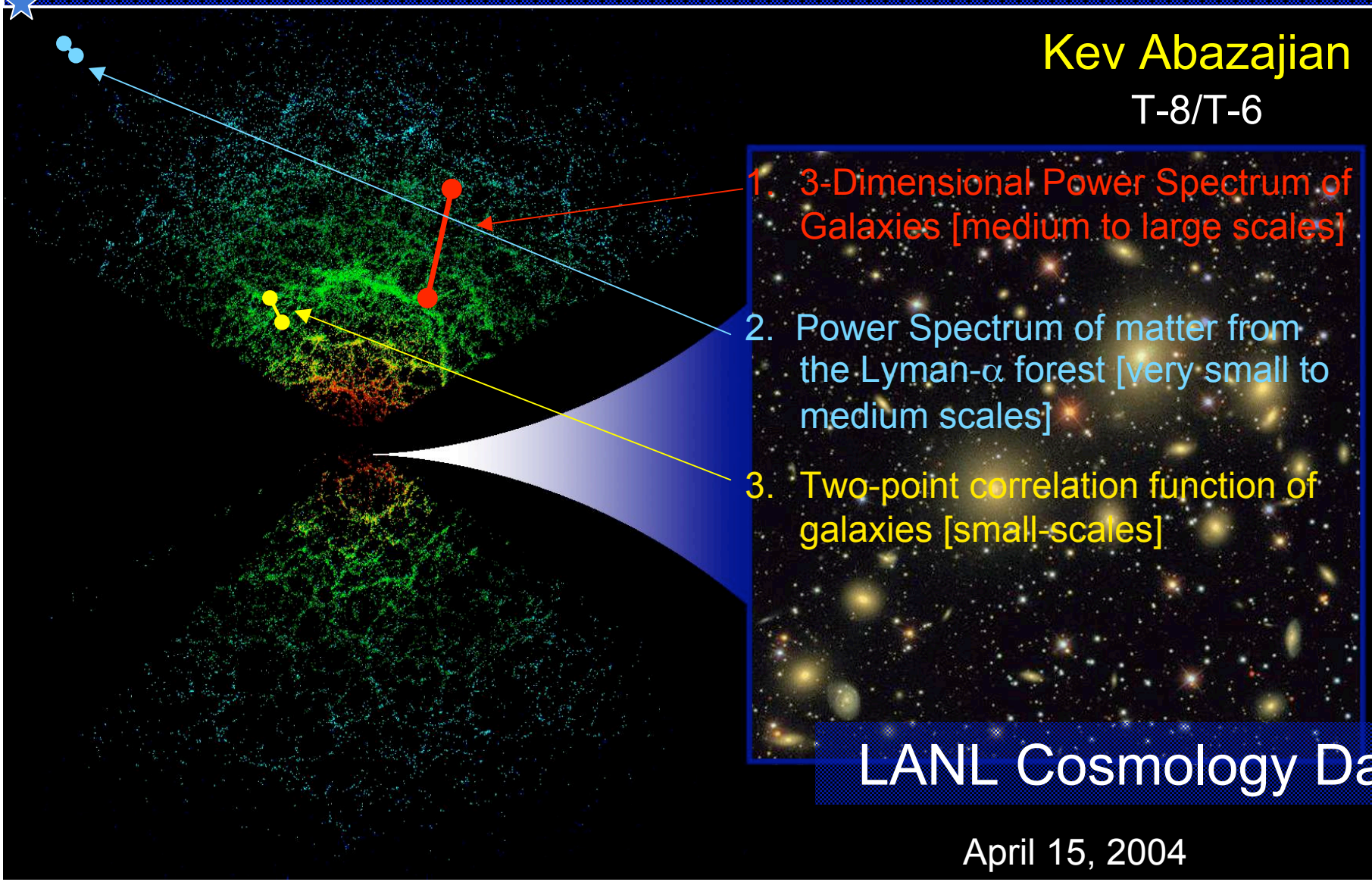
Cosmological Parameters from SDSS

Kev Abazajian
T-8/T-6



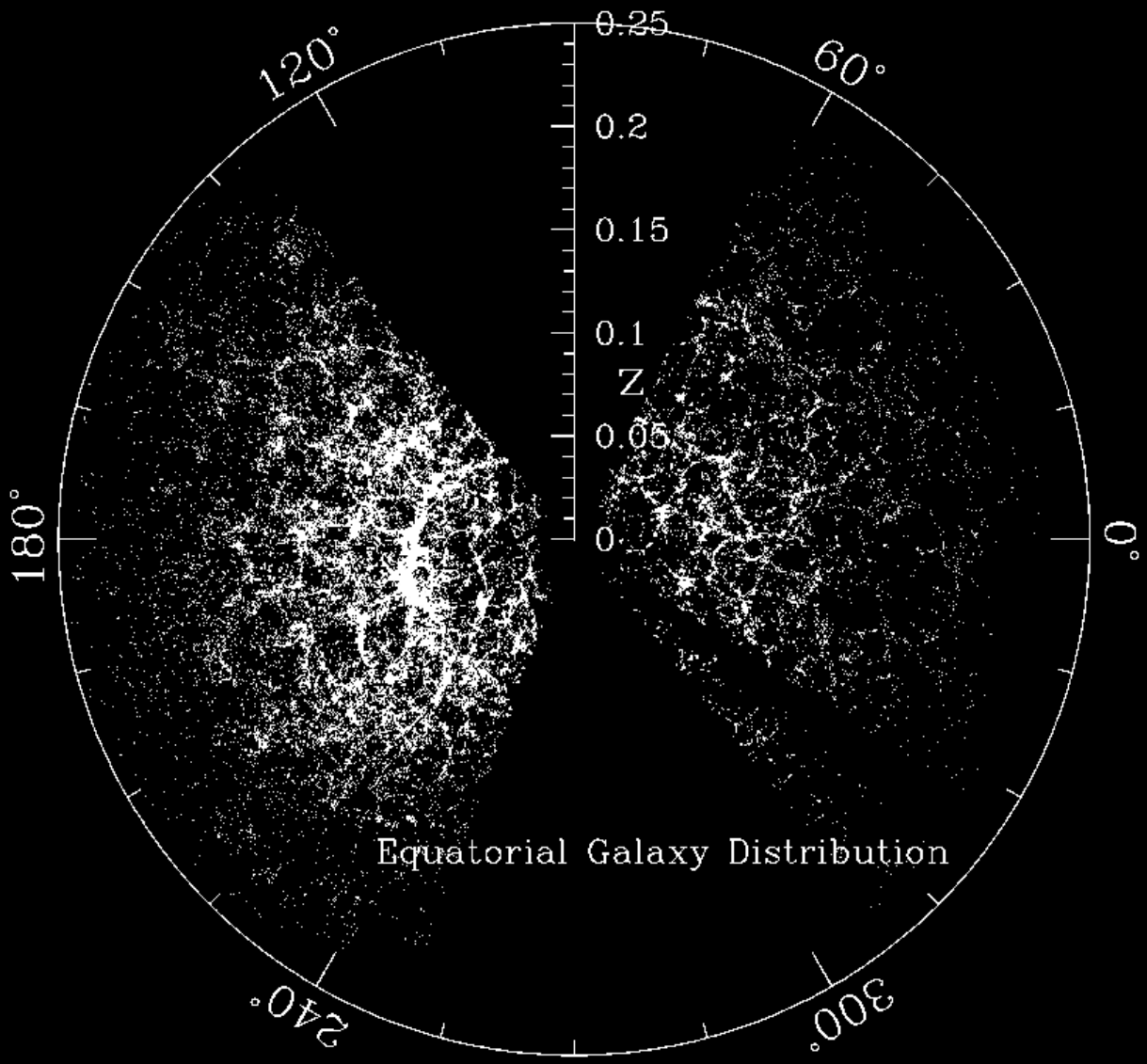
LANL Cosmology Day

April 15, 2004

Cosmological Parameters from The 3D Power Spectrum of Galaxies and Dark Matter from SDSS

Max Tegmark (U Penn), Michael Blanton (NYU), Kev Abazajian (T-8/T-6), Michael Strauss (Princeton), Scott Dodelson (FNAL/Chicago), Yongzhong Xu (T-8),

The SDSS Collaboration

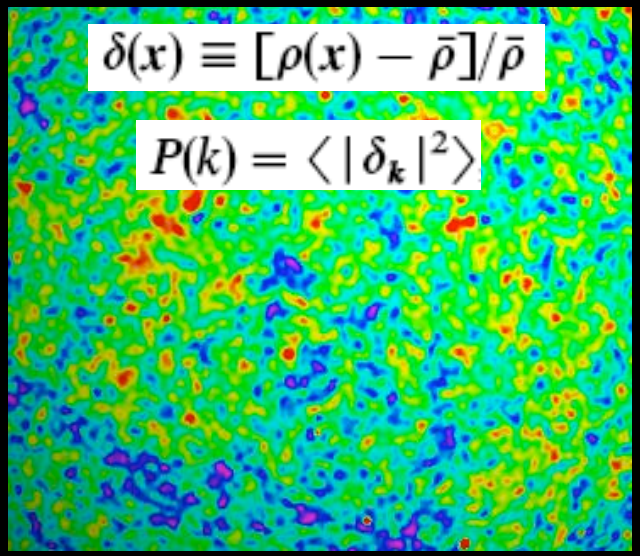


Sloan Digital Sky Survey

1/4 of sky

Position of 10^6 galaxies, 10^5 quasars

The cosmological density perturbation spectrum

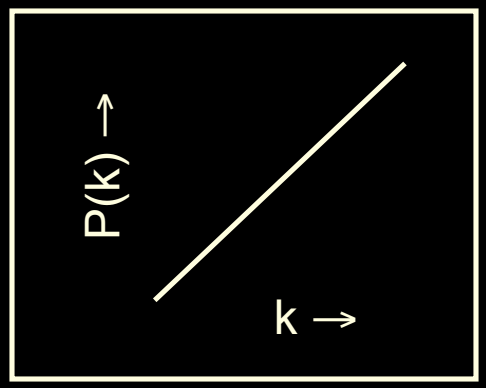


- Power spectrum of cosmological density fluctuations:
  P(*k*) ~ wave number *k*

- Primordial Harrison-Zeldovich: from scale invariance

$$P(k) \propto k$$

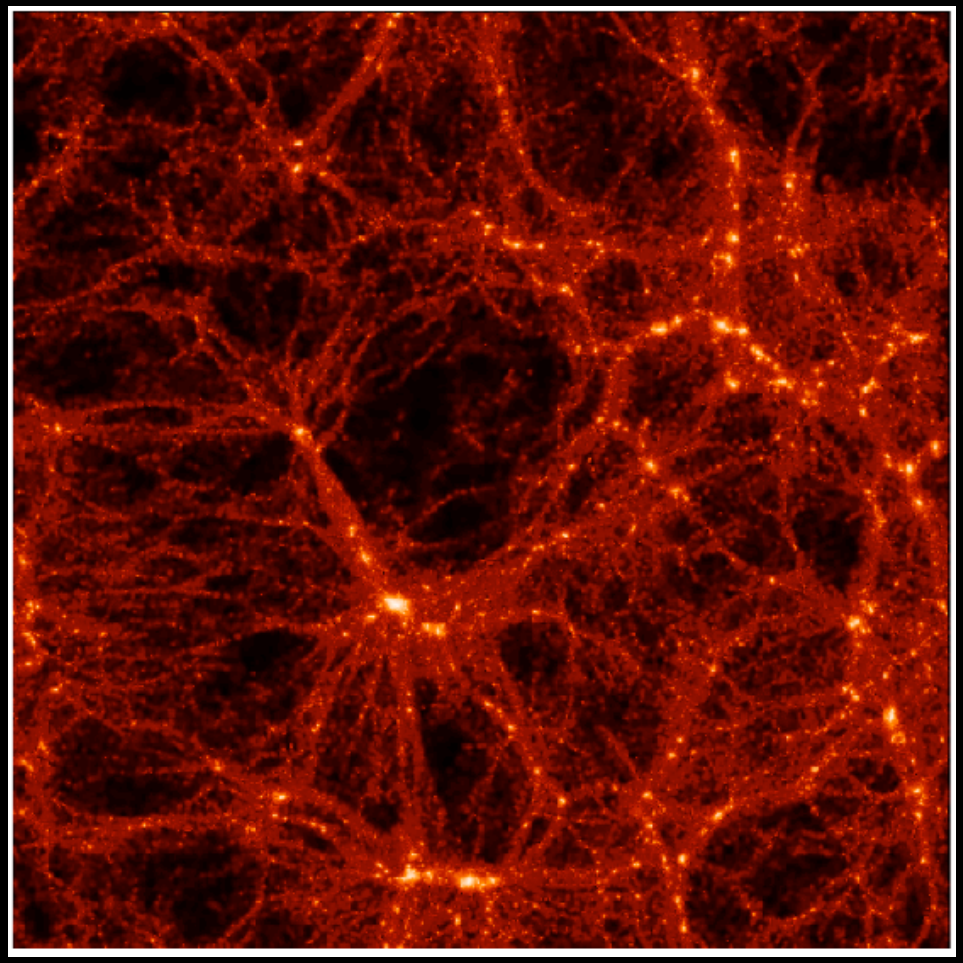
  – Natural solution to perturbation spectrum: self-similar evolution

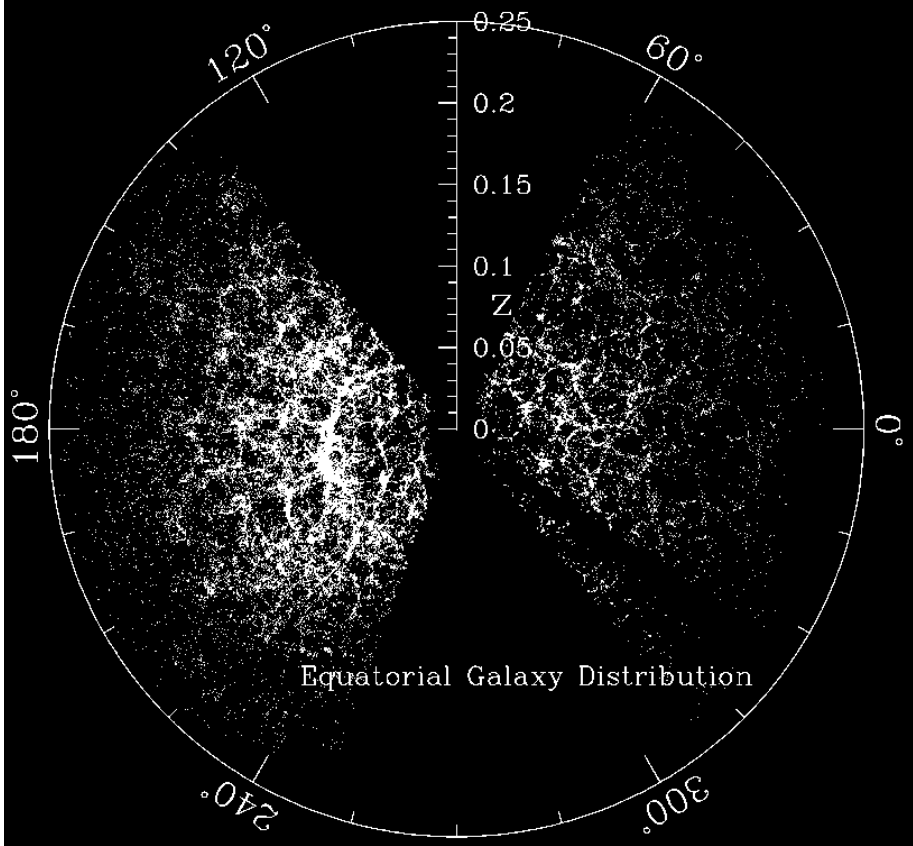


- Predicted by inflation

$$P(k) \propto k^n \quad n \approx 1$$

Statistical properties of DM & Galaxies

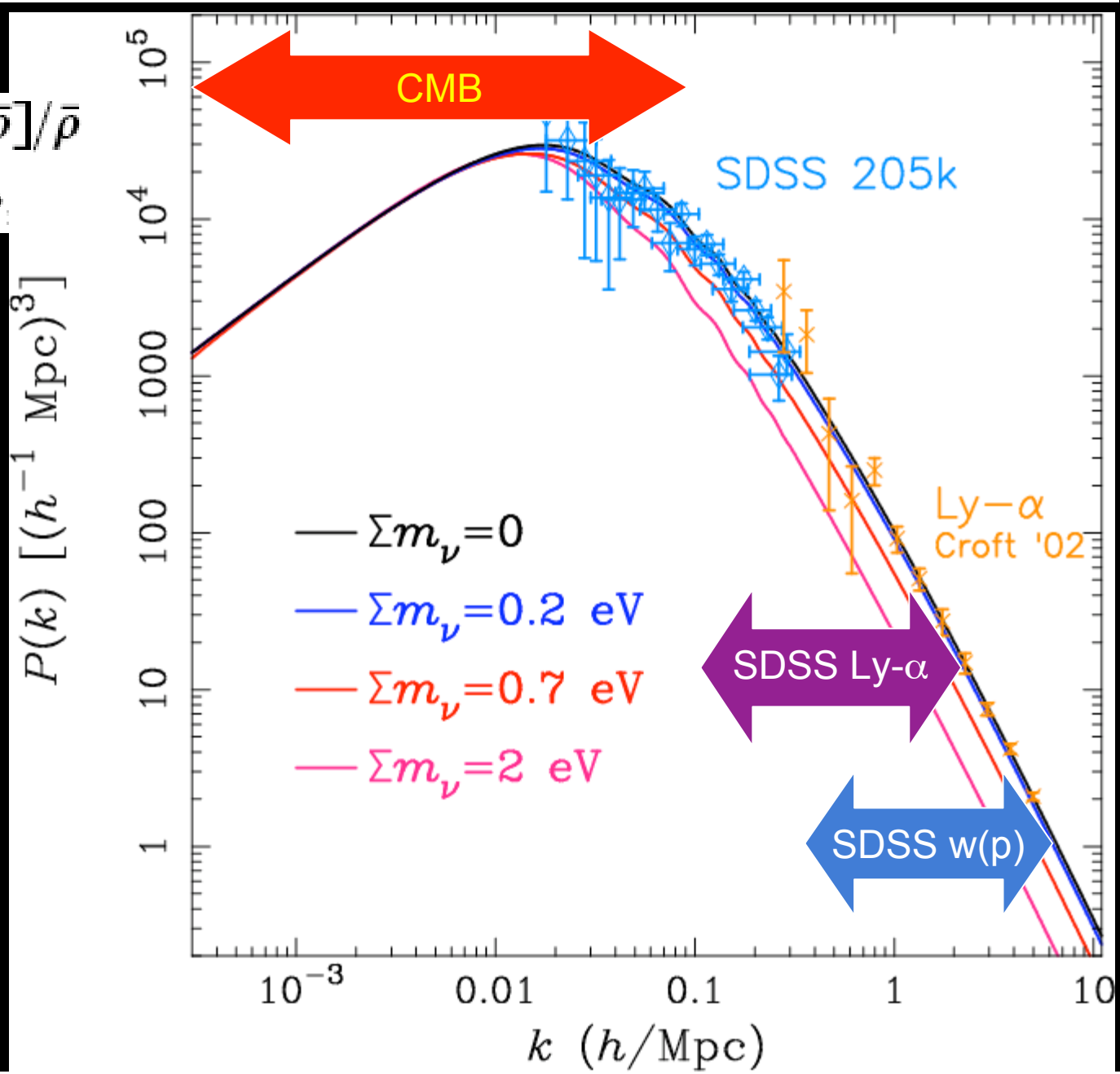


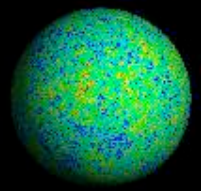


Measuring P(k)

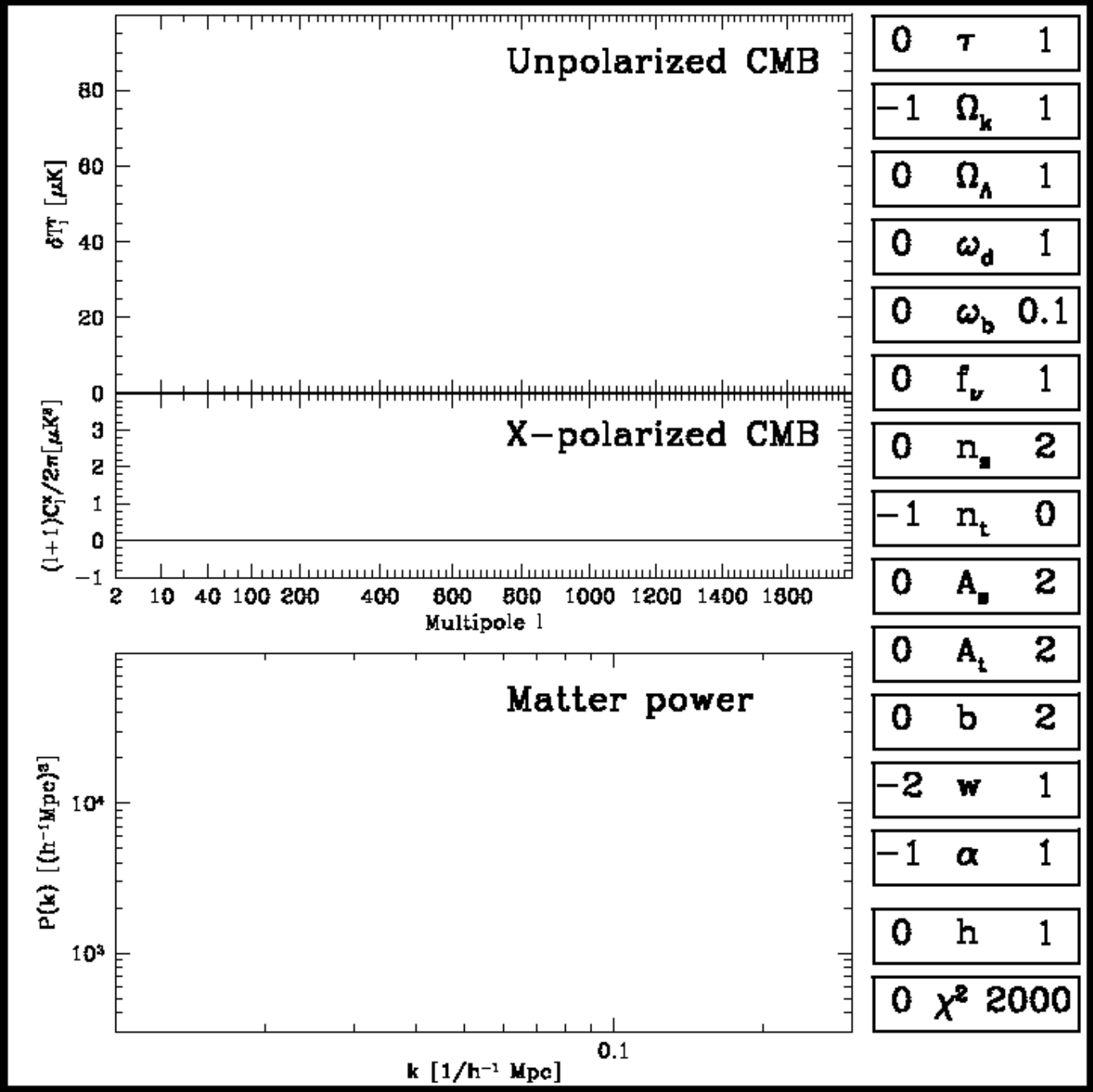
$$\delta(x) \equiv [\rho(x) - \bar{\rho}]/\bar{\rho}$$

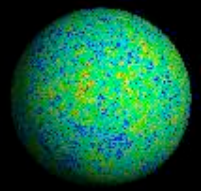
$$P(k) = \langle |\delta_k|^2 \rangle$$



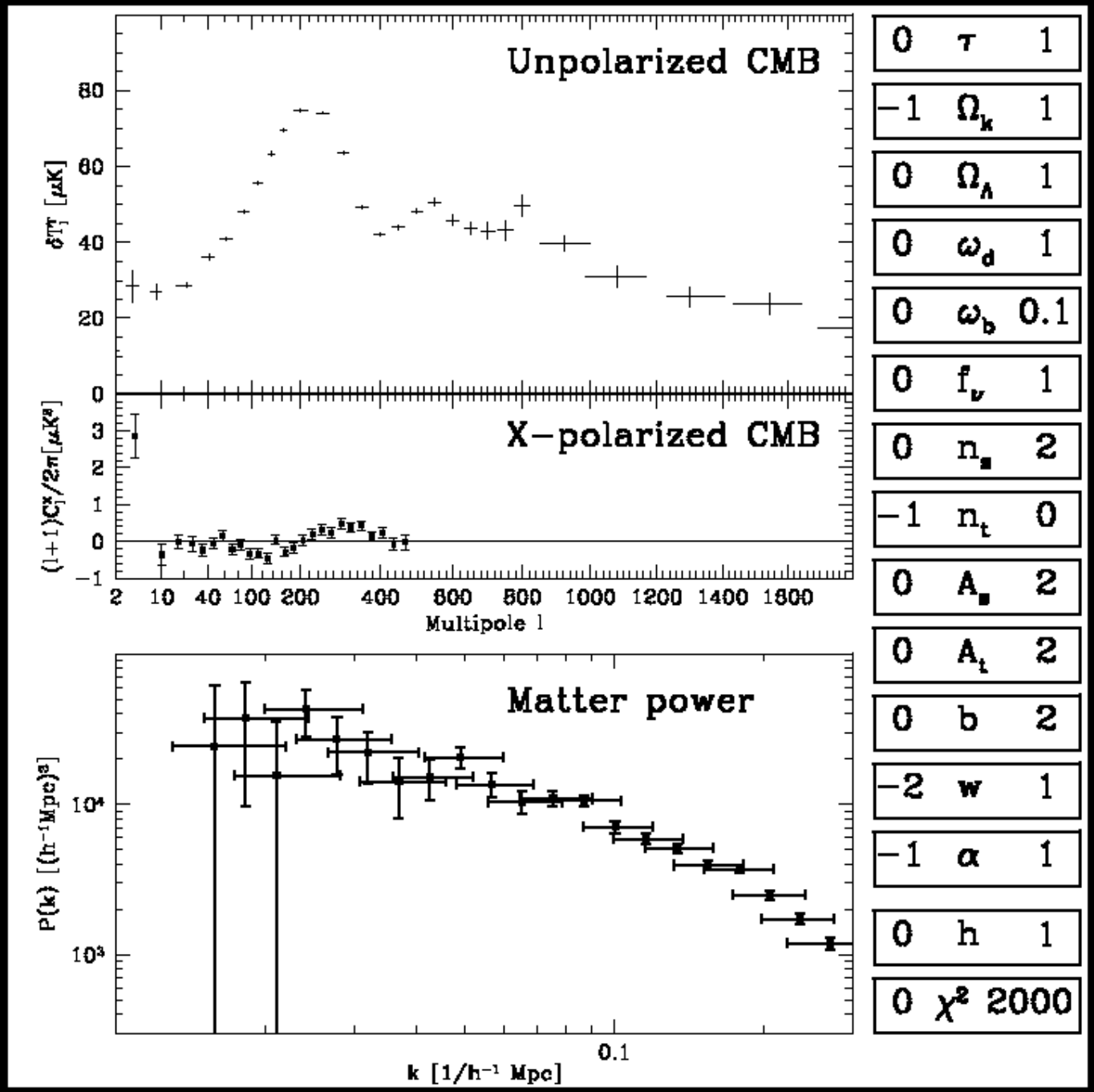


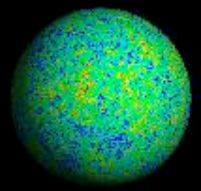
CMB


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

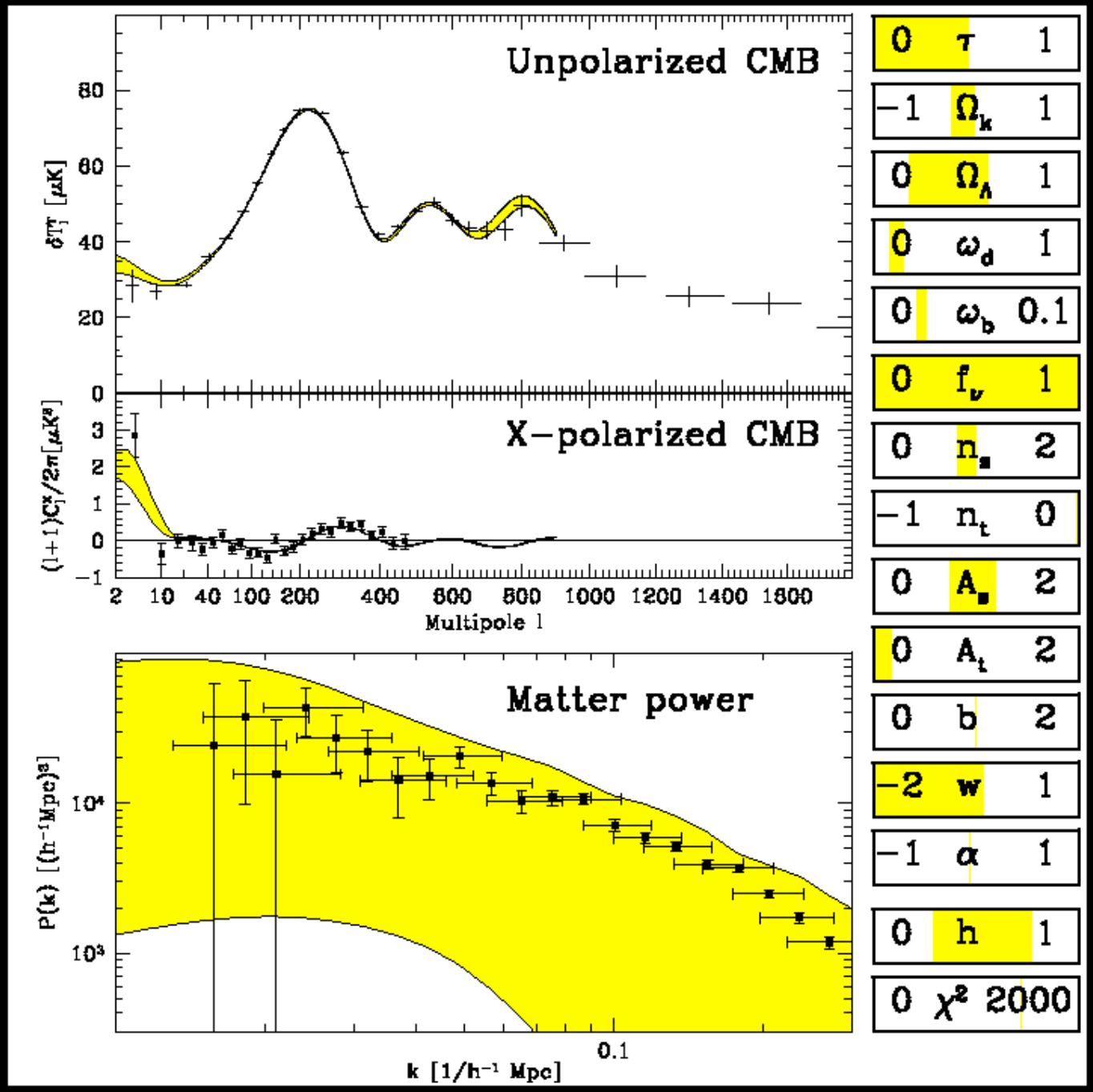


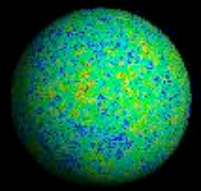
CMB


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

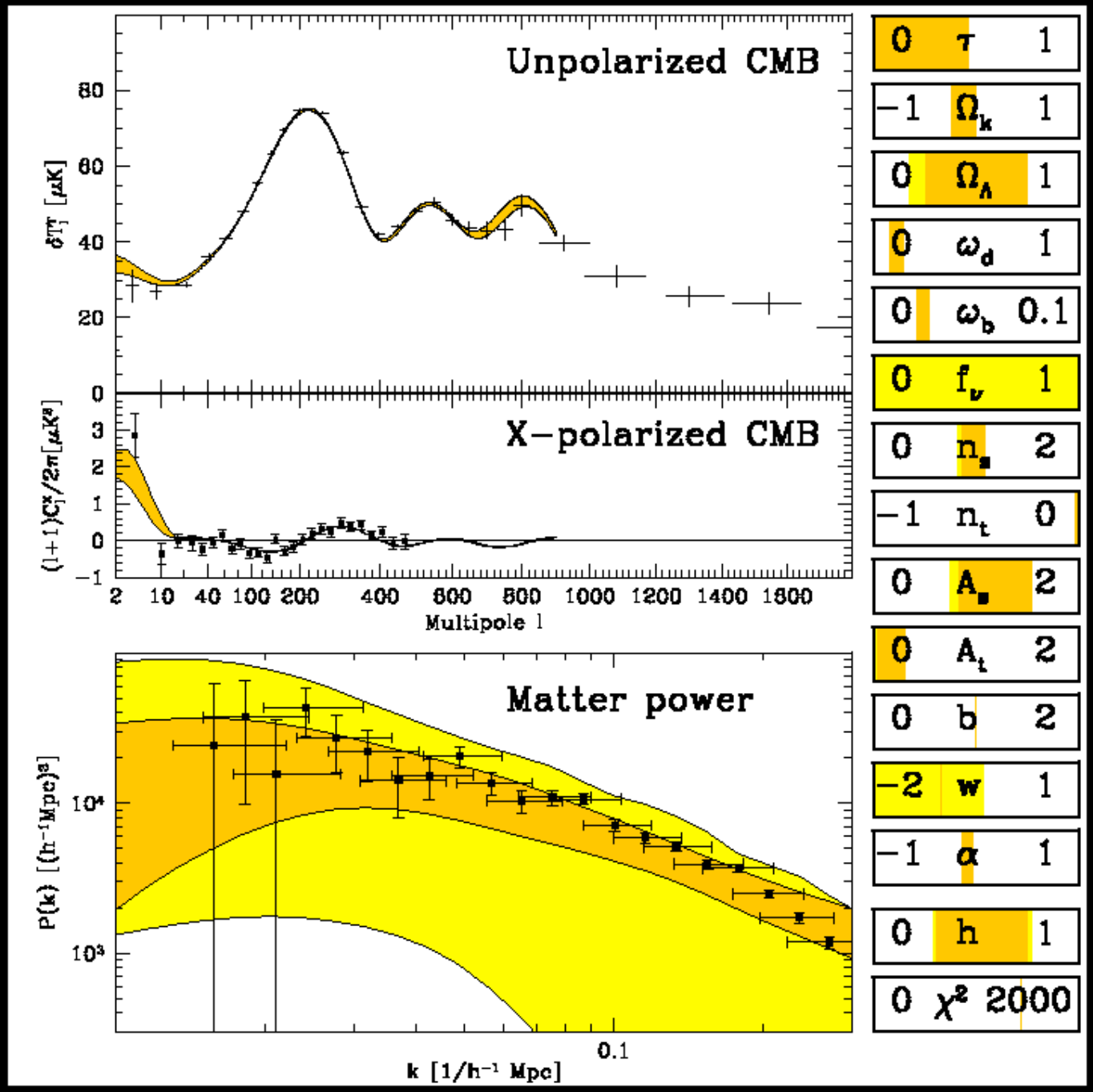


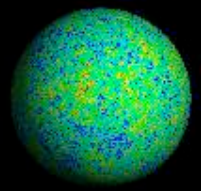
CMB


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

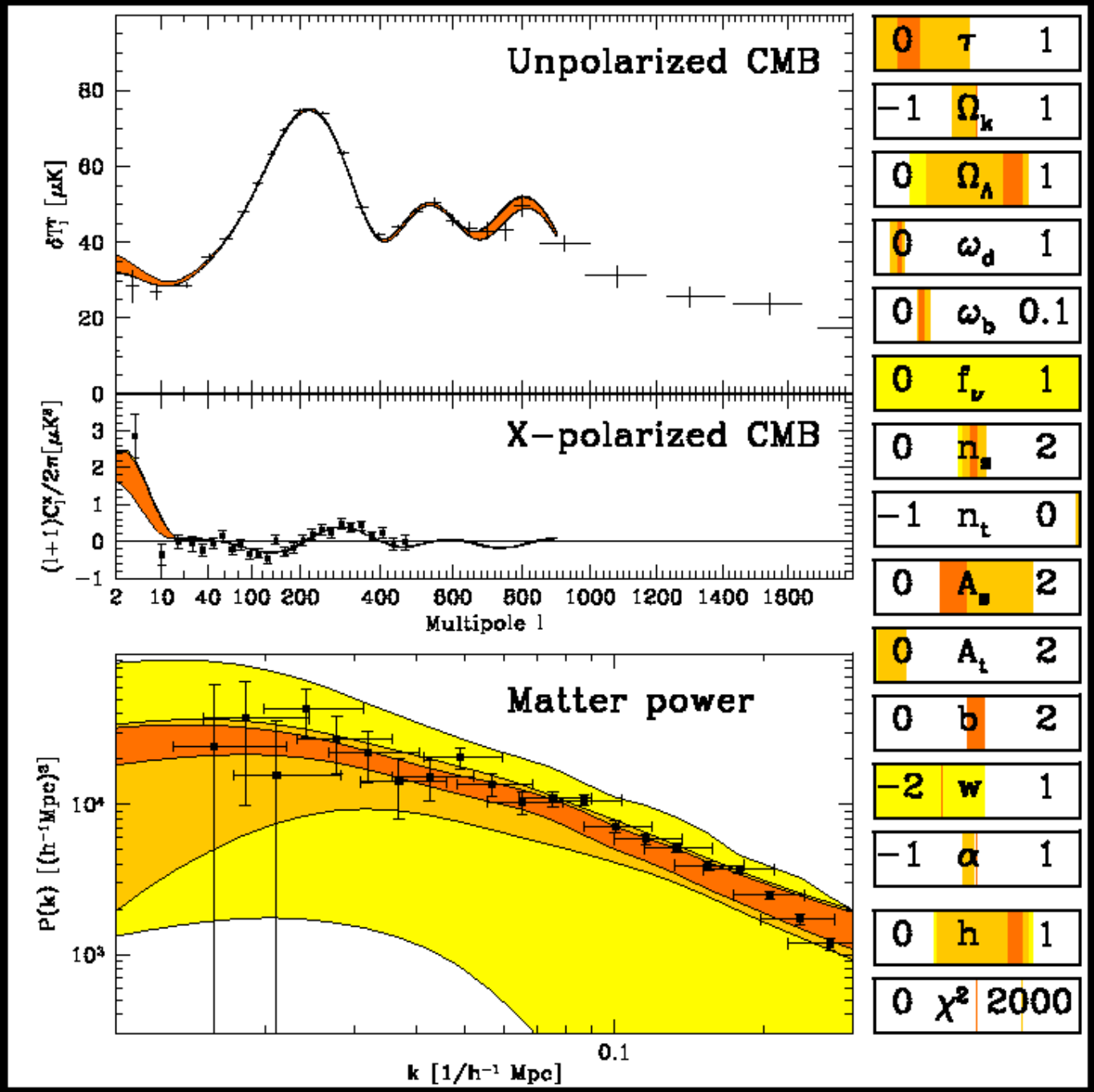


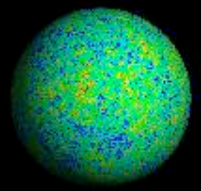
CMB


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



CMB

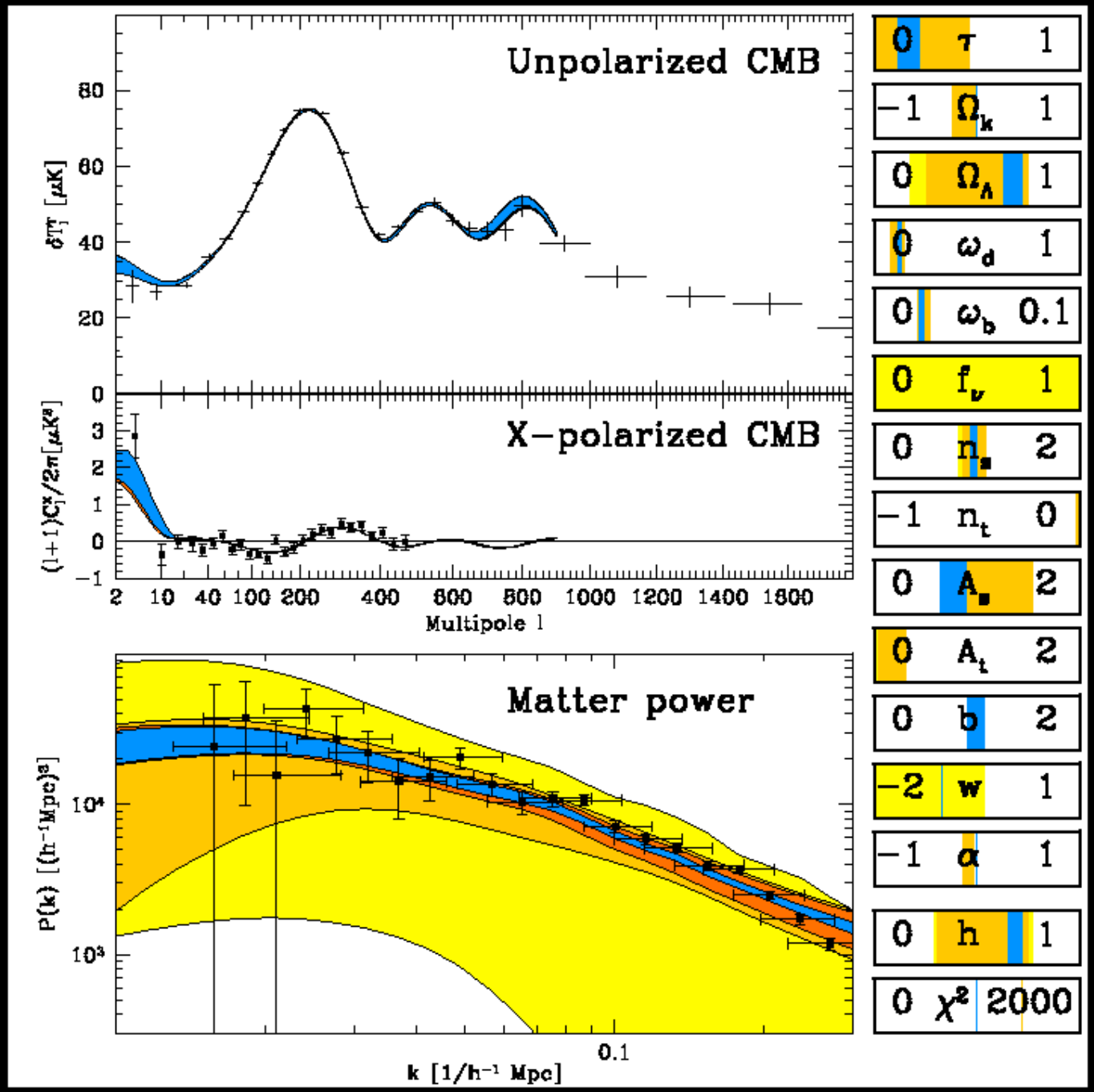

Unpolarized CMB
X−polarized CMB
Matter power
Multipole l
k [1/h⁻¹ Mpc]
P(k) [(h⁻¹Mpc)³]
0 τ 1
−1 Ω_k 1
0 Ω_Λ 1
0 ω_d 1
0 ω_b 0.1
0 f_ν 1
0 n_s 2
−1 n_t 0
0 A_s 2
0 A_t 2
0 b 2
−2 w 1
−1 α 1
0 h 1
0 χ² 2000

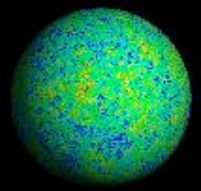


CMB

+

LSS

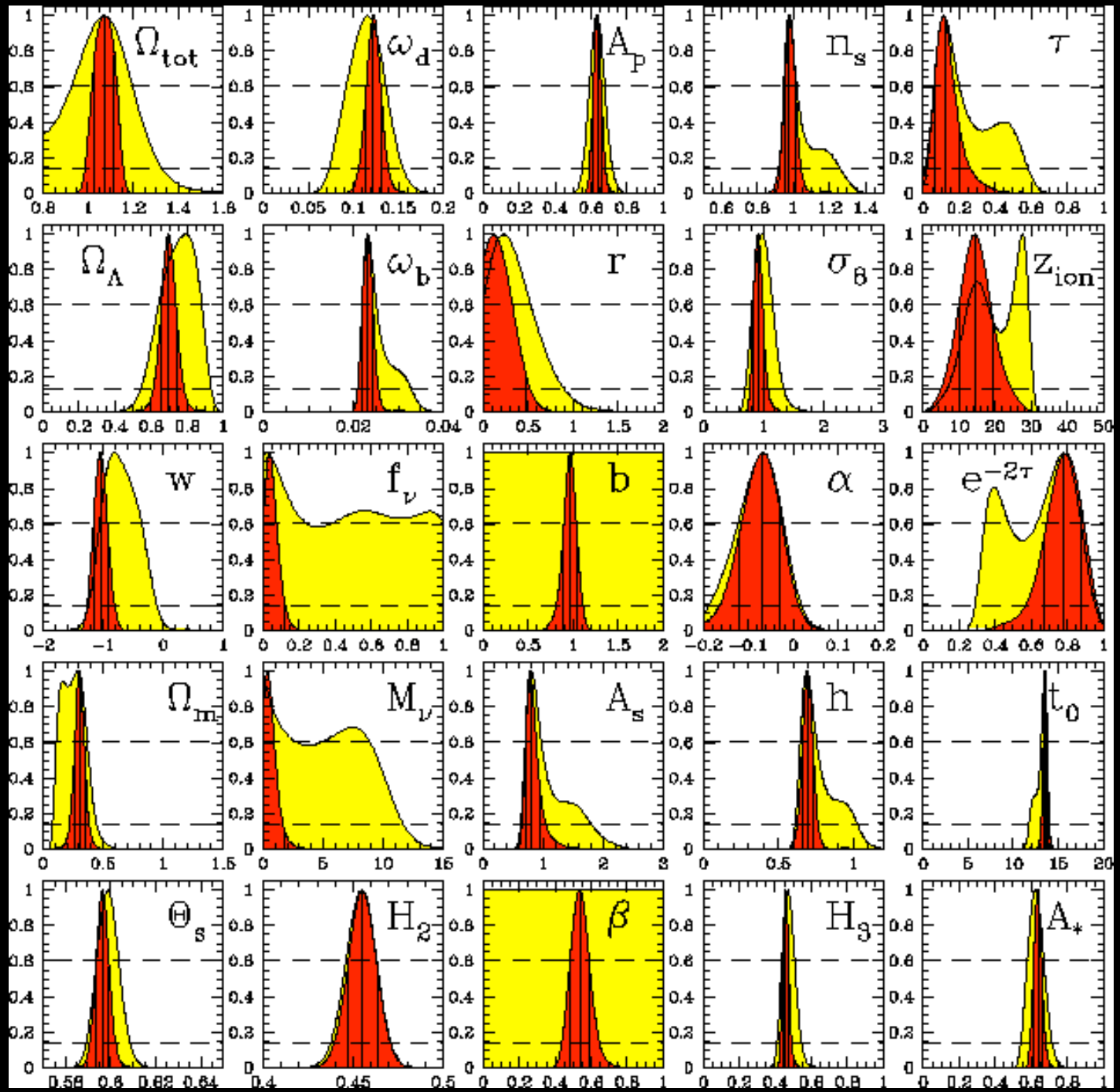

Unpolarized CMB
δT_l^T [μK]
X−polarized CMB
$(l+1)C_l^X/2\pi[\mu K^2]$
Multipole l
Matter power
P(k) [(h⁻¹Mpc)³]
k [1/h⁻¹ Mpc]
0 τ 1
−1 Ω_k 1
0 Ω_Λ 1
0 ω_d 1
0 ω_b 0.1
0 f_ν 1
0 n_s 2
−1 n_t 0
0 A_s 2
0 A_t 2
0 b 2
−2 w 1
−1 α 1
0 h 1
0 χ^2 2000



CMB

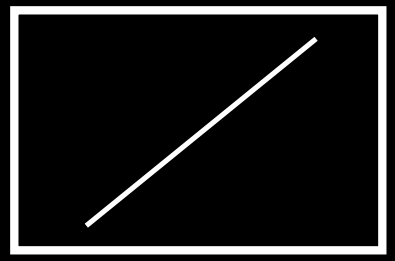
+

LSS

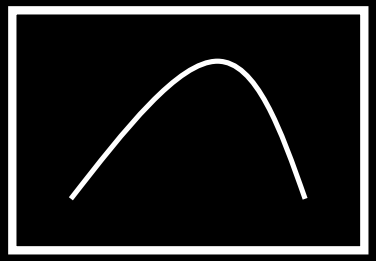

Ω_{tot}
ω_d
A_P
n_s
τ
Ω_Λ
ω_b
r
σ_8
z_{ion}
w
f_ν
b
α
$e^{-2\tau}$
Ω_m
M_ν
A_s
h
t_0
Θ_s
H_2
β
H_3
A_*

Neutrino Cosmology

$$P(k) \propto k$$



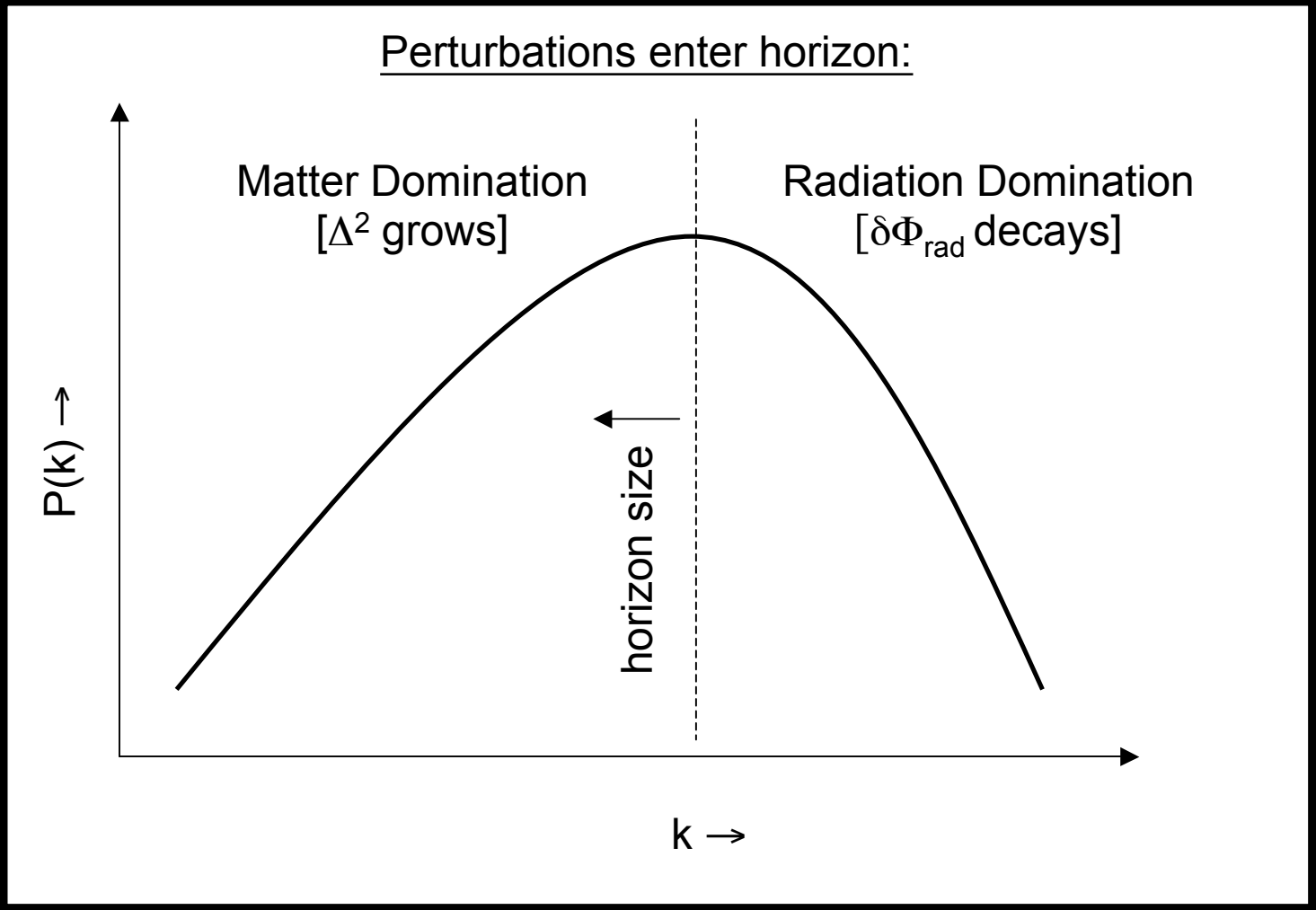
$\rightarrow$

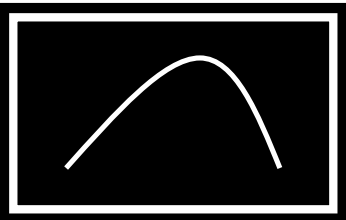


?

$$\rho_{mat} \propto a^{-3}$$

$$\rho_{rad} \propto a^{-4}$$



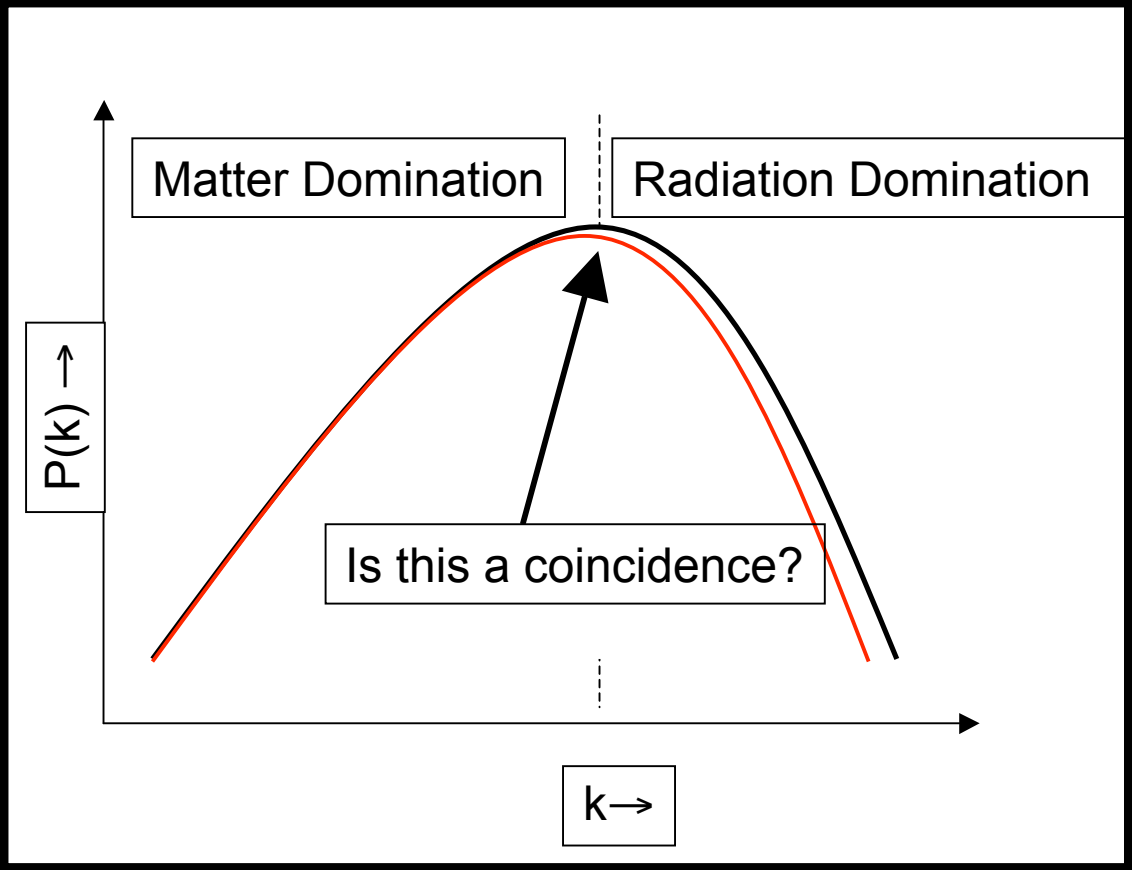
How does  probe neutrinos?

$$n_\nu \approx N_\nu \times \left(\frac{3}{11}\right) n_\gamma \approx 340\ \mathrm{cm}^{-3}$$ *(Assuming thermal equilibrium)*

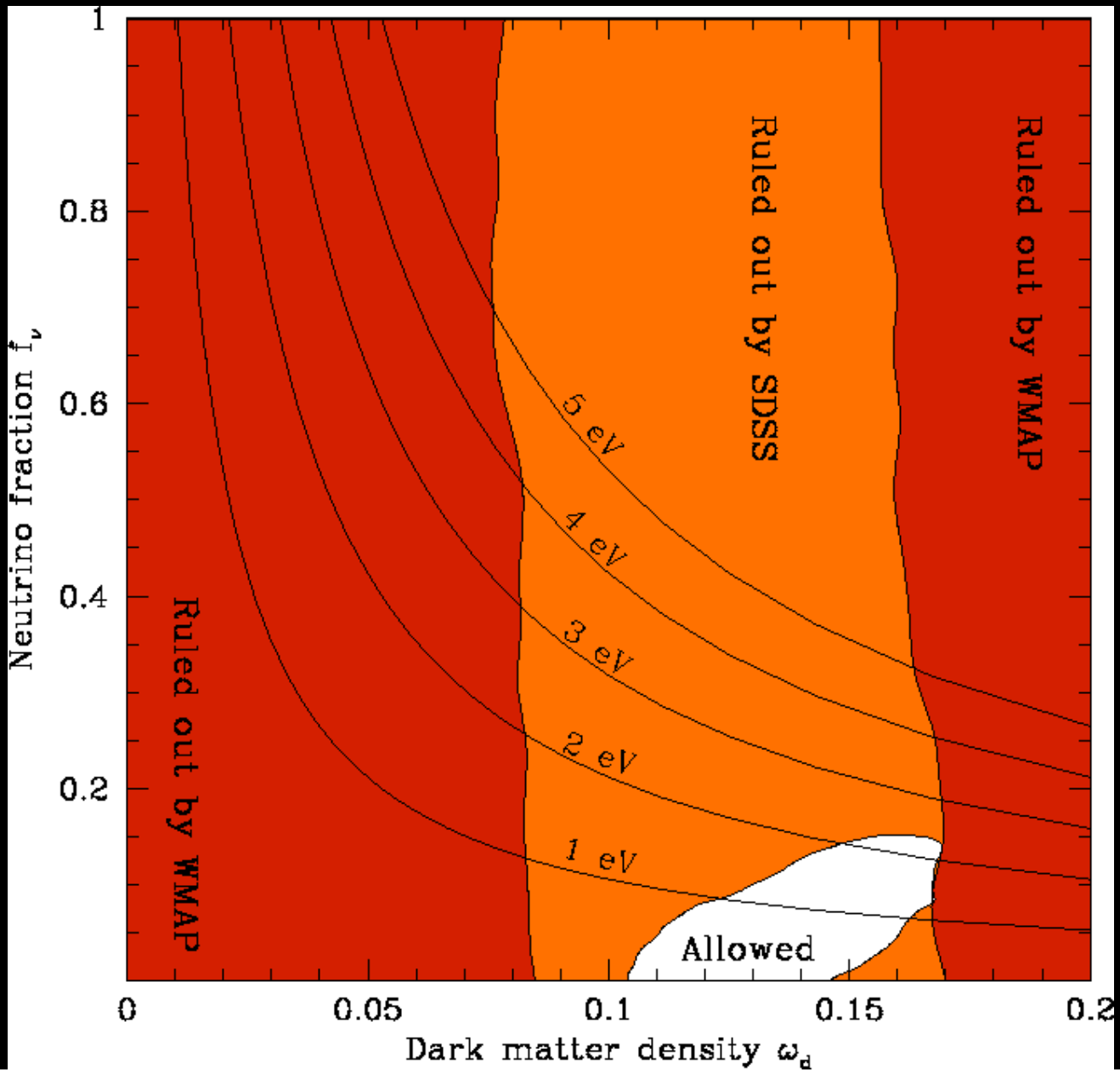
$$\rho_\nu = \sum m_i\, n_{\nu i}$$

$$\Omega_\nu = \frac{\sum m_i\, n_{\nu i}}{\rho_{crit}} = \frac{\sum m_i}{92.5\ \mathrm{eV}\ h^2}$$

$$E_\nu = \sqrt{p^2 + m^2}$$



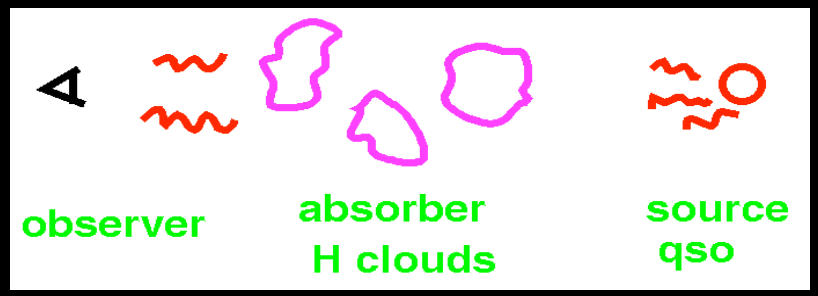
Neutrino Fraction from CMB and 3D P(k)

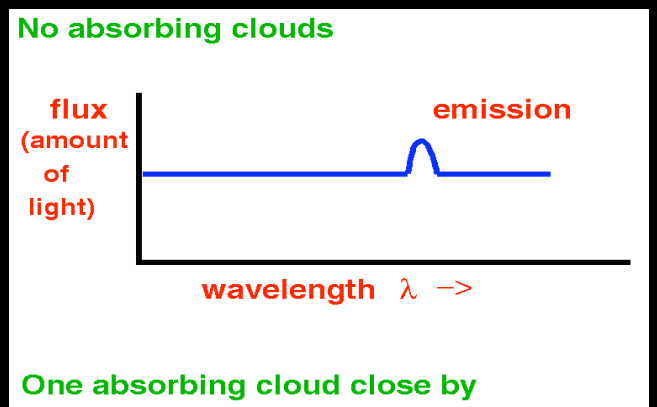


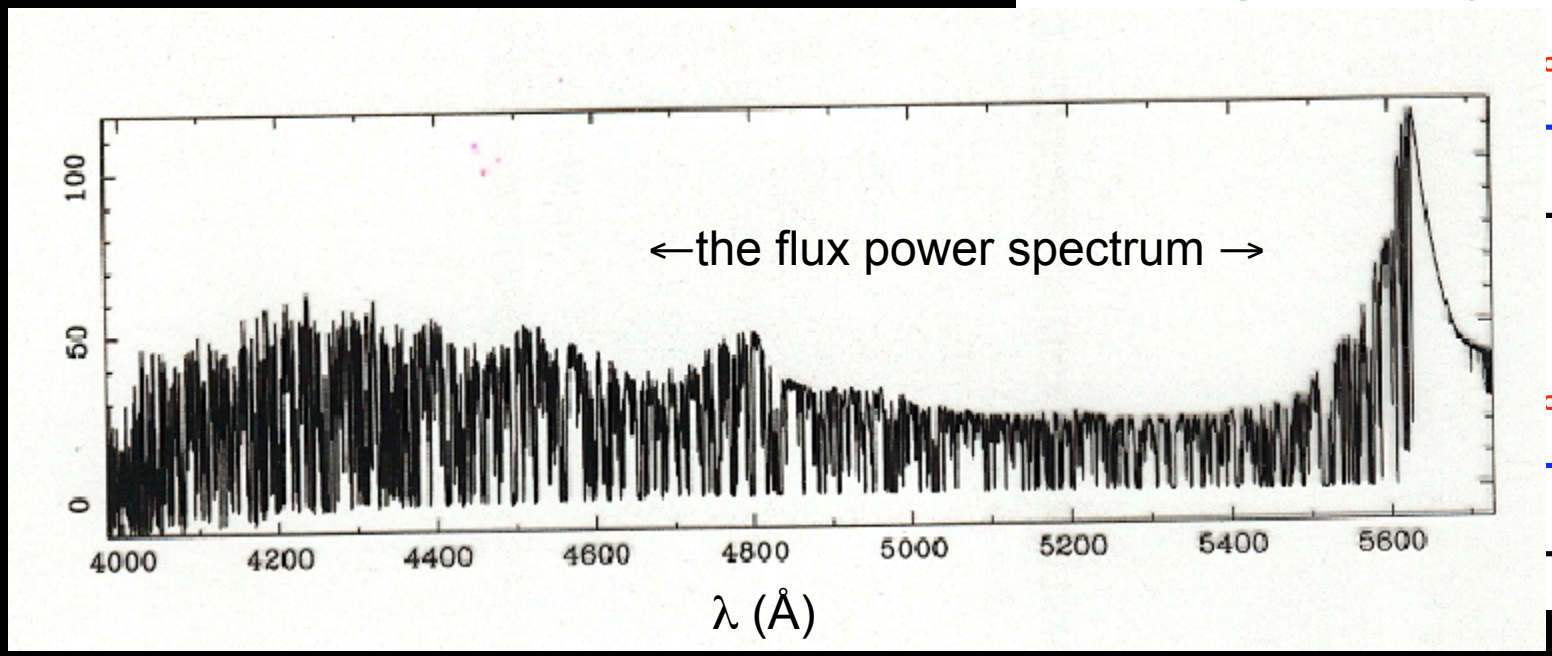
Cosmological Parameters from The Flux and Matter Power Spectrum from the SDSS Lyman-α Forest

Kev Abazajian (T-8/T-6), Adam Lidz (Columbia/FNAL), Lam Hui (Columbia/FNAL), Katrin Heitmann (ISR-1), Salman Habib (T-8), Scott Dodelson (FNAL/Chicago)

SDSS Measurement of the Lyman-α forest





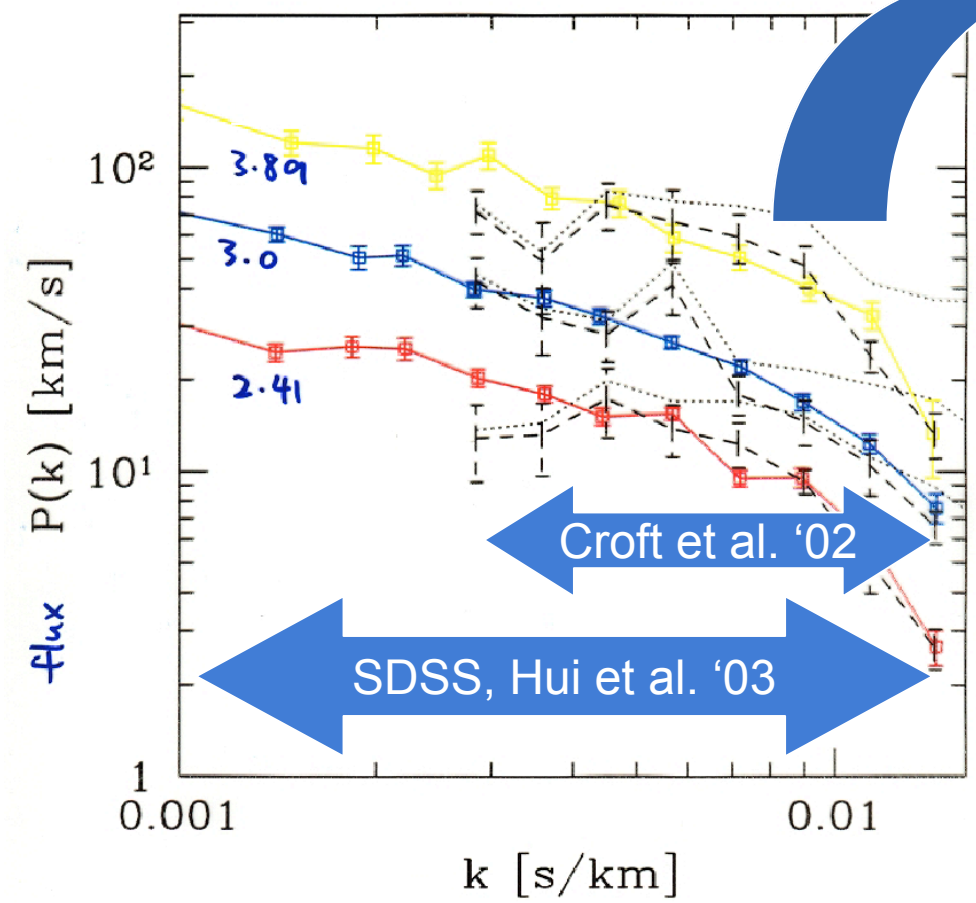


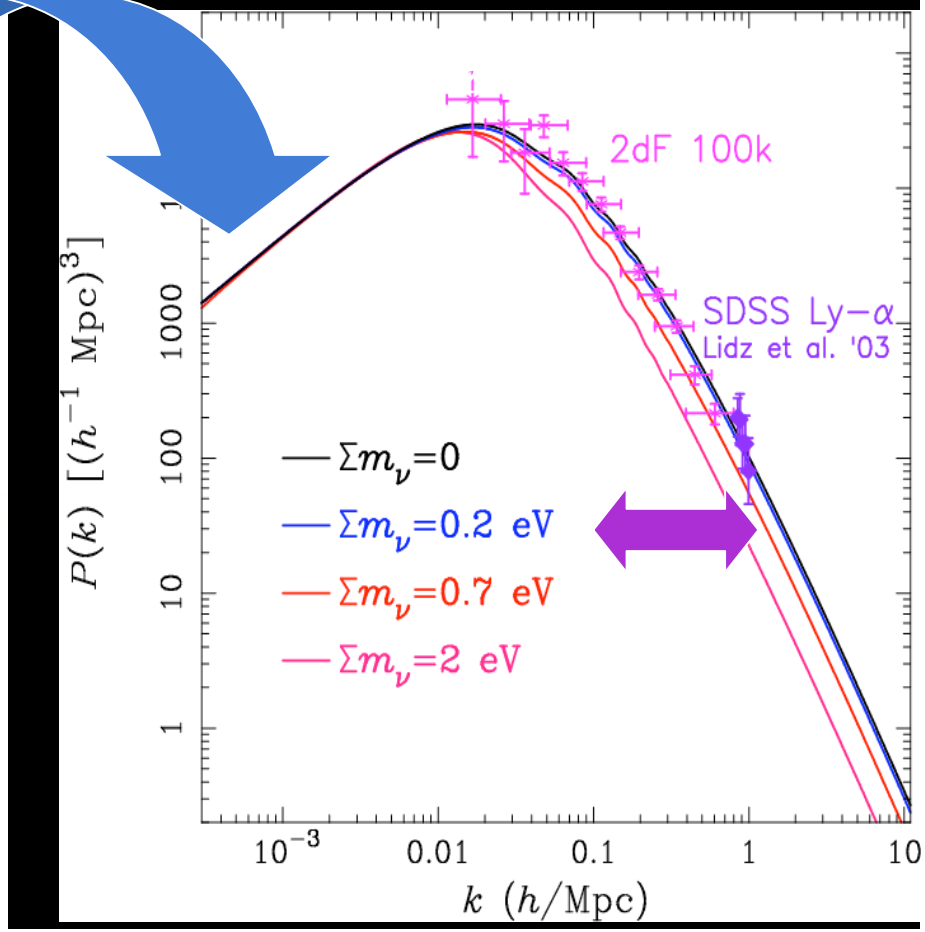
Measuring $P_m(k)$ with Lyman-α forest $P_F(k)$

Using > 3000 quasar spectra from the SDSS quasar survey…
Much broader range in *k* and much higher statistical precision

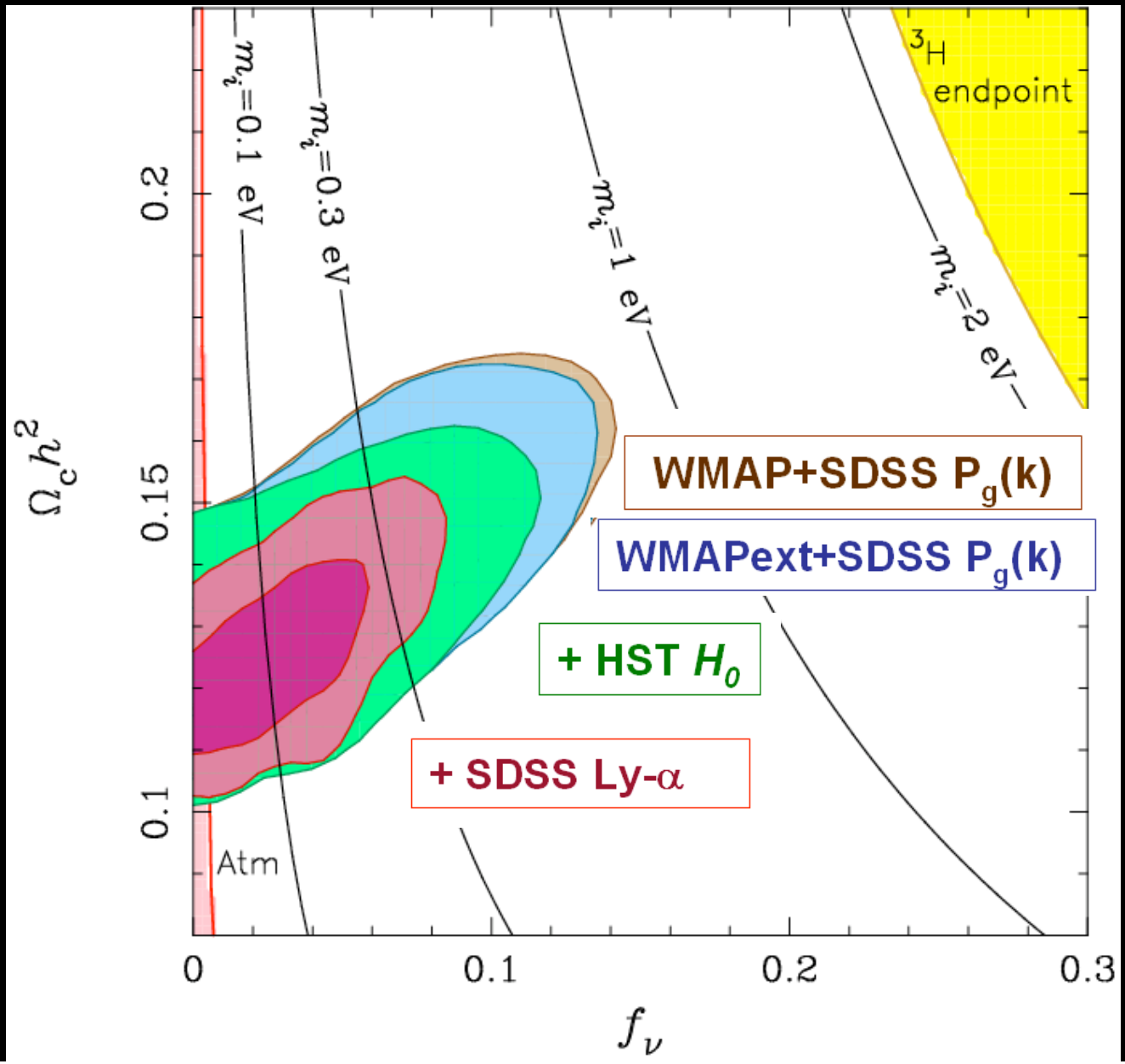
$$P_{\rm flux}(k) = b^2(k, {\rm cosmology}) P_m(k)$$

- Normalized through LANL *N*-body simulations
- Monte-Carlo of likelihood for $(P_m(k)|P_F(k))$





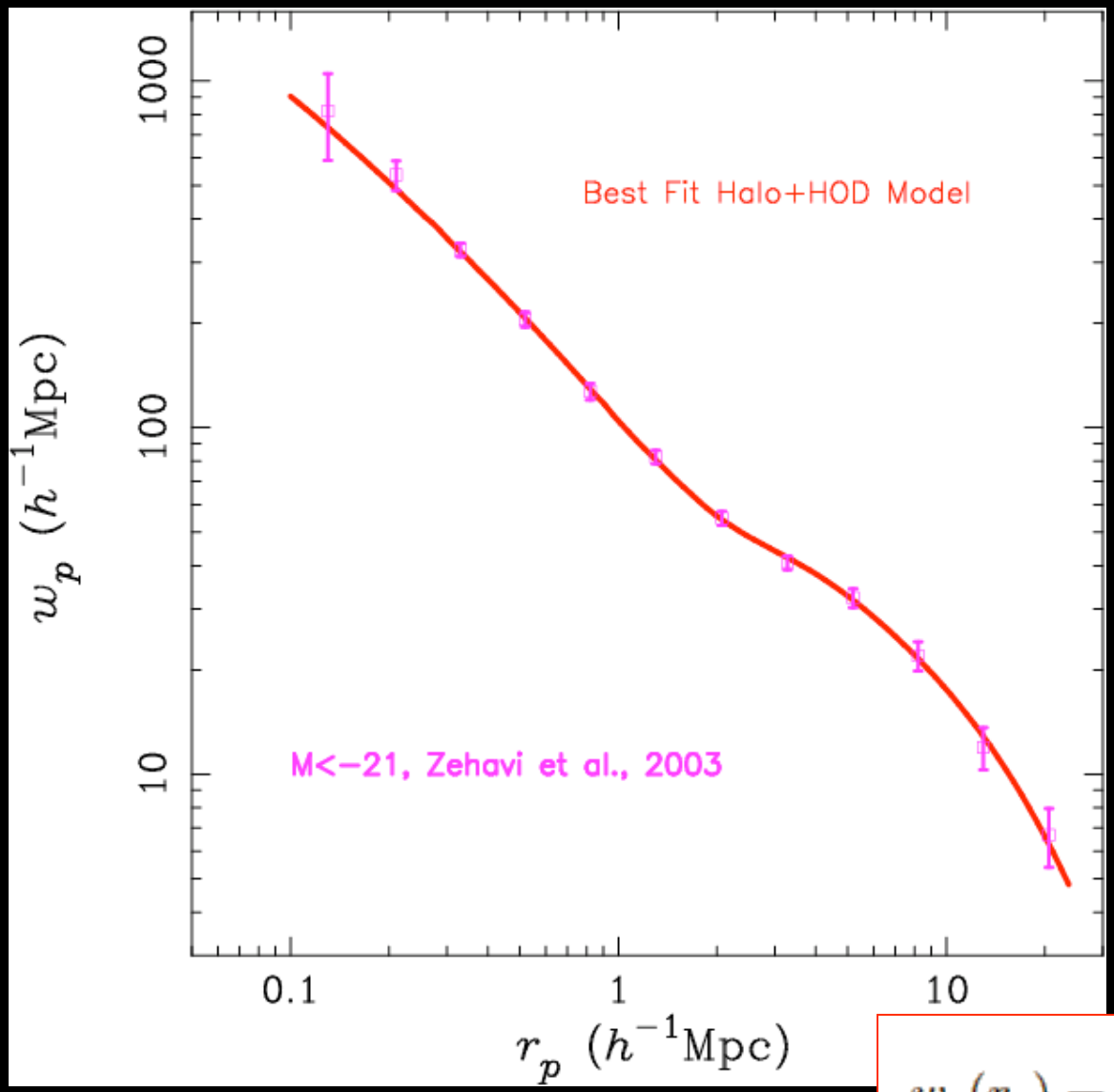
WMAP$_{+ACBAR+CBI}$ + SDSS Galaxies + SDSS Ly-α + HST: Dark Matter



Cosmological Parameters from Small-scale Galaxy Clustering in the SDSS

Kev Abazajian (T-8/T-6), Zheng Zheng (Ohio), Idit Zehavi (Arizona), Andreas Berlind (NYU), Michael Blanton (NYU), David Weinberg (Ohio), Josh Frieman (FNAL/Chicago)

Theory & measurement of the **Galaxy Correlation Function**

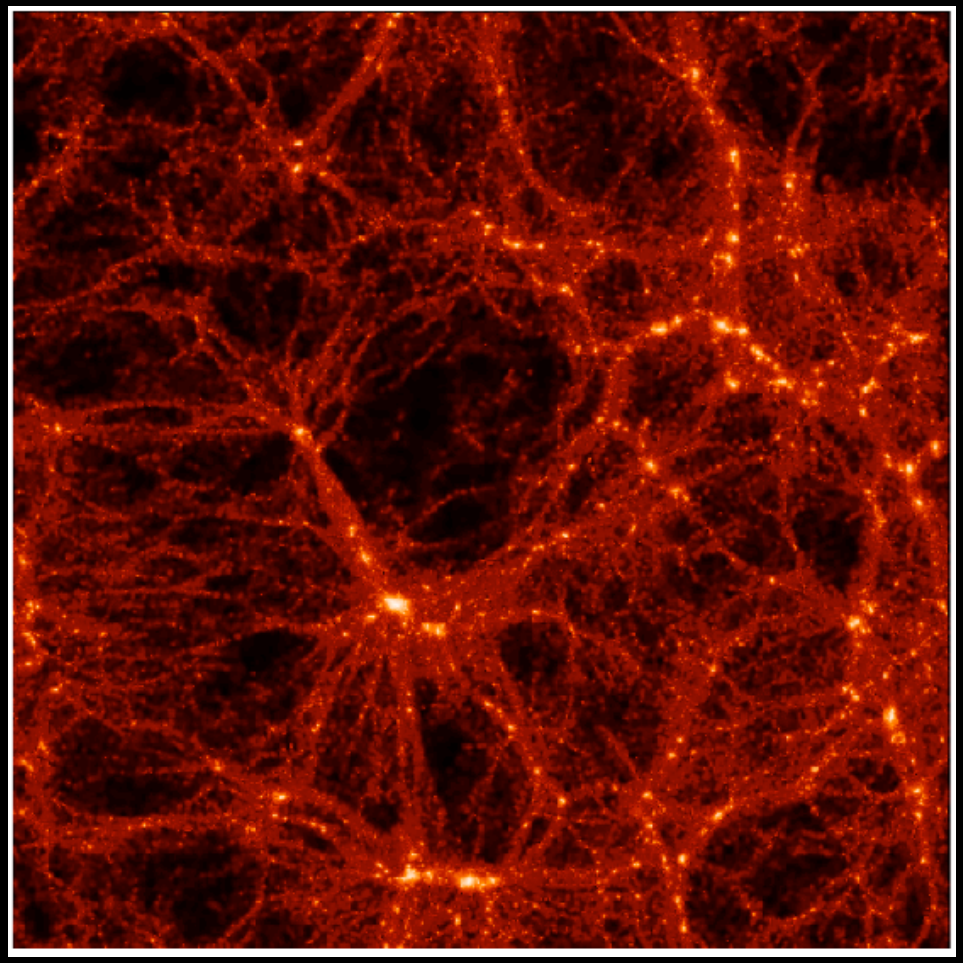


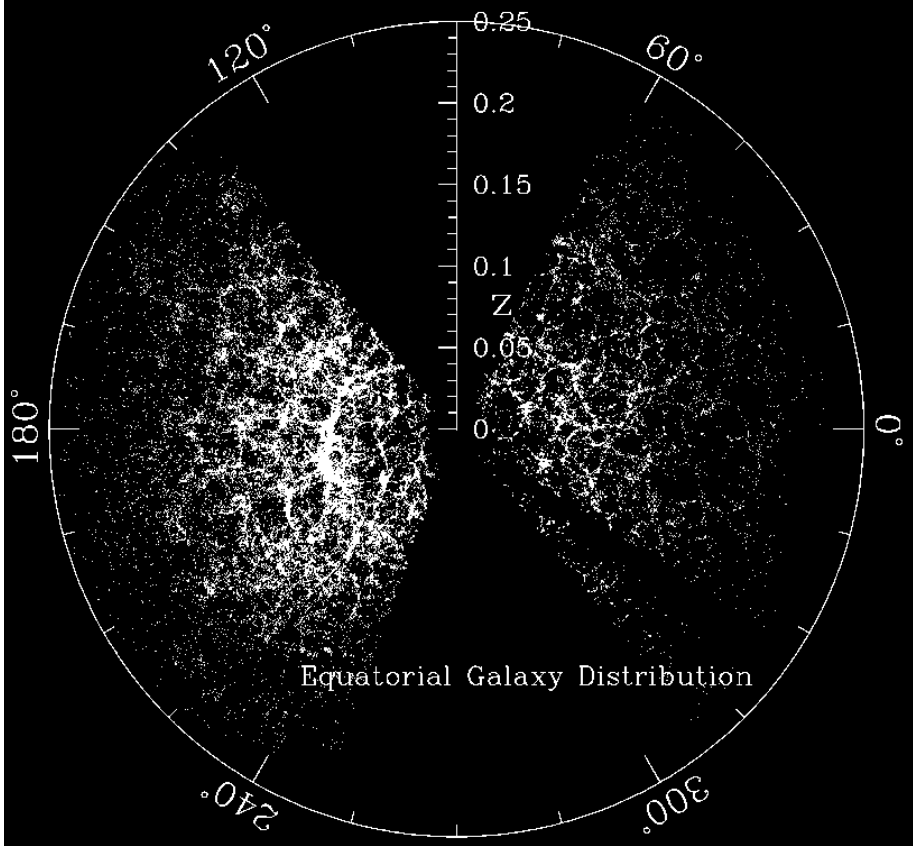
Zehavi et al., 2003:

A high-statistics measurement of the galaxy correlation function over a large range of scale…

$$w_p(r_p) = 2\int_0^\infty \xi\left[(r_p^2 + y^2)^{1/2}\right] dy,$$

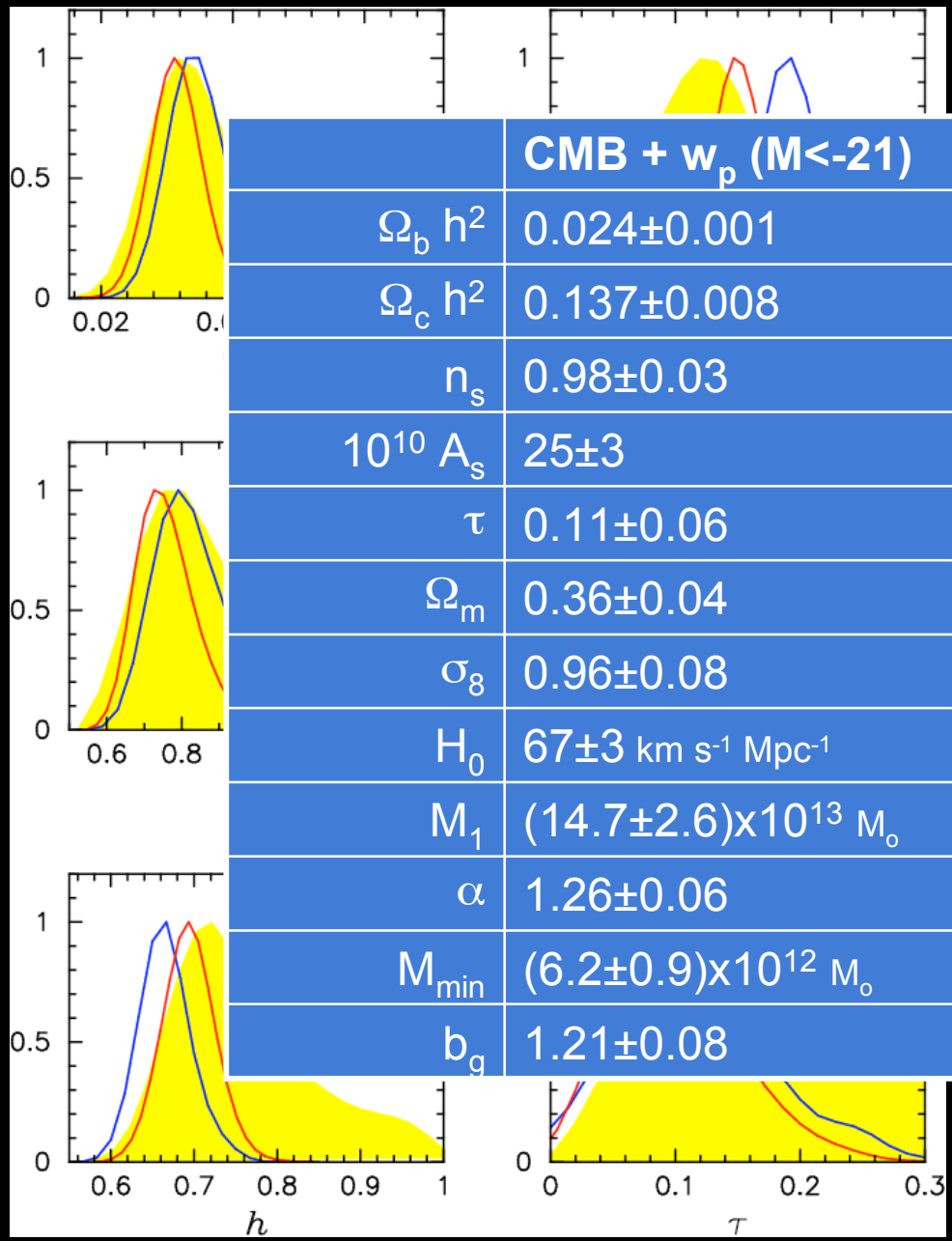
Statistical properties of DM & Galaxies



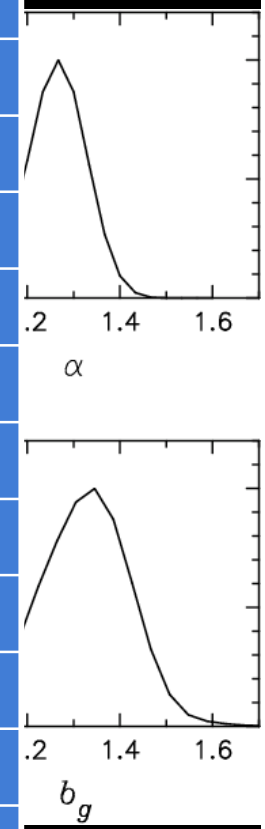


$w_p(r)$ Parameter Results:

$p=(\theta, \Omega_b h^2, \Omega_c h^2, A_s, n_s, M_1, \alpha)$



	CMB + w_p (M<-21)	WMAP + SDSS $P_g(k)$
$\Omega_b h^2$	0.024±0.001	0.023±0.001
$\Omega_c h^2$	0.137±0.008	0.122±0.009
n_s	0.98±0.03	0.98±0.03
$10^{10} A_s$	25±3	24±3
τ	0.11±0.06	0.12±0.06
Ω_m	0.36±0.04	0.30±0.04
σ_8	0.96±0.08	0.92±0.08
H_0	67±3 km s^{-1} Mpc^{-1}	70±3 km s^{-1} Mpc^{-1}
M_1	$(14.7\pm2.6)\times10^{13}$ M_o	-
α	1.26±0.06	-
M_{min}	$(6.2\pm0.9)\times10^{12}$ M_o	-
b_g	1.21±0.08	-



Summary

- The Sloan Digital Sky Survey provides a wealth of information on the distribution of galaxies, gas, and dark matter in the universe
- The fraction of cold dark matter, dark energy, and neutrinos.
- The properties of the primordial density perturbation spectrum and thus the process that produced this spectrum.
- Fundamental particle physics
- Astrophysics of galaxy formation