Weak Lensing and Dark Energy

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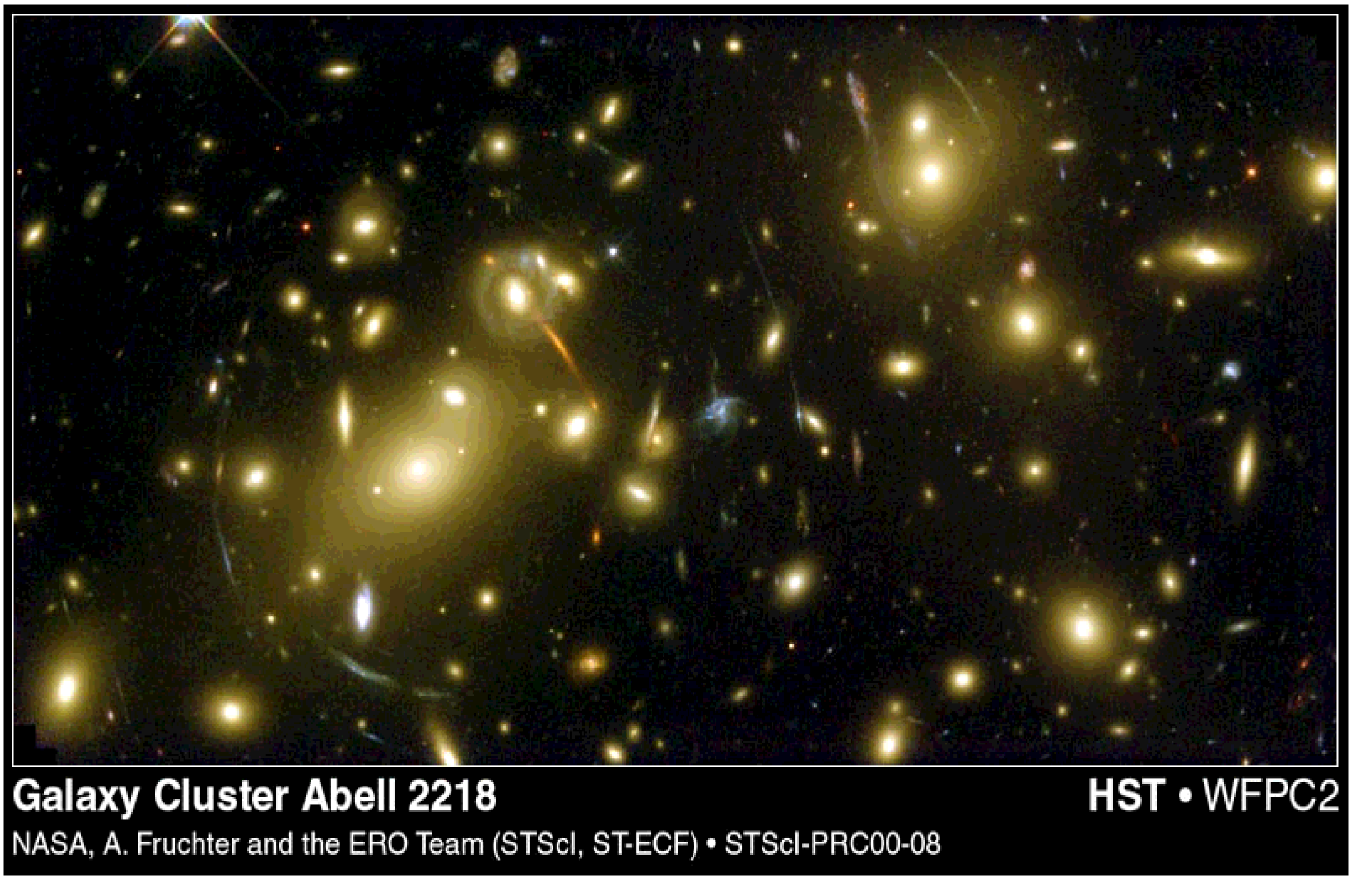
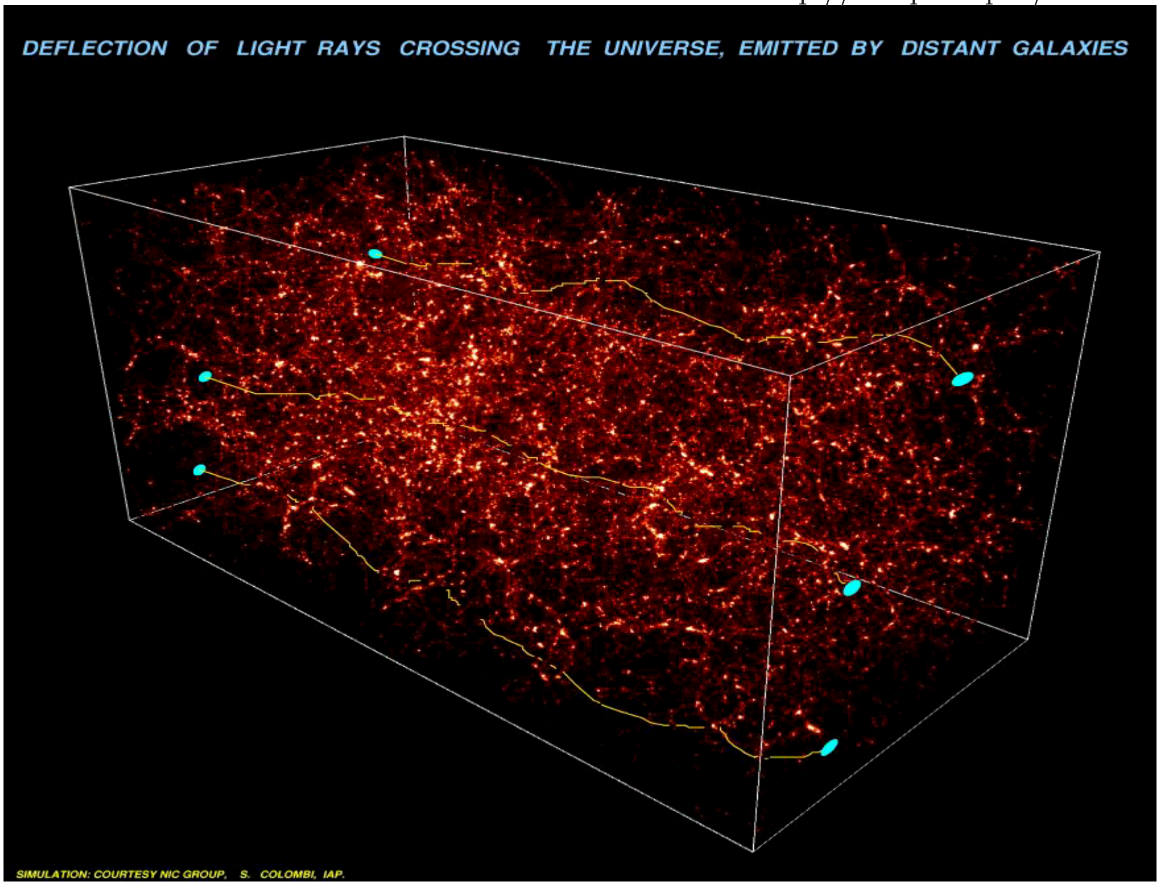


http://terapix.iap.fr/Descart



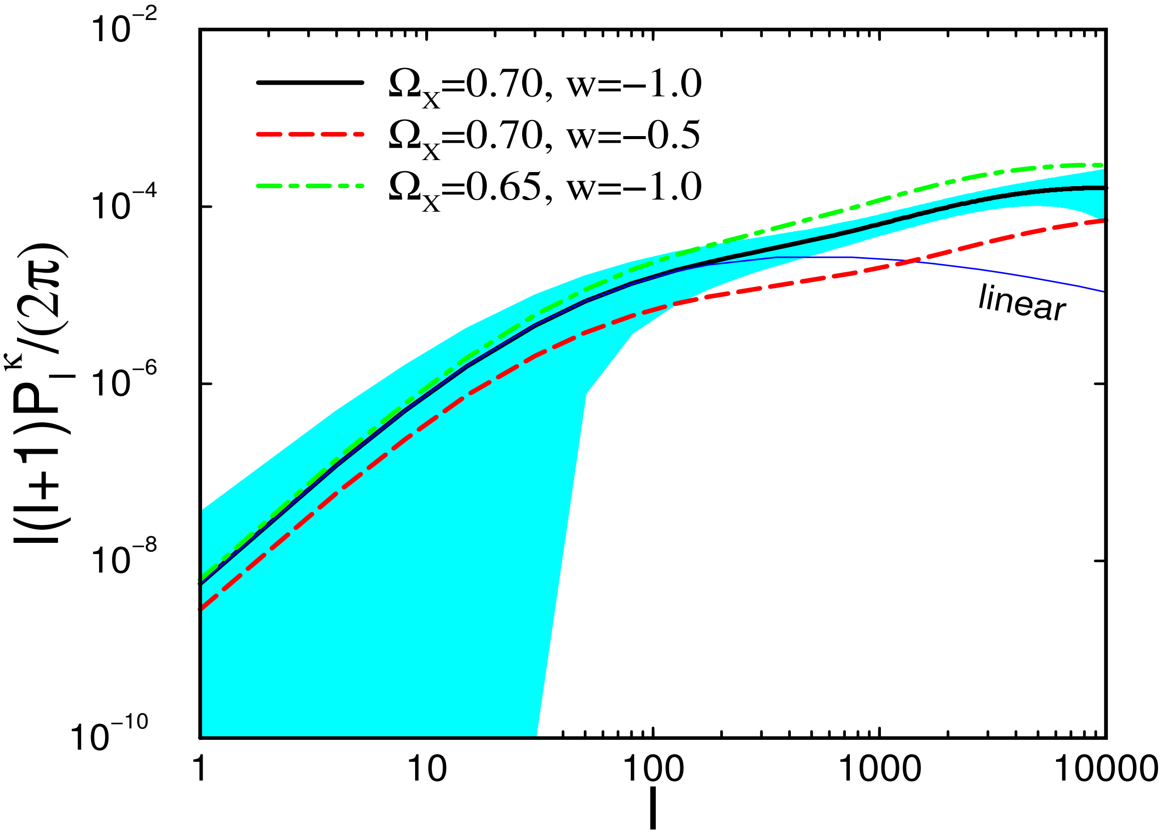
Power Spectrum of the Convergence

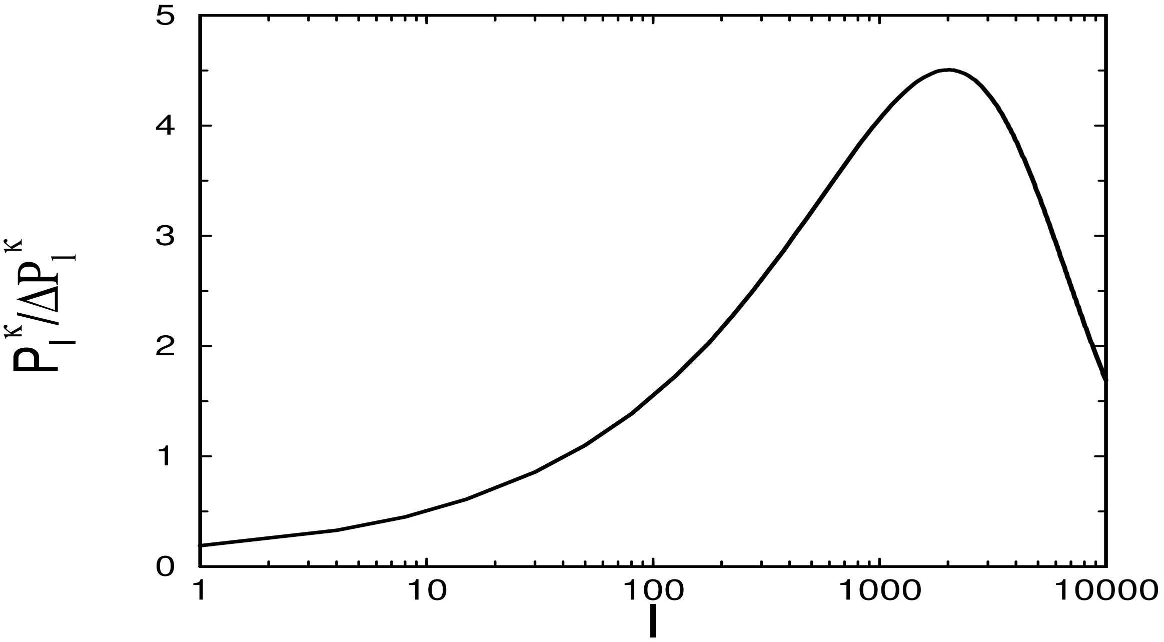
$$\kappa(\hat{\mathbf{n}}, \chi) = \int_0^{\chi} W(\chi')\, \delta(\chi')\, d\chi'$$

$$\langle \kappa_{lm} \kappa_{l'm'} \rangle = \delta_{l_1 l_2}\, \delta_{m_1 m_2}\, P_l^{\kappa}$$

$$P_l^{\kappa} \;=\; \frac{2\pi^2}{l^3} \int_0^{z_s} dz\, \frac{W^2(z) r(z)}{H(z)}\, \Delta^2 \left(\frac{l}{r(z)}; z \right)$$

$$\Delta P_l^{\kappa} \;=\; \sqrt{\frac{2}{(2l+1) f_{\rm sky}}} \left(P_l^{\kappa} + \frac{\langle \gamma_{\rm int}^2 \rangle}{\bar{n}} \right)$$

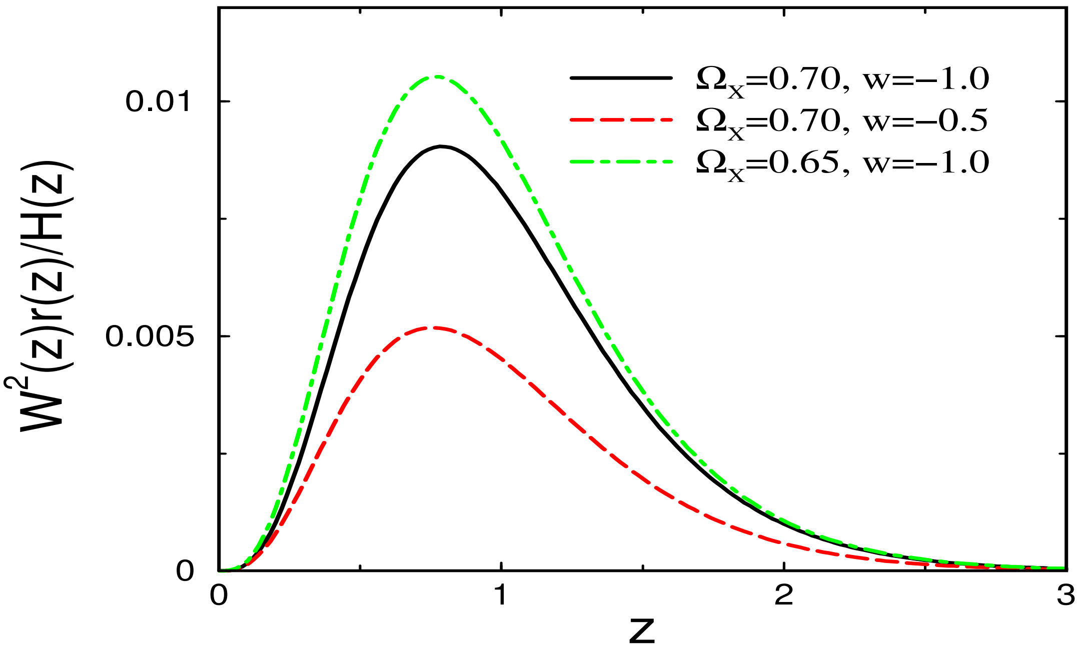




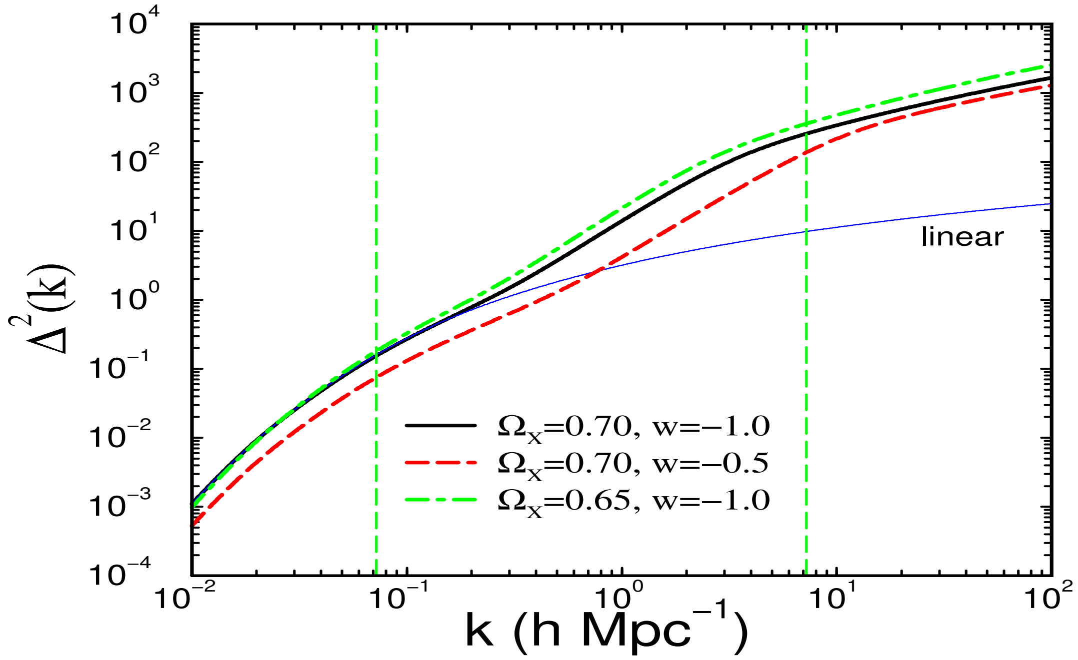
In order for systematics not to dominate:

$$\frac{\delta\sqrt{\langle\gamma^2(\theta)\rangle}}{\sqrt{\langle\gamma^2(\theta)\rangle}} \lesssim 0.01$$

Dependence on Dark Energy



$$\Delta^2(k,z) = \delta_H^2 \left(\frac{k}{H_0}\right)^{n+3} T^2(k,z)\,\frac{D^2(z)}{D^2(0)}\,T_{NL}$$



Cosmological Constraints

Parameters:

$\delta_H =$ COBE value

$\Omega_X = 0.7$

$w = -1$

$\Omega_M h^2 = 0.3 \times 0.65^2$

$n_s = 1.0$

$\Omega_B h^2 = 0.019$

$m_\nu = 0.1\,\mathrm{eV}$

Fisher Matrix formalism:

$$F_{ij} = -\left\langle \frac{\partial^2 \ln L}{\partial p_i \partial p_j} \right\rangle = \sum_l \frac{1}{(\Delta P_l^\kappa)^2} \frac{\partial P_l^\kappa}{\partial p_i} \frac{\partial P_l^\kappa}{\partial p_j}$$

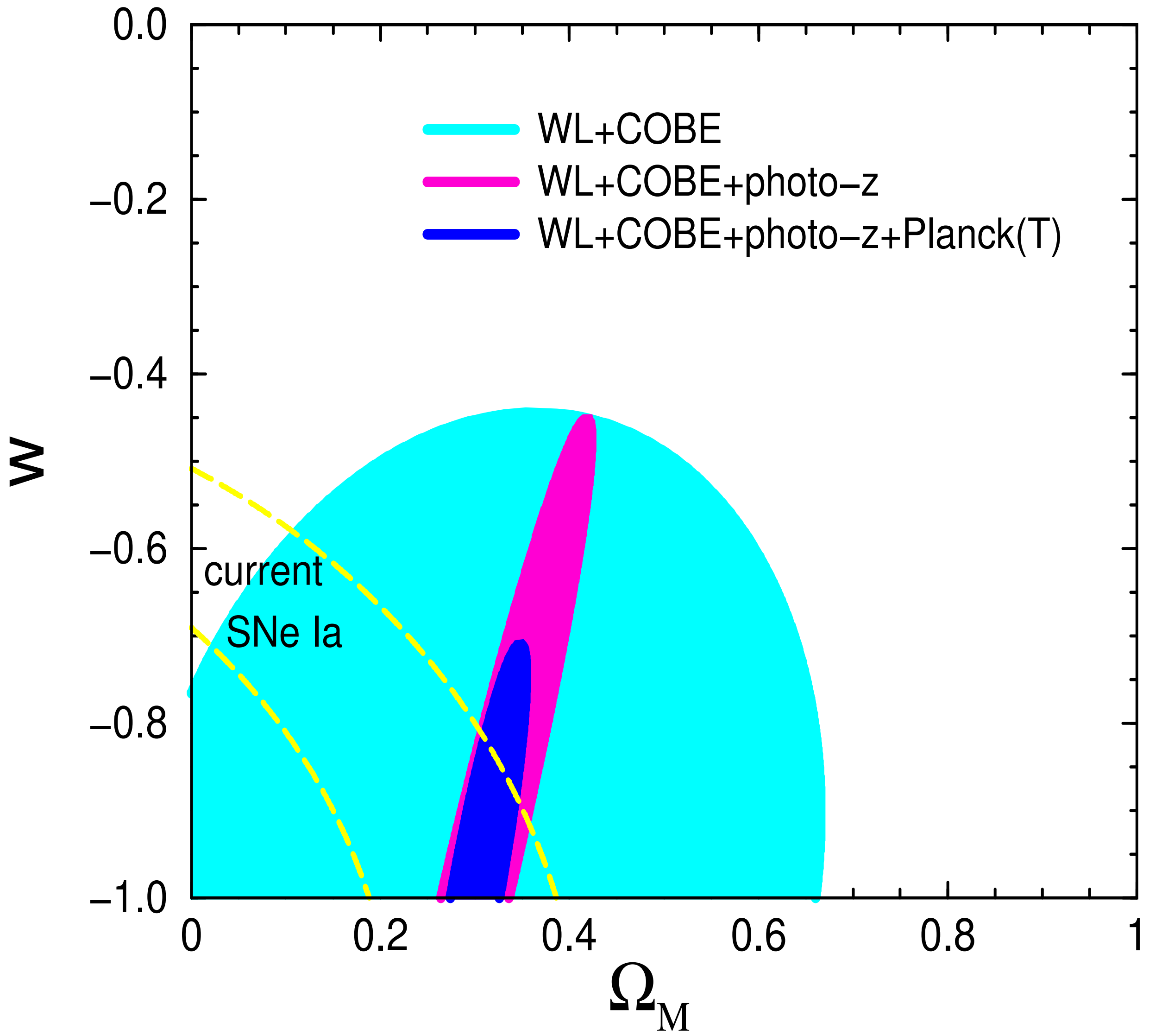
Errors: Statistical only

Gaussian priors:

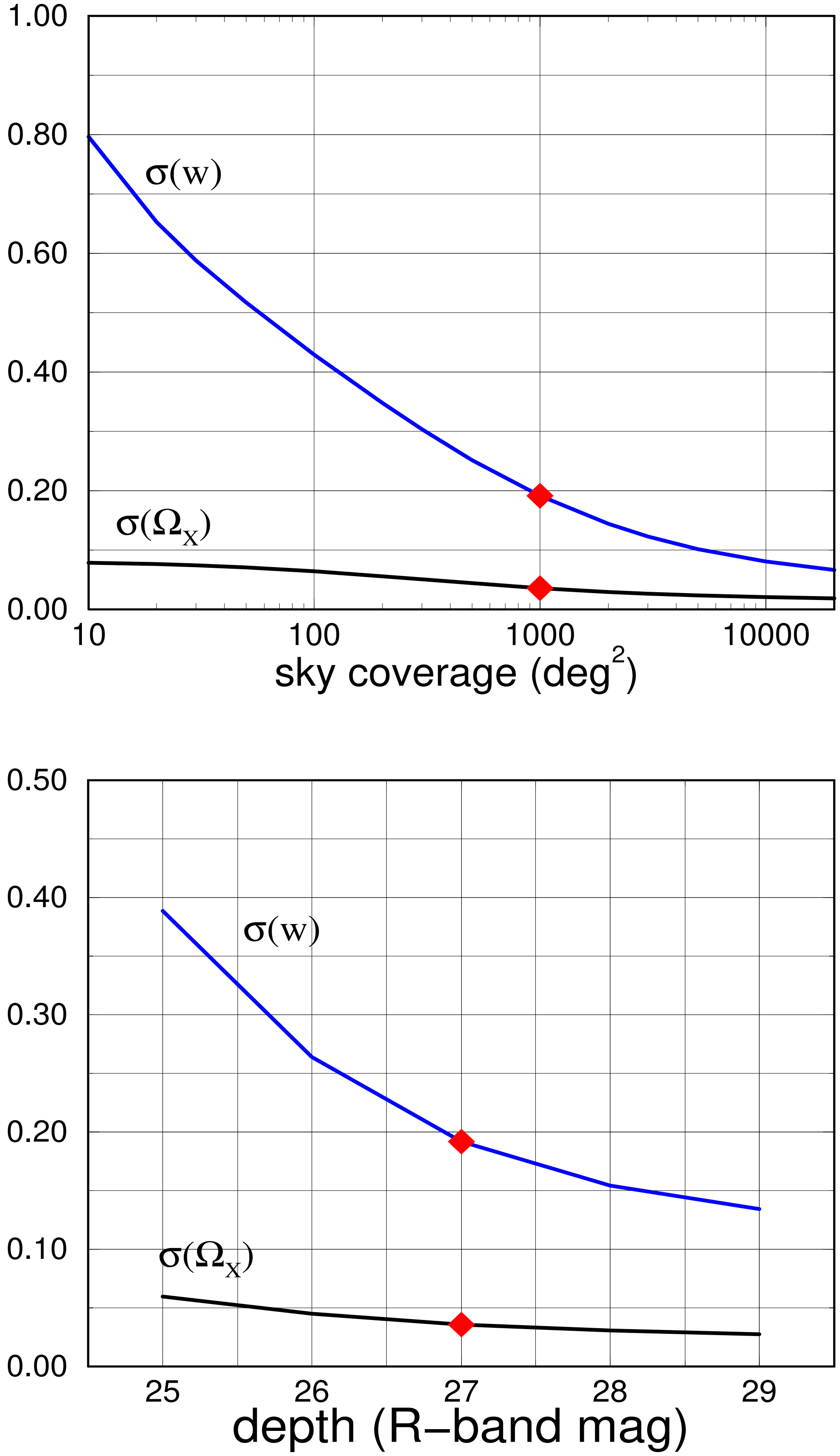
1) COBE + photo-z

2) COBE + photo-z + Planck(T)

Results



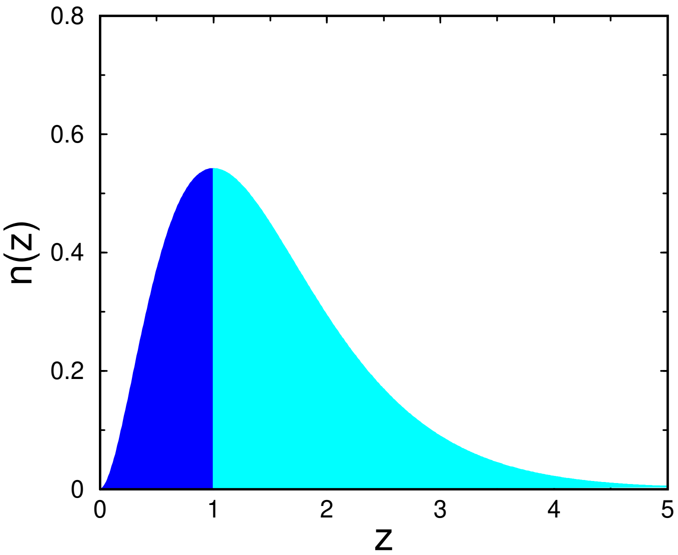
WL+COBE
WL+COBE+photo−z
WL+COBE+photo−z+Planck(T)
current
SNe Ia
w
Ω_M
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
0.2
0.4
0.6
0.8
1

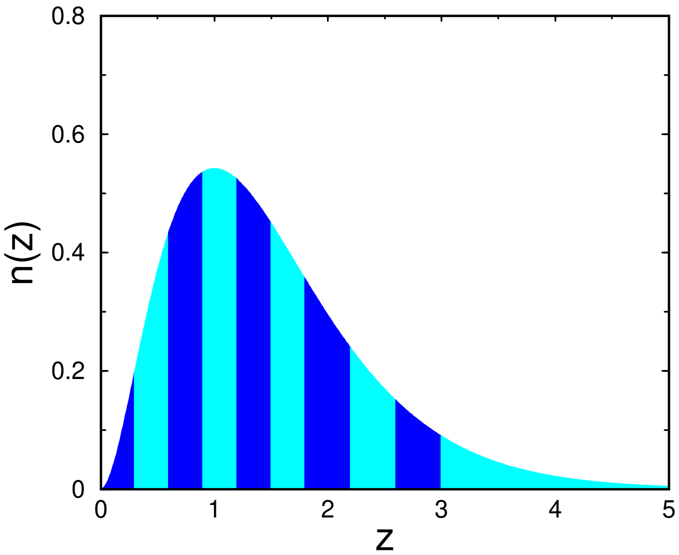


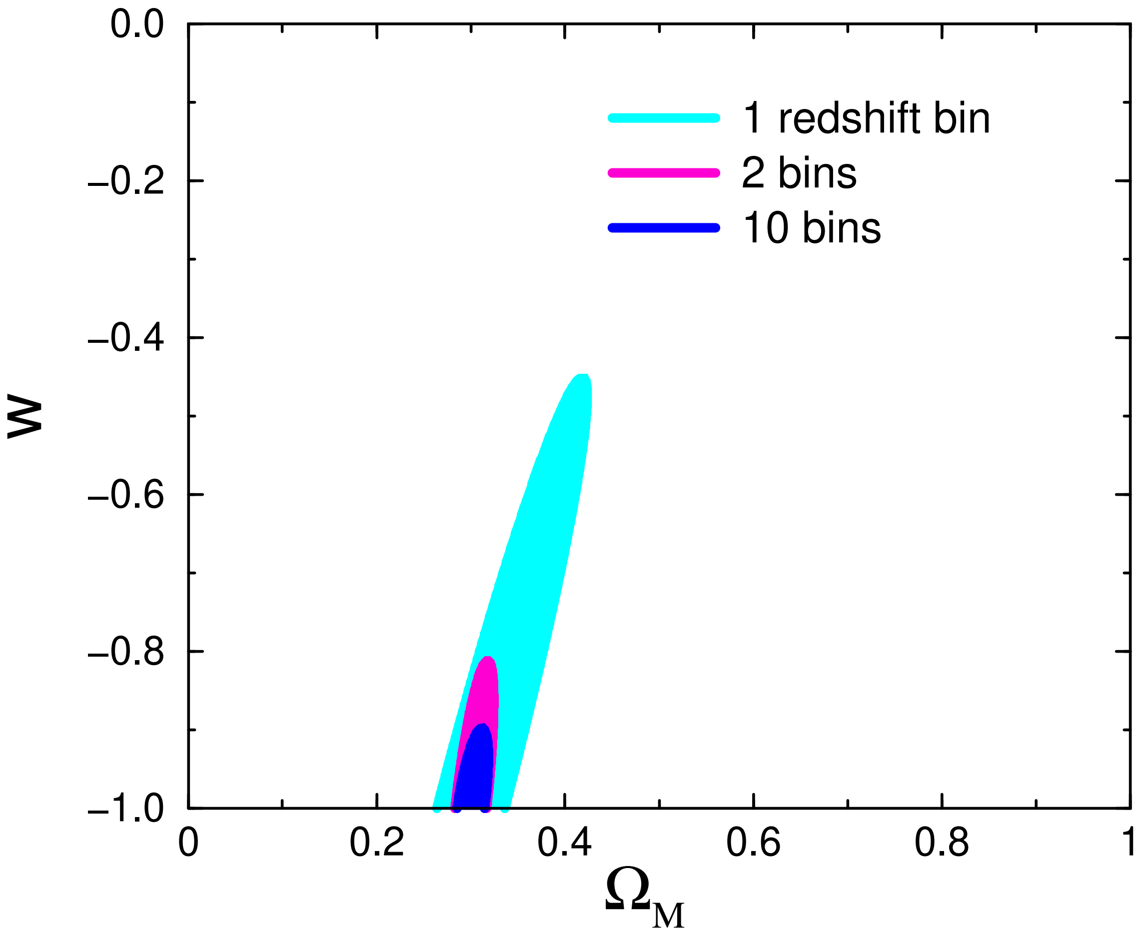
1.00
0.80
0.60
0.40
0.20
0.00
σ(w)
σ(Ω_X)
10
100
1000
10000
sky coverage (deg^2)
0.50
0.40
0.30
0.20
0.10
0.00
σ(w)
σ(Ω_X)
25
26
27
28
29
depth (R–band mag)

WL Tomography

(Hu 1999)

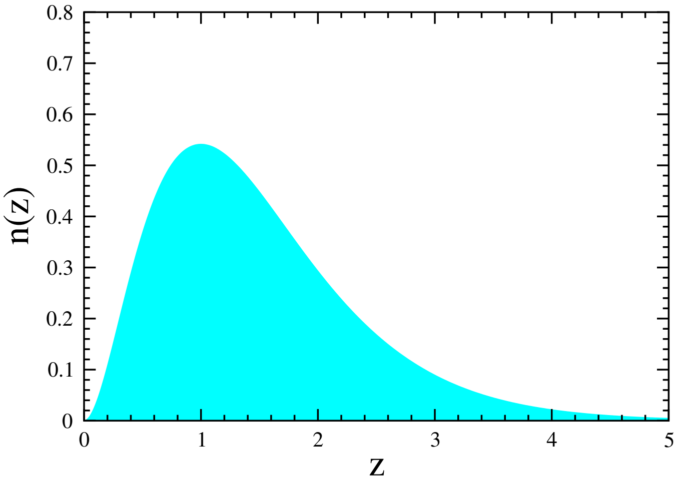




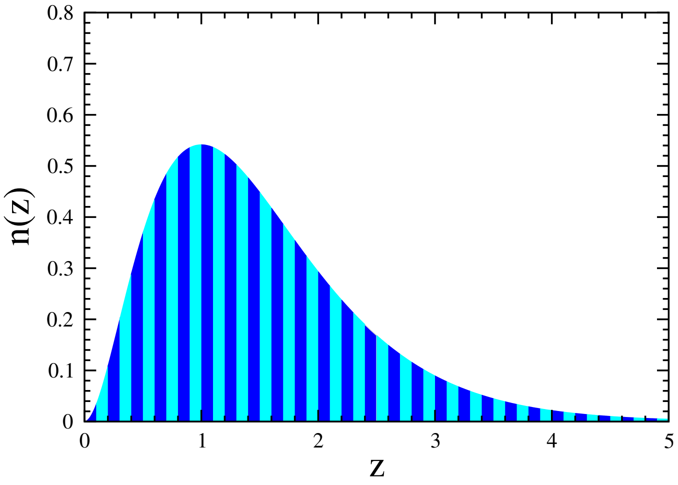


Tomography – Optimal Strategy?

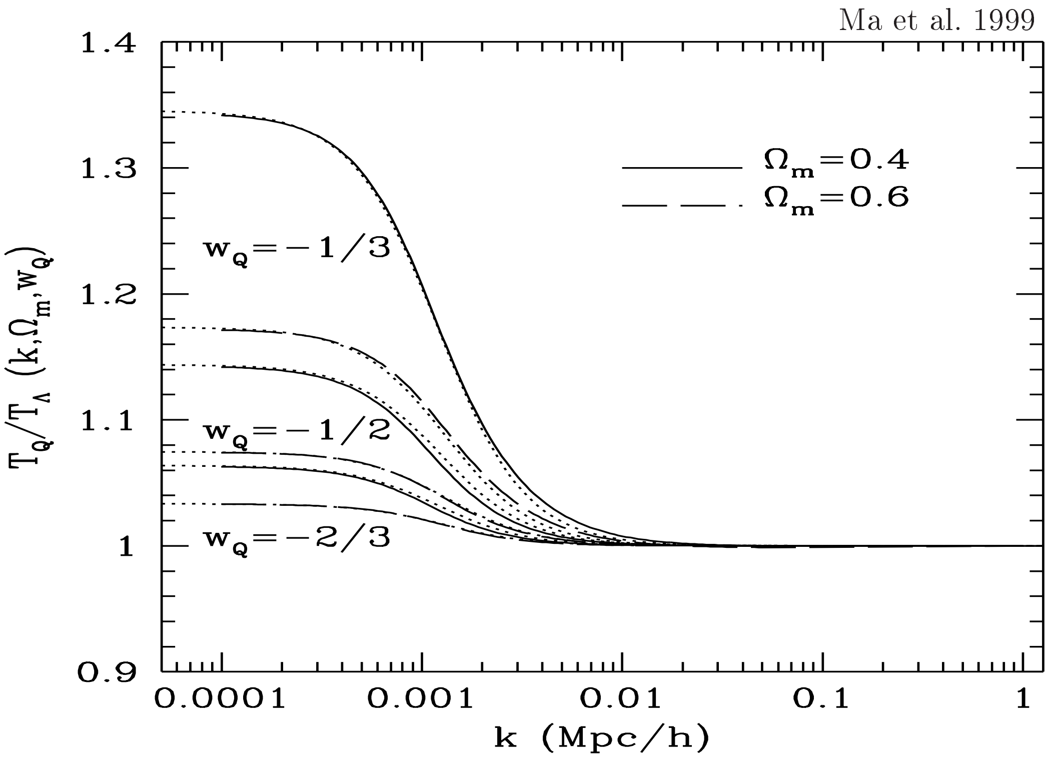
Finer divisions than in...

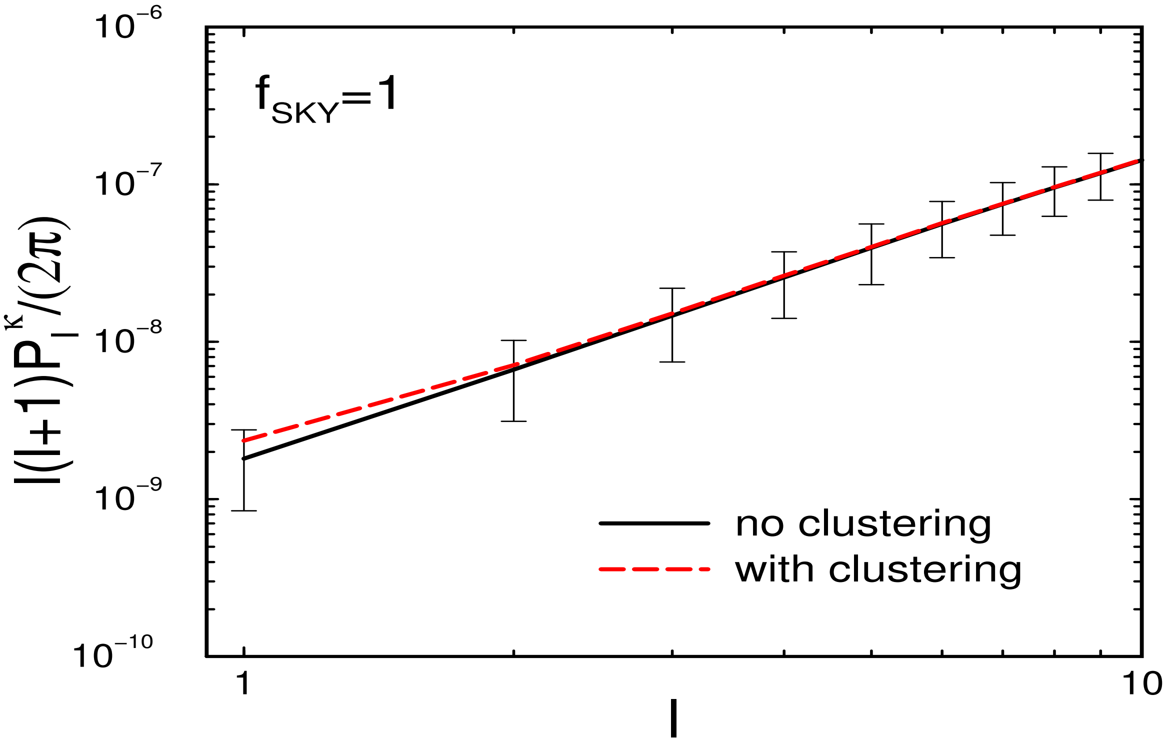


but not as ambitious as...



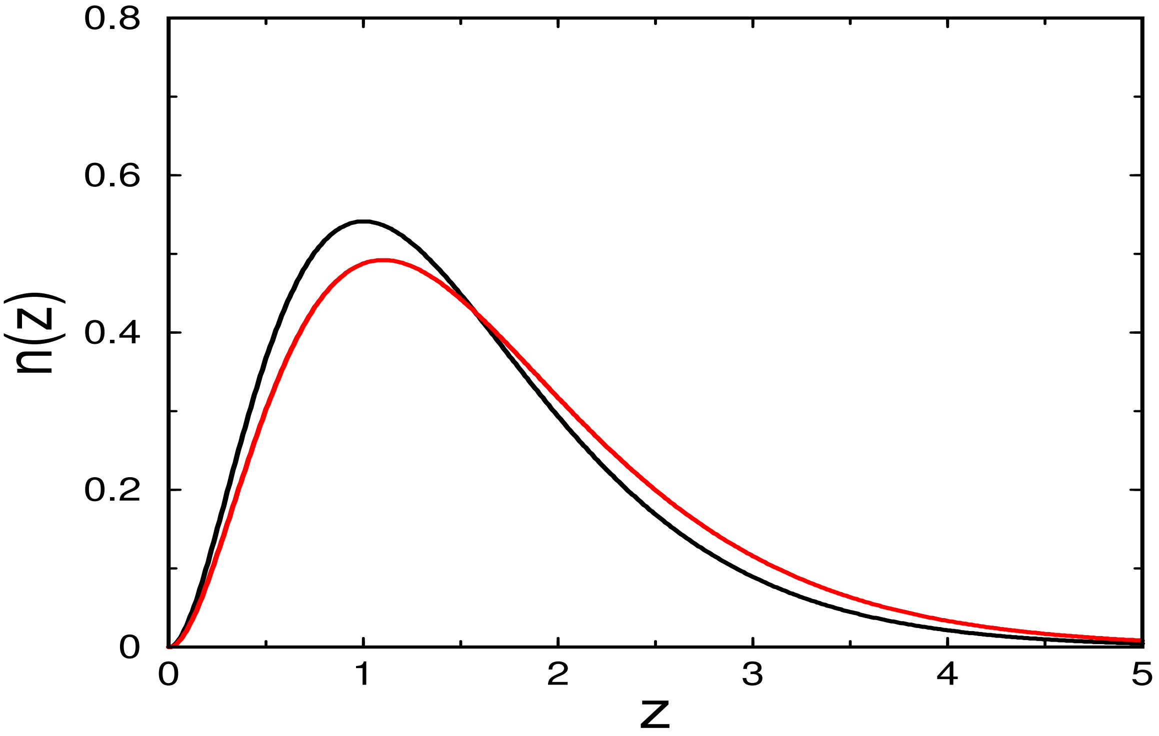
Can clustering of Dark Energy be seen in WL?





Biases: distribution of galaxies

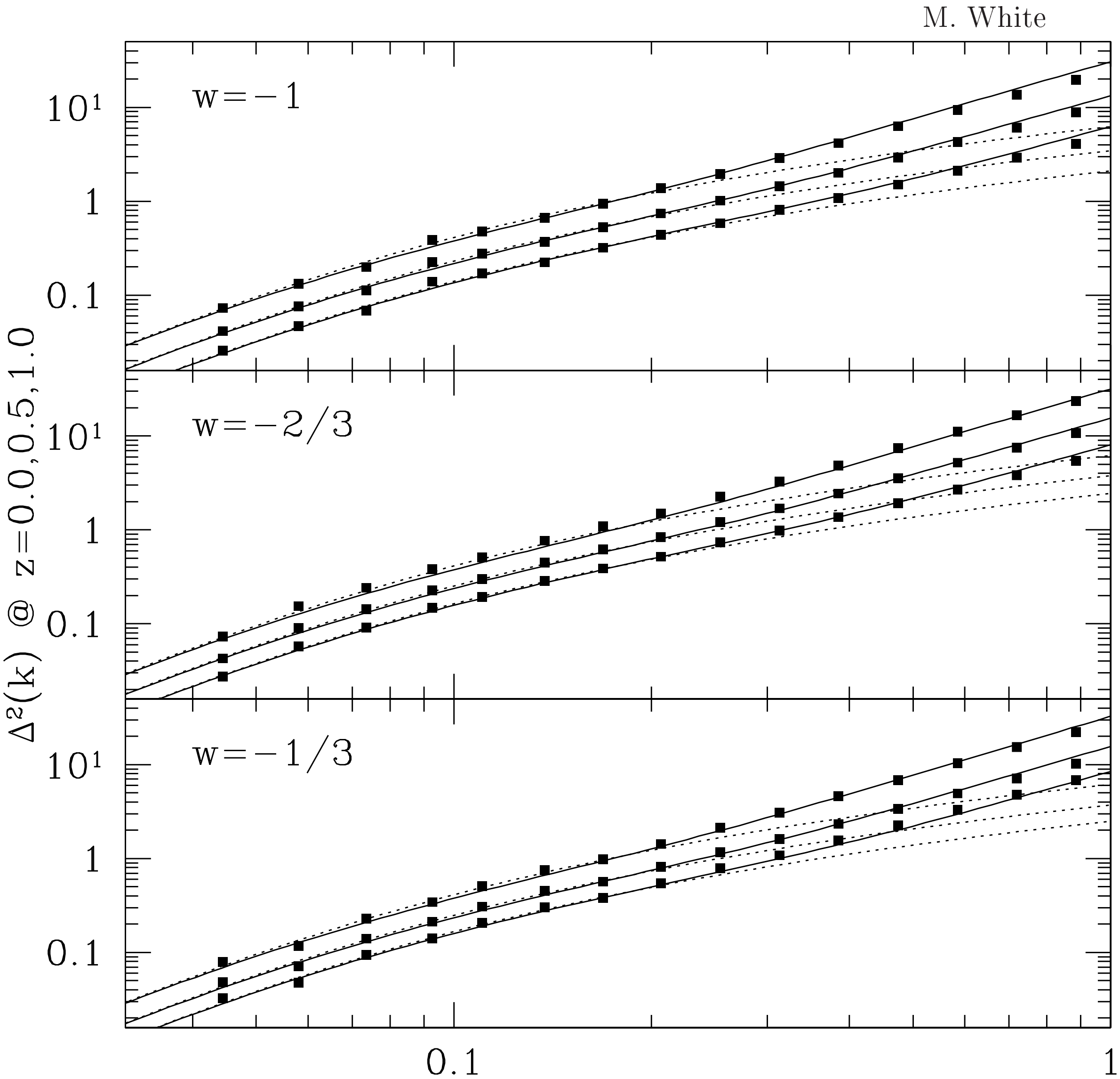
$$\delta p_i = F_{ij}^{-1} \sum_l \frac{1}{(\Delta P_l^\kappa)^2} (P_l^\kappa - \bar{P}_l^\kappa) \frac{\partial \bar{P}_l^\kappa}{\partial p_j}$$



$$|\delta \Omega_X| / \sigma(\Omega_X) \approx 1.2$$

$$|\delta w| / \sigma(w) \approx 3.0$$

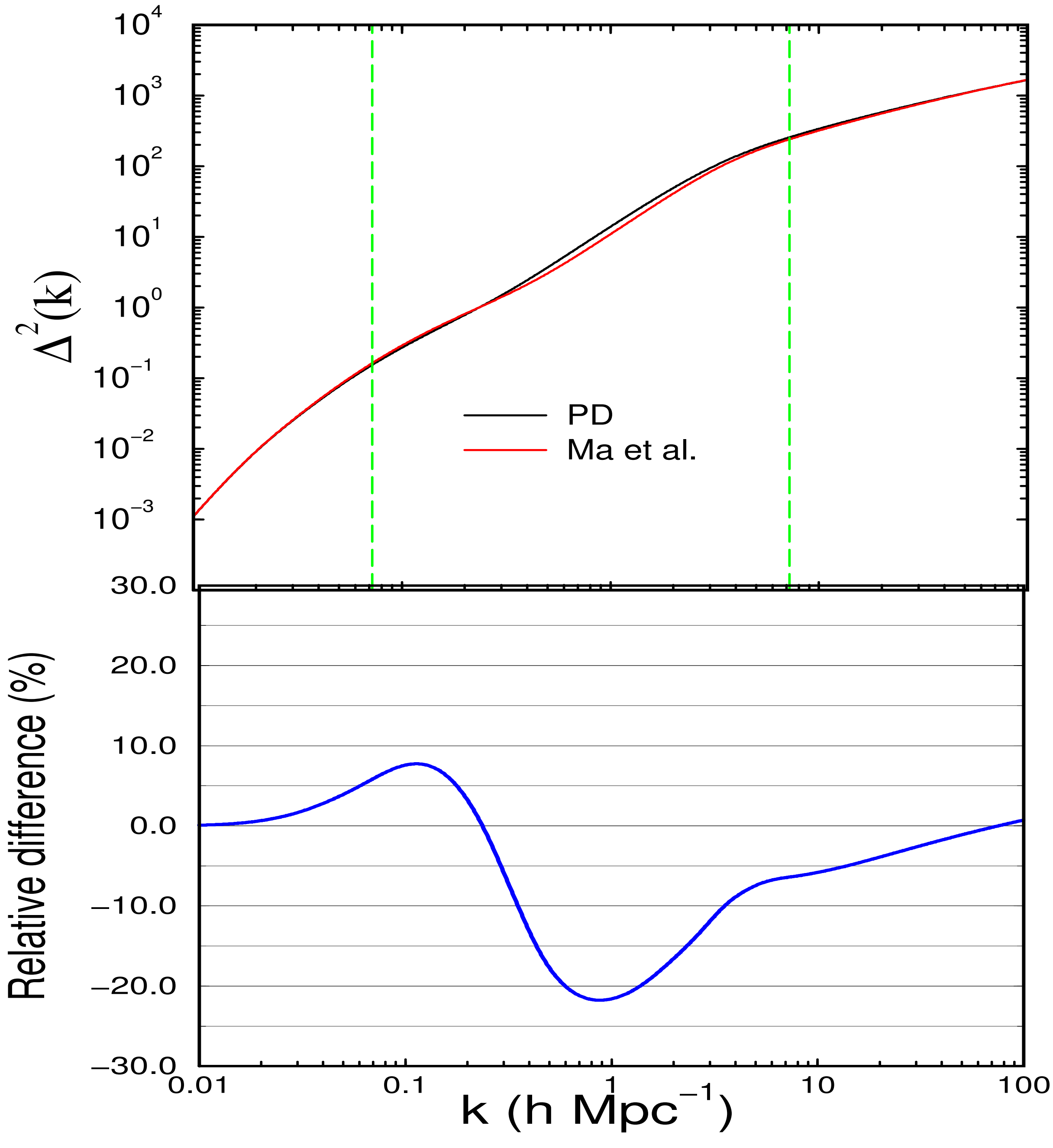
The nonlinear power spectrum (for dark-energy models)



Also:

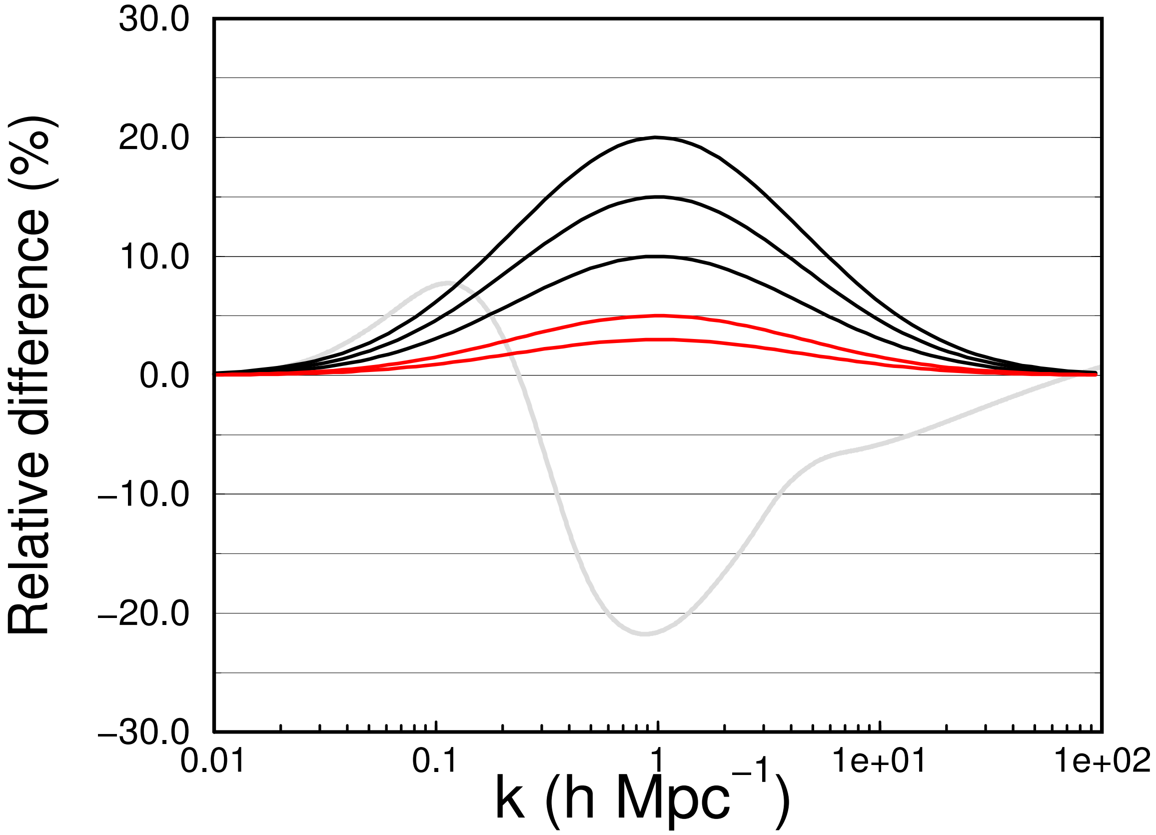
- Ma et al.(1999)
- Jain, Mo and White (1995)

Biases: Non-linear Power Spectrum



$$|\delta\Omega_X|/\sigma(\Omega_X) \sim 2.5$$

$$|\delta w|/\sigma(w) \sim 4.8$$



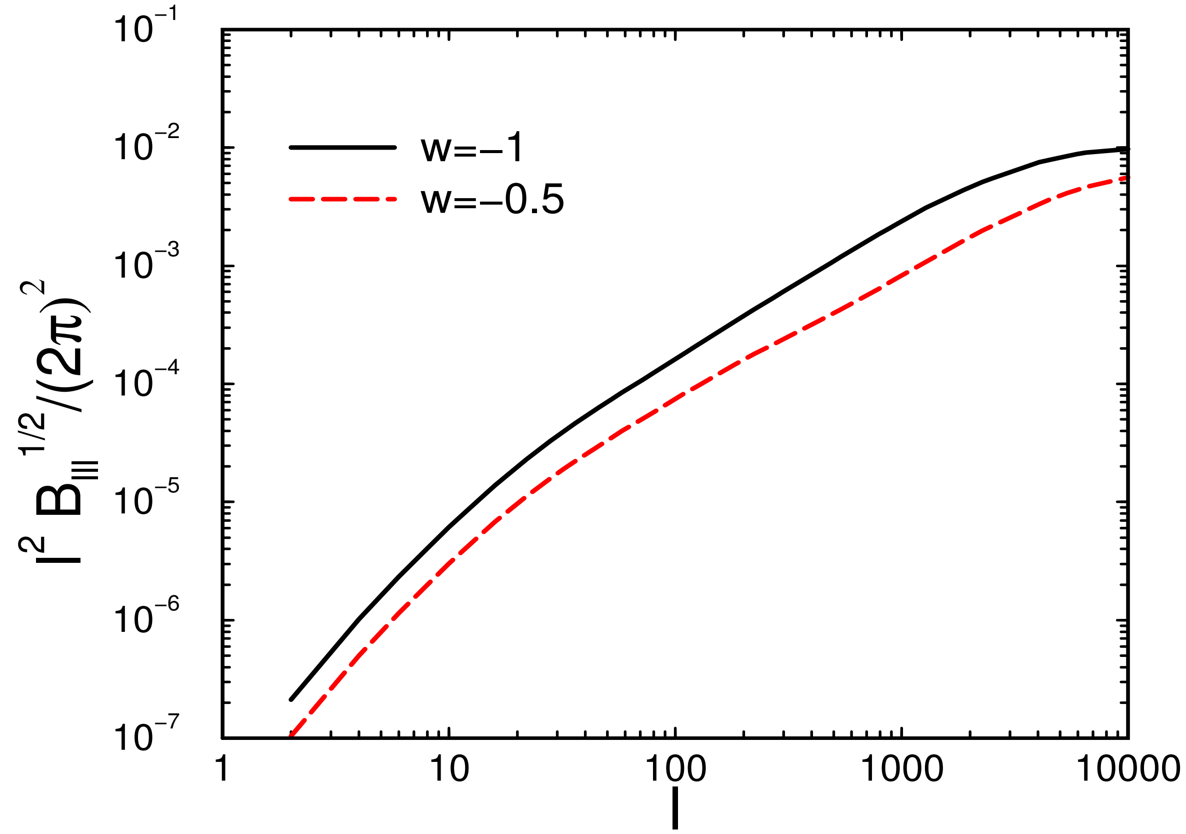
$\Rightarrow$ would like to know the non-linear power spectrum
to between 3% and 5%.

Bispectrum

$$B^{\kappa}_{l_1 l_2 l_3} \;\propto\; \langle \kappa_{l_1 m_1} \kappa_{l_2 m_2} \kappa_{l_3 m_3} \rangle \;\propto\; B(\vec{k}_1, \vec{k}_2, \vec{k}_3)$$

$$B(\vec{k}_1, \vec{k}_2, \vec{k}_3) \;=\; 2\, F_2^{eff}(\vec{k}_1, \vec{k}_2) P(k_1) P(k_2) + \text{cycl.}$$

Computable in linear and strongly nonlinear regimes; can be interpolated from simulations (Scoccimarro and Couchman, 2001).

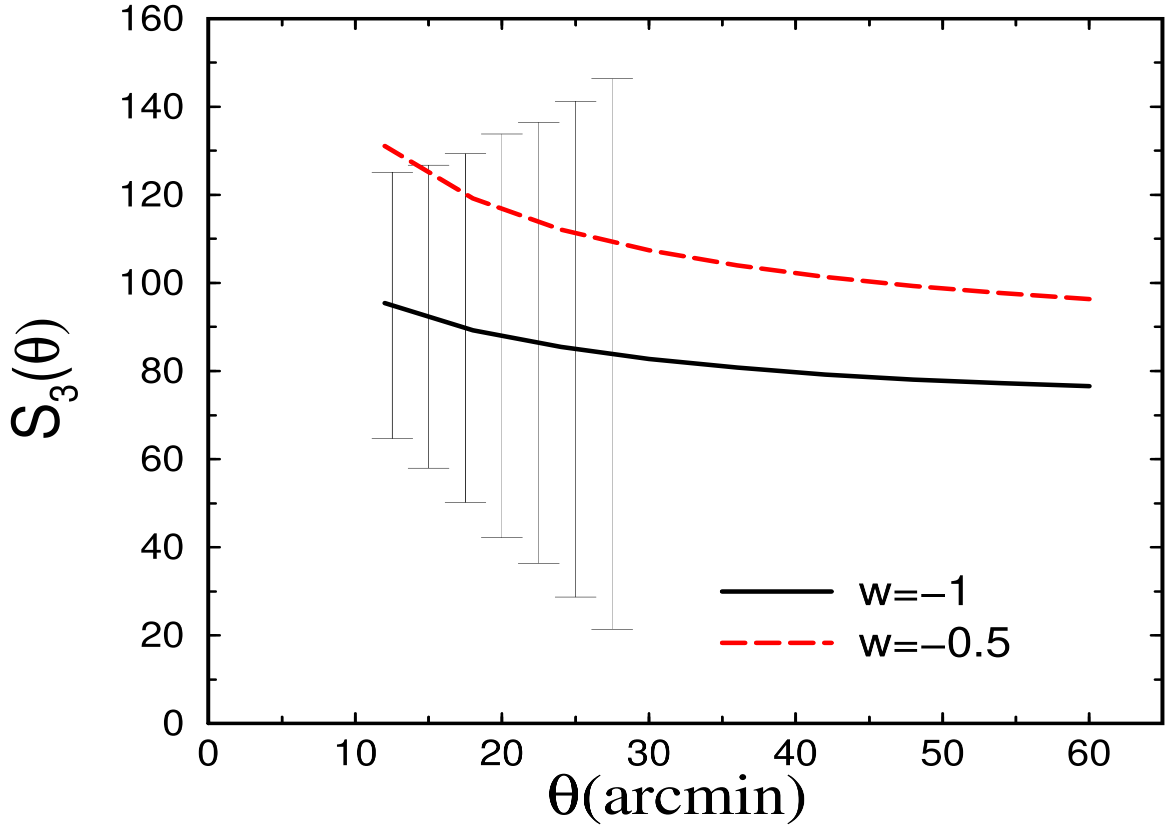


Skewness

$$S_3(\theta) = \frac{\langle \kappa^3(\theta) \rangle}{\langle \kappa^2(\theta) \rangle^2}$$

$$\langle \kappa^2(\theta) \rangle = \frac{1}{4\pi} \sum_l (2l+1) P_l^\kappa \mathcal{W}_l^2(\theta)$$

$$\langle \kappa^3(\theta) \rangle \propto \sum_{l_1 l_2 l_3} B^\kappa_{l_1 l_2 l_3} \mathcal{W}_{l_1}(\theta) \mathcal{W}_{l_2}(\theta) \mathcal{W}_{l_3}(\theta)$$



Conclusions

- WL is an indirect, but promising probe of dark energy
- However, need to know quite accurately:

  — nonlinear power spectrum (to $\sim 5\%$ accuracy)

  — galaxy redshifts

  and, of course, control systematics.
- Nonlinear physics can be probed using weak lensing observations
- Bispectrum and skewness are likely to provide additional information on dark energy