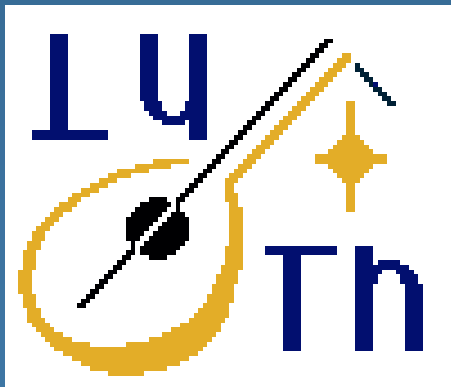


ISW-correlation: Systematic Effects and Dark Energy Parameter Inference



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Introduction

CMB-LSS correlation

$$C_{mT}(\theta) = \left\langle \frac{\Delta T}{T}(\hat{n}_1) \cdot \delta_m(\hat{n}_2) \right\rangle = \sum_l \frac{2l+1}{4\pi} X_l^{mT} P_l(\cos\vartheta)$$

Cross-power spectrum

$$X_l^{mT} = 4\pi \frac{9}{25} \int \frac{dk}{k} \Delta_R^2(k) \Delta_l^T(k) \Delta_l^m(k)$$

Ideal case for future surveys & Planck: $\sigma_{\langle w \rangle} = 0.03$ $\sigma_{\Delta w} = 0.2$

(Pogosian et al. '04)

Several contributions

$$X_l^{mT} = X_l^{ISW} + \text{direct correlations}(l) + \text{spurious correlations}(l)$$

Outline

Direct Correlations:

- CMB Point Sources, Dust Extinction, Galactic Foregrounds
- Thermal SZ
- Ostriker-Vishniac

Spurious Correlations:

- Model Dependent Selection Function
- Galaxy Bias
- Magnification Bias

WMAP Point Sources, Dust Extinction and Galactic Foregrounds

Dust Extinction:

- Residual IGM dust emission and extinction of LSS sample
- Residual cross-correlation with LSS reddening maps
- Contribution to WMAP-LSS correlation 0.23σ (Ho et al. '08)

Galactic Foregrounds:

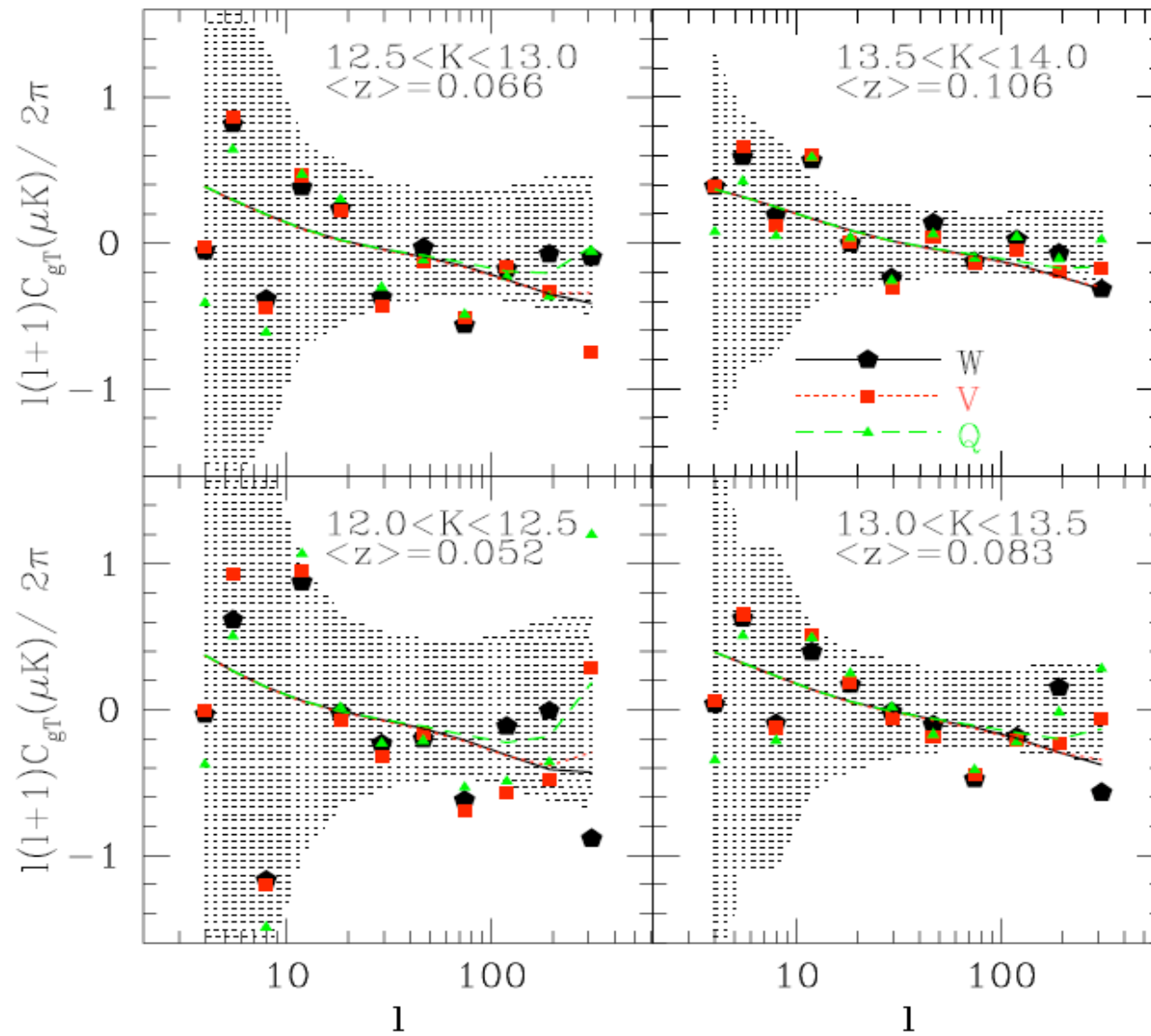
- Residual Galactic emission maps and LSS sample
- Contribution to WMAP-LSS correlation 0.66σ (Ho et al. '08)

Point Sources:

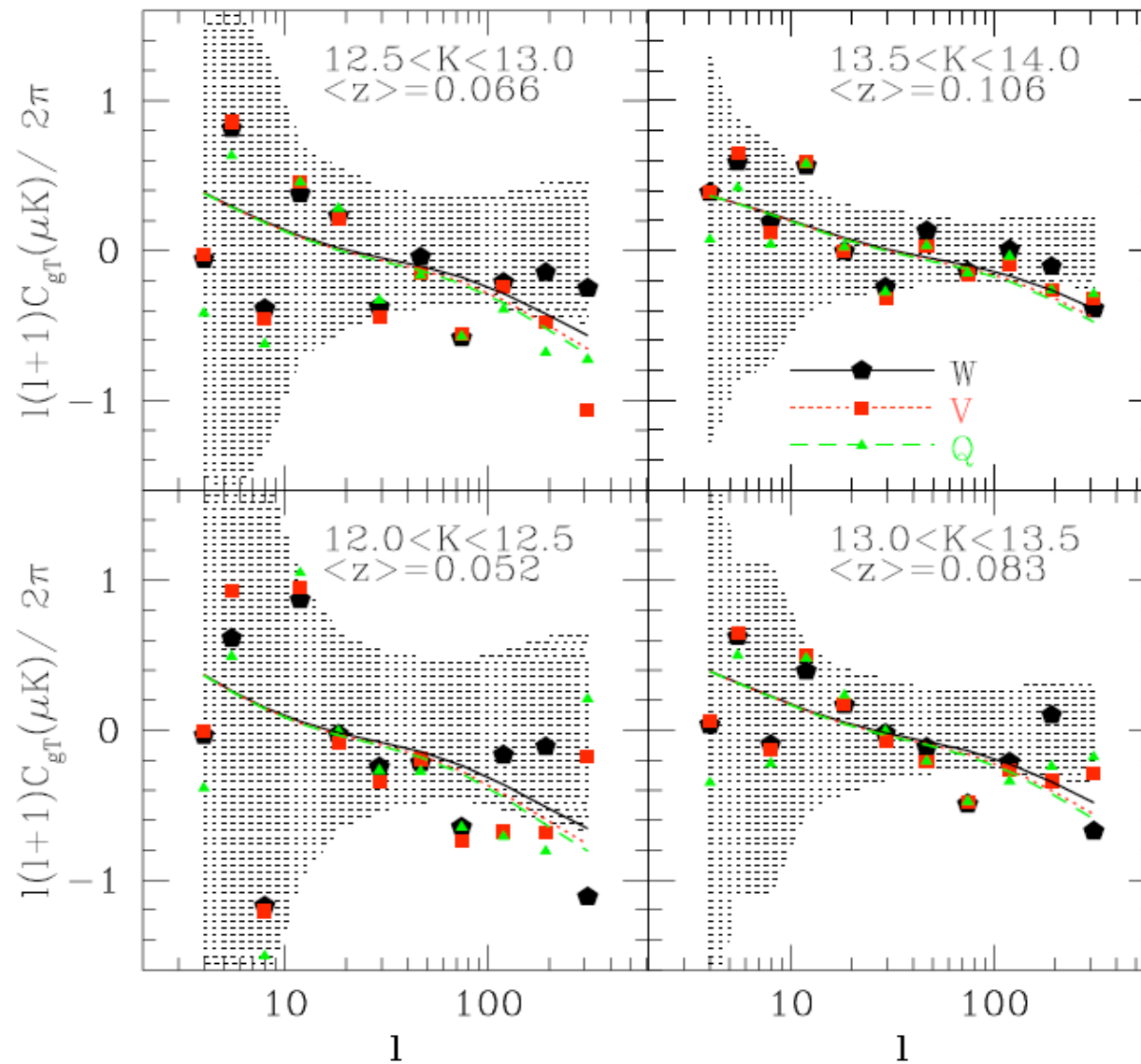
- Tracers of LSS
- Residual cross-correlation with frequency maps

$$C_l^{ps} = \frac{C_l(Ka) - C_l(V)}{r_{Ka} \nu_{Ka}^{-2} - r_V \nu_V^{-2}} \frac{r_V}{\nu_V^2}$$

- Contribution to WMAP-LSS correlation 0.49σ (Ho et al. '08)

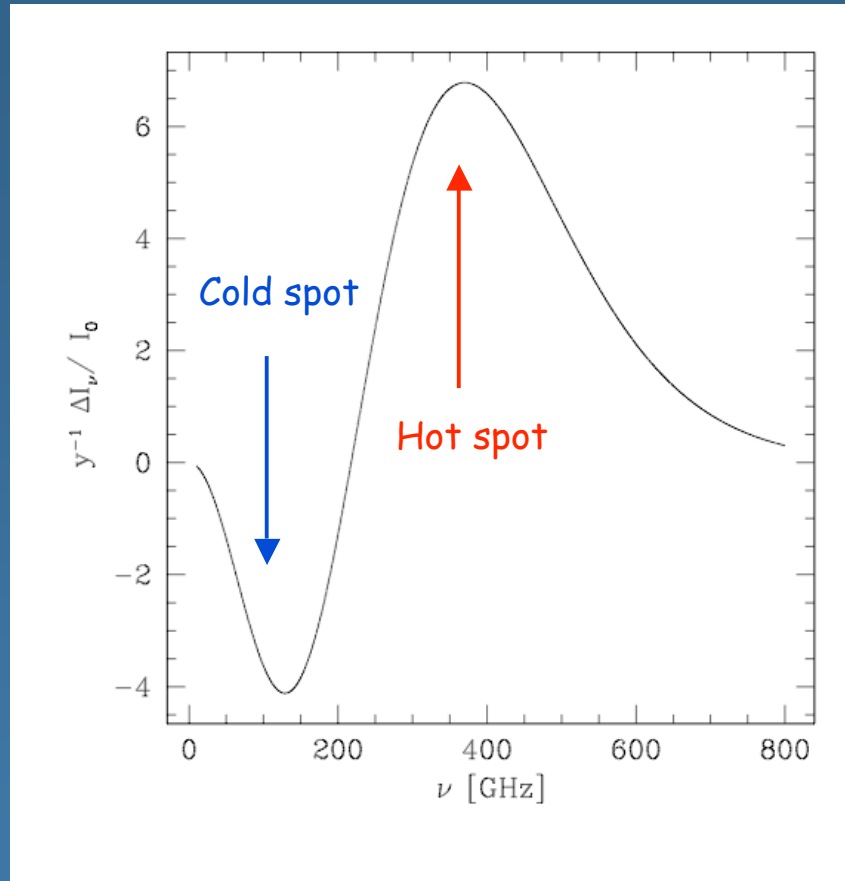


(Afshordi, Loh and Strauss '03)



(Afshordi, Loh and Strauss '03)

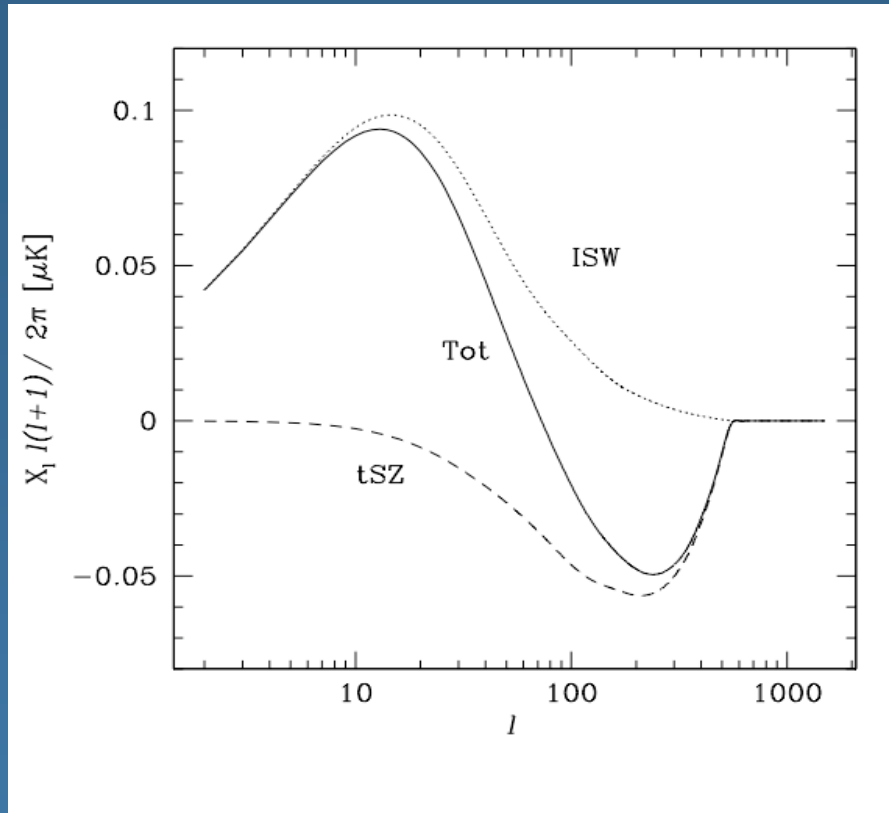
Thermal SZ-effect



- Free electrons in hot ICM gas scattering CMB photons
- Amplitude proportional to density of scatterers
- Spectral distortions inducing decrement in Rayleigh-Jeans region and excess at higher frequencies
- Cross-correlation sign is frequency dependent:
 - Decrease total cross-correlation signal in the RJ region
 - Adds power at higher frequencies

- $|C_{SZ}(\theta)| > C_{ISW}(\theta)$ on sub-degree scales
- Redshift dependence depends on cluster number evolution

Cross SZ-LSS signal



- Conservative estimate following Refregier, Spergel & Herbig '00

$$X_l^{tSZ} = -b_{gas} \bar{\Delta}_T M_l^{mm}$$

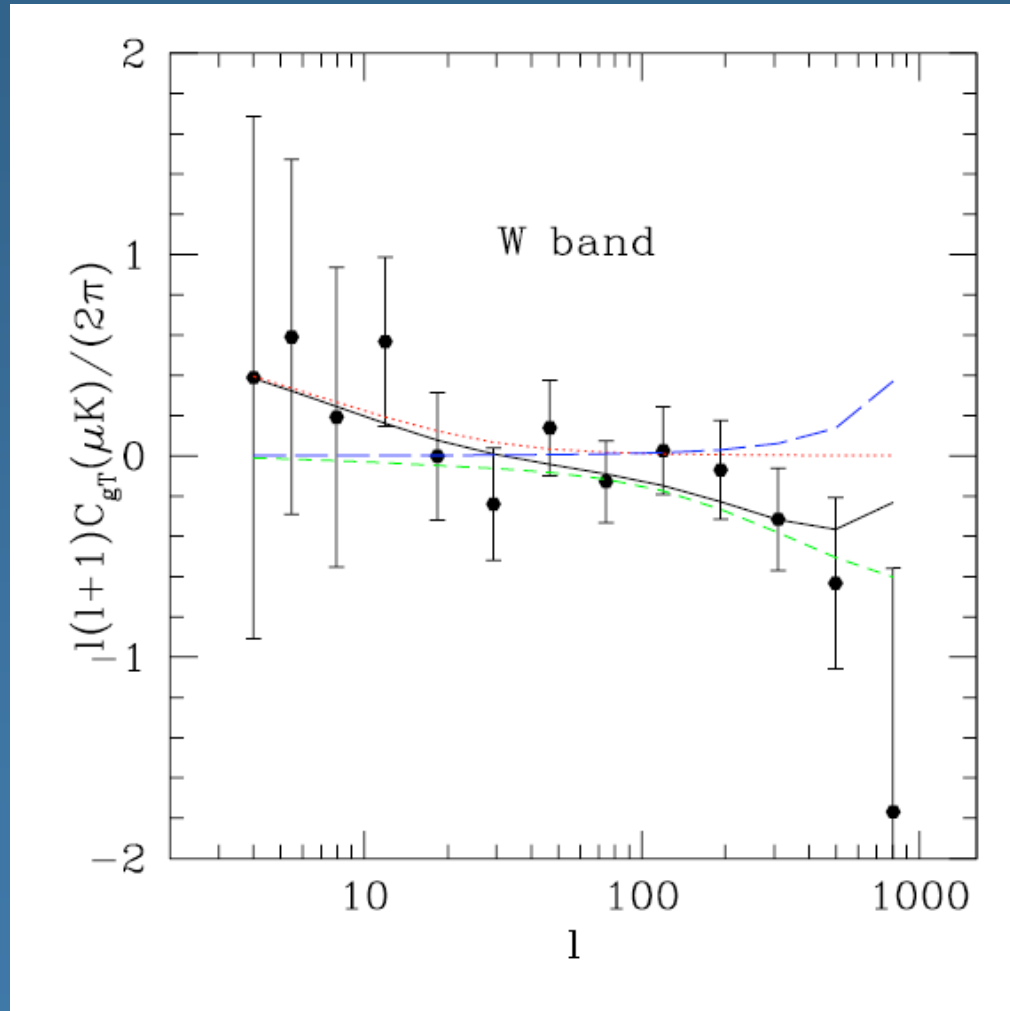
$$b_{gas} = 2 \quad \Delta_T = 6.6 \mu\text{K}$$

- Cross_CMBFAST evaluation:
 - LCDM fiducial cosmology
 - Redshift bin: $z = 0.8$
 $\sigma = 0.02$

Limiting the biasing effect:

- Smooth CMB maps on sub-degree scales
- Test for frequency dependence of the cross-correlation

tSZ in WMAP-2MASS correlation



(Afshordi, Loh and Strauss '03)

Inferred limits:

$$b_{gas} \bar{\Delta}_T = 1.04 \pm 0.33 \text{ keV}$$

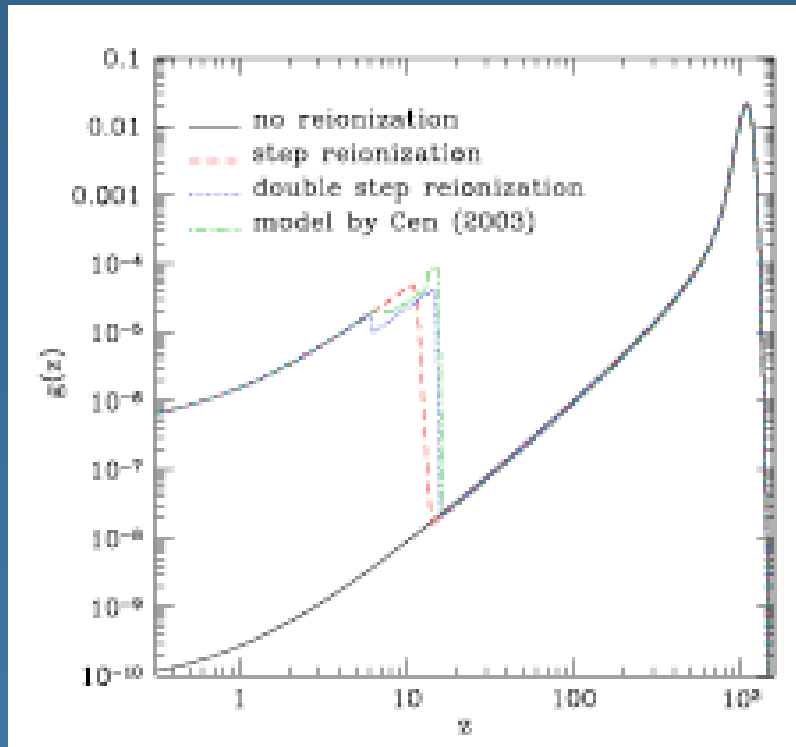
3.1σ detection

WMAP-APM/SDSS:

$$\bar{y} \cong 10^{-6} \quad 2.7\sigma \text{ detection}$$

(Fosalba, Gaztanaga and Castander '03)

Ostriker-Vishniac effect



- Scattering of CMB photons after reionization on free electrons moving along large scale velocity fields
- Evolution of the visibility function, more scatterers at high-z than low-z
- Doppler induced anisotropies

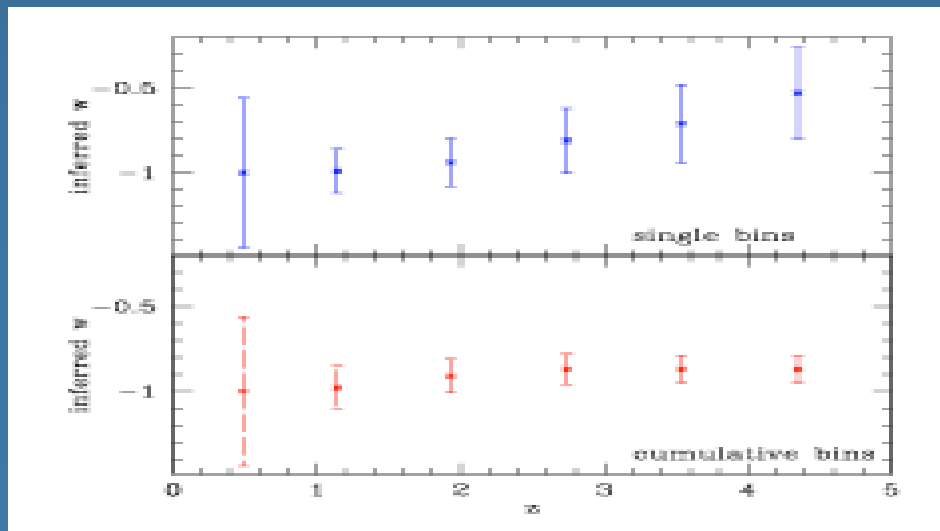
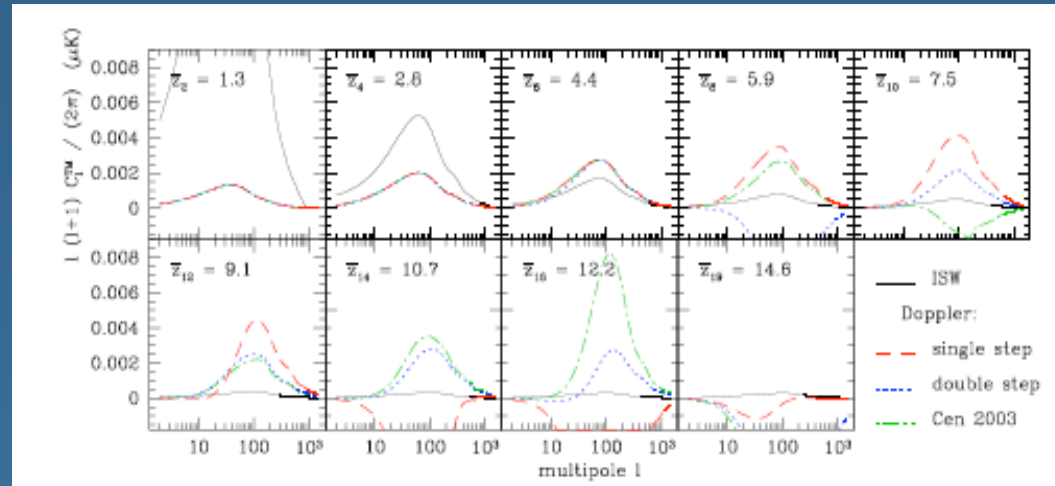
$$\frac{\Delta T}{T}(\hat{n}) = - \int_{\eta_i}^{\eta_0} g(\eta) \mathbf{v}[(\eta_0 - \eta)\hat{n}, \eta] \cdot \hat{n} d\eta$$

- velocity fields tracing matter distribution

(Giannantonio & Crittenden '07)

OV cross-correlation signal

- Increases correlation signal at high- z
- Amplitude and sign of the correlation are reionization model dependent



Fisher Matrix Analysis:

- Biasing the inferred values of w in high redshift bins

(Giannantonio & Crittenden '07)

LSS source bias: the WMAP-NVSS case

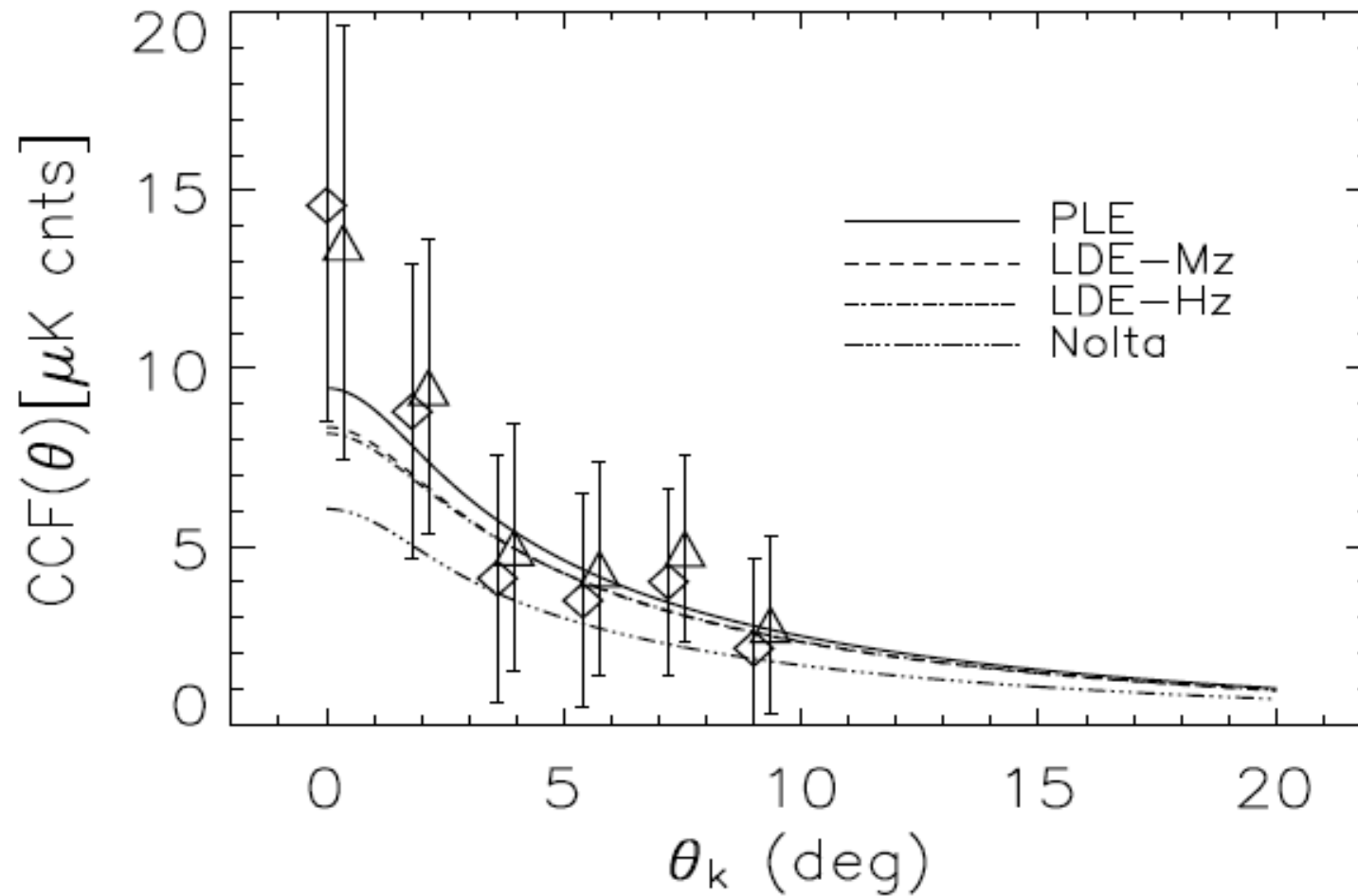
- NVSS radio survey, currently largest sky coverage
- Redshifts known only for a small fraction of sources
- Selection function inferred through modeling:
 - Dunlop & Peacock (1990) model reproduce the observed 2-point auto-correlation function
 - Inconsistent with recent measurements of the local luminosity function of NVSS sources
- key factor: **bias evolution of radio sources**
- 2-point NVSS correlation and luminosity function can be reproduced if:
 - local sources are rare resides in most massive halos (clusters)
 - abundance increase with z , host halos of smaller mass

What consequences for the WMAP-NVSS correlation?

- Cross-correlation signal enhanced at large angular scales
- No more 2σ excess over WMAP-LCDM model as found in Ho et al. '08

(Raccanelli et al. '07)

WMAP-NVSS Cross-Correlation

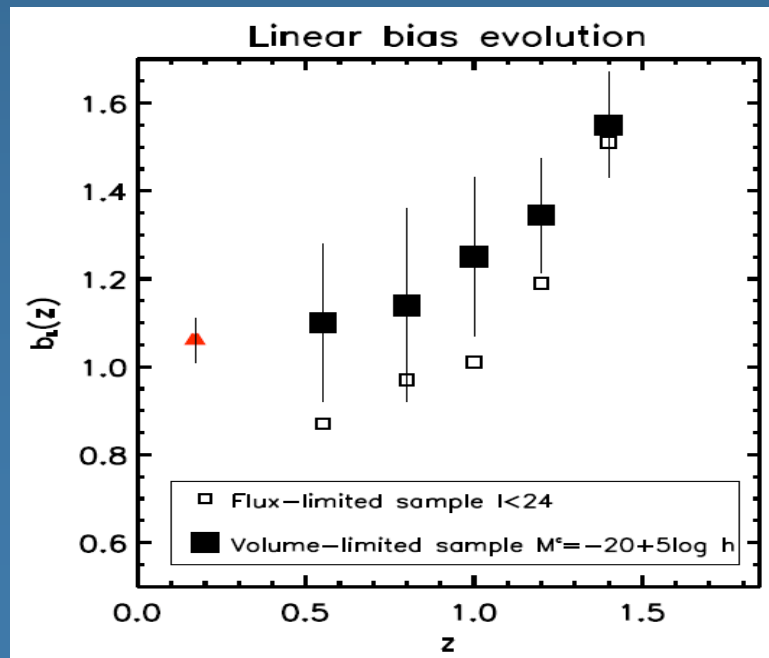


(Raccanelli et al. '07)

Galaxy Bias Evolution

- Galaxies are a biased tracer of mass distribution
- Bias can be luminosity, color, scale and redshift dependent
- b measurements are cosmology model dependent
- Little information about bias evolution, needs large redshift surveys with uniform selection criteria

$$\delta_g = b\delta_m$$



VIMOS-VLT Deep Survey:

- 0.4×0.4 deg and $0.4 < z < 1.5$
- Assuming $P_g(\delta_g)d\delta_g = P_m(\delta_m)d\delta_m$ and confronting the observed $P_g(\delta_g)$ with $P_m(\delta_m)$ from simulations:

$$b_L = 1 + (0.03 \pm 0.01)(1 + z)^{3.3 \pm 0.6}$$

(Marinoni et al. '05)

Biassing the ISW-correlation signal

$$\delta_g(\hat{n}) = \int dz b(z) \frac{dN}{dz}(z) \delta_m(\hat{n}, z)$$

- Bias modifies cross-correlation integral

- Cross_CMBFAST evaluation:

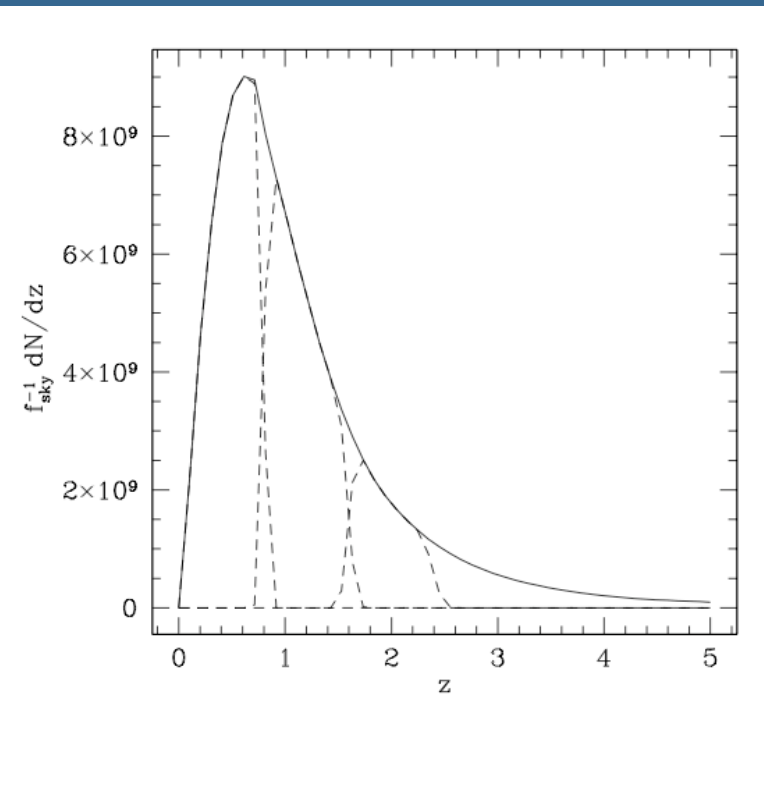
- LCDM fiducial cosmology
- VVDS measured bias evolution
- LSST-like survey configuration:

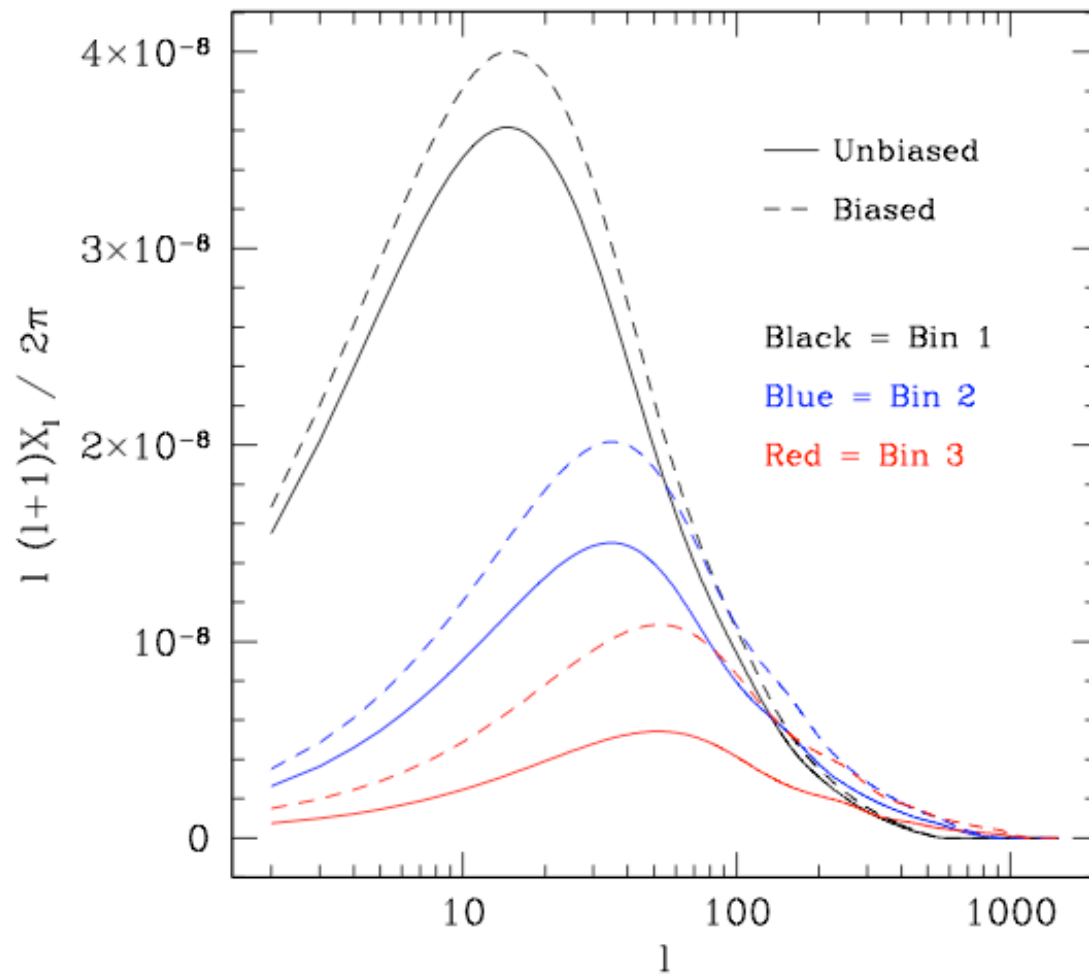
- $n_g = 80$ galaxies/ arcmin²

- 3 redshift bins with:

$$z_{i\text{-th}} = 0.8 * i\text{-th bin}$$

$$\sigma(z) = 0.02(1+z)$$

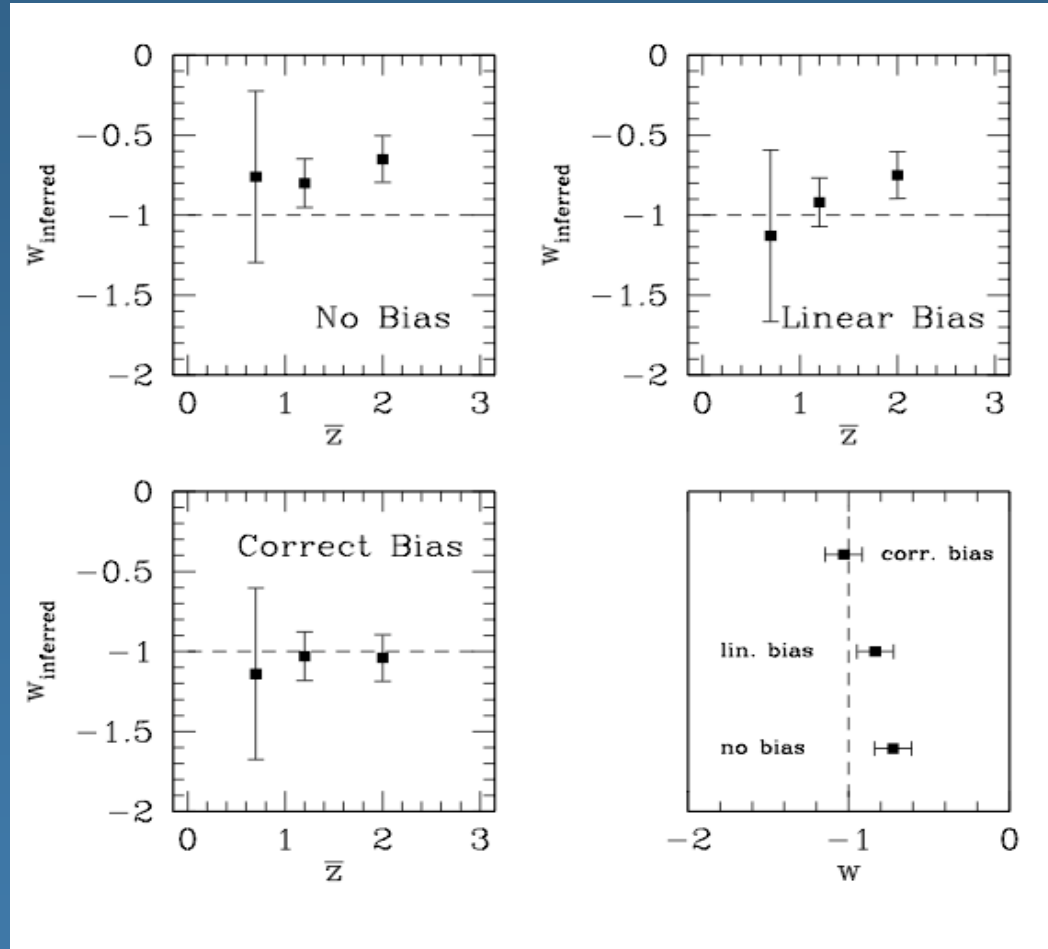




Bias Effect:

- Bias evolution systematically enhance cross-correlation signal
- For the fiducial model bias the effects increases with redshift
- Can mimic non-LCDM dark energy models

Model bias uncertainties and DE inference



Fisher Matrix Analysis

- LCDM fiducial cosmology
 - VVDS bias
- vs
- no bias
 - linearly evolving bias
- $b(z)=1+0.03(1+z)$
- correct fiducial model bias

- Measuring $X_l^{gT} / \sqrt{M_l^{gg}}$ may not help
- We observe $\delta n/n$

$$\frac{\delta n}{n}(\hat{n}) \neq \delta_g(\hat{n})$$

Lensing Magnification Bias

Volume Limited Surveys

- Lensing alters survey sky patch observed \Rightarrow changes apparent #-density
- At a given redshift faint galaxies are magnified above survey threshold and viceversa

$$\frac{\delta n}{n}(\hat{n}) = \delta_g(\hat{n}) + \delta_\mu(\hat{n}) \quad \longrightarrow \quad X_l^{nT} = X_l^{gT} + X_l^{\mu T}$$

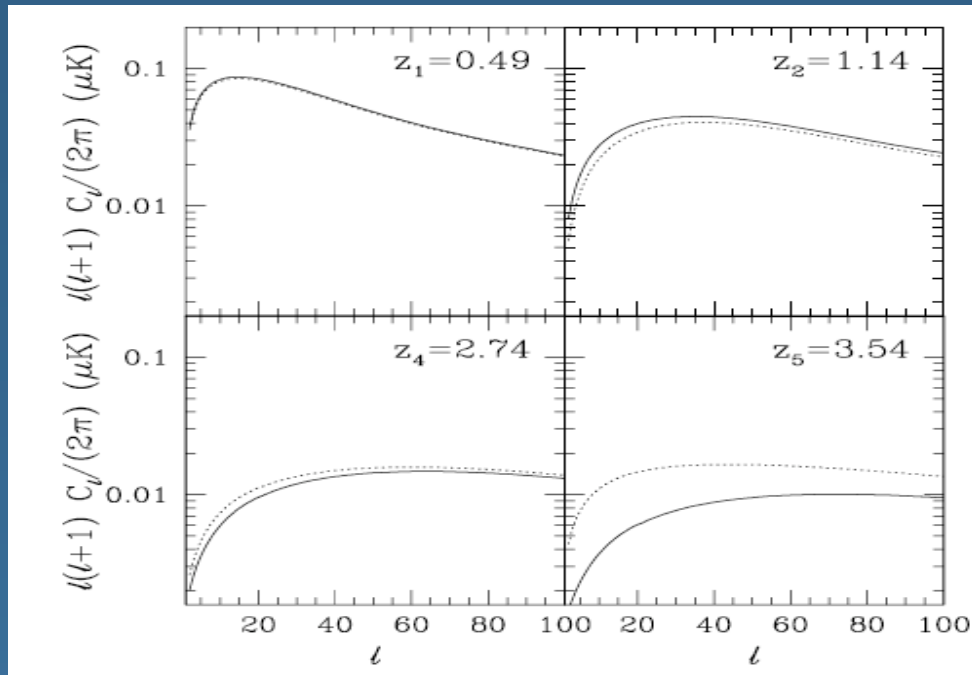
$$\delta_\mu(\hat{n}, z_i) = 3\Omega_m \frac{H_0^2}{c^2} [2.5s(z_i) - 1] \int \frac{cdz}{H(z)} g(z, z_i) (1+z) \delta_m(r(z)\hat{n}, z)$$

$$g(z, z_i) = r(z) \int_z^\infty dz' \frac{r(z') - r(z)}{r(z')} W(z', z_i)$$

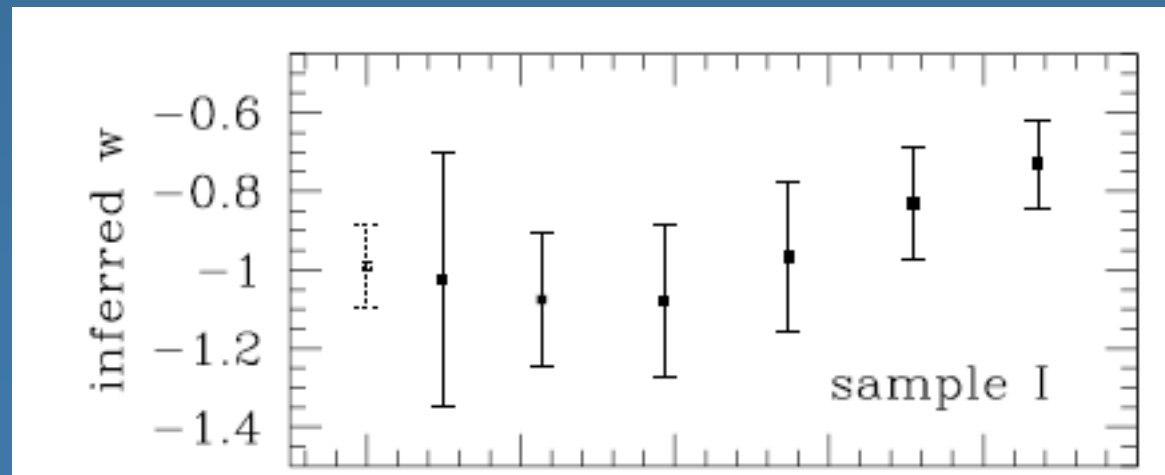
$$s \equiv \frac{d \log_{10} N(< m)}{dm}$$

- Contribution can be positive or negative depending on $s(z)$
- $m < 28$ transition occurs at low-redshift
- Bias effect adds cross-power in high-redshift bins

(LoVerde, Hui and Gaztanaga '06)



- X_l^{gT} (solid) vs $X_l^{gT} + X_l^{\mu T}$ (dot)
- Affects DE parameter inference

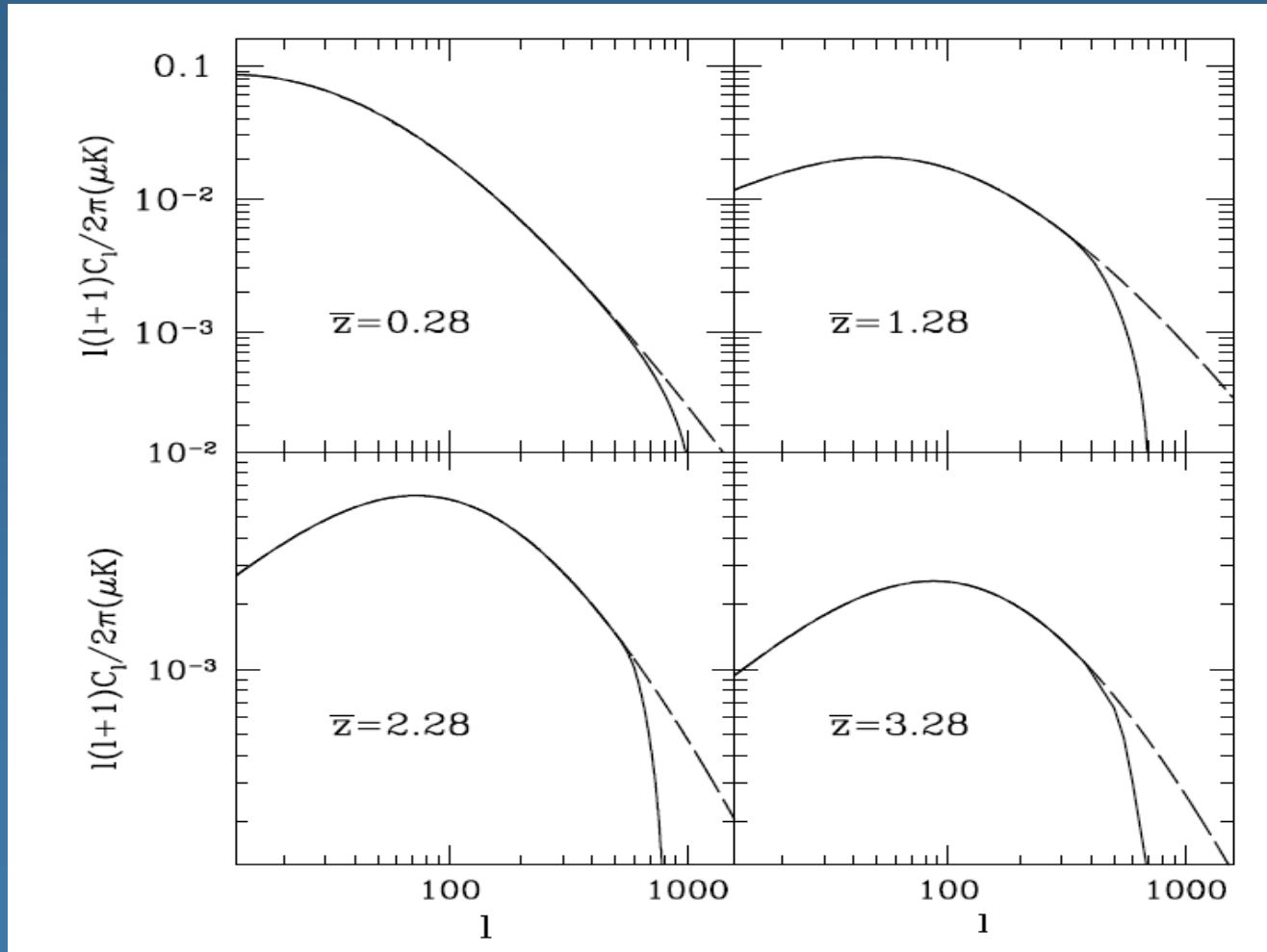


(LoVerde, Hui and Gaztanaga '06)

Conclusions

- CMB/LSS correlation provides unique and complementary information on DE/ModG through the ISW-effect
- Many other mechanisms can contribute to this correlation:
 - tSZ
 - OV-effect
 - Galaxy Bias
 - Magnification Bias
- These are of astrophysical origin, but depends on cosmology as well
- Subdominant on the angular scale of the ISW at low-z, while dominant at higher redshifts
- They can bias the dark energy parameter inference
- Better understanding and modeling of these effects is needed, but to be used for DE constraints keep an open mind about their cosmological dependencies as well

Non-Linear Corrections to $P(k)$



(Cai, Cole, Jenkins & Frenk '08)