Luminous Red Galaxies +WMAP

ISW & Lensing

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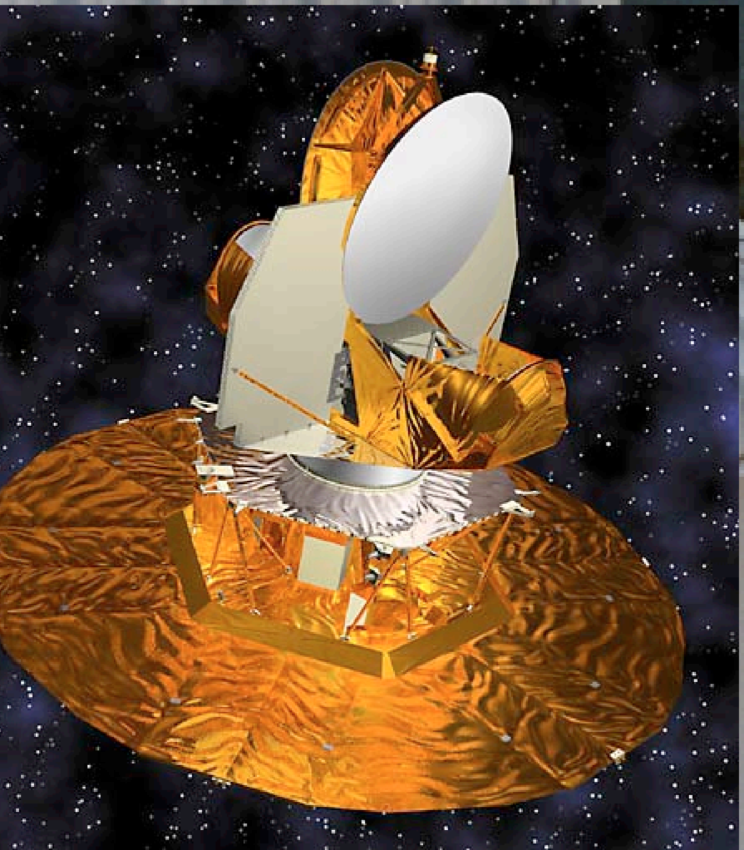
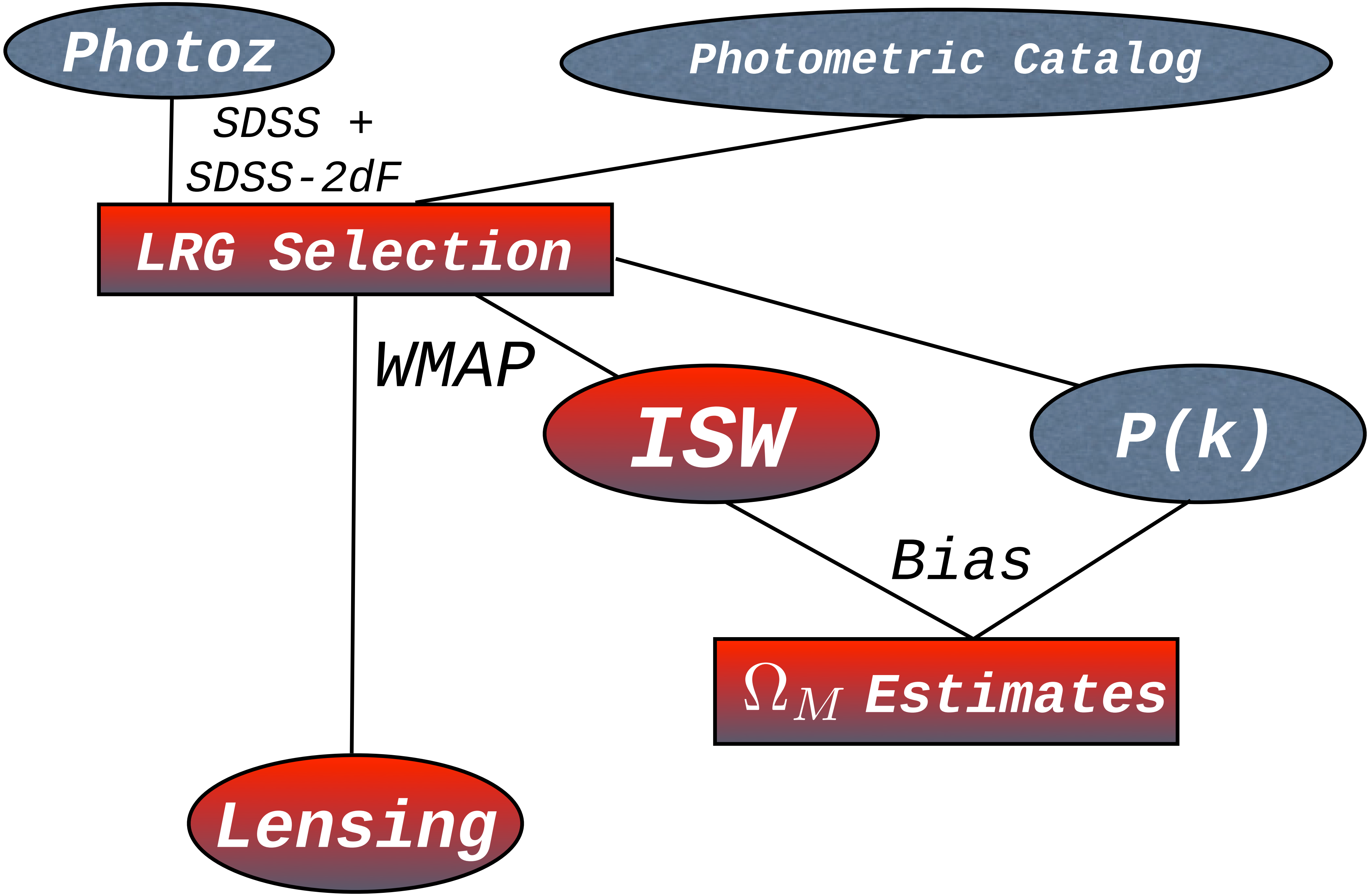


Fig:map.gsfc.nasa.gov

Cosmology with LRGs : An outline



The ISW Effect : Introduction

$$\left(\frac{\Delta T}{T}\right)_{ISW} = -2\int_0^{r_0} dr\,\dot{\Phi}$$

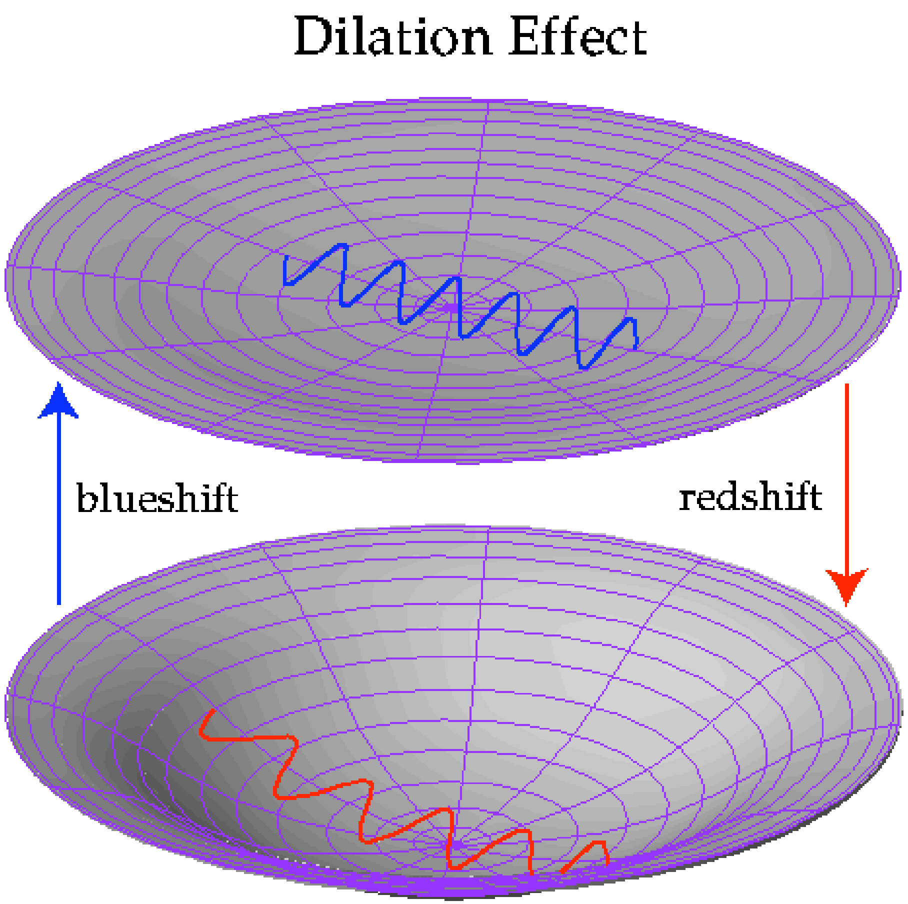


Fig: Wayne Hu

$$\Phi(k) \propto \frac{D(r)}{a(r)}\frac{\delta(k)}{k^2}$$

For matter domination :

$$D(r) \propto a(r)$$

No ISW!!!

The ISW Effect : Cross Correlation

Linear bias : $\delta_g = b\delta$

Projection : $\delta_g(\hat{n}) = \int dy\, y^2 \phi(y) \delta_g(y, y\hat{n})$

SHT : $C_l = \left\langle \left(\frac{\Delta T}{T}\right)_{lm} \delta_{g,lm} \right\rangle$

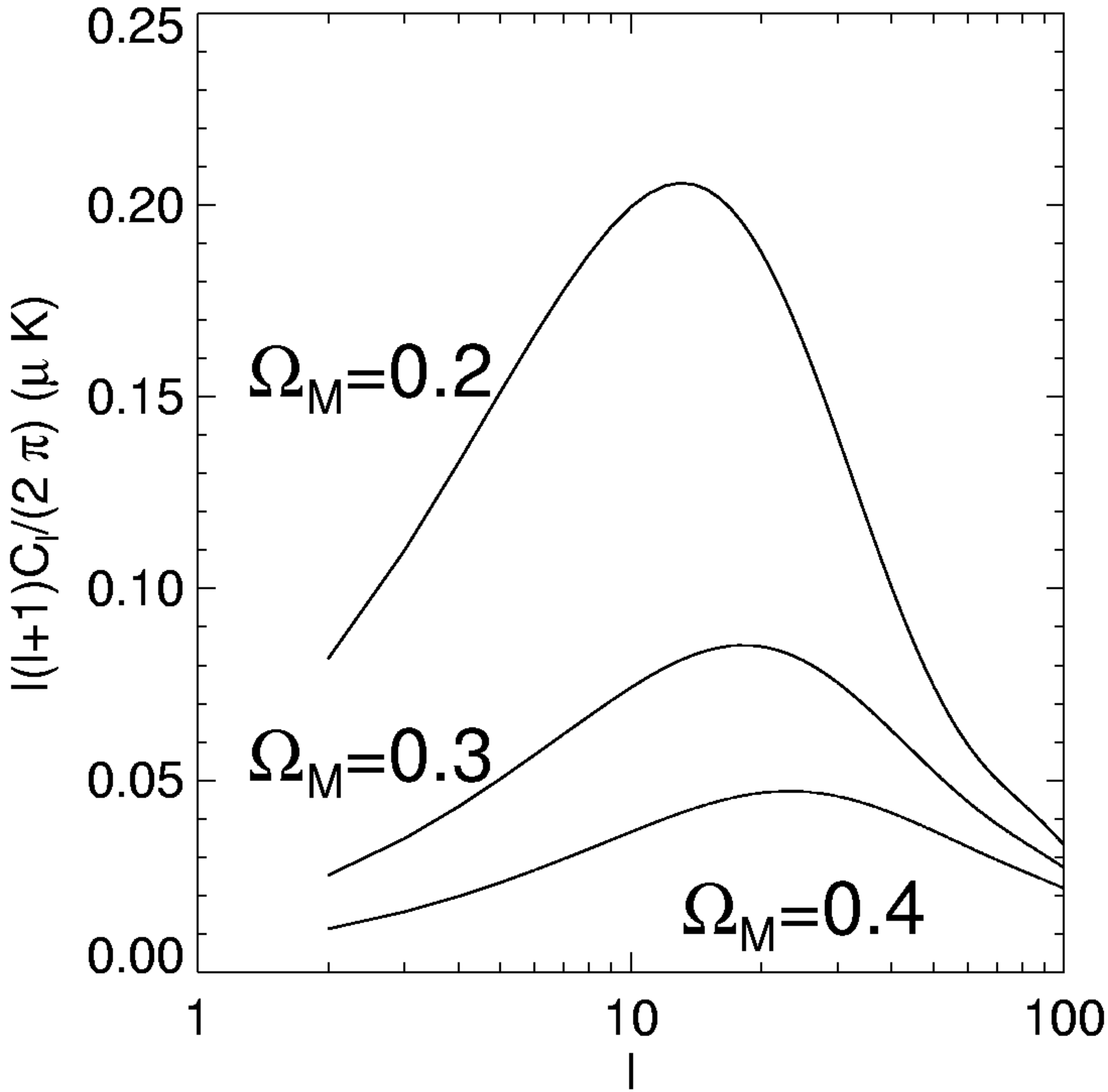
- Involves integrals over Bessel functions
- Fast evaluation using Fast Hankel Transforms
- Limber approximation illuminating

$$C_l = -3b\Omega_M H_0^2 \int dy\, \phi(y) \left(\frac{y}{l}\right)^2 \left(\frac{\dot{D}}{a}\right) P\left(\frac{l}{y}\right)$$

The ISW Effect : Models

$$\Omega_M + \Omega_\Lambda = 1$$

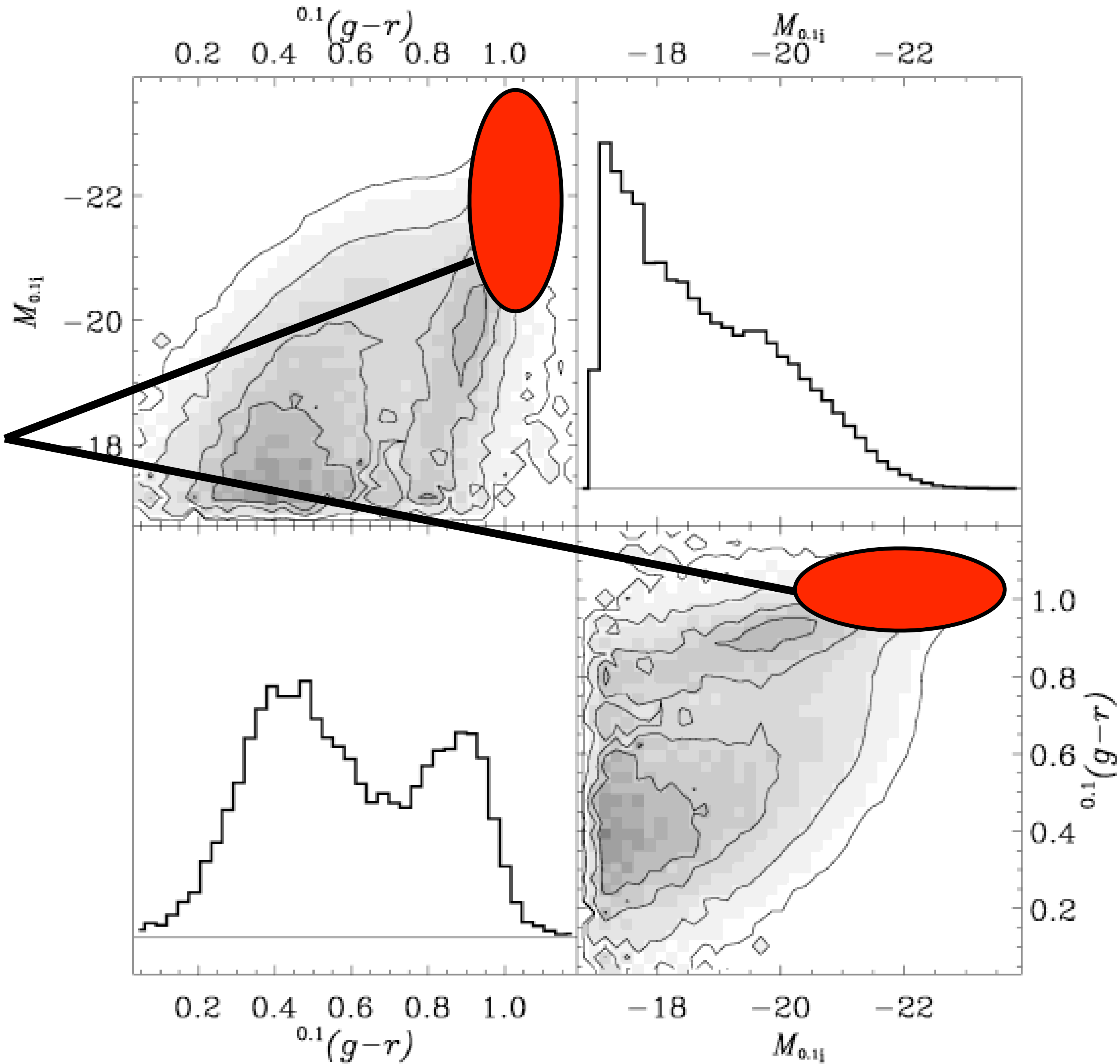
Note rapid increase of amplitude with decreasing matter



Choosing a Galaxy Catalog : Desiderata

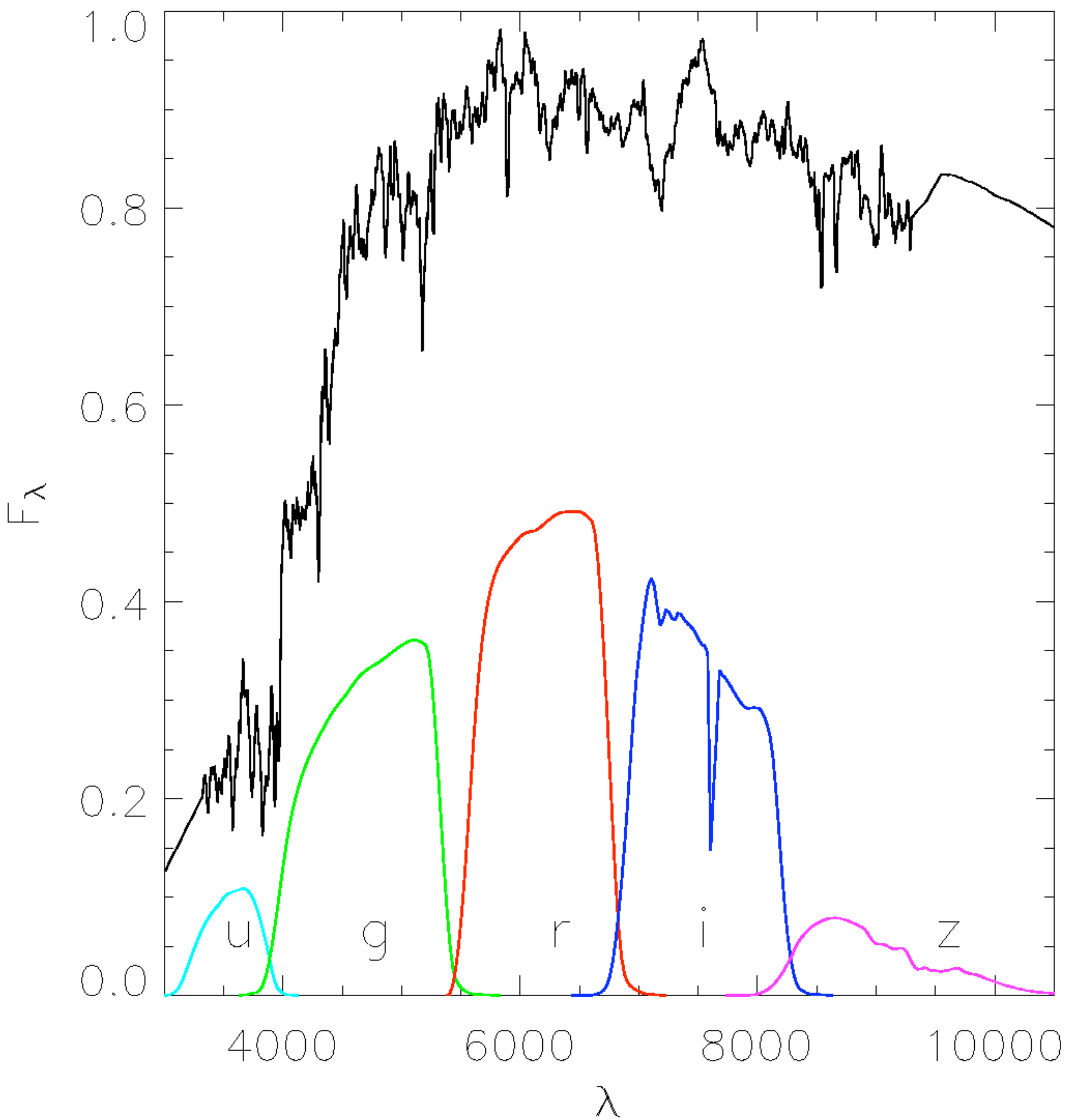
- Photometric selection criteria with few interlopers.
- Uniform sample properties
- Photometric redshifts
- Large volume

Luminous, Red Galaxies

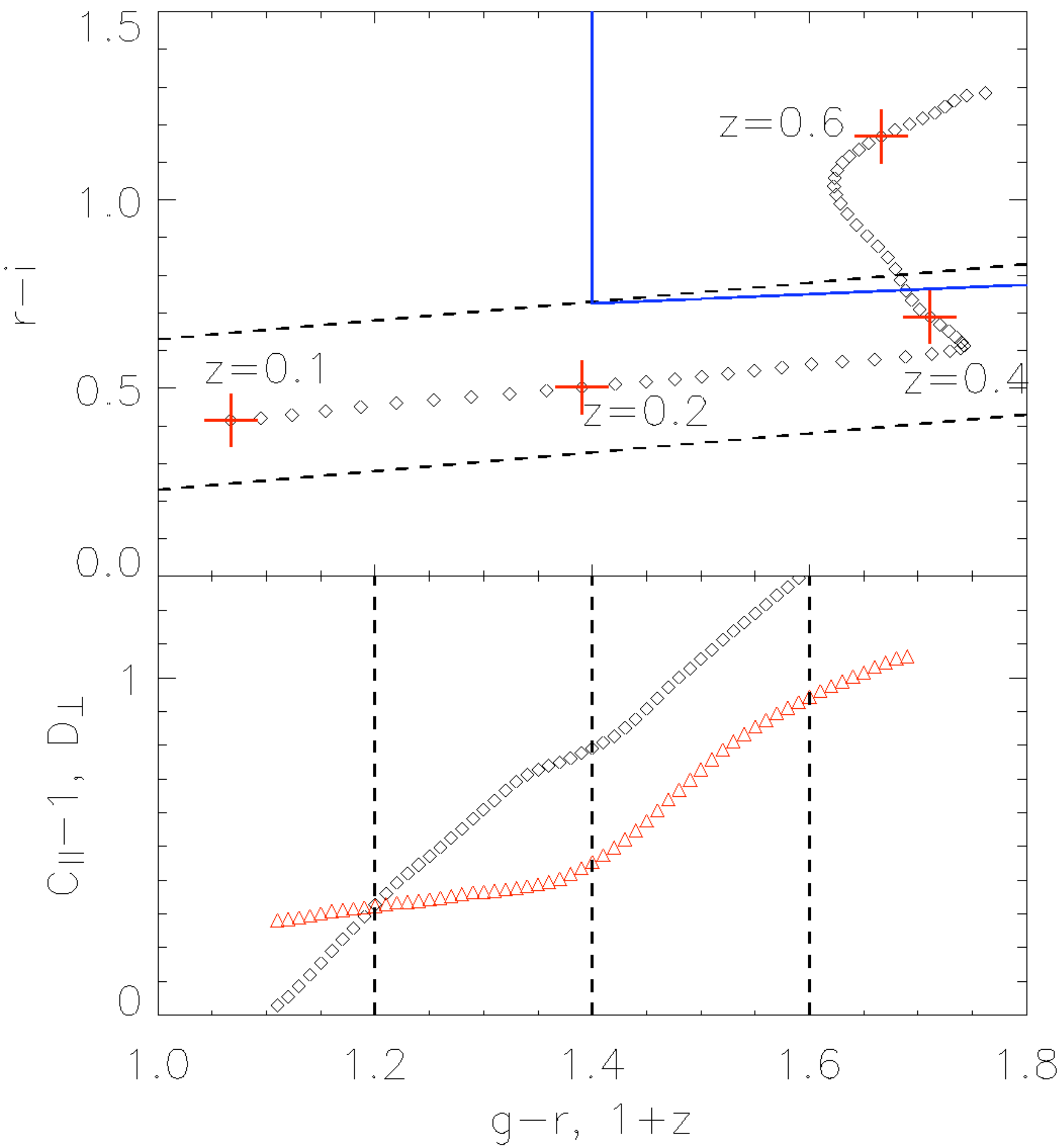


Blanton et al, 2003

Photometric Selection of LRGs

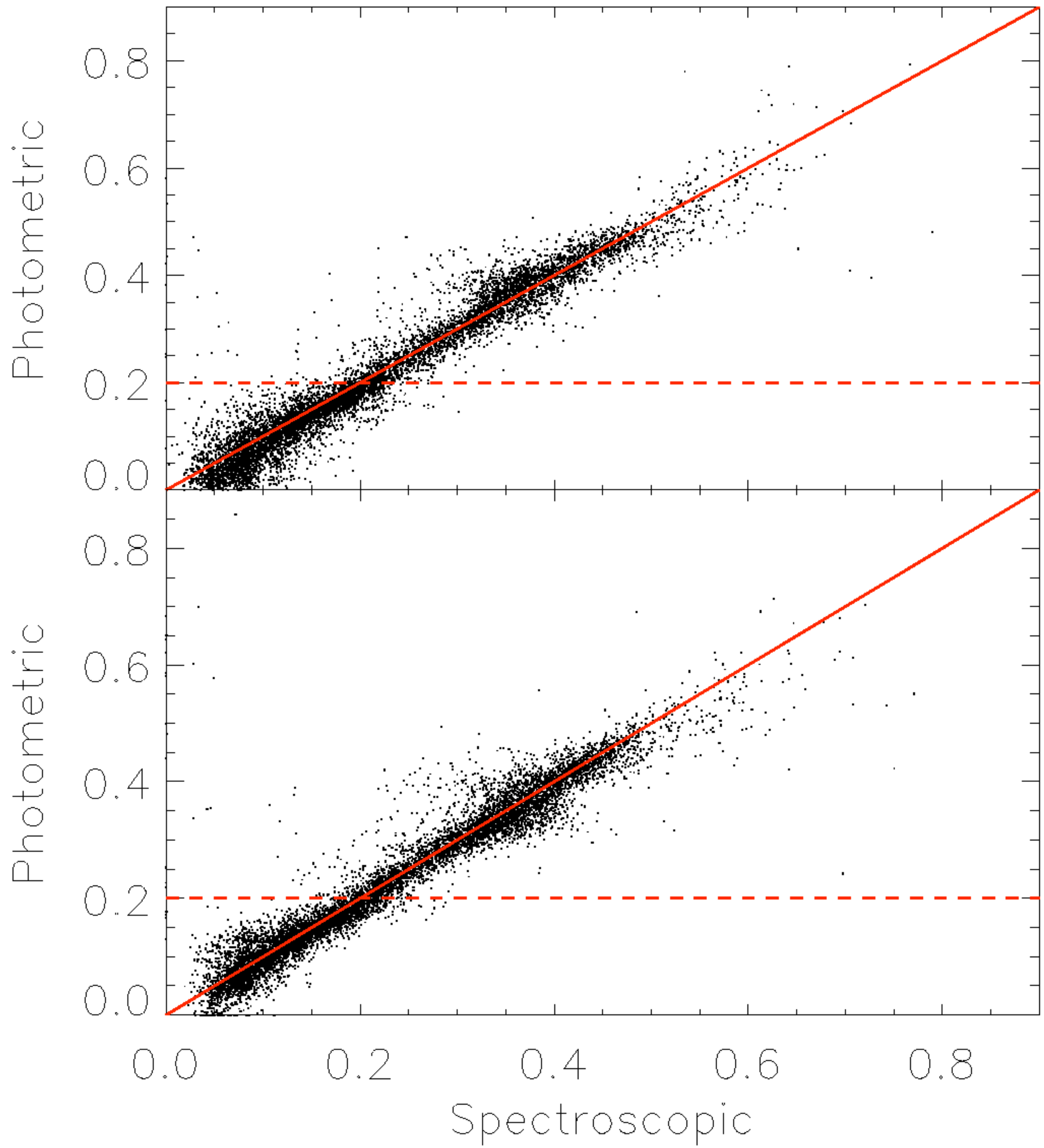


Photometric Selection of LRGs

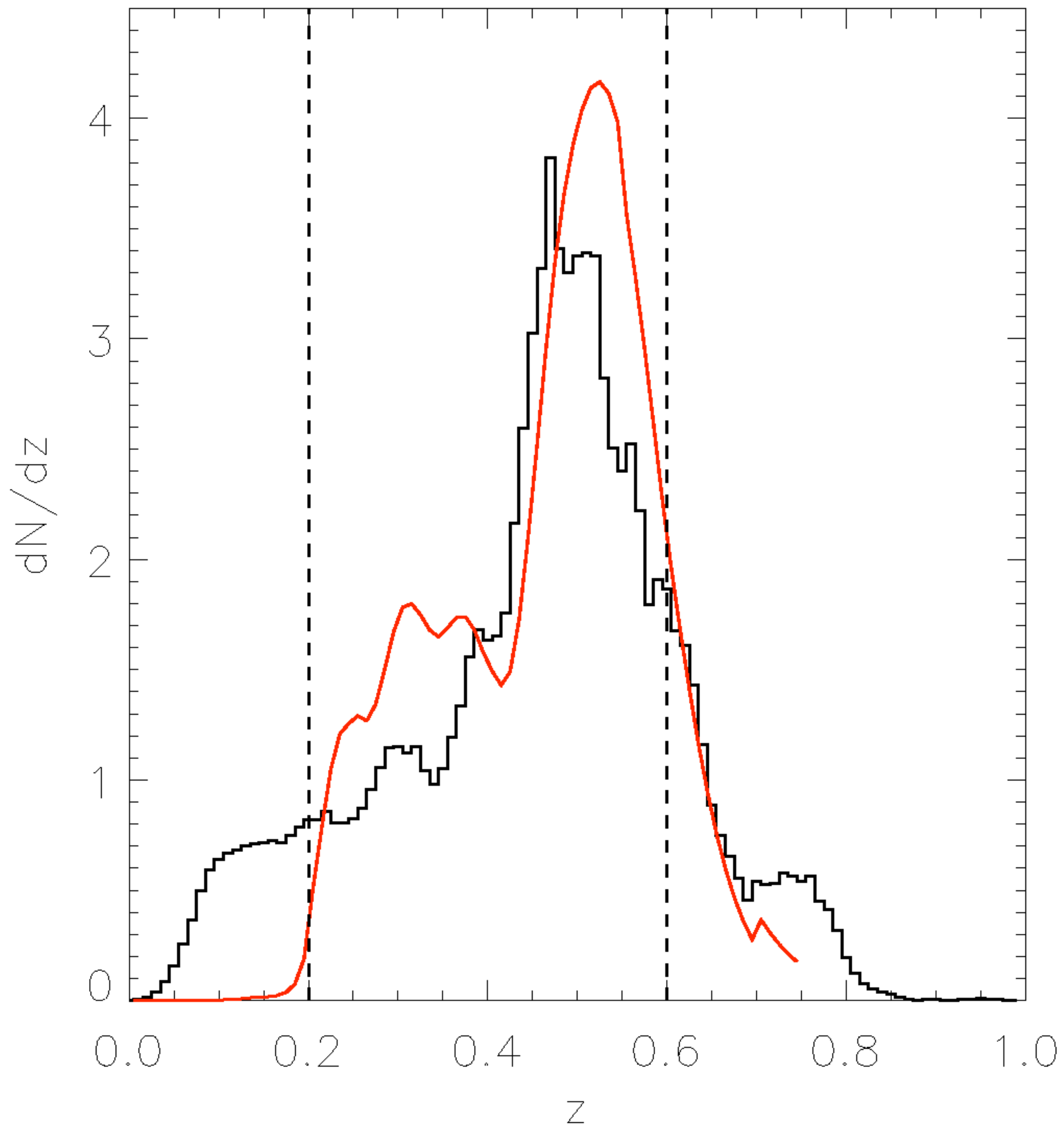


Photometric Redshifts

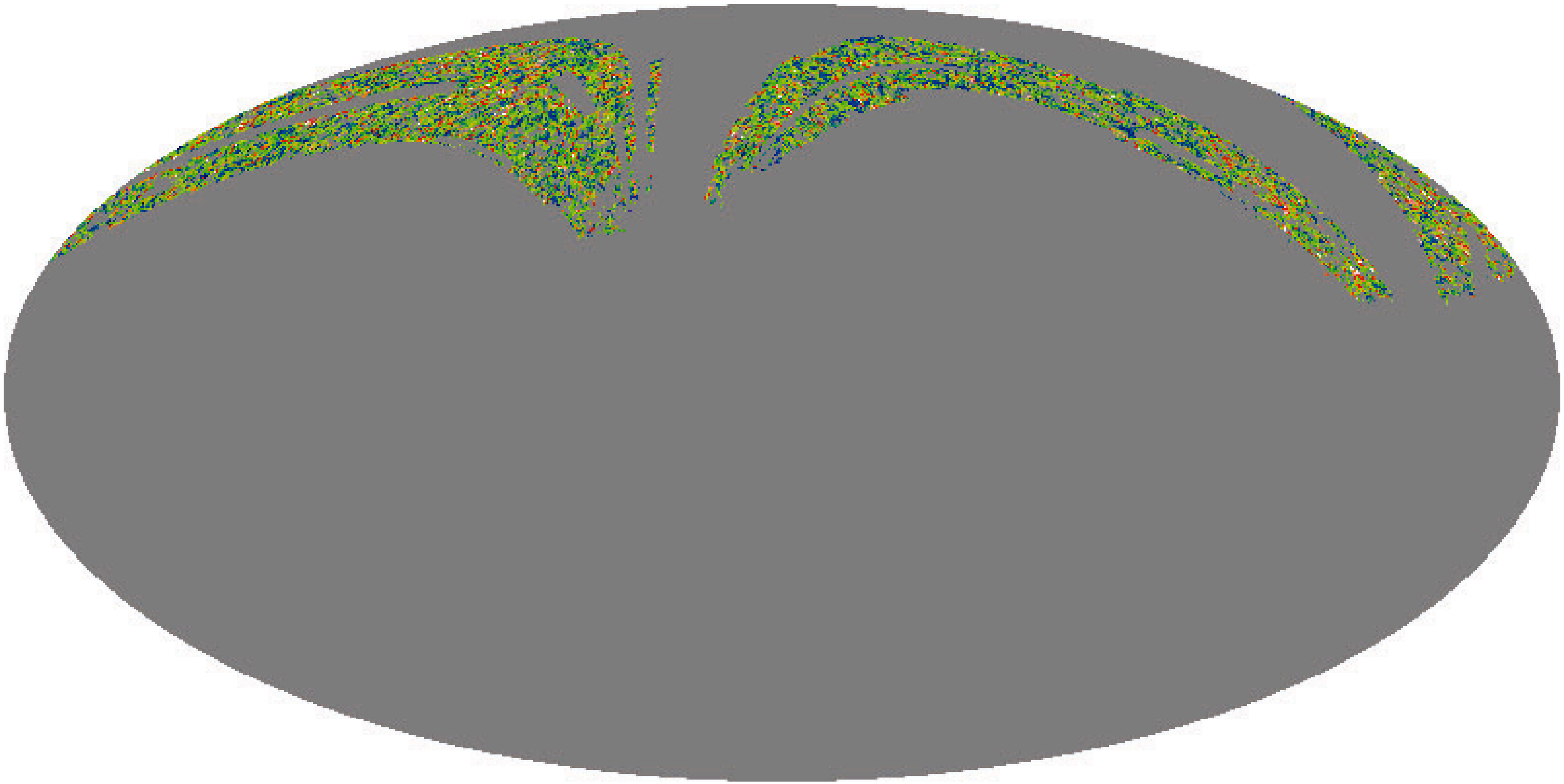
$$\Delta z \sim 0.03$$



The LRG Sample : Redshift Distribution



The LRG Sample : Angular Distribution



3900 sq. deg

Power Spectrum Estimation

- Construct optimal quadratic combination of data

$$Q = \frac{1}{2} x^T C^{-1} \frac{dC}{dp_A} C^{-1} x$$

where {p} is the set of parameters to be estimated (eg. flat bandpasses, ISW template)

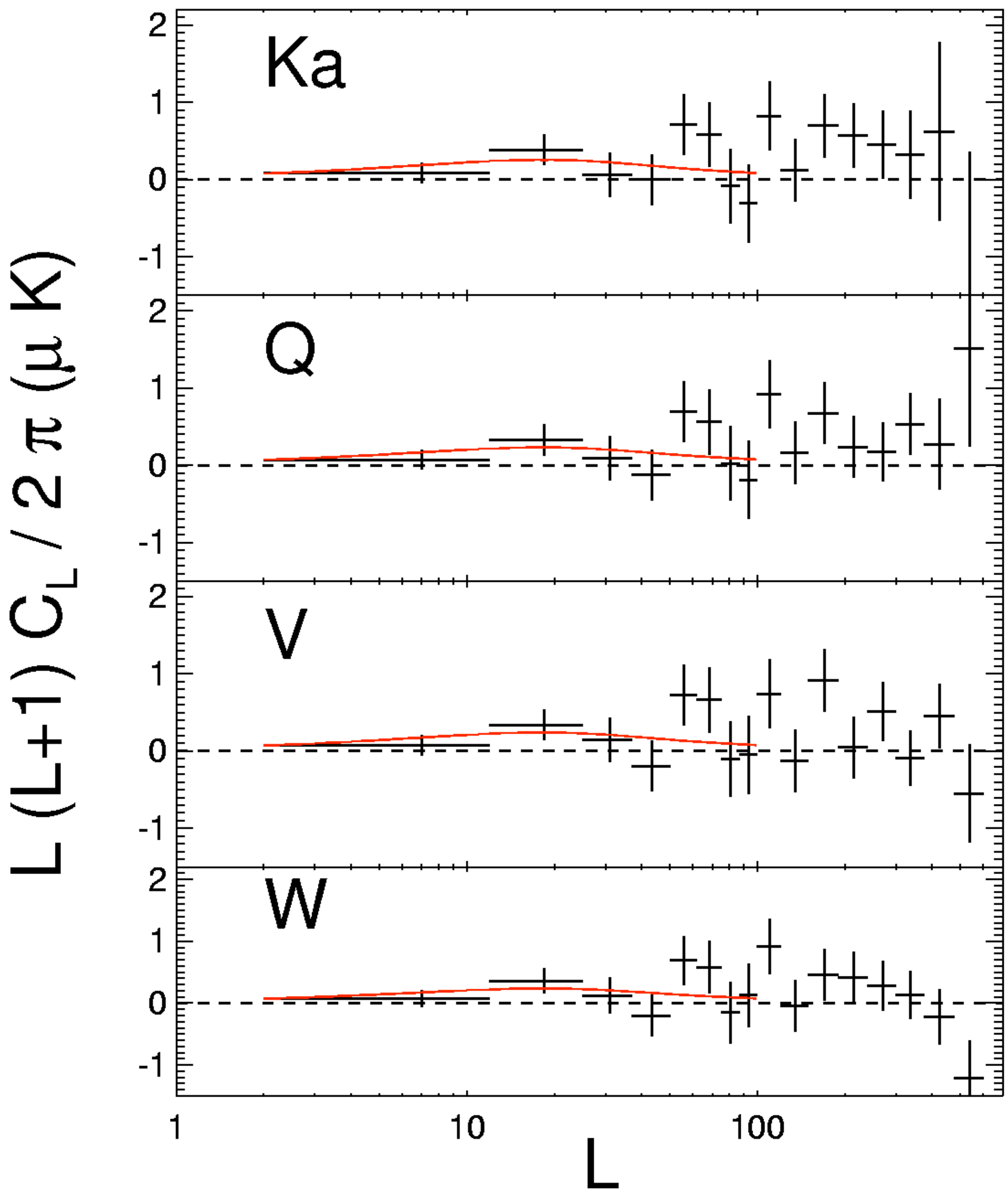
- Errors given by the inverse Fisher matrix

$$F_{AB} = \frac{1}{2} tr \left(C^{-1} \frac{dC}{dp_A} C^{-1} \frac{dC}{dp_B} \right)$$

- Fisher errors calibrated against 110 WMAP sims including 1/f noise

- All computations done in real space

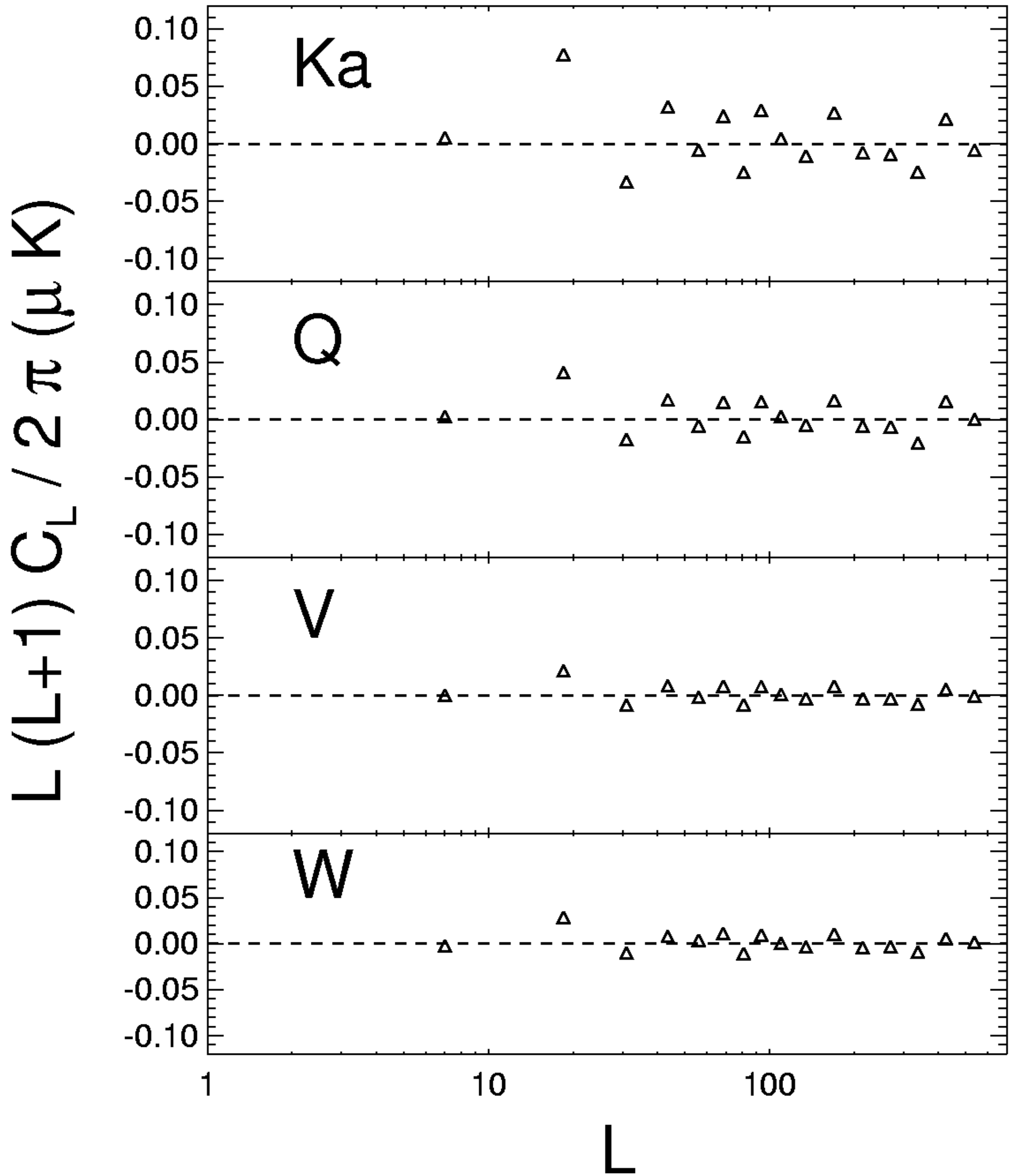
WMAP-SDSS Correlation



Foreground-SDSS Correlation

Foregrounds:
1. Dust
2. Free-Free
3. Spinning Dust/ Hard Synchrotron

Foregrounds negligible at low l



ISW Detection

- Fiducial template : $\Omega_M = 0.3, \Omega_\Lambda = 0.7$

Band	Ka	Q	V	W
Bias	2.99	2.72	2.84	2.78
Error	1.40	1.40	1.40	1.41

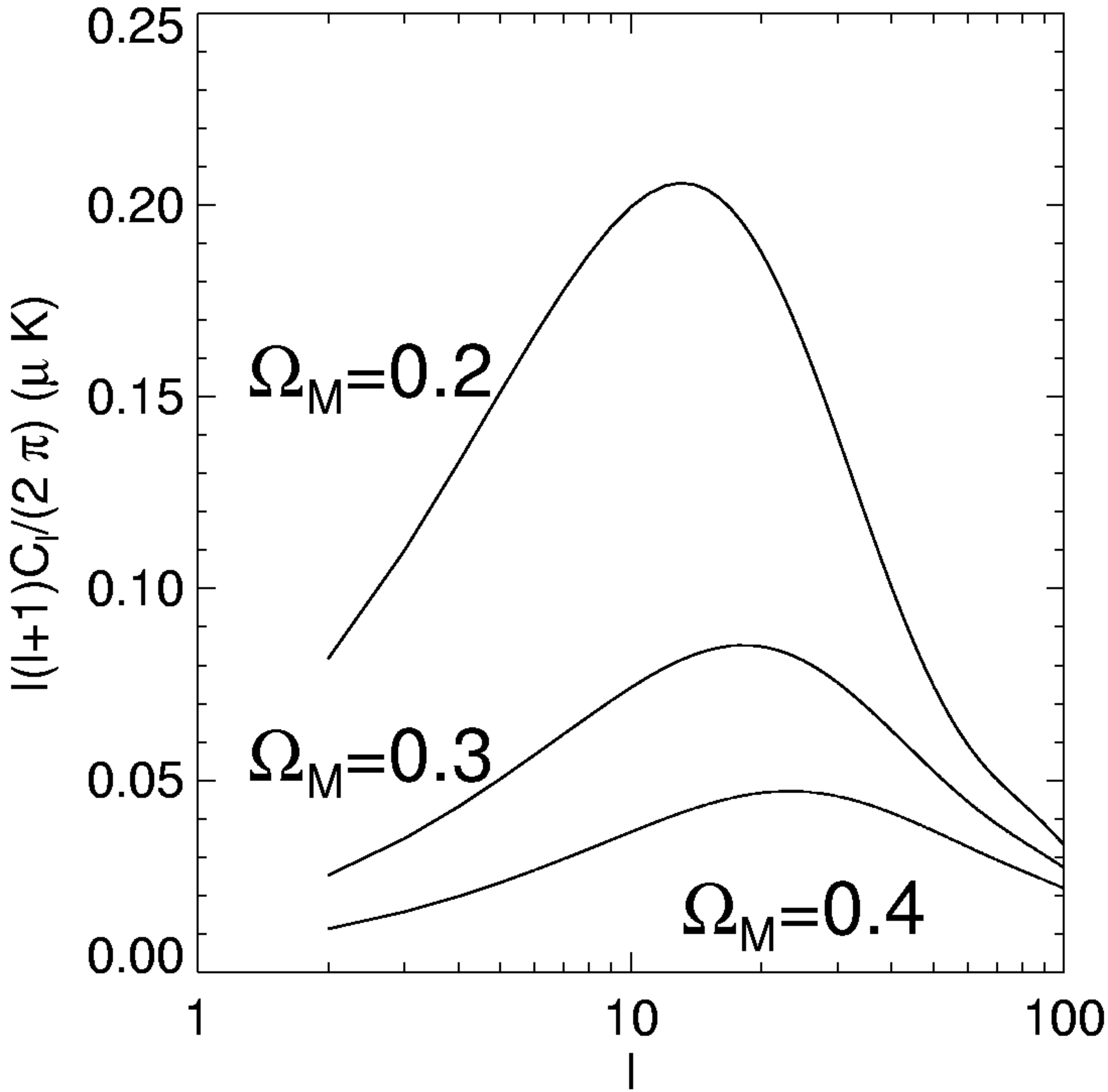
- Achromatic
- $\sim 2\sigma$
- Consistent with galaxy bias:

Bias (gg) : 1.81 +/- 0.02

The ISW Effect : Models

$$\Omega_M + \Omega_\Lambda = 1$$

Note rapid increase of amplitude with decreasing matter

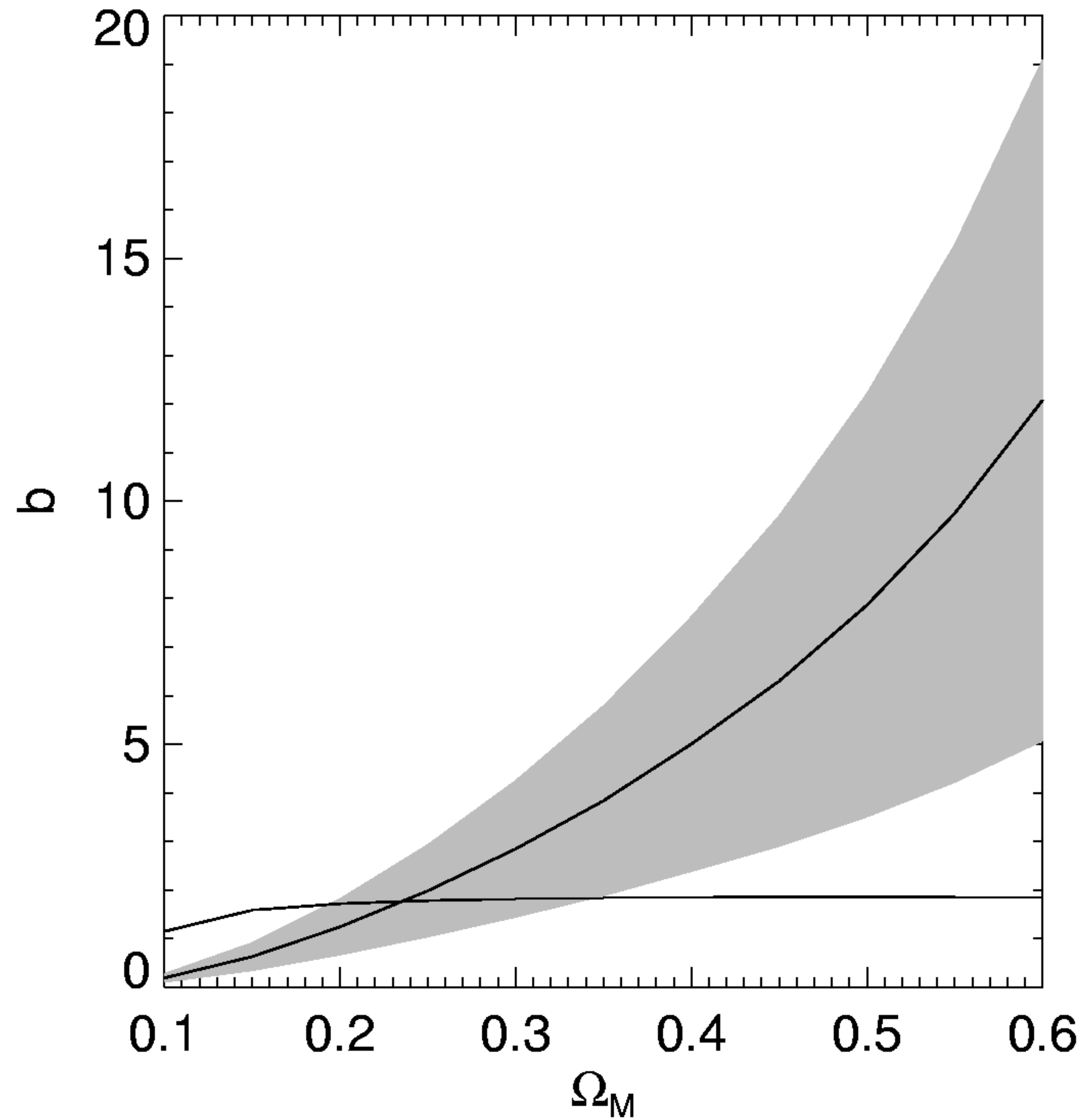


ISW Cosmology

$$\Omega_M = 0.24^{+0.1}_{-0.05}$$

$$\Omega_M = 0.17$$

ruled out at 2σ



CMB Lensing

- Why Lensing :
  - Directly measure matter power spectrum, galaxy-matter correlation.
  - Known physics
- CMB Lensing :
  - Known redshift distribution
  - No selection systematics
  - No intrinsic alignments
- Aim : Proof of principle, no major systematics

CMB Lensing II

- Gravitational lensing re-maps the primordial CMB

$$T(\hat{n}) \rightarrow T(\hat{n} + \mathbf{d}(\hat{n}))$$

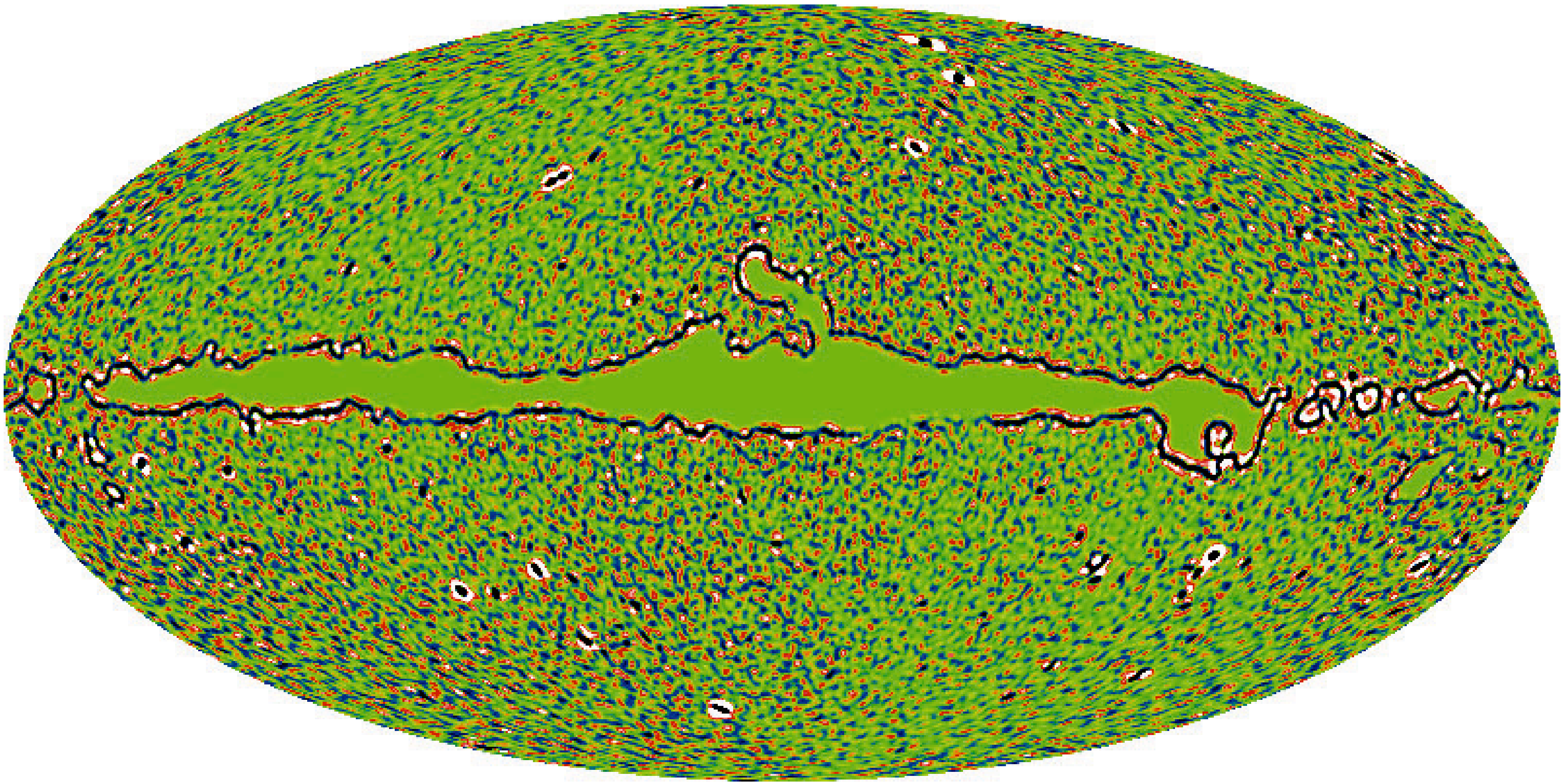
- Deflection angle is (to linear order) the gradient of a scalar lensing potential.

- Convergence field : $\kappa = -\frac{1}{2}\nabla \cdot \mathbf{d}$

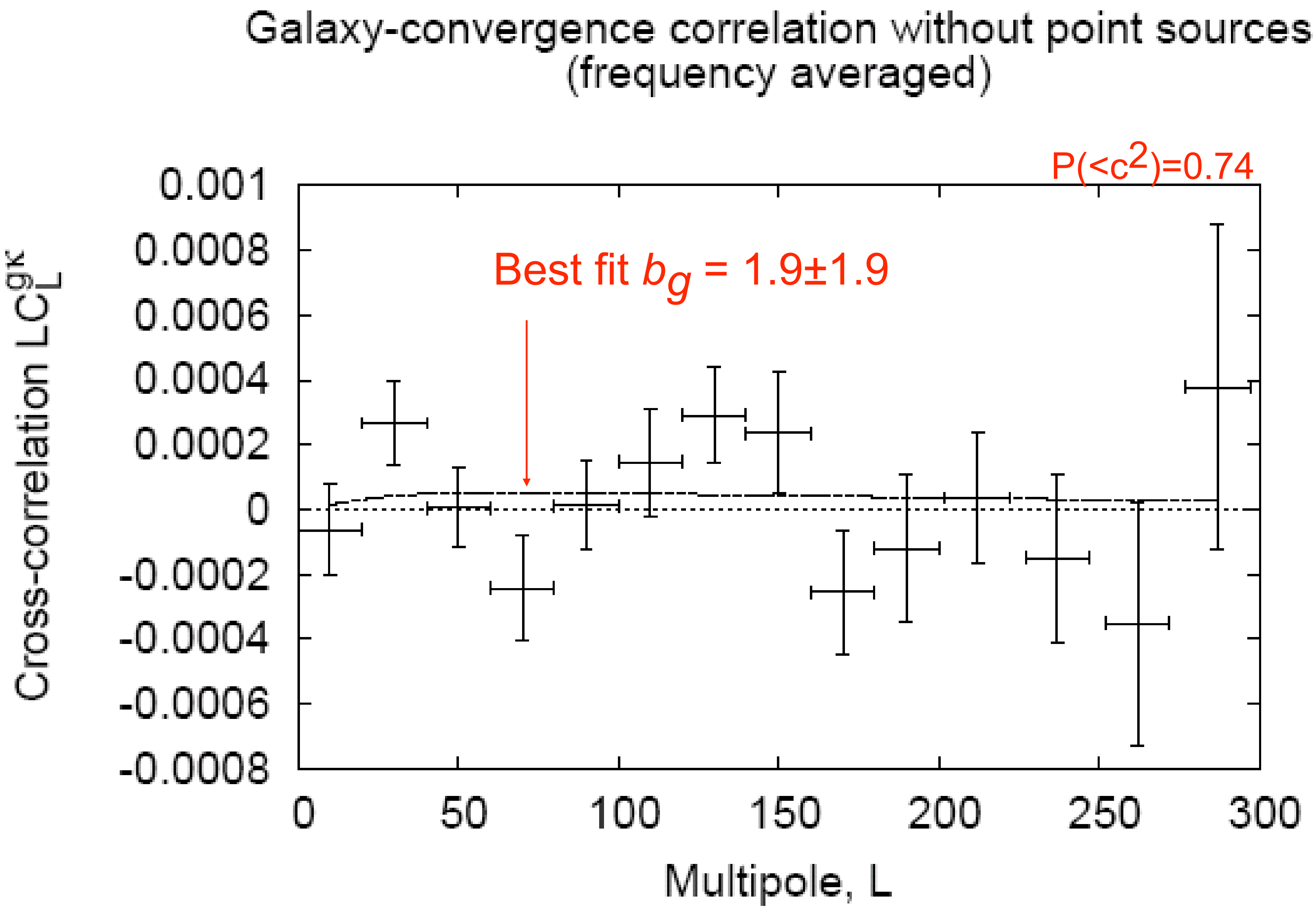
- Compute the deflection field using a quadratic reconstruction method (Hirata and Seljak 2003)

- Directly cross-correlate galaxies with this field

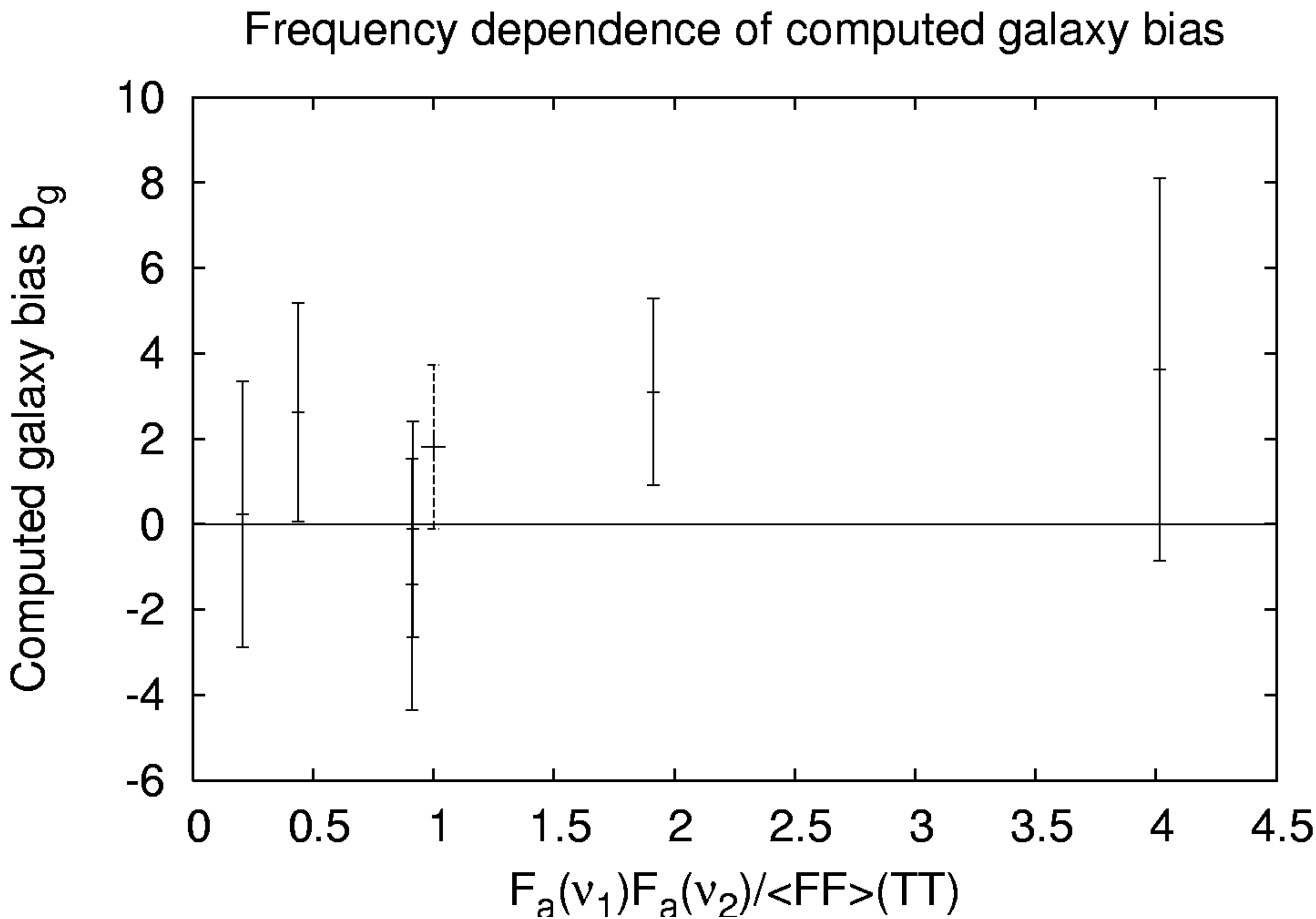
Lensing Map



$\nabla \cdot \mathbf{v}$



Galaxy-convergence correlation without point sources
(frequency averaged)
P(<c2)=0.74
Best fit bg = 1.9±1.9
Cross-correlation LCLgκ
Multipole, L
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
0
50
100
150
200
250
300



$$\chi^2 = 6.31 \ (5\, dof)$$