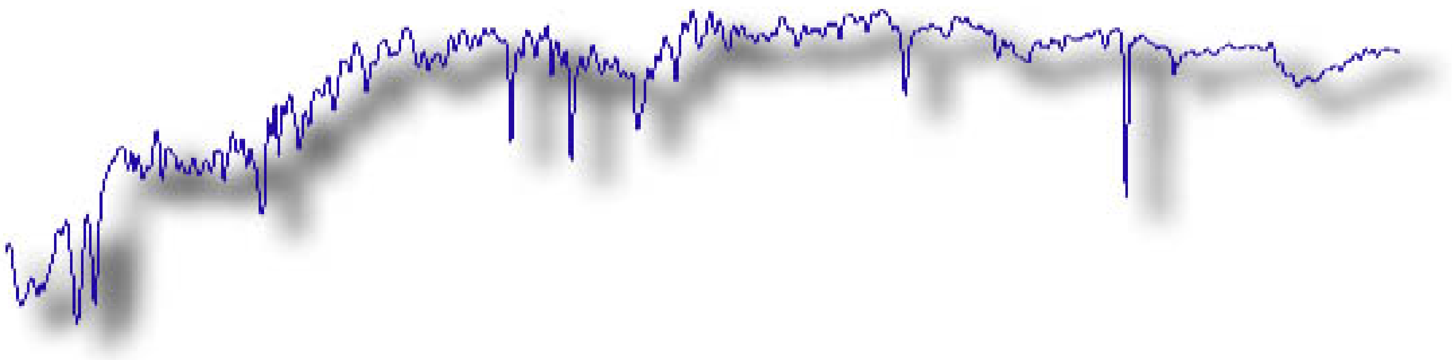
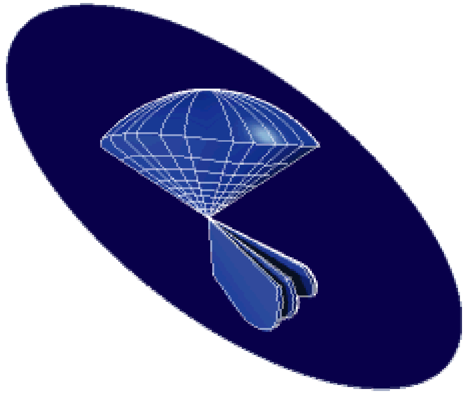


Findings and Prospects for the SDSS Search



Tamás Budavári

Johns Hopkins University

for the SDSS Collaboration

Outline

- The Sloan Digital Sky Survey
  - SDSS overview – the ultimate galaxy machine
  - Over 600 papers published to date
- Cosmology with SDSS
  - Halo mass from weak gravitational lensing
  - Recent results on baryon oscillations
- The future with SDSS
  - Progress, current work, forecast…

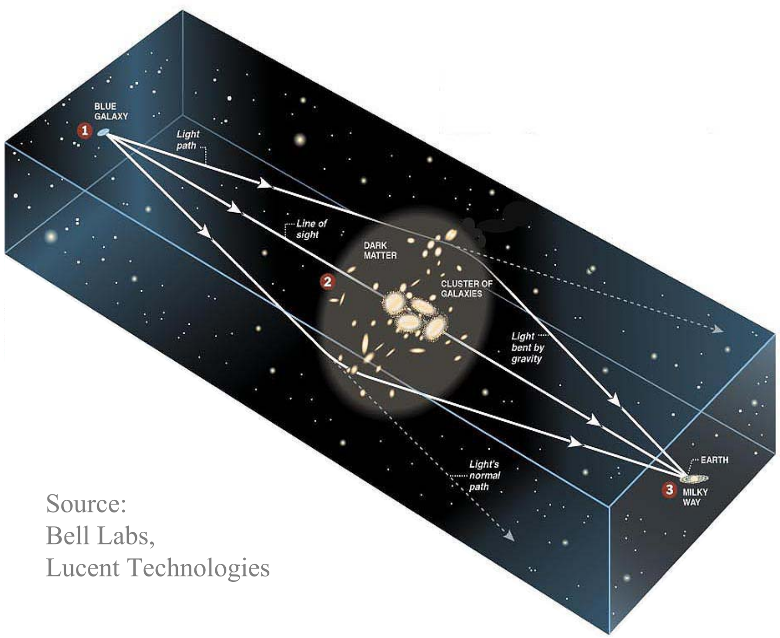
Sloan Digital Sky Survey

- Dedicated 2.5m telescope
  - Located at Apache Point, NM
- Two surveys in one
  - Spectroscopic redshifts (1M galaxies)
  - 5-band photometry (300M galaxies)
- Huge CCD mosaic in drift scan
  - 30 imaging (2k×2k), 22 astrometry (2k×400)
- Special multifiber spectrographs
  - 2×320 fibers with 3 arcsec diameter
  - R=2000 w/ 4096 pixels, 3900 < λ < 9600Å

Courtesy of Robert Lupton

Gravitational Lensing

- Strong Lensing
  - Arcs and multiple instances
  - “Golden” lens



Source:
Bell Labs,
Lucent Technologies

- Weak Lensing
  - Shear and magnification
  - Statistical shape measures
    - Adaptive moments

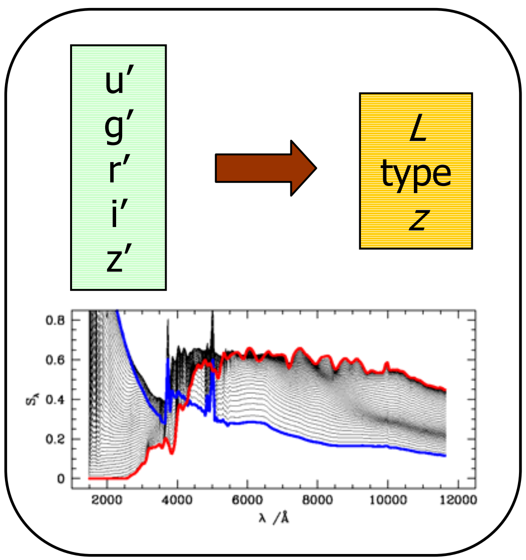
- Tangential shear is related to projected surface mass density of lens

$$\gamma_T \Sigma_{\text{crit}} = \bar{\Sigma}(< R) - \bar{\Sigma}(R)$$

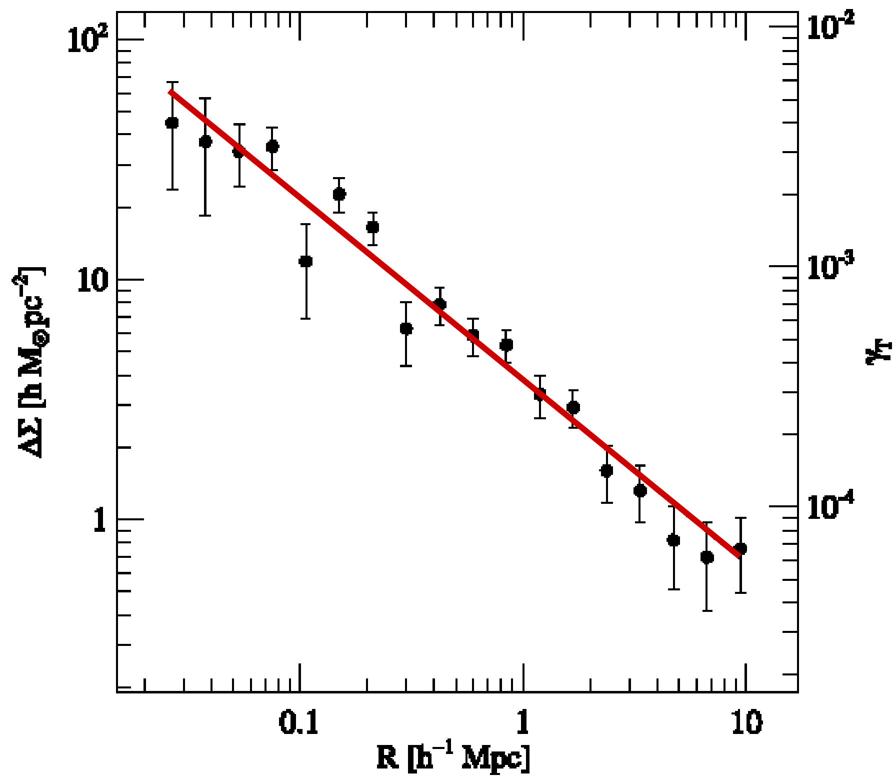
$$\Sigma_{\text{crit}}^{-1} = \frac{4\pi G D_{LS} D_L}{c^2 D_S}$$

SDSS Weak Lensing

- Distances to galaxies
  - Lenses – spectroscopic *z*
  - Sources – photometric *z*
- Photometric redshifts

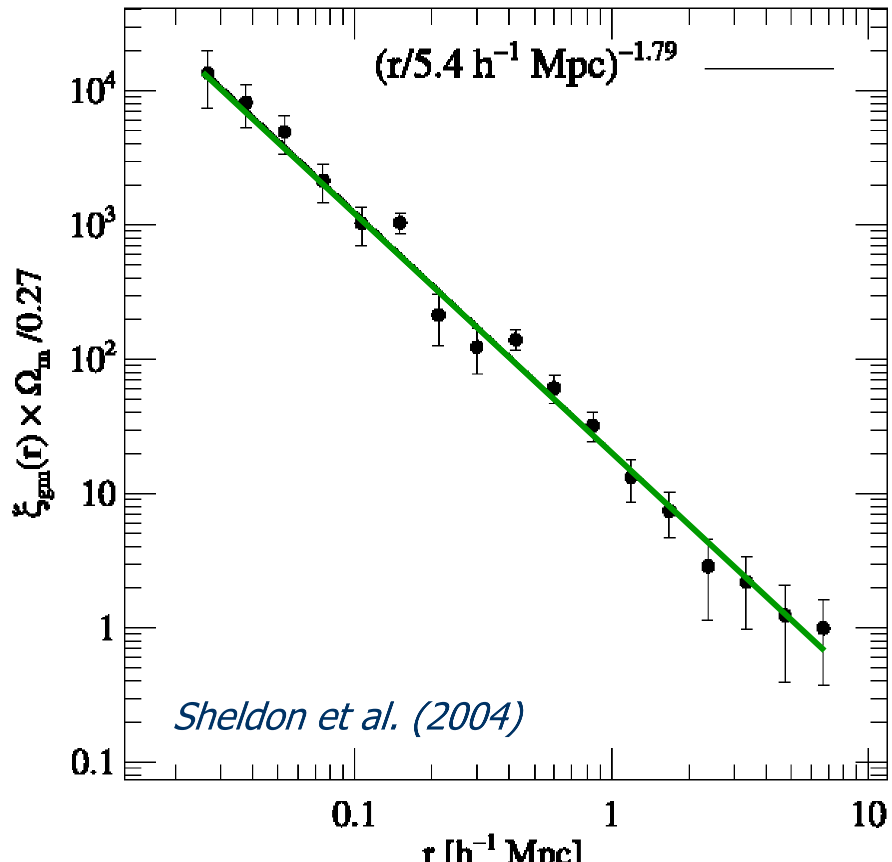


- Surface mass density
  - Sheldon et al. (2004)



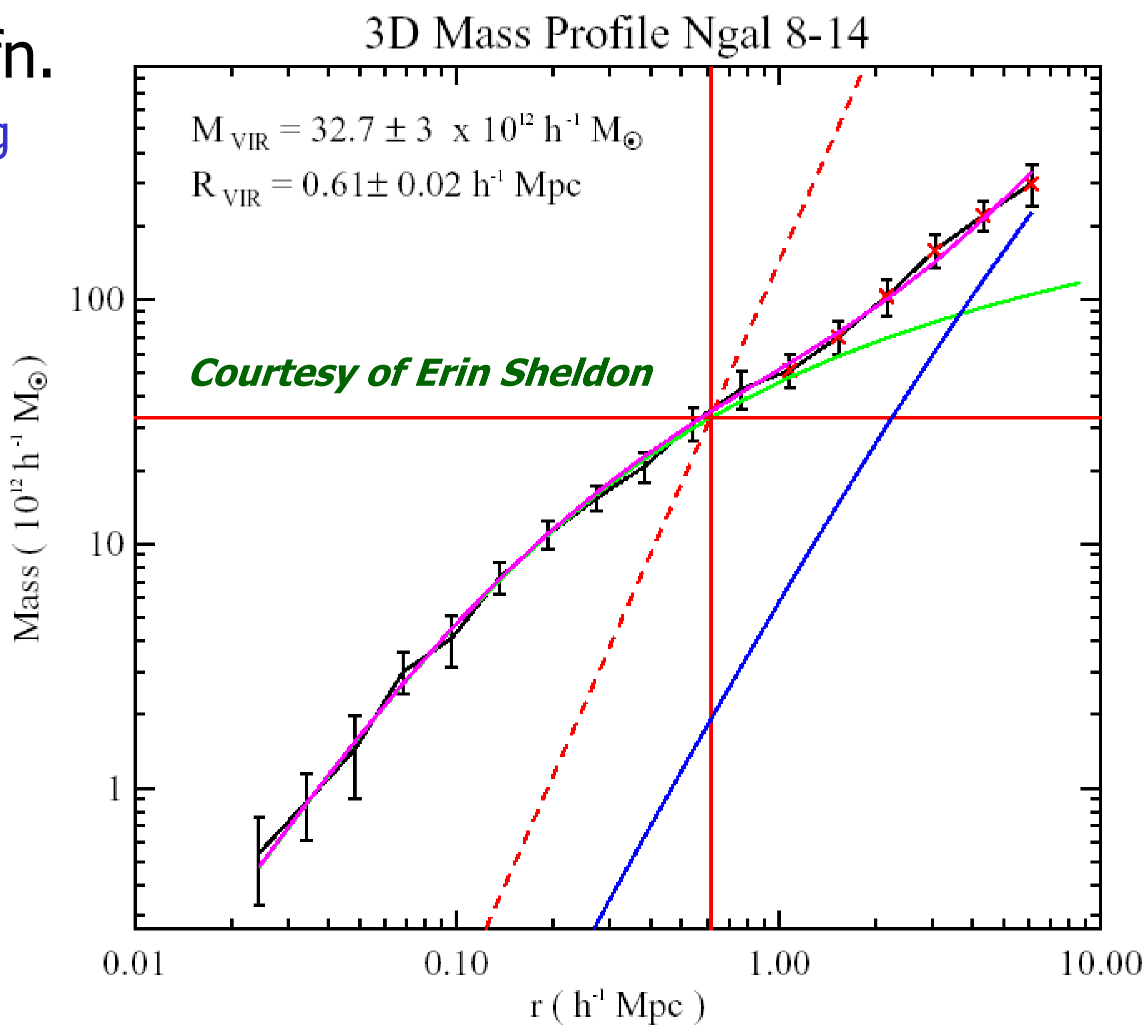
Mean Mass Profile

- Mass-galaxy corr. fn.
  - From $\Delta\Sigma(R)$ assuming spherical symmetry



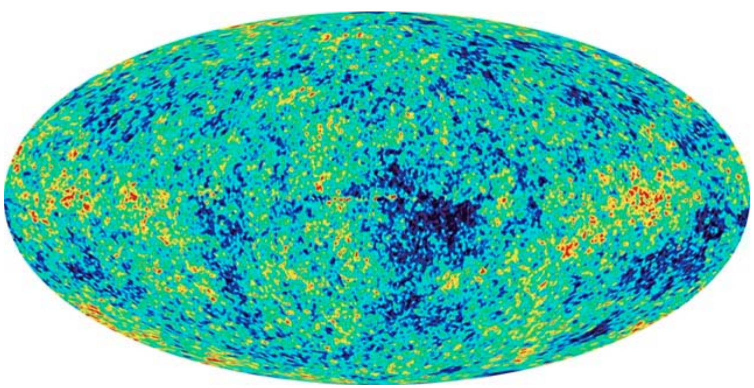
Mean Mass Profile

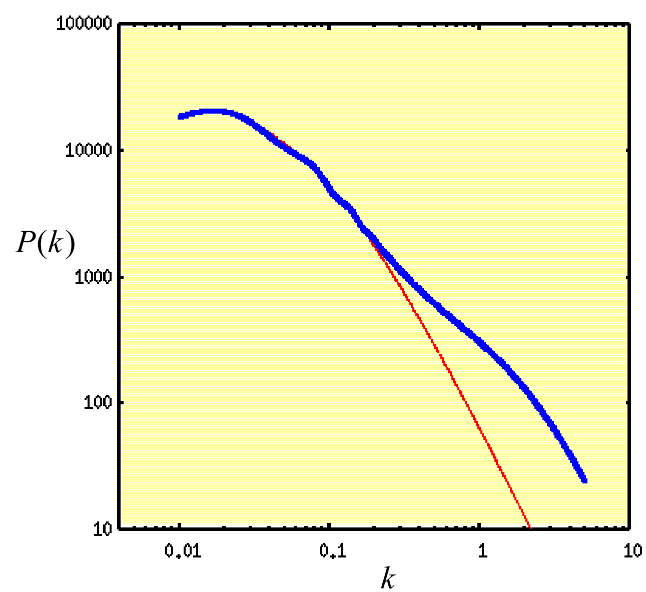
- Mass-galaxy corr. fn.
  - From $\Delta\Sigma(R)$ assuming spherical symmetry
- Halo mass
  - Around clusters with between 8 and 14 luminous ellipticals
  - Model independent
- Stacking
  - Spherical symmetry
  - Cancels mass bias along line-of-sight
  - Superb S/N ratio



Baryon Oscillations

- Early Universe was hot and dense
  - Acoustic waves in the photon-baryon fluid
  - Decoupled at t~400,000 yr when T~3000 K
    - See it in the CMB and should be in the LSS
      - Confirm role of gravity in structure formation

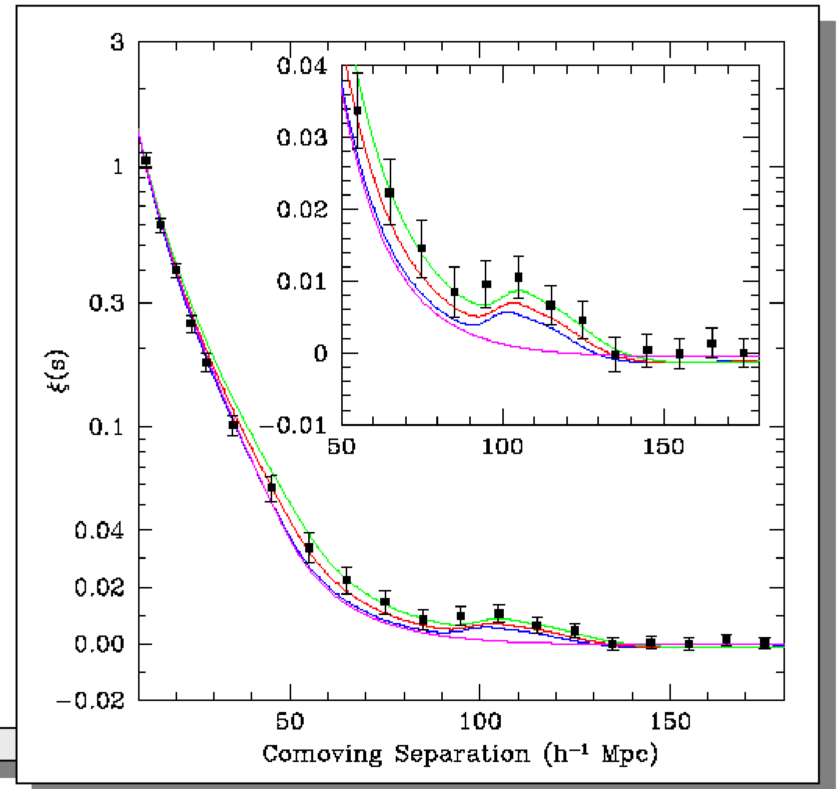




Correlation Function

- Large SDSS sample
  - Luminous red galaxies
  - 47,000 LRGs w/ redshift
  - 3800 sq.deg, $0.7h^{-3}$Gpc^3
- 3.4σ significance
  - Large-scale correlations
  - Bump at ~100h^{-1}Mpc is consistent w/ prediction
  - Proof for DM at z~1100

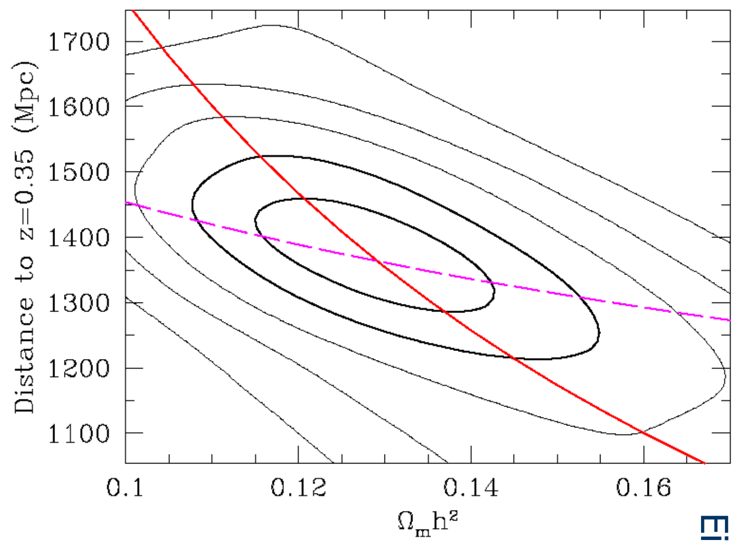
Eisenstein et al. (2005)



Constraints on Cosmology

- Standard ruler
  - Calibrated by WMAP
  - Angular-diameter distance
    - Complement SN Ia work

$$D_V(z) = \left[D_M(z)^2 \frac{cz}{H(z)} \right]^{1/3}$$



Eisenstein et al. (2005)

Summary of Parameter Constraints from LRGs

$\Omega_m h^2$	$0.130(n/0.98)^{1.2} \pm 0.011$
$D_V(0.35)$	1370 ± 64 Mpc (4.7%)
$R_{0.35} \equiv D_V(0.35)/D_M(1089)$	0.0979 ± 0.0036 (3.7%)
$A \equiv D_V(0.35)\sqrt{\Omega_m H_0^2}/0.35c$	$0.469(n/0.98)^{-0.35} \pm 0.017$ (3.6%)

Constraints on Cosmology

- Standard ruler
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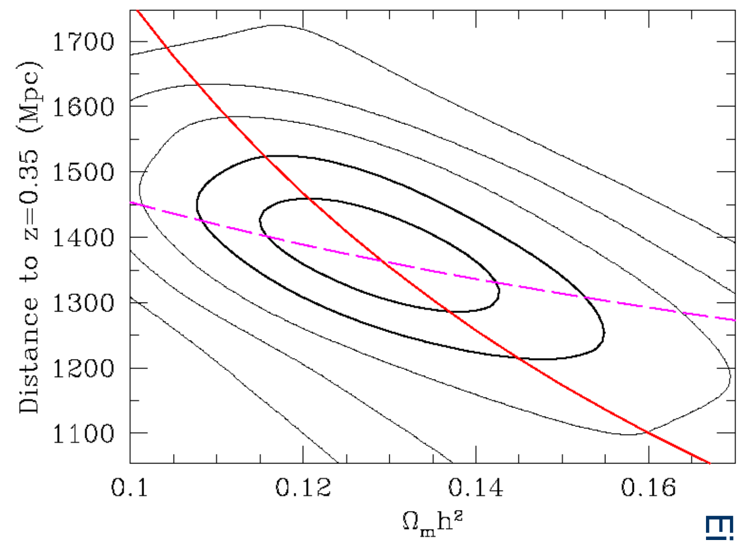
$$D_V(z) = \left[D_M(z)^2 \frac{cz}{H(z)} \right]^{1/3}$$



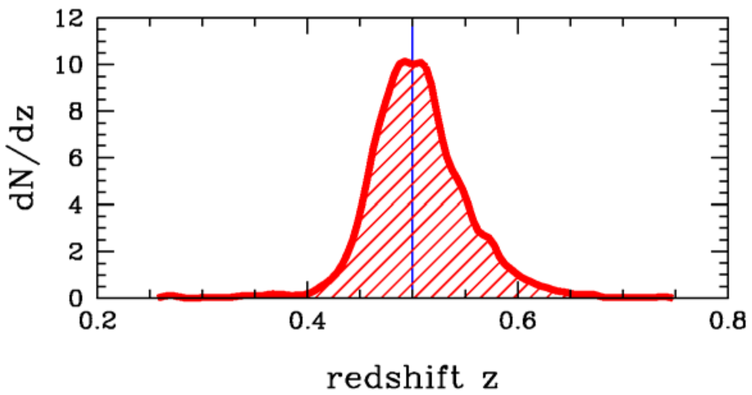
Joint Constraints on Cosmological Parameters including CMB data

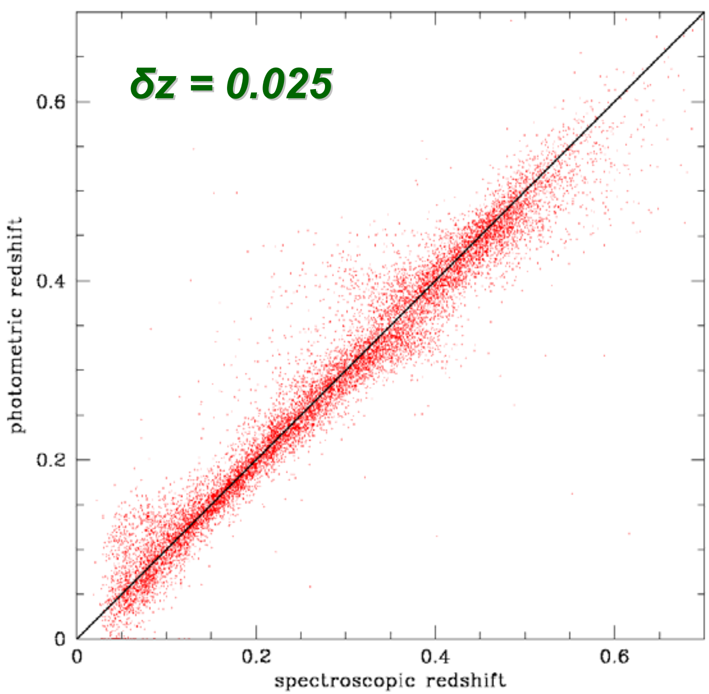
Parameter	Constant w flat WMAP+Main	Constant w flat +LRG	$w=-1$ curved WMAP+Main	$w=-1$ curved +LRG	$w=-1$ flat WMAP+Main	$w=-1$ flat +LRG
w	-0.92 ± 0.30	-0.80 ± 0.18	...	...	...	...
Ω_K	...	...	-0.045 ± 0.032	-0.010 ± 0.009	...	...
$\Omega_m h^2$	0.145 ± 0.014	0.135 ± 0.008	0.134 ± 0.012	0.136 ± 0.008	0.146 ± 0.009	0.142 ± 0.005
Ω_m	0.329 ± 0.074	0.326 ± 0.037	0.431 ± 0.096	0.306 ± 0.027	0.305 ± 0.042	0.298 ± 0.025
h	0.679 ± 0.100	0.648 ± 0.045	0.569 ± 0.082	0.669 ± 0.028	0.696 ± 0.033	0.692 ± 0.021
n	0.984 ± 0.033	0.983 ± 0.035	0.964 ± 0.032	0.973 ± 0.030	0.980 ± 0.031	0.963 ± 0.022

Eisenstein et al. (2005)

Angular Power Spectrum

- Redshift slices
  - Using photometric redshifts
  - Known redshift distribution





Angular Power Spectrum

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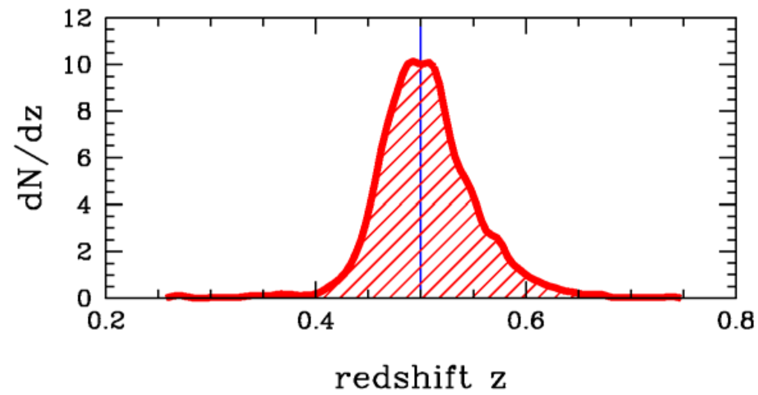
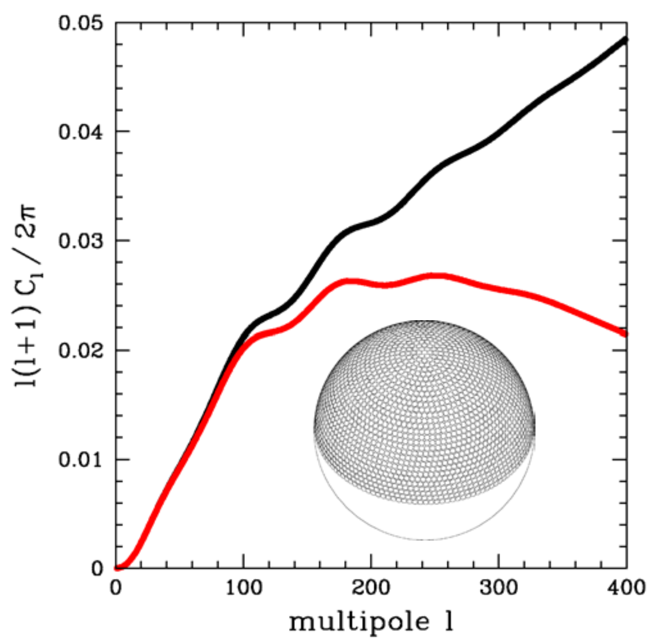




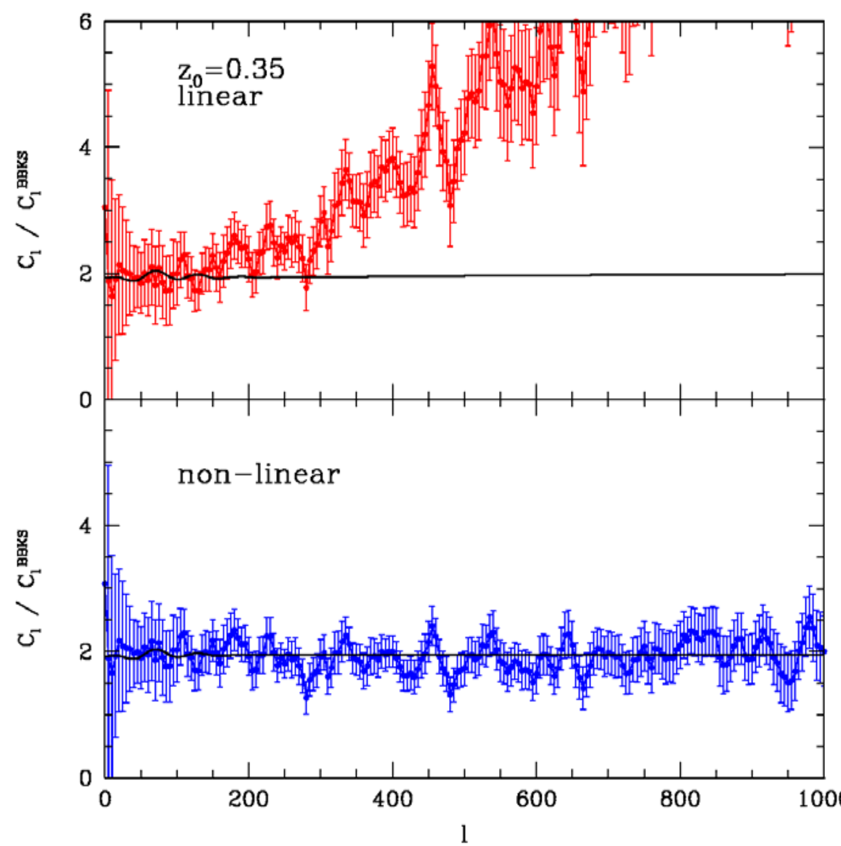
- Project 3D P(k)

$$C_l = \frac{2}{\pi} \int k^2\, dk P(k) f_l(k)^2$$

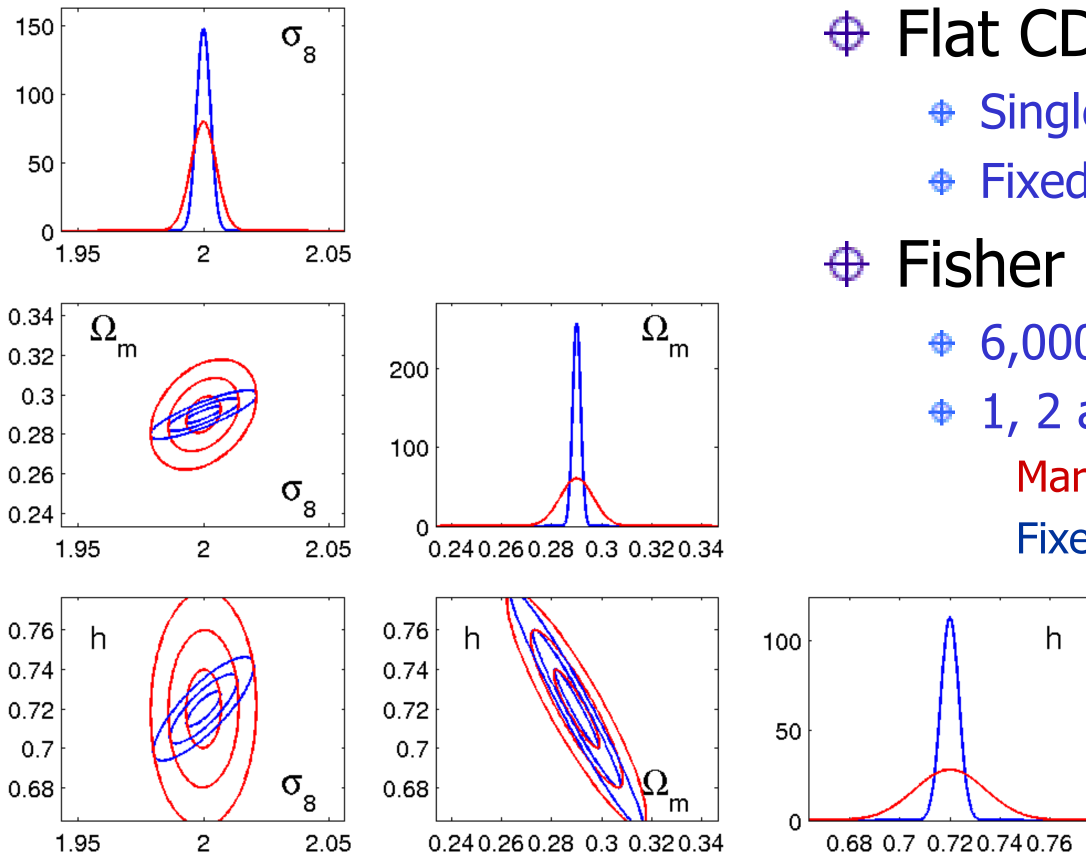
$$f_l(k) \equiv \frac{1}{\bar{G}} \int \frac{dx}{F(x)} j_l(kx) x^2 \bar{g}(x) D(x) b(x)$$

Comparing to Models

- Measurement
  - Radial selection
  - Cells on the sky
- Theoretical P(k)
  - Galaxy bias complicates
  - Non-linear prescriptions
    - e.g. Smith et al. (2003)
- Likelihood fit
  - Correlated errors



Standard Model

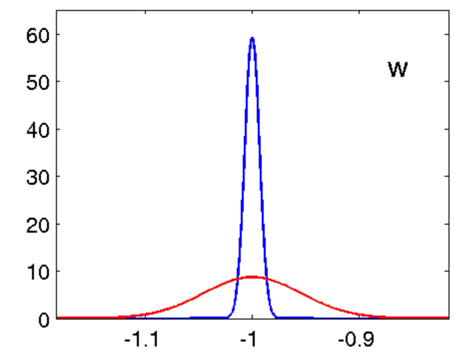


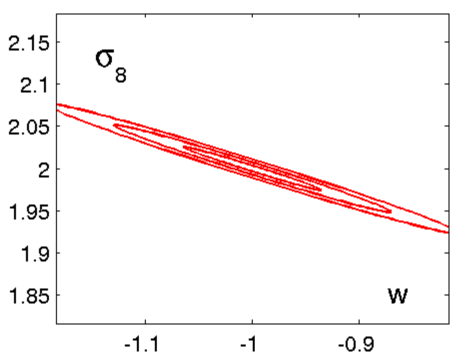
- Flat CDM cosmology
  - Single slice at z = 0.5
  - Fixed w = -1
- Fisher matrix (noiseless)
  - 6,000 square degrees
  - 1, 2 and 3σ contours

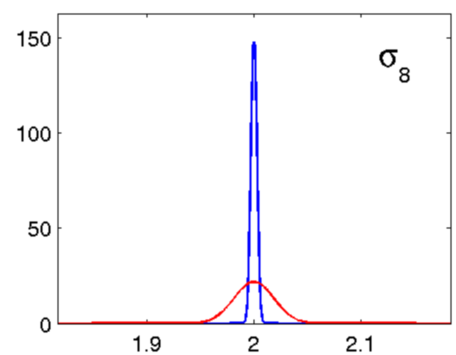
    Marginalized parameters

    Fixed other parameters

Dark Energy





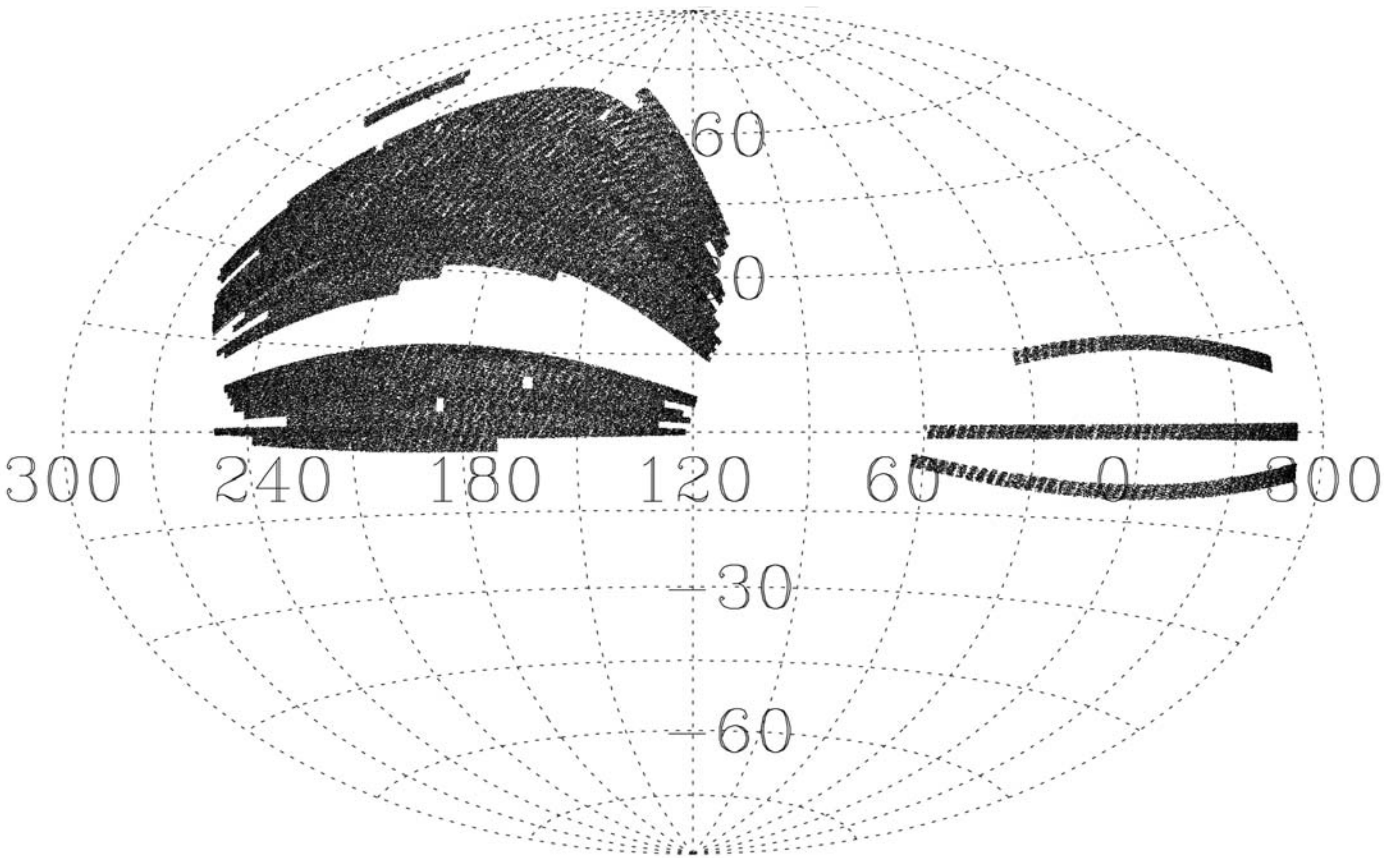


- Flat CDM cosmology
  - Single slice at z = 0.5
  - Free w parameter
- Fisher matrix (noiseless)
  - 6,000 square degrees
  - 1, 2 and 3σ contours

Marginalized parameters

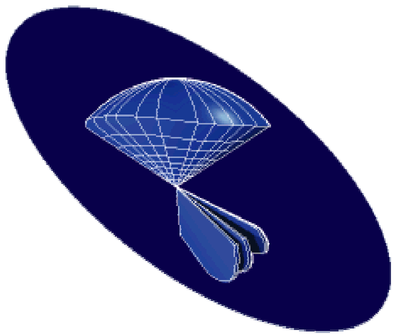
Fixed other parameters

Data Release 4



Summary

- Sloan Digital Sky Survey
  - Over 200 man year of development
  - The cosmic genome project
- Advanced statistical analyses
  - Elegant but observationally difficult, e.g.
    - Halo mass profile from weak lensing
    - Baryon bump in correlation function
- Going strong
  - More data: up to ~ 7,000 sq.deg
  - Promising novel techniques



http://www.sdss.org