Detection of the Baryon Acoustic Peak in the Large-Scale Correlation Function of SDSS Luminous Red Galaxies

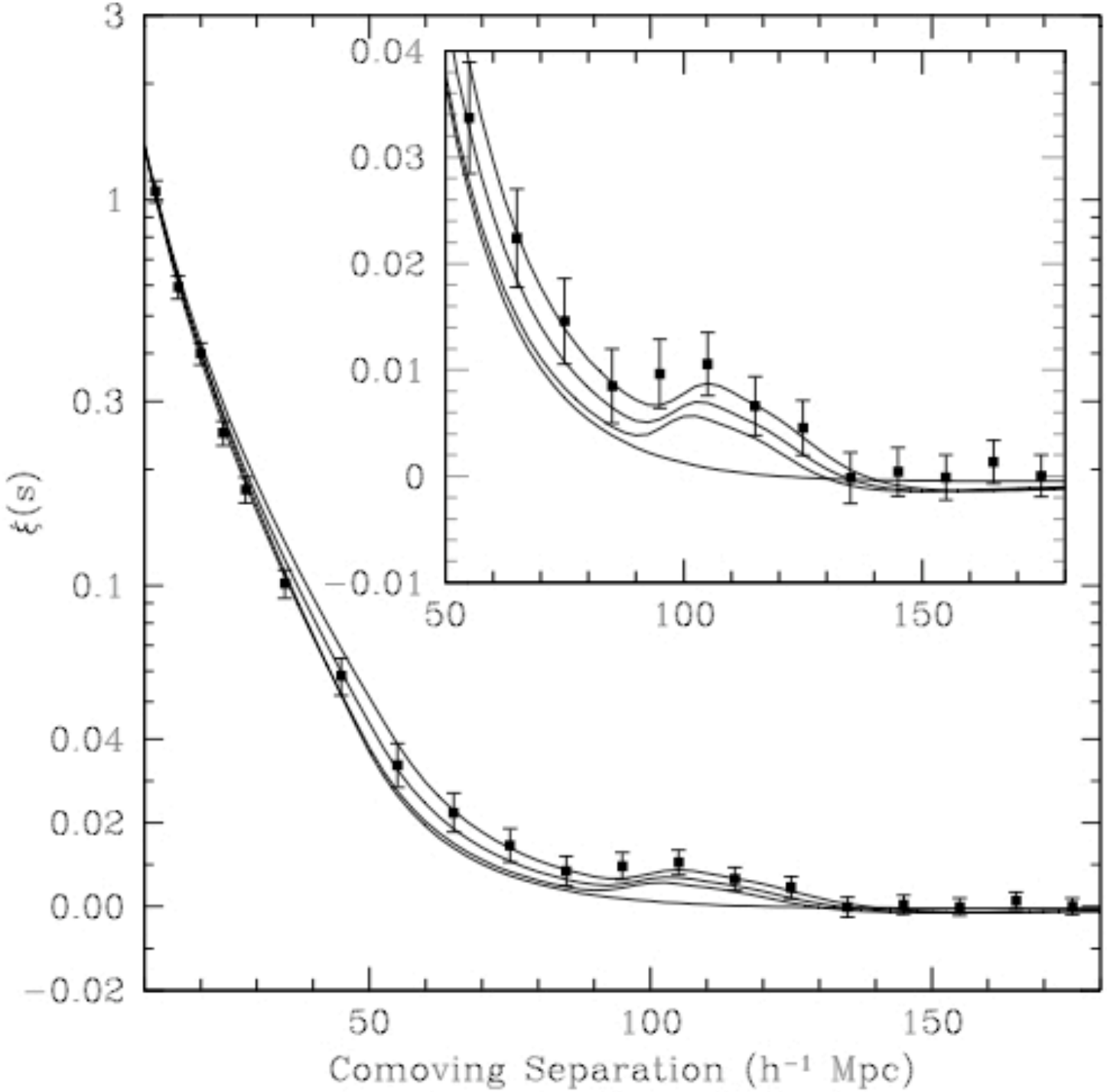
Eisenstein et al. 2005, ApJ, 633, 560

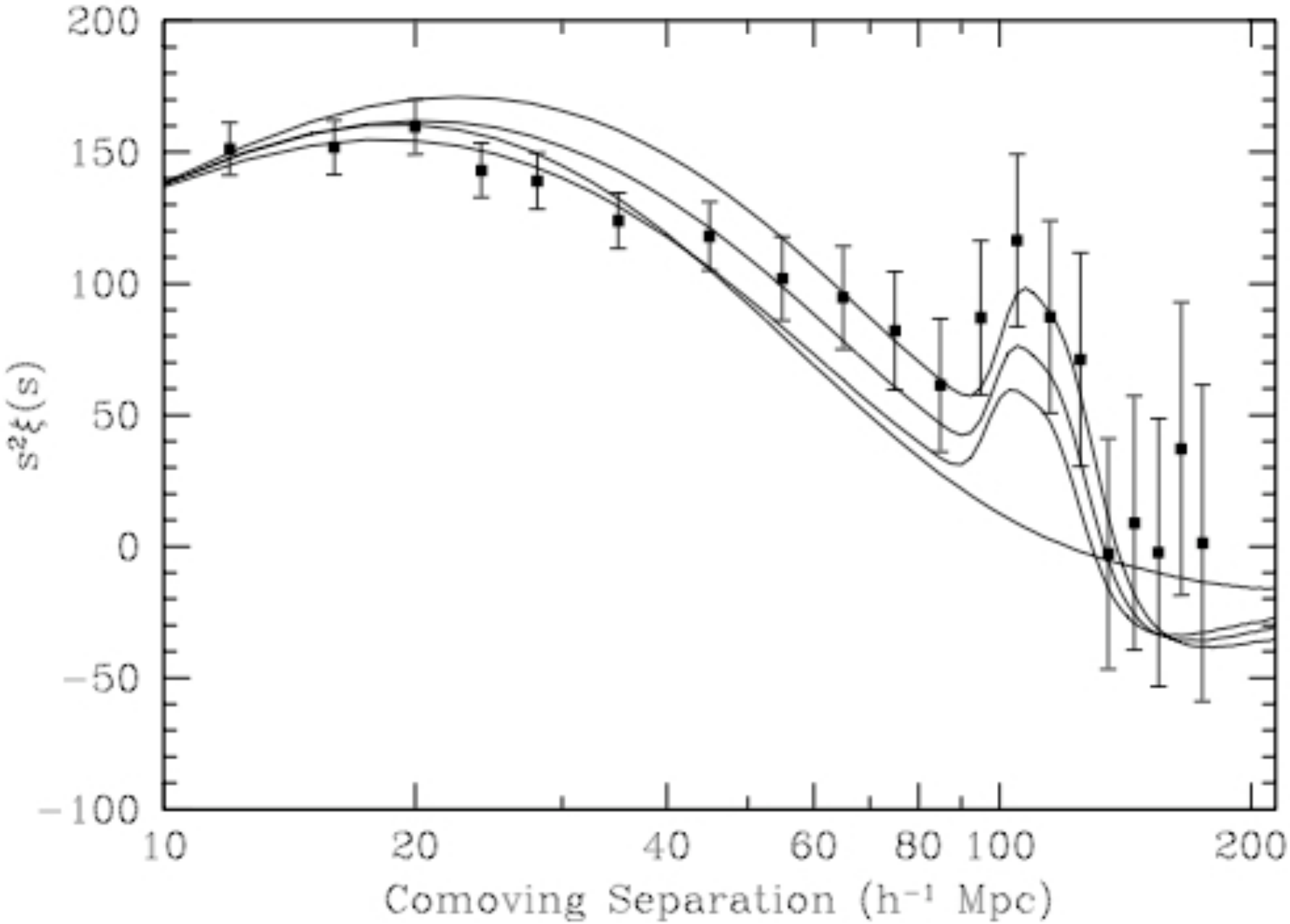
Quick Summary

- Presented large-scale correlation function calculated from 46,748 luminous red galaxies from SDSS.
- Survey covered 0.72 h^{-3} Gpc^3 over 3816 deg^2 and $0.16 < z < 0.47$
- Detected peak in correlation function at 100 h^{-1} Mpc
- Peak represents imprint of acoustic oscillations on low-redshift matter
- Demonstrates linear growth of gravitational instability
- Provides standard ruler to measure hi-z distances to great accuracy
- Provides constraints on cosmological parameters

Observations

- Uses Sloan Digital Sky Survey (SDSS) to get spectroscopic redshifts for 46,748 luminous red (early-type) galaxies.
  - 3816 deg^2
  - $0.16 < z < 0.47$
  - 0.72 $h^{-3}\,Gpc^3$
- Volume-limited out to z=0.36
- Largest ‘effective volume’ survey (by ~4x)
- Why use only LRG’s?


3
1
0.3
0.1
0.04
0.02
0.00
−0.02
ξ(s)
50
100
150
Comoving Separation (h⁻¹ Mpc)
0.04
0.03
0.02
0.01
0
−0.01
50
100
150


200
150
100
50
0
−50
−100
$s^2\xi(s)$
10
20
40
60
80
100
200
Comoving Separation (h^{-1} Mpc)

Baryon Acoustic Oscillations

- Why would you expect to see acoustic oscillation imprint on low-redshift matter?
- What does peak at 100 h^{-1} Mpc correspond to?
- What would a pure baryon model look like?
- What information does size of acoustic oscillation yield?

Correlation Function

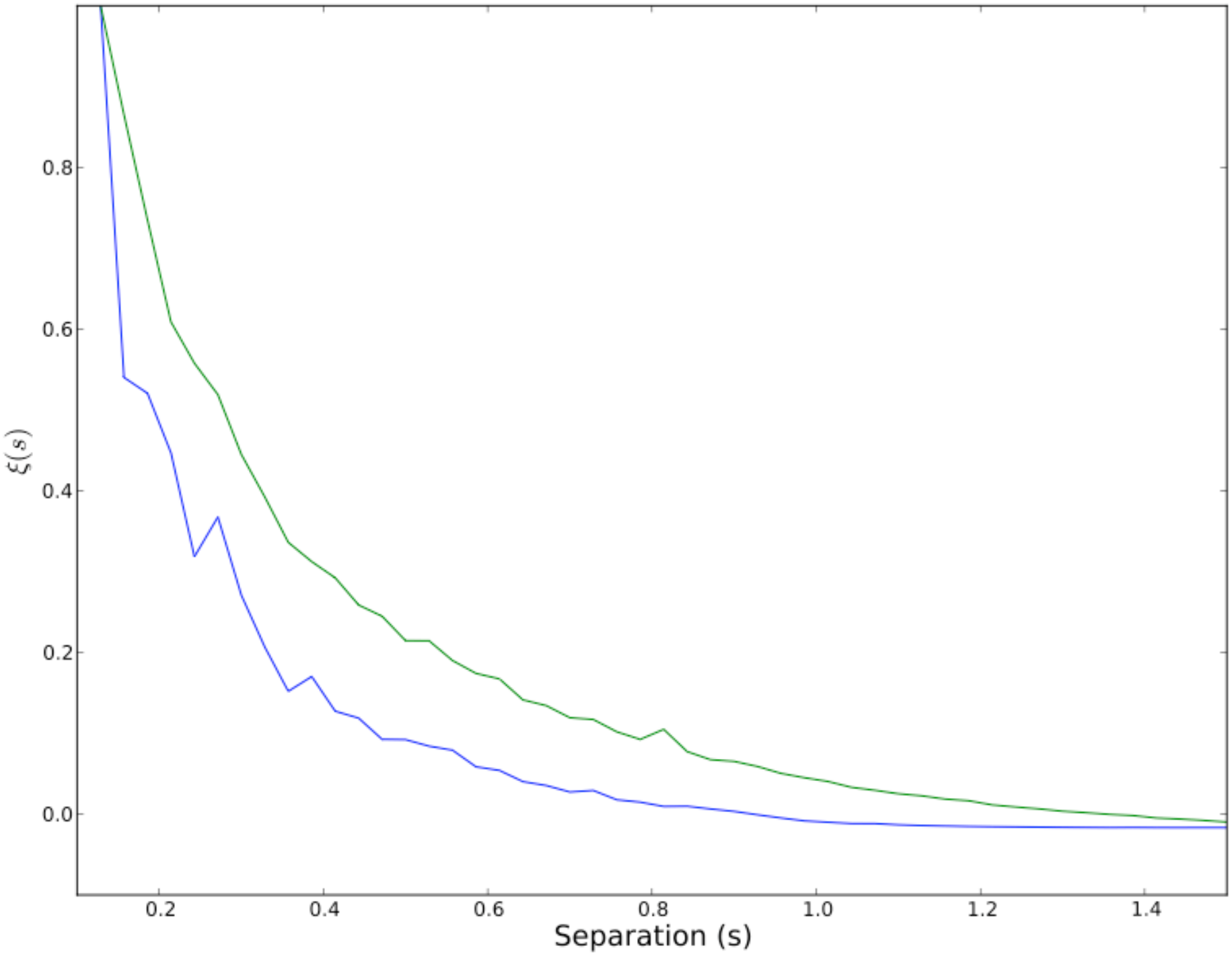
- Correlation function is Fourier Transform of Power Spectrum
- Correlation function is *excess* probability of finding a galaxy within a given separation
- Mean number of neighbors within separation r:

$$\langle N \rangle = \frac{4}{3}\pi r^3 n + n \int_0^r \xi(r)\, dV$$

- Correlation Function:

$$\xi(r) = \frac{N(r)}{n\frac{4}{3}\pi r^3} - 1$$

  - Where N(r) is number of galaxies separated by r (histogram)


0.8
0.6
0.4
0.2
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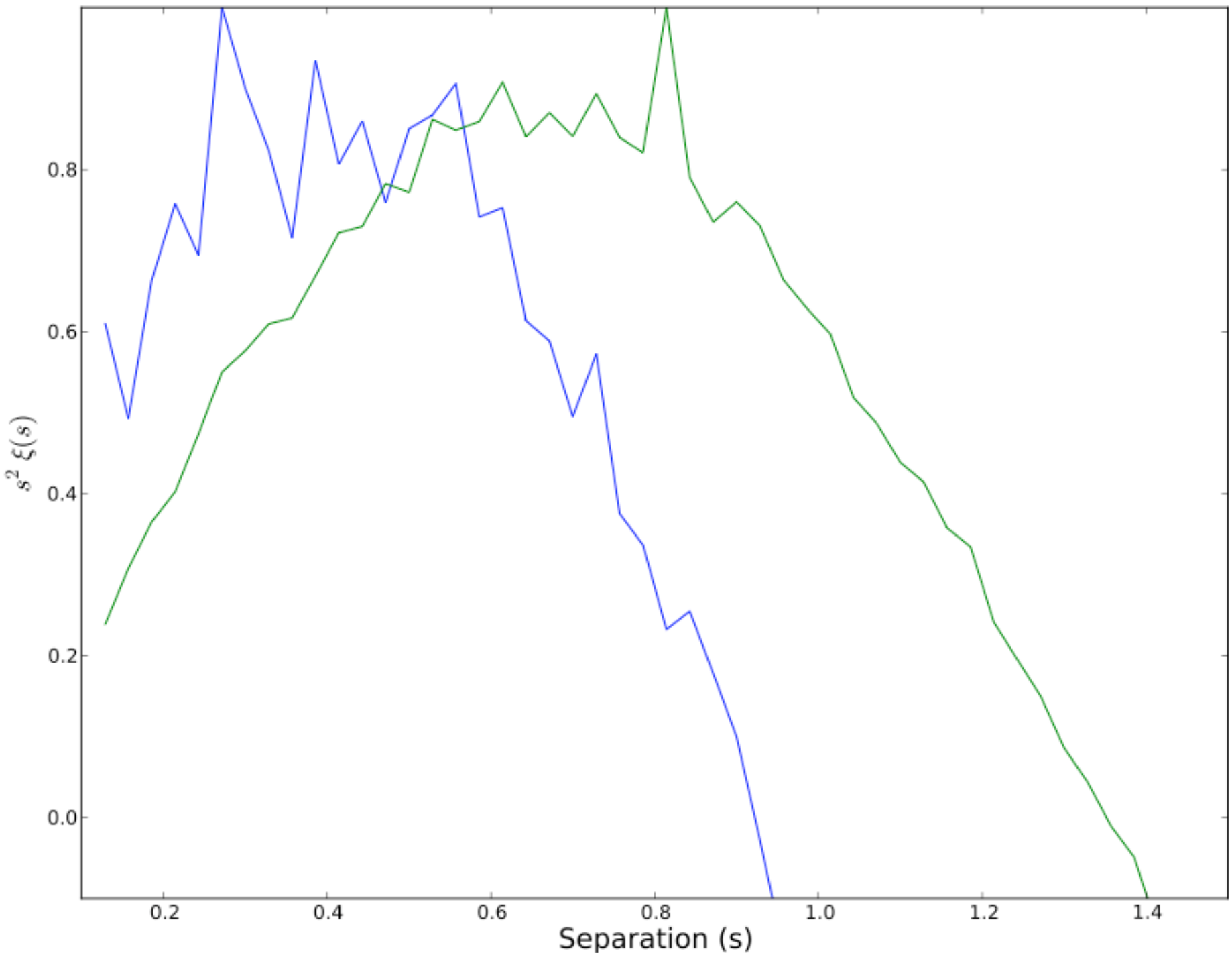
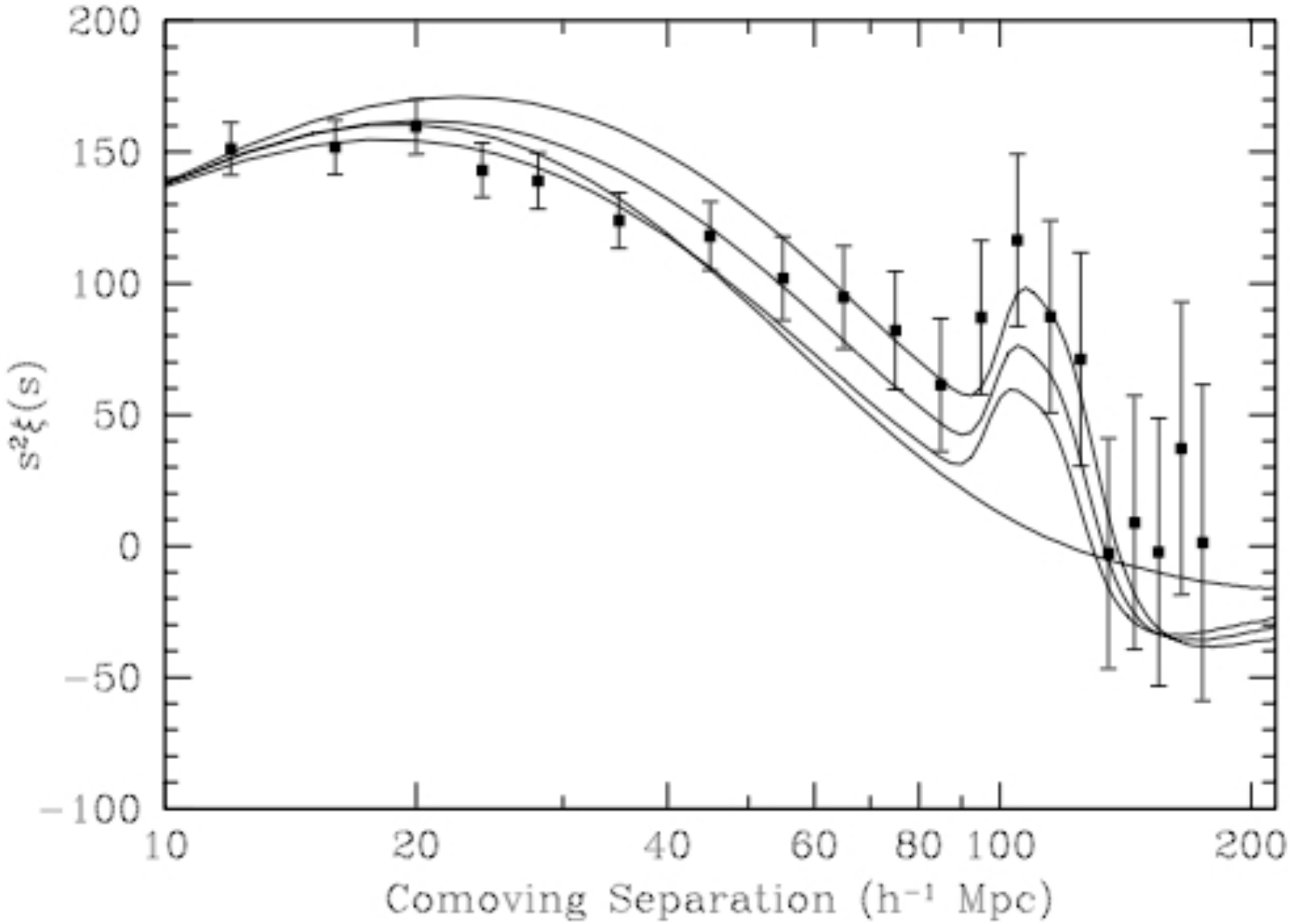
$\xi(s)$
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Separation (s)


0.8
0.6
0.4
0.2
0.0
$s^2\,\xi(s)$
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Separation (s)

Redshift-Space Correlation Function

- Analysis Steps:
  - Place each data point in its co-moving coordinate based on its redshift and angular position.
  - Compute the vector difference between one galaxy and all others.
  - Repeat for each galaxy.
- Each point is weighted by the inverse of the number density at its redshift. Why?

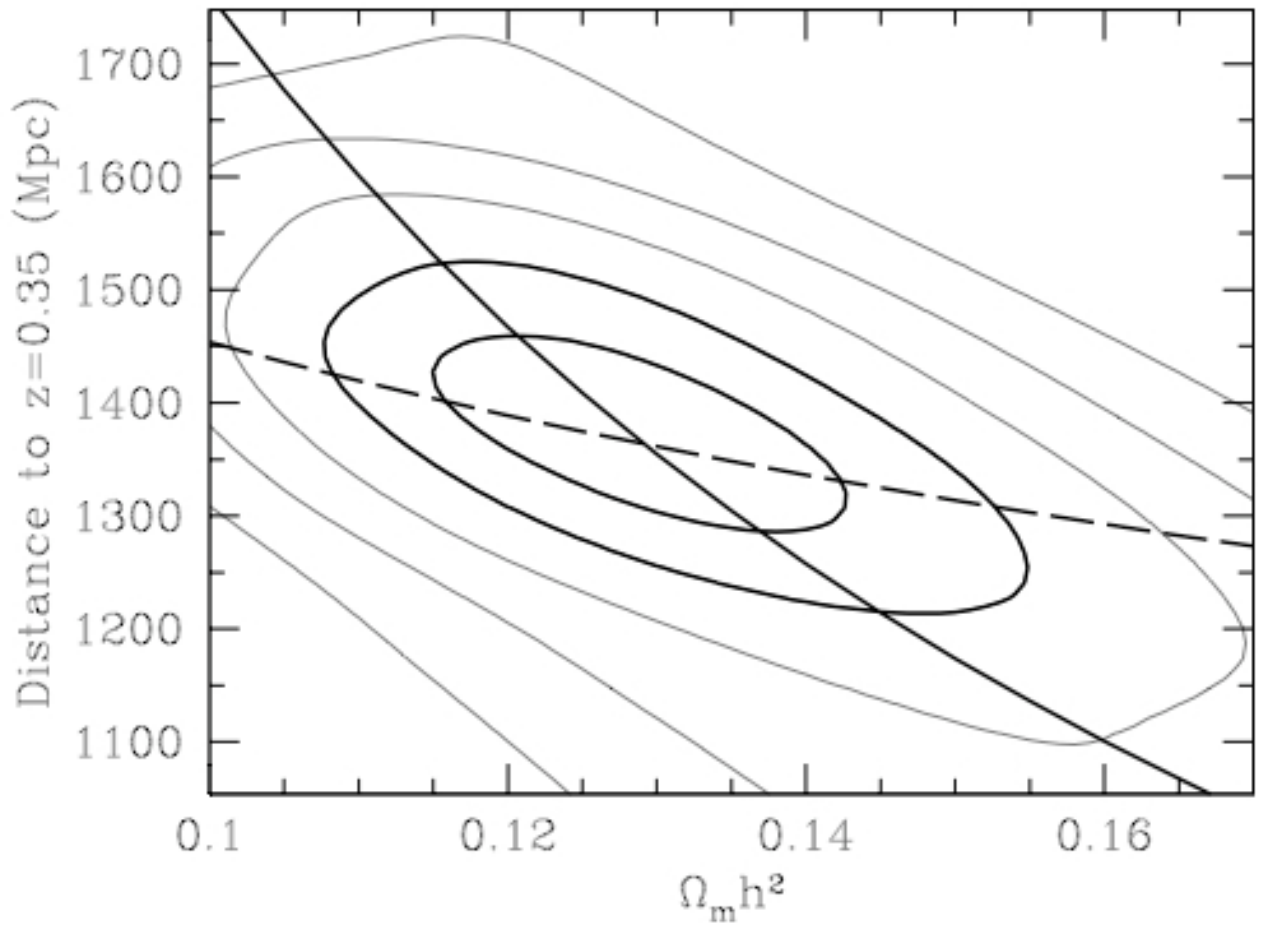

200
150
100
50
0
−50
−100
$s^2\xi(s)$
10
20
40
60
80
100
200
Comoving Separation (h^{-1} Mpc)

Tests for Systematic Errors

- Radial selection function (negligible)
- Photometric calibration (will average down on large scales?)
  - Will not introduce narrow correlations. They will be broad due to projection effects
- Break correlation into two redshift splices, which yield similar results. They say errors would enter the slices differently. True?

Covariance Matrix

- Must know covariance matrix fully to calculate correlation function
- Not feasible to use jackknife sampling (too many bins)
- Generate large set (1278) of mock catalogs
  - Compute correlation function in each
  - Compute covariance matrix from variations between them
- Best fit cosmo. model has χ^2=16.1 on 17 DOF (p=0.52).
  - Authors claim this indicates covariance matrix is on the correct scale.
- Hybrid model:
  - Use mock catalogs covariance to find best fit cosmo model for 10 jackknifed samples
  - Use rms of 10 best-fit parameters sets to determine errors

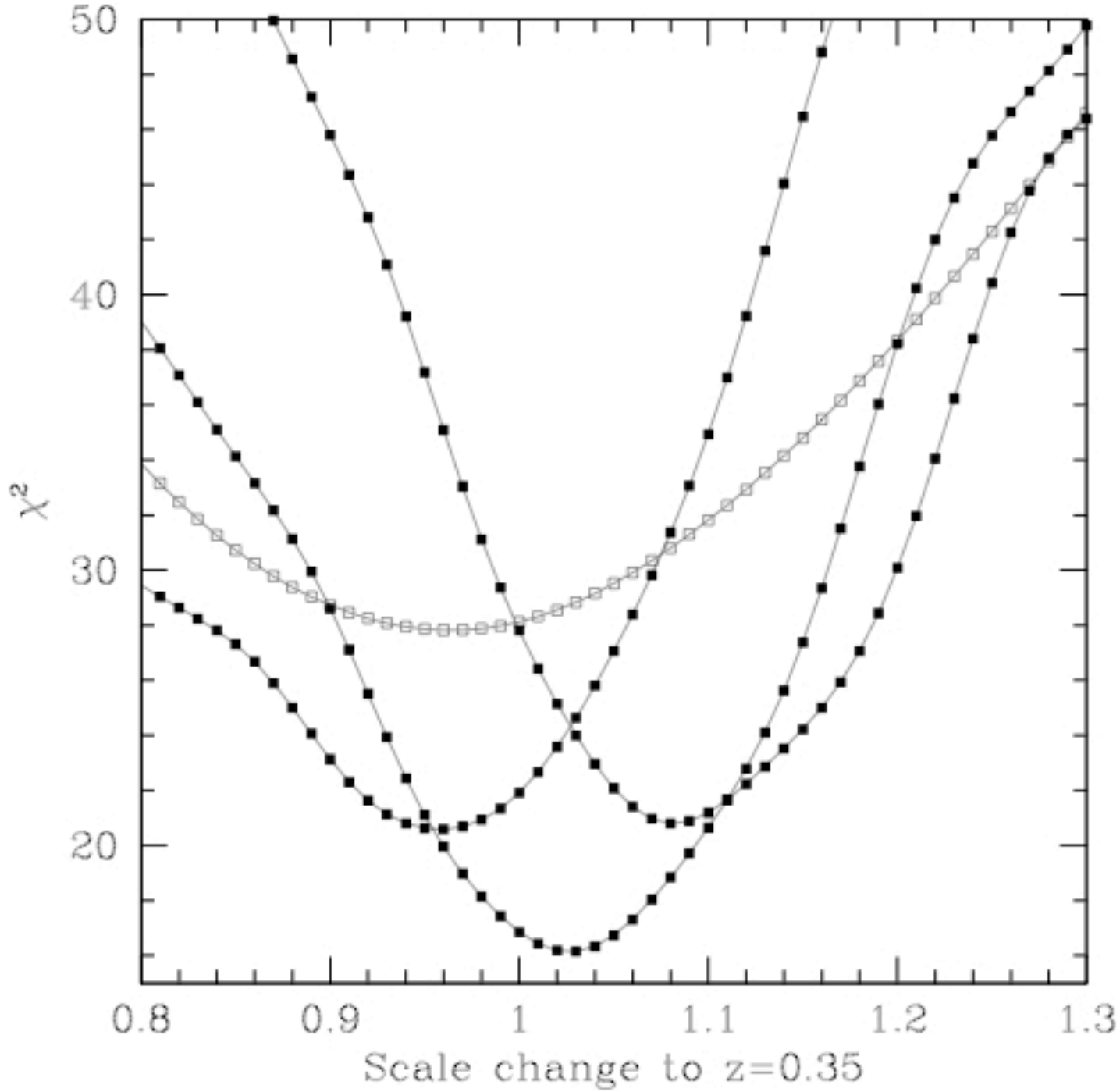


Summary of Parameter Constraints from LRGs

Parameter	Constraint
$\Omega_m h^2$	$0.130(n/0.98)^{1.2} \pm 0.011$
$D_V(0.35)$	1370 ± 64 Mpc (4.7%)
$R_{0:35} \equiv D_V(0{:}35)/D_M(1089)$	0.0979 ± 0.0036 (3.7%)
$A \equiv D_V(0{:}35)(\Omega_m H_0^2)^{1/2}/0{:}35c$	$0.469(n/0.98)^{-0.35} \pm 0.017$ (3.6%)

Constraints on Cosmology

- Size of ‘sound horizon’ depends on expansion history and sound speed of early universe plasma
- “Smoking-gun” evidence for linear growth
  - Why?
- Another confirmation of dark matter
- Provides standard ruler to use at various redshifts
  - $R_{0.35} = D_V(0.35) / D_M(1089)$
  - Purely geometrical (simple)
  - Describes evolution of Hubble Parameter
  - Provides constrains on acceleration of universe, ie, dark energy


50
40
30
20
χ^2
0.8
0.9
1
1.1
1.2
1.3
Scale change to z=0.35