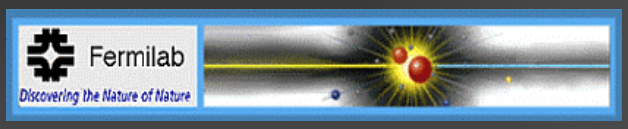
The Sloan Digital Sky Survey: Large-scale Structure Results

Josh Frieman

KITP, August 2002



SLOAN DIGITAL SKY SURVEY

http://www.sdss.org

GOAL: MAP THE UNIVERSE IN 3 DIMENSIONS OVER A LARGE VOLUME

- Photometric Survey: ~10^8 5-band CCD images
- Spectroscopic Survey: ~10^6 galaxy and 10^5 QSO redshifts

University of Chicago Fermilab Princeton University New Mexico State
Johns Hopkins University Institute for Advanced Study Max-Planck A and IA
U.S. Naval Observatory University of Washington Japan Participation Group
Los Alamos National Lab
University of Pittsburgh

Funding: Sloan Foundation, NSF, DOE, NASA, member institutions, Japan Ministry of Education

Builders of the Sloan Digital Sky Survey

The Builders of the SDSS are those individuals whose contributions to project infrastructure make the exciting SDSS science possible. Specifically, these are the individuals who have contributed two years or more of effort to the infrastructure of the project writing pipeline software, building hardware, or through leadership and fundraising. The list will grow with time.

John Anderson
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Steve Bastian
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Michael Vogeley
Patrick Waddell
Shu-i Wang
David Weinberg
Brian Yanny
Naoki Yasuda
Don York

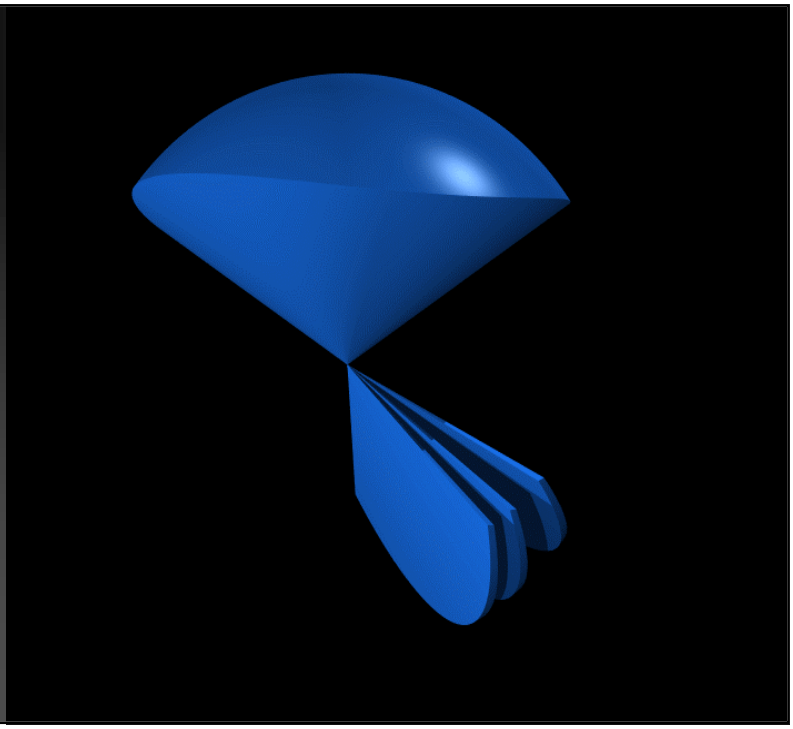
Scott Burles
David Schlegel
Mark Subbarao

Survey Geometry:

Northern Survey: 6,600 sq. deg around North Galactic Cap

Southern Survey:

3 slices; central slice scanned repeatedly to go deeper and find variable objects



SDSS Nuts & Bolts

•2.5m Dedicated Telescope:
Ritchey-Chretien design with 3 deg corrected FOV,
sited at Apache Point Observatory (NM)

•Large multi-CCD Camera:
Filters u'g'r'i'z' (3540-9250 A) for star/galaxy/QSO selection and photometric redshift estimates
30 primary 2048x2048 chips (0.4 arcsec/pixel) + astrometric chips
Drift-scan mode: 55 sec exposures ➔ limiting magnitude r' ~23

•Multi-fiber spectrographs:
2 double fiber-fed spectrographs covering ~3900-9200 A
640 fibers on the sky, using pre-drilled plug plates
Obtain redshifts for galaxies with r'<17.7, QSOs with g'<19.7, and luminous red galaxies selected by color

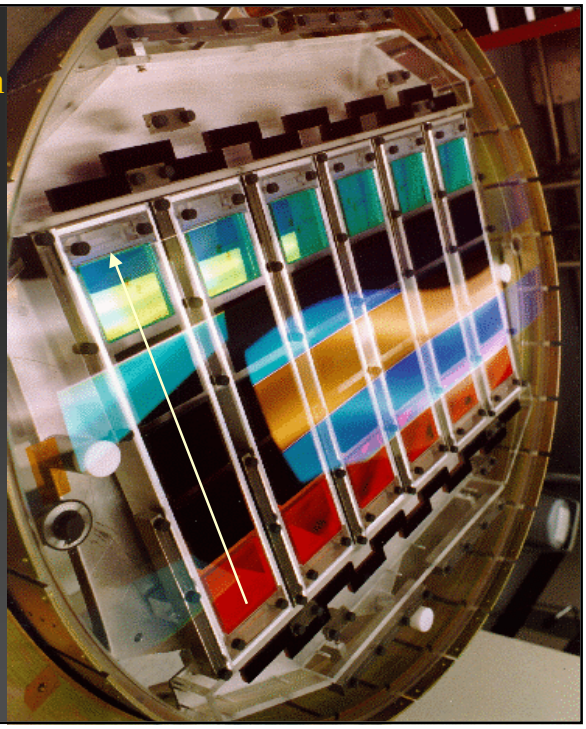
•Data processing: 10s of Terabytes of raw imaging data, processed promptly at Fermilab for follow-up spectroscopy

SDSS Imaging Camera

Top to bottom:

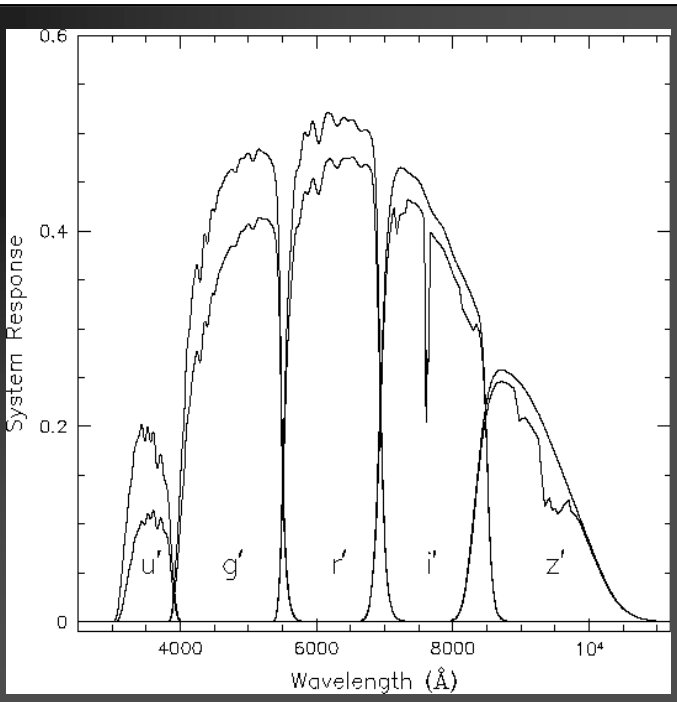
g'
z'
u'
i'
r'

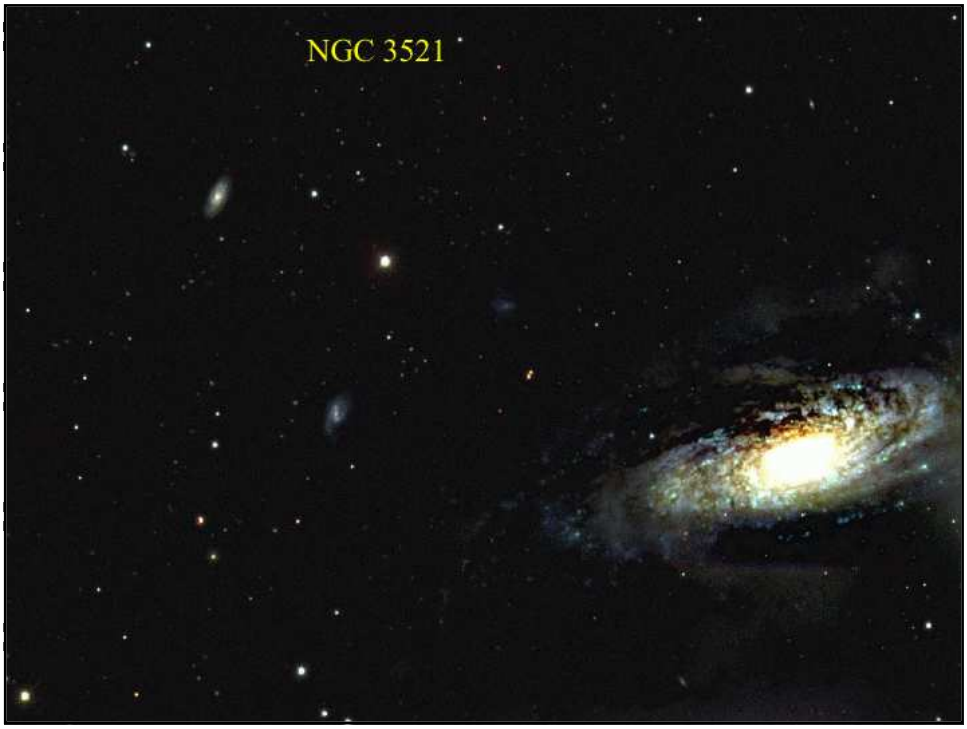
Drift Scan Mode

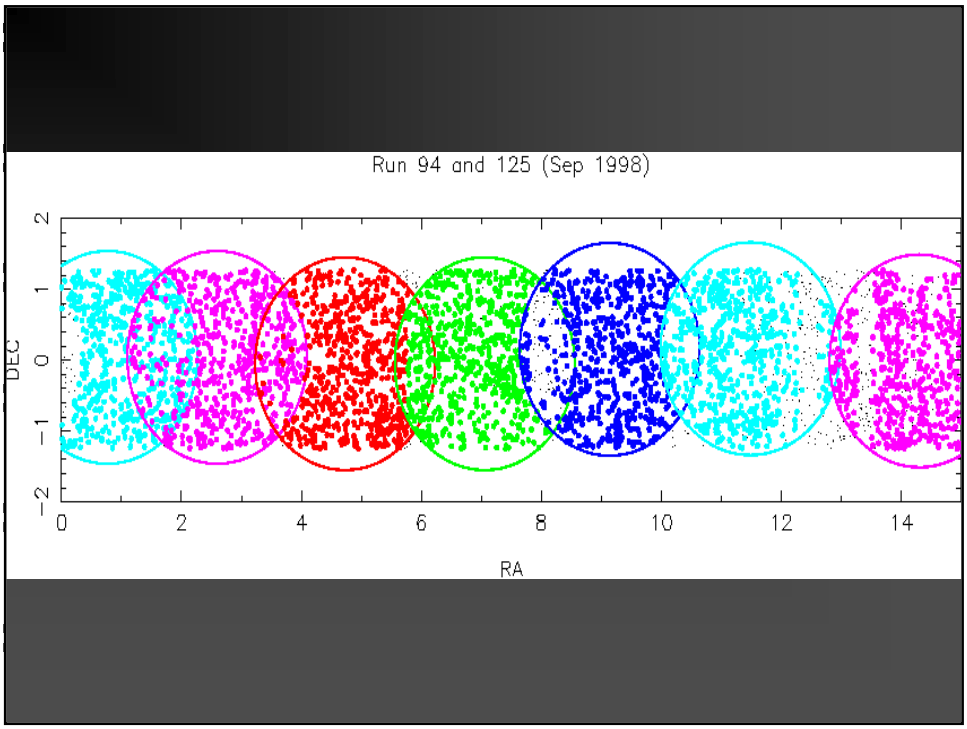


Photometric Camera filter response

with and w/o atmospheric extinction of 1.2 airmasses




NGC 3521


Run 94 and 125 (Sep 1998)
DEC
RA
2
1
0
−1
−2
0
2
4
6
8
10
12
14

Plugging Spectroscopic Plates

640 fibers per plate

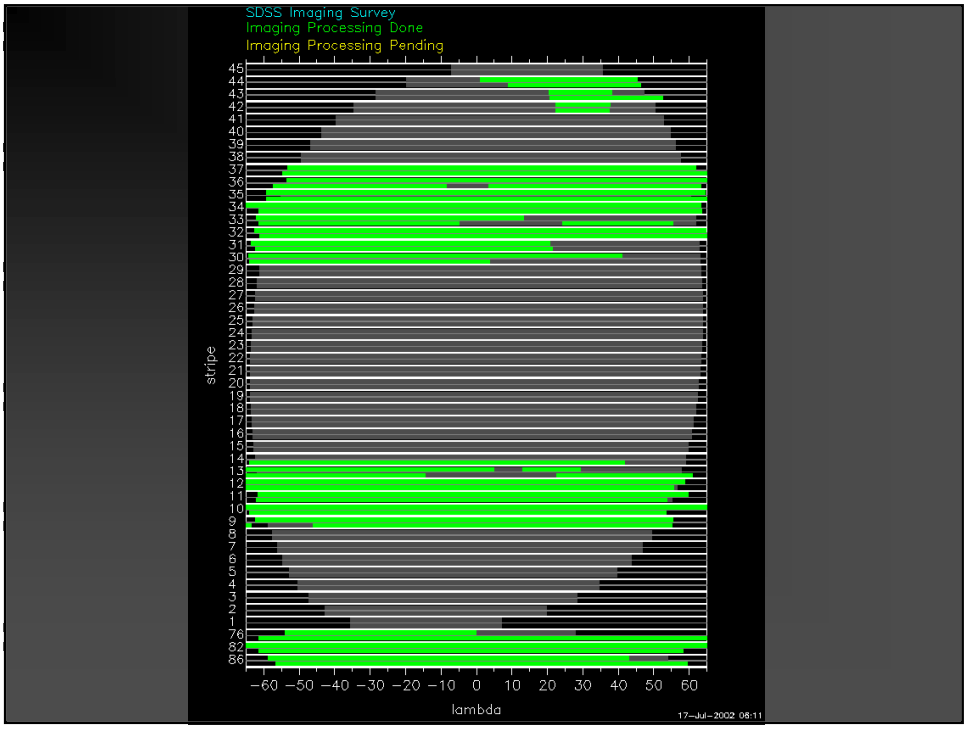
SDSS Data

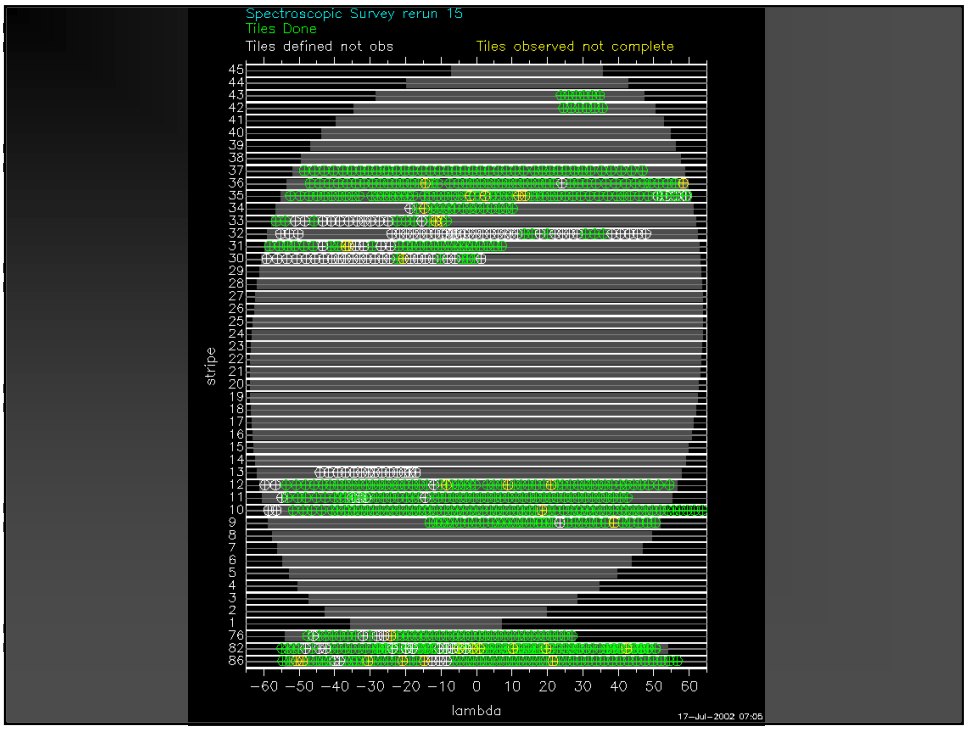
April 2000: Survey begins (commissioning ends)
June 2005: Survey finishes

Data so far: ~3,264 unique square degrees of 5-band imaging (7/02) (~60 million objects)
~375,000 object spectra (G,Q,S redshifts)

Samples currently being analyzed (preliminary results today):

~2,500 sq. deg. imaging with photometric redshifts
~140,000 main galaxy (spectroscopic) redshifts
~30,000 QSO redshifts
~25,000 LRG redshifts

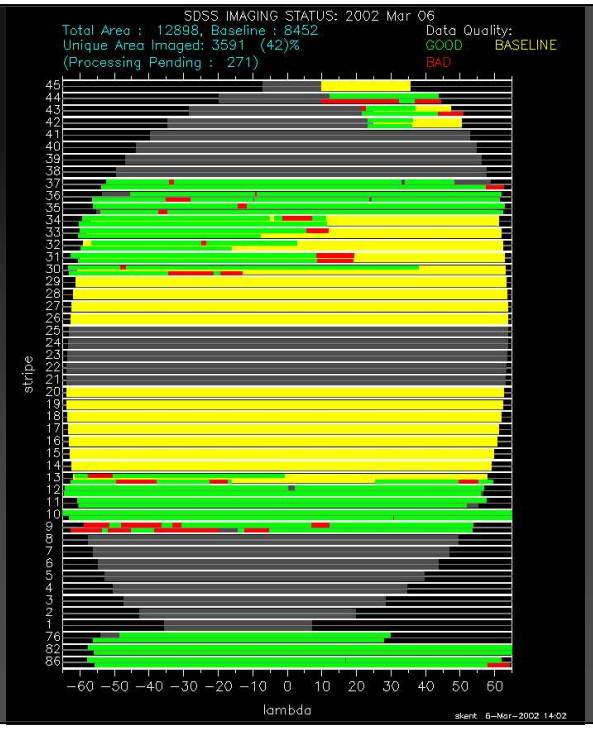

SDSS Imaging Survey
Imaging Processing Done
Imaging Processing Pending
stripe
lambda
17-Jul-2002 08:11


Spectroscopic Survey rerun 15
Tiles Done
Tiles defined not obs
Tiles observed not complete
stripe
lambda
17-Jul-2002 07:05

Projected to June 2005:

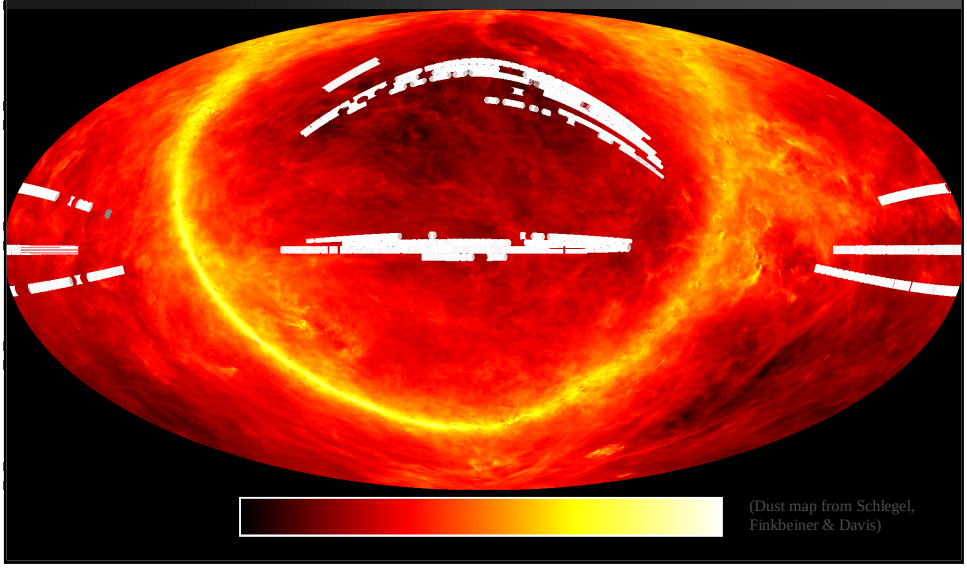
6600 sq deg imaging

600,000 spectra



Sky coverage of SDSS redshift survey

(Aitoff projection, equatorial coordinates)



SDSS Public Data Releases

•Series of Staged Data Releases (cf. COBE)

•June 2001: Early Data Release

~600 square degrees of 5-band imaging
(~8 million galaxies to r* < 22.5)

~60,000 object spectra (redshifts)

•January 2003: First Data Release

~2,800 sq. deg. imaging
~200,000 spectra/redshifts

Large-scale Structure Results

•Results of the LSS Working Group

•Angular Clustering of Galaxies in the Photometric Survey

--incorporation of photometric redshifts Budavari,etal
--clustering by galaxy type (color and luminosity)

•Power spectrum and Two-point correlation of Galaxies in the Spectroscopic Survey

--clustering by galaxy type Zehavi, etal Tegmark, etal

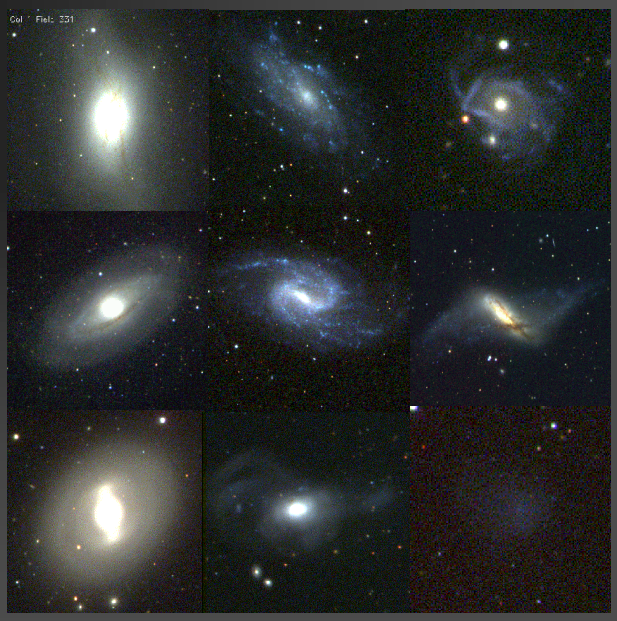
•In the works: clustering of LRGs, clusters, QSOs, Ly-a forest; higher order correlations of galaxies; clustering by spectroscopic type and stellar mass

Galaxy Clustering varies with Galaxy Type

How are each of them related to the underlying Mass distribution?

Bias depends upon Galaxy Color & Luminosity

Need large, carefully selected samples to study this



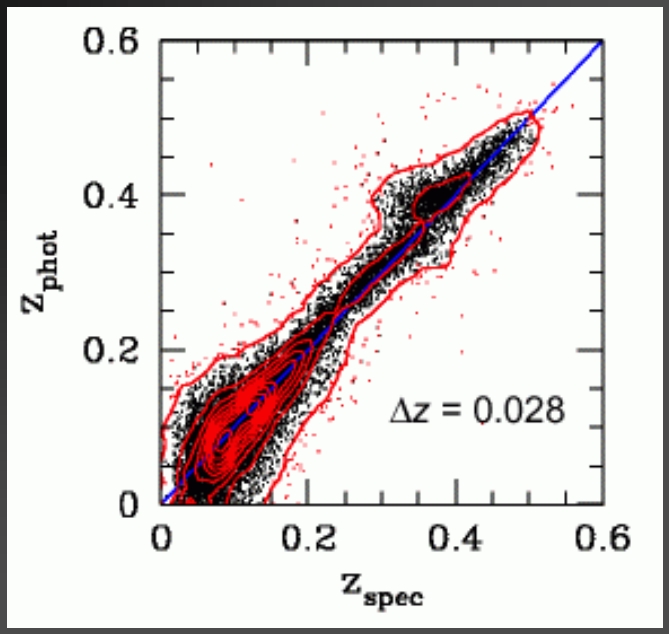
Angular Clustering with Photometric Redshifts

T. Budavari, A. Connolly, I. Csabai, I. Szapudi, A. Szalay, S. Dodelson, J. Frieman, R. Scranton, D. Johnston and the SDSS Collaboration

- Sample selection based on rest-frame quantities
- Strictly volume limited samples
- Largest angular correlation study to date
- Very clear detection of
  - Luminosity dependence
  - Color dependence
- Results consistent with 3D clustering

Galaxy photometric redshift estimates

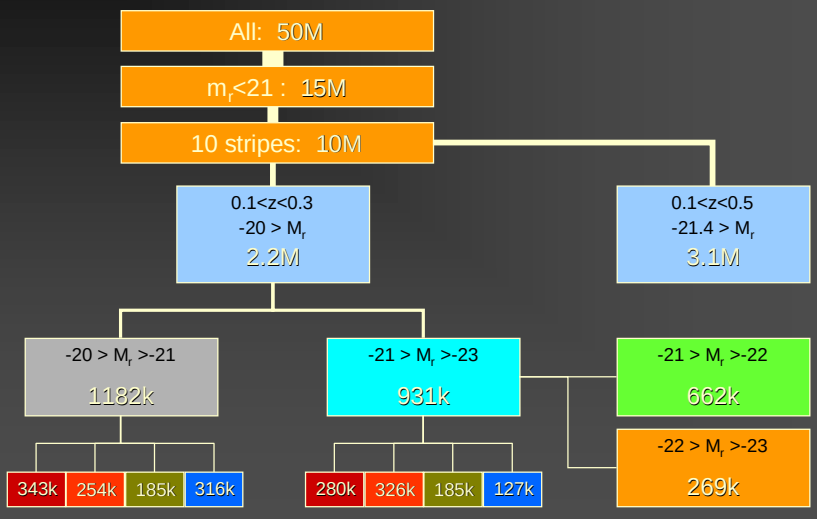
Predicted redshift from 5-band SDSS Photometry



Connolly, etal
Csabai, etal

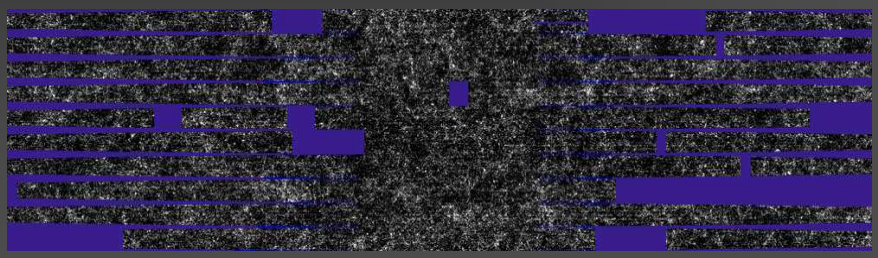
Spectroscopic measured redshift

The Photo-z Samples



The Imaging Stripes

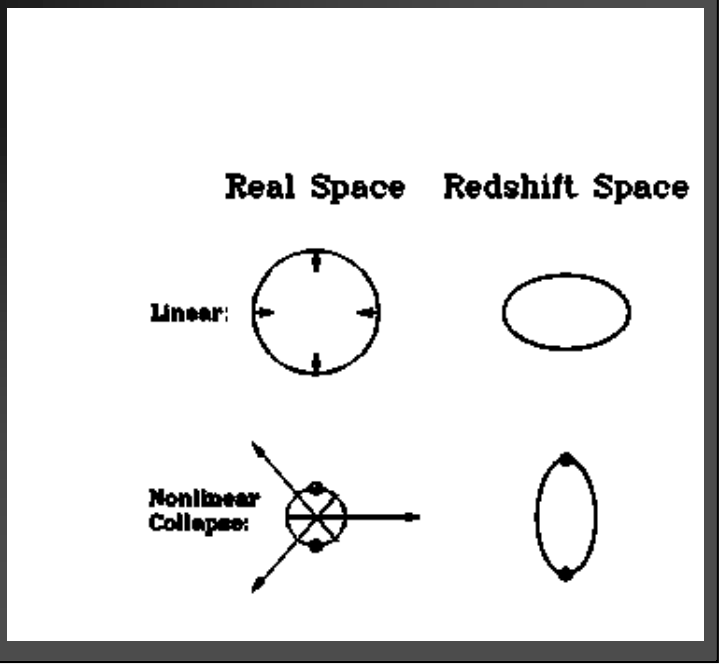
- 10 stripes over the SDSS area, covering about 2800 square degrees
- About 20% lost due to bad seeing
- Masks: seeing, bright stars, etc.



Angular Summary

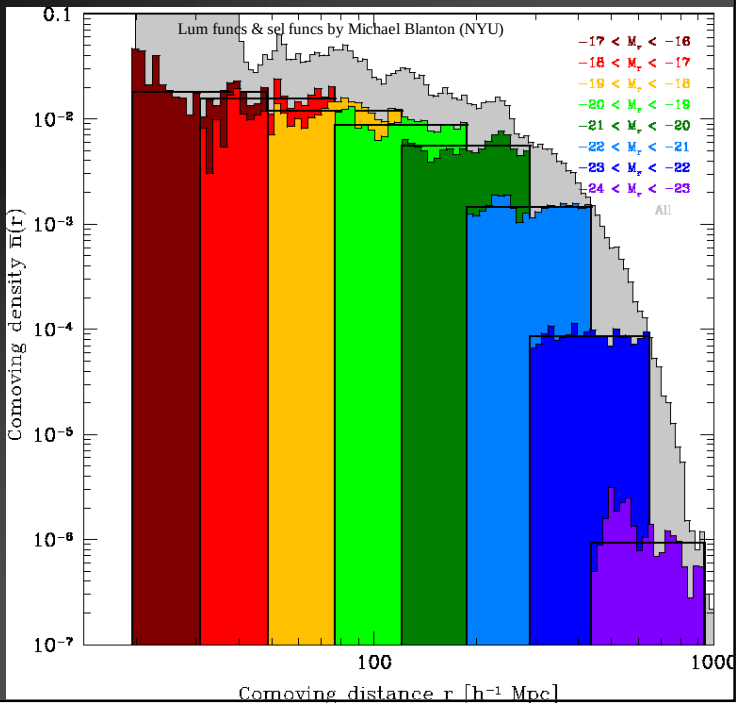
- Photometric redshifts
  - Excellent sample selection
    - Volume limited, luminosity dependence, color dependence
  - Large samples
    - Over 10 million galaxies in sample
- Results
  - Error bars tiny, very low systematics
  - Strong dependence of clustering on type and luminosity
  - Signal much cleaner than ever before
  - Excellent agreement with 3D data
- Next
  - Go to higher redshifts => evolutionary effects
  - Large scale power spectrum with Photo-z samples

Redshift Distortions

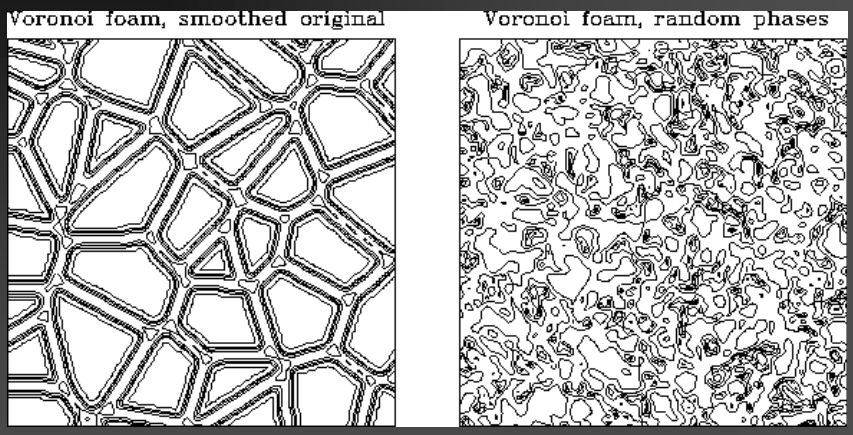


Divide Galaxies by Intrinsic Luminosity:

Volume-limited subsamples



Non-Gaussian structure: beyond Two-point statistics



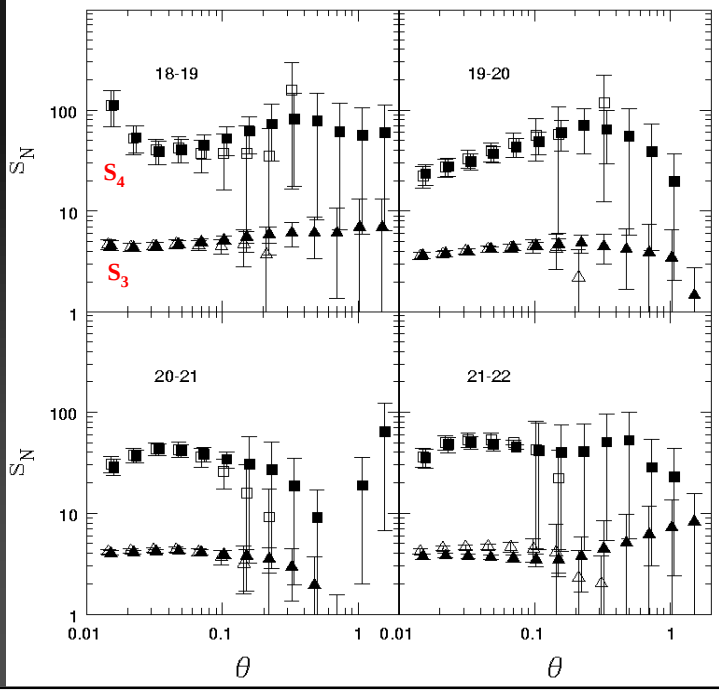
Szalay

Higher Order Angular Correlations in early SDSS imaging data

S_N =

$\langle \delta^N \rangle / \langle \delta^2(\theta) \rangle^{N-1}$

Higher order Correlations probe Bias & initial Non-Gaussianity



Szapudi, etal

Comparison with Biased ΛCDM model

Higher Order Correlations consistent with Non-linear evolution from Gaussian Initial Conditions

➔Constrain models of Inflation