

# **BOSS**

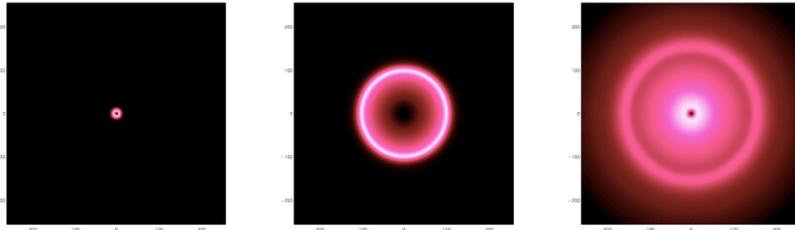
## **The Baryon Oscillation Spectroscopic Survey**

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(on behalf of the BOSS team)

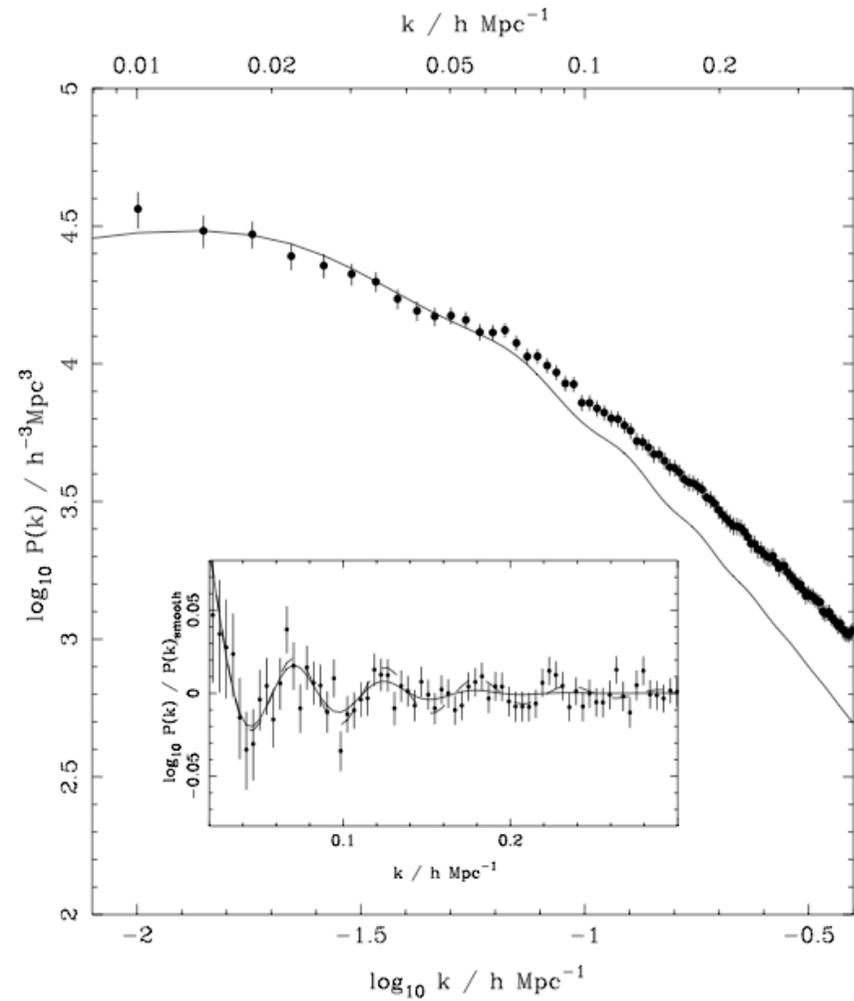
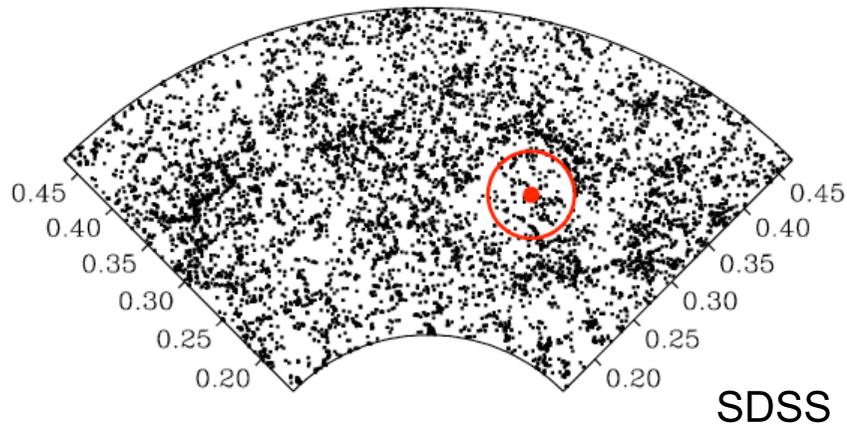
## Outline

- Introduction to BAO
- BOSS: a next generation BAO survey
- BOSS as part of SDSS-III
- LRGs
- QSOs
- Dark Energy constraints from BAO
- Other science
- Summary

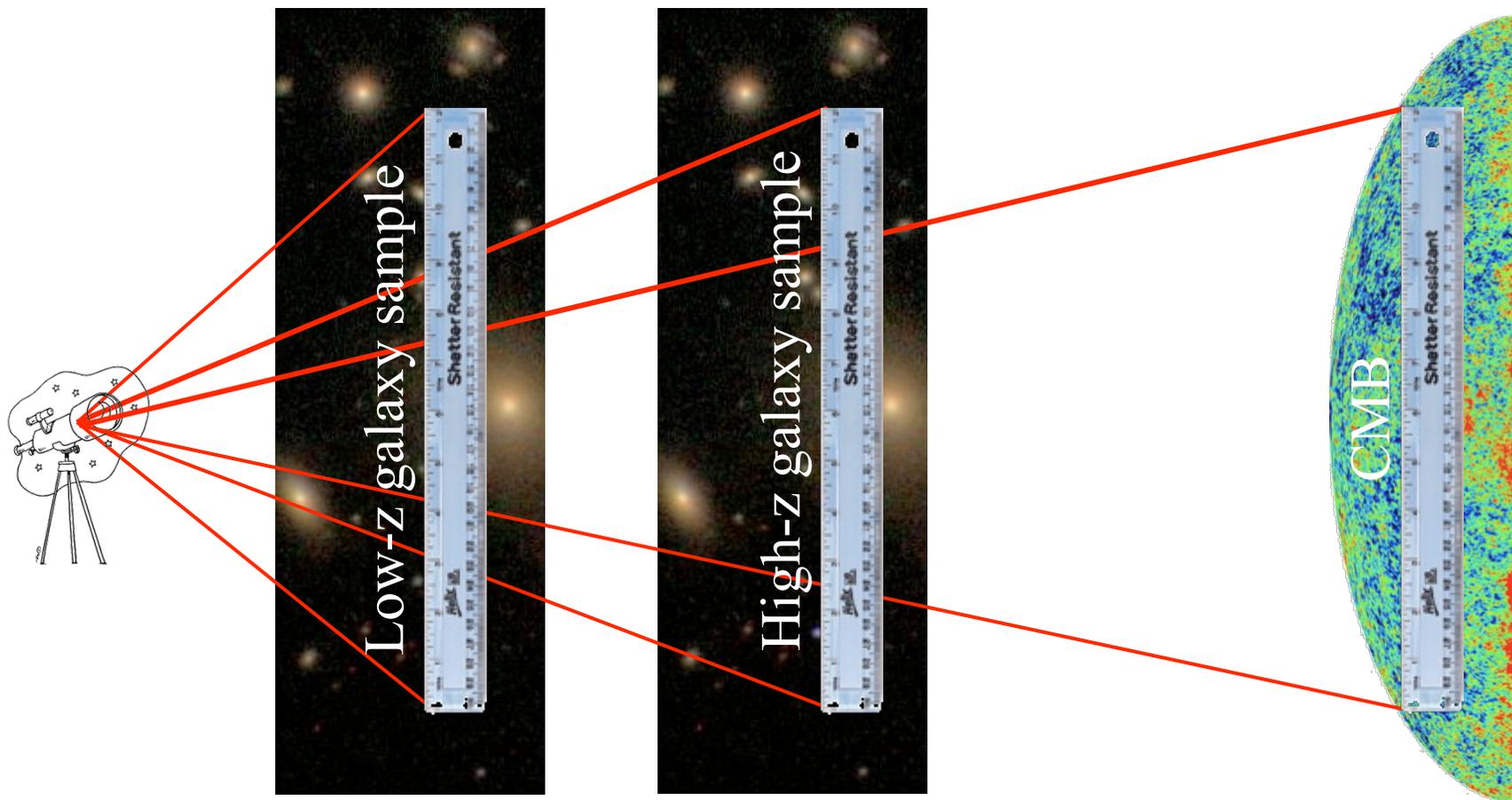
# Baryon Acoustic Oscillations (BAO)



(images from Martin White)



## Using BAO to test Dark Energy



Sunyaev & Zel'dovich (1970); Peebles & Yu (1970); Doroshkevitch, Sunyaev & Zel'dovich (1978); ...  
Cooray, Hu, Huterer & Joffre (2001); Eisenstein (2003); Seo & Eisenstein (2003);  
Blake & Glazebrook (2003); Hu & Haiman (2003); ...

## BOSS: A next generation BAO experiment

- SDSS finished its original, legacy survey in 2008
- Spectroscopic survey role identified as remaining world-class (7.5deg<sup>2</sup> field-of-view, even though 2.5m telescope)
- SDSS Imaging detects and can distinguish luminous red galaxies out to  $z < 0.7$  (e.g. AGES, 2SLAQ)
- Obvious next step: large survey for LRGs to measure BAO for  $z < 0.7$



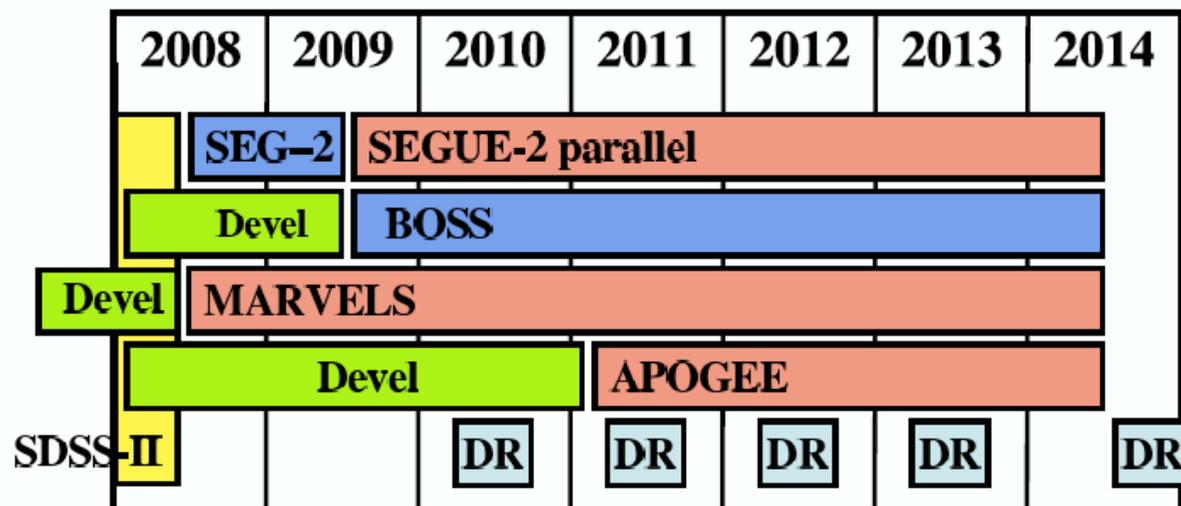
- Can also pick up high- $z$  BAO signal in Ly- $\alpha$  forest in QSO spectra
- Very efficient: each spectra gives skewer though density field, rather than single point

## BOSS: Summary

- $\Omega = 10,000\text{deg}^2$
- Selected from  $11,000\text{deg}^2$  of imaging
  - $8,500\text{deg}^2$  in North
  - $2,500\text{deg}^2$  in South (fill in SDSS-II Southern stripes)
- LRGs :  $150/\text{deg}^2$ ,  $z \sim 0.1 - 0.7$  (direct BAO)
- $1\% d_A$ ,  $1.8\% H$  at  $z \sim 0.35, 0.6$
- QSOs :  $20/\text{deg}^2$ ,  $z \sim 2.1 - 3.0$  (BAO from Ly- $\alpha$  forest)
- $1.5\% d_A$ ,  $1.2\% H$  at  $z \sim 2.5$
- Cosmic variance limited to  $z \sim 0.6$  : as good as LSS mapping will get with a single ground based telescope
- Leverage existing SDSS hardware & software where possible
- Sufficient funding is in place and project is underway
- [www.sdss3.org/boss](http://www.sdss3.org/boss)

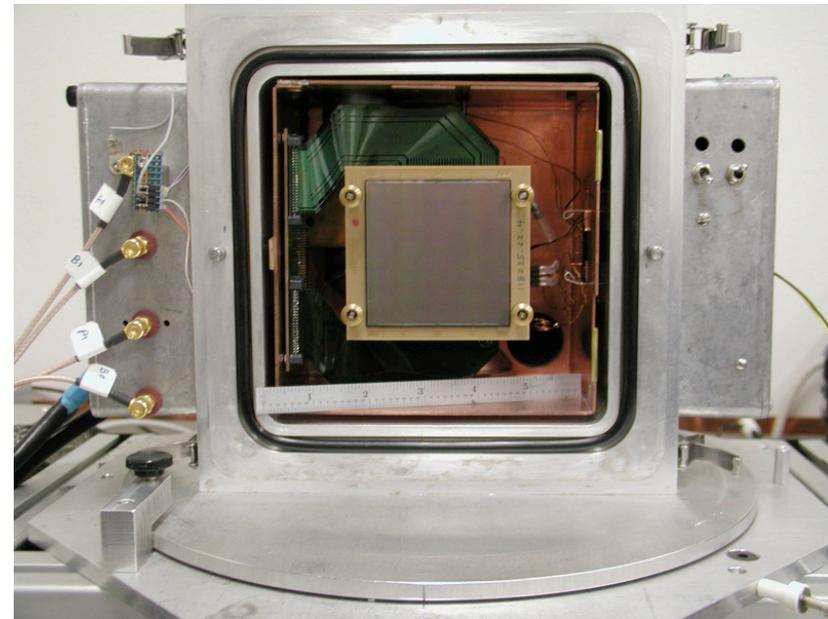
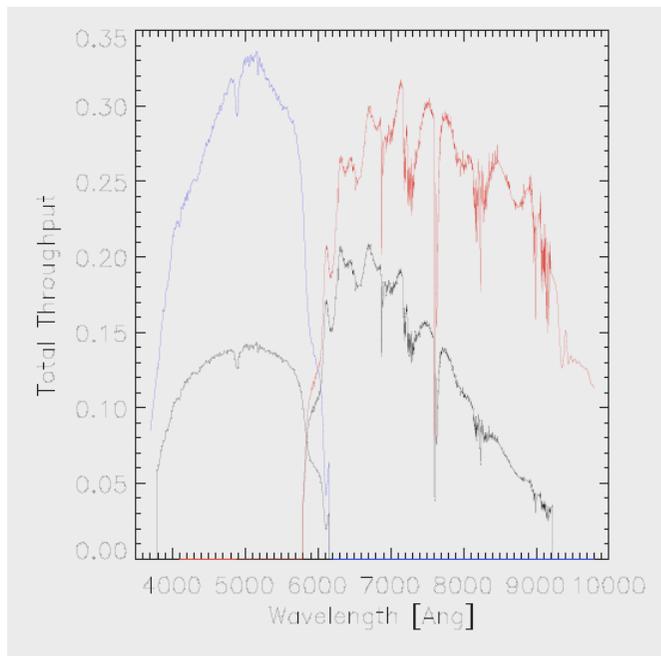
## BOSS: part of SDSS-III

- SEGUE-2: Kinematic and chemical structure from 350,000 stars in the outer Galaxy.
- APOGEE: High resolution IR spectroscopy of stars in the Galactic bulge, bar and disk.
- MARVELS: Radial velocity planet search around 11,000 stars
- BOSS: BAO with 1.5 million LRGs ( $z < 0.7$ ) and 160,000 QSOs ( $2.3 < z < 3.3$ )



## Hardware upgrades

- Replace 640×3arcsec fibers with 1000×2arcsec fibers
- Replace existing red/blue CCDs with (larger & better LBL/Fairchild/E2V CCDs)
- Replace existing gratings with VPH grisms
- Increase wavelength range to 3700-9800Å

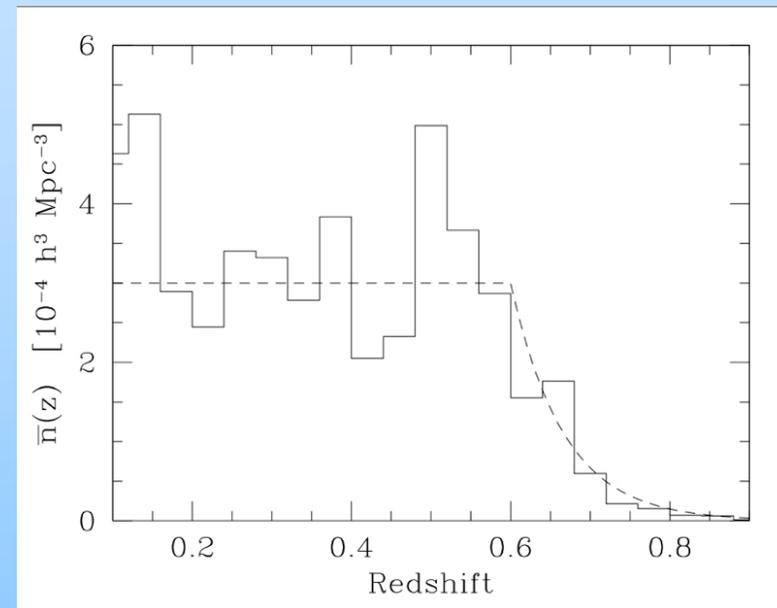


## Luminous Red Galaxies

- Targeting based on SDSS gri photometry
  - $i < 19.9$
  - colour select for constant number density / stellar mass
  - experience from SDSS, AGES, 2SLAQ
- $\sim 150/\text{deg}^2$ ,  $n \sim 3 \times 10^{-4} (h/\text{Mpc})^3$
- sample similar to photometric samples

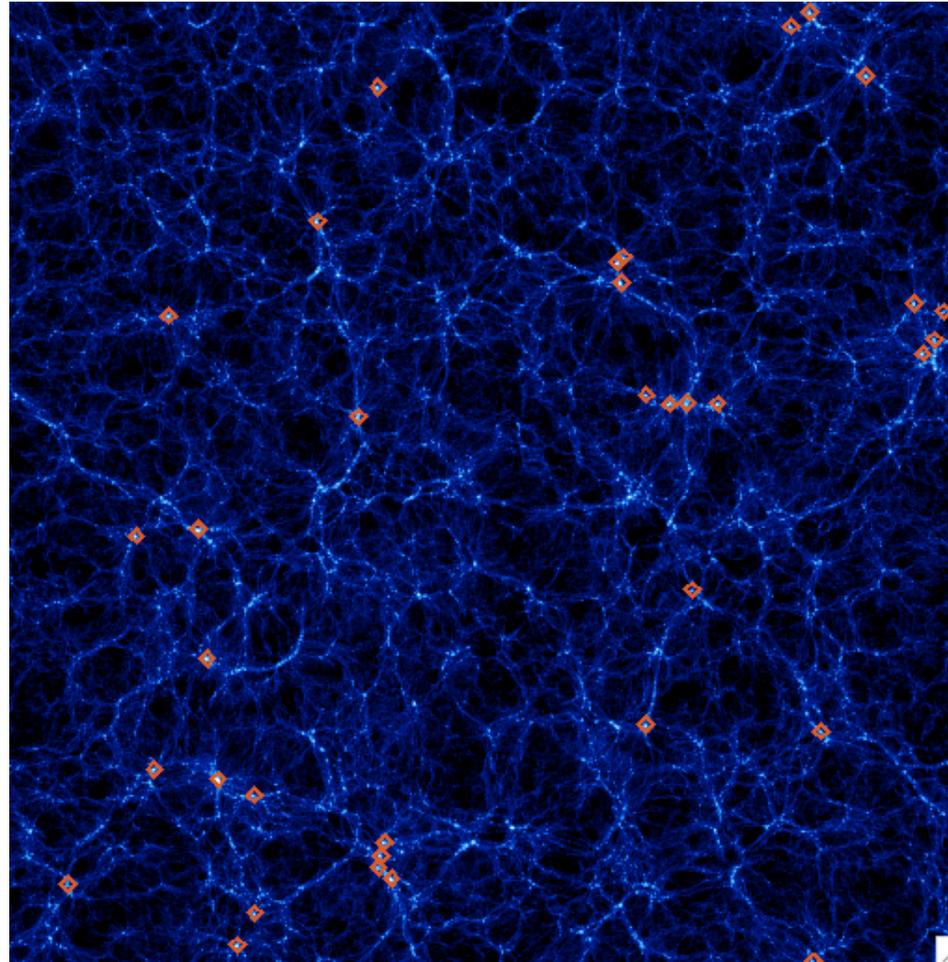
previously analysed in

- Padmanabhan et al (2007)
- Blake et al. (2007)
- Bias passively evolving:  
 $b(z)D(z) \sim 1.7$  ( $\sigma_8 = 0.8$ )
- Small-scale clustering well understood in terms of HODs



## LRGs as tracers of LSS

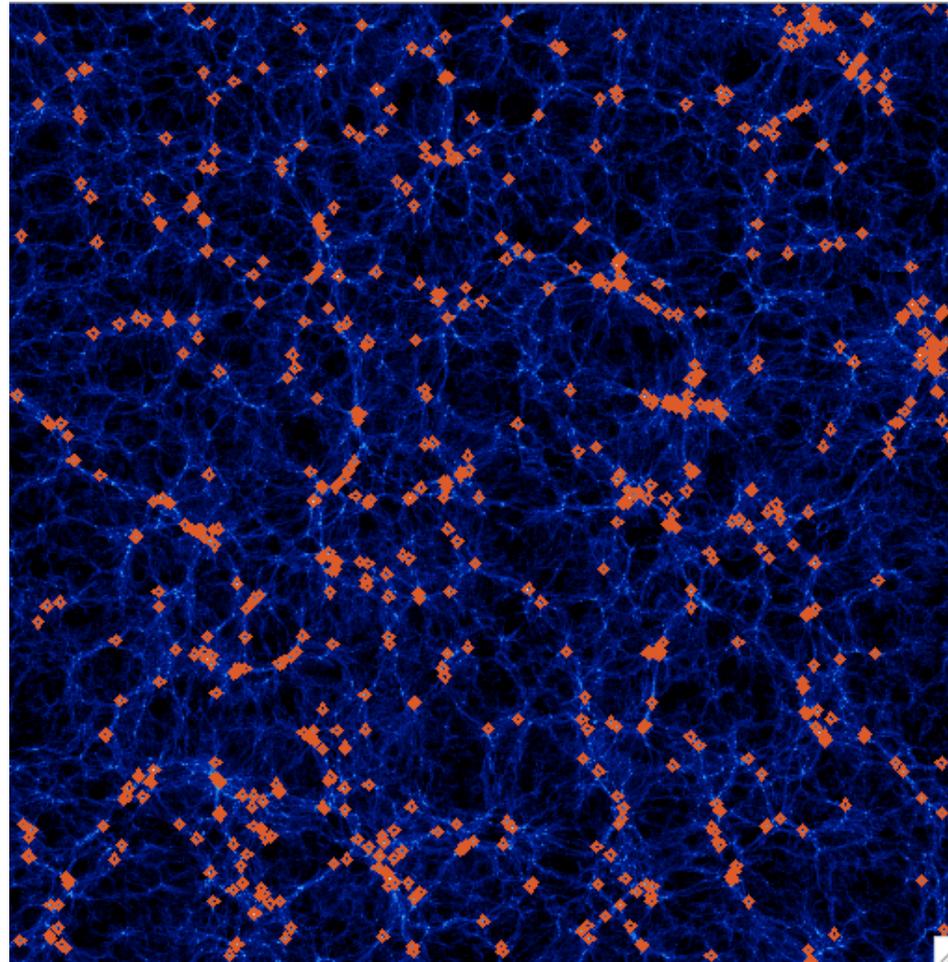
A slice  $500 h^{-1} \text{ Mpc}$  across and  $10 h^{-1} \text{ Mpc}$  thick



density of  
SDSS LRGs  
 $z \sim 0.5$

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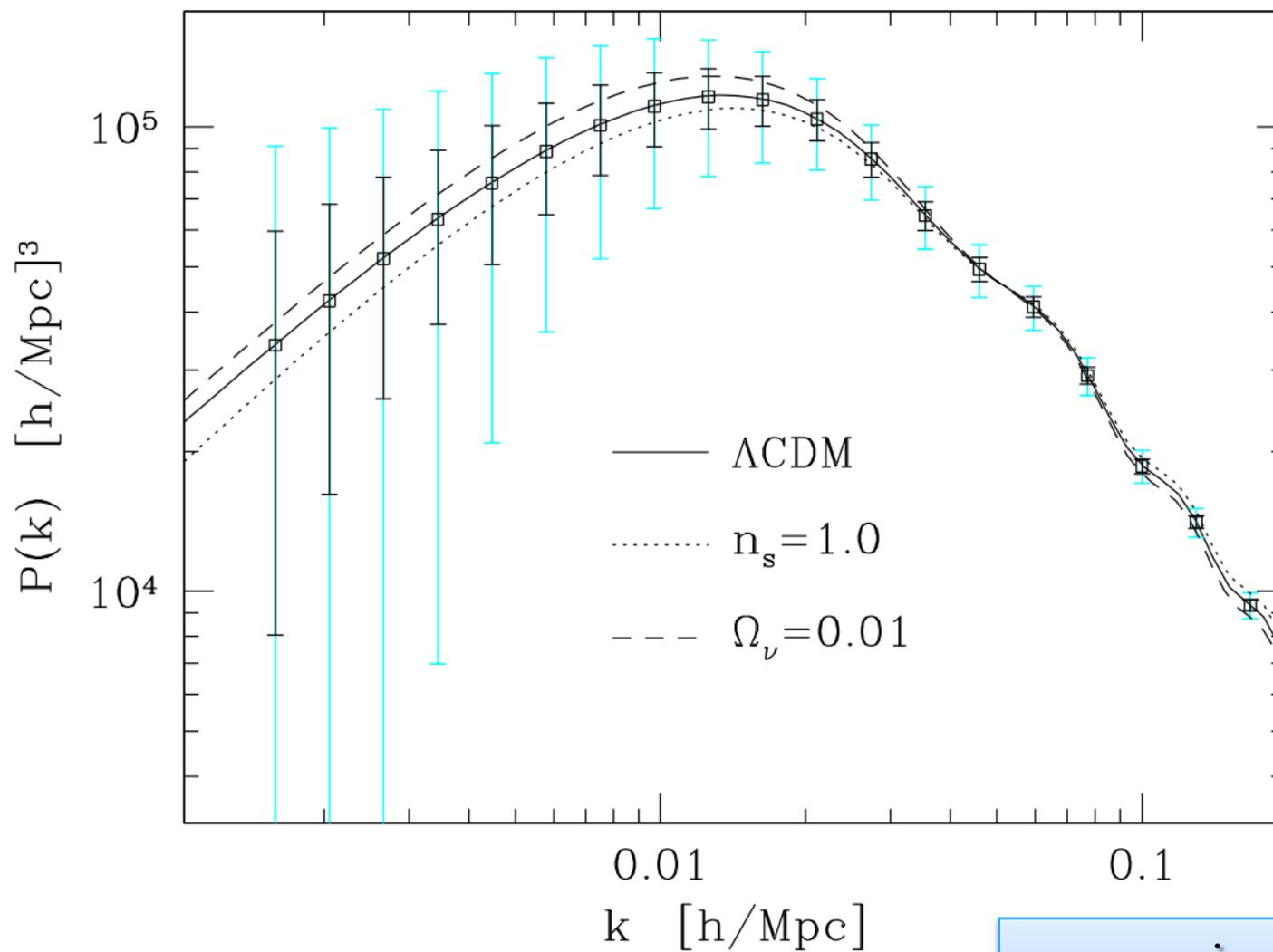


density of  
BOSS LRGs  
 $z \sim 0.5$

## LRG forecasts for cosmology

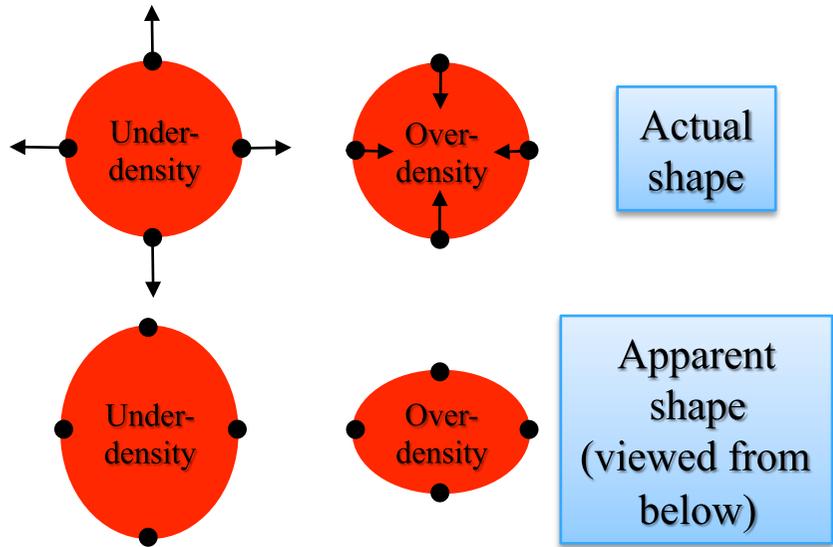
- Fisher matrix BAO analysis
  - Use Seo & Eisenstein (2006) code
  - Marginalize over shape information (retain only acoustic signature)
  - $V_{\text{eff}} \sim 5 \text{ (Gpc/h)}^3$
  - Measure  $d_A$  (1%) and  $H$  (1.8%) at  $z \sim 0.35, 0.6$
- Combine with CMB to give precision measurement of  $H_0$  (1%),  $\Omega_k$  (0.2%)
- Improved large-scale power spectrum constraints
  - neutrino masses
  - $f_{\text{nl}}$
- Redshift-space distortion constraints on structure growth

# LRG forecasts for LSS



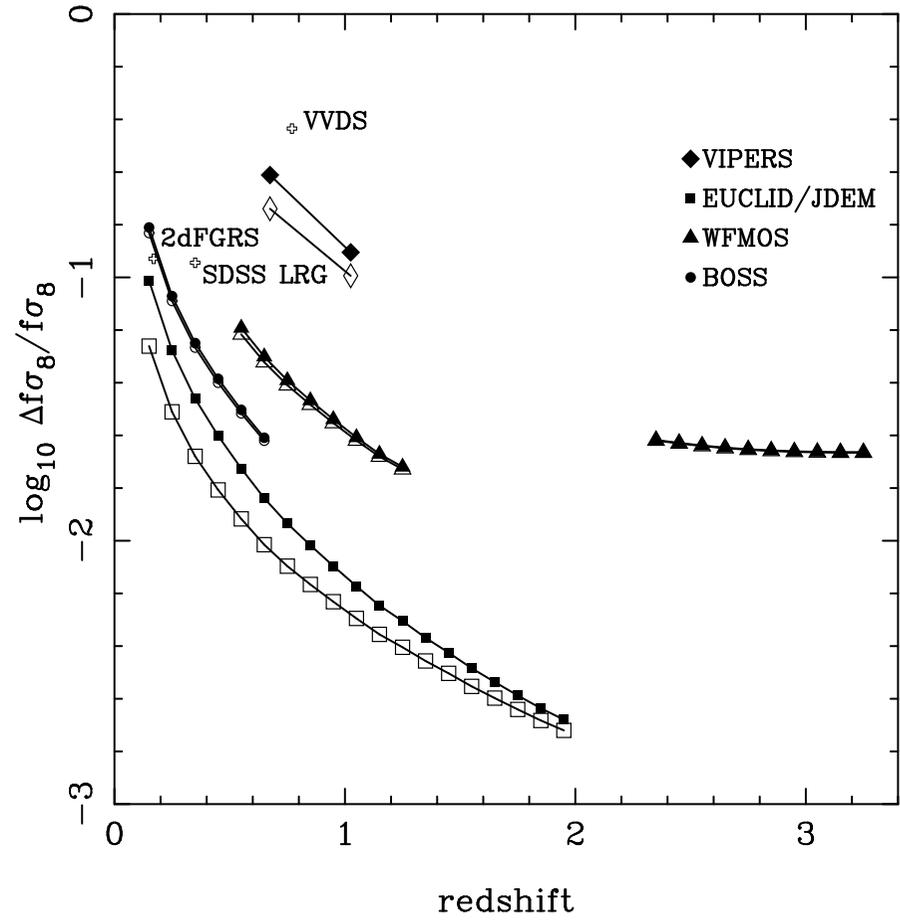
comparison of errors  
SDSS vs. BOSS

# LRG forecasts for redshift-space distortions



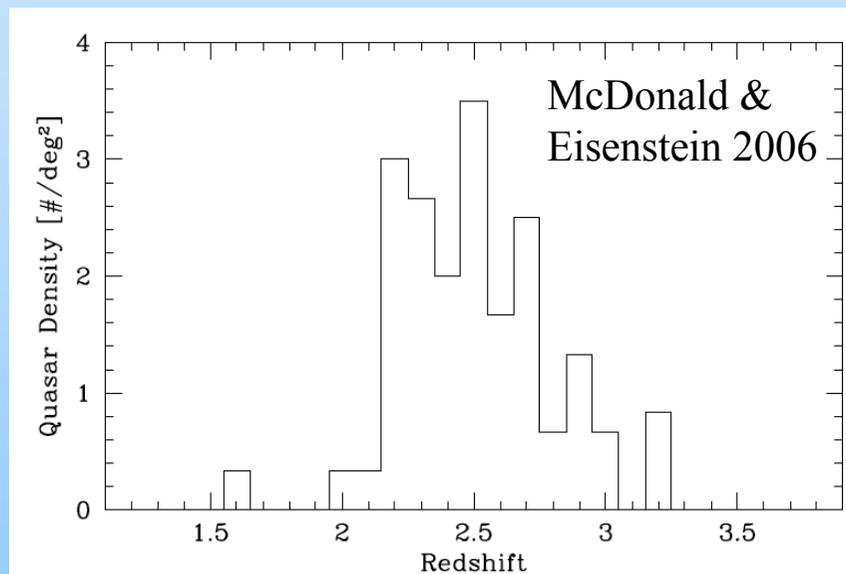
Motion of galaxies is independent of galaxy properties – galaxies act as test particles in flow of matter

Code to estimate errors on  $f\sigma_8$  is available from:  
<http://mwhite.berkeley.edu/Redshift>



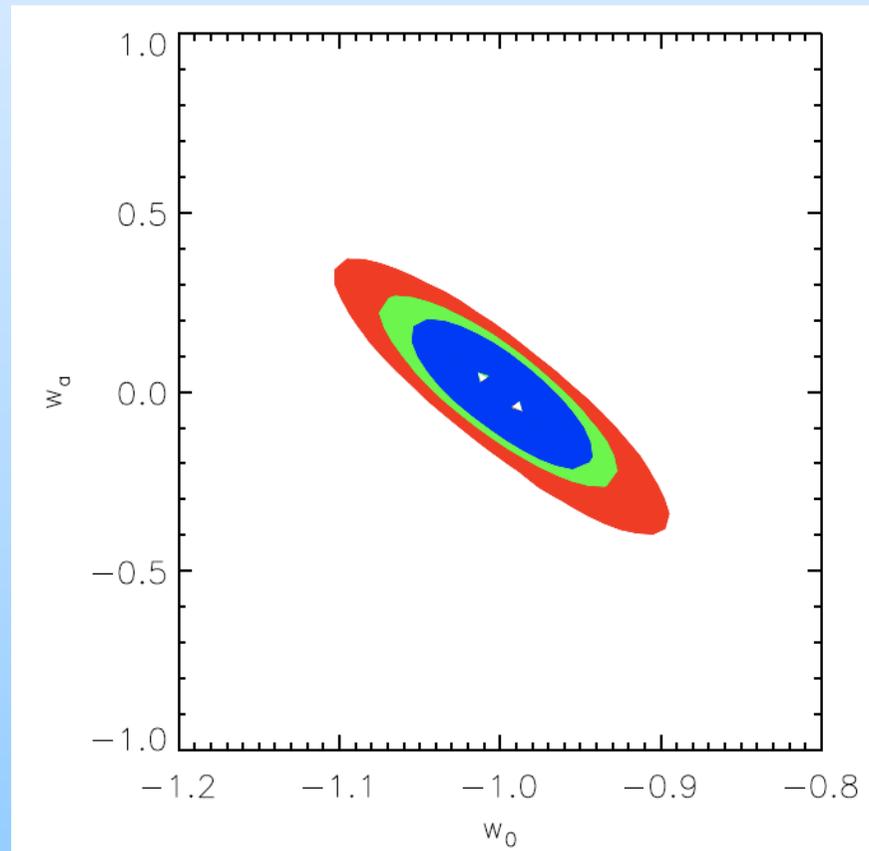
## QSOs

- 8000deg<sup>2</sup> (dark time only)
- $g = 22$
- 20 / deg<sup>2</sup>
- Selection based on SDSS colours + variability (if available)
- 1.5% on  $d_A$ , H
- comparable to other high- $z$  surveys, but with 2.5m telescope



## DE constraints

- standard DETF FOM calculation
  - stage II 53
  - with LRGs 86
  - with QSOs 122
  - with  $P(k)$  257
  - with stage III 479

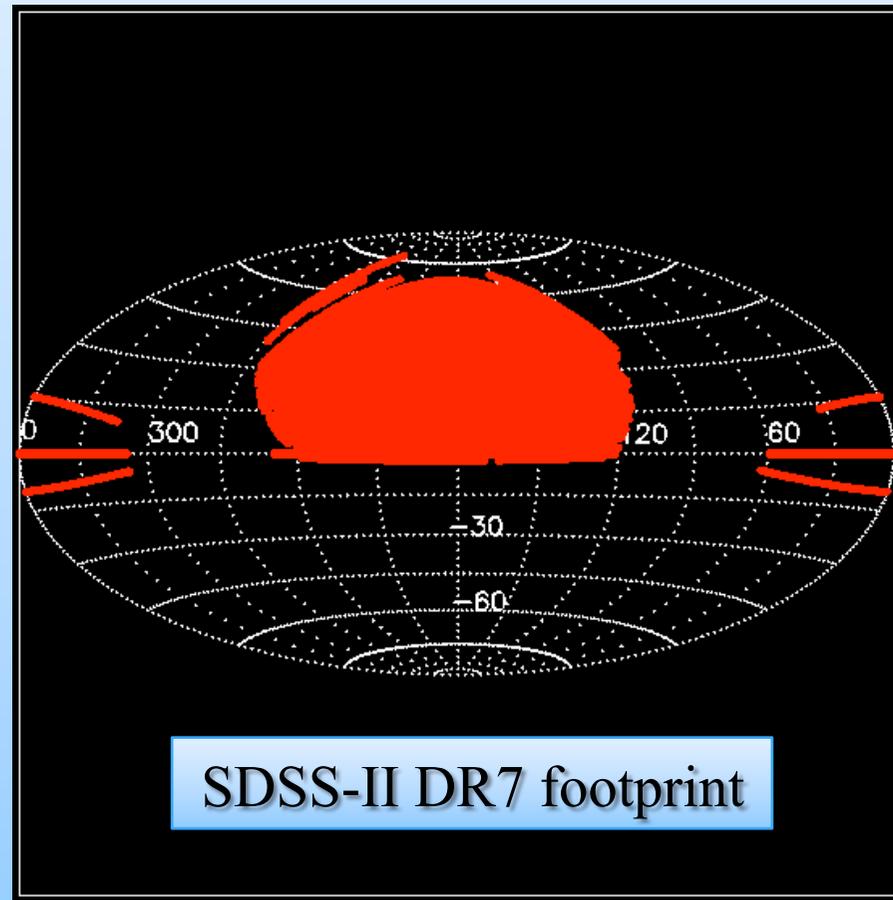


## Other science

- Evolution of massive galaxies
- Galaxy bias evolution
- Quasar clustering, luminosity function at  $z \sim 2.1 - 3.0$
- Piggy-back programs now being considered for “spare” fibres
- One program will double  $N_{\text{QSO}}$  with  $z > 3.6$
- Serendipitous stellar studies (from QSO targeting)
- Spectroscopic detection of galactic scale strong lensing systems
- Projects no-one has thought of yet ...

## What's happening right now?

- imaging to fill in Southern stripes is underway
- Will increase target density in the South (autumn/winter)
- In October, camera is moved to museum
- By end of year: new spectrograph commissioned
- Upgrade currently on time



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