BAO Observations

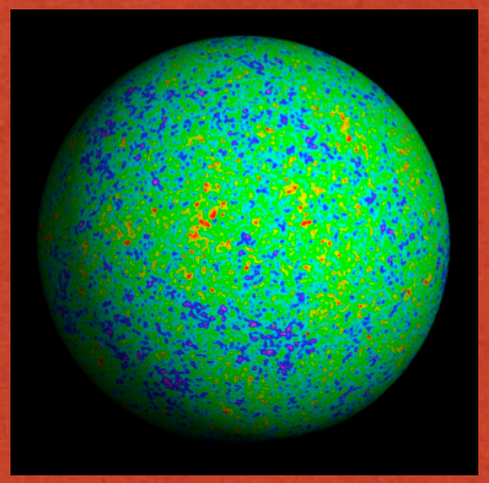
Éric Aubourg - APC

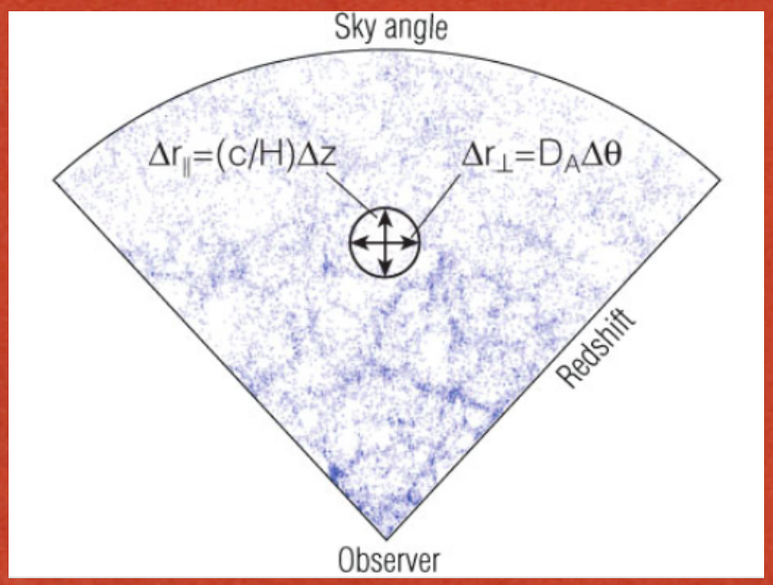
IAS November 2008

BAO Observations

- Past, present and future observations
- Which tracers ?
- Which z range ?
- 2D, global 3D, full 3D ?

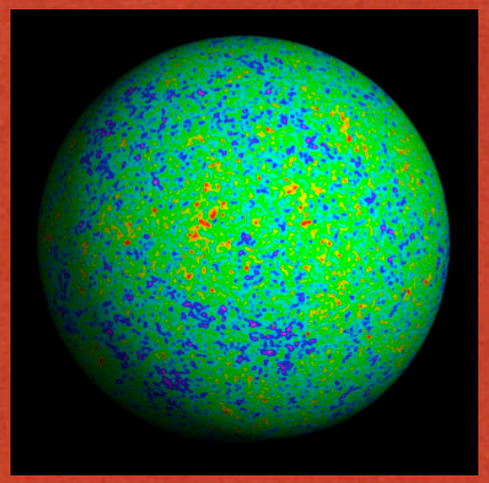
Tracers and redshift

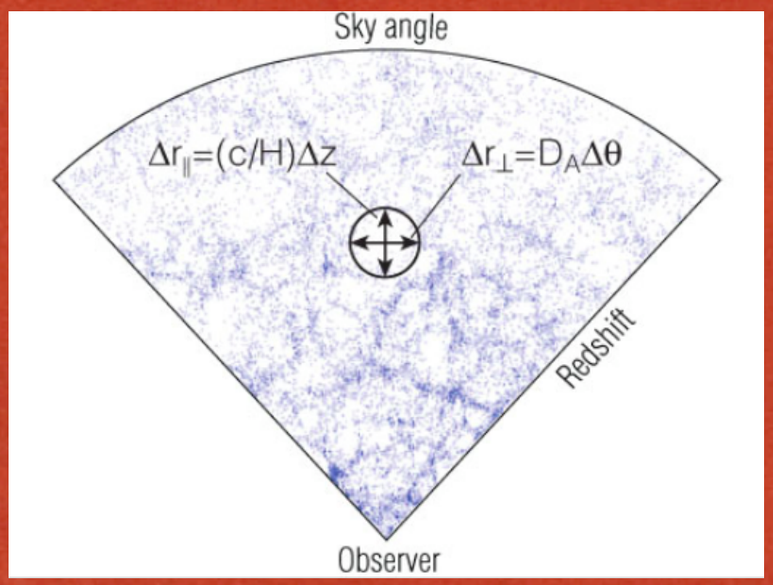




- z = 1100 CMB
- z = 20 H gas at 21cm
- z = 5 Lyα emitter gals, QSO absorption lines
- z = 2
- z = 0 Galaxies, clusters, SNe, GRB

Tracers and redshift





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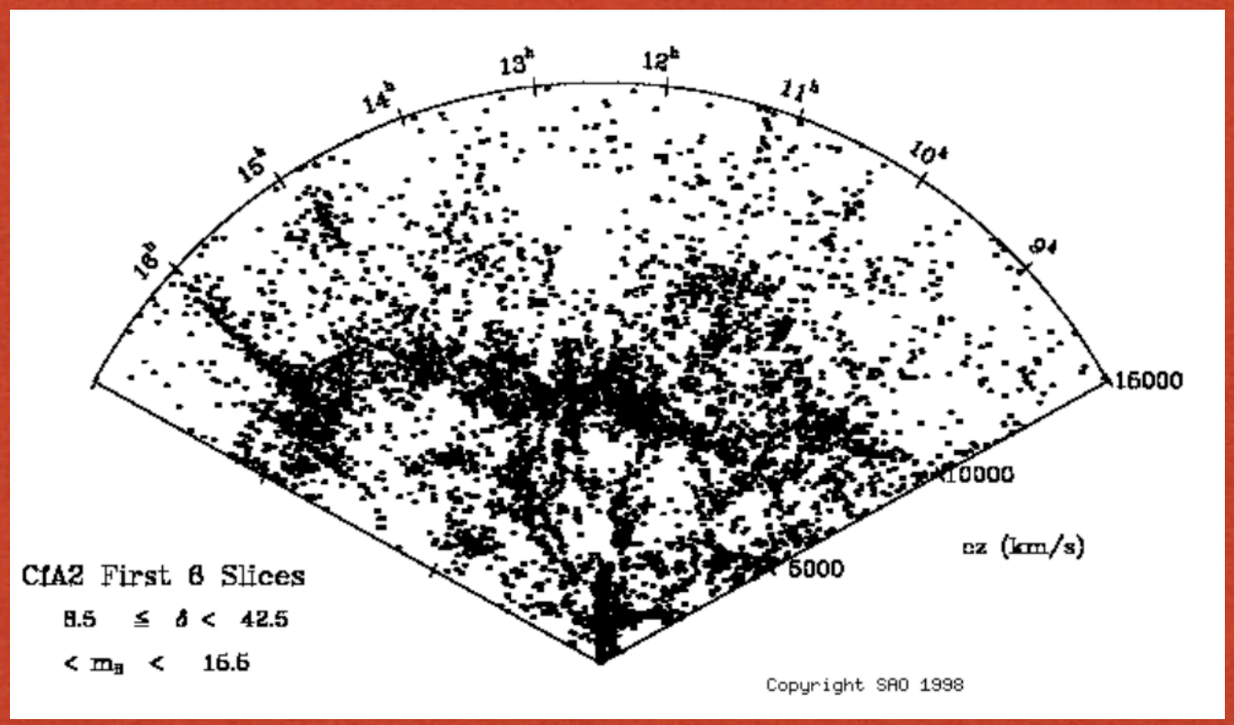
Tracers

- Sparse sampling is ok, we want linear modes around 100 h^{-1} Mpc
- Basically one tracer per $(10\ h^{-1}\ \mathrm{Mpc})^3$ to beat shot noise
  - Even less if tracers are strongly biased
- For each z range, there is a cosmic variance limit
  - Will soon be hit for $z<0.5$

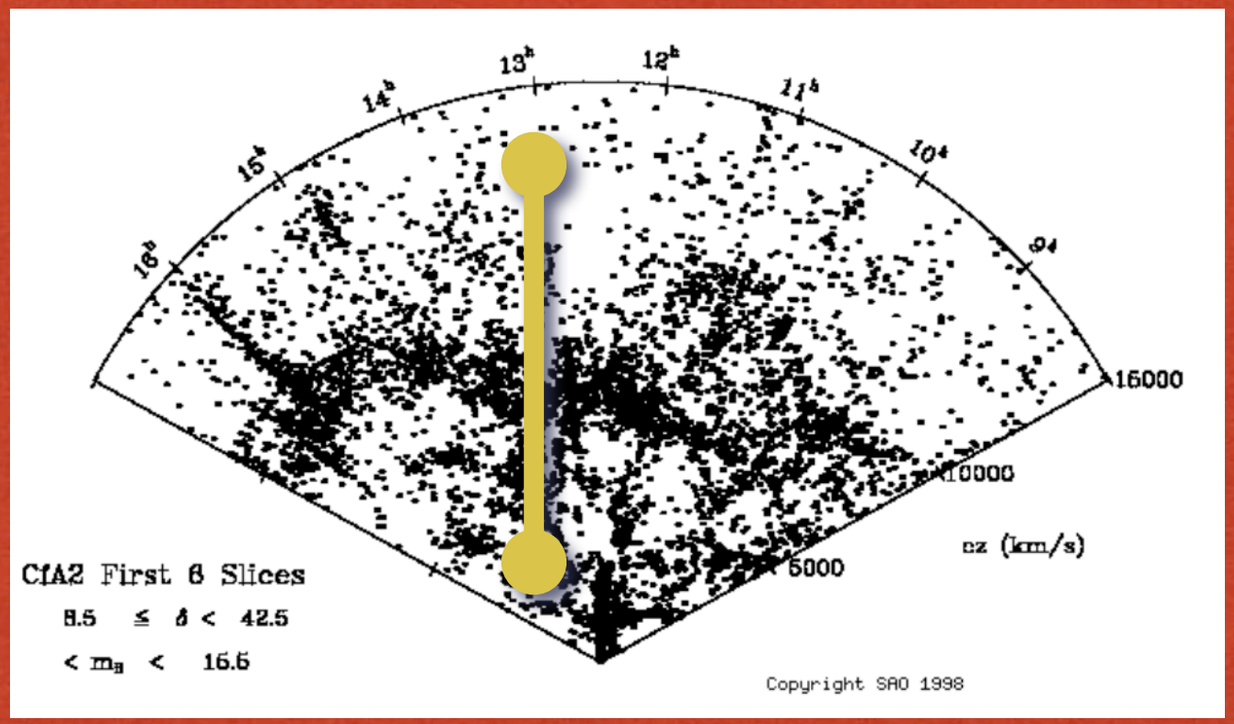
Volume



CfA survey, 1989

- We need to sample 150 Mpc many times!

Volume



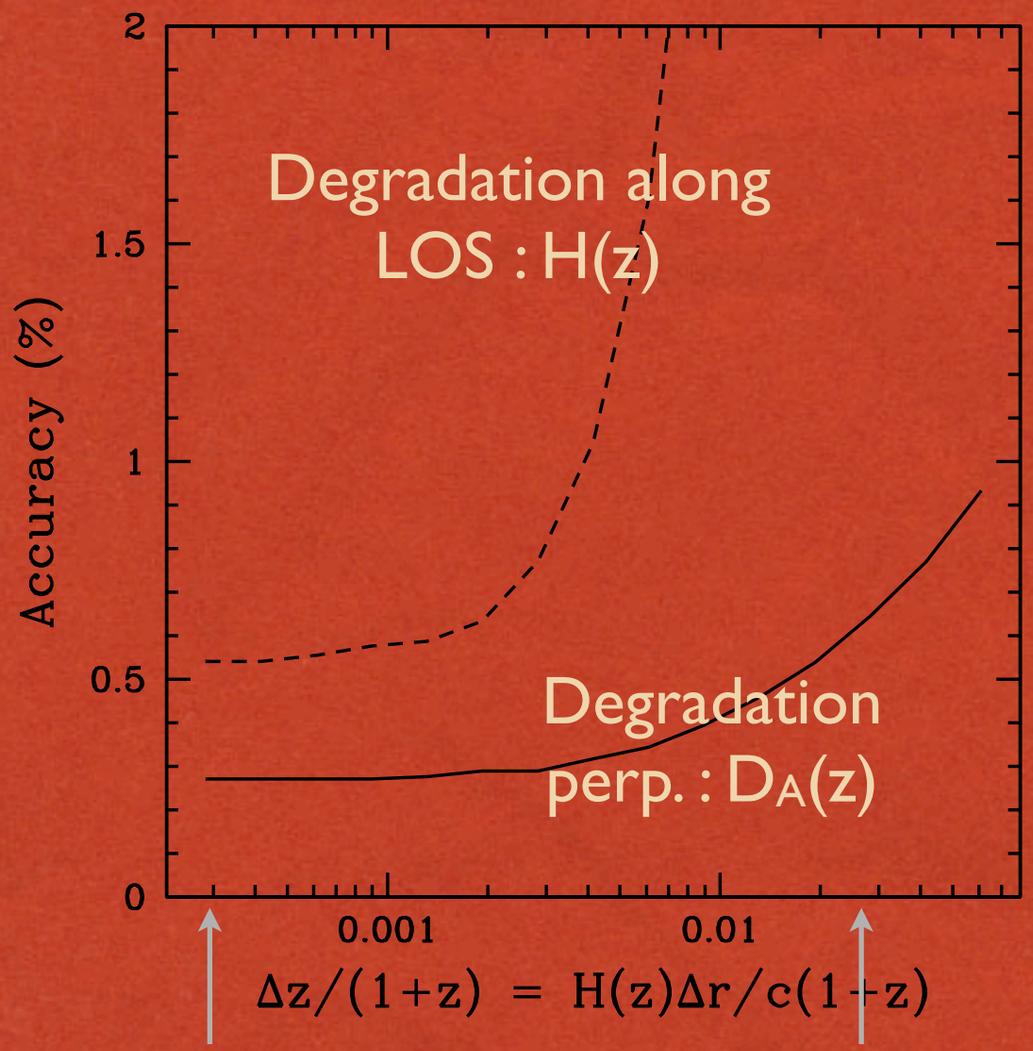
CfA survey, 1989

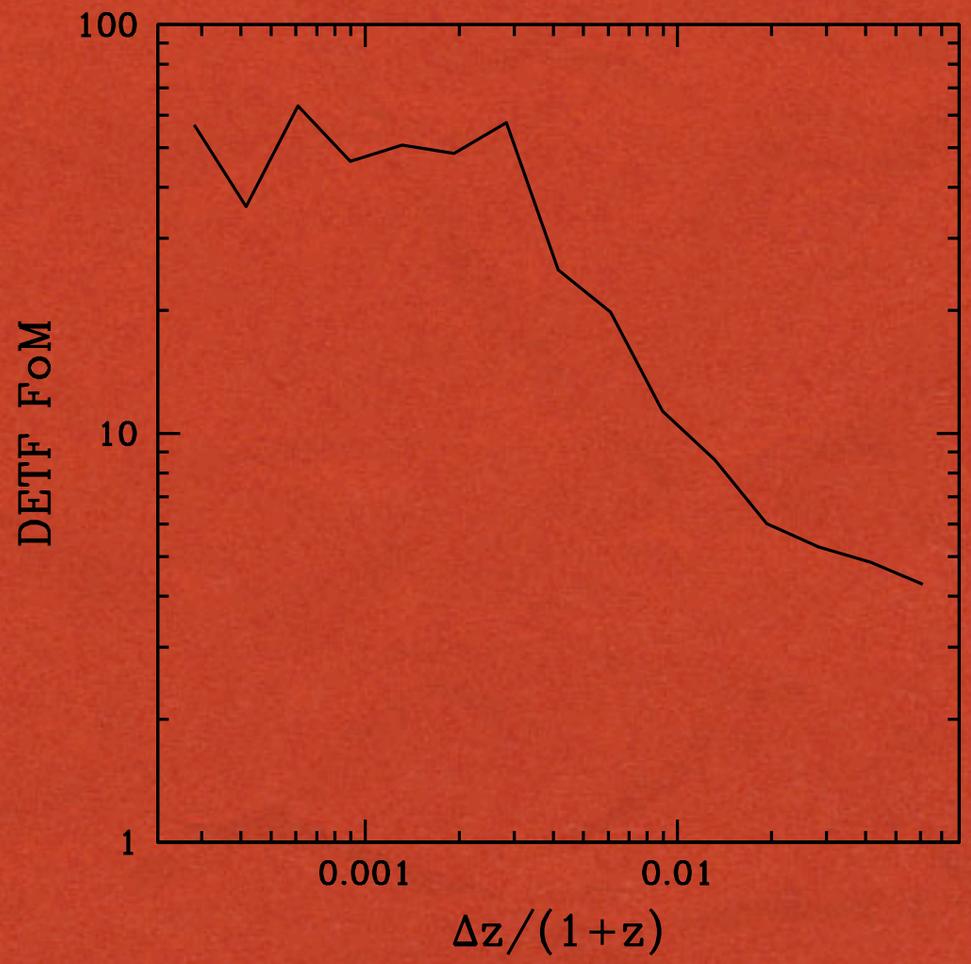
- We need to sample 150 Mpc many times!

3D or 2D ?

- With a redshift survey, each tracer is located in 3D (in redshift space…)
  - Full 3D power spectrum
  - Ability to measure separately H(z) and $D_A(z)$
- With only photo-z, radial measurement is blurred
  - 2D measurement, ~5 times less efficient. No A-P test.

3D or 2D ?



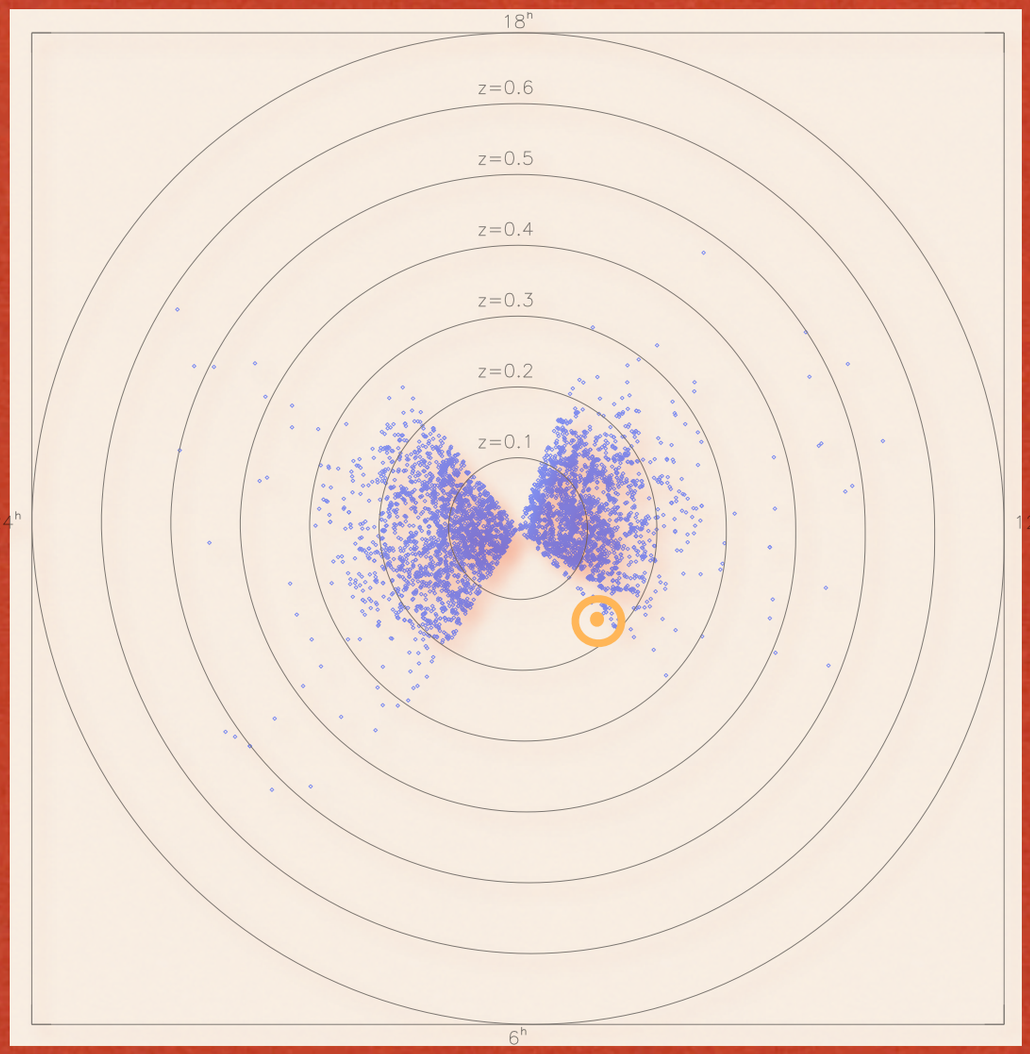


Padmanabhan/Schegel

Current mesurements

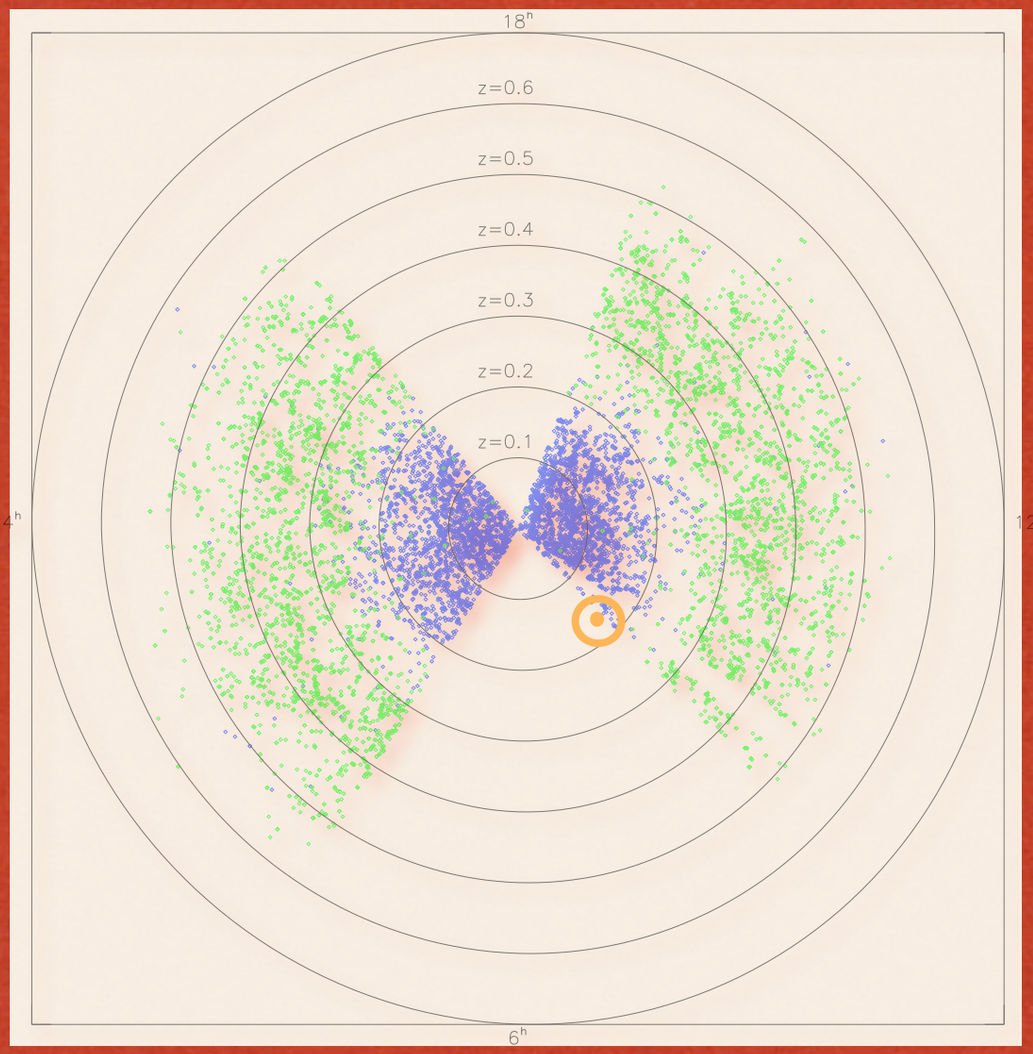
- 3-D, LRG : SDSS (Eisenstein et al.), 2dF (Cole et al.), Percival, Gaztanaga…
- 2-D, clusters : MaxBCG
- 2-D, LRG : SDSS (Padmanabhan et al. 2006)
- WiggleZ…

SDSS-I and II



SDSS main survey

SDSS-I and II

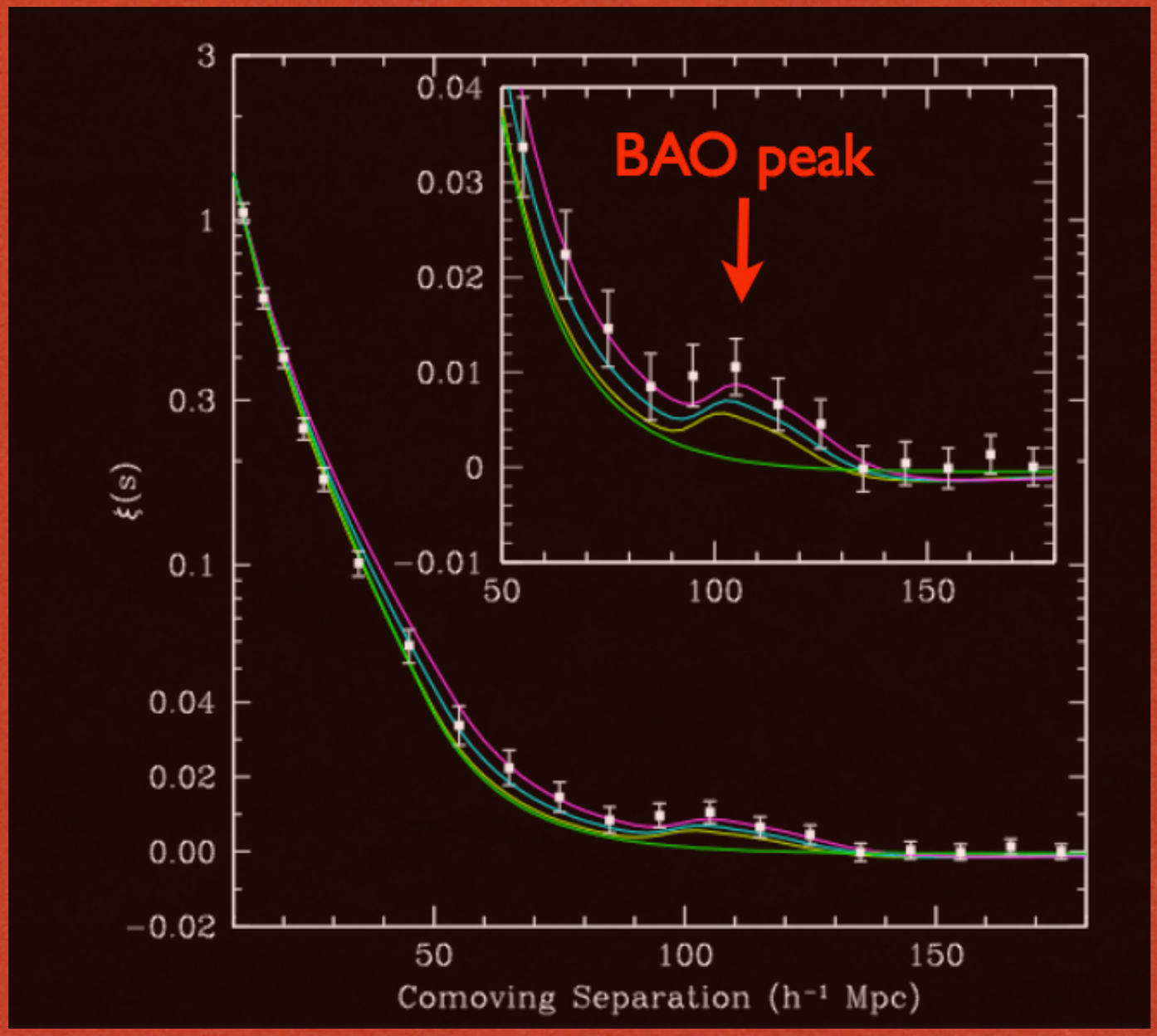


SDSS main survey

SDSS-I + SDSS-II
LRG, 8000 deg^2
(ended in 2008)
10^{-4} galaxies/Mpc^3

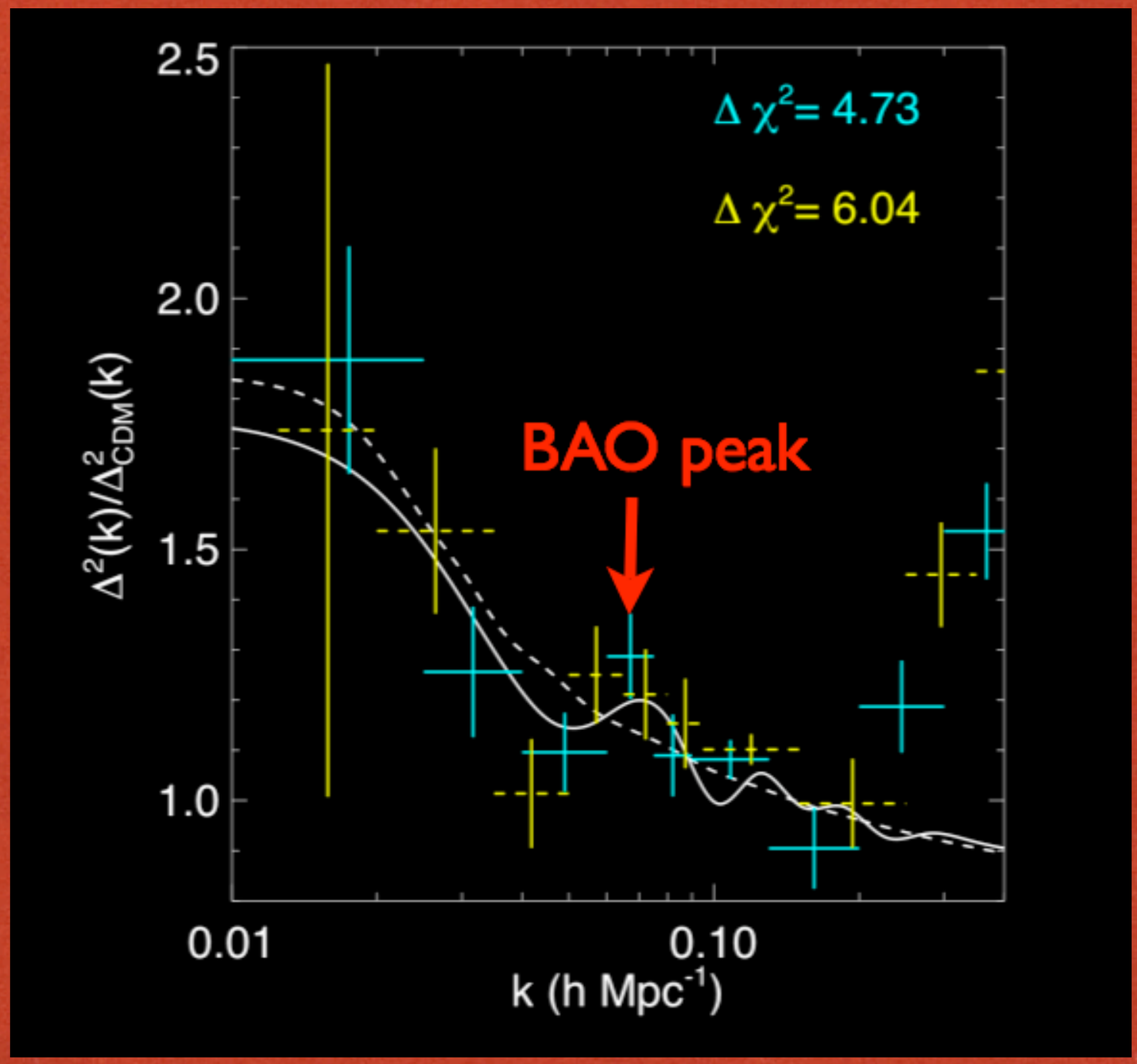
Current SDSS analyses

- Original Eisenstein et al. 2005
- 47000 LRGs at z~0.35 on 3700 deg^2
- SDSS-II ended with 80000 LRGs in 2008, on 8500 deg^2



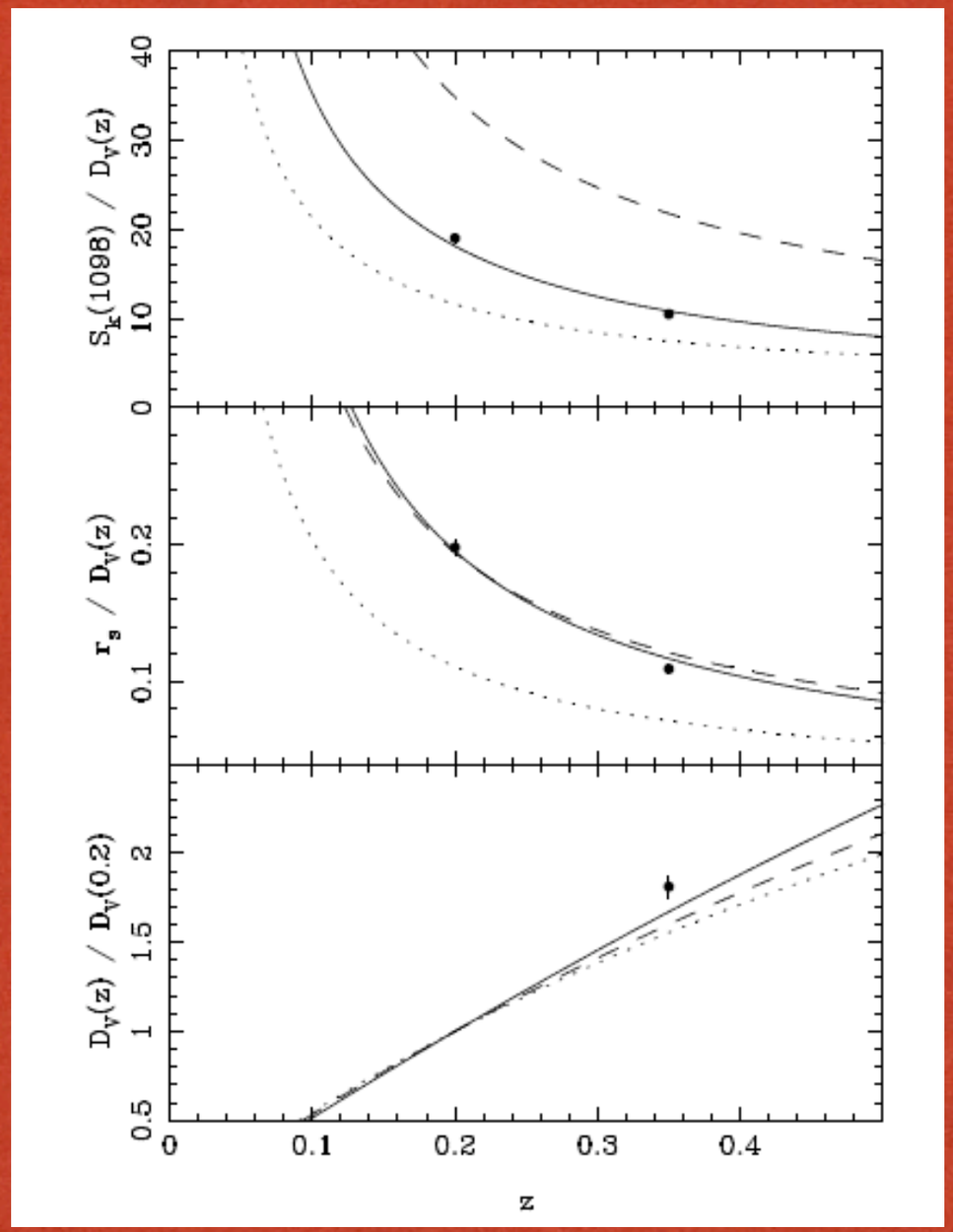
Current SDSS analyses

- Photo-z, Padmanabhan et al 2006
- 600,000 LRGs over 3500 deg^2



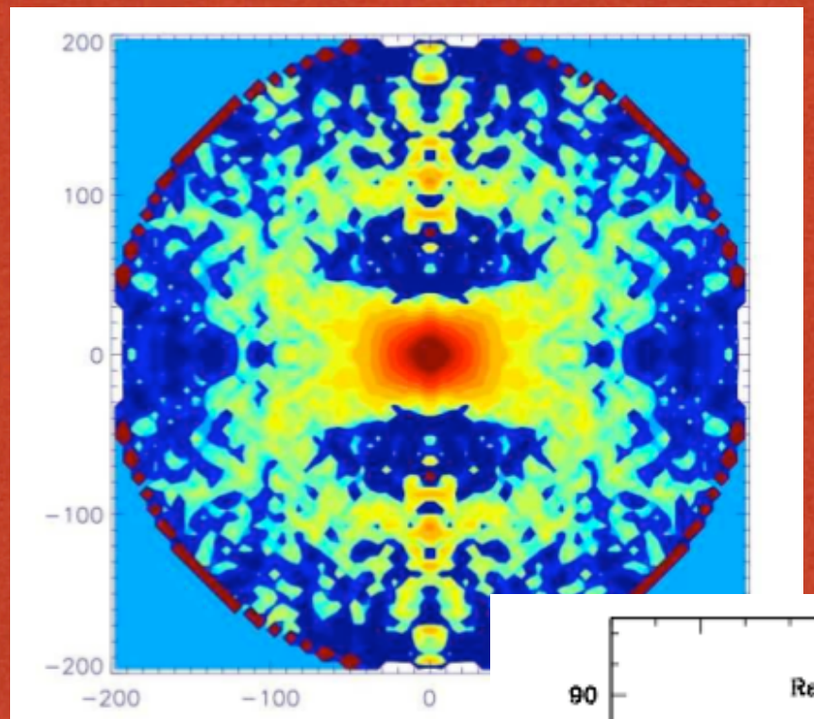
Current SDSS analyses

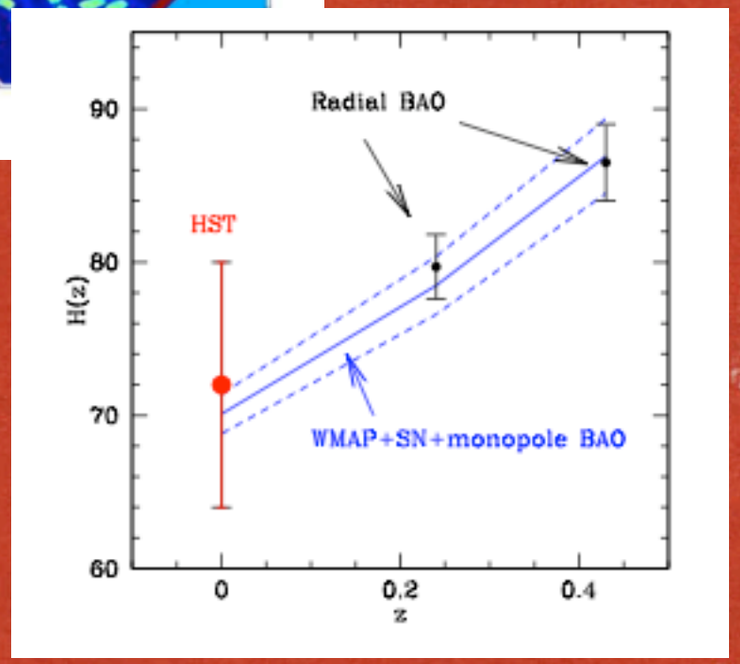
- Percival et al 2007
- SDSS MGS + SDSS LRF + 2dF



Current SDSS Analyses

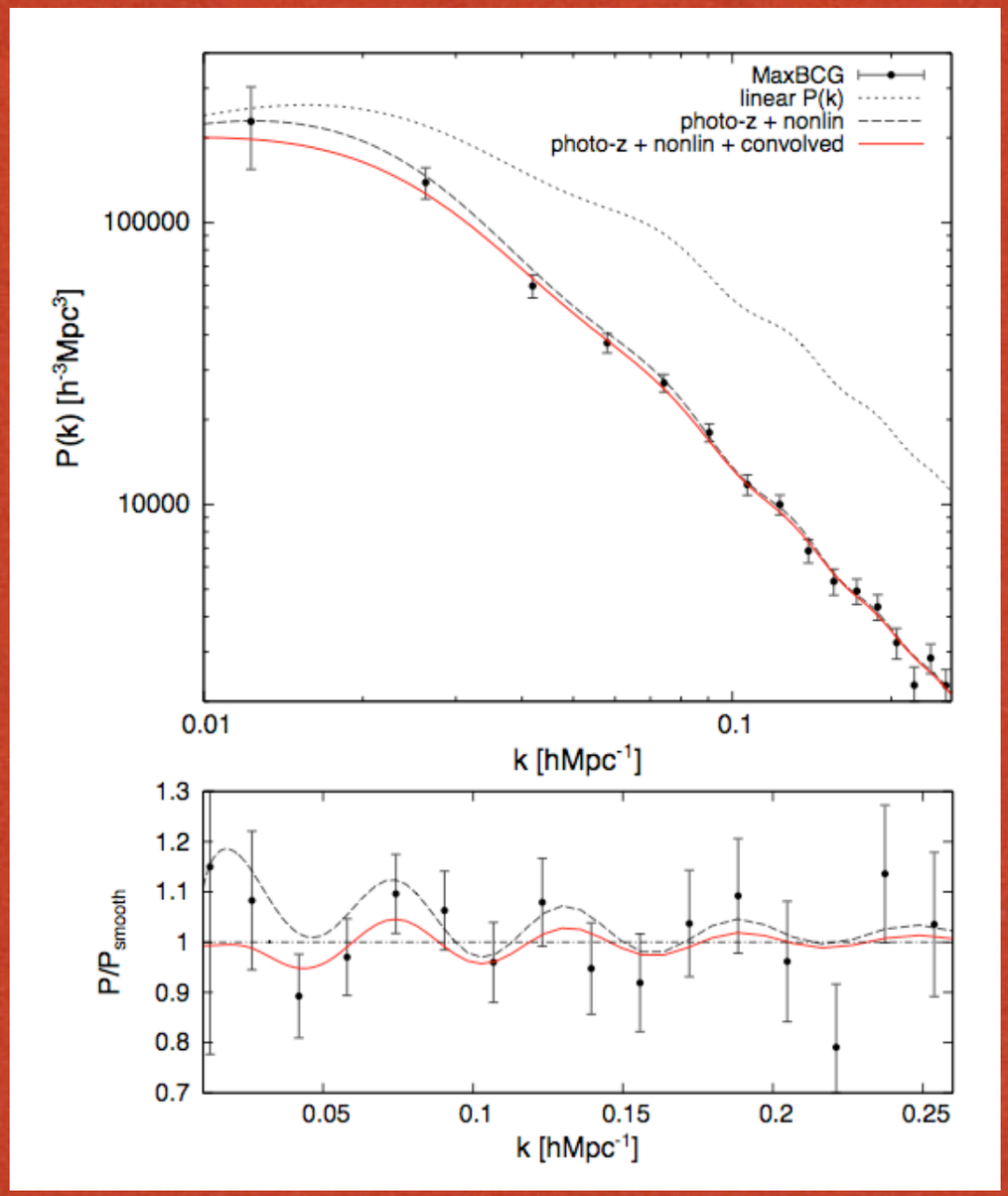
- Gaztanaga et al. 2008
- Full 3D, radial and transverse measurements





MaxBCG cluster sample

- 13,000 clusters on 7000 deg^2, very strongly biased
- From SDSS data
- photo-z, $0.1<z<0.3$



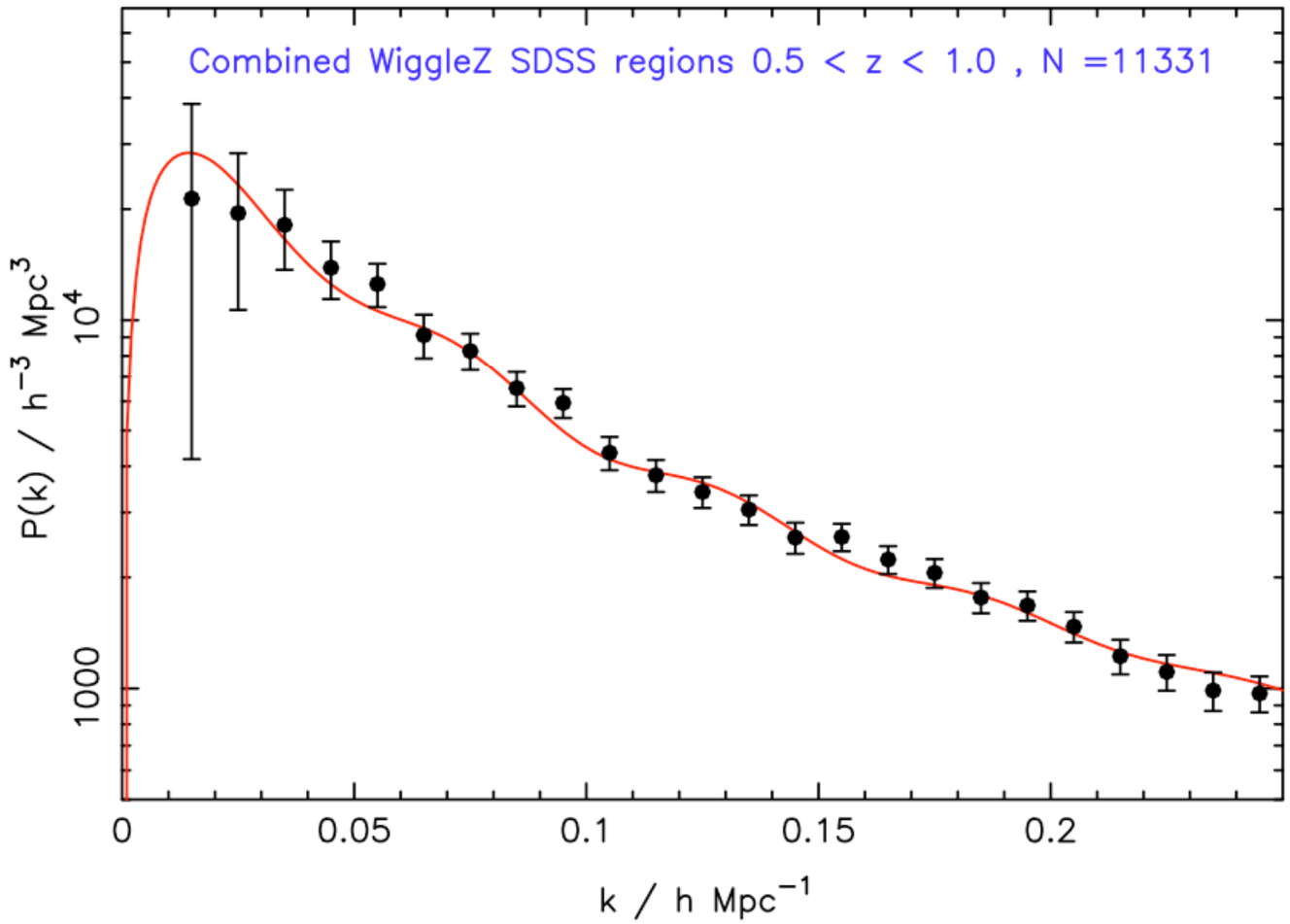
WiggleZ

- 280,000 star-forming galaxies (selected with GALEX + SDSS)
- AAO spectrograph, 0.5<z<1
- 2006-2009

WiggleZ

Galaxy power spectrum : combined regions

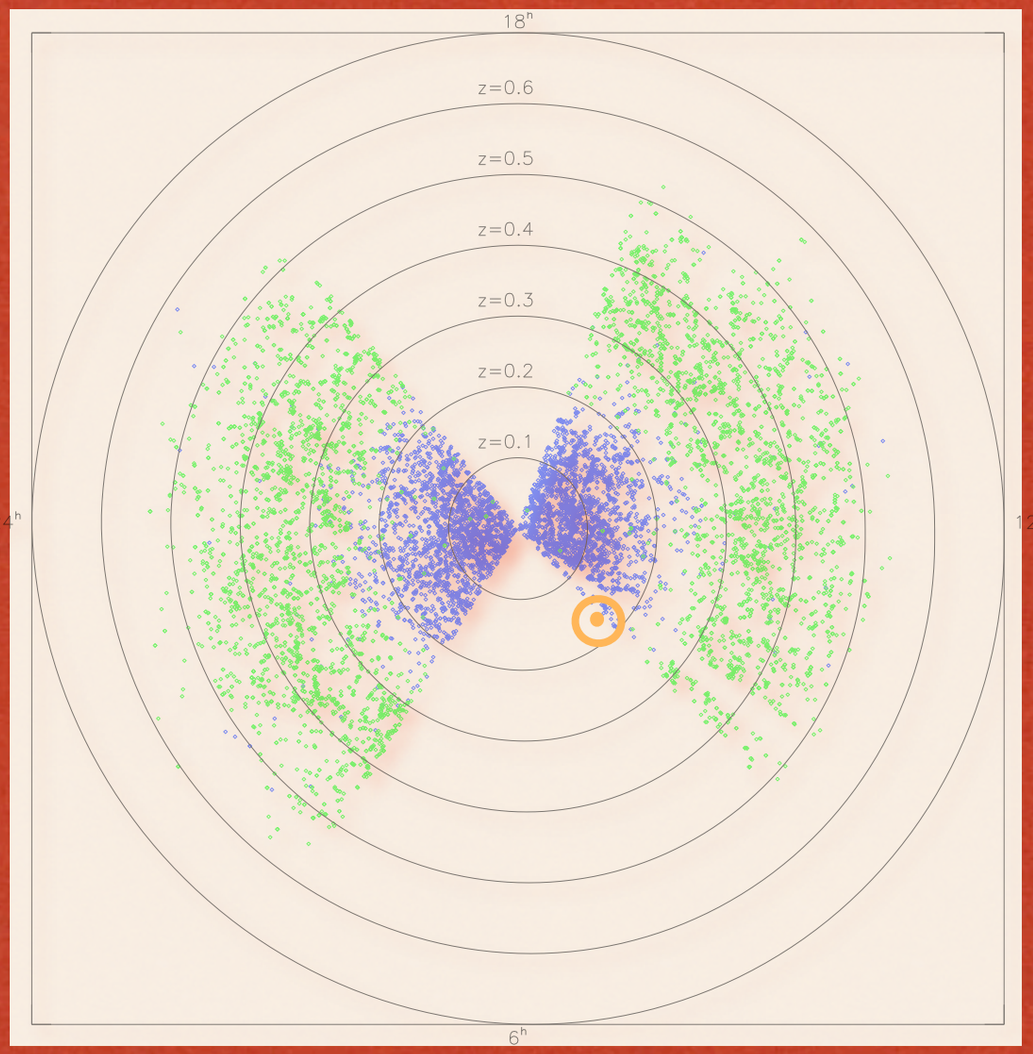
Overplotted model is $(\Omega_{\rm m} = 0.25, f_{\rm b} = 0.2, h = 0.7)$.



Near future experiments

- SDSS-III/BOSS
- LAMOST
- HETDEX
- DES

SDSS-III



SDSS main survey

SDSS-I + SDSS-II
LRG, 8000 deg^2
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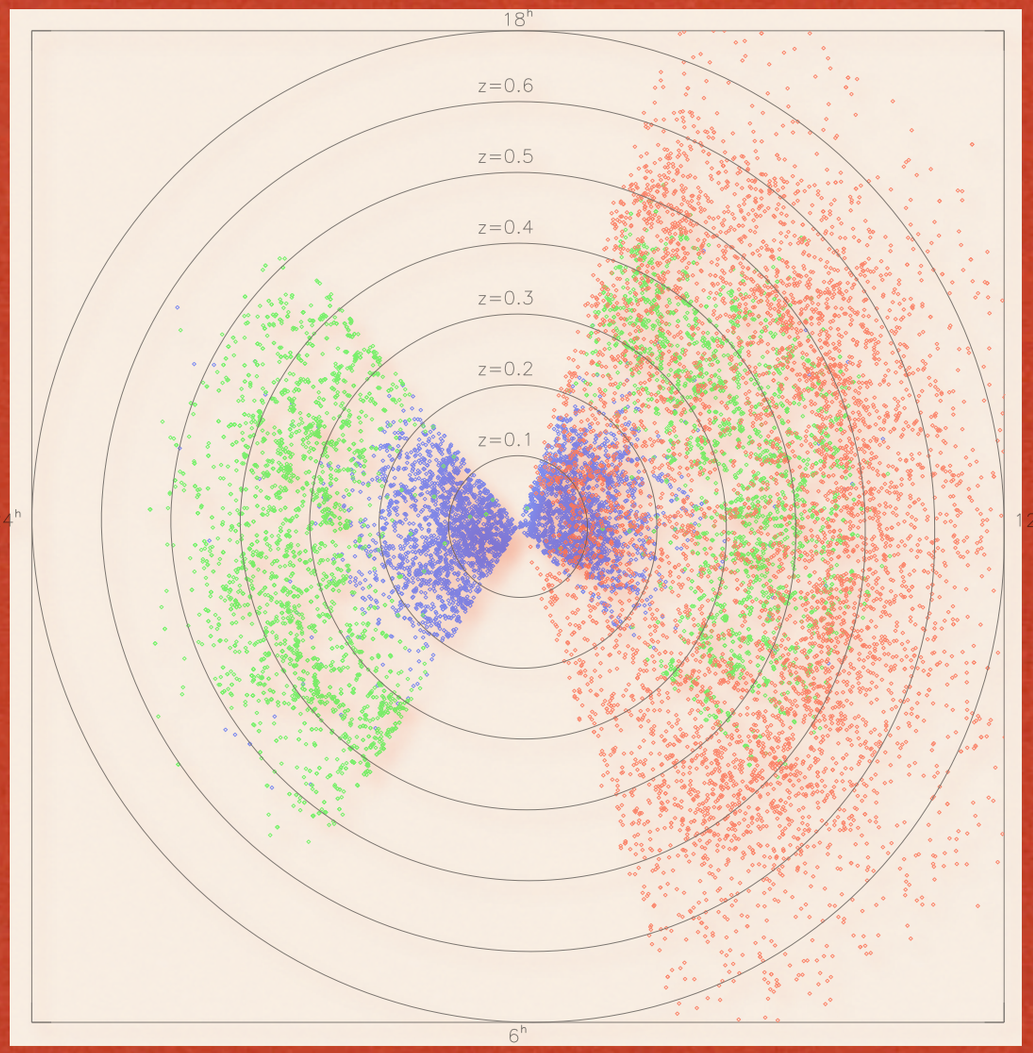
SDSS-III



SDSS main survey

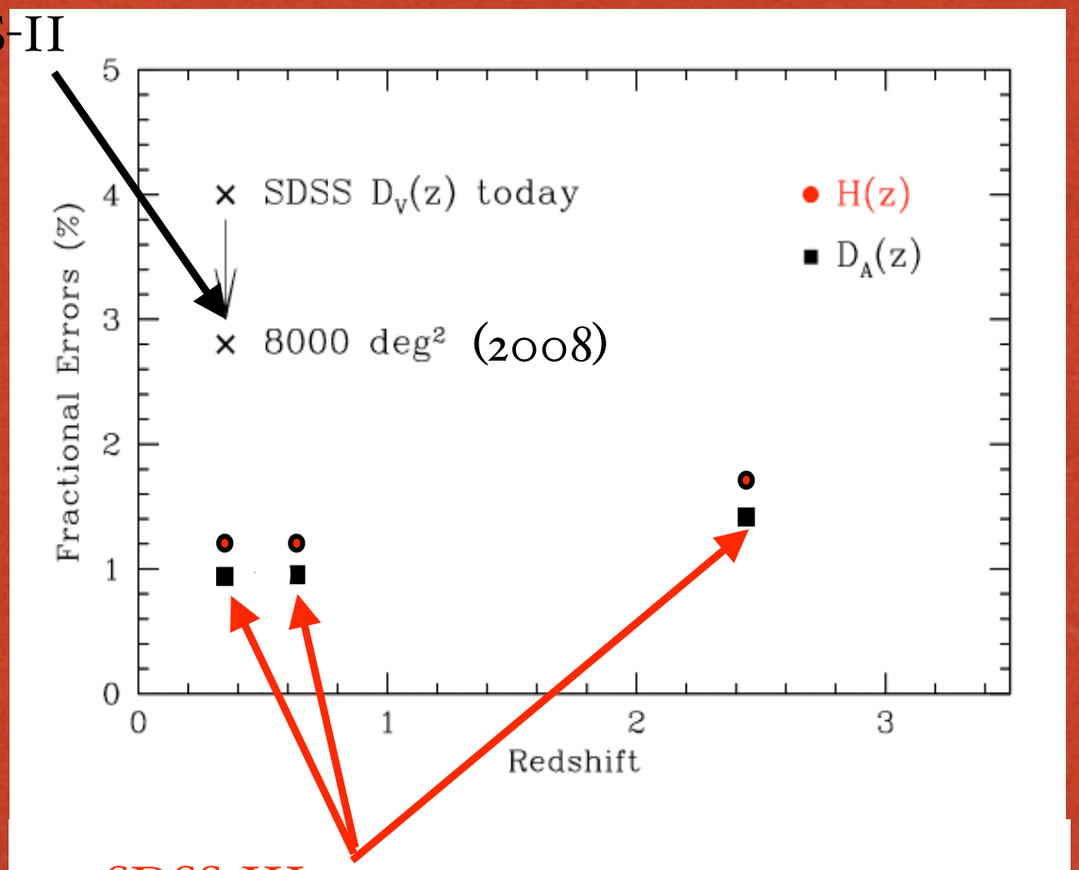
SDSS-I + SDSS-II
LRG, 8000 deg^2
(ended in 2008)
10^{-4} galaxies/Mpc^3

SDSS-III LRG
10,000 deg^2
5x density, 2x volume

similar to photo-z sample of
Padmanabhan et al.

SDSS-III

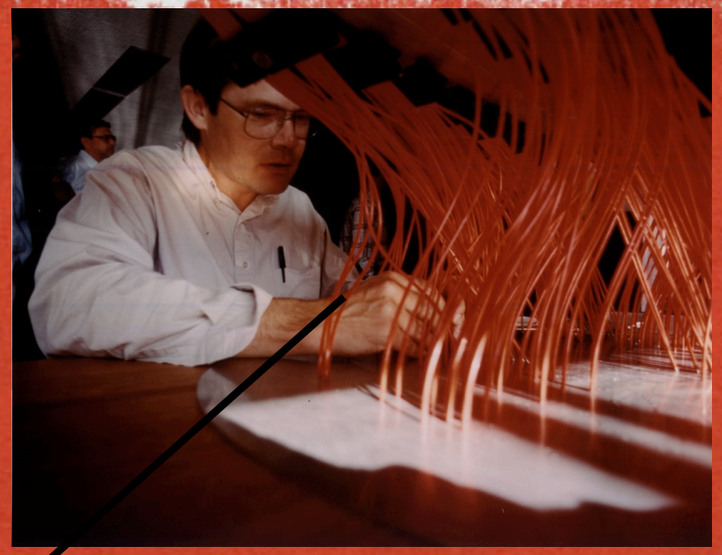
- Cosmic-variance limited at low z
- Also targeting QSO at z ~ 2.5 : BAO in the Lyman-α forest



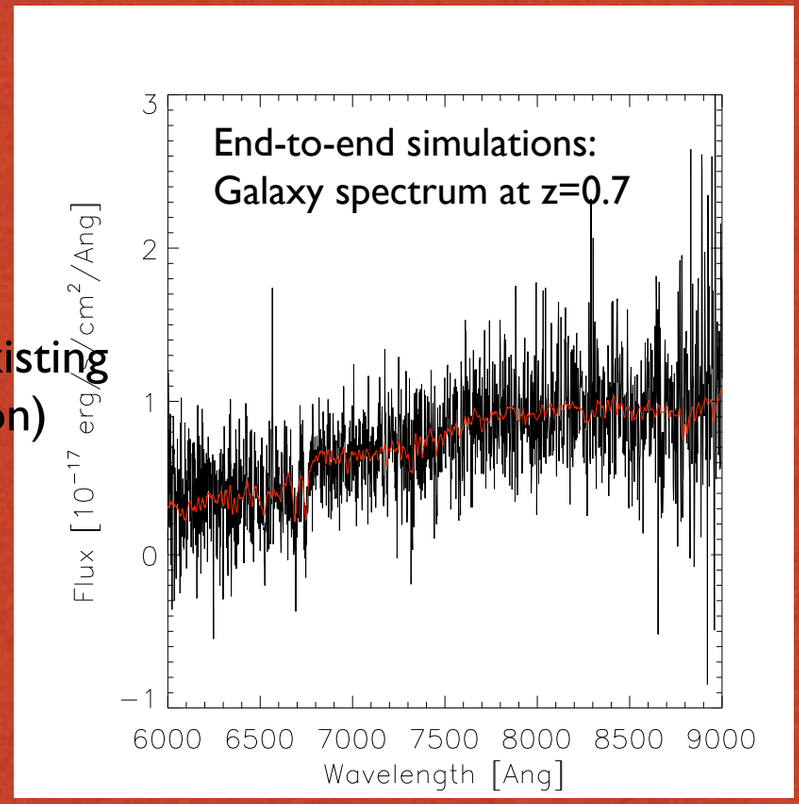
SDSS-III
2008-
10 000 deg^2 z=0.4,0.6
5 000 deg^2 z=2.4

Hardware upgrades

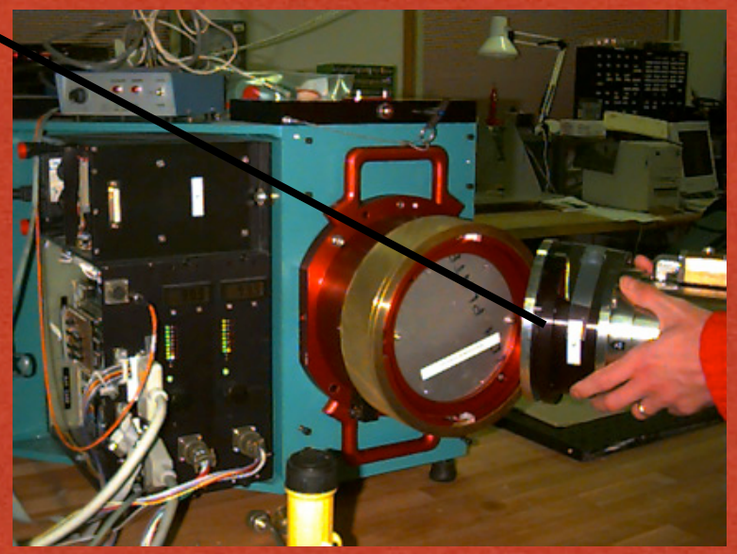
Largest field-of-view of
any large telescope -- DONE!



1000 small-core fibers to replace existing
(more objects, less sky contamination)



Software development underway
at LBL, Princeton, NYU



Swap gratings for VPH

Replace red CCDs w/red-sensitive
LBL/SNAP CCDs, making it possible
to go to higher-z

Replace blue CCDs w/UV-sensitive
Fairchild CCDs, making it possible
for Lyα at z=2.3→3

LAMOST

- Large Area Multi-Object Spectroscopy Telecope (China)
- 4 meters, 4000 fibers
- Galaxies, LRGs, z<2 quasars

LAMOST

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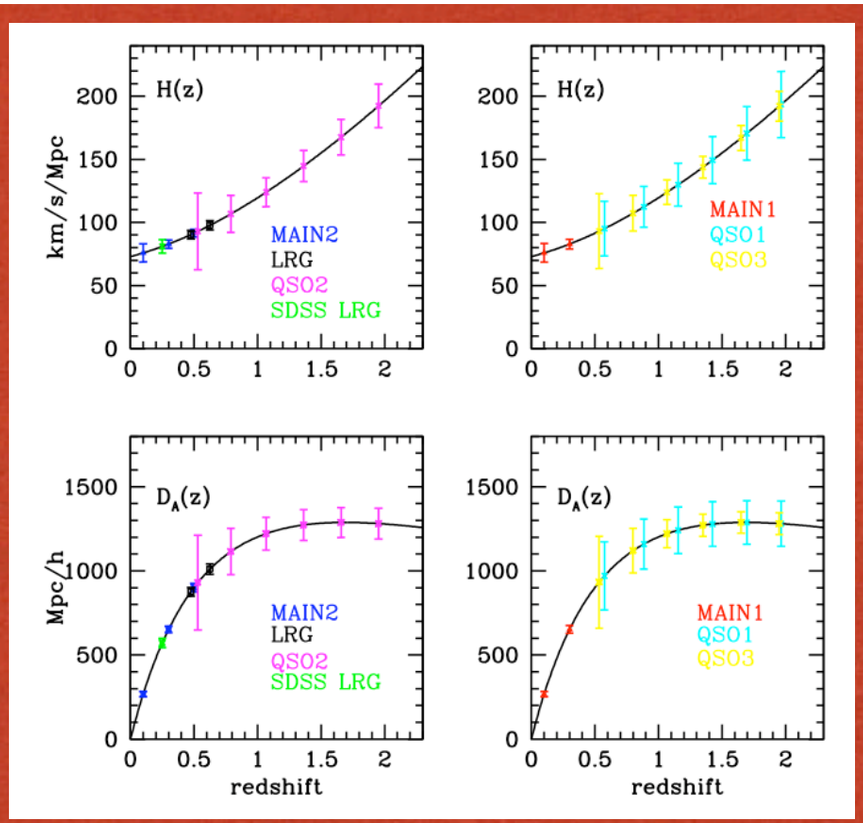
Sample	Magnitude Limit	Surface Density (deg^{-2})	Targets (10^6)	Fiber Hours (10^6)
MAIN1	$r < 18.8$	330	2.6	0.88
MAIN2	$r < 19.8$	1050	8.4	14
LRG	$i_{dev} < 20$	205	1.5	1.9
QSO1	$g < 20.5$	30	0.24	0.24
QSO2	$g < 21$	45	0.36	0.72
QSO3	$g < 21.65$	72	0.57	3.5

Forecasts



DES

- BAO measurement is one of the objectives of DES, with photo-z only

- 5000 deg^2 in griz, 5 years, 3 deg^2 camera on 4-m Blanco@CTIO

- 300 10^6 galaxies at z up to 1

- DOE phase "CD3b" approved oct 08.

HETDEX

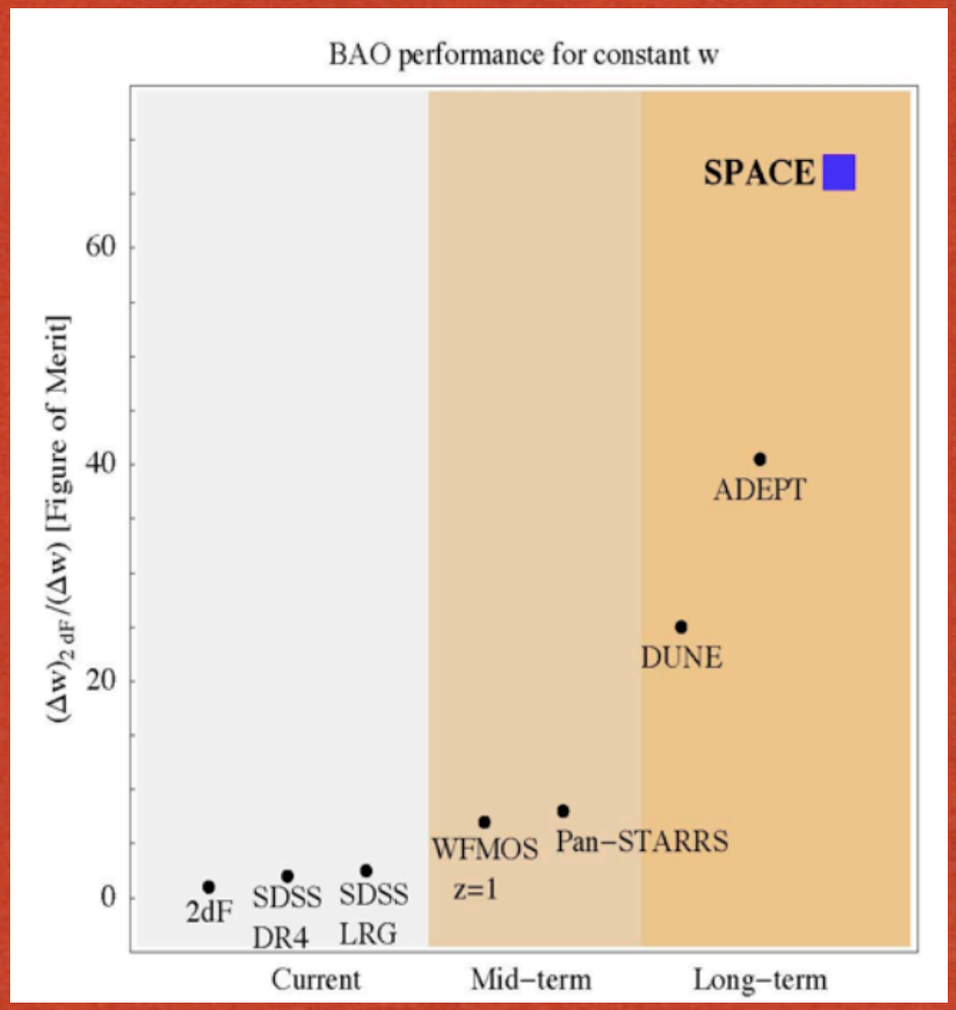
- Hobby-Eberly Telescope Dark Energy Experiment
- High-z (> 1.5) spectroscopic BAO on 10-m HET
- 0.8 million tracers (Lyα gals) on 400 deg^2 $1.9<z<3.5$
- 200 replicated IFU spectrographs : 34000 spectra/exp
- 2010 – 2013 ?

LATER…

- JDEM / Cosmic Vision Dark Energy
- WFMOS
- LSST
- 21-cm

ADEPT/SPACE concepts

- Spatial low resolution near-IR spectroscopy
- Billions of redshifts
- 2015+
- Situation should be clearer soon on status of JDEM and Euclid.

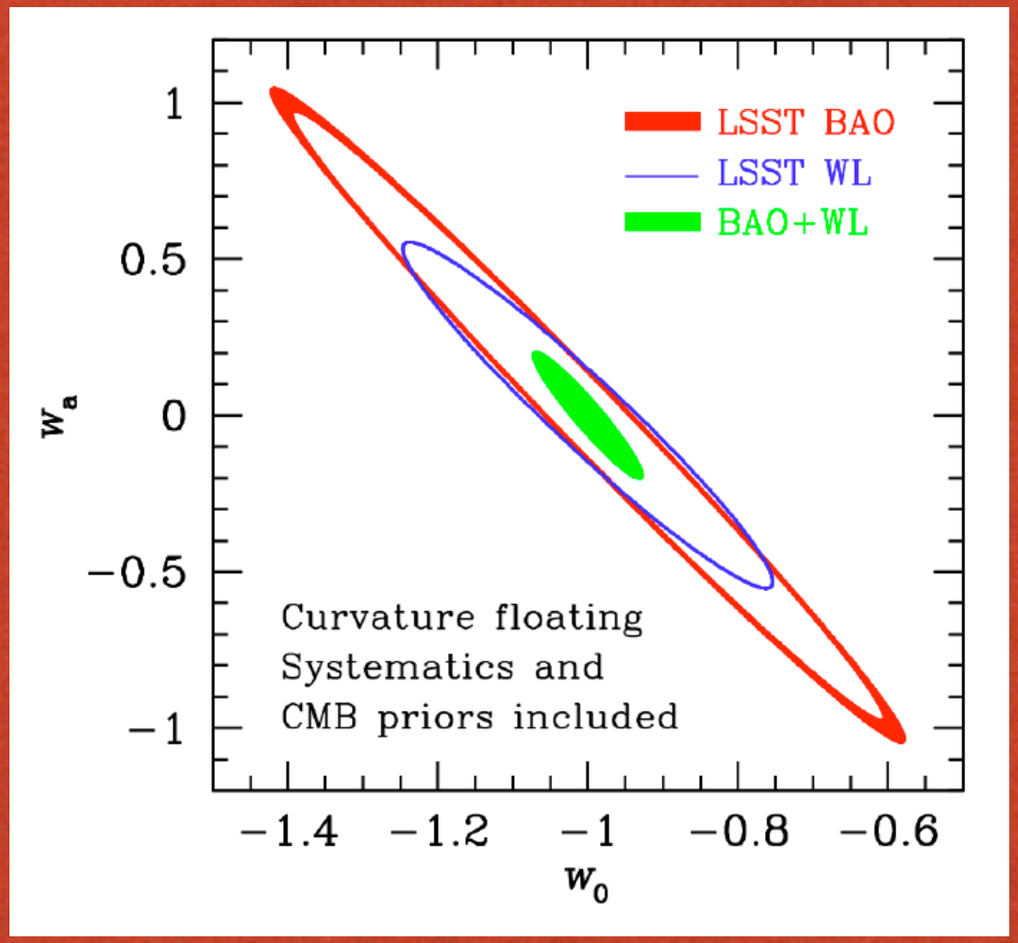


WFMOS

- 3000 fibers on Subaru 8.4-m, 1 deg FOV
- 2 10^6 objects at 0.5<z<1.3
- 5 10^5 objects at 2.3<z<3.3
- 2016 ?

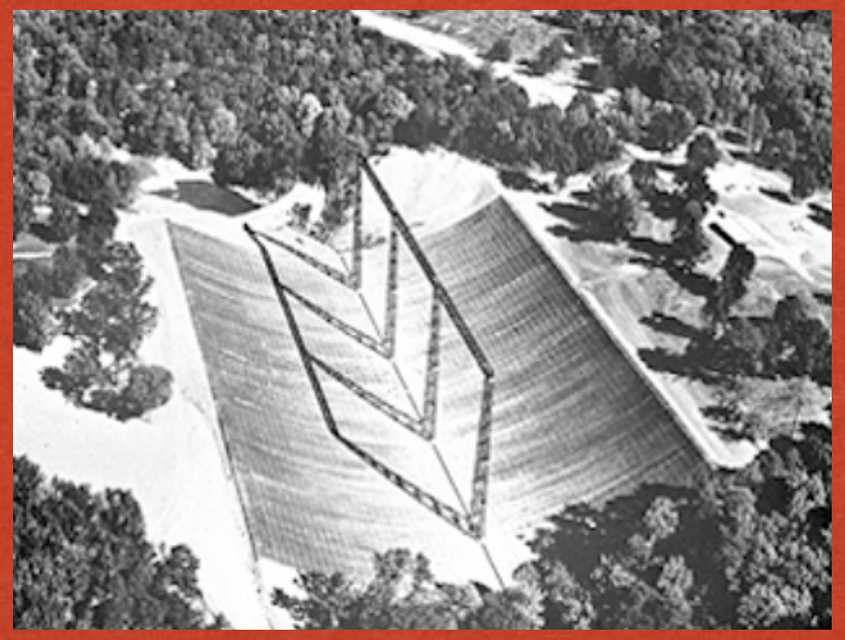
LSST

- Photo-z BAO on 8.4 m, 10 deg^2 fov
- 4 billion galaxies, z peak = 1 and 10% beyond 2.5
- D_A at % level between z=0.3 and z=3.6
- Nice complementarity with WL (biasing)



21-cm

- Very long term : SKA (square kilometer array), 2020?
- HSHS (Hubble Sphere Hydrogen Survey) : 0.5<z<3?
  - R&D in progress



Summary

SDSS & SDSS-II	ARC 2.5-m, 3° FOV	640 fibers	2000-2008	8000 deg^2	<z>=0.35
AGES (Eisenstein)	MMT 6.5-m, 1° FOV	300 fibers	2005-...	(small)	
SDSS-III LRGs	ARC 2.5-m, 3° FOV	1000 fibers	2009-2013	10,000 deg^2	<z>=0.7
SDSS-III QSOs	ARC 2.5-m, 3° FOV	1000 fibers	2009-2013	5,000 deg^2	<z>=2.5
LAMOST	Chinese 6-m, 2° FOV	4000 fibers	???	???	<z>=0.7
AAOmega LRG	AAT 4-m, 2° FOV	400 fibers	Rejected		
AAOmega WiggleZ	AAT 4-m, 2° FOV	400 fibers	2006-... (200 nights)	1,000 deg^2	<z>=0.8
HETDEX	Hobby Eberly 11-m	200 IFUs	???	200 deg^2	z=1.8→3.8???
FMOS	Subaru 8.4-m, 0.5° FOV	200 fibers	2007-... (200 nights)	200 deg^2	<z>=1.4
WFMOS (previously KAOS)	Subaru 8.4-m, 1° FOV	~3000 fibers	2014? (120 nights)	1000 deg^2	<z>=1
WFMOS (previously KAOS)	Subaru 8.4-m, 1° FOV	~3000 fibers	2014? (60 nights)	150 deg^2	<z>=3
ADEPT (JDEM proposal)	Earth orbit 1.3-m	Grism 1→2μm	2014?	30,000 deg^2	z=1→2
Cosmic Inflation Probe	L2 orbit 1.8-m, 0.3° FOV	Grism 2.5→5μm	???	140 deg^2	z=3→6.5