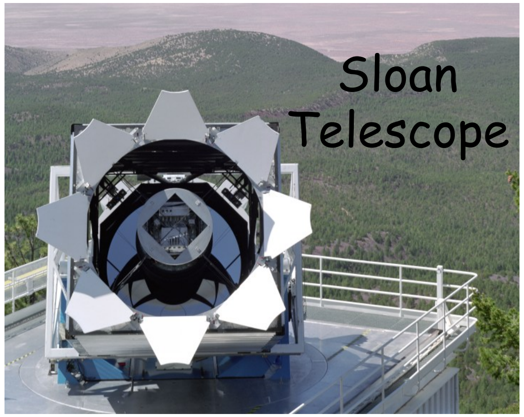
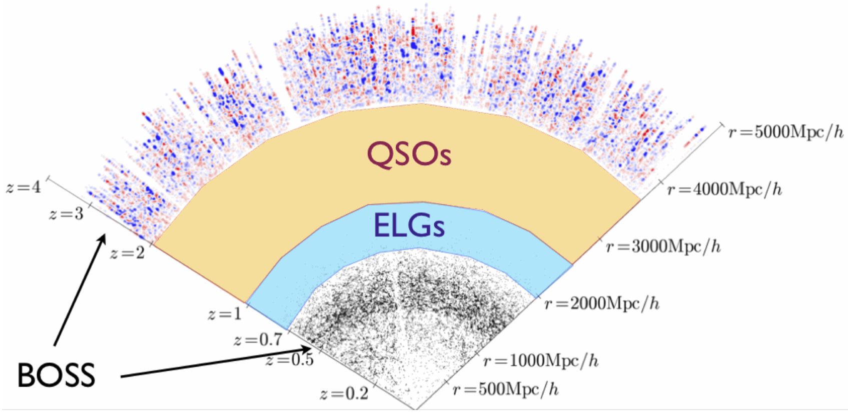
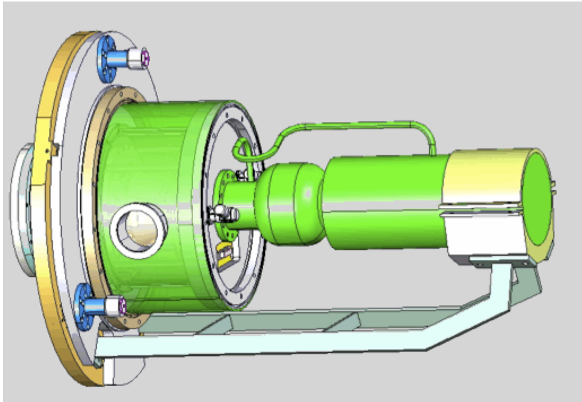
Extended BOSS
e-BOSS







Outline:

- Scientific Context
- eBOSS project
- Instrument upgrade

CSTS/SPP - Saclay – June 1, 2012

Saclay Group for e-BOSS

Scientists:

- **BOSS:** J.-M. Le Goff, N. Palanque-Delabrouille, J. Rich and Ch. Yèche.
- **New members (already in BigBOSS team):** E. Armengaud, Ch. Magneville and V. Ruhlmann-Kleider

Technical support (BigBOSS prototype)

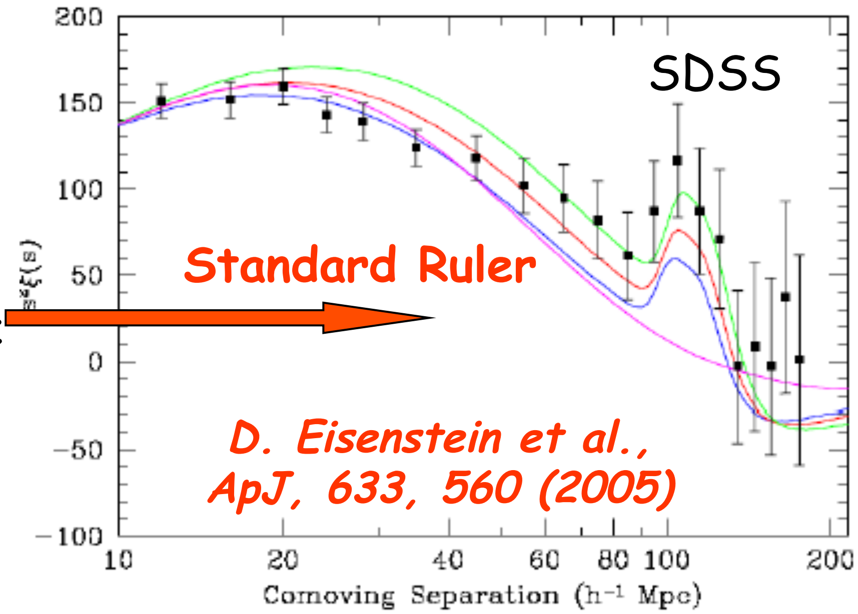
- **Sédi:** P.-H. Carton (project leader), P. Starzynski
- **SIS:** S. Cazaux, D. Eppelle…

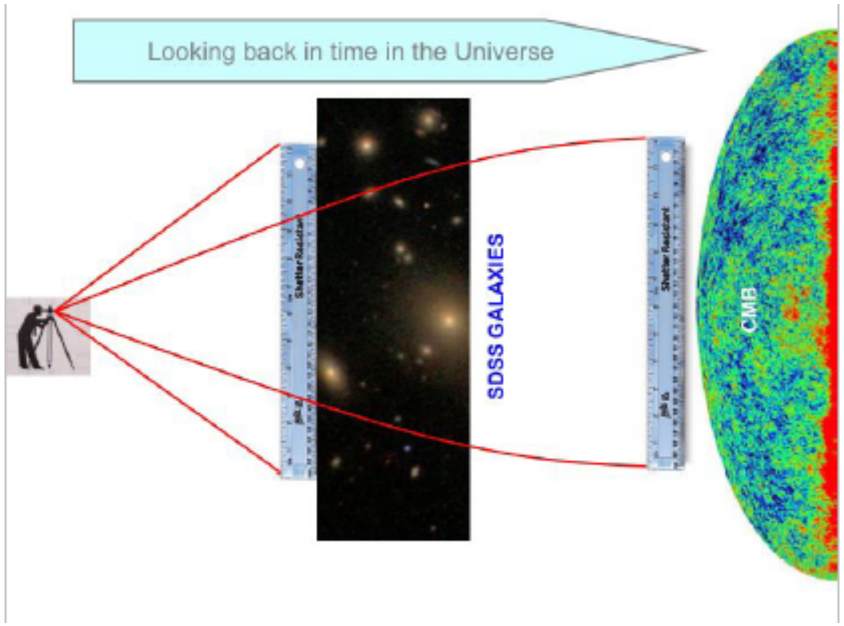
Scientific Context

Observation of baryonic acoustic peak

First observation:

- In 2005: First observations of baryonic oscillations by 2 teams (2dFGRS and SDSS)
- SDSS observe a peak at ~150 Mpc
- SDSS: ~50 000 LRGs
  "Luminous Red Galaxies"
  <z> ~ 0.35





A 3D measurements:

- Position of acoustic peak ⇒ Size of the sound horizon s
- Transverse direction:

$\Delta\theta = s/(1+z)/D_A(z)$

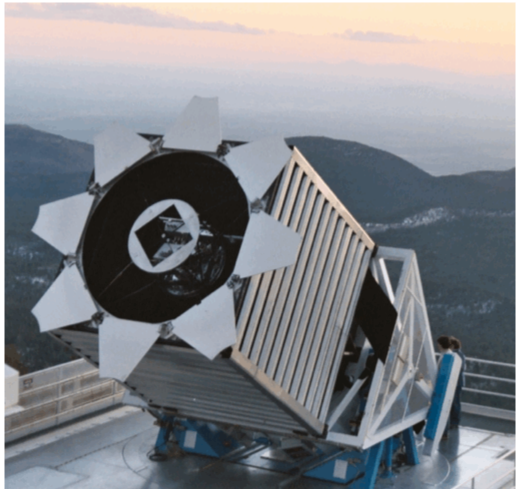
⇒ Sensitive to angular distance $D_A(z)$

- Radial direction (along the line of sight):

$\Delta z = s \cdot H(z)/c$

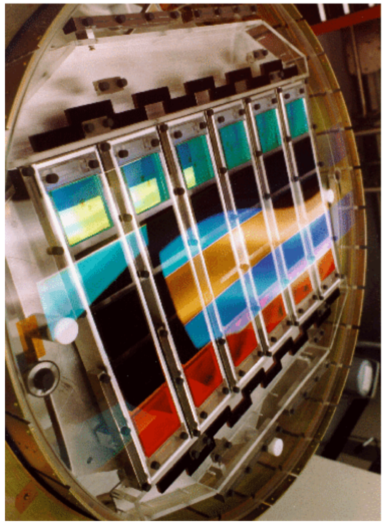
⇒ Sensitive to Hubble parameter $H(z)$.

From SDSS to SDSS-III



SDSS Consortium

- 2.5m Sloan Telescope
- Apache Point, NM
- Wide field telescope ~ 7 deg^2
- Camera equipped with 5 filters (~120 millions pixels)
- Extension of imaging survey in SGC



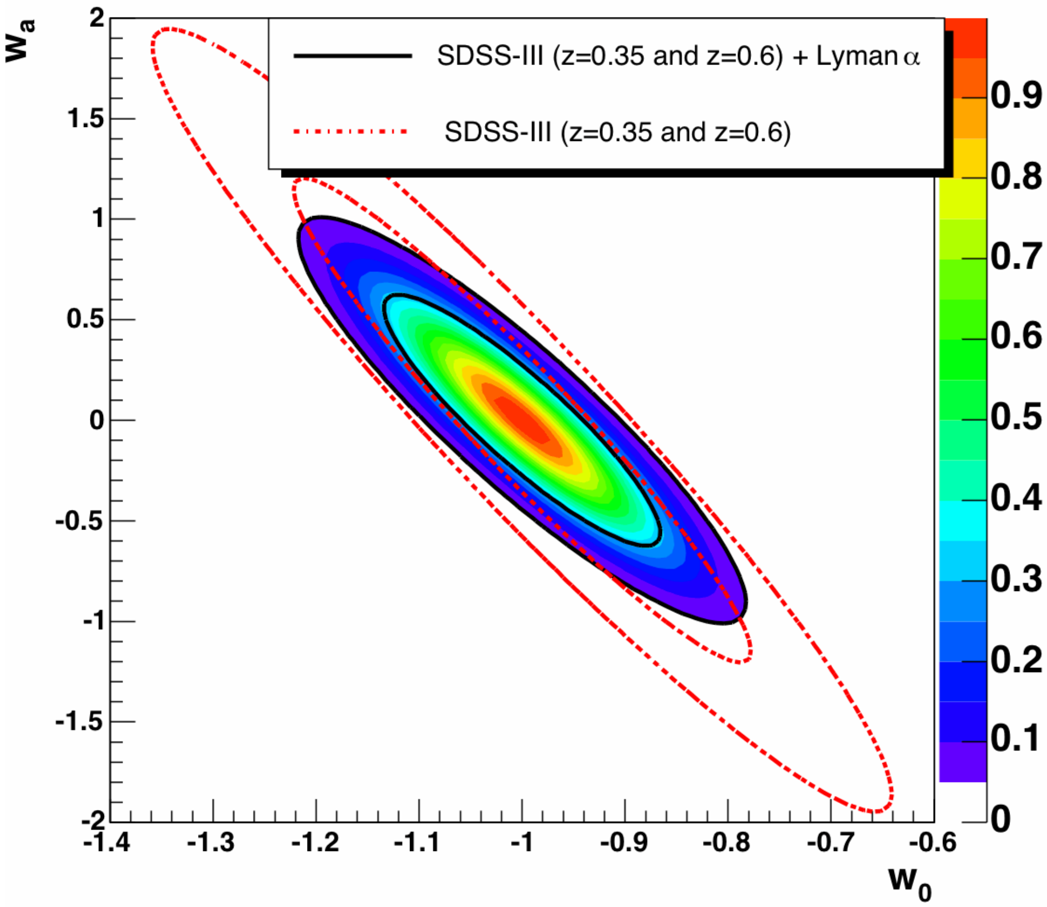
Upgrade for SDSS-III

- New fiber system ⇒ 1000 fibers
- Replacement of red CCDs by LBNL CCDs ⇒ LRG with higher z
- Replacement of blue CCDs with e2v CCDs with better throughput in UV

⇒ Lyman-α forest program

BAO with BOSS

$w = P_{DE}/\rho_{DE} = w_0 + w_a z/(1+z)$



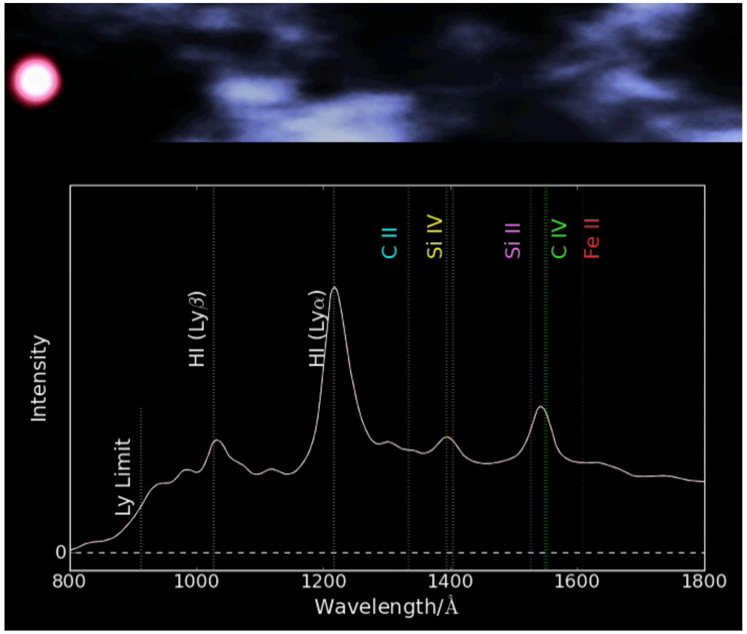
With LRG: ~1.5M galaxies

- ~11000 deg^2, 0.3<z<0.7 Volume x2 , Density x5
- BAO scale: 1.0% at z~0.35
  1.1% at z~0.6
- Observation of BAO both in transverse and radial directions

With Ly-α forests: ~150k QSOs

- 2.2<z<4.0
- BAO scale: 1.7% at z~2.5
- New approach (see next slide)
- Method studied by Saclay group

Additional method: Ly-α forests



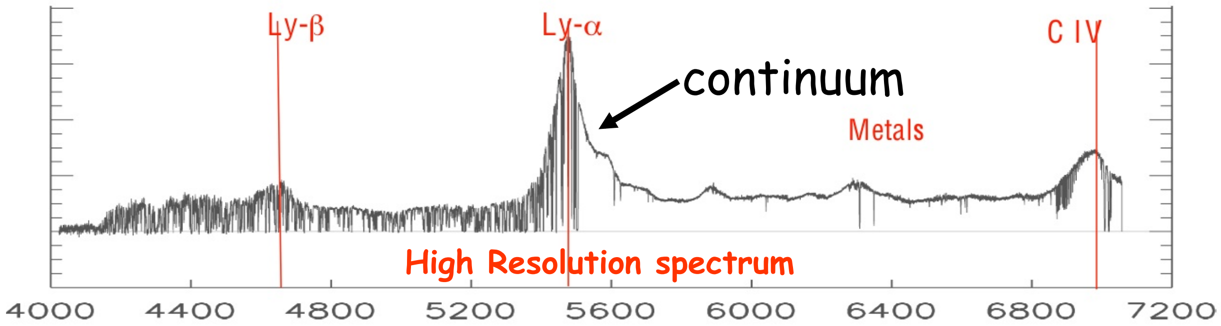
Principles

- Use Ly-α forests of quasars (2.2<z<4)
- HI absorption in IGM along the line of sight of QSOs
- We expect low density gas (IGM) to follow the dark matter density (validations : measured 1D power spectrum, N-body simulations and 3D power spectrum…)

BAO specifications:

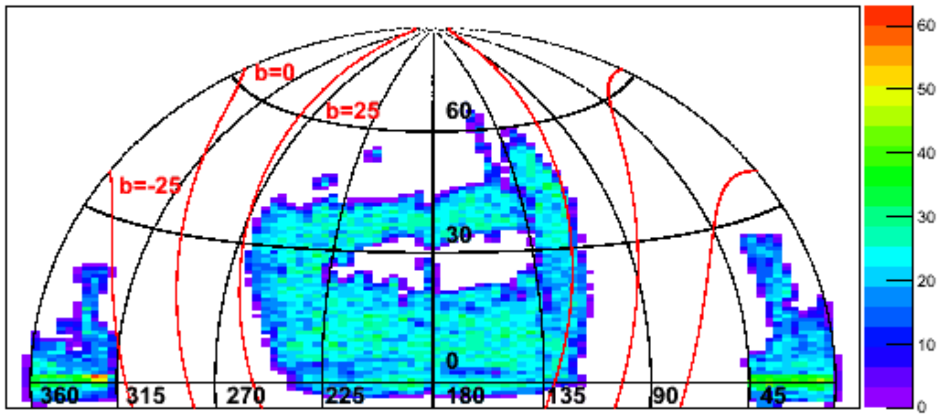
- 3D BAO: Correlation between the different lines of sight
- BAO measurement for z~2.5
- Better precision in radial direction (H(z) measurement).

z~3.6 Quasar

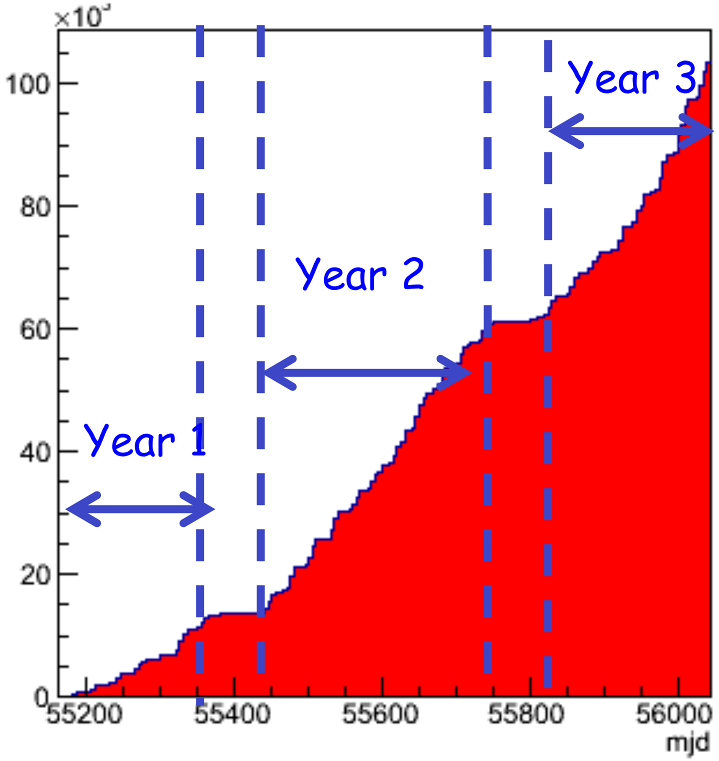


Status of the survey

QSO density



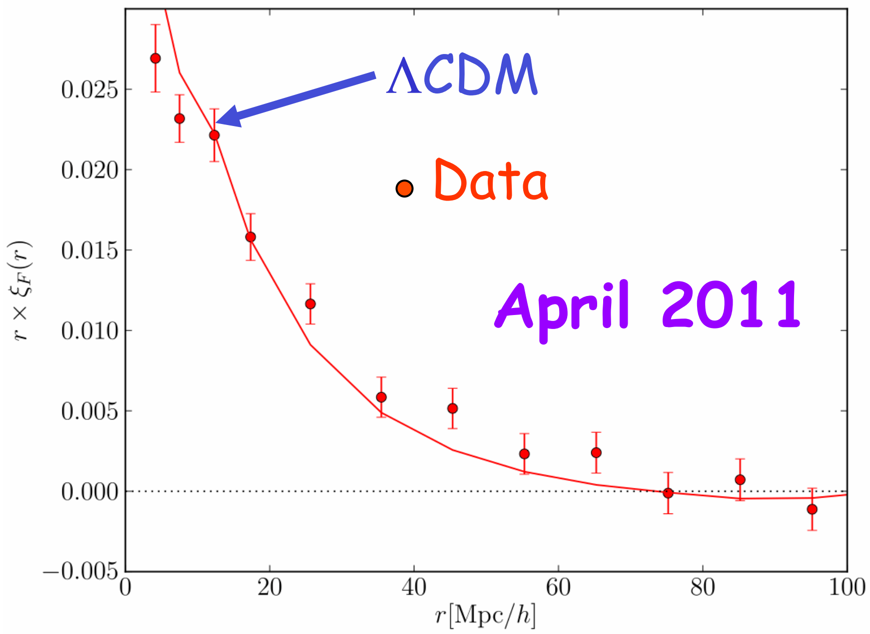
High-z QSO



- So far, **~110 000 QSOs and ~700 000 galaxies** over ~6700 deg²
- On average ~5000 high-z QSOs per month
- **End of the survey (10700 deg²):**
  - 1.2-1.5M galaxies !!!
  - 150k - 200k high-z QSOs !!!

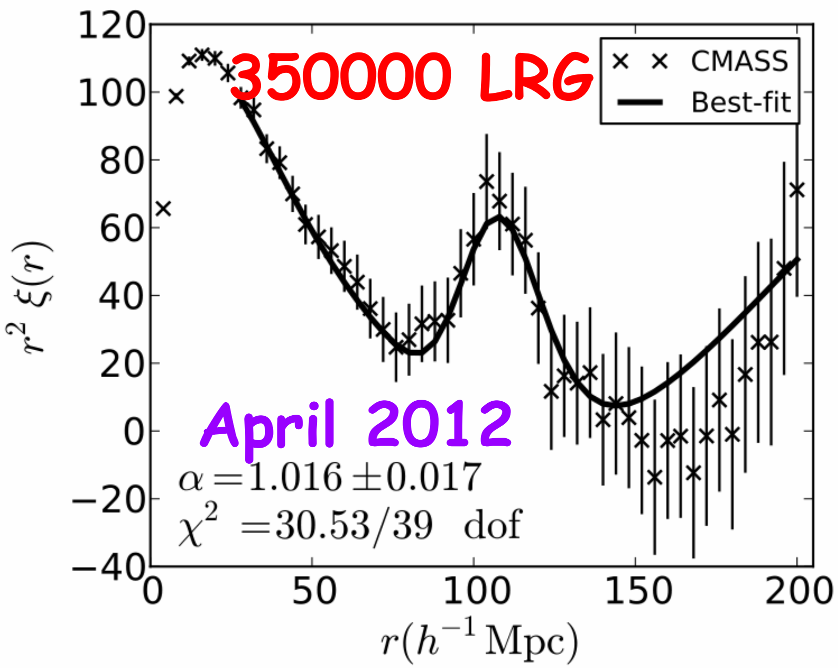
First Results

Ly-a forest – 14000 QSOs



Ly-α forest approach:

- First observation in 3D of matter in IGM
- Proof that Ly-α absorption is a reliable techniques for cosmology



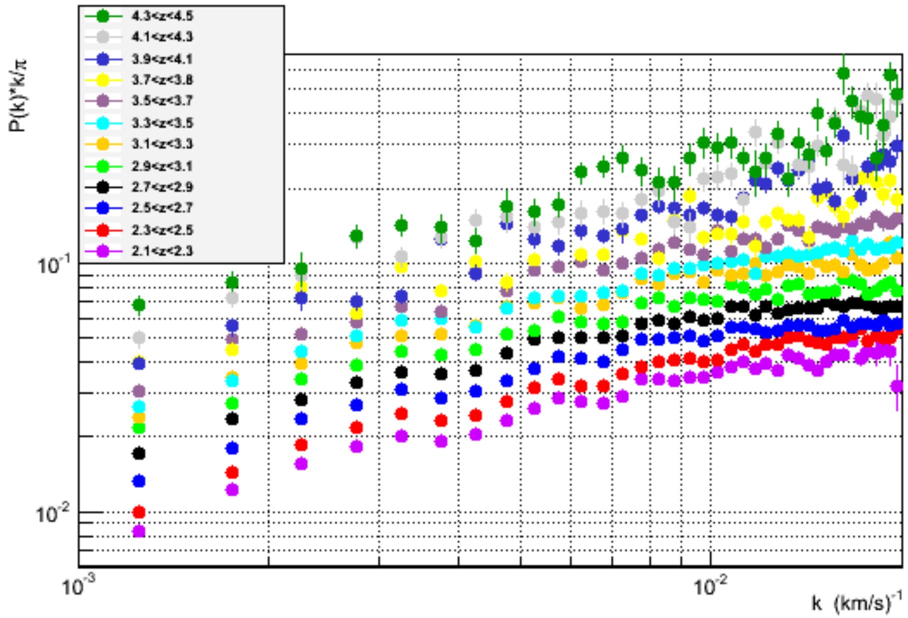
BAO with LRG:

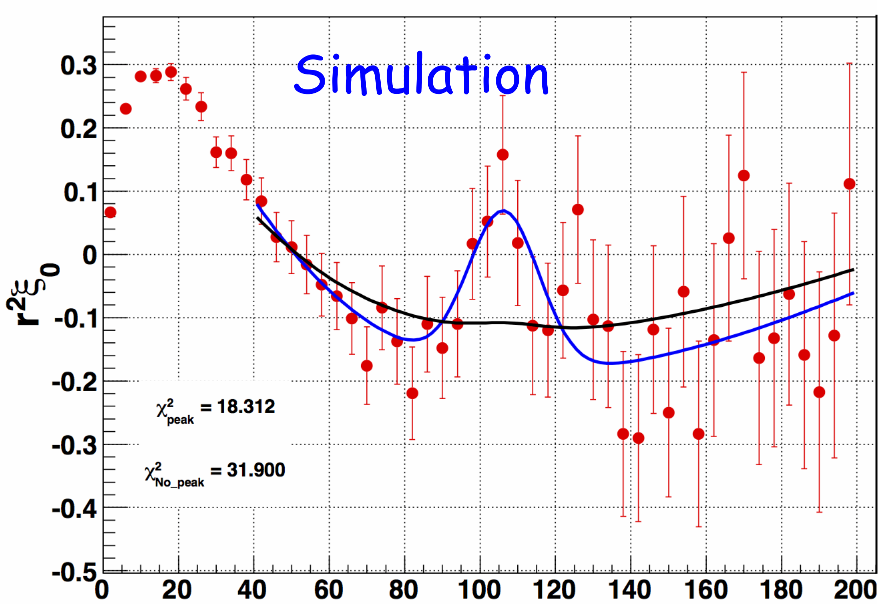
- BOSS-only 5-σ observation
- BOSS + SDSS-II: 7-σ
- BAO will be the best probe of DE for this decade

Saclay group contribution in BOSS

Overview:

- ➢ Duration: 2009-2014
- ➢ 4 senior scientists + 1 post-doc+
2 PhD students + 2 EC
- ➢ Running cost: ~10k€/year/scientist
- ➢ No construction of instrument
- ➢ Target selection of the quasars:
Responsibility (convener)





Analyses:

- ➢ Luminosity function of quasars
- ➢ Power spectrum along the line of sight (constraint on neutrinos mass) – **ANR funding** (project NUMASS)
- ➢ BAO with Ly-α (**convener**) :
Blind analysis – if lucky 3σ observation expected for summer 2012

e-BOSS

project

eBOSS : Extending BOSS on the Sloan Telescope

e-BOSS: Extending BOSS on the Sloan Telescope

Jean-Paul Kneib (CNRS/LAM), Christophe Yeche (CEA DSM/Irfu), Robert Cahn (LBL), Johan Comparat (LAM), Sudeep Das (UC Berkeley), Alexie Leauthaud (LBNL), Pat McDonald (LBNL), Adam Myers (Illinois), Nick Mostek (LBNL), Nathalie Palanque-Delabrouille (CEA DSM/Irfu), David Schlegel (LBNL), Uros Seljak (UC Berkeley), and Martin White (UC Berkeley).

Abstract

Building upon SDSS-I, SDSS-II, and SDSS-III/BOSS, this proposal **e-BOSS** *(extending BOSS) presents a four-year cosmology project that pushes the reach of the Sloan Telescope to higher redshift for galaxies, and fainter fluxes at lower redshift for QSOs, and extracts the full potential of next-generation imaging surveys. The SDSS redshift maps will be extended to* $0.6 < z < 1$ *using emission line galaxies (ELGs) and to* $1 < z < 2$ *using QSOs. These will yield dark energy constraints from baryon acoustic oscillations (BAO) at these redshifts.*

Furthermore the signal in the Ly-alpha forest for $z > 2.2$ *will be tripled compared to BOSS, resulting in significant improvements in dark energy and curvature constraints at high redshift.*

Overlaps with imaging surveys on the same timescale (Dark Energy Survey, Pan-STARRS and Hy-perSuprimeCam) and CMB maps (ACT, ACTPol) will maximize the cosmology reach of those programs. The BOSS spectrographs allow one to probe the full redshift range $0 < z < 3$ *using galaxies, QSOs and Ly-alpha forest. Even by 2014, no other spectrograph will have this capability over thousands square degree survey areas.*

LOI in early 2011

AS3 (After Sloan 3) call:

- Response with a LOI (LAM, LBL and Saclay) in early 2011
- Saclay group proposed to use the QSOs as tracers in e-BOSS

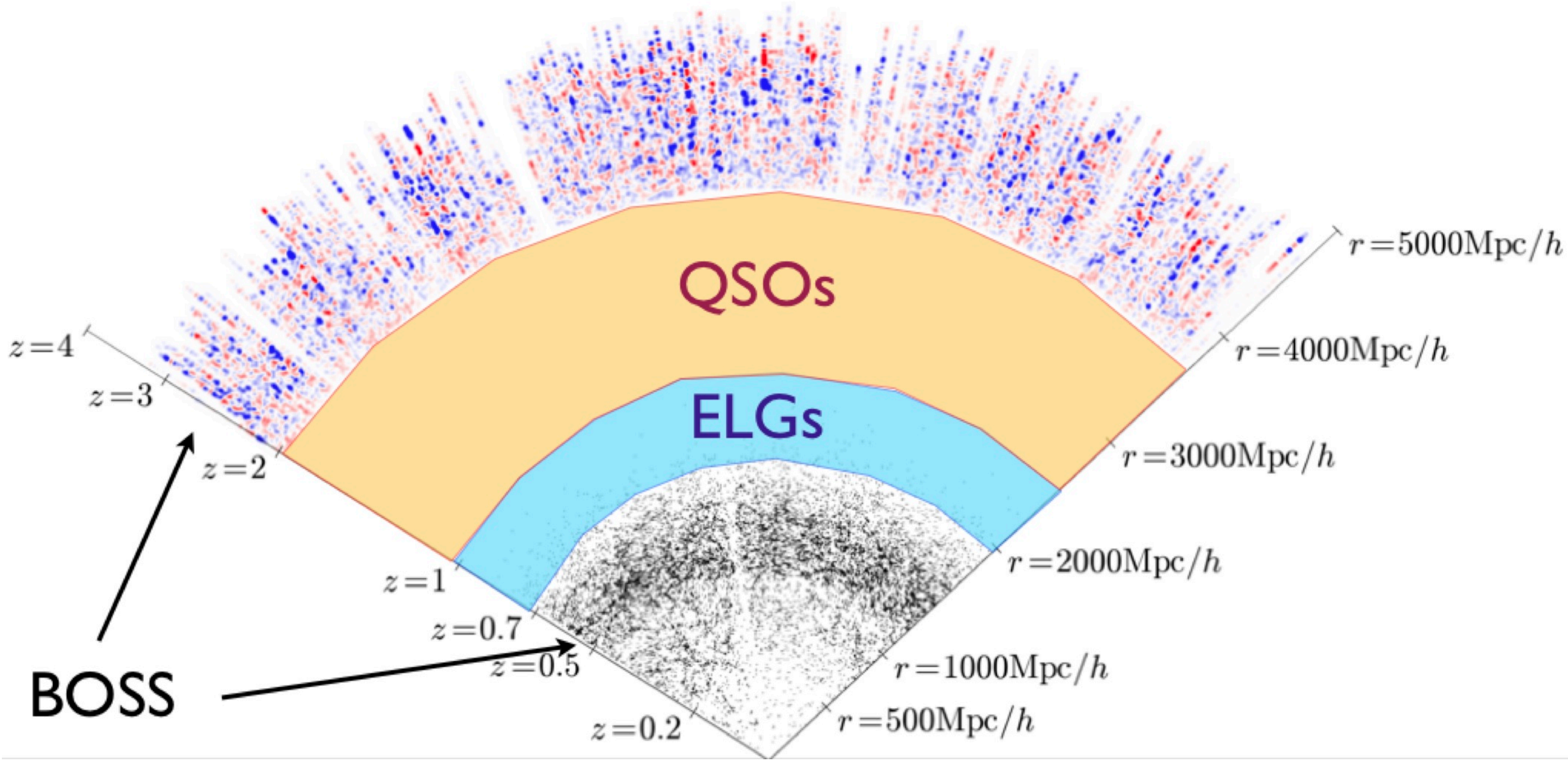
Approval:

- Proposal in September 2011 (~70 Co-Is, 30 institutes)
- Approved in November 2011 (3 years instead of 4 years)

Hardware contribution:

- Construction of a 3rd spectro.

e-BOSS : Fill the Gap….

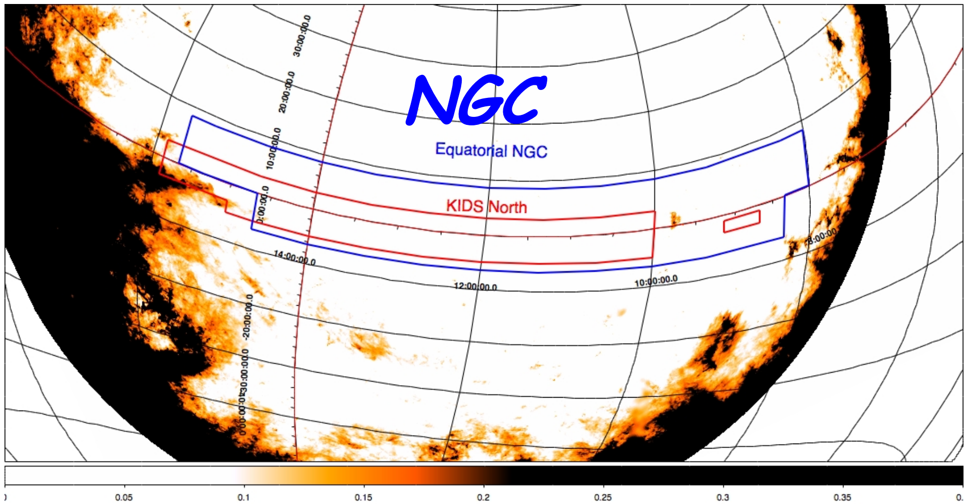


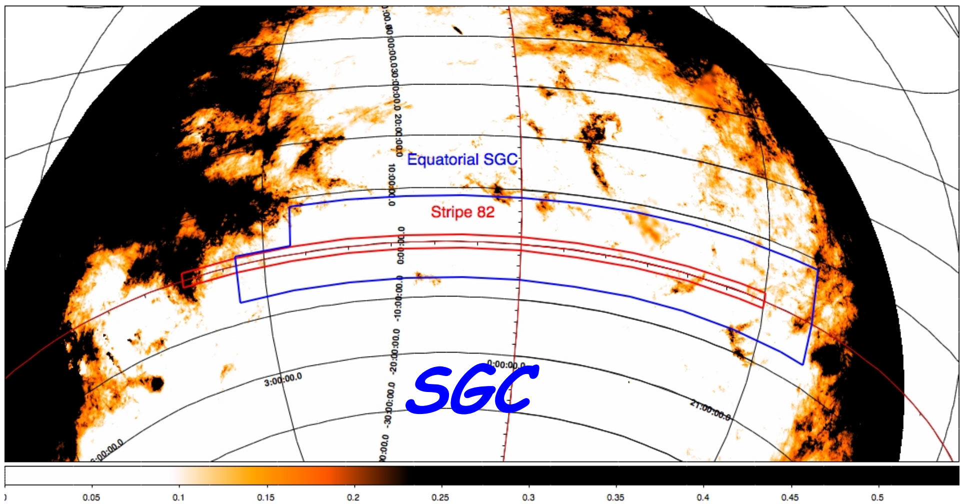
0.6<z<1.5 ELG:
- Emission line galaxies (stars forming)

1<z<2.2 QSOs:
- Tracers of cosmic structures
- LF peaks at z ~1.5-2

Ly-α QSOs, 2.2<z<5:
- g<22 ⇒ g<22.5
- Improvement of selection
- ~15 deg^{-2} ⇒ ~35 deg^{-2}

e-BOSS overview





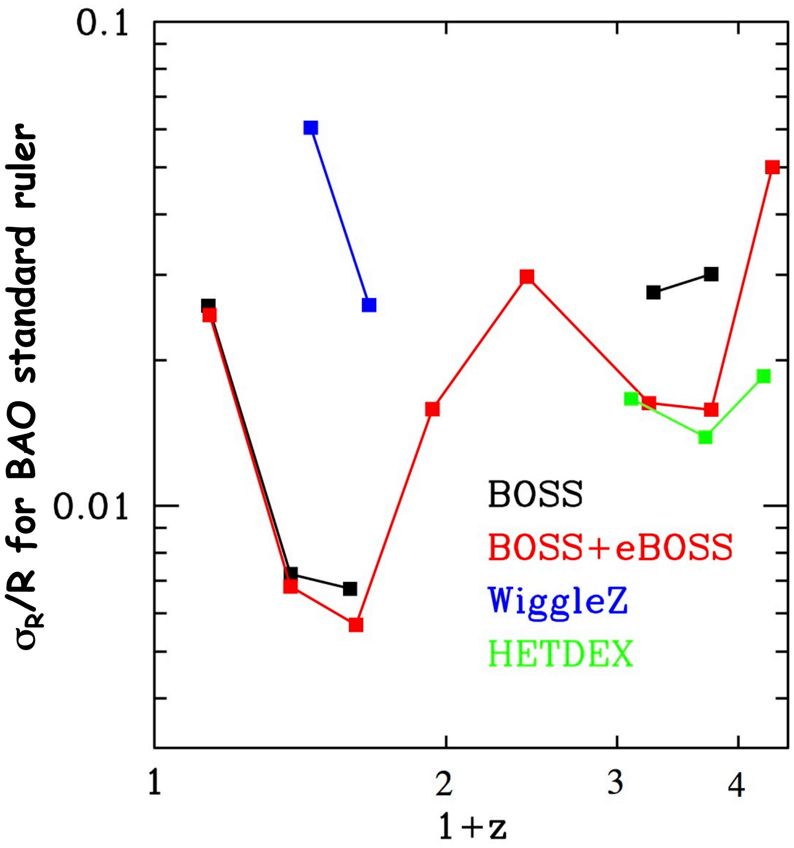
e-BOSS status:

- 2.5m Sloan Telescope
- ~70 Co-Is, 30 institutes
- Approved by ARC
- Funding plan in definition
- 2014-2020: shared time with MaNGA and APOGEE

e-BOSS strategy:

- ~3000 deg^2 in NGC and SGC
- Target selection with SDSS
- Deeper photometry : DES and (CFHT and NOAO) calls
- ~100k LRGs ($0.3<z<0.8$)
- ~1 million ELGs ($0.6<z<1.5$)
- ~400k QSOs (~1/3 with $z>2.2$)

e-BOSS performances



BAO

- Continuous measurement for 0.3<z<4.0
- Improvement in Ly-α
- Improvement by a factor 2 of FoM (precision on the measurement of $\sigma(w_0) \times \sigma(w_a)$)

$$\boxed{w=P_{DE}/\rho_{DE}=w_0+w_a z/(1+z)}$$

Saclay contribution to e-BOSS

Observation preparations

- Target selection of QSOs
- New strategy using the QSO intrinsic variability
- Responsibility of TS for e-BOSS

Data analysis

- 1D and 3D power spectrum with Ly-α forest
(ν masses and BAO at $z \sim 2.5$)
- Clustering with QSO (BAO $1.0 < z < 2.0$)

Upgrade of instruments

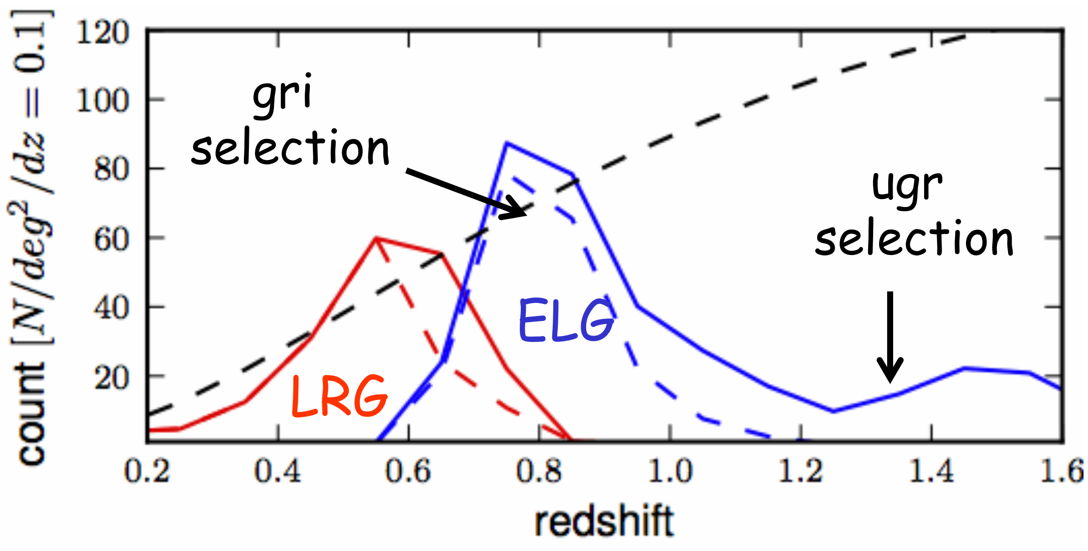
- Construction of a 3rd spectrograph
- Use Cryostat developed for BigBOSS (see next slides)
- Instrument scientist of the 3rd spectrograph

Instrument Upgrade

–

3rd Spectrograph

Why a 3rd spectrograph?



Motivations:

- Increase the survey speed (40%)
- Improvement of the resolution for high-z ELGs

Overview:

- No room available at the bottom of the telescope
  - ⟹ 20m fibers to a conditioned room **(like BigBOSS)**
- Additional spectrograph (only one arm)
  - ⟹ **wavelength range [650nm;950nm]**
- Dedicated for ELGs (and LRGs)
- 400 additional fibers, i.e. 350 new objects
  - ⟹ **~40% gain in survey efficiency**
- For ELGs with z>1.0, OII doublet has to be resolved
  - ⟹ **$R=\lambda/\Delta\lambda$~3500-4000**
  - ⟹ **~25% gain in redshift determination for ELGs**

Gains for BAO

	Without third arm	With third arm	Gain on BAO
Duration Coverage	3 years 2200 deg^2	3 years 3000 deg^2	
LRG redshift	105,000	145,000	18%
gri ELG redshift	365,000	495,000	18%
ugr ELG redshift	300,000	510,000	48%
QSO redshift	280,00	380,000	18%

Increase in survey efficiency and in density

- Recover the descope after AS3 decision
- With 3rd arm, a 3-year survey equivalent to a 4-year survey
- **One year operation \$2.5M to compare to 3rd arm cost ~\$1M**

Strategy

Cost optimization

- Re-use existing instruments
- MUSE spectrograph
- Demonstrator of cryostat for BigBOSS
- LBNL CCDs (BOSS and DES)
- APOGEE fiber system

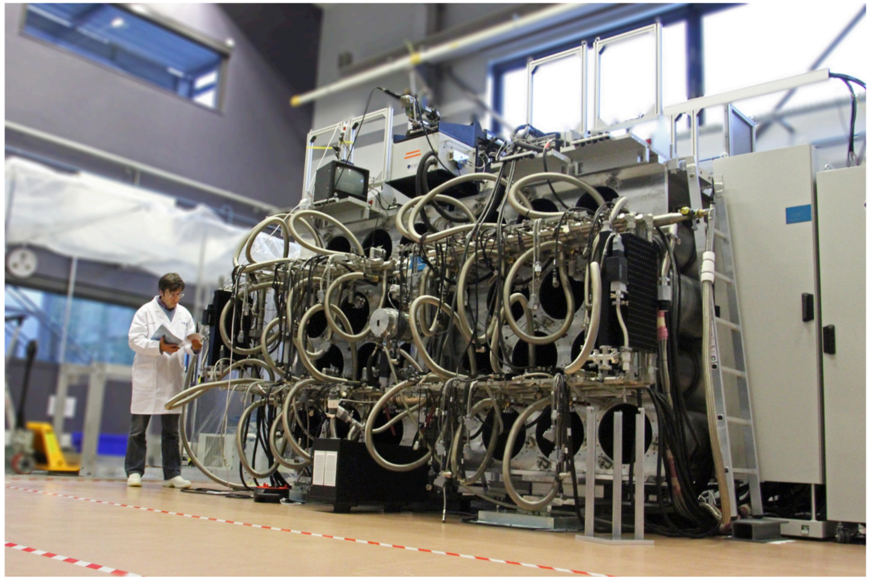
Minimal developments

- Use the same dark-time system to fix fibers to plates
- Re-use current DAQ
- Adaptation of the current data reduction pipeline for BOSS

Cost estimate

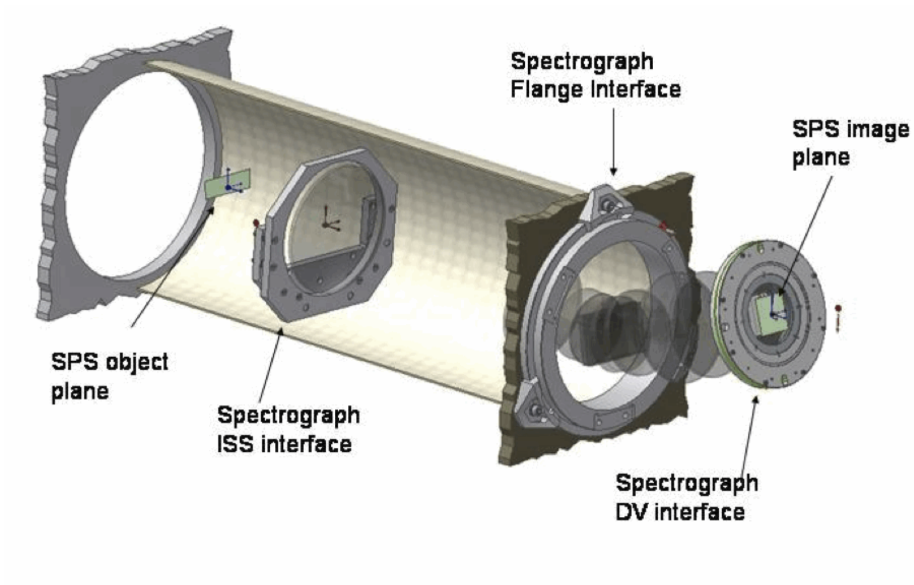
- ~$1.3M (including manpower)
- French participation : $0.7M ($0.4M for manpower)

Spectrograph - CRAL



Re-use of MUSE spectrograph

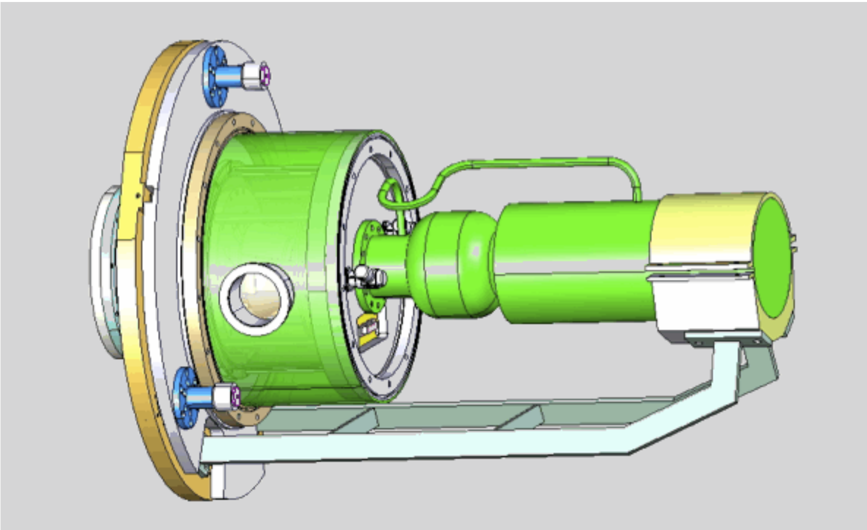
- MUSE: IFU : 2nd generation instrument for VLT
- 24 units: 90,000 spectra in one exposure
- Commissioning at Lyon (CRAL) in October 2012⇒Shipping
- First light in early 2013



Modifications of spectrograph

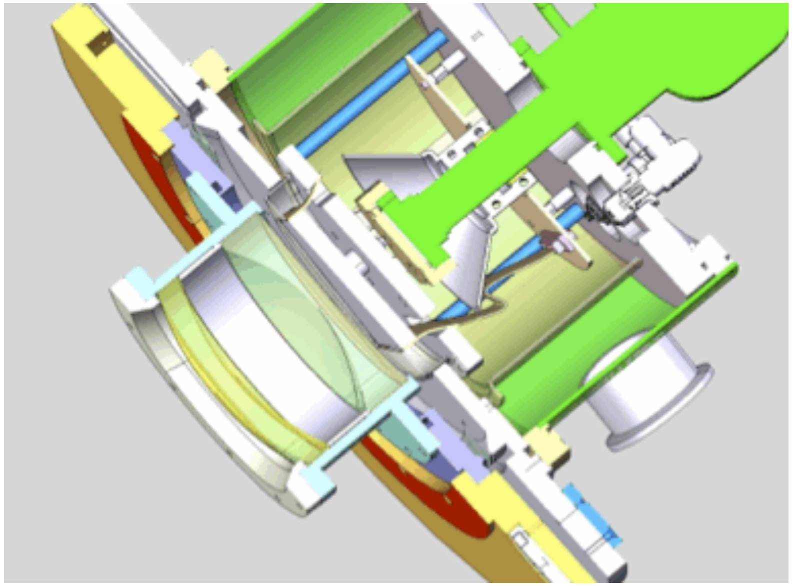
- Reduction of the wavelength range to get a better resolution: 650-950nm
- New VPHG: R~3500-4000
- New angle for spectrograph
- Re-optimization of the optics (0.3 FTE – optical engineer)

Cryostat and detectors – LBNL + CEA



Specifications:

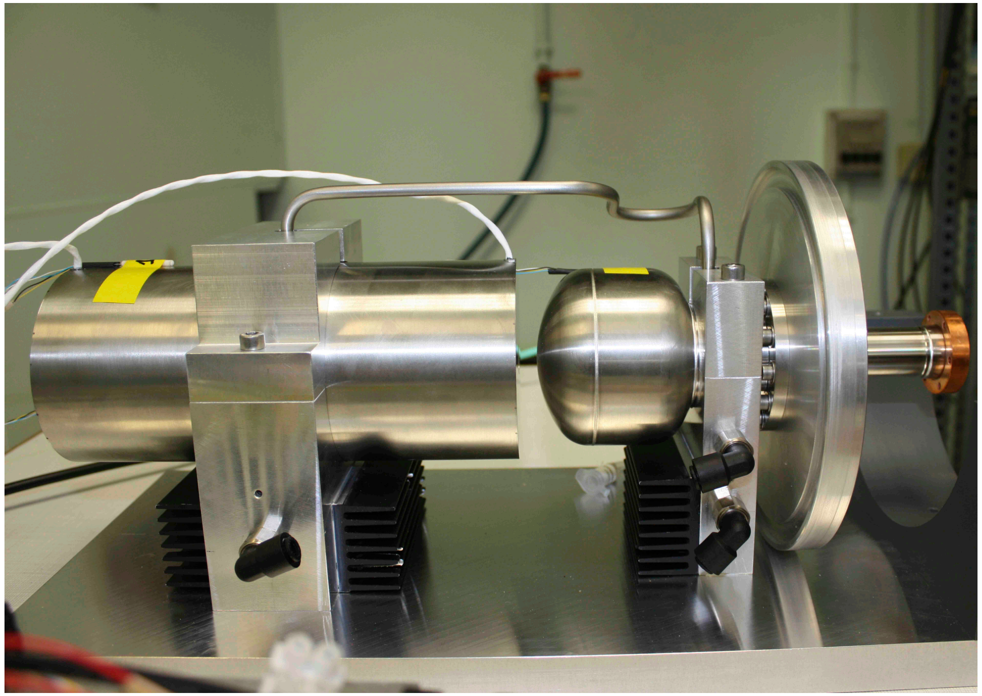
- Cryocooler: Linear Pulse Tube (LPT) : 4W at 80K, 16W at 160K
- No Nitrogen refill
- Low operational maintenance
- Tip-tilt alignment (15μm along optical axis - 50μm in transverse plane)

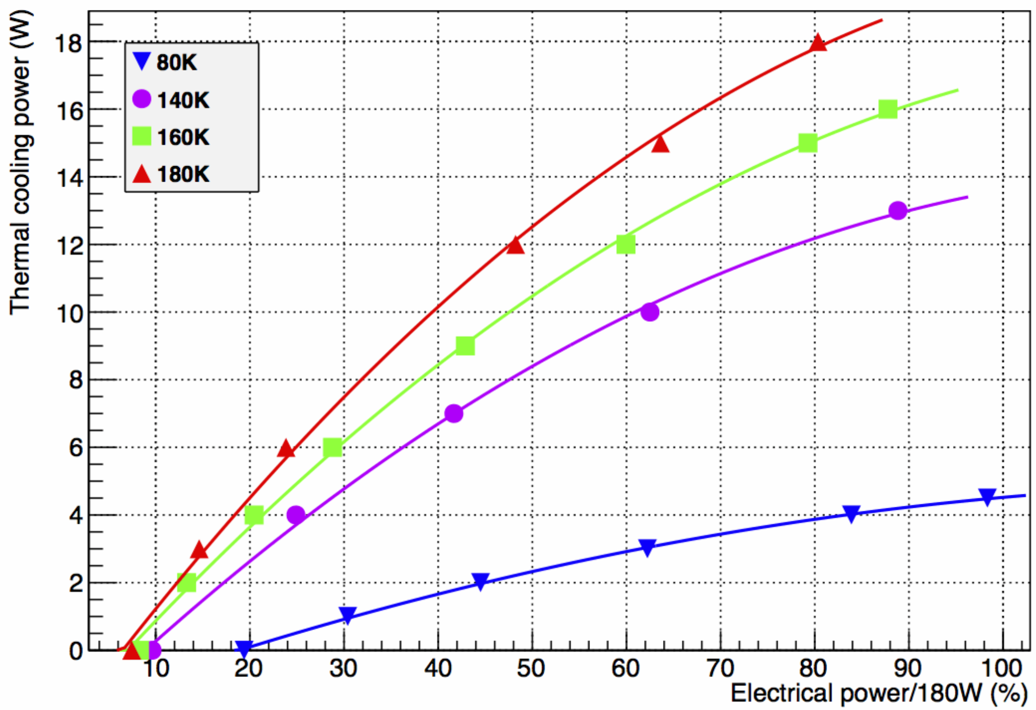


Strategy:

- Re-use the demonstrator developed for BigBOSS
- LPT tested and validated with a temporary cryostat
- Cryostat under construction
- Fully assembled with a LBNL CCD in early 2013

First results with BigBOSS prototype





First tests of the LPT:

- Final mechanics will be delivered next week, test with a temporary cryostat
- Cool-down tests: 80K achieved without any problem and cooling power used consistent with nominal values
- Vibration tests: ~4 μm at cold plate within requirements.

Conclusions

Budget

Running costs (6 years-7 scientists) :

- ~10k€ /scientist/year ⟹ 70 k€ /year
- Travels and meetings ⟹ 30 k€ /year

Total : ~100 k€ /year

In-kind contribution:

- Construction of cryostat ~230 k€
- Can be subtracted from running costs

LPT	22k€
Mechanics	25k€
Vacuum System	13k€
Slow control	15k€
Tools	5k€
manpower	150k€
Total	**230k€**

Summary

- BAO will be the best probe of Dark Energy for this decade.

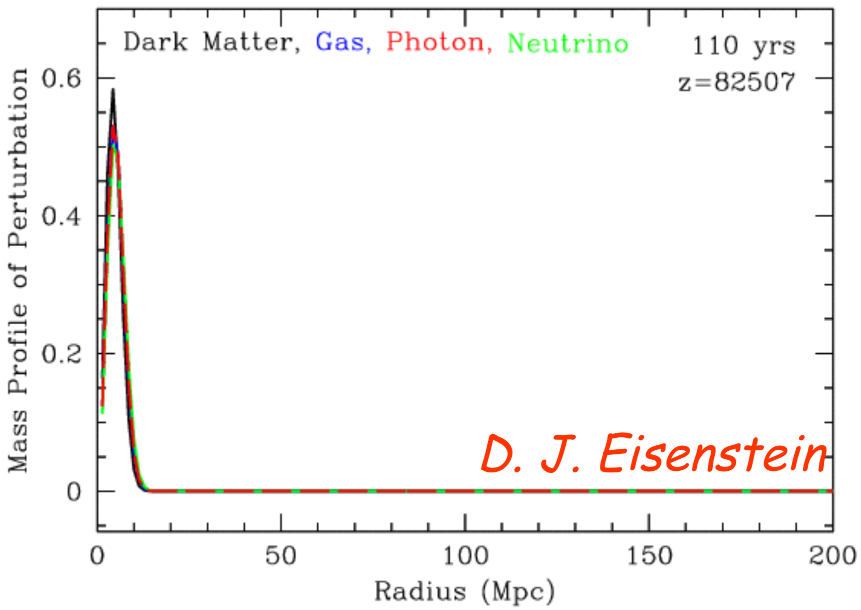
- e-BOSS offers an unique opportunity to participate in the effort of studying Dark Energy.

- We can have a significant hardware contribution to the upgrade of the instrument.

- e-BOSS is a precursor of BigBOSS

Additional Slides

A probe for Dark Energy: Baryonic Acoustic Oscillations



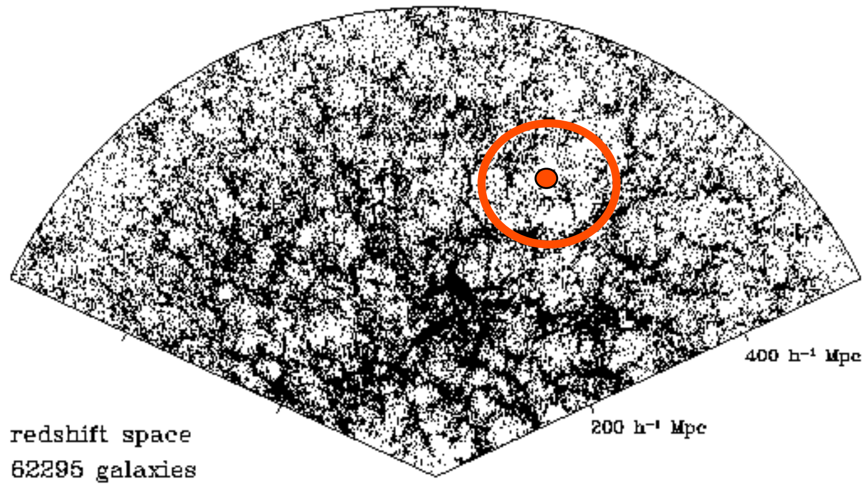
Acoustic propagation of an overdensity:

- Sound wave through relativistic plasma (baryons, electrons, photons).
- Baryon and photon perturbations travel together till recombination (z~1100).
- Then, the radius of the baryonic overdensity is frozen at 150 Mpc.

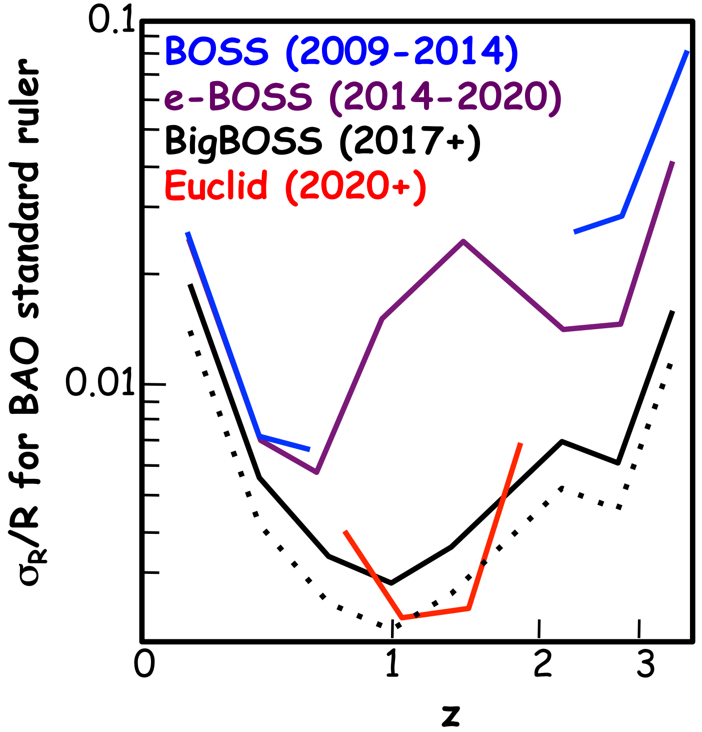
A special distance:

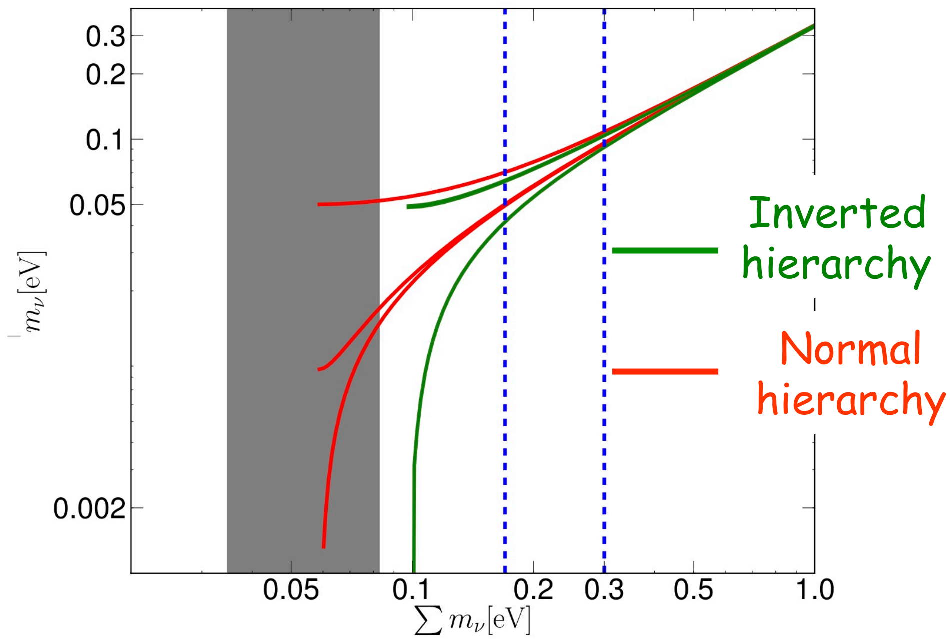
- Galaxies form in the overdense shells about 150 Mpc in radius.
- For all z, small excess of galaxies 150 Mpc (in comobile coordinates) away from other galaxies.

⇒ **Standard Ruler**



Sensitivity to Dark Energy and neutrinos mass





- **BAO:** 1 order of magnitude over 0.6<z<4 range
- **Neutrinos mass:** accuracy 25 meV on Σm_ν