# What will we learn with eBOSS?

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on behalf of the eBOSS/SDSS-IV collaboration

Rencontres du Vietnam
Cosmology 2015

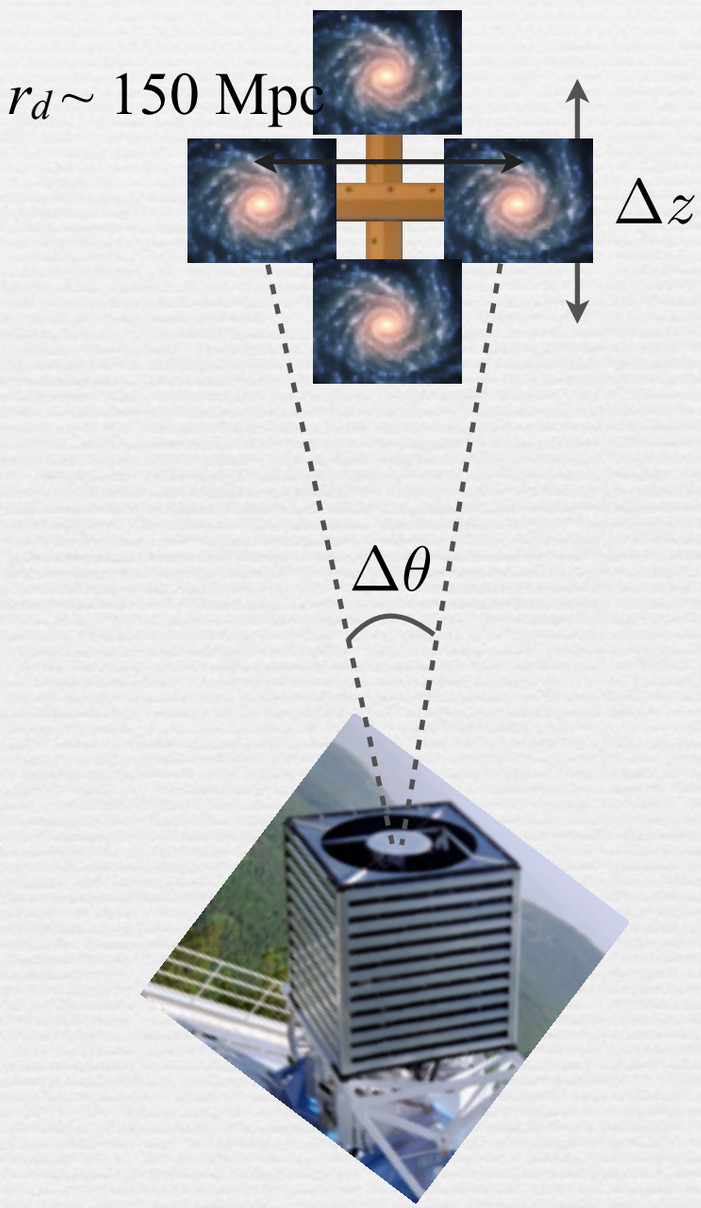
# Outline

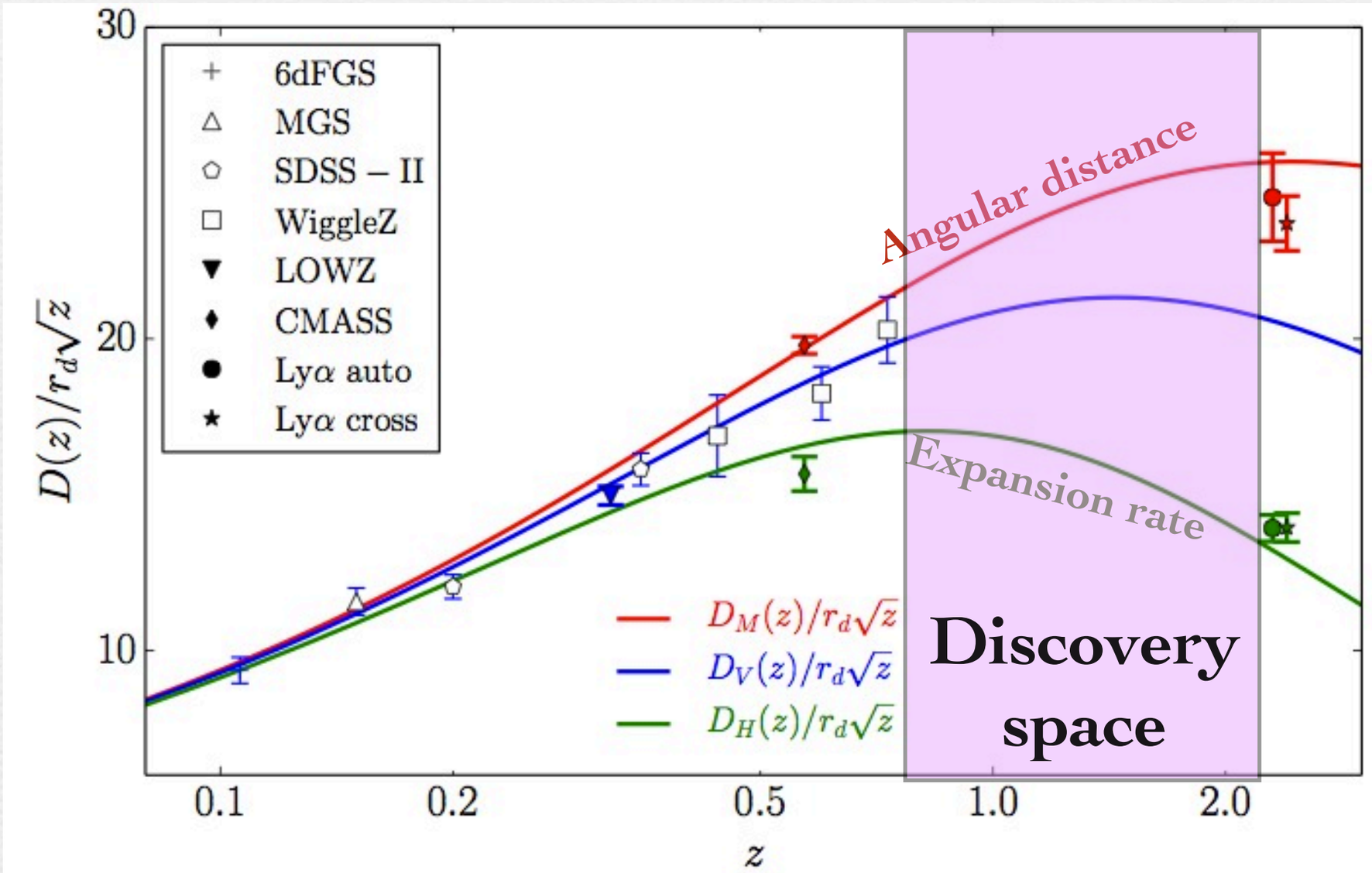
- Current status of spectroscopic survey measurements
- The survey strategy and forecasts
- A pilot survey: SEQUELS
- Astrophysics with eBOSS

# Current status of LSS measurements

# Hubble Diagram

## from BAO measurements




Aubourg et al. 2014

# Redshift-space distortions

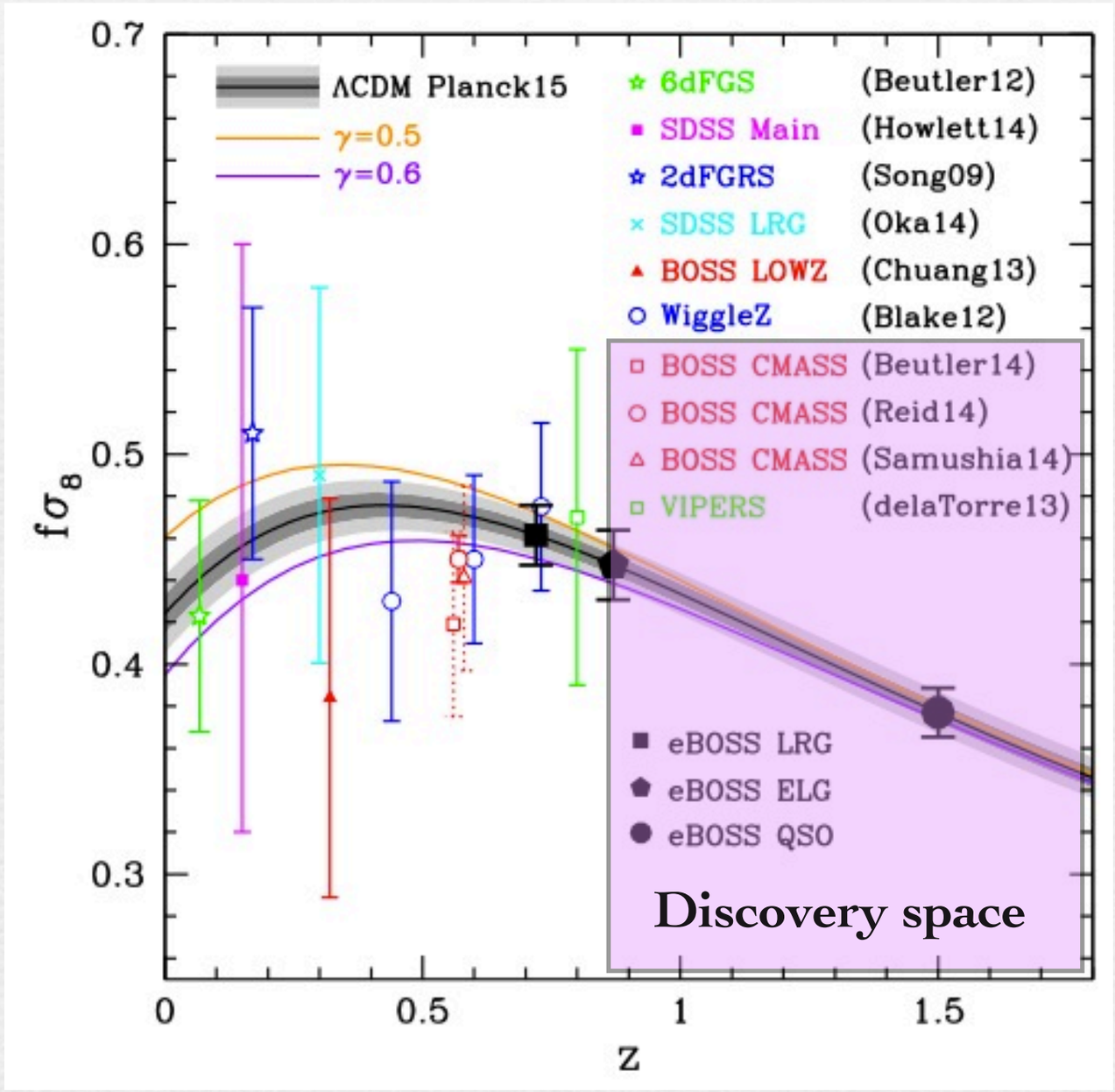
Peculiar velocities

$$\nabla \cdot \vec{v}_p = -\frac{H(z)}{1+z} f \delta_m$$

$$f \propto \Omega_m^{\gamma}$$

In GR: $\gamma = 0.55$

Is GR consistent with anisotropic clustering measurements?

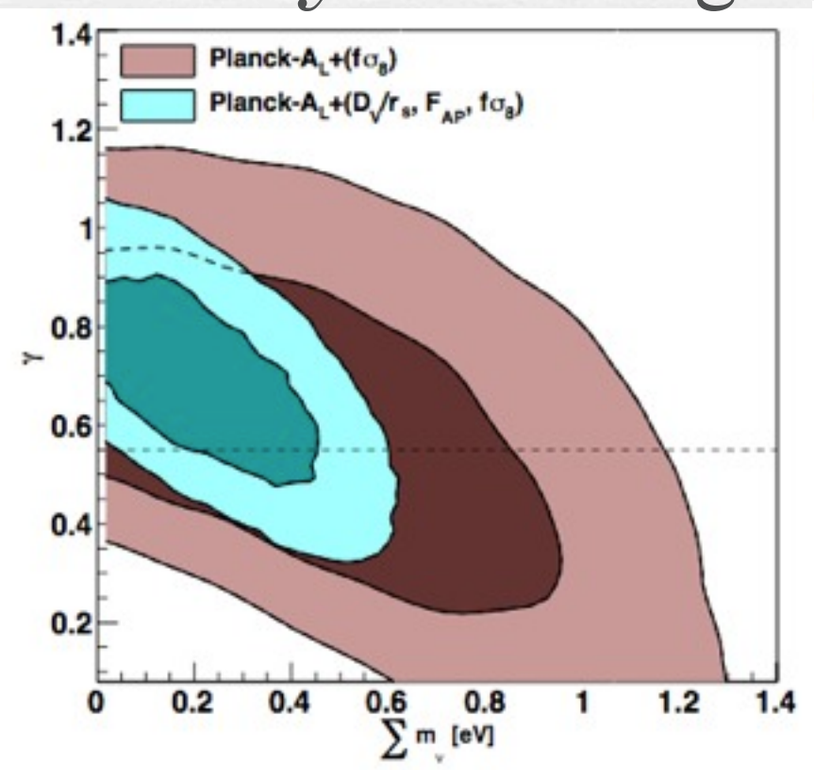


# More cosmology

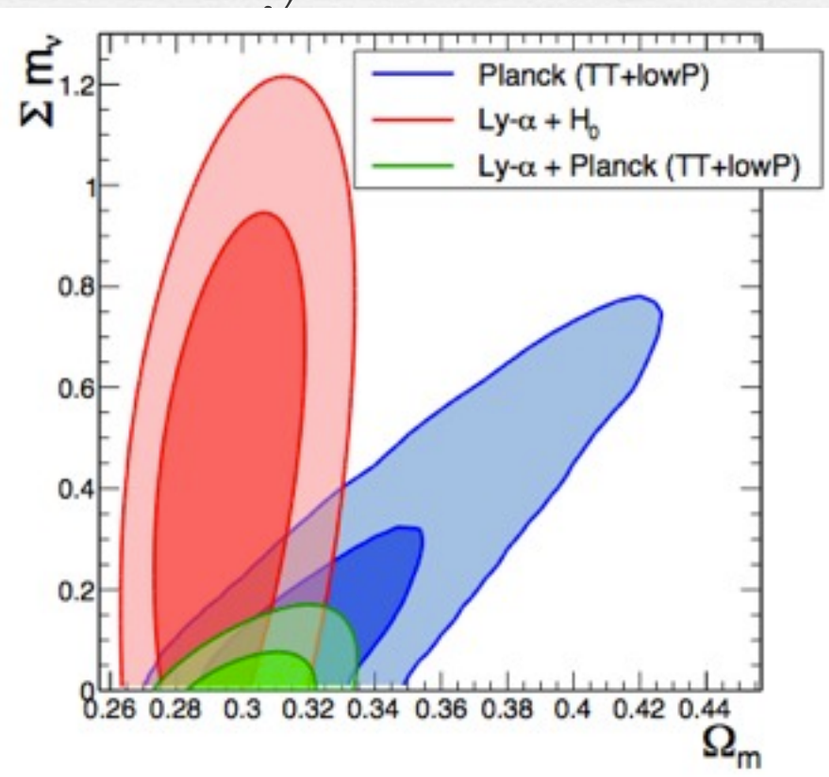
## Neutrino masses

## Primordial Non-Gaussianity

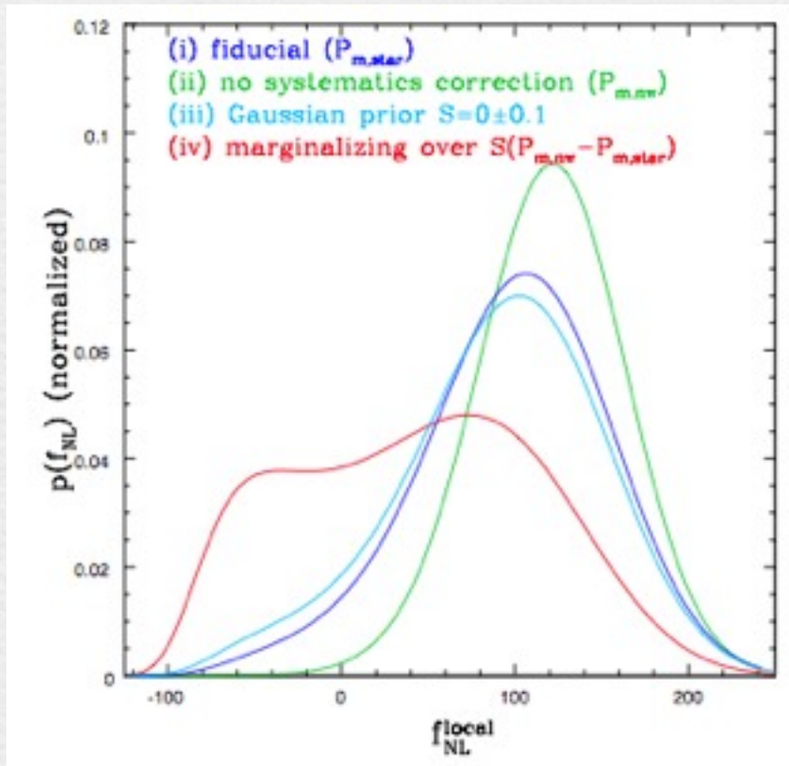
### Galaxy clustering




### Lyα forest




Zhao et al. 2013,
Beutler et al. 2014
Palanque-Delabrouille et al. 2014, 2015




Ross et al. 2013

# The survey

## Strategy and forecasts

# SDSS-IV

- Fourth generation of the Sloan Survey
- 2.5m telescope @ Apache Point: wide-field, multiplex spectroscopy, wide wavelength coverage, $R = \lambda / \Delta\lambda \sim 2500$
- eBOSS will use 50% of dark time
- Observing and data management similar to BOSS

# Tracers

| | Redshifts | Number | Area |
|---|---|---|---|
| Quasars | 0.9 < z < 2.2 (clustering) | 500k | 7500 deg$^2$ |
| | z > 2.1 (Lyman- forest) | 60k (new) + 60k (re-obs) | |
| Luminous Red Galaxies (LRG) | 0.6 < z < 0.9 | 250k | 7000 deg$^2$ |
| Emission Line Galaxies (ELG) | 0.7 < z < 1.1 | 200k | 1500 deg$^2$ |

# Forecasts

| | $z_{eff}$ | BAO $\sigma_{D_V}/D_V$ | RSD $\sigma_{f\sigma_8}/f\sigma_8$ |
|---|---|---|---|
| Quasars | | | |
| - Clustering | 1.4 | 1.8% | 3.2% |
| - Lyα forest (+BOSS) | 2.4 | 1.4% | |
| Luminous Red Galaxies (LRG) | 0.7 | 0.8% | 2.6% |
| Emission Line Galaxies (ELG) | 0.85 | 2.0% | 3.8% |

# Selecting targets

## Imaging information available

SDSS (optical)

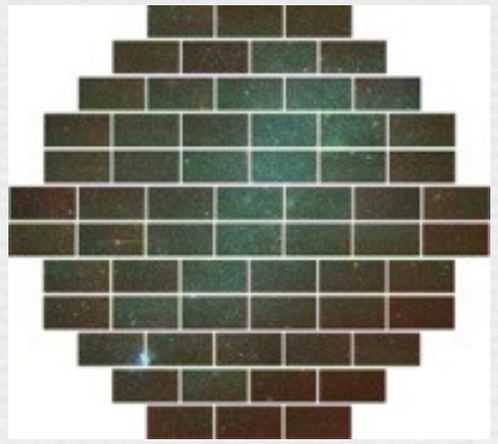
WISE (IR)

SCUSS (U-band)

PTF (Variability)

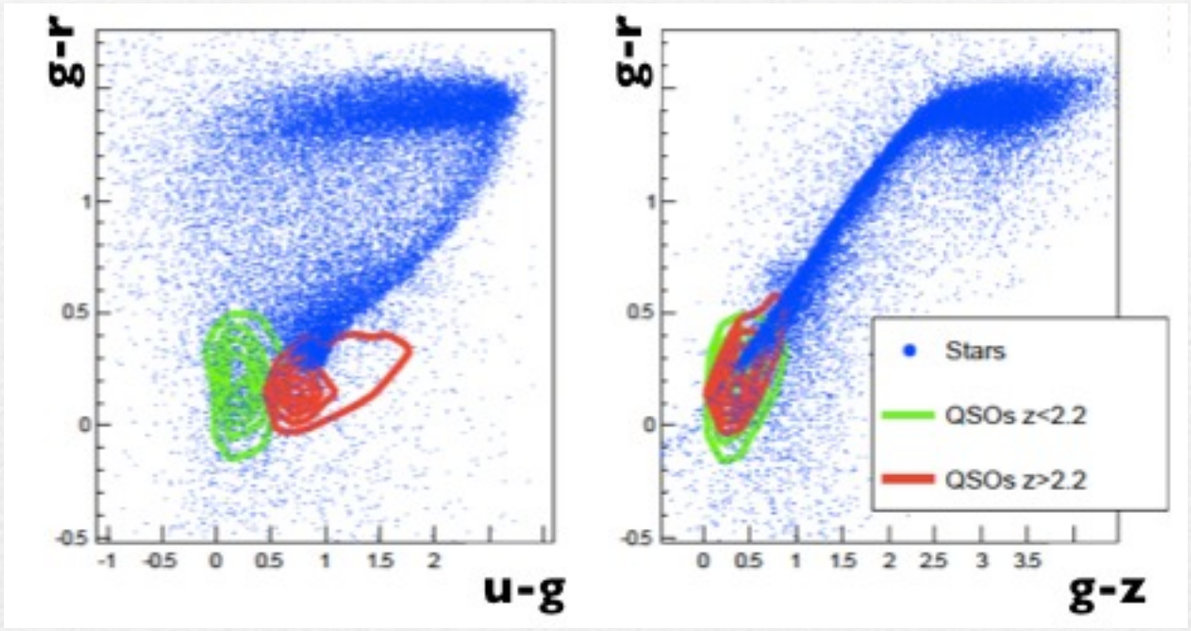
Pan-STARRS

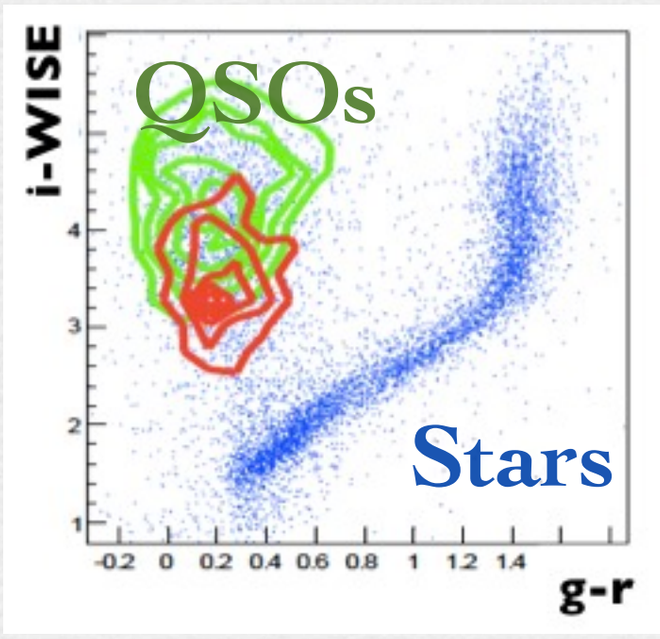
DES



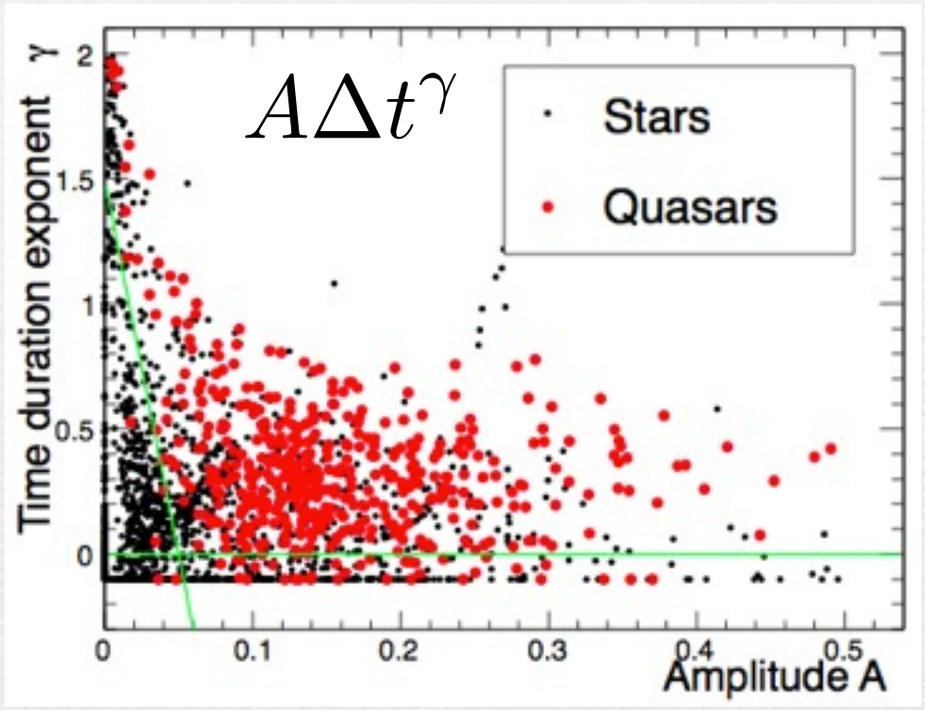
# Selecting Quasars

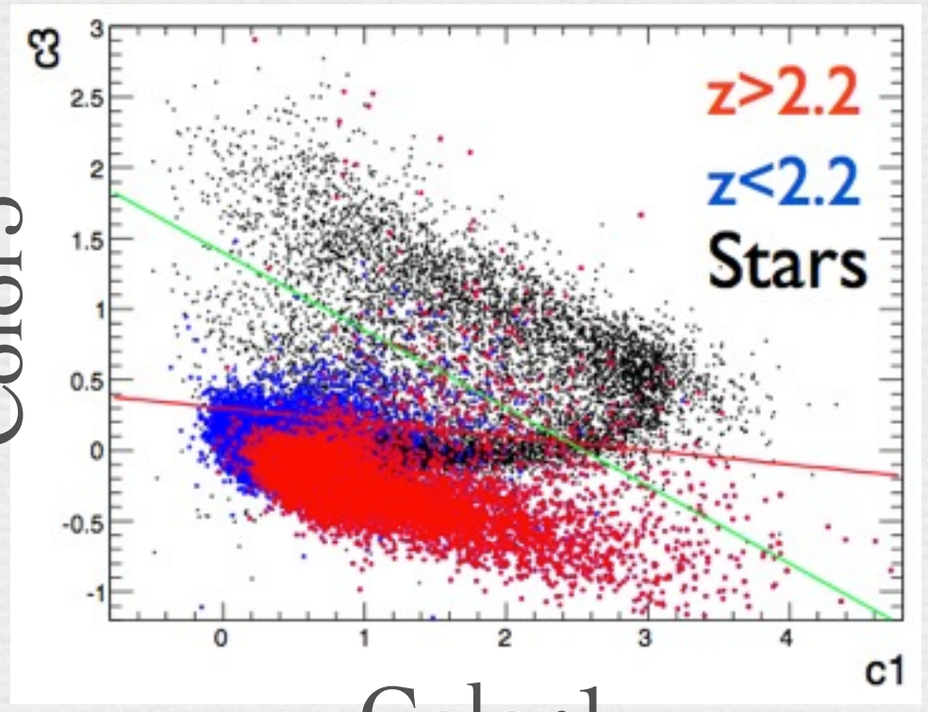
- Extreme deconvolution XDQSOz (Bovy et al 2011, 2012)
  $P_{QSO}(z > 0.9) > 0.2$
- WISE 3.4 and 5.6 μm bands improve selection
- Requirement 90 deg$^{-2}$ at 0.9 < z < 2.2 for clustering
- 1.8% on BAO



# Selecting Lyα Quasars

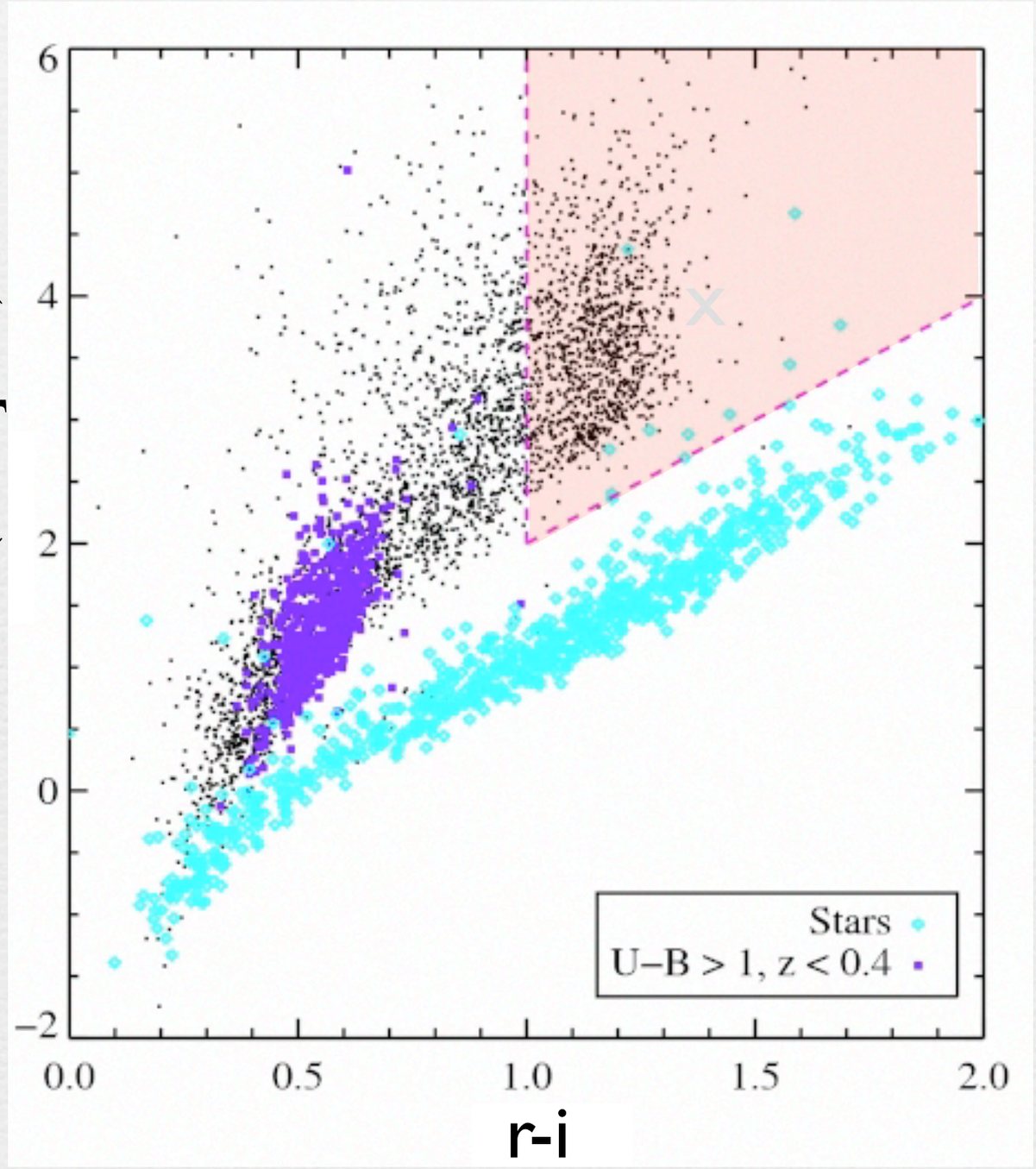


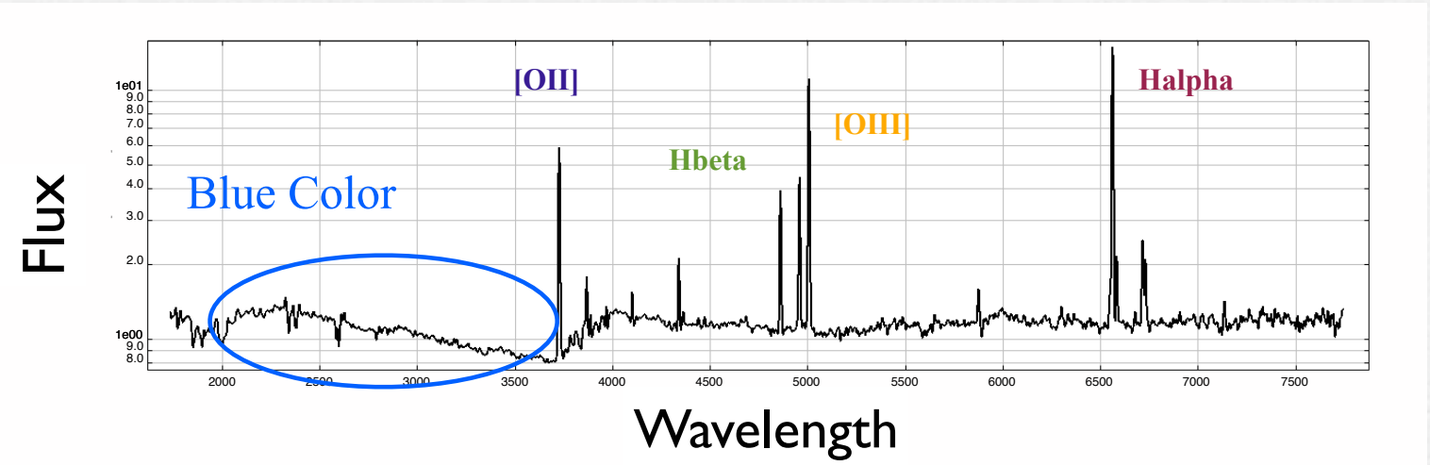

- Intrinsic **variability** of quasars observed with PTF and Pan-STARRS over years
- 20 deg$^{-2}$ additional quasar targets for Lyα-forest (z>2.1)
- 1.4% on BAO
  (including BOSS forests)

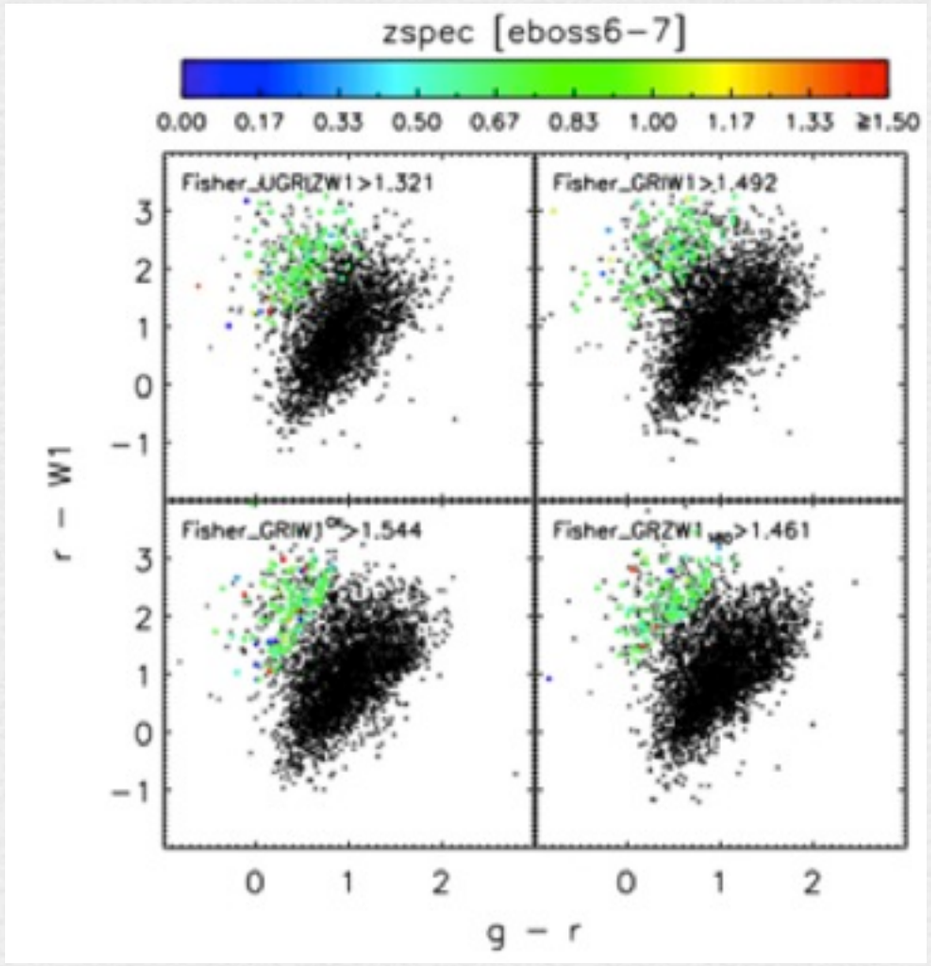
# Selecting LRGs

- Bolometric SED of LRGs peaks at 1.5μm
- LRGs at z ~ 1 are brighter in IR than in optical compared to stars
- Requirement of 40 LRGs/ deg$^2$ at $0.6 < z < 0.9$
- 1.0% on BAO
  (including fraction of BOSS CMASS)



# Selecting ELGs



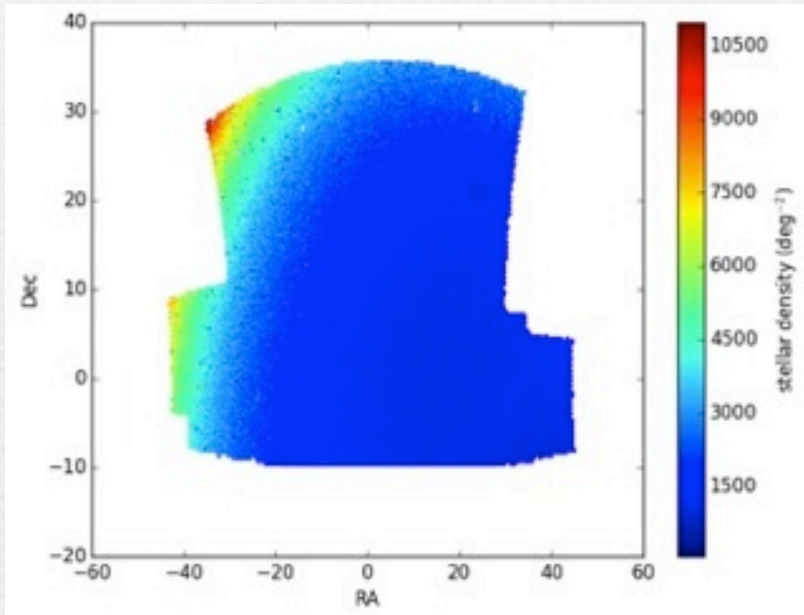




- Star formation rate is higher at $z \sim 1$, so galaxies are bluer and contain strong emission lines
- SCUSS U-band + WISE improves the selection (Raichoor et al 2015)
- Deeper photometry from DES in some regions
- Requirement of 190 000 ELGs at 0.7<z<1.1
- 2.0% on BAO

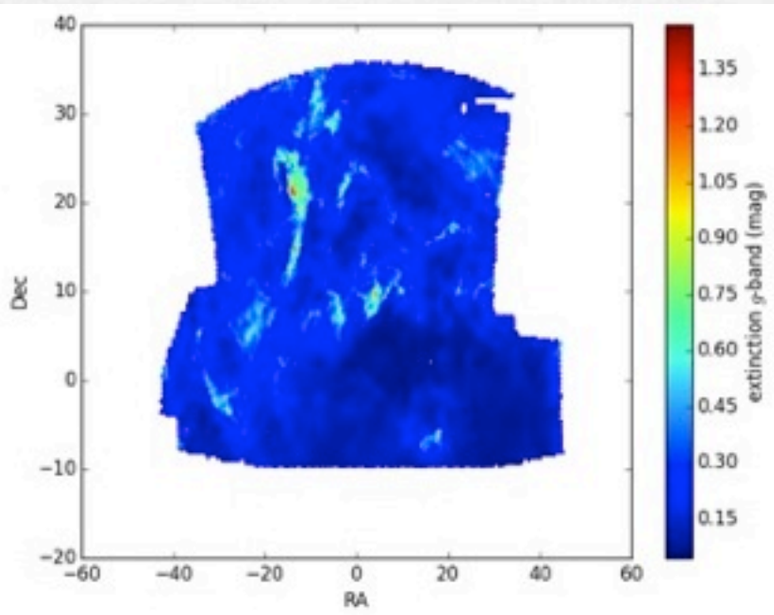
# Common requirements

Less than 15% tracer density fluctuations
over footprint to avoid systematics (Ross et al. 2012b)

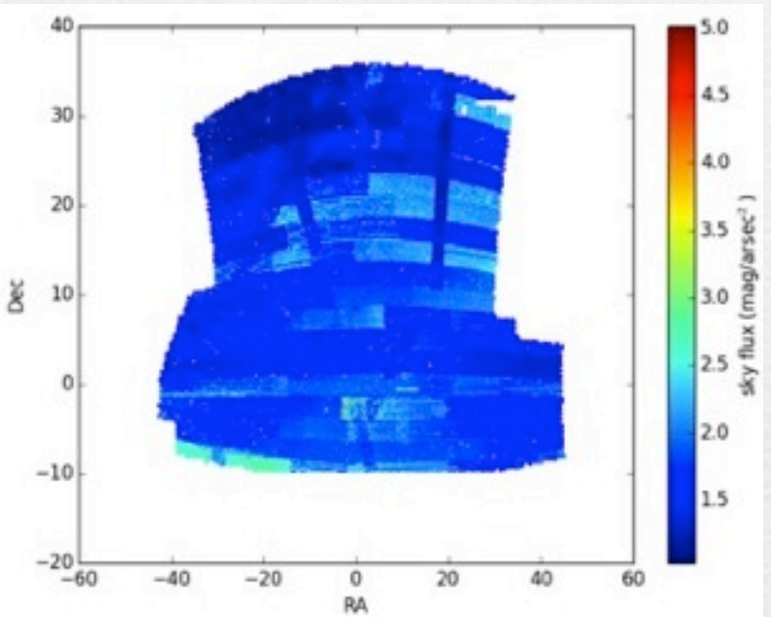
**Stellar density**



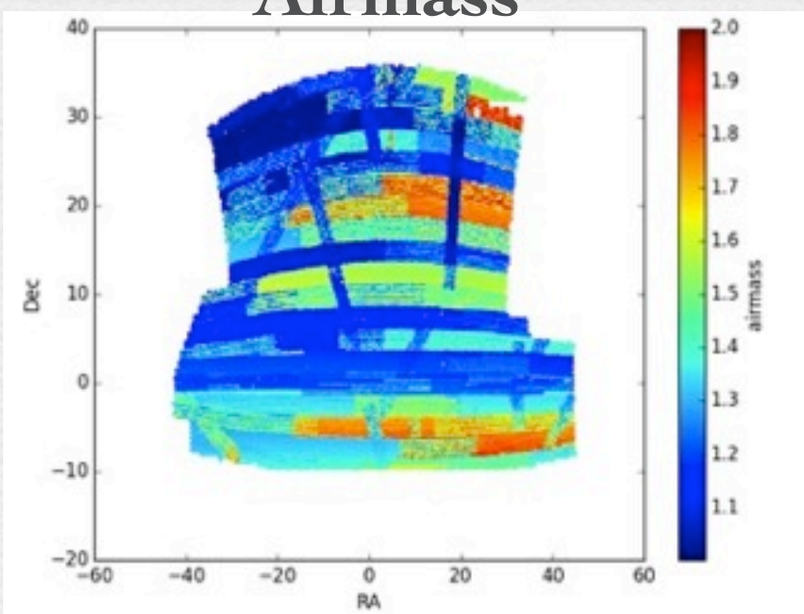

**Galactic Dust**



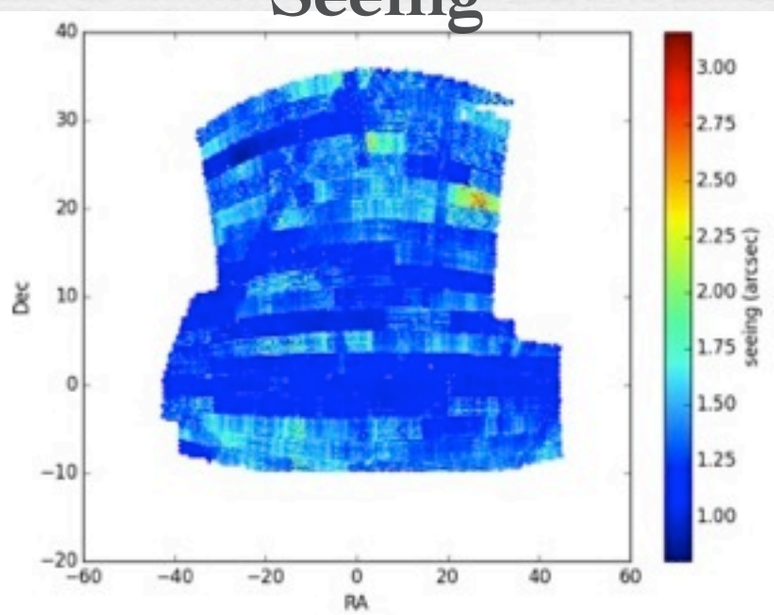

**Sky flux**



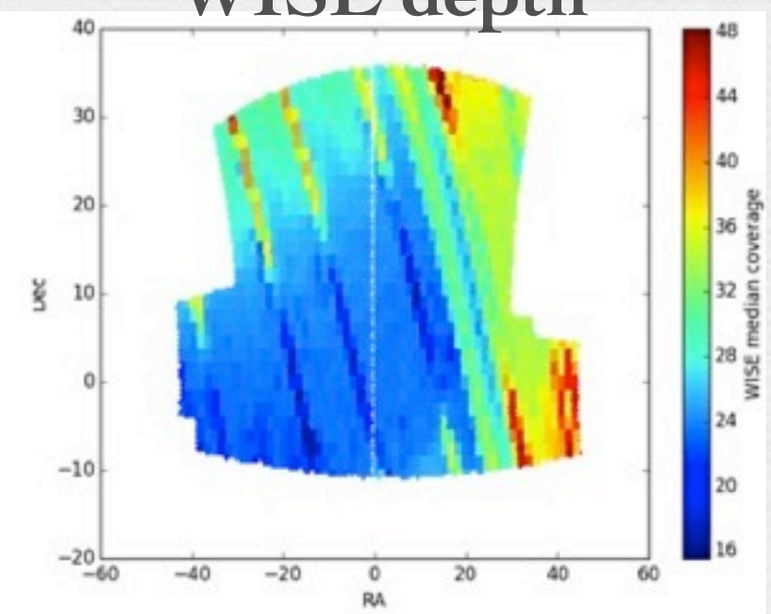

**Airmass**




**Seeing**




**WISE depth**

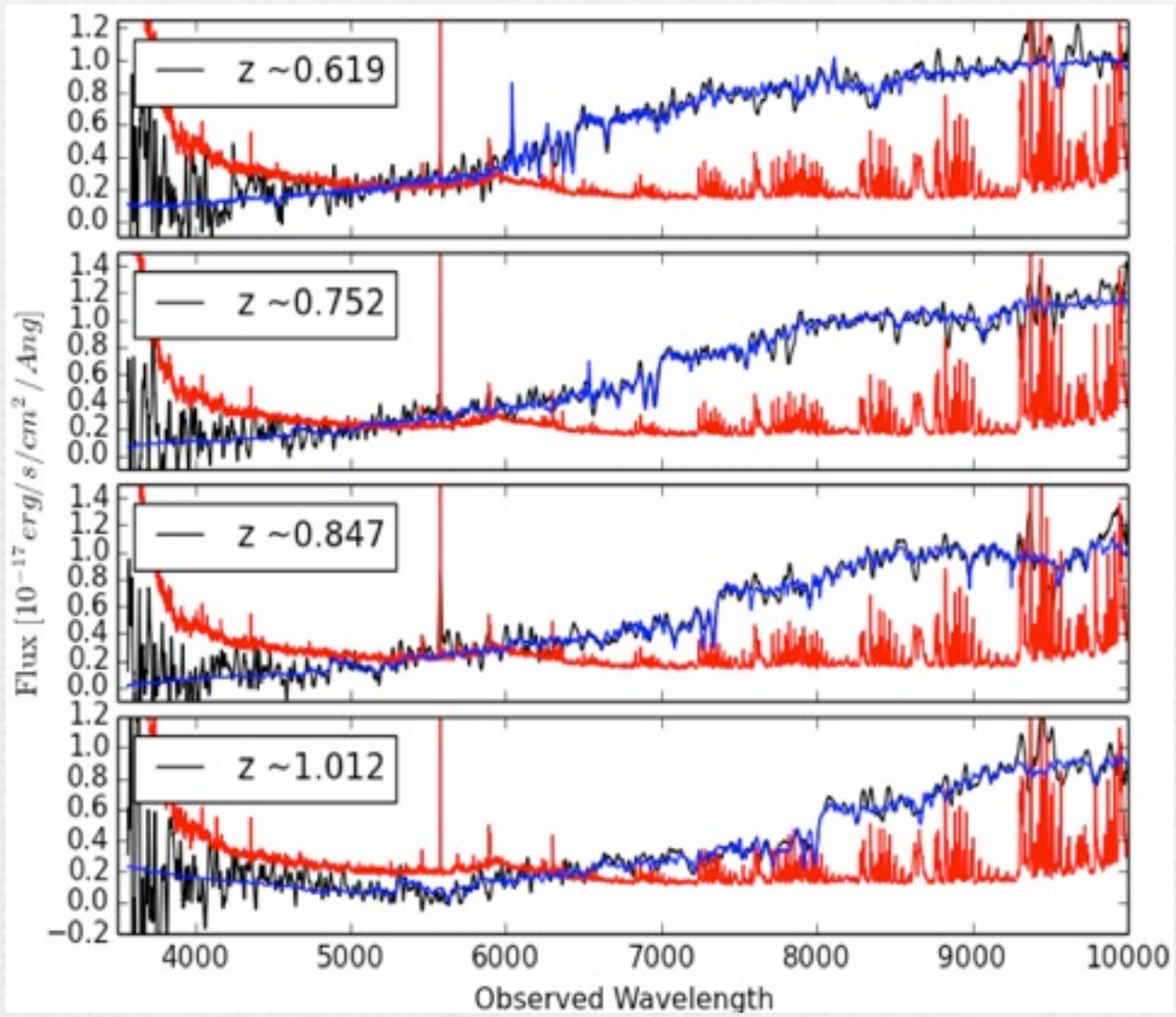


# Common requirements

**Get accurate and precise redshifts!**

- Redshift estimate accuracy < 300 km/s
- Less than 1% of catastrophic redshifts
- Targeting efficiency depends on type of tracer

LRG spectra



# A pilot survey

## SEQUELS

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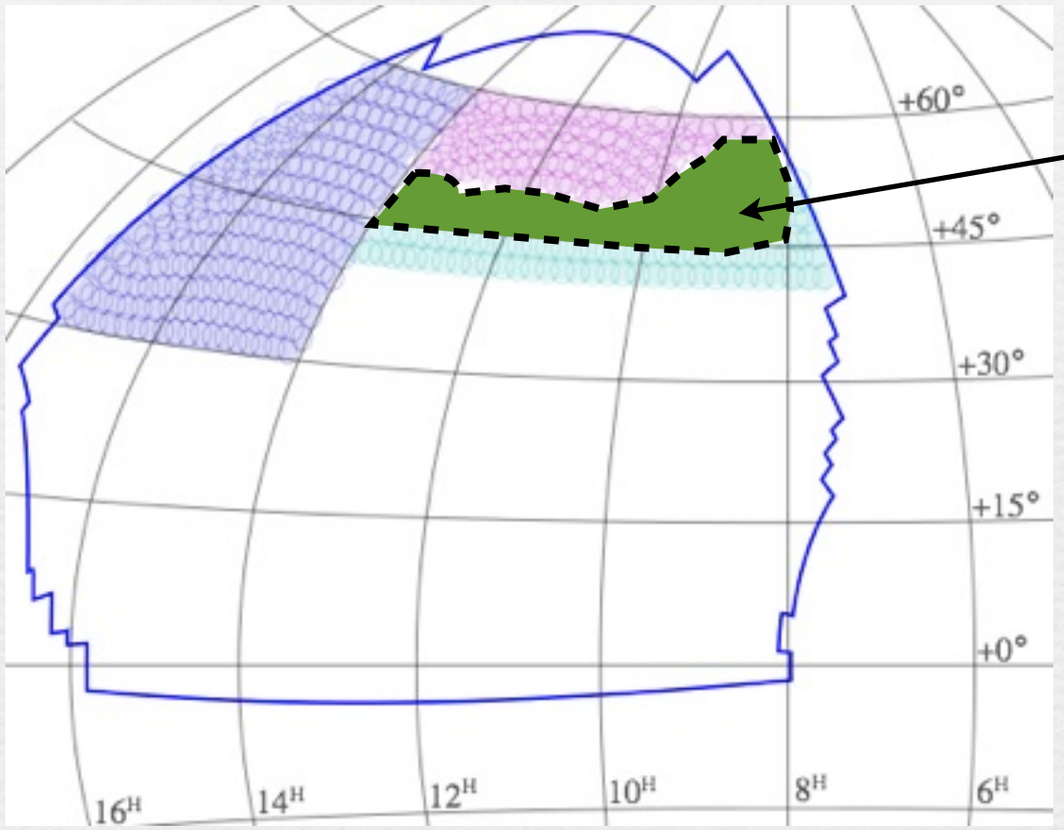
## Sloan Extended Quasar, ELG and LRG Survey




- 466 deg$^2$ of the footprint
- Tests of target selection algorithms
- Efficiency of automatic redshift estimates

Half of this data is public at **sdss.org**
The other half will be public in July 2016

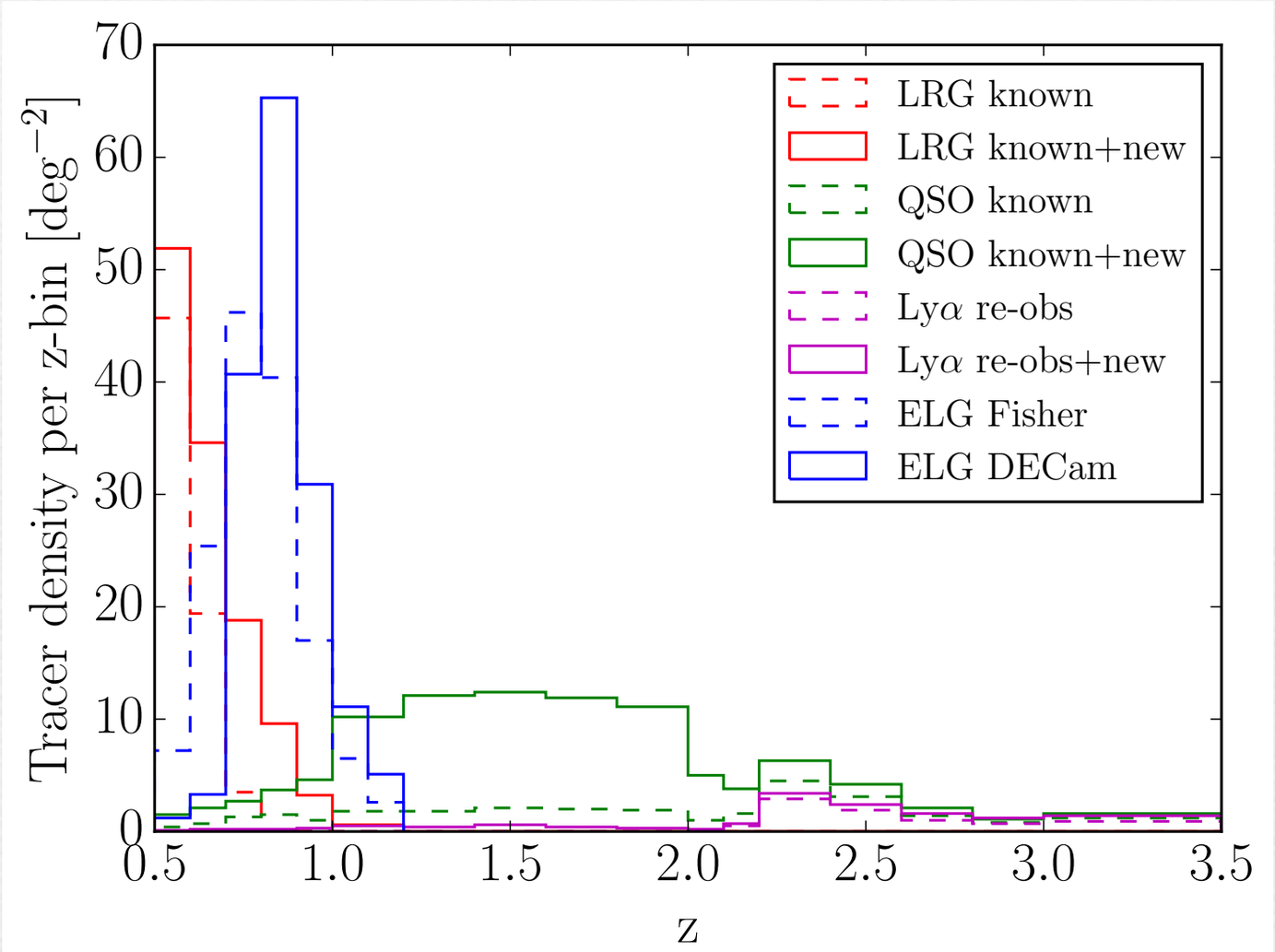
# Redshift distribution

## Targeting Efficiency

QSOs: 71% (clustering)
16% (new Lyα forest)

LRGs: 68-72%

ELGs: 71-78% (depending on selection algorithm)

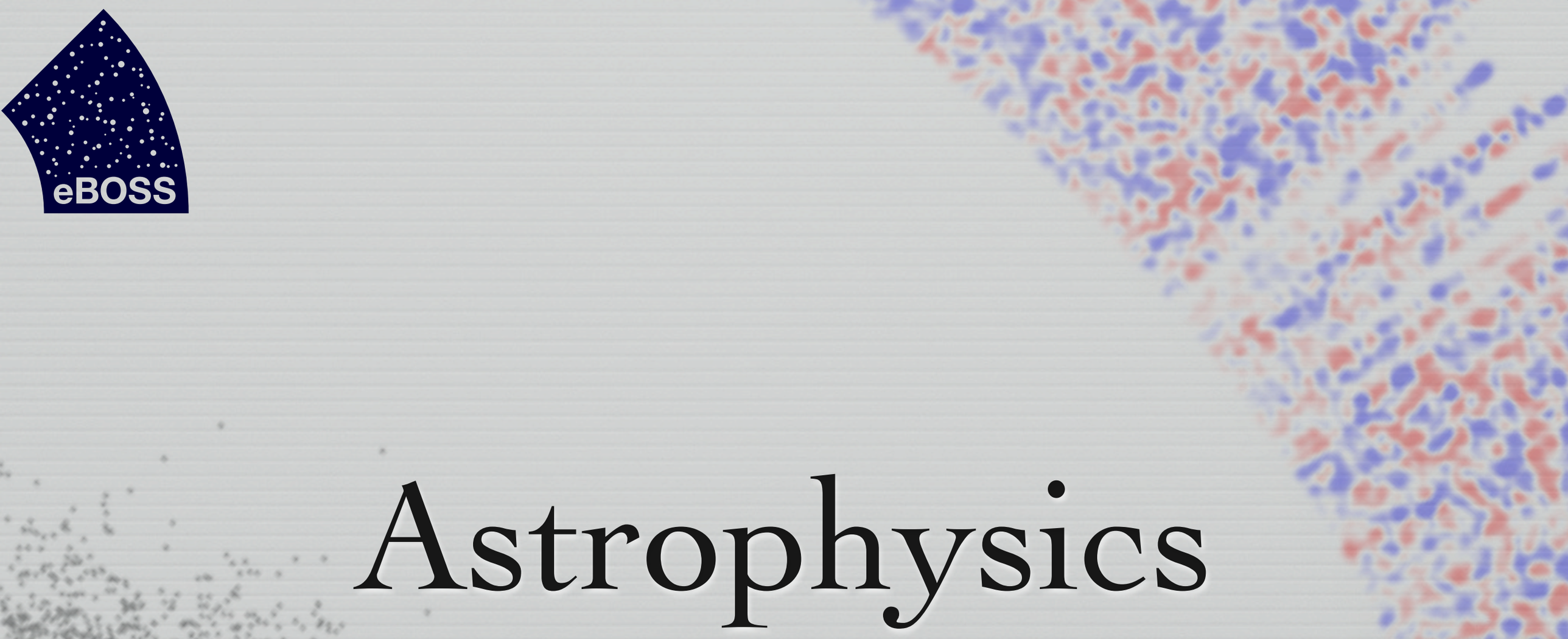



All* tracers are satisfying BAO requirements!

*LRGs need some BOSS galaxies


# Work in progress!


- Improved selection algorithms
- Robust data-reduction especially for fainter galaxies
- More confident spectral classification and redshift estimation
- And keep observing !

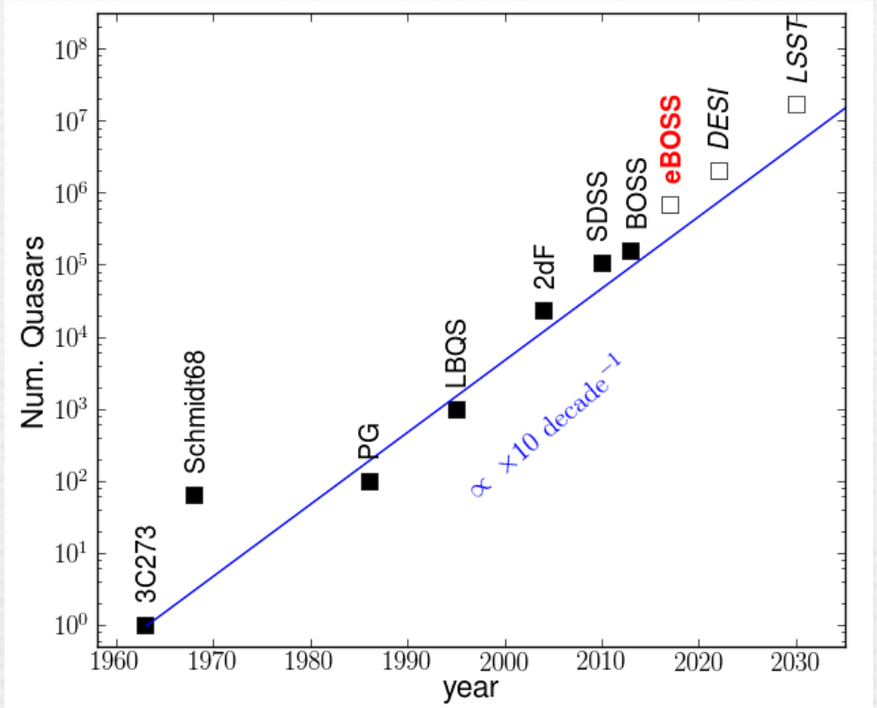


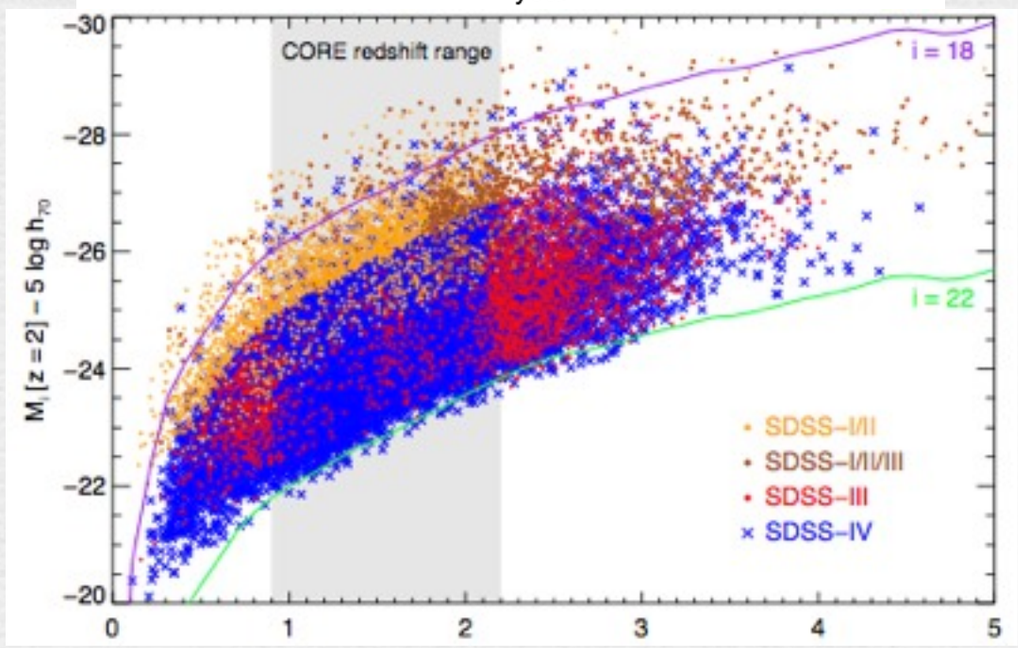

# Astrophysics

# Quasars

eBOSS will be soon the largest quasar survey ever

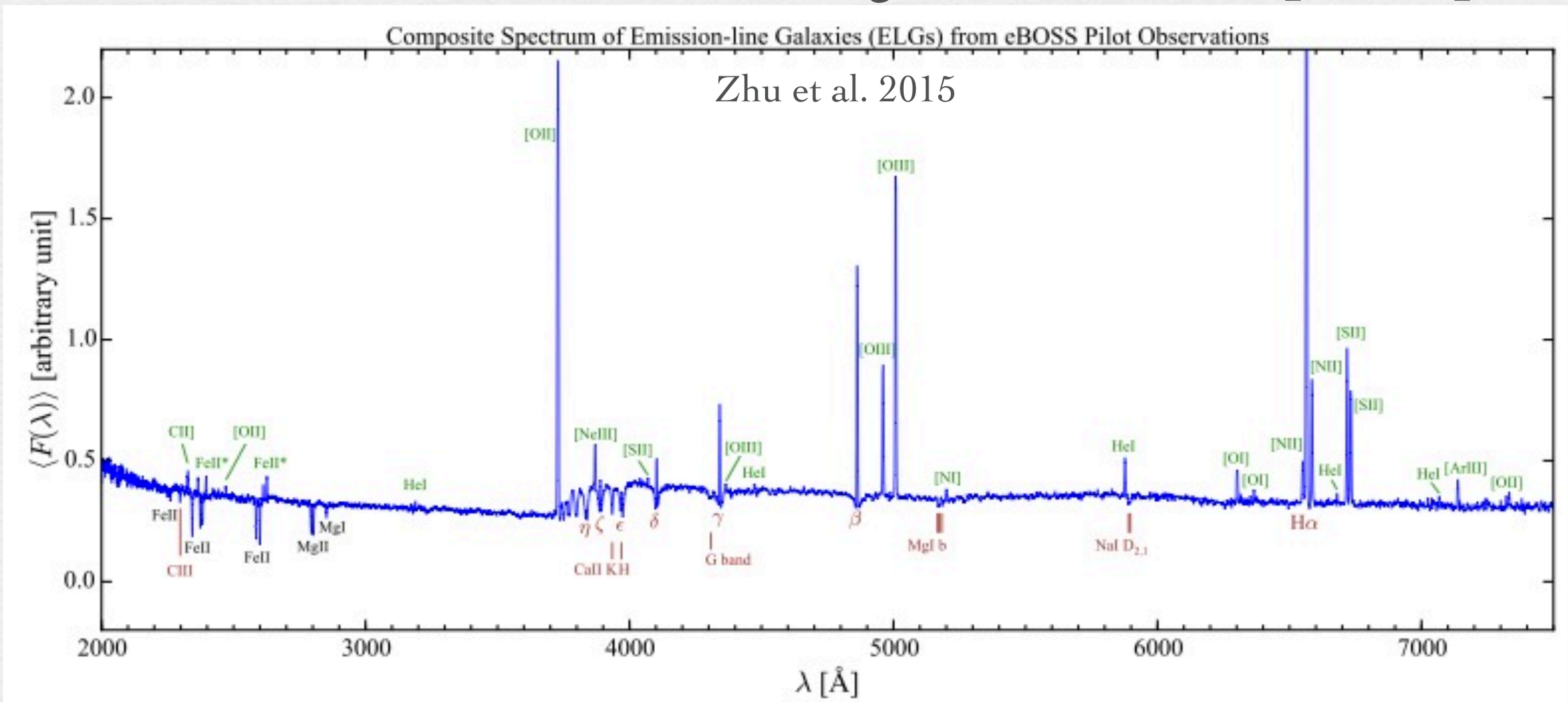
- Quasar luminosity function for fainter quasars
- Bias and halo occupation
- Black-hole mass estimates
- Composite spectra and modelling
- Metal absorbers in the IGM



# Galaxies

- Small-scale clustering and halo properties
- Cross-correlations with Lyα forest or CMB
- Gas and metal distribution around galaxies
- Strong lensing
- Cluster of galaxies
- Composite spectra



# Conclusions

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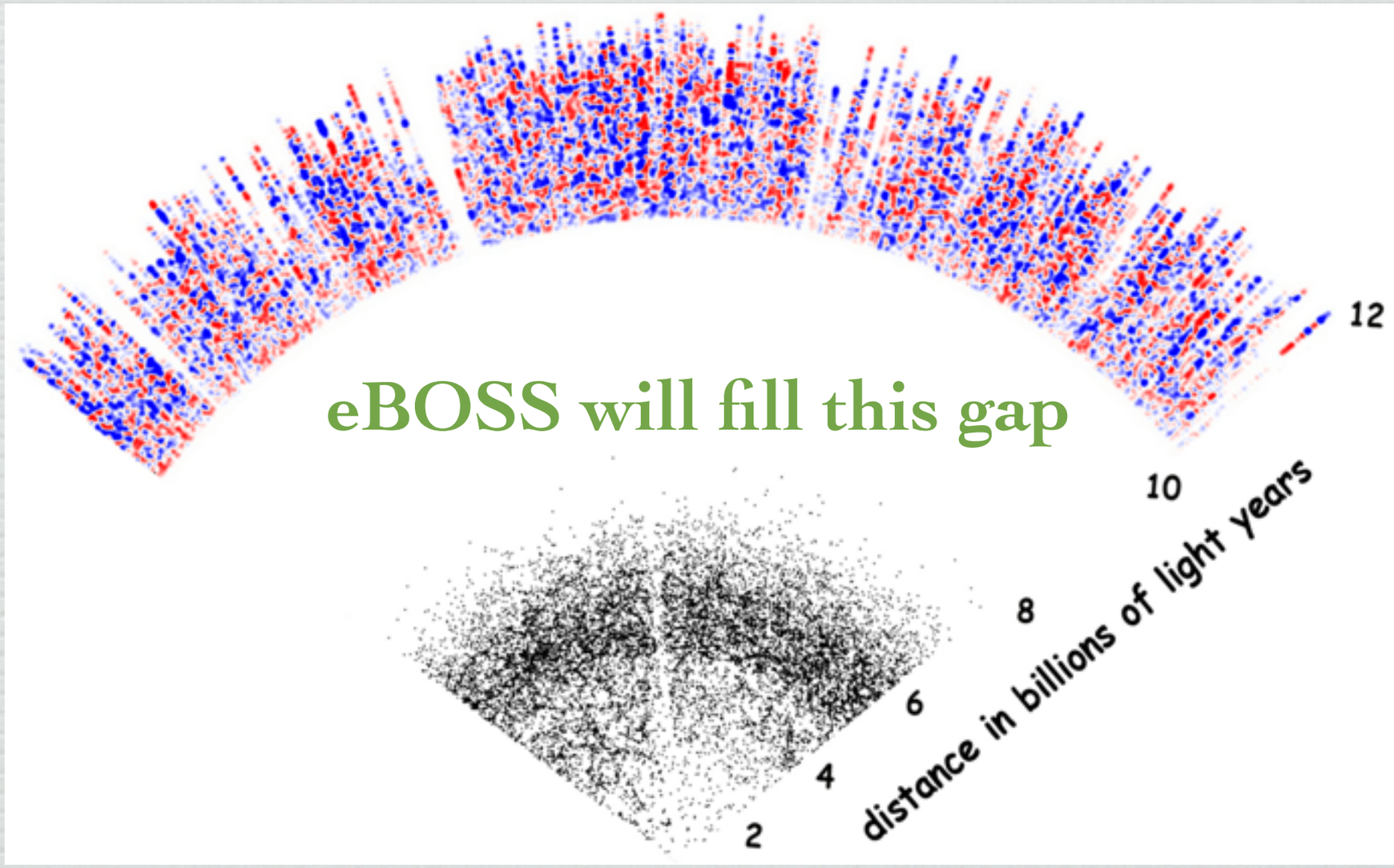
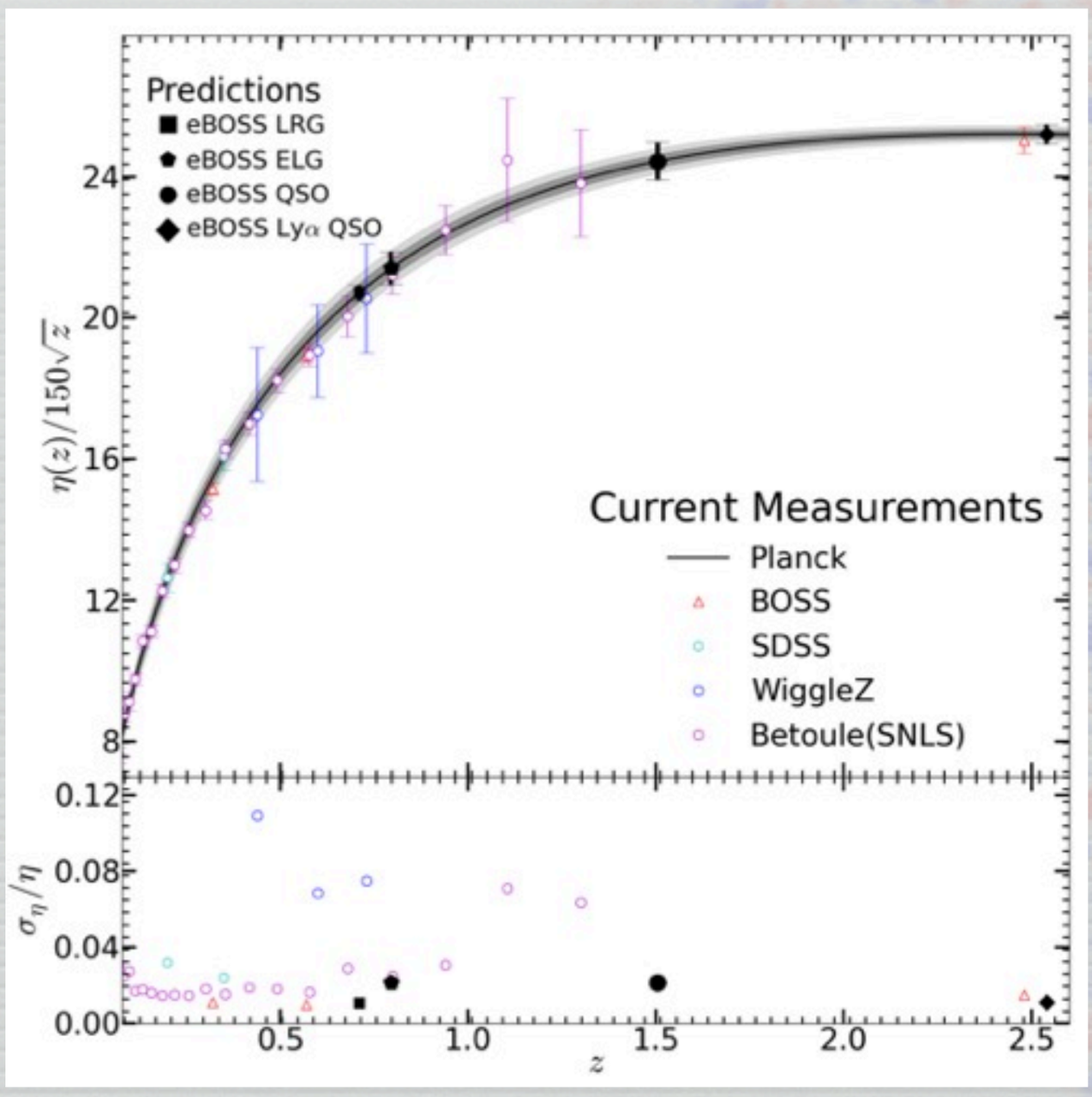


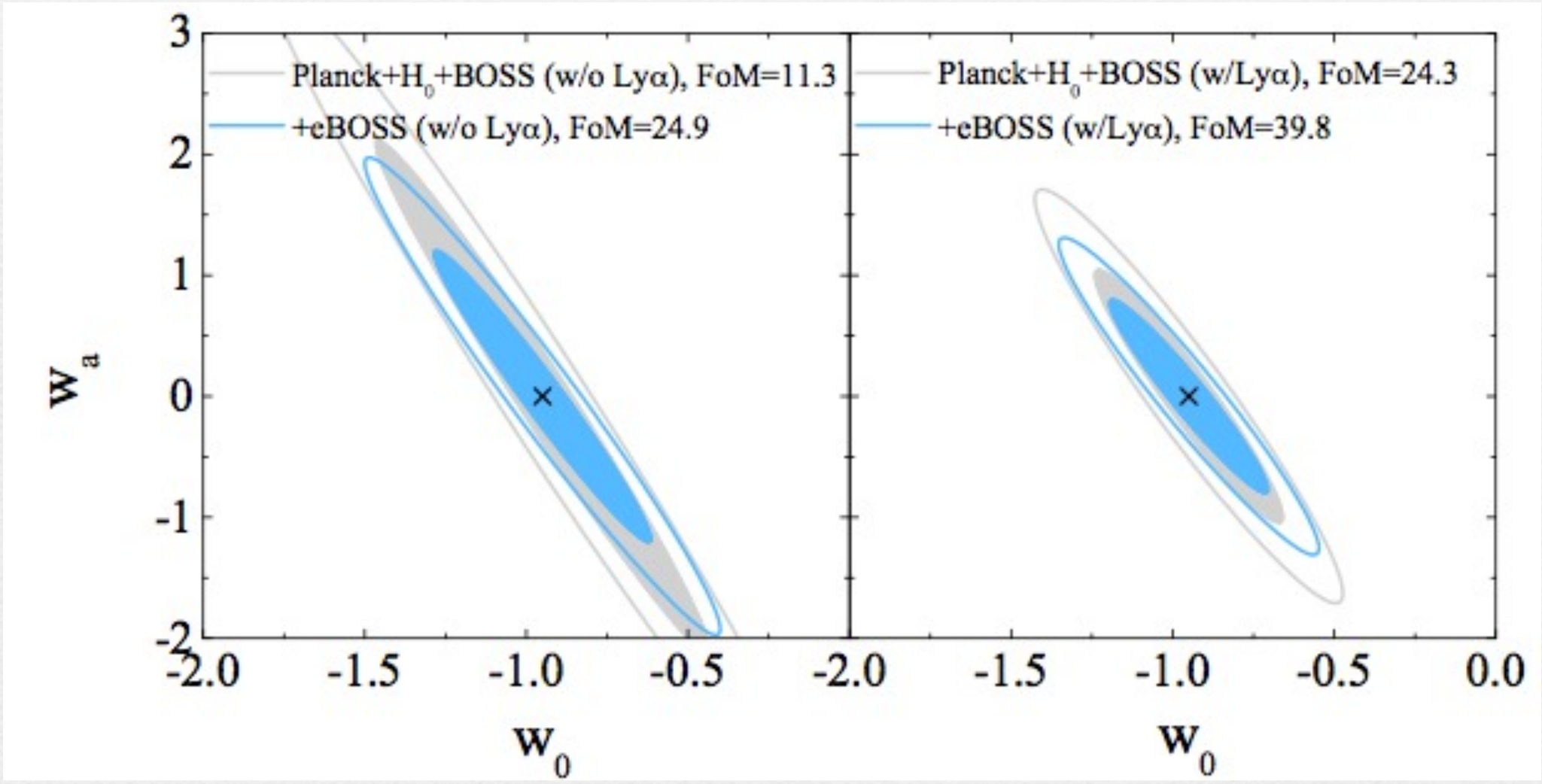
# Conclusions

- eBOSS first year is done!
- Pilot survey show targeting algorithms and data reductions are performing well
- First clustering measurements and data release next summer
- BAO forecasts for 6 years: **1.8% (QSO)**, **1.4%(Lyα)**, **0.8% (LRGs)** and **2.0% (ELGs)**
- An enormous potential for new discoveries in astrophysics of quasars and galaxies



Thank you

# Dark energy


Planck+H0+BOSS (w/o Lyα), FoM=11.3
+eBOSS (w/o Lyα), FoM=24.9
Planck+H0+BOSS (w/Lyα), FoM=24.3
+eBOSS (w/Lyα), FoM=39.8
wa
w0
w0
3
2
1
0
-1
-2
-2.0
-1.5
-1.0
-0.5
-2.0
-1.5
-1.0
-0.5
0.0

# Other forecasts

| Parameter | Constraint from CMB | Constraint from BOSS and CMB | Constraint from BOSS, eBOSS, and CMB |
|---|---|---|---|
| $\Omega_M h^2$ | 0.008 | 0.0028 | 0.0017 |
| $w_0$ | 0.52 | 0.17 | 0.15 |
| $w_a$ | 1.4 | 0.67 | 0.48 |
| $\gamma$ | 30. | 0.13 | 0.10 |
| $\sum m_\nu$ | 0.81 eV | 0.29 eV | 0.16 eV |
| $n_s$ | 0.0045 | 0.0026 | 0.0022 |

# Some eBOSS spectra