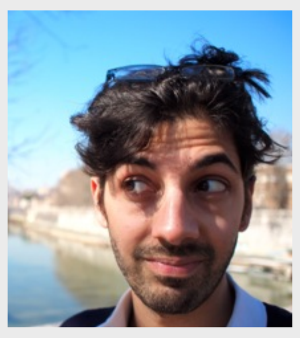
# Study of the dark energy with BAOs in eBOSS and LSST



**A. Raichoor**

raichoor@lal.in2p3.fr

**Supervisors:** Ch. Yèche & R. Ansari

# Abstract

Baryon Acoustic Oscillations (BAOs), one of the probes to constrain dark energy, are key in current (SDSS/eBOSS) and future large cosmological experiments (DESI, Euclid, LSST).
Our work is to provide a galaxy target sample at a redshift ~0.8 for the SDSS/eBOSS experiment. We demonstrate the we can provide a target sample fulfilling the requirements.
We have now started an analysis of the 2D-correlation for such a target sample to detect a possible BAO signal; this last part is completed with a theoretical analysis.

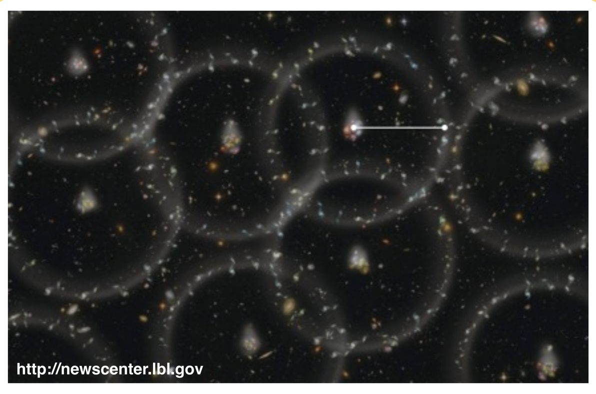
# 1. Dark energy and BAOs

• **Dark energy**
▸ 70% of the energy of the Universe; main goal of future large cosmological experiments (DESI, Euclid, LSST).

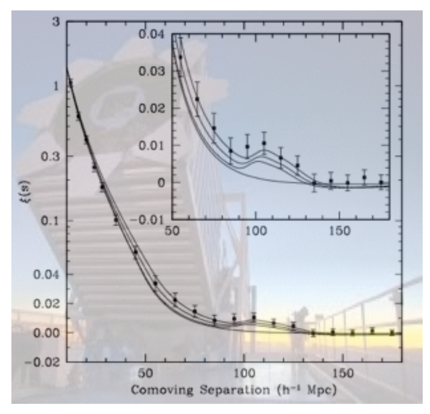
• **BAOs (Baryon Acoustic Oscillations)**
▸ « standard ruler » to constrain dark energy;
▸ measured through 2D- or 3D-correlation function of a large number of galaxies, at a given redshift.

### Complementary information

• **BAOs**:
▸ due to the acoustic waves propagating in the Universe before the light-matter decoupling;
▸ observable as a statistical overdensity of galaxies separated by a given distance;
▸ 3D-correlation function (R.A., DEC., zspec): one pre-selects through imaging a sample, which will be observed spectroscopically to obtain the precise redshift (zspec); this method provides an accurate correlation function, but requires a large amount of spectroscopical observations; it is the approach of the SDSS/eBOSS and DESI experiments;
▸ 2D-correlation function (R.A., DEC.): one selects through imaging a sample of galaxies in a narrow redshift range; for instance this can be done with photometric redshifts (zphot). This method provides a less accurate correlation function, but is less costly in observing time; it is the approach of the LSST experiment.




**Artist's view of the BAO** : the clustering is greatly exaggerated in this illustration. The radius of the spheres (white line) is the scale of a « standard ruler ».



**First measurement of the BAO signal**, obtained by the SDSS collaboration (z~0.3, Eisenstein et al. 2005)

# 2. SDSS/eBOSS ELG target selection at z~0.8

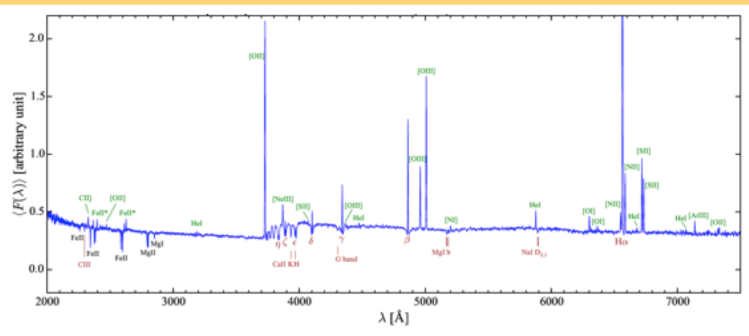
• **ELGs in eBOSS/SDSS (2014-2020)**
▸ 190,000 Emission Line Galaxies (ELGs) to measure the BAOs at z~0.8;
▸ ELG program: start in 2016, September; challenging: first time that this tracer is used;
▸ ELG target sample requirements: density>180 deg$^2$, median(redshift)>0.7, efficiency>70%;
▸ our goal: provide the sample of the ELGs which will be observed
▸ we provide two options, the final choice being made at the SDSS meeting at the end of 2016, June.

• **Option #1: ELG selection with SDSS+WISE (Raichoor et al., A&A 585, A50 (2016))**
▸ imaging: SDSS (ugriz-bands, $r_{AB}$~22.5 mag, 10,000 deg$^2$) and WISE (near-infrared satellite);
▸ selection method: Fisher discriminant;
▸ selection results: density=180/deg$^2$, median(redshift)=0.76, efficiency=71%.

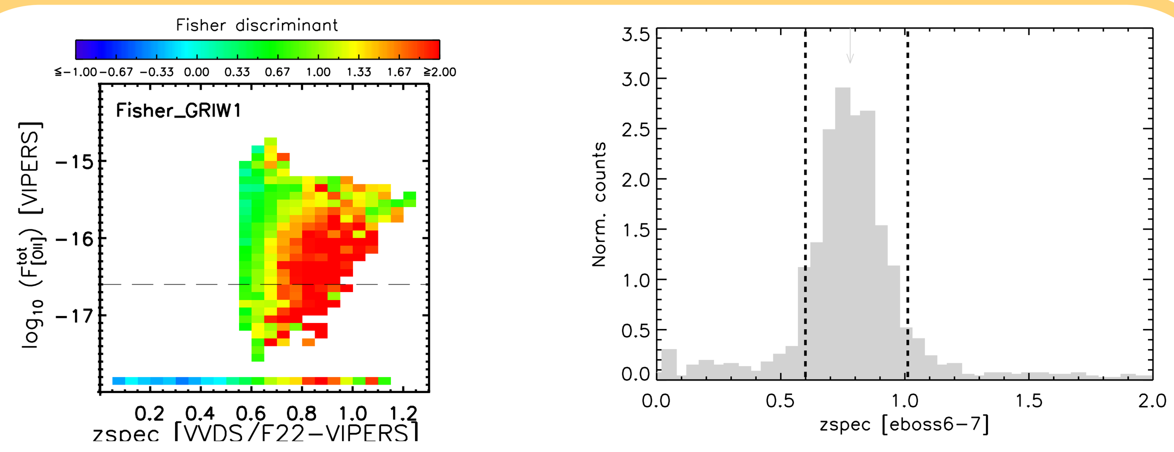
• **Option #2: ELG selection with DECaLS**
▸ imaging: DECaLS (grz-bands, $r_{AB}$~23.9 mag, 6,700 deg$^2$);
▸ selection method: box in the (g-r) vs. (r-z) color-color diagram;
▸ selection results: density=190/deg$^2$, median(redshift)=0.85, efficiency>70%.

### Complementary information

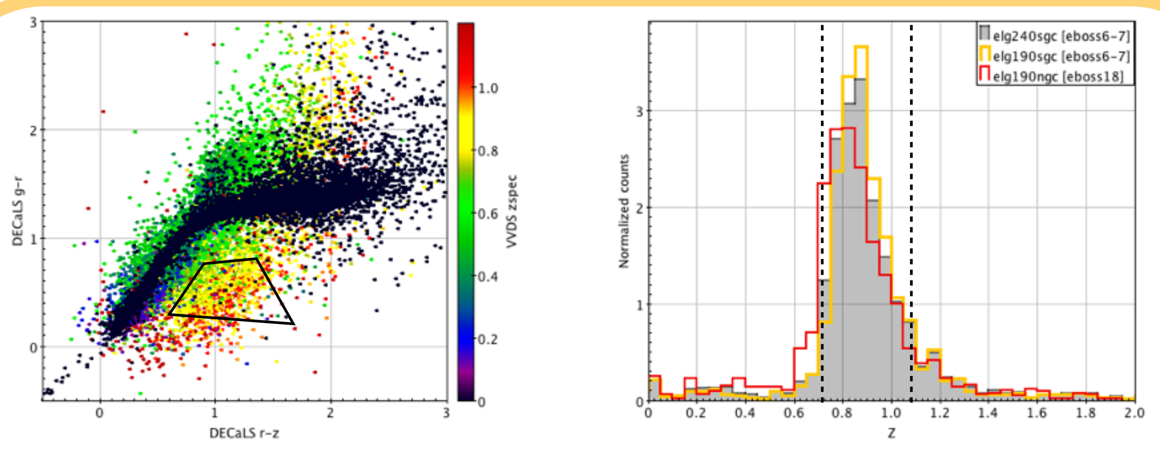
• **eBOSS/SDSS (2014-2020):**
▸ BAOs at a percent level over 0.6<z<2.2 with ~1e6 spectra at the 2.5-meter SDSS telescope; four different tracers, each one dedicated to a redshift range;
▸ ELGs: those star-forming galaxies have emission lines in their spectra, which allows one to measure the redshift with a reasonable exposure time (1h);
▸ target selection efficiency definition: percentage of the sample having a secure redshift with 0.6<z<1.0 or 0.7<z<1.1.
• **ELG selection with SDSS+WISE (Raichoor et al., A&A 585, A50 (2016))**
▸ the SDSS imaging is rather shallow for z~0.8 objects: we developed a specific method, using a training algorithm based on the galaxy colors to define a quantity, the Fisher discriminant, which correlates best with redshift and star-formation ([OII] flux).
• **ELG selection with DECaLS**
▸ DECaLS: one magnitude deeper than the SDSS; will be used for the DESI target selection;
▸ challenge: the DECaLS survey is on-going, which means that the data and the reduction pipelines are still evolving;
▸ thanks to the deeper photometry, we can select our targets with a simple cut in the (g-r) vs. (r-z) color-color diagram;
▸ we can increase — on about half of the footprint — the density (e.g., 240/deg$^2$) with marginally degrading the properties (<z> and efficiency).



**Composite ELG spectrum** built from ~1e4 individual spectra. The emission lines (noticely [OII] at 3727 Angstroms) allow us to measure the redshift of the galaxy in ~1h of exposure time (Zhu et al. 2015)




**Option #1 (SDSS+WISE)**: we built the Fisher discriminant, which correlates with redshift and [OII] flux (left). Applying a cut on this quantity allows us to obtain a selection with 71% of it having 0.6<zspec<1.0 (right).



**Option #2 (DECaLS)**: we select the sample with a simple box in the grz-diagram (left); the obtained selection has better properties (higher redshift & efficiency) than with option #1 (right).

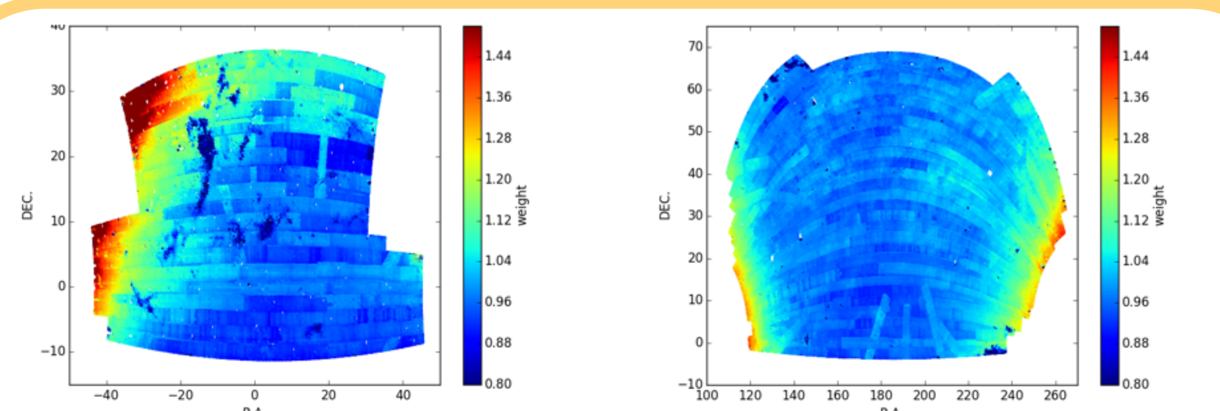
# 3. BAO at z~0.8 with 2D-correlation?

• **Aim**
▸ BAO signal in the 2D-correlation function for option #1 over the whole SDSS footprint (10,000 deg$^2$, 2e6 objects);
▸ would constitute the first BAO measurement at z~0.75.

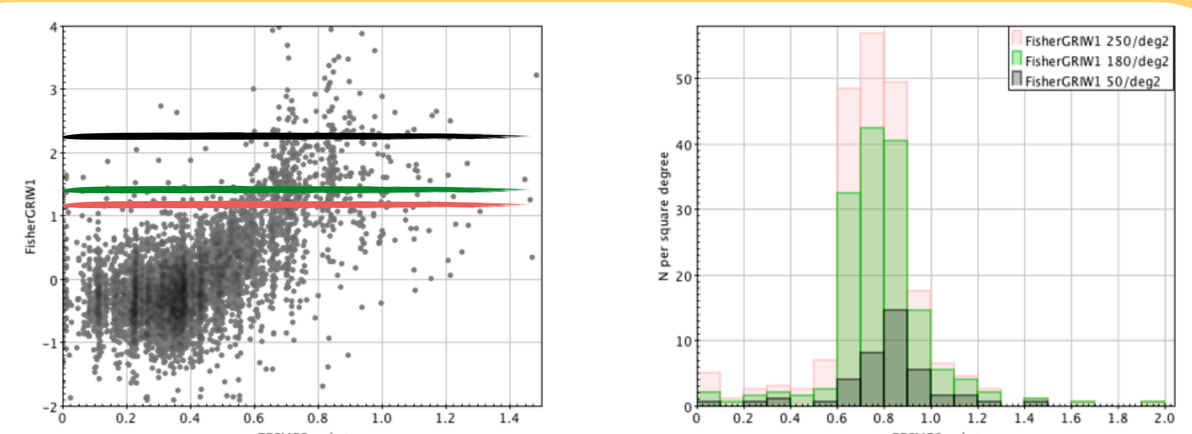
• **Method**
▸ data:
▸ estimate weights to correct the dependency of our sample selection on observational (airmass, seeing) and external (Galactic extinction, stellar density) parameters;
▸ compute the 2D-correlation function with applying those weights.
▸ theoretical side:
▸ develop tool to analytically estimate the 2D-correlation function from a given redshift distribution (J.Neveu @LAL);
▸ once this tool is set up, we will be able to see if we can adjust our selection to enhance the significance of the BAO signal; actually, our selection method based on the Fisher discriminant offers some flexibility on the object density and on the redshift distribution width.

### Complementary information

• **Aim**
▸ even if, the BAO signal is reduced by the width of the redshift distribution of our selection, it has already been observed at lower redshift with photometric selections having width of the same order; this work is in progress;
▸ this work is also preparatory for the LSST, as this experiment will measure the BAO signal using the 2D-correlation function.



**Weight maps**: allow to correct for the dependency of our selection on observational and external parameters.



**Tuning the selection**: our selection is based on a cut on the Fisher discriminant, which correlates with redshift (left); we can modify the selection by adjusting this cut (right).