Mapping and simulating the large scale structure of the universe with galaxies

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LA PLATA WORKSHOP, ARGENTINA SEPT. 2016

Challenges in cosmology

THEORY

Successful concordance Lambda CDM model lead to the puzzle of gravity:

- "How does gravity work on large scales, i.e. larger than the solar system"

The model, via N-body simulations, predicts the BAO to be an unbiased standard ruler to <0.5% precision

OBSERVATIONS

CMB (1965) and SN1A (1998)

Weinberg et al. 2013 reviewed the possible observations and their biases to provided data to test models against:

- CMB, BAO, SN1A, clusters, WL

BAO measurements are based on large galaxy maps

MultiDark Galaxies

Mapping the Universe

USING GALAXIES AS TRACERS OF THE MATTER FIELD

BAO measurement

redshift range	Shot Noise req. $\bar{n}(k_1)$ $\bar{n}(k_2)$ $10^{-4}h^3\mathrm{Mpc}^{-3}$		observed density req. [deg^{-2}] for k_1	for k_2	Sample variance area req. [deg^2] [1Gpc3/h3]	N_{req} [10^3 redshifts] for k_1	for k_2
[0.3, 0.6]	1.0	2.1	33	71	6188	204	440
[0.6, 0.9]	1.1	2.5	75	162	2585	194	419
[0.9, 1.2]	1.3	2.9	121	261	1615	195	421
[1.2, 1.5]	1.5	3.2	164	354	1227	201	435
[1.5, 1.8]	1.7	3.6	273	589	1041	284	613

Needs :
 - cover the largest volume with the minimum number of accurate redshifts (<300km/s) to overcome shot noise
 - <1% catastrophic redshifts (>1000 km/s) to avoid biases in the 2PCF estimation

Comparat et al. 2013

SDSS-IV eBOSS survey

eBOSS will precisely measure the expansion history of the Universe throughout eighty percent of cosmic history, back to when the Universe was less than three billion years old, and improve constraints on the nature of dark energy.
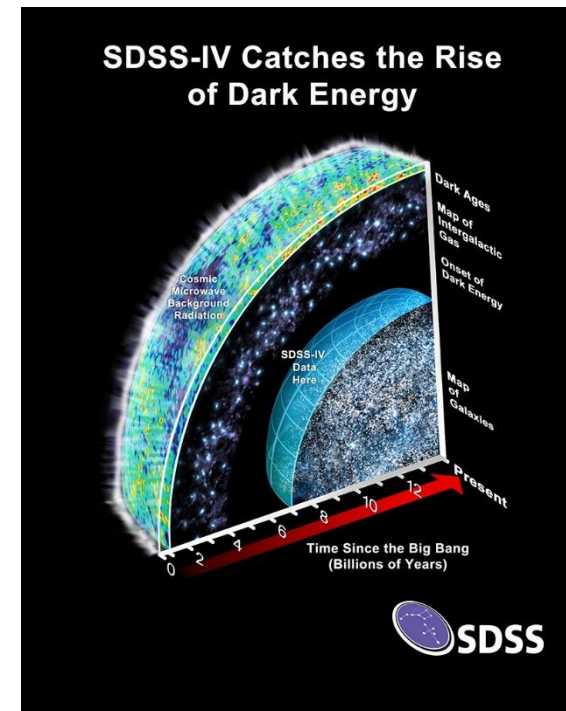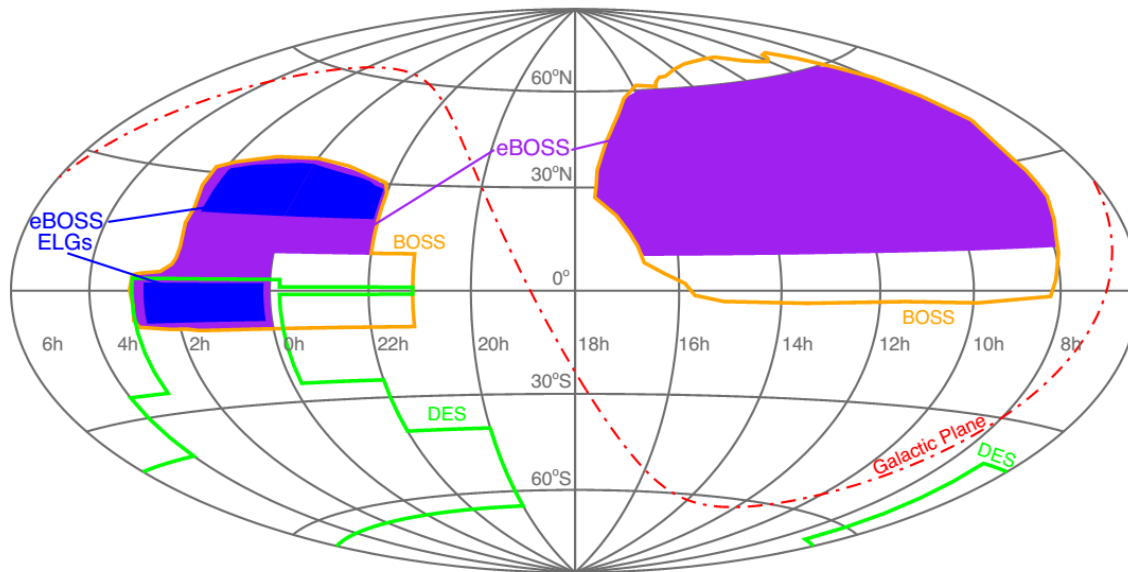
www.sdss.org/surveys/eboss

SDSS-IV eBOSS survey
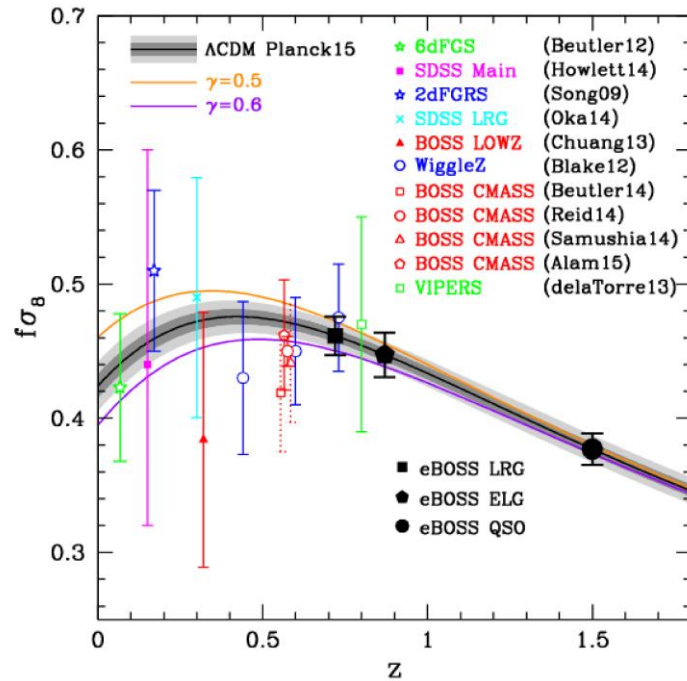

Zhao et al. 2016, Dawson et al. 2015, Ilbert et al. 2013
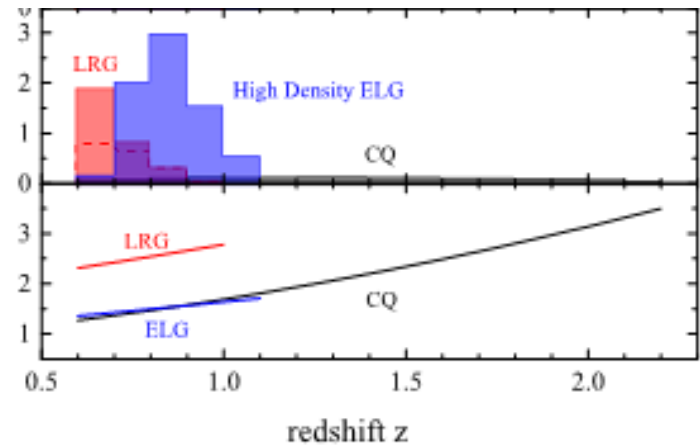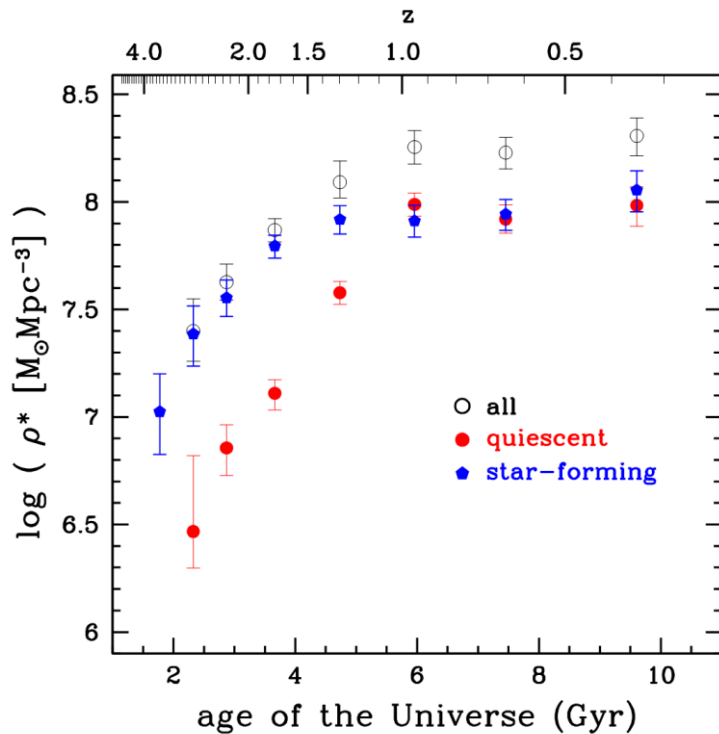
250k LRG at z=0.72 : dA at 1% and H at 2%

500k QSO at z=1.5 : dA at 3% and H at 4%

200k ELG at z=0.87 : dA at 3% and H at 5%
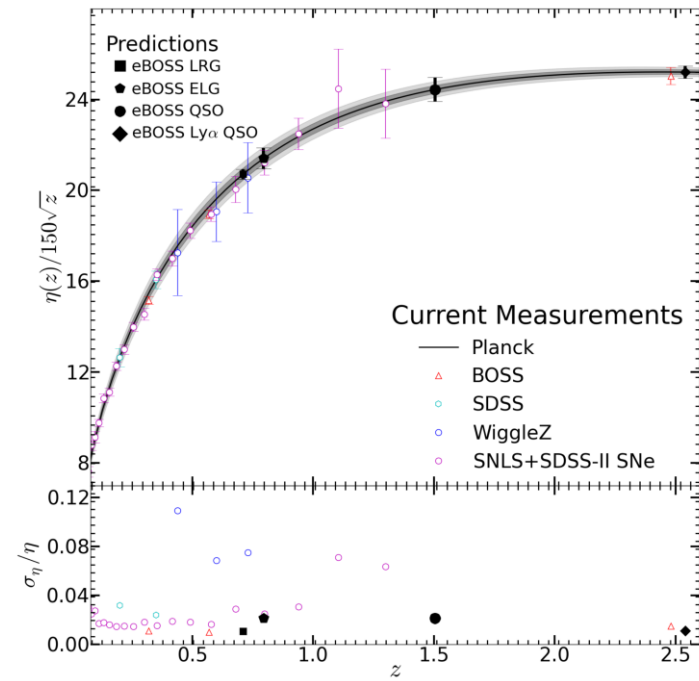
40% enhancement of Ly alpha forest relatively to BOSS

Cosmology with eBOSS

RSD

BAO

Dawson et al. 2015

Challenge: mocks !

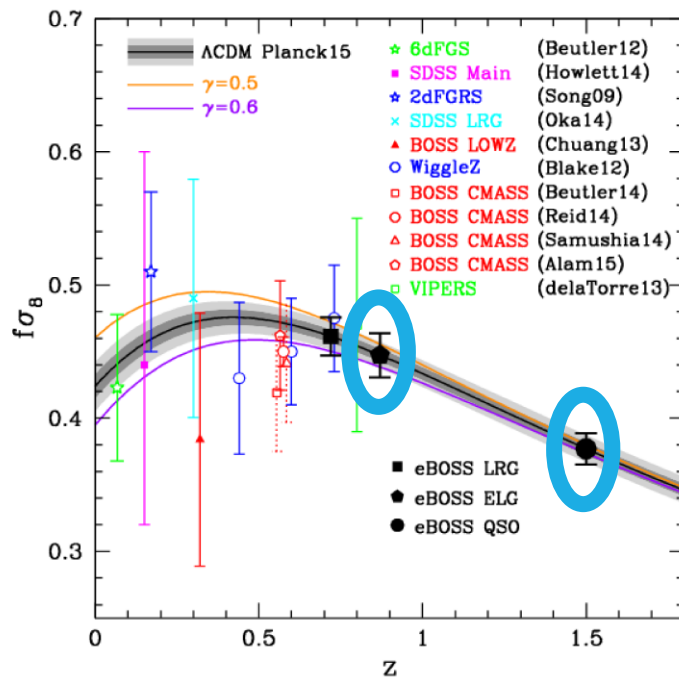Dawson et al. 2015

ELG and QSO are "new" tracers of the large scale structure:

- HOD or SHAM methods to construct mocks are currently investigated

- crucial to
  * understand measurements, their connection to theory,
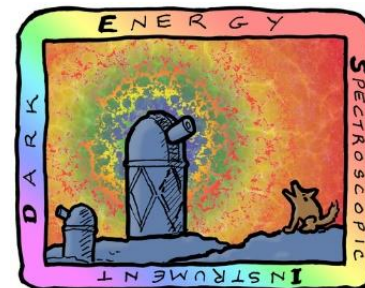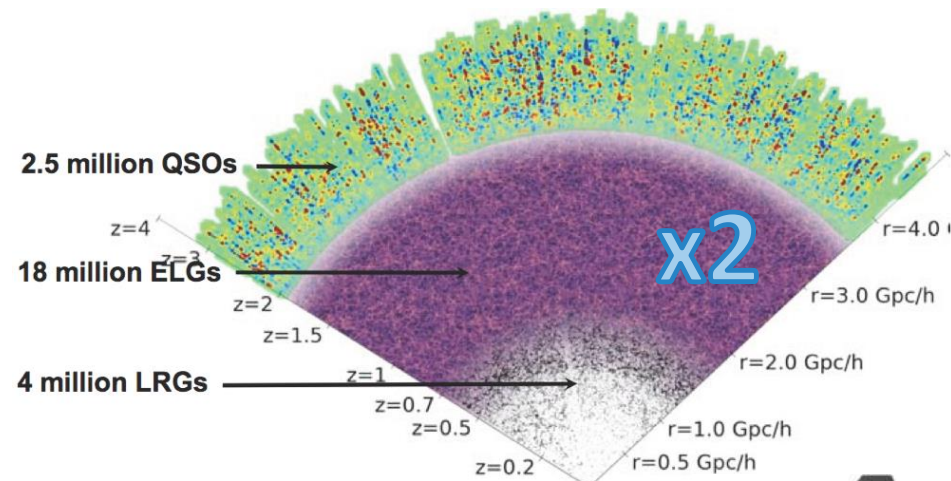 * estimate uncertainty, covariance

DESI (north) 4MOST (south)

Emission line galaxies and quasars as pixels for the most precise far-universe map

2 multiplexed fiber-fed spectrographs are built :

- ◦ At Kitt Peak (USA), DESI (desi.lbl.gov)
- ◦ At Paranal (chile), 4MOST (4most.eu)

By 2025, we will have an exhaustive map of 40 000 000 galaxies and quasars covering $0.6 < z < 2.2$

2.5 million QSOs
18 million ELGs
4 million LRGs

z=4
z=3
z=2
z=1.5
z=1
z=0.7
z=0.5
z=0.2

r=4.0
r=3.0 Gpc/h
r=2.0 Gpc/h
r=1.0 Gpc/h
r=0.5 Gpc/h

x2

DARK ENERGY SPECTROSCOPIC INSTRUMENT

Simulating the Universe

USING N BODY SIMULATIONS + MODELS

Simulations in Planck cosmo

Box Name	setup parameters			
	L_{box} h^{-1} Mpc	$N_p^{1/3}$	ϵ h^{-1}kpc	M_p $h^{-1}M_\odot$
SMD	400	3,840	1.5	9.63×10^7
MDPL	1,000	3,840	5	1.51×10^9
BigMD	2,500	3,840	10	2.4×10^{10}
BigMDNW	2,500	3,840	10	2.4×10^{10}
HMD	4,000	4,096	25	9.6×10^{10}
HMDNW	4,000	4,096	25	9.6×10^{10}
DarkSkies	8,000	10,240	36.8	3.9×10^{10}
–	1600	4,096	18.4	4.9×10^9
–	800	4,096	9.2	6.1×10^8
–	200	2,048	4.6	7.6×10^7
–	100	2,048	2.3	9.5×10^6
Ada	62.5	1024^3	1.5	1.94×10^7
Bice	125	–	3	1.55×10^8
Cloe	250	–	6	1.24×10^9
Dora	500	–	12	9.92×10^9
Emma	1000	–	24	7.94×10^{10}
Flora	2000	–	48	6.35×10^{11}
OuterRim	3,000	10,240	5	1.9×10^9
QContinuum	1,300	8,192	2	1.5×10^8
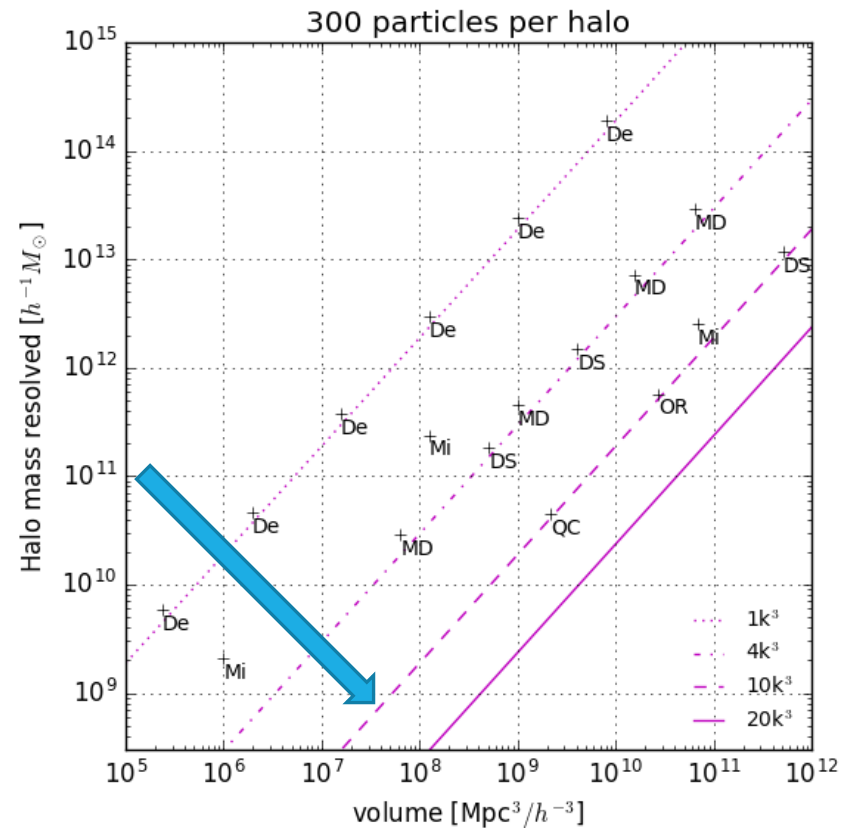
Comparat et al. In preparation

Simulations and surveys
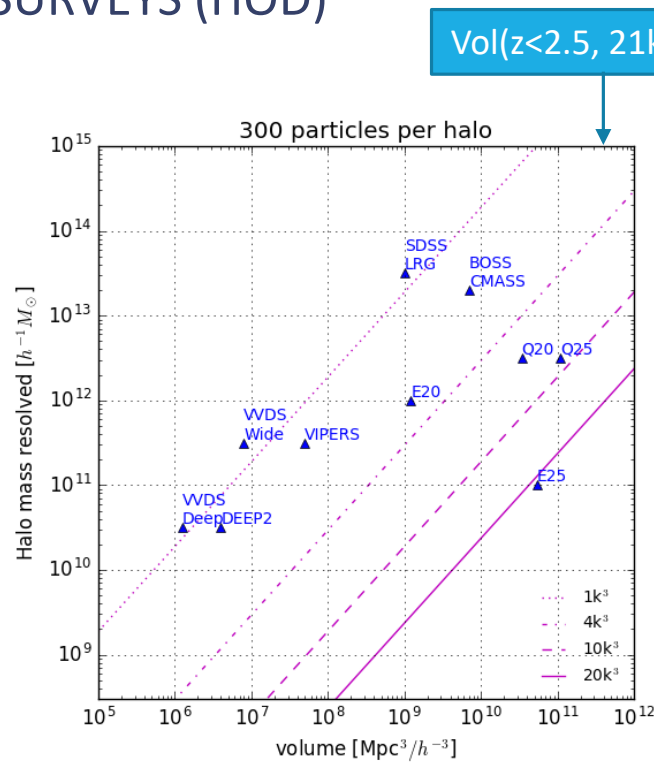
Comparat et al. In preparation

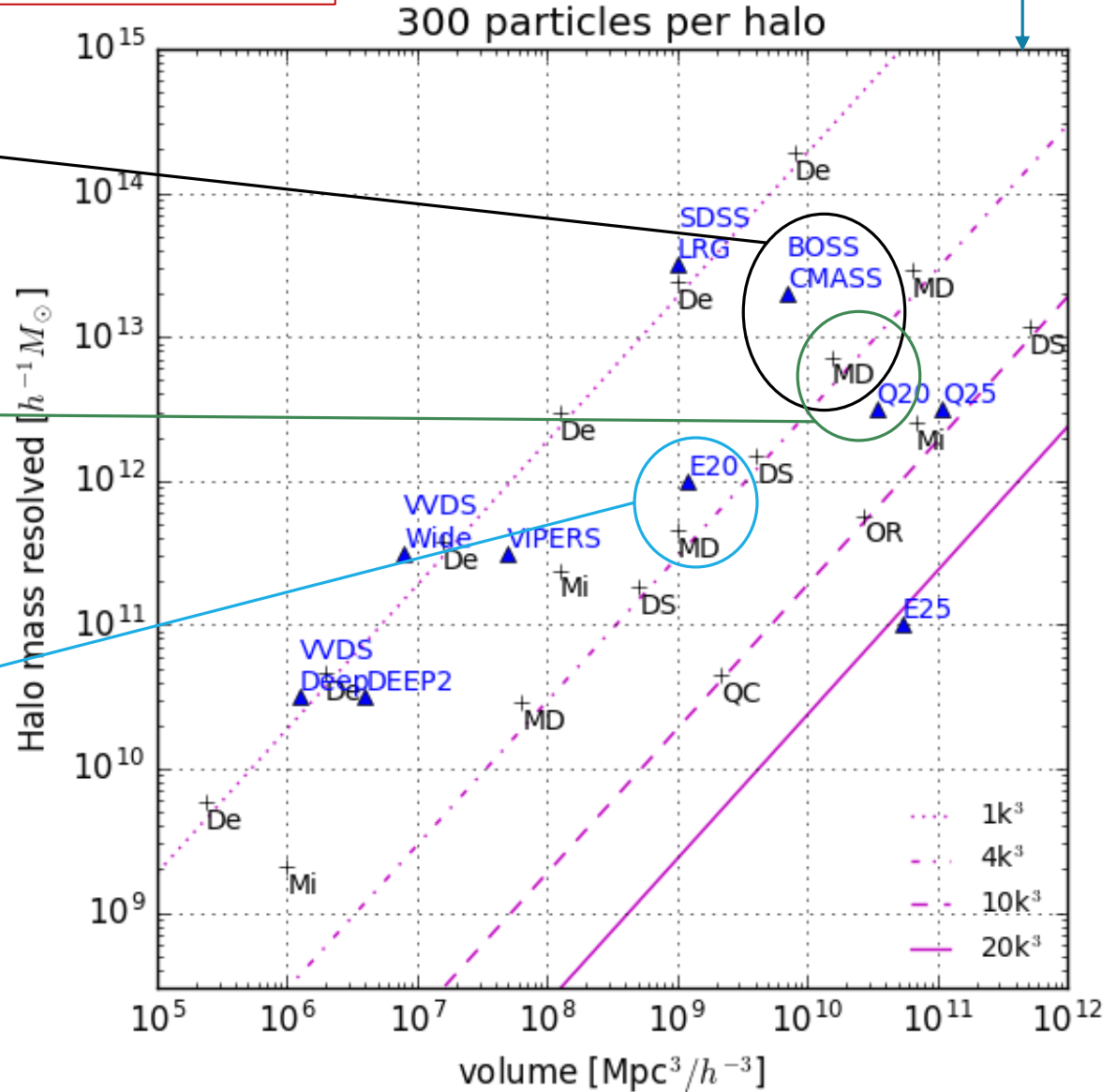V(z<2.5, 21k deg2)
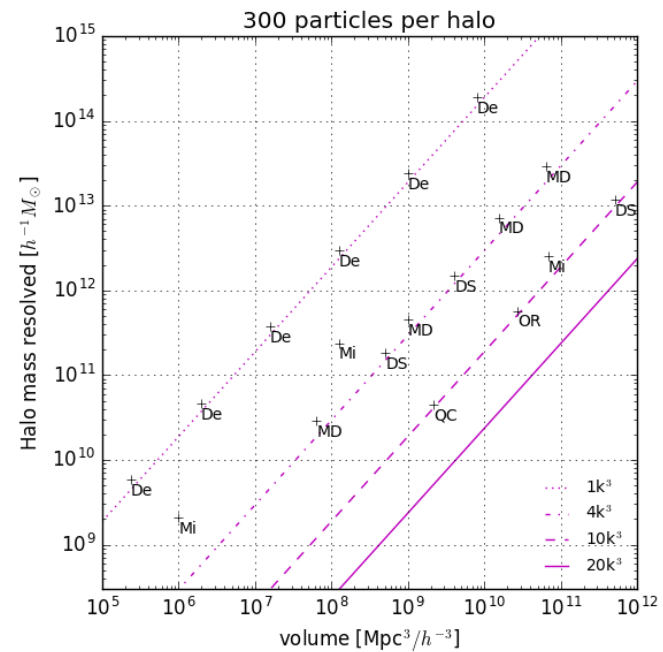
Rodriguez-Torres et al. 2015 SHAM for BOSS CMASS LRG

Rodriguez-Torres et al. submitted SHAM for eBOSS QSO

Favole et al. 2016 SHAM for eBOSS-like ELGs

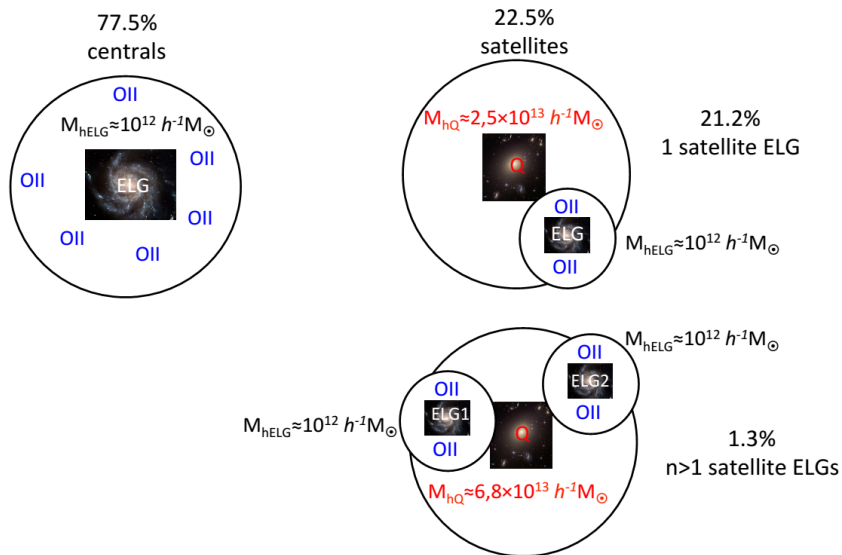Model = SHAM + incompleteness + fraction of satellite
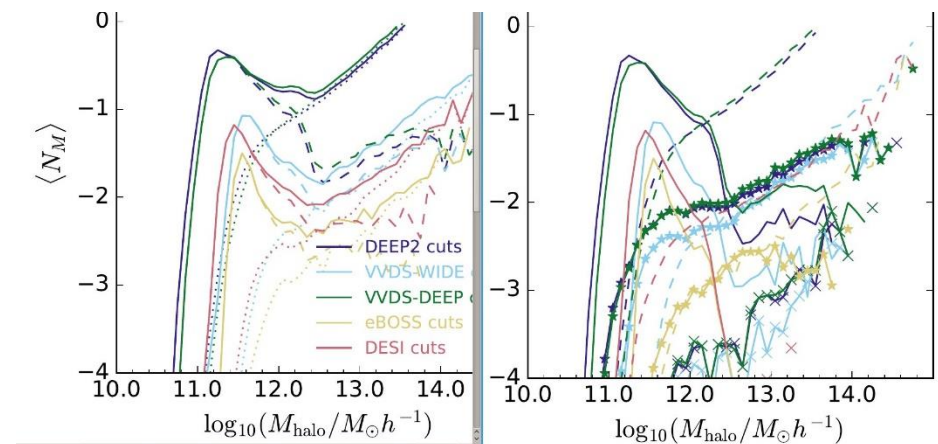

Comparat et al. In preparation

SHAM-SAMS for ELGs

SHAM ELG MODEL

Favole, Comparat et al. 2016

77.5% centrals

$M_{hELG} \approx 10^{12}\ h^{-1}M_\odot$

OII ELG OII OII OII OII OII

22.5% satellites

$M_{hQ} \approx 2,5 \times 10^{13}\ h^{-1}M_\odot$

21.2% 1 satellite ELG

$M_{hELG} \approx 10^{12}\ h^{-1}M_\odot$

$M_{hELG} \approx 10^{12}\ h^{-1}M_\odot$

$M_{hELG} \approx 10^{12}\ h^{-1}M_\odot$

$M_{hQ} \approx 6,8 \times 10^{13}\ h^{-1}M_\odot$
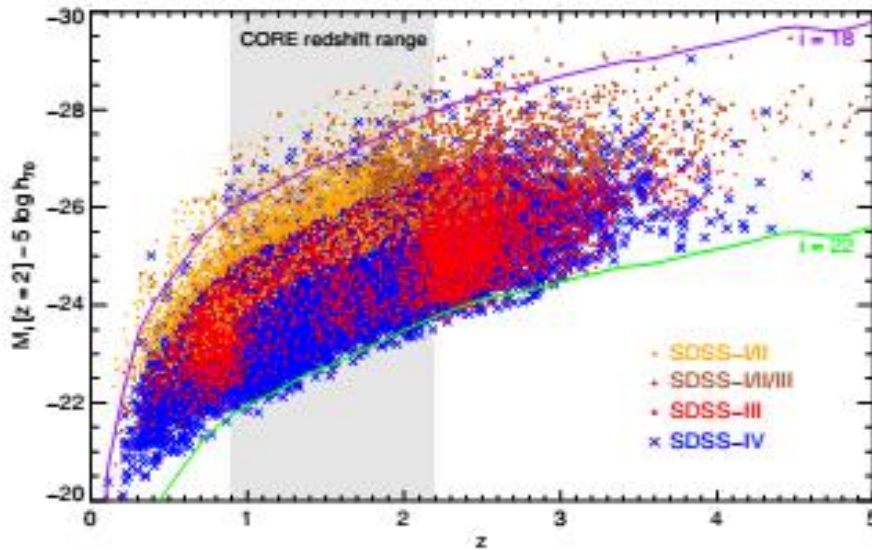
1.3% n>1 satellite ELGs

SAMS ELG MODEL

Gonzalez-Perez et al. In preparation

SHAM model: A 2 component simple model would say that "ELGs live in 10^12 halos and that 20% are satellites".
SAMS approach: Some of these satellites are central with an ongoing star burst. It allows to re think the model in more physical terms and eventually add components

eBOSS ongoing Quasar map

How accurately is the QSO population modeled in SAMS ?
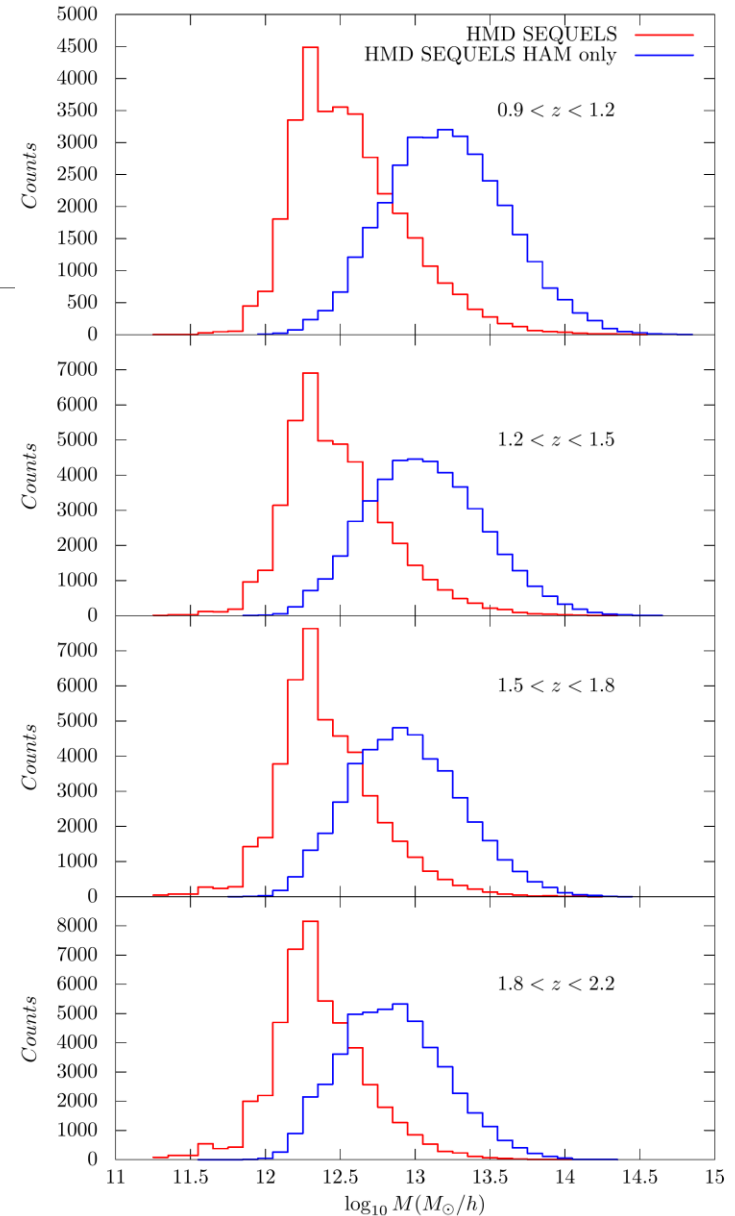
Myers et al. 2015, Rodriguez-Torres et al. submitted

Future maps, a challenge for simulation

QSO and ELG maps on the horizon 2020 and 2025 populate low mass halos and span gigantic volumes

SAMS are the key to study in depth the galaxy – halo connection and create new methods to construct simulated skies

Proof of concept using OR to mock eBOSS ELG (Gonzalez-Perez + in prep.)

Comparat et al. In preparation

V(z<2.5, 21k deg2)

300 particles per halo
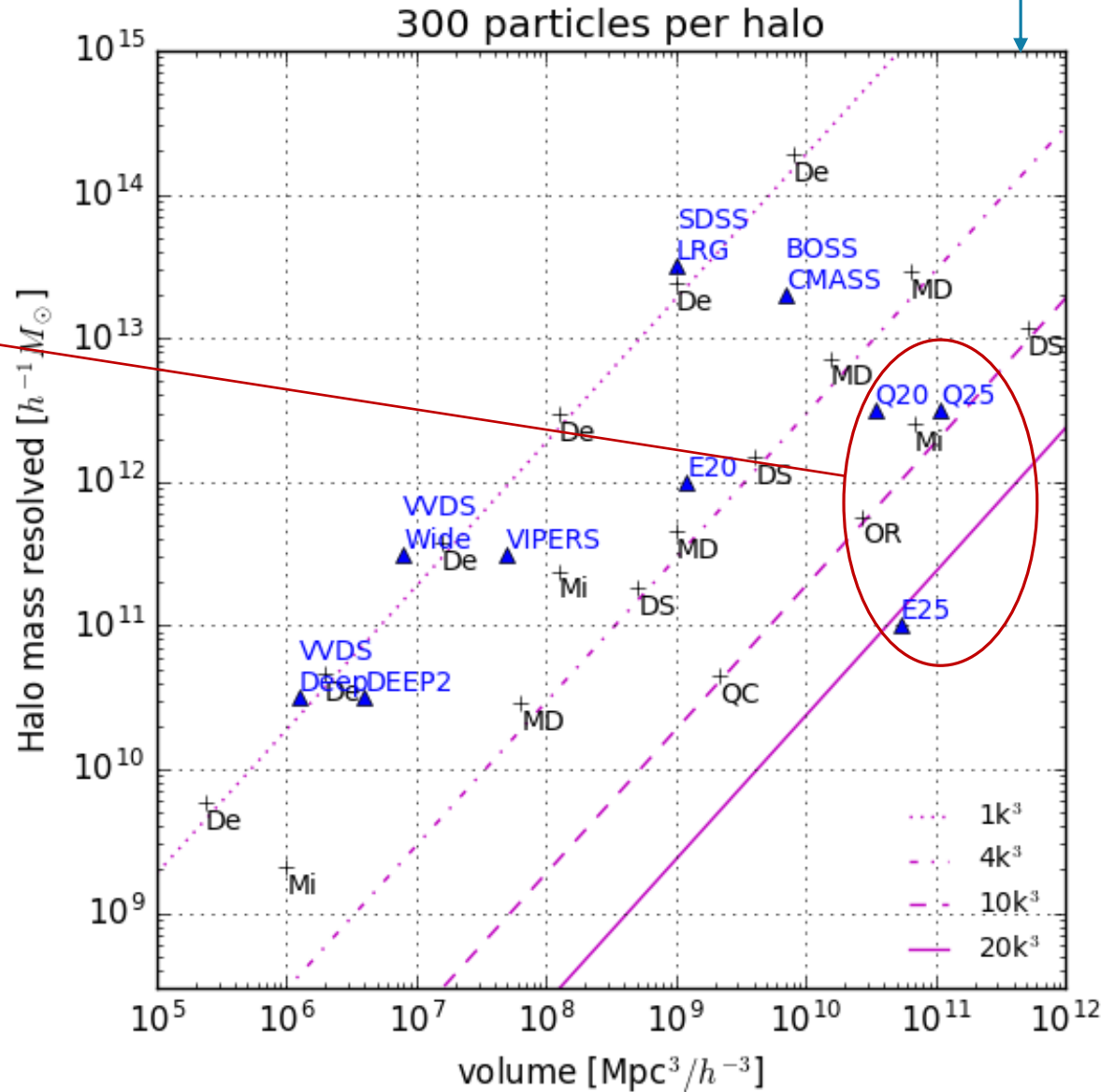
Summary

In <2 years, we will have good clustering measurements of ELG and QSO with eBOSS.

In <10 years, with DESI, 4MOST the uncertainty on the clustering will be <1%.

Simulating faithful Universes with LRG, ELG, QSO clustering correctly mimicked is well underway for eBOSS. It still is a challenge for 4MOST and DESI.

MultiDark Galaxies is a unique tool in Planck cosmology where galaxy evolution and cosmology meet :

◦ Creation of accurate methods to analyze galaxy clustering in full (in particular systematics !)
◦ Study the link galaxy – dark matter