CONNECTING N-BODY SIMULATION AND OBSERVATIONS – FROM DM BOXES TO GALAXY LIGHTCONES

Sergio Rodríguez-Torres
Dep. de Física Teórica – Universidad Autónoma de Madrid

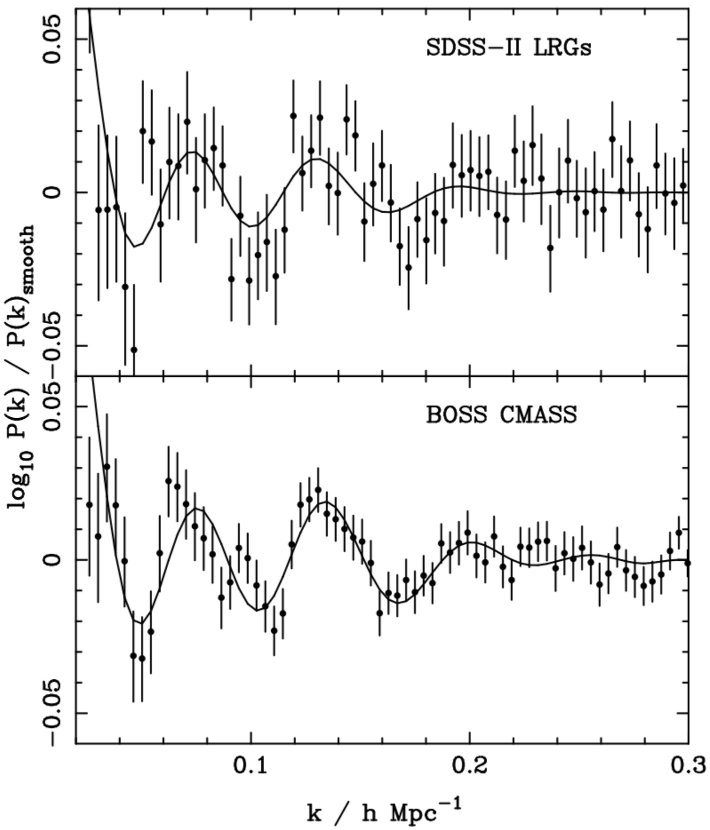
Simulated skies for new-generation spectroscopic surveys

Madrid, Spain

Outline

- SDSS-III/IV projects (BOSS/eBOSS)
- Modelling LRG sample: Halo Abundance Matching
- Modelling QSO sample: Incomplete Halo Abundance Matching
- Survey Generator code
- Upcoming projects

Baryon Oscillation Spectroscopic Survey (BOSS)

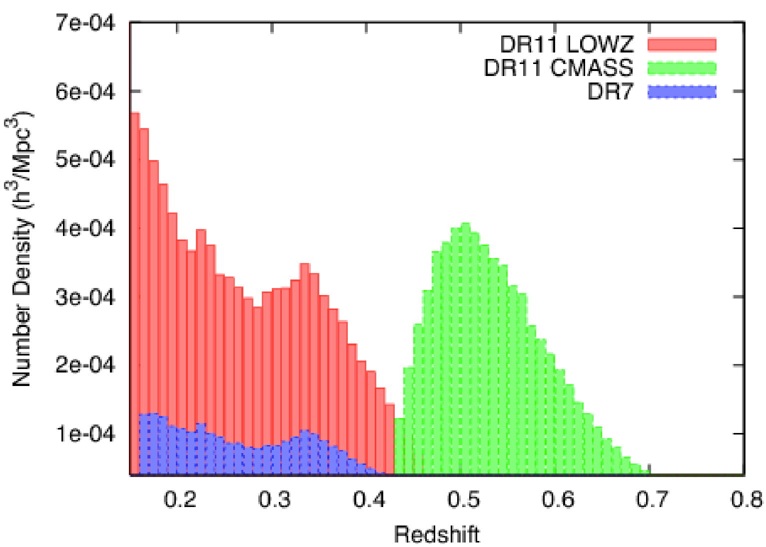


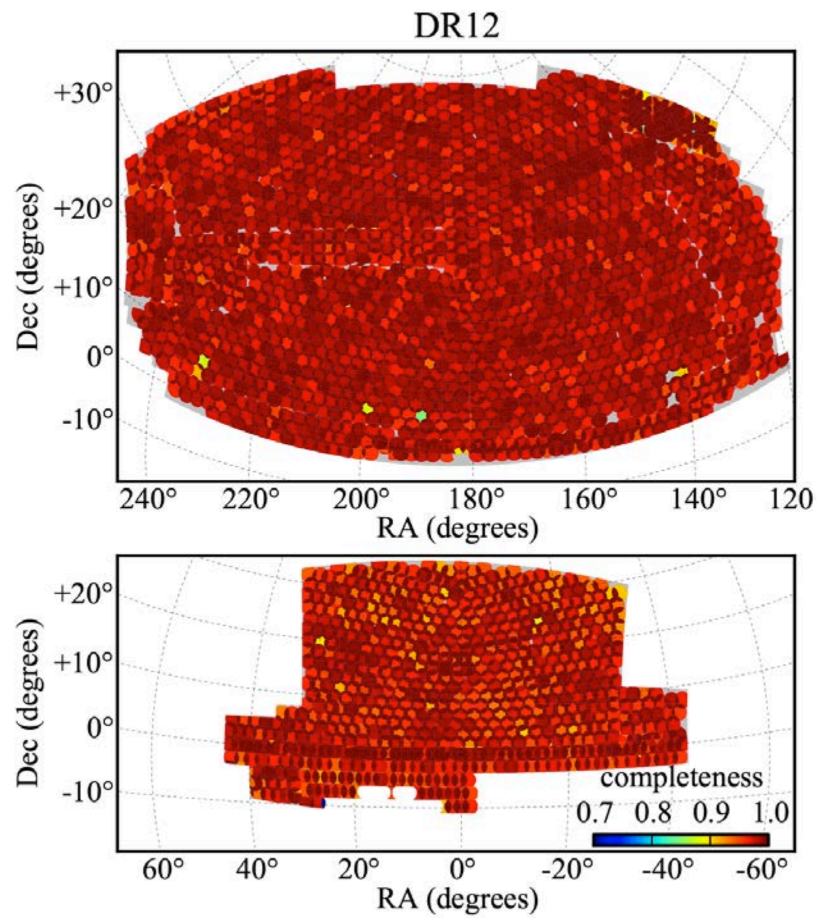
Anderson et al. 2014

- Map LRG and Quasars in the low redshift region.
- Detection of the baryonic acoustic oscillations.
- 10000 square degrees
- ~1.5 millions of luminous galaxies
- Redshift 0.15 to 0.75

CMASS/LOWZ

- LOWZ: brightest and reddest galaxies at low redshift (0.15-0.43), extending the SDSS-I/II LRG.
- CMASS: Designed to select galaxies at high redshift (0.43-0.75), most of them LRG





Alam et al. 2016

extended Baryon Oscillation Spectroscopic Survey (eBOSS)

- Map Luminous Red Galaxies, Emission line Galaxies and Quasars.
- Increasing the LRG redshift range $0.6<z<1.0$, ~300.000 new galaxies
- New sample of ~200.000 ELGs for $z>0.6$
- ~500.000 new spectroscopically-confirmed QSO, in the redshift range $0.9<z<2.2$
- ~120.000 new quasars at $z<2.1$ detected via Lyman-alpha forest

Dawson et al. 2016

Methods

- Hydro Simulations
  - Galaxy Formation Models
  - Computationally expensive
  - There are not simulations with enough volume to reproduce the current data

- Semi-Analytical Models (SAM)
  - Phenomenological Model
  - Large Number of parameters

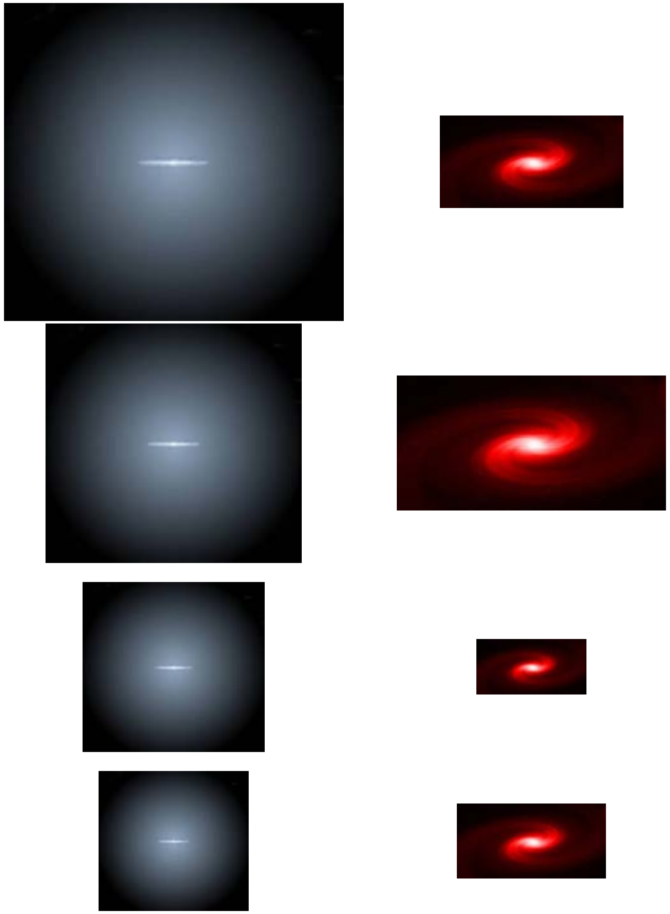
Galaxy Formation is not well understood yet, and combined with the complexity of each model (large number of parameters) can provide no good conclusions.

Statistical methods

- Halo Occupation Distribution (HOD)
  - One of the most common methods
  - Probability to find N galaxies in a host halo with mass M
  - ~5 parameters to fix the clustering
  - How is the distribution of satellite galaxies inside the halo host?
  - Velocities of satellites?
- Halo Abundance Matching
  - Match the observed luminosity/stellar mass function with the halo distribution

Connecting Dark Matter and Galaxies

- Scatter between DM halos and galaxies should be constraint from the data
- Stellar Mass – Vpeak(halos)
- Direct impact on the clustering
- Velocity dispersion – stellar mass (luminosity)
- Circular velocity – stellar mass (luminosity)

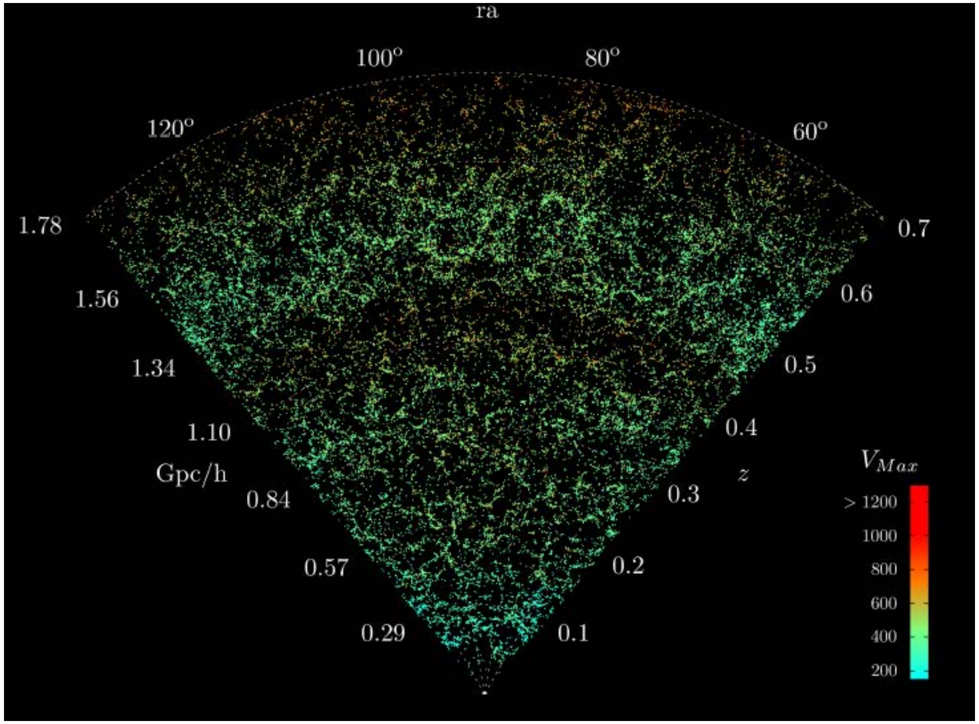


MultiDark simulations

Table 1. Numerical and cosmological parameters for the simulations. The columns give the simulation identifier, the size of the simulated box in h^{-1} Gpc, the number of particles, the mass per simulation particle m_p in units $h^{-1} M_{\odot}$, the Plummer equivalent gravitational softening length ϵ in units of physical h^{-1} kpc, the adopted values for $\Omega_{\rm Matter}$, $\Omega_{\rm Baryon}$, Ω_{Λ} , the clustering at $8h^{-1}$ Mpc, σ_8, the spectral index n_s and the Hubble constant H_0 in km/s/Mpc.

Simulation	box	particles	m_p	ϵ	Ω_M	Ω_B	Ω_Λ	σ_8	n_s	H_0	Code	Ref.
BigMD27	2.5	3840^3	2.1×10^{10}	10.0	0.270	0.047	0.730	0.820	0.95	70.0	GADGET-2	1
BigMD29	2.5	3840^3	2.2×10^{10}	10.0	0.289	0.047	0.711	0.820	0.95	70.0	GADGET-2	1
BigMD31	2.5	3840^3	2.4×10^{10}	10.0	0.309	0.047	0.691	0.820	0.95	70.0	GADGET-2	1
BigMDPL	2.5	3840^3	2.4×10^{10}	10.0	0.307	0.048	0.693	0.829	0.96	67.8	GADGET-2	1
BigMDPLnw	2.5	3840^3	2.4×10^{10}	10.0	0.307	0.048	0.693	0.829	0.96	67.8	GADGET-2	1
MDPL	1.0	3840^3	1.5×10^{9}	5	0.307	0.048	0.693	0.829	0.96	67.8	GADGET-2	1
MultiDark	1.0	2048^3	8.7×10^{9}	7.0	0.270	0.047	0.730	0.820	0.95	70.0	ART	2
SMDPL	0.4	3840^3	9.6×10^{7}	1.5	0.307	0.048	0.693	0.829	0.96	67.8	GADGET-2	1
BolshoiP	0.25	2048^3	1.5×10^{8}	1.0	0.307	0.048	0.693	0.829	0.96	67.8	ART	1
Bolshoi	0.25	2048^3	1.3×10^{8}	1.0	0.270	0.047	0.730	0.820	0.95	70.0	ART	3

The BigMultiDark Planck Simulation



- 2.5 Gpc/h, 3840^3
- RockStar halo finder
- Planck Cosmology

www.multidark.org

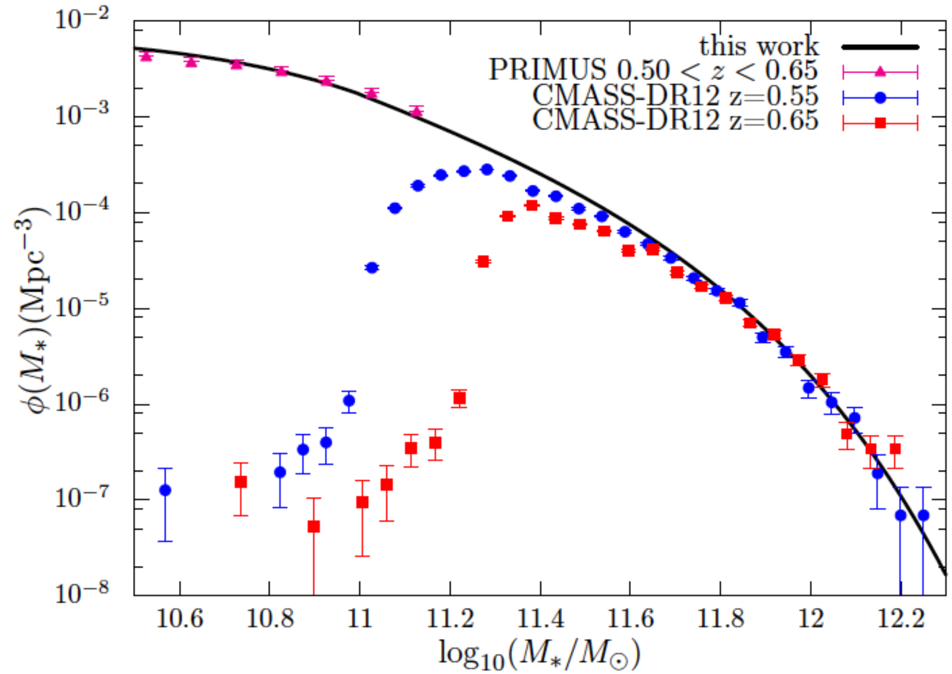
Galaxy clustering of BOSS

- Goal: Construct light-cone for the full CMASS-NGC sample
- Assign galaxies to dark matter halos (HAM)
- Stellar mass function
- Fix the linear bias of our galaxy population to reproduce observations
- Incompleteness of the sample
- Fiber collisions
- Selection function of the sample (Angular and radial)

Rodríguez-Torres et al. 2016a

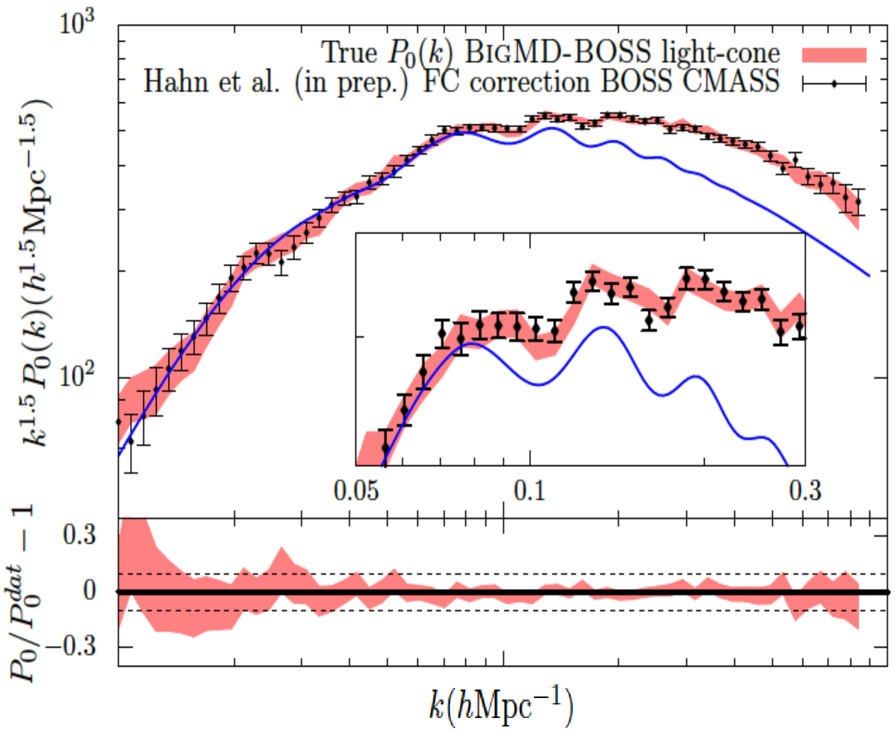
Halo Abundance Matching- Stellar Mass

Portsmouth DR12 SM catalogs (Maraston et al. 2013)
+
Compele Stellar Mass catalog at low mass

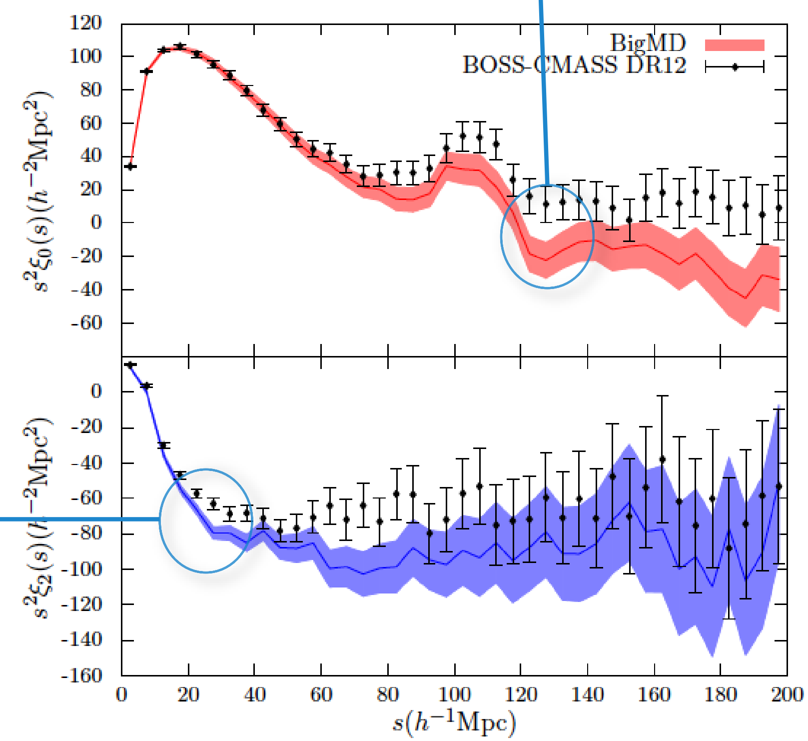


Mass range $[M_\odot]$	ϕ_* $[\mathrm{Mpc}^3 \log_{10} M_\odot^{-1}]$	α	$\log_{10} M_*$ $[M_\odot]$
$\log_{10} M_* \leq 11.00$	4.002×10^{-3}	-0.938	10.76
$\log_{10} M_* > 11.00$	2.663×10^{-3}	-2.447	11.42

2-pt correlation function

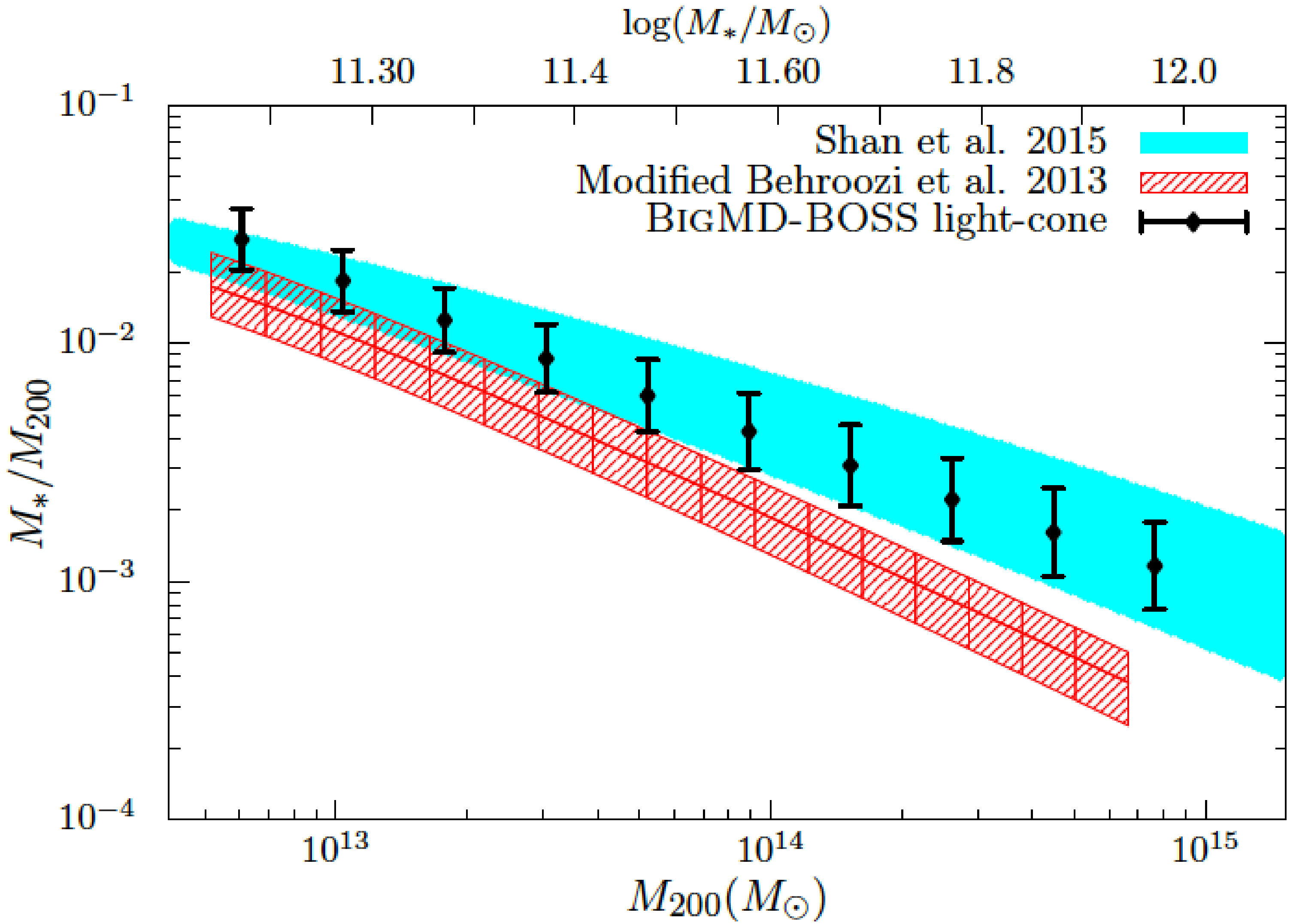


Remaining Systematics errors?



- Selection effects
- Dependency of the intrinsic scatter with stellar mas
- Off centering galaxies
- …

Halo Mass and Stellar Mass

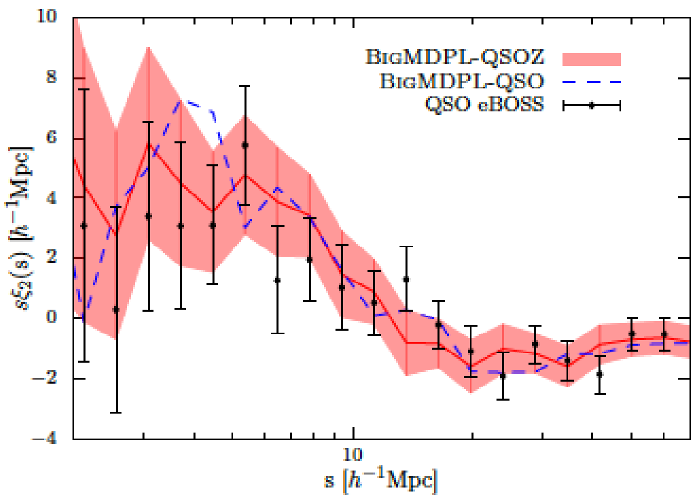


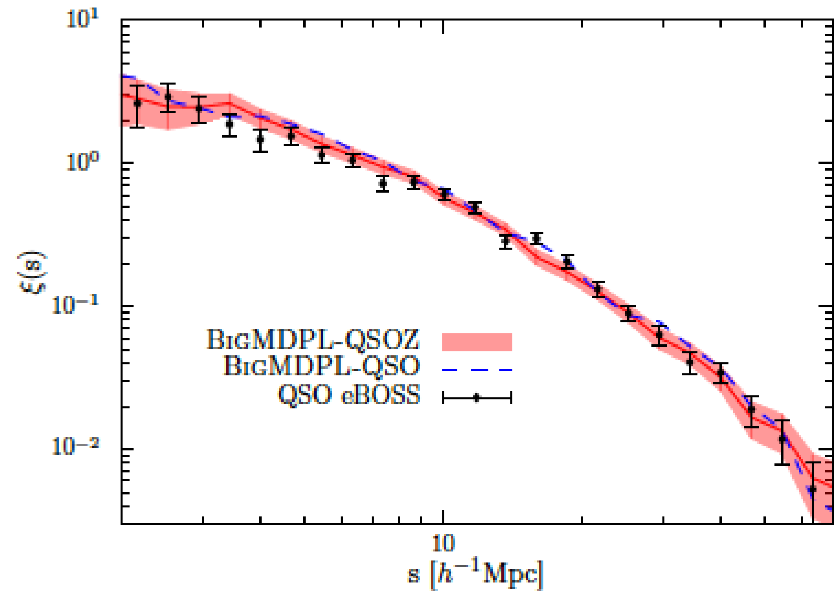
HAM: Incomplete samples

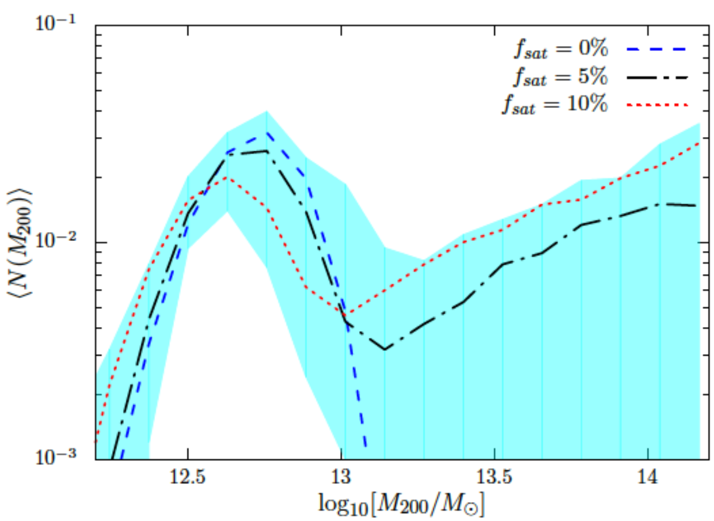
- Combining the intrinsic scatter between dark matter halos and galaxies/quasars with the incompleteness of the sample.
- We use a Gaussian function to model the incomplete sample.
- Our model consist in three parameters: Mean Vpeak, width of the distribution and fraction of satellite.
- In the case of quasars we reduce the model to one parameter due to the poor information of the one halo term.

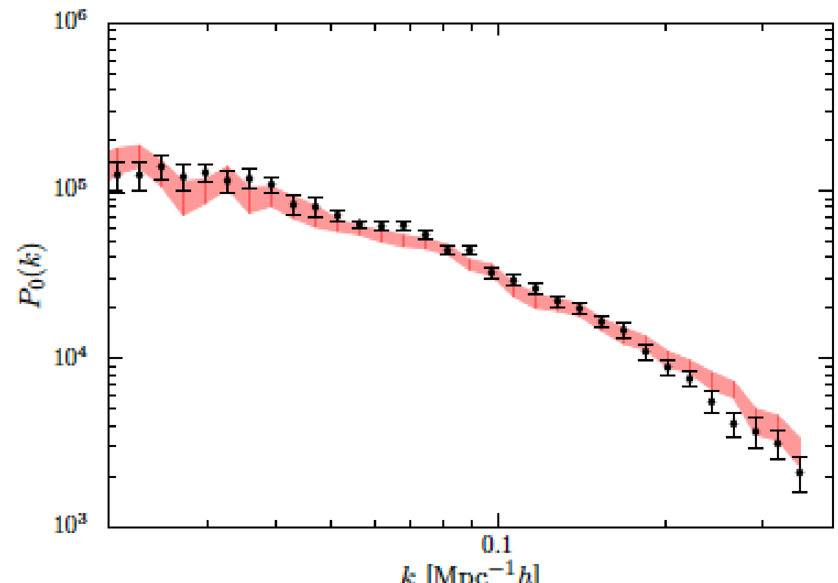
Rodríguez-Torres et al. 2016b

eBOSS First Year Quasar (Y1Q)

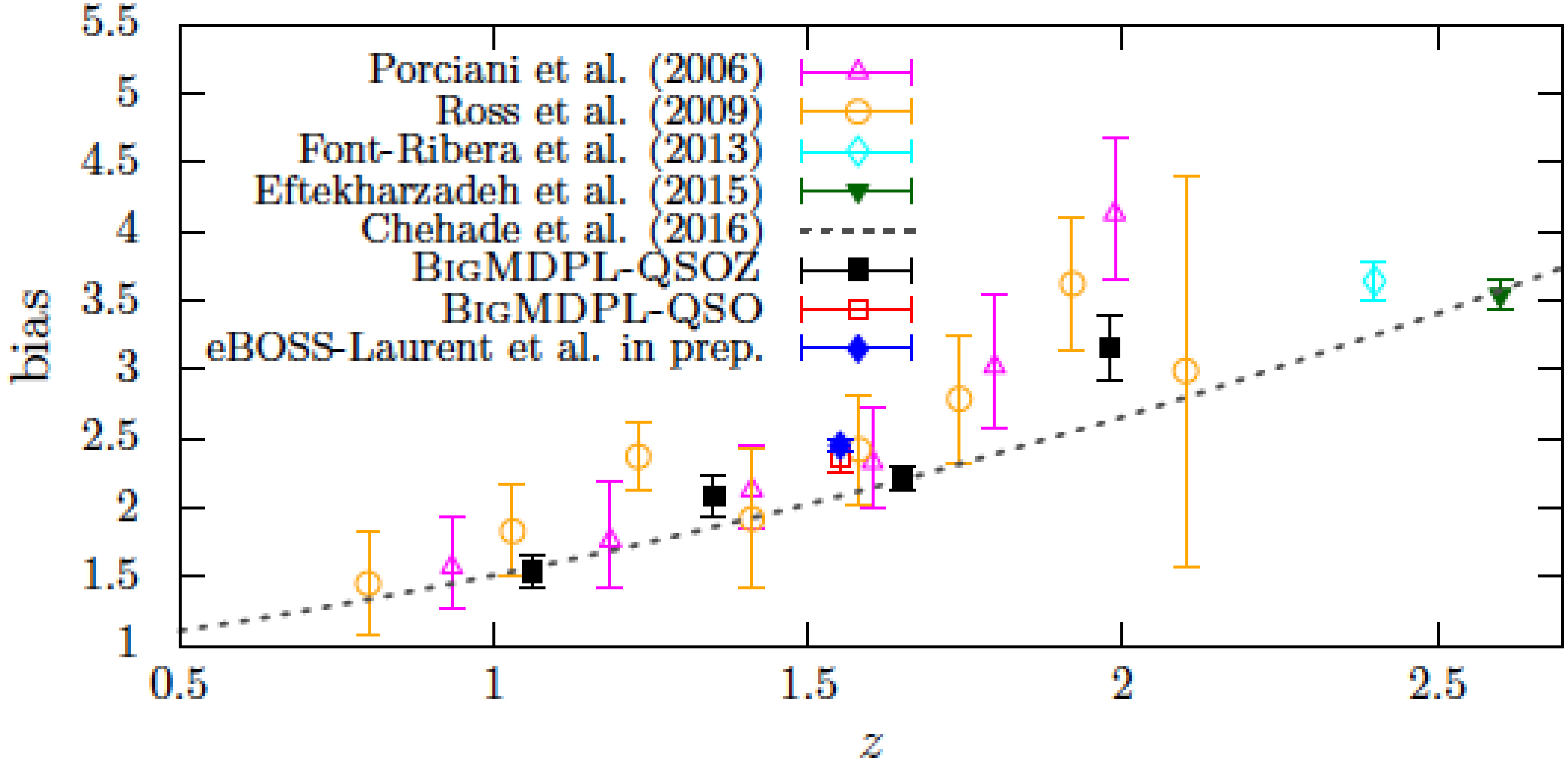






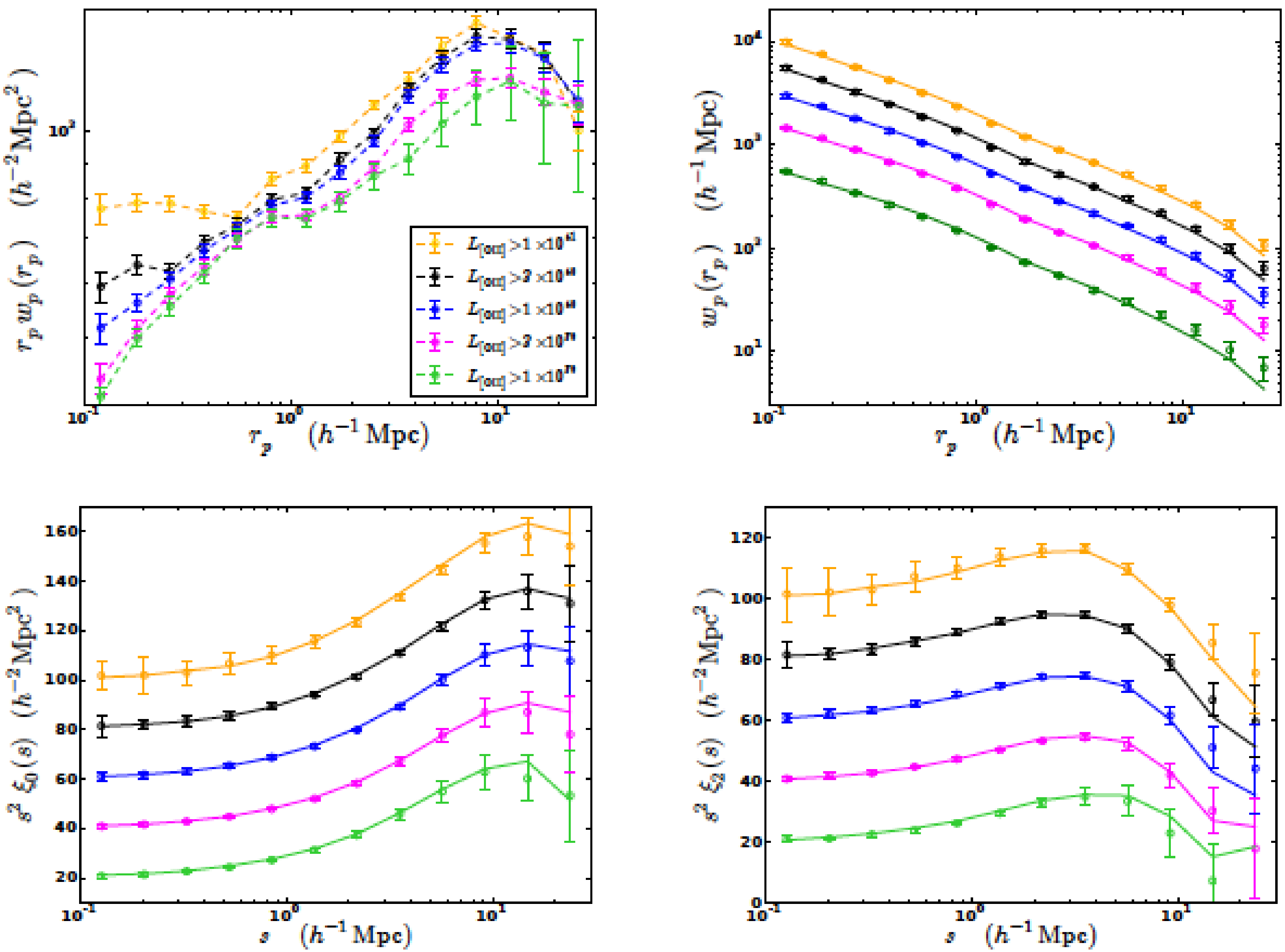


Bias evolution of quasars



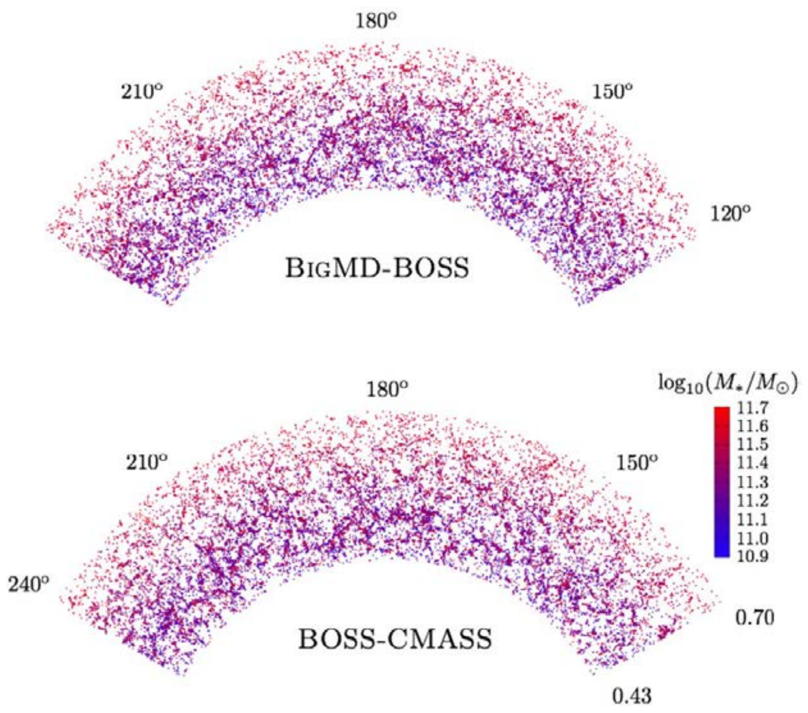
Emission line galaxies

(Favole et al. 2017)



SUrvey GenerAtoR code (SUGAR)

- Code designed to construct light-cones from N-Body simulations.
- Uses different snapshots of the simulation to include the evolution of the dark matter
- Can include observational effects such as the geometry of the survey.
- For Dark Matter simulation the code applies HAM or HOD models to construct galaxy samples



Future Projects

- Produce high fidelity mocks combining different populations.
- Use cross-correlations to understand better the distribution of ELG at high redshift.
- Study effects of assembly bias in samples as Luminous Red Galaxies.
- Produce methodologies that can be implement in the massive production of simulations for covariance matrices.

Summary

- We produced a galaxy catalog from simulations that reproduce the stellar mass function and correlation function in configuration space for LRG samples.
- The light-cone reproduces the survey geometry, radial selection function, stellar mass incompleteness and fiber collisions effect.
- HAM provides good predictions for 2-point and 3-point statistics, using one single parameter.
- Halo occupation distribution and halo to stellar mass relation are in agreement with previous works.
- Our model for incomplete samples produces coherent results with previous studies.
- Future surveys will allows to explore the cross-correlation between samples and understand the distribution of quasars within dark matter halos.

Thanks you!