ICE-COLA Mocks for Cosmological Surveys

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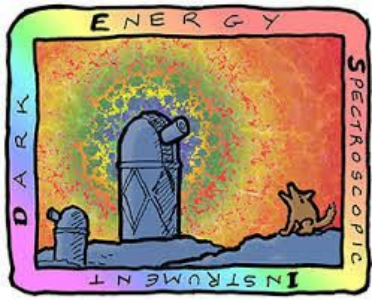
Project motivation

Present and planned galaxy surveys like

DARK ENERGY SURVEY



euclid consortium

LSST Large Synoptic Survey Telescope

Will generate a wealth of high-quality data that will allow to test the nature of dark-energy and constrain possible deviations from the standard cosmological model.

An optimal extraction of cosmological parameters from those very large and complex datasets will ultimately rely on our ability to model cosmological observables and their covariances with high accuracy

This entails the development of synthetic observations based on mock catalogues produced from numerical simulations.

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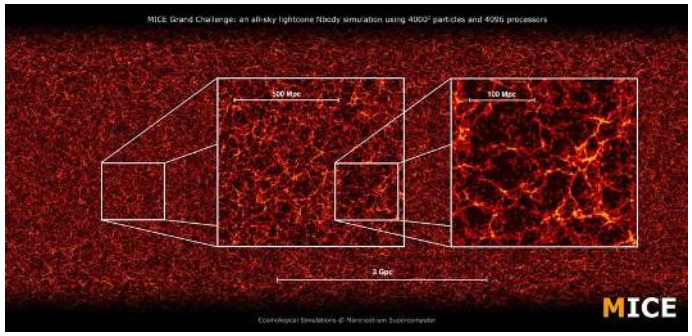
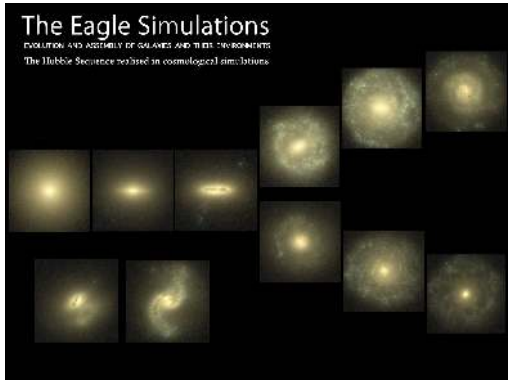
Computational problem

The requirement of sampling large cosmological volumes while still resolving small scales is a big challenge to current N-body simulation codes.





Moreover, hundreds or thousands of realizations are needed for robustly estimating covariance matrices or for propagating errors in complex and non-linear analysis .

Yet, producing massive ensembles of N-body mocks is computationally prohibitive and alternative routes need to be devised in order to face the enormous challenge

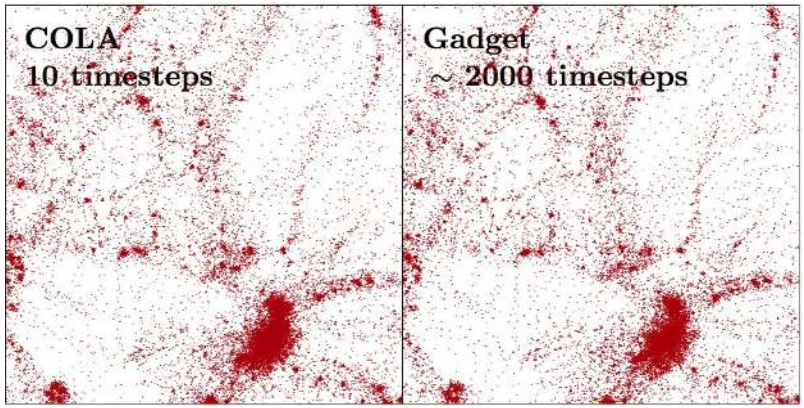
Alternative Solution

To use fast simulations

COLA
COmoving
Lagrangian
Accelerator

An N-body method for solving for Large Scale Structure (LSS) in a frame that is comoving with observers following trajectories calculated in Lagrangian Perturbation Theory (LPT)

Evolve particles according to the 2LPT trajectories + residual displacement evaluated by the N-body solver (Particle-Mesh)



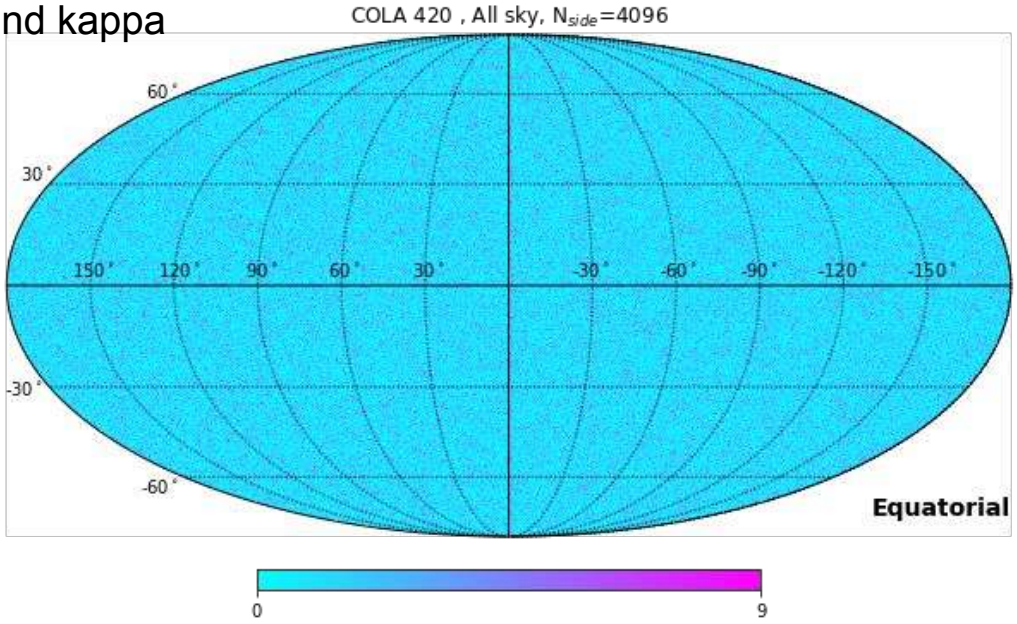
Tassev, Zaldarriaga, Eisenstein, 2013

- Orders of magnitude faster than a high-force accuracy N-body run
- With COLA one can straightforwardly trade accuracy at small-scales in order to gain computational speed, without sacrificing the accuracy at large scales

What do we have?

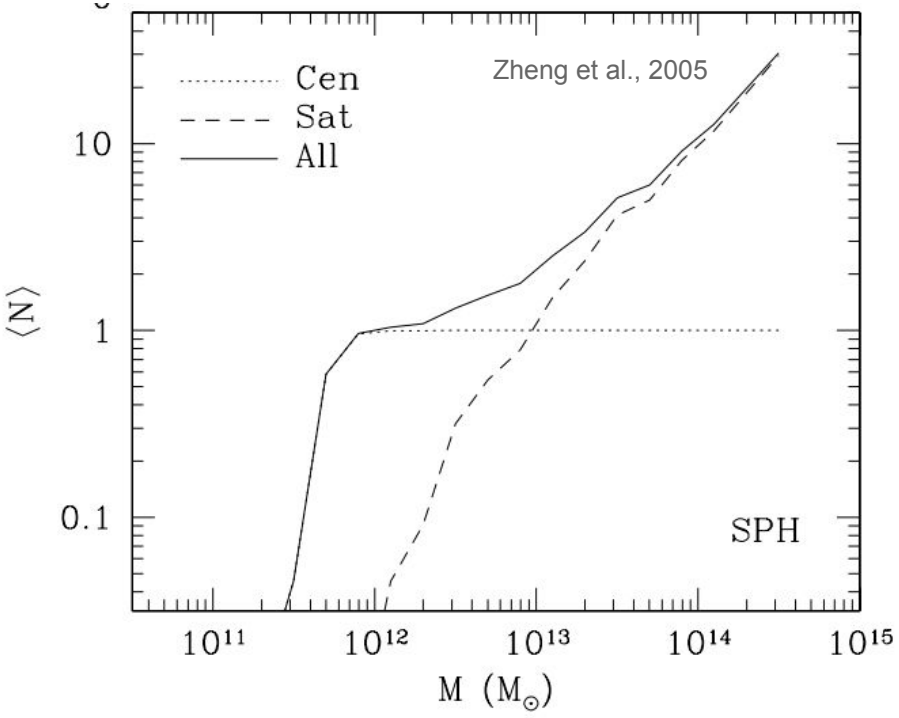
- 490 full sky runs.
- Lbox=1536, npart=2048^3, LC on the fly from z=1.42, MICE cosmology.
- Mass particle = 2,927 x 10^{10} ---> Min. halo mass = 5,84 x 10^{11} (20 part.)
- FoF lightcone: nº of particles, positions and velocities
- Healpix maps: particle counts, shear and kappa
- HOD assignment pipeline in place

What is the HOD ?



Halo Occupation Distribution (HOD), for all kind of galaxies

Provides a view of how galactic matter is distributed within each of the dark matter clumps



$$< N_c >_M = \frac{1}{2}\left[1 + erf\left(\frac{logM - logM_{min}}{\sigma_{logM}}\right)\right]$$

$$< N_s >_M = \left(\frac{M}{M_1}\right)^{\alpha} \longrightarrow M > M_{cut}$$

$$< N_s >_M = 0 \longrightarrow M < M_{cut}$$

$M_{\rm min}$ = characteristic minimum mass of haloes that host centrals above luminosity threshold

$\sigma_{\log M}$ = characteristic transition width due to scatter in L-M relation of centrals

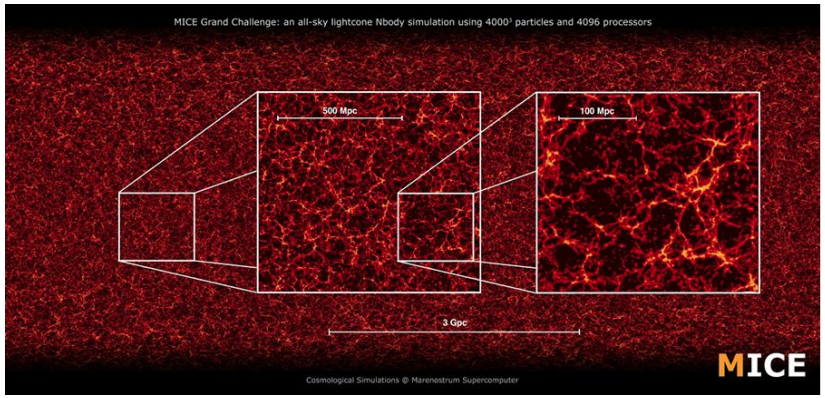
$M_{\rm cut}$ = cut-off mass below which you have zero satellites above luminosity threshold

M_1 = normalization of satellite occupation numbers

α = slope of satellite occupation numbers

MICE grand challenge lightcone simulation

Marenostrum Institut de Ciències de l'Espai Simulations



DARK ENERGY SURVEY

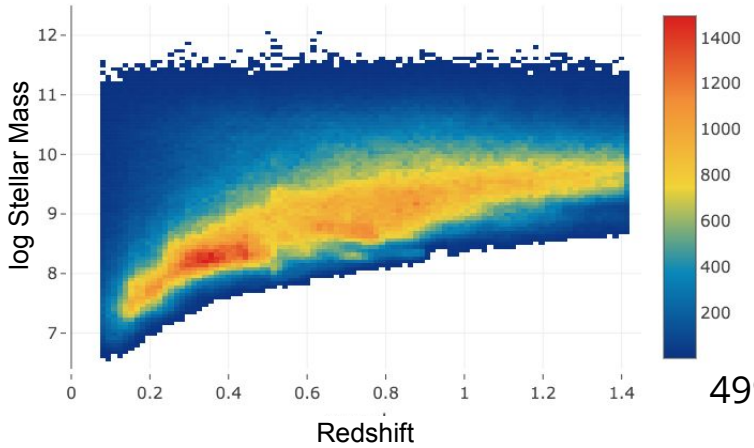
Uses MICE Grand Challenge simulation:

- 70 billion particles,
- 3 Gpc/h box,
- mp=3x10^10 M

Full-sky Lightcone without repetition to z=1.4

One Octant (~5000 deg2) filled with galaxies:

- positions, velocities
- luminosities
- colours
- galaxy properties
- lensing



499.61 Millions of galaxies

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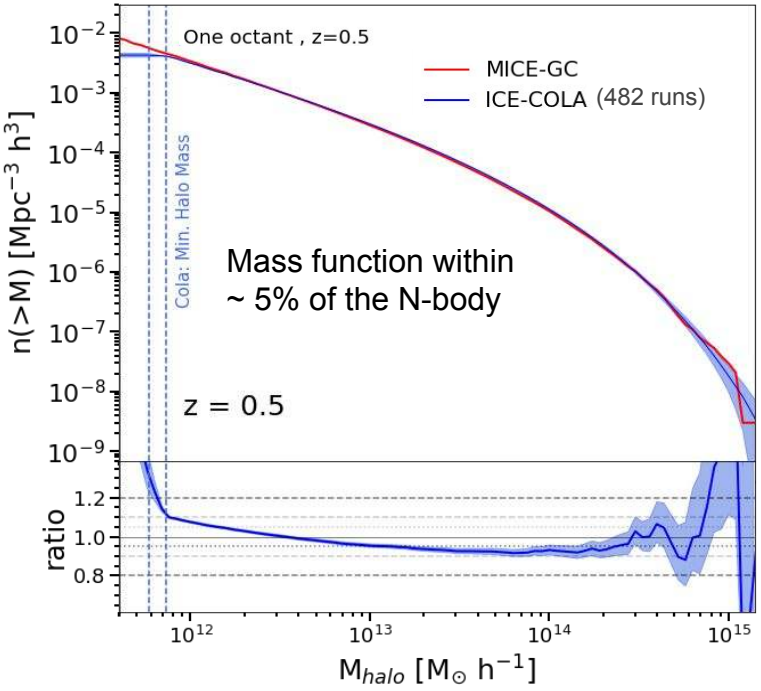
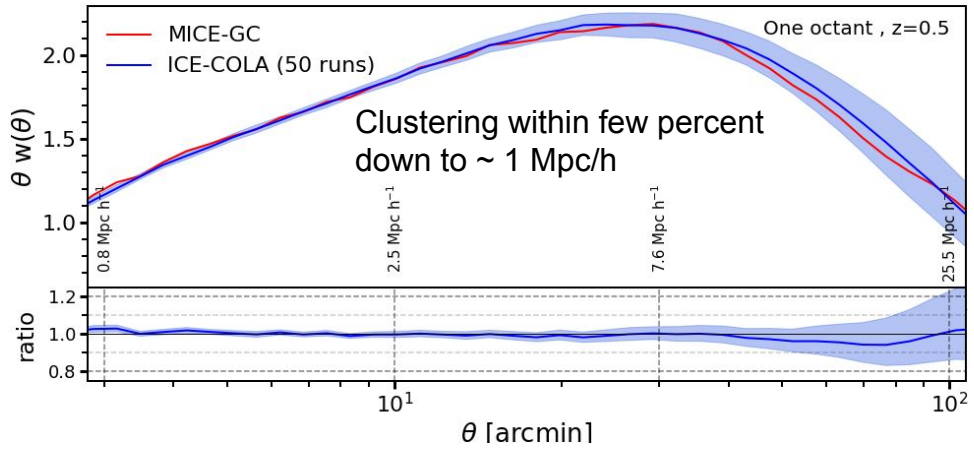
Cola validation

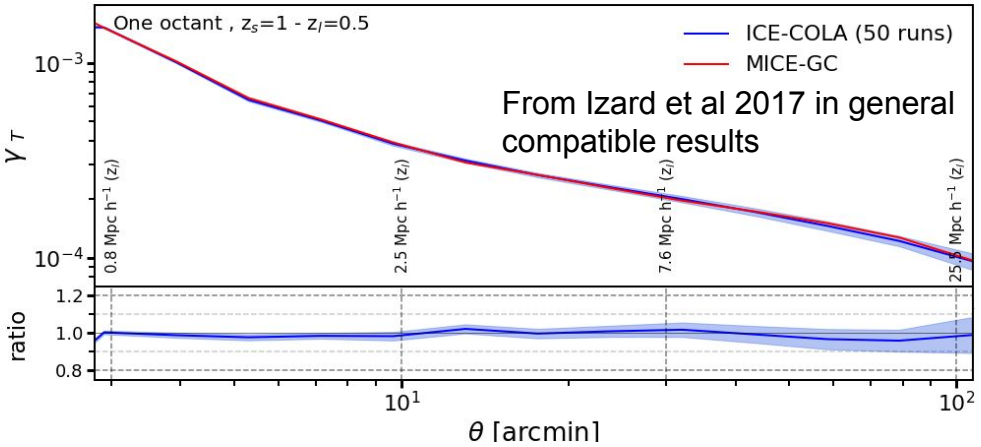
Halo Mass function at z=0.5



Pos-pos 2pcf at z=0.5



Pos-shear 2pcf at z_l=0.5

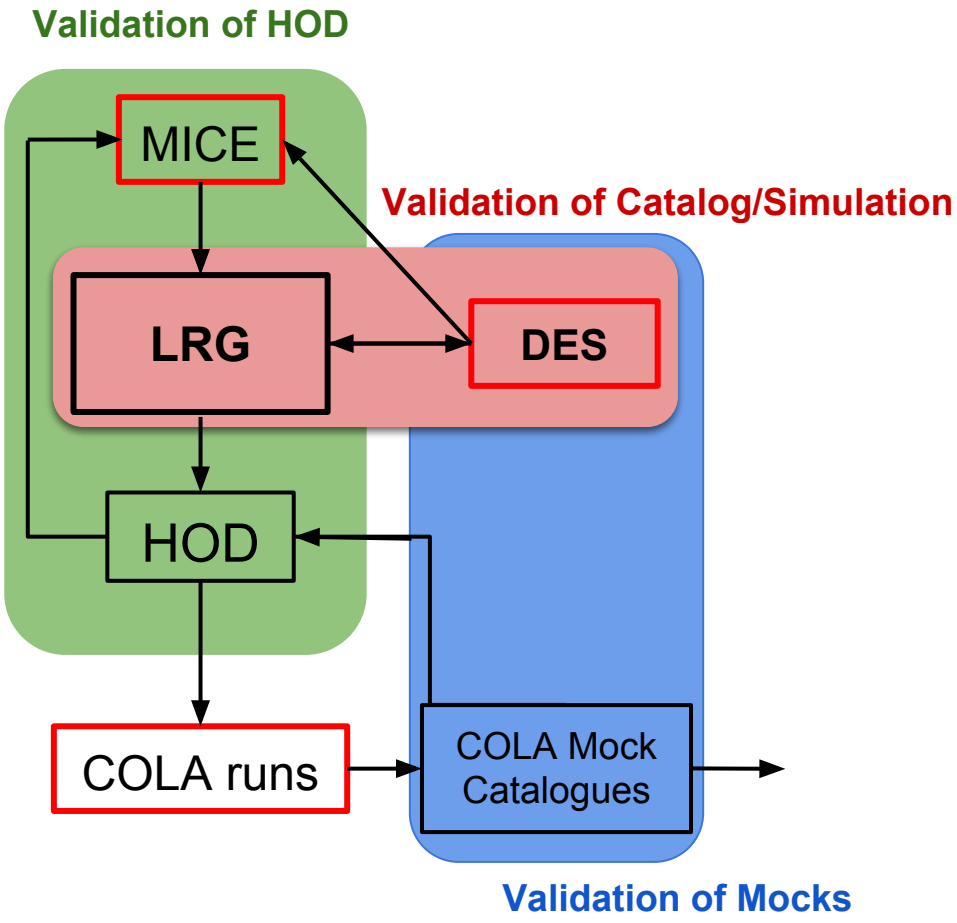


+ shear-shear
+ cls
+ also z=1

How we do to create catalogos (example done for LGRs in DES)

Example: We want to create thousand of catalog that mimic the sample of LGRs of the DES data.

1. **Select from MICE a sample of LRG**
2. **Read off the HOD of sample of LRG**
   spline, parameterized function, nº bins,..
3. **Apply that HOD back to MICE**
   triaxiality, concentration, …
4. **Test of HOD and implementation**
   n(z), clustering
5. **Test against Survey data**
   n(z), clustering
6. **Calibrate HOD**
   parameters, implementation
7. **Apply resulting HOD to COLA halo catalogues**
   mask
8. **Test against Survey data**
   n(z), clustering
9. **Assign properties to galaxies**
   SHAM, colors, luminosities,...



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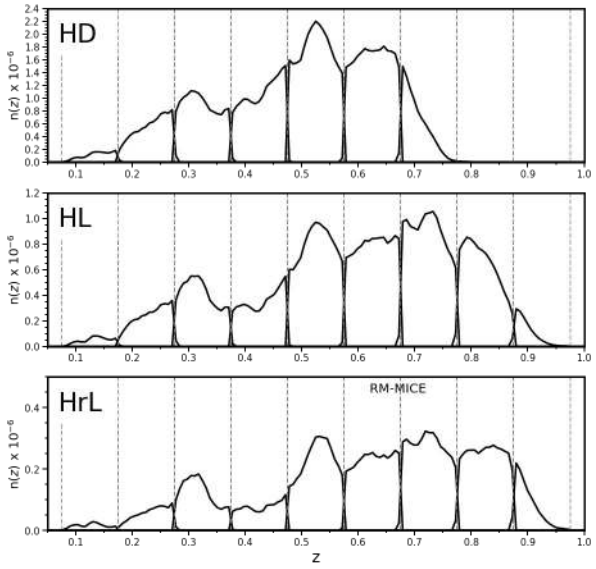

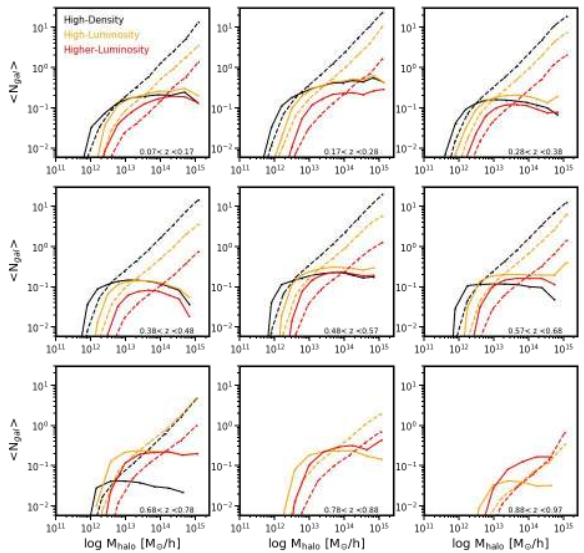

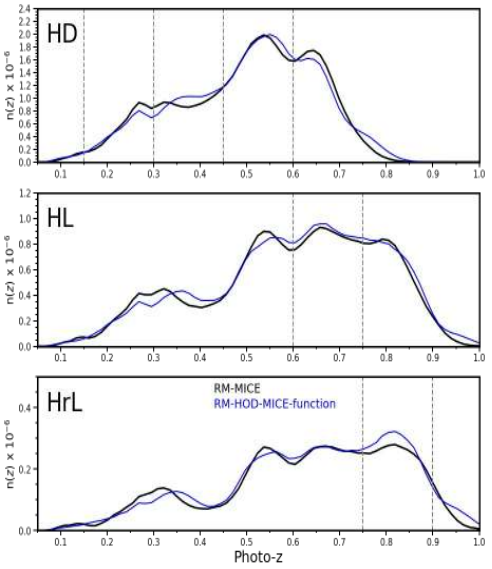

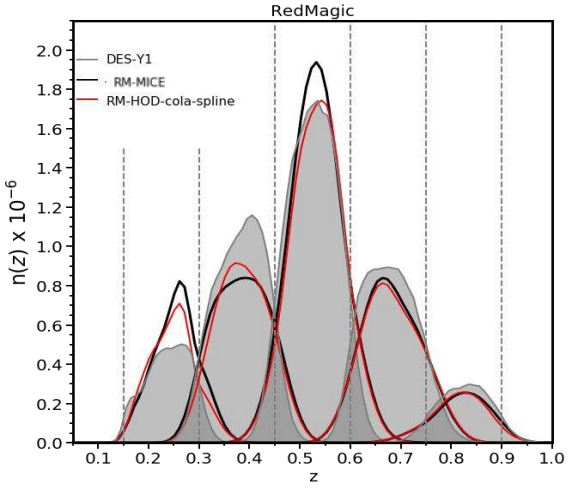

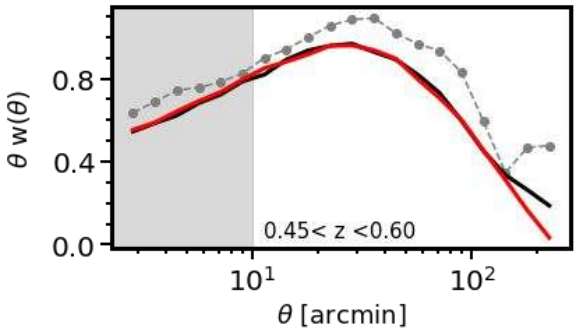

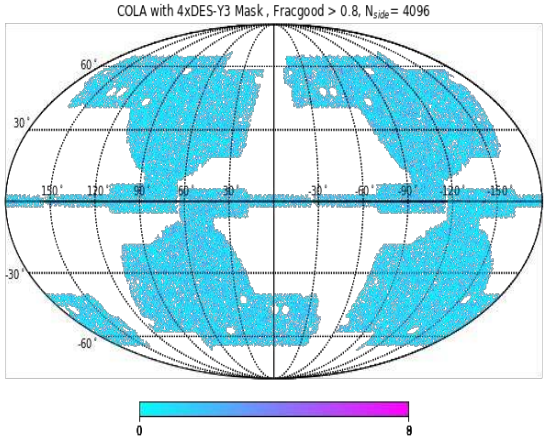

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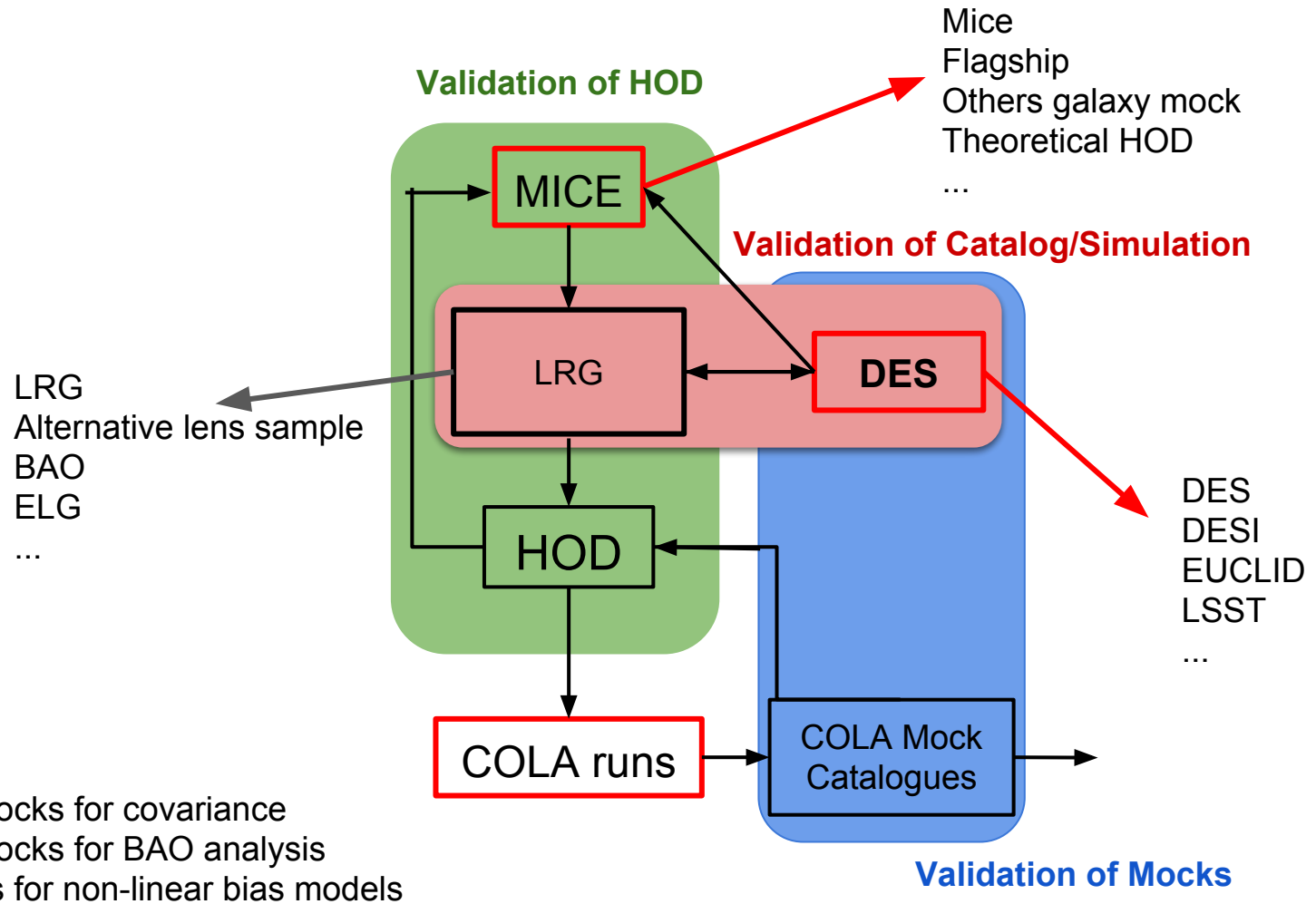
Pipeline can be used for any survey, for any kind of sample and using any reference catalog or HOD.



- ICE-COLA Mocks for covariance
- ICE-COLA Mocks for BAO analysis
- HOD analysis for non-linear bias models (using MICE)

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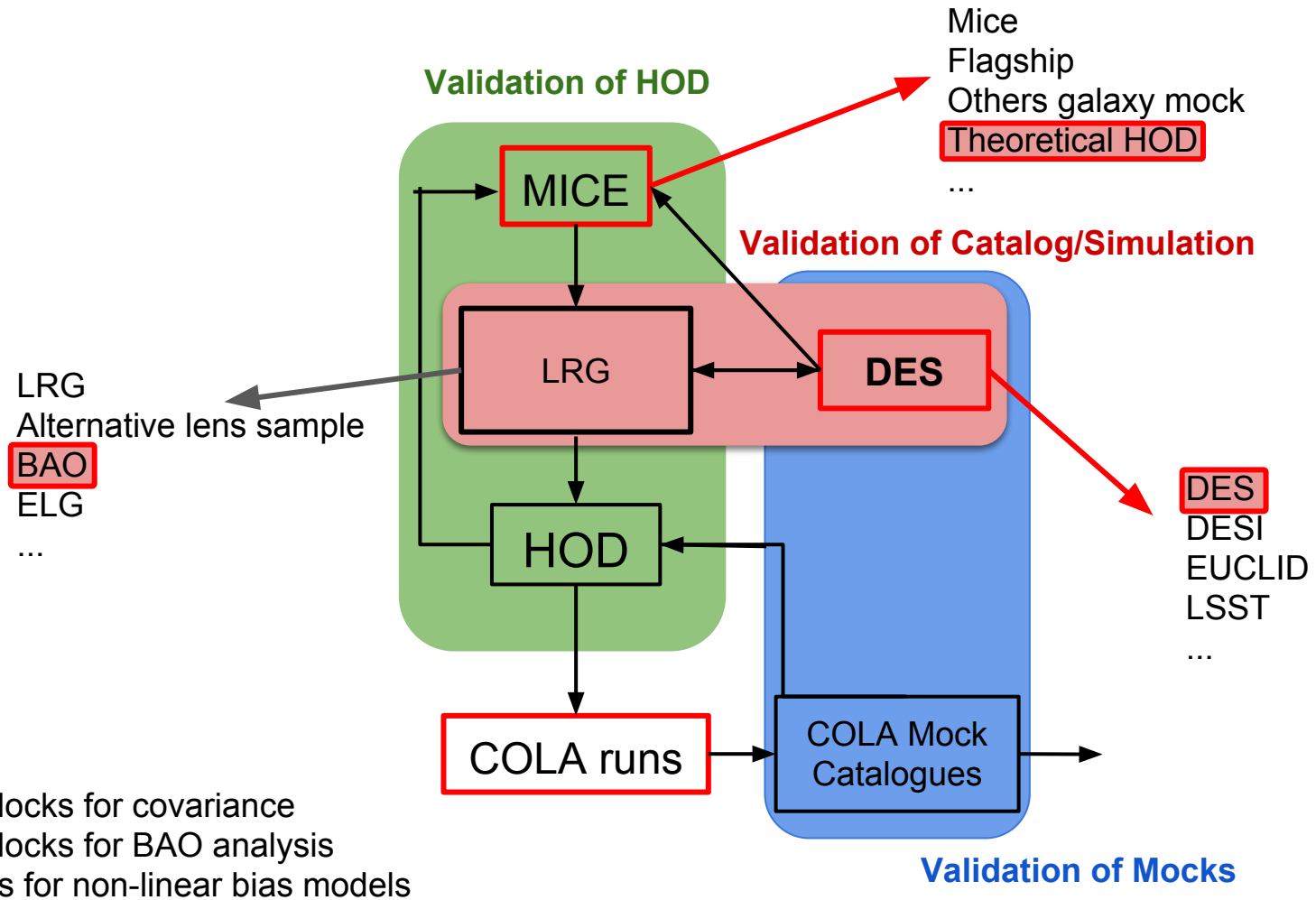
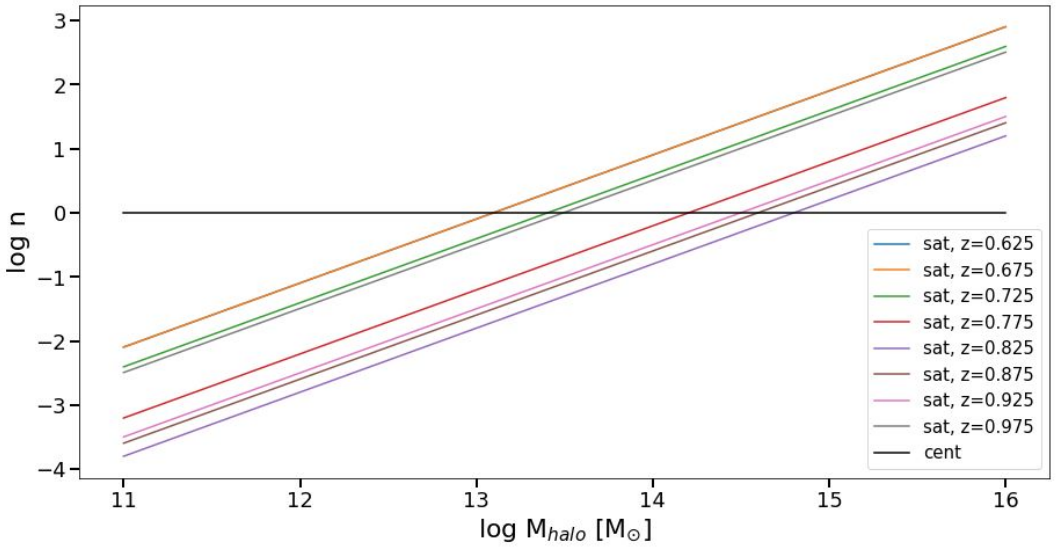


- ICE-COLA Mocks for covariance
- ICE-COLA Mocks for BAO analysis
- HOD analysis for non-linear bias models (using MICE)

ICE-COLA Mocks for BAO

First attempt is do with COLA the same as Avila S. did with Y1 data.
https://arxiv.org/abs/1712.06232



Simple HOD. Only 1 parameter

$$N_{\rm cent} = 1 \ , \qquad \langle N_{\rm sat} \rangle = \frac{M_h}{M_1} \ ,$$

Also assign luminosity

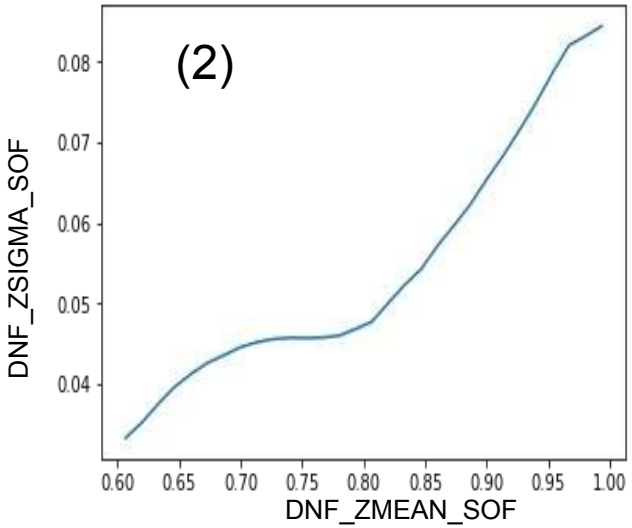
$$\log_{10}(l_p) = \log_{10}(M_h) + \Delta_{LM} \cdot R^{\rm gauss}_{\mu=0\ \sigma=1}$$

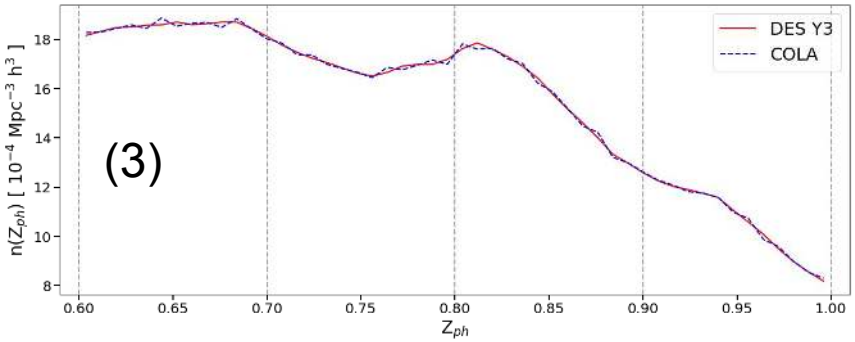
The abundance is then fixed by setting luminosity thresholds (like a second parameter for HOD)

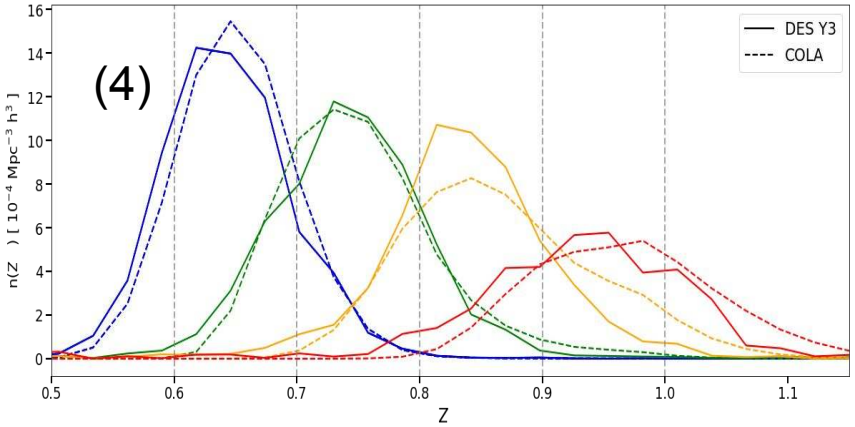
1- Use HOD of Avila S (previous)
2- Assign photo_z using **BAO_DESY3['DNF_ZSIGMA_SOF']** (median in z-bins)
3- Luminosity threshold in order to match n(photo_z)
4- Select sample in photo_z bins,
5 - Measure clustering

Next steps

- Theory predictions (i.e. fit those w(theta)) (6)
- Theory covariance
- BAO fits



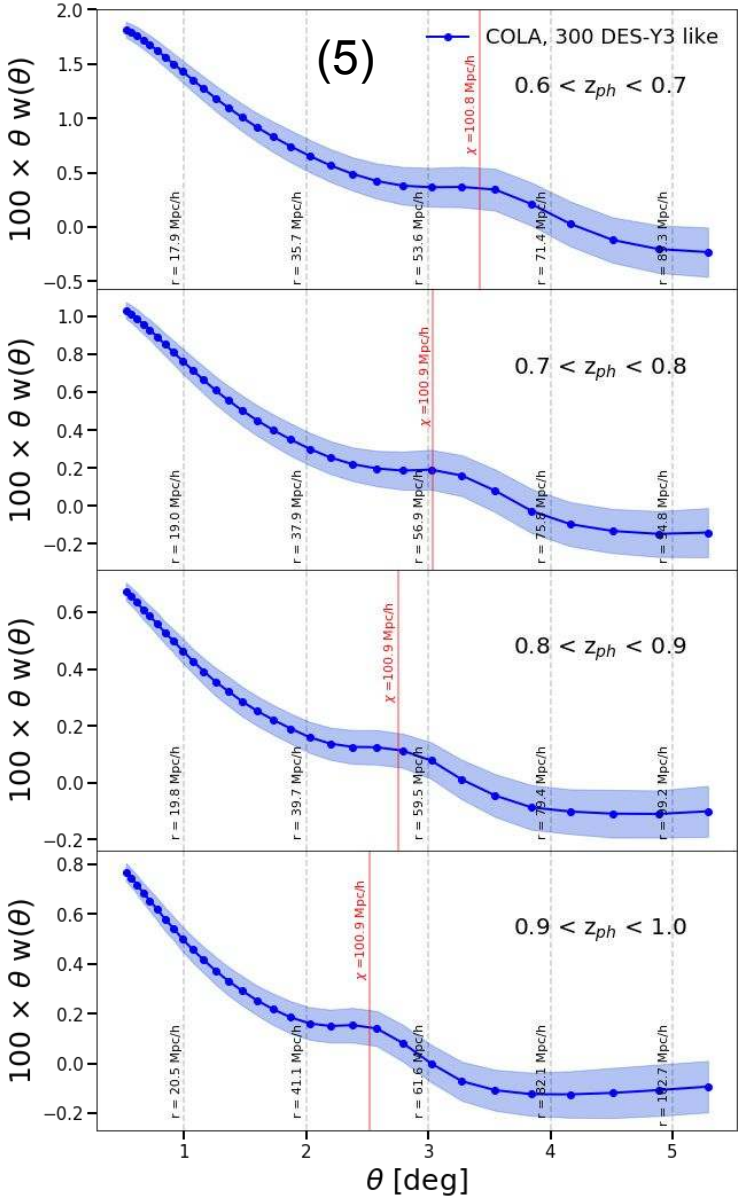


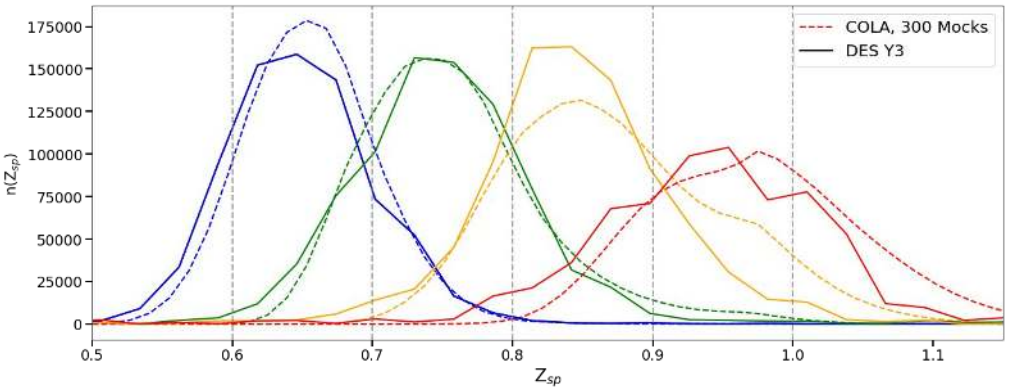


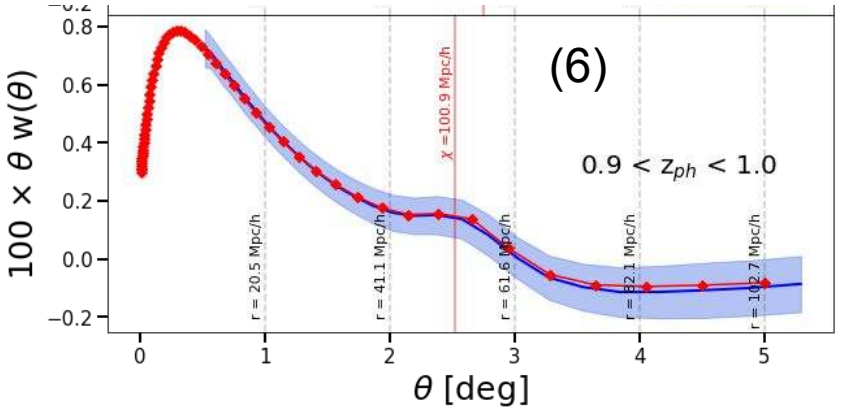
What we have so far

- 75 COLA runs
- 300 DES-Y3 like (4 Y3-mask per full sky) halo lightcones

- 300 Y3 mocks with HOD implemented
- 1200 Angular 2pcf measured (300 mocks x 4 bins)







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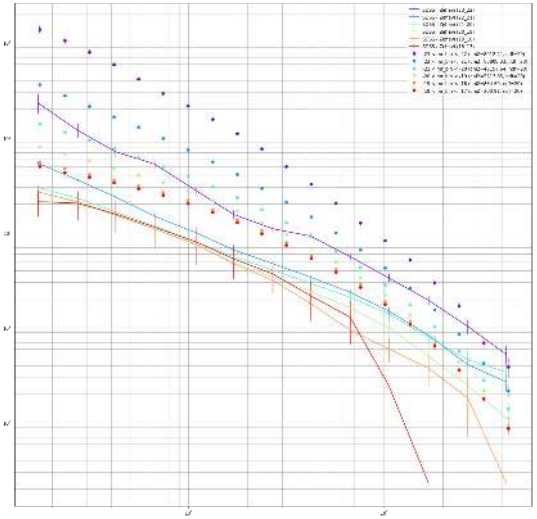
Other complementary works

TreeCorr code on hadoop
We have implemented this clustering code to run massively in parallel in a big-data platform

Code allow to apply mask, bins, jacknife, … whatever you want

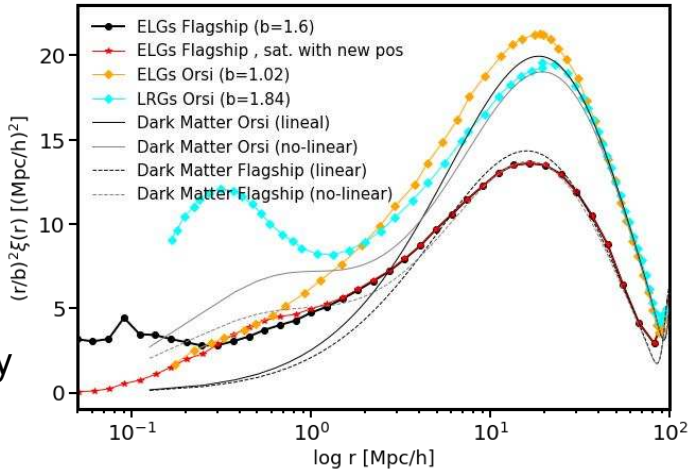
Example: Projected 2pcf of 66M gal. for different luminosities bins in 40’



Modeling LRGs and ELGs in galaxy mocks
Needed to provide a more realistic description of these samples

Analysing the way in how we place satellites and how this impact on real/redshift space and on cosmological parameters prediction.

Radial distribution: NFW, triaxiality, concentration, ….
Velocity structure: single Gaussian distribution, fit to line-of-sight velocity distribution, a two-Gaussian fit,...



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Thanks!