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THE THREE HUNDRED PROJECT

CLUSTERS GALAXY DENSITY FROM HIGH RESOLUTION DARK MATTER ONLY SIMULATIONS WITH REALISTIC SAMS AND ITS APPLICATION TO THE EUCLID SURVEY

UAM Universidad Autónoma de Madrid

mm Universe 2023

OUTLINE

I. Cluster Cosmology and Selection function

II. Cluster injection method

III. Resolution effects in cluster properties from simulations

IV. Galaxy density profiles in Dark matter only vs Hydro simulations

V. Conclusions and Perspectives

CLUSTER COSMOLOGY

Cluster number counts

Catalog Selection Function (SF)

$$\frac{dN}{dz} = \int d\Omega \int \widehat{X}(z, M, l, b) \frac{dn}{dz dM d\Omega} dM$$

volume

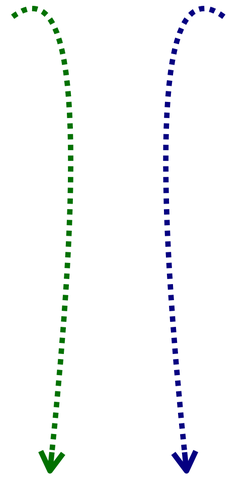
Halo Mass Function (HMF)

- **The Selection Function is the Instrumental Capability to detect a cluster. How to determine it?**
  - **Simulated Mock Catalogue**
  - **Cluster injection method**
  - **Others**

DETERMINE SELECTION FUNCTION

MOCK simulations

- Given a synthetic catalog of galaxies from numerical simulations (MOCK catalog)
- Apply detection algorithm
- Compared the Clusters from MOCK and detection algorithm catalog
- PROBLEM: Depends on simulations, which not necessary reproduce the real data



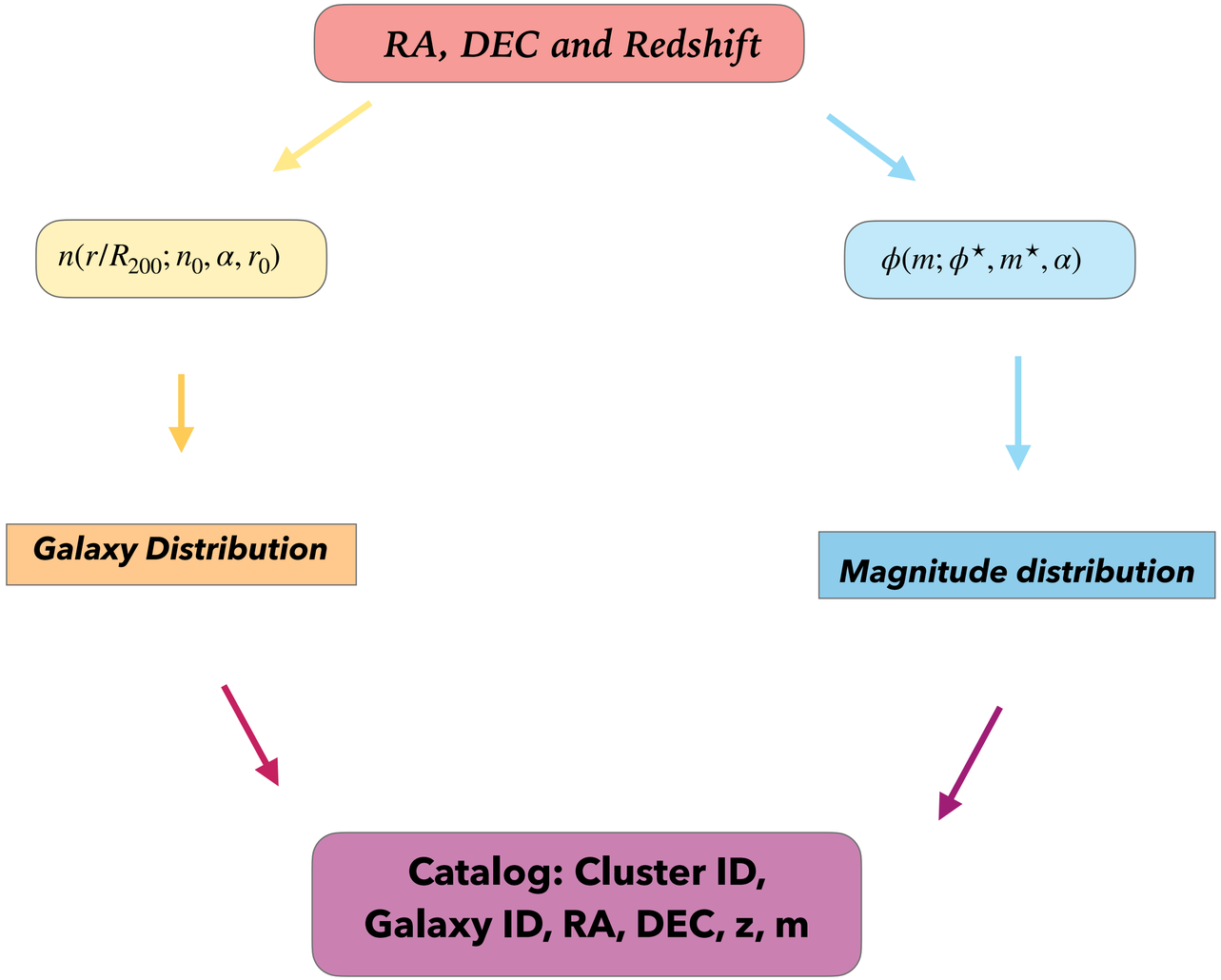
Cluster Injection

- From Survey Data we apply detection algorithm
- Study properties of detected clusters
- Simulate a cluster catalogue with this properties
- Inject it into the Survey Data
- Reapply Detection algorithm and look for the clusters we have defined

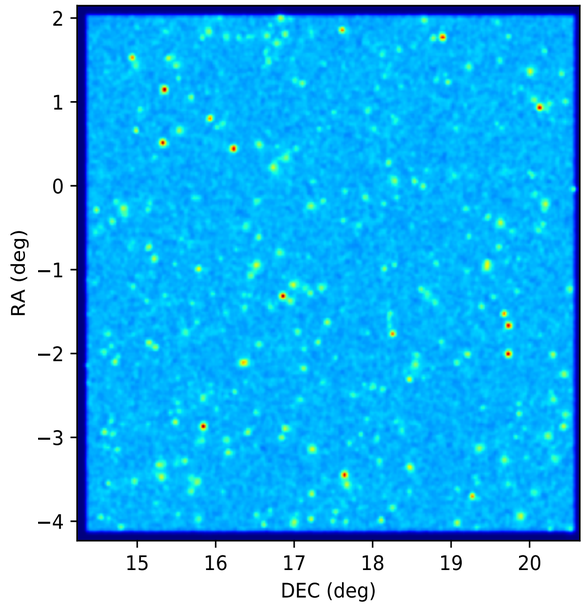
GOAL

- **Using cluster injection for Euclid survey data**
- **Data not available for the moment so we use simulations**

CATALOGUE SIMULATION FOR CLUSTER INJECTION METHOD



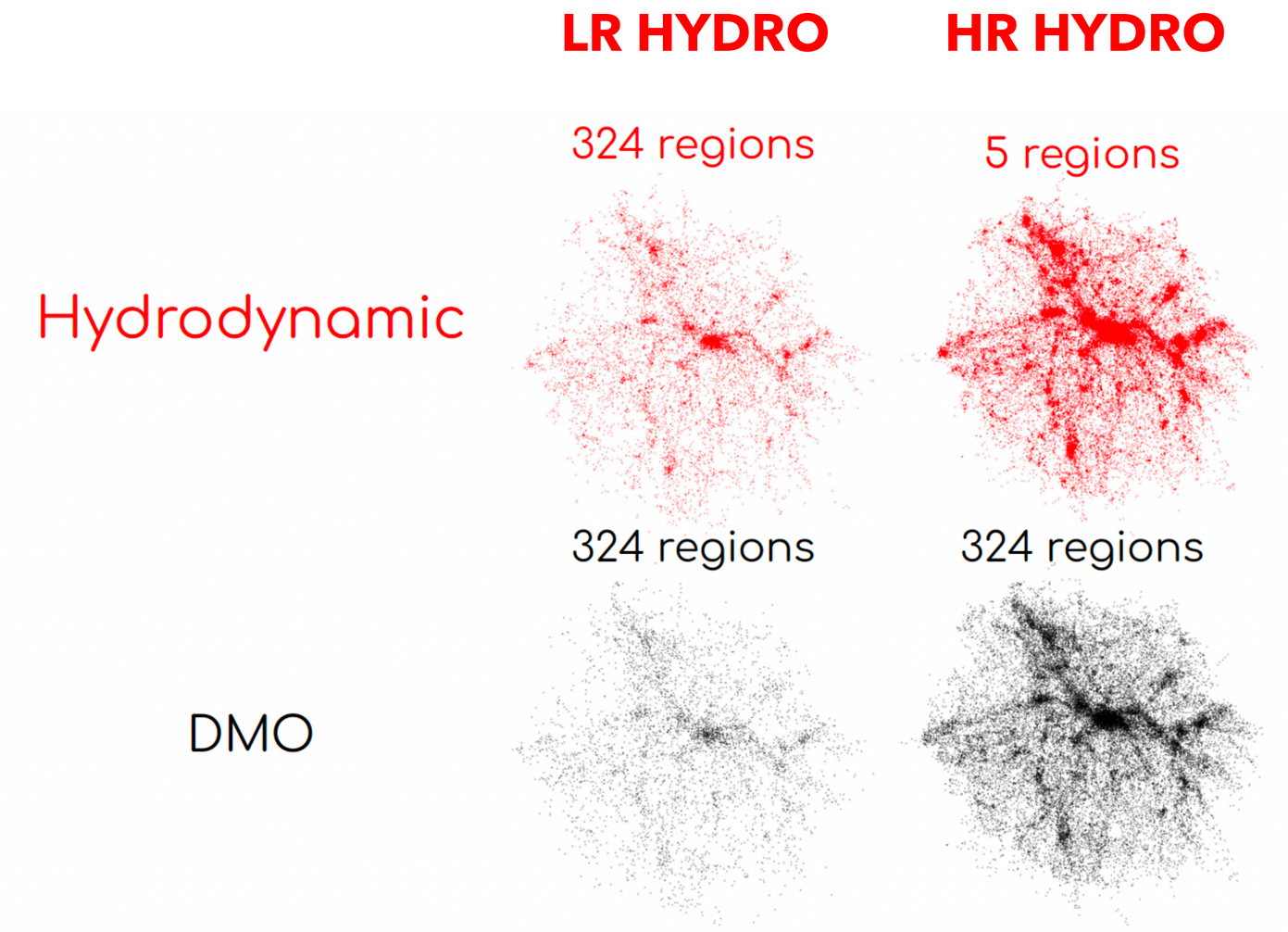
- Synthetic cluster galaxy member catalogue based on Euclid MOCK Catalogue cluster properties



Advantages of analytical clusters catalogue

- We keep the catalogue properties
- It can be used in real data with some modifications

TYPE OF SIMULATIONS AND CONVENTION NAME



- **Example of resolution for a 1 Gpc box**
  - **Millenium (EUCLID) -> 5200^3 particles**
  - **The 300th -> 3840^3 particles (3K)**
  - **The 300th HR -> 7680^3 particles (7K)**
- **GOAL:**
  - Compute LF and cluster galaxy distribution with Hydro simulations.
  - Check resolution effects in the cluster galaxy distribution for low and high resolution in dark matter only simulations and comparing with baryonic effects in low resolution hydrodynamical simulations
    - Previous similar analysis Dolag et al 2009 used only 8 clusters.
    - We use 324 cluster regions

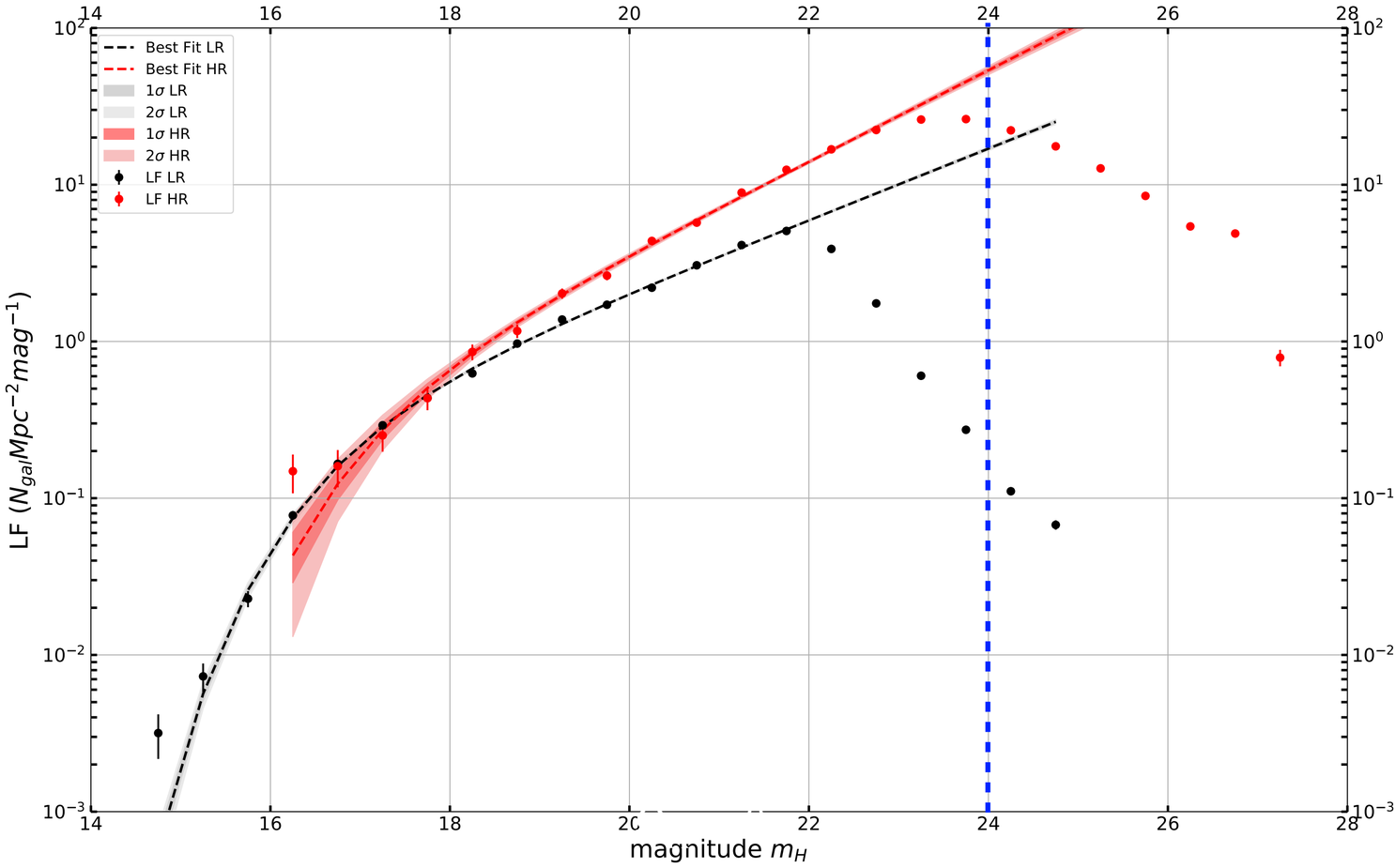
LUMINOSITY FUNCTION

Plot information

- Number of galaxies per area and magnitude vs Apparent magnitude in the H band.
- HR HYDRO (**Red**) and LR HYDRO (**Black**)
- Schechter Function for the fit
- Vertical **Blue** line -> Euclid Observational Magnitude Limit

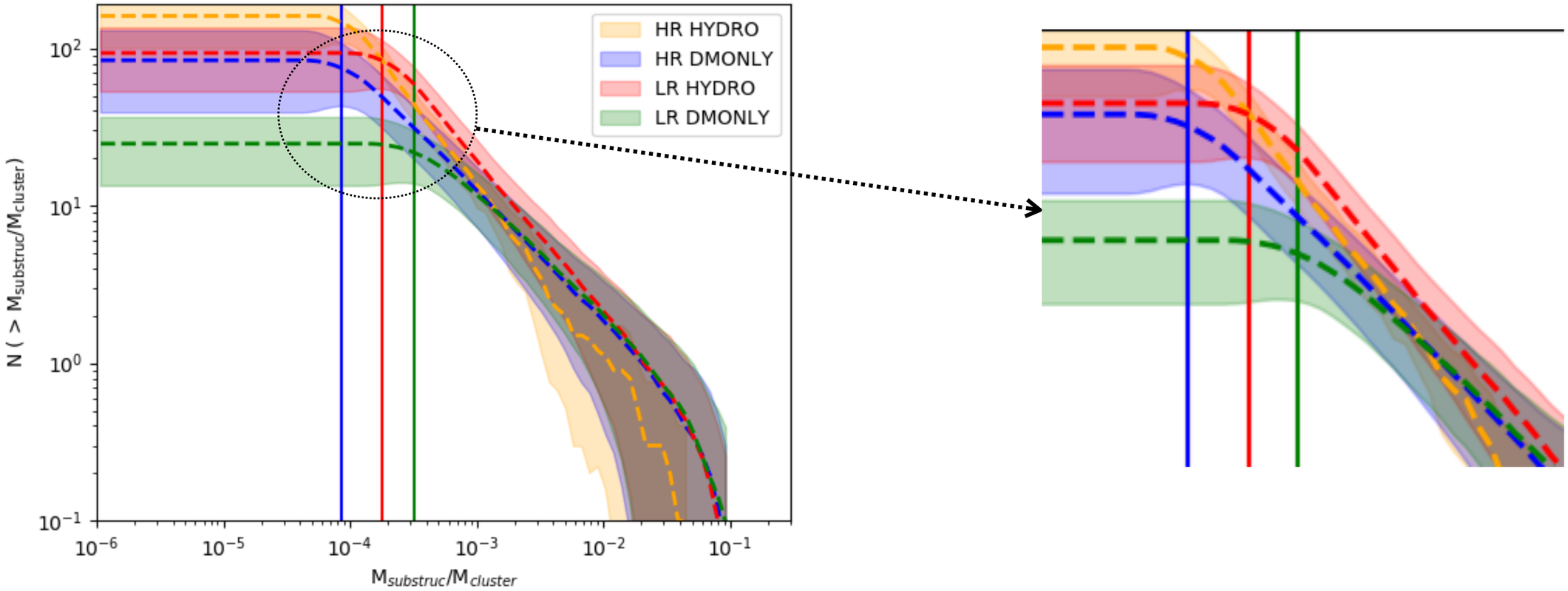
Conclusions

- The Schechter Model for the HR cluster gives a good fit to the data
- Not enough resolution for computing LF in the LR HYDRO simulations
- HR HYDRO simulations are really expensive computationally talking
- Can we compute accurately the galaxy distribution? -> HR DMONLY simulations



3D SUBHALO MASS FUNCTION

- Cumulative number of galaxies as a function of the ratio between their masses and their cluster mass.
- Baryonic physics produces small galaxies than DM-only simulations for the same resolution.
- Increasing resolution in DM-only simulations produce as much galaxies as LR HYDRO. However, HR DMONLY produces smaller galaxies.
- Resolution effects start affecting the results when we observe the flattering of the curves.
- We will use a mass cut (red vertical line) to study cluster properties avoiding resolution effects between HR DMONLY and LR HYDRO.
- Jimenez et al 2023 in preparation



3D GALAXY DENSITY RADIAL PROFILE

- We will compare the HR DMONLY with LR HYDRO simulations
- We compute the Density Profile for the actual 300th cluster simulations establishing a mass cut in the 3D subhalo mass function for avoiding resolution problems.
- Theoretical 3D Einasto model and MCMC fit
- We find more clusters in the inner region for Hydro simulations

$$\rho(\mathbf{r}/\mathbf{R_{200}}) = \rho_0 \exp\left(\frac{-2}{\alpha}\left[\left(\frac{\mathbf{r}}{\mathbf{r_0}}\right)^{\alpha} - 1\right]\right)$$

Curvature

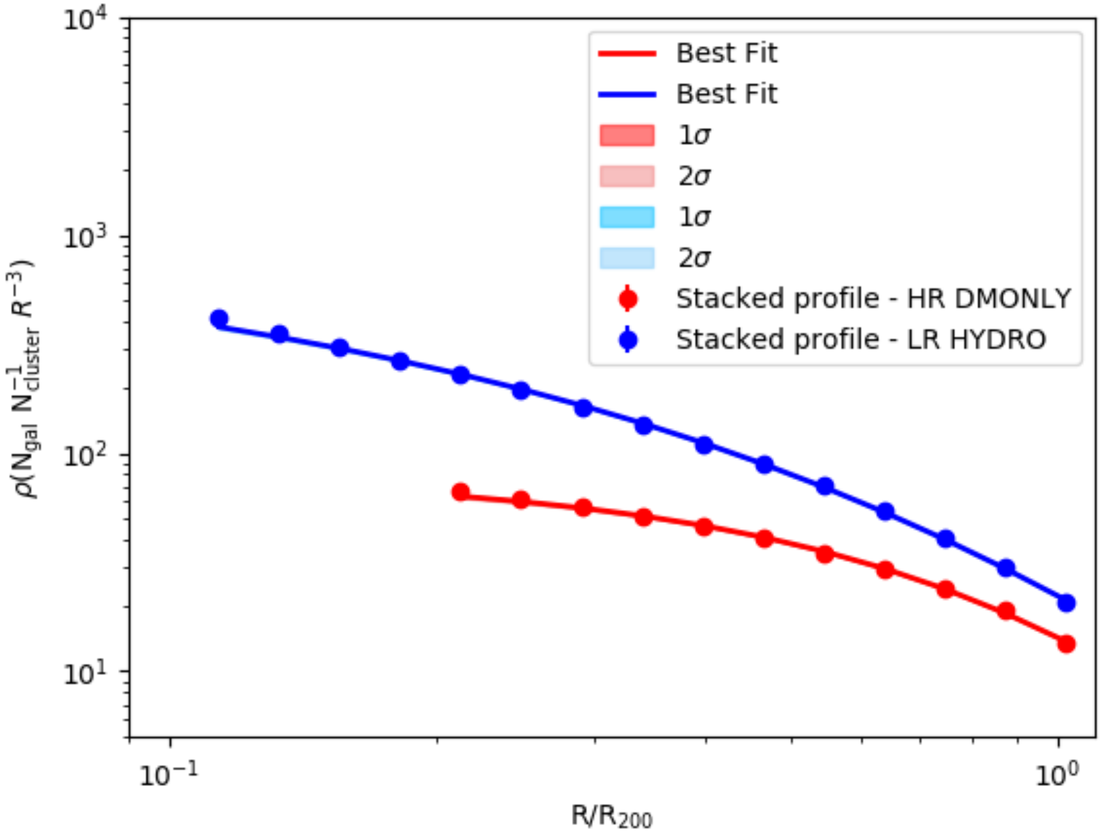
Einasto et al 1965
Springel et al 2008

Normalization

Curvature change point

z = 1

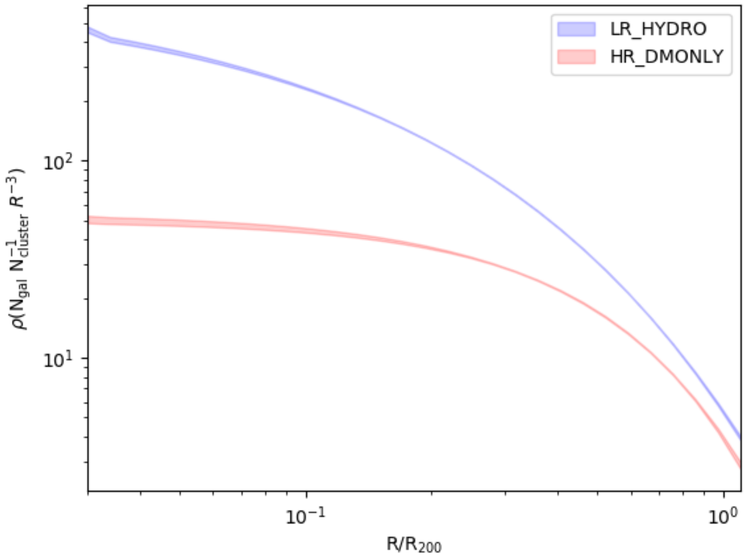
$M < 10^{15} M_{\odot}$



3D GALAXY DENSITY RADIAL PROFILE FROM EINASTO FIT

Plot information

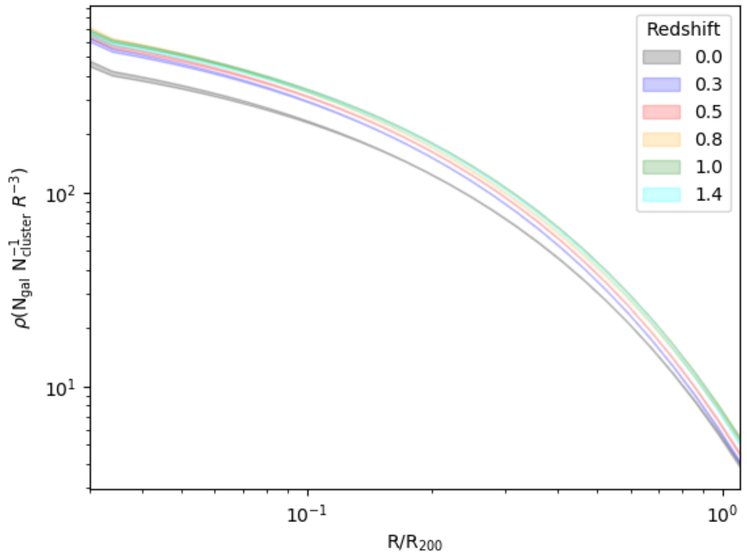
- Top: Galaxy Density Radial Profile for LR HYDRO (Blue) and HR DMONLY (Red) from Einasto Model's Best-Fit. Redshift: z = 0, Mass: $M < 10^{15} M_{\odot}$
- Bottom: Galaxy Density Radial Profile evolution with redshift for LR HYDRO (LEFT) and HR DMONLY (RIGHT) from Einasto Model's Best-Fit. Mass: $M < 10^{15} M_{\odot}$



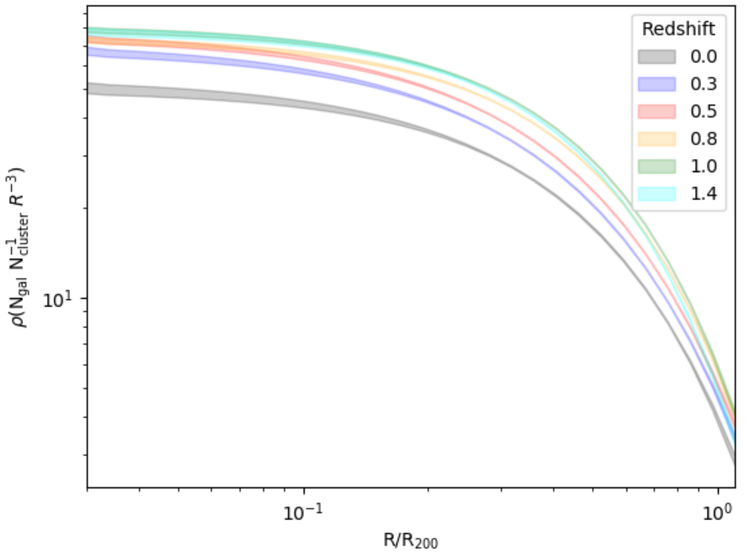
Conclusions

- We've been able to simulate the galaxy density radial profile from an analytical model.
- When applying the resolution mass cut, the LR HYDRO simulations produces more galaxies both in the inner and outer part of the cluster. With a steep drop towards the outskirt
- At low mass, when redshift increase so it does the galaxy density

LR HYDRO



HR DMONLY

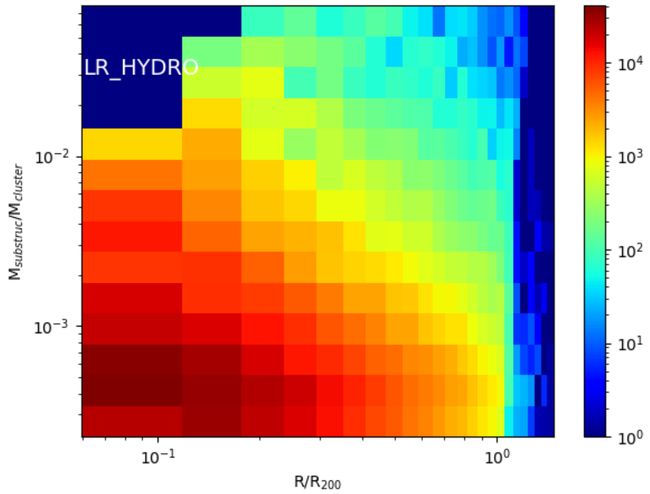


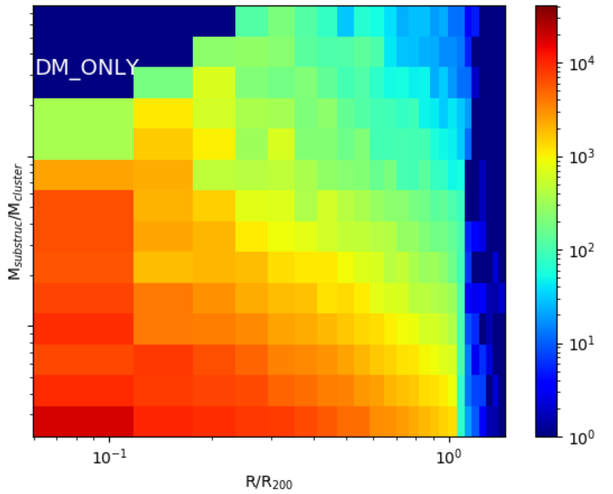
RADIAL GALAXY DENSITY DISTRIBUTION

LR HYDRO **HR DMONLY**

Z = 0

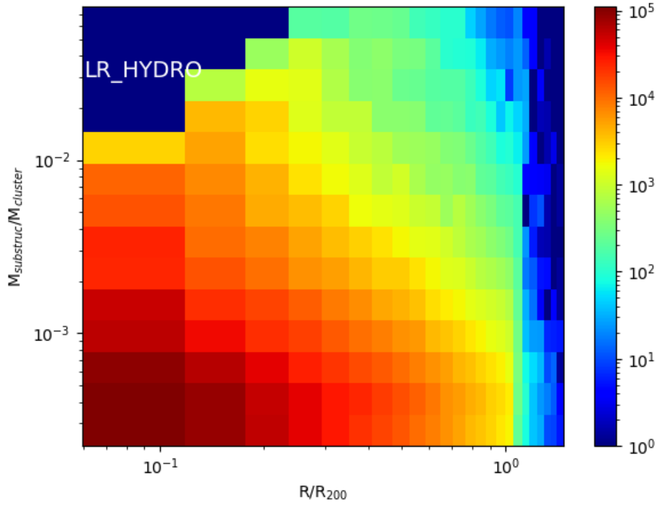
$M < 10^{15} M_{\odot}$

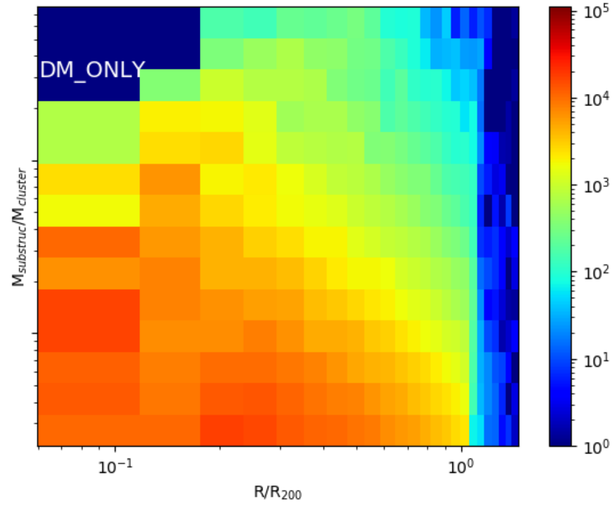




Z = 1

$M < 10^{15} M_{\odot}$





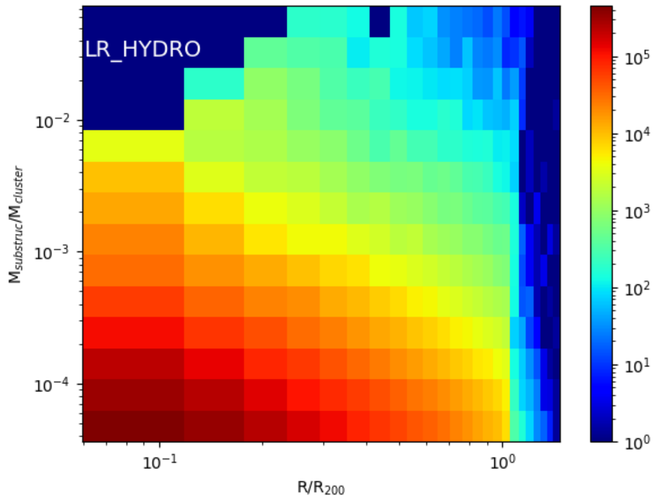
- Overall LR HYDRO present more galaxies than HR DMONLY
- Low mass galaxies are the main component in number density for both simulations
- Lower mass galaxies are present at higher redshift
- Galaxy density in the inner part of the cluster increase with redshift at low mass

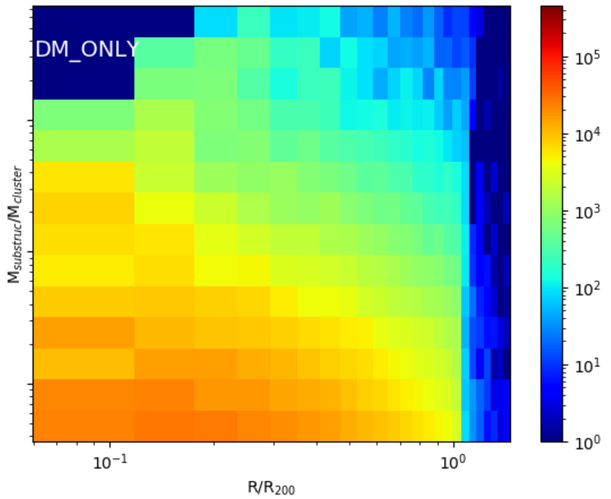
RADIAL GALAXY DENSITY DISTRIBUTION

LR HYDRO | **HR DMONLY**

Z = 0

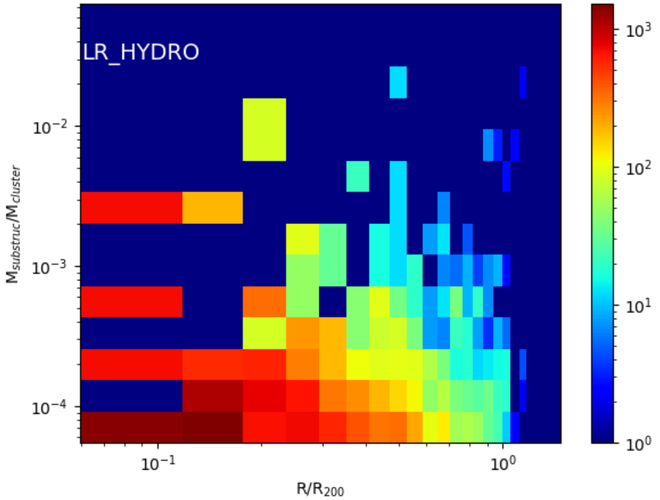
$M > 10^{15} M_{\odot}$

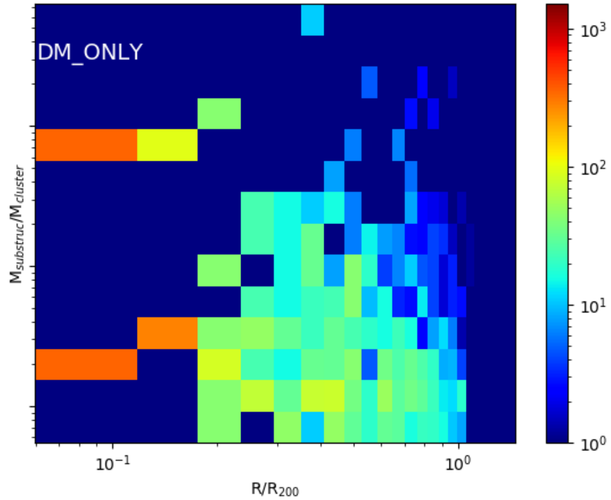




Z = 1

$M > 10^{15} M_{\odot}$

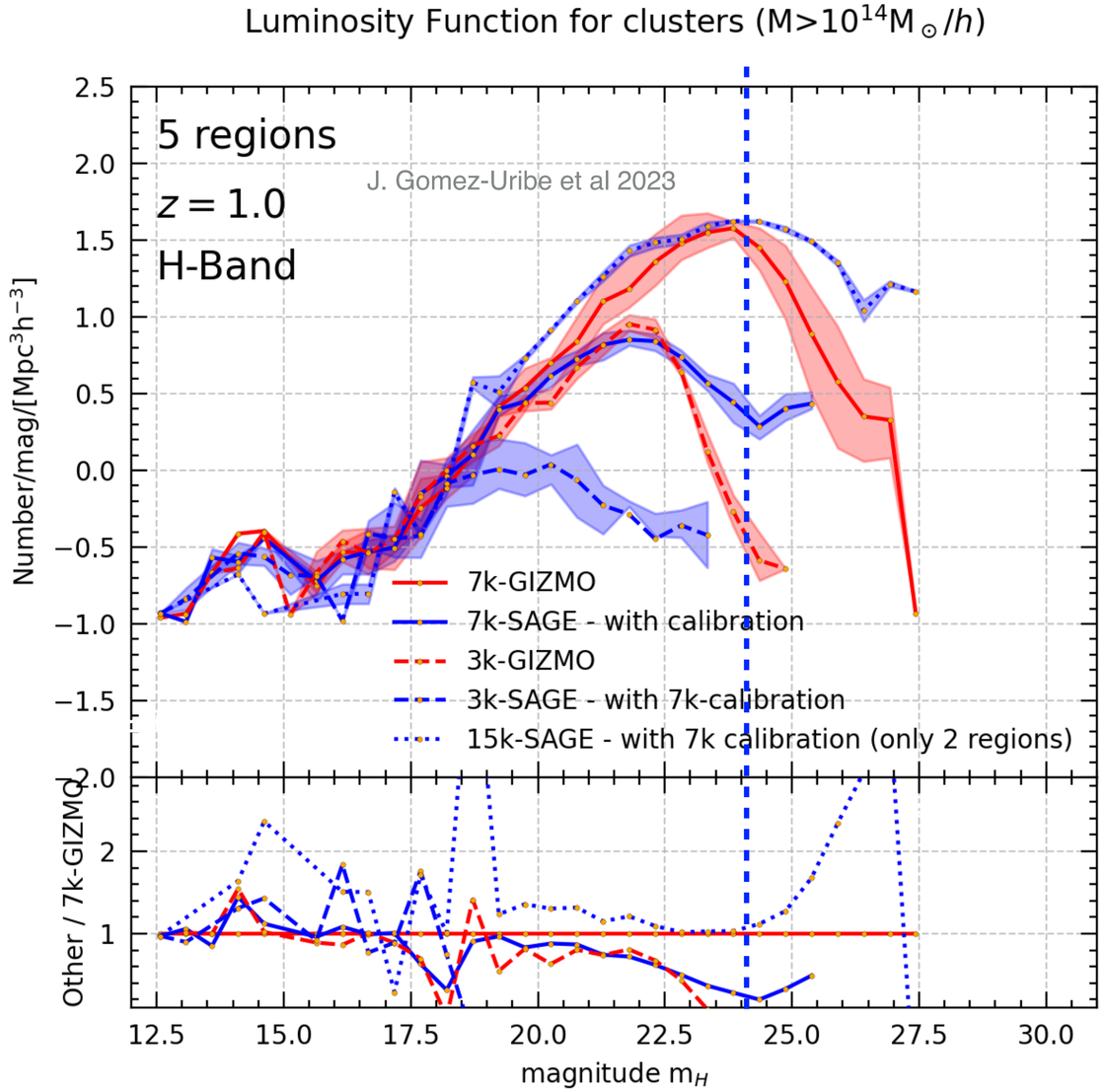




- Overall LR HYDRO present more galaxies than HR DMONLY
- Low mass galaxies are the main component in number density for both simulations
- Galaxy density increase with redshift
- Low mass galaxies are present at high mass and redshift for LR HYDRO while they don't survive in HR DMONLY simulations

FUTURE WORK

- Vertical dashed line -> Euclid Observational Limit
- 15K DMONLY converges with 7K HYDRO (a higher resolution in DMONLY shows the baryonic effect that make small particles survives)
- Run all the regions in 15K DMONLY and calibrate with SAGE.
- Construct a synthetic catalogue with the properties of the Einasto profile and Schechter function
- Run detection algorithm. Compare results with SAMs simulations.
- Combined this dataset with other photometric and spectroscopic surveys to reach small galaxies in massive clusters. Study properties for several filters like LF or colors.



CONCLUSIONS

- We use the 300th clusters for deriving cluster properties: LF and Galaxy distribution
- Luminosity function needs a higher resolution to be computed. However galaxy distribution can be inferred from this simulations if resolution effects are taken into account.
- It is possible to find a threshold in mass for which resolution effects are negligible
    - HYDRO shows more structures towards the center and an evolution with redshift
- Detection algorithm performance might be affected by these differences.
- 15k DMONLY simulations combined with SAMs could be used to estimate 7K HYDRO cluster properties

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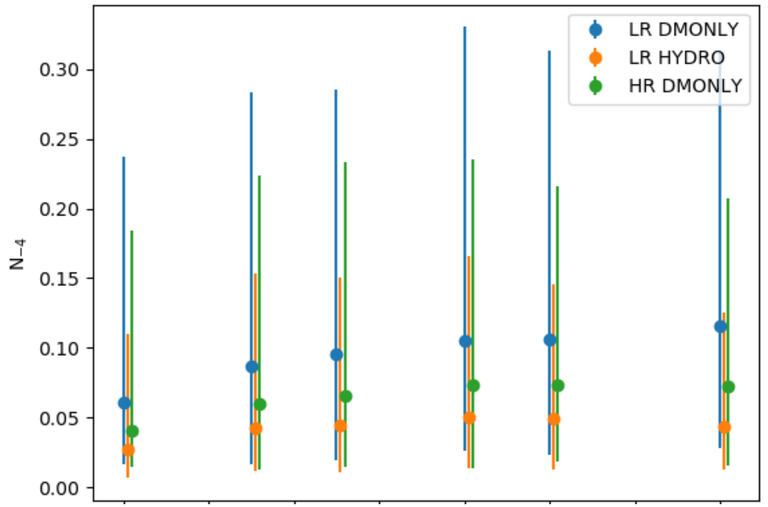
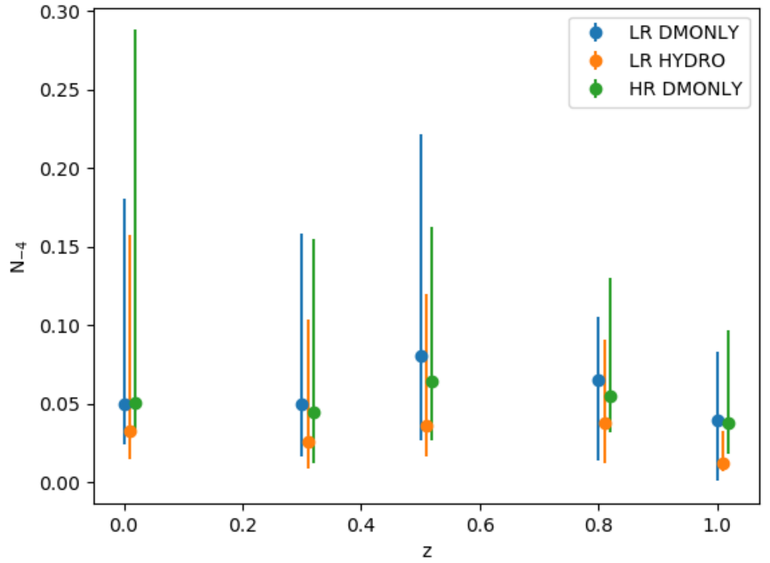
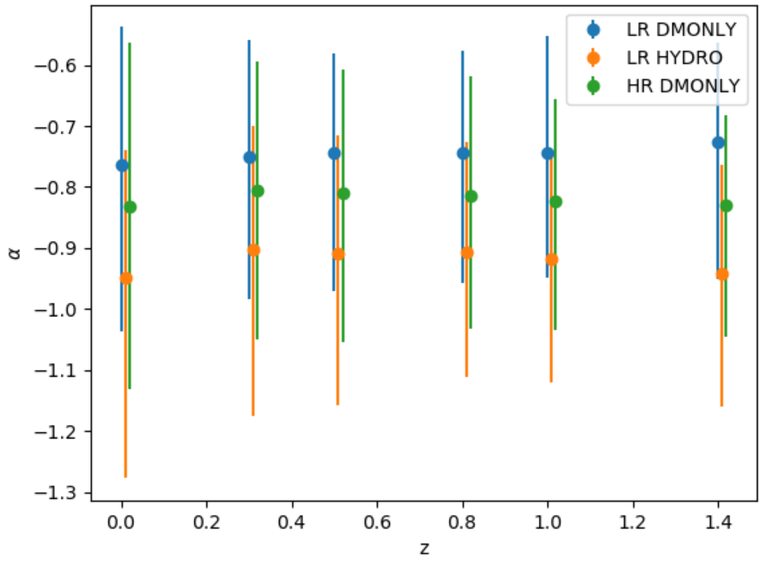
THANKS FOR YOU ATTENTION !

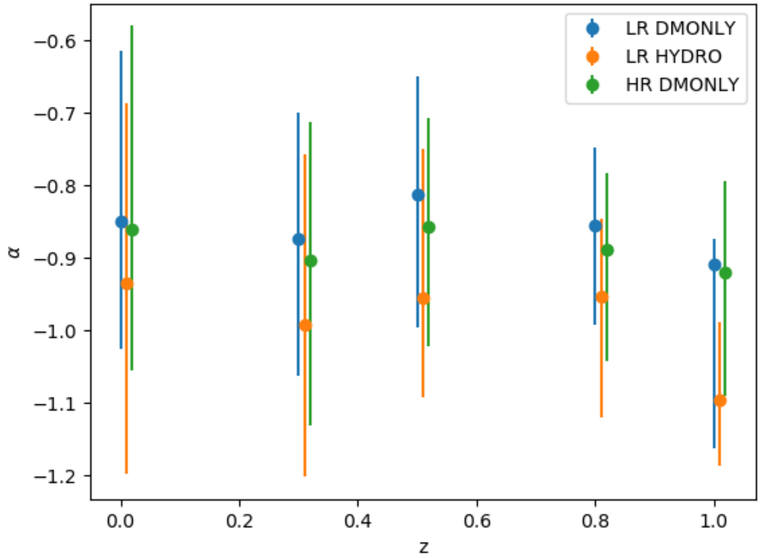
3D SUBHALO MASS FUNCTION REDSHIFT PROPERTIES

- Powerlaw fit:
  - $$N_{gal} = N\left(\frac{M_{substructure}}{M_{parent}}\right)^{\alpha}$$

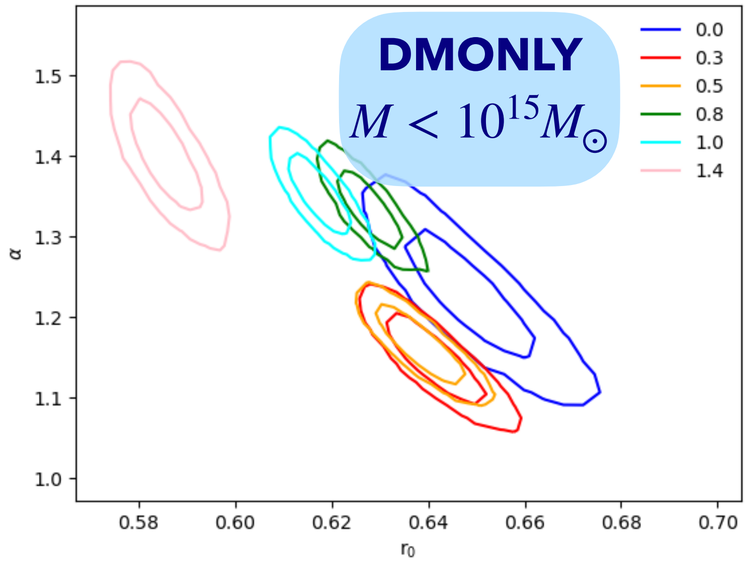


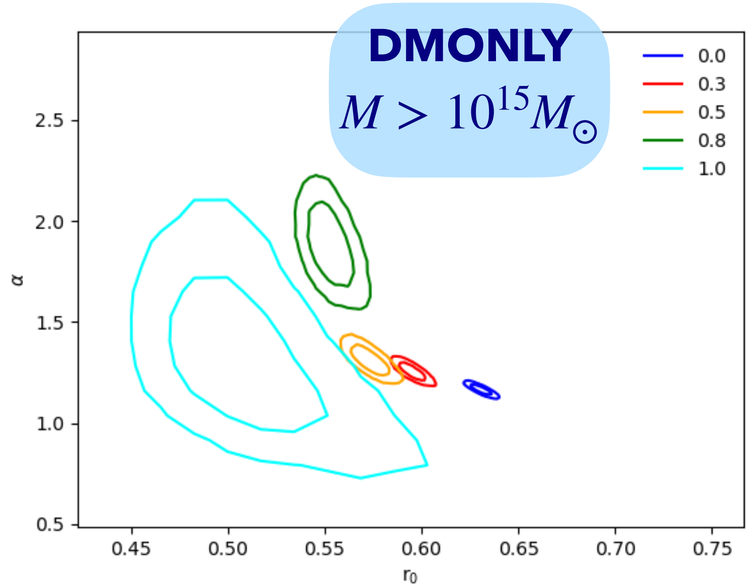


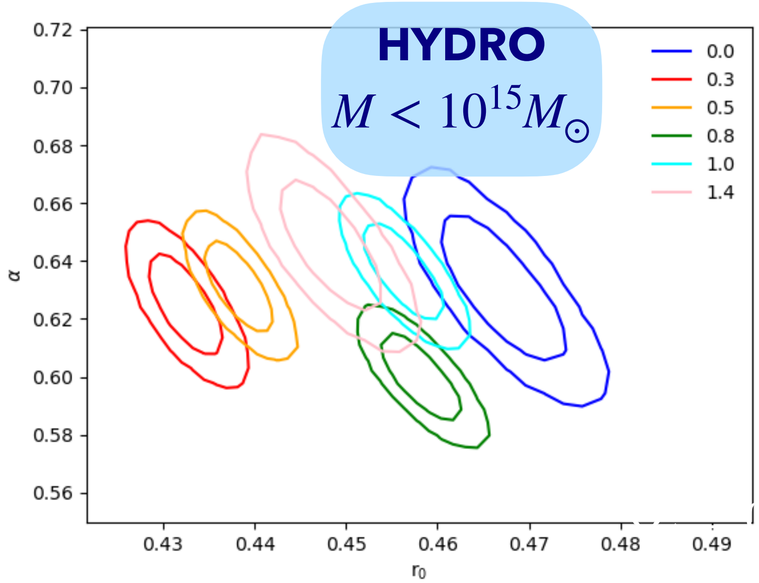


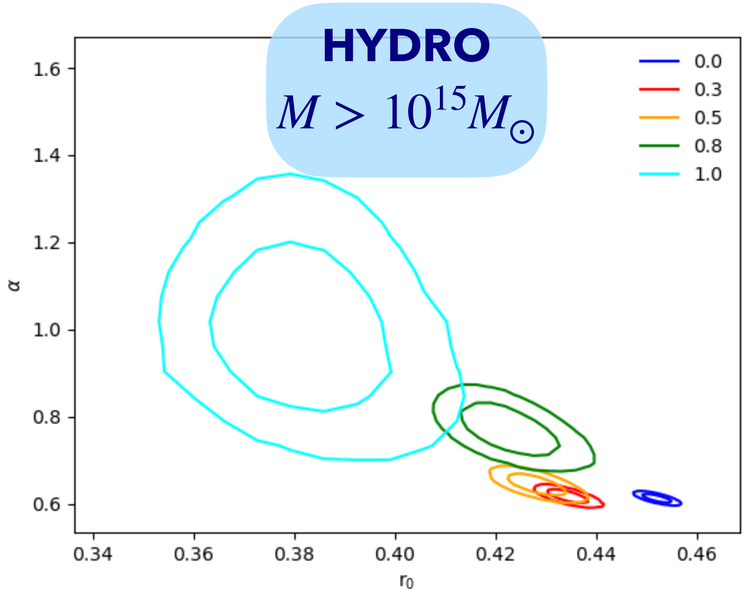


α VS r_0


DMONLY
$M < 10^{15} M_\odot$
0.0
0.3
0.5
0.8
1.0
1.4
α
r0

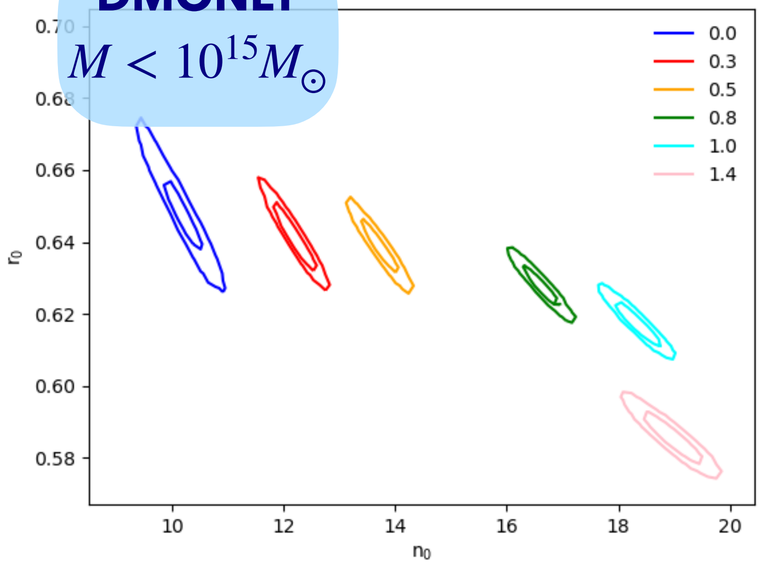

DMONLY
$M > 10^{15} M_\odot$
0.0
0.3
0.5
0.8
1.0
α
r0


HYDRO
$M < 10^{15} M_\odot$
0.0
0.3
0.5
0.8
1.0
1.4
α
r0

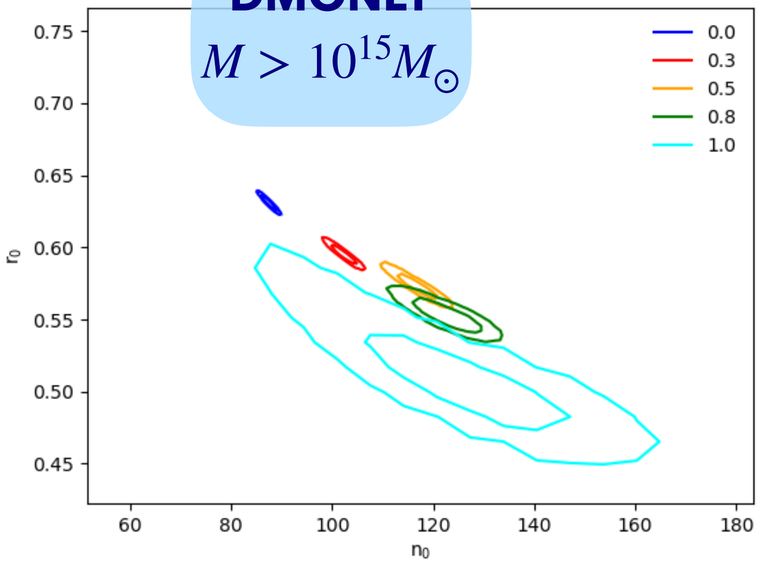

HYDRO
$M > 10^{15} M_\odot$
0.0
0.3
0.5
0.8
1.0
α
r0

α VS n_0

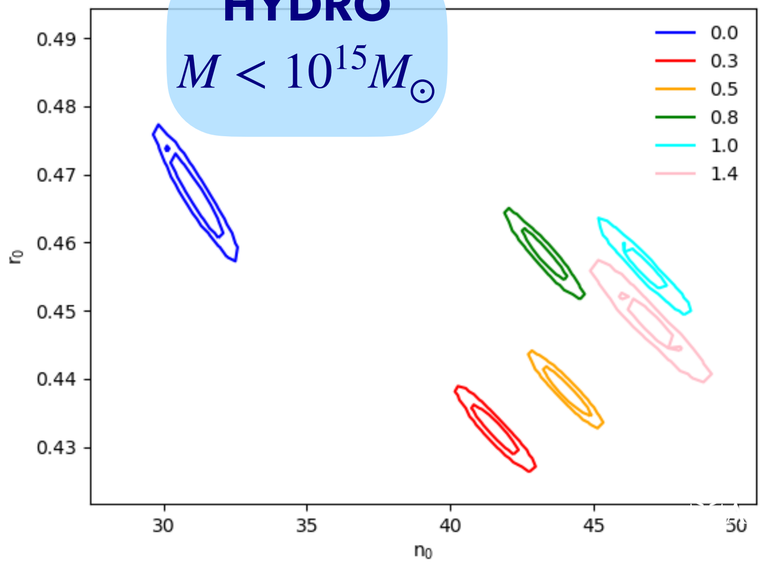
DMONLY
$M < 10^{15} M_\odot$



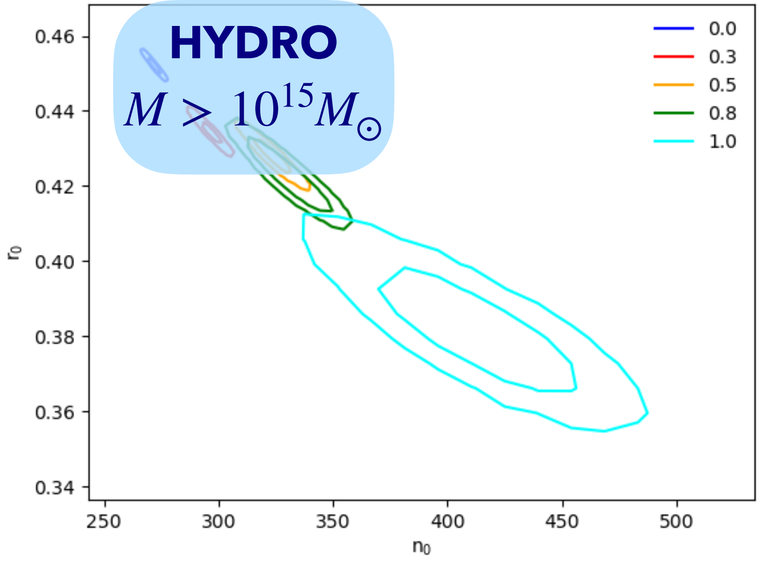
DMONLY
$M > 10^{15} M_\odot$



HYDRO
$M < 10^{15} M_\odot$



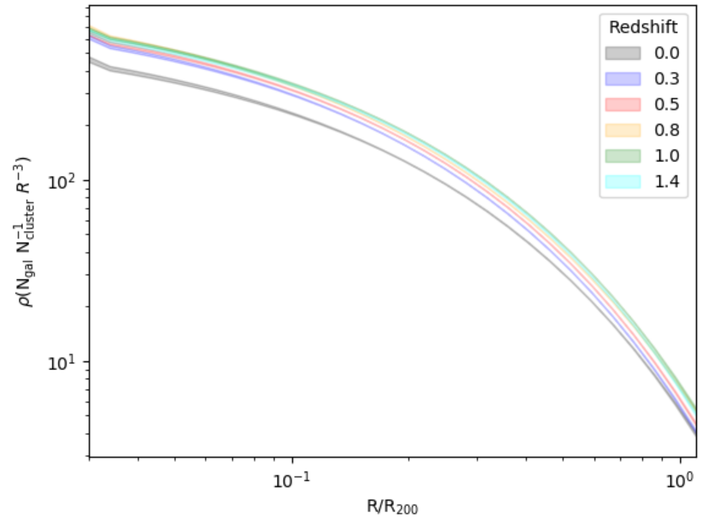
HYDRO
$M > 10^{15} M_\odot$

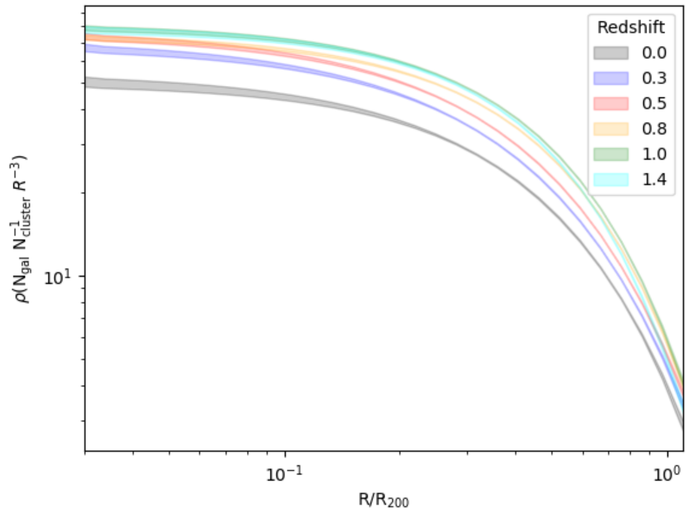


3D GALAXY DENSITY RADIAL PROFILE REDSHIFT EVOLUTION

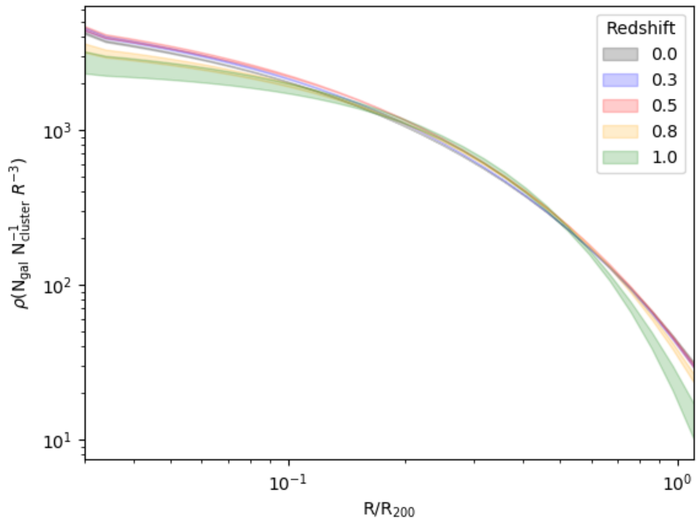
HYDRO **DMONLY**

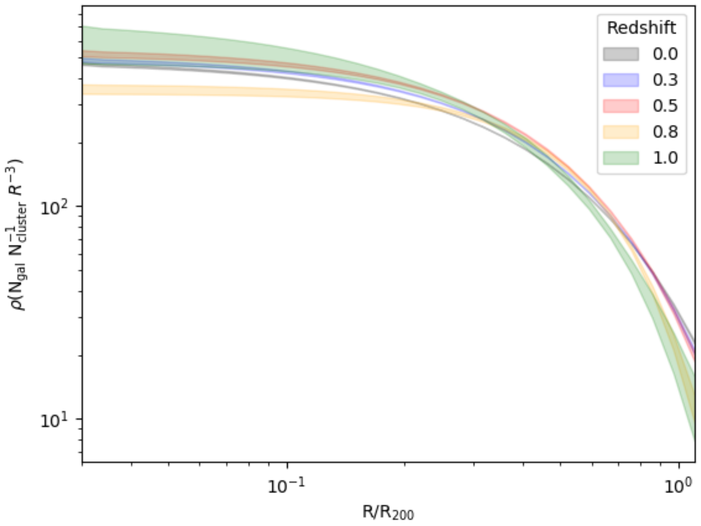
$M < 10^{15} M_{\odot}$





$M > 10^{15} M_{\odot}$





- Overall the galaxy density increase with redshift and mass.
- LR HYDRO present much more galaxies than HR DMONLY

LUMINOSITY FUNCTION

Plot information

- Number of galaxies vs Apparent magnitude in the H band.
- HR HYDRO (Red) and LR HYDRO (Blue / Black)
- Schechter Function for the fit
- Vertical Black line -> Euclid Observational Magnitude Limit