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THE THREE HUNDRED PROJECT: CONTRASTING CLUSTERS GALAXY DENSITY IN HYDRODYNAMICAL AND DARK MATTER SIMULATIONS

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

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

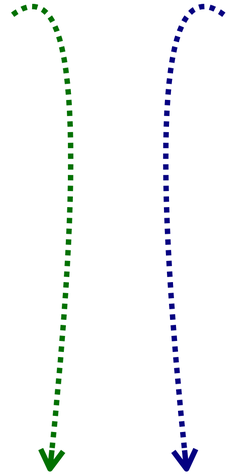
Halo Mass Function (HMF)

- **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

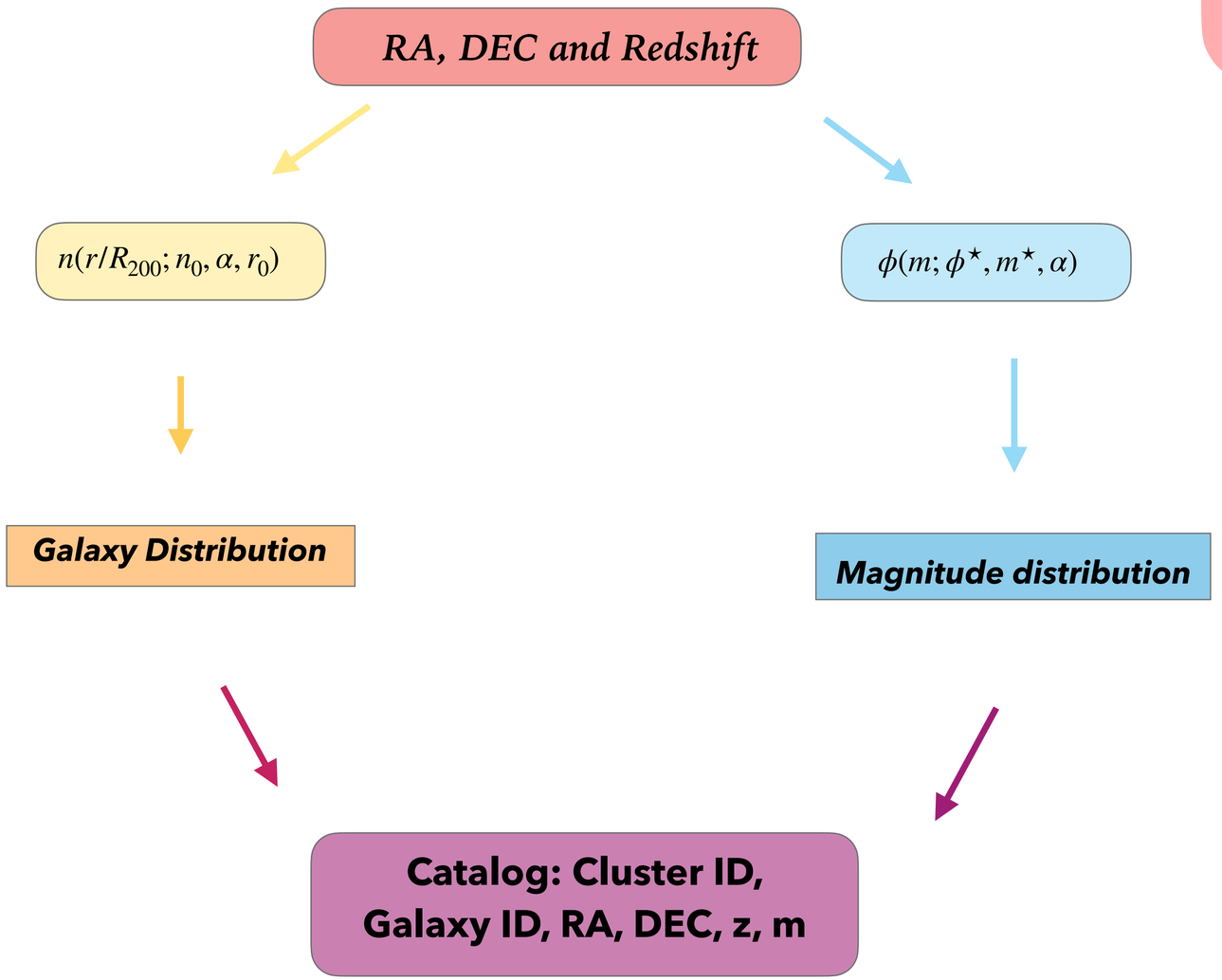
- From Survey Data we apply detection algorithm
- Study properties of detected clusters
- Simulate a cluster catalogue with this properties
- Inject it into the Survey Data
- Reapply Detection algorithm and look for the clusters we have defined

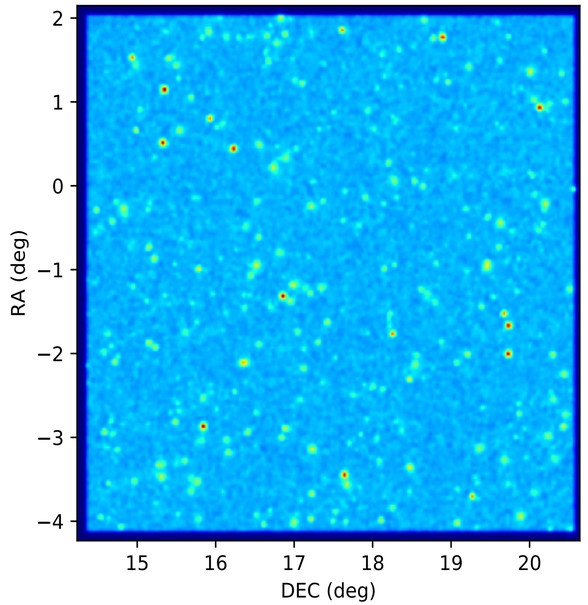
GOAL

- **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



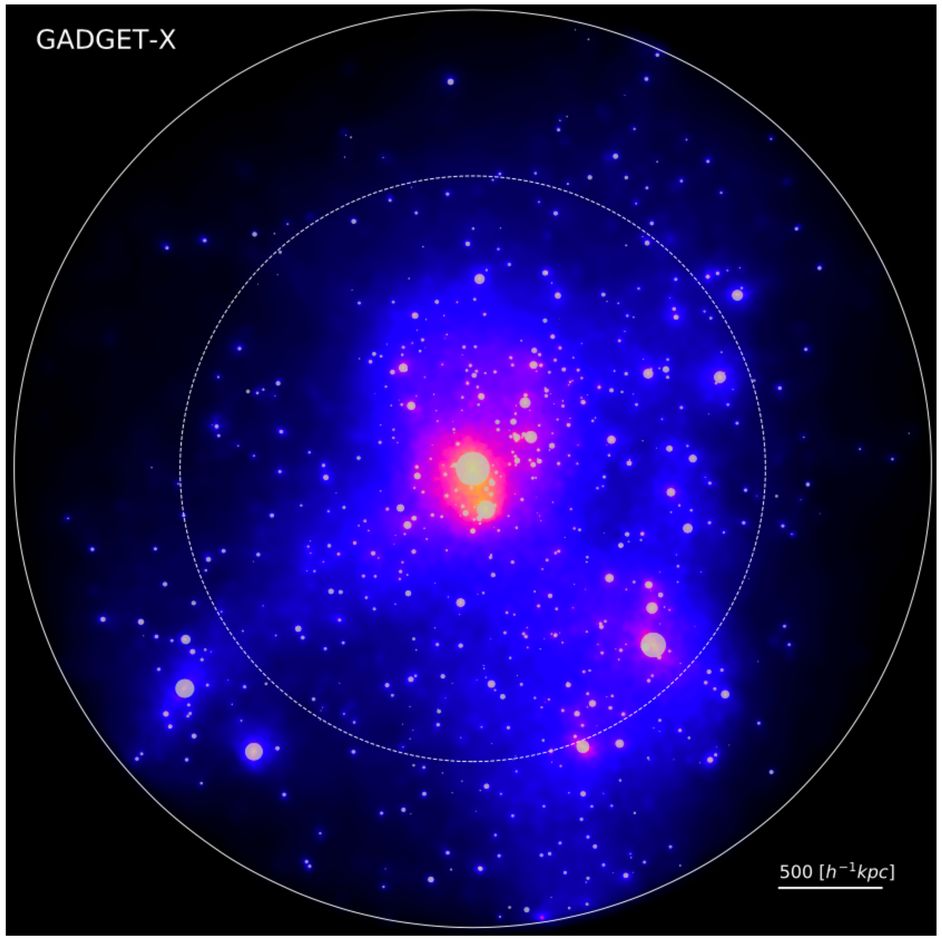


Advantages of analytical clusters catalogue

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

THE 300 PROJECT

- To determine “realistic” cluster properties we use the 300th Project hydrodynamical simulations
- We concentrate in the luminosity function (LF) and galaxy density profiles
- 324 Clusters at low resolution (DM and Hydro) and 68 at high resolution (DM) + 1 Hydro
- Resolution: $m_{DM} + m_{gas} = 1.5 \times 10^9 h^{-1} M_\odot$
- 1Gpc box –> 3840^3 particles



Blue color - Dark matter density
Red color - galaxy brightness
Symbol size - proportional to stellar mass

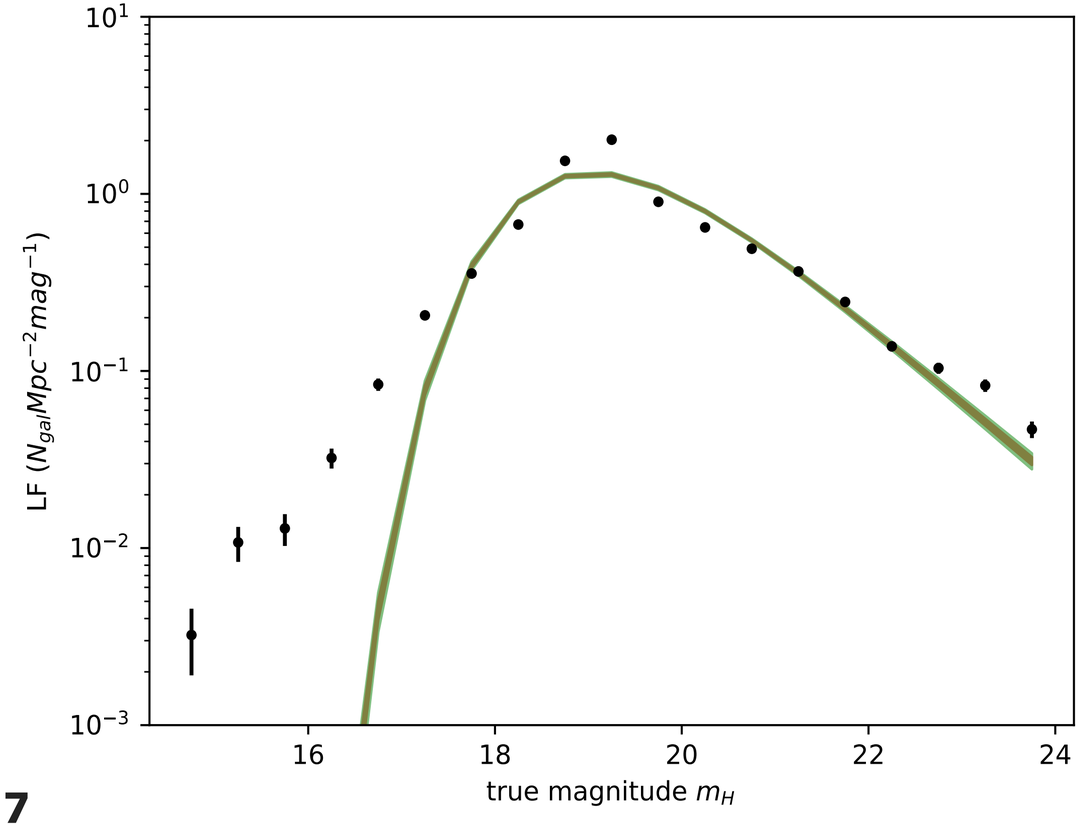
LUMINOSITY FUNCTION

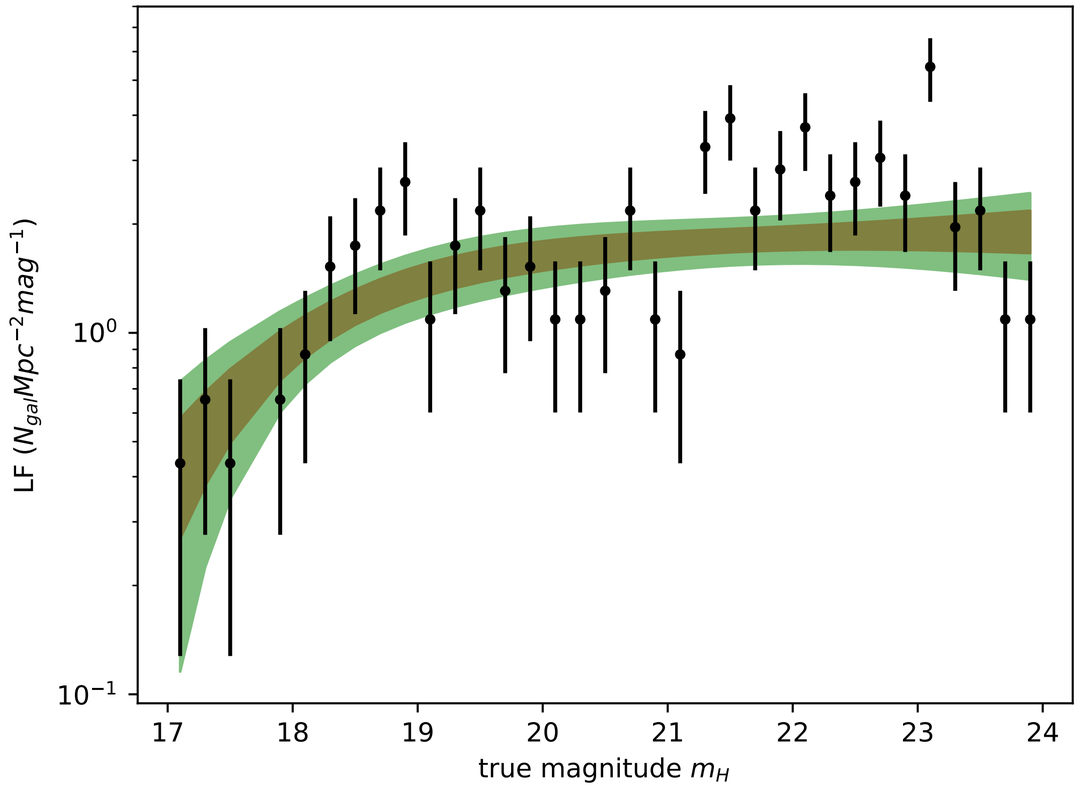
Plot information

- LEFT PLOT: 324 clusters with LOW resolution hydrodynamical simulations (LR HYDRO)
- RIGHT PLOT: 1 cluster with HIGH resolution hydrodynamical simulations (HR HYDRO)
- Schechter Function for the fit

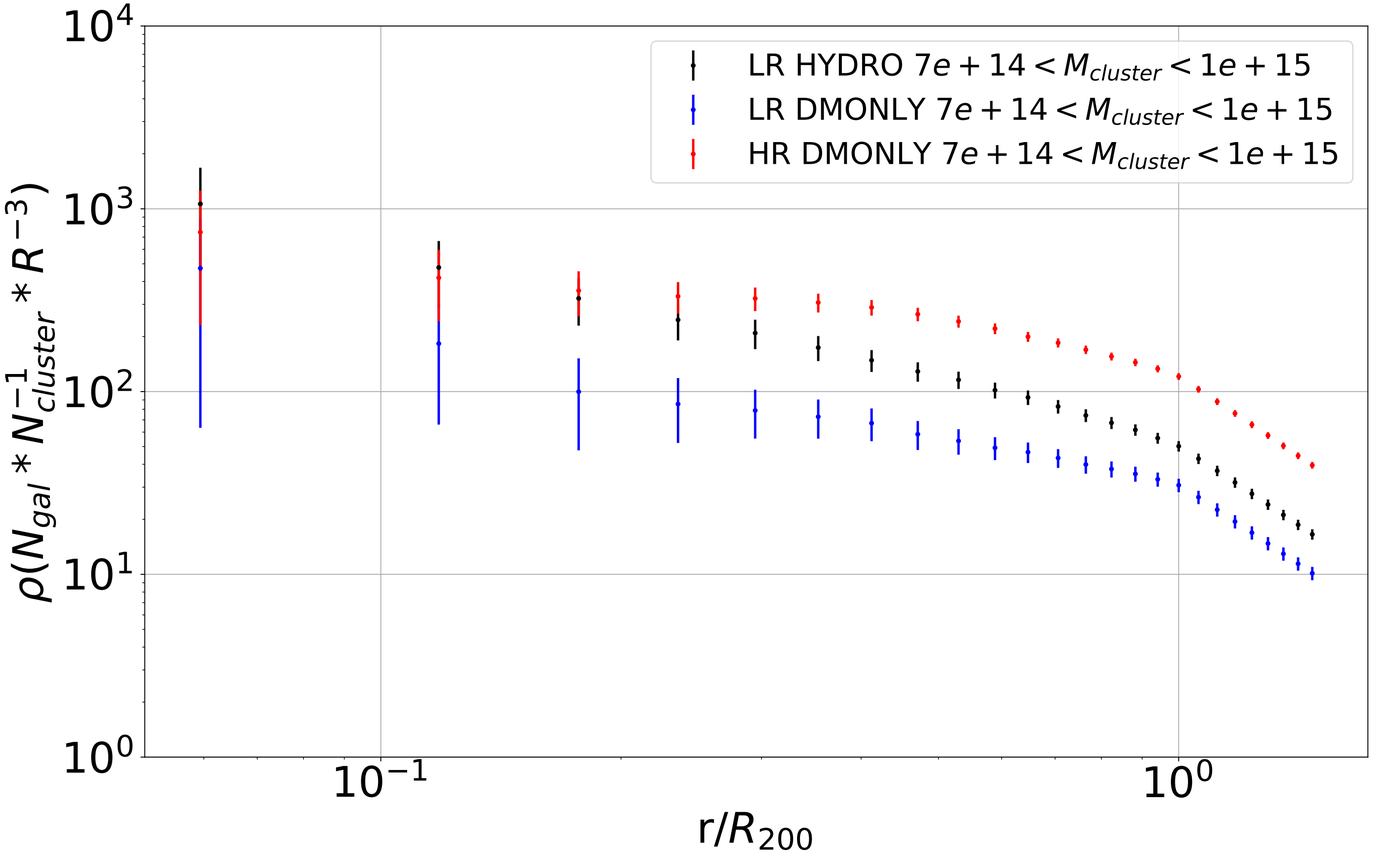
Conclusion

- The Schechter Model for the HD 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





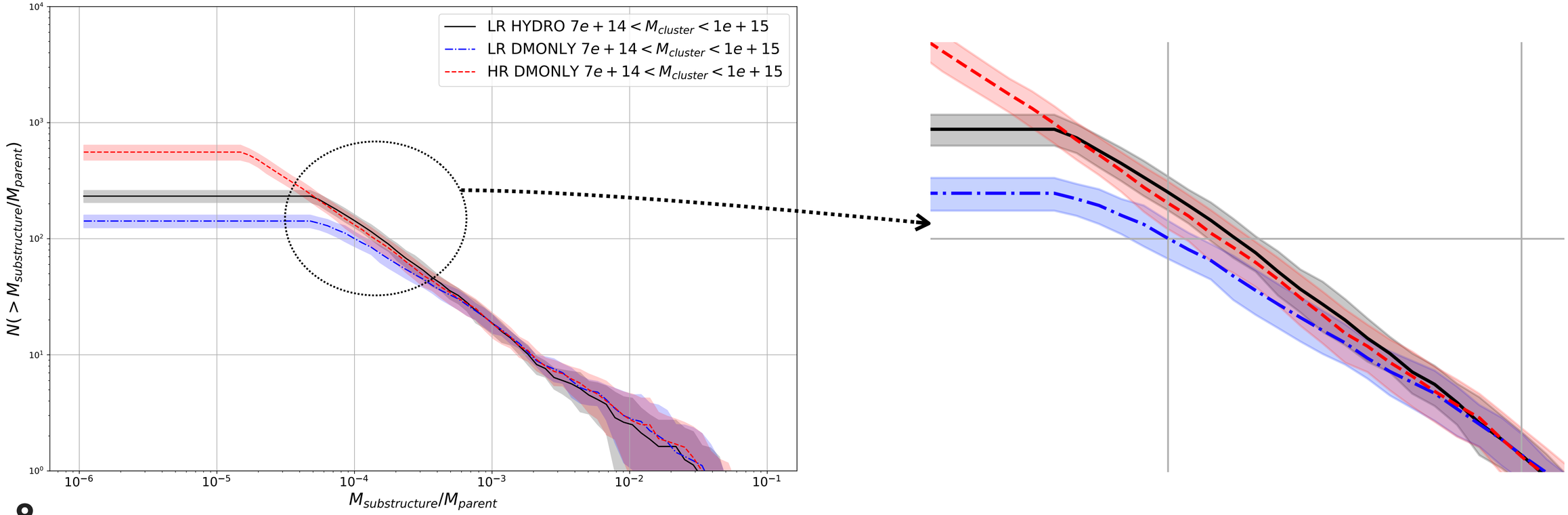
Galaxy density distribution



- **Example of resolution for a 1 Gpc box**
  - **Millenium (EUCLID) -> 5200^3 particles**
  - **The 300th -> 3840^3 particles**
  - **The 300th HD -> 7680^3 particles**
- GOAL: 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
- We use 68 cluster regions
- Previous similar analysis Dolag et al 2009 used only 8 clusters

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 substructures that DM-only simulations for the same resolution can't form.
- Increasing resolution in DM-only simulations approximates the 3d subhalo mass function slope with the hydro simulations one. Still there is a bulge for hydro simulations at low mass.
- Resolution effects start affecting the results when we observe the flattering of the curves.
- Jimenez et al 2021 in preparation

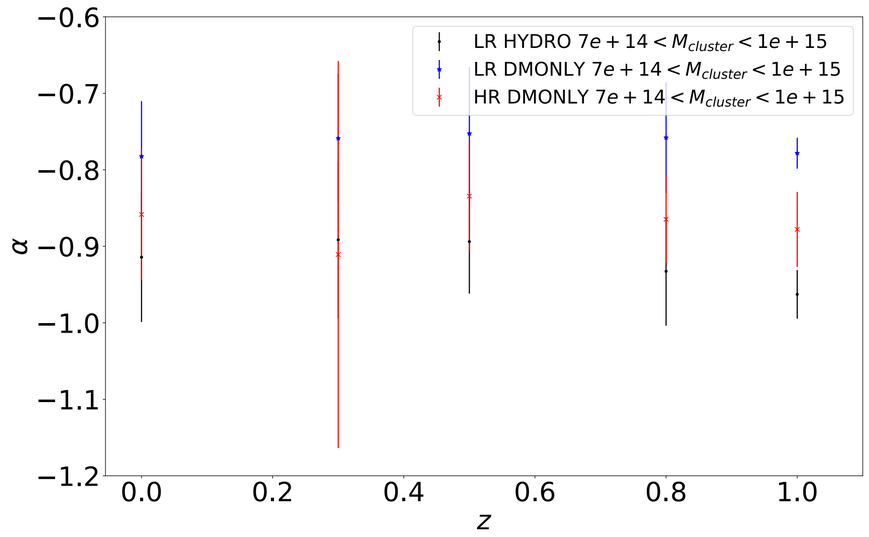


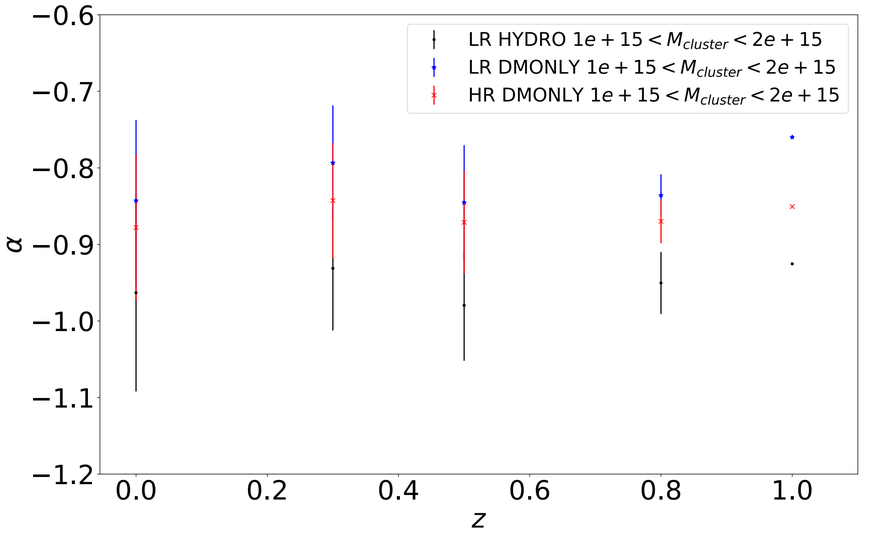
3D SUBHALO MASS FUNCTION REDSHIFT PROPERTIES

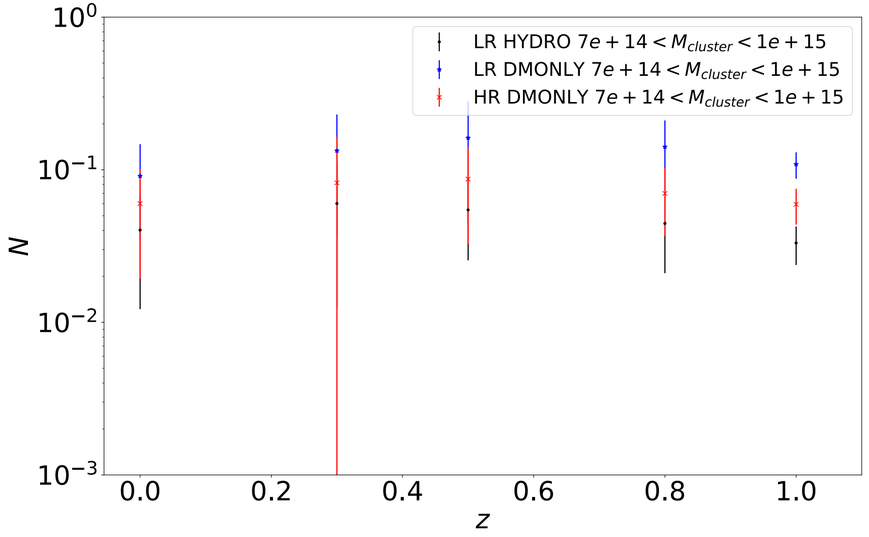
- Powerlaw fit:

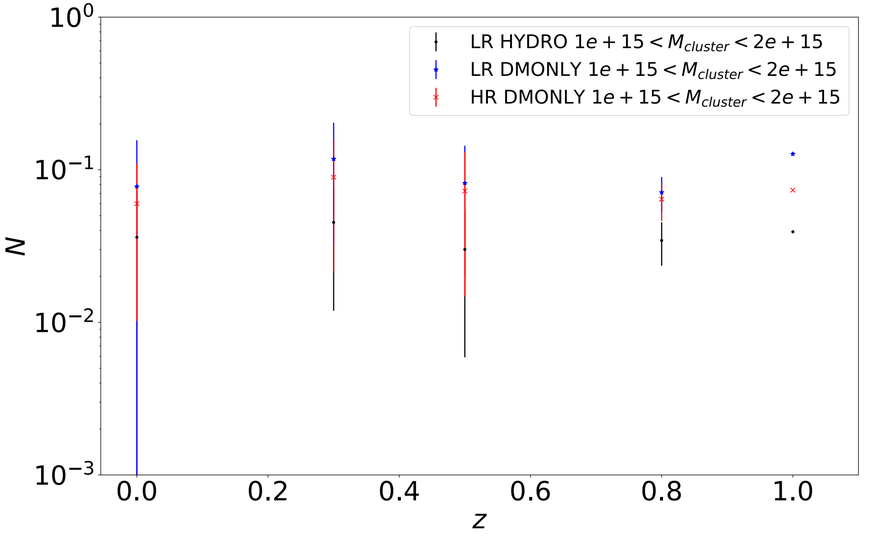
$$\mathbf{N_{gal} = N\left(\frac{M_{substructure}}{M_{parent}}\right)^{\alpha}}$$

- There is no evolution with redshift nor mass for the parameters.
- At high mass and high redshift we find only one cluster (no error bars)
- HR DM-only simulations can not reproduce the mass distribution of LR hydro simulations.
- Results in agreement with Dolag et al 2009
- First work with this many clusters in the properties of the 3D subhalo mass function for different resolutions



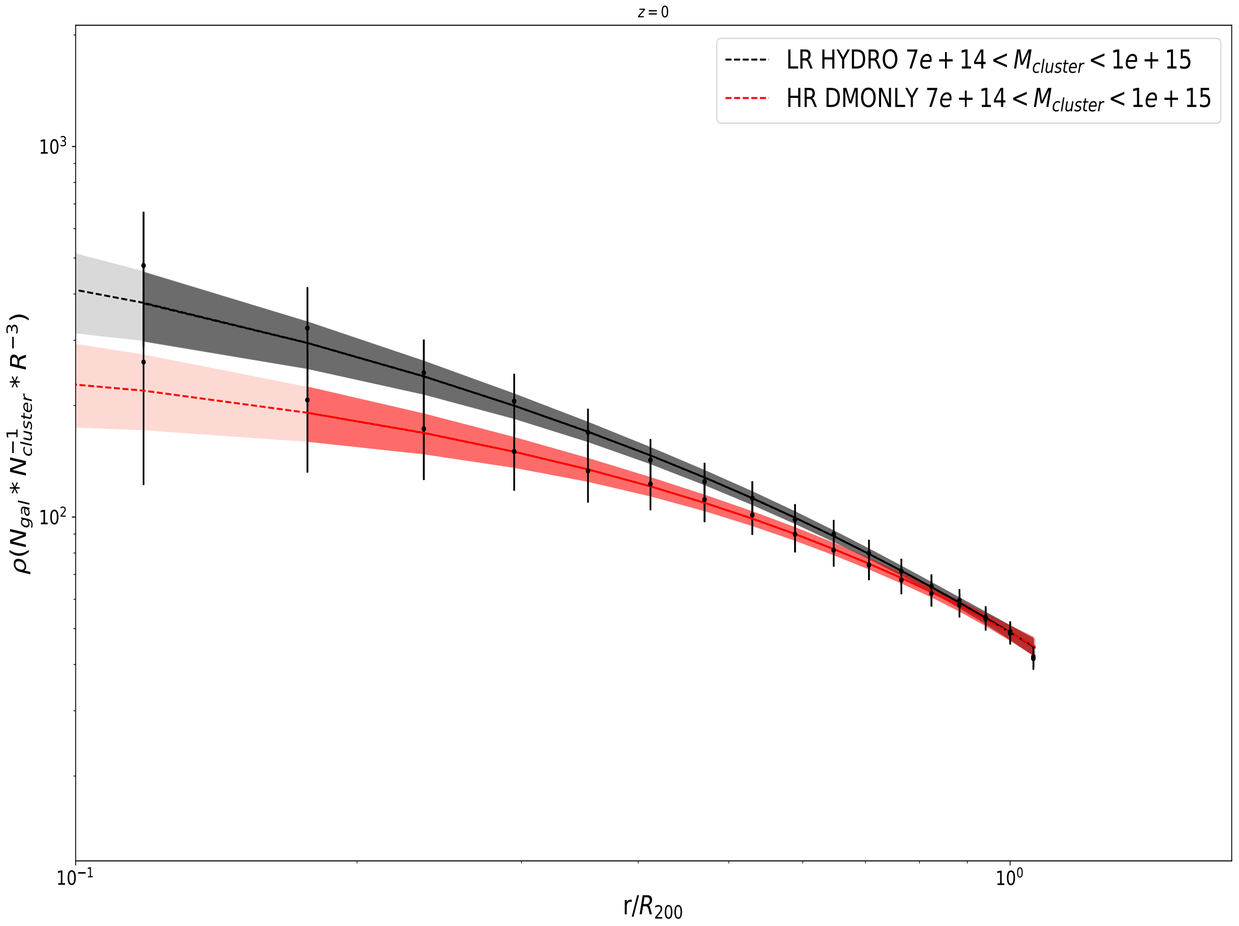






3D GALAXY DENSITY RADIAL PROFILE

- *We will compare the HR DMONLY with LR HYDRO simulations*
- *We compute the Density Profile for the actual 300th cluster simulations establishing a 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*
- *Both profiles converge in the outskirts of the clusters*



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

Curvature

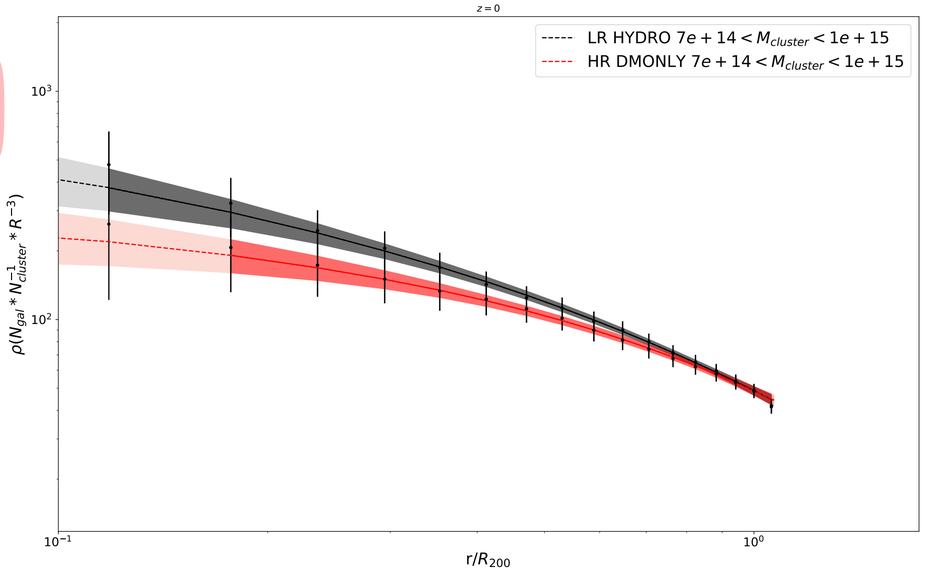
Einasto et al 1965
Springel et al 2008

Normalization

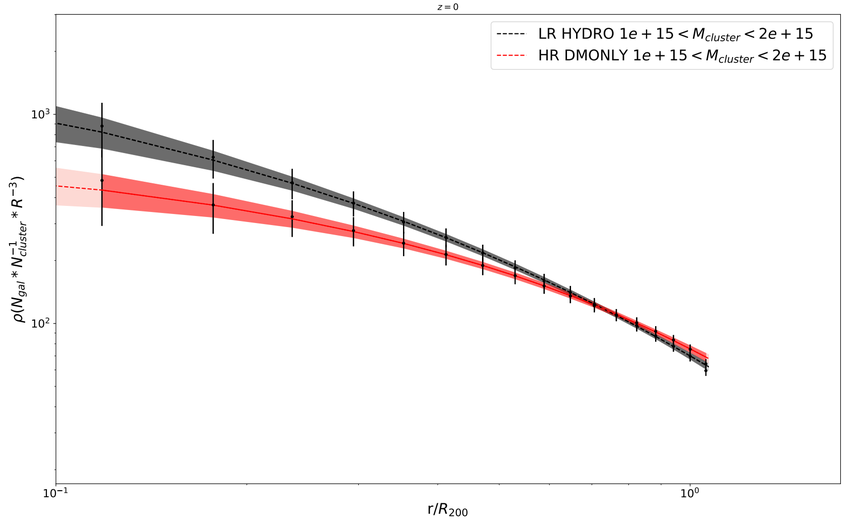
Curvature change point

3D GALAXY DENSITY RADIAL PROFILE

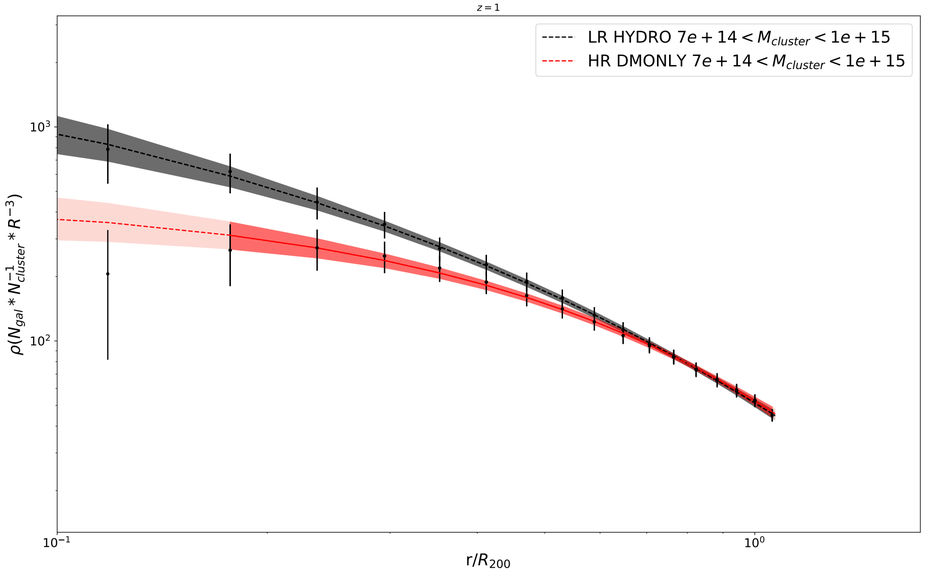
Z = 0
$M < 10^{15} M_{\odot}$



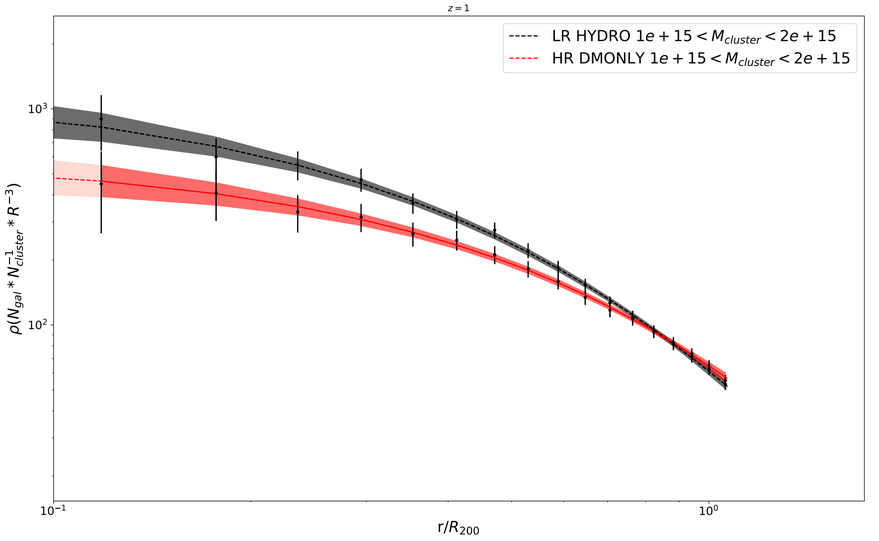
Z = 0
$M > 10^{15} M_{\odot}$



Z = 1
$M < 10^{15} M_{\odot}$

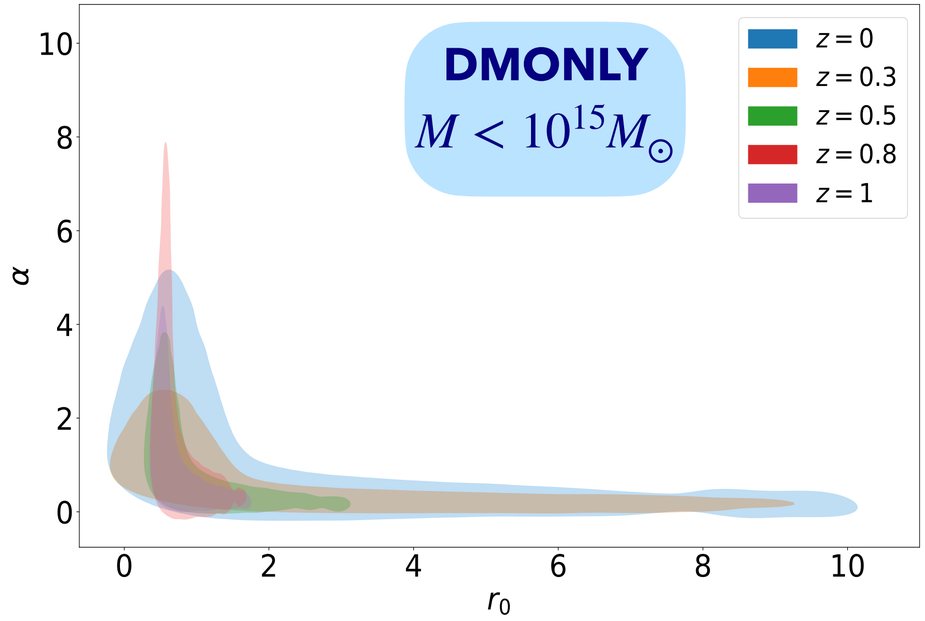


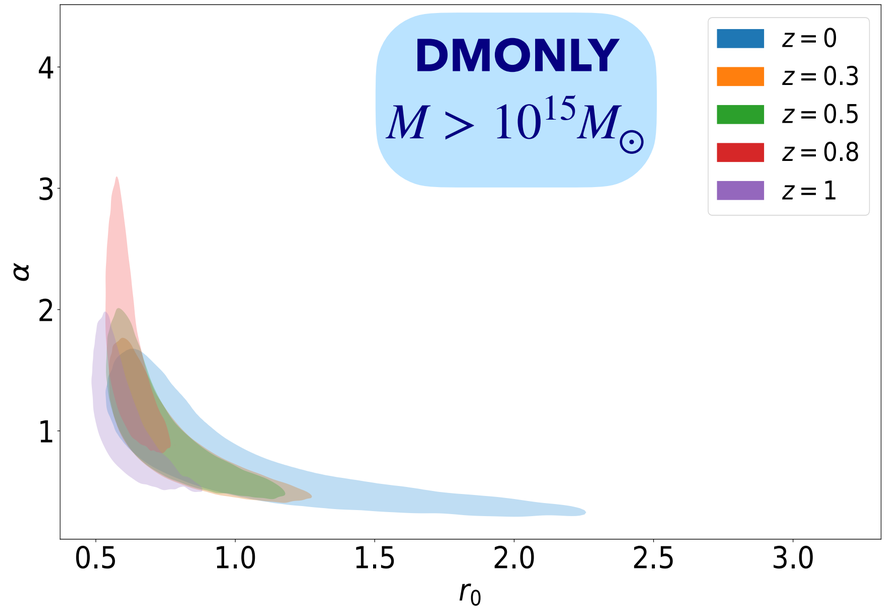
Z = 1
$M > 10^{15} M_{\odot}$

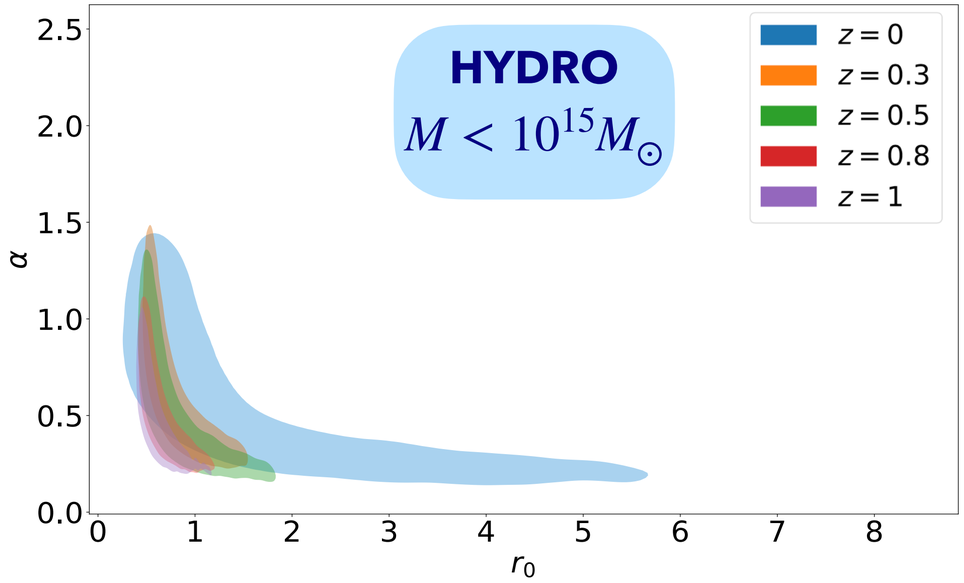


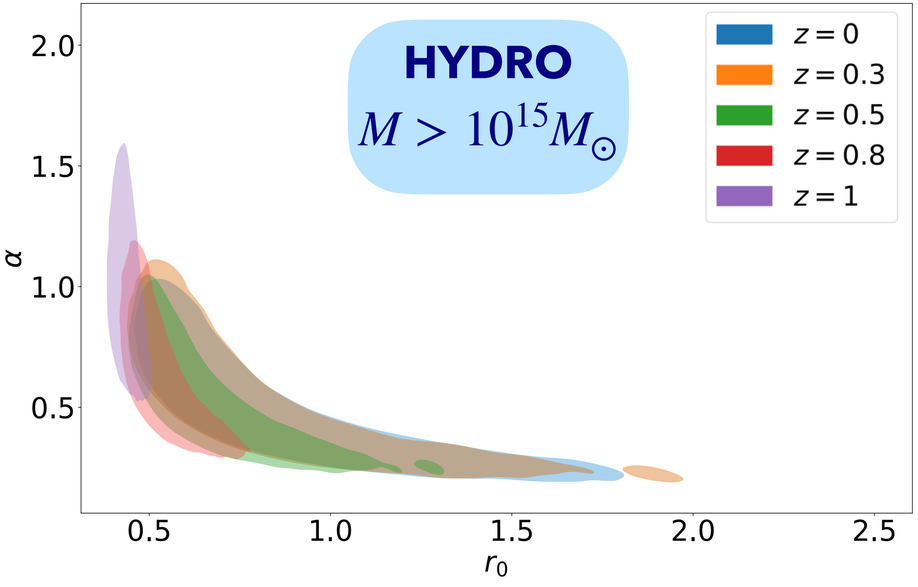
α VS r_0

- α decreases with mass and redshift.
- r_0 decreases with mass and redshift.
- When the curvature decrease (smooth profile towards the center), so does the inflection point
- This means that fragmentation that occurs at high redshift reduces the number of galaxies in the outskirt of the cluster
- Lower value of α and r_0 for HYDRO simulations - denser in the center



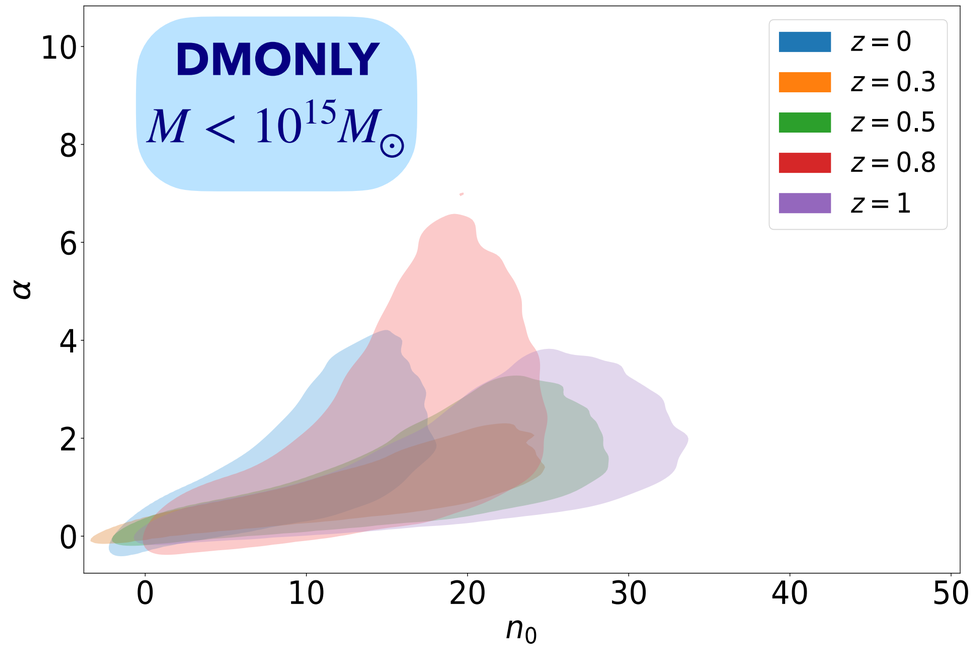


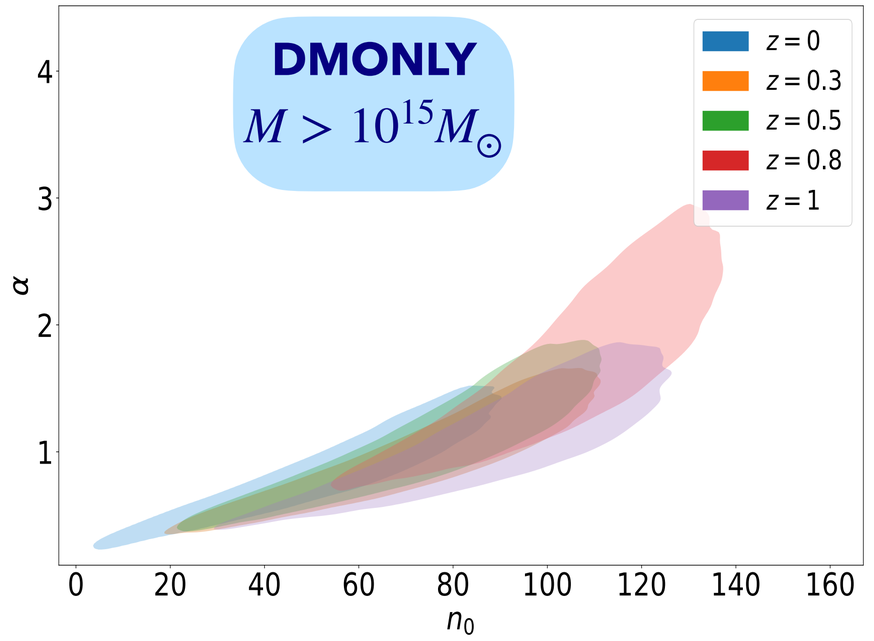


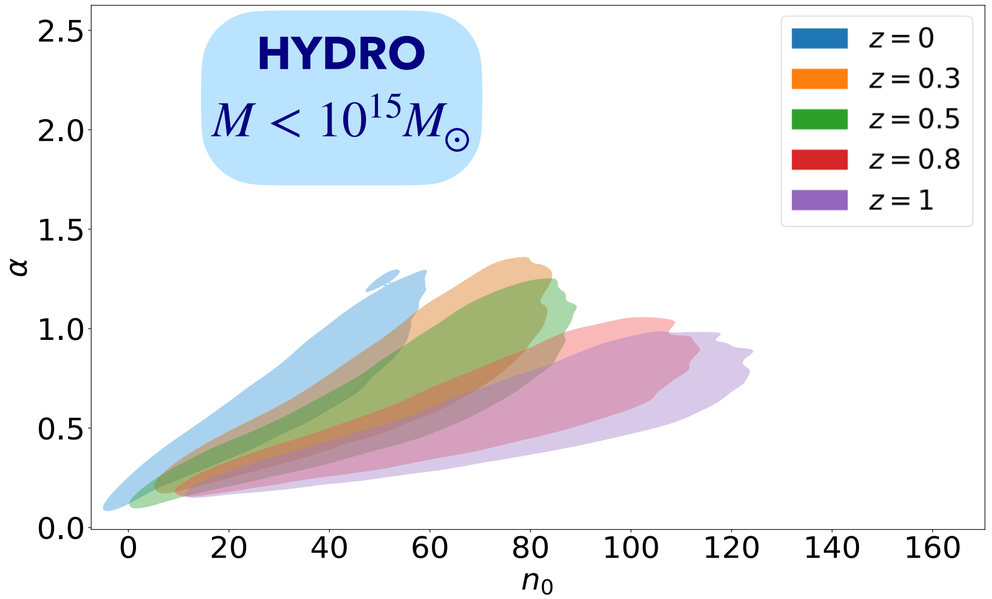


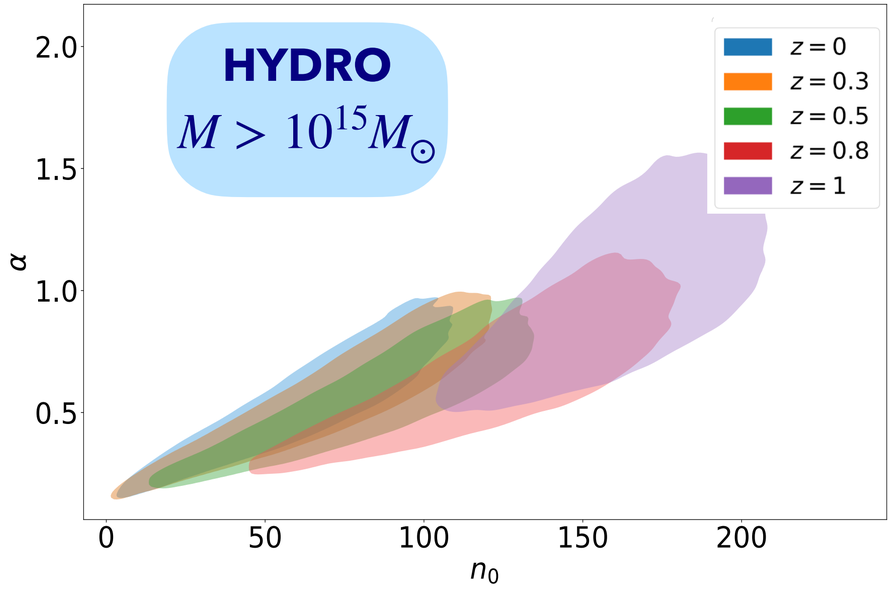
α VS n_0

- α decreases with mass and redshift.
- n_0 increases with mass and redshift.
- Lower α value for higher n_0 means a steeper curve for HYDRO simulations towards the center.









CONCLUSIONS AND FUTURE WORK

- **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 taking into account.**
  - **It is possible to find a threshold in mass for which resolution effects are negligible**
  - **Using this threshold we have been able to compare DMONLY and HYDRO simulations:**
    - **3D subhalo mass function very similar for both**
    - **Galaxy density profiles show significant differences: HYDRO shows more structures towards the center and an evolution with redshift**
  - **Detection algorithm performance might be affected by these differences.**
- **Perspectives:**
  - **GIZMO clusters (Weiguang talk) for a computing LF.**
  - **Constructing a synthetic catalogue with the properties of the Einasto profile and Schechter function**
  - **Run detection algorithm. Compare results with SAMs simulations.**

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THANKS FOR YOU ATTENTION !