Universidad Autónoma de Madrid

mm Universe 2023

Galaxy catalogs from SAM (SAGE) calibration using the The300 hydrodynamical simulations

A method to push the limits toward lower mass galaxies in clusters simulations

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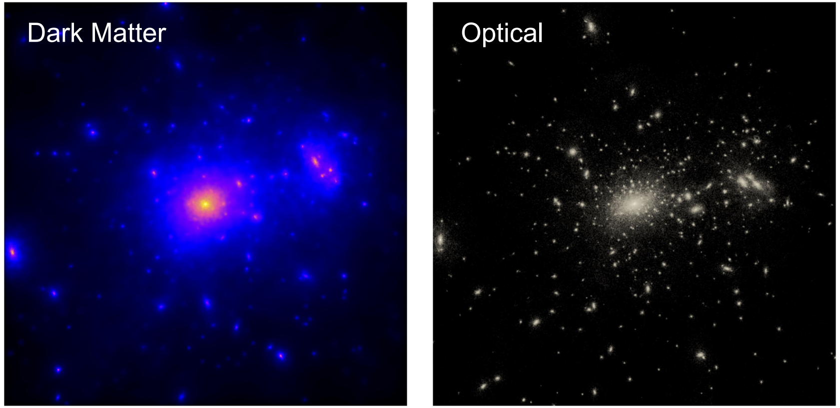
Universidad Autónoma de Madrid

mm Universe 2023
June 28, 2023

THE THREE HUNDRED project

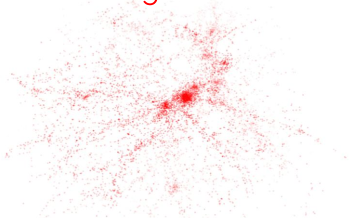
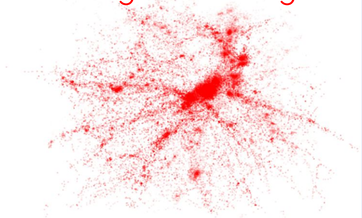
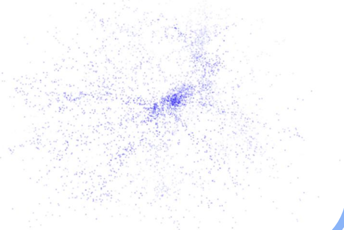
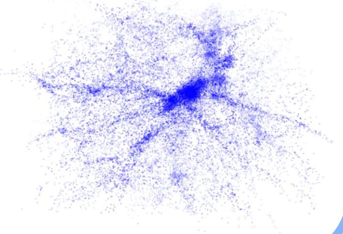
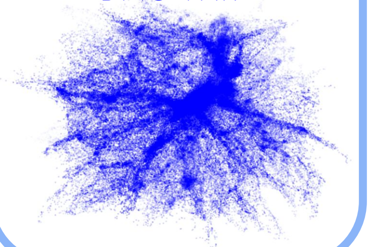
Modelling Galaxy Clusters and their Environment



The Three Hundred simulations: a suite of 324 hydrodynamical resimulations of cluster-sized halos (Klypin et al. 2016).

http://www.the300-project.org

Hydrodynamic and DMO simulations from The300

	3K 3840^3 particles	7K 7680^3 particles	15K 15360^3 particles
Hydrodynamic	324 regions GIZMO-LR GadgetX-LR 	5 regions GIZMO-HR GadgetX-Coming 	X
DMO	324 regions DMO-LR 	324 regions DMO-HR 	3 regions DMO-VHR 

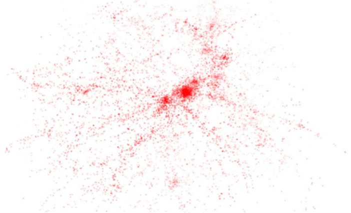
Hydrodynamic and DMO simulations from The300

3K

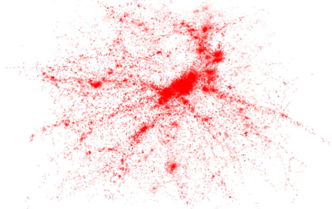
- 3840^3 particles
- Mp ~ 1.5× 10^9 M/h
- Mhalo (100ρ) ~ 10^{11} M/h

Hydrodynamic

324 regions
GIZMO-LR
GadgetX-LR

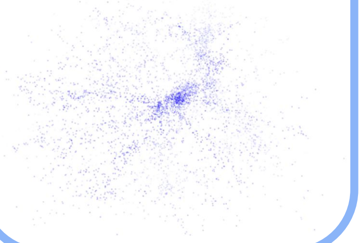


5 regions
GIZMO-HR
GadgetX-Coming

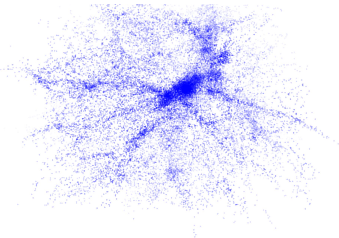


DMO

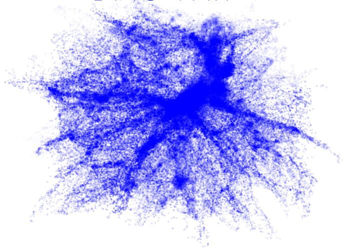
324 regions
DMO-LR



324 regions
DMO-HR



3 regions
DMO-VHR



Hydrodynamic and DMO simulations from The300

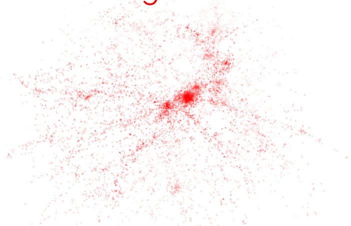
7K

- 7680^3 particles
- Mp ~ 1.8× 10^8 M/h
- Mhalo (100ρ) ~ 10^{10} M/h

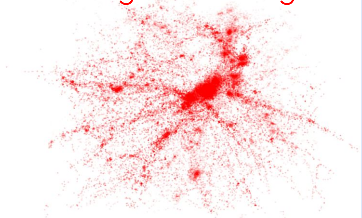
$$\frac{\text{7K DMO cpu hours}}{\text{7k GIZMO cpu hours}} = 0.08$$

Hydrodynamic

324 regions
GIZMO-LR
GadgetX-LR

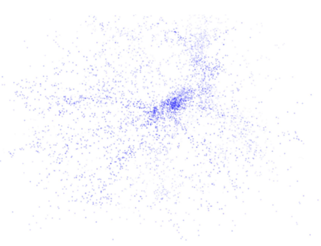


5 regions
GIZMO-HR
GadgetX-Coming

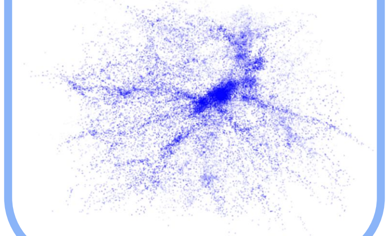


DMO

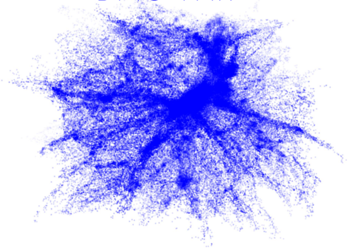
324 regions
DMO-LR



324 regions
DMO-HR



3 regions
DMO-VHR



Hydrodynamic and DMO simulations from The300

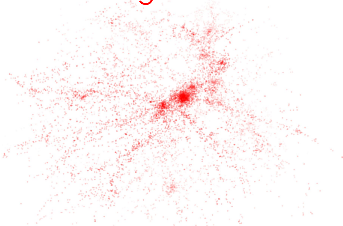
- ~10^7 merger trees from 324 regions of the DMO-HR.
- ~10^6 merger trees from 3 regions of the DMO-VRH at the moment.

15K

- 15360^3 particles
- Mρ ~ 2.3× 10^7 M/h
- Mhalo (100ρ) ~ 10^9 M/h

Hydrodynamic

324 regions
GIZMO-LR
GadgetX-LR

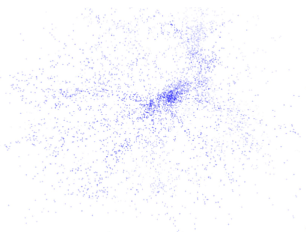


5 regions
GIZMO-HR
GadgetX-Coming

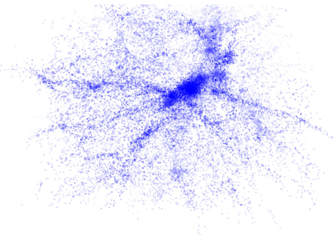
X

DMO

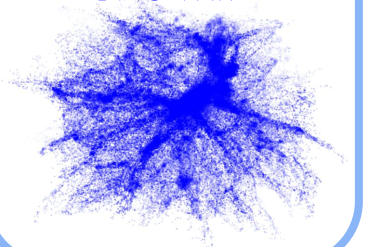
324 regions
DMO-LR



324 regions
DMO-HR



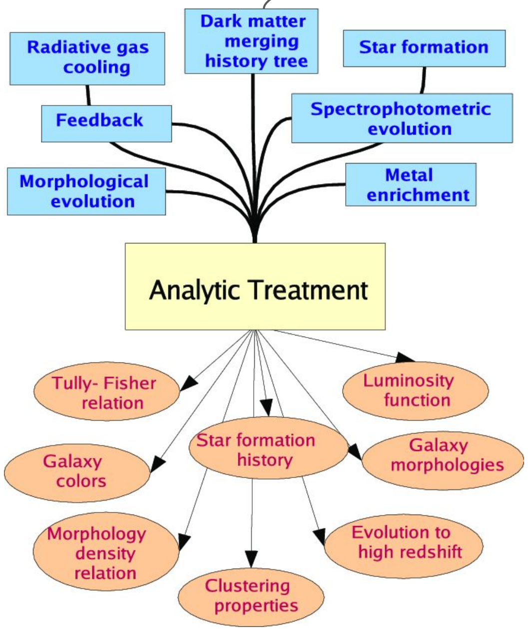
3 regions
DMO-VHR

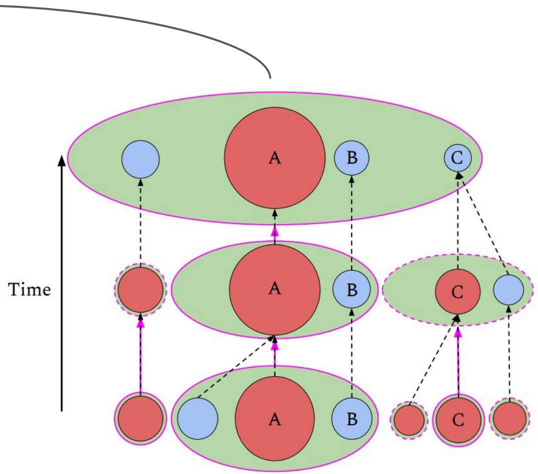


$$\frac{\text{15K DMO cpu hours}}{\text{7k DMO cpu hours}} = 18.22$$

Semi-Analytic Model (SAM) of galaxy formation and evolution

A semi-analytical model of galaxy formation is a computational tool that uses simplified mathematical equations and analytical methods to simulate the formation and evolution of galaxies.





Scheme of a merger tree of dark matter haloes containing galaxies (red=centrals, blue=satellites)

Jonathan S. Gómez et al. 2021

SAGE: SEMI-ANALYTIC GALAXY EVOLUTION

An emulator for galaxy properties in DMO clusters

Croton et al. 2016

Parameter	Description	Value
$f_b^{(\mathrm{cosmic})}$	(Cosmic) baryon fraction	0.17, 0.13
z_0	Redshift when H II regions overlap	8.0
z_r	Redshift when the intergalactic medium is fully reionized	7.0
α_{SF}	Star formation efficiency	0.05
Y	Yield of metals from new stars	0.025
$\mathcal{R}$	Instantaneous recycling fraction	0.43
ϵ_{disk}	Mass-loading factor due to supernovae	3.0
ϵ_{halo}	Efficiency of supernovae to unbind gas from the hot halo	0.3
k_{reinc}	Sets velocity scale for gas reincorporation	0.15
κ_{R}	Radio mode feedback efficiency	0.08
κ_{Q}	Quasar mode feedback efficiency	0.005
f_{BH}	Rate of black hole growth during quasar mode	0.015
f_{friction}	Threshold subhalo-to-baryonic mass for satellite disruption or merging	1.0
f_{major}	Threshold mass ratio for merger to be major	0.3

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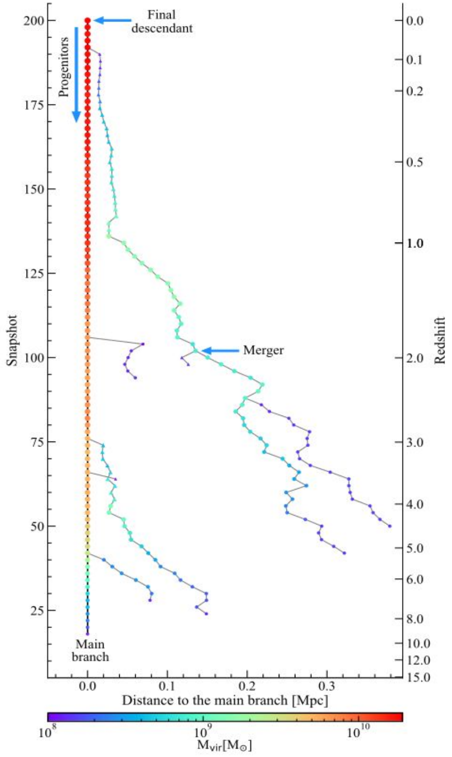


Example of a merger tree of DM haloes

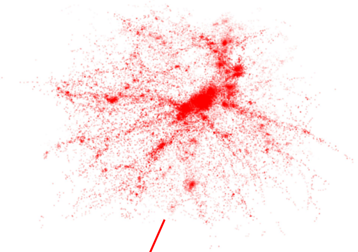
Sandra Robles & Jonathan S. Gómez 2022

MAIN GOAL

Create a method in which we are able to push the limits toward lower mass galaxies in clusters simulations as if we had available the 324 regions of the GIZMO-HR simulation

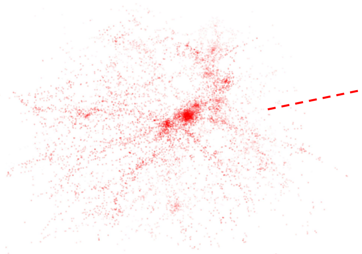
5 regions

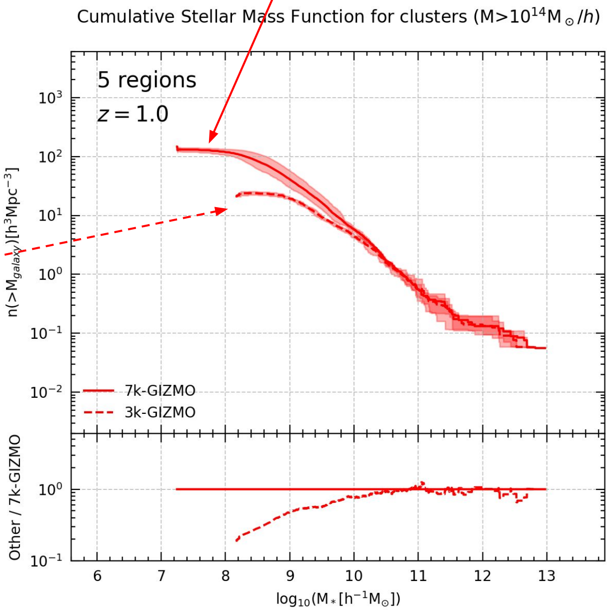
7680^3 particles (7K)



324 regions

3840^3 particles (3K)



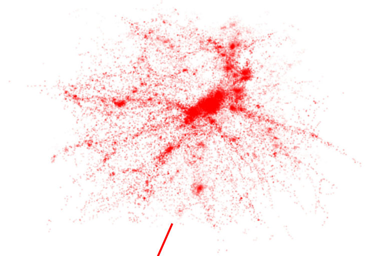


MAIN GOAL

Use SAGE in the merger trees of the The300-DMHR simulation calibrated with the GIZMO-HR results (luminosity and stellar mass).

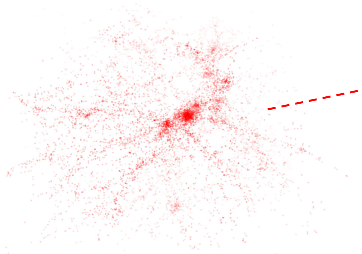
5 regions

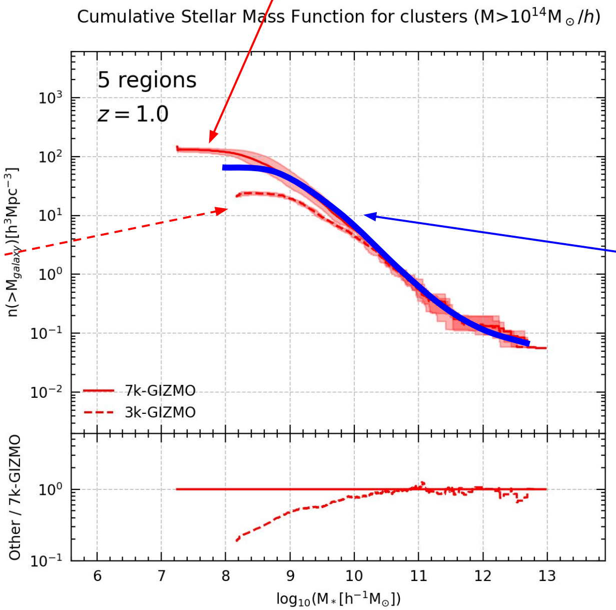
7680^3 particles (7K)



324 regions

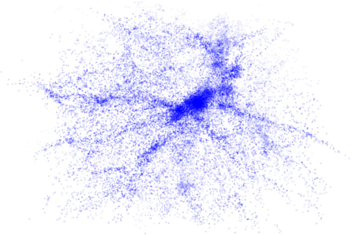
3840^3 particles (3K)





SAGE

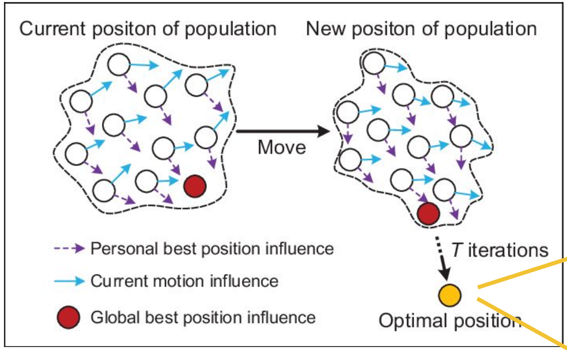
\+



DMO

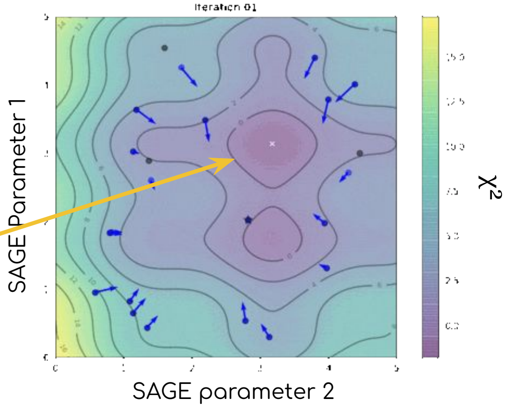
Particle Swarm Optimization (PSO)

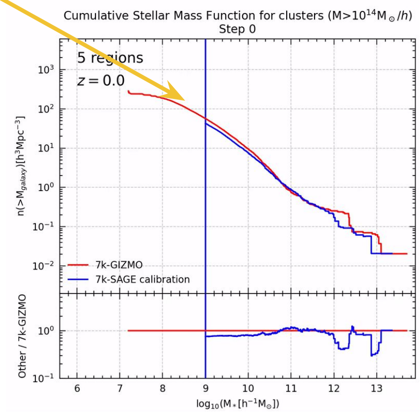
PSO is a computational technique originally introduced by Kennedy & Eberhart 1995 to optimise multidimensional parameter explorations



- The parameter values of a SAGE run is the position of a PSO particle.
- Each PSO particle has the information of the other particles.
- The new position of a PSO particle is calculated with the best position of this PSO particle and the best global position until that step.
- This intelligent search method is at least 30 times faster than a Monte Carlo simulation.

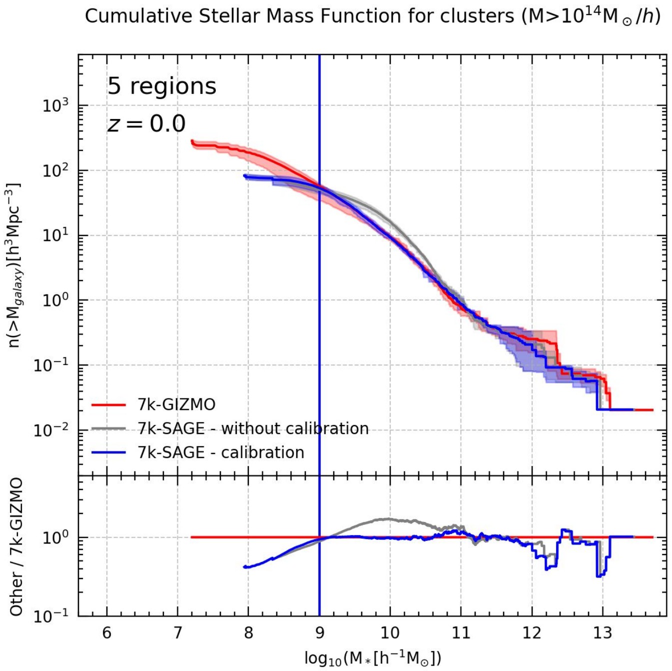
Example of changing positions of PSO particles





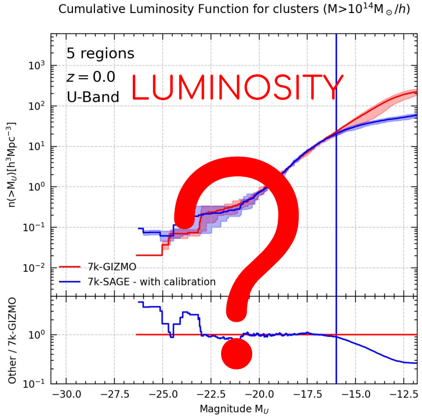
Calibration Process

Stellar mass at z=0 calibrated



When calibrating a single property of the galaxies, the SAM is not interested in what happens with the other properties of the galaxies.

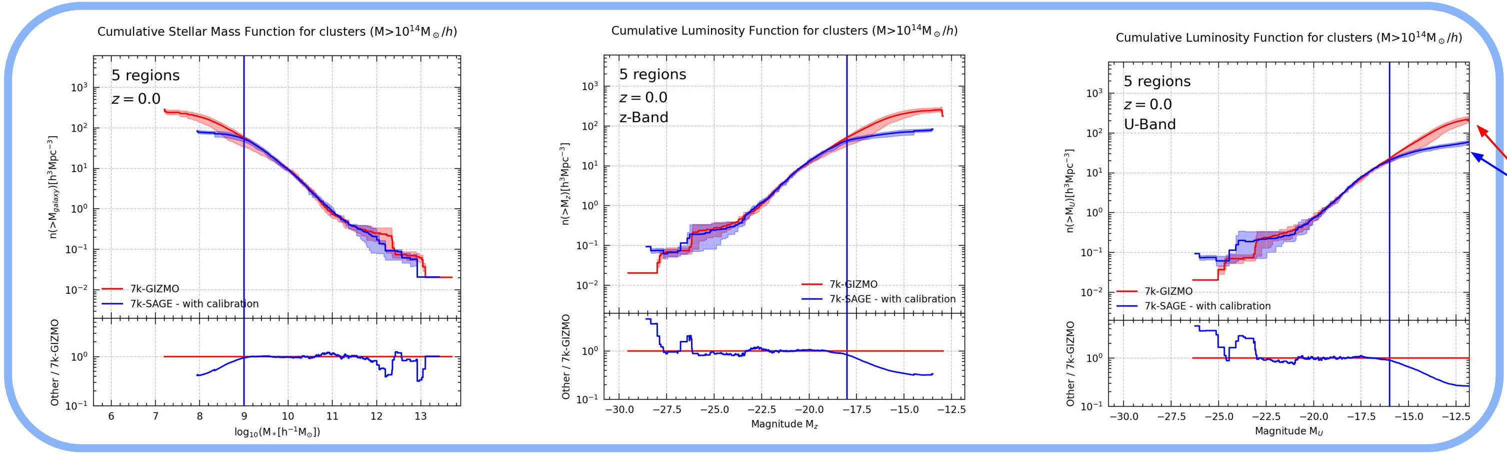
What about the other galactic properties?



Calibration Process

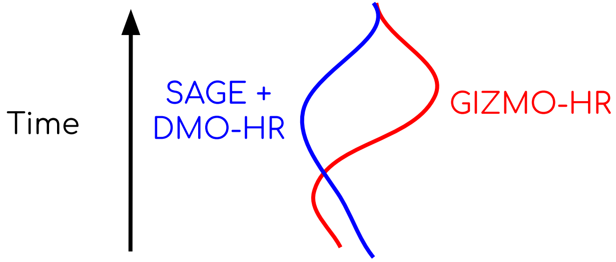
Stellar mass & Luminosities at z=0 calibrated

Stellar mass | z-band | U-band



SPS model STARDUST for both SAGE-HR and GIZMO-HR

Galactic Property at z=0



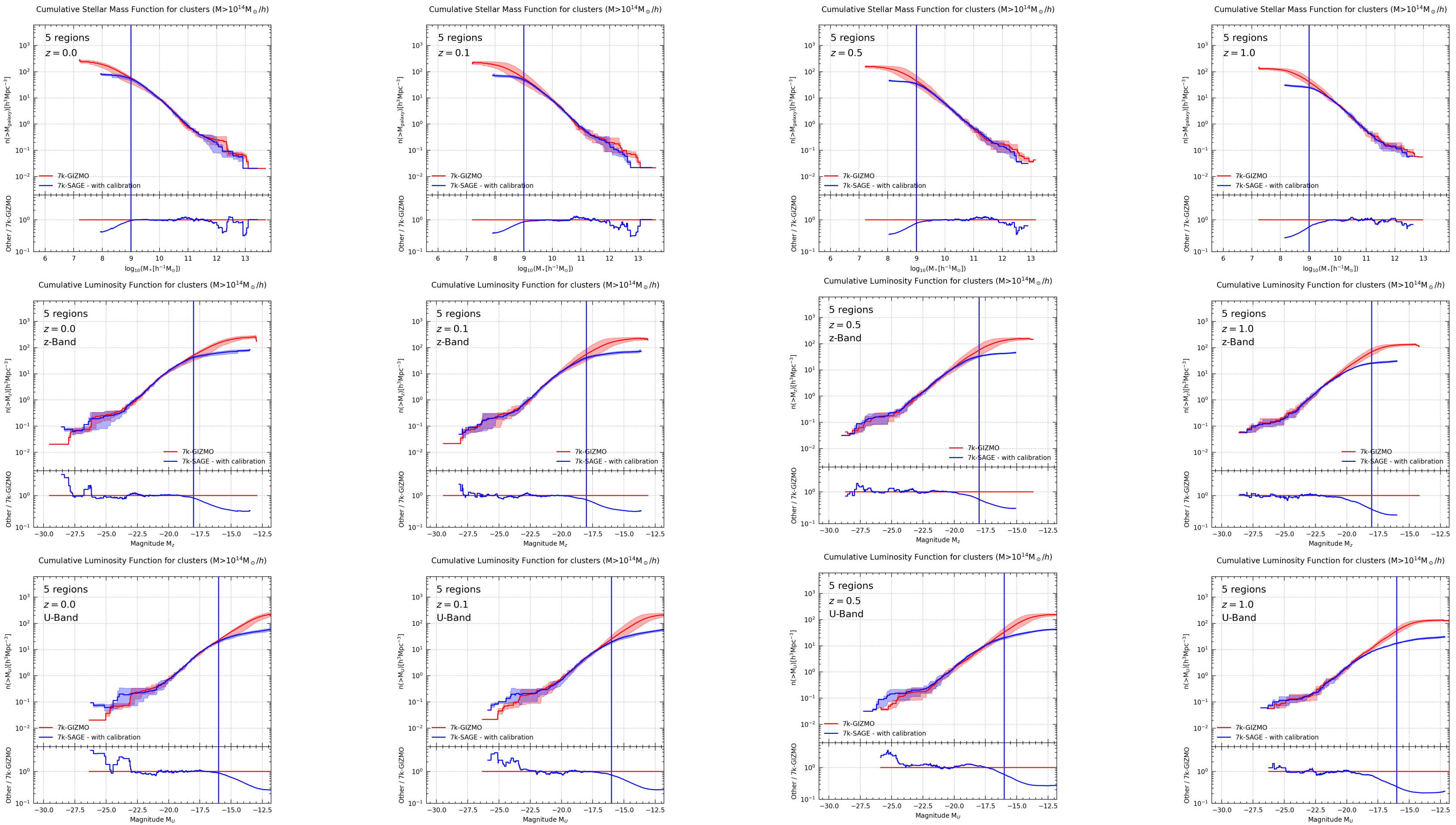
Galactic Property at z=1

Is the galactic evolution of the SAGE consistent with that of GIZMO?

When calibrating galactic properties for a single redshift, SAM is not interested in what happens to the evolution of these properties.

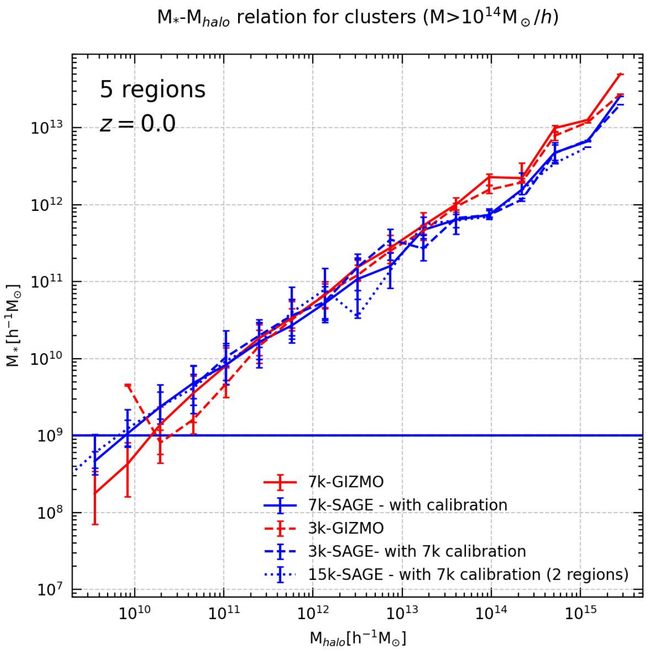
Calibration Process

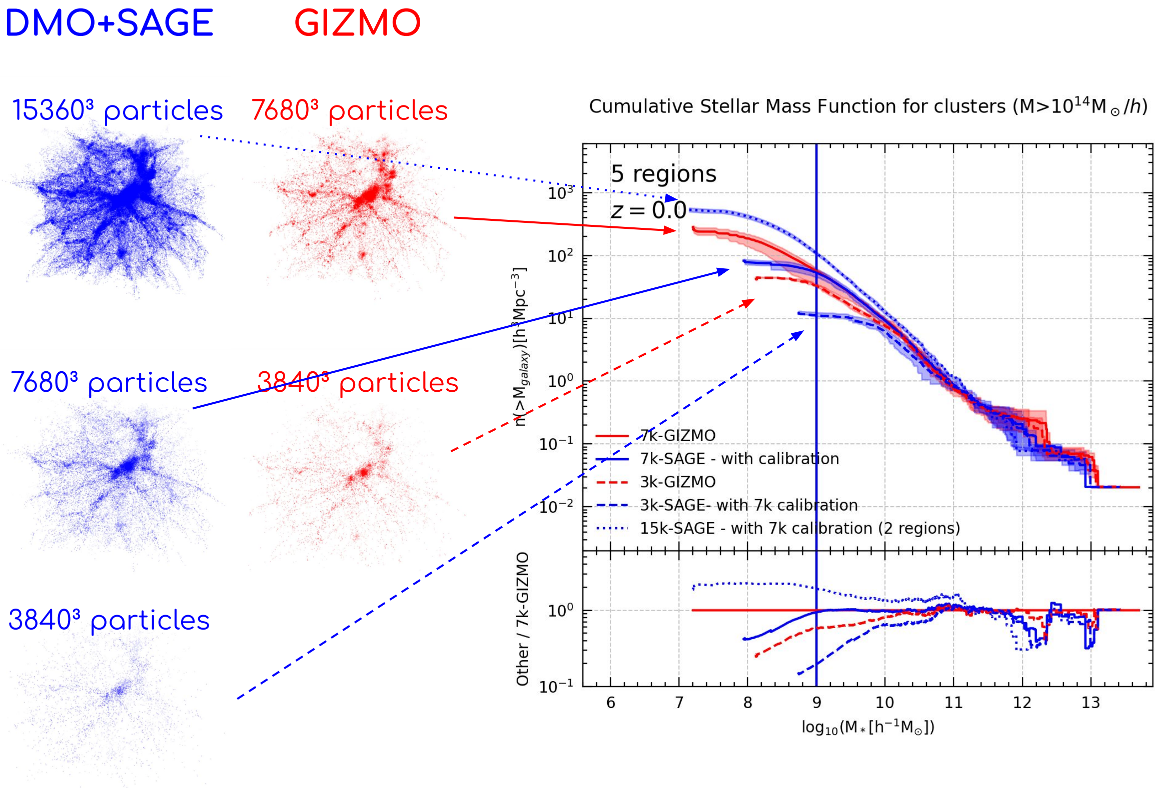
Stellar mass & Luminosities at 4 redshifts calibrated



Calibration summary

- ~10^7 galaxies from 324 regions of the DMO-HR.
- ~10^6 galaxies from 3 regions of the DMO-VRH at the moment.





Ongoing and Future Projects

- Compare other SAGE properties with hydrodynamical simulations, such as:
  - colors
  - metallicities
  - and black hole masses

- This mock catalog can be completed with the results from ICM information from ML inference by (Andrés et al. 2022 including information of:
  - Temperature
  - SZ
  - and Mass of gas.
  - YX

- Apply SAGE on clusters from full box N-body simulations
  - Multidark (cosmosim.org)
  - UNITSIMS (unitsims.ft.uam.es) up to 3Gpc volume

Conclusions

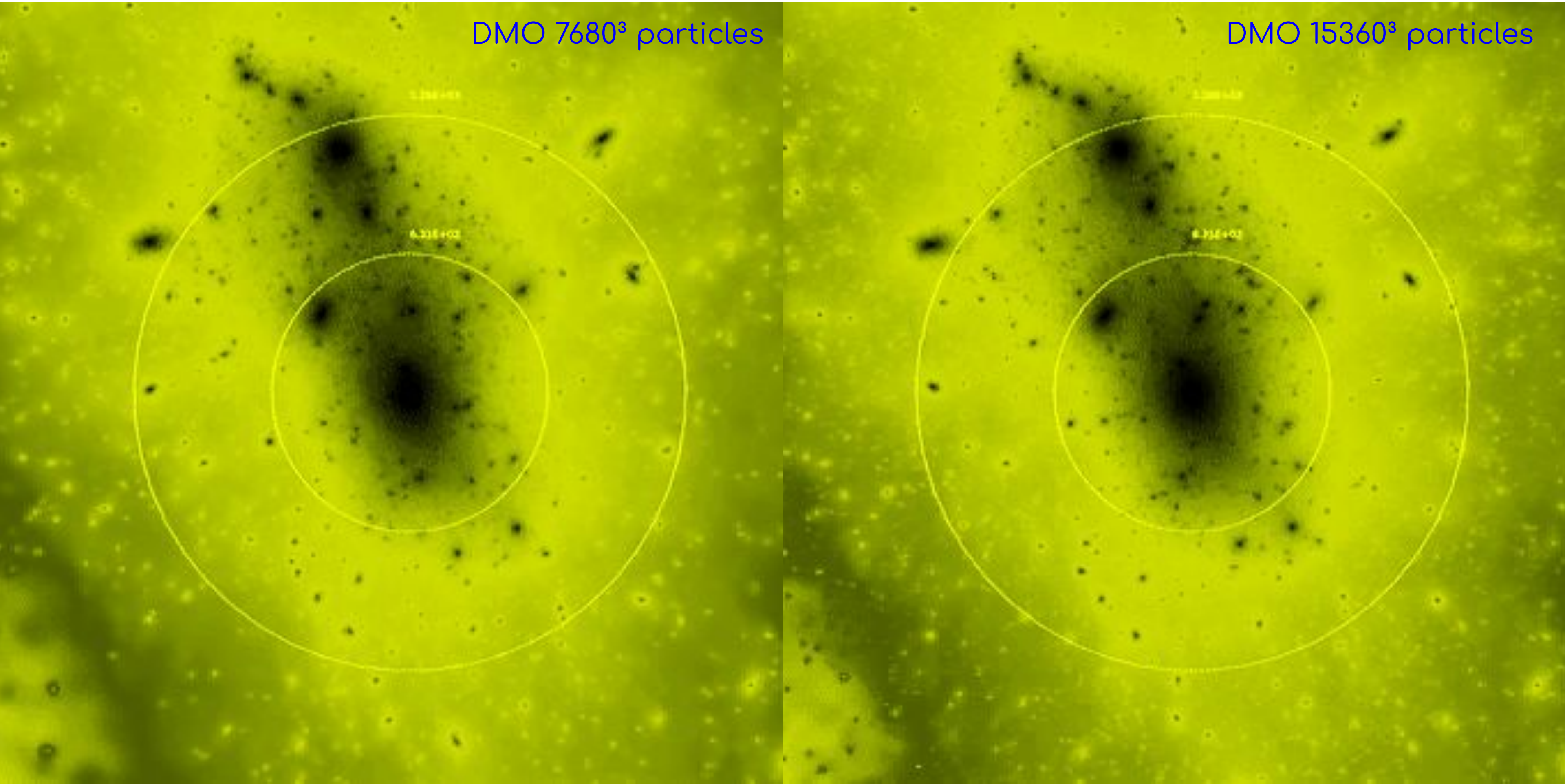
- A galaxy emulator has been developed by SAGE model applied to The300 DMO simulations to reproduce results from GIZMO-HR simulations such as stellar and luminosity properties of halos at several redshift (0 to 1)

- Given the low computational cost of DMO simulations + SAMs compared to hydrodynamical simulations we are able to push the limit towards lower mass galaxies in clusters simulations that can be very useful to make predictions for upcoming deep surveys (EUCLID, 4MOST, WEAVE, etc).

- The SAGE calibration seems not to be sensitive to the resolution of the DMO simulation, so the calibration in 7680^3 resolution can be applied in 15360^3 resolution.

- A mock catalog of galaxies from the calibrated SAGE is ready to be used!

Thanks



Particle Swarm Optimization (PSO)

Standard values for SAGE parameters

Parameter	Description	Value
$f_b^{(\mathrm{cosmic})}$	(Cosmic) baryon fraction	0.17, 0.13
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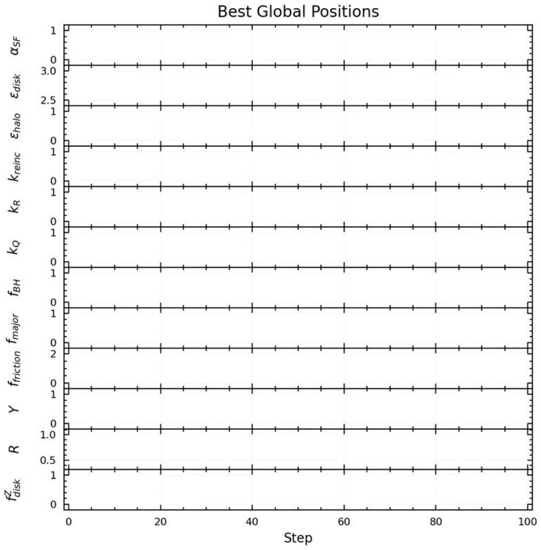
Evolution of SAGE parameters



Final parameter values

Parameter	
$f_b^{(\mathrm{cosmic})}$	
z_0	
z_r	
α_{SF}	0.285
Y	0.422
$\mathcal{R}$	0.750
ϵ_{disk}	2.732
ϵ_{halo}	0.847
k_{reinc}	0.065
κ_{R}	0.035
κ_{Q}	0.063
f_{BH}	0.024
f_{friction}	0.503
f_{major}	0.717