

The history and mass content of cluster galaxies in the EAGLE simulation

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ABSTRACT

We explore the mass content of cluster galaxies in the EAGLE cosmological hydrodynamical simulation.

We explore changes in satellite stellar mass/halo mass as a function of (the observationally accessible) distance from host/nearest cluster, as well as the more physical change as a function of time for the same satellites.

We identify the progenitors of $z = 0.18$ satellites as **some population of centrals at some earlier time**, and find **the following problems arise when interpreting differences between present-day satellites with present-day centrals**

1 WISH/THOUGHT LIST

are all quantities in the HBT catalogs in units of h , or is the value of h already included?

(Given in the order they came to my head)

(i) Explore what difference does it make where did the satellite come from, by binning as a function of cluster-centric distance but also, for galaxies not part of the cluster, by host mass (probably do not need groups less massive than $10^{12} h^{-1} M_{\odot}$, as that's already the mass of the Milky Way). Another way is, for galaxies not part of a massive cluster, to see how far they are to a massive cluster and what is their host mass. For a given distance to a massive cluster, does the mass relation change with host mass? We may need to control by distance from host center as well, and then it may become too noisy...

(ii) try to find a good definition for subhalo size using the density profiles. Perhaps differences between our measurements and EAGLE are caused by a model error?

(iii) Plot stellar-to-total mass *ratios* as a function of cluster-centric distance.

(iv) When plotting “distance to nearest cluster” as opposed to distance to *host* cluster, should

(v) Use some definition of “phase-space distance”, similar to the bins in Fig 1 of Muzzin+14.

1.1 Literature notes

(i) Rhee et al. (2017): weak preprocessing in general ($< 30\%$ mass loss prior to entering cluster). Mass lost up to 1st pericenter $\sim 20\text{--}30\%$, constant with time (Fig 4)

1.2 New thoughts emerging from my HBT+ exploration:

(i) To see what produces changes (especially fluctuations) in mass, should look at the location of the (sub)halo and its neighbors. It's probably that their spiraling into each other or so.

2 INTRODUCTION

In this paper we refer generically to “galaxy groups” as all galaxy associations more massive than $M_{200m} = 10^{11} h^{-1} M_{\odot}$, and to “clusters” as the subset of those groups which have $M_{200m} > 10^{13} M_{\odot}$. (This is a more relaxed definition of “cluster” than usual.) Throughout, we refer to masses $M_{\Delta m}$ ($M_{\Delta c}$) as the mass containing Δ times the mean (critical) density of the Universe at the group redshift. Where appropriate, we adopt the cosmology used in the EAGLE simulations, with **parameters...**

3 SIMULATION

Our study is based on the upgraded Hierarchical Bound Tree (HBT+, ?) post-processing Evolution and Assembly of Galaxies and their Environment (EAGLE) simulations (Schaye et al. 2015; Crain et al. 2015). EAGLE is a suite of cosmological hydrodynamical simulations with varying box sizes, resolutions, and baryonic feedback prescriptions. The simulation we use here is labelled RefL0100N1504 and has a box size of $(100 h^{-1} \text{ Mpc})^3$, with N particles and mass resolutions of X, Y, Z for dark matter, gas and stars, respectively.

Haloed were identified in EAGLE using a standard friends-of-friends algorithm with a linking length of X , and subhaloes were identified using the upgraded . Knebe et al. (2011) found that SUBFIND tends to underpredict subhalo masses at all halo-centric distances. While uncertainties on the bias were not reported by Knebe et al. (2011), the smooth behaviour of the bias as a function of halo-centric distance suggests that uncertainties are rather small, and we neglect them in our analysis. By interpolating figure 8 of Knebe et al. (2011), we apply the following correction to all subhalo and galaxy masses reported in the EAGLE database:

$$\Delta m_{\text{sub}}(x) = \dots \quad (1)$$

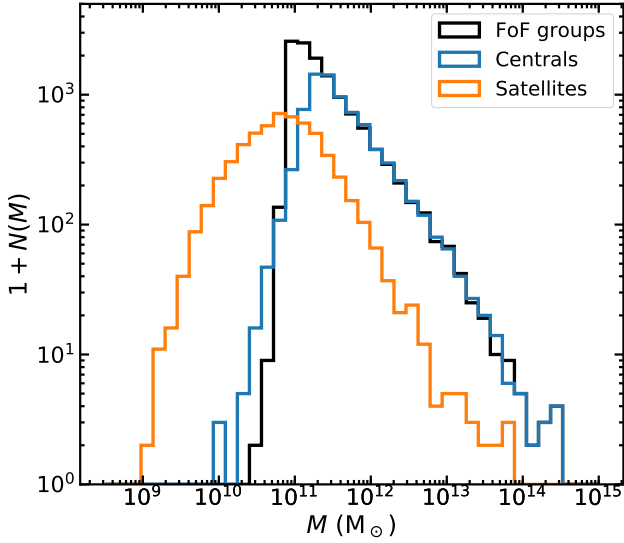


Figure 1. Mass function of galaxy groups with $M_{200m} > 10^{11} h^{-1} M_{\odot}$ and central and satellite galaxies in the EAGLE RefL0100N1504 simulation.

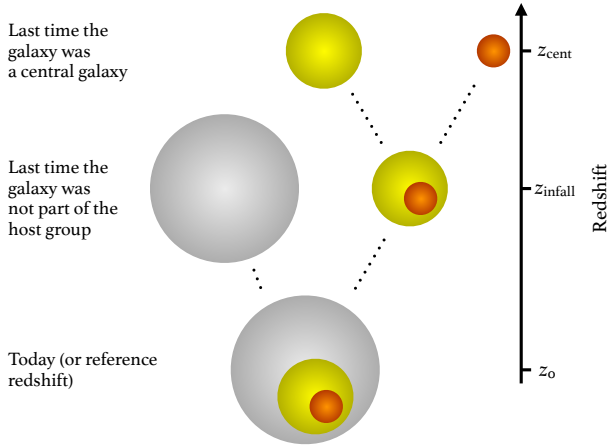


Figure 2. Schematic figure showing the relevant times we consider in this work. The brown circle represents a galaxy of interest, which is a satellite at redshift z_0 , part of a host group shown in grey. We identify the last redshift at which the brown satellite was hosted by the grey host as z_{infall} . The last time at which the brown satellite was a central galaxy is labelled z_{cent} . When the brown satellite fell into the grey host (identified at present with GroupID), it may in fact have already been part of another group, shown in green. If this is the case, then $z_{cent} \neq z_{infall}$.

where $x = R/R_{200m}$ is the three-dimensional distance normalized by the halo size.¹

We adopt the location of the minimum of the gravitational potential as the position of all subhaloes, consistent with Velliscig et al. (2017).

Figure 1 shows the mass functions of

4 THE EVOLUTION OF PRESENT-DAY SUBHALOS

• show something like the fraction of subhalos that were centrals at infall (i.e., $t_{cent} = t_{infall}$) as a function of halo mass, subhalo mass, and infall time.

Figure 3 shows that:

(i) the TSMR of subhaloes is approximately a factor 4 lower than that of centrals.

(ii) the TSMR decreases in amplitude as we get closer to the cluster centre, but its shape does not change.

(iii) If cluster size is accounted for, the TSMR of subhaloes does not depend on cluster mass (i.e., dashed and dotted lines of the same color overlap), except perhaps for low-mass galaxies outside R_{200m} . This suggests that massive clusters exert their influence out to larger radius compared to low-mass clusters, especially for low-mass galaxies ($m_{gal} \lesssim 10^{-2} M_{cl}$).

Caveats:

(i) Need to check how much of point (ii) may be caused by biases in subfind (compare to the curve of recovered versus true mass as a function of radius from Knebe+11).

(ii) Remove centrals of massive groups from the coloured curves.

(iii) Remember that Marco showed that the satellite fraction is really off in EAGLE (compared to GAMA), so should not mix centrals and satellites, nor take the satellite fraction seriously (?).

(iv) It seems like the subfind bias is pretty large and may be driving most if not all the changes we see as a function of R . Perhaps I could gauge this bias by comparing an EAGLE DM only sim with a DM only Rockstar catalog? Even then, baryonic effects on density profiles could conceivably change the comparison.

5 APPLICATION TO SATELLITE LENSING MEASUREMENTS

REFERENCES

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 Knebe A., et al., 2011, *MNRAS*, **415**, 2293
 Rhee J., Smith R., Choi H., Yi S. K., Jaffé Y., Candlish G., Sánchez-Jánssen R., 2017, *ApJ*, **843**, 128
 Schaye J., et al., 2015, *MNRAS*, **446**, 521
 Velliscig M., et al., 2017, *MNRAS*, **471**, 2856

¹ Knebe et al. (2011) reported their results in terms of R_{200c} and M_{200c} . We convert from R_{200c} to R_{200m} using a mass-concentration relation consistent with EAGLE – look for one.

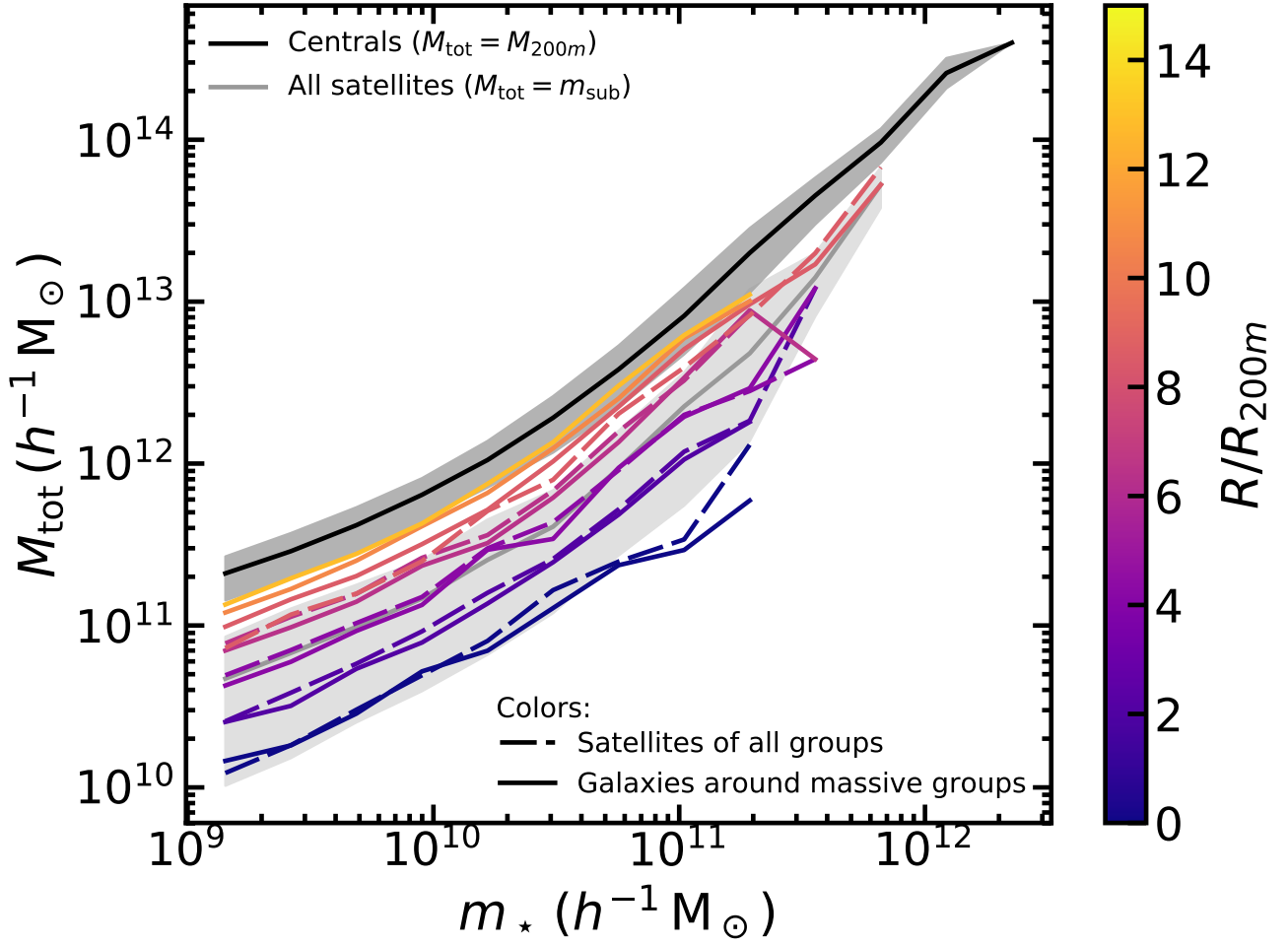


Figure 3. The total-to-stellar mass relation of galaxies as a function of distance to their *host* group (dashed lines), and as a function of their distance to the *nearest* massive ($M_{200m} > 10^{13} h^{-1} M_{\odot}$) cluster (dotted lines), each normalized by the size of the group/cluster. The blue line shows the average total-to-stellar mass relation of all satellites belonging to all groups, and the black line shows the total-to-stellar mass relation of central galaxies. In the latter two, the respective shaded regions show the scatter in each.