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 $z = 0$ 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 $10^{12}\,h^{-1}\,\mathrm{M}_{\odot}$, 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 ~20-30%, 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 $M_{200\mathrm{m}} = 10^{11}\,\mathrm{M}_{\odot}$, and to "clusters" as the subset of those groups which have $M_{200\mathrm{m}} > 10^{13}\,\mathrm{M}_{\odot}$. (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

We use the 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 $(100\,h^{-1}\,\mathrm{Mpc})^3$, with N particles and mass resolutions of X,Y,Z for dark matter, gas and stars, respectively. Our study is based on the upgraded Hierarchical Bound Tree (HBT+, Han et al. 2018) post-processing of EAGLE, in which subhalos are found ... .

3.1 Mass definitions

For clarity, we compare here the different mass definitions

- plot mass functions for different host mass definitions (Mbound, M200Mean, etc) and for subhalos
- show plots comparing those masses directly

4 PRESENT-DAY CLUSTER GALAXIES IN EAGLE

- make a plot similar to Figure 1 but showing how this depends on the subhalo-to-host mass ratio (e.g., with different lines, or normalizing an axis or both axes)

• also make a plot with total-to-stellar mass ratio as a function of cluster-centric distance (also showing the effect of host halo mass)

4.1 The relations between total and stellar mass

Figure 1 shows the stellar-to-halo mass relation (SHMR) and the halo-to-stellar mass relation (HSMR)[1] We also show two observational results for comparison: the central HSMR by van Uitert et al. (2016), and the satellite HSMR by Sifón et al. (2018).

5 THE EVOLUTION OF CLUSTER GALAXIES

• reproduce the 2d histograms in Figure 1 but now show tracks for a few subhalos, i.e., how do they move along this plane as they are accreted and orbit the cluster?

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

?? 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 ($m_{\rm gal} \lesssim 10^{-2} M_{\rm cl}$).

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.

6 APPLICATION TO SATELLITE LENSING MEASUREMENTS

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[1] Note that due to intrinsic scatter, one cannot be obtained by simply inverting the other.

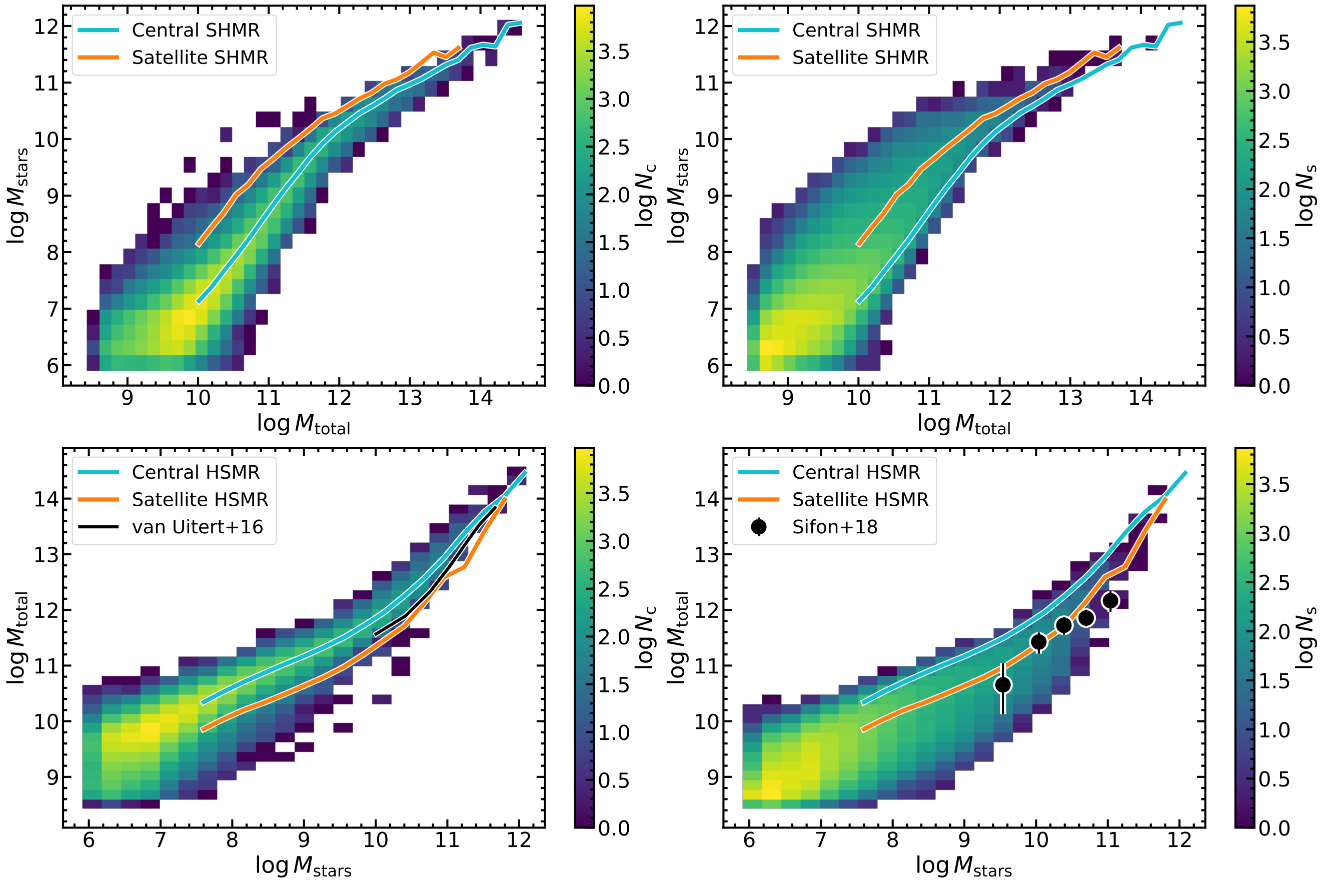

Figure 1. The stellar-to-halo mass relations (SHMR, top panels) and halo-to-stellar mass relations (HSMR, bottom panels) for central (left panels) and satellite (right panels) cluster galaxies in EAGLE. Color scales represent the lof of the number of central and satellite galaxies, respectively, and lines are the means in each panel, as labelled, and are only shown where the samples are complete in the independent (i.e., x-axis) variable. Central total masses refer to $M_{200\rm m}$, while subhalo masses are total HBT+ masses. The central HSMR is compared to that derived from KiDS data by van Uitert et al. (2016), while the satellite HSMR to that measured in MENeaCS clusters by Sifón et al. (2018).