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# Hydrodynamical simulations of realistic massive cluster populations

**David J. Barnes*[,1], Monique A. Henson[1], Scott T. Kay[1], Ian G. McCarthy[2], Yannick M. Bahe[3]**
**& the EAGLE collaboration**

[1]*Jodrell Bank Centre for Astrophysics, The University of Manchester, Manchester M13 9PL, UK*
[2]*Astrophysics Research Institute, Liverpool John Moores University, Liverpool L3 5RF, UK*
[3]*Max-Planck-Institut für Astrophysik, Karl-Schwarzschild Str. 1, 85748 Garching, Germany*
***Email: david.barnes@manchester.ac.uk**

Seeded by the largest and rarest density fluctuations in the early Universe, galaxy clusters are the most massive virialized objects observed. Their formation, a complex interplay between gravitational collapse and feedback processes, means that they are a sensitive probe of both cosmology and astrophysical processes. We present two samples of hydrodynamical simulations that yield realistic galaxy clusters. First, the MACSIS project is a sample of 390 massive clusters that enable us to study the evolution of their properties and the biases introduced by cluster survey selection. Second, we present a sample of clusters run using the EAGLE code that provides exquisite detail of the internal structures of galaxy clusters and captures the formation of the cluster galaxy population and their interactions with the intracluster medium (ICM).

## The MACSIS Project

The Massive Clusters and Intercluster Structures project studies the properties of the population of galaxy clusters:

+ 390 haloes with $M_{FoF} > 10^{15}\ M_{\odot}$ are selected from a 3.2 Gpc dark matter (DM) only simulation.
+ Resimulated using the Cosmo-OWLS model (Le Brun et al. 2014) and resolution ($m_{gas} = 8.1\times10^{8}\ M_{\odot}/h$).
+ Extends a model that produces groups and low mass clusters in agreement with the observations to massive clusters.
+ Combing the samples allows us to study cluster properties over the full mass range, see Fig. 1.

On going work includes:

+ Comparison of massive cluster properties versus less massive clusters
+ How the population evolves with redshift, the progenitors of massive clusters will be preferentially found at high redshift by future X-ray missions.
+ Production of X-ray and SZ lightcones that have a footprint of 1000 square degrees, extend to z = 2.5 and contain 3 million groups and clusters. These will enable to investigation of biases introduced by selection methods in cluster surveys.

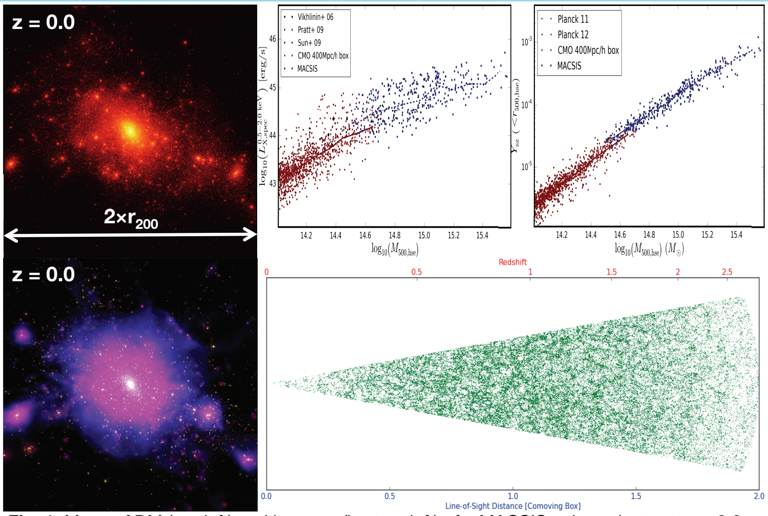


**Fig. 1:** Maps of DM (top left) and baryons (bottom left) of a MACSIS galaxy cluster at z = 0.0. The 0.5-2.0 KeV X-ray luminosity (top middle) and SZ Y signal (top right) of the Cosmo-OWLS (red) and MACSIS (blue) samples against observational data (black). The X-ray lightcone produced from the 3.2 Gpc DM simulation (bottom right).

## Unprecedented detail with EAGLE

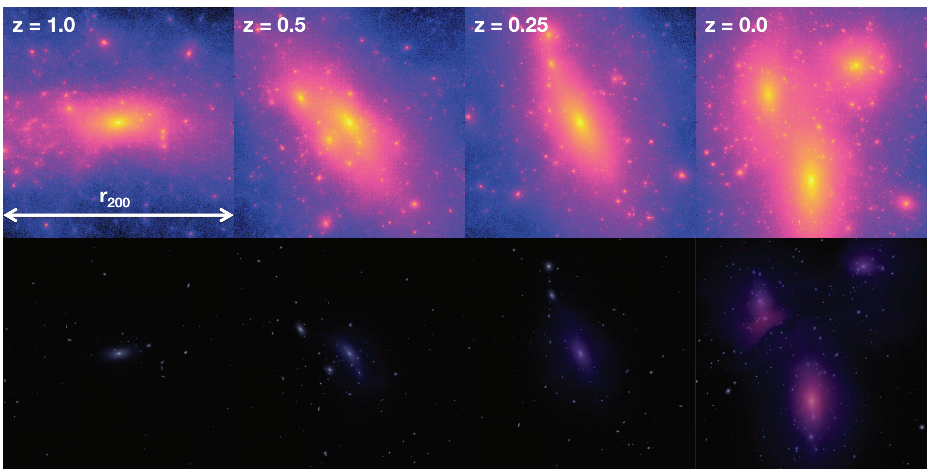


**Fig. 2:** Maps of the dark matter (top) and stars (bottom) of a galaxy cluster simulated using the Eagle model at redshifts of z = 1.0 (left), 0.5 (left centre), 0.25 (right centre) and 0.0 (right). The stars maps are overlaid with maps of the 0.5-2.0 keV X-ray emission. The resolution of the simulations enables features in the ICM, such as the shock front at z = 0.0, to be resolved in exquisite detail.

To look in detail at internal cluster processes we are re-simulating 30 haloes at very high resolution:

+ 30 representative haloes selected from the DM only simulation
+ Using the Eagle model which has been shown to reproduce the field galaxy population
+ Fiducial resolution of $m_{gas} = 1.8\times10^{6}\ M_{\odot}/h$
+ Resolves the cluster galaxy population
+ Simulations provide unprecedented detail on the formation of the ICM, such as the resolved shock front between the merging objects in Fig. 2

The detail of these simulations will enable us to study many as aspects of cluster physics simultaneously:

+ Structure of the ICM
+ Impact of feedback from the central black hole
+ Dynamical impact of the baryons on the dark matter
+ The interaction of infalling galaxies with the ICM

The improved understanding of the internal processes of clusters will enhance their use a probes of cosmology and astrophysics.

**References**

Le Brun A. et al., 2014, MNRAS, 441, 1270
Schaye J. et al., 2015, MNRAS, 446, 521