The mass and internal structure of clusters in a ΛCDM simulation including the effects of baryons

Results from the EAGLE simulation suite

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The EAGLE simulation suite
Yet another cosmological hydro simulation...

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The EAGLE simulation suite

Technical aspects

- Hydro simulation using an improved version of GADGET-3 (SPH),
- Up to $100^3 \text{ Mpc}^3$ box at $1.8 \times 10^6 \text{M}_\odot$ gas mass resolution,
- Planck best-fit $\Lambda$CDM cosmology,
- State-of-the-art subgrid models:
  - Metal-line cooling (Wiersma+ 2009b),
  - SF recipe obeying Kennicutt-Schmidt law (Dalla Vecchia & Schaye 2008),
  - Stellar evolution (Portinari+ 1998),
  - Gas enrichment from SNe & AGB stars (Wiersma+ 2009a),
  - Stellar feedback from SNe (Schaye & Dalla Vecchia 2012),
  - BH accretion (Rosas-Guevara+ 2013),
  - AGN feedback (Booth & Schaye 2009).
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A quick glance

EAGLE: Evolution and Assembly of GaLaxies and their Environments
The evolution of intergalactic gas. Colour encodes temperature

$z = 1.8$
$t = 3.6 \text{ Gyr}$
$L = 25.0 \text{ cMpc}$

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Goal: Reproduce the observed $z = 0$ GSMF...
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... while getting reasonable sizes and evolution

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More visually: A population of realistic looking galaxies

The Eagle Simulations
EVOLUTION AND ASSEMBLY OF GALAXIES AND THEIR ENVIRONMENTS
The Hubble Sequence realised in cosmological simulations
The EAGLE simulation suite
Comparison with recent work from other groups

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Effect of baryons

Mass of halos with and without baryon physics

$\Omega_m - \Omega_b$

$= 0.843$

$M_{12} = 10^{11.3} M_\odot$

$M_{23} = 10^{13.2} M_\odot$
Effect of baryons

Baryon fractions
Simulated Clusters
SDSS-like fake colours $ugr$ image
Simulated Clusters

Colour-magnitude diagram

Image credit: J. Trayford
Simulated Clusters
Density profiles

- Green: Total
- Black: Dark matter
- Red: Stars
- Blue: Gas

NFW is a good fit to the DM
Inner total profile more cuspy due to the stars
New fit for total: \( \frac{\rho(r)}{\rho_{cr}} = \frac{\delta_c}{(r/r_s)(1+r/r_s)^2} + \frac{\delta_i}{(r/r_i)(1+(r/r_i)^2)} \)
The slope of the total matter profile in the inner regions is compatible with recent detailed observations of clusters.
Simulated Clusters

BCG surface brightness profiles

HST filters:
F606W, F625W, F702W, F850LP

- Surface brightness profile in agreement with data
- Colour also in good agreement
Simulated Clusters
BCG velocity dispersion profiles

Good agreement with data
Simulated Clusters

BCG velocity dispersion profiles

Orientation bias is a worry

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If there is no bias, simple Jeans modelling can however recover the right profile
Conclusions

- EAGLE and other hydro simulations are great tools to study galaxy formation and its effect on the DM.
- Halo masses are systematically lower in the simulation with baryon physics included. This will impact future cosmological probes and lensing.
- At $r \gtrsim 0.05R_{\text{vir}}$, the profiles are well described by an NFW profile.
- The total matter profile can be well fit by a simple profile consisting of an NFW part for the outskirts of the halo and a NFW-like component for the stars and the contracted DM in the centre.
- Realistic looking simulated cluster could be used to test lensing mass reconstruction pipelines.