Semi-Analytic Model Predictions of the Galaxy Population in Proto-Clusters

Emanuele Contini (PMO)
Gabriella De Lucia (INAF), Nina Hatch (Univ. of Nott.), Stefano Borgani (UNITS, INAF, INFN)

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• Our set of simulations;
• Brief introduction to the semi-analytic model (SAM) of galaxy formation;
• Introduction to Proto-Clusters;
• Preliminary results (Contini et al. in prep.);
• Conclusions;
Simulating Dark Matter Haloes

Large set of High Resolution Simulations:

- 27 simulations of very massive clusters, $\gtrsim 5 \cdot 10^{14} \, M_\odot$;
- $\Lambda$CDM cosmology;
- Particle Mass $= 10^8 \, h^{-1} M_\odot$;
- $R_{200} =$ radius that encloses a mean density of 200 times the critical density of the Universe at the redshift of interest;
- $M_{200} =$ mass within $R_{200}$. 
The Semi-Analytic Model of Galaxy Formation

Standard scenario of galaxy formation (White & Rees 1978)

The current model now includes a prescription for the formation of the Intra-Cluster Light (ICL, Contini et al. 14), an important component of galaxy clusters.

(De Lucia & Blaizot 07)
Proto-Clusters

- Overdense regions in the early Universe;
- Not yet virialized;
- \( M \gtrsim 10^{14} M_\odot \), dense enough to collapse before \( z = 0 \);
- Found around massive galaxies at high-z (e.g. Miley+06, Venemans+07);
- Tracers: \( \text{Ly}_\alpha \) and \( \text{H}_\alpha \).

MRC 1138-262, a.k.a Spiderweb galaxy
Simulations of Proto-Clusters

Example of our most massive proto-cluster at $z \sim 3$

- Proto-Clusters are very extended regions (Hatch+11, Toshikawa+12);
- Dominated by a blue galaxy population (Hatch+11, Hayashi+12);
- Traces of red galaxies at high-$z$ (Gobat+11).

Contini et al. in prep.
a) Proto-cluster regions are very extended: only \( \sim 40 \) per cent of progenitors in a box of \( 15 \text{[}h^{-1}\text{Mpc]} \);
b) Up to 30\% of objects are outliers (not actual progenitors of \( z = 0 \) galaxies in clusters). Their fraction depends on stellar mass;
c) Virtually impossible to distinguish between outliers and actual progenitors.
Star forming galaxies are the dominant population at high-z, where we expect to find proto-clusters.

When do they get passive?
No difference between progenitors of $z = 0$ passive galaxies and other progenitors at high-$z$;

At low-$z$, progenitors of star forming galaxies keep to be active, while progenitors of passive galaxies start to get passive;

At $z \sim 1.3$, 20 per cent of them are already passive;

The fraction of centrals decreases faster for $z = 0$ passive galaxy progenitors.
Conclusions

1) Proto-clusters are very extended objects (> 20 \( Mpc \)), dominated by a star forming population, and environments of intense star formation;

2) Few Mpc regions around massive high-z galaxies are not enough to characterise proto-clusters. Larger regions (> 20 \( Mpc \) at \( z \gtrsim 2 \)) are needed in order to consider most of their members;

3) Typical observed proto-cluster regions might contain a significant fraction of outliers (20 – 30%);

4) Passive galaxies in clusters were active in proto-clusters.
"I think you should be more explicit here in step two."

Thank you!