Dark Matter Halos in the Cosmic Web

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Does the Structure of the Universe Affect the Formation of Dark Halos and Galaxies?

Introduction

Dark matter halos make up the structure of the universe.

It's been found that halos show a bias to where they are situated in the environment. Bigger halos are found in denser regions.

Assembly bias : at fixed halo mass there is a dependence in the way the environment and other factors affect the clustering of halos. [1]

Today, the universe's structure is a vast, complex network of filaments of matter: the **cosmic web**.

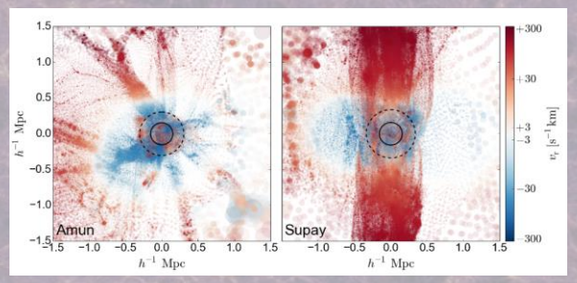

Fig 1. Here is a plot from Borzyskowski et al. [2] showing this assembly bias using simulations.
Left: Halo in a node of the cosmic web connected to a series of thin filaments. Particles are falling inwards in a radial orbit.
Right: Halo embedded in a thick filament. Matter is receding from the halo.

In simulations, the location in the cosmic web affects both the growth of halos, and the growth of stellar matter. But we haven't looked very deeply to how these relate to each other. How does it tie into the **galaxy-halo connection**?

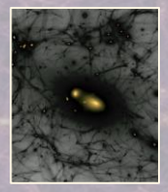

Fig 2. Credit: Ralf Kaehler

125 Mpc

V. Springel, Virgo Consortium

Objective

What is the galaxy-halo connection within the cosmic web?

- Can we see that cosmic web location affects halo and stellar growth?
- Does the bias from the cosmic web affect these two in the same way?
- How does baryonic matter affect the halo growth?

Methods

I used the IllustrisTNG simulations to carry out the research. Each simulation evolves a large volume of a mock Universe from soon after the big bang until present day. The simulation I used is roughly a cubic volume of 100Mpc. [3][4]

Mass assembly (MAH) and star formation histories (SFH) were provided and analysed separately. And the MAH were analysed again in a dark matter only run of the simulation. [5]

Sample selection:
- Only subhalos with $\log M_* > 9.5$ and halo mass $\log M_h > 11$.
- Bright MAH: 9570, Dark MAH: 1960, SFH: 2047

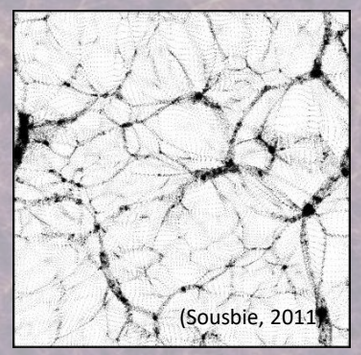

Fig 3. The IllustrisTNG DisPerSE catalog (C. Duckworth) was used to obtain distances to filaments, nodes and saddle points within the cosmic web. The nodes are a maximum critical point. The midpoint along the filament from the node is the saddle point (minimum).[6][7]

Results

Cosmic web bias: The mean MAH and SFH were plotted from galaxies closest to nodes, filaments and saddle points, and those farthest away. Fig 4 is an example of this.

- Bias strongest in highest mass bins (different than some research). Could be due to large range in halo mass in the highest bin
- Denser environments had higher stellar mass increase
- Mass accretion rate higher closer to filaments in highest mass bin
- Closer to nodes and filaments, SFR increases earlier on for highest mass bin

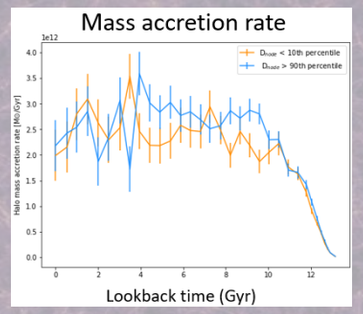

Fig 4. Mean halo mass accretion vs lookback time for bright MAH. Yellow line are halos close to node and blue are farthest away.

Difference in SFH and MAH: Compare MAH and SFH by comparing the percentage change in mass.

- Highest mass bins shows more bias
- Slight mirroring effect

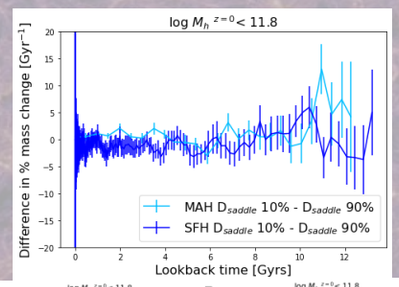

Fig 5. Mean difference in change in mass between closest and farthest away from saddle (blue), filament (red) and nodes (yellow). Lighter lines show the change in mass for MAH, darker lines show change in mass for SFH

Is this difference due to baryonic matter?

There was minimal difference when looking at MAH between the dark only and the bright run, meaning that the baryonic matter isn't affecting the growth of the halo.

Conclusion

The location in the web did show some bias on the SFH and MAH inline with current research, although the change was somewhat minimal.

There is a slight change in bias between SFH and MAH. This means the growth of the halo isn't the only thing that affects the galaxy.

Lastly does baryonic matter affect MAH? No. What does this mean? That there are other baryonic processes affecting the stellar mass and star formation history. This could be linked to the gas supply in the cosmic web, or the gas accretion rate.

Future work?
- Investigate mirroring effect and closer analyse the correlation between how SFH and MAH affect each other.
- Looking into stellar and gas kinematics could be helpful in understanding the complex relationship.

References

[1] Tojeiro et al (2017)
[2] Borzyszkowski et al. (2017)
[3] Nelson et al. (2015)
[4] Springel et al (2018)
[5] Chittenden, H
[6] Duckworth, D
[7] Sousbie, T. (2011)