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FLOWS AROUND GALAXIES I – THE DEPENDENCE OF GALAXY CONNECTIVITY ON COSMIC ENVIRONMENTS AND EFFECTS ON THE STAR FORMATION RATE

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Abstract. How galaxies acquire their material to form stars is still not well understood. With the goal of bringing substantial insight to this fundamental question, this talk presents a comprehensive characterisation of the galaxy connectivity (i.e., the number of kpc-scale filamentary streams connected to a galaxy) in relation to the cosmic web environment. I show statistical results obtained by analysing the streams around ~ 3000 central galaxies at the peak of star formation activity ($z = 2$) in the TNG50 simulation. Results show how galaxy connectivity depends on environmental factors such as the galaxy's local density and position within the cosmic web, besides the expected trends with mass. The impact of these streams on the galaxies' SFR was presented, emphasizing on the importance of considering large-scale matter reservoirs and anisotropic tidal fields to better understand galaxy evolution.

Keywords: (cosmology:) large-scale structure of Universe, galaxies: evolution , galaxies: star formation, galaxies: statistics, methods: numerical, methods: statistical

1 Introduction

What drives star formation quenching in galaxies is one of the most pressing questions in the field of galaxy evolution. Previous research in simulations and observations has tried to identify the main factor behind star-formation quenching by studying how specific properties (e.g., mass, environment, AGN activity) impact galaxy. While these efforts have produced informative statistical relations, conclusive results remain elusive due to the intricate interplay of various parameters across different mass and spatial scales.

We adopt a novel approach by focusing on the primary source of cold gas –the main fuel for star formation in galaxies. Theoretical models suggest that this gas is accreted onto haloes at high redshifts via filamentary streams with widths of only a few kiloparsecs, directly connecting to haloes (e.g. Dekel et al. 2009; Ramsøy et al. 2021; Lu et al. 2024, and references therein). However, galaxies are rarely isolated; they are embedded within the large-scale cosmic web, often residing in filaments of widths ∼Mpc (see illustration in Fig. 1). This research aims to reassess the influence of these filamentary streams on galaxy evolution within a cosmological framework. Specifically, we seek to understand how these kpc-scale structures impact star formation in galaxies.

In this talk, based on Galárraga-Espinosa et al. (2023), I provide a complete caracterisation of galaxy connectivity –defined as the number of kpc-scale filaments intersecting the virial radius of the host halo– and explore its relation with the specific star-formation rate (sSFR) of ~ 3000 centrals of masses $M_* \geq 10^8\,\mathrm{M}_\odot/h$ in the TNG50-1 simulation at $z = 2$.

2 Galaxy connectivity

The small-scale filaments (hereafter streams) are detected from the dark matter distribution using the filament finder algorithm DisPerSE (Sousbie 2011). The detection is performed by focusing on the 3 cMpc/h environment of each central system with the goal of identifying the local gravitational potential wells around the galaxy. One

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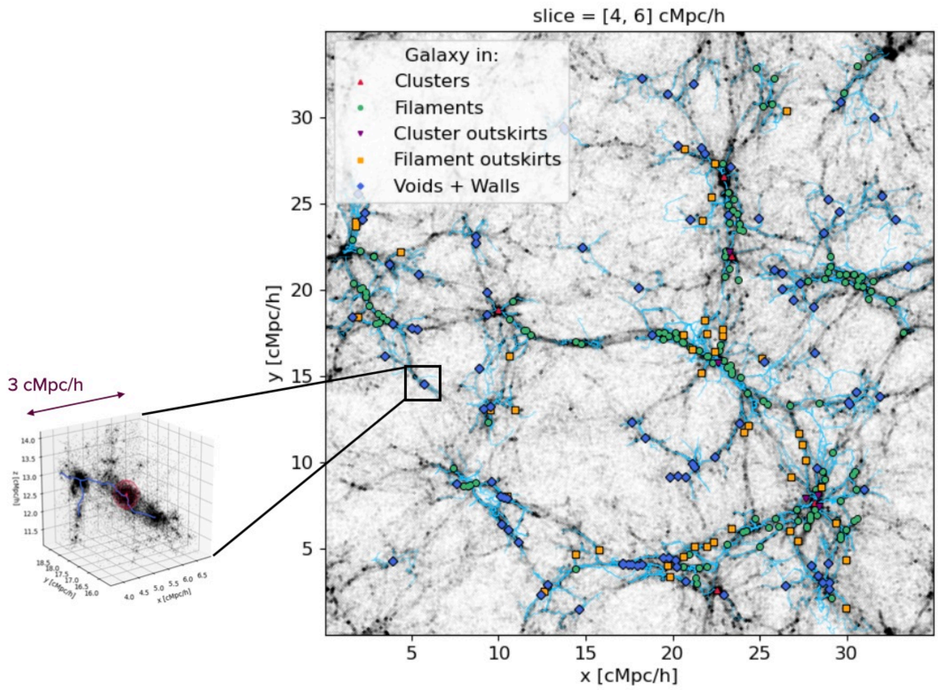

Fig. 1. Illustration of the multi-scale cosmic web using a slice of the TNG50-1 simulation. The galaxy distribution at the large-scales is seen in the right, together with the underlying DM distribution (gray). Galaxies are colour-coded according to the cosmic structure they belong to. Small-scale (or kpc-scale) filaments are shown by the cyan lines. A zoom into the environment of one of the central galaxies considered in this work is shown by the small box in the left. In this example the galaxy connectivity is two.

of such systems in presented in Fig. 1. We measure the connectivity for all the considered central galaxies and we explore the dependencies of this property with mass, local density, and large-scale environment.

We find that galaxy connectivity:

- spans a broad range, going from 0 to 9 streams. Most of the galaxies ($> 50\%$) are connected to two or three streams, and less than 5% of them are connected to five streams or more.
- strongly depends on galaxy mass, with low mass galaxies being less connected than high mass galaxies.
- also depends on local environment, reflecting the different effect of tidal forces in high over-density environments for low and high mass galaxies (Hahn et al. 2009; Aragon Calvo et al. 2019).
- strongly varies with cosmic environments, most likely due to the different strengths of the cosmic tides in different locations of the large-scale cosmic web (e.g. Musso et al. 2018; Paranjape et al. 2018; Kraljic et al. 2019).

3 Impact on sSFR and importance of matter reservoirs

After understanding the dependencies of galaxy connectivity, we explore the relation between this property and the sSFR of central galaxies by keeping the mass, local-density, and cosmic web environment fixed. We find that galaxy connectivity significantly enhances (up to $\sim 6\sigma$) the sSFR of low mass galaxies, but no significant effect is seen in high mass galaxies. This hints at different dominant accretion modes in low mass and high mass galaxies.

Furthermore we find that, if they manage to keep the connections despite the strong tides, low mass galaxies in matter rich regions of the cosmic web (such as cosmic filaments) present star-formation activities that are boosted with respect to their analogues in emptier large-scale environments. This explicitly shows the importance of the large-scale matter reservoirs in fueling the star-formation of low-mass galaxies.

4 Conclusions

These results draw a picture in which star-formation is linked to an external parameter describing topology, the galaxy connectivity. Within this picture, high number of connected streams might favour the accretion of cold material from the large-scales and thus boost the galaxy star-formation, especially in the case of low mass galaxies.

To conclude the talk, preliminary results on the gas content of the streams were presented. These findings revealed that the location of star-forming (cold) gas generally aligns with the positions of the DM streams, thus building a coherent picture on the importance of small-scale filaments in the context of galaxy evolution.

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