THE BOUNDARY OF COSMIC FILAMENTS

ARXIV:2402.11678

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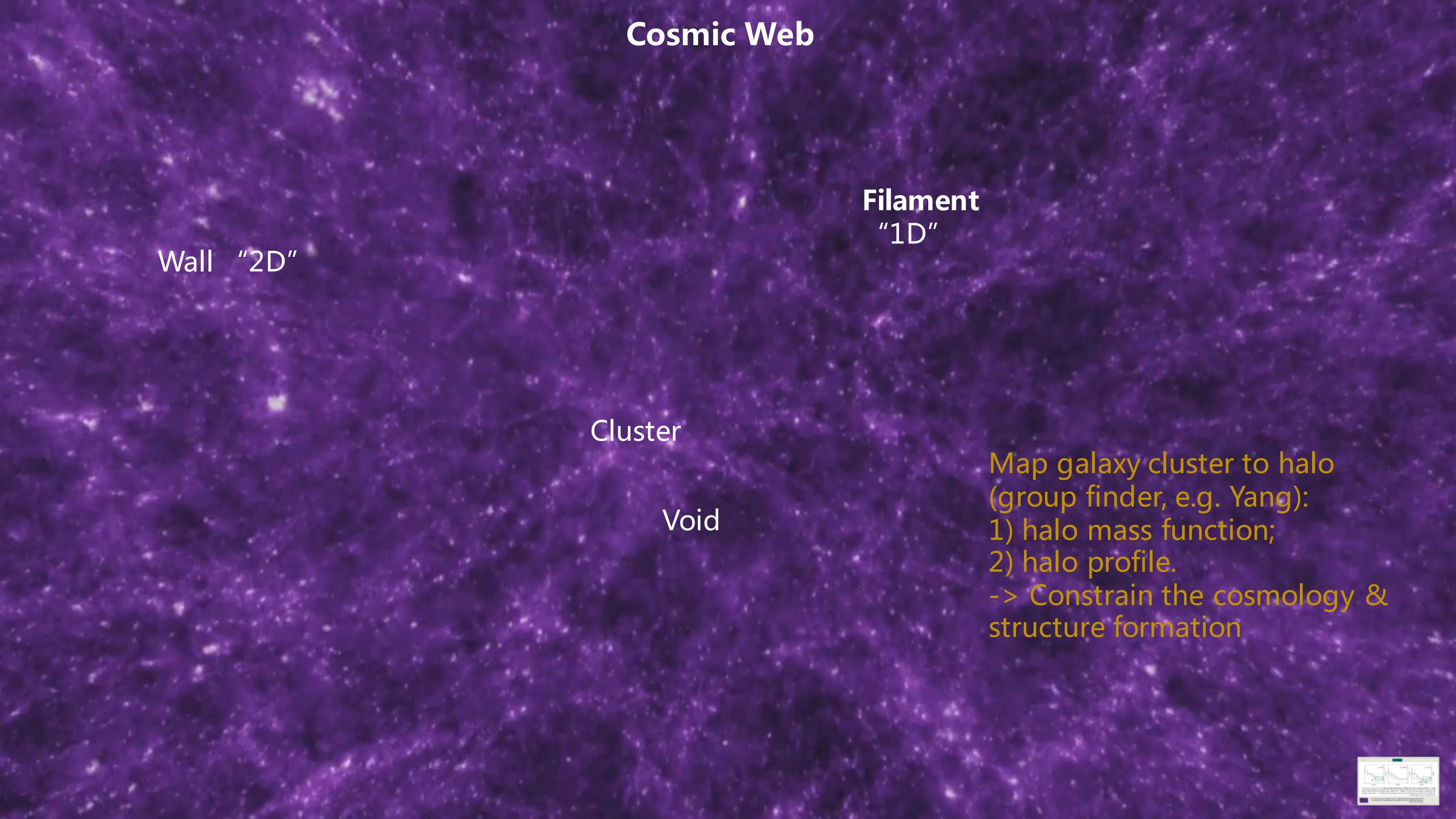
Cosmic Web



Map galaxy cluster to halo (group finder, e.g. Yang):
1) halo mass function;
2) halo profile.
-> Constrain the cosmology & structure formation

EXISTING PROBLEM IN FILAMENT RESEARCH

1) Filaments are crucial for studying galaxy properties and distribution

A significant portion of cosmic matter is found in the filaments, and there is a growing consensus that they play a major role in the formation and evolution of galaxies. This influence is evident in various galaxy properties, including their mass, shape, star formation rate, spatial alignment, abundance of satellite galaxies, and correlation of angular momentum

2) It is unclear of the spatial information of the "1D" filament & how does it influence galaxy properties

Several different algorithms have been developed to identify filaments based on the distribution of galaxies. However, most algorithms have limitations in extracting spatial information and describe filaments as one-dimensional structures without considering their radial extent. Without a clear understanding of the boundary of filaments, it is difficult to quantify how filaments affect the properties of the galaxy.

arXiv:2402.11678

Aim:
Having a well-defined physical radius for filaments would then greatly enhance our understanding of their formation and evolution.

Methodology:
Study the galaxy number density profile around filament along redshift (tomographically).

FILAMENT PROFILE

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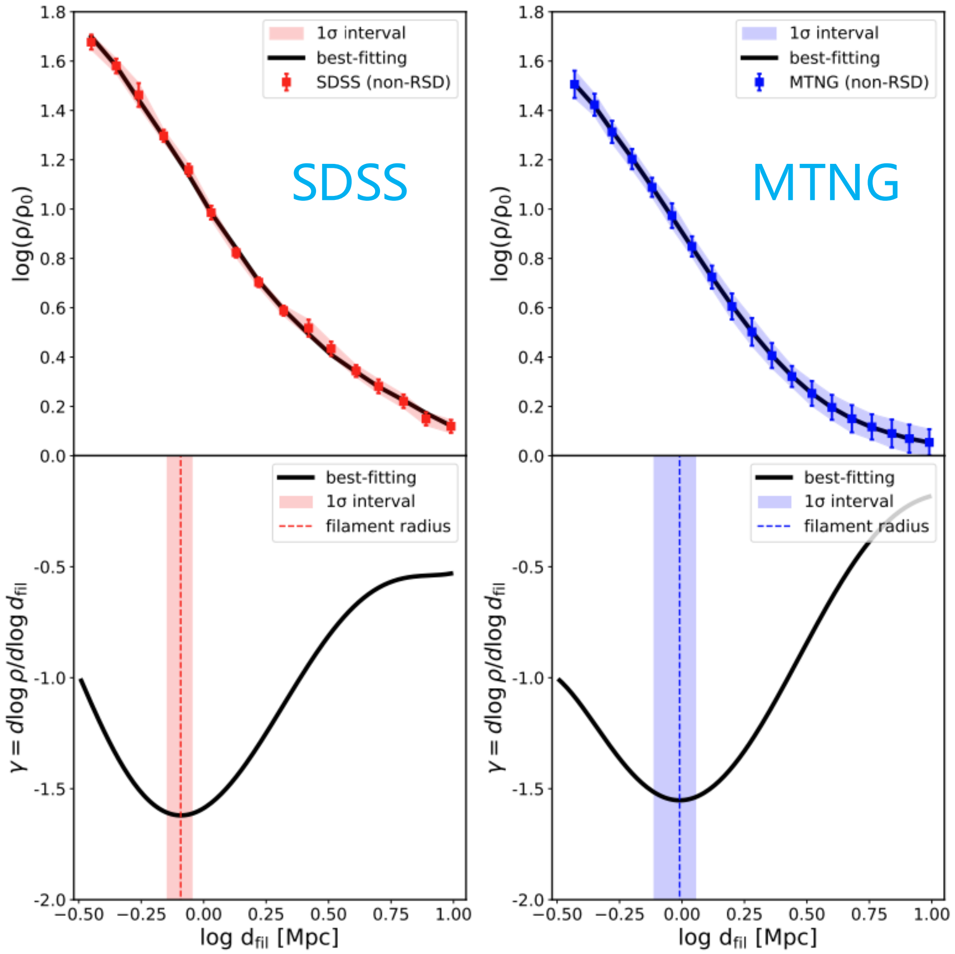

Figure 1 – **Upper panels**: the relative number density profile of galaxies around their host cosmic filaments, ρ/ρ_0, as a function of the perpendicular distance to the filament spine, $d_{\rm fil}$, where ρ_0 is the background density of galaxies above a threshold mass of $10^9\,{\rm M}_\odot$ in the sample. The colour symbols with error bars are measured from SDSS (left) at $0 < z < 0.1$ and MTNG (right) at $z = 0$, respectively. The errors are measured from the Jackknife resampling method of 32 subsamples with equal volumes. Solid black lines show the best-fitting models using the MCMC method. **Bottom panels**: The logarithmic slope of the number density profile, $\gamma \equiv d\log\rho/d\log d_{\rm fil}$, derived directly from the best-fit profile shown in the upper panels. The mean values of the filament radius are represented by vertical dashed lines (0.81 Mpc for SDSS and 0.98 Mpc for MTNG), while the shaded area illustrates the 16th to 84th percentile range obtained from the MCMC chains.

$$\frac{\rho(r)}{\rho_{backgroud}}$$

Background: dividing the total number of galaxies by the volume.

Data:

1) SDSS DR12;
2) Millennium-TNG hydrodynamical simulation.

Definition of filament radius:
the point corresponding to the minimum slope.
(similar to the splashback radius of dark matter halo)

EVOLUTION

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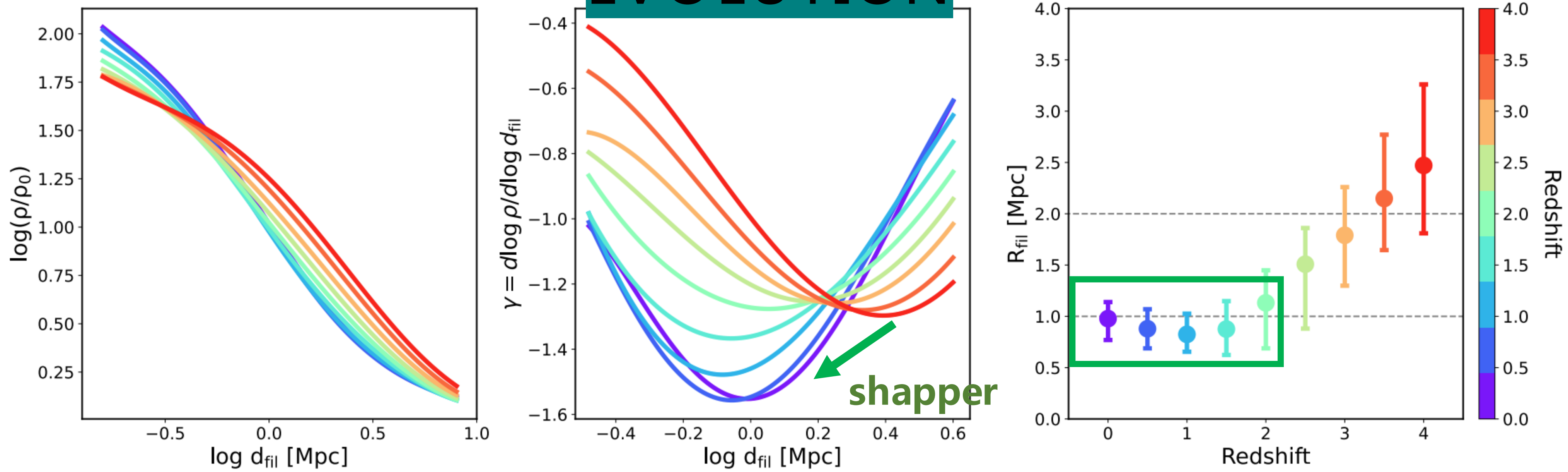

Figure 3 – Evolution of the galaxy number density profile around filament spines, its slope, and the corresponding filament radius. Similar to Figure 1, but we consider the redshift dependence of the filament radius. Measurements at different redshifts are shown in different colours, as indicated by the colour bar on the right. **Left panel:** the density profiles of the galaxy number around filaments as a function of the distance to the filament spine $d_{\rm fil}$ at the corresponding redshifts. **Middle panel:** the variation of the best-fitting slope γ with $d_{\rm fil}$ at different redshifts. **Right panel:** the best-fitting radius of filaments as a function of redshift. The dashed lines indicate the filament radius of 1 Mpc and 2 Mpc, respectively. The average filament radius has undergone a rapid decrease from $z = 4$ to $z = 1$ and a slow growth afterwards. The slope γ at $R_{\rm fil}$ also becomes steeper with time.

The galaxy number density profile becomes quite consistent since the formation of filaments around z = 1. This suggests that the structure of cosmic filaments was formed essentially around z = 1. According to Zel' dovich' s theory, the formation of a filamentary structure occurs after the completion of the wall structure. This implies that the most rapid collapse along the first direction has been finished, and the second direction is now collapsing to form the filaments.

EVOLUTION

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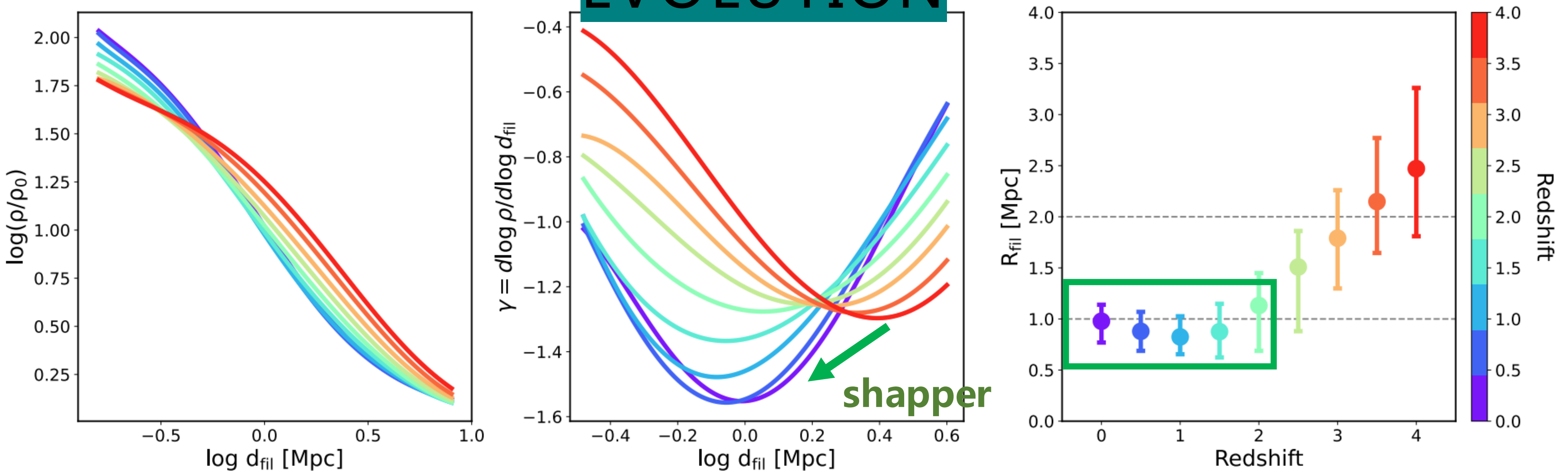

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It is evident that filament formation has gone through two stages: a rapid radial collapse before z =1 and a slower growth along the radial direction afterward.

LENGTH

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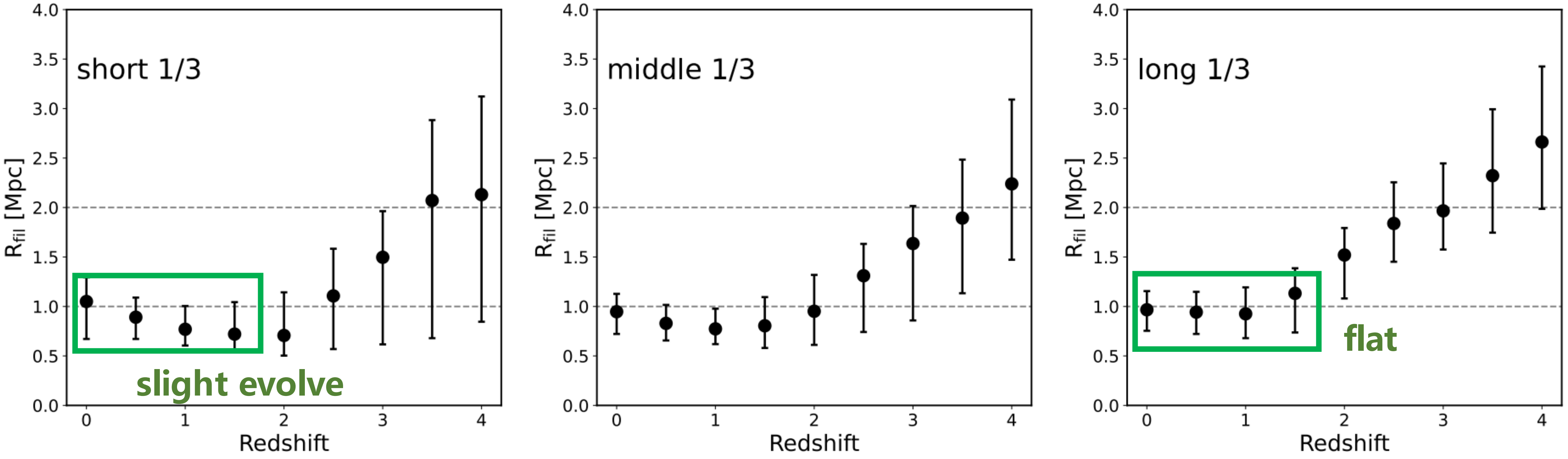
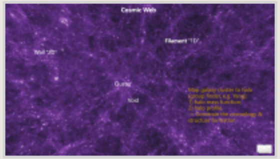


Figure 4 – Evolution of filament radius with redshift by considering the filament length. We categorize the entire sample into three sub-samples of equal size based on the length distribution of the filaments. These subsamples are labelled as short, middle, and long filaments, arranged from left to right. At redshift $z = 0$, the median filament lengths for the short, middle and long subsamples are 7.56, 14.61, and 25.05 Mpc, respectively. The longer filaments have larger $R_{\rm dfil}$ at $z > 1$, and the shorter filaments show a stronger growth of the filament radius.

Short filaments appear to be connected to clusters located in node structures. This increase in the filament radii of short filaments is probably due to the accretion of matter near the nodes.



CONCLUSION

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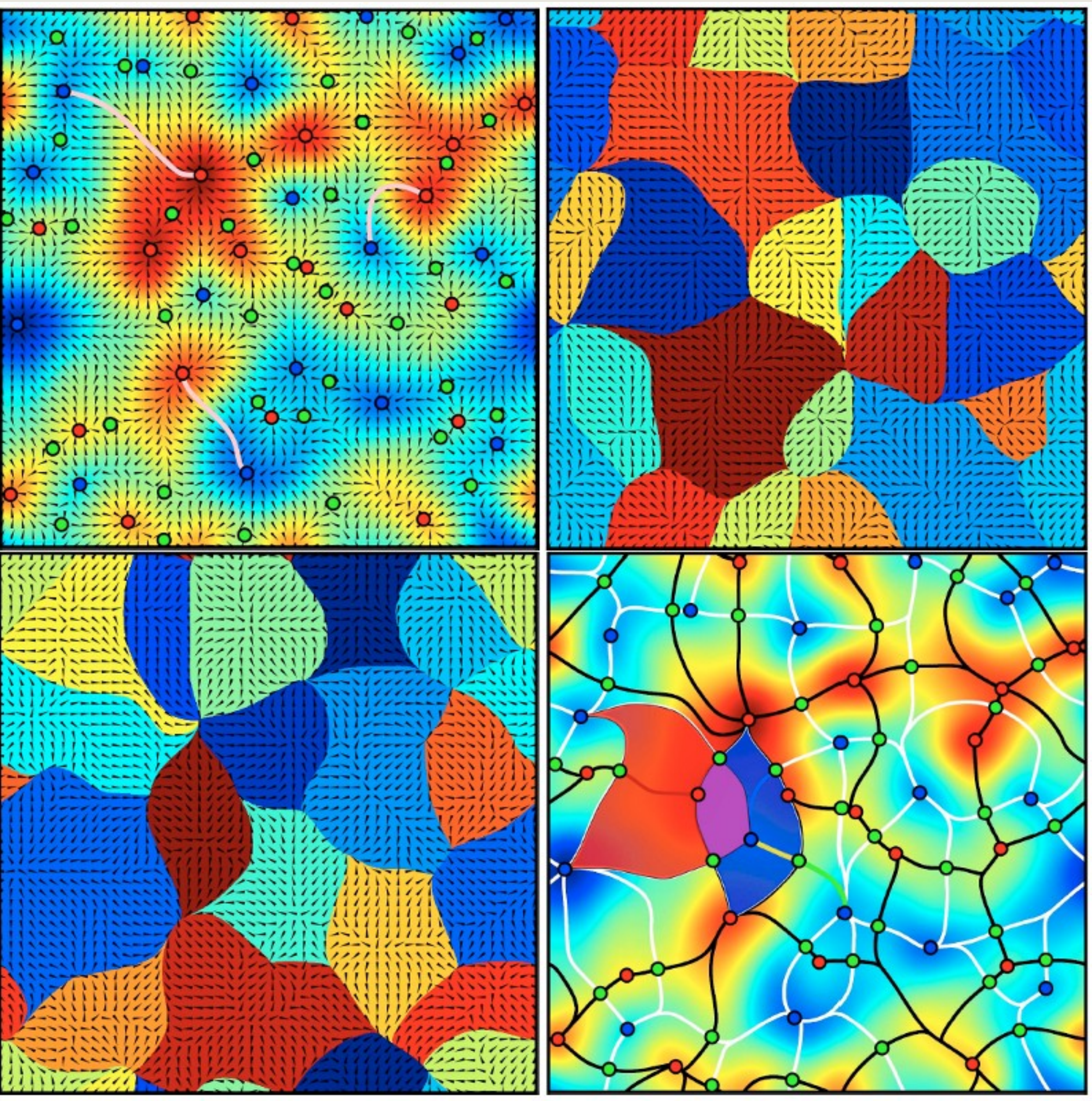
1. we have **developed a physically-motivated definition of the radius of filaments** in terms of the minimum slope of the galaxy number density distribution around the filament spines.

2. Our analysis reveals that **the average radius of cosmic filaments** in the **MTNG simulation** at **z =0** is approximately **1Mpc**, which agrees with the filament radius derived from **SDSS** galaxies after correcting for redshift space distortions (RSD).

4. We can observe that **the formation of filaments occurs in two distinct phases**. Before z = 1, the filaments undergo rapid collapse, resulting in a significant decrease in their radius from z = 4 to z = 1. By z = 1, the filaments are more collapsed in the radial direction, and the galaxy number density profile remains relatively stable.

3. We observe a decreasing trend in the slope (γ) at the radius of the filament from approximately −1.2 at z = 4 to approximately −1.6 at z = 0, indicating sharper filament edges.



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Filament identification algorithm

Overview - DisPerSE - persistent structures identification (iap.fr)

1) white line: green(saddle)-blue(void);
2) **Black line: green(saddle)-red(peak);**

The second defines filament