Zakharova Daria

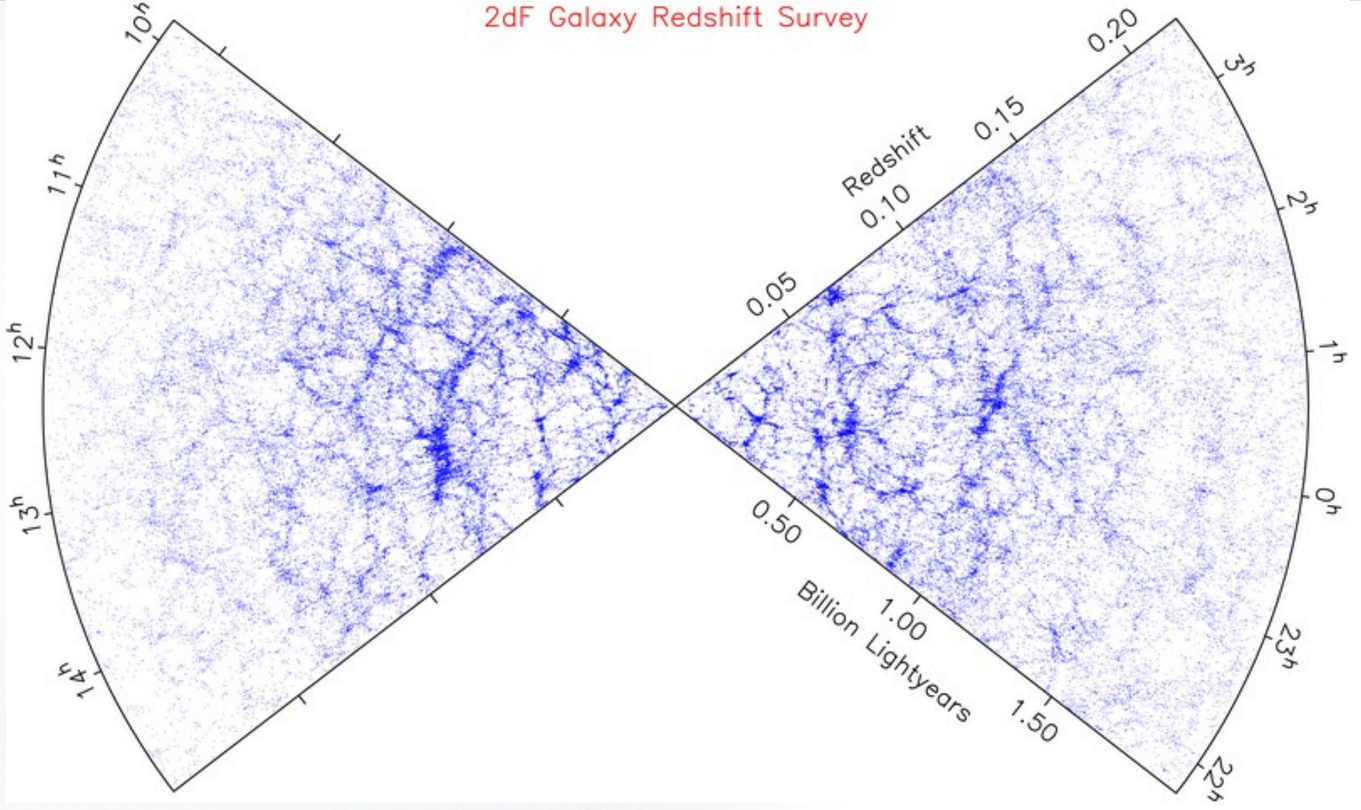
INAF Trieste

Galaxies and cosmic web

in observations and simulations

Cosmic web

The observed galaxy distribution strongly points to the presence of an underlying large-scale structure.



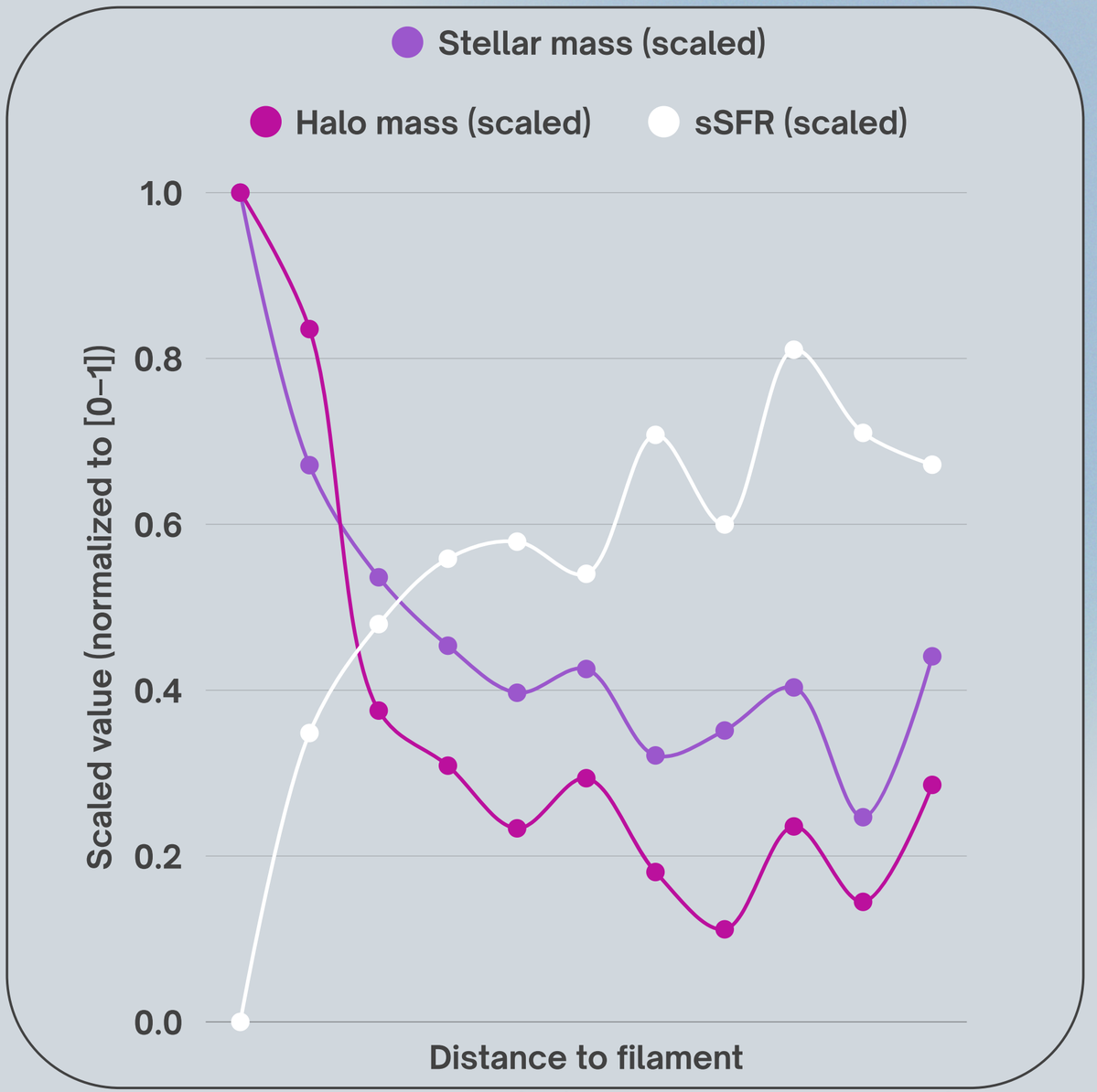
Properties of galaxies inside filaments

Both observations and theory agree that the properties of galaxies correlate with their distance to filaments.

More massive

Less star-formation

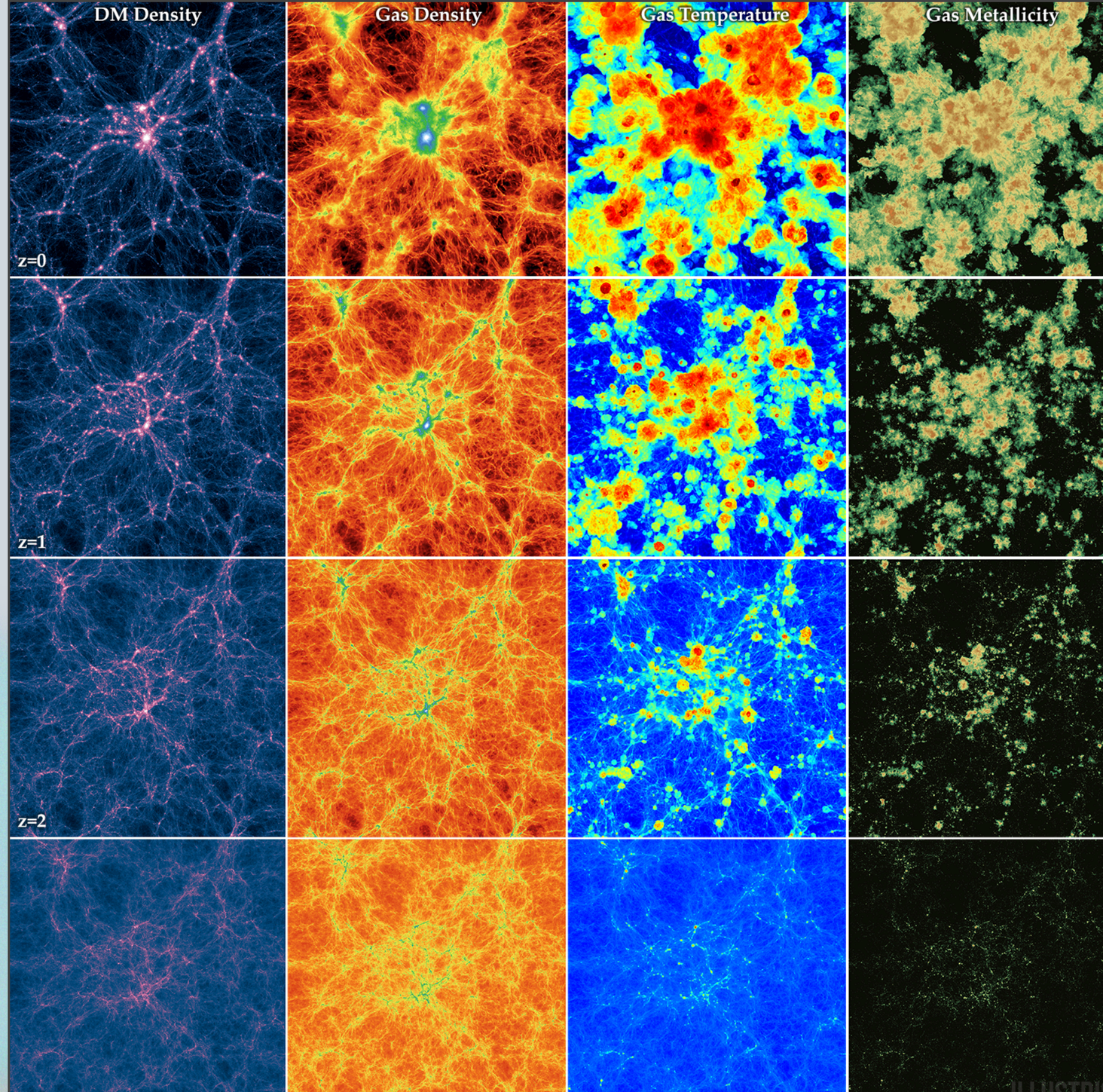
Aligned with filaments



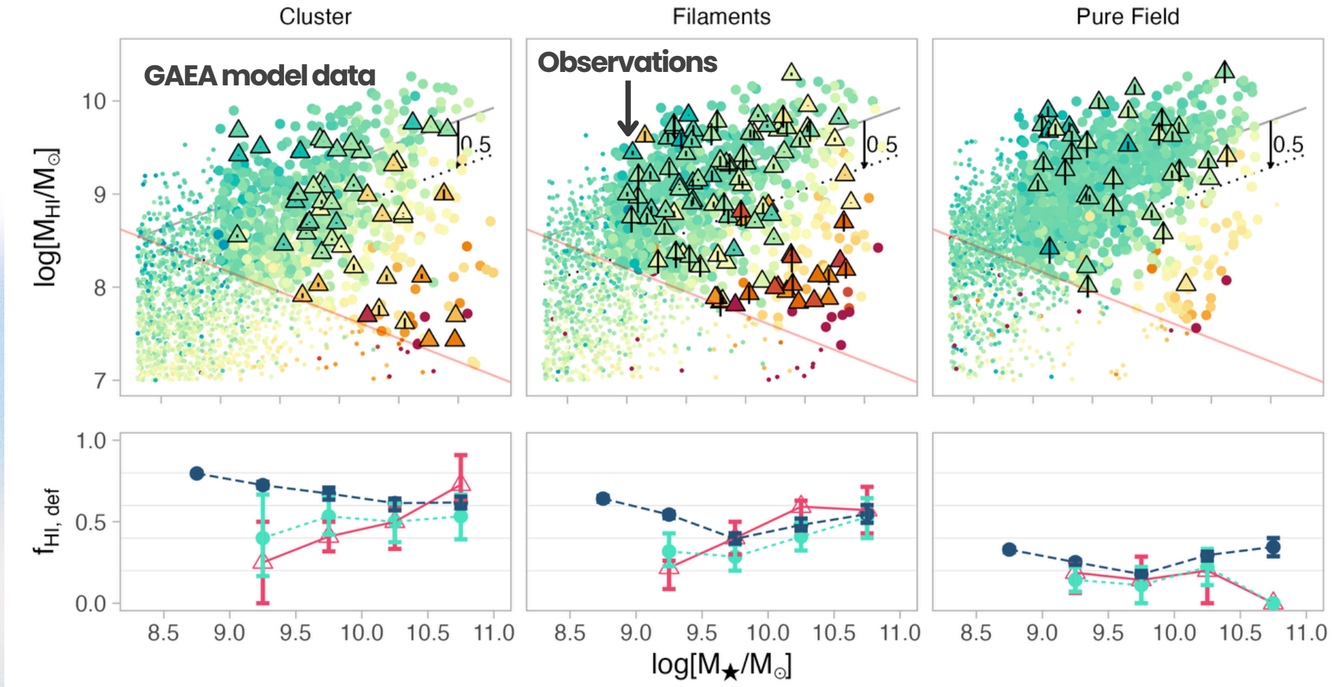
just few Guo et al 2015, Chen et al 2017,Codis et al 2012, Laigle et al 2015, Welker et al 2020,Kuchner et al 2022, Castignani et al 2022, Kraljic 2018, Zakharova et al 2023, 2024,2025, there are many more

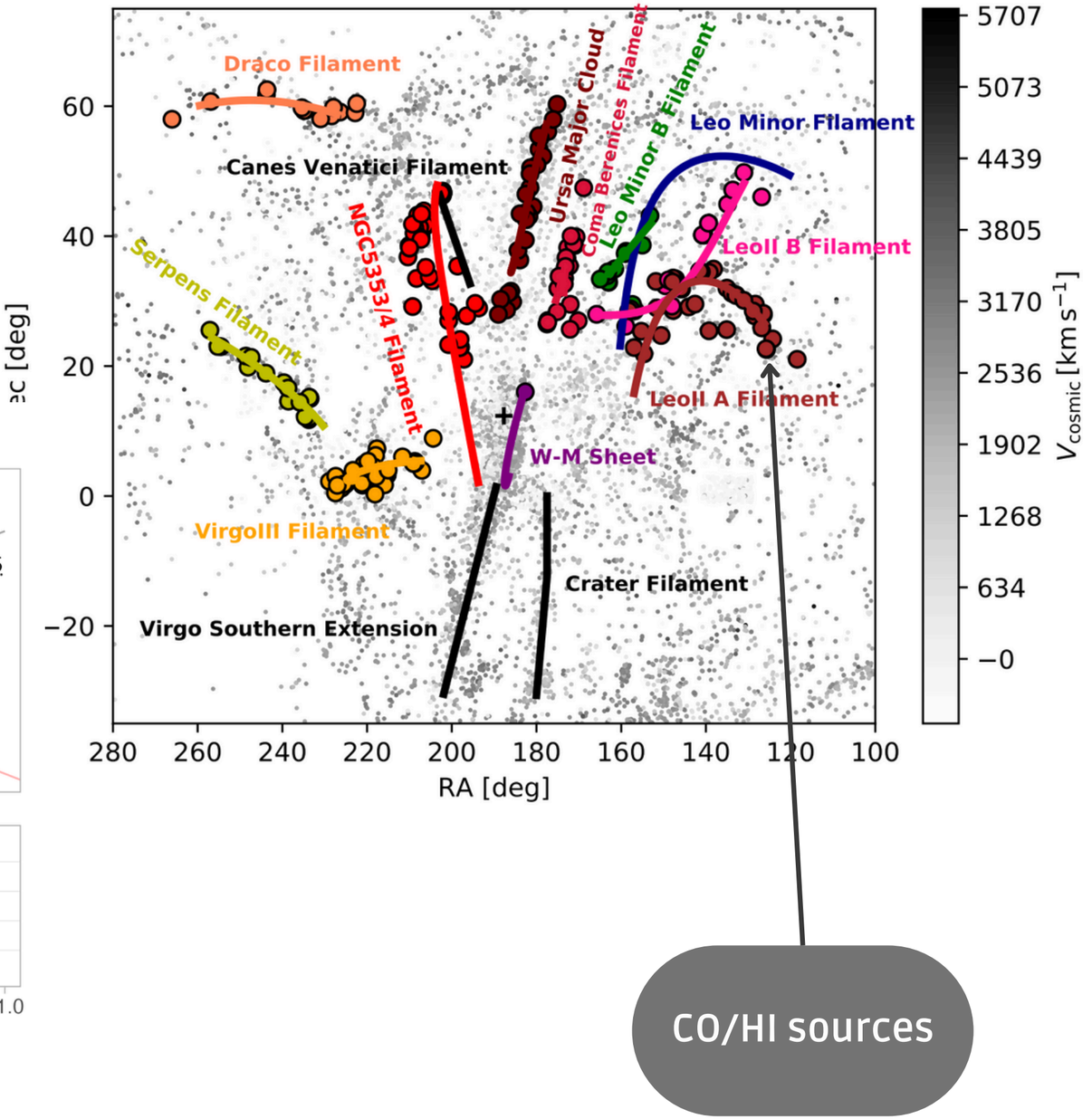
Environment of galaxies

- Access to accretion material regulates halo mass assembly.
- Cold-gas supply controls star-formation efficiency.
- The state of the surrounding medium governs cooling and inflow.
- Filamentary inflows enhance anisotropic growth.
- The interaction/merger rate depends on the environment.



Virgo cluster

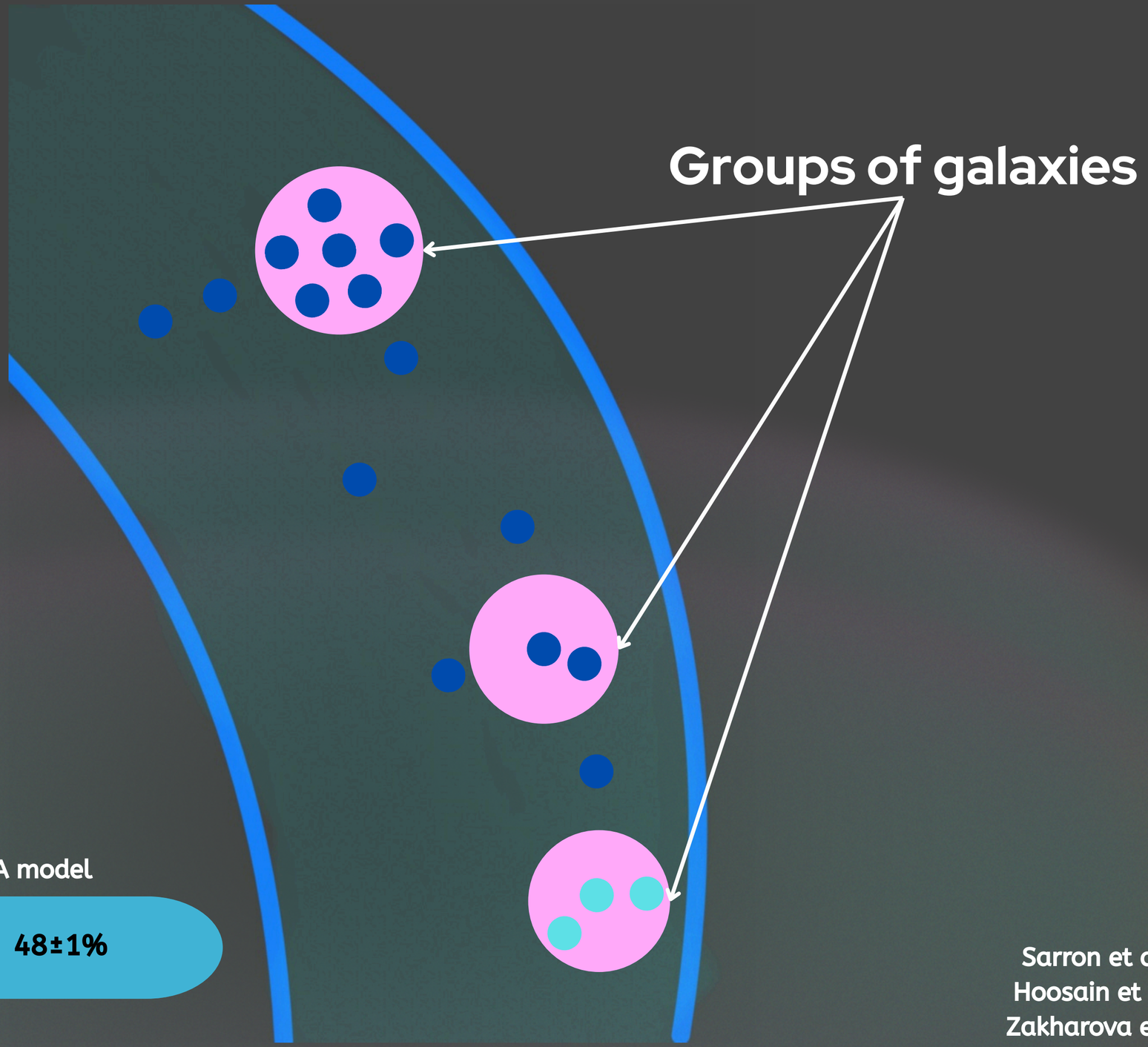


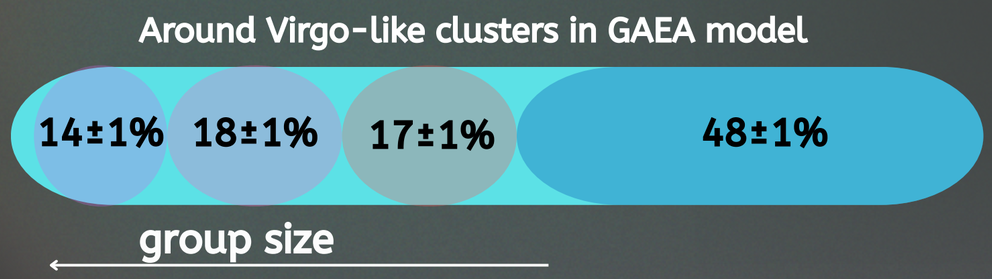


CO/HI sources

Castignani et al. 2022, Zakharova et al 2024

Filaments are heterogeneous, and their coupling with group environments complicates separating intrinsic filament effects





Sarron et al 2019,
Hoosain et al 2024,
Zakharova et al 2024

Gas in galaxies in filaments around Virgo cluster

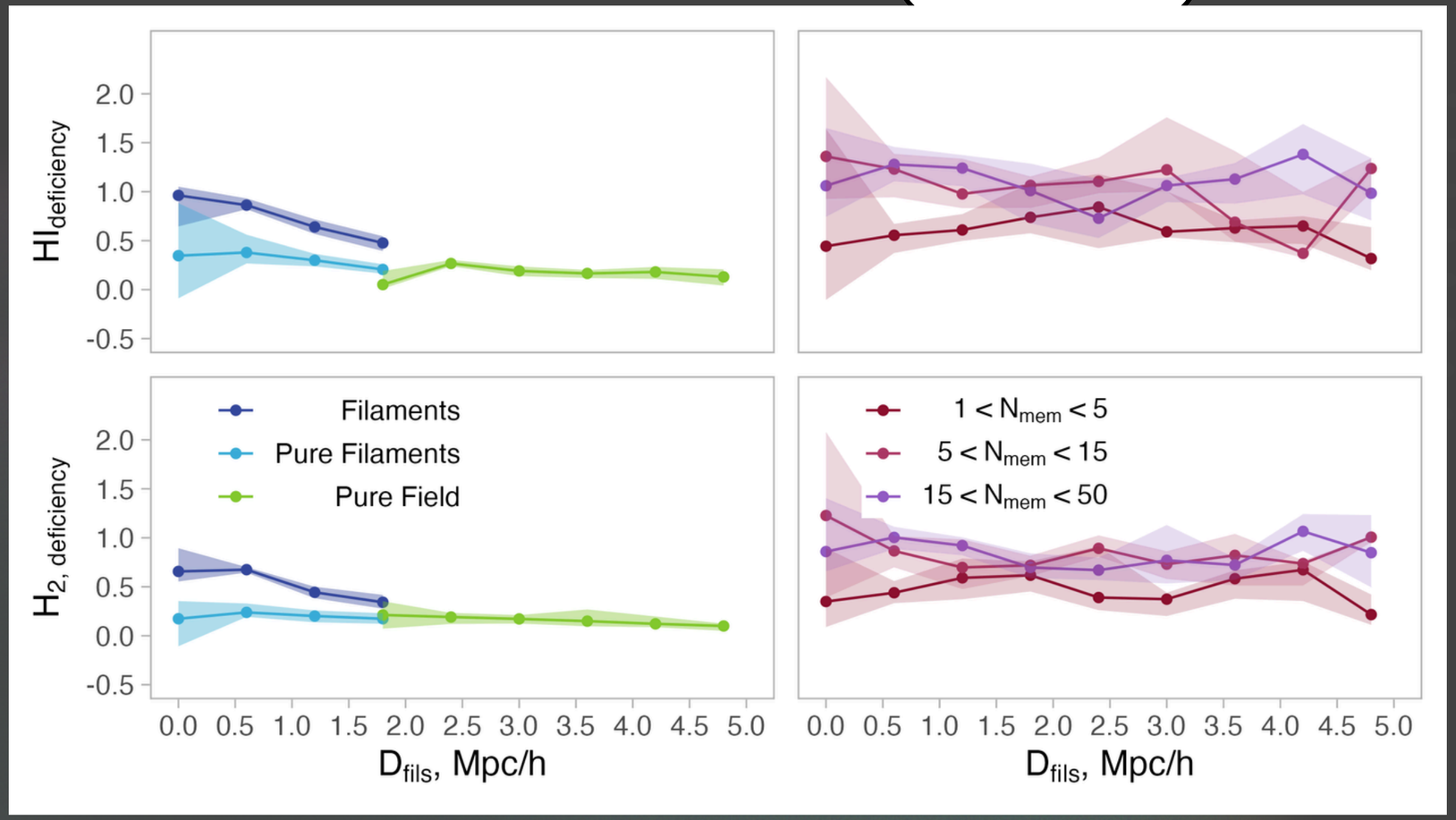
Galaxies in filaments are more HI- and H2-deficient near the filaments axis

Isolated galaxies do not demonstrate the same trend

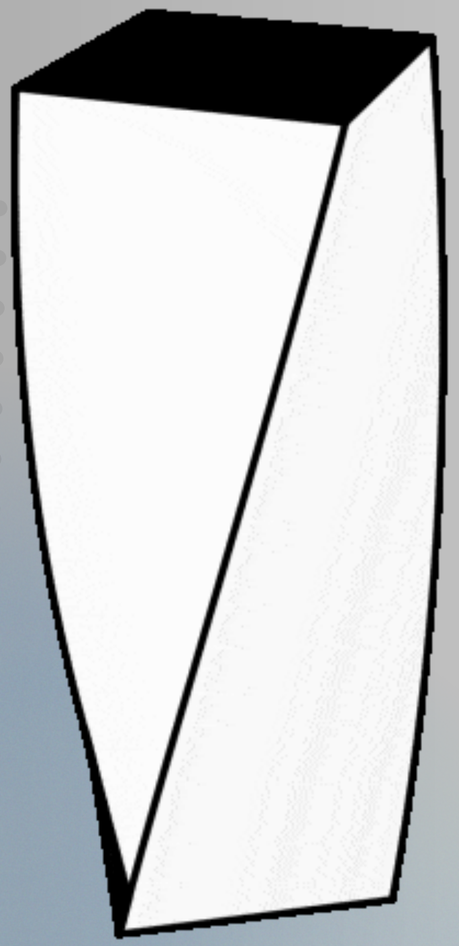
Galaxies in rich groups shows the dependency of HI- and H2-deficiency with distance to filaments

GAEA model, around Virgo-like clusters

Group members



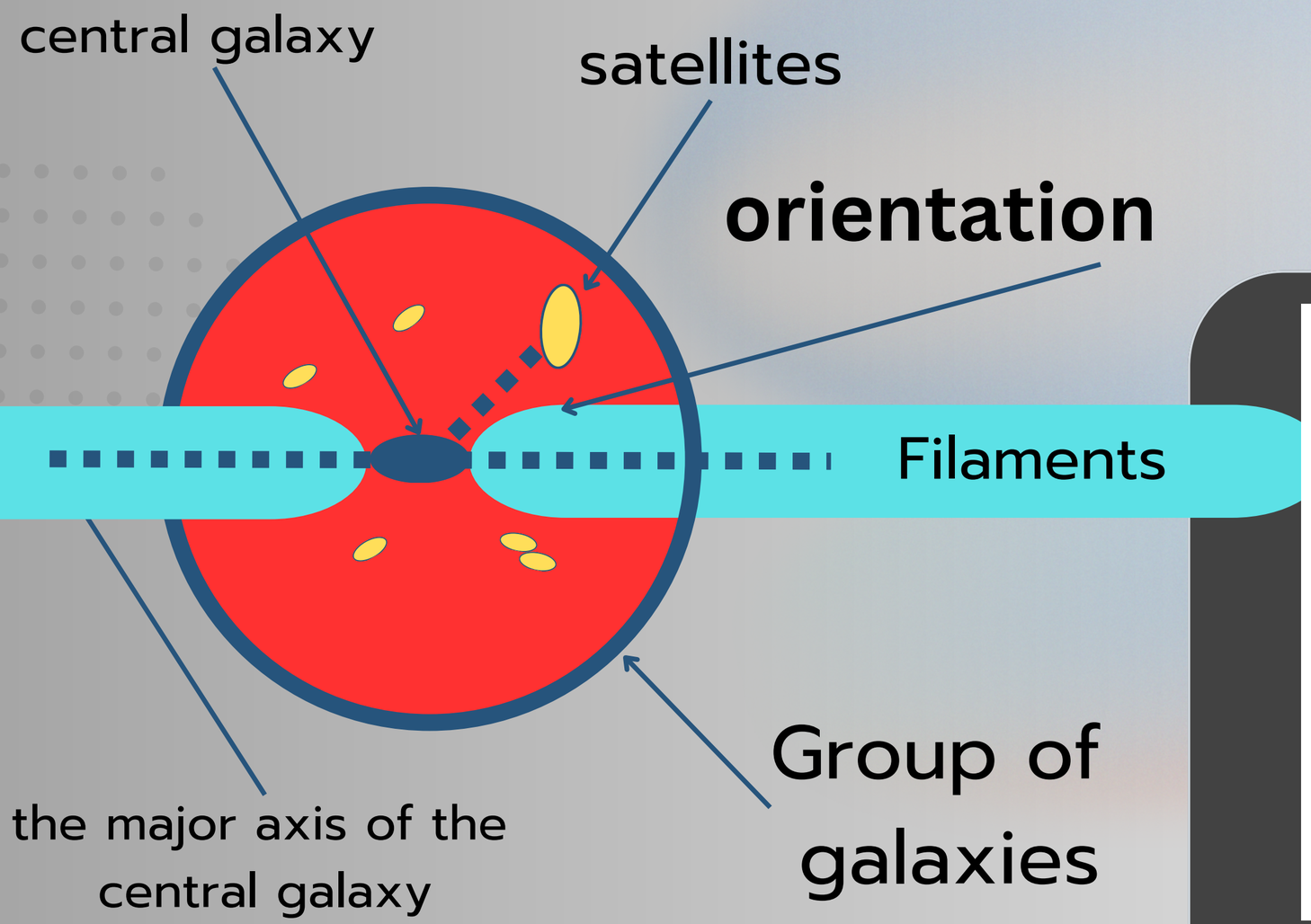
Hossain et al 2024, Zakharova et al 2024

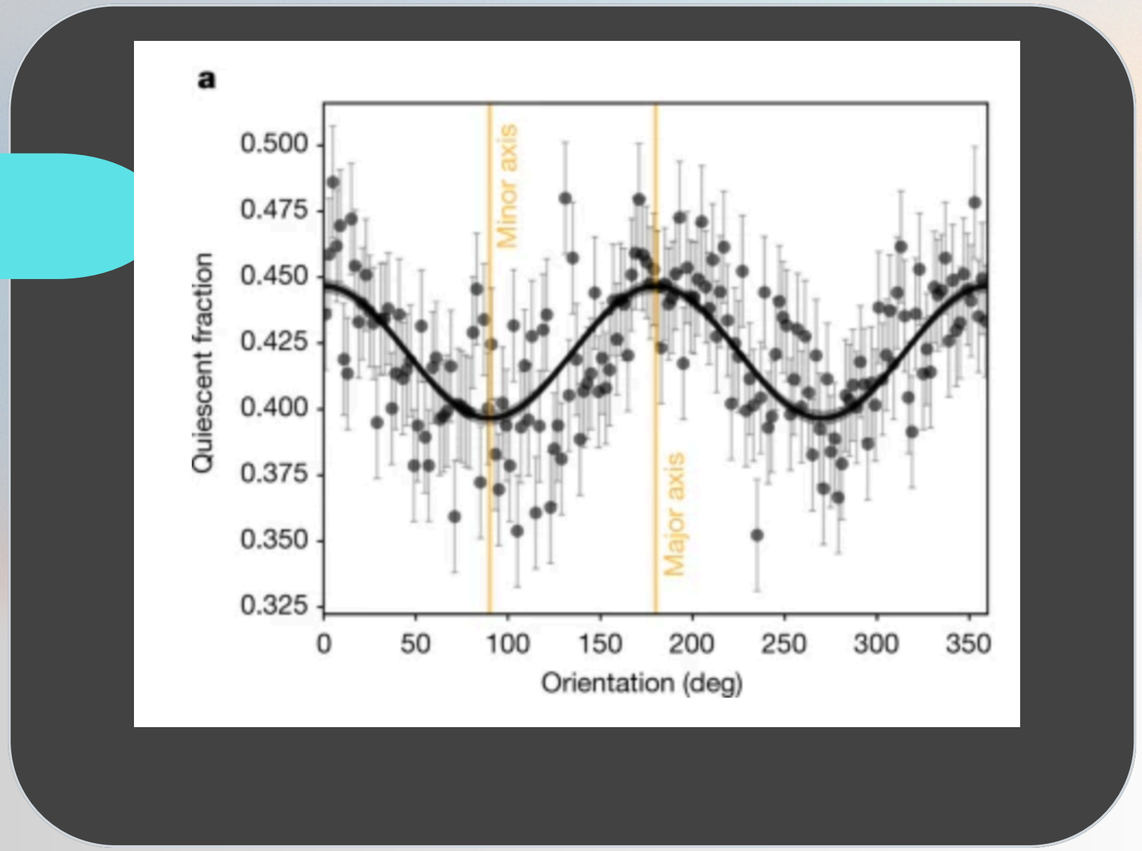


Filaments contain 60% of the total budget of matter

Cautun et al. 2014; see Cui et al. 2017, Martizzi et al. 2019, Cui 2019 for higher fractions

Filaments feeding clusters

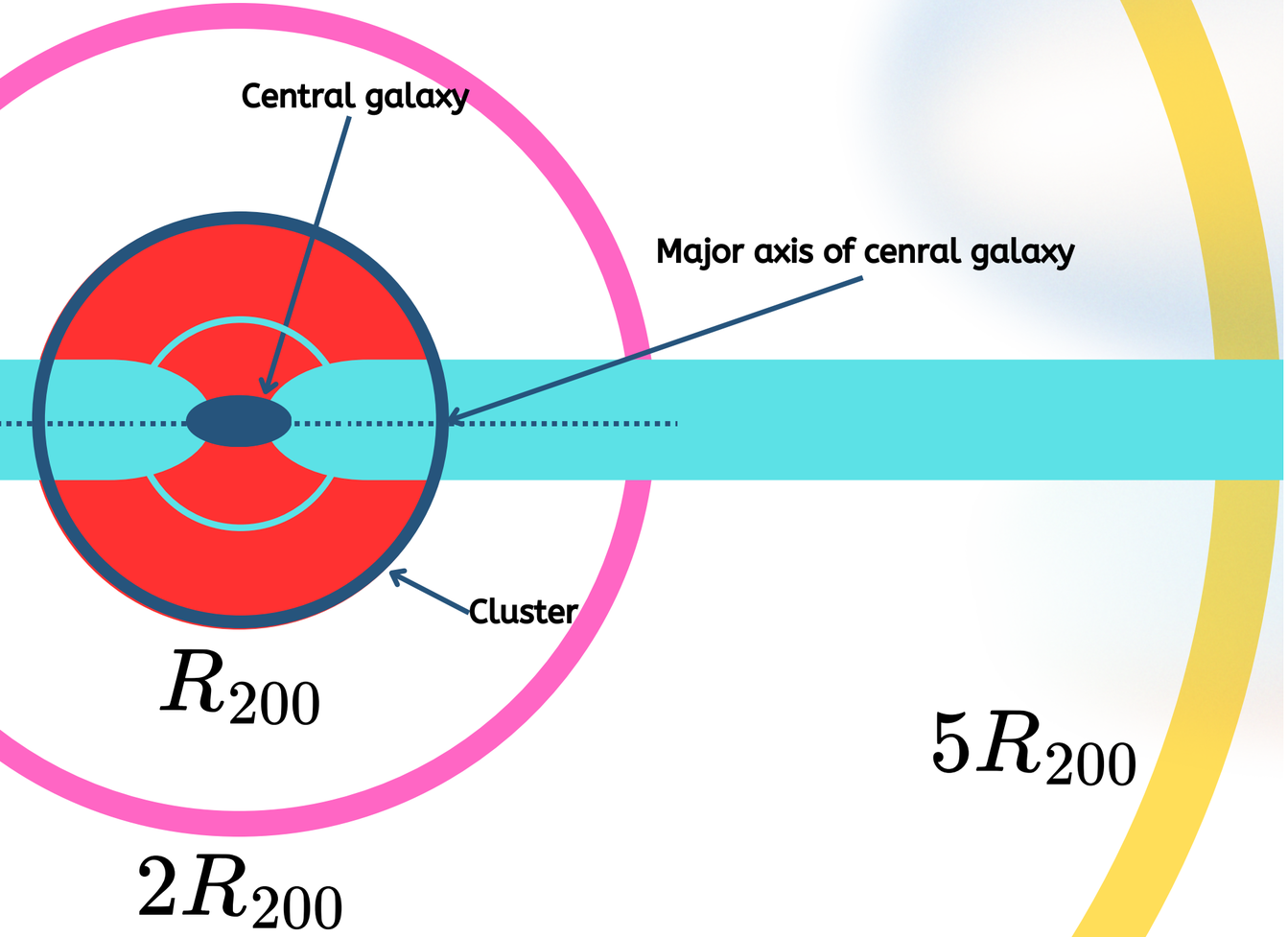


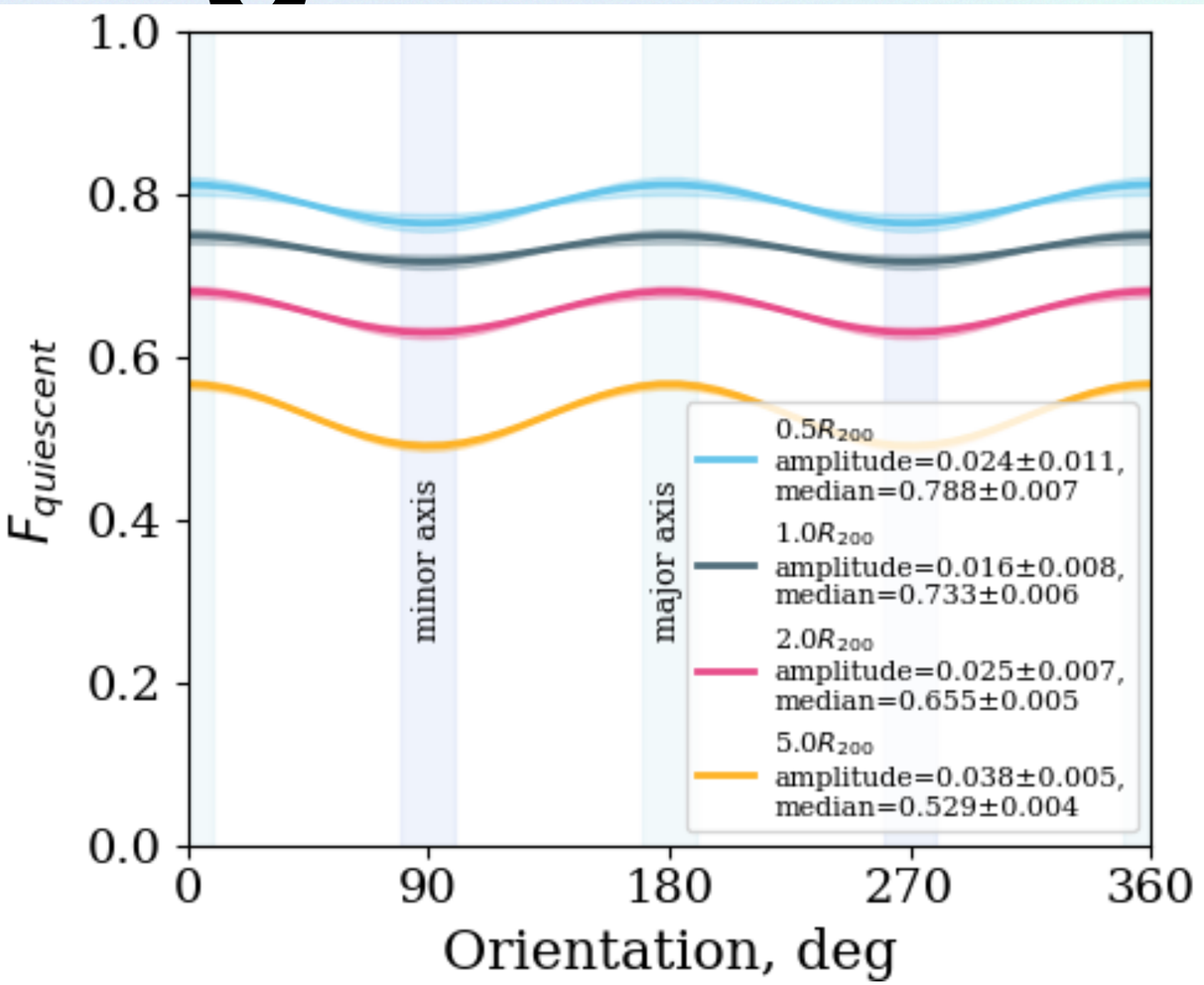


SDSS data from Martín-Navarro et al. 2021,
also Yang et al. 2006, Kang et al. 2007, Stott et al. 2022, Ando et al. 2023

Zakharova et al. 2025a

Filaments feeding clusters





Zakharova et al. 2025a,
Stephenson et al. 2025,

What about only filaments?

01 Cosmic web

02 Cosmic web dynamics

03 Tidal fields

04 Assembly history of haloes

05 Local density

06 Baryon physics

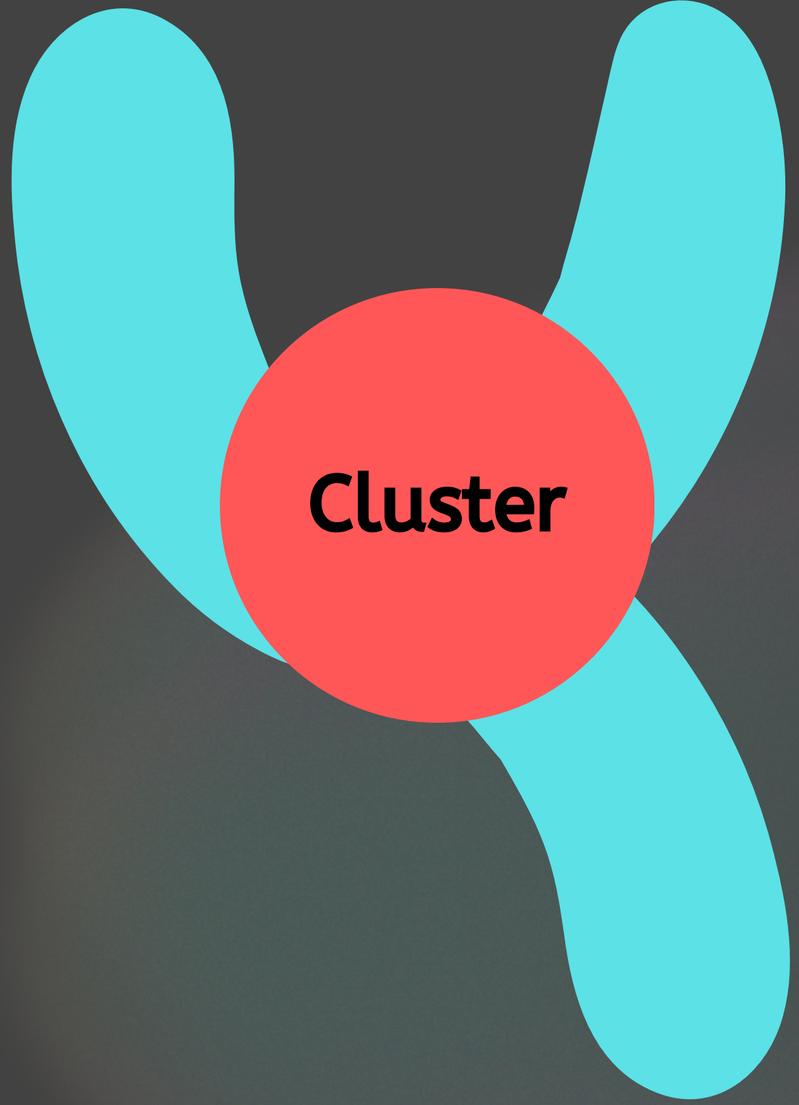
07 AGN activity

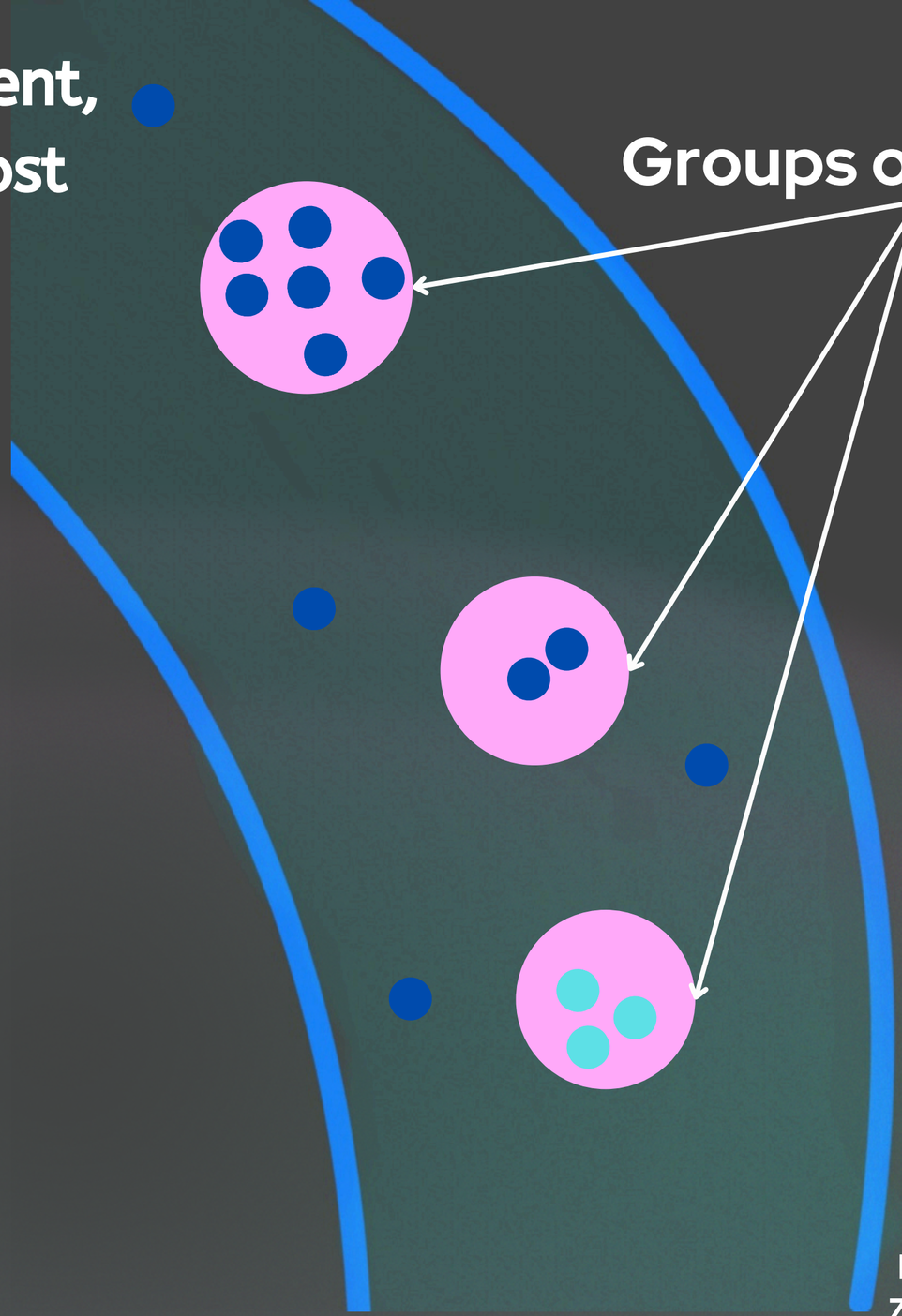
08 Stellar feedback

09 Secular evolution

10 Galaxies

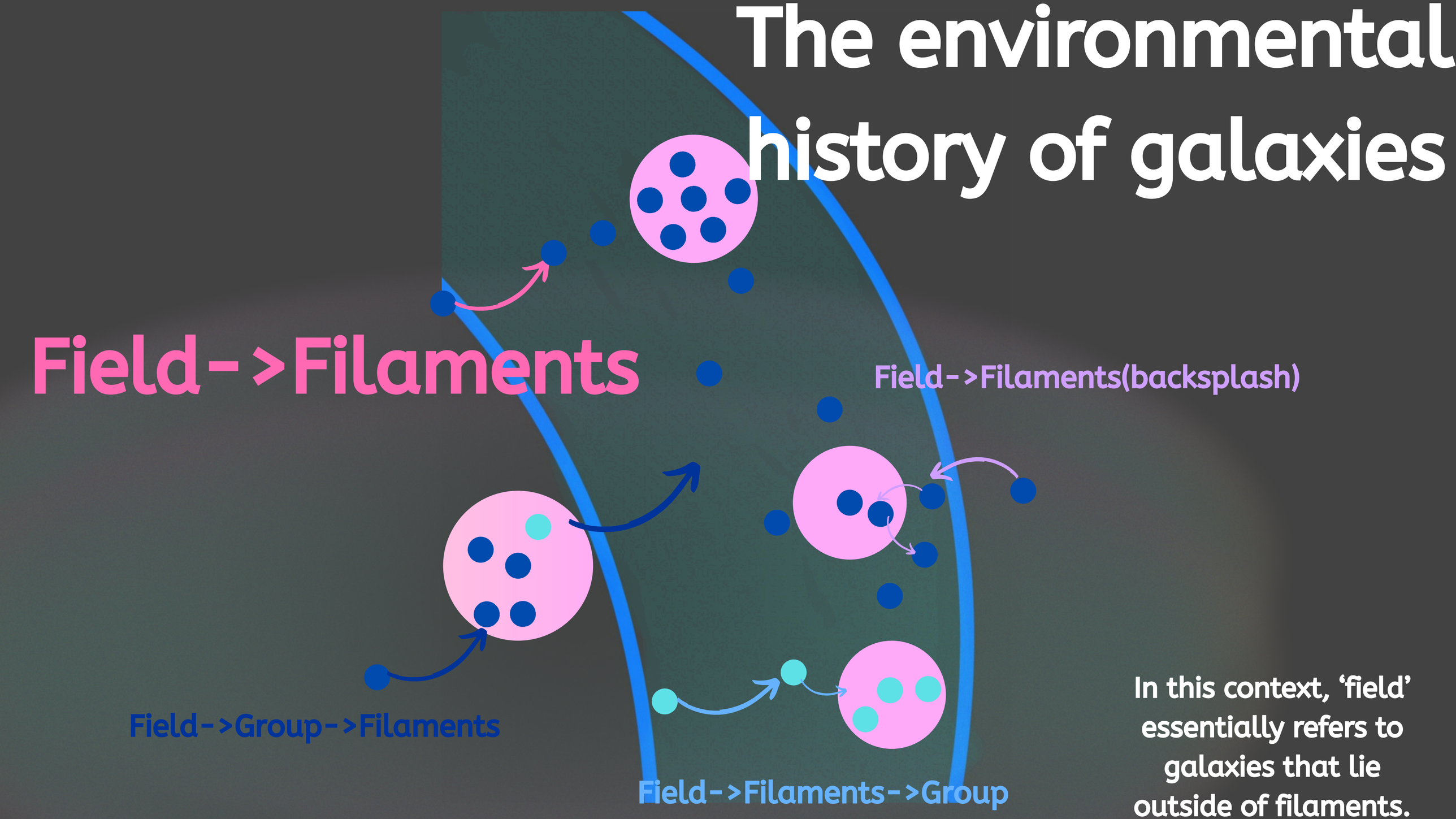
We consider only today's environment, so only the correlation with the host environment is observed





Sarron et al 2019,
Hoosain et al 2024,
Zakharova et al 2024

The environmental history of galaxies

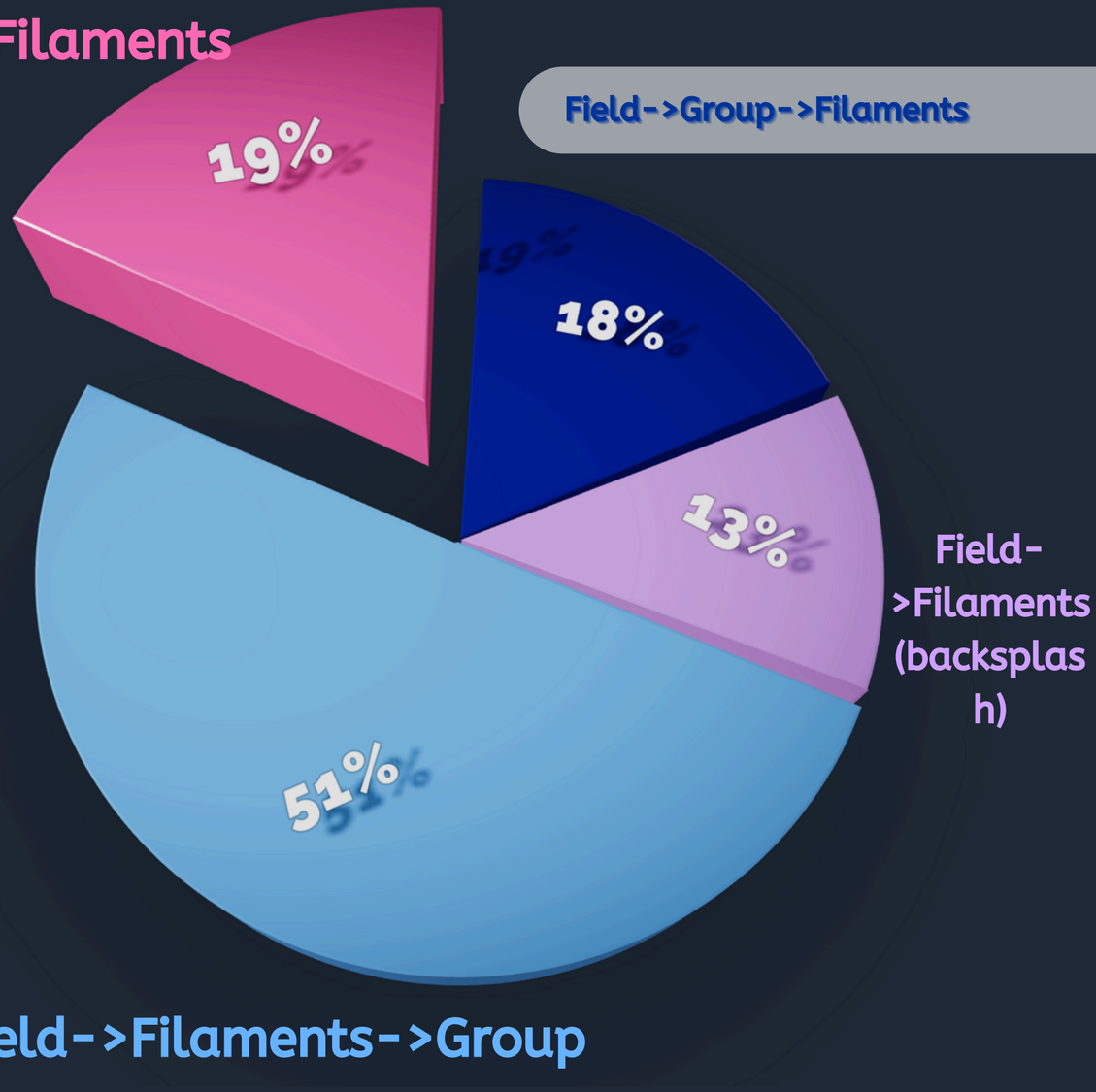


In this context, ‘field’ essentially refers to galaxies that lie outside of filaments.

Only 1/5 of filament galaxies at z=0 never been pre-process as satellite galaxy (0 < z < 4)

reaches ⅓ for massive galaxies

Properties of filament galaxies infused by the group populations

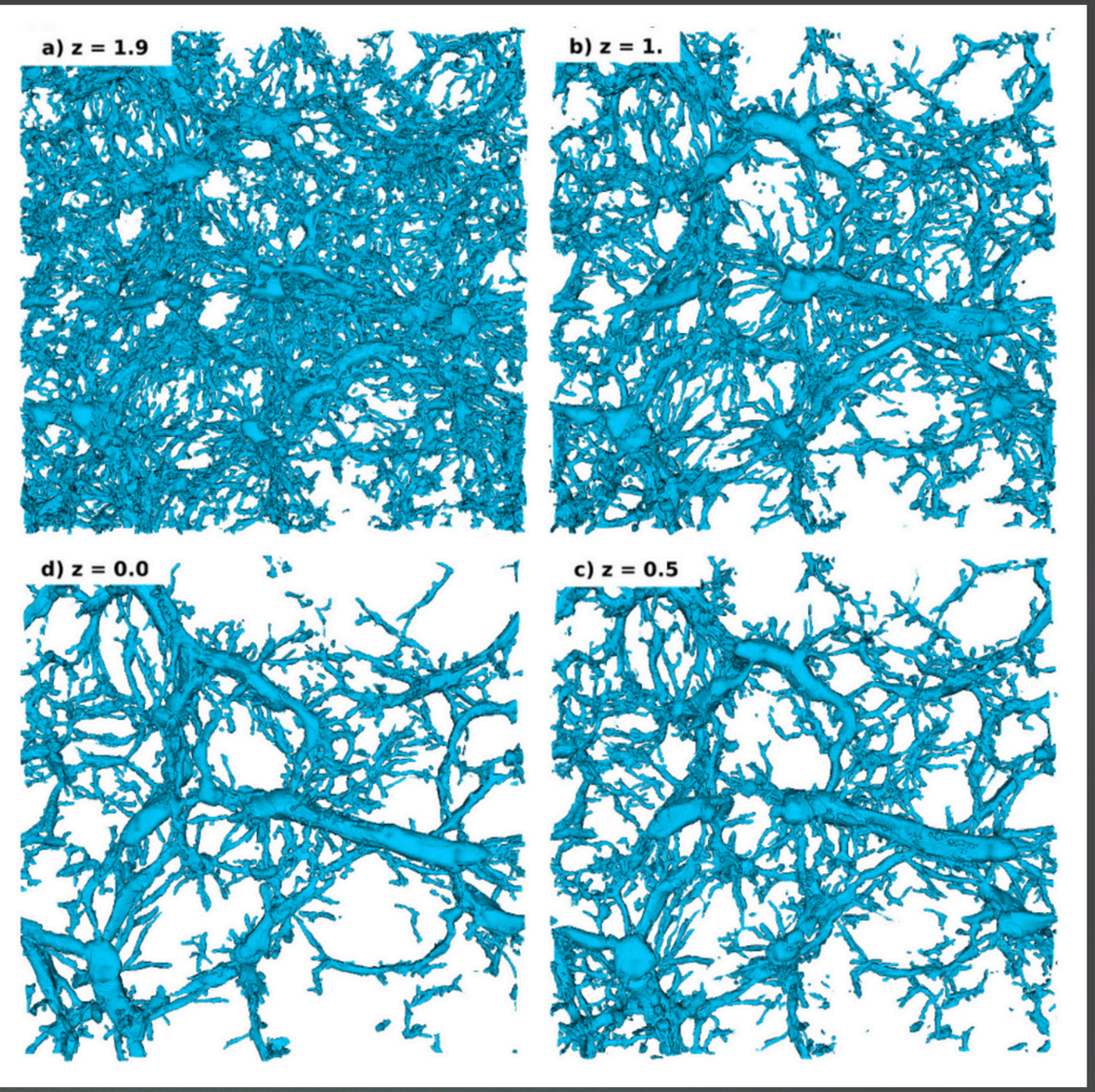


according to GAEA and TNG100

$$log_{10}\left(\frac{M_{star}}{M_{sun}}\right) > 9$$

Zakharova et al 2025b

The environmental history of galaxies



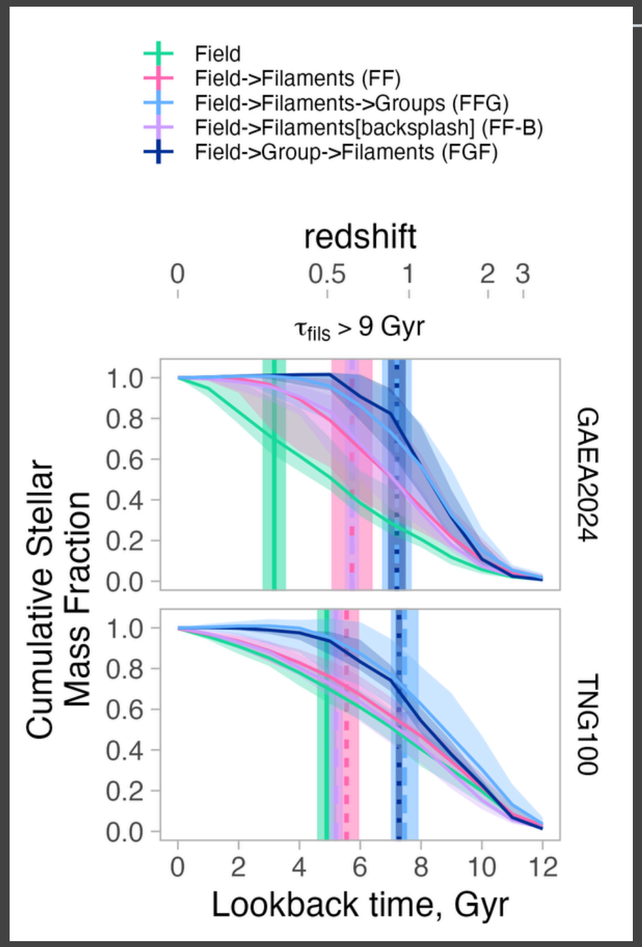
Cautun et al. 2014, Bahe et al. 2025

The environment also evolves,
as does its impact

See Vulcani el al 2026, subm

Environment impact

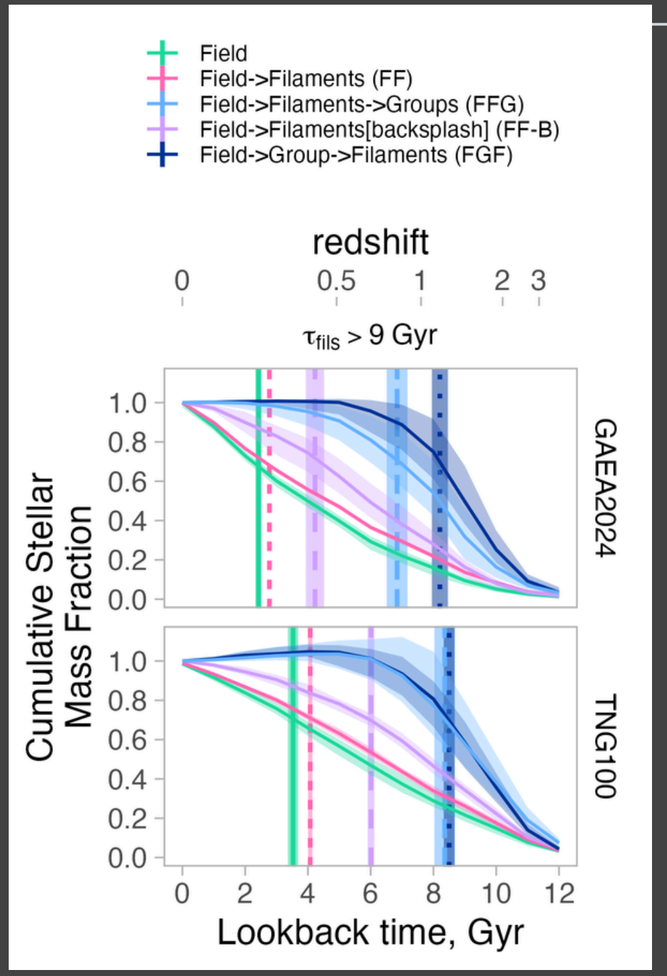
Enhanced reservoir



$$log_{10}\left(\frac{M_{star}}{M_{sun}}\right) > 10$$

faster assembly in filaments for high mass end

Tidal fields ?



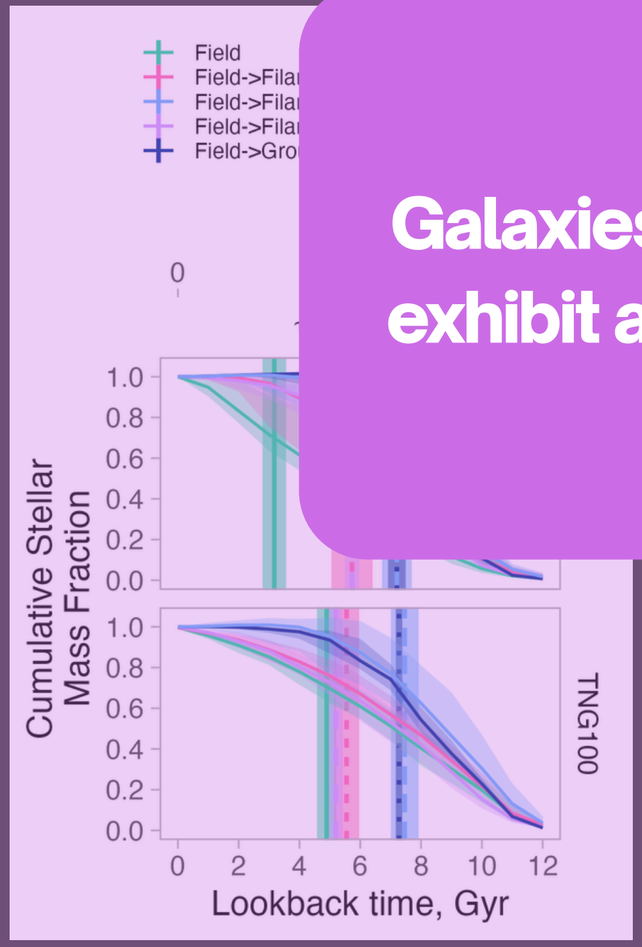
$$9 < log_{10}\left(\frac{M_{star}}{M_{sun}}\right) < 10$$

almost nothing for low-mass end

Zakharova et al 2025b

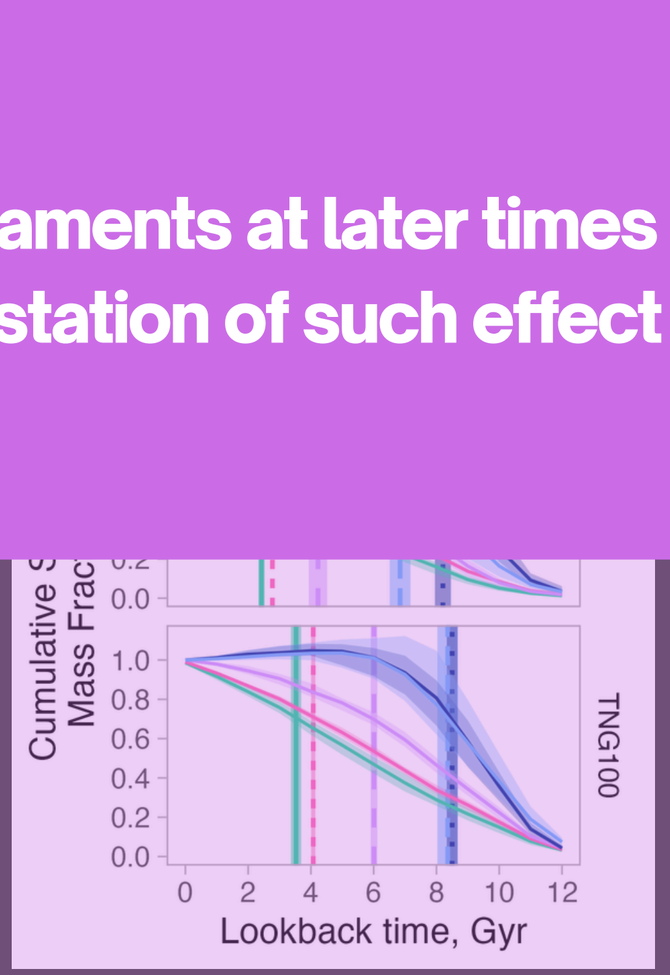
Environment impact

Enhanced reservoir



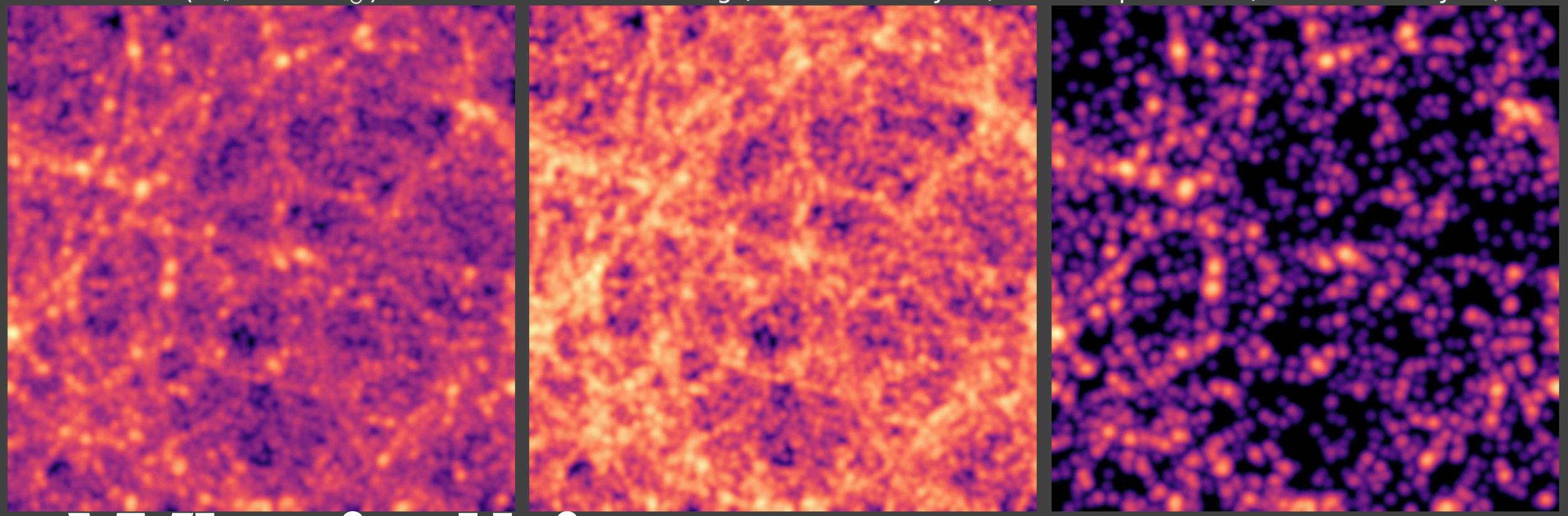
Tidal fields ?

$$log_{10}\left(\frac{M_{star}}{M_{sun}}\right) < 10$$



Galaxies accreted by filaments at later times exhibit a weaker manifestation of such effect

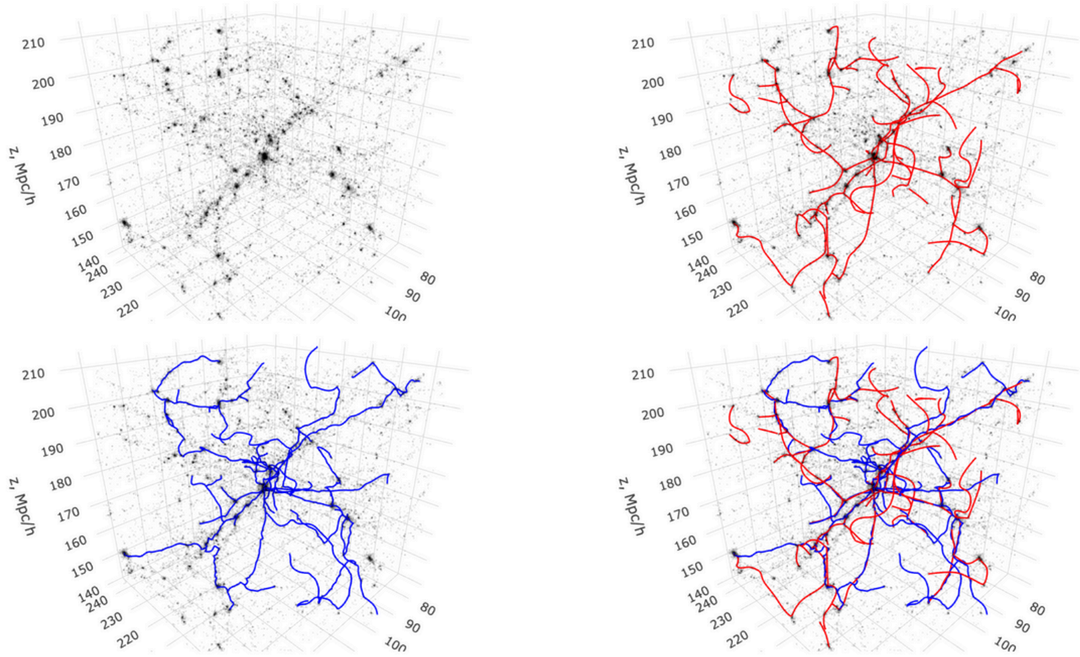
Zakharova et al 2025b



Why is this important?

Galaxies are a biased indicator of dark matter distribution

Tracers

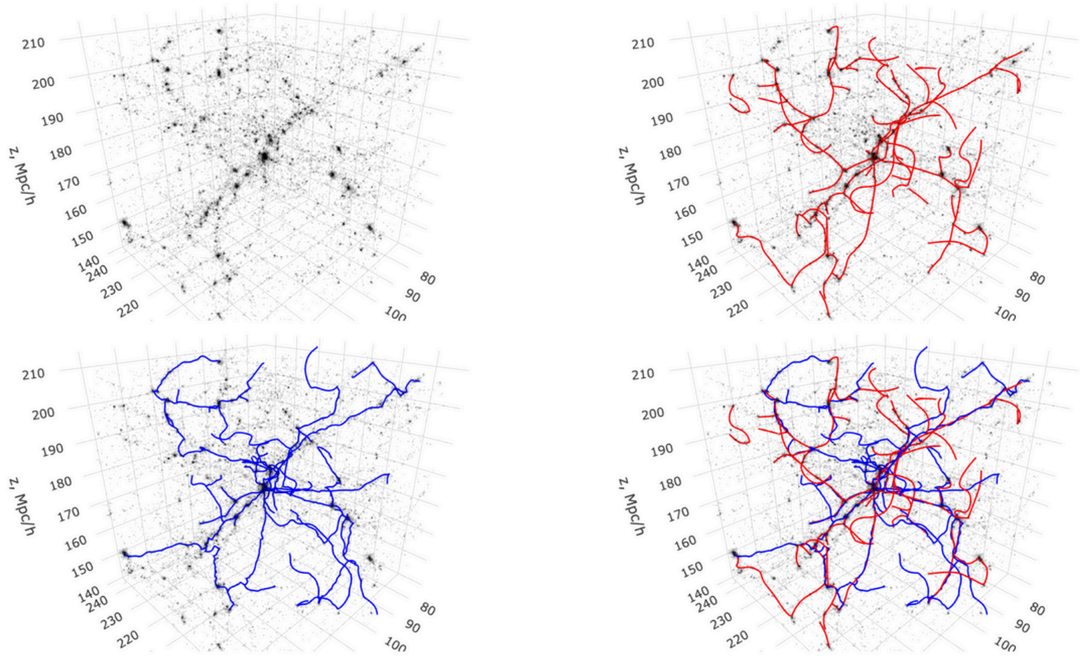


Comparison between filamentary structures extracted from the dark-matter distribution (left panels; Millennium DM-only simulation, blue skeleton) and from the corresponding galaxy distribution (right panels; semi-analytic GAEA model, red skeleton). Filaments in both cases are identified with the same method (DisPerSE), and their total length is matched within the analysed volume. The bottom-right panel overlays the two skeletons, revealing the degree of agreement as well as systematic differences between the underlying dark-matter filamentary network and the filamentary features that can be recovered using galaxies as tracers. **Zakharova et al. 2023.**

Tracers

~60%

of DARK MATTER FILAMENT IDENTIFIED BY GALAXIES DISTRIBUTION



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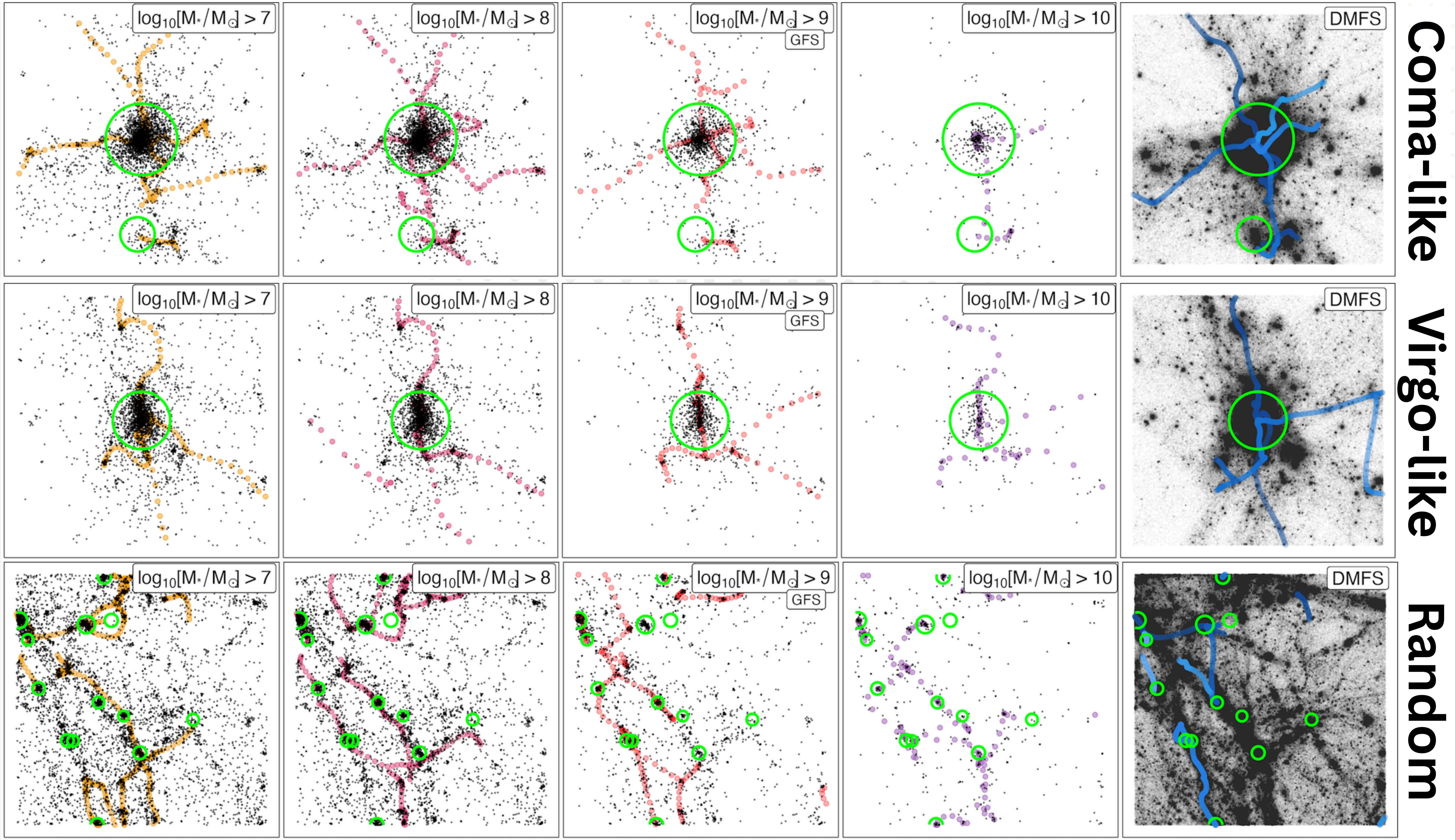
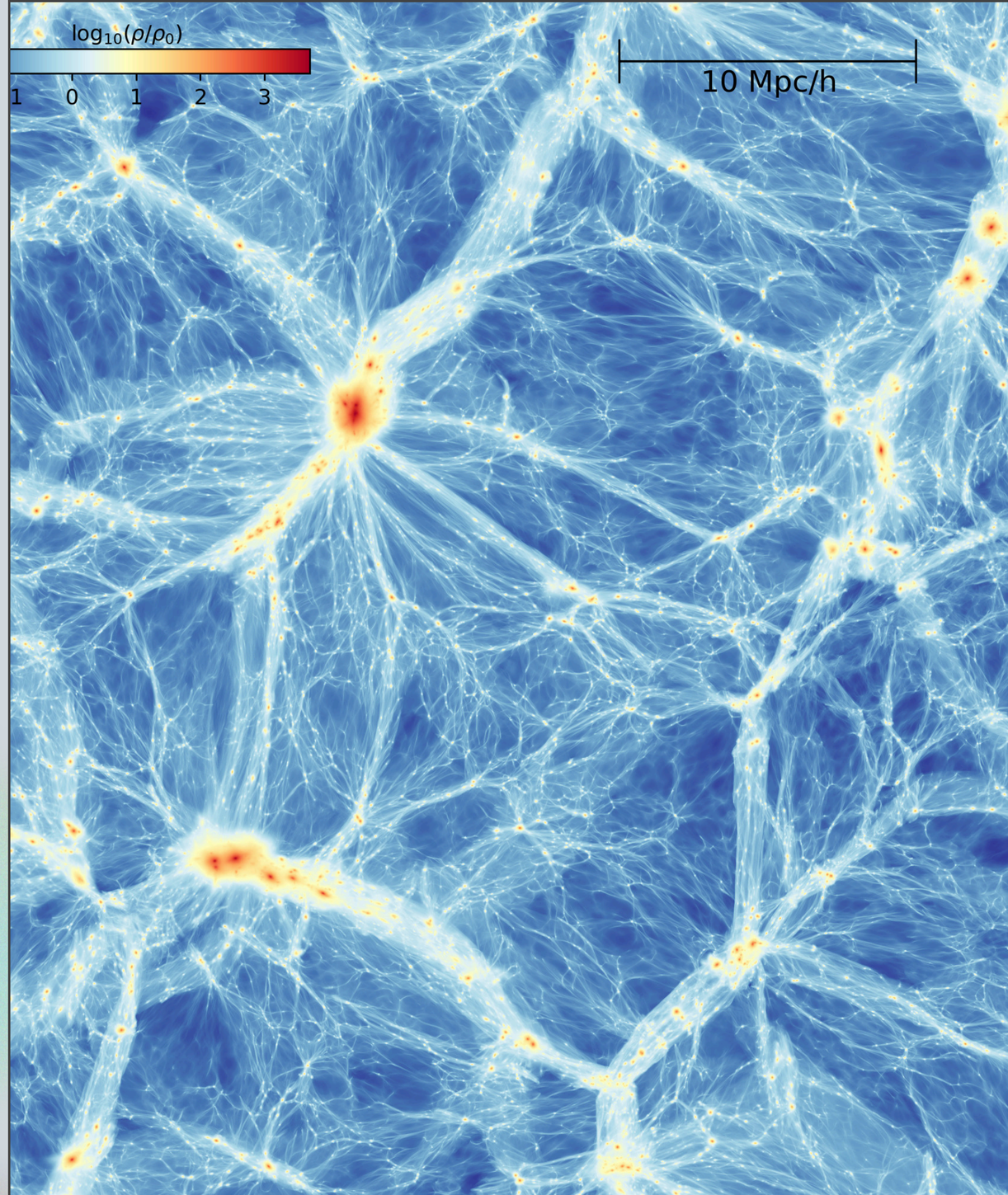


Zakharova et al. 2023

Co-evolution of galaxies and cosmic web



Thank You