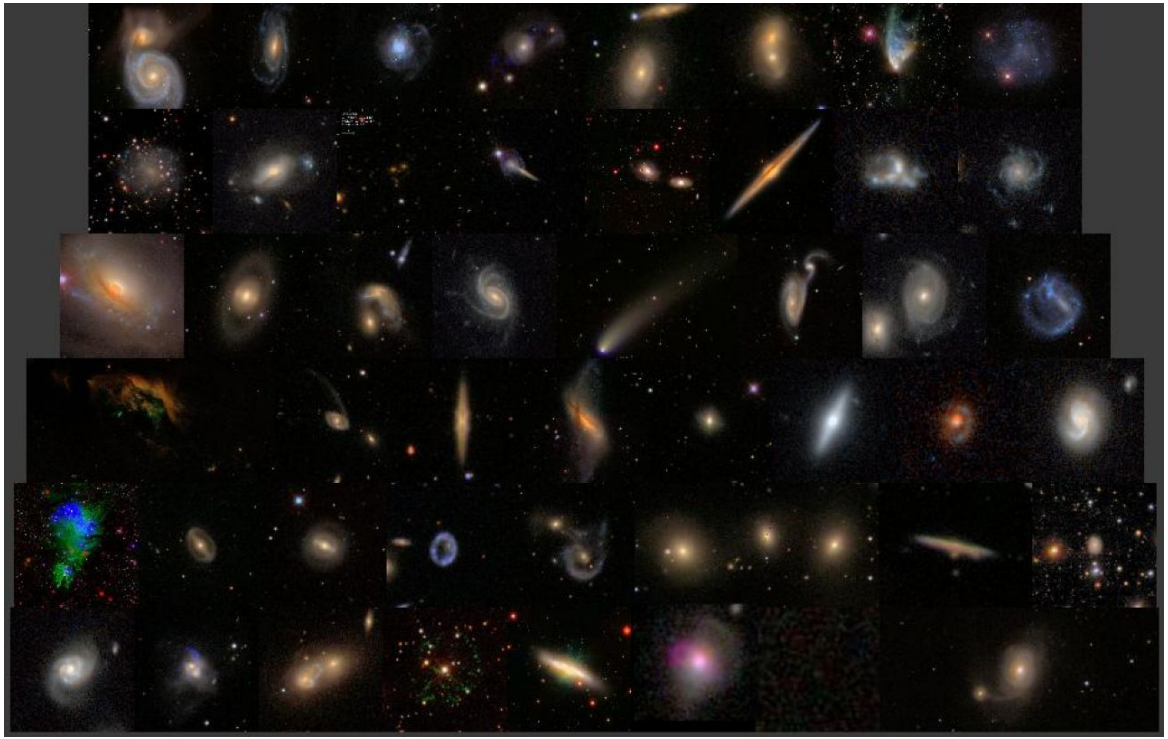
Song, Laigle et al. (2021, MNRAS, 501, 4635; arXiv: 2009.00013)

Beyond halo mass: the role of vorticity-rich filaments in quenching galaxy mass assembly

Hyunmi Song (CNU), Clotilde Laigle (IAP), Ho Seong Hwang (SNU), Julien Devriendt (Oxford), Yohan Dubois (IAP), Katarina Kraljic (UDS), Christophe Pichon (IAP), Adrianne Slyz (Oxford), Rory Smith (USM)

6-9 February 2023 - KITP - The Co-evolution of the Cosmic Web and Galaxies across Cosmic Time

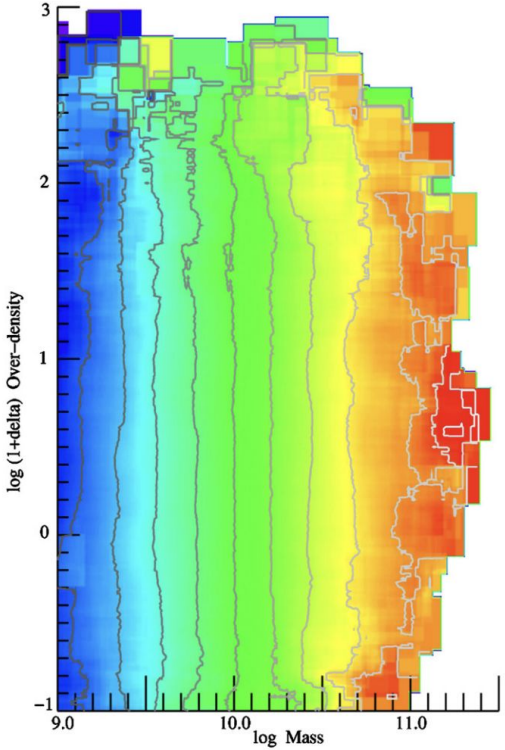
Diversity in Galaxies



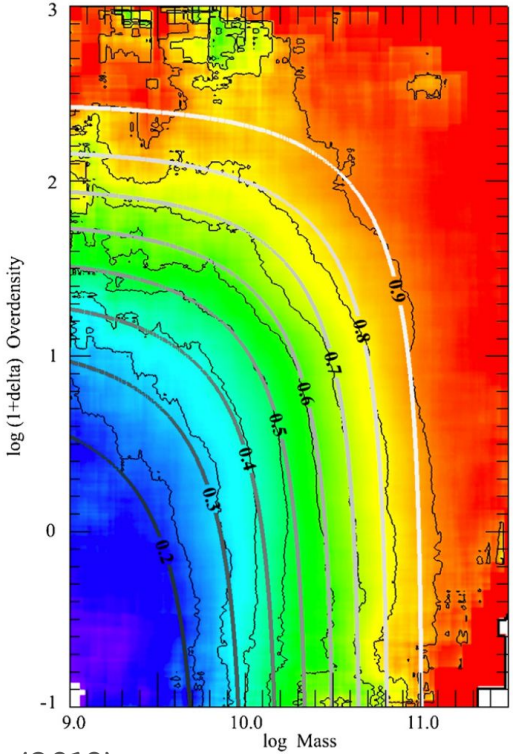
Galaxy Zoo

Diversity in Galaxies

SFR



Red fraction

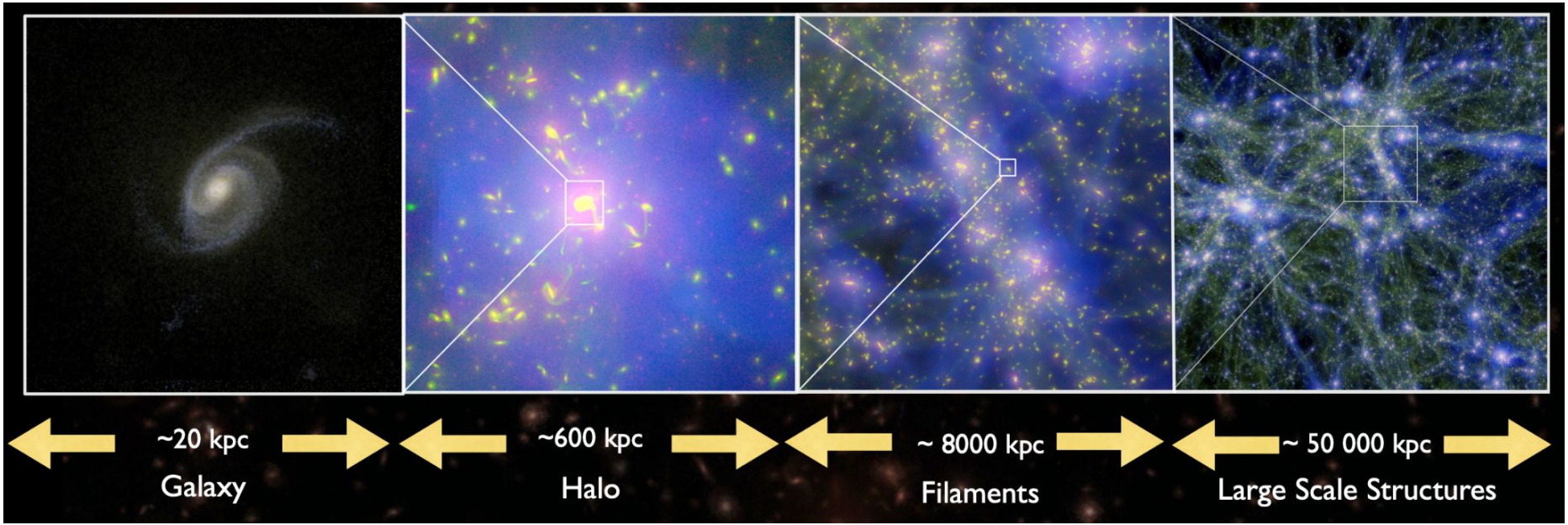


Peng+ (2018)

Stellar mass
Star formation rate
Gas content
Spin
Morphology
...

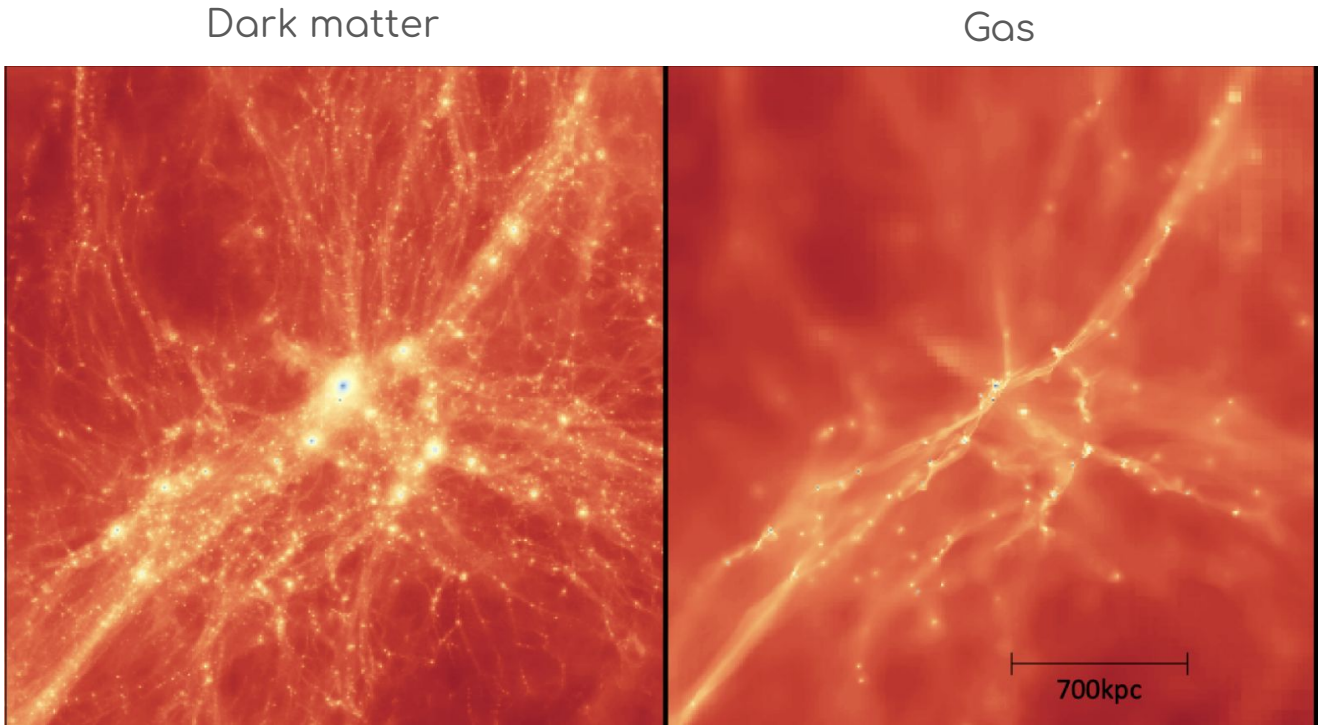
Halo mass
=f(Local density)

Galaxies Do Live in Cosmic Web



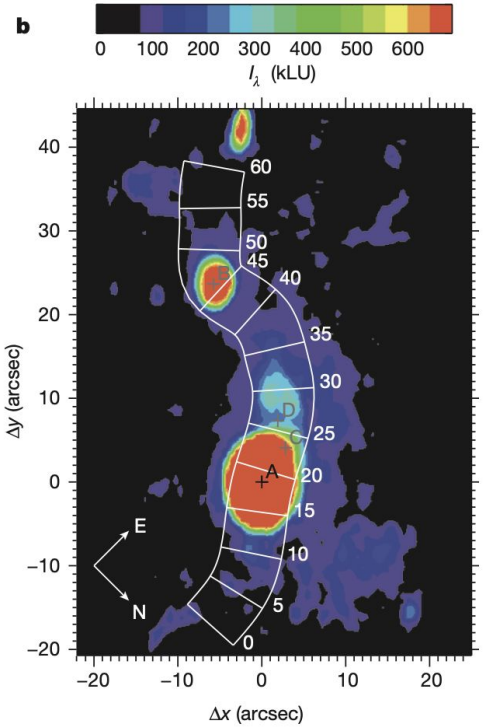
MareNostrum
(borrowed from Christophe Pichon's slide)

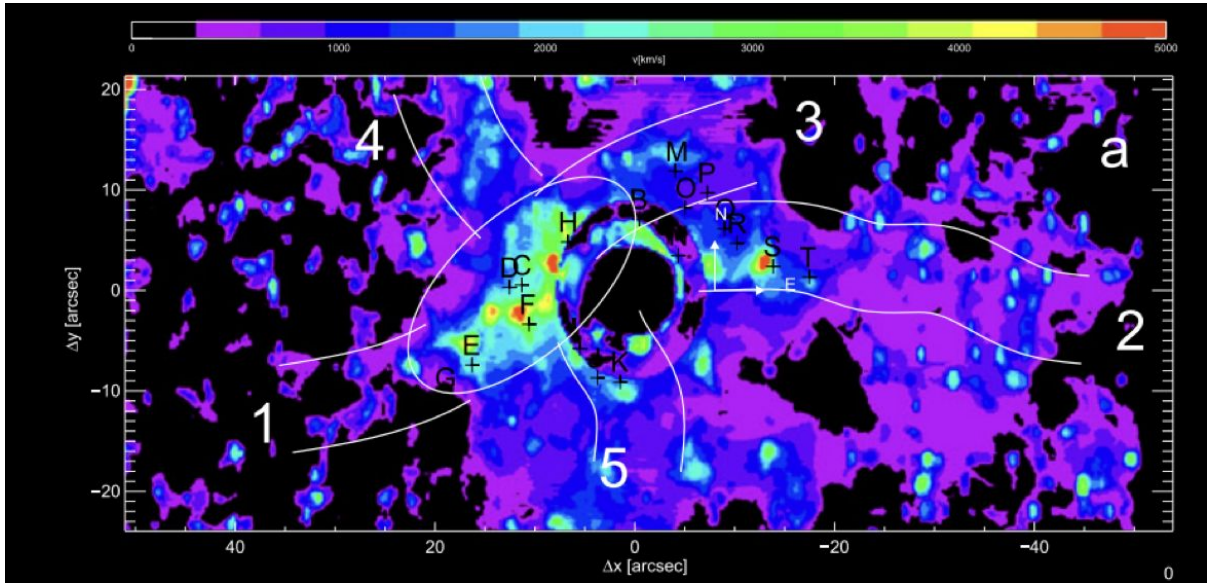
Gas along Cosmic Web



NUT zoom-in simulation (Slyz, Devriendt+ 2010)

Gas along Cosmic Web

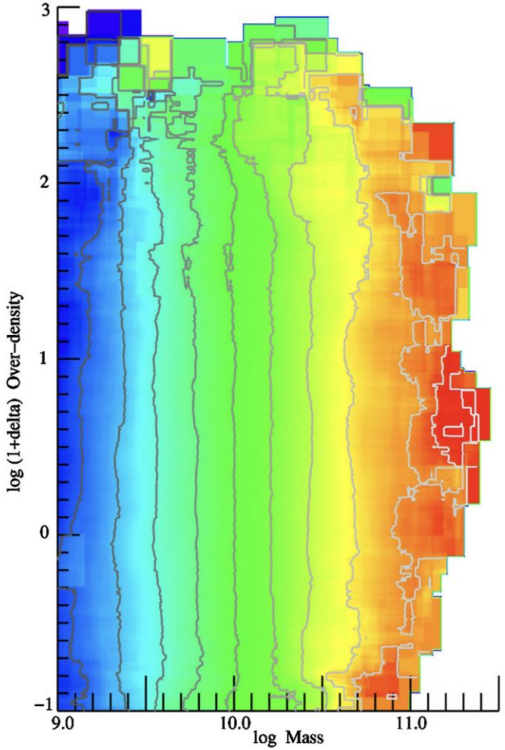




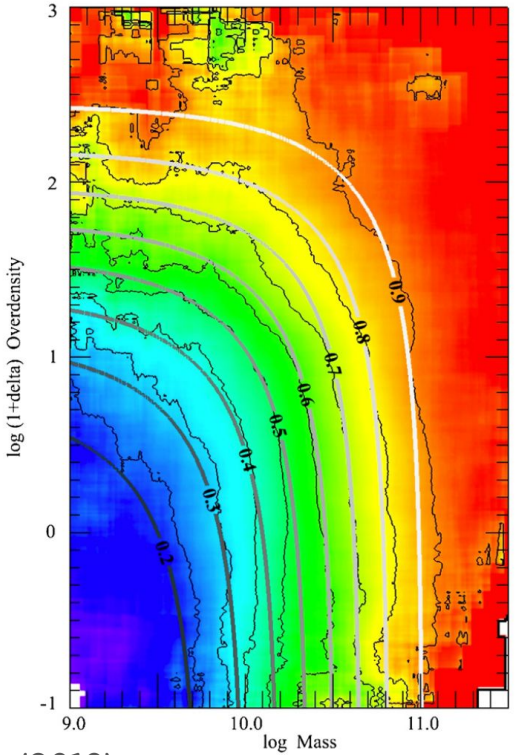
Martin+ (2015, 2016)

Diversity in Galaxies

SFR



Red fraction



Peng+ (2018)

Stellar mass
Star formation rate
Gas content
Spin
Morphology
...

Halo mass
=f(Local density)
Cosmic web

Properties of galaxies in cosmic filaments from z=0 to z=1
A review

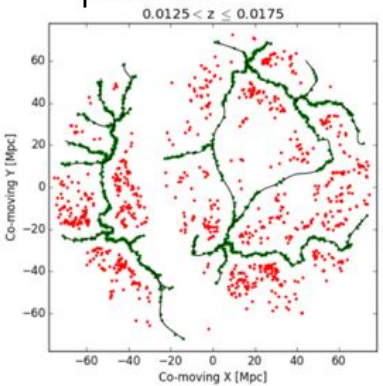
⚠ Different scales/filaments extractors/mass ranges …

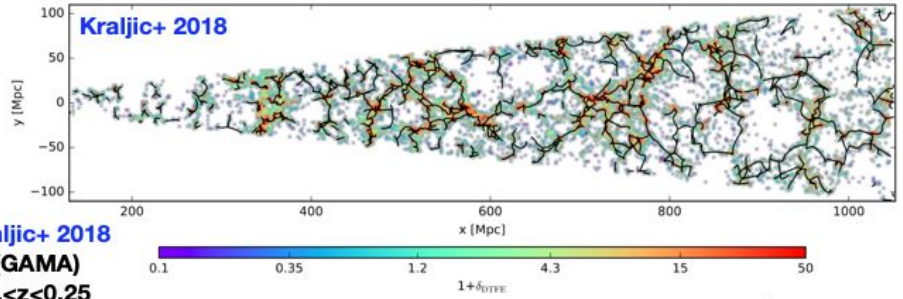
z=0 — z=0.9

Bird+2019
(CHILES)
z=0.1
HI content

Odekon+2018
(SDSS/ALFALFA)
HI content/quenching. tendrils

Kleiner+2017
(6dFGS, 2D)
HI content





Kraljic+ 2018
(GAMA)
0.<z<0.25
mass/SFR/quenching

Alpaslan+ 2016
(GAMA)
0.<z<0.25
SFR

Chen+ 2017
(SDSS, LOWZ, CMASS)
0.<z<0.7
mass/quenching

Malavasi+ 2017
(VIPERS)
z=0.7
mass/quenching

Poudel+ 2018
(SDSS)
luminosity/quenching
Groups

Sarron+ 2019
(CFHTLS, 2D)
0.15<z<0.7
mass/quenching

Bonjean+ 2019
(WISExCOS)
0.1<z<0.3
mass/SFR/quenching

Laigle+ 2018
(COSMOS, 2D)
0.5<z<0.9
mass/quenching

(borrowed from Clotilde Laigle's slide)

Searching for the unique role of filaments

d_{fil}

d_{fil}

d_{fil}

d_{fil}

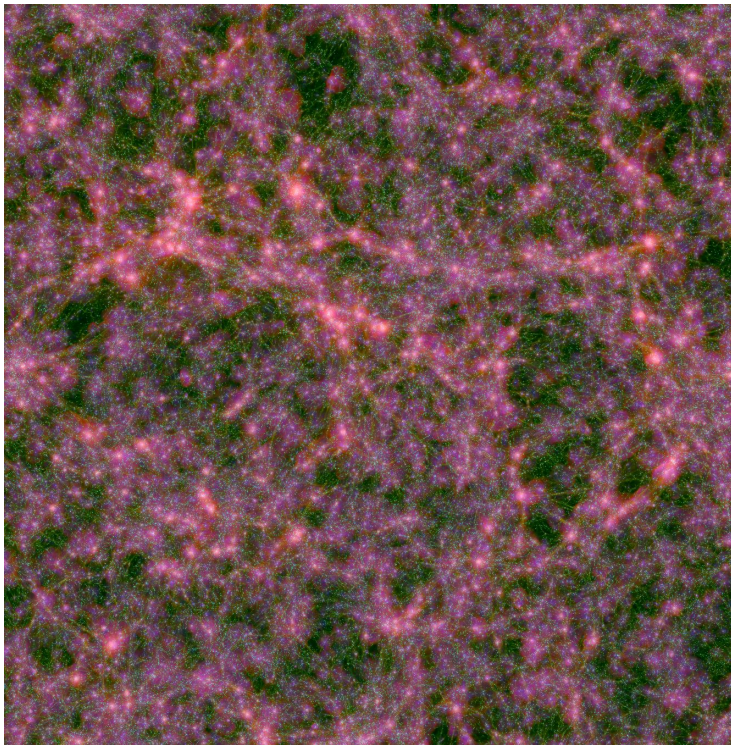
Galaxy properties
$=f(d_{fil} \mid M_h$, local density)

At redshift 2

Horizon-AGN sky map (gas density in blue and galaxies with white circles)

Horizon-AGN

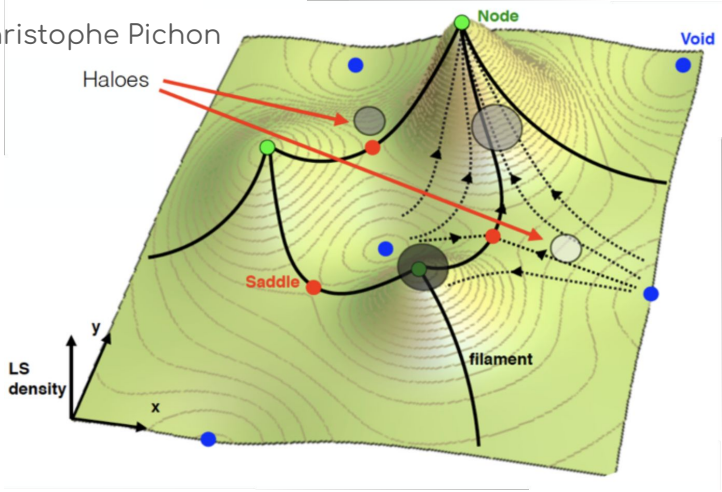
- Cosmological hydrodynamic simulation
- $(100cMpc/h)^3$ box
- 1024^3 dark matter particles
- Maximum resolution 1pkpc
- Feedback from stellar winds,
  SN type II and Ia, and AGN



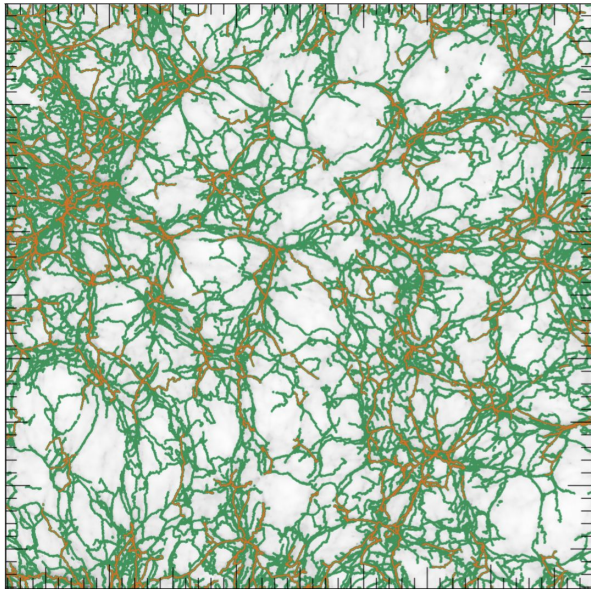
Dubois+(2014), horizon-simulation.org

Filament Extraction

- DisPerSe
  - Discrete Persistent Structure Extractor
  - Sousbie (2011), Sousbie+ (2011)
- Dark matter particle distribution
  - Delaunay tessellated density field
- Persistence level of 7 sigma



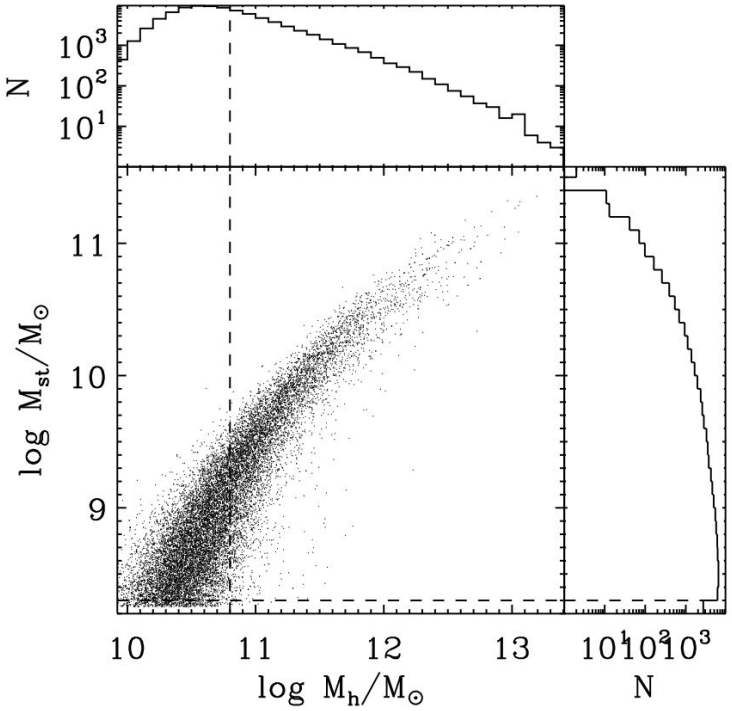
5 sigma versus 7 sigma



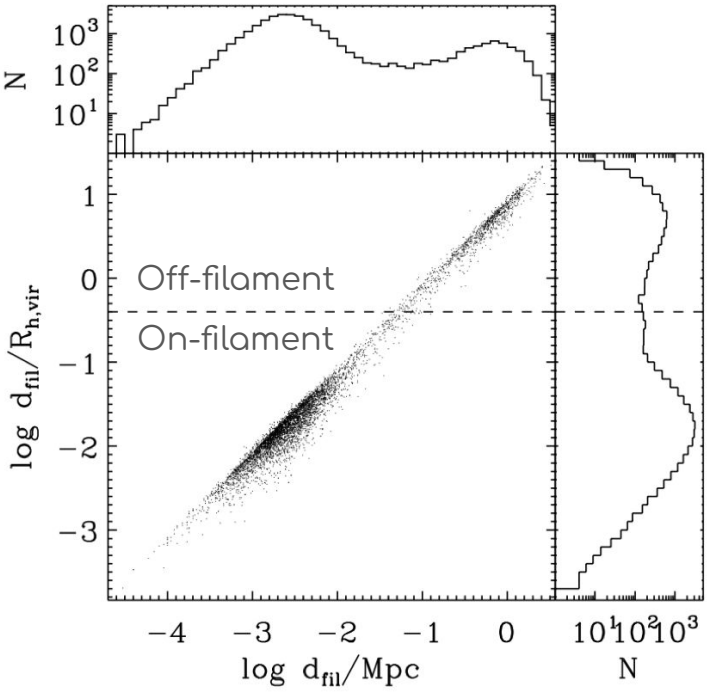
Galaxy Sample

Central galaxies (cluster galaxies excluded)

Mass complete



Subsampled by d_{fil}/R_{vir}

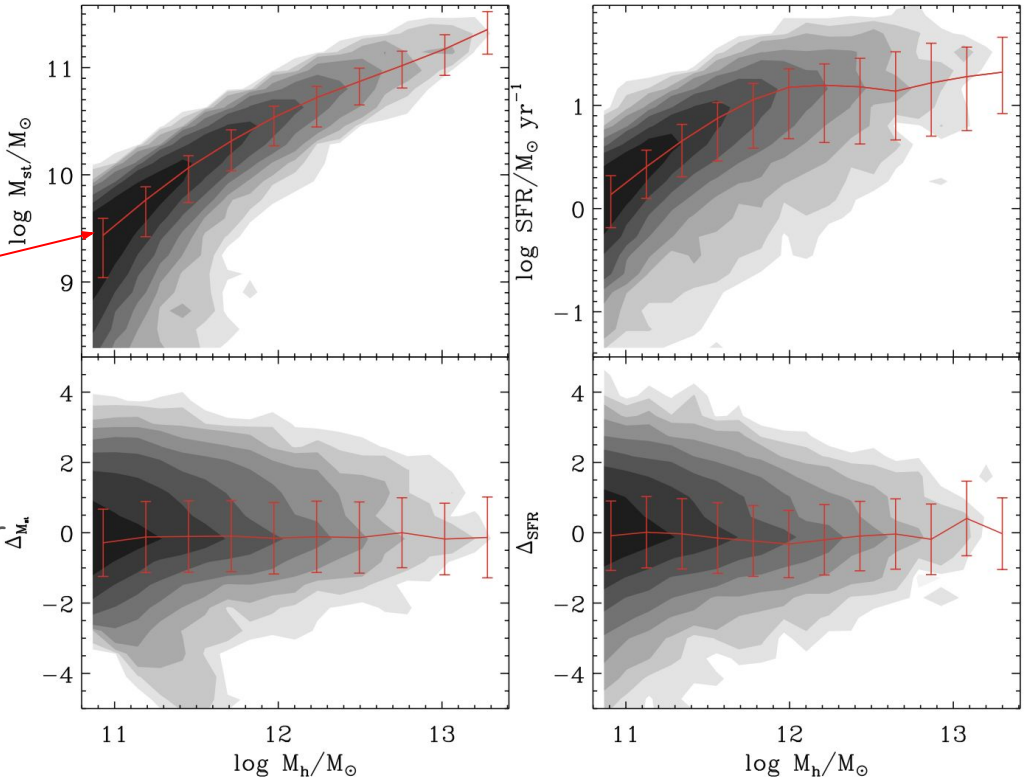


To go beyond halo mass

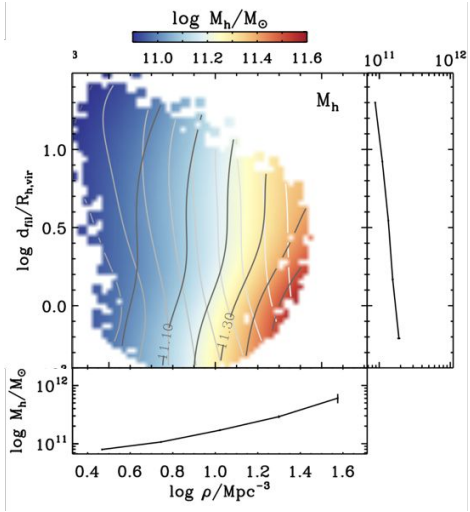
Median trend
with 1 sigma scatter

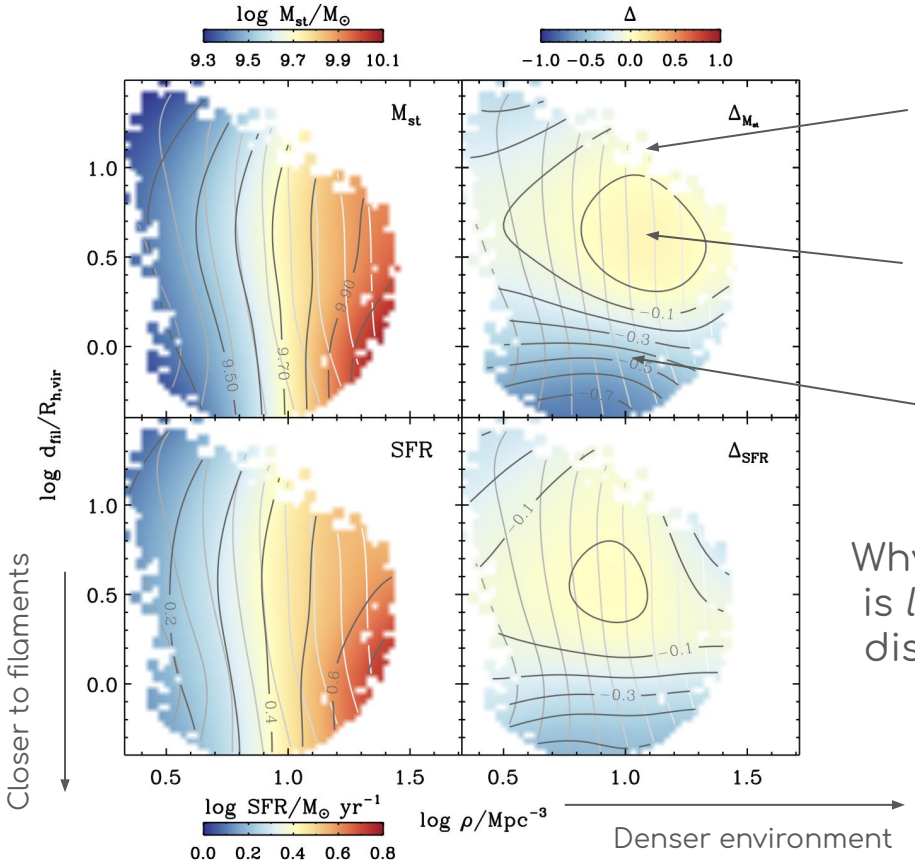
Offset from
median trend
normalized by scatter

= RESIDUAL (Δ)



Impact of Cosmic Web on Galaxy Mass Assembly



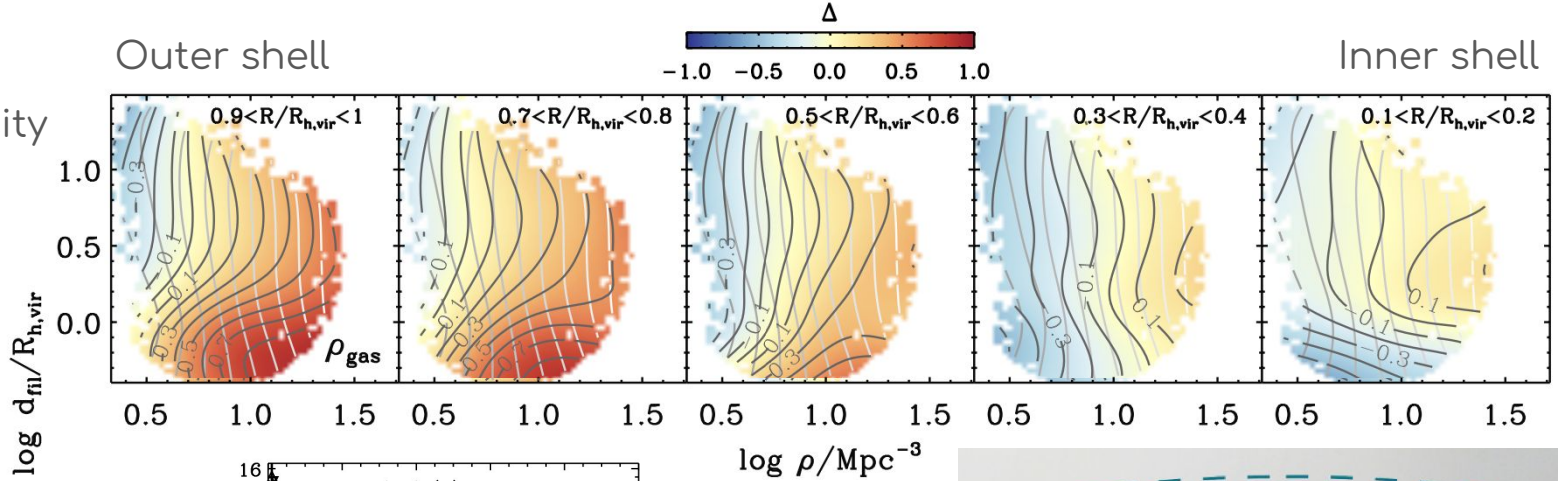


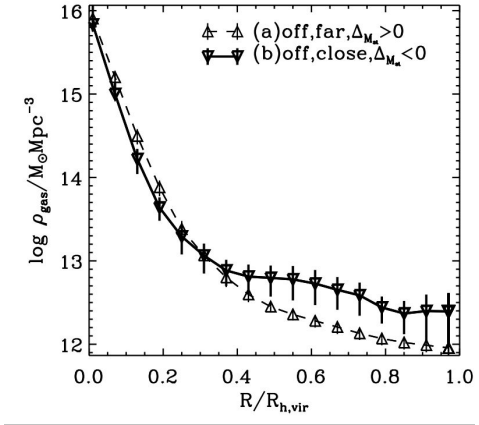
Same halo mass

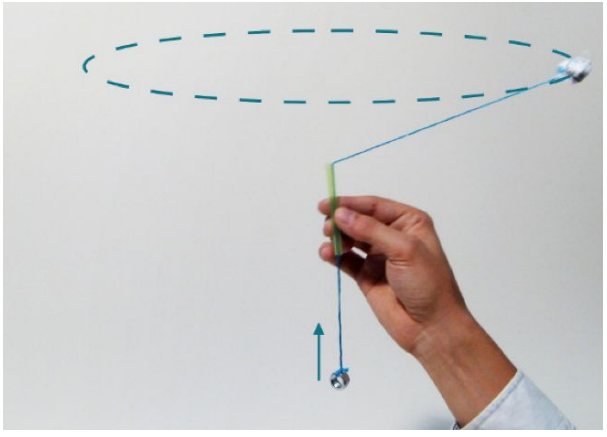
Why galaxy mass assembly is *least* efficient at *closest* distances from filaments?

Gas Transfer Hindered Within Halos

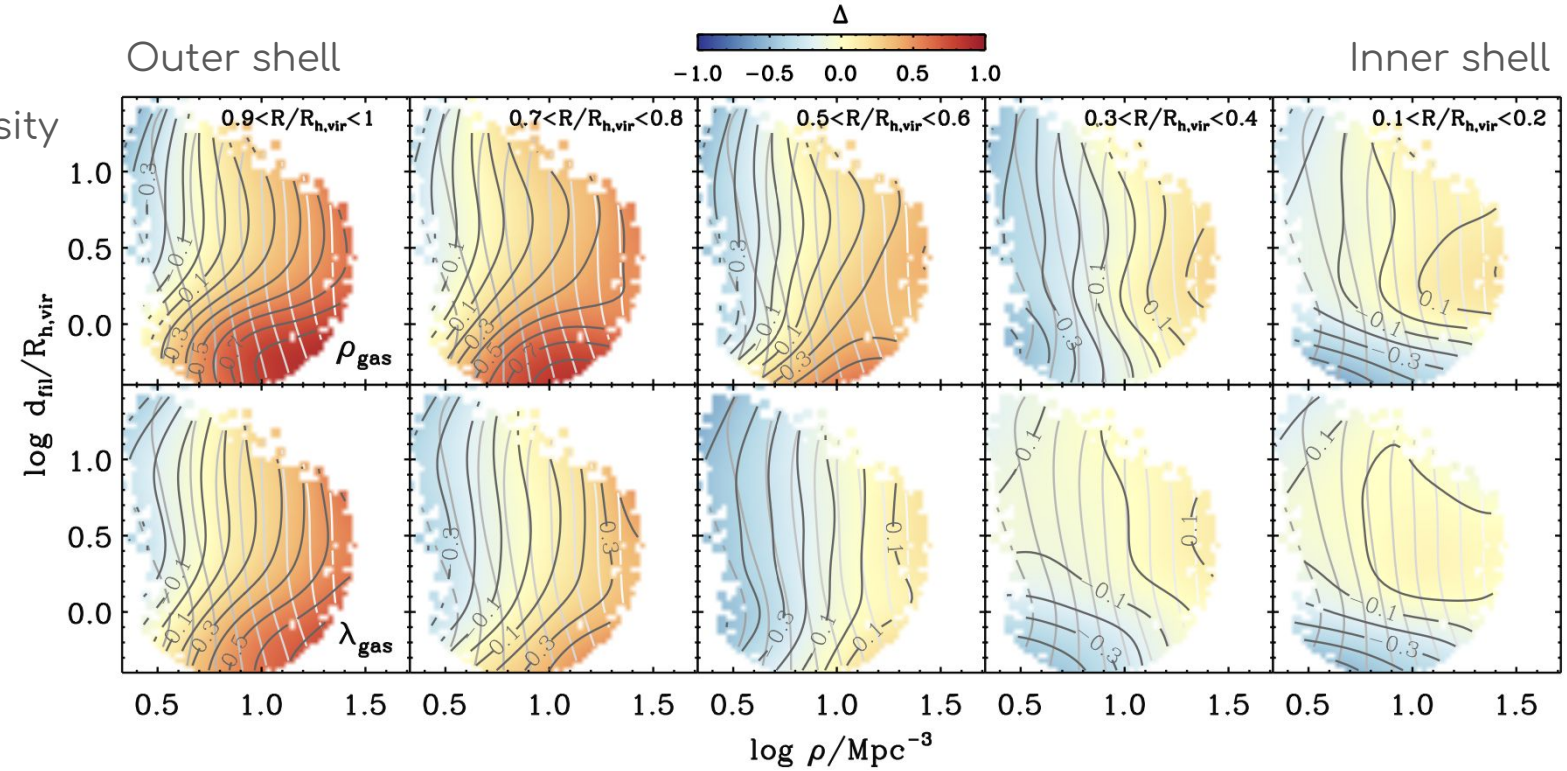
Gas density
residual





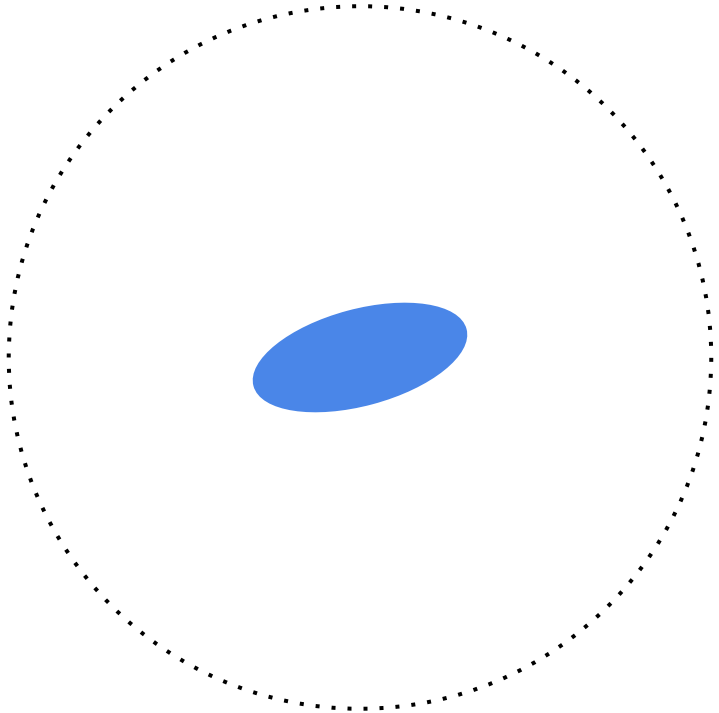


Gas Transfer Hindered Within Halos



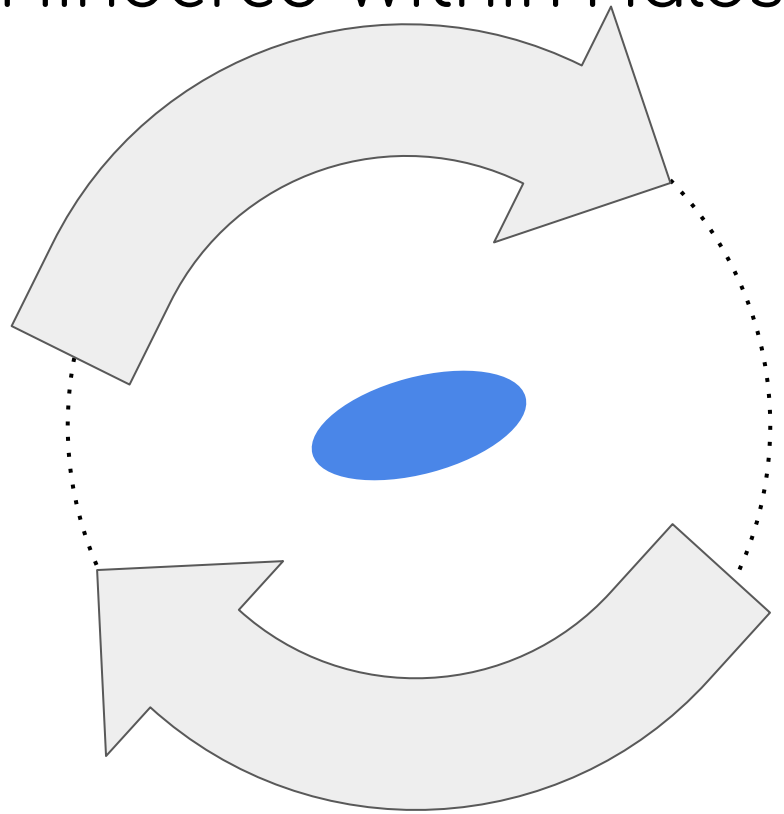
Gas Transfer Hindered Within Halos

Halo close to filament



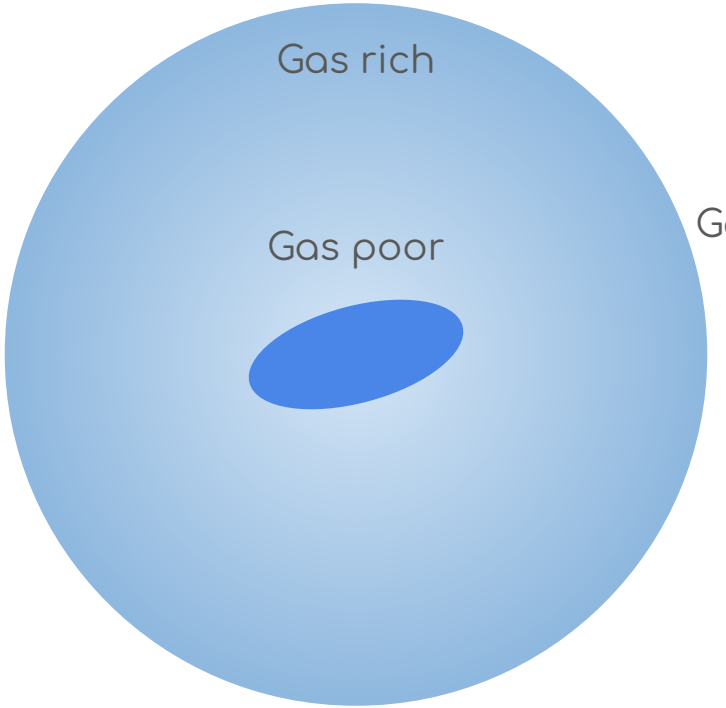
Gas Transfer Hindered Within Halos

Large angular momentum
in the outer halo



A halo close to filaments

Gas Transfer Hindered Within Halos



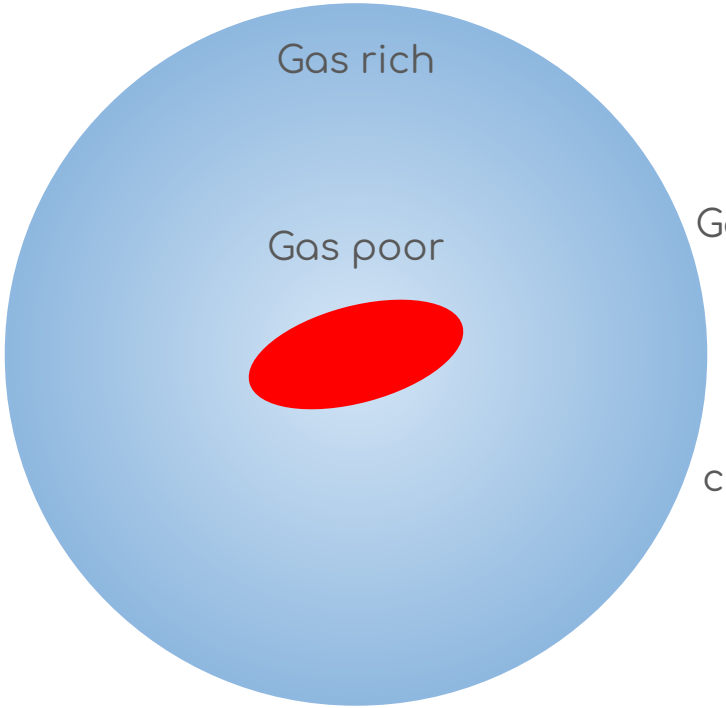
Large angular momentum
in the outer halo

Gas transfer to the inner halo
(to the galaxy) hindered

A halo close to filaments

Gas Transfer Hindered Within Halos

A halo close to filaments



Large angular momentum
in the outer halo

Gas transfer to the inner halo
(to the galaxy) hindered

The galaxy at the center
cannot form stars efficiently!

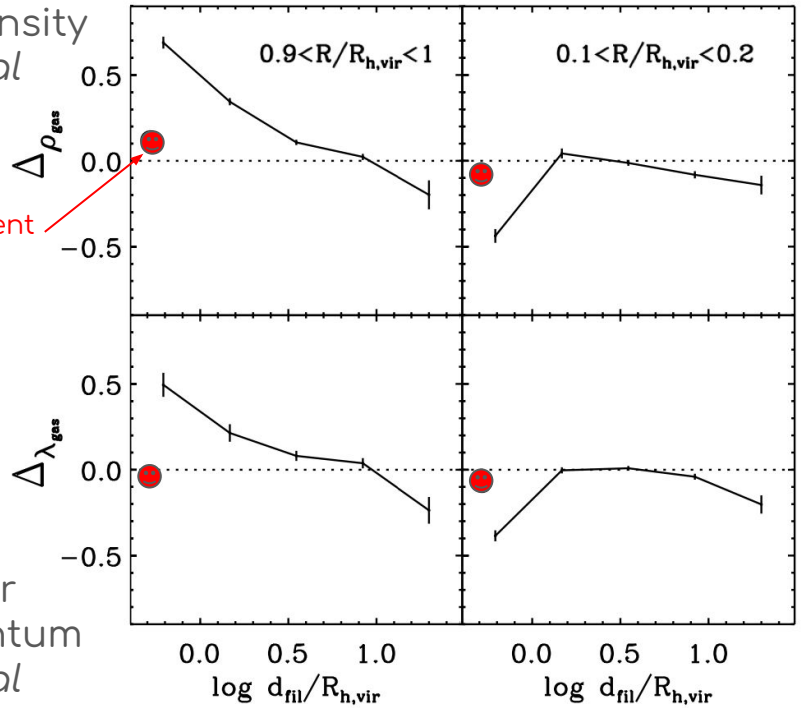
Quenching at the Edges of Filaments

Quenching at the edges of filaments

Gas density *residual*

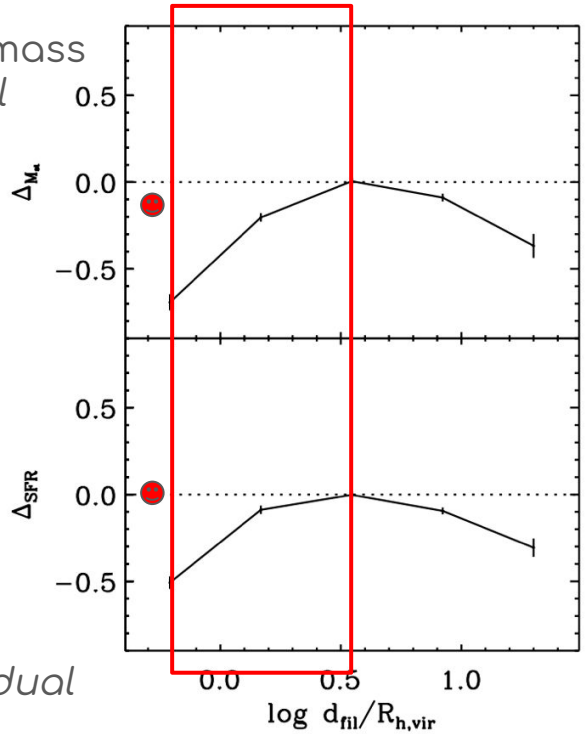
Angular momentum *residual*

On-filament halos

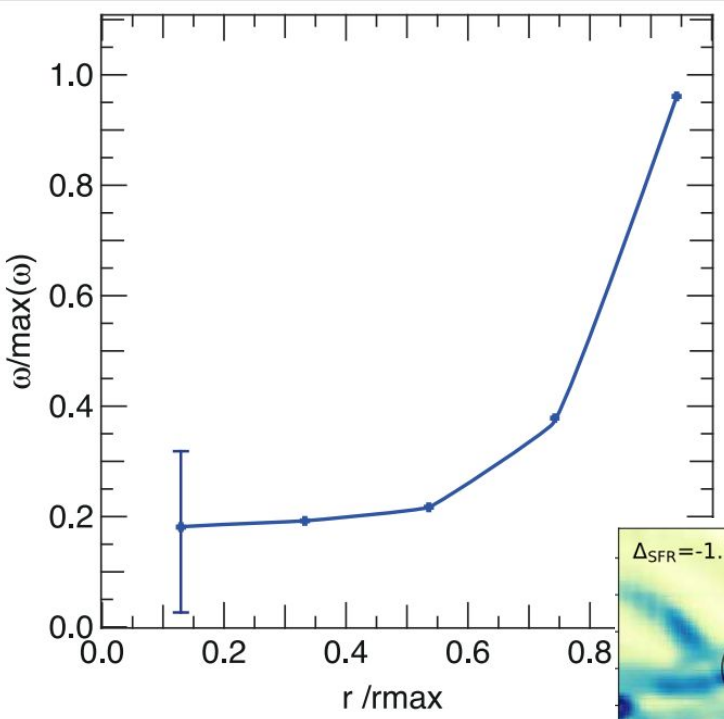


Stellar mass *residual*

SFR *residual*



High Vorticity at the Edges of Filaments



Laigle+ (2015)

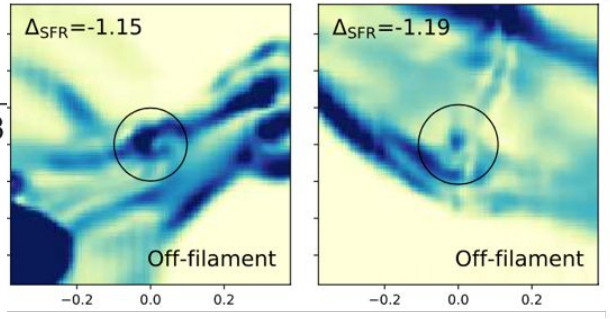
Filament

Like a spinning top?

Vorticity

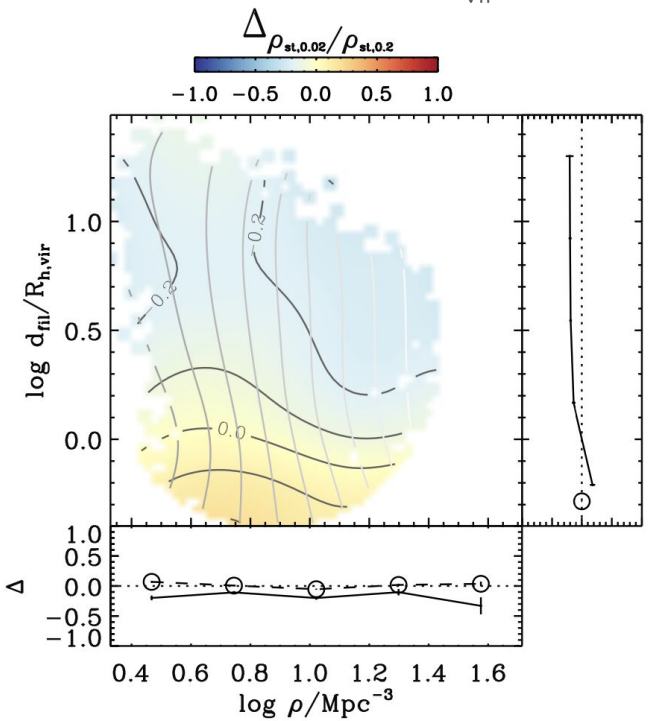
Halo

Vorticity map

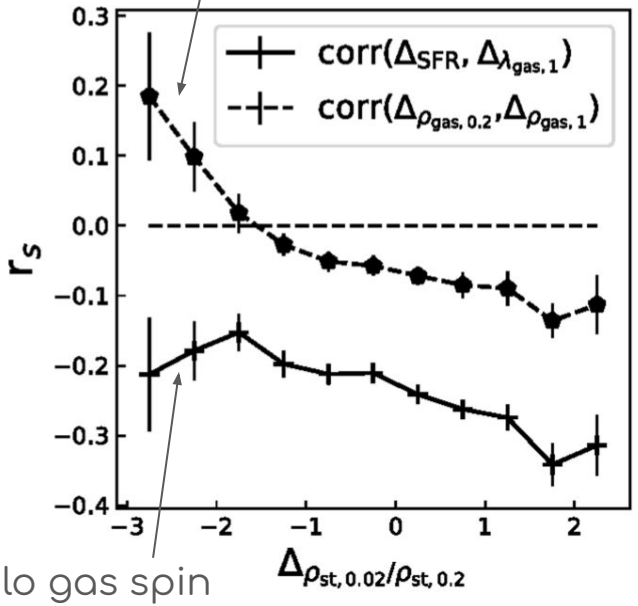


Morphological Quenching, too?

Stellar compactness
=stellar density within $0.02R_{vir}$/within $0.2R_{vir}$



Inner-outer halo gas densities



SFR-outer halo gas spin

Summary

- We have disentangled the effects of halo mass, local density, and distance to filaments on stellar mass and SFR at a high redshift using Horizon-AGN.
- We have found quenching at the edges of filaments due to inefficient gas transfer within a halo.
  - It is due to large angular momentum of outer halo gas,
  - Which is seemingly due to high vorticity at the edges of filaments.
  - We have also found a hint of morphological quenching.
- Further investigations being conducted by tracking individual halos in time (Hannah's talk this morning), and will be conducted with higher resolution simulations and for lower redshifts

Thank you for your attention!