The impact of filaments on the evolution of isolated galaxies and galaxy clusters

Stefano Zarattini (CEFCA, Teruel, Spain)

In collaboration with: S. Andreon, E. Puddu, J.A.L. Aguerri

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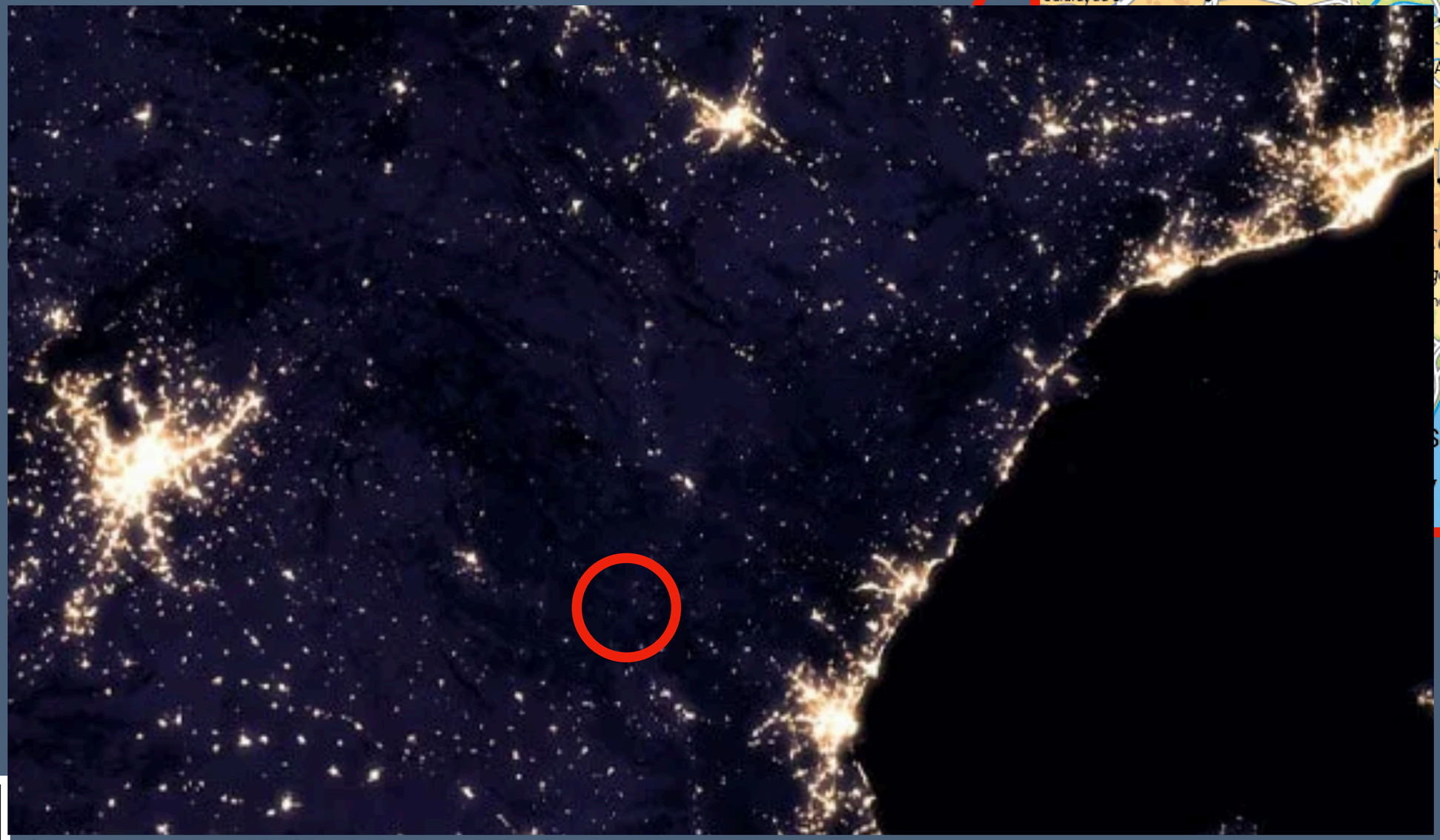

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V-band median seeing ~ 0.7”

V-band nigth sky brigthness

NSB ~ 22.1 mag arcsec^{-2}

(Moles+2010)

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For comparison:

(mag/arcsec^2)	MAUNA KEA[a]	PARANAL[b,c]	LA SILLA[d,e]	TOLOLO[e]	SAN PEDRO MÁRTIR[f]	ORM[g]	OT[g]
V	20.78	21.61; 21.50	21.80; 21.90	21.80	21.84	21.70	21.20

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Two ongoing photometric surveys

J-PLUS

- 80 cm telescope
- T80Cam, FoV ~ 2 deg in diameter
- 8500 deg^2
- 12 filters
- Accurate z_{phot} of ~ 20 million local galaxies

J-PAS

- 250 cm telescope
- JPCam, FoV ~ 3 deg in diameter
- 8000 deg^2
- 54 contiguous narrow-band filters
- z_{phot} of ~14 million red galaxies within $0.1 < z < 1.2$ and $\Delta z \sim 0.003*(1+z)$

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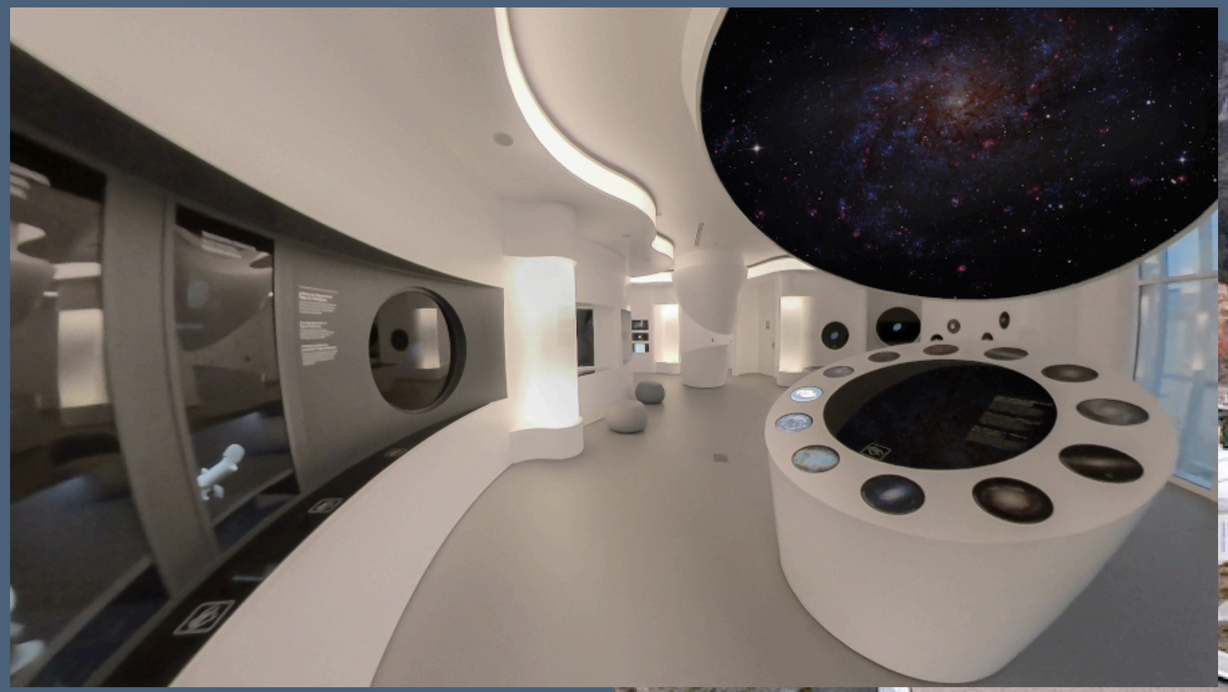

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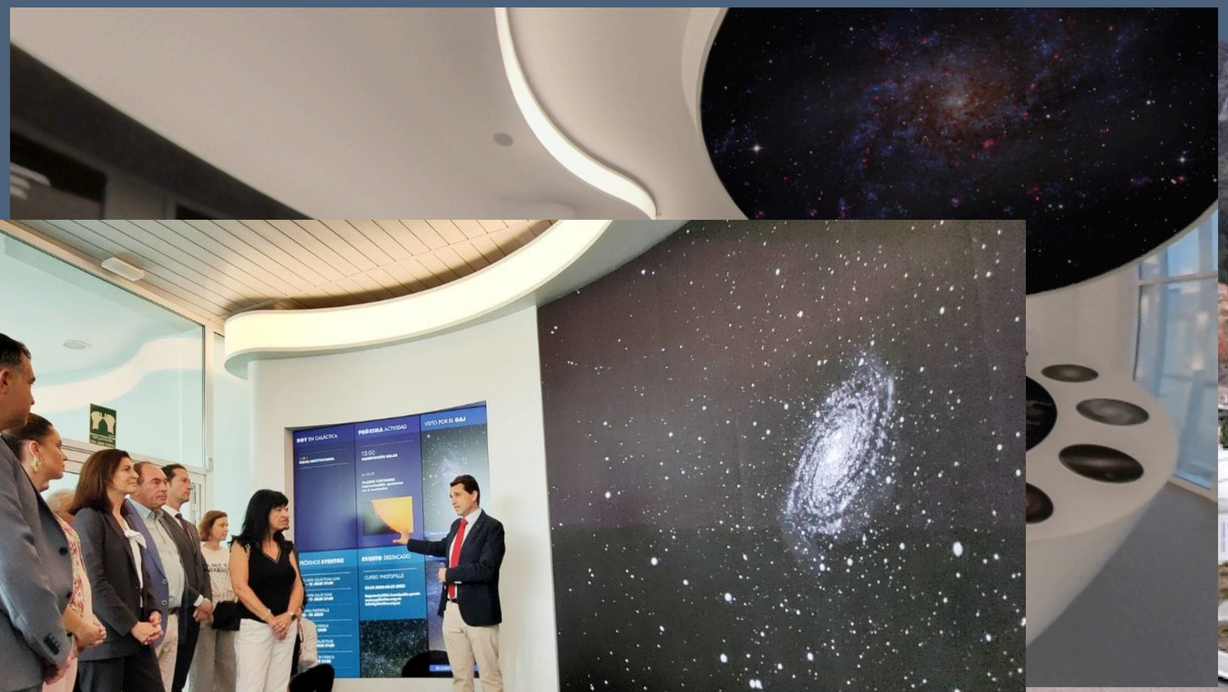

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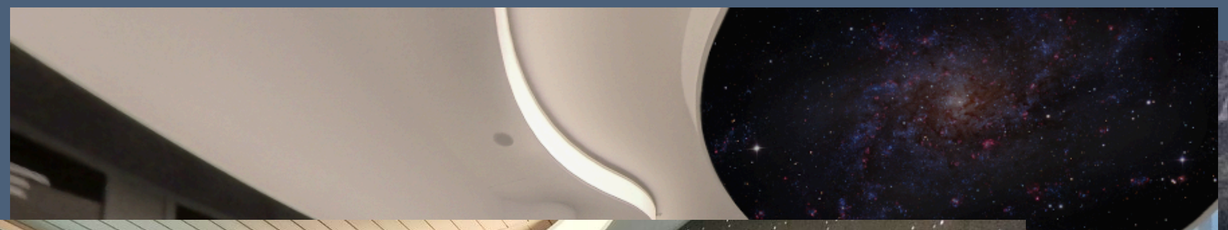

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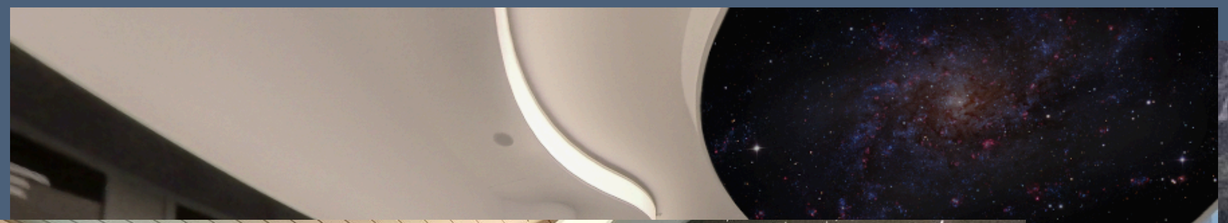

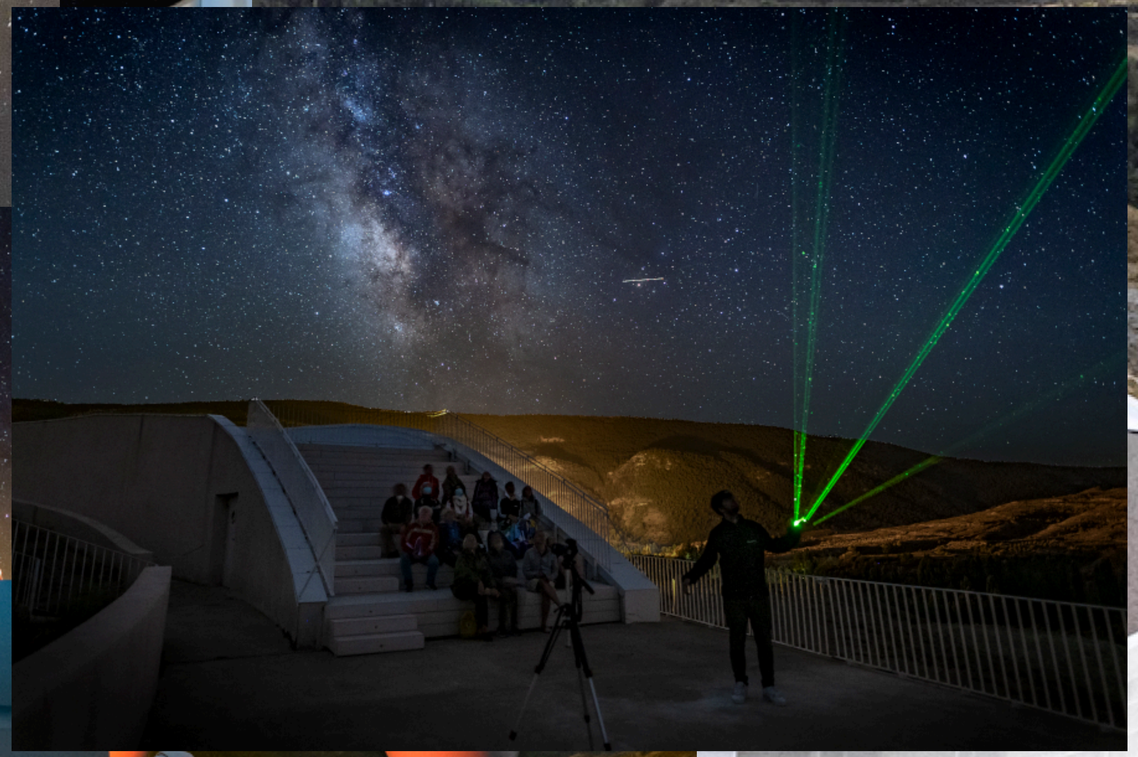

Outline of the talk

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The gas distribution of galaxy clusters

- Is the gas fraction depending on the position of the cluster within the cosmic web?

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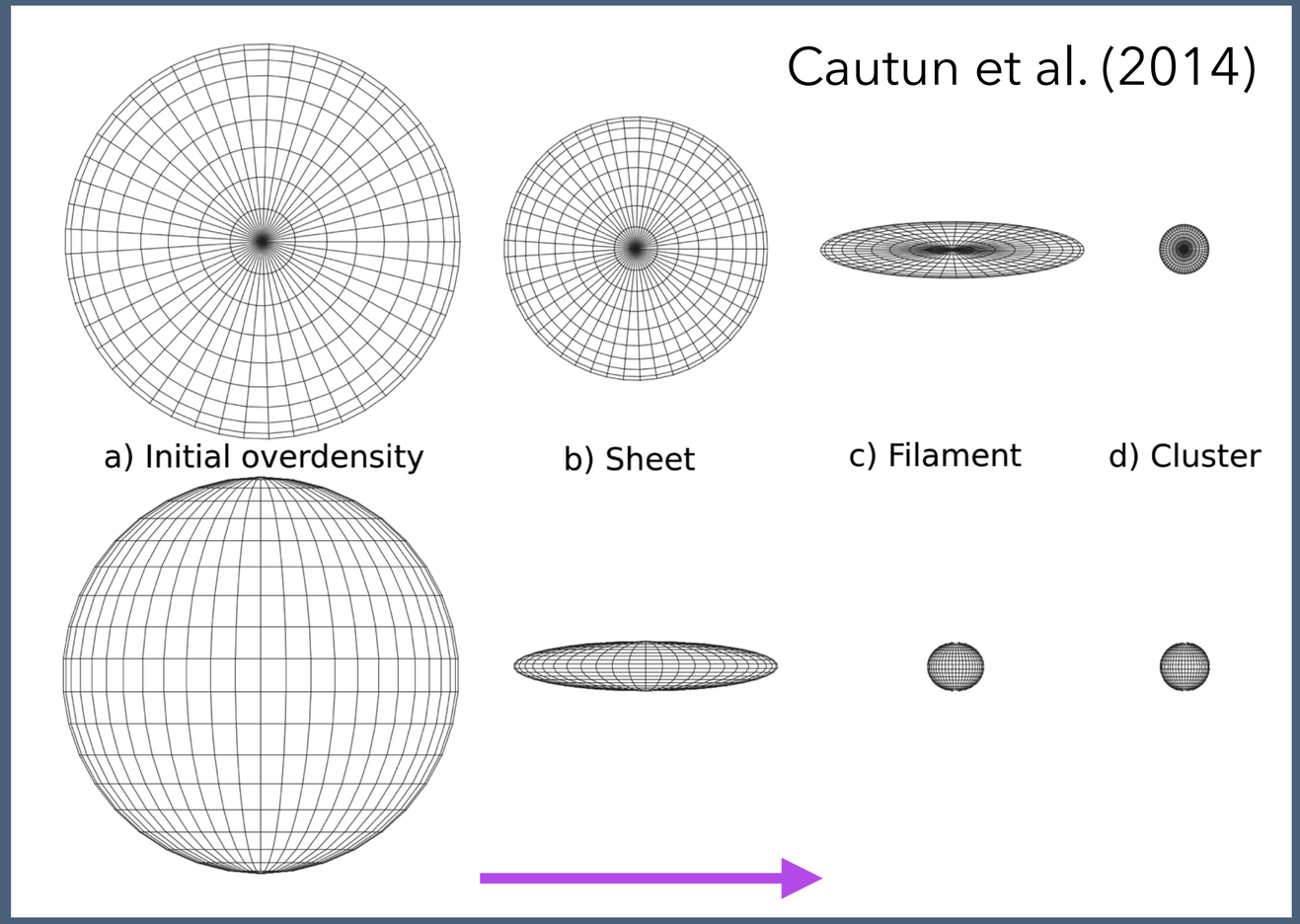
The properties of individual galaxies

- Can filaments modify the colour and SFR of galaxies?
- Can we estimate the width of filaments using the density of galaxies as tracer?
- Is there an evolution with redshift in the width of filaments?

The cosmic web



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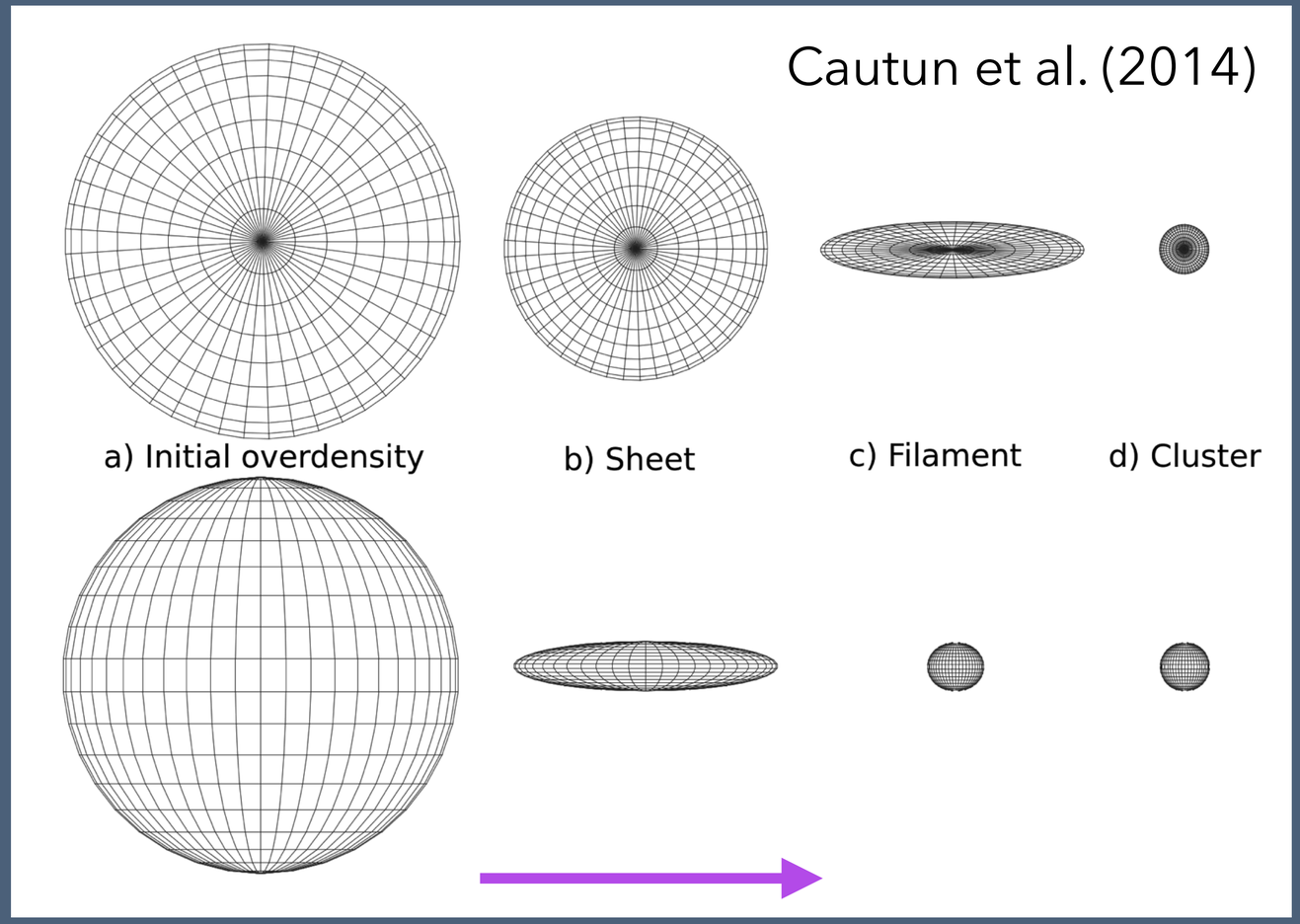

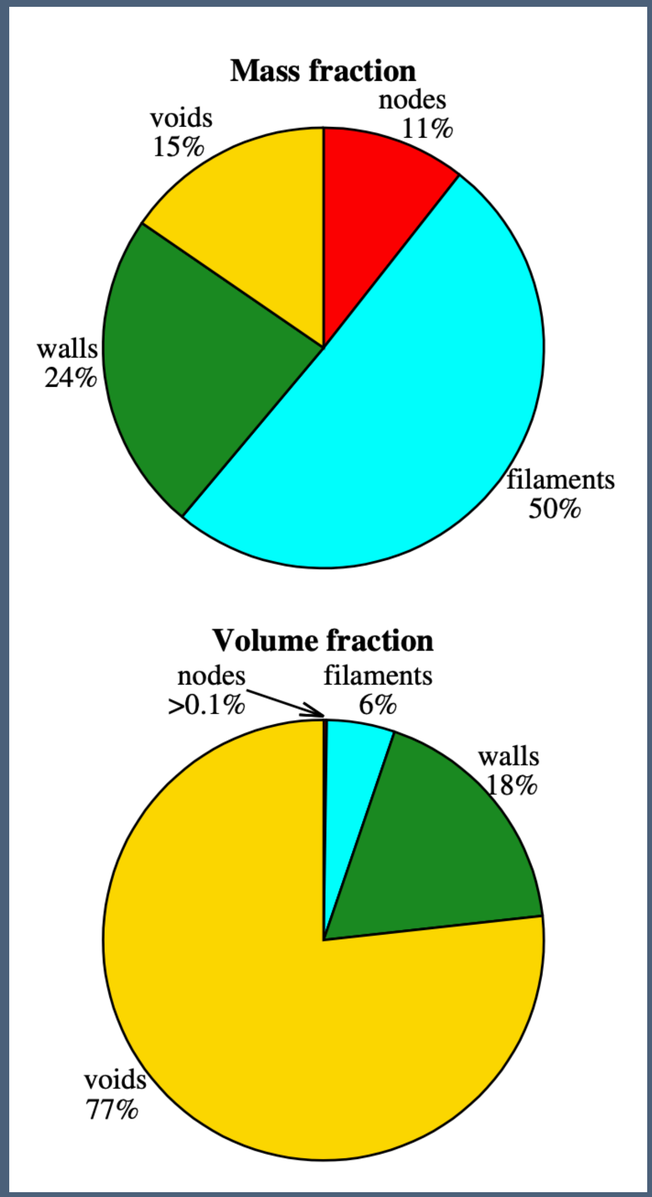

The cosmic web

- We use the cosmic web catalogue by Chen et al. (2014)
- Based on the Subspace Constraint Mean Shift method
- It provides multiple two dimensional maps between $0.05<z<0.7$
- The cosmic web is divided in filaments and intersections

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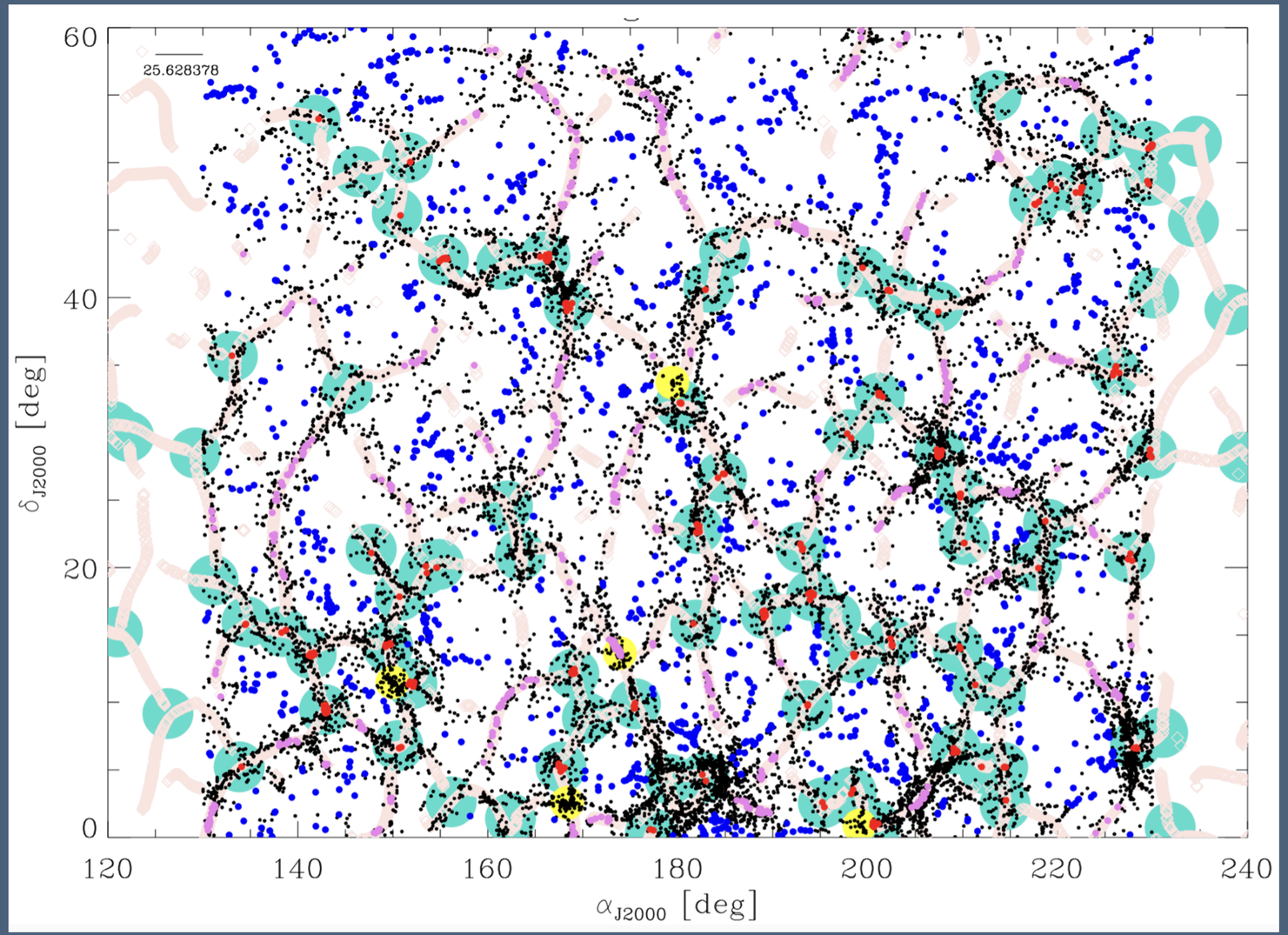
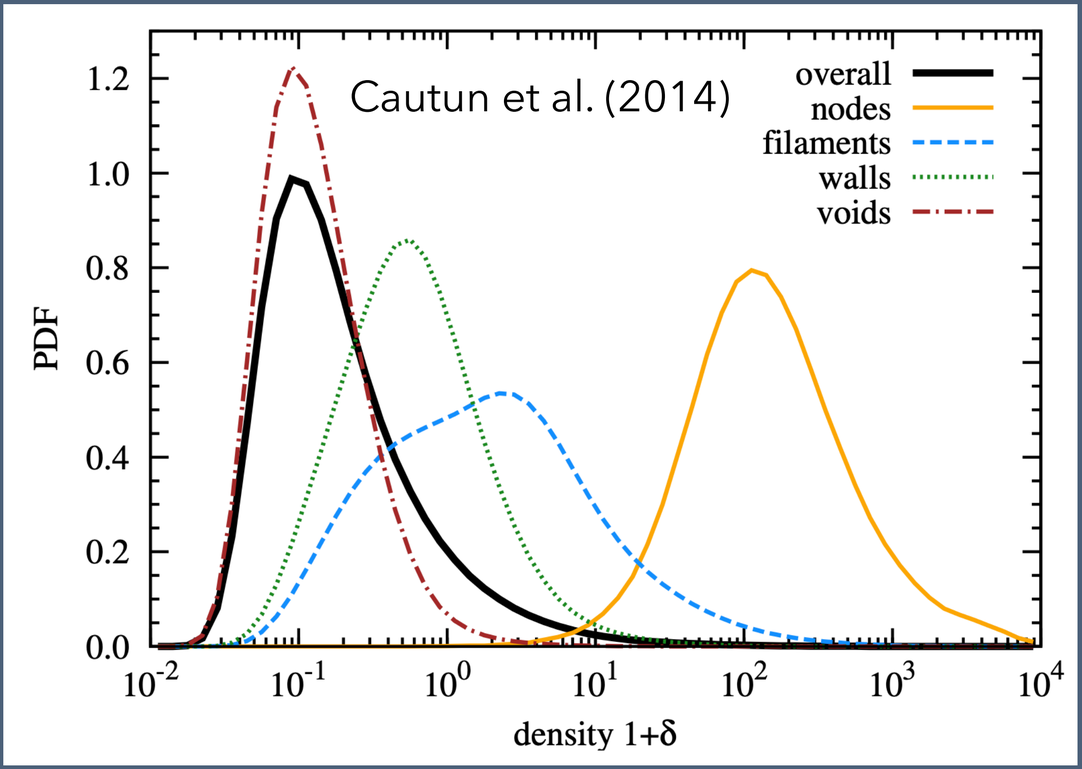


The cosmic web

- Question: are intersections the same as nodes?



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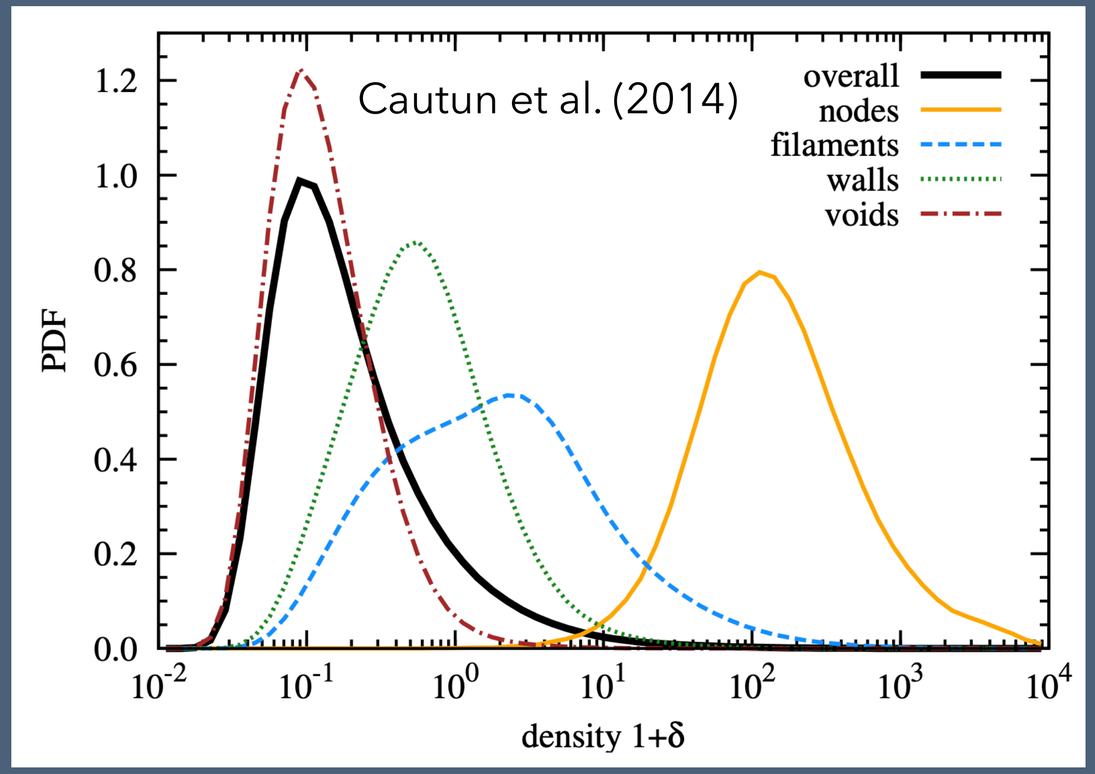

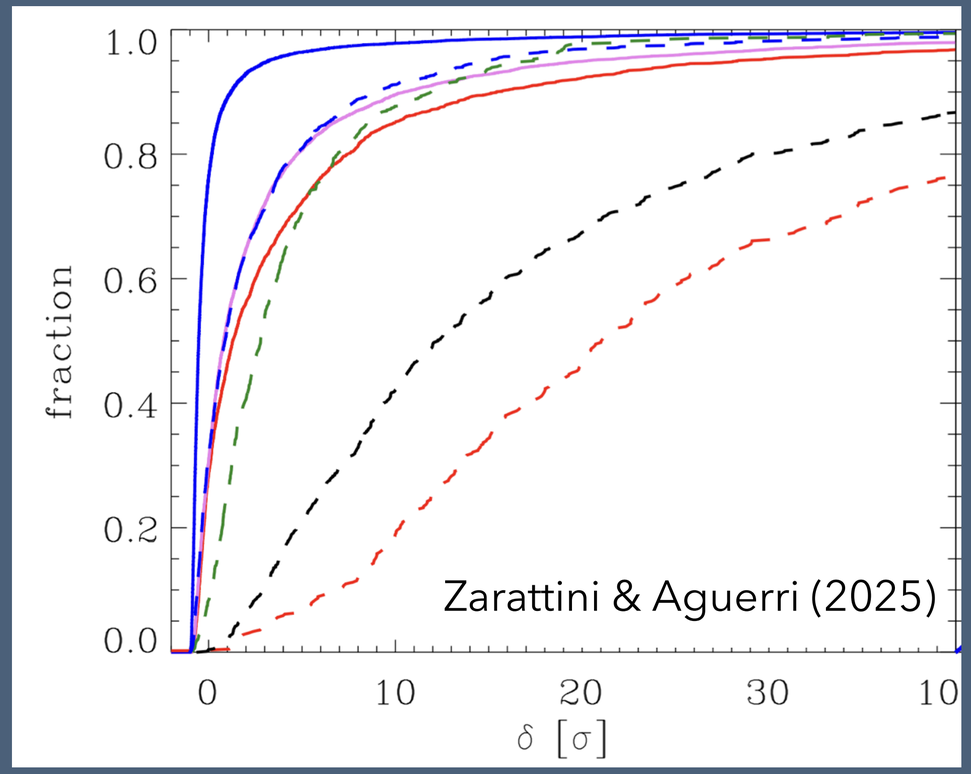

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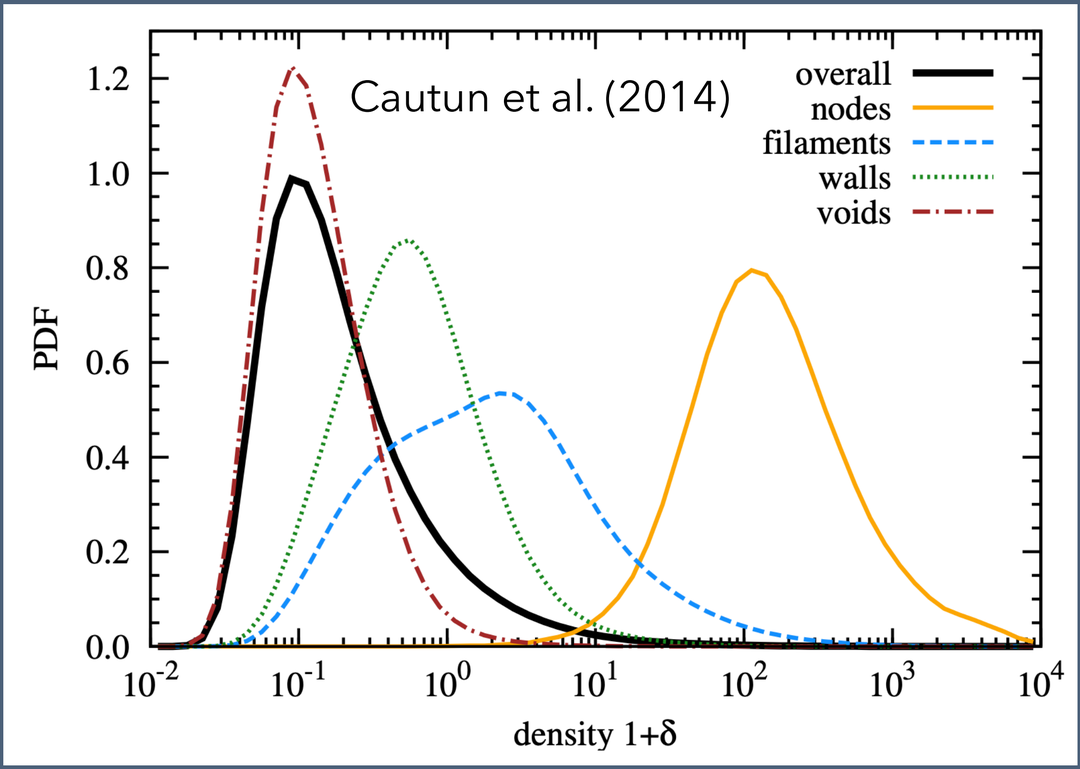
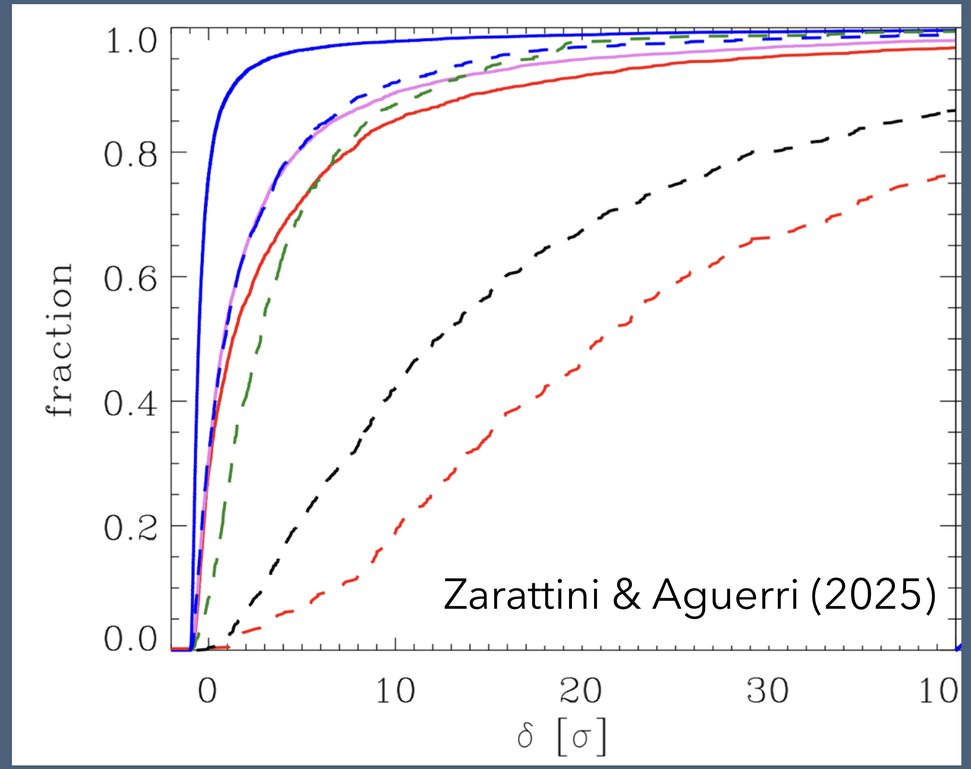


solid lines:
filaments (D_{int} > 20 Mpc & D_{fila} < 1Mpc)
intersections (D_{int} < 2 Mpc)
field (D_{fila} > 10 Mpc)



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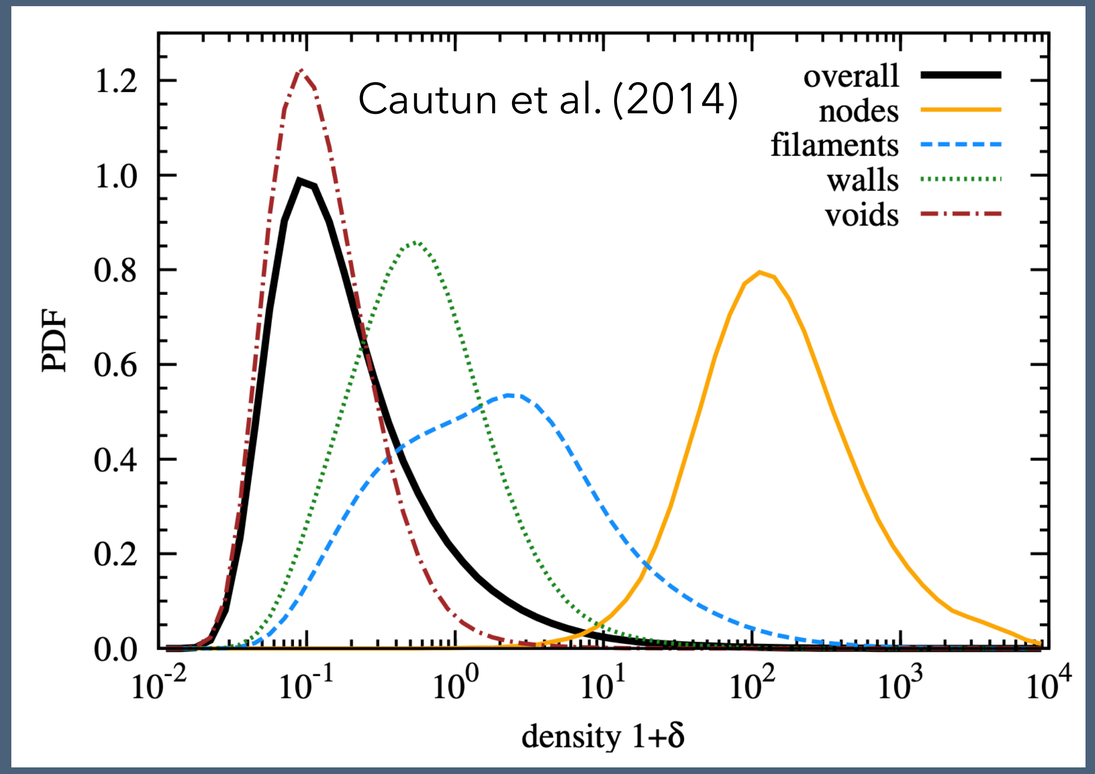
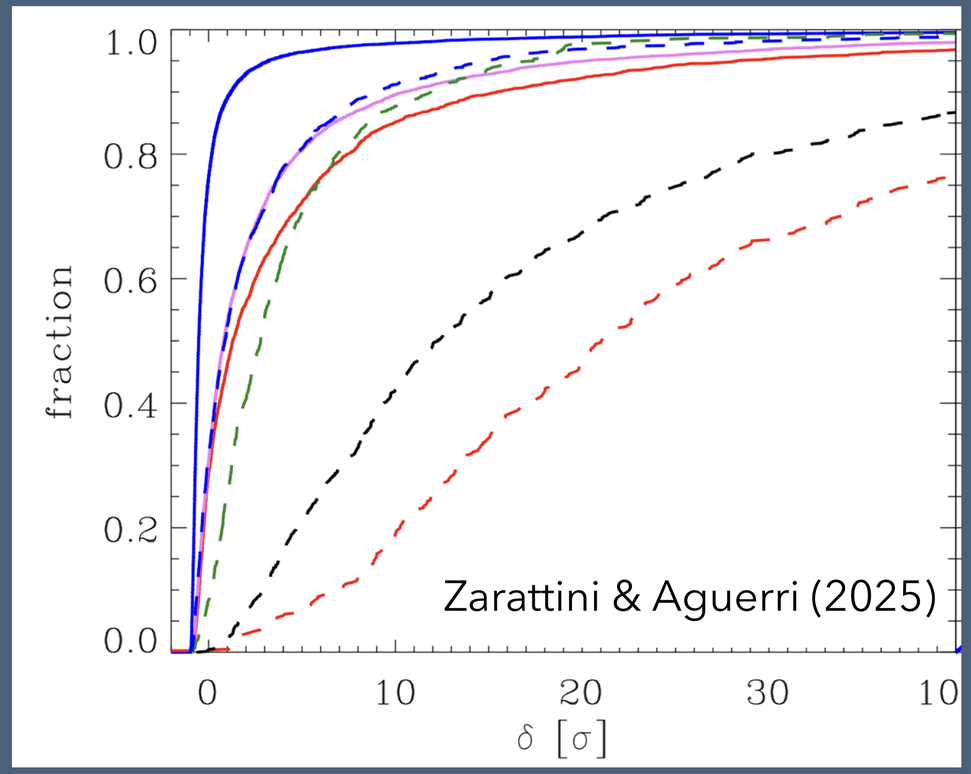


dashed lines:
eRosita < 0.5 r_{200}
eRosita < r_{200}
eRosita 1–2 r_{200}
eRosita 2–5 r_{200}



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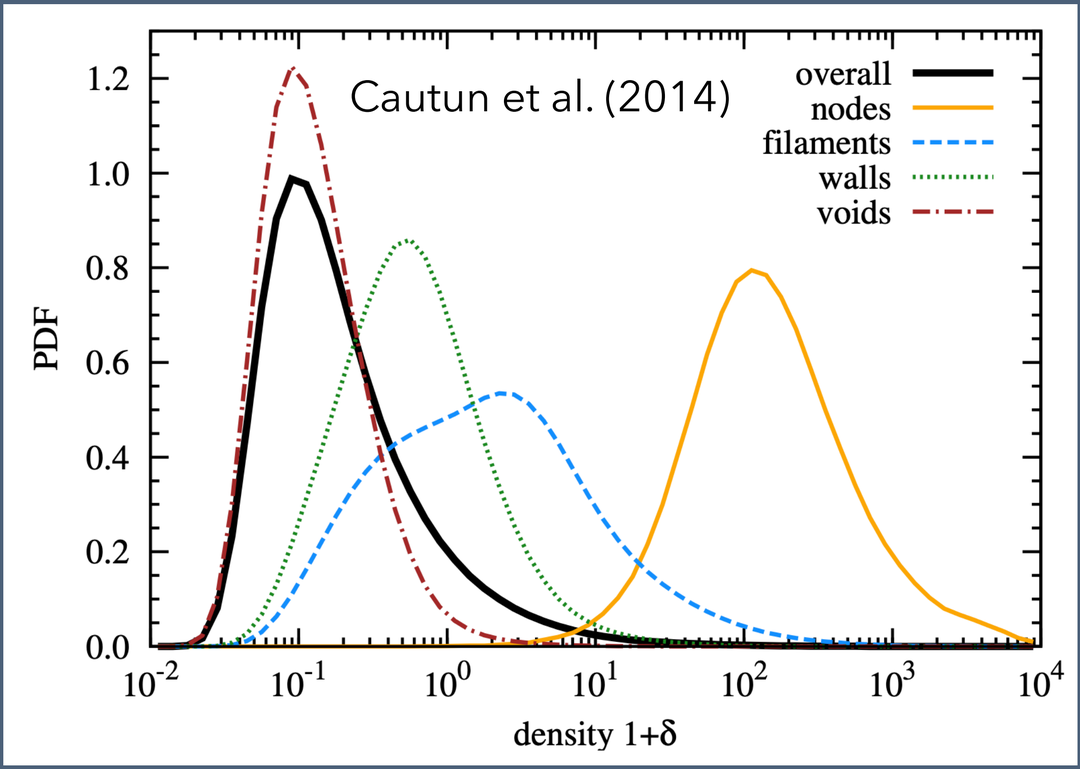

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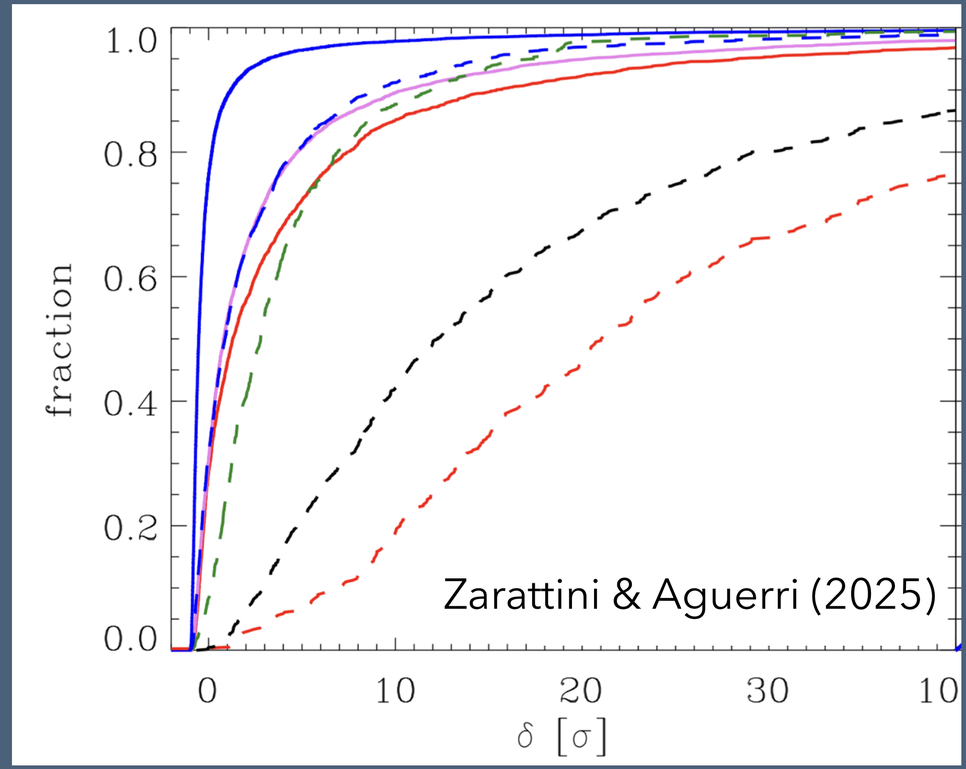

The cosmic web

- Question: are intersections the same as nodes?

NO!!

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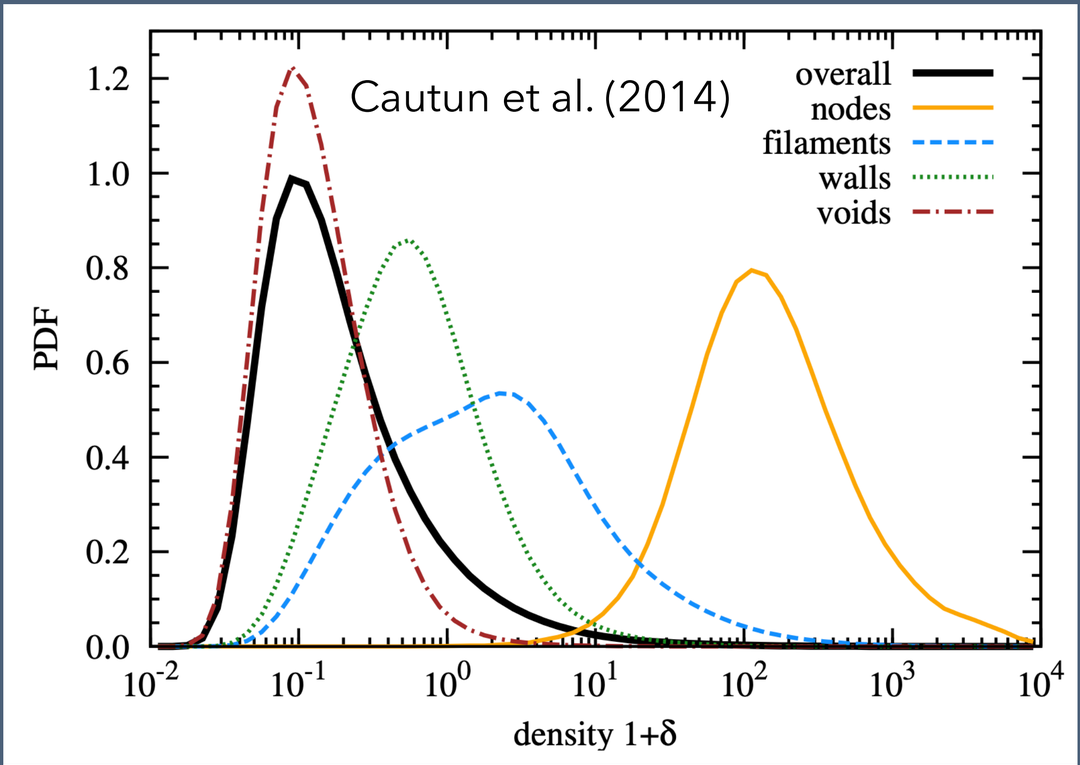
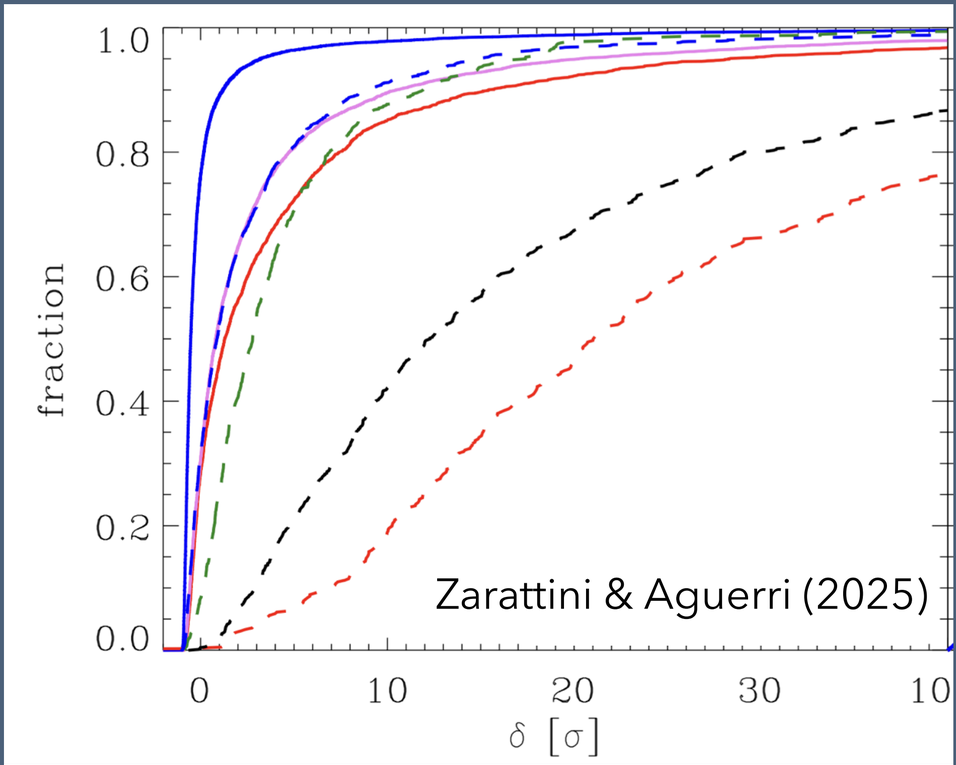
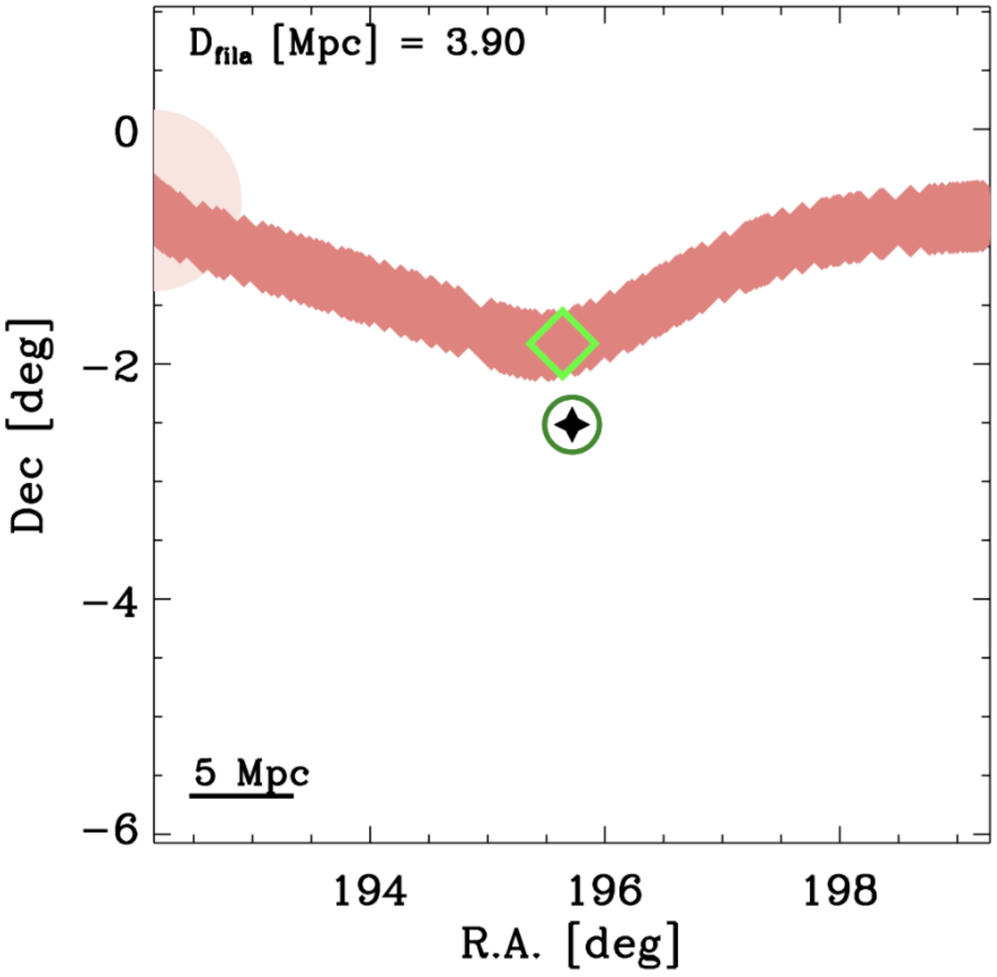
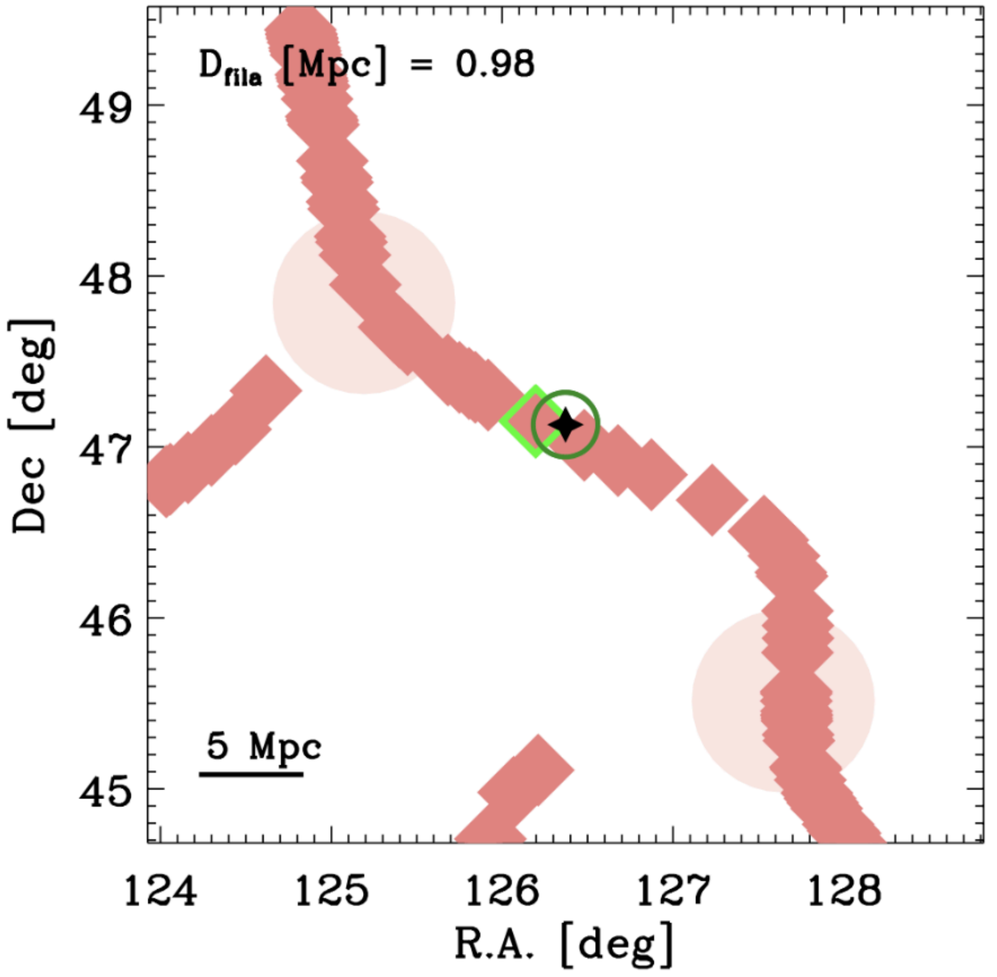




Distance to filaments





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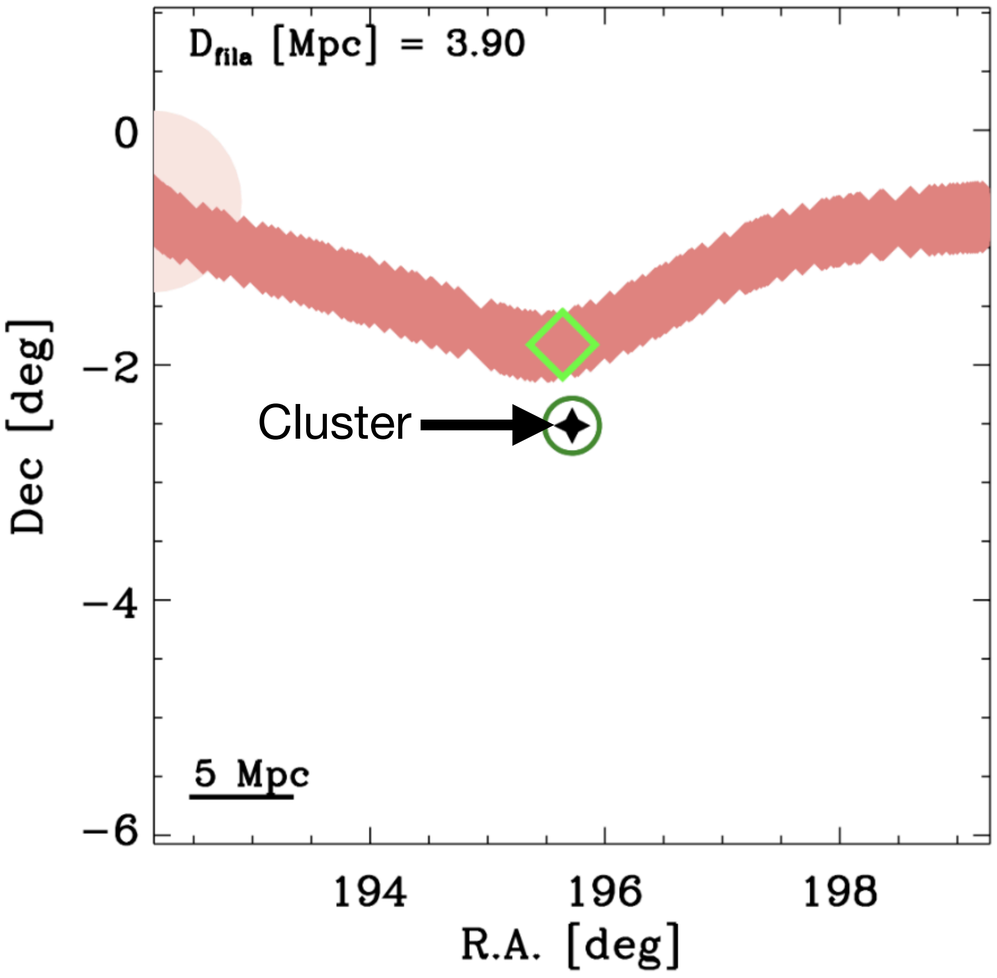

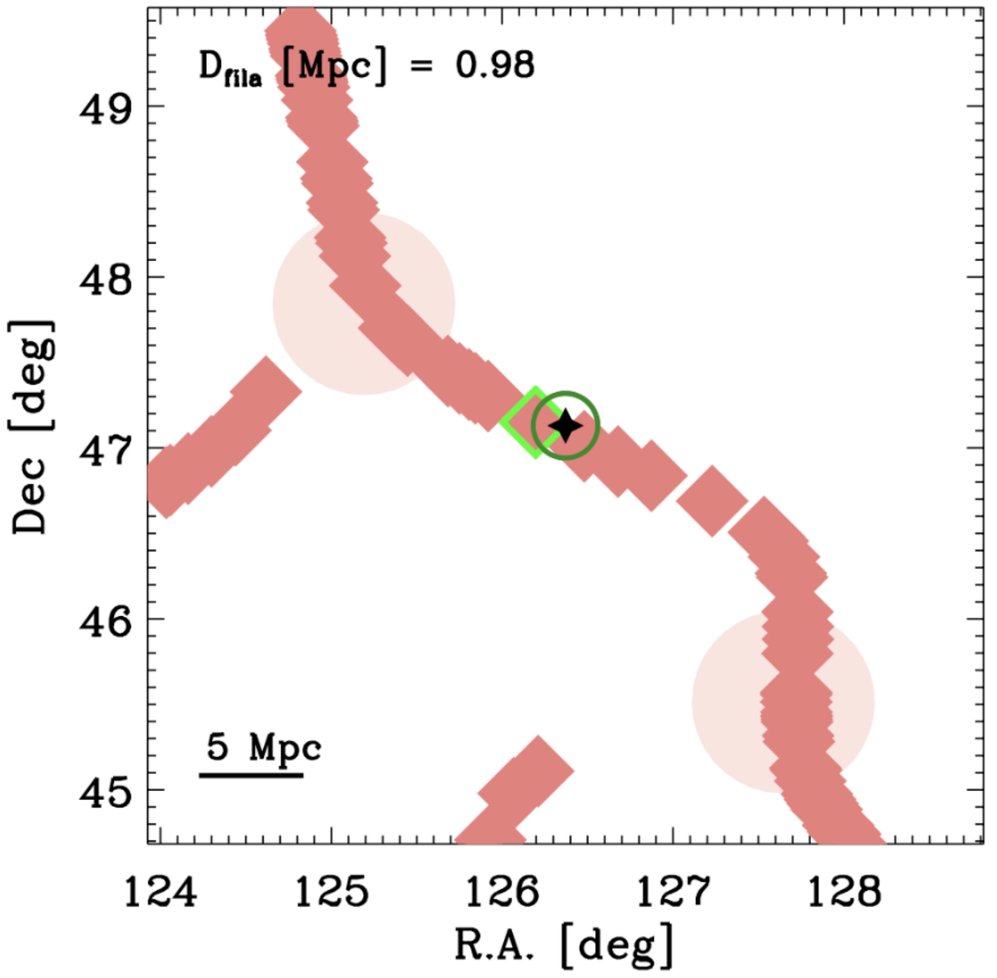

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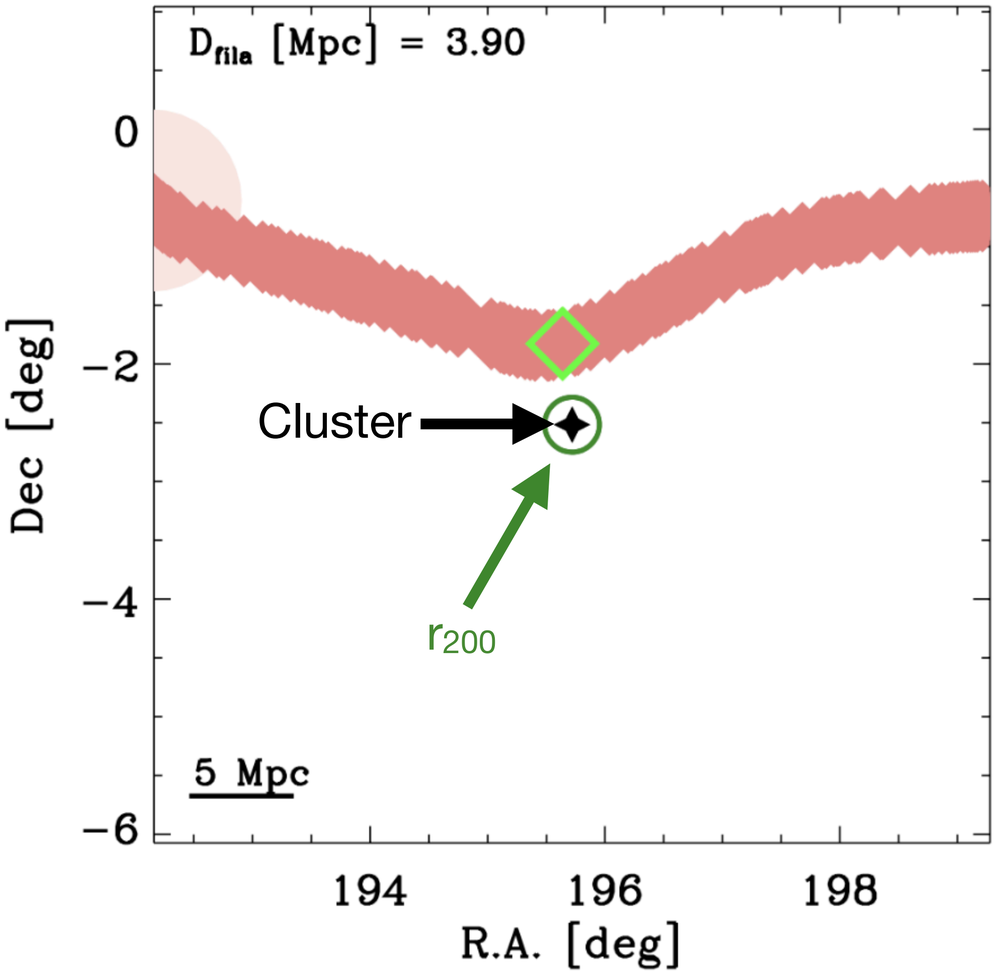

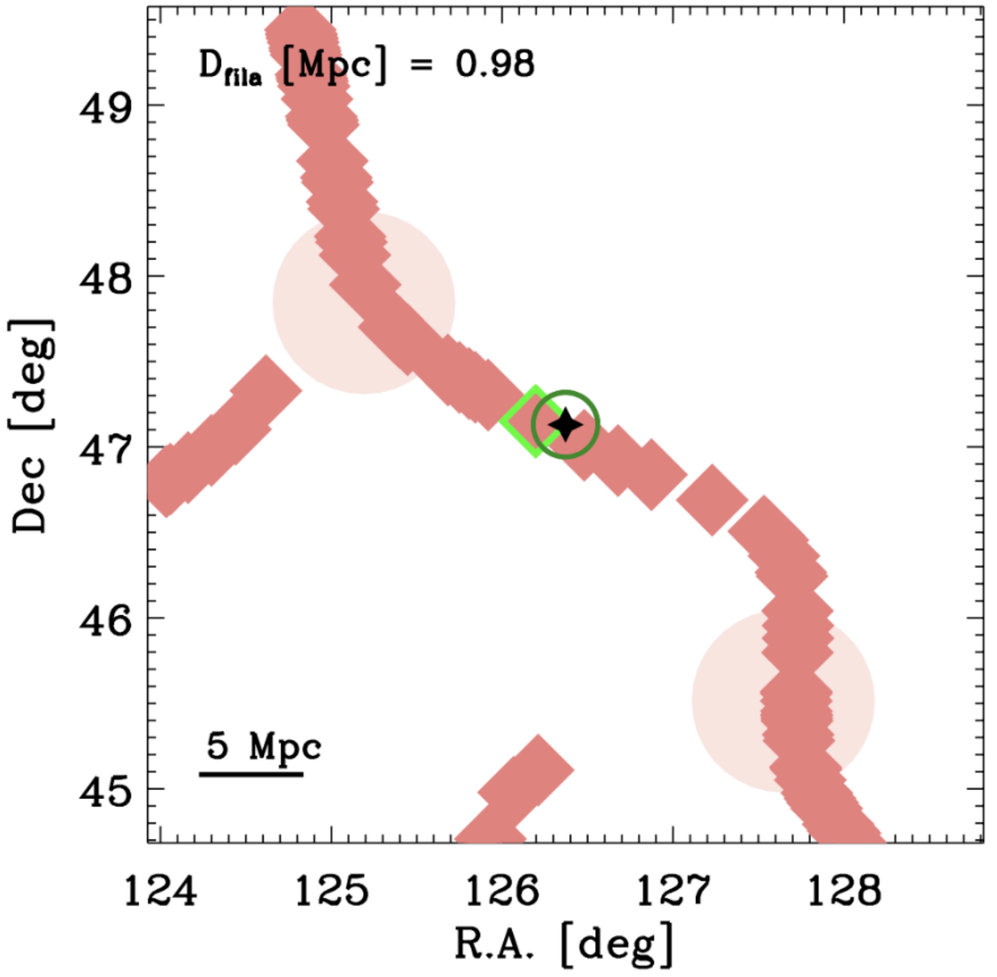

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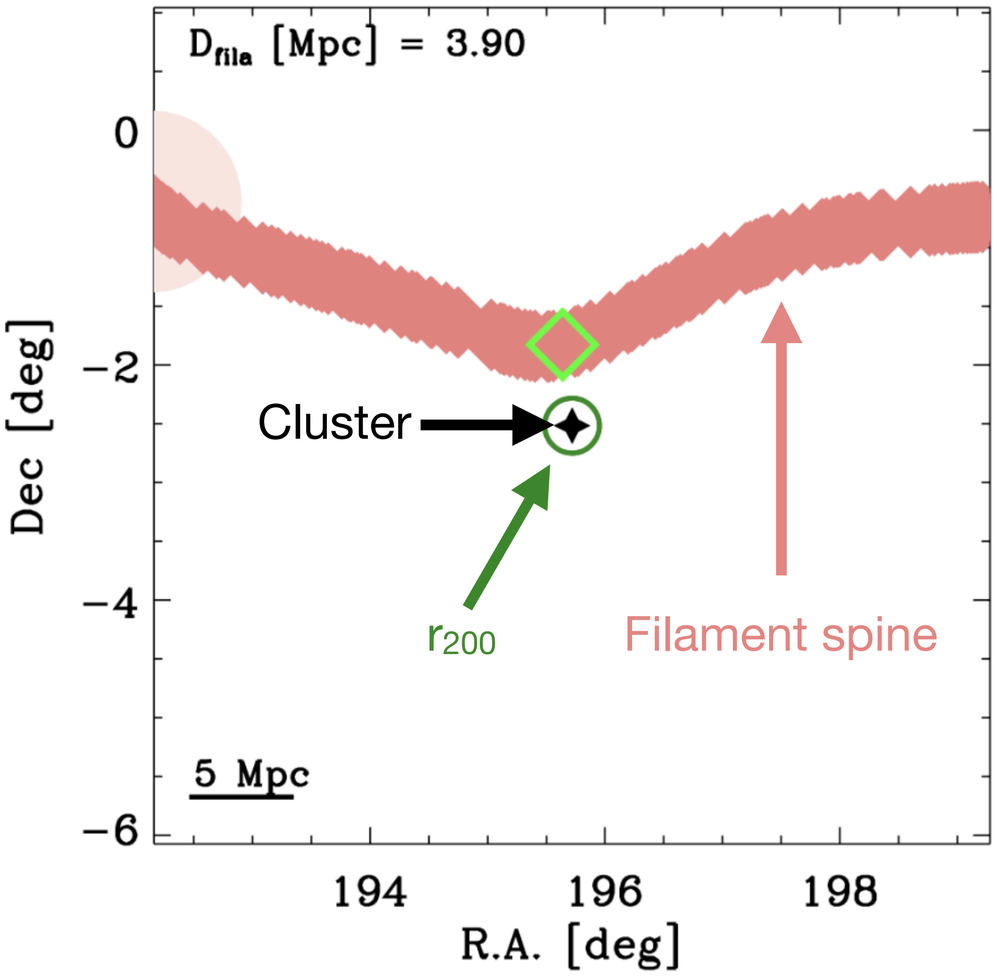

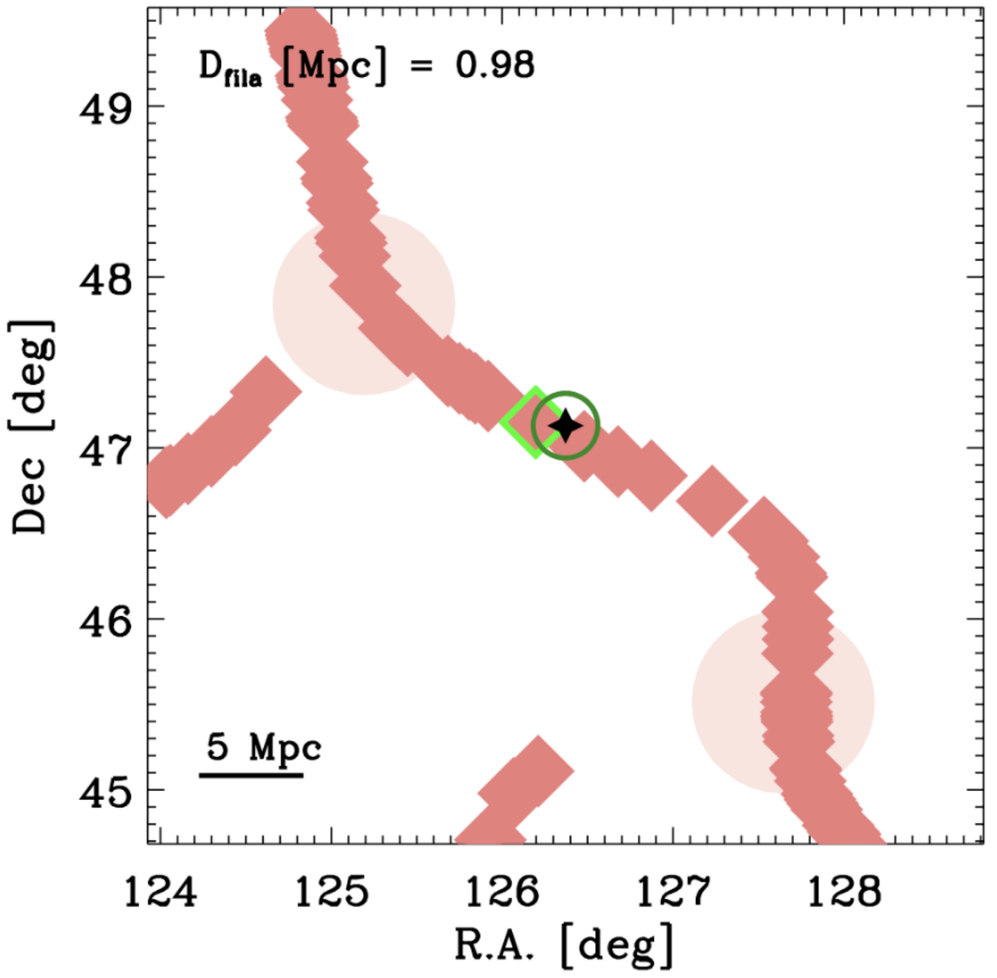

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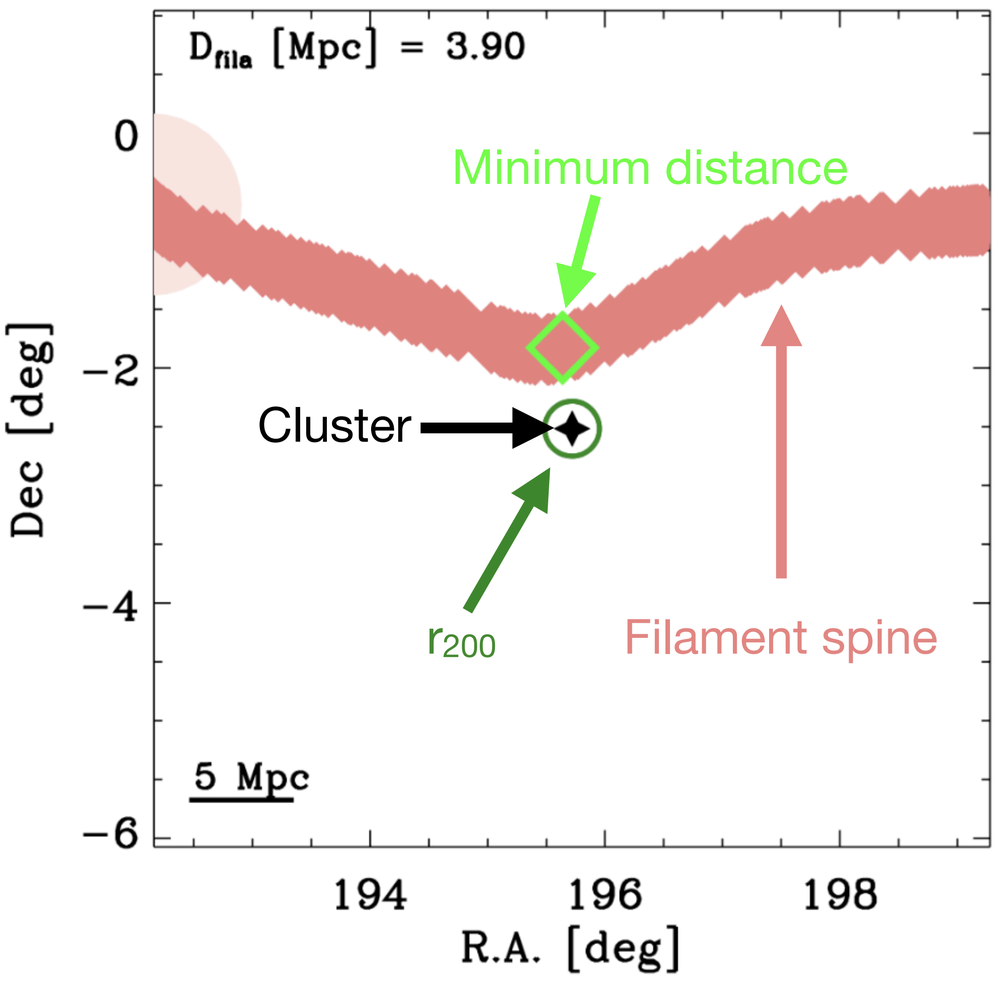

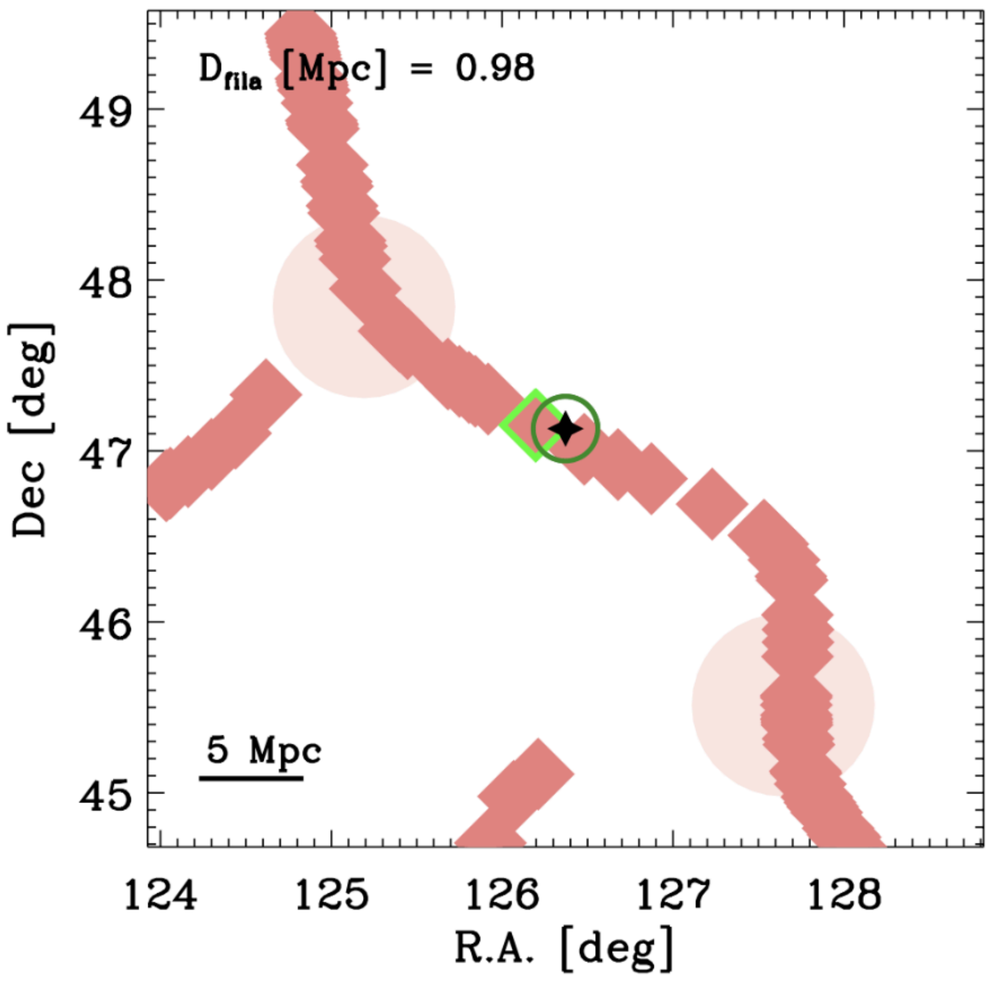

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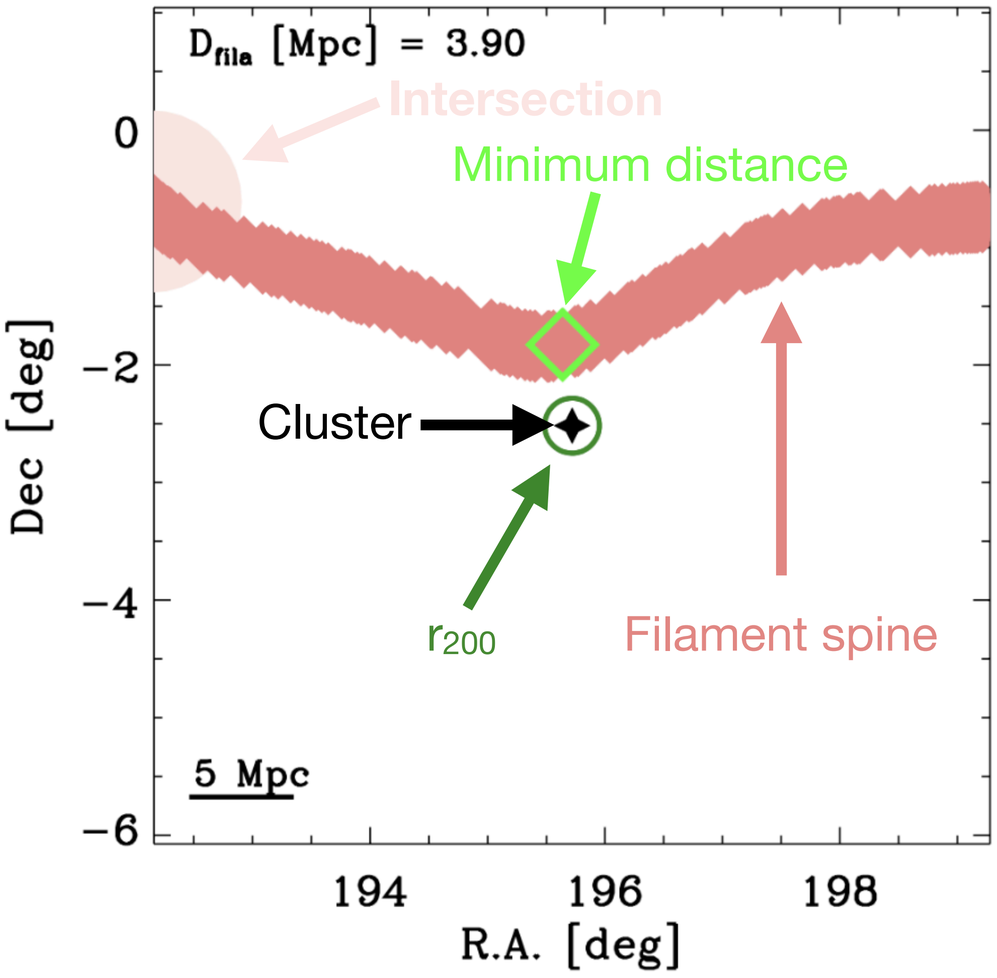

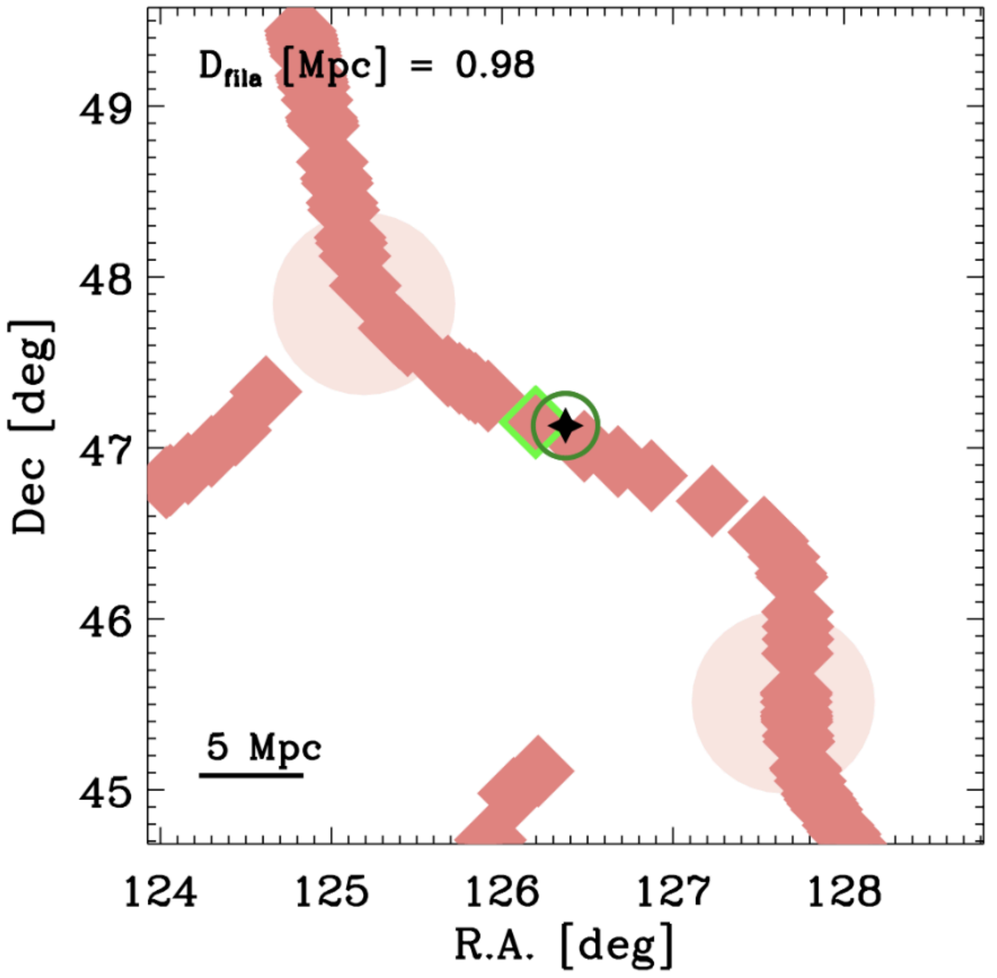

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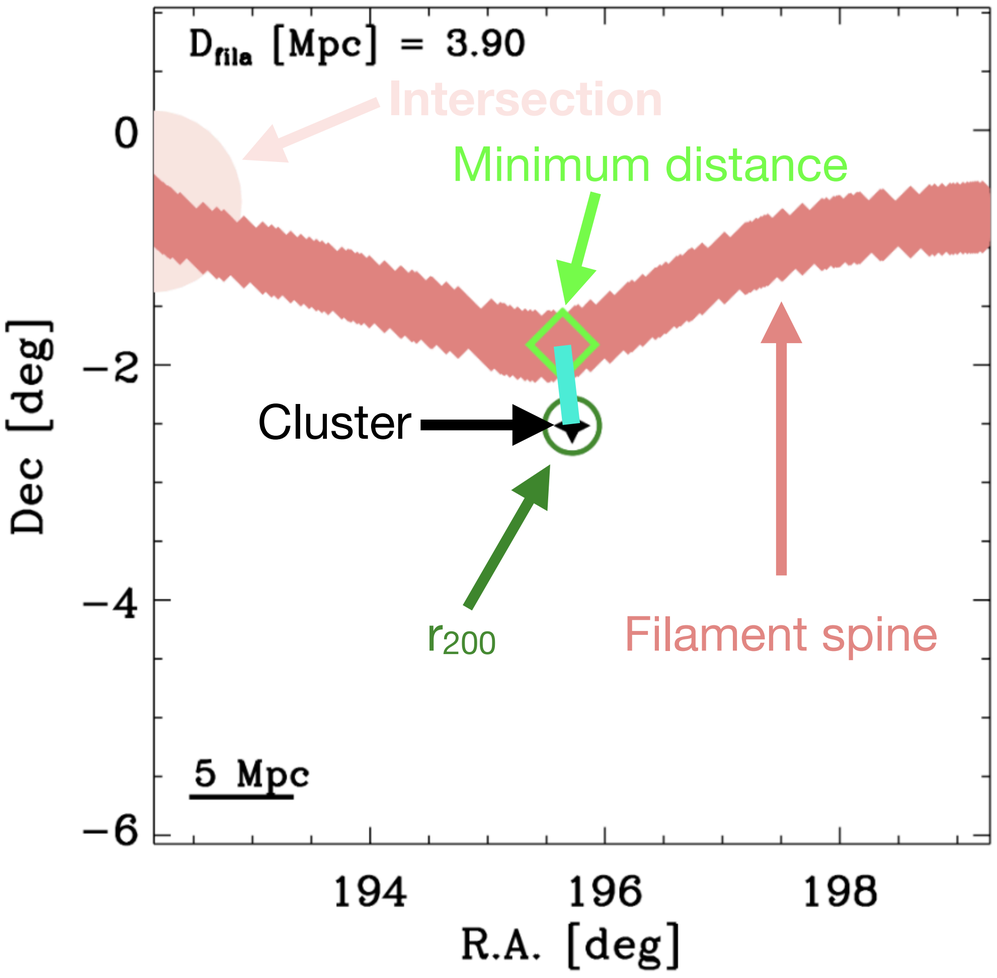

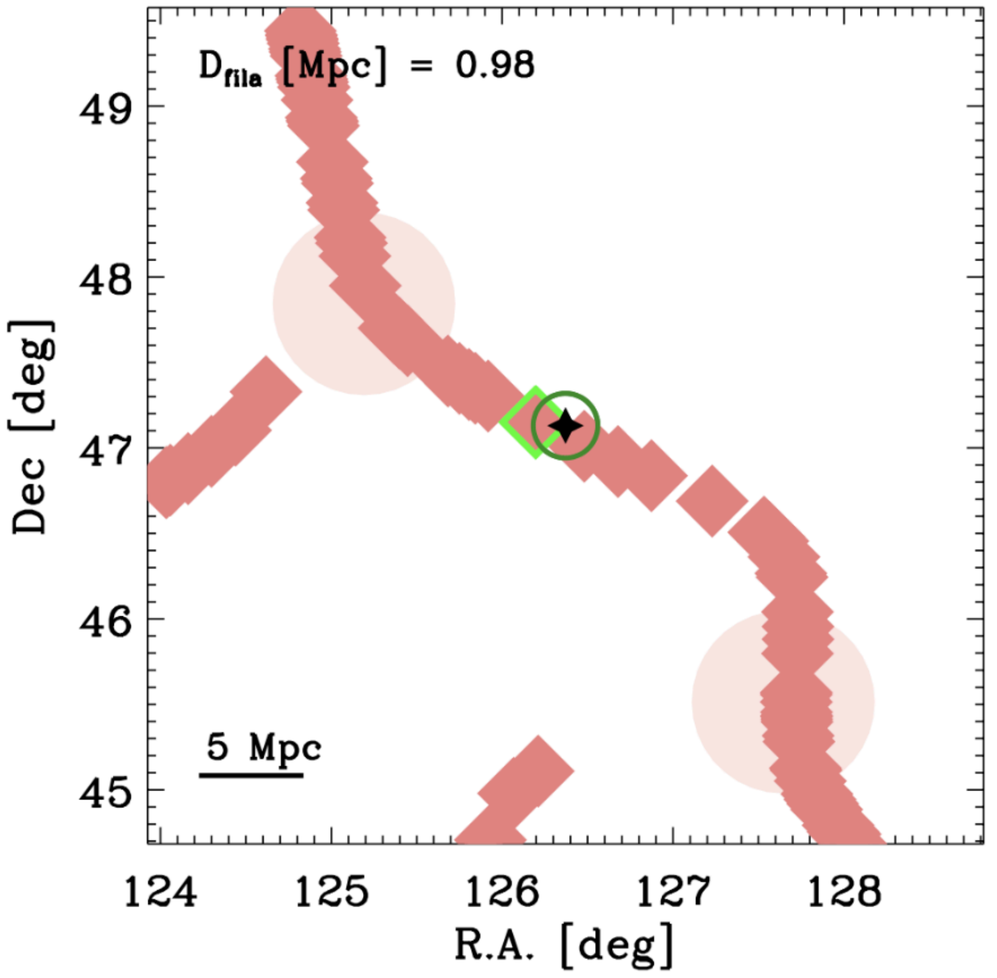

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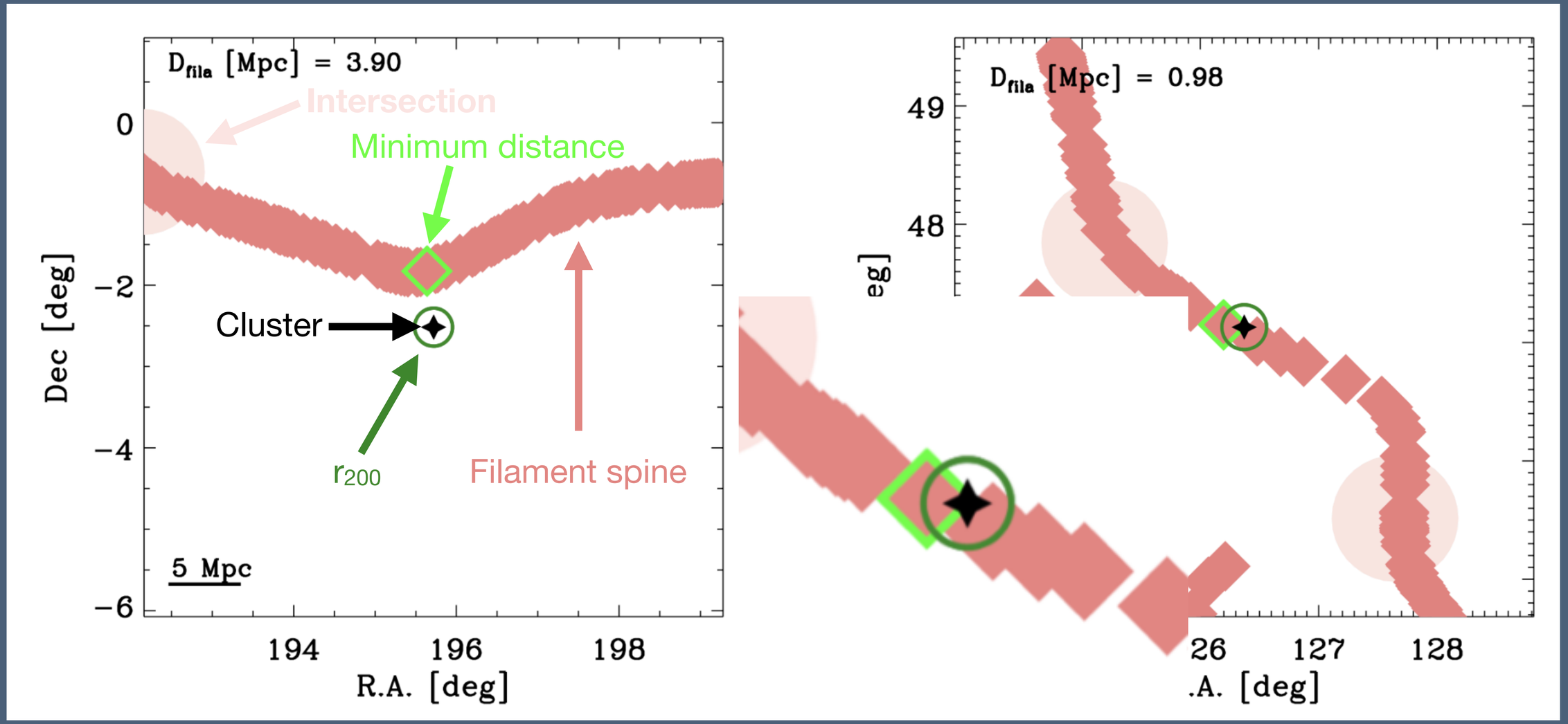

Outline of the talk

The impact of filaments on

The gas distribution of galaxy clusters

- Is the gas fraction depending on the position of the cluster within the cosmic web?

The properties of individual galaxies

- Can filaments modify the colour and SFR of galaxies?
- Can we estimate the width of filaments using the density of galaxies as tracer?
- Is there an evolution with redshift in the width of filaments?

The impact of filaments on the gas distribution of galaxy clusters

Sample

29 clusters from the XUCS sample:

- > 50 spectroscopic members
- Redshift $0.05 < z < 0.14$
- $\sigma_v > 500$ km/s
- $13.5 < \log(M_{500}) < 14.6$

Puddu & Andreon (2022)

- The authors computed the X-ray surface brightness within R_{500} (SBx)
- Clusters are divided into:
  - High-SBx > 43.35 erg/s
  - Low-SBx < 42.55 erg/s
- Gas-poor, low SBx, X-ray faint-for-their-mass, show 25% lower richness

The impact of filaments on the gas distribution of galaxy clusters

Goal

Understand if there is a relation between SBx (so, the gas fraction) and the distance to filaments of the cosmic web.

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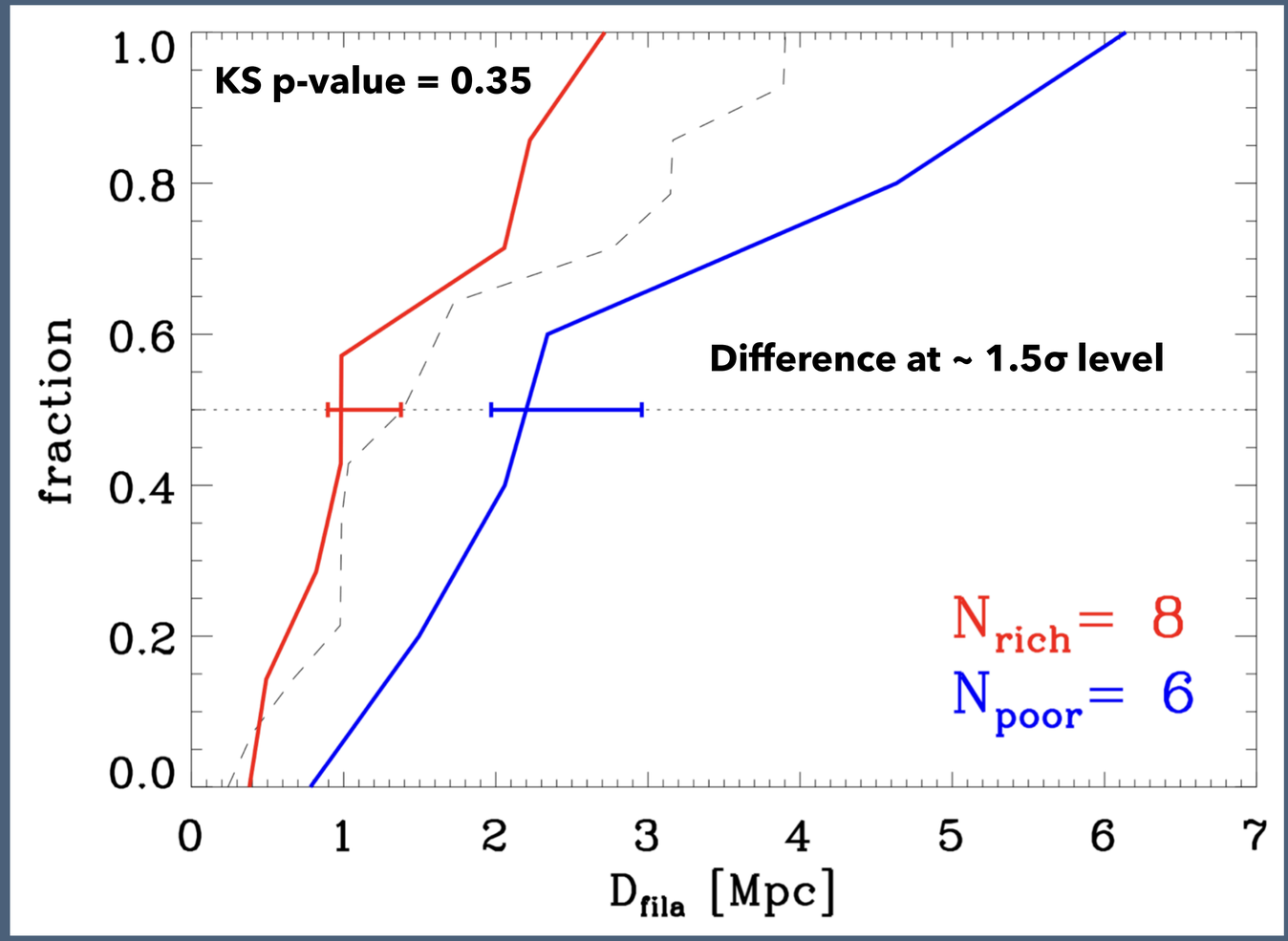

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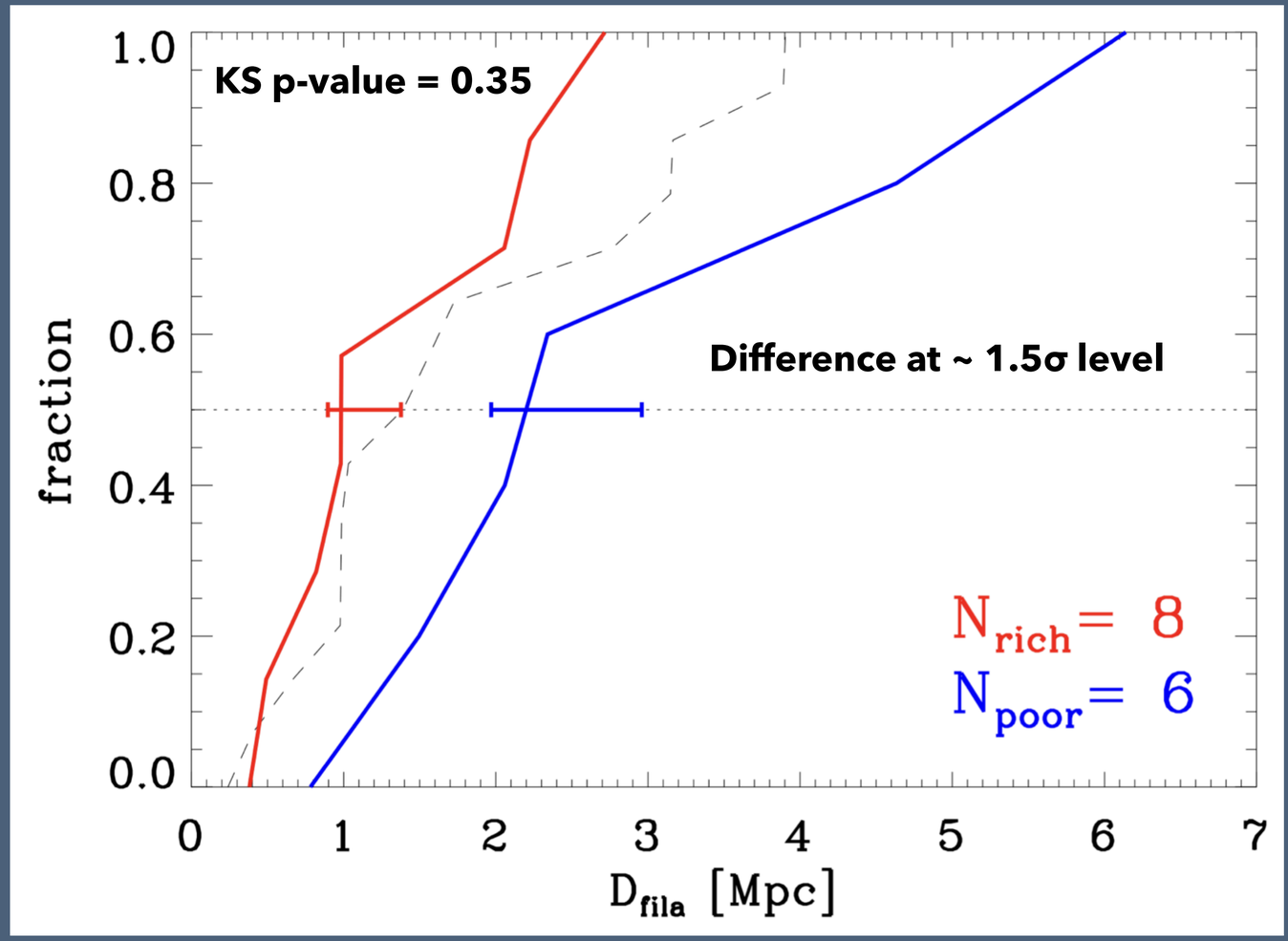
Result

Gas-rich clusters are found, on average, closer to the spine of filaments



The impact of filaments on the gas distribution of galaxy clusters

Interpretation

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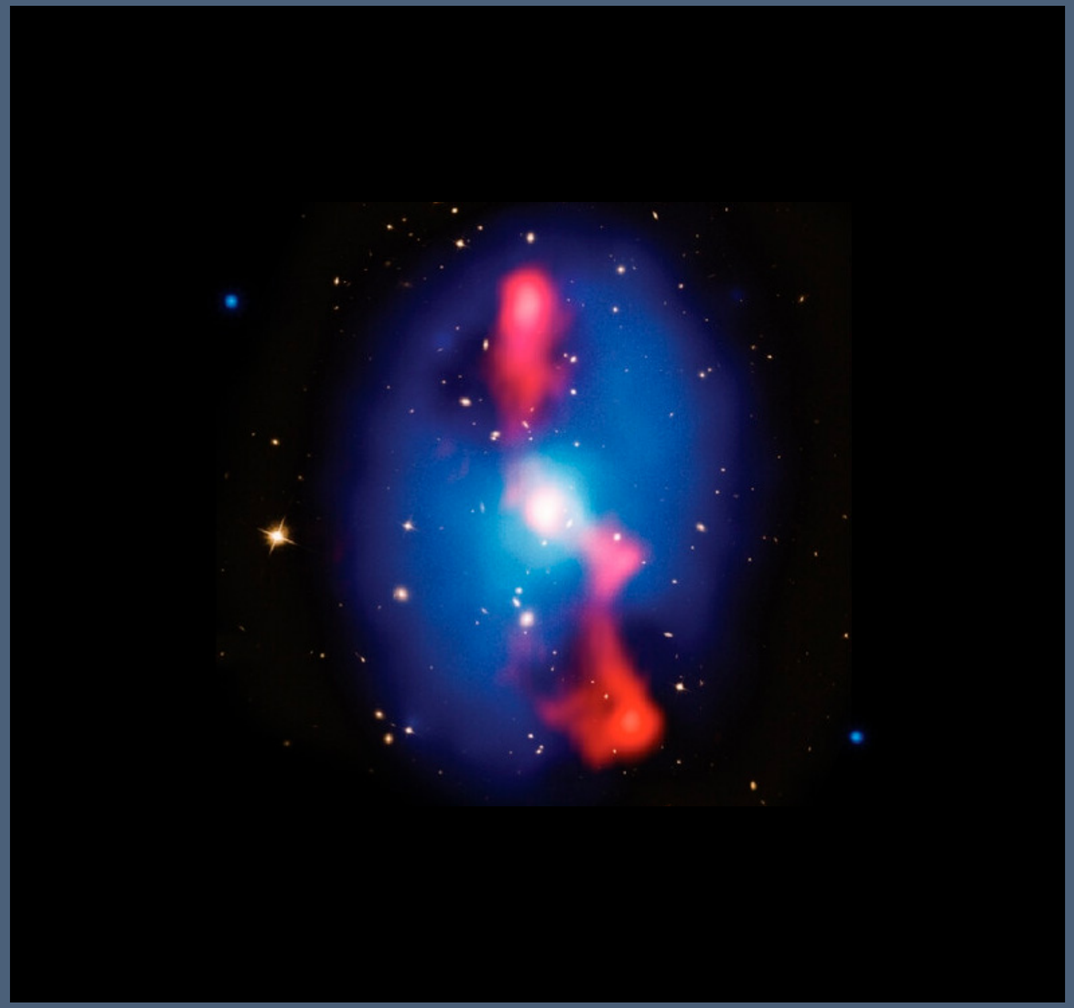
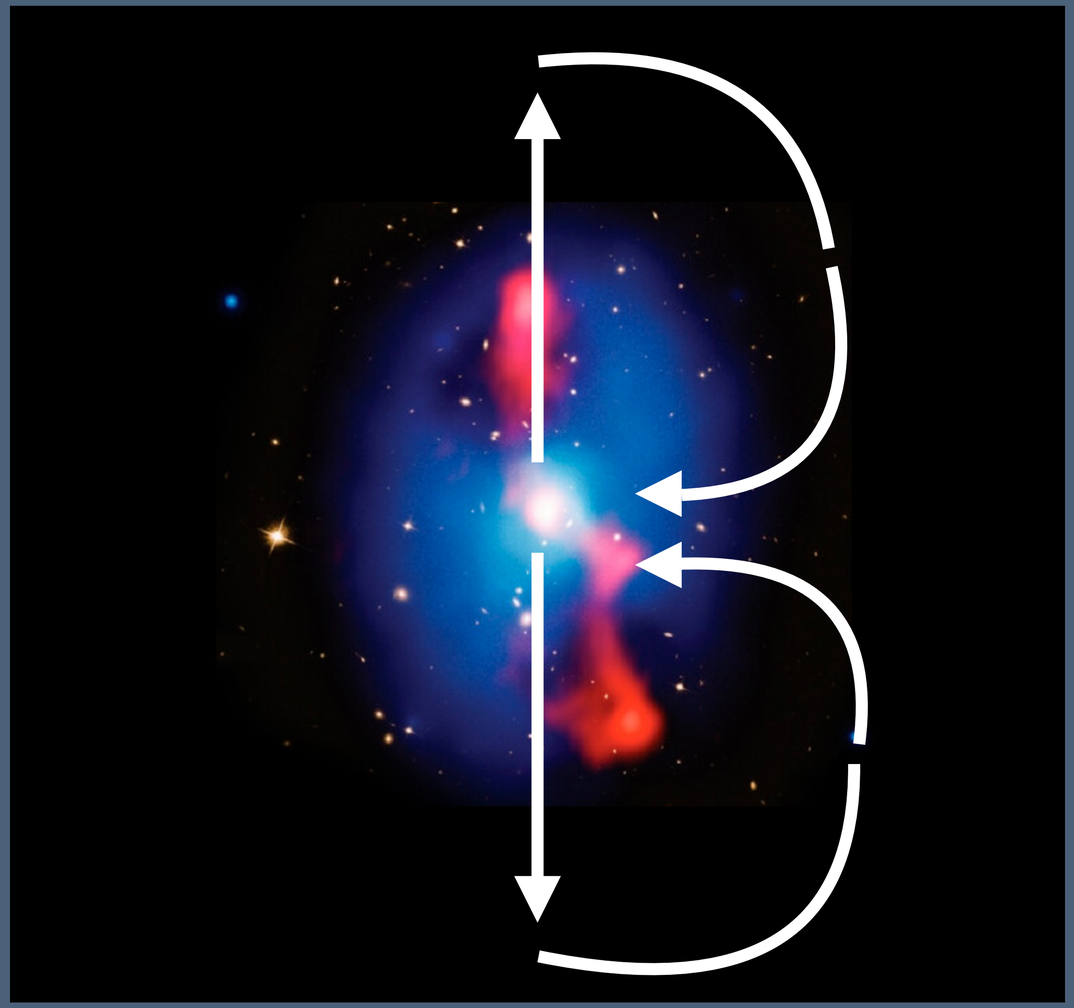


The impact of filaments on the gas distribution of galaxy clusters

Interpretation

No filament:

- Gas is pushed away from the AGN
- Then, it comes back due to the gravitational attraction



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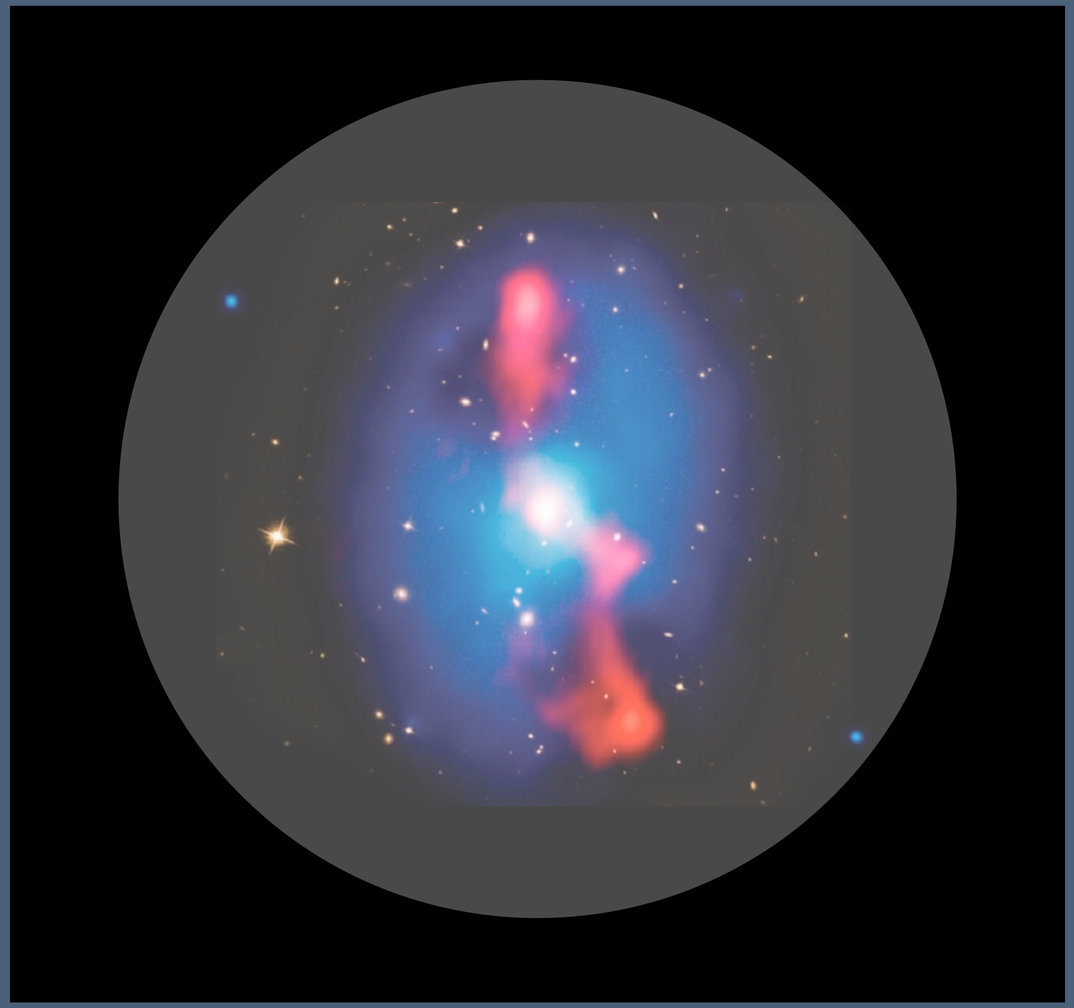

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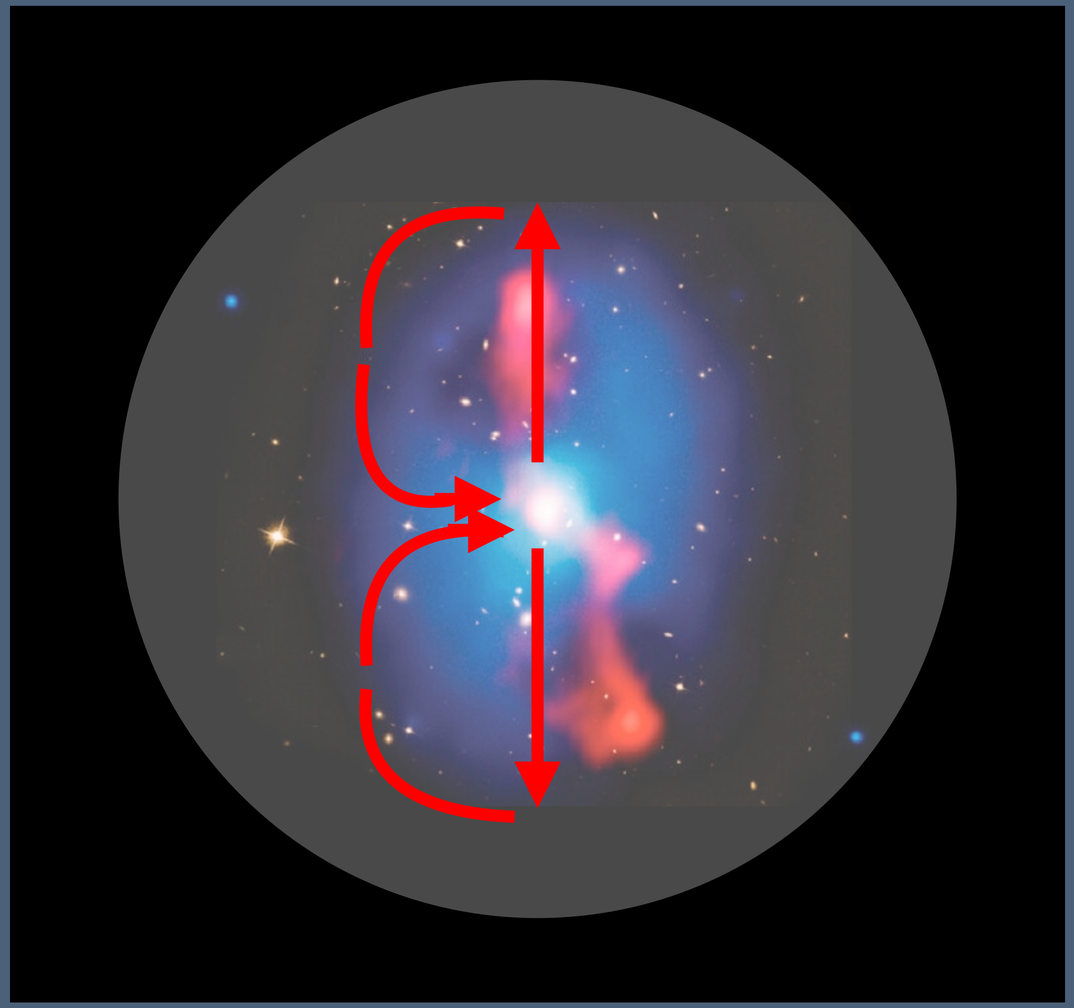

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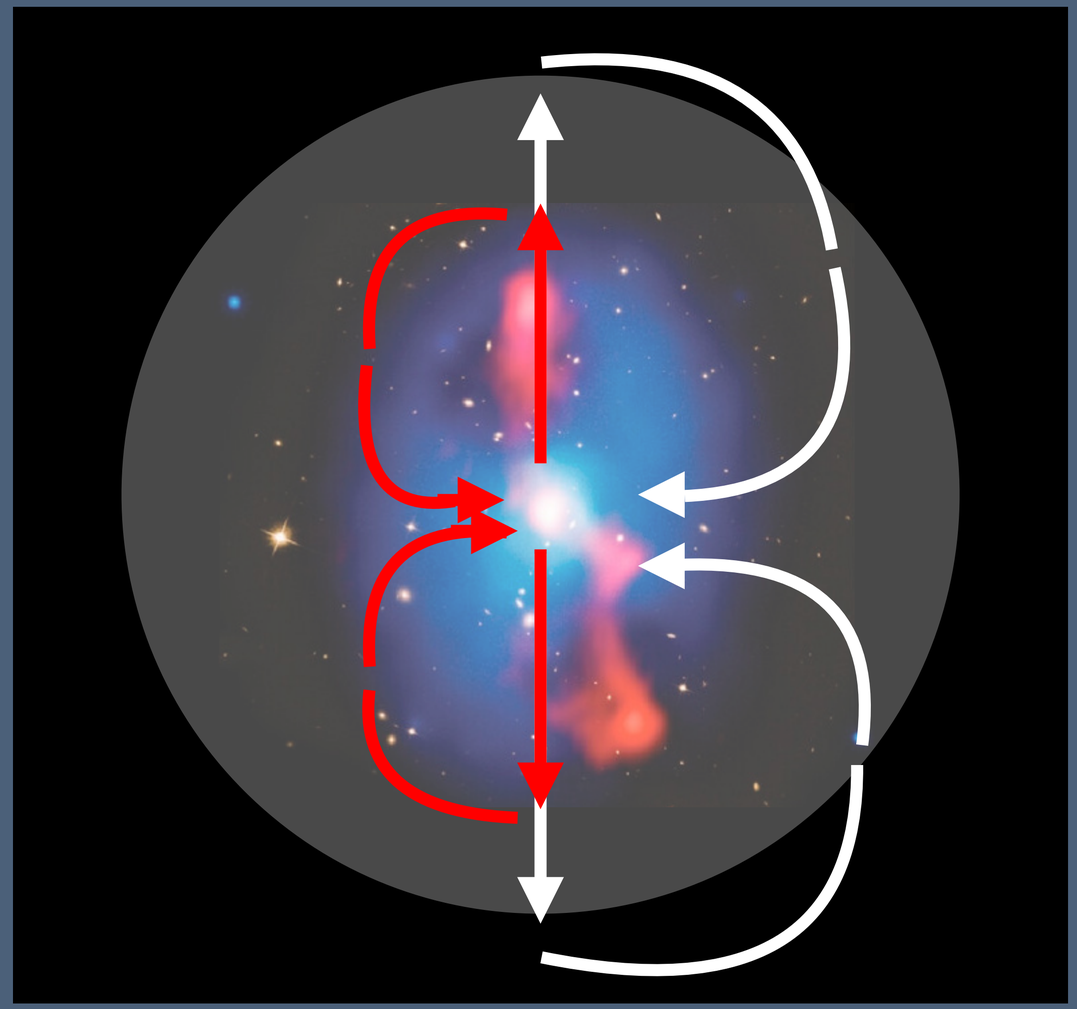
Filament:

- Same mechanism, but shorter timescale for the gas cycle!



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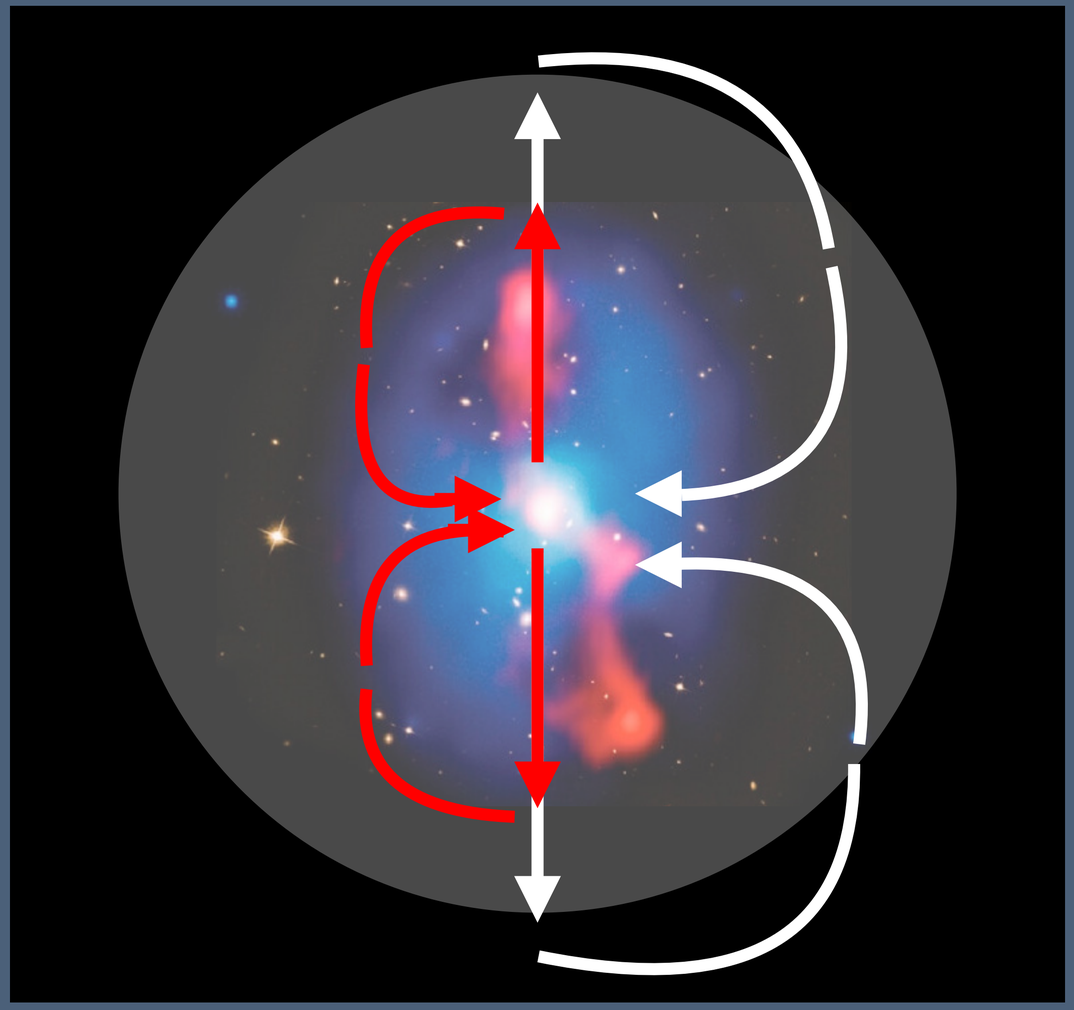

Zarattini, Andreon, and Puddu (2025)

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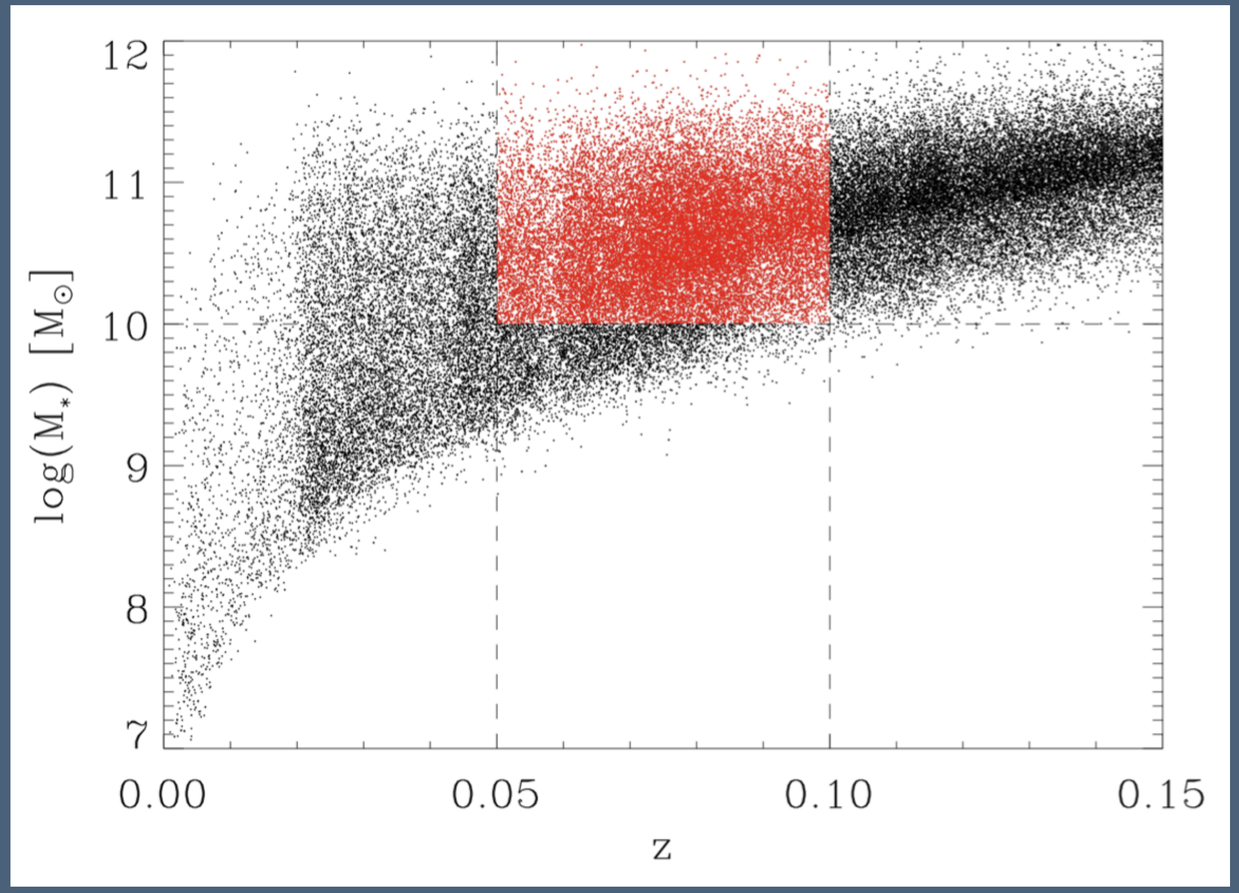
The impact of filaments on the colour and SFR of galaxies

Sample

All galaxies with spectroscopic redshift in SDSS with:

- $0.05 < z < 0.1$
- $M^* > 10^{10}$ Msun

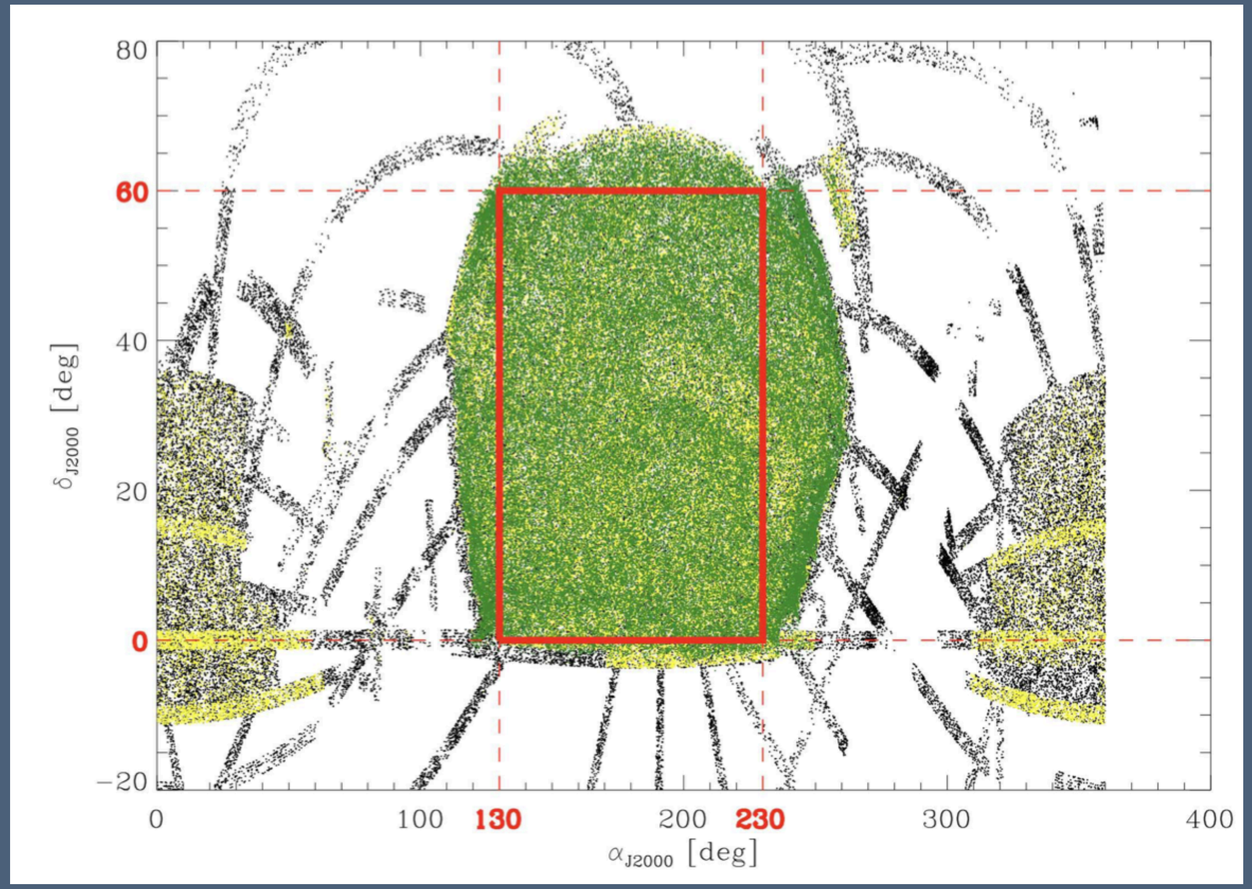


The impact of filaments on the colour and SFR of galaxies

Sample

All galaxies with spectroscopic redshift in SDSS with:

- $0.05 < z < 0.1$
- $M^* > 10^{10}$ Msun
- $130 < \text{R.A.} < 230$ degrees
- $0 < \text{Dec} < 60$ degrees



The impact of filaments on the colour and SFR of galaxies

Sample

All galaxies with spectroscopic redshift in SDSS with:

- $0.05 < z < 0.1$
- $M^* > 10^{10}$ Msun
- $130 < \text{R.A.} < 230$ degrees
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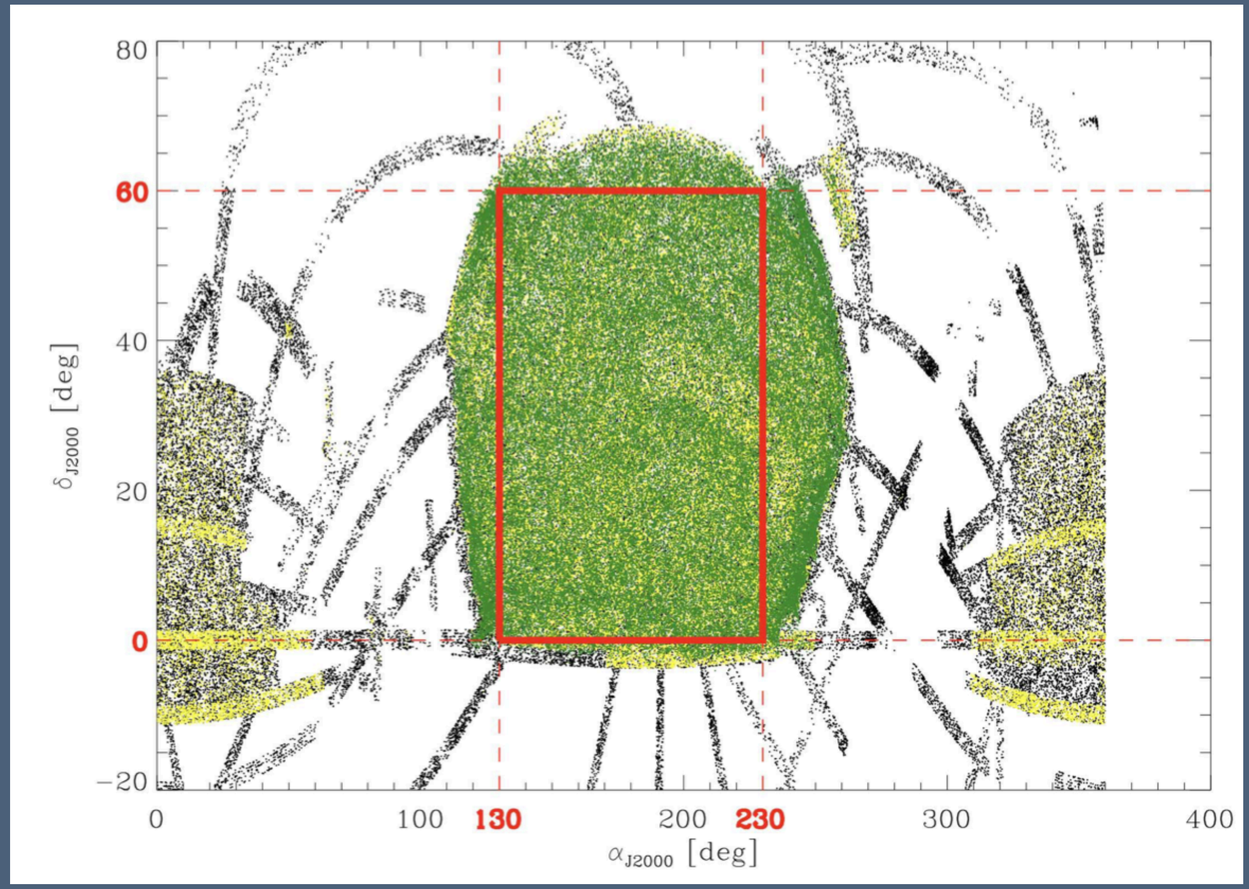


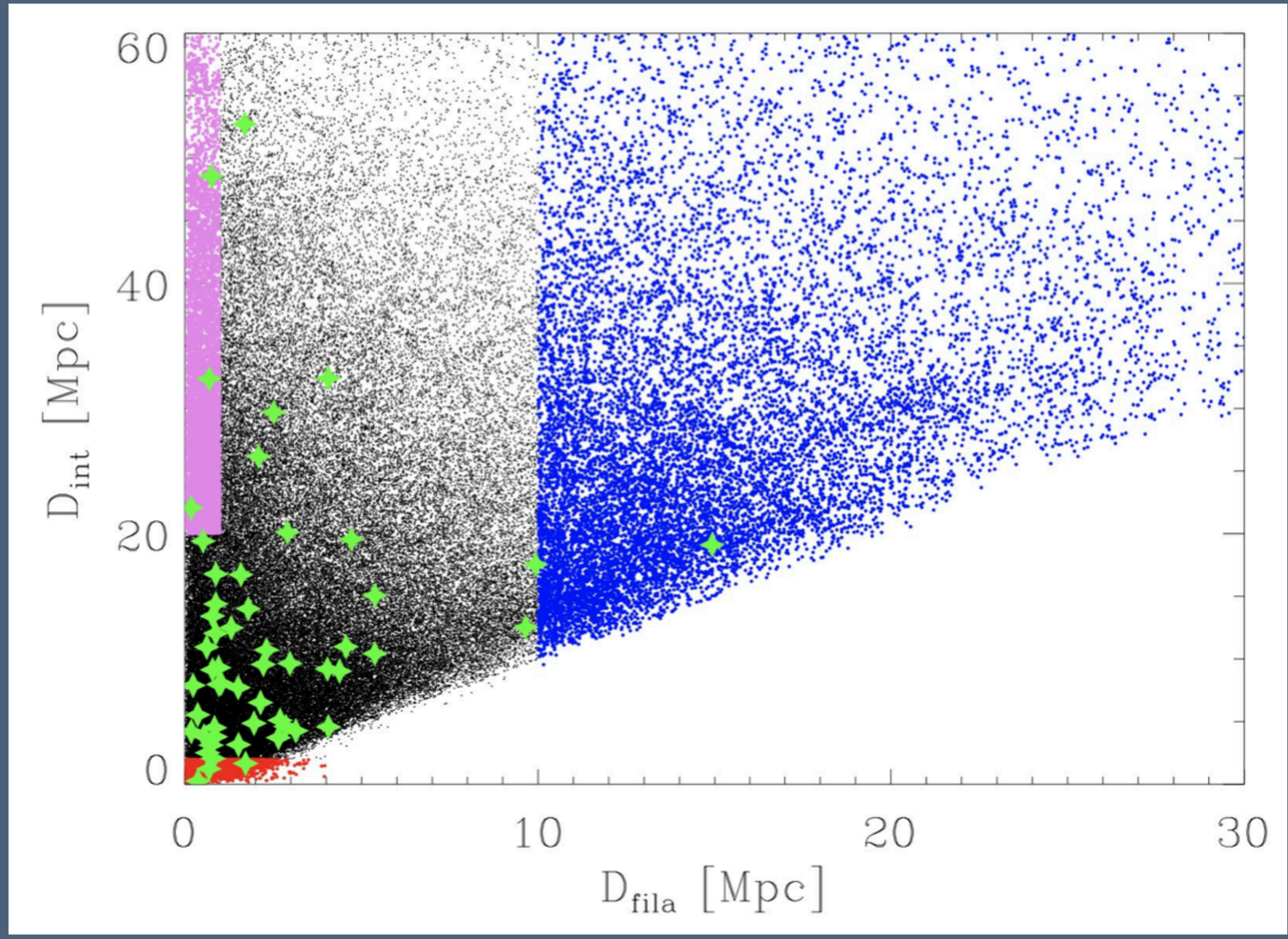
TOTAL = 120 927 galaxies

The impact of filaments on the colour and SFR of galaxies

Sample

Three main populations:

- Galaxies in filaments
- Galaxies in intersections
- Galaxies in the field



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The impact of filaments on the colour and SFR of galaxies

Results

(g - r) colours from SDSS

The impact of filaments on the colour and SFR of galaxies

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SFR (Msun/yr) = $7.9 \times 10^{-42} L_{H\alpha}$ [erg/s]

(Salpeter IMF, Kennicut+1998)

($L_{H\alpha}$ from SDSS spectra, MPA-JHU)

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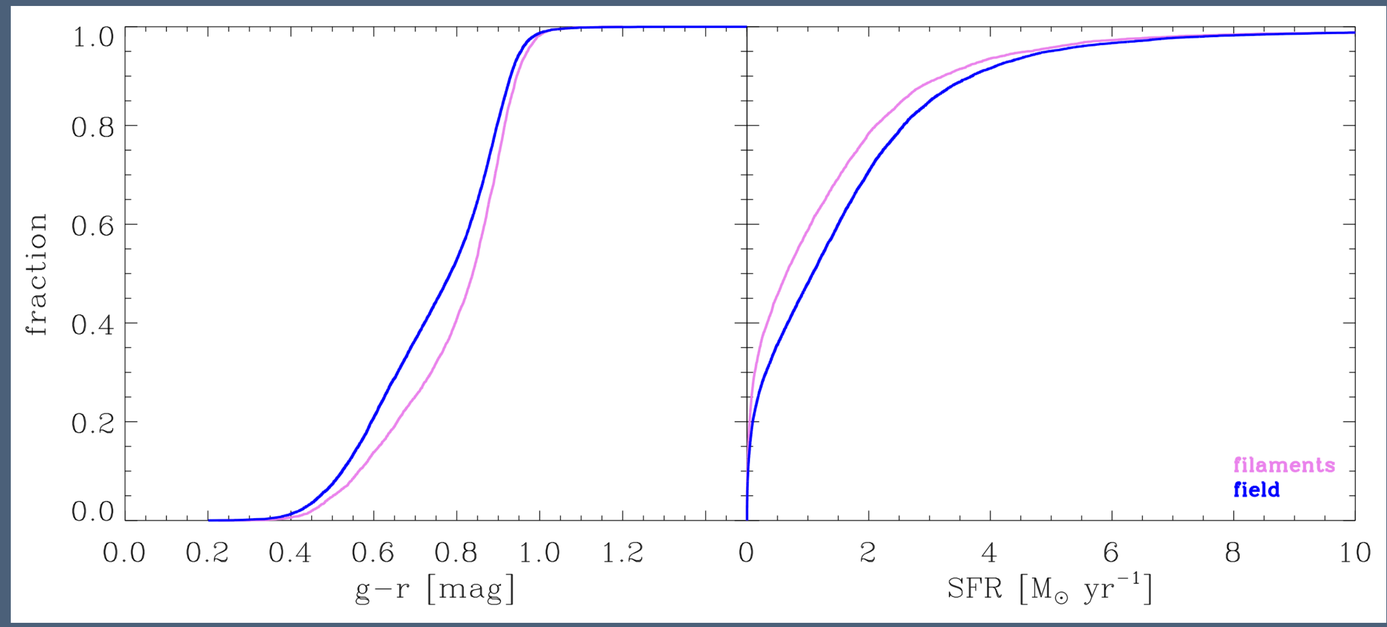

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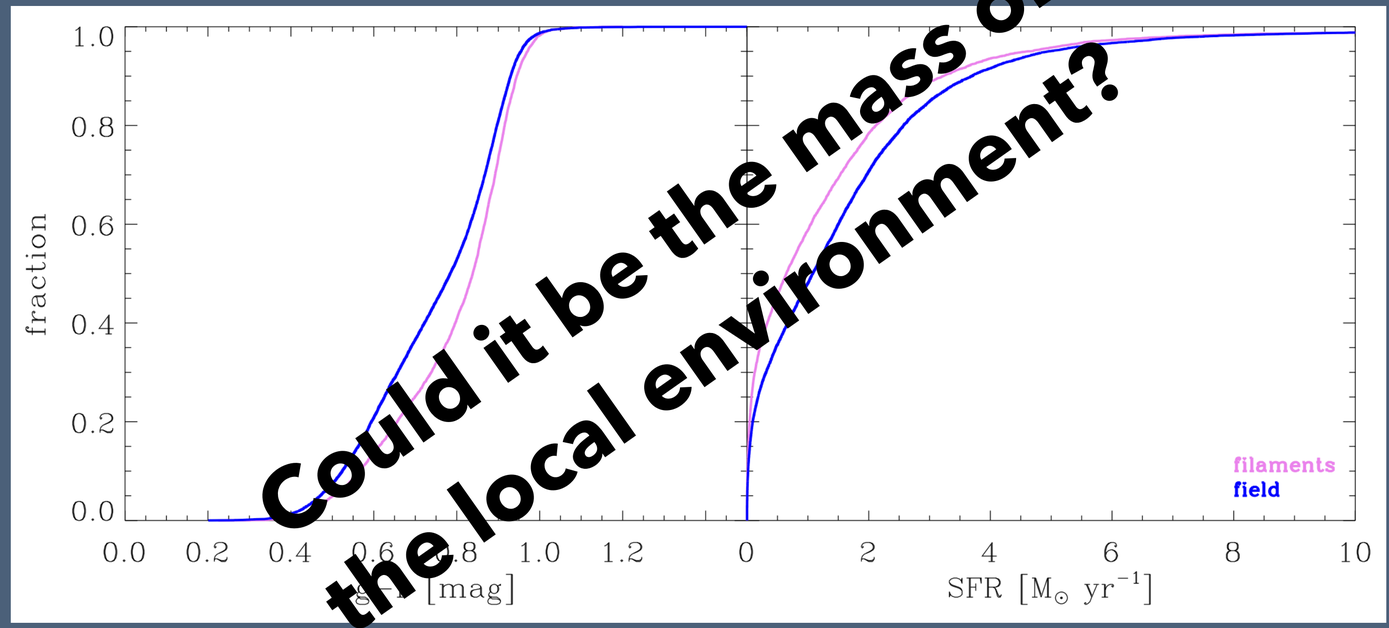

Could it be the mass or the local environment?

The impact of filaments on the colour and SFR of galaxies

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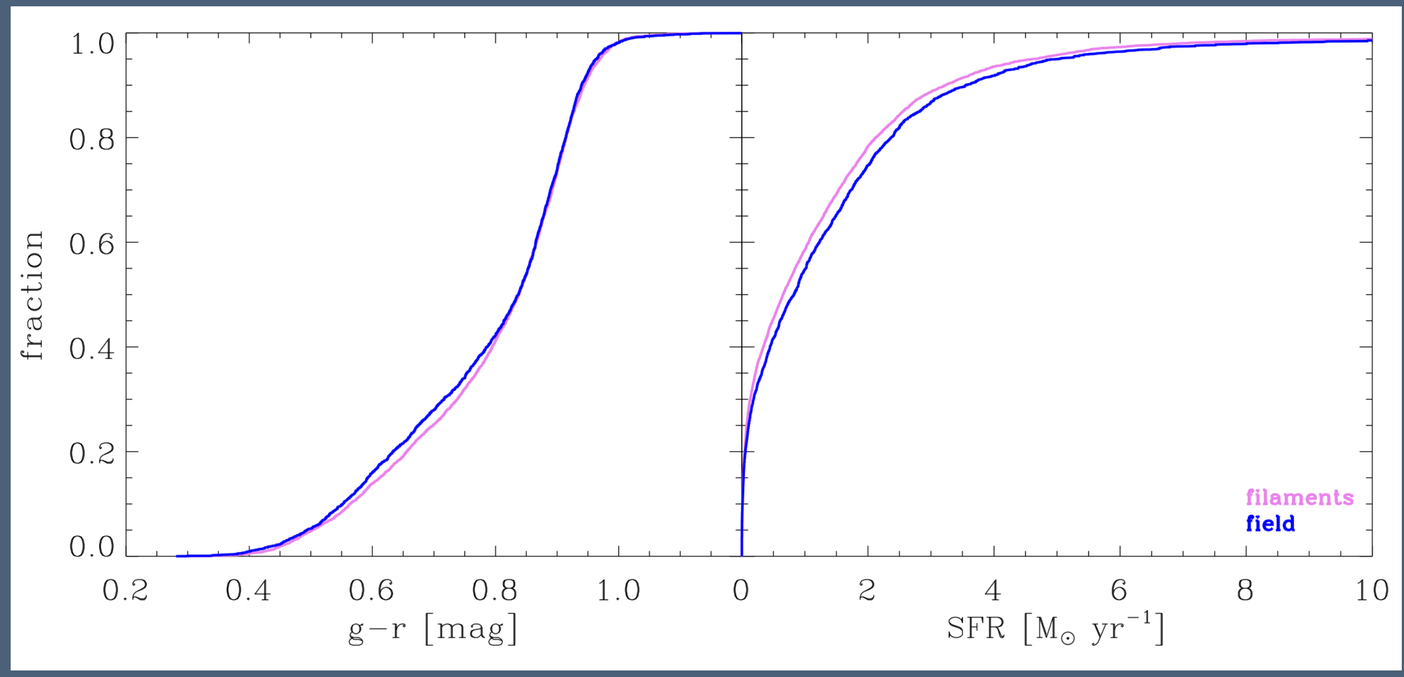
Mass and local overdensity matched samples confirms that second-order effects on colours and SFR are due to the filaments alone.



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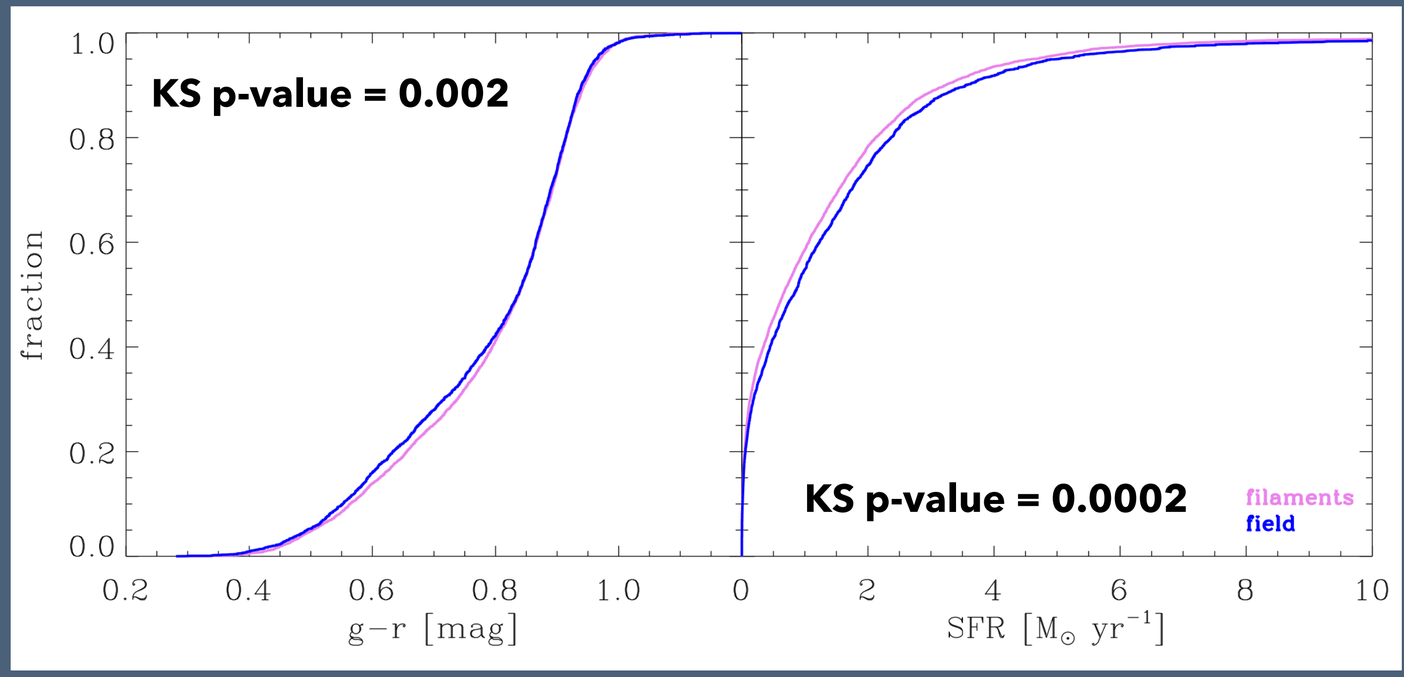

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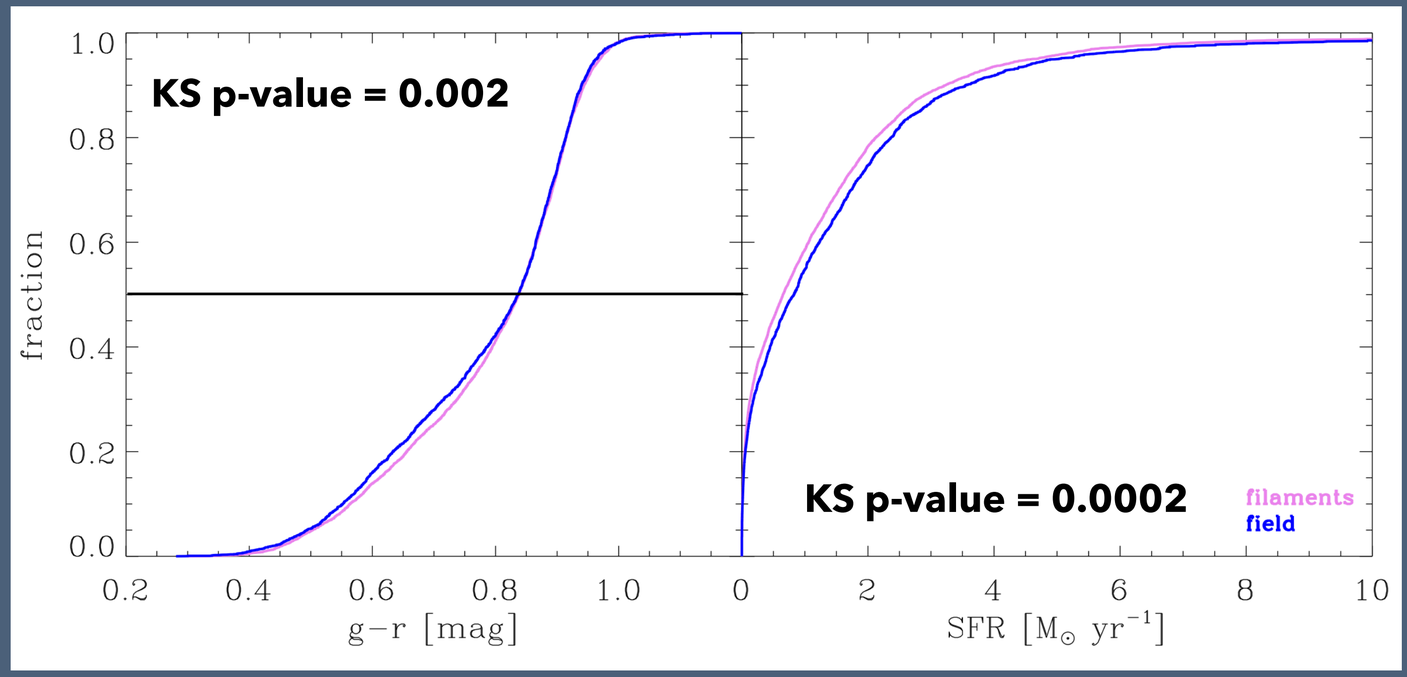

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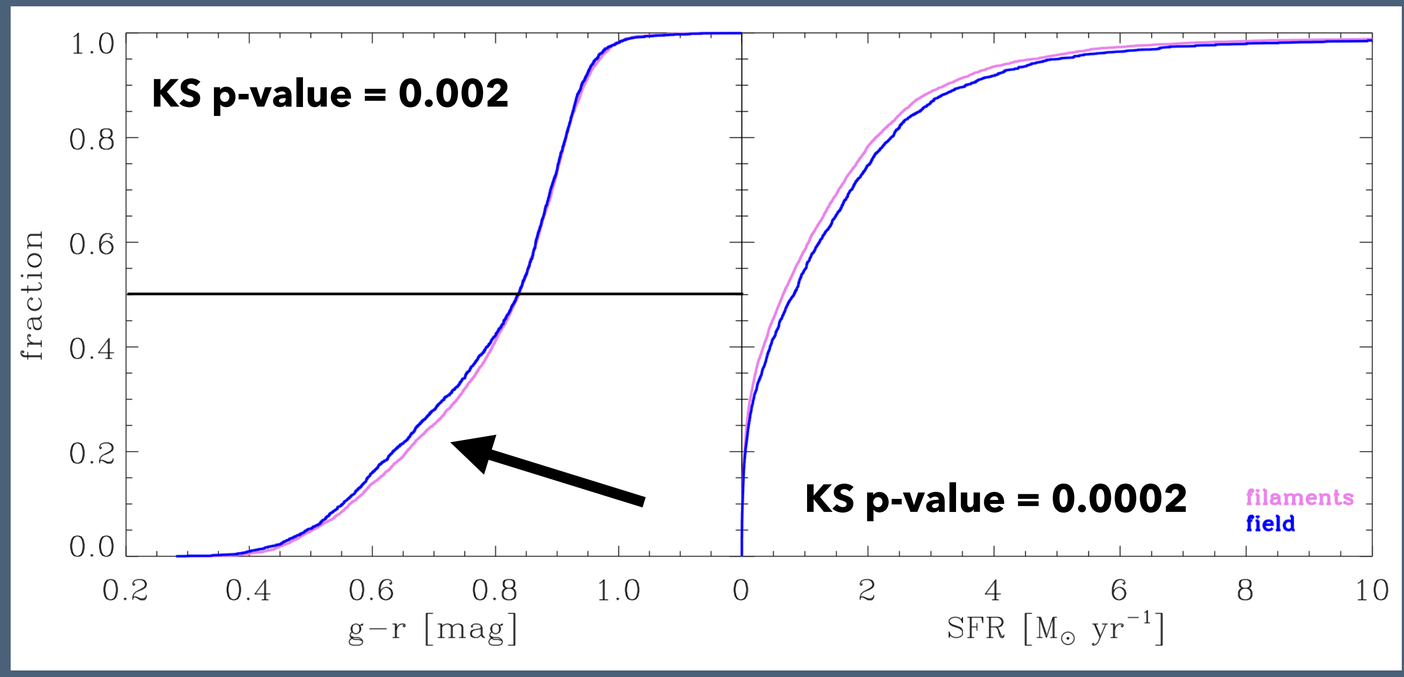

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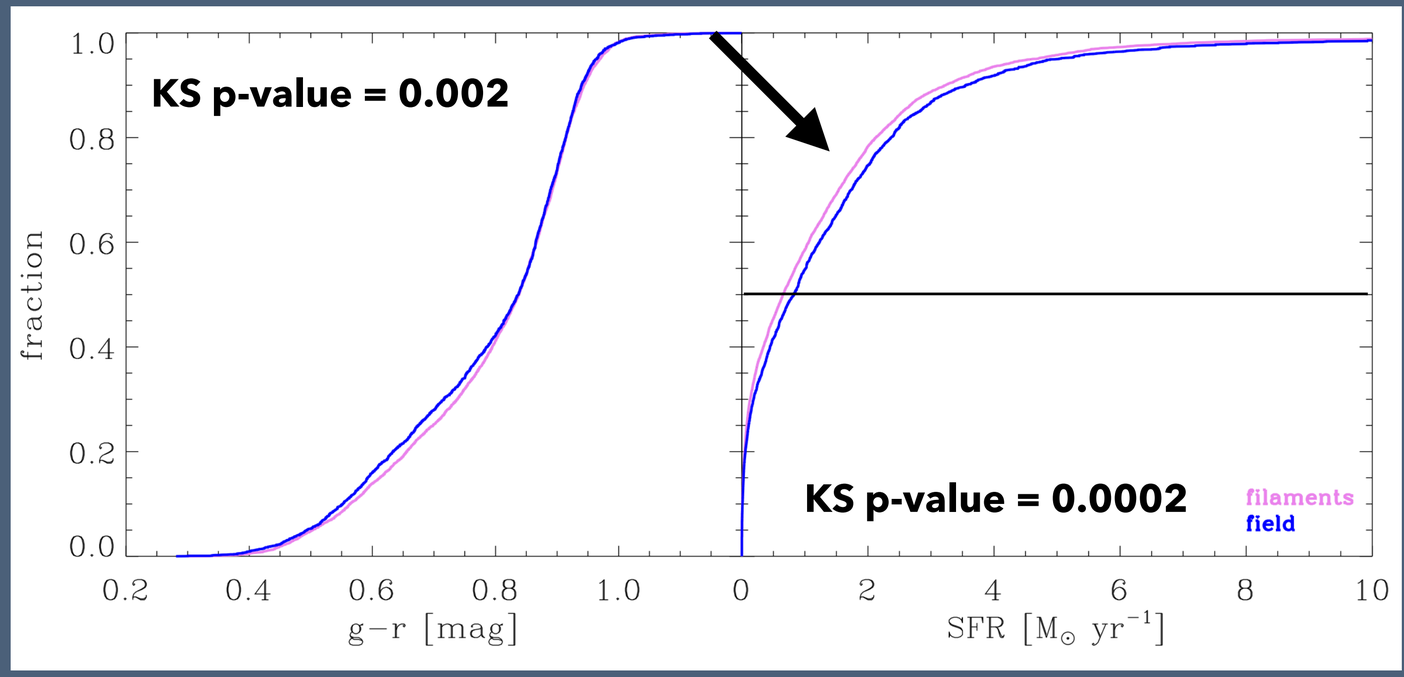

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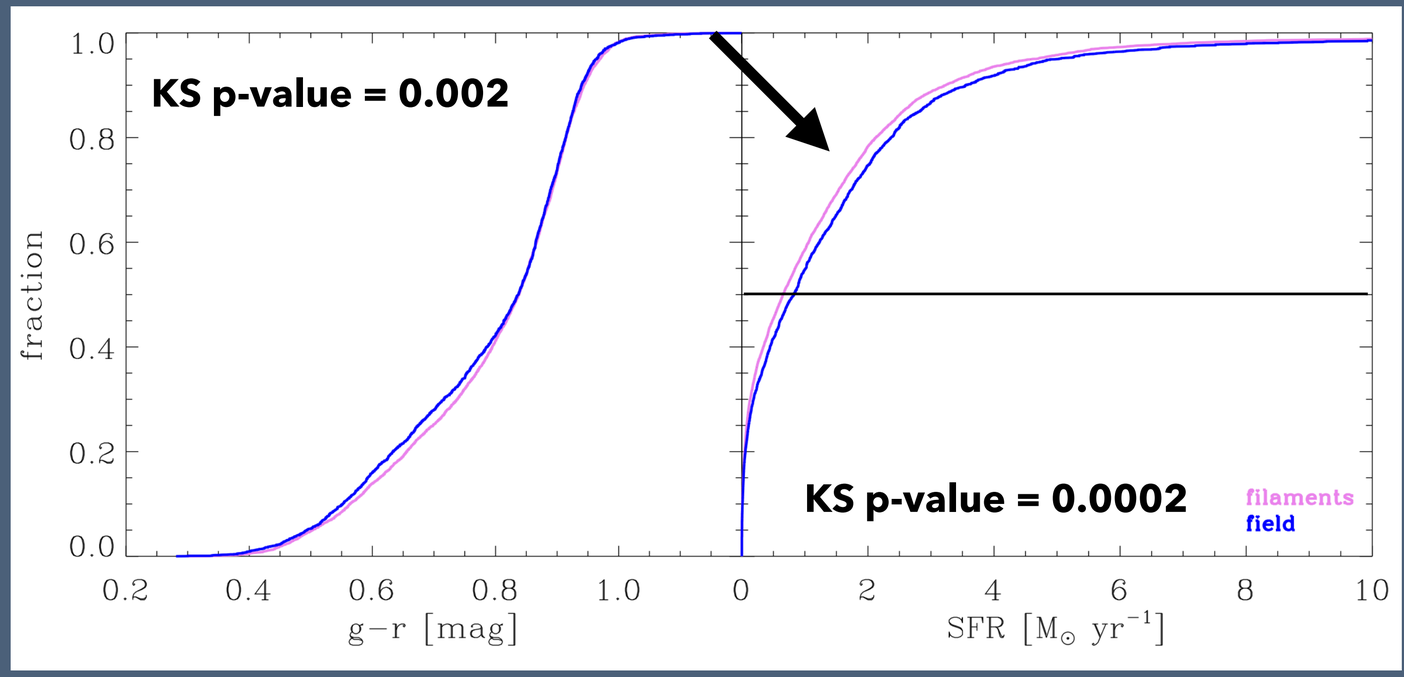

Zarattini & Aguerri (2025)

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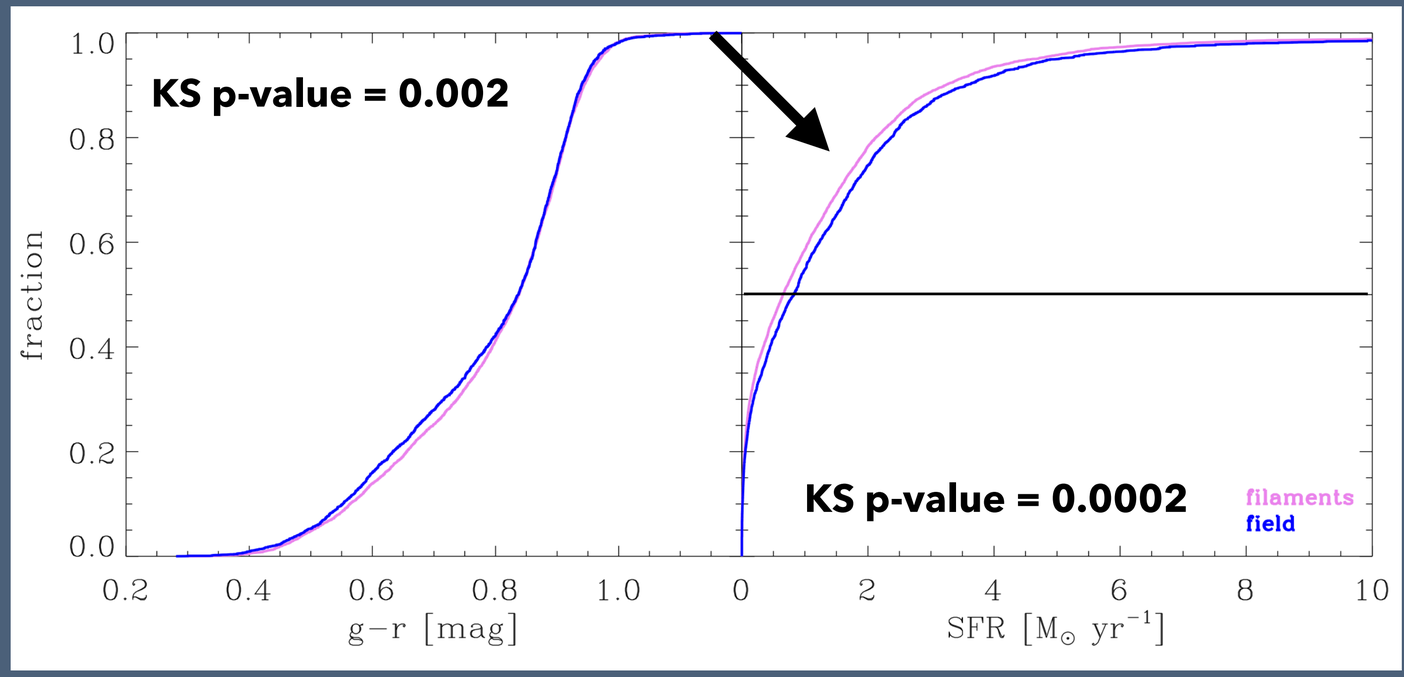

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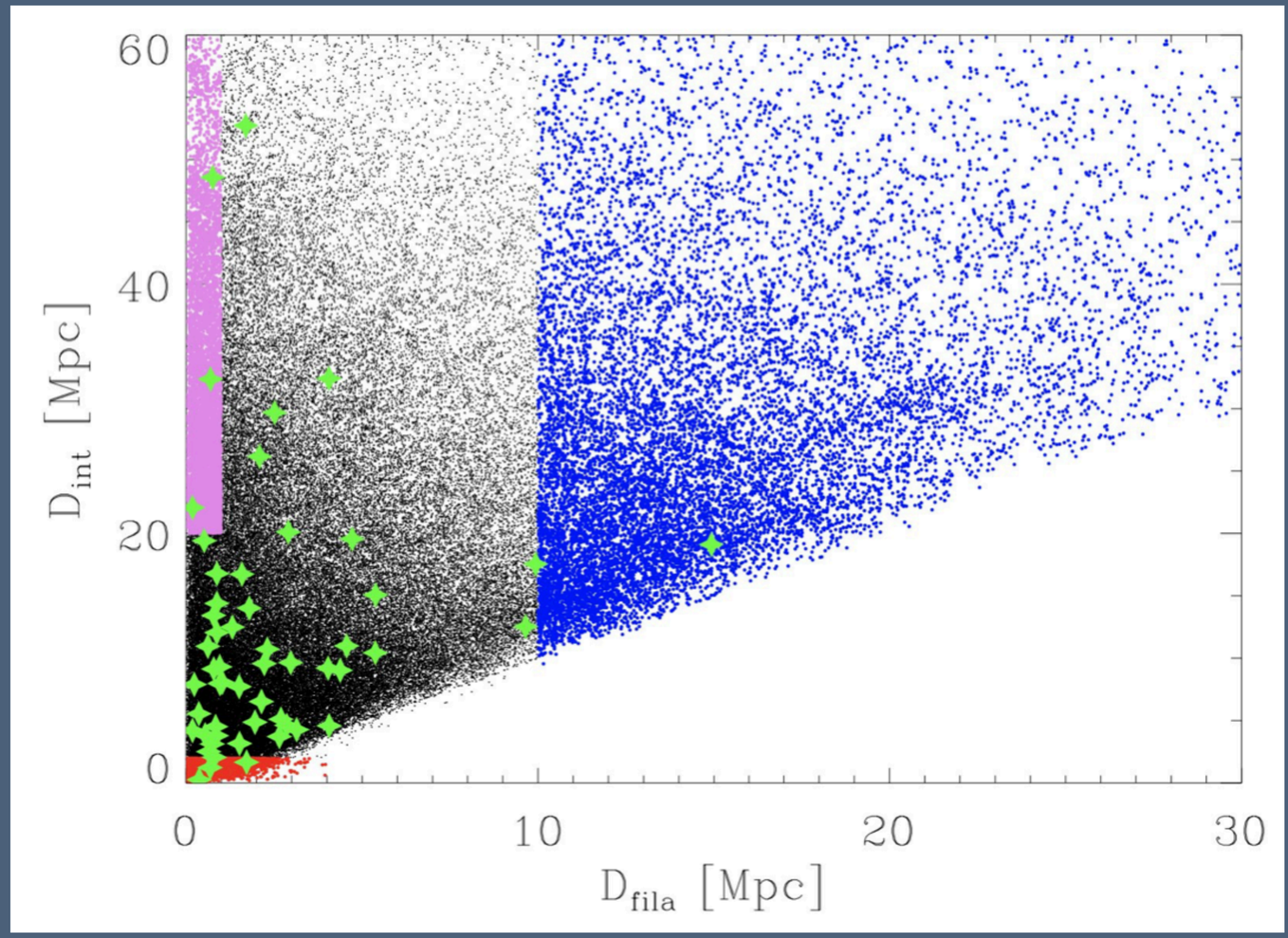

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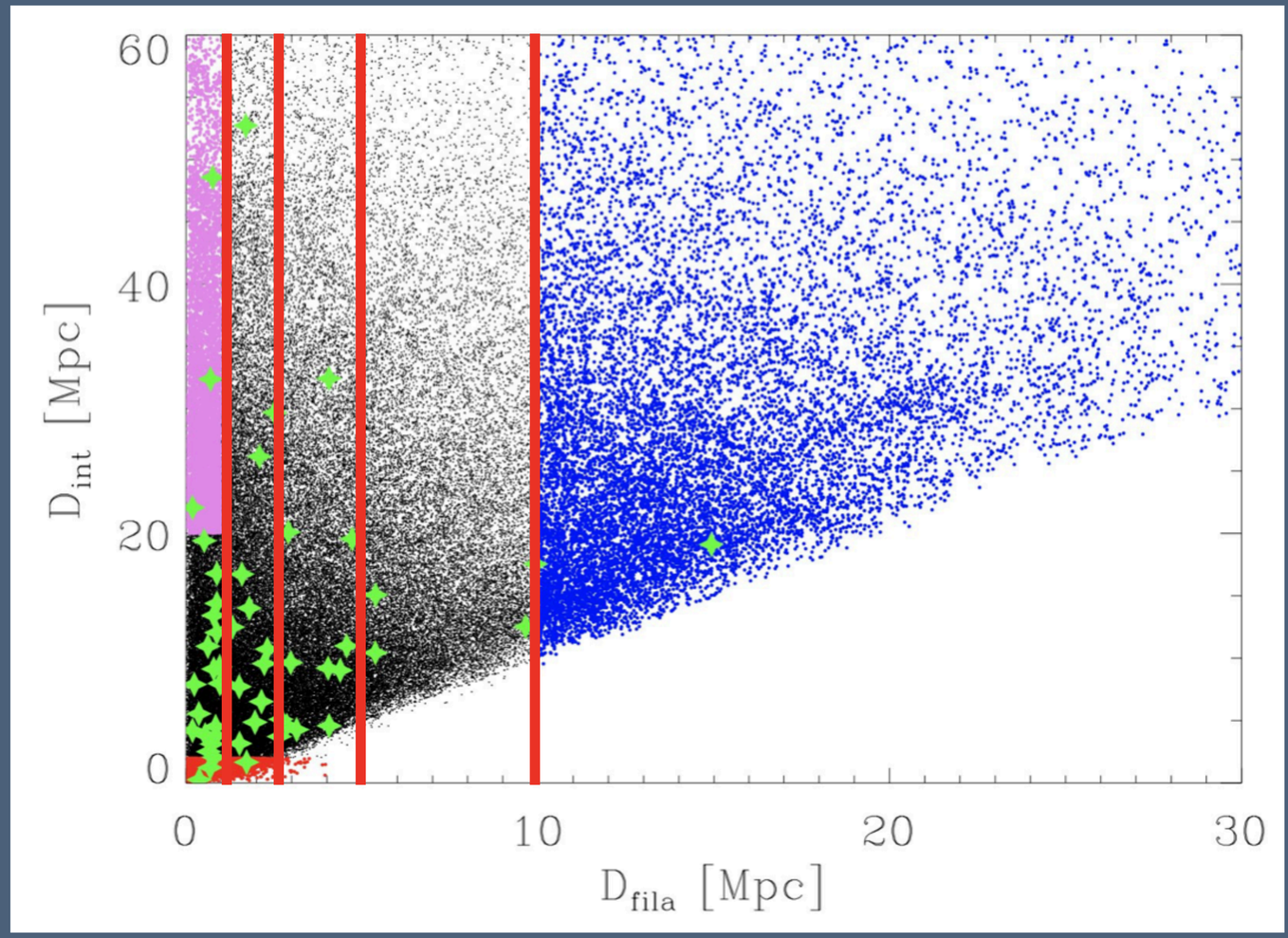

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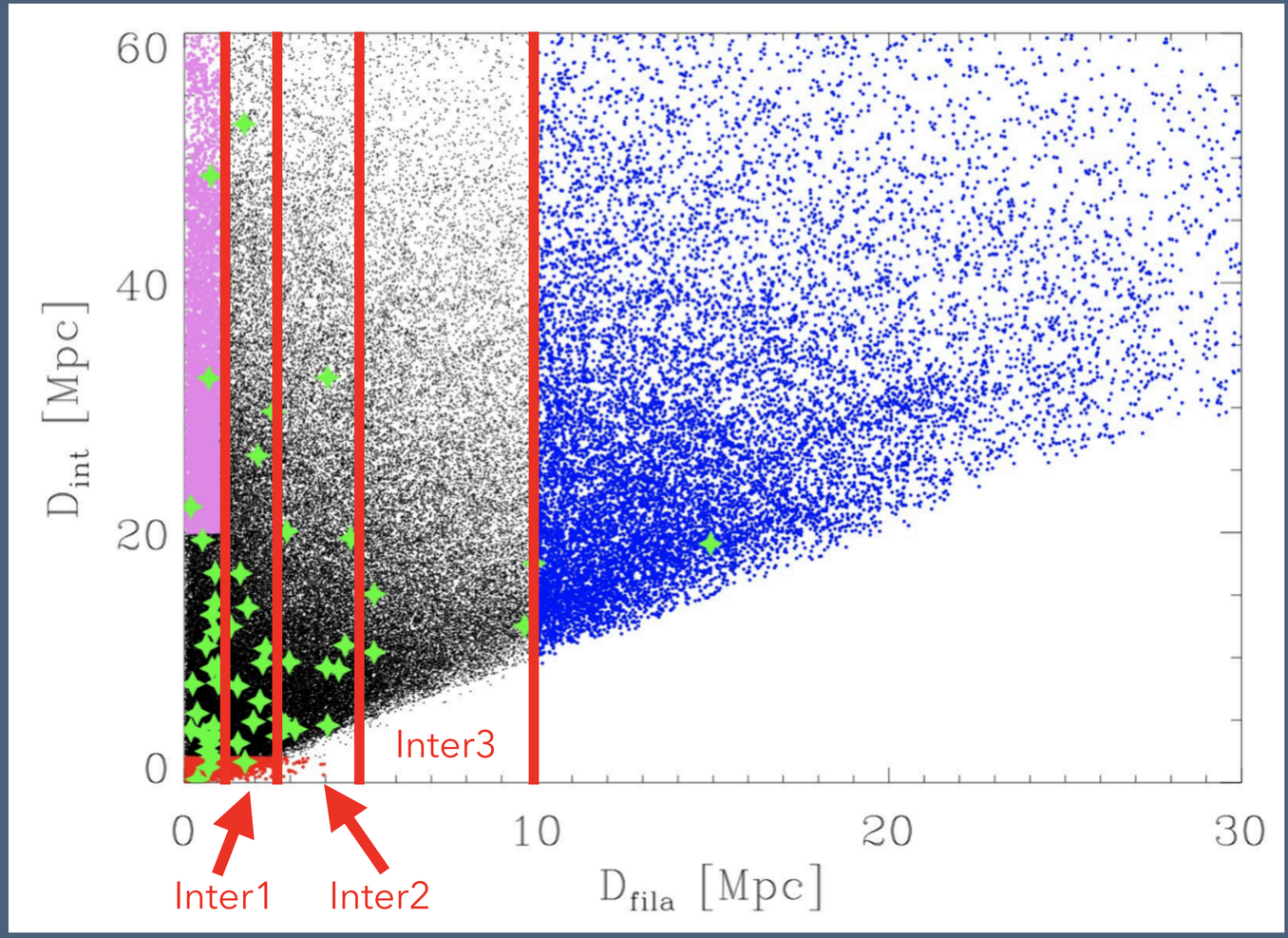

The impact of filaments on the colour and SFR of galaxies

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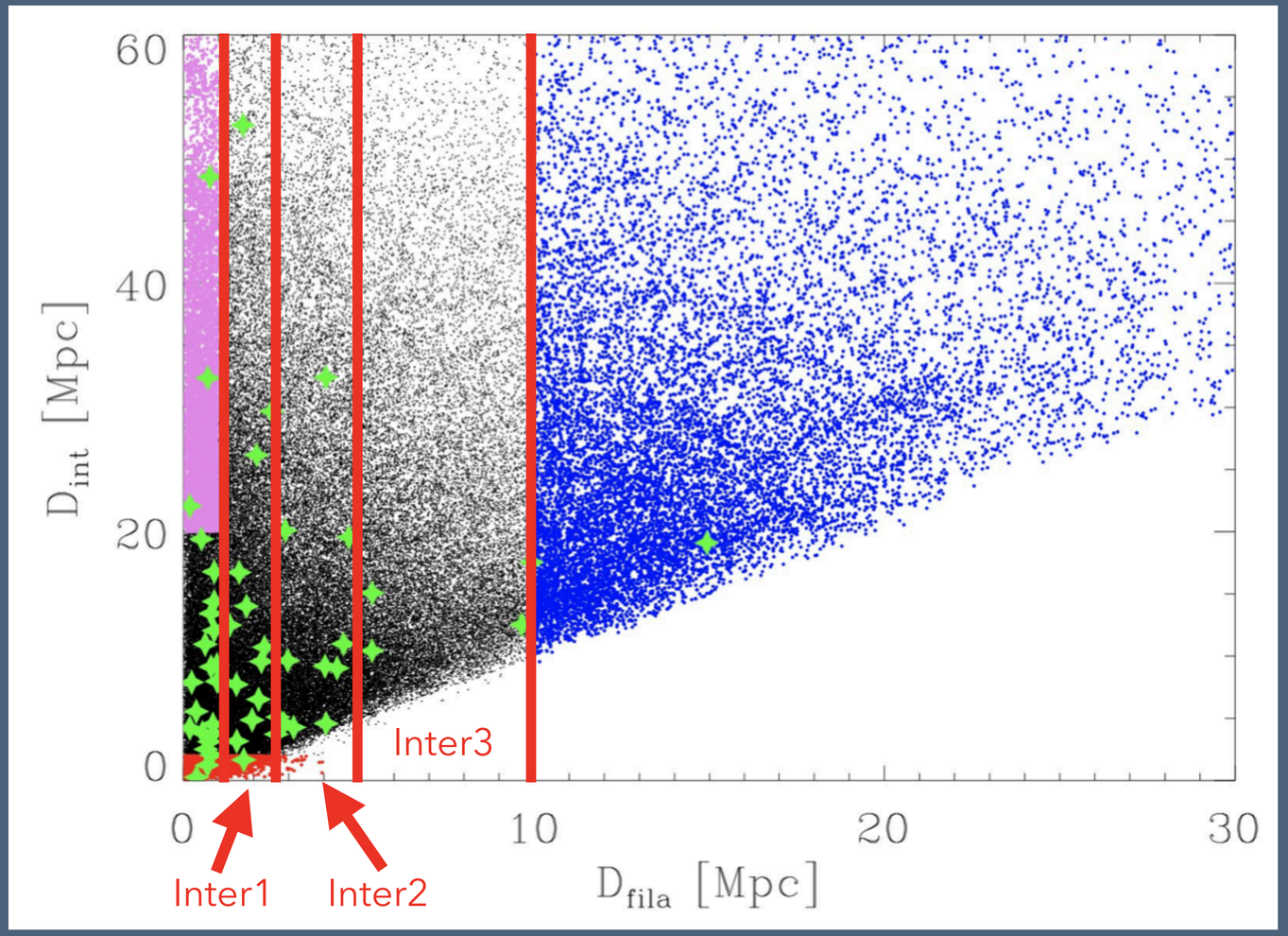

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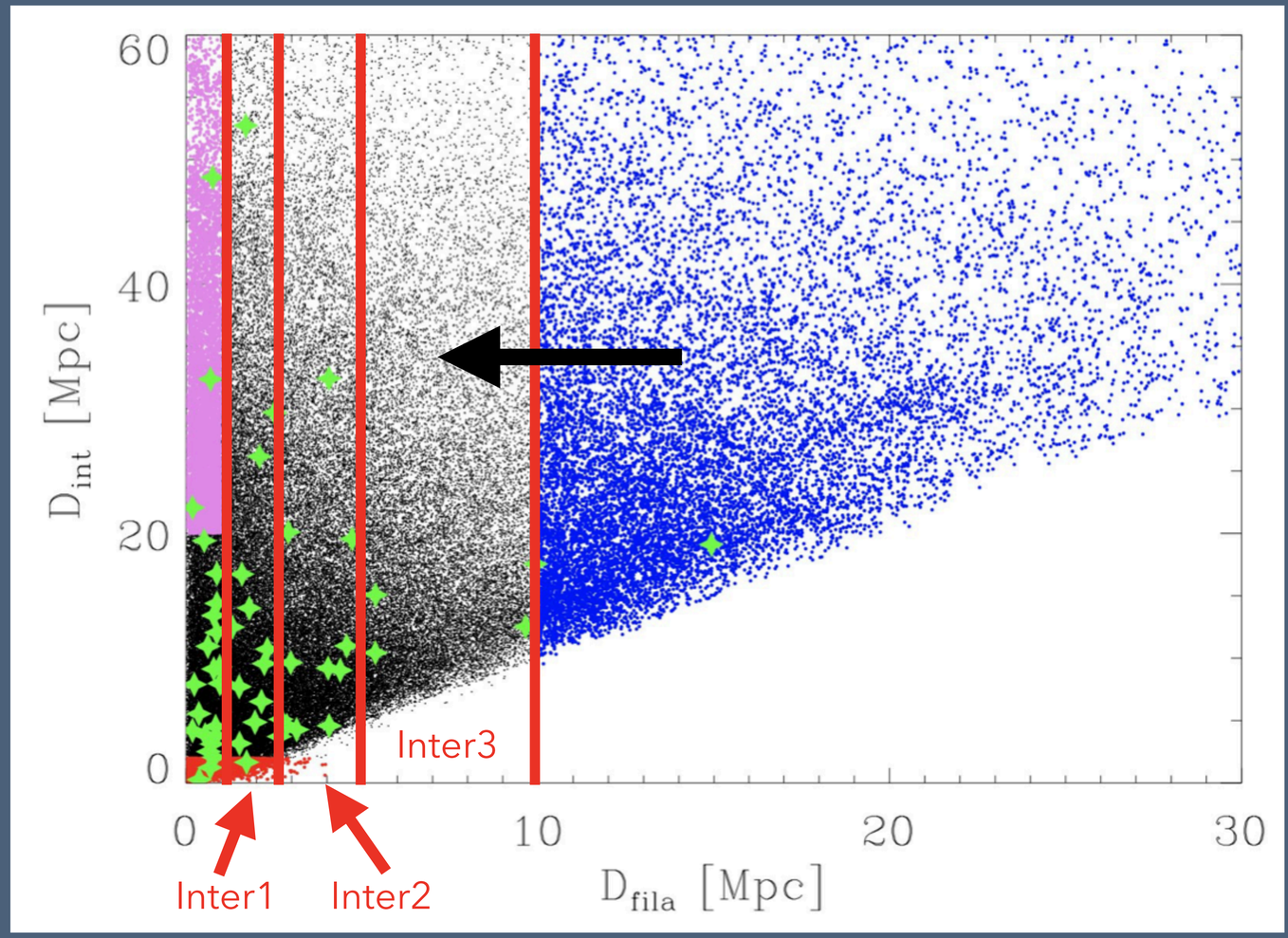

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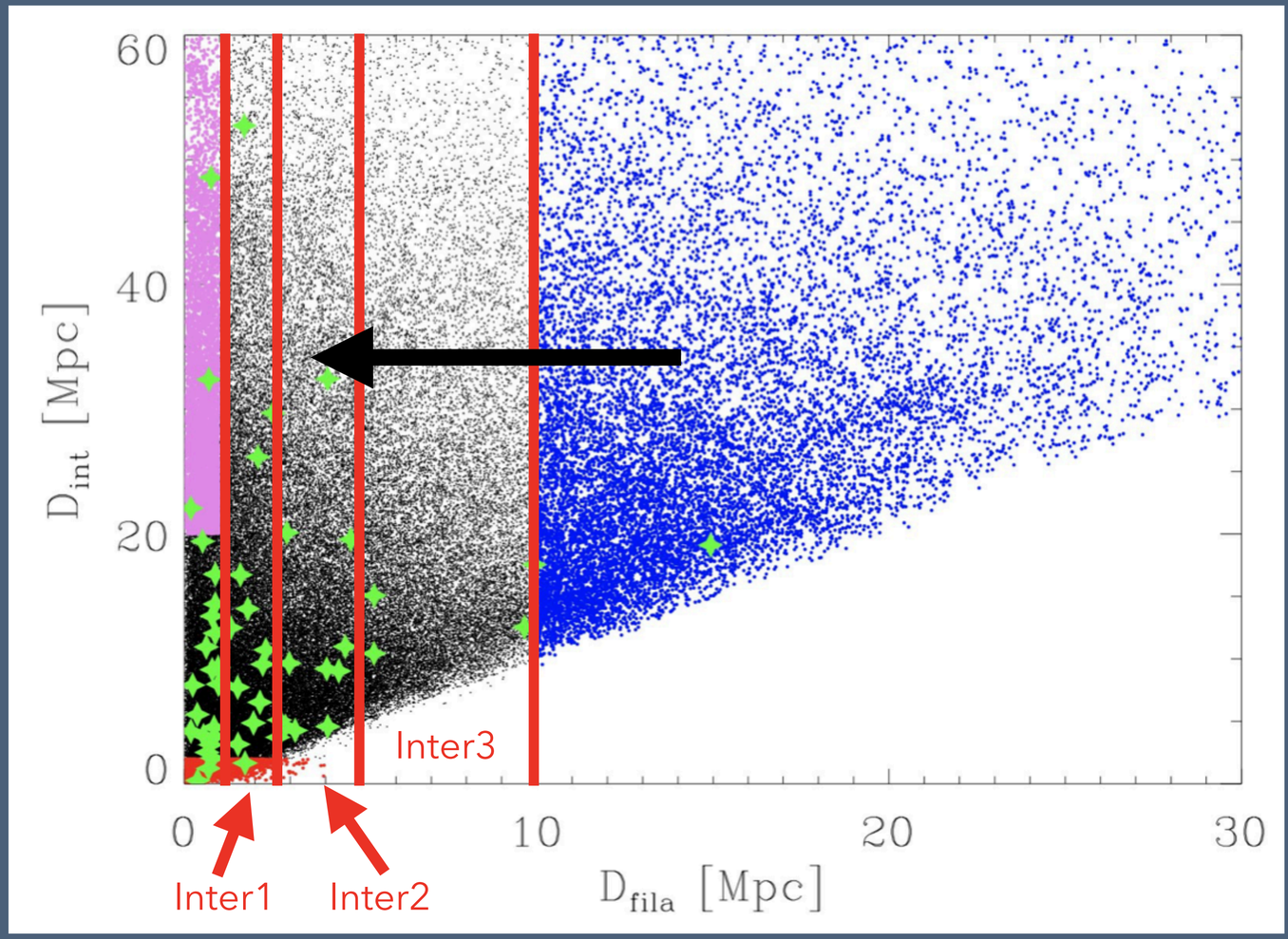

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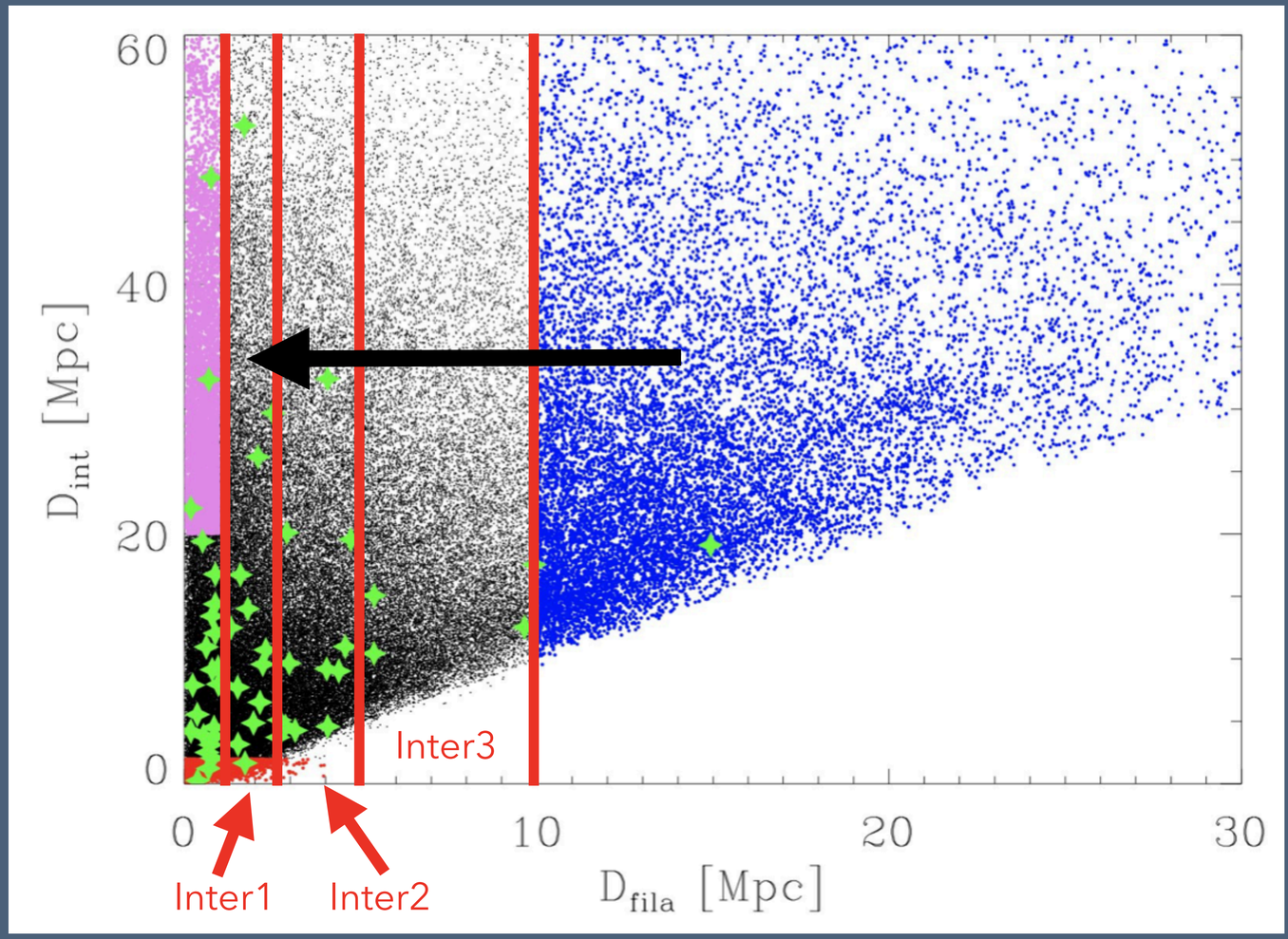

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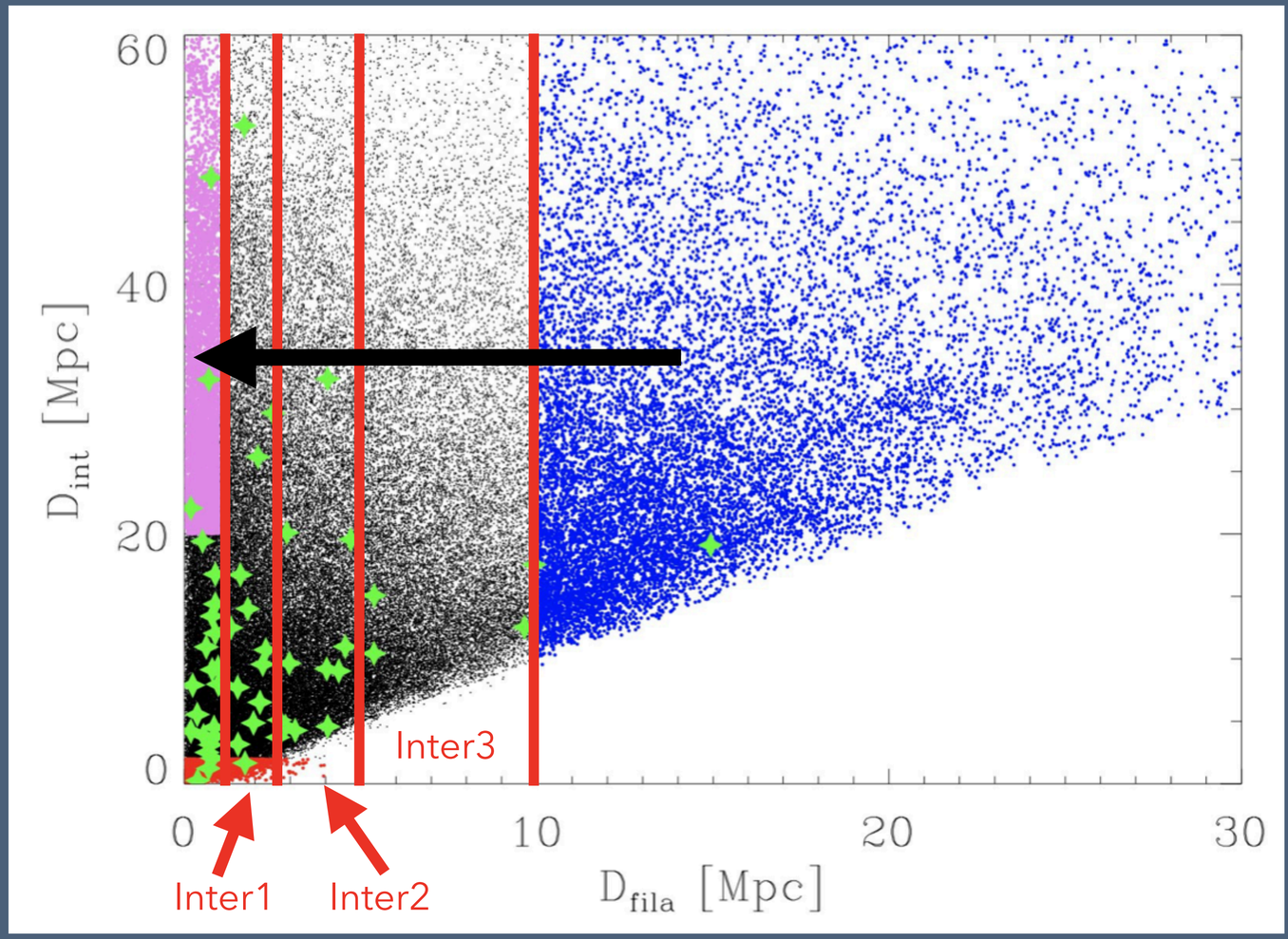

The impact of filaments on the colour and SFR of galaxies

Interpretation

Aragón-Calvo et al. (2019) proposed the so-called Cosmic Web Detachment model to justify galaxy quenching

The model unified different starvation processes know to stop the star formation

The gas flow that falls on the galaxy is detached when it reaches the filament

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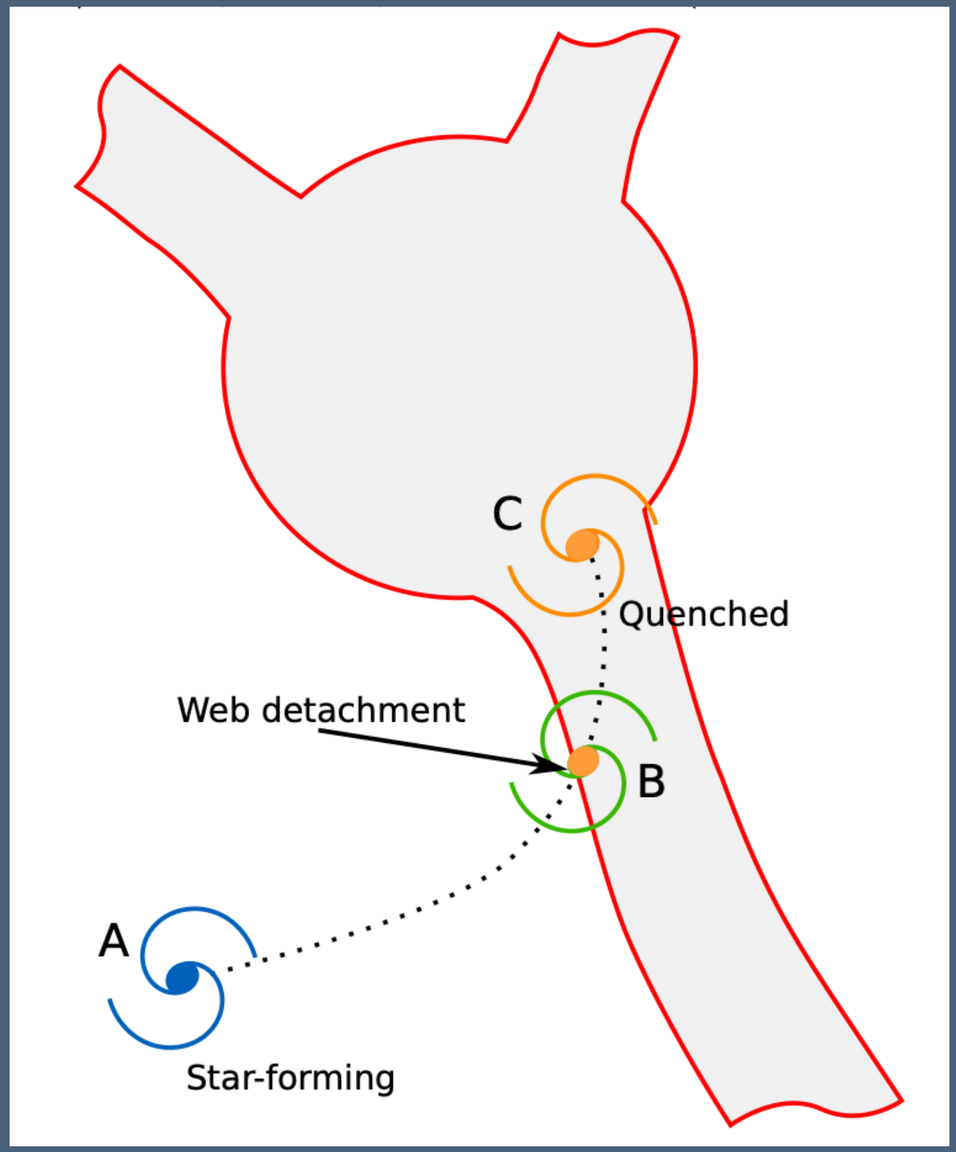

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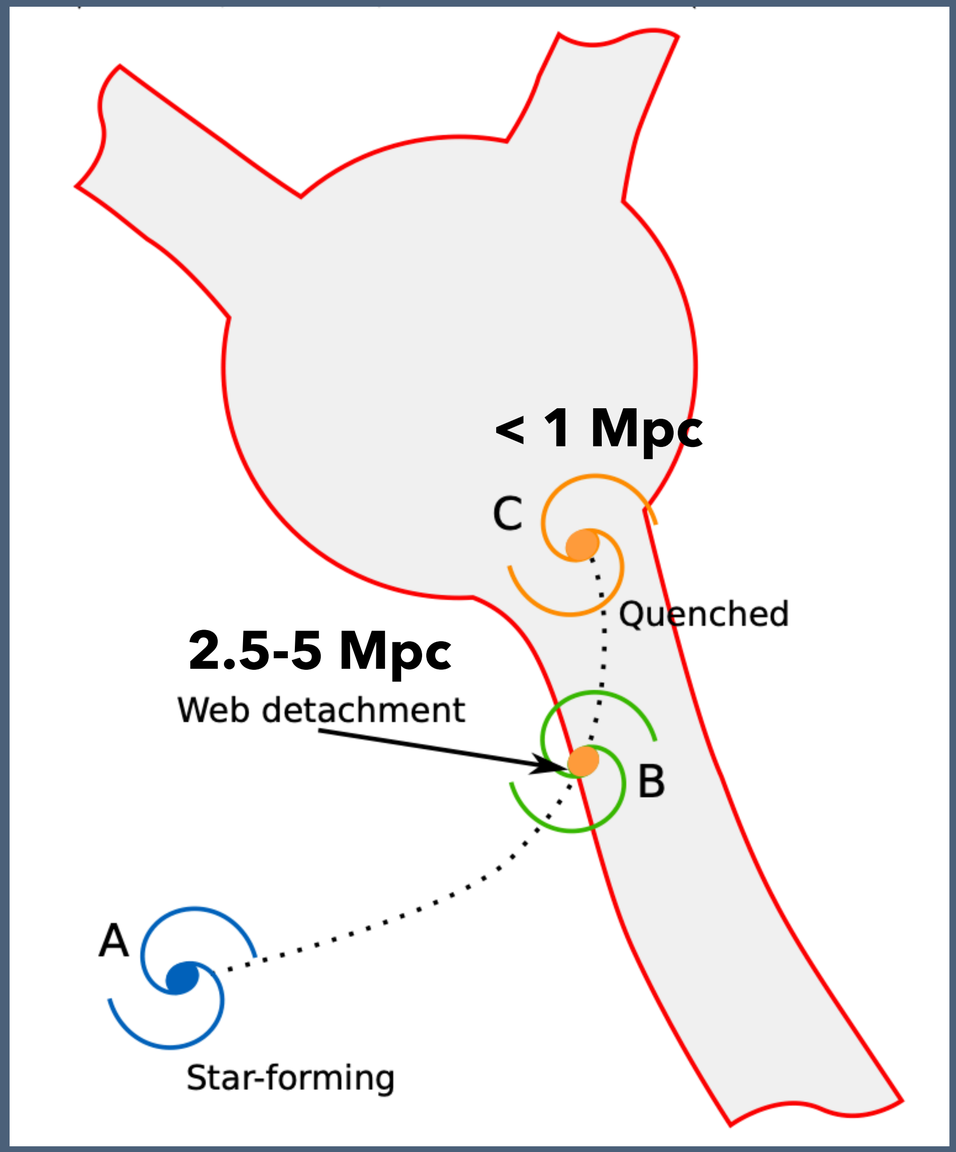

The area of influence of filaments and intersections

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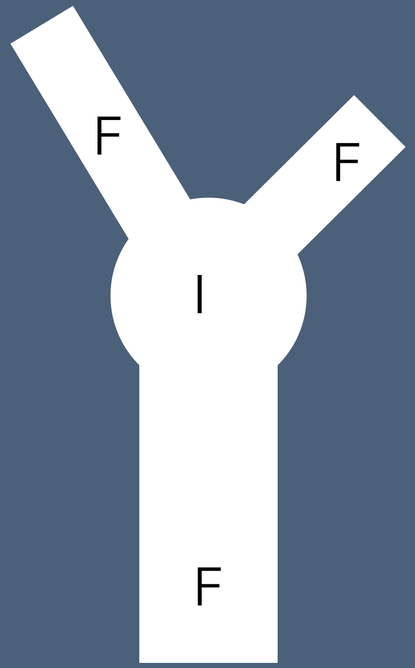
Can we define, with the data in hand, which is the area of influence of filaments and intersections?



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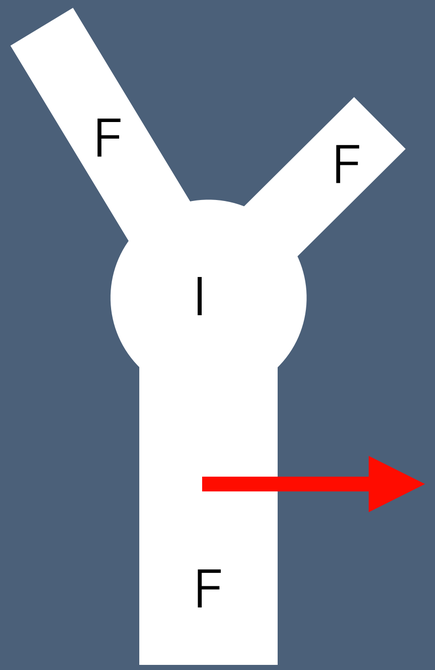

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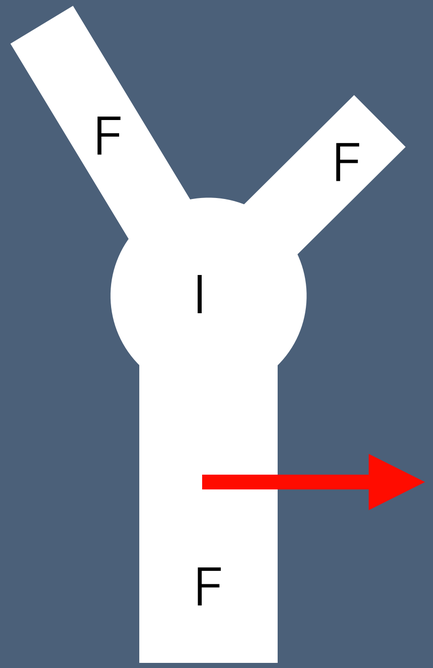

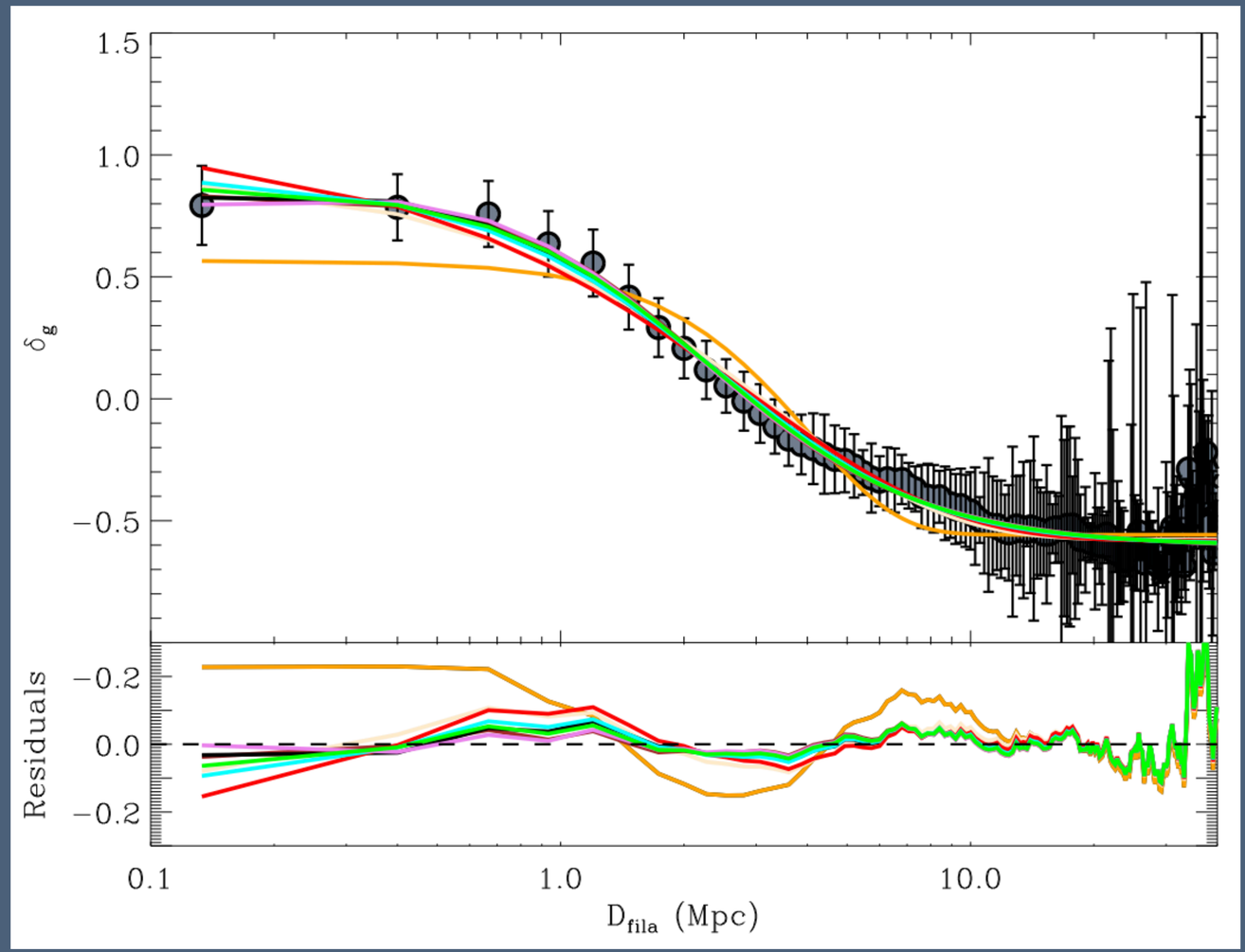

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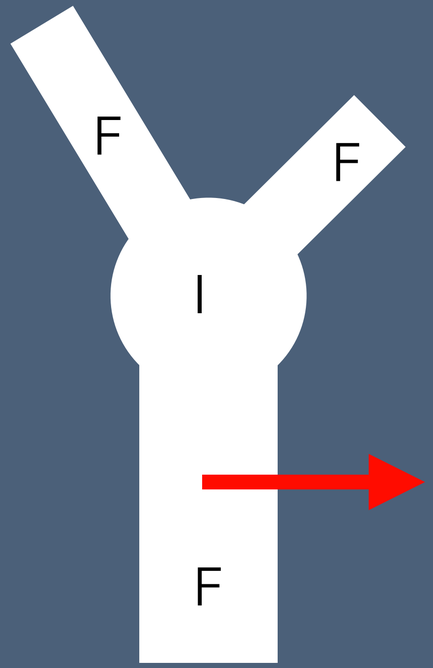

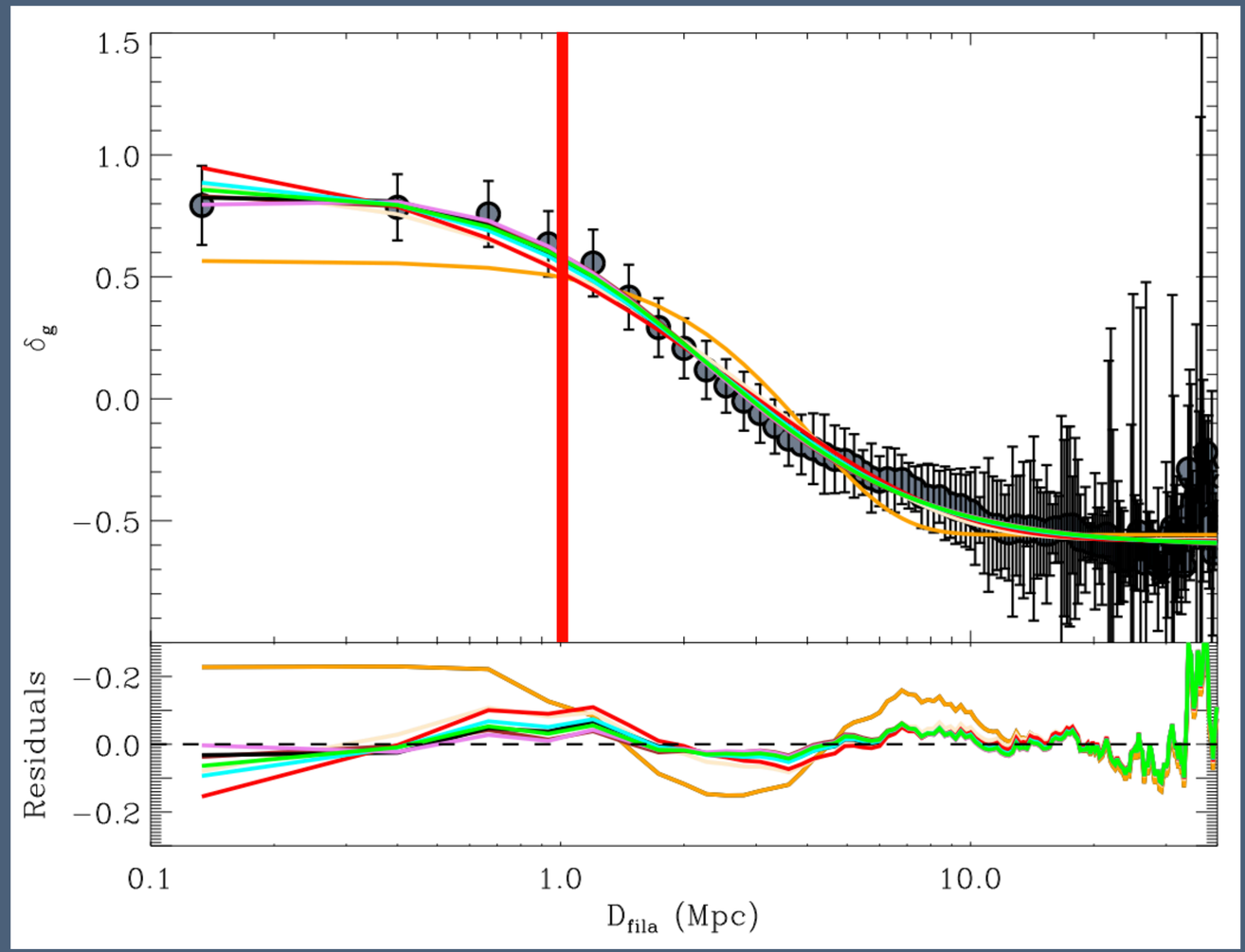

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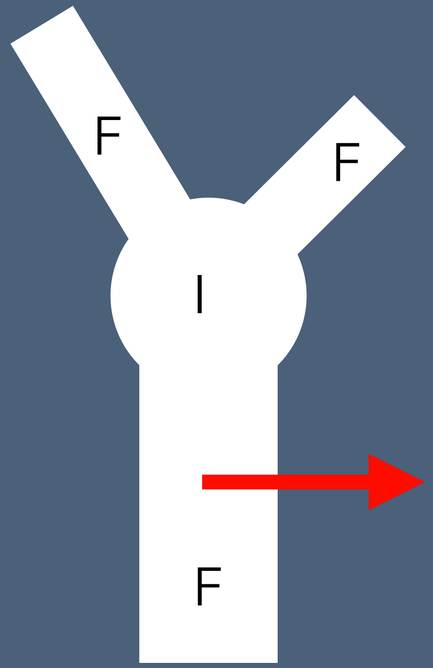

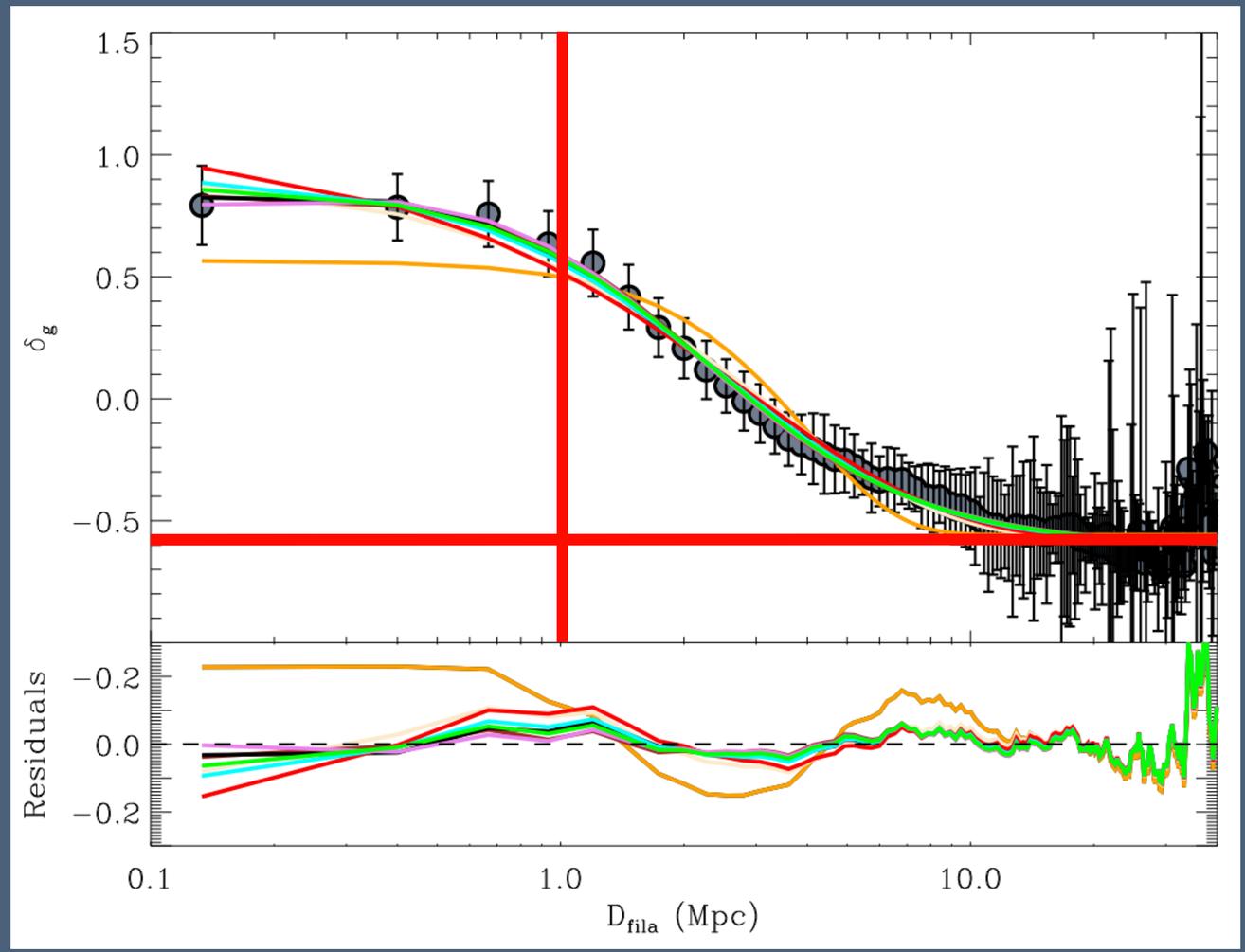

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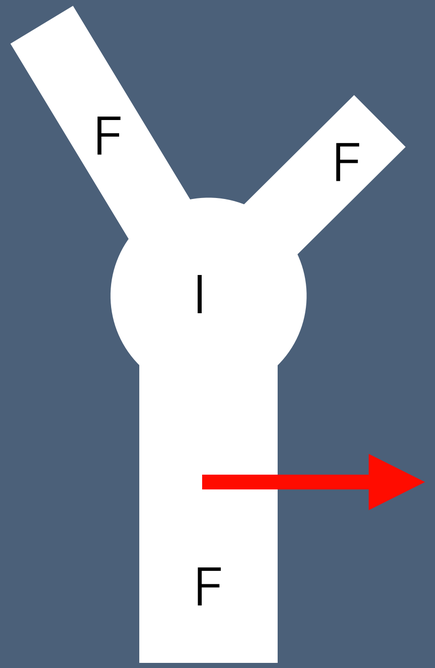

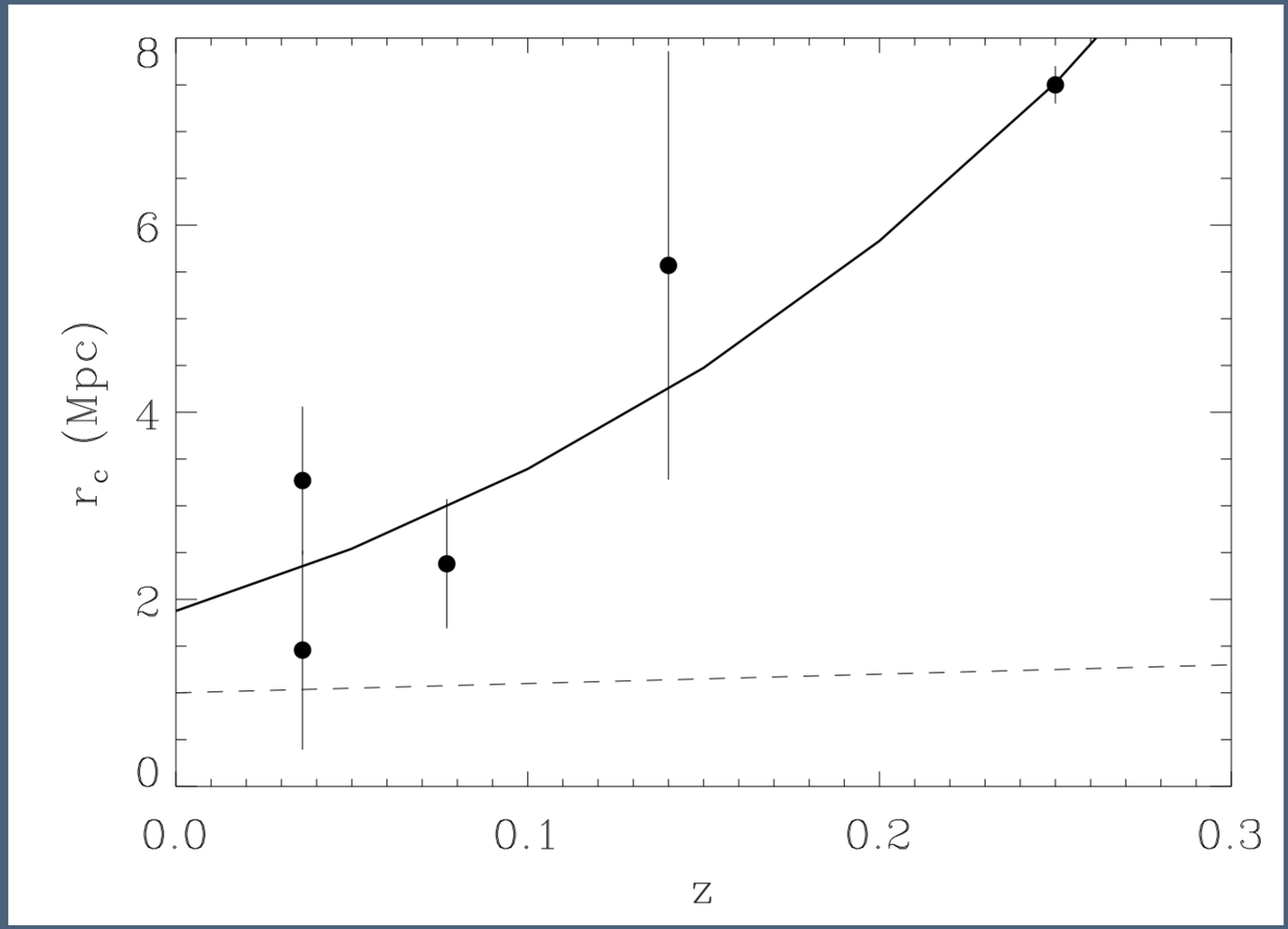

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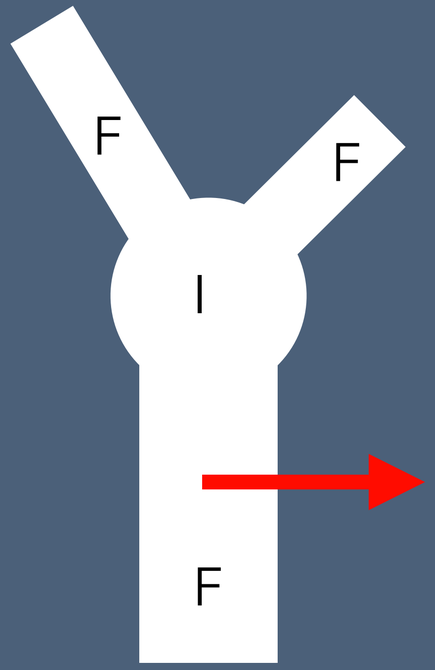

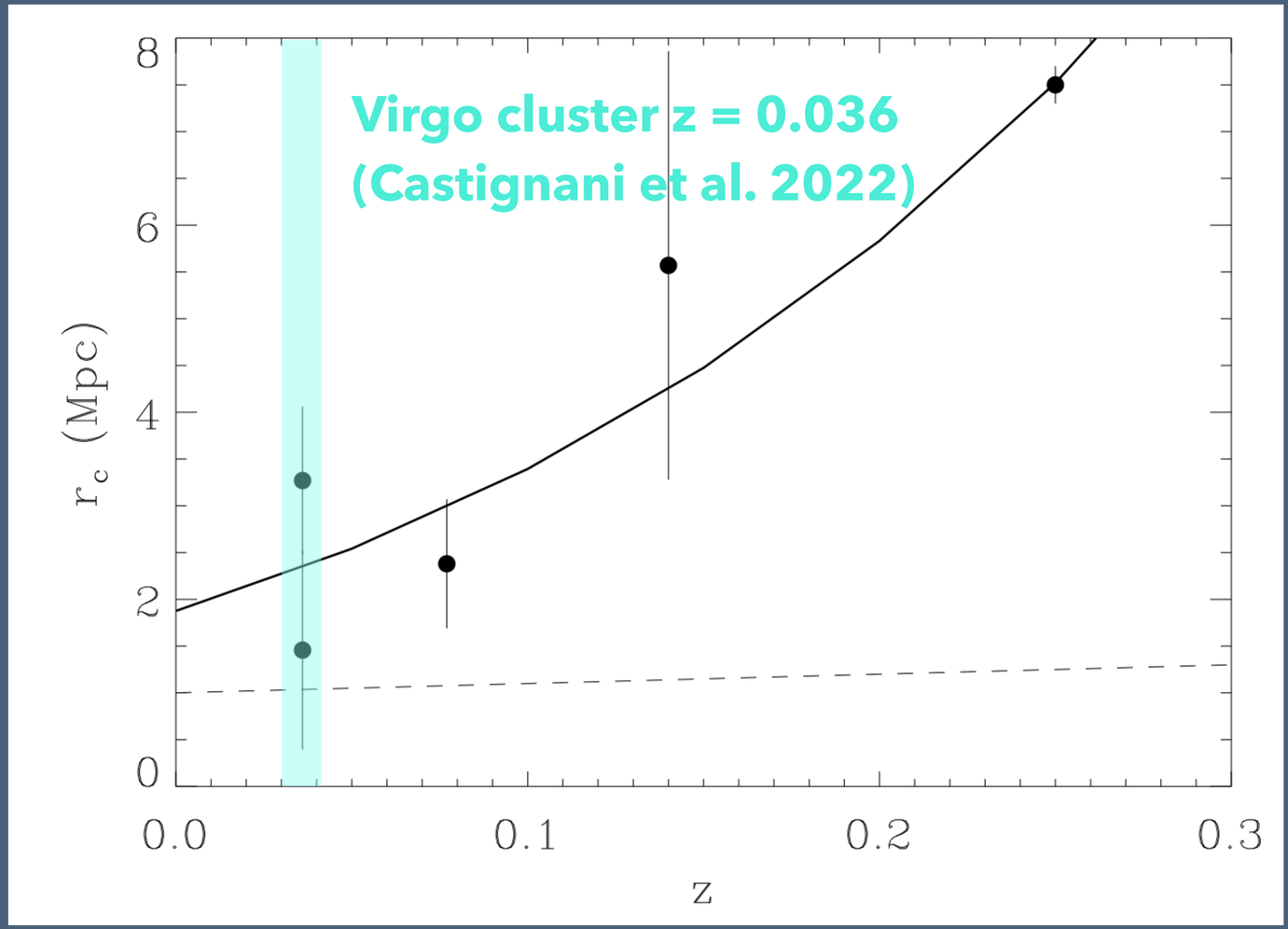

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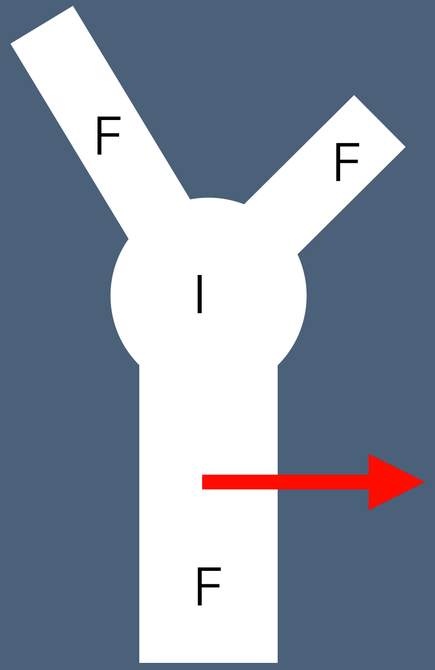

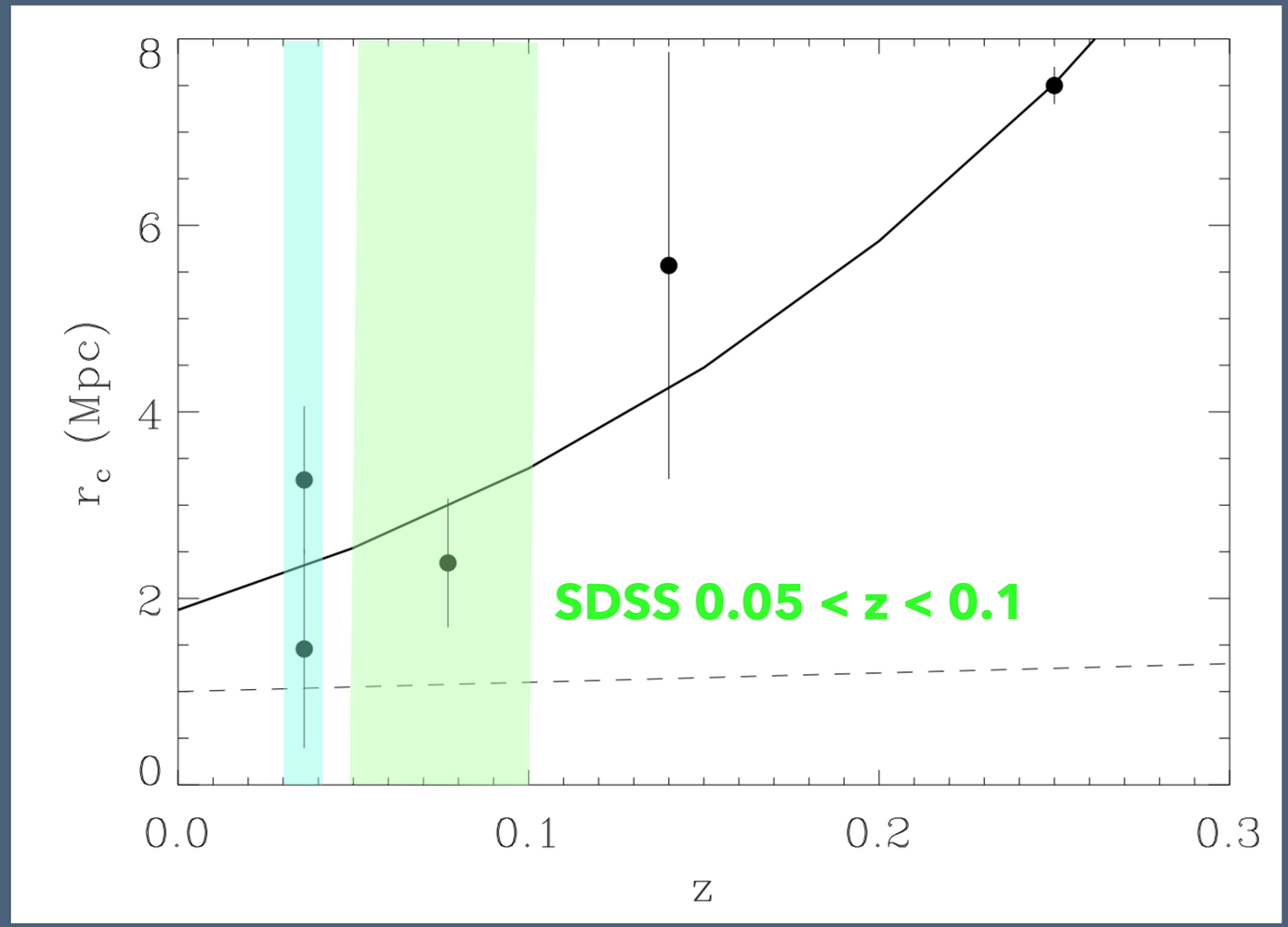

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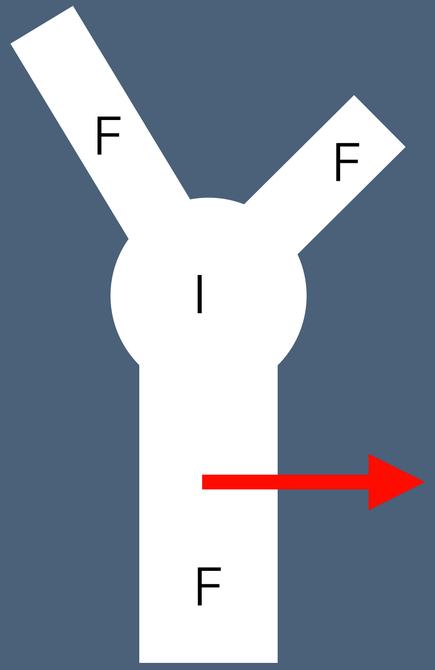

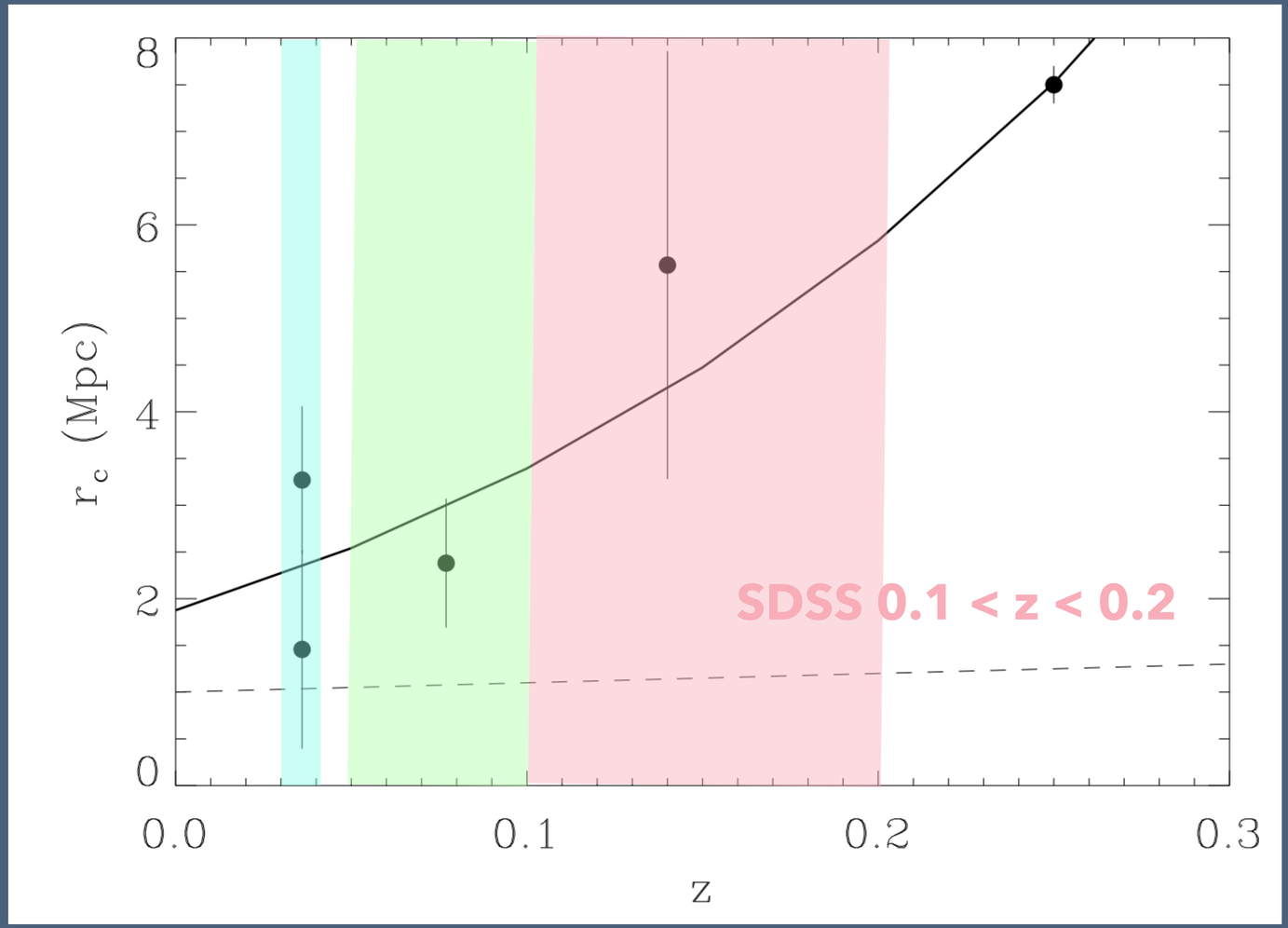

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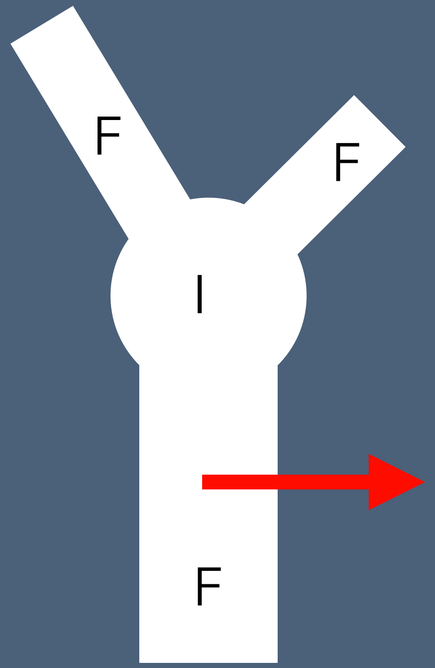

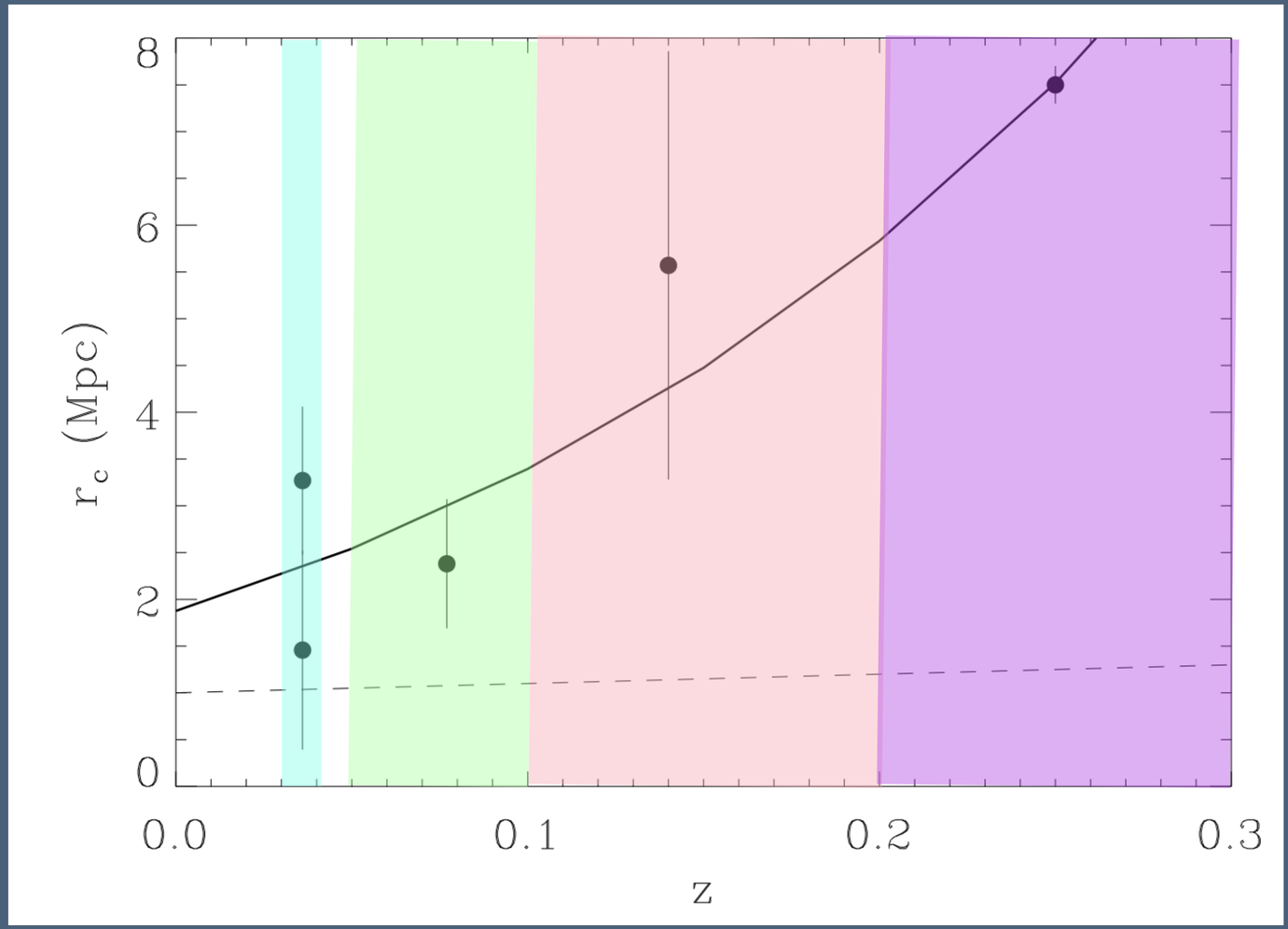

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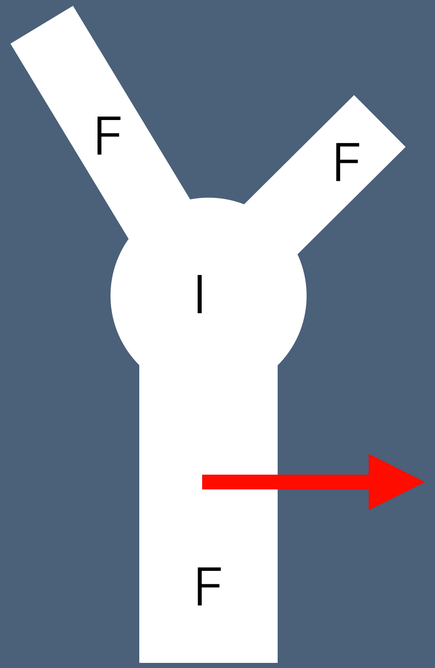

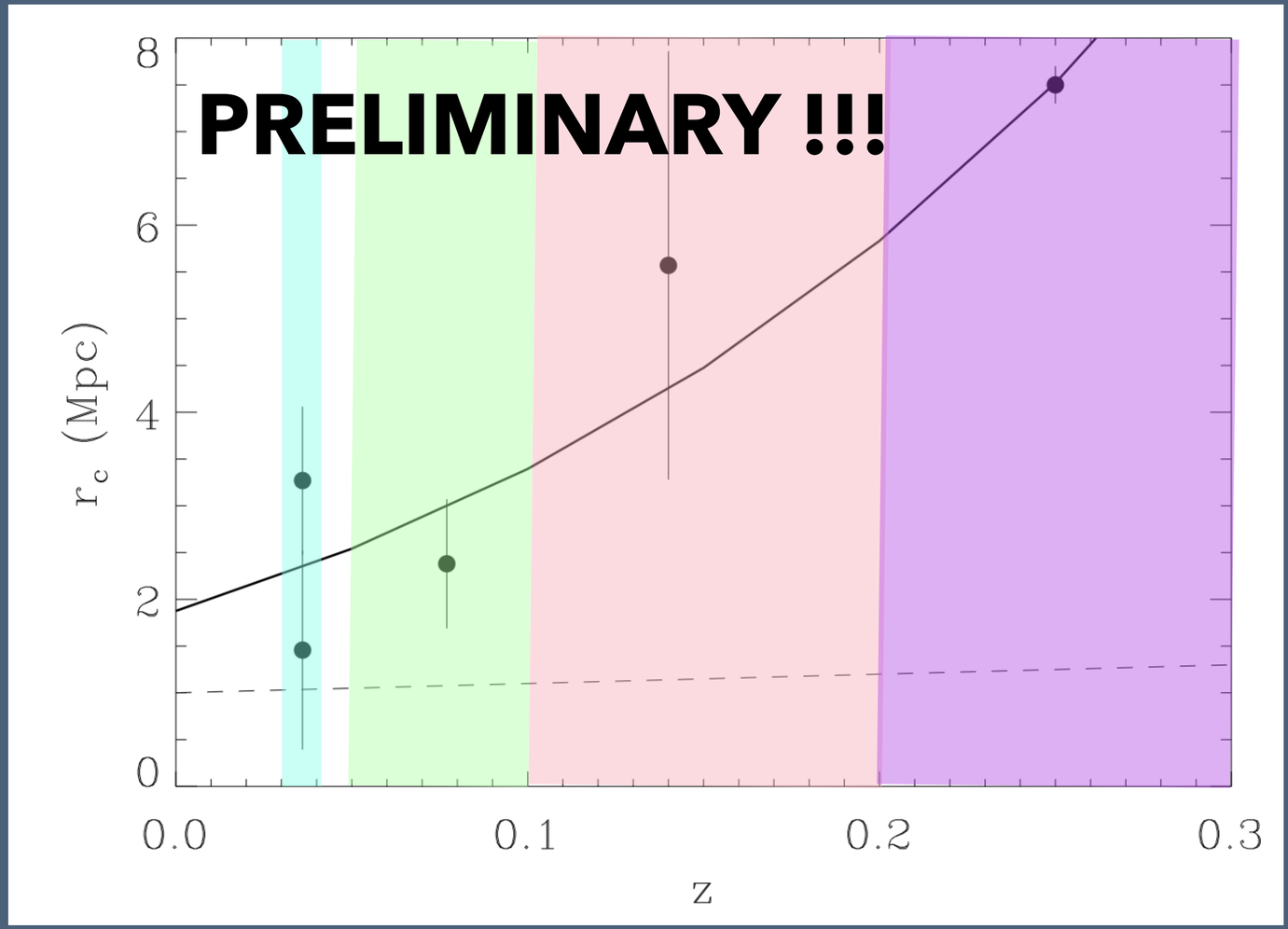

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Conclusions (1)

The impact of filaments on the gas cycle of galaxy clusters

- We use a sample of 29 galaxy clusters form the XUCS sample
- Clusters with low SBx (gas poor systems) are far from the spine of filaments
- We propose a model for which the presence of the filament act as a “cage”, reducing the timescale of the gas cycle and thus favouring the presence of gas in the central regions of the cluster
- The result is significant only at 1.5 σ

Future Work (1)

The impact of filaments on the gas cycle of galaxy clusters

- The XUCS sample is drawn by the C4 sample (Miller et al., 2004) using only clusters with Nmemb > 50
- For this sample a lot of spectroscopy was obtained in the last 15 years
- Many more clusters now accomplish the XUCS criteria
- Select these new clusters and propose them for an X-ray follow up to extend the sample of gas-rich and gas-poor clusters

Conclusions (2)

The impact of filaments on individual galaxies

- Filaments have a (small but) measurable impact on the colour and SFR of galaxies
- Filaments contribute to the quenching of galaxies by stopping the star formation
- A possible explanation is the Cosmic Web Detachment model (filaments disconnect galaxies from their cosmic gas supply –> SF is suppressed and galaxies become red without changing morphology)

Conclusions (2)

The impact of filaments on individual galaxies

- We also measure the influence regions of filaments and intersections, evaluating their scale radii

- We found hints of redshift evolution in the scale radius of filaments:

  - At higher redshift, the scale radius is larger

…BUT…

Be aware of surveys' incompleteness!

Future Work (2)

The impact of filaments on individual galaxies

- Extend the redshift coverage of our SDSS sample (moving from the main spectroscopic sample to BOSS eBOSS, etc)

- Analyse the normalised distances to filaments (e.g. if the survey is incomplete at high z, the mean distance increases with z too. We can use this mean distance to normalise and compare measurements)

THANK YOU FOR YOUR ATTENTION!