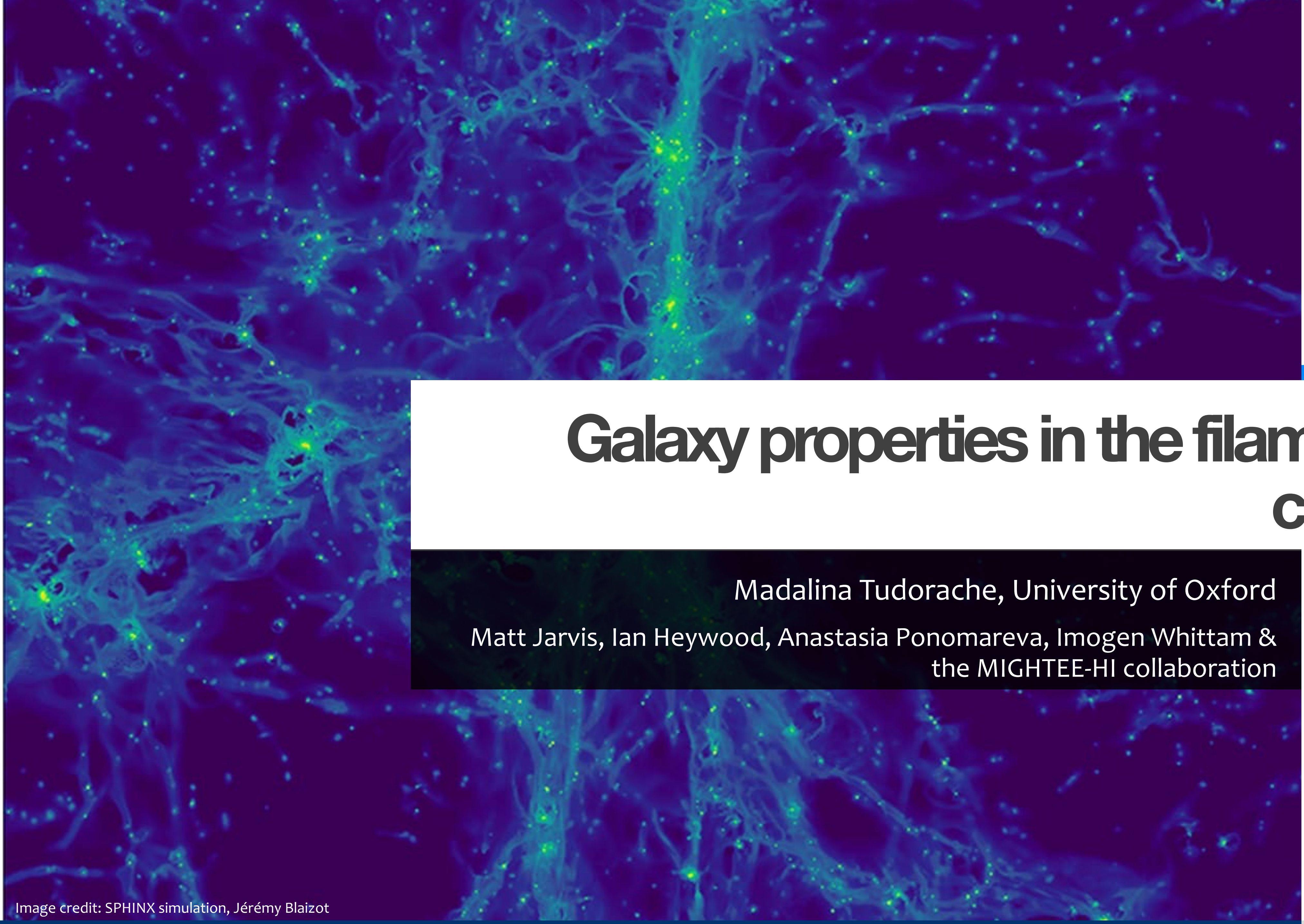

Image credit: SPHINX simulation, Jérémy Blaizot

Galaxy properties in the filaments of the cosmic web

Madalina Tudorache, University of Oxford

Matt Jarvis, Ian Heywood, Anastasia Ponomareva, Imogen Whittam & the MIGHTEE-HI collaboration

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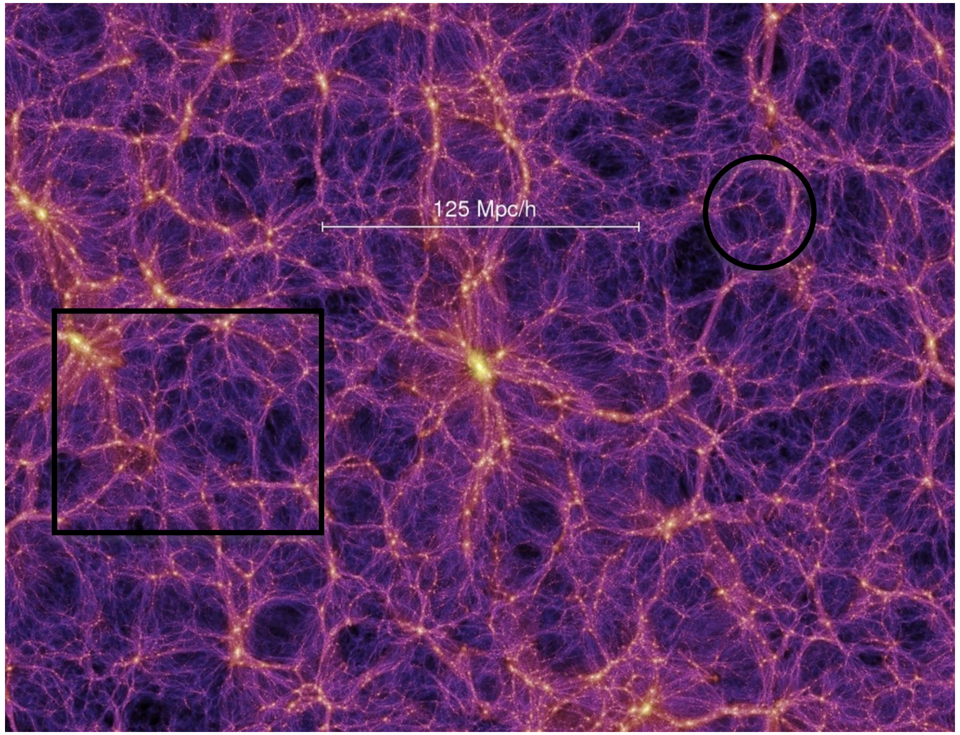
Outline

- Introduction
  - Filaments of the cosmic web
- Galaxy spins + cosmic web
- Other galaxy properties + cosmic web

The Cosmic Web: Introduction

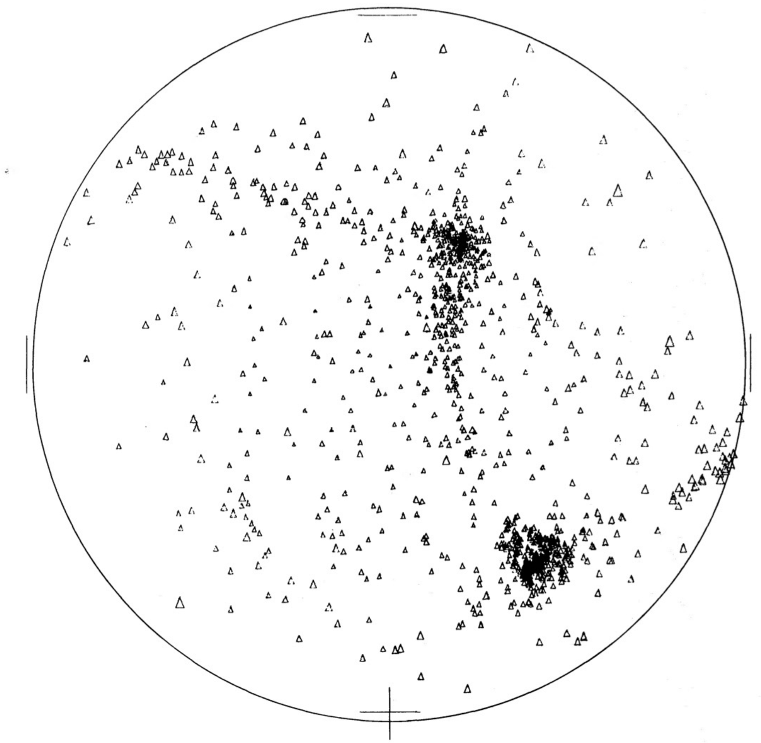
- The Universe contains a network-like distribution of galaxies and matter - the cosmic web

- We want to understand how do the filaments and the galaxies influence each other

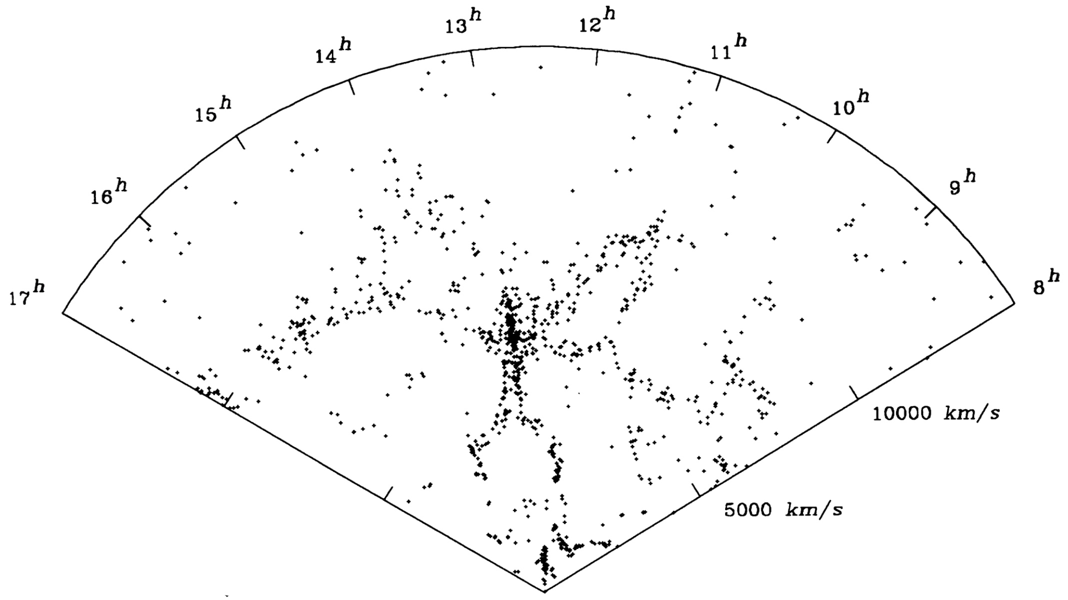


Reproduced from the Millennium Simulation (Springel et al. 2005)

The Cosmic Web: From theory to observations

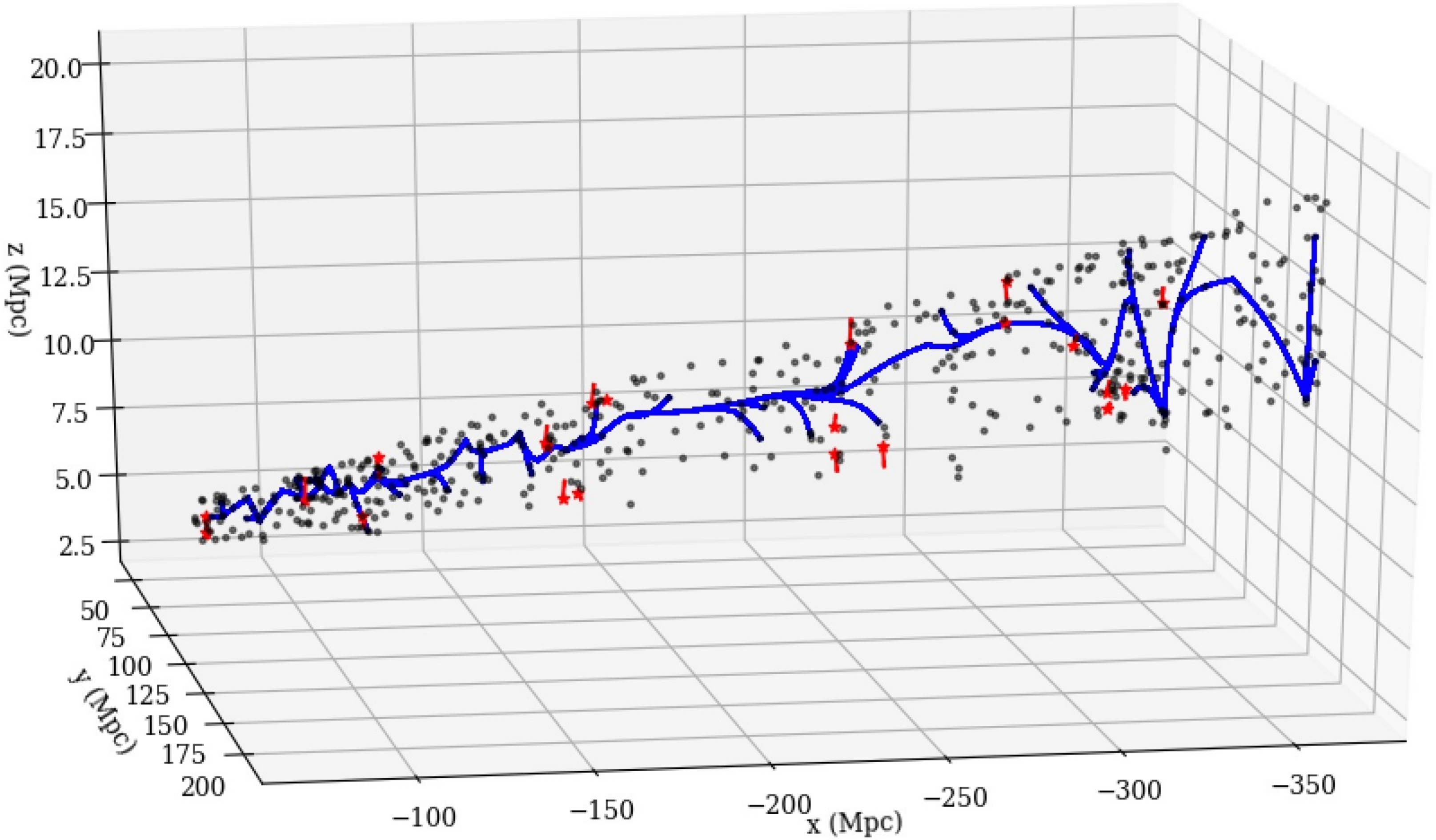


Klypin and Shandarin (1982)



de Lapparent et al. (1986)

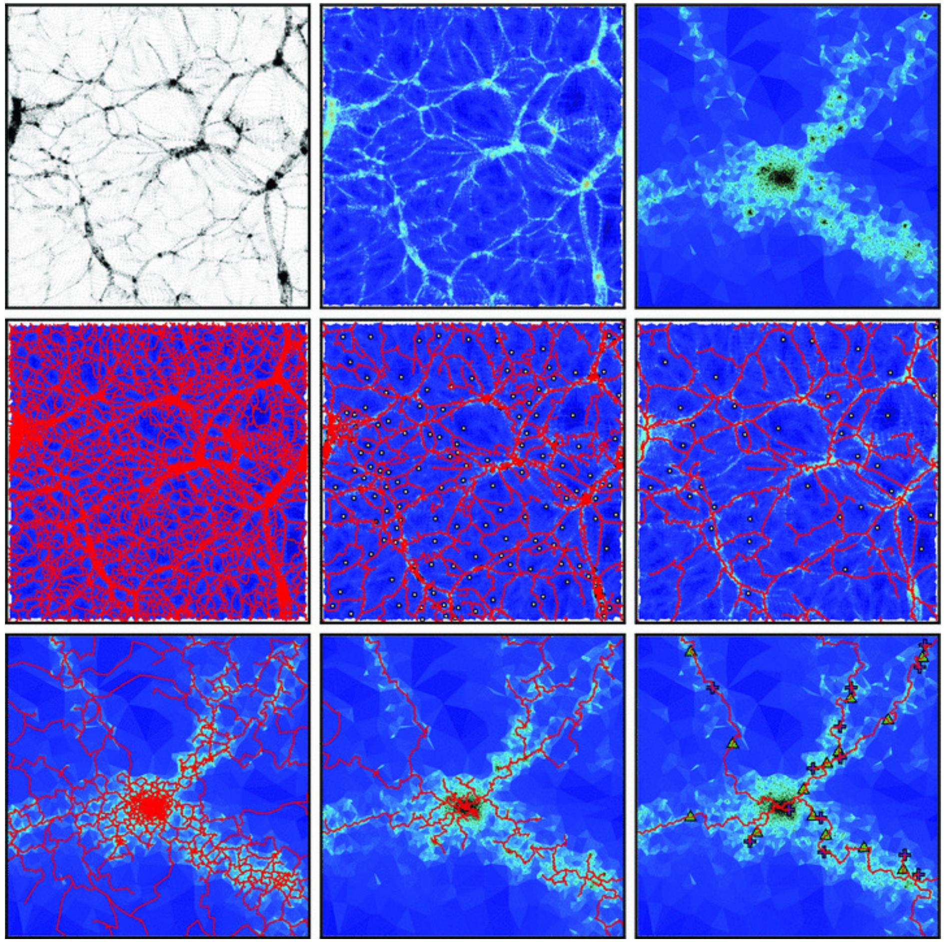
The Cosmic Web: From theory to observations



The Cosmic Web: DisPerSE

- Based on Delaunay tessellation

- Parameters
  - Persistence ratio - significance
  - Boundary conditions – periodic, mirror, void, smooth



Sousbie et al. (2011)

Outline

- Introduction
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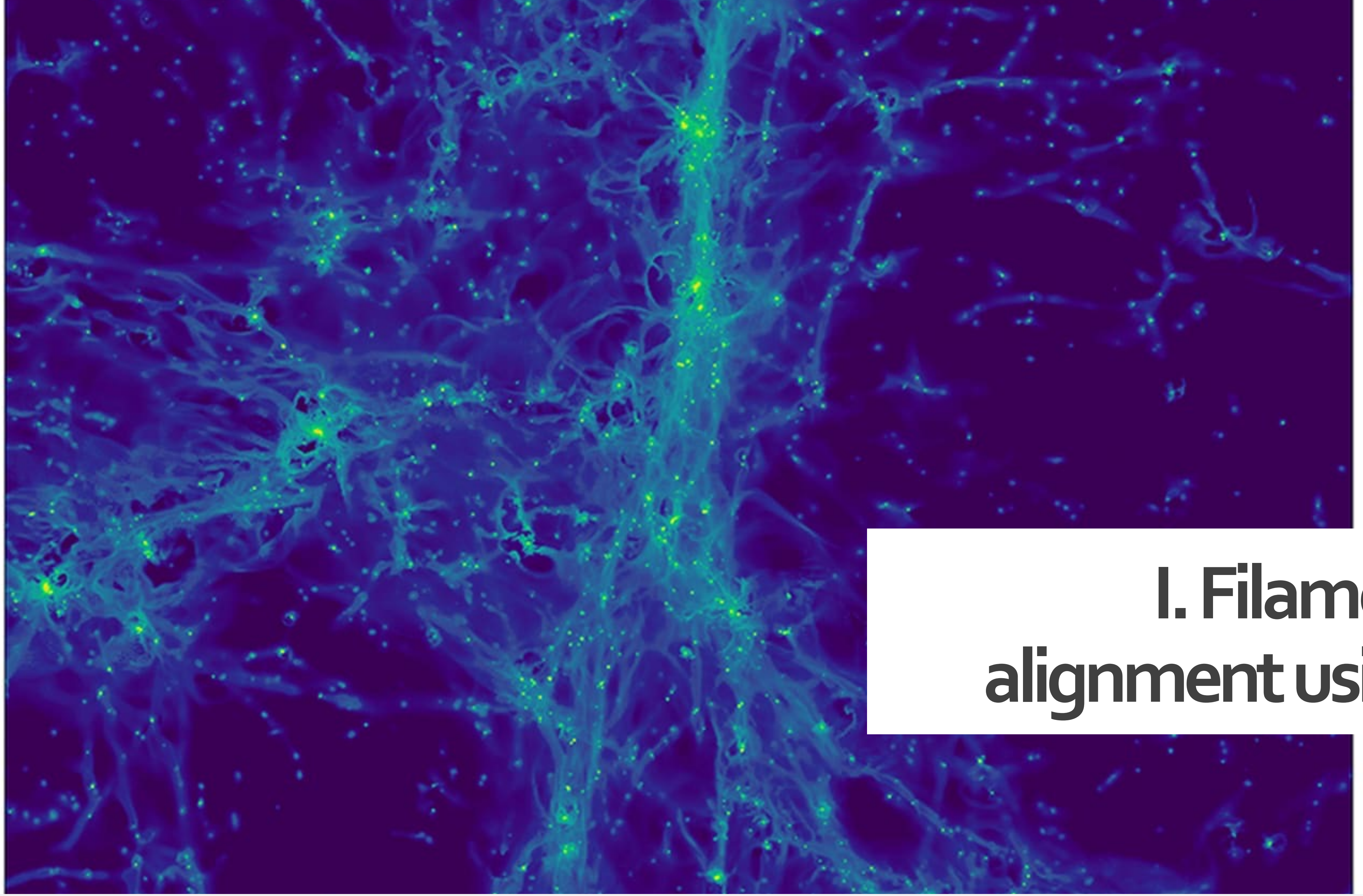
- Galaxy spins + cosmic web
- Other galaxy properties + cosmic web



I. Filament-galaxy alignment using HI data

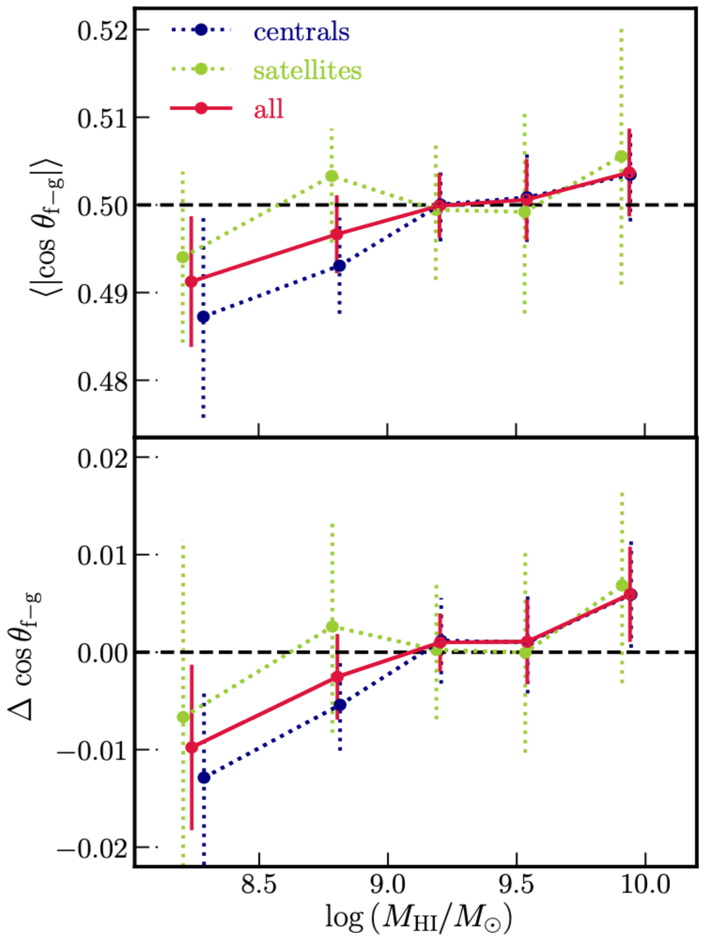
Neutral hydrogen (HI): why and how

- Observed using radio telescopes

- Can be used for measurements of:
  Position Angle (PA) of galaxy
  Inclination (i) of galaxy
  Dynamical mass of galaxy -- $M_{\rm dyn} = \frac{R}{G} V_{\rm rot}^2$

MIGHTEE/HSC

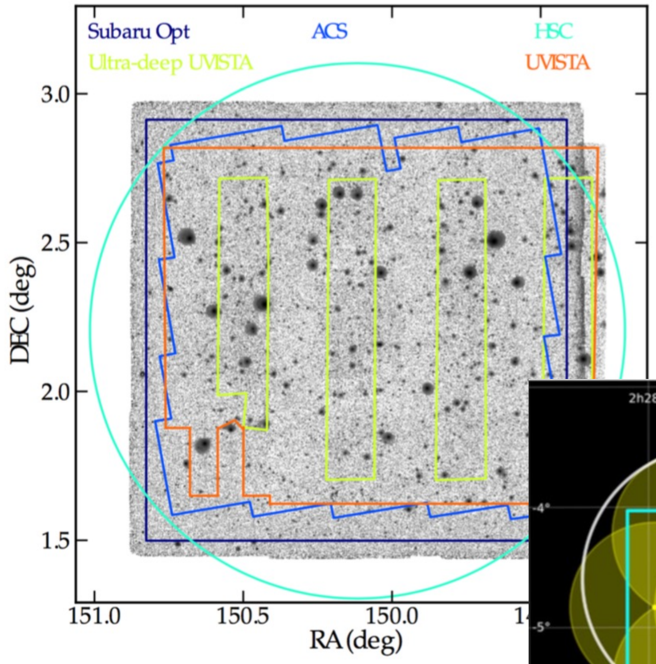
Galaxy alignments in literature

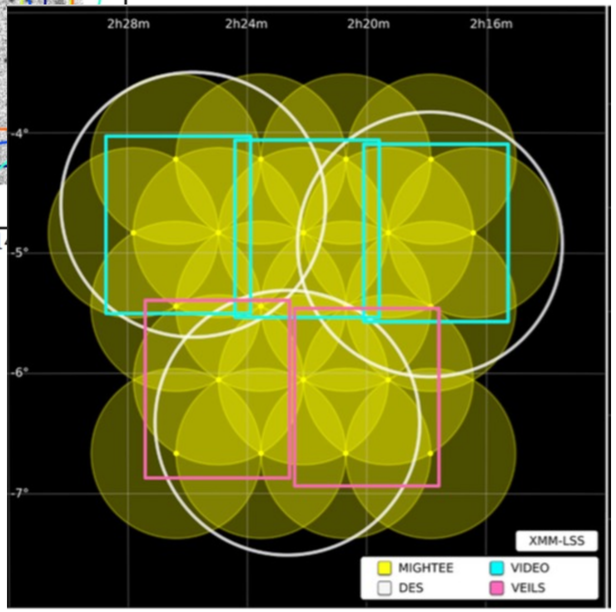


Kraljic et al. (2019)

- Simulations predict a transition between the aligned and perpendicular orientations of galaxy spins depending on the HI mass (Kraljic et al. 2019)
- HI spin of the galaxies and the filaments tend to be aligned (Blue Bird et al. 2020)

Data: COSMOS and XMM-LSS

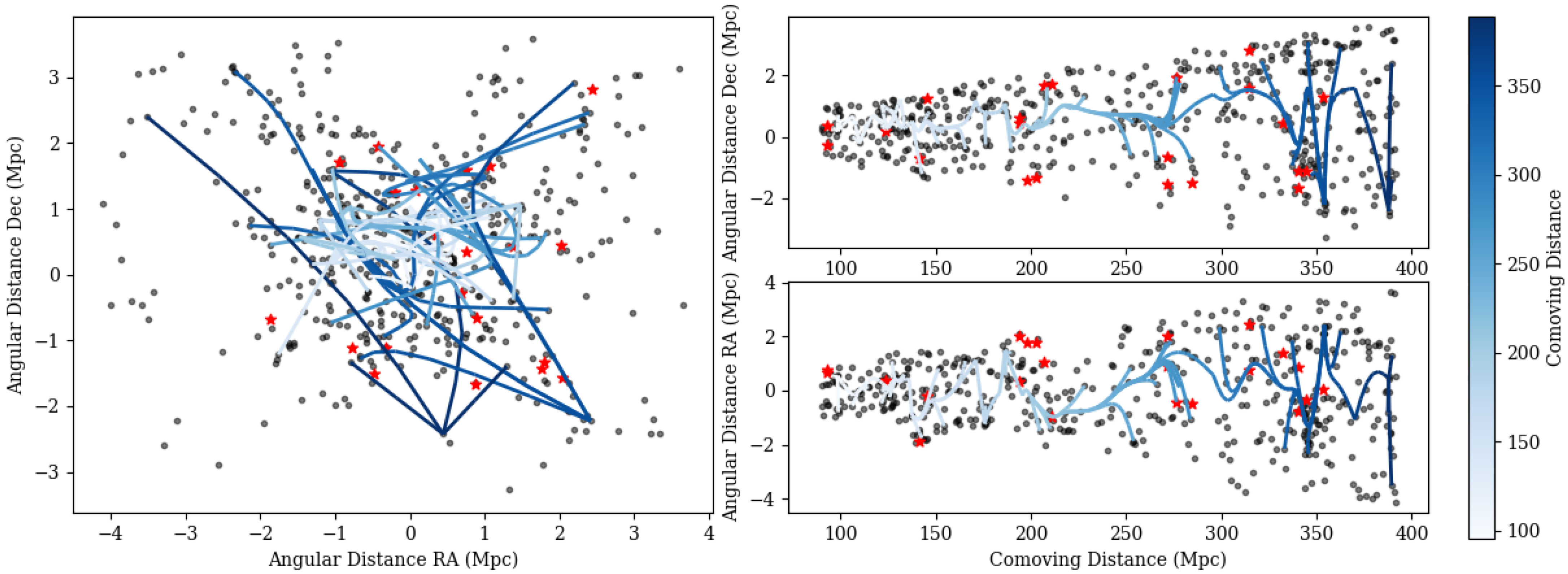




Find filaments using the optical/NIR data from the COSMOS and the XMM-LSS fields:

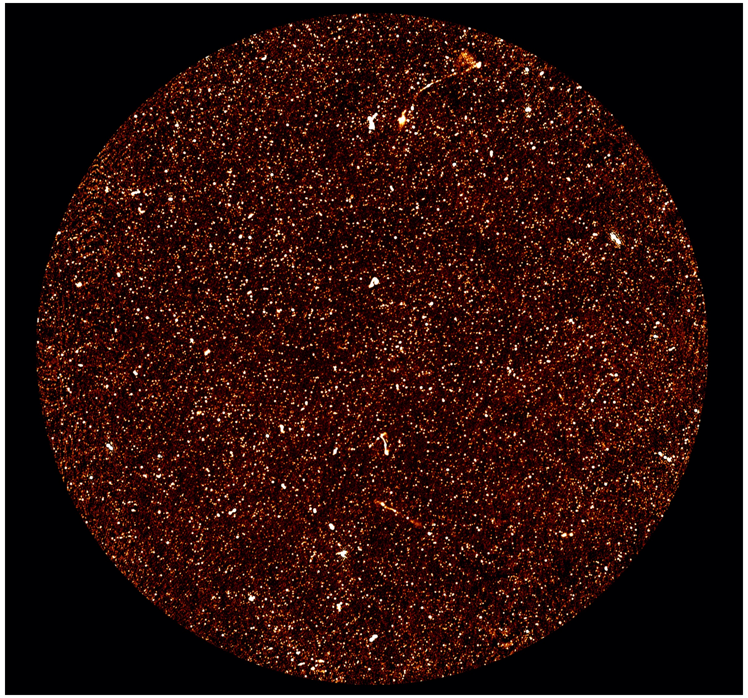
- COSMOS: CFHTLS & Subaru HSC
- XMM-LSS VIDEO and UltraVISTA

Spectroscopic redshift filaments



Tudorache et al. (2022)

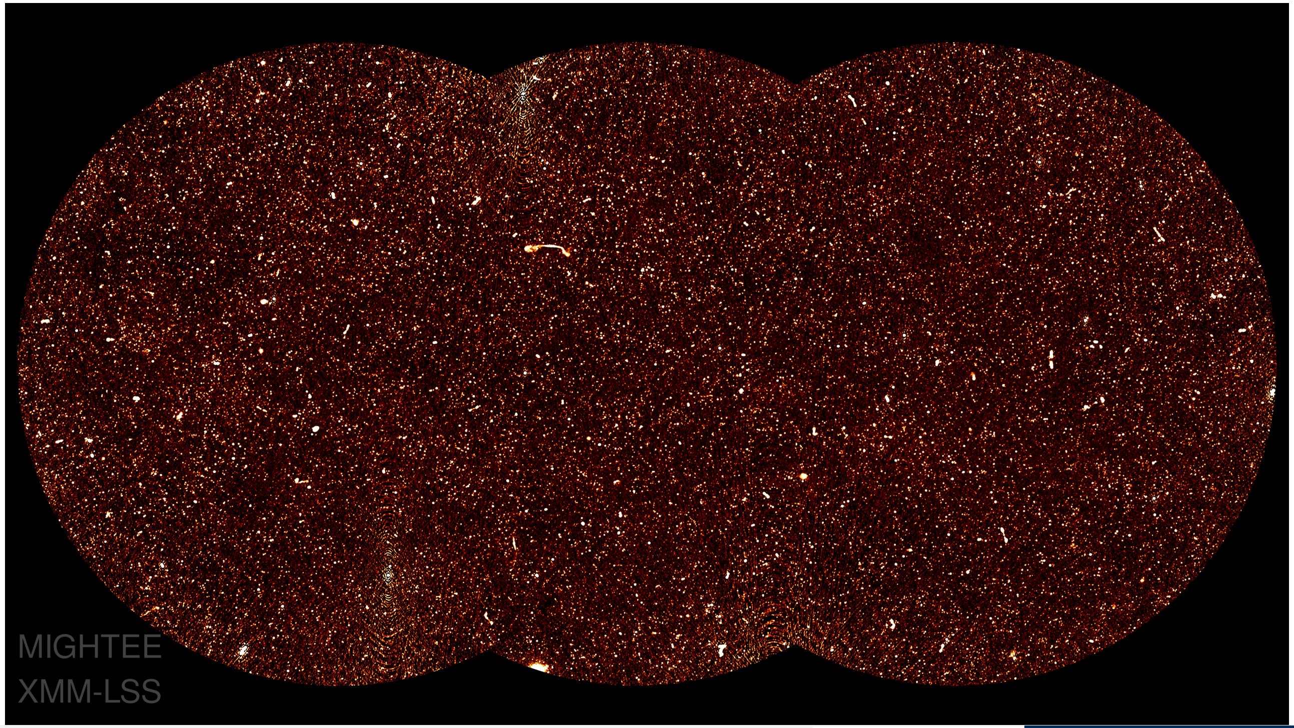
Meerkat & The MIGHTEE survey



COSMOS Radio continuum, Heywood et al. (2022)

- Radio survey in L-band, spanning 900-1670 MHz
- Spans four fields: COSMOS, XMM-LSS, ELAIS-S1, ECDFS

XMM-LSS Radio continuum, Heywood et al. (2022)



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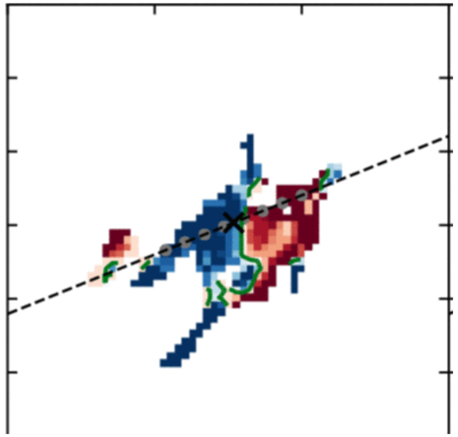
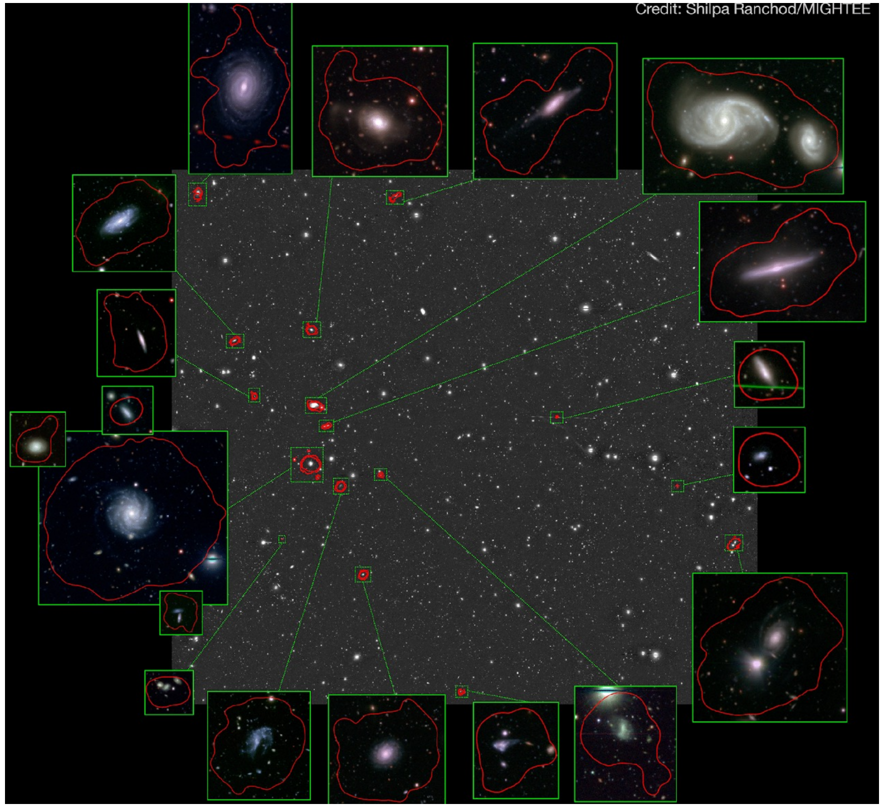
MIGHTEE-HI

- HI emission project within the MIGHTEE survey using the MeerKAT radio telescope (Maddox et al. 2020)

- 77 HI galaxies from the MIGHTEE-HI Early Science observations

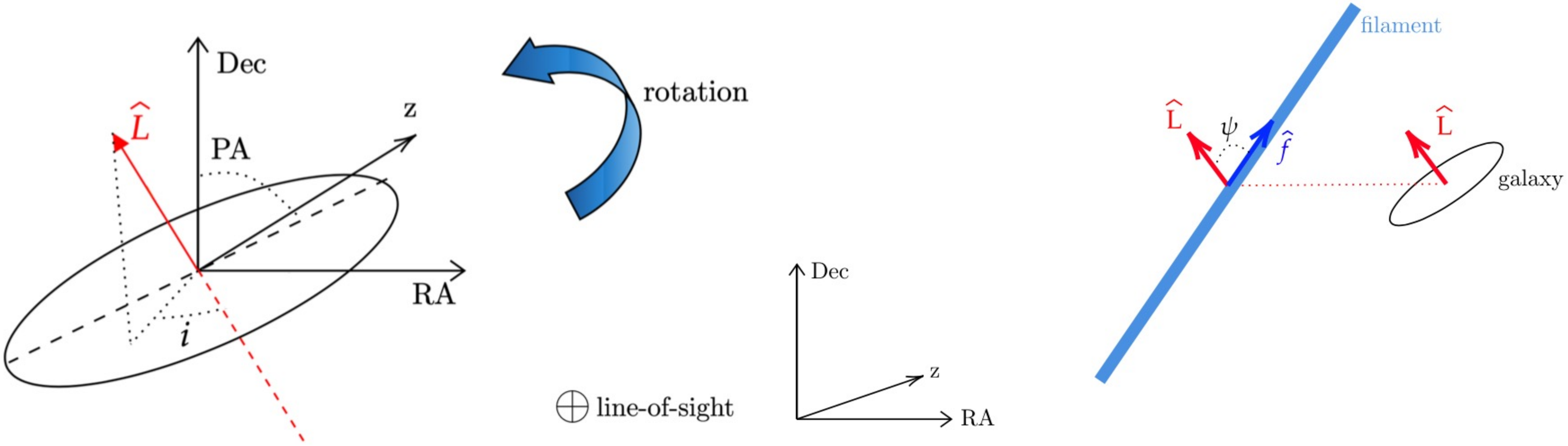


Ponomareva et al. (2021)



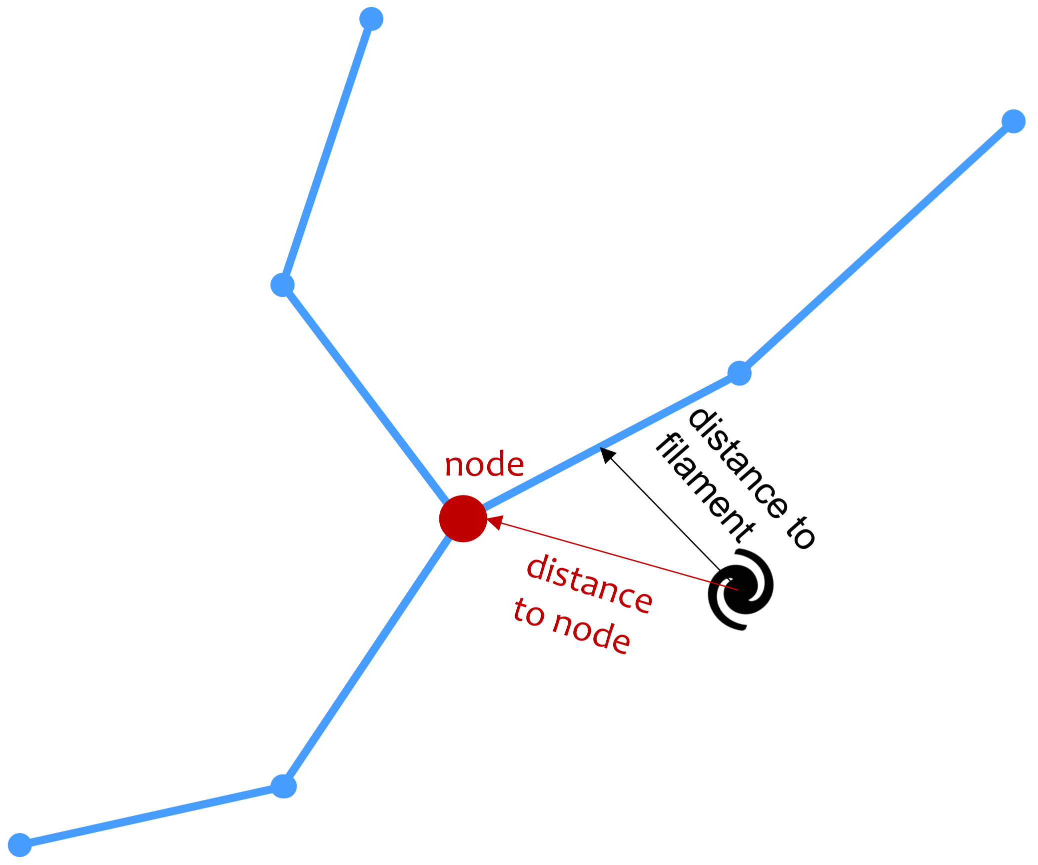
Ranchod et al. (2020)

The angle between filaments and galaxies

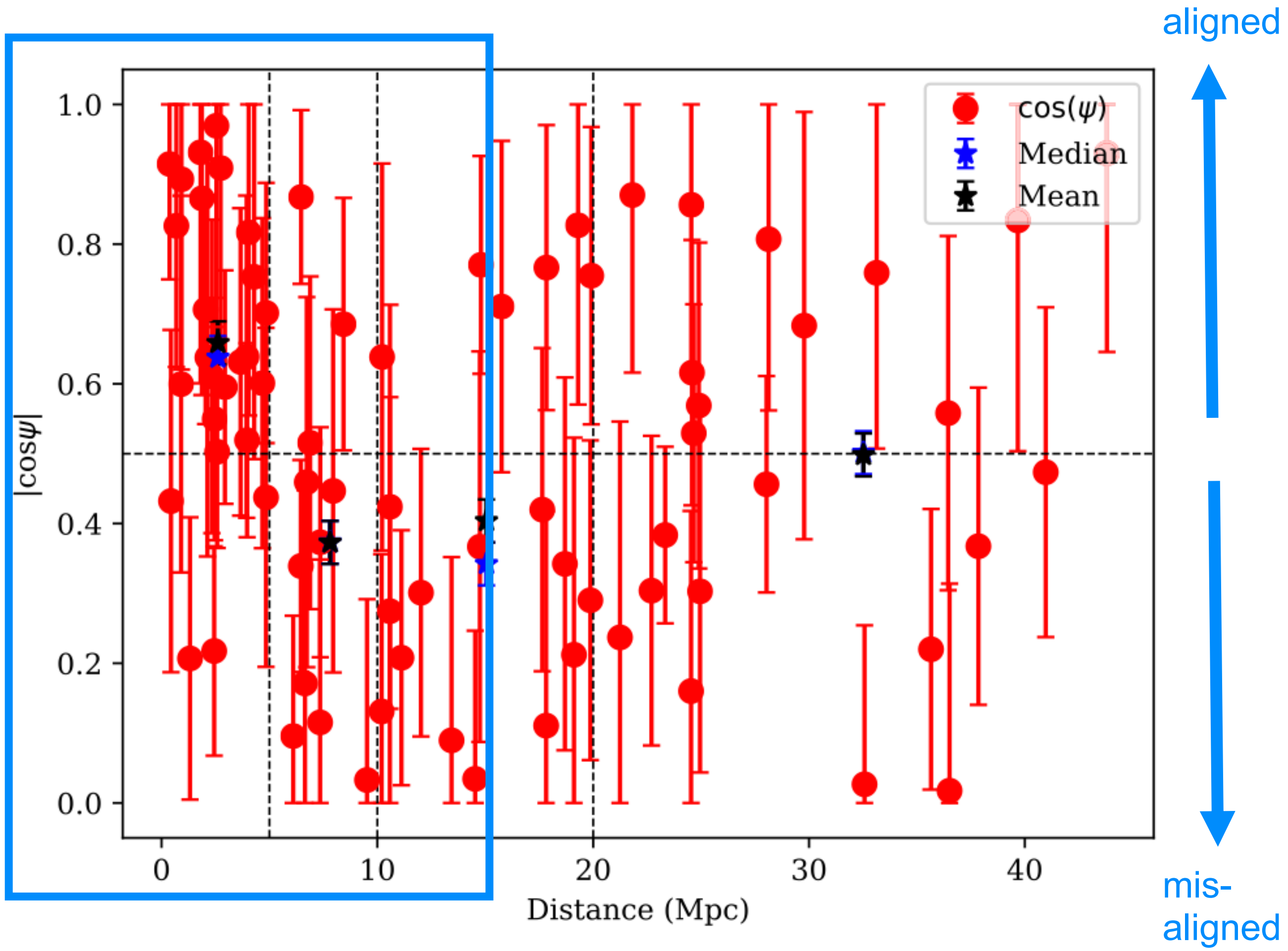


Tudorache et al. (2022)

Compute distance to filaments

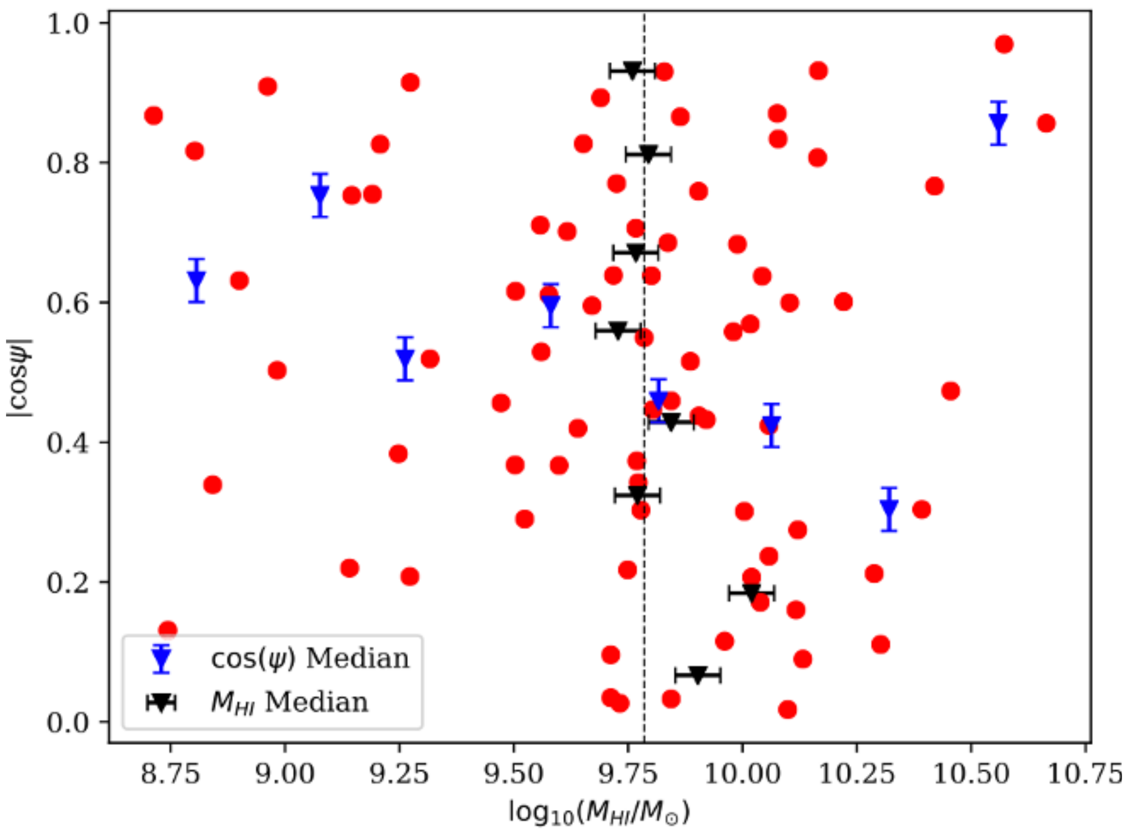


Distance-to-filament



Distance Cut	$\langle \lvert\cos\psi\rvert \rangle$	p_{KS}
$0\,\mathrm{Mpc} < d < 5\,\mathrm{Mpc}$	0.66 ± 0.04	$5 \cdot 10^{-2}$
$5\,\mathrm{Mpc} < d < 10\,\mathrm{Mpc}$	0.37 ± 0.08	$9 \cdot 10^{-2}$

HI Mass



aligned

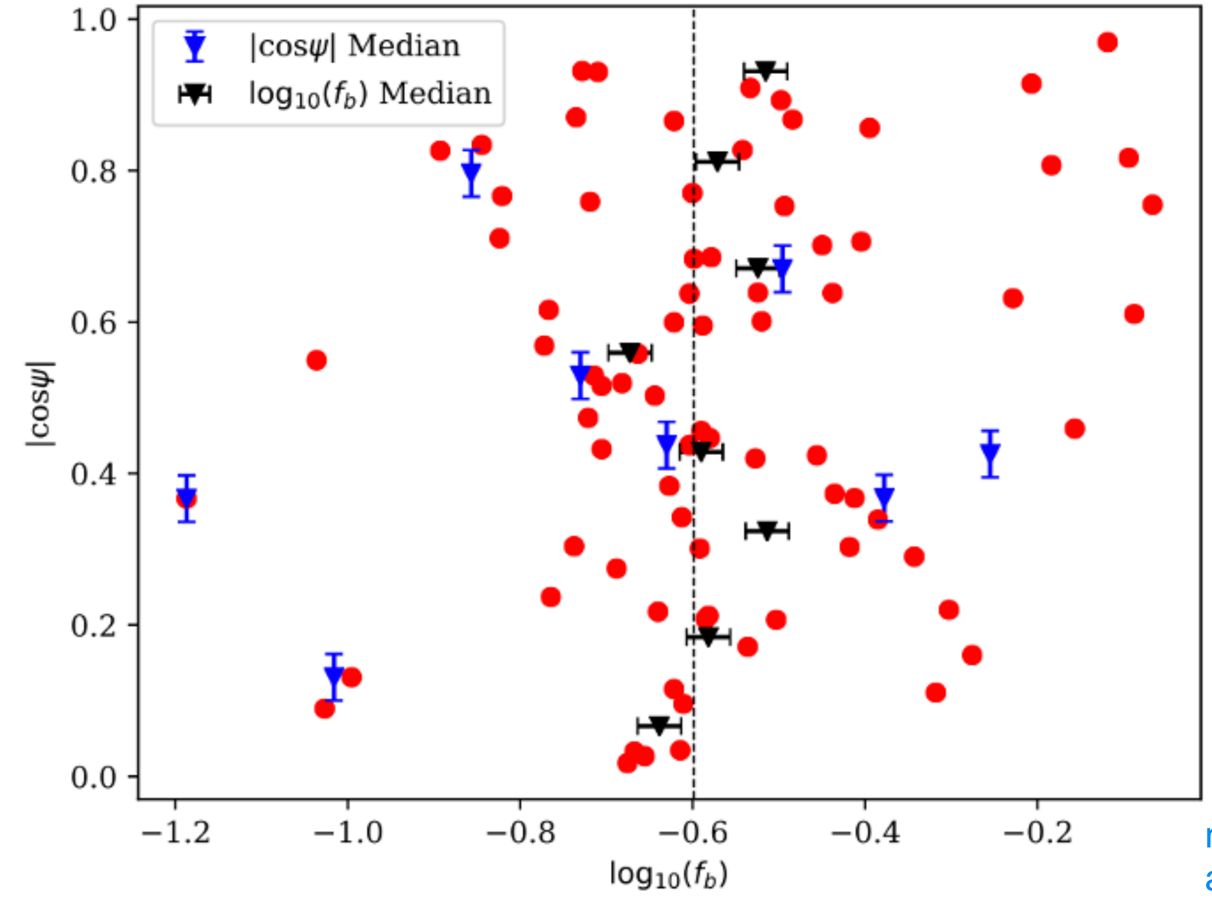
mis-aligned

Parameter	Cut	$\langle\lvert\cos\psi\rvert\rangle$	p_{MW}
$\log_{10}\left(\frac{M_{HI}}{M_\odot}\right)$	< 9.78	0.52 ± 0.04	0.40
	> 9.78	0.50 ± 0.05	

Parameter	Kendall's Tau τ	p-value	Spearman Rank coefficient	p-value
M_{HI}	−0.058	0.452	−0.083	0.472

Baryon Mass fraction

$$f_b = M_{\rm baryon}/M_{\rm dyn}$$



Parameter	Cut	$\langle|\cos\psi|\rangle$	p_{MW}
$\log_{10}(f_b)$	< -0.598	0.47 ± 0.05	0.13
	> -0.598	0.55 ± 0.04	

Parameter	Kendall's Tau		Spearman Rank	
	τ	p-value	coefficient	p-value
f_b	0.069	0.377	0.107	0.355

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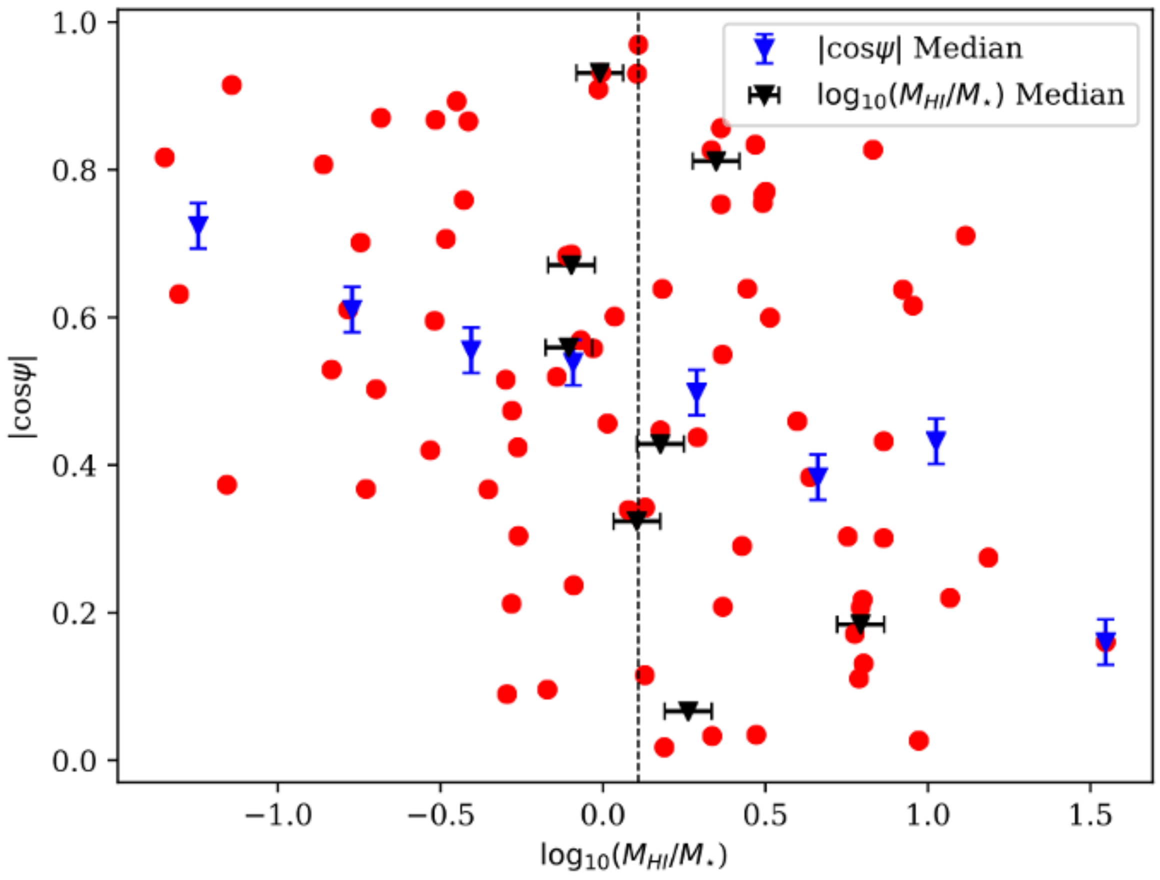
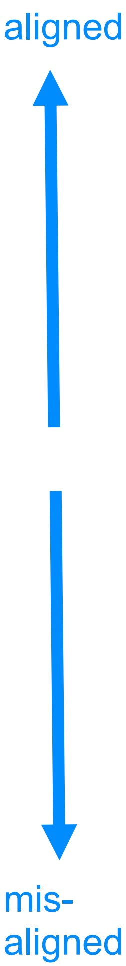
HI-to-stellar mass fraction





Parameter	Cut	$\langle \lvert\cos\psi\rvert \rangle$	p_{MW}
$\log_{10}\left(\frac{M_{HI}}{M_\star}\right)$	< 0.11	0.58 ± 0.04	0.01
	> 0.11	0.44 ± 0.05	

Parameter	Kendall's Tau		Spearman Rank	
	τ	p-value	coefficient	p-value
$M_{HI}/M_\star$	−0.209	0.007	−0.311	0.006

Summary of Part I

- Used DisPerSE to compute filaments based on the COSMOS and XMM-LSS spectroscopic catalogues

- Crossmatching these filaments with HI galaxies we found that:
  - distance-to-filament: lower distances correspond to aligned spin
  - HI content of galaxy: no correlation found
  - baryon mass fraction: no correlation found
  - HI-to-stellar mass ratio: lower ratios correspond to aligned spin

Outline

- Introduction
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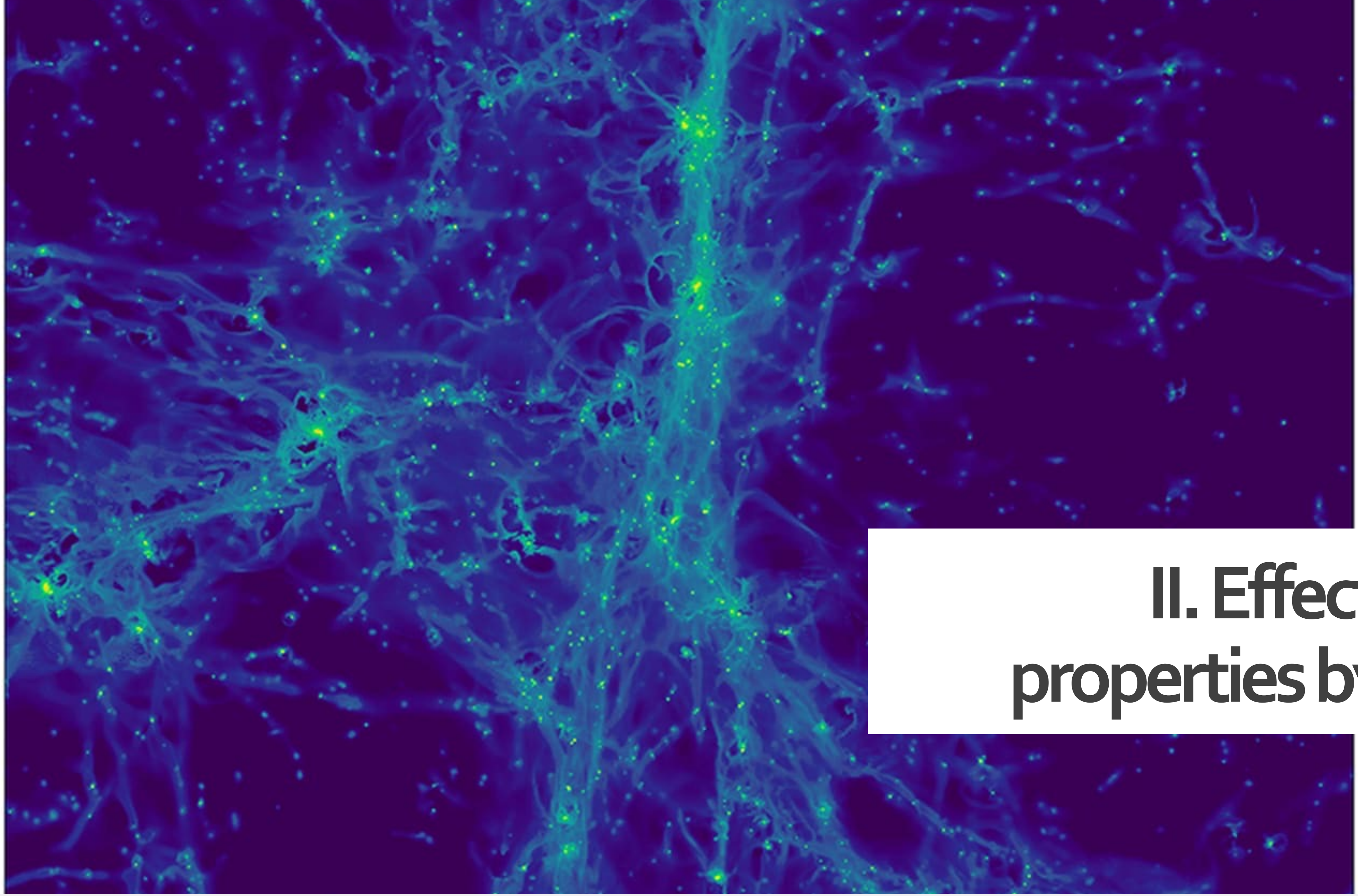
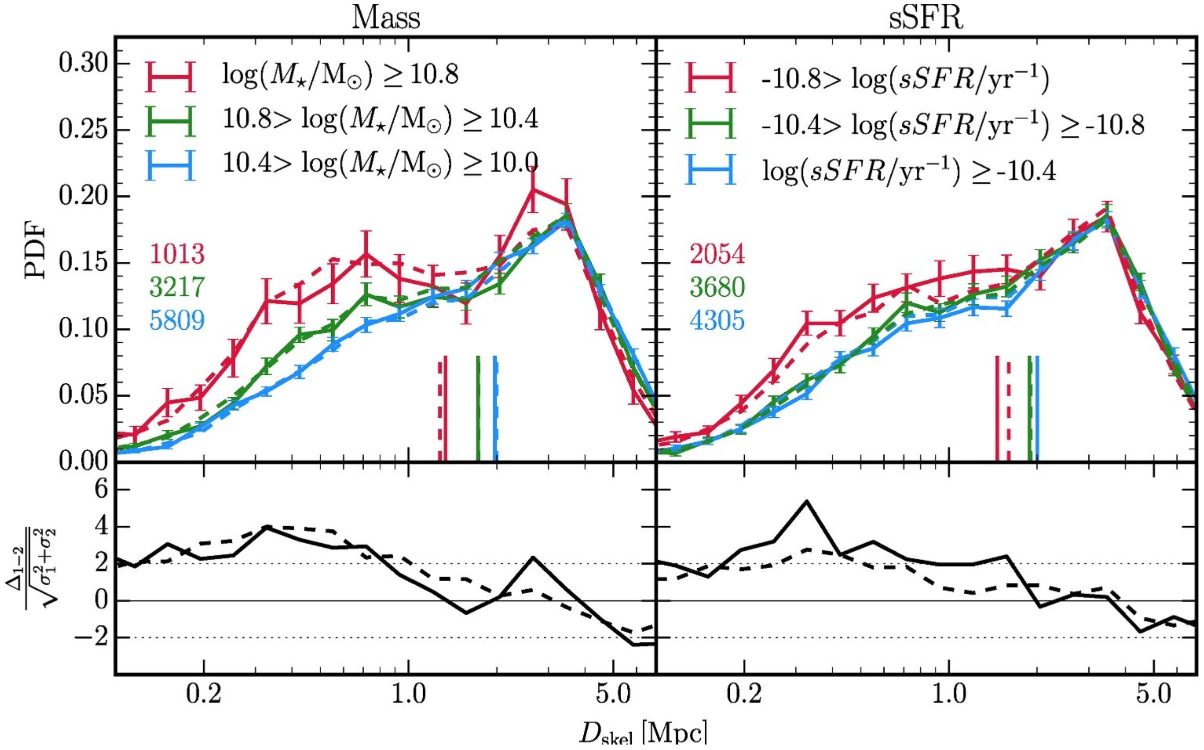


II. Effect on galaxy properties by filaments

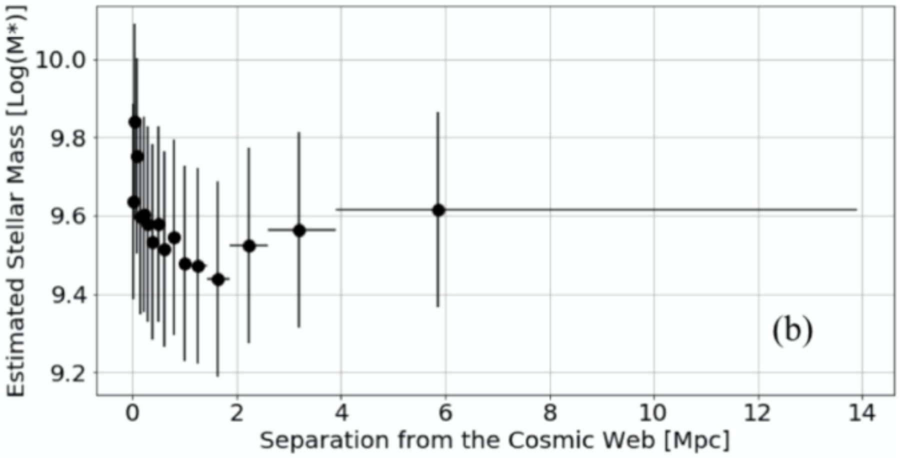
Stellar mass/sSFR and filament distance: simulations



Kraljic et al. (2018)

- At low redshift, massive galaxies, as well as galaxies with a low sSFR can be usually found residing in the core of the filaments

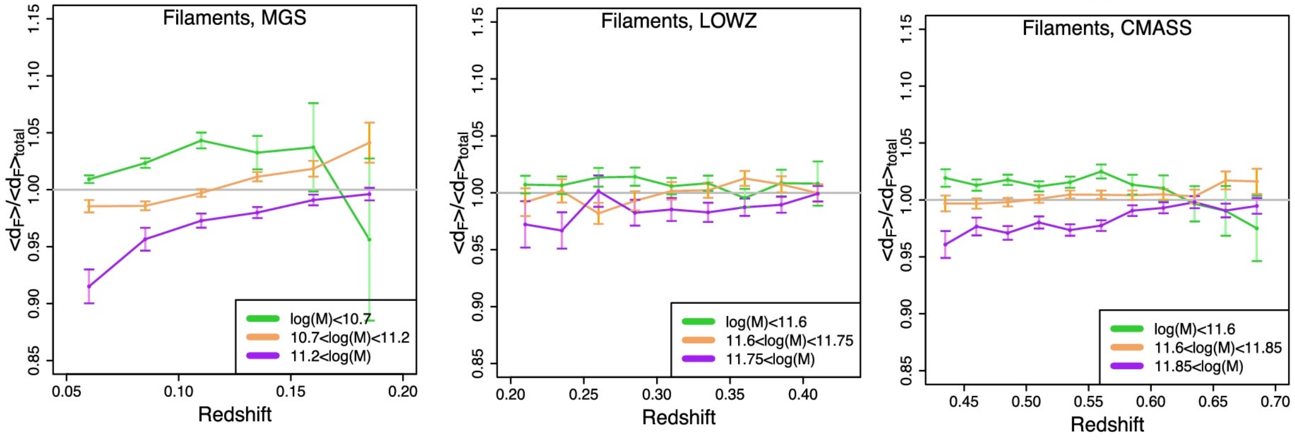
Stellar mass as a function of filament distance: observations



Luber et al. (2019)

- At low redshift, massive galaxies can be usually found closer to filaments

Chen et al. (2017)

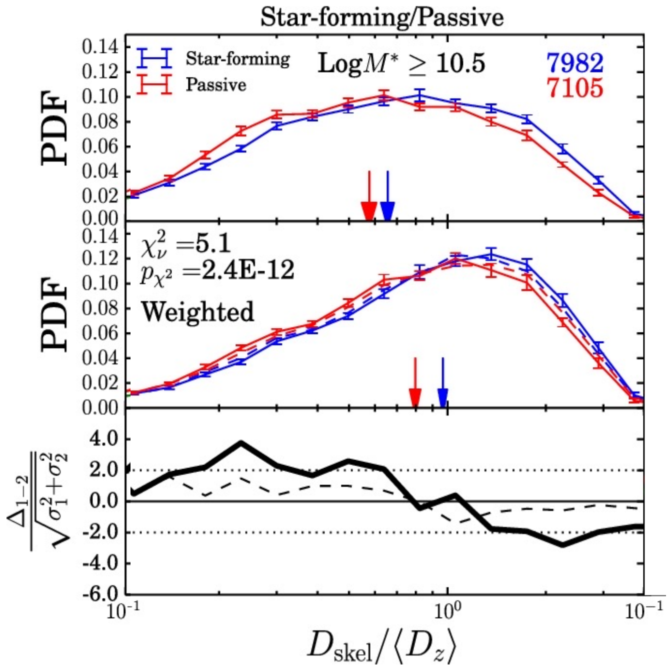


Also see: Alpalsan et al. (2015), Laigle et al. (2017)

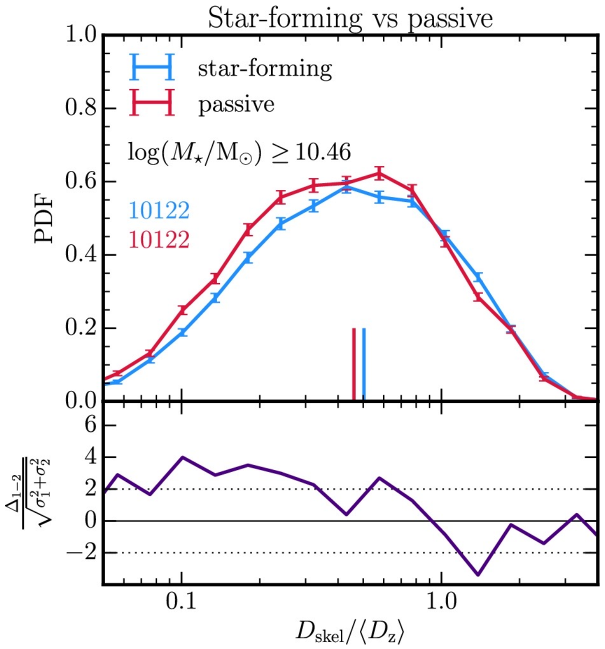
sSFR as a function of filament distance: observations

- At low redshift, passive galaxies can be usually found closer to filaments

Malavasi et al. (2017)



Kraljic et al. (2018)



Also see: Darvish et al. (2014), Bonjean et al. (2020)

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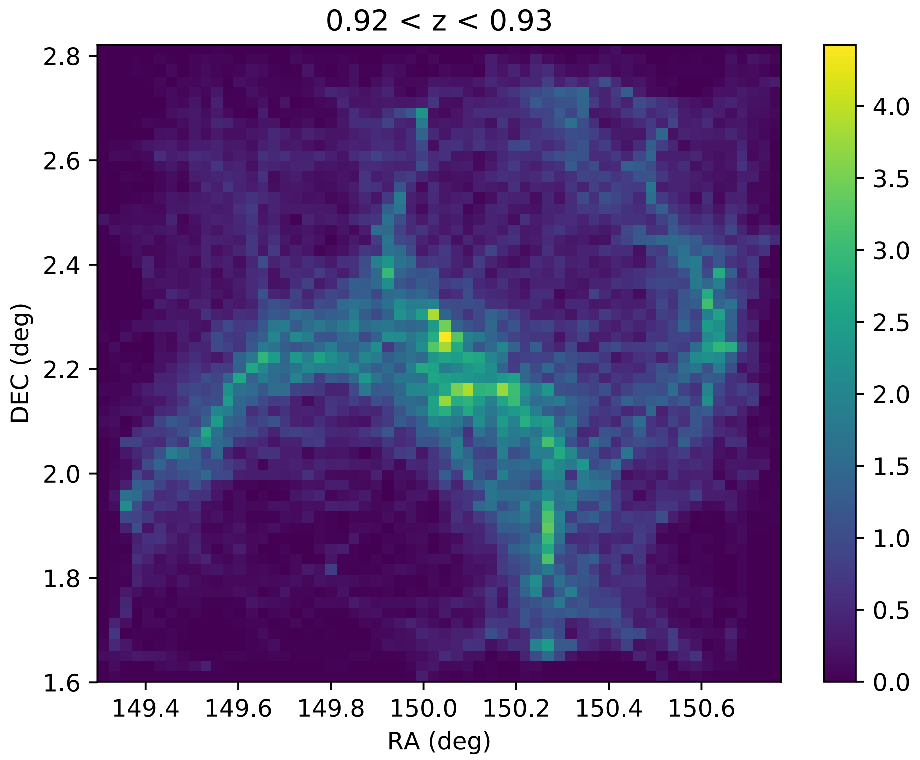
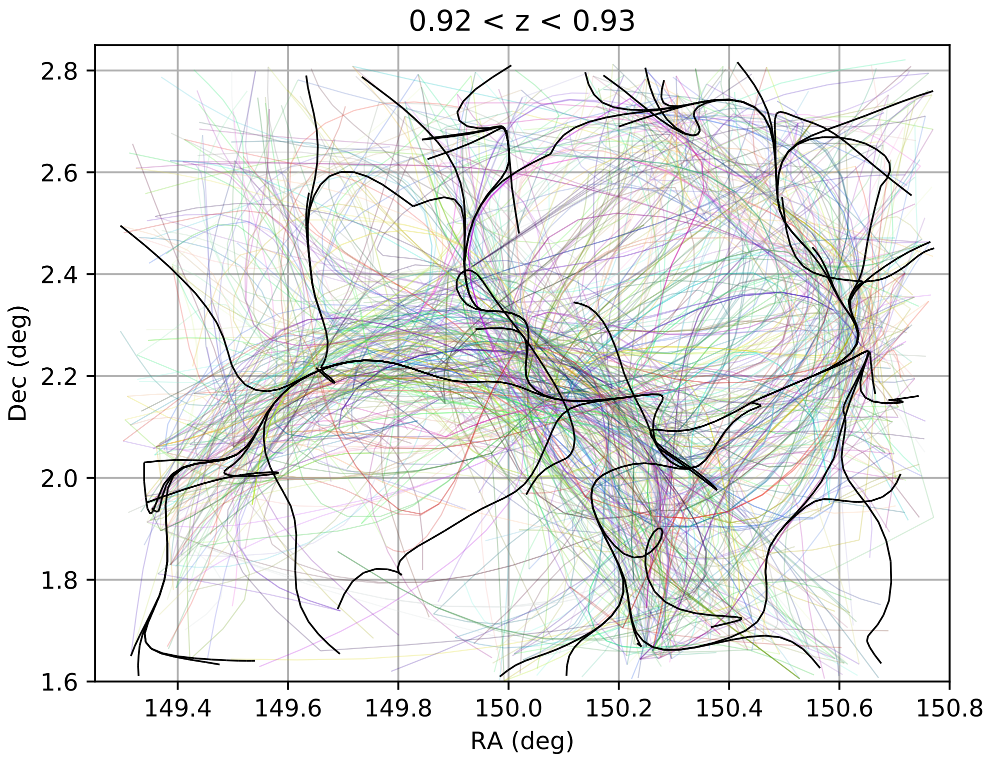
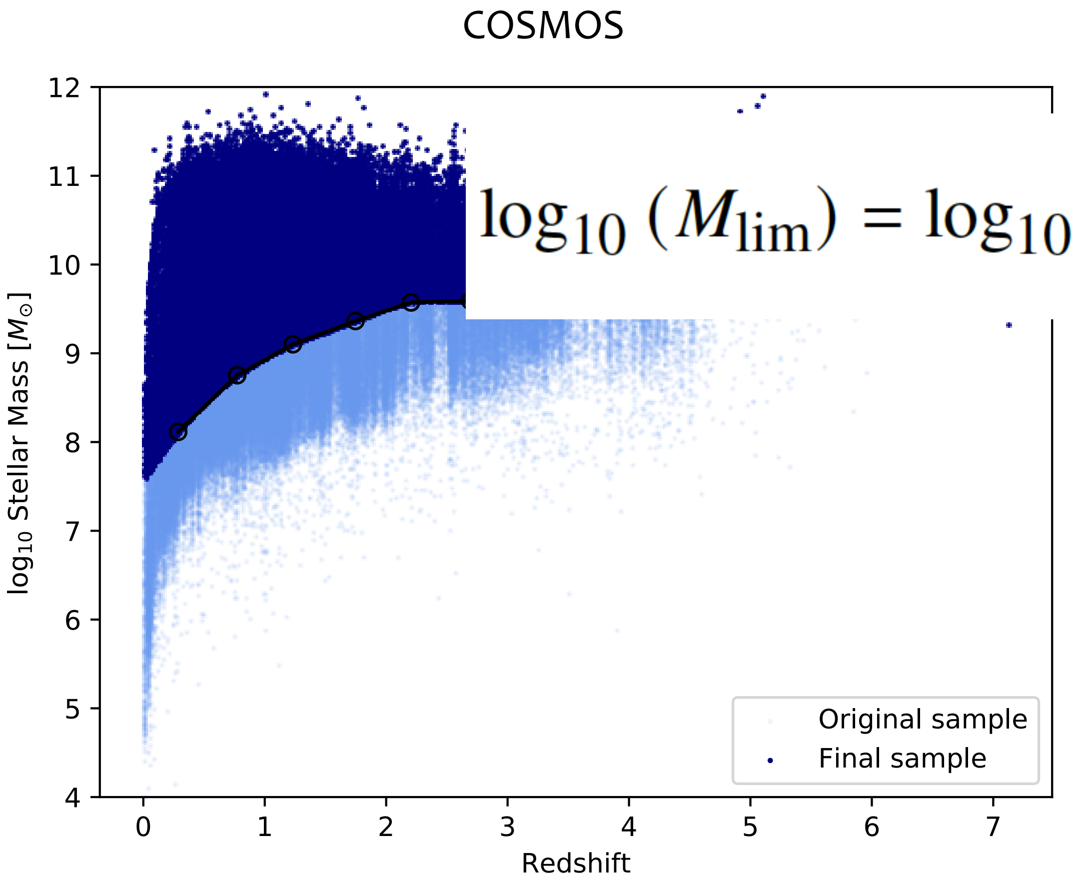
Photometric redshift filaments

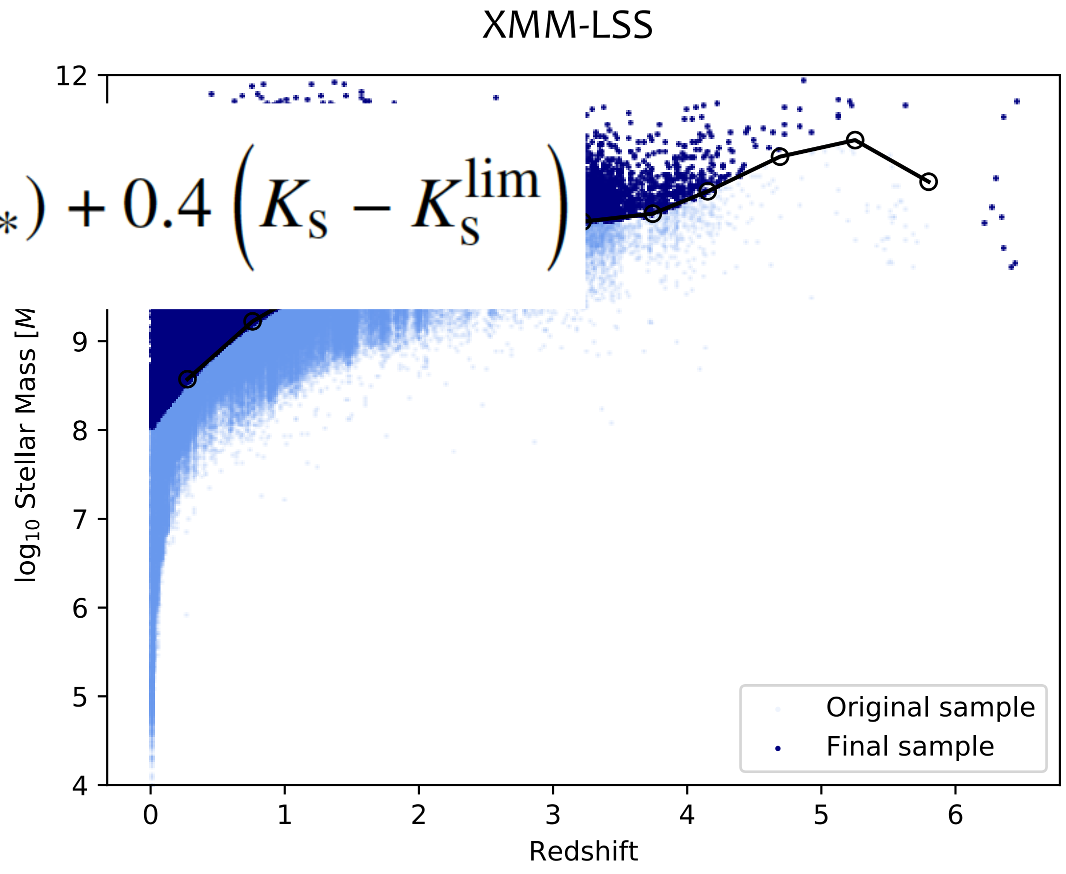




Tudorache et al. in prep

Completeness of sample





$$\log_{10}\left(M_{\mathrm{lim}}\right) = \log_{10}\left(M_{*}\right) + 0.4\left(K_{\mathrm{s}} - K_{\mathrm{s}}^{\mathrm{lim}}\right)$$

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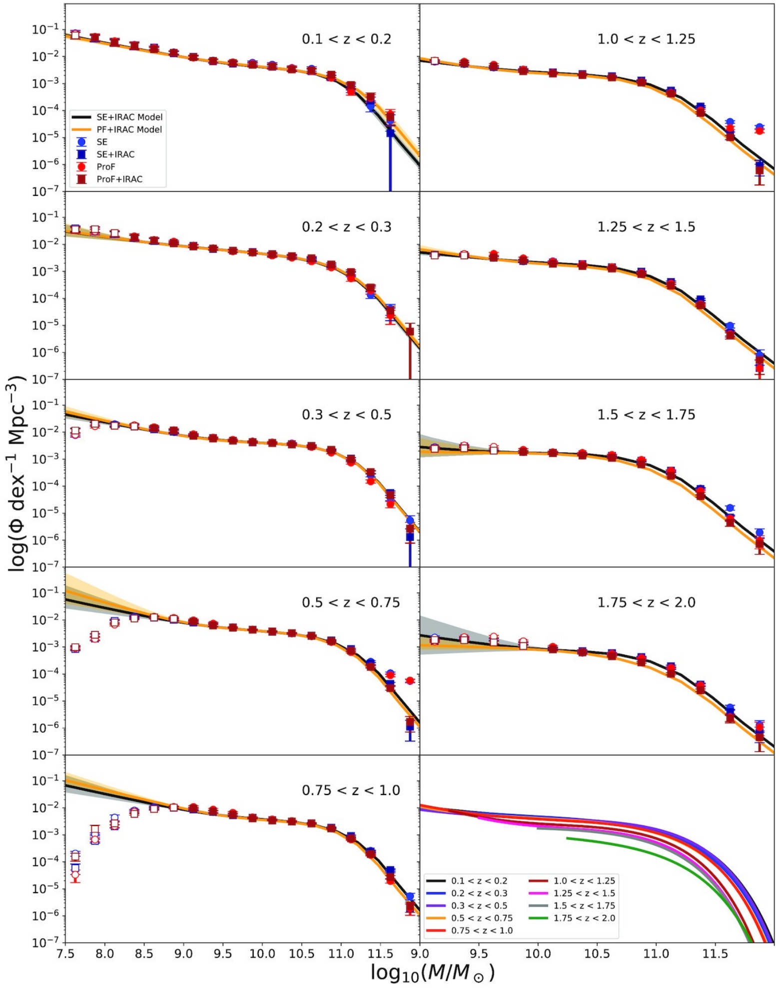
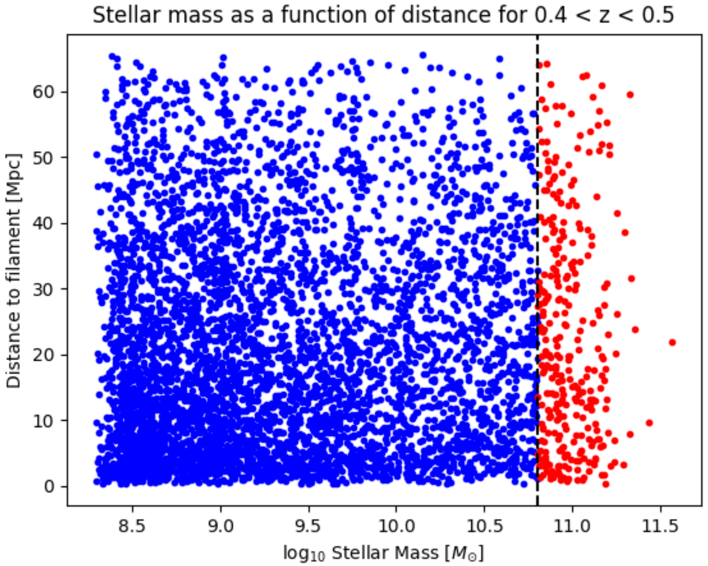
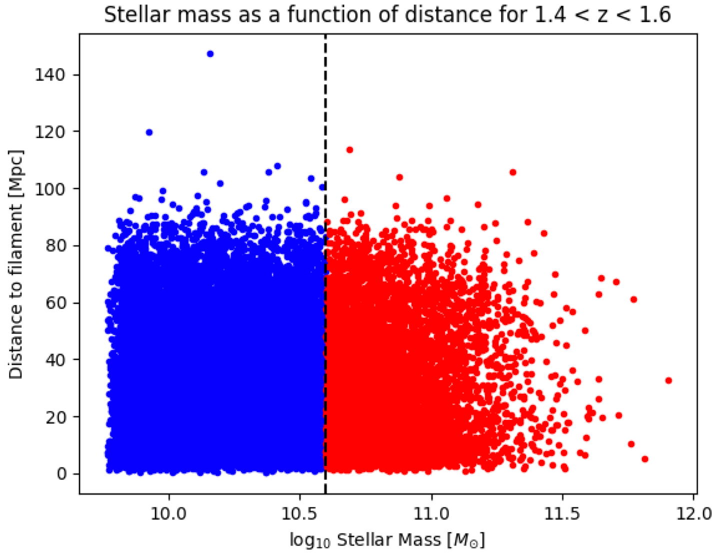
Stellar mass sample



Adams et al. (2021)





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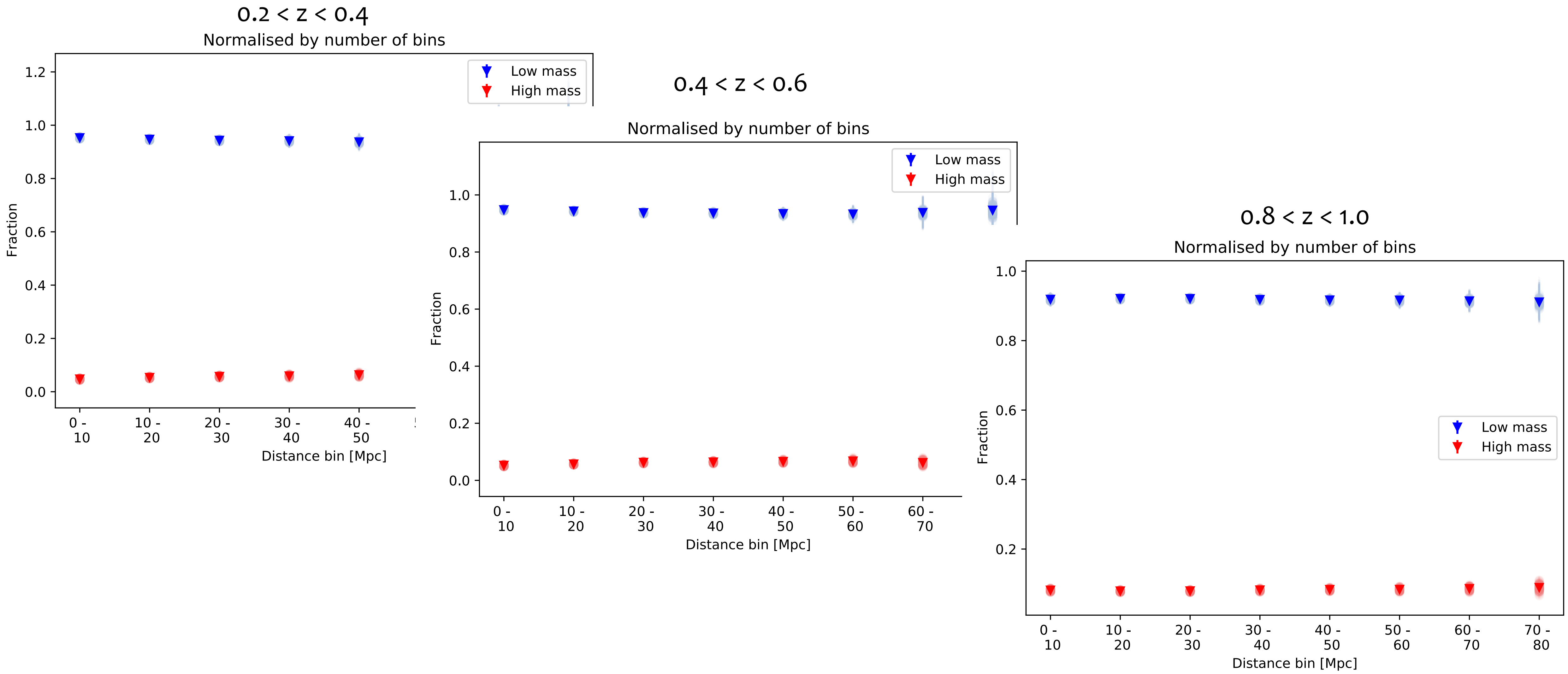
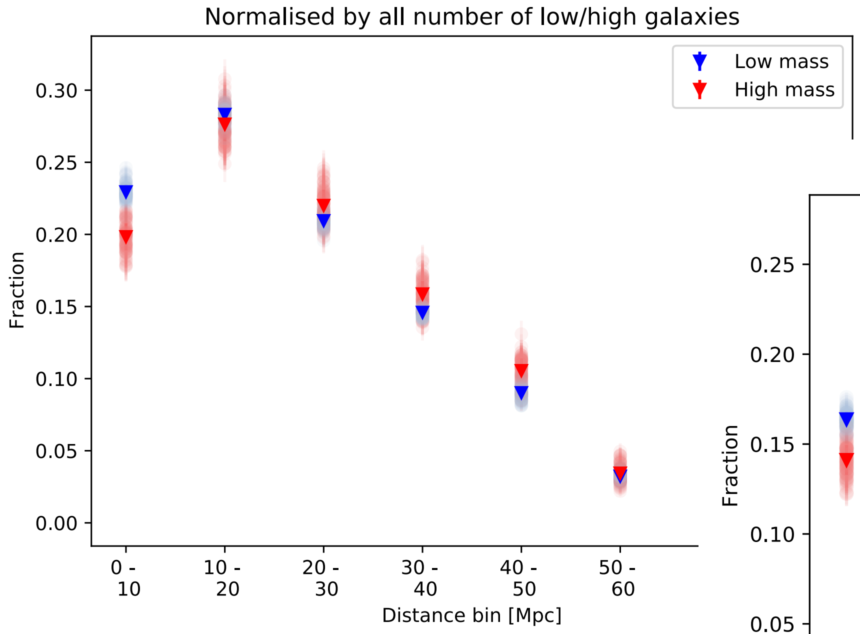
Stellar mass - D_{fil}

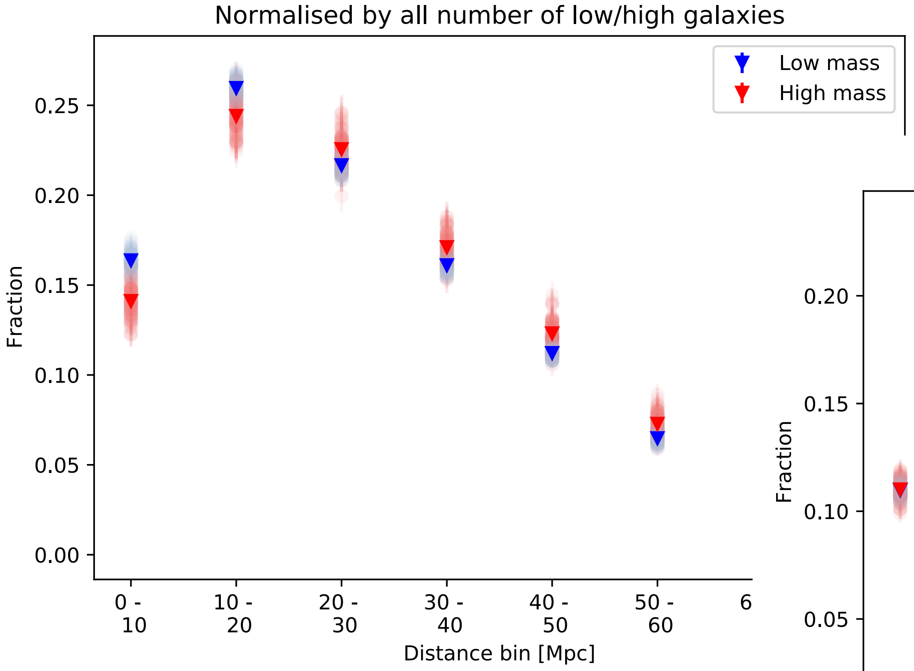


Stellar mass - D_{fil}

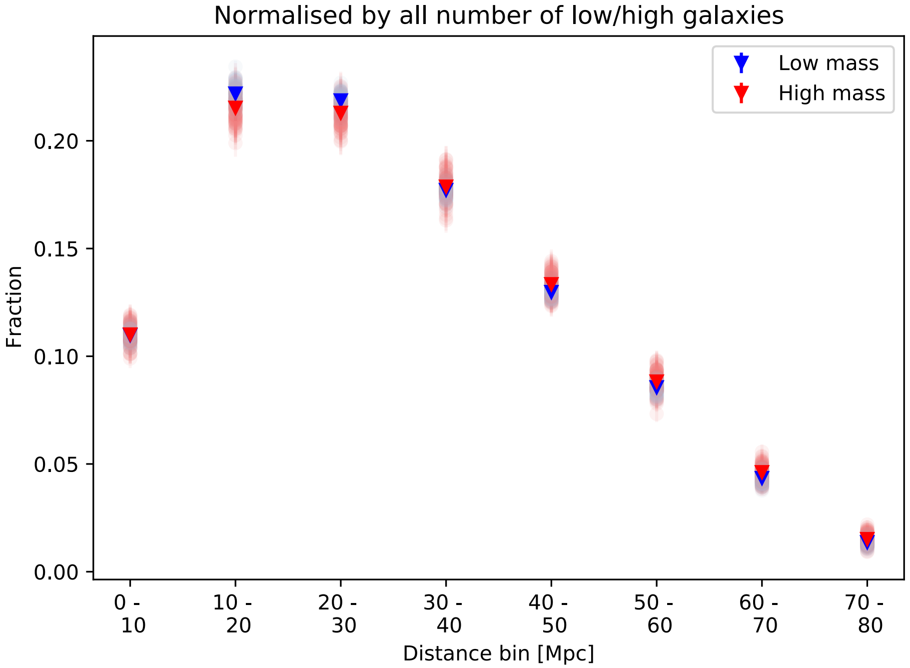
$0.2 < z < 0.4$



$0.4 < z < 0.6$

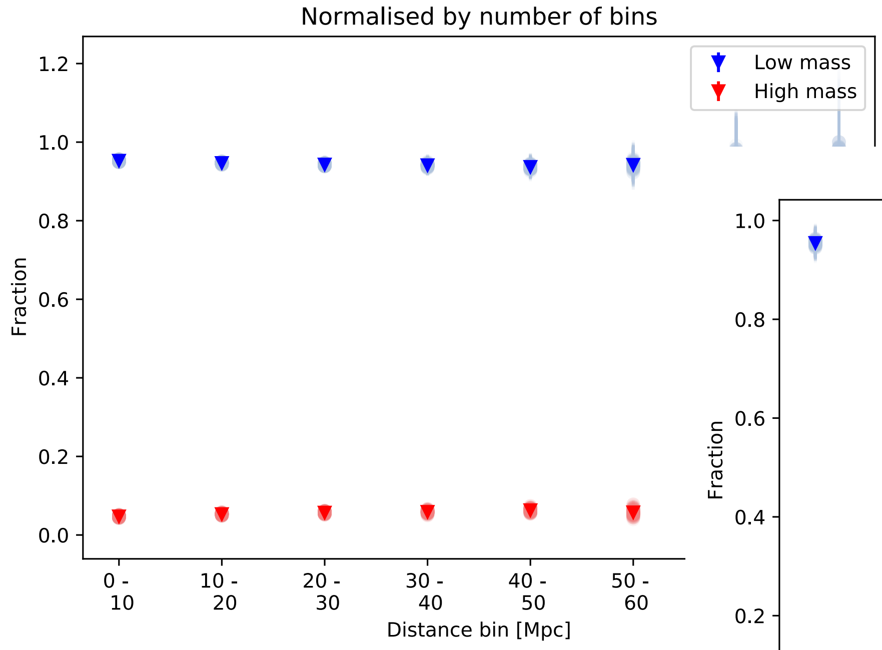


$0.8 < z < 1.0$

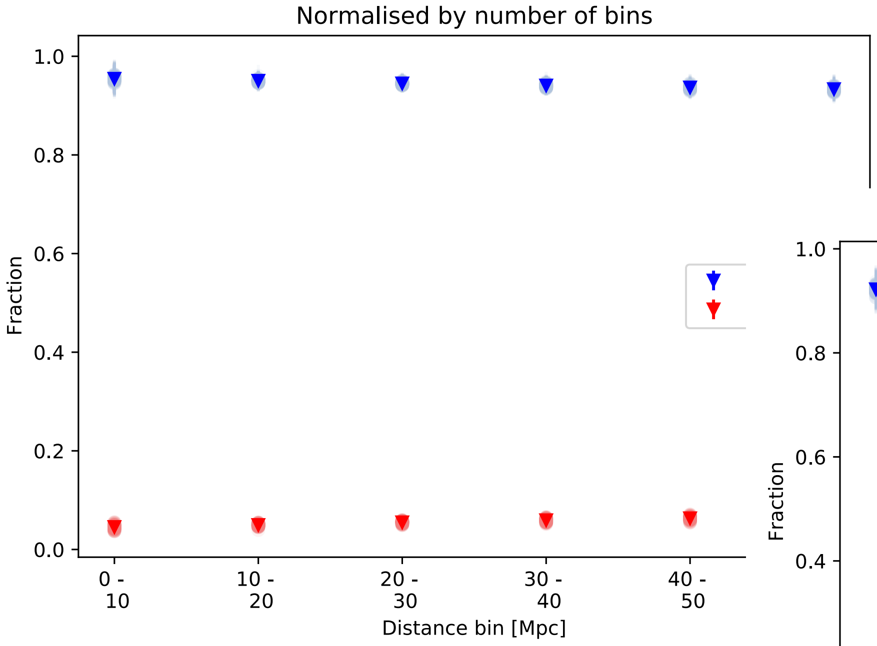


Stellar mass - D_{node}

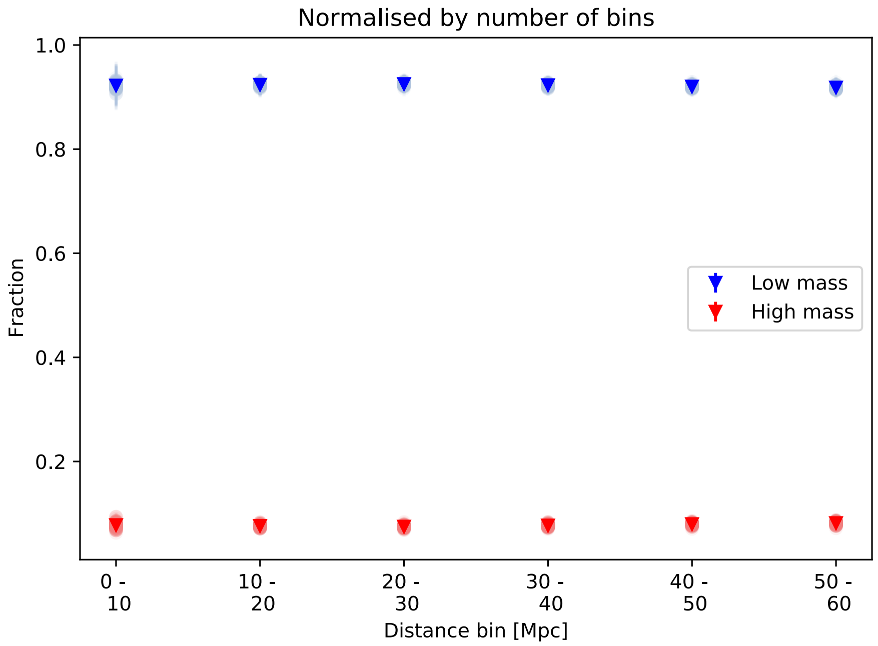
0.2 < z < 0.4



0.4 < z < 0.6

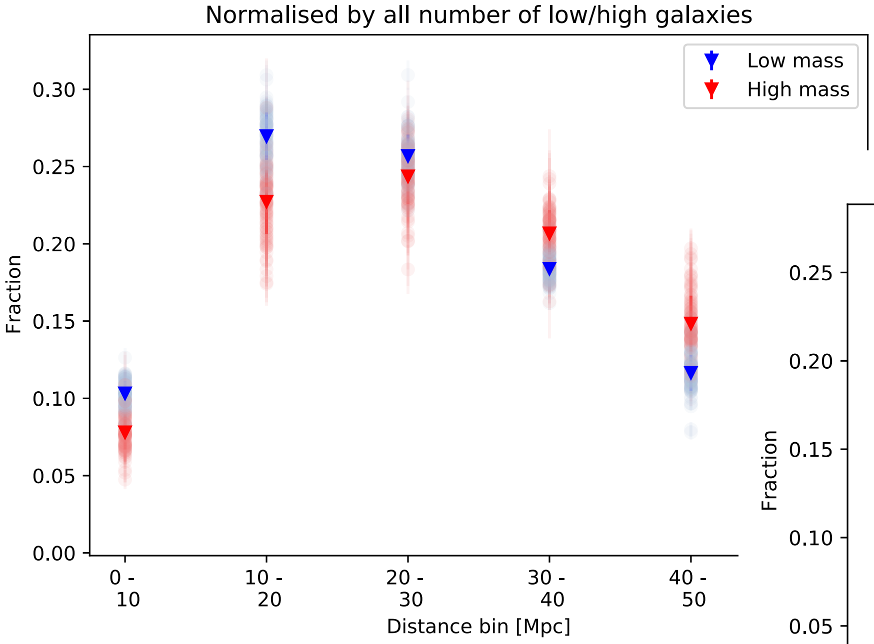


0.8 < z < 1.0

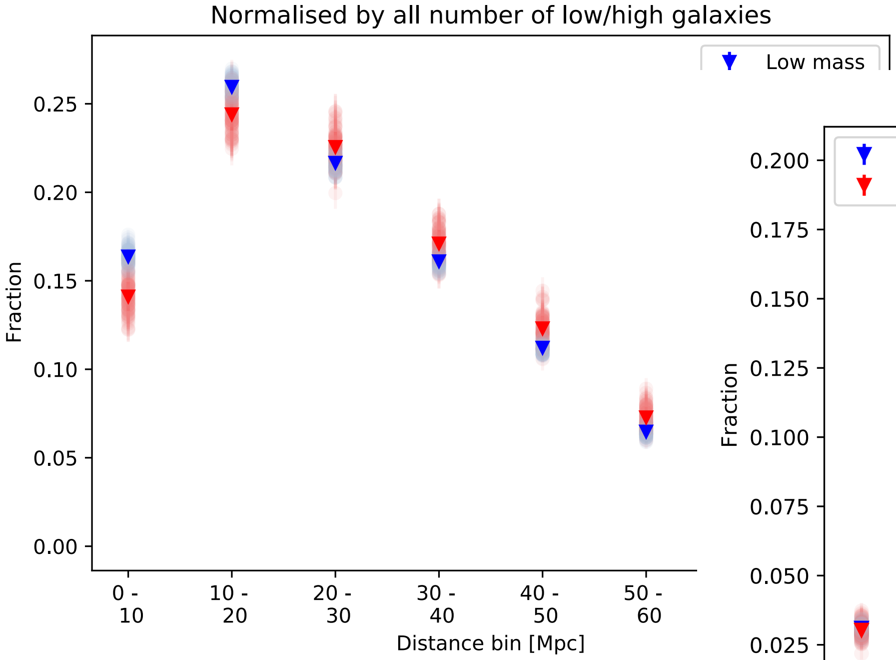


Stellar mass - D_{node}

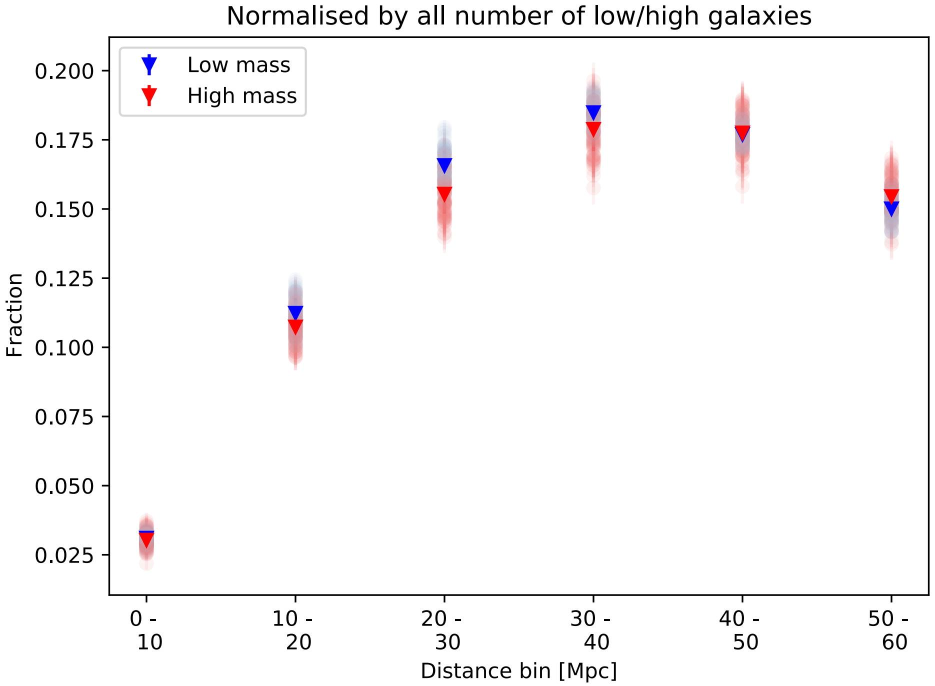
0.2 < z < 0.4



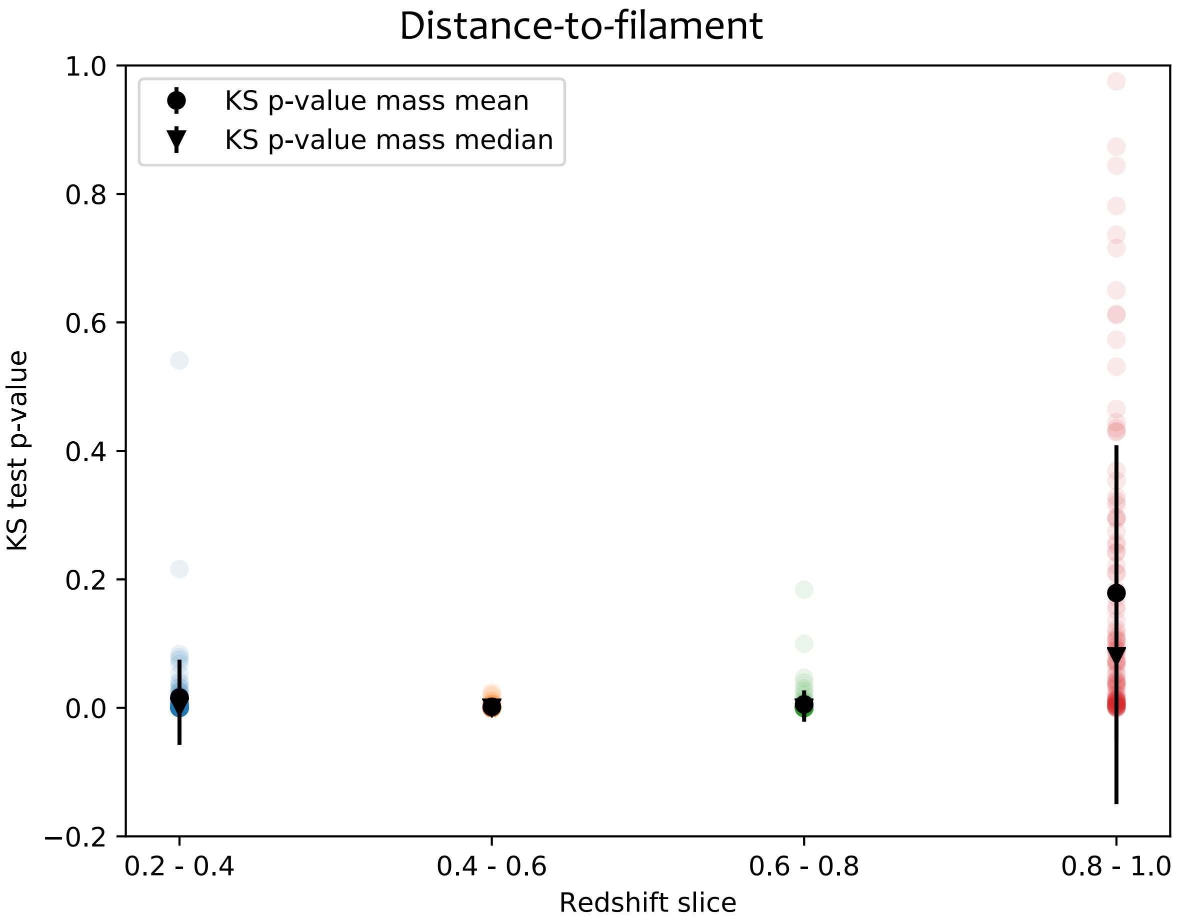
0.4 < z < 0.6

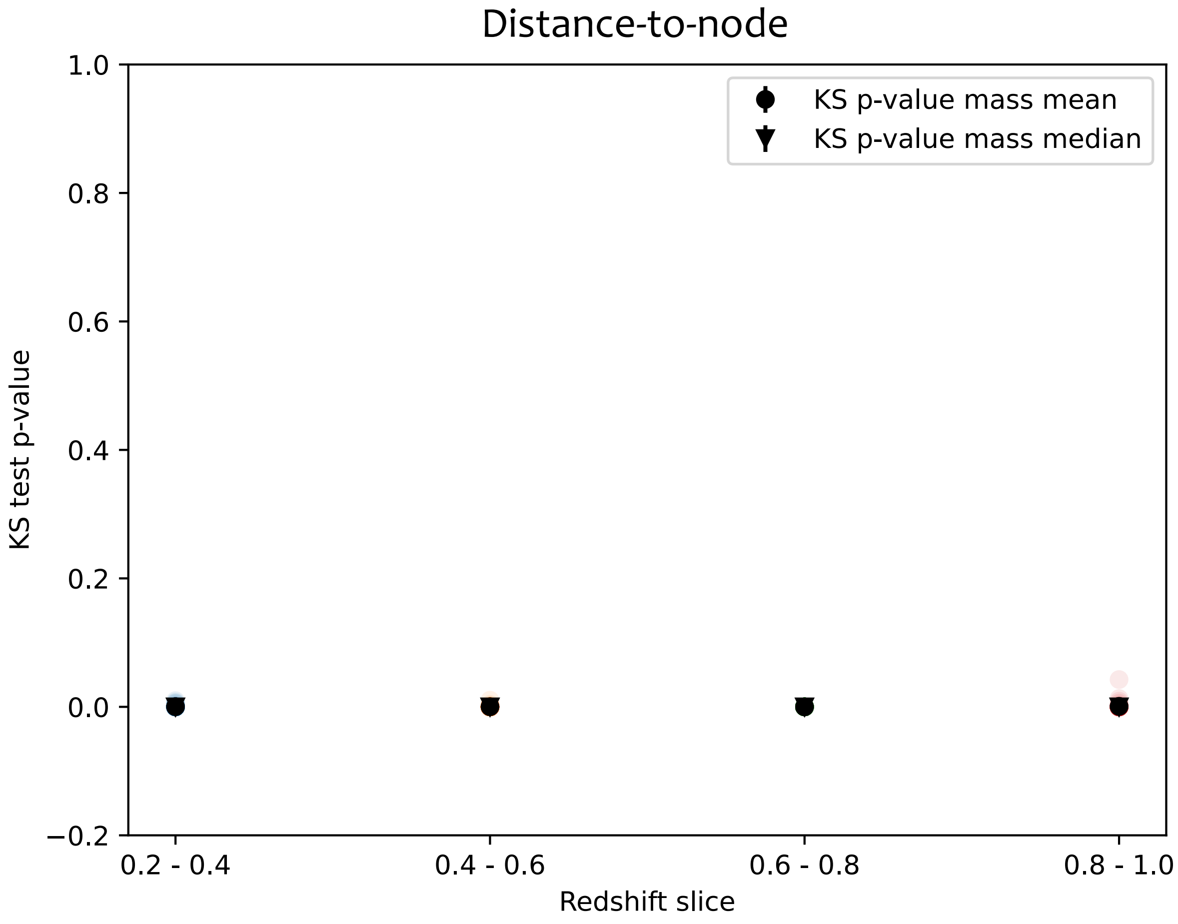


0.8 < z < 1.0

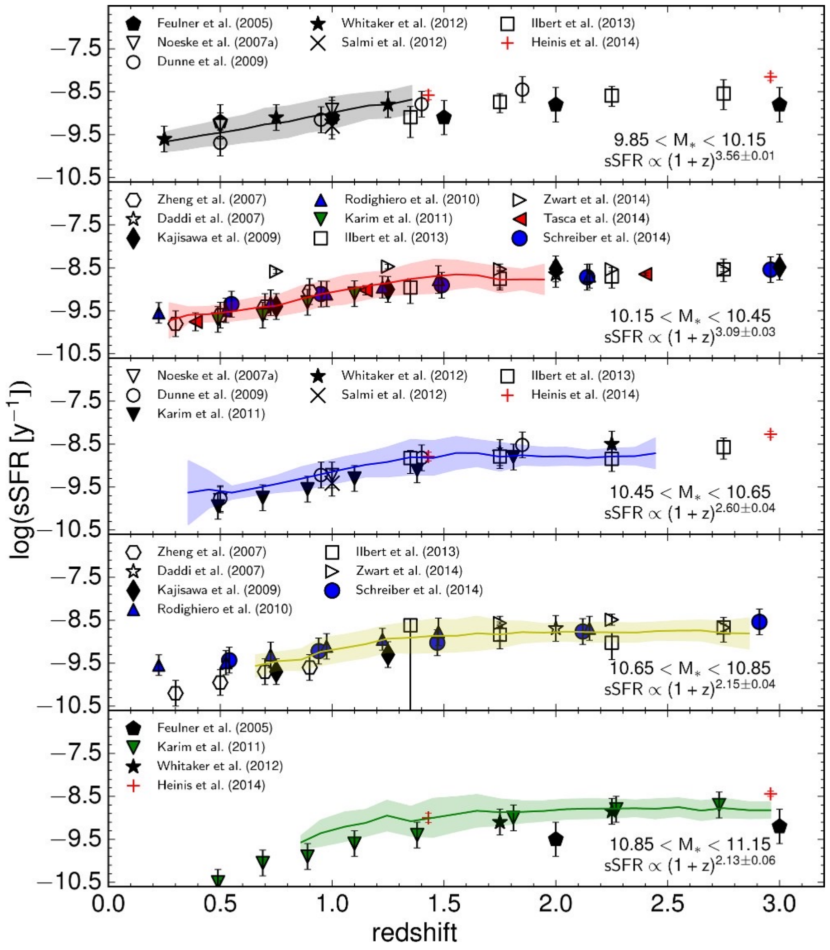


Stellar mass distributions

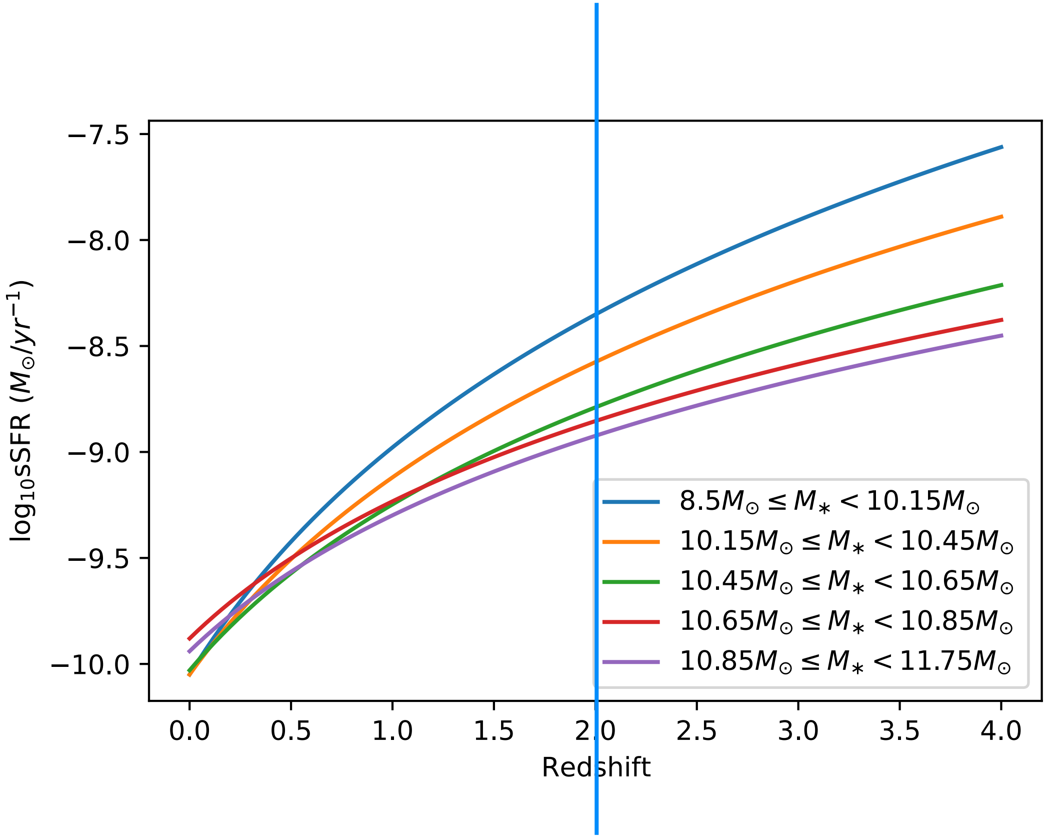




sSFR-z relationship

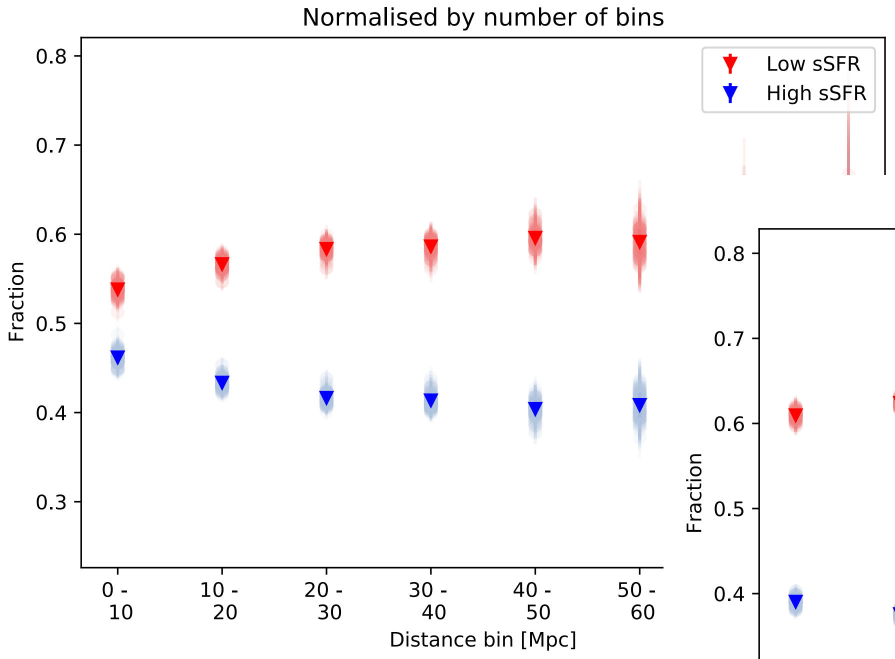


Johnston et al. (2015)

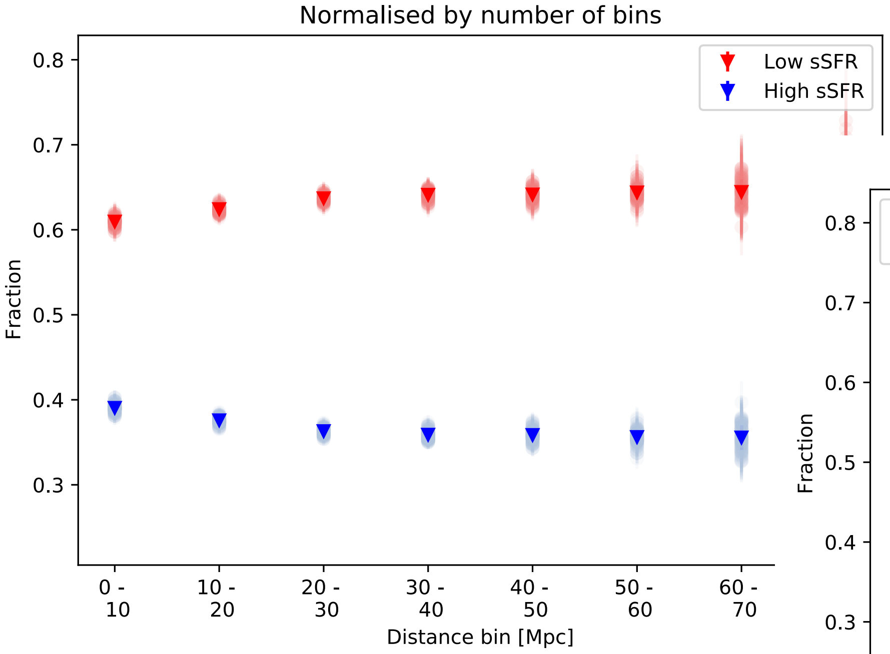


sSFR - D_{fil}

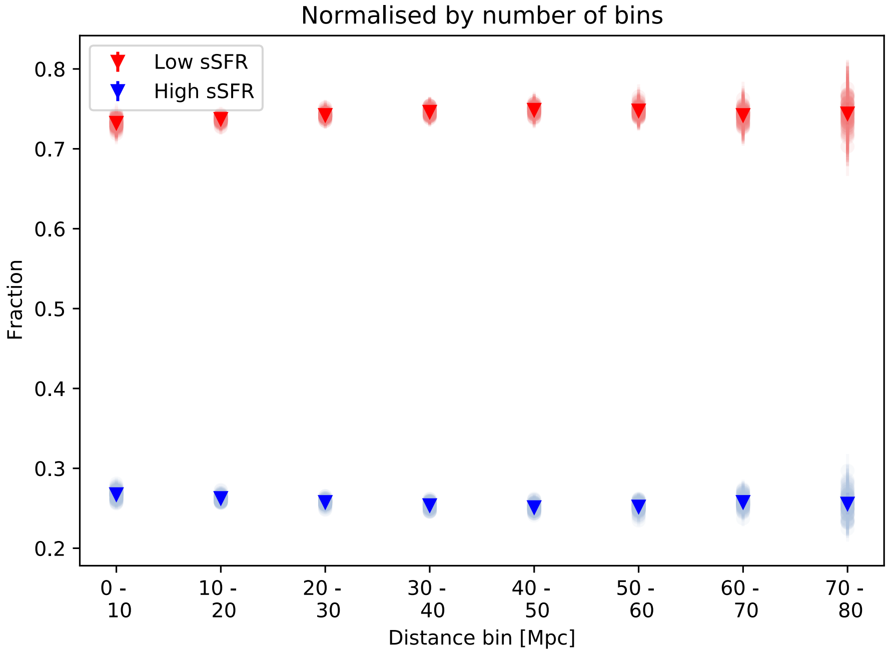
$0.2 < z < 0.4$



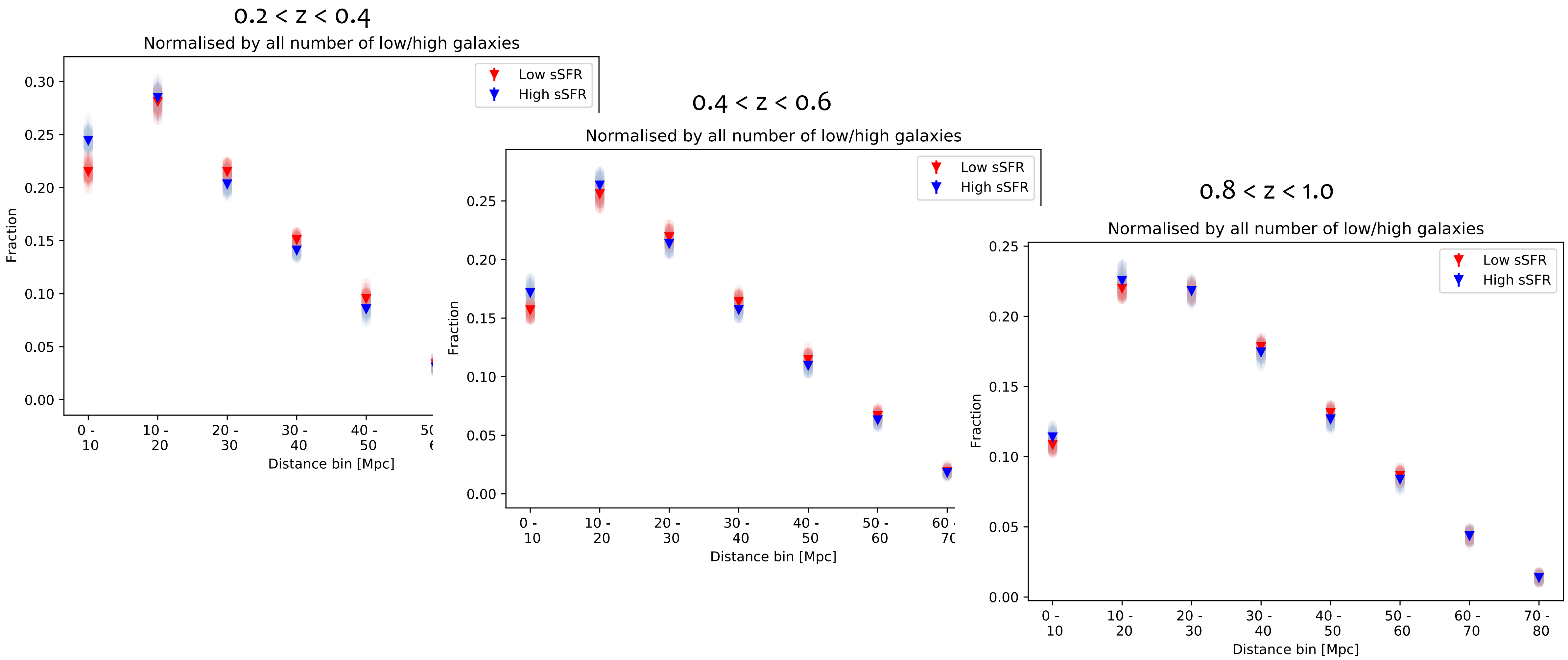
$0.4 < z < 0.6$



$0.8 < z < 1.0$



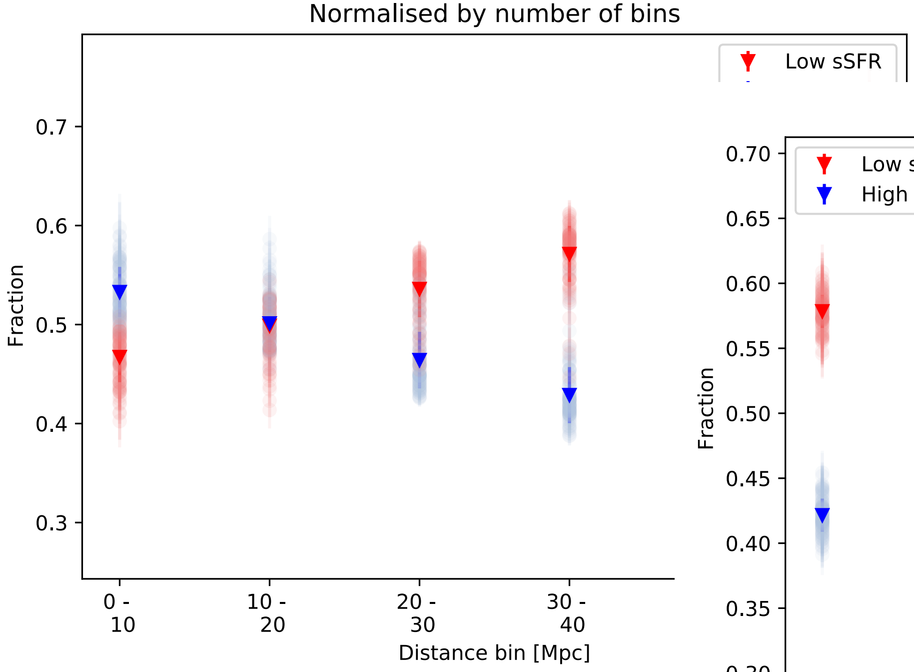
sSFR - D_{fil}



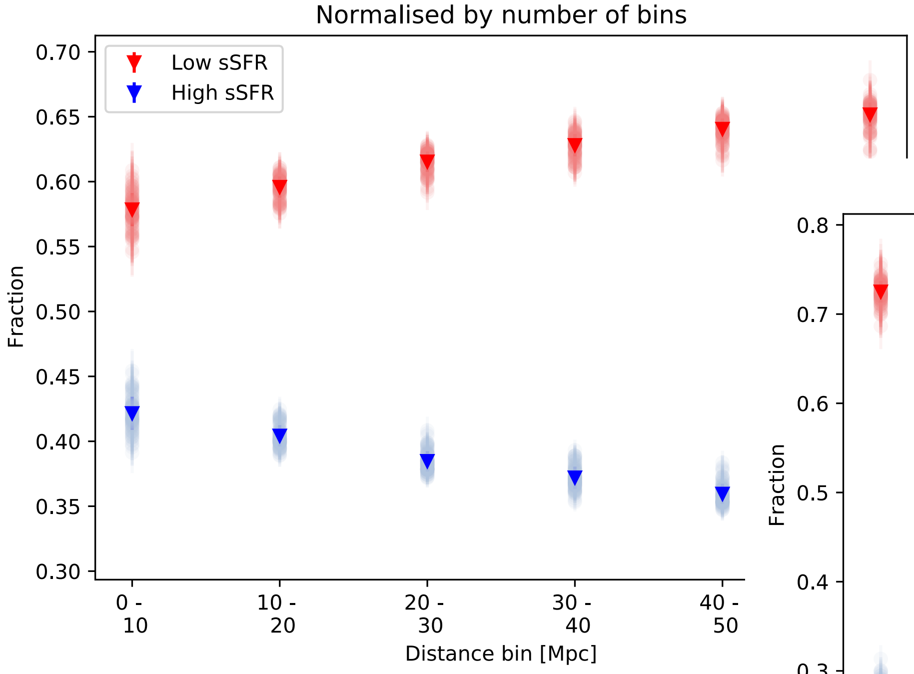
0.2 < z < 0.4
Normalised by all number of low/high galaxies
Low sSFR
High sSFR
Fraction
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
Distance bin [Mpc]
0.4 < z < 0.6
Normalised by all number of low/high galaxies
Low sSFR
High sSFR
Fraction
0.25
0.20
0.15
0.10
0.05
0.00
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
Distance bin [Mpc]
0.8 < z < 1.0
Normalised by all number of low/high galaxies
Low sSFR
High sSFR
Fraction
0.25
0.20
0.15
0.10
0.05
0.00
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
Distance bin [Mpc]

sSFR – D_{node}

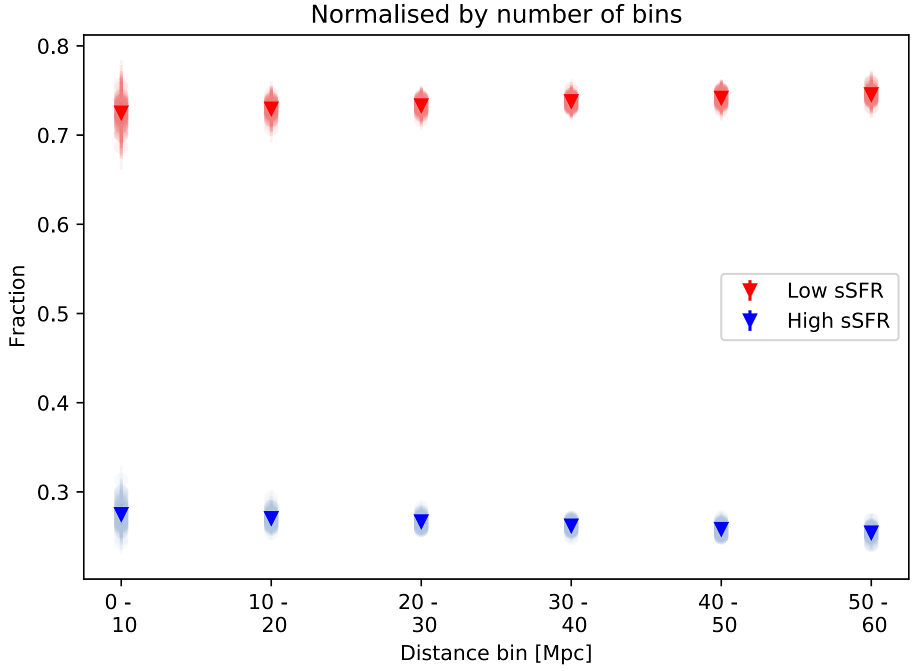
$0.2 < z < 0.4$



$0.4 < z < 0.6$

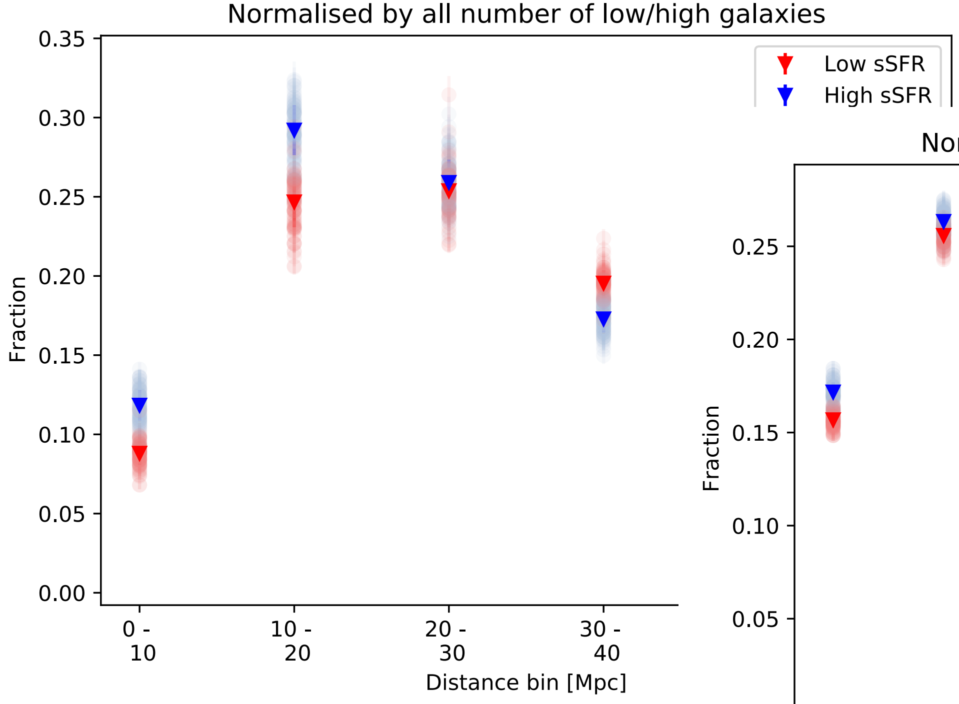


$0.8 < z < 1.0$

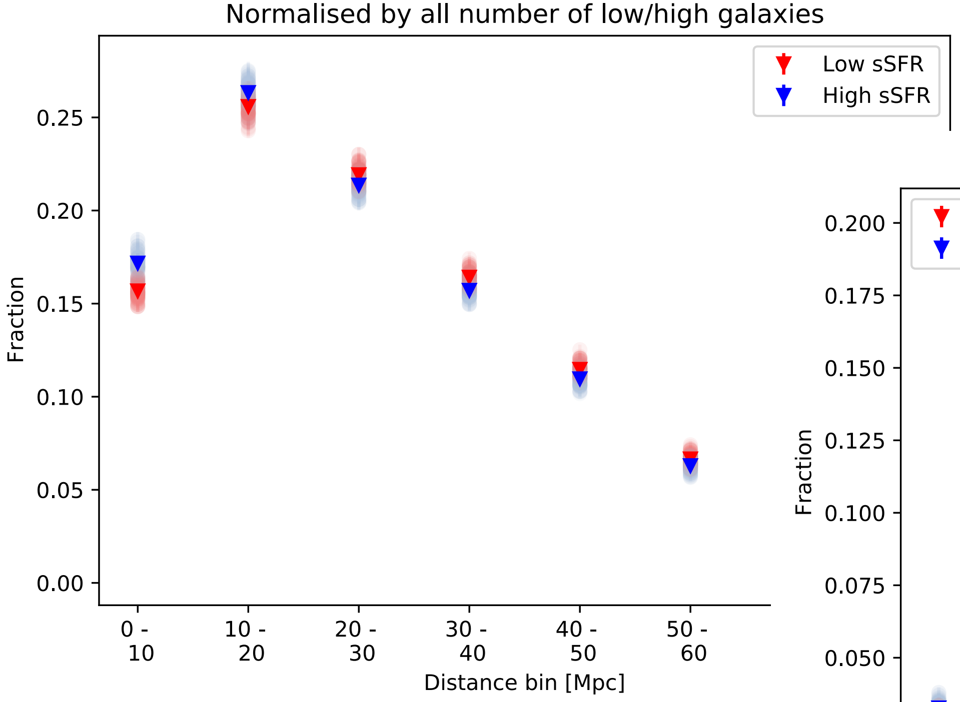


sSFR – D_{node}

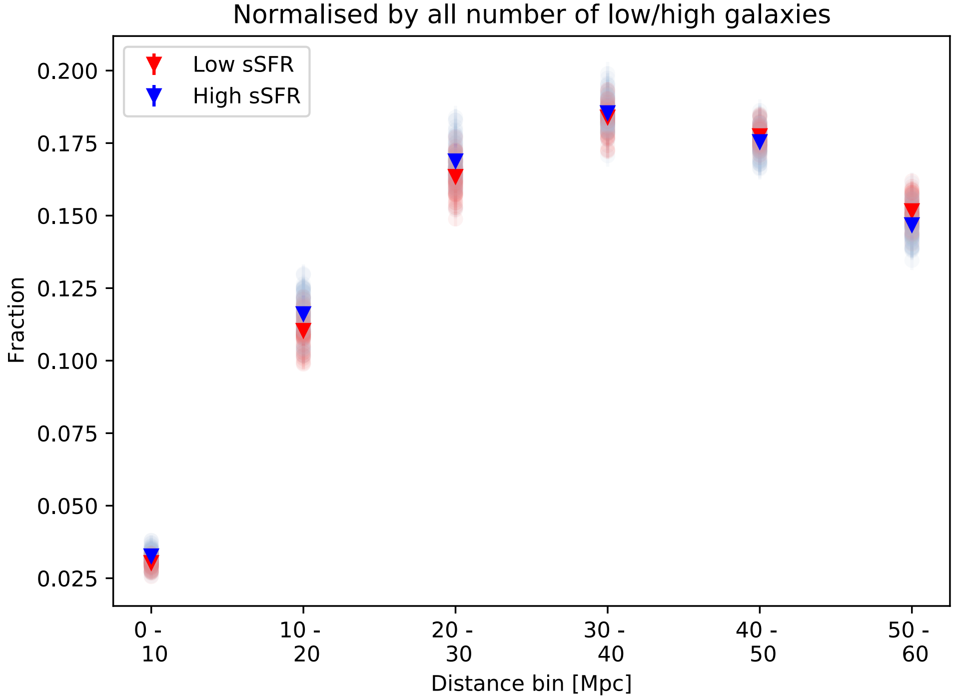
0.2 < z < 0.4



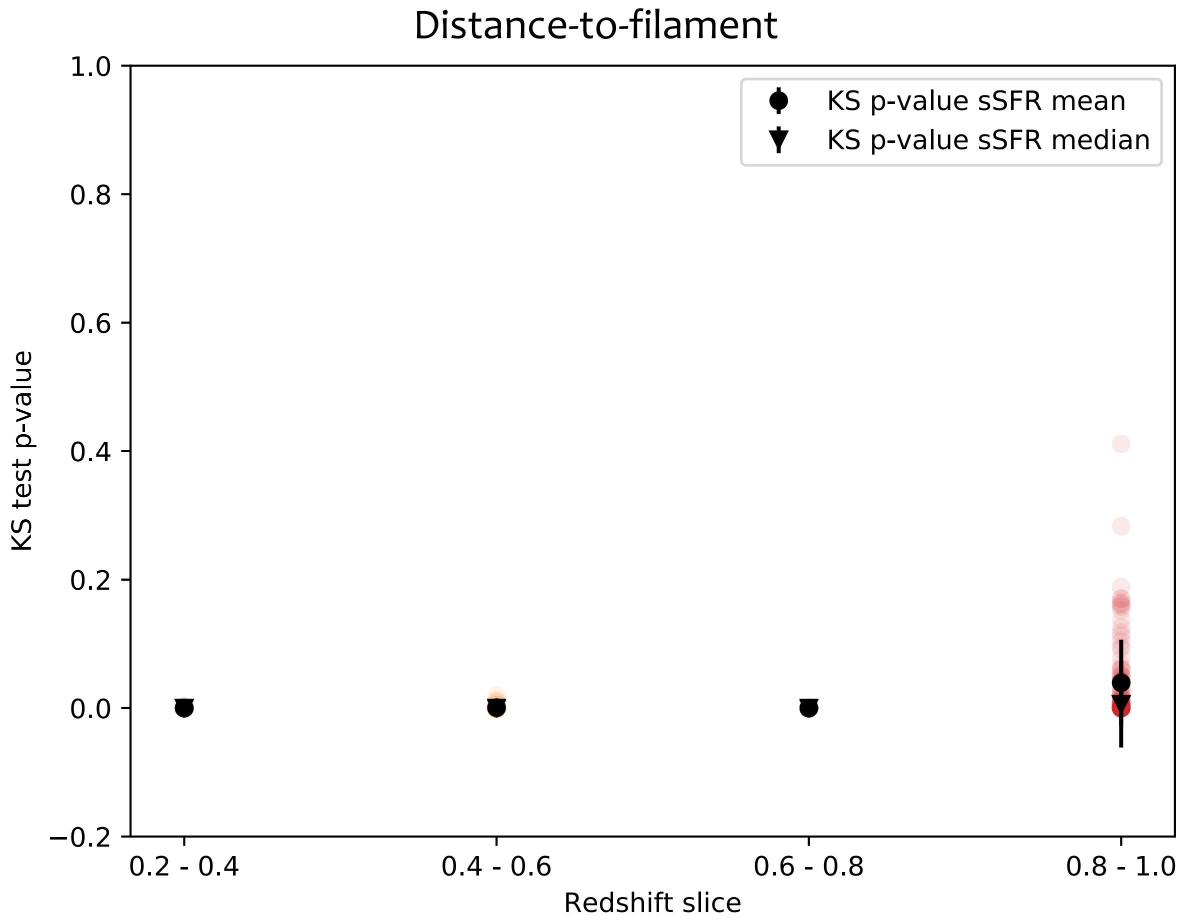
0.4 < z < 0.6

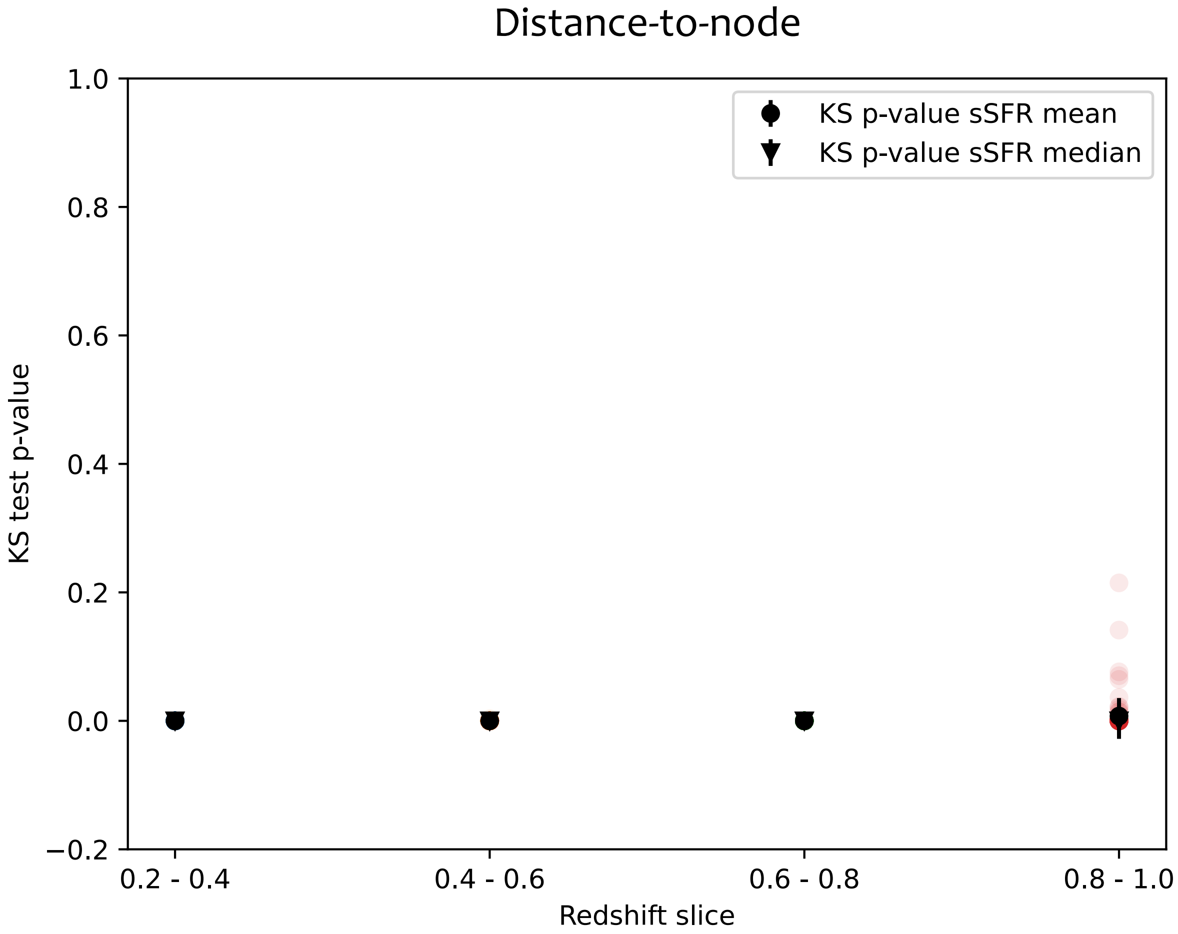


0.8 < z < 1.0



sSFR distributions





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Summary of Part II

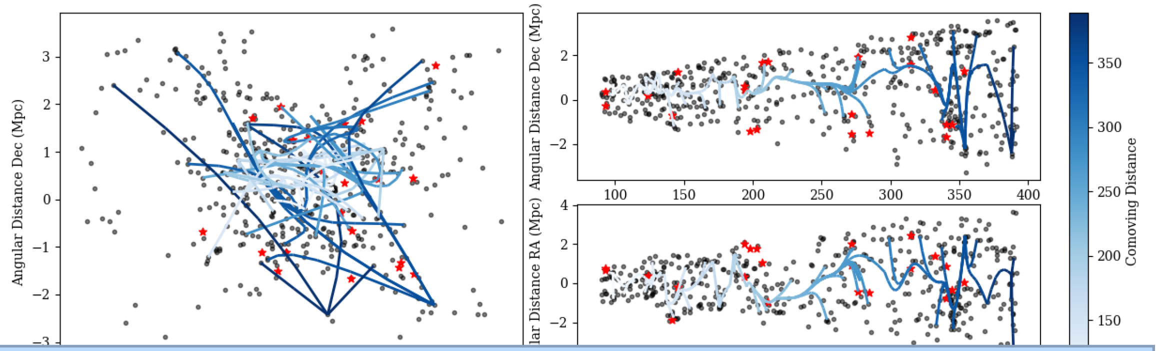
- Used DisPerSE to compute filaments based on the COSMOS and XMM-LSS photometric catalogues and quantified possible filament distributions

- Crossmatching these filaments with galaxies we investigated:
  - Stellar mass and filament/node distance
  - sSFR and filament/node distance

→ Two distinct distributions!

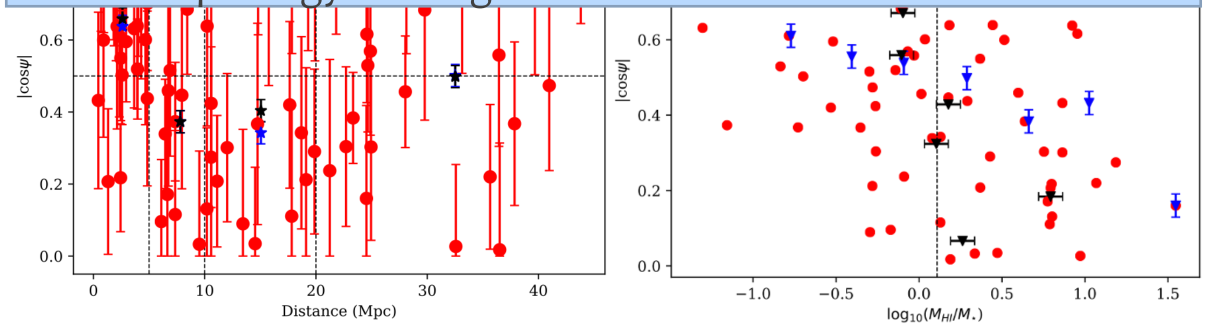
Conclusions

Part I

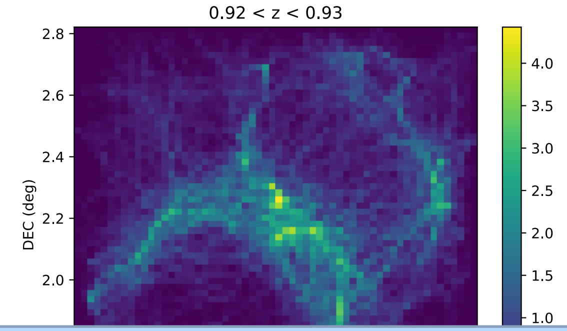


Stellar mass as well as filaments have a strong influence on the spin of galaxies

- Mergers
- Morphology of the galaxies

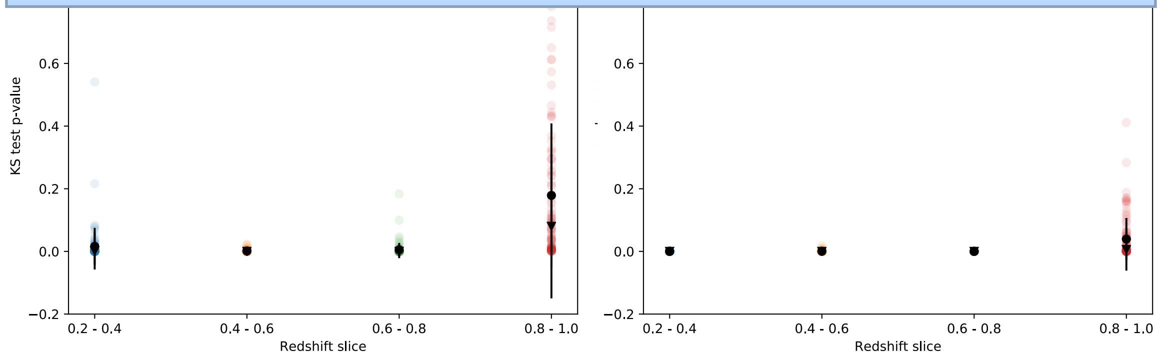


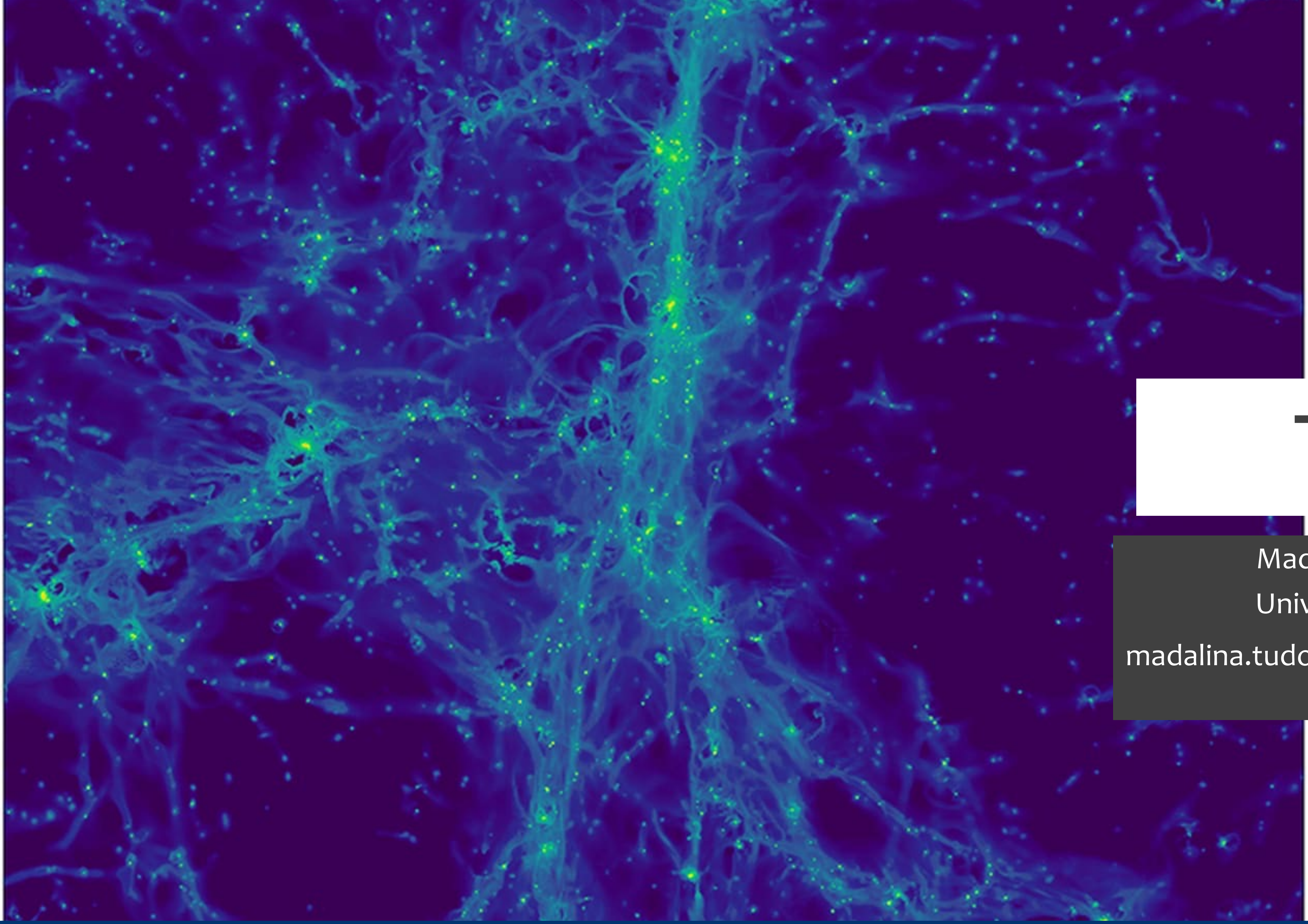
Part II



Filaments can be computed at higher redshifts using photometry

Position of galaxies within filaments will affect their properties





Thank you!

Madalina Tudorache

University of Oxford

madalina.tudorache@physics.ox.ac.uk

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