The relative effect of filaments and nodes on the spin and star-formation of galaxies

Nicola Malavasi

with: Nabila Aghanim, Mathieu Langer, Daniela Galárraga, Céline Gouin

IAS Orsay - ByoPiC team

Latin American Workshop
On Observational Cosmology

14-18/12/2020

The cosmic web

Credits: Horizon-AGN

Matter departs from voids → reaches walls
matter flows inside walls → reaches filaments
matter flows inside filaments → reaches clusters

The cosmic web

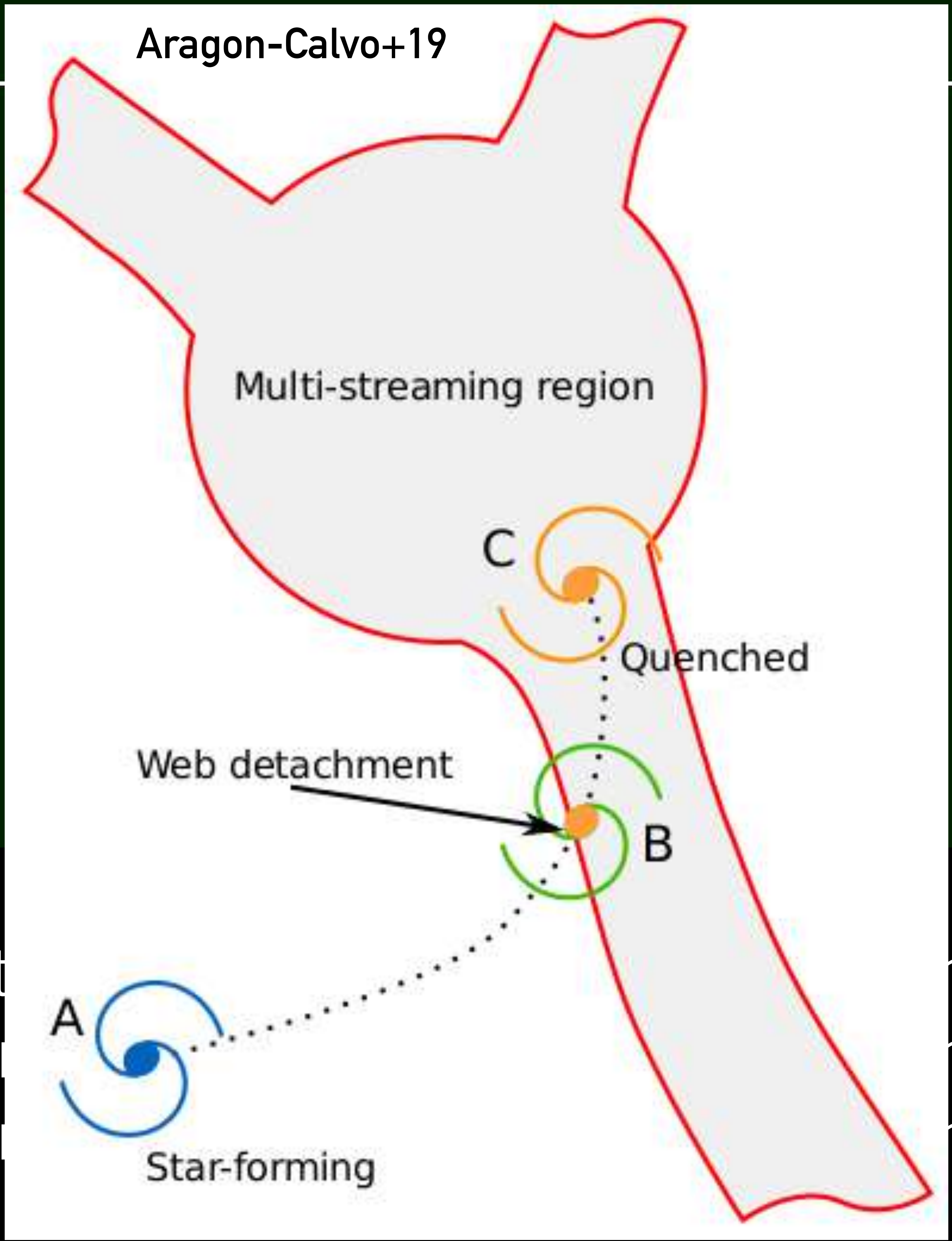
Credits: Horizon-AGN

Matter departs from voids → reaches walls

matter flows inside walls → reaches filaments

matter flows inside filaments → reaches clusters

THE COSMIC WEB

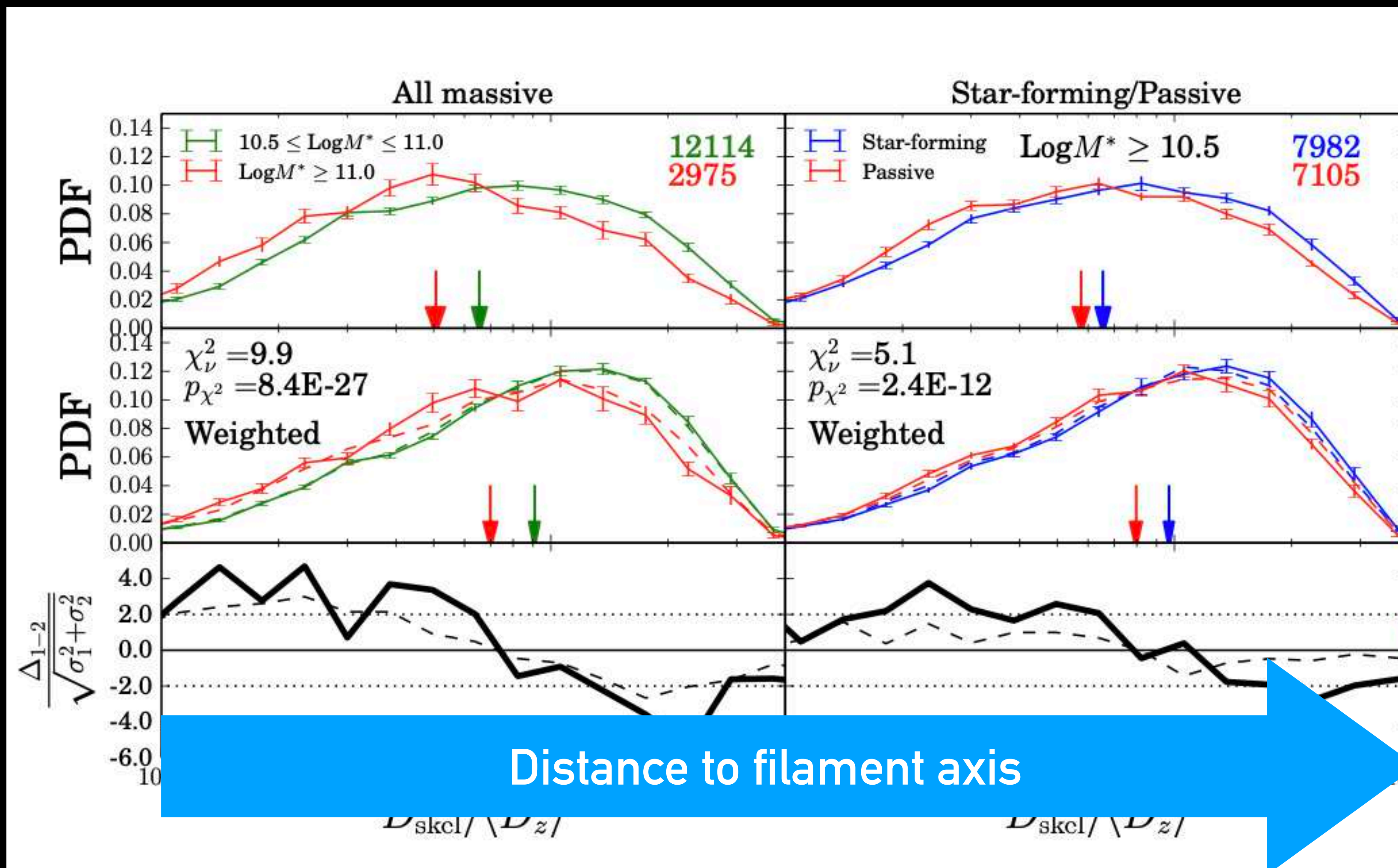


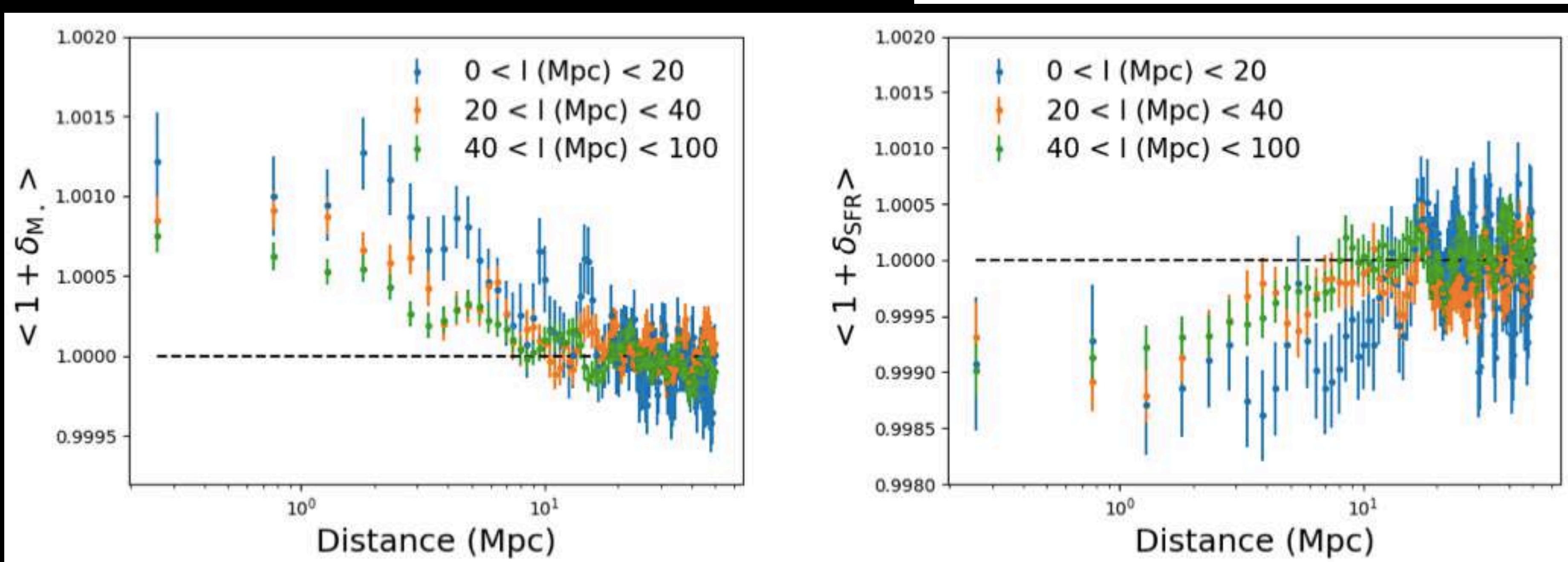
Matter depart… …nes walls
matter flows i… …nes filaments
matter flows i… …nes clusters

The cosmic web & galaxy evolution

Clusters and filaments affect SFR and M* of galaxies.

Malavasi+17: filaments detected in VIPERS. Massive and passive galaxies are closer to the axis of filaments.

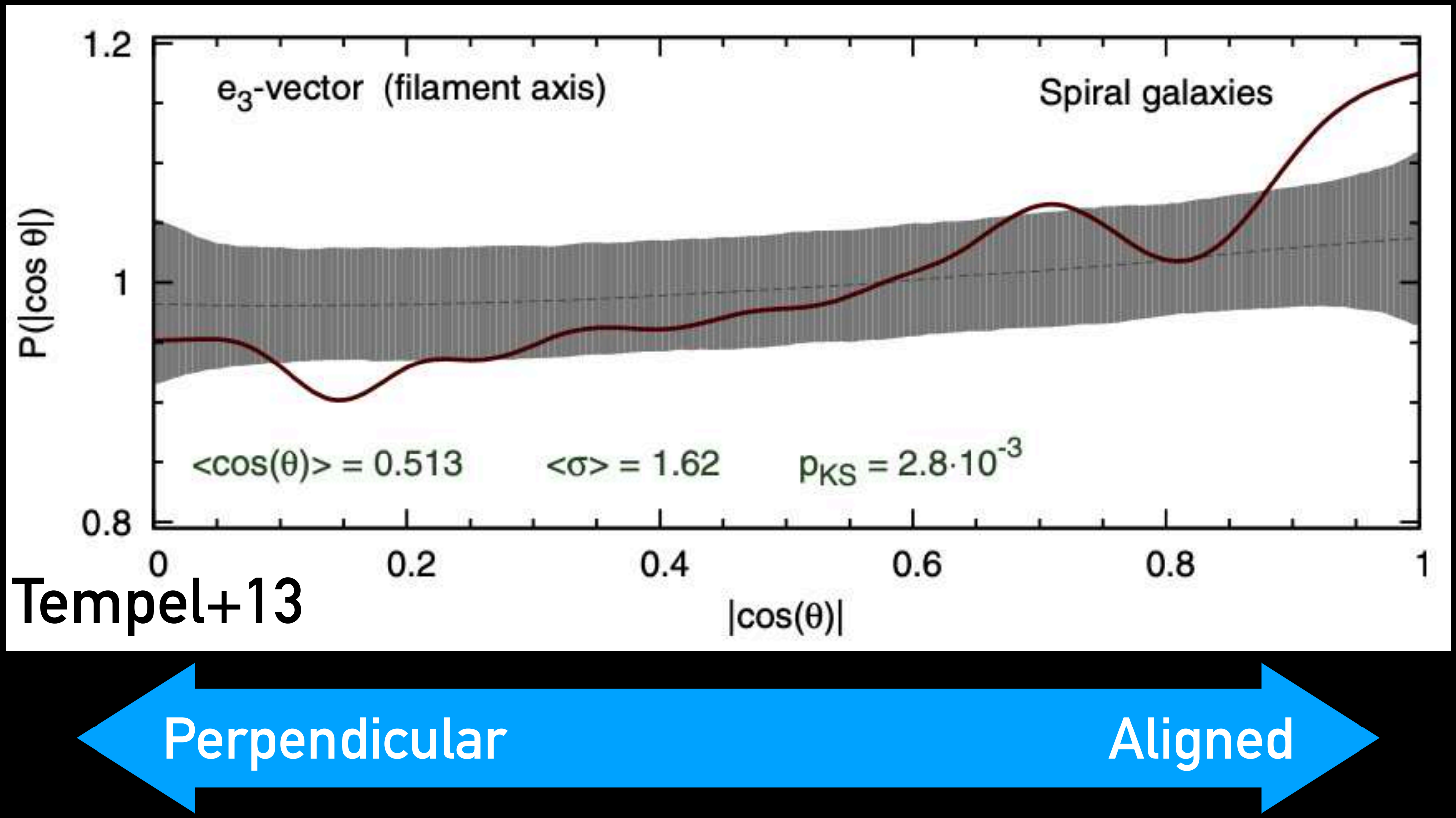




Bonjean+20: filaments detected in the SDSS (Malavasi+20). Gradients of mass and SFR from the axis of filaments.

Laigle+18, Kraljic+18, Salerno+20, Vulcani+19

THE EFFECT OF THE COSMIC WEB: SPIN



Cosine of angle between spin of spiral galaxies and axis of filaments.

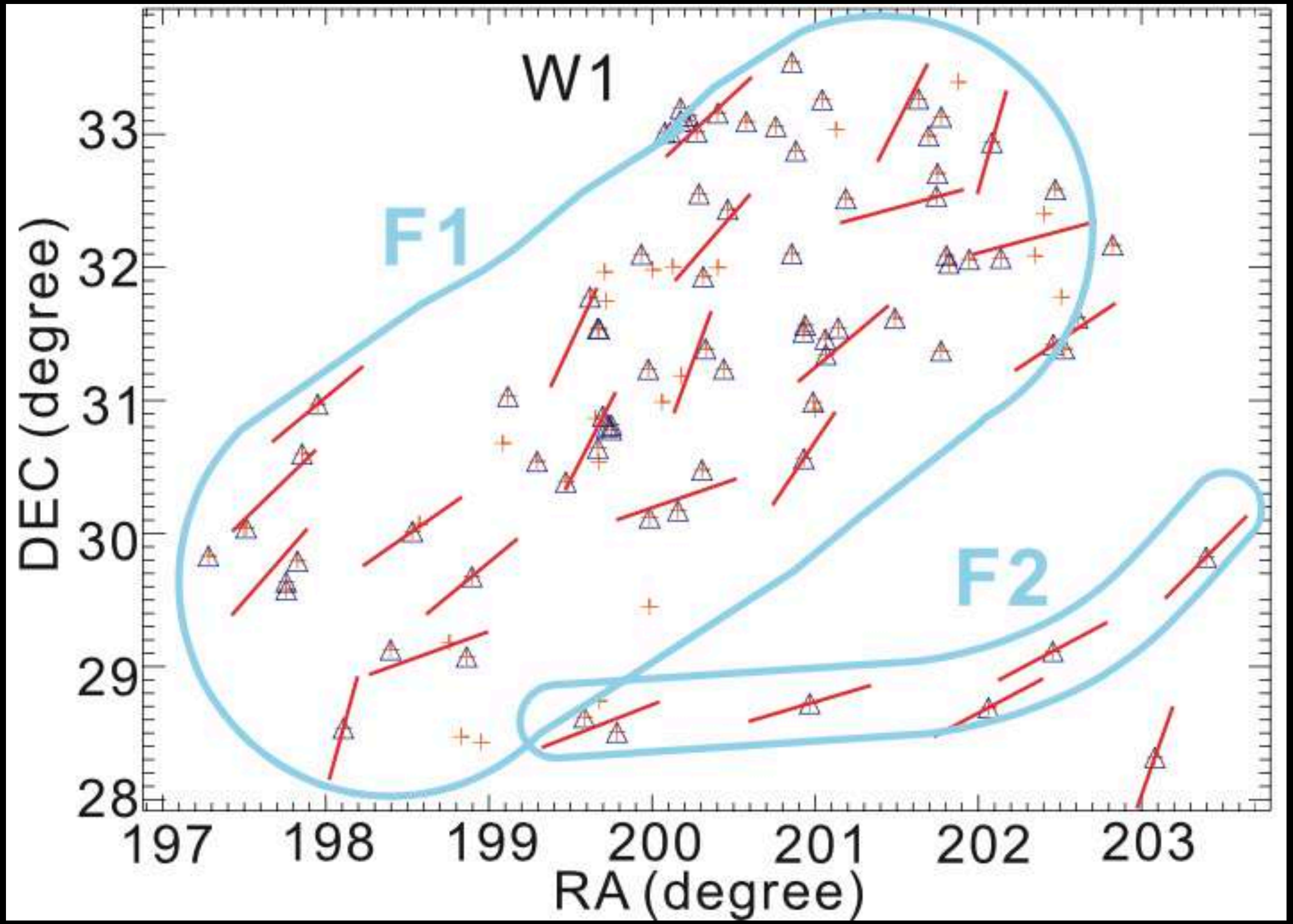
Filament influence on angular momentum of galaxies. The spin of galaxies is aligned or perpendicular with the direction of the filaments.

Codis+18, Ganeshaiah-Veena+19, Krolewski+19, Laigle+15, Welker+19

Our goal

- Which structures affects the most a given property? E.g. is SFR affected more by filaments or clusters?
- Understand which property better traces a given structure: e.g. is it better to use the quenched fraction or the spin to trace filaments?

E.g. use of the red sequence to improve cluster detection algorithms or use of the spin alignment to detect filaments.

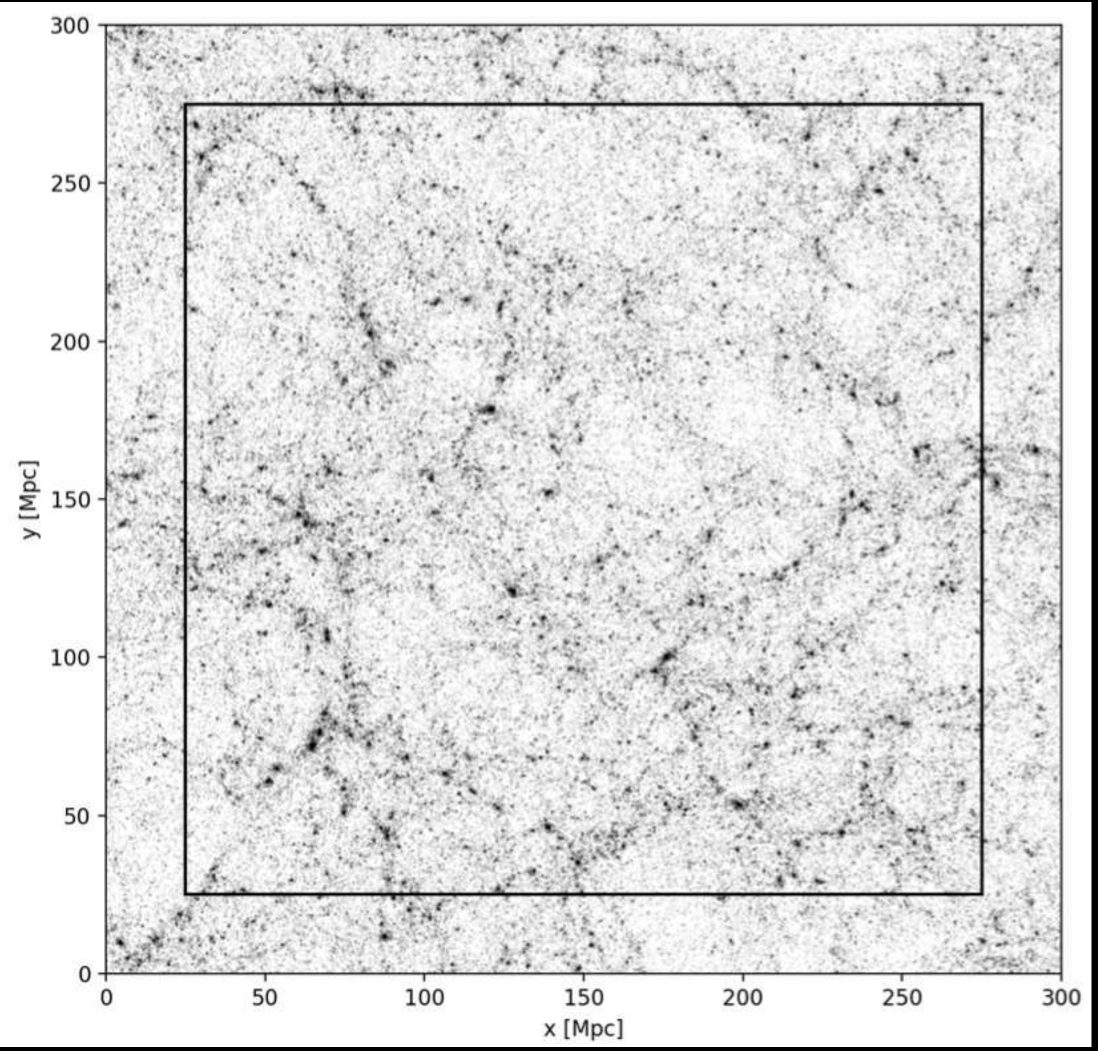


Rong+15: filaments detected around Coma with galaxy alignment.

THE ILLUSTRIS TNG SIMULATION

- IllustrisTNG300-1 cosmological simulation (Nelson+19)
- ~276˙000 subhalos
- ~300 Mpc^3 box
- $10^9 \leq M^*[M_\odot] \leq 10^{12}$
- $z = 0$

	TNG300-1
Box size [Mpc^3]	302.6^3
DM resolution [$M_\odot/h$]	4.0×10^7
Density of tracers [Mpc^{-3}]	10.0×10^{-3}
Cosmology	*Planck* 2015
Number of filaments	5550
Min and Max filament lengths [Mpc]	[0.4, 65.6]
Mean filament length [Mpc]	10.9
Median filament length [Mpc]	8.8

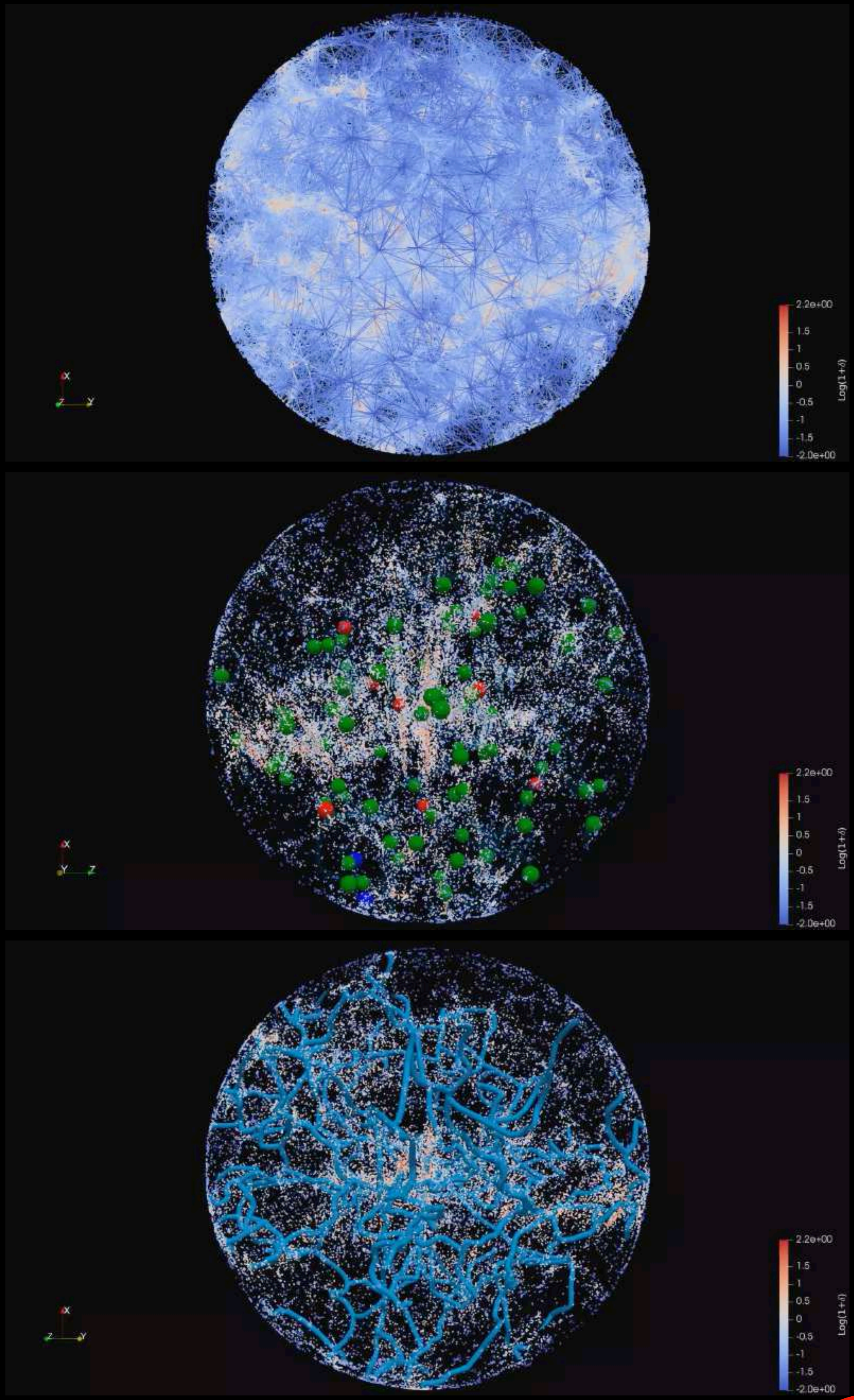


Subhalo selection and filament extraction described in Galárraga-Espinosa+20

The DisPerSE algorithm

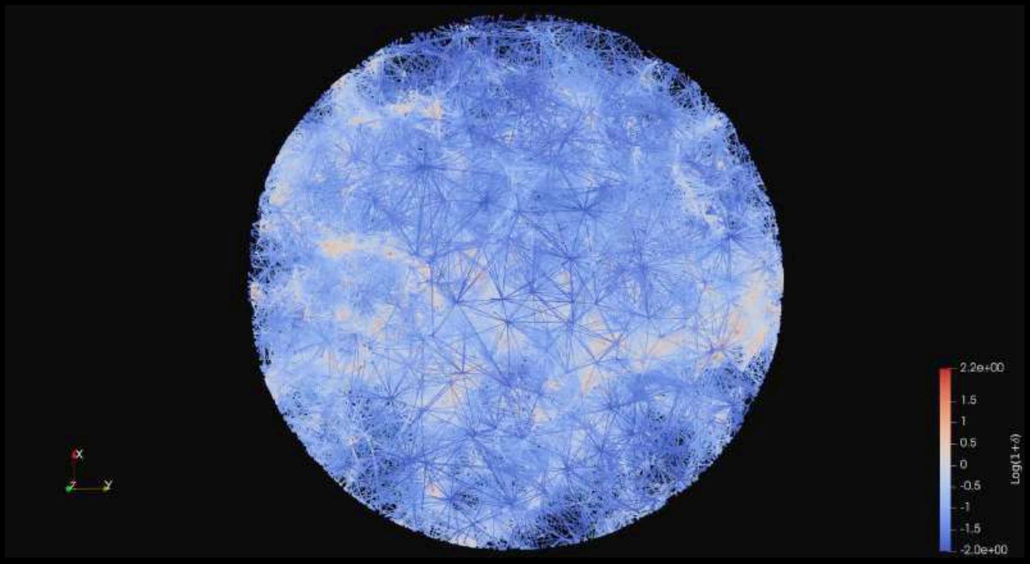
Discrete Persistent Structure Extractor (DisPerSE, Sousbie11, Sousbie+11)

Powerful algorithm, works with discrete density fields, no smoothing necessary.



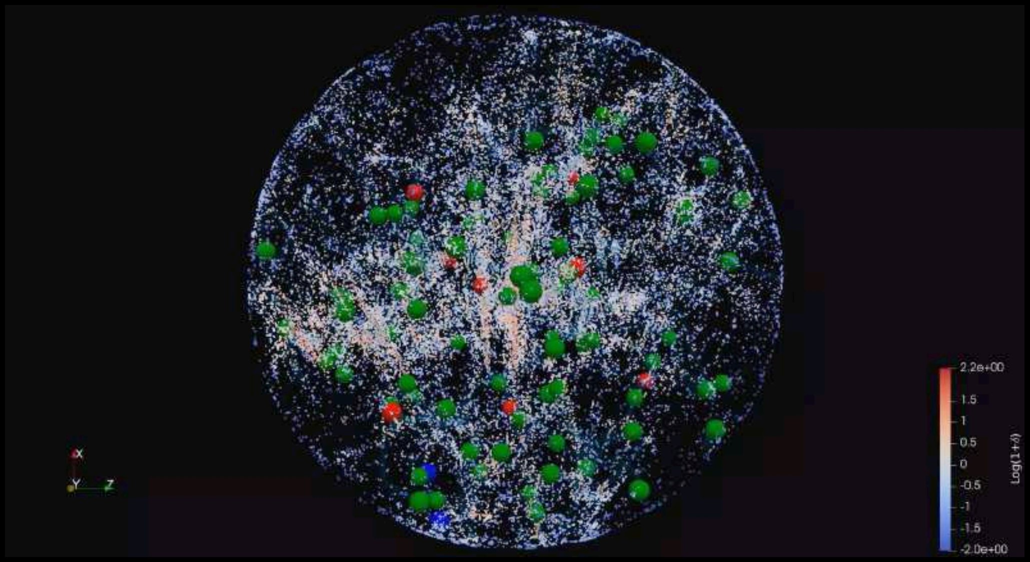
THE DISPERSE ALGORITHM

Measure of the density field (e.g. DTFE)



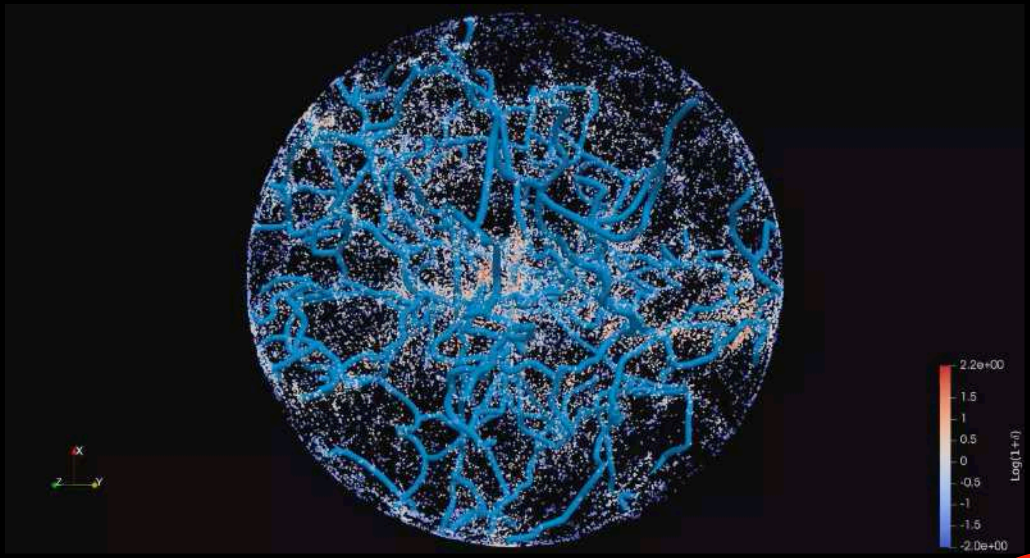
Computation of the discrete gradient

Detection of critical points (maxima, minima, saddles)



Connection of critical points with filaments

Persistence cut to eliminate spurious structures due to noise



THE

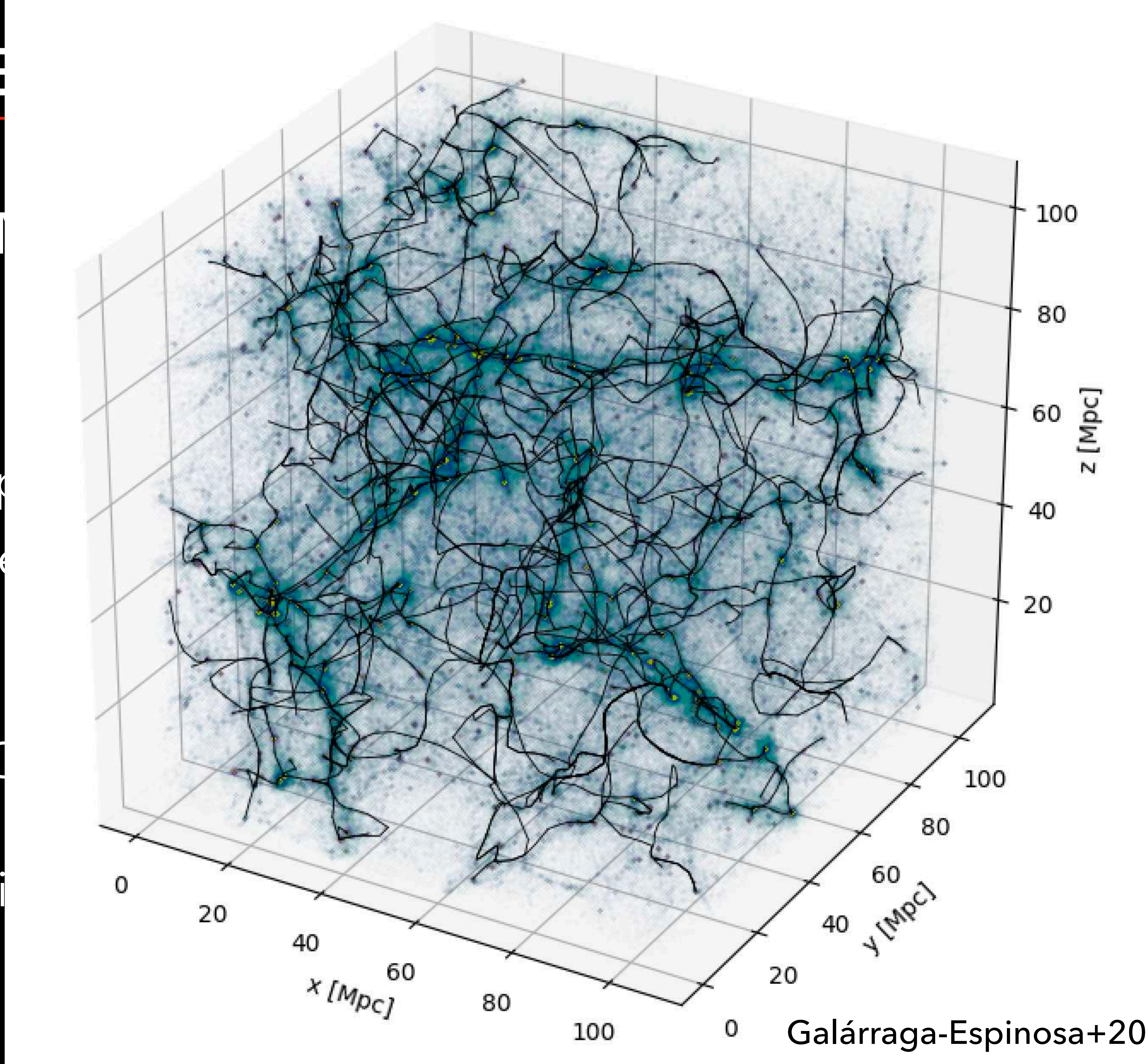
N

Comp

Dete

C

Persi



Galárraga-Espinosa+20

Quantities and distances

Malavasi et al. to be submitted

QUANTITIES AND DISTANCES

- Stellar mass M*

Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_{Q})

Malavasi et al. to be submitted

QUANTITIES AND DISTANCES

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin

  θ - aligned (0°), perpendicular (90°), random (45°)

Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_{Q})
- Angle between filaments and subhalo spin
  θ - aligned (0°), perpendicular (90°), random (45°)
- $\cos(4\theta), f_{||}, f_{\perp}, f_{\mathrm{Ord}}$

Malavasi et al. to be submitted

QUANTITIES AND DISTANCES

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin
  θ - aligned (0°), perpendicular (90°), random (45°)
- $\boxed{\cos(4\theta),}\, f_{||}, f_{\perp}, f_{\rm Ord}$

Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_{Q})
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\boxed{\cos(4\theta)}$, $f_{||}$, $f_{\perp}$, f_{Ord}

Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\cos(4\theta)$, $f_{||}$, $f_{\perp}$, f_{Ord}

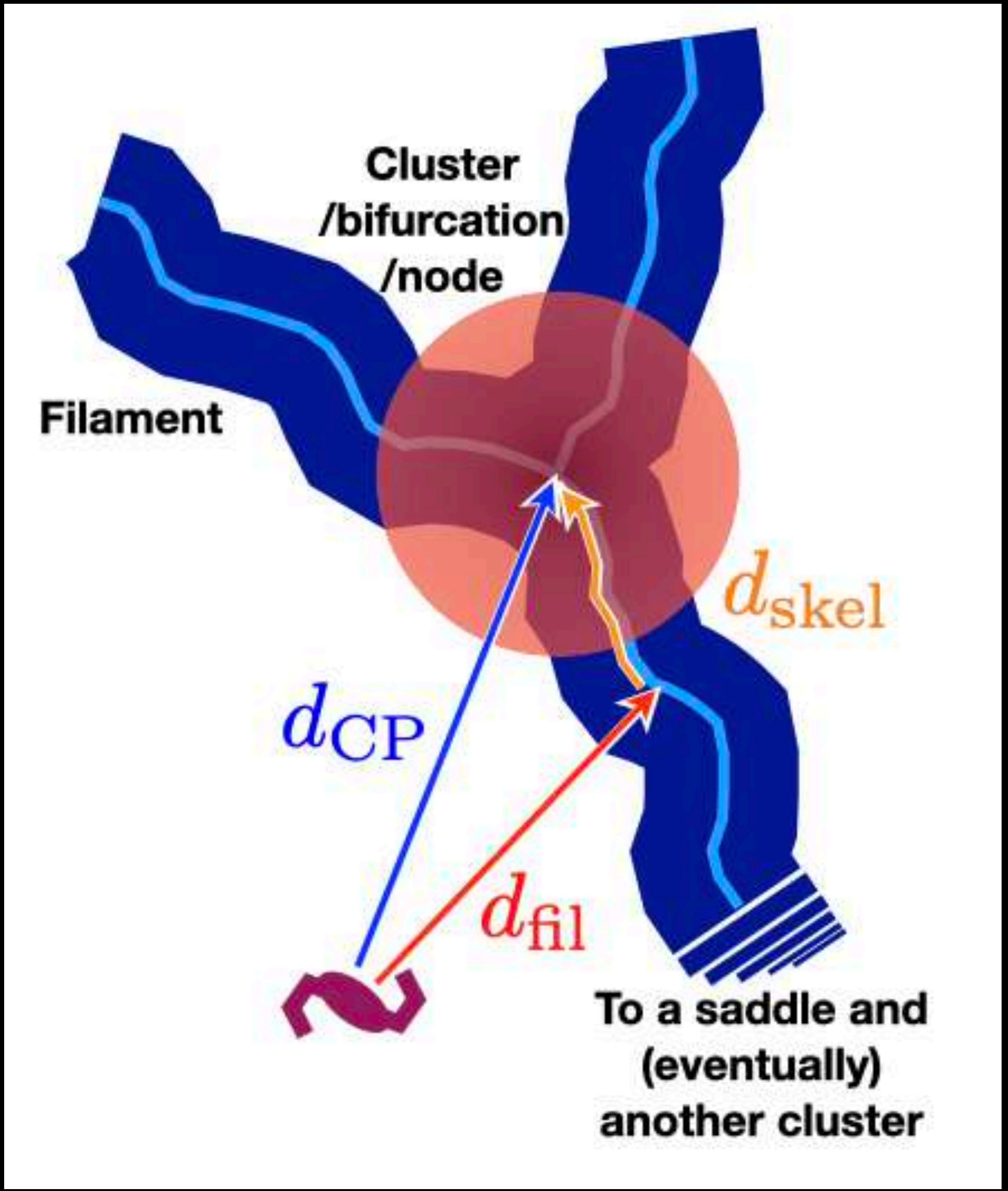
Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\cos(4\theta)$, $f_{||}$, $f_{\perp}$, f_{Ord}

We focus on the following distances:

- Distance from the nodes (for haloes outside of 1 Mpc from filament axis)
- Distance from the axis of filaments
- Distance from the nodes following the filaments (for haloes within 1 Mpc from filament axis)



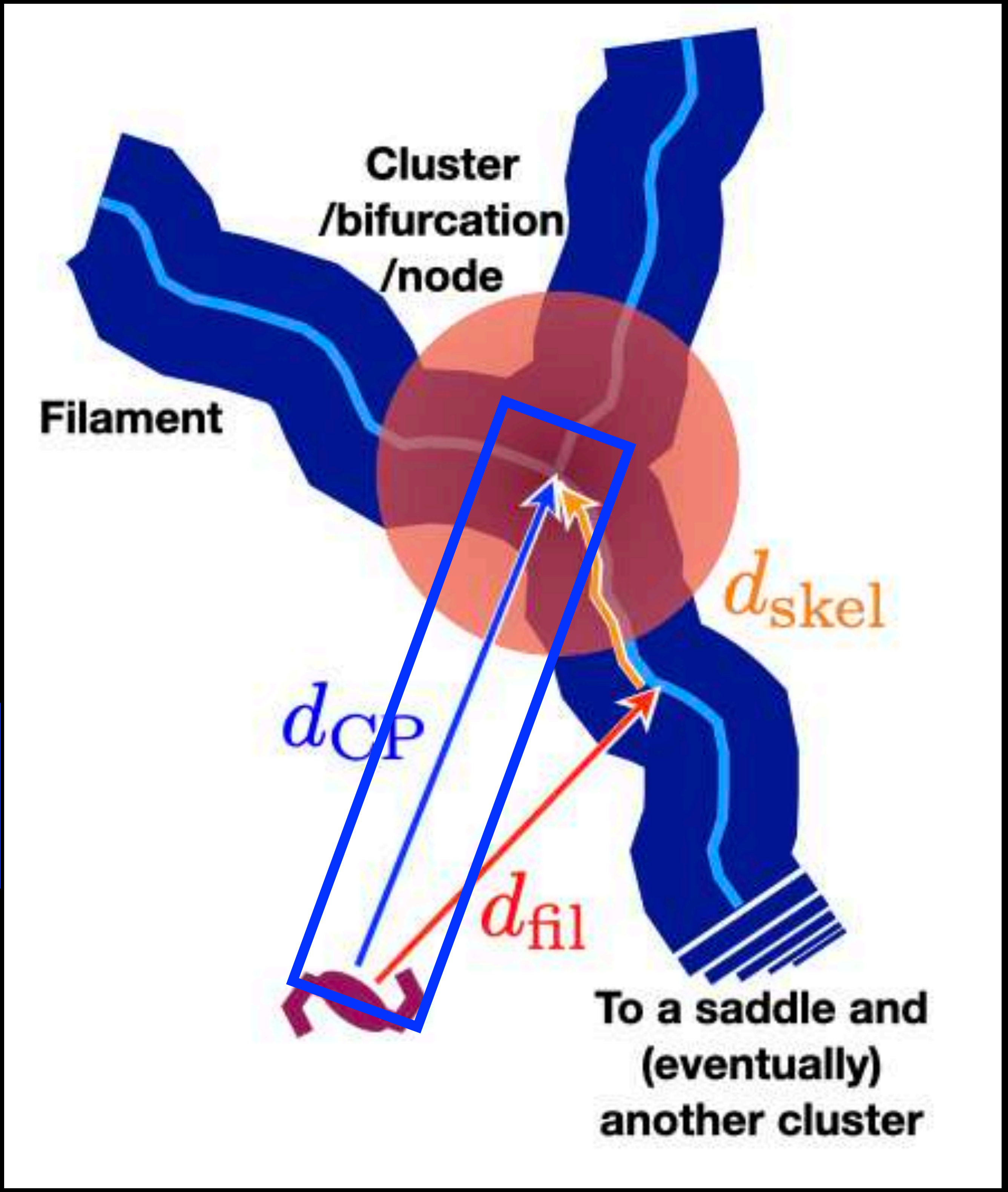
Malavasi et al. to be submitted

Quantities and distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\boxed{\cos(4\theta)}, f_{||}, f_{\perp}, f_{\mathrm{Ord}}$

We focus on the following distances:

- Distance from the nodes (for haloes outside of 1 Mpc from filament axis)
- Distance from the axis of filaments
- Distance from the nodes following the filaments (for haloes within 1 Mpc from filament axis)

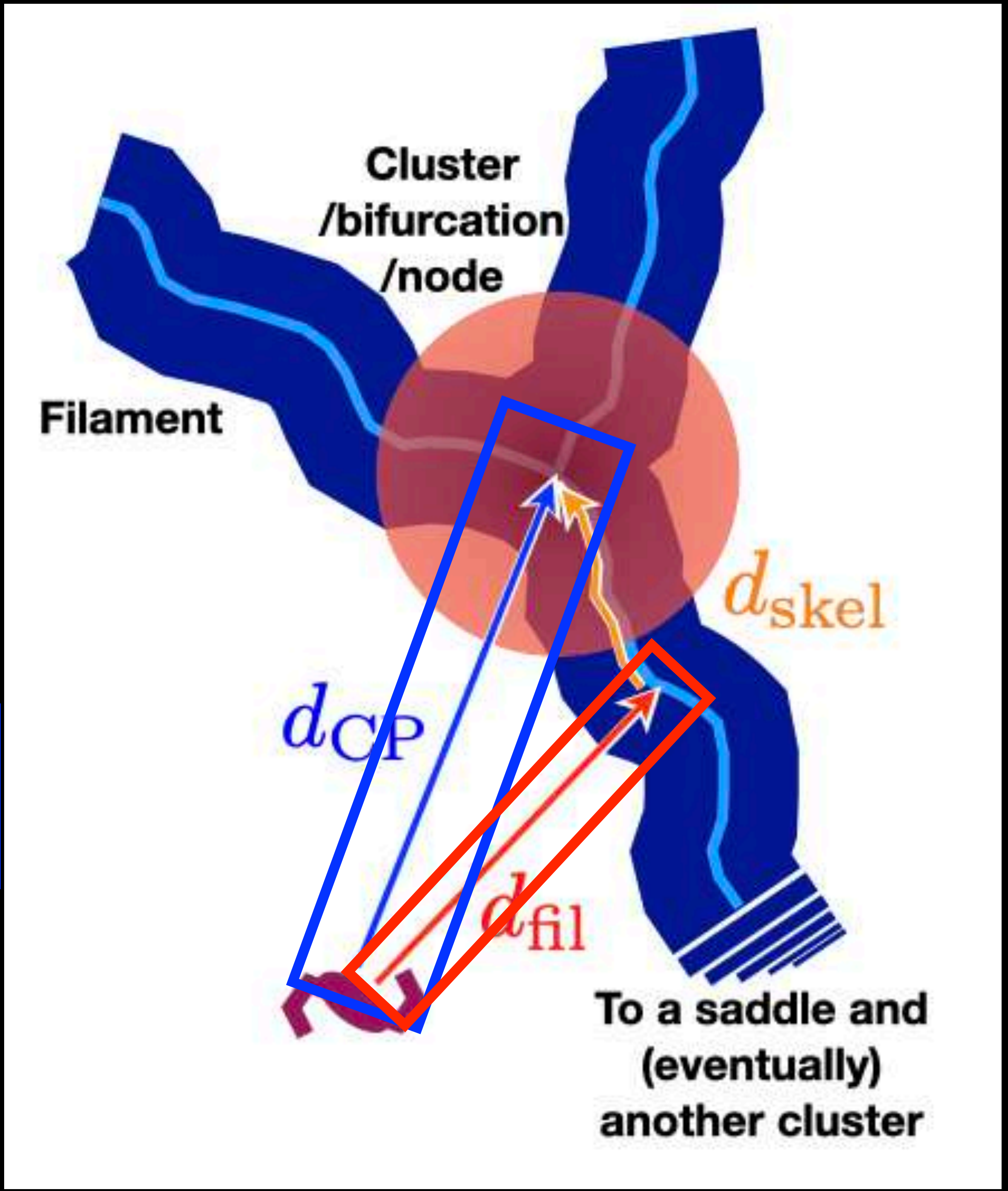


Quantities and Distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_{Q})
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\cos(4\theta)$, $f_{||}, f_{\perp}, f_{\mathrm{Ord}}$

We focus on the following distances:

- Distance from the nodes (for haloes outside of 1 Mpc from filament axis)
- Distance from the axis of filaments
- Distance from the nodes following the filaments (for haloes within 1 Mpc from filament axis)



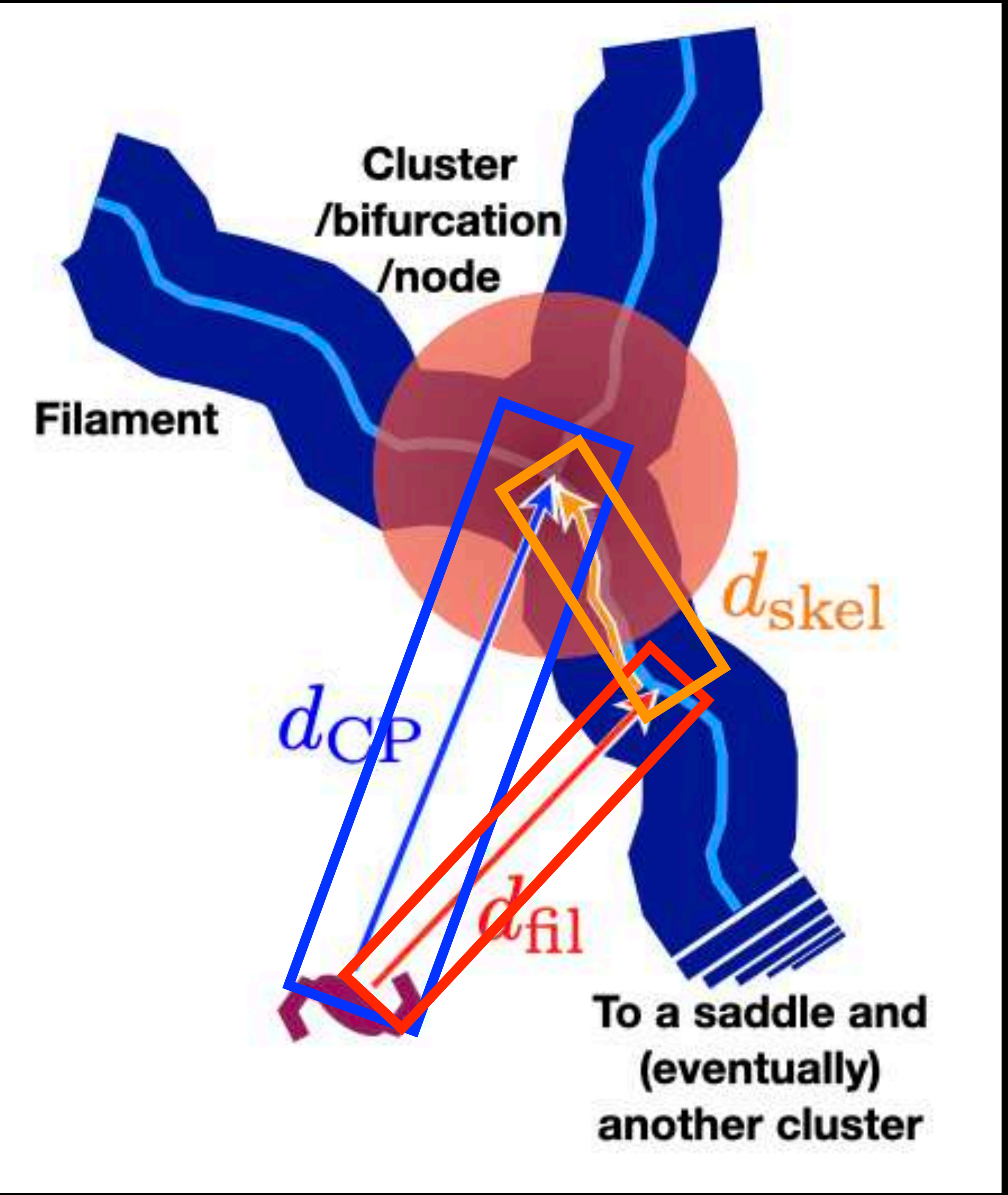
Malavasi et al. to be submitted

Quantities and Distances

- Stellar mass M*
- Star-formation (SFR, sSFR, f_Q)
- Angle between filaments and subhalo spin θ - aligned (0°), perpendicular (90°), random (45°)
- $\cos(4\theta), f_{||}, f_{\perp}, f_{\mathrm{Ord}}$

We focus on the following distances:

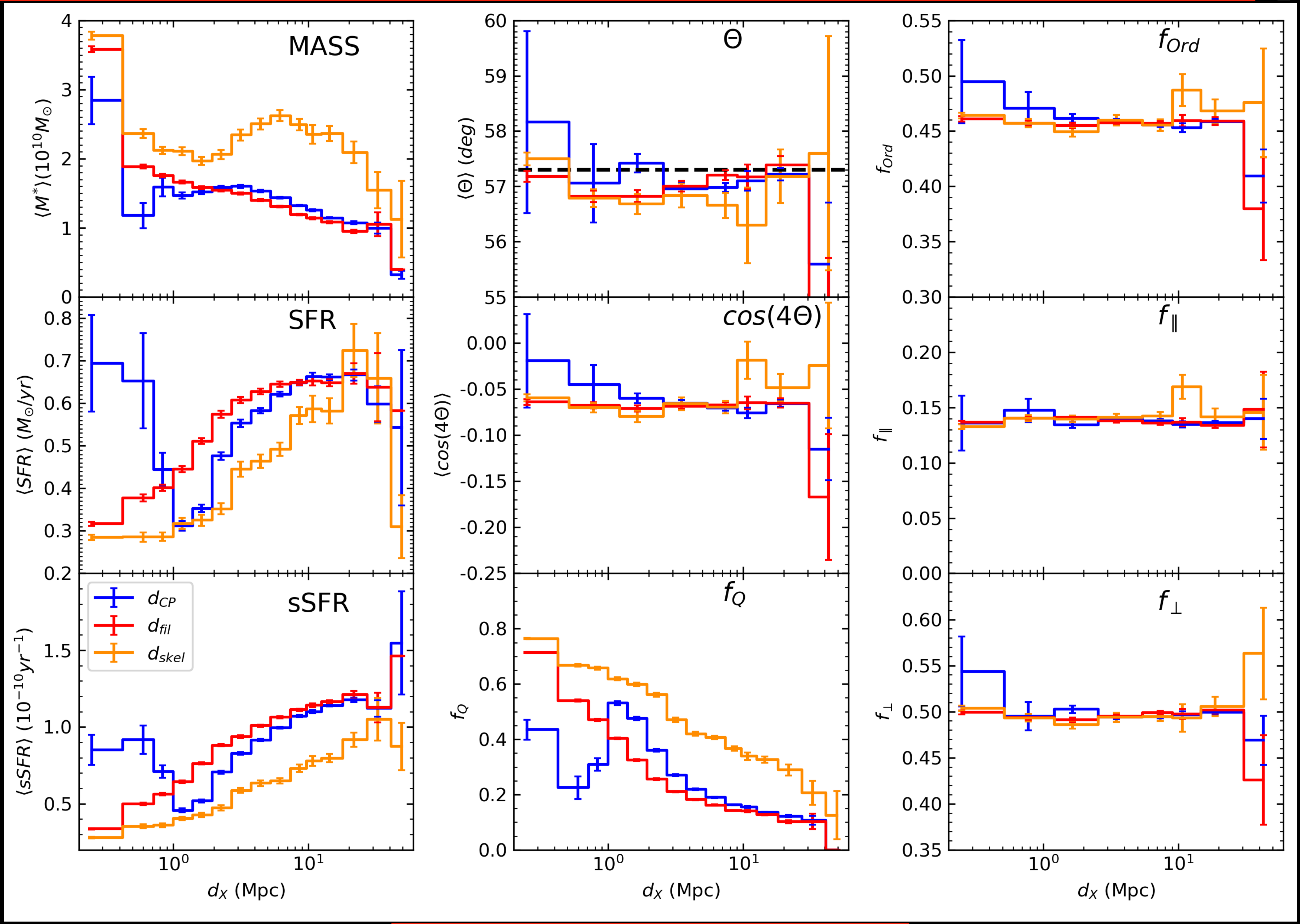
- Distance from the nodes (for haloes outside of 1 Mpc from filament axis)
- Distance from the axis of filaments
- Distance from the nodes following the filaments (for haloes within 1 Mpc from filament axis)



Malavasi et al. to be submitted

RESULTS

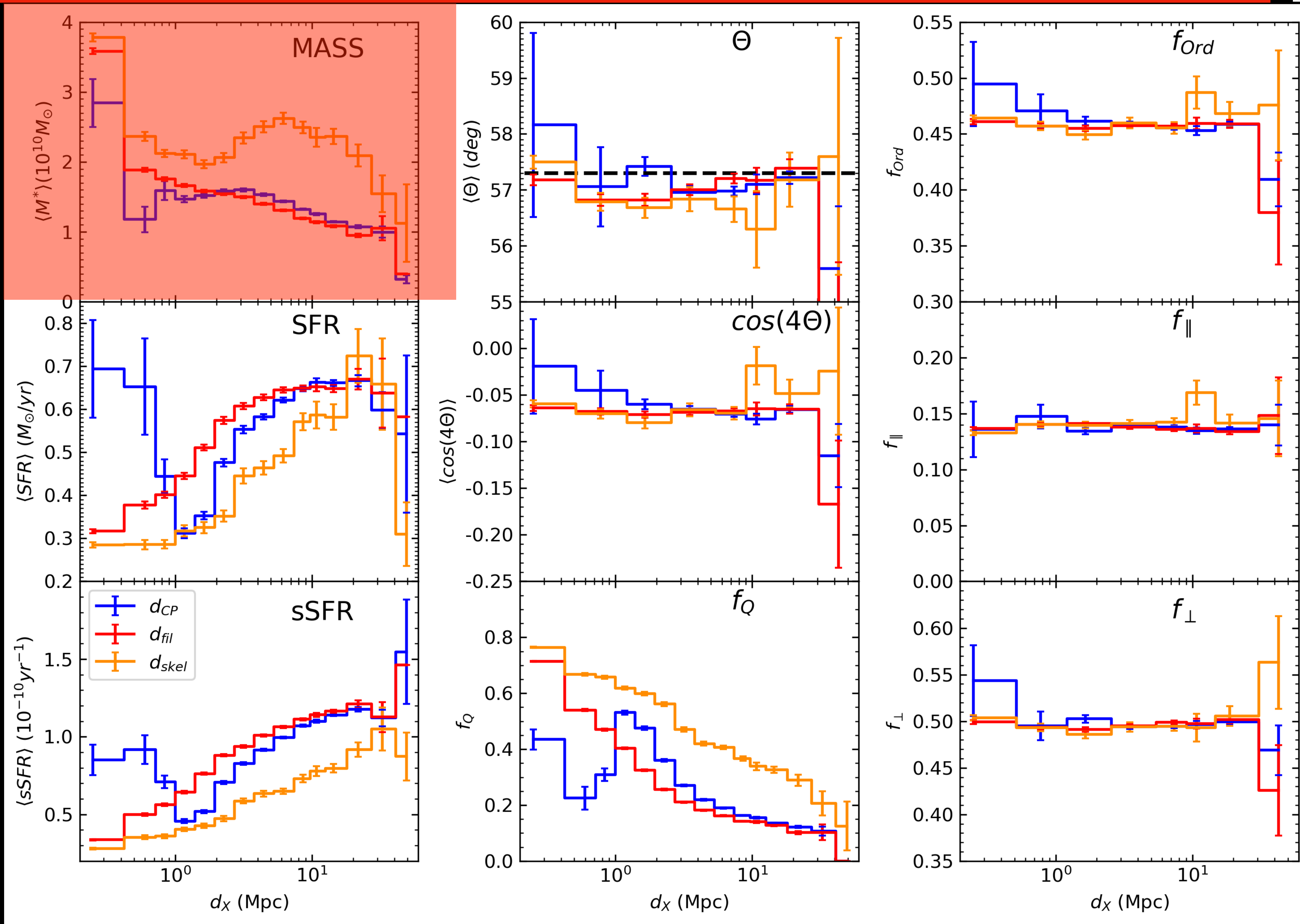
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results

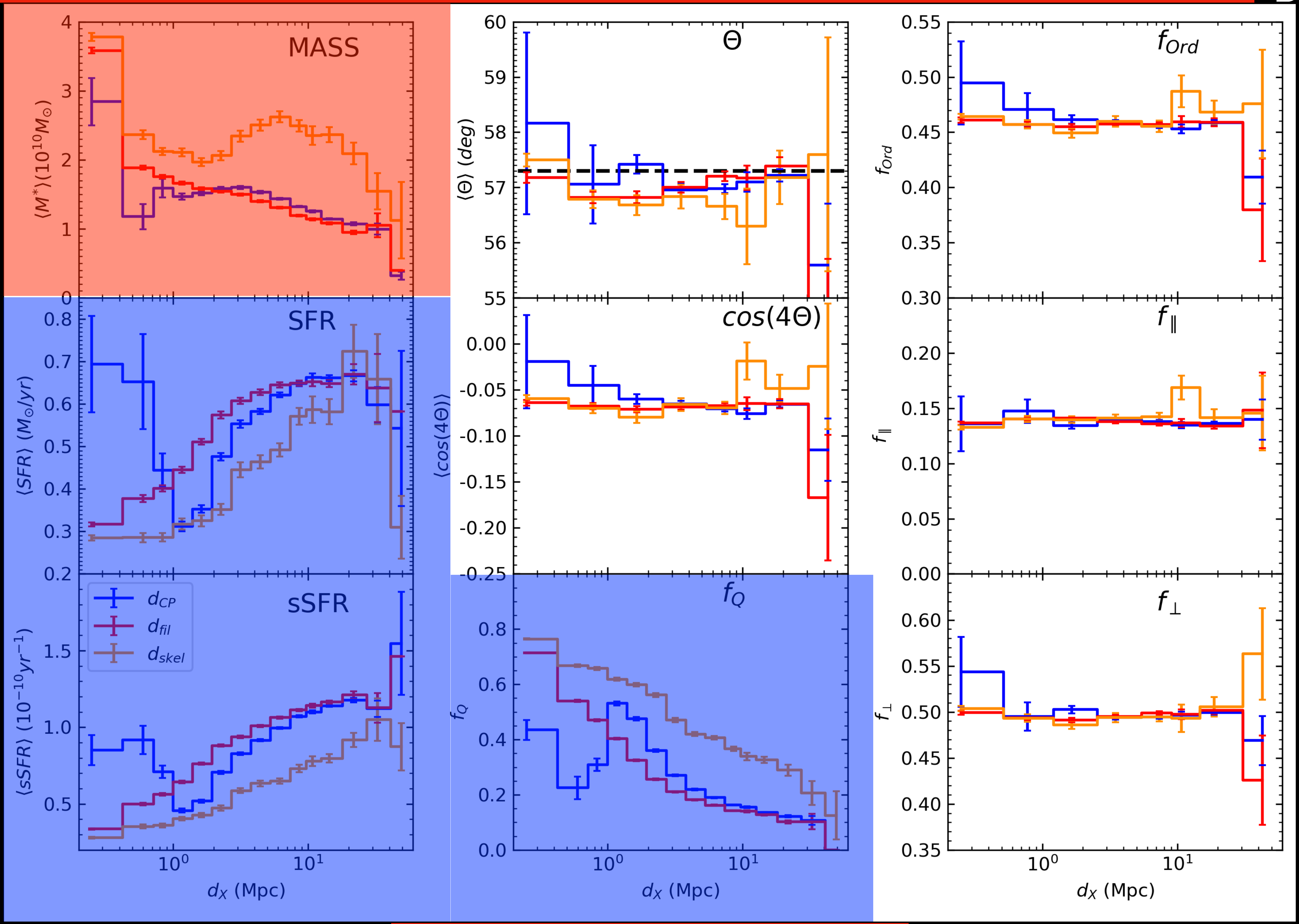
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results

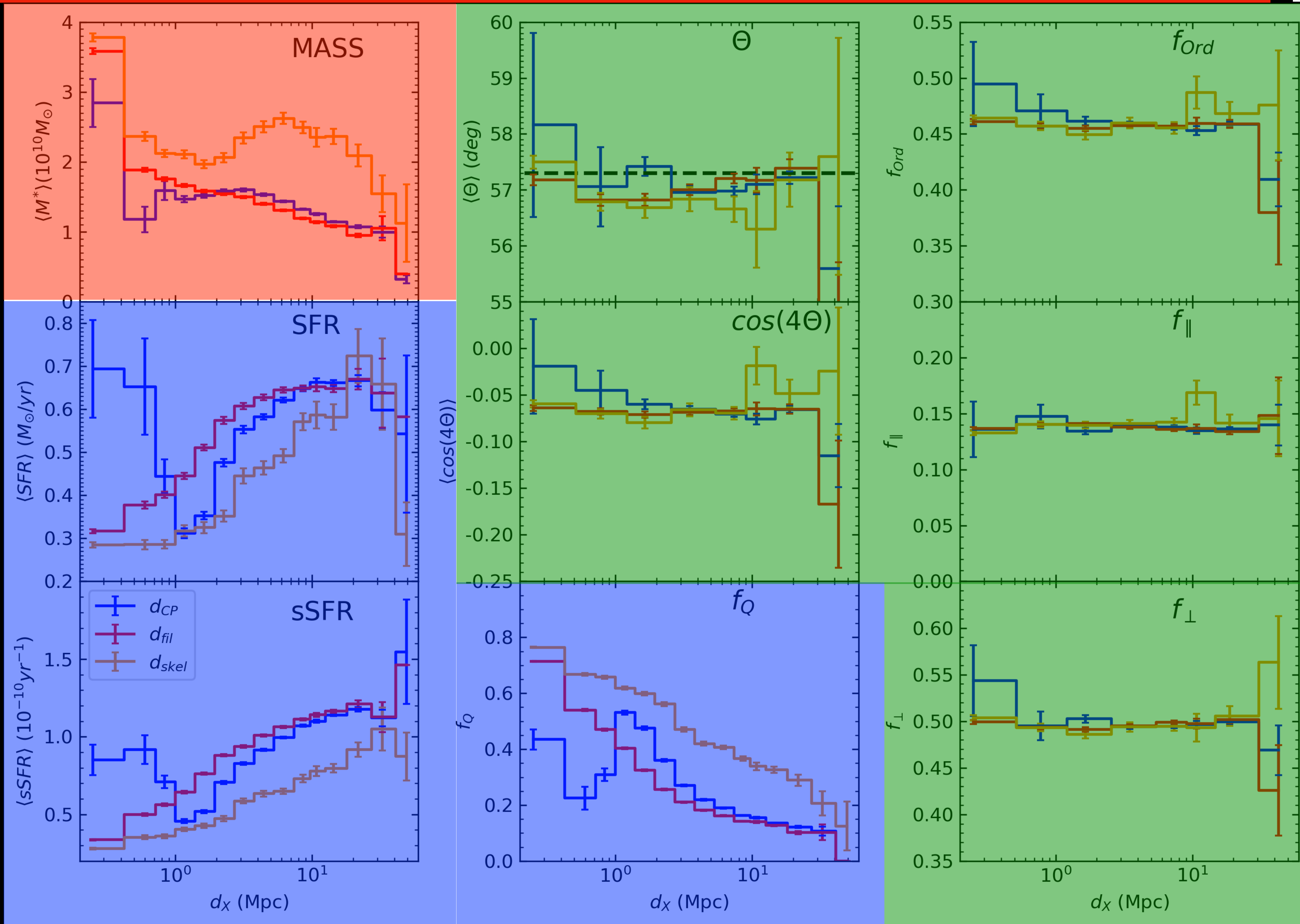
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results

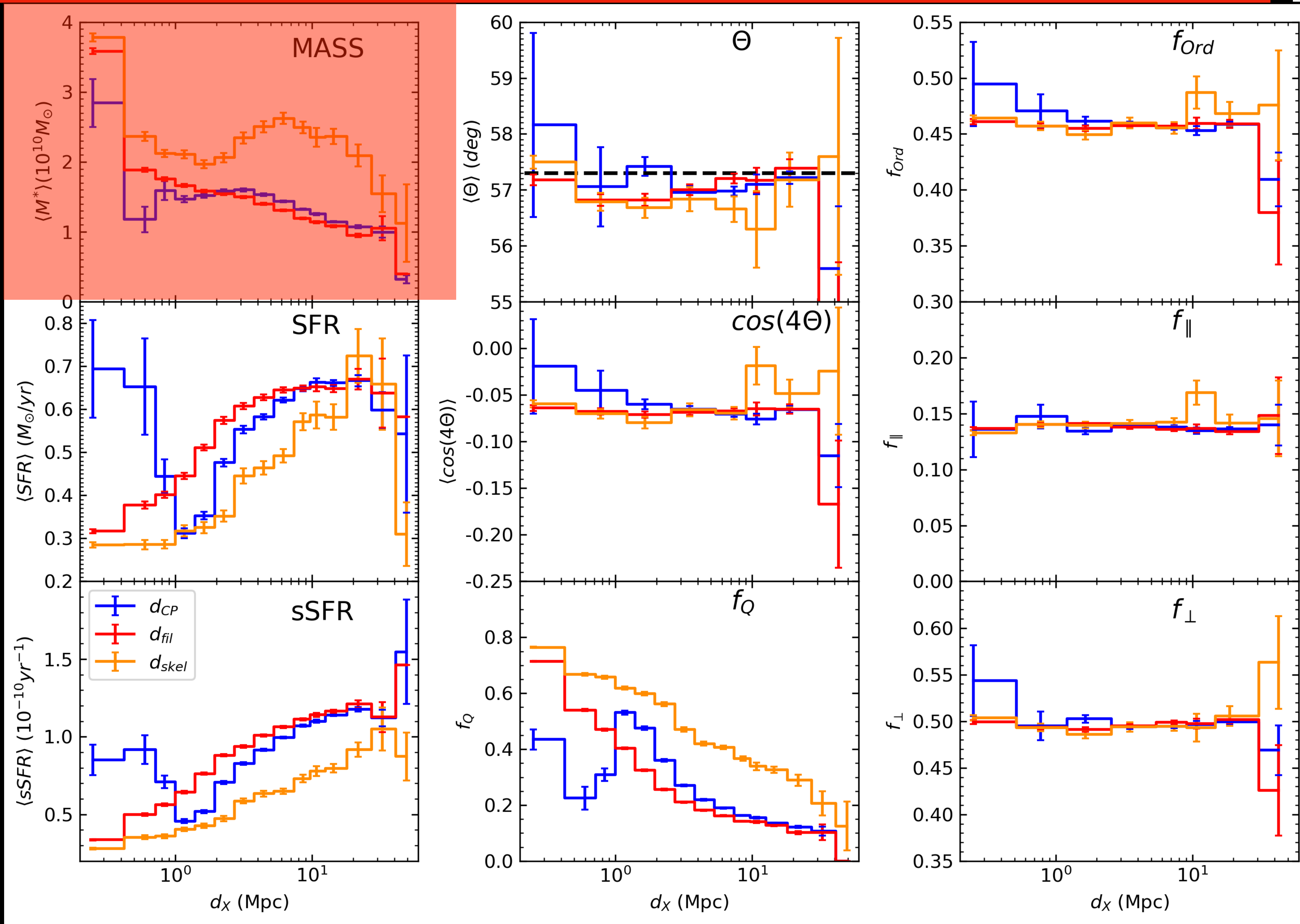
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results

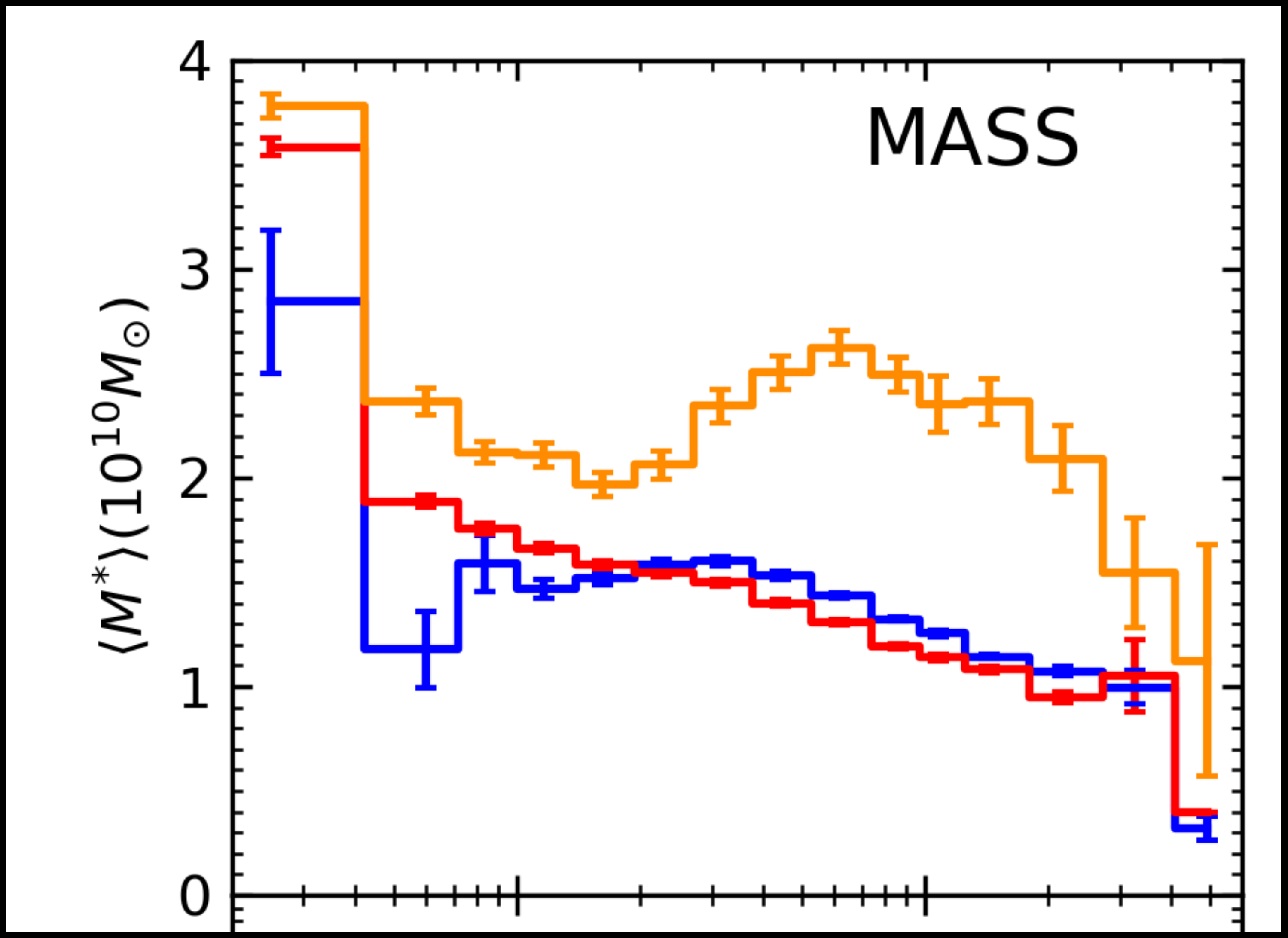
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

RESULTS – STELLAR MASS

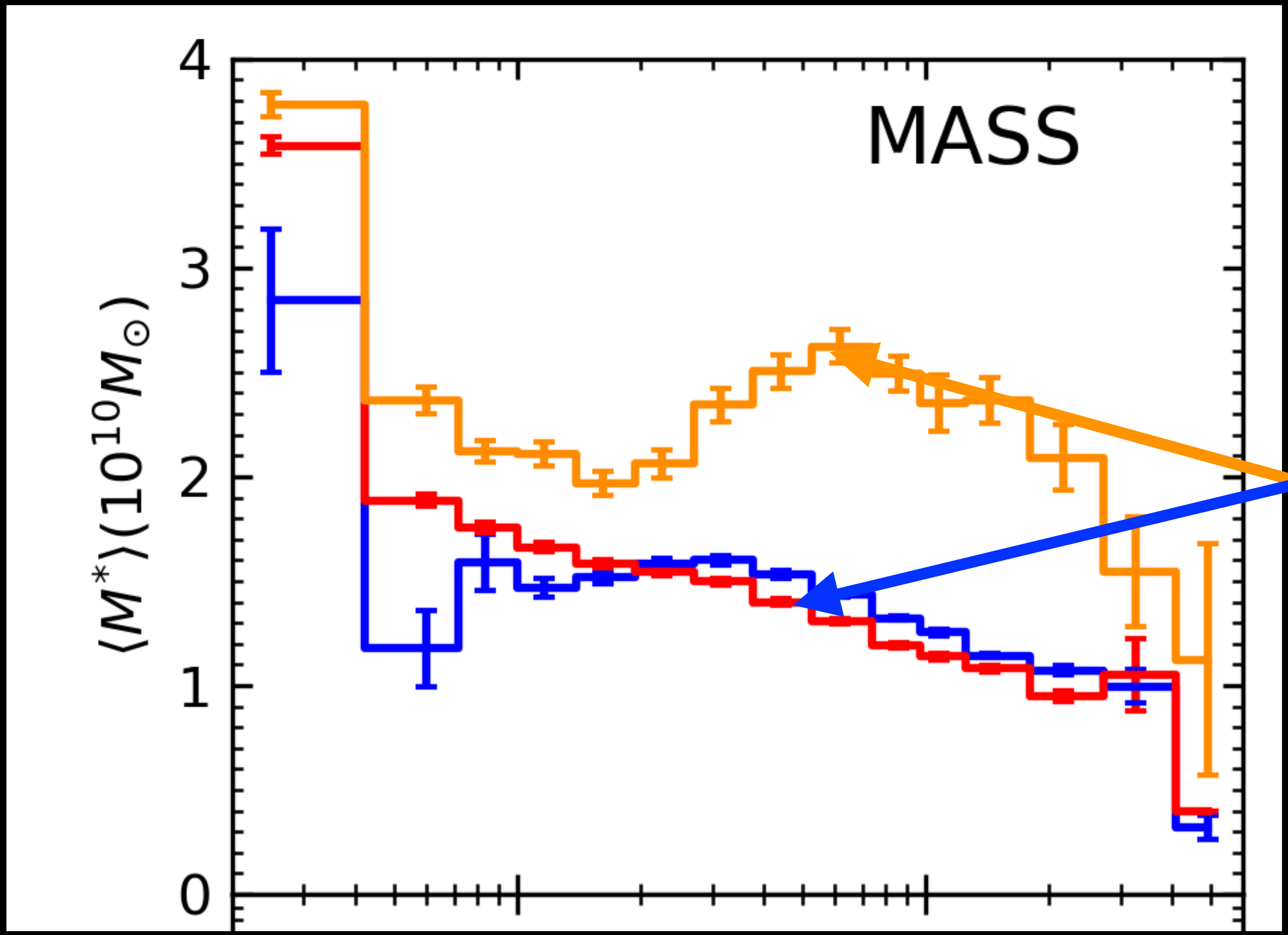
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results – Stellar mass

Nodes
Filaments
Nodes - following filaments

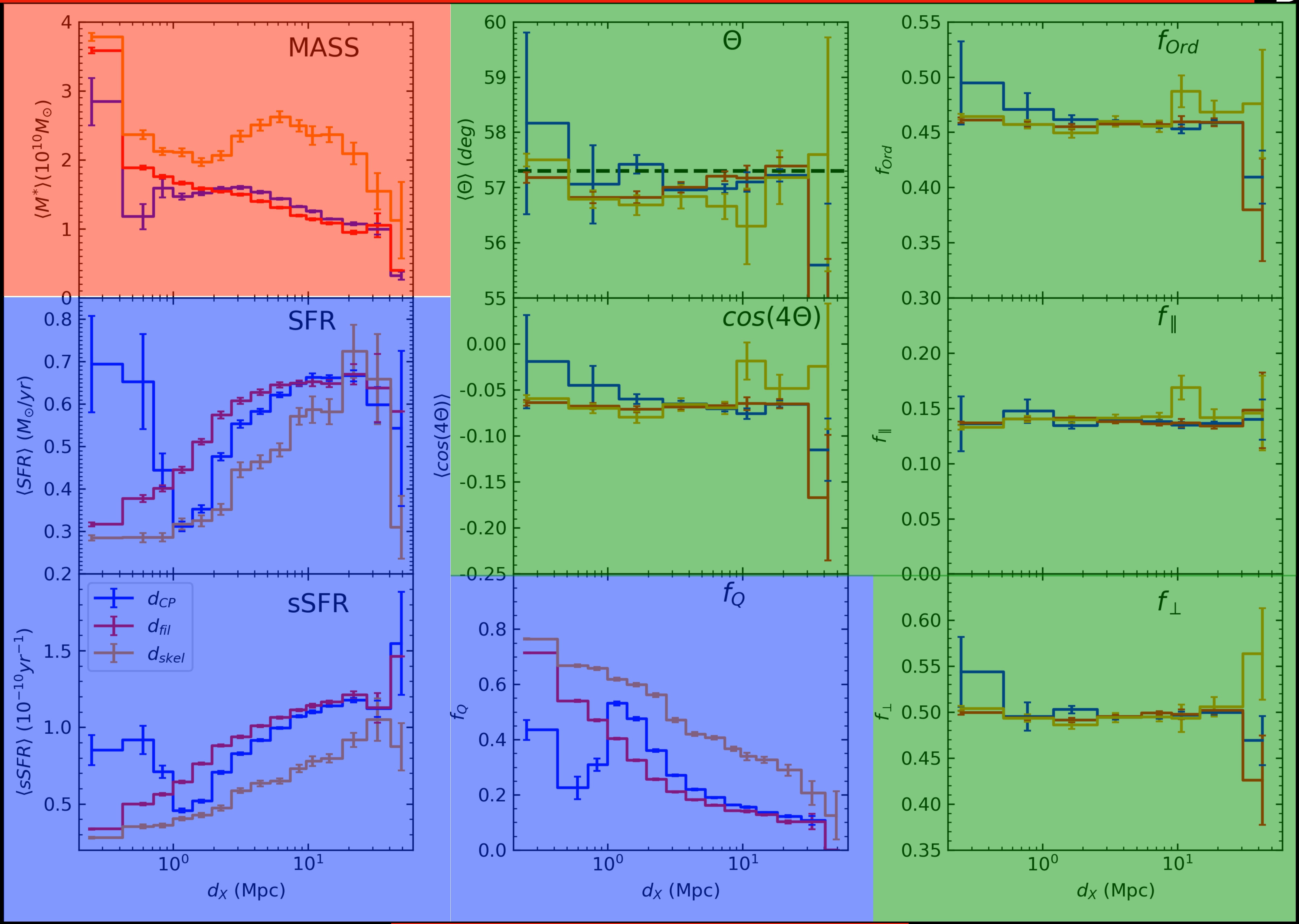


- Stellar mass decreases with distance from structures.
- Difference between in-filament and off-filament population.
- Small differences between the three type of distances

Malavasi et al. to be submitted

Results

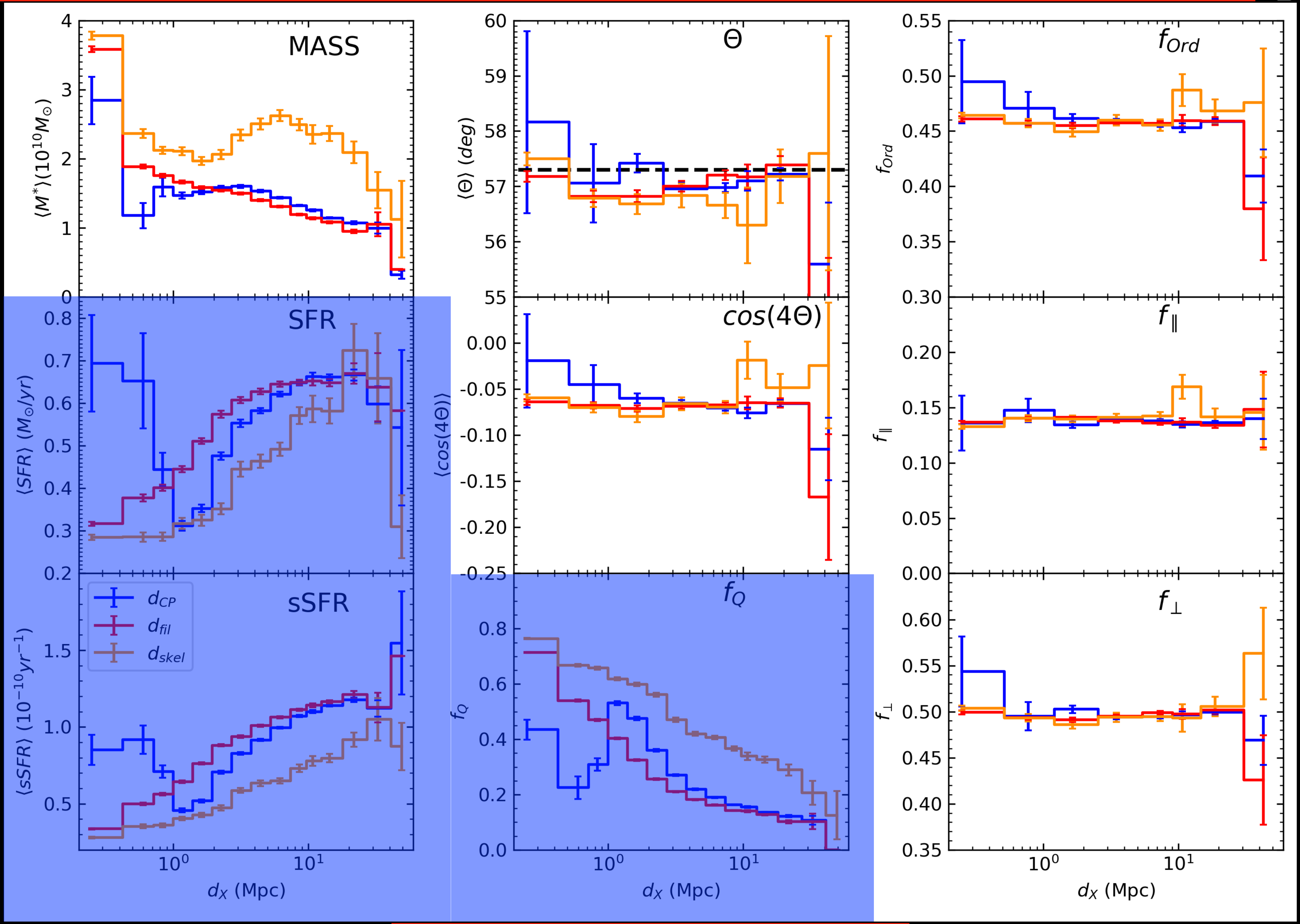
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results

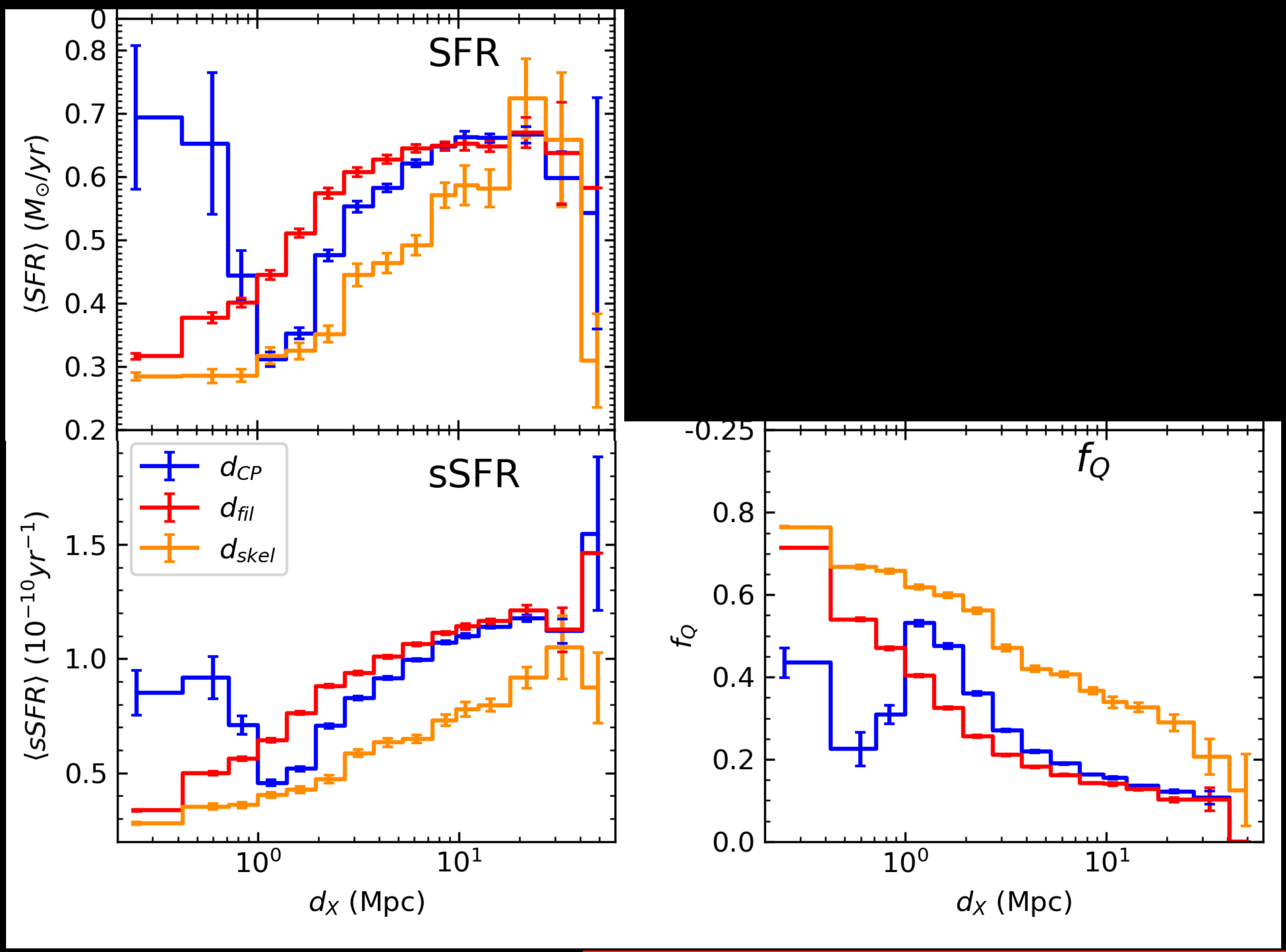
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

Results – Star Formation

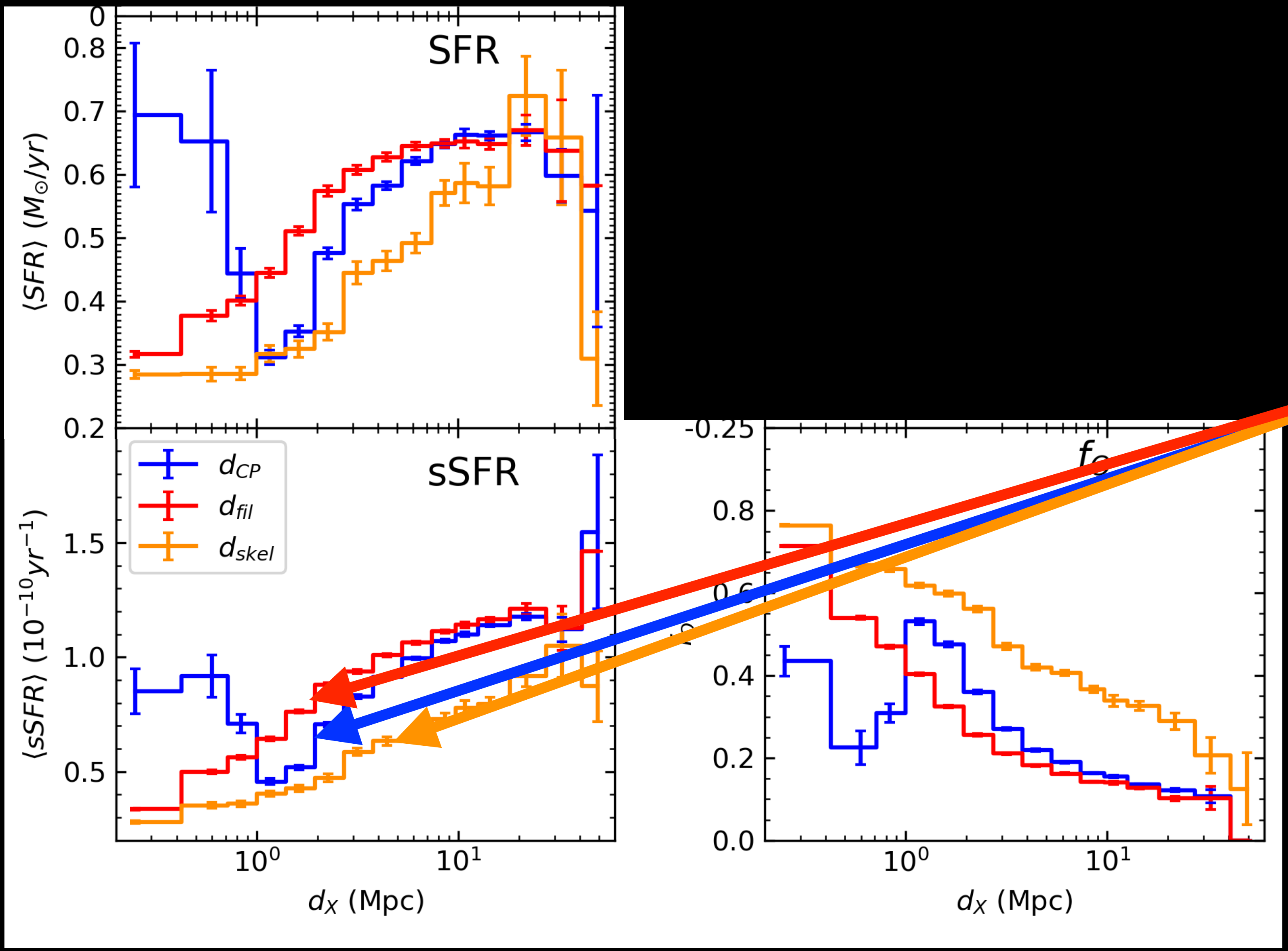
Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

RESULTS – STAR FORMATION

Nodes
Filaments
Nodes - following filaments

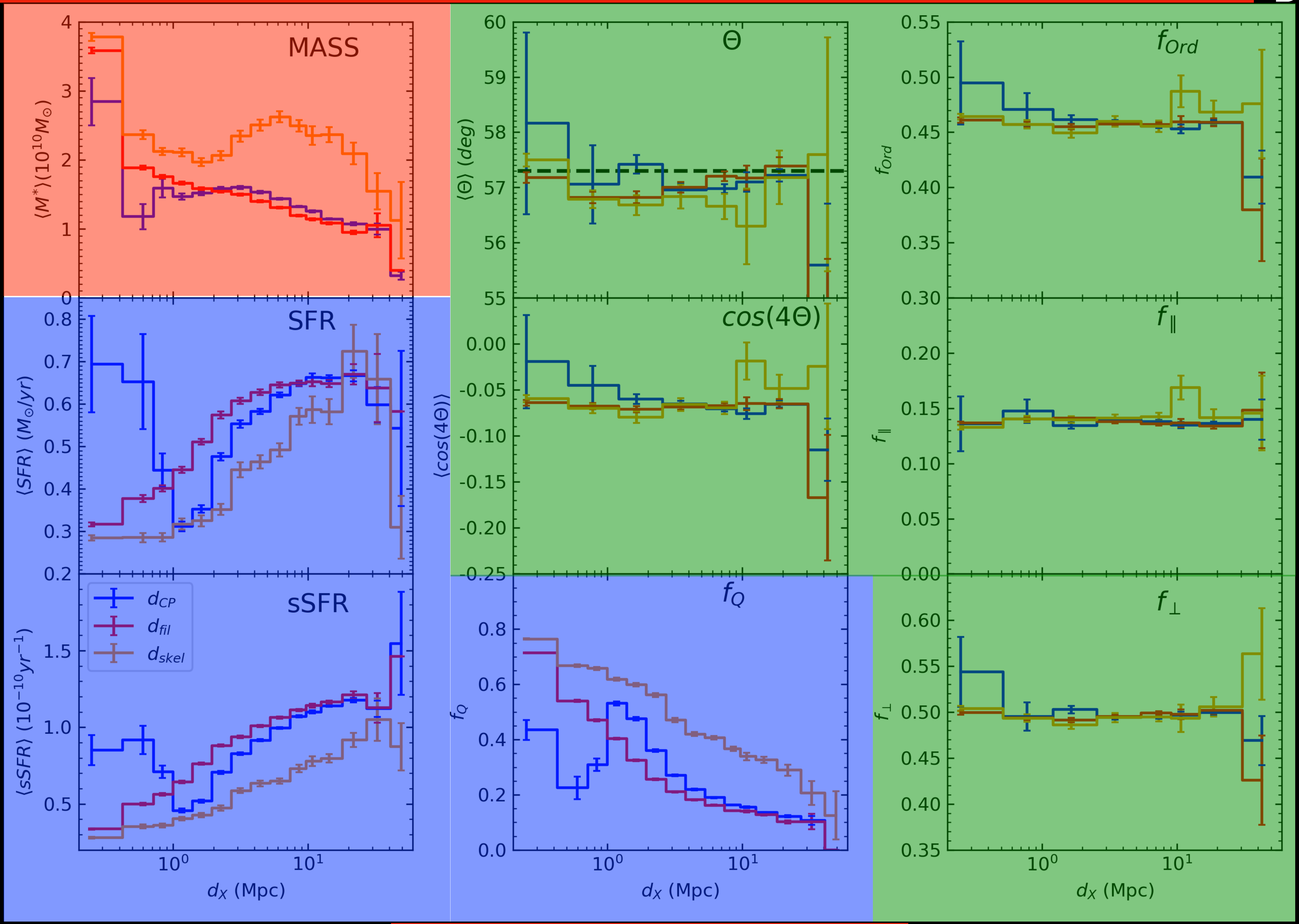


- (specific-)SFR increases/f_Q decreases with distance to structures.
- Difference between distances in amplitude and gradient.
- SFR-related quantities allow to distinguish between structures.

Malavasi et al. to be submitted

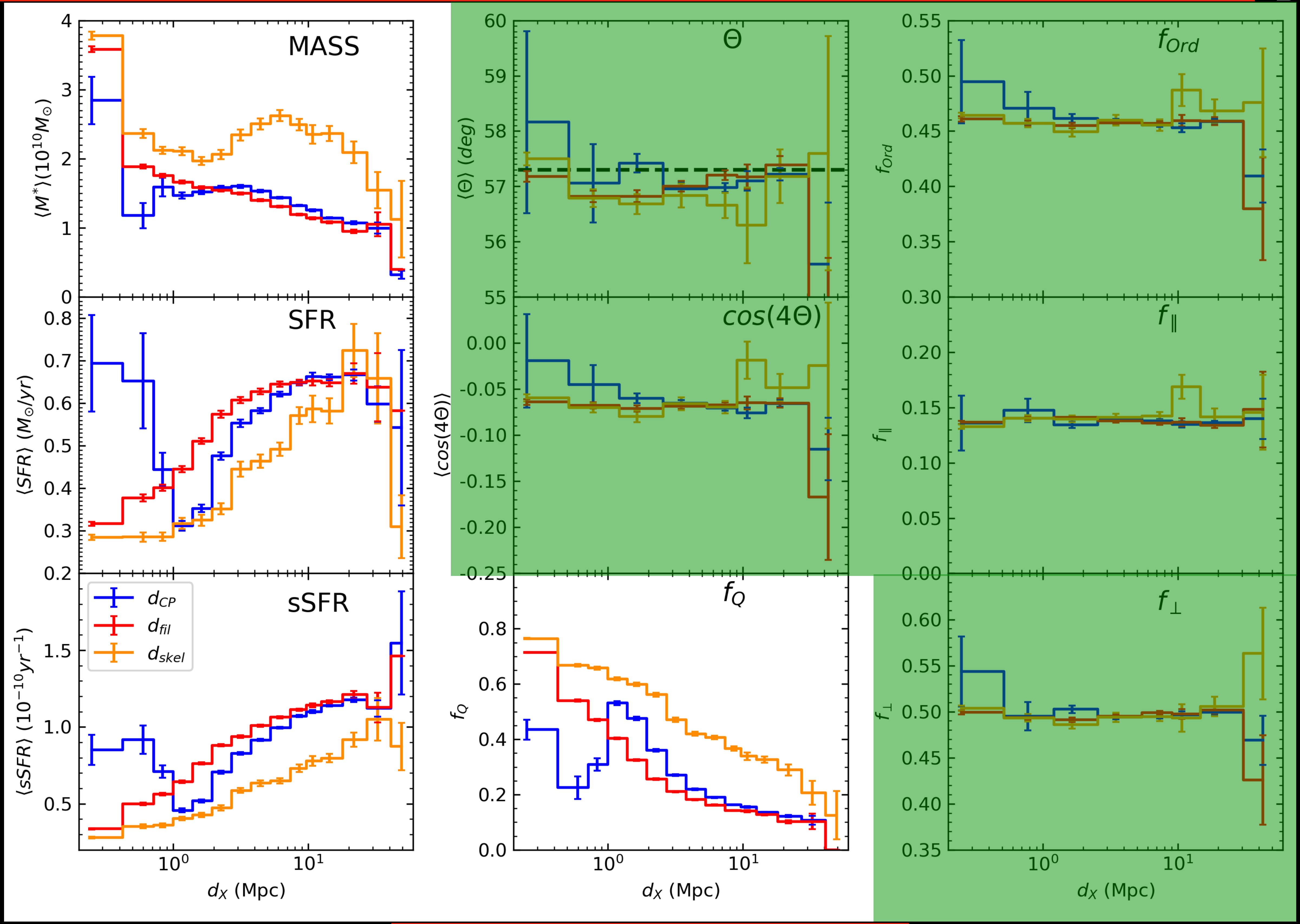
RESULTS

Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

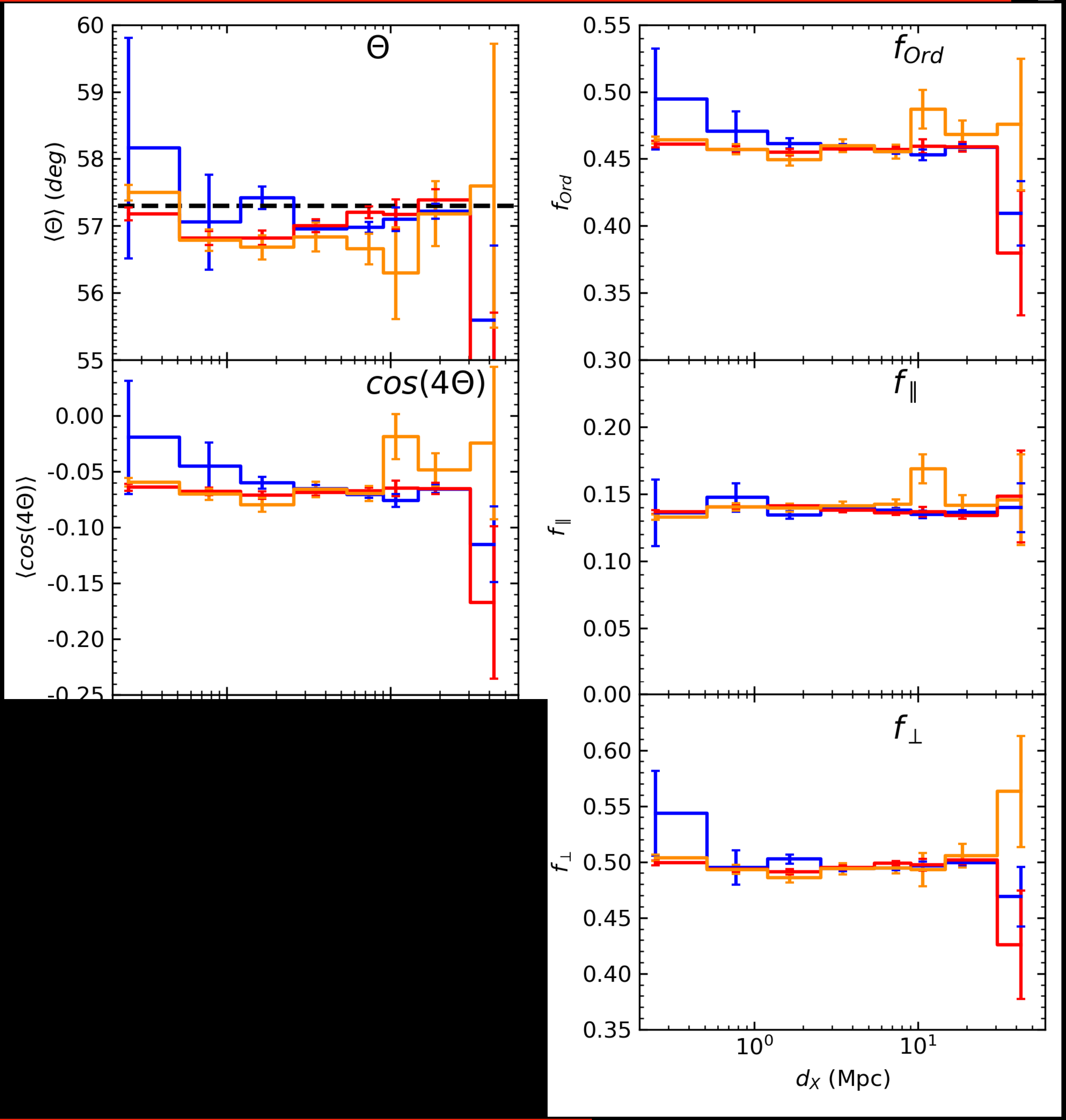
Results



Malavasi et al. to be submitted

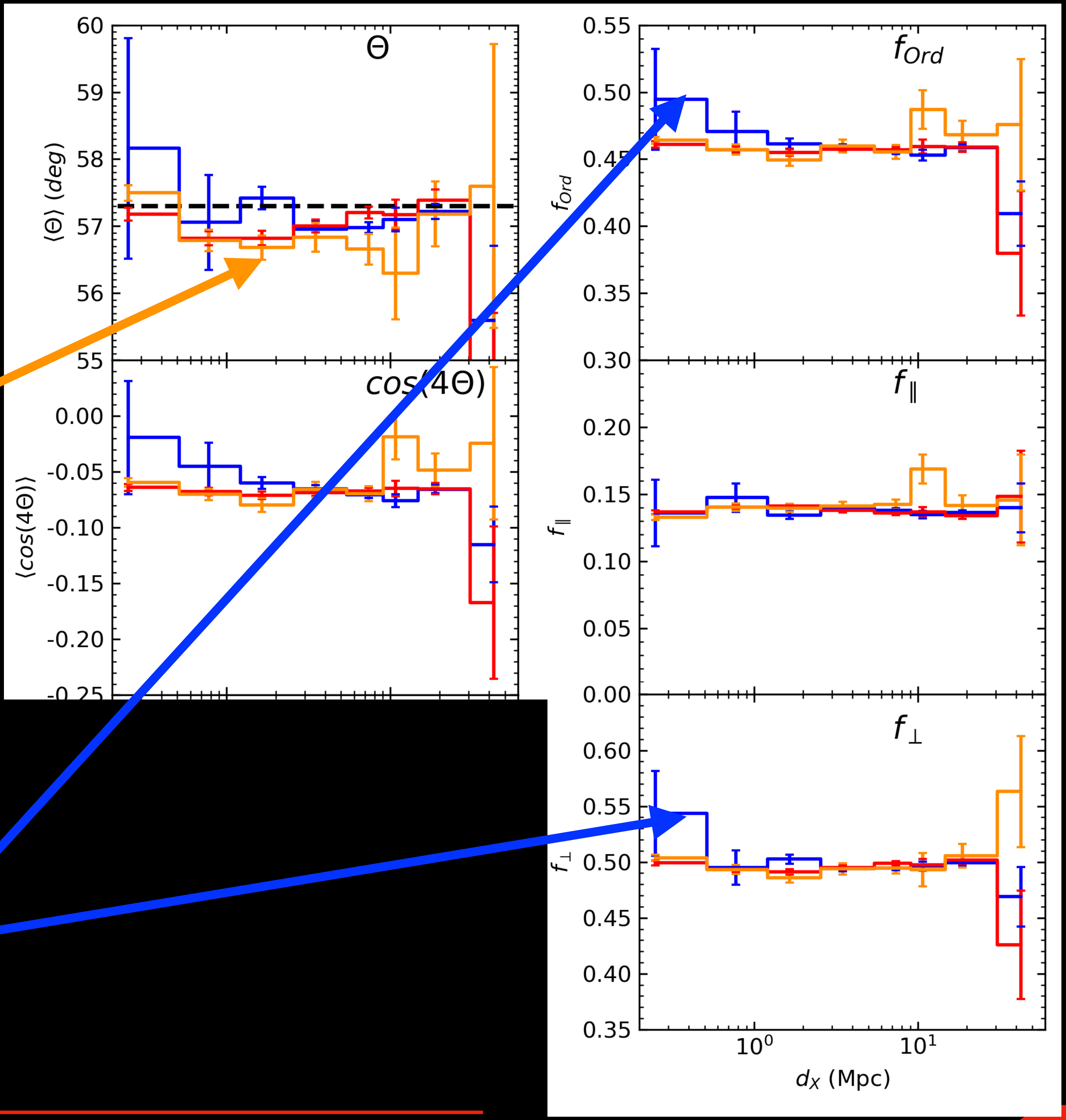
Results - Spin

Nodes
Filaments
Nodes - following filaments



Malavasi et al. to be submitted

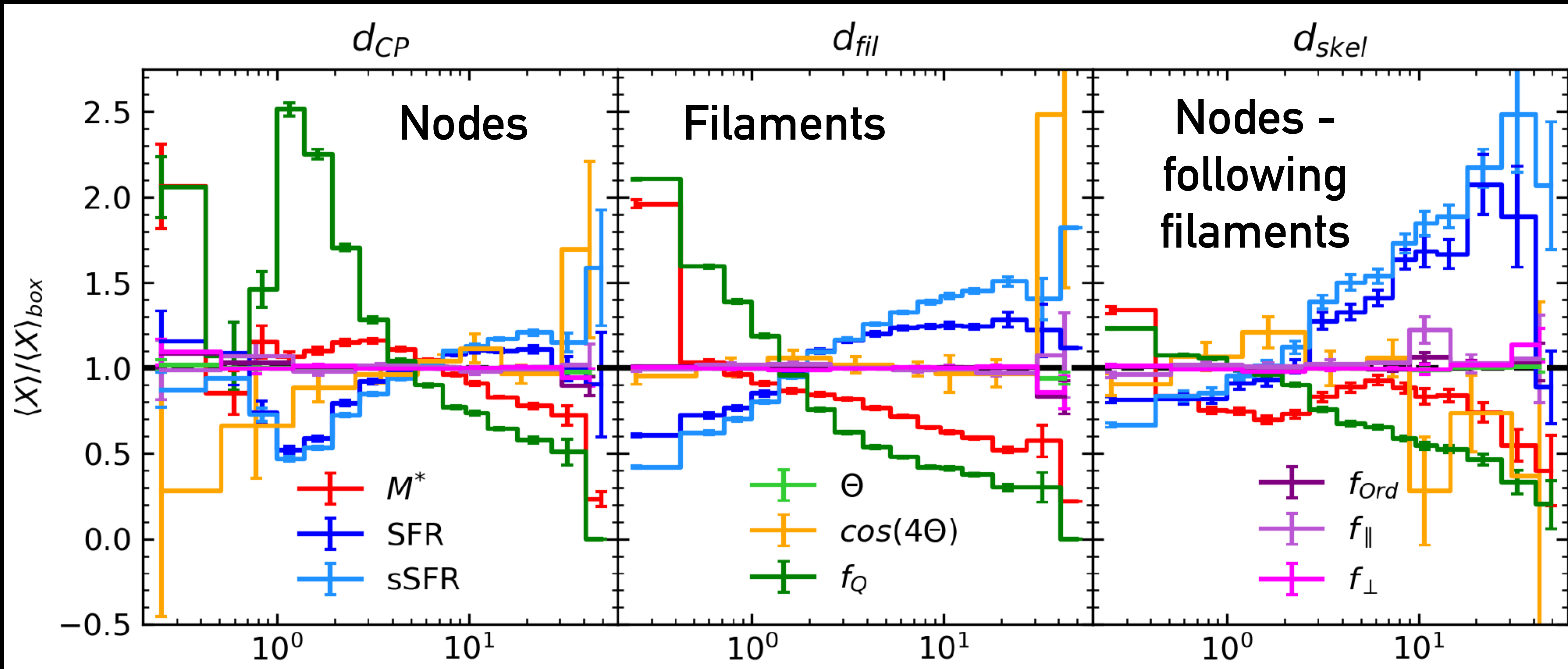
Results – Spin



- Spin-related quantities show weak trends with distances.
- Trend between distance from nodes following filaments and angle between spin and filaments. Galaxies become perpendicular flowing within filaments.
- Fraction of galaxies with spin perpendicular to filaments decreases with distance from nodes, isotropically.

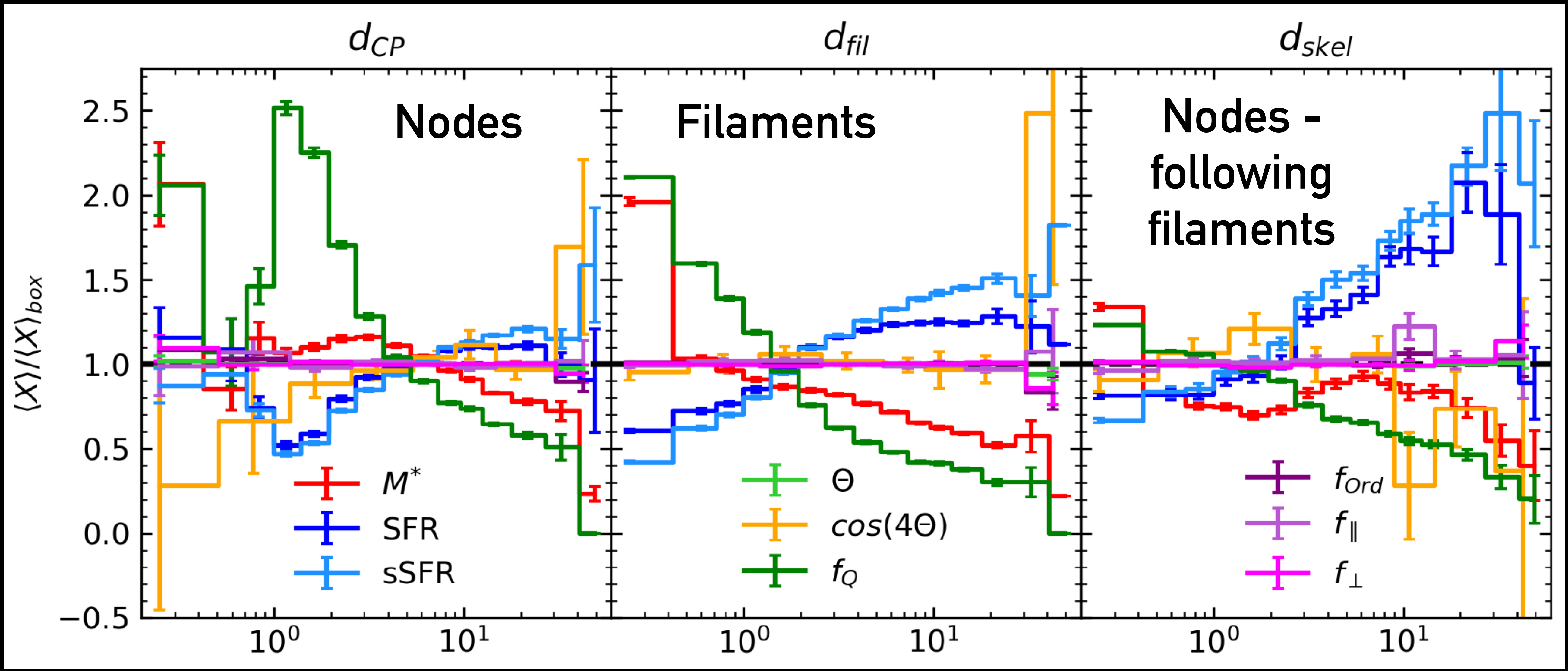
Malavasi et al. to be submitted

Results – Tracing structures



Malavasi et al. to be submitted

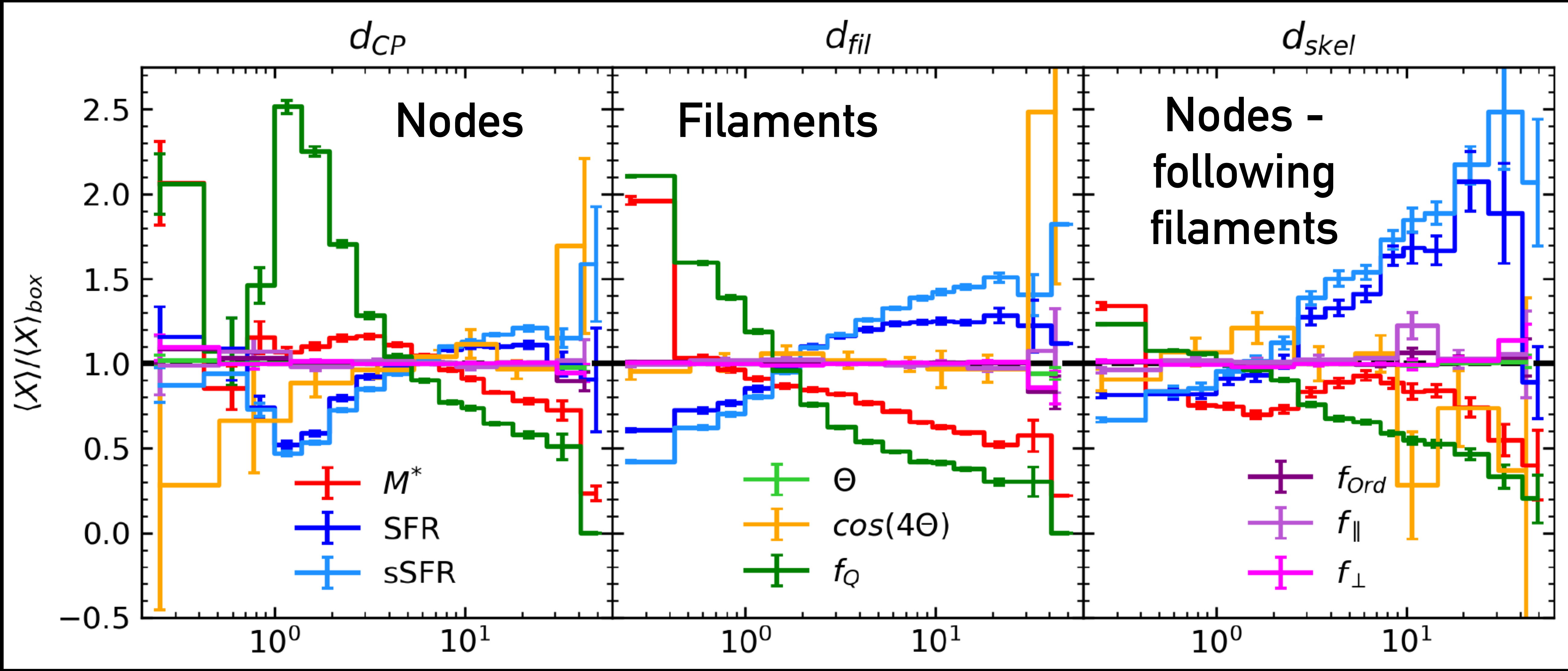
Results – Tracing structures



- SFR-related quantities are those that vary the most in response to the distance from structures. f_Q is the quantity that varies the most.

Malavasi et al. to be submitted

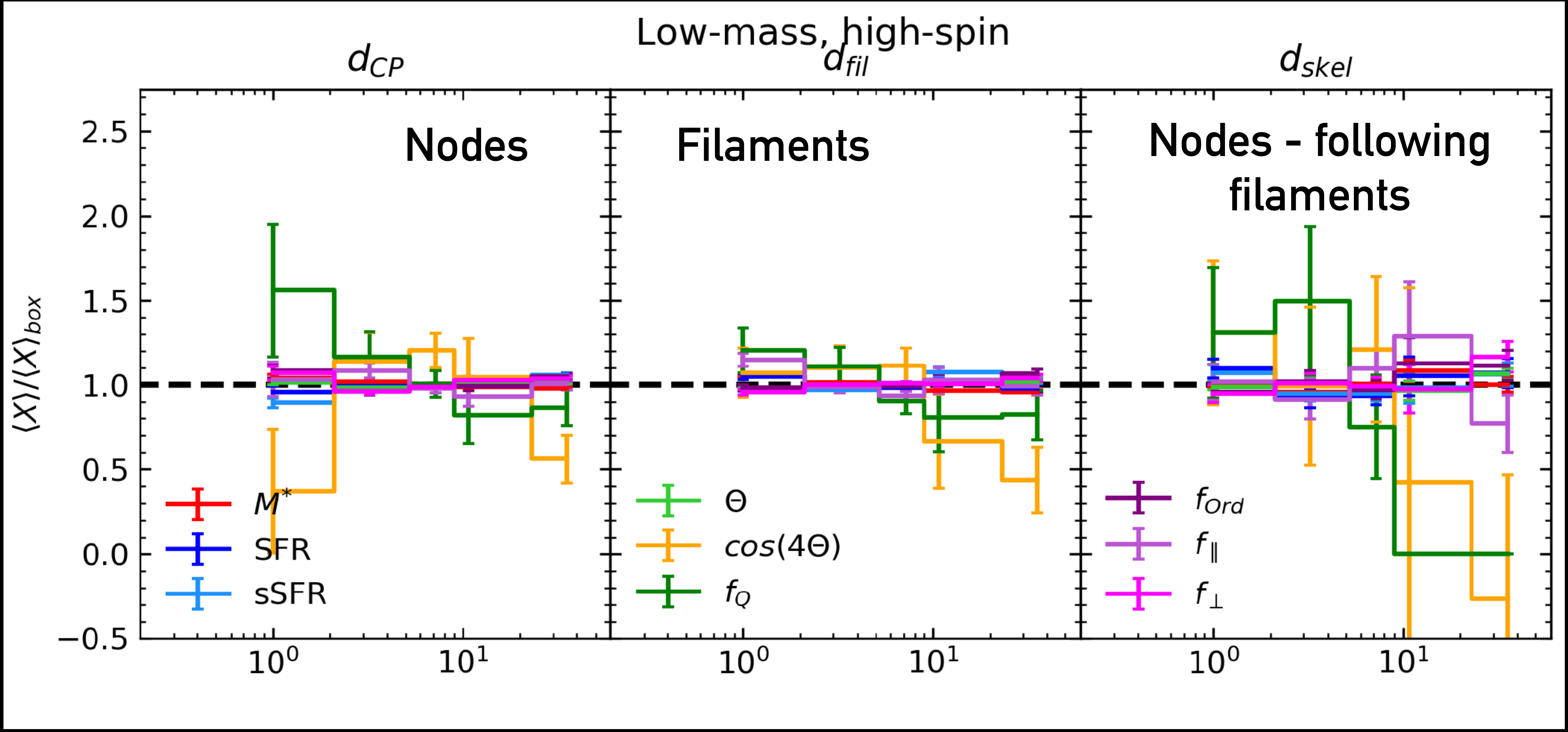
Results – Tracing structures



- SFR-related quantities are those that vary the most in response to the distance from structures. f_Q is the quantity that varies the most.
- Stellar mass also shows a large variation, especially with the distance from filaments.

Malavasi et al. to be submitted

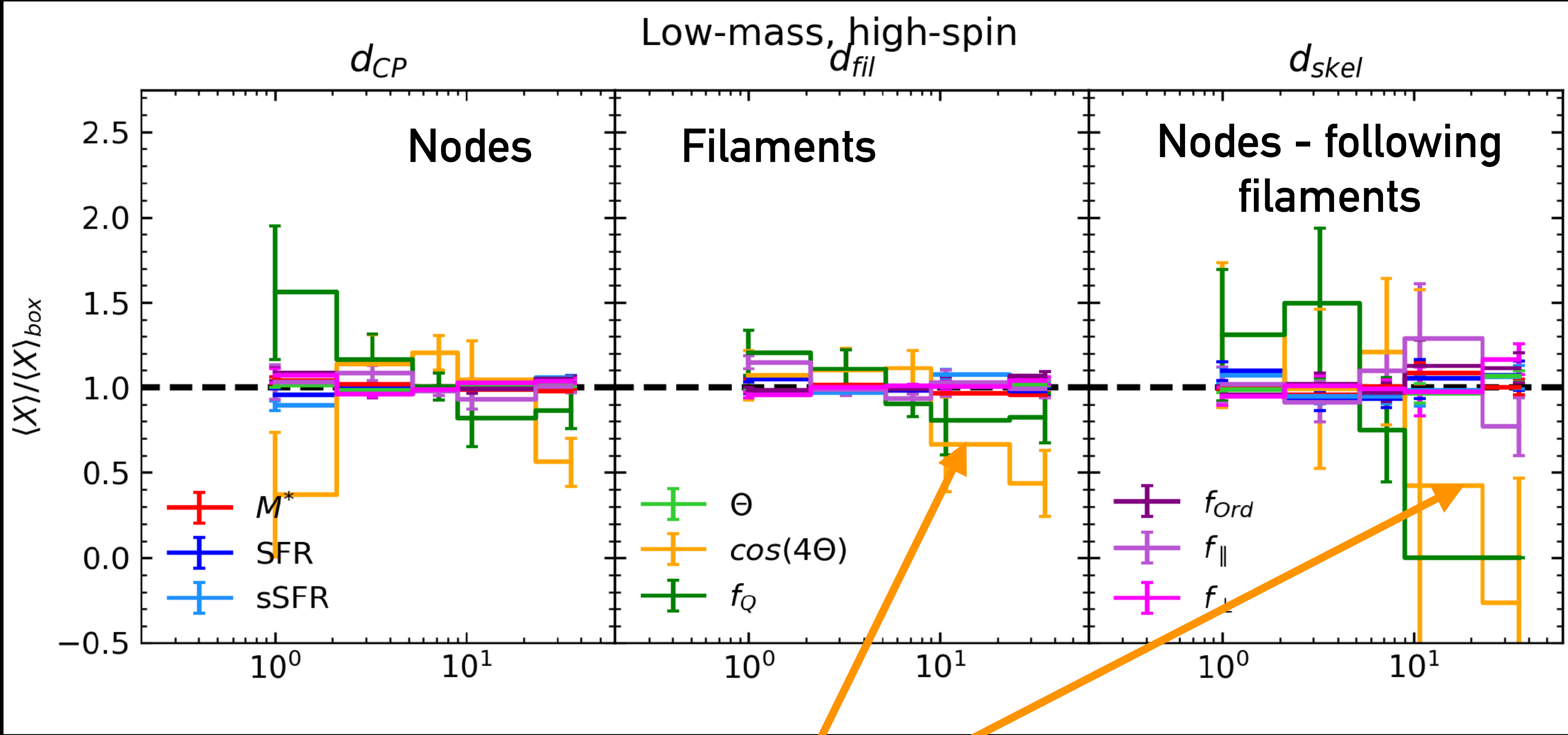
Results – High-spin galaxies



If only high-spin galaxies are considered, then at large distances from nodes following filaments and filaments $\cos(4\theta)$ varies as much as the fraction of quenched galaxies.

Malavasi et al. to be submitted

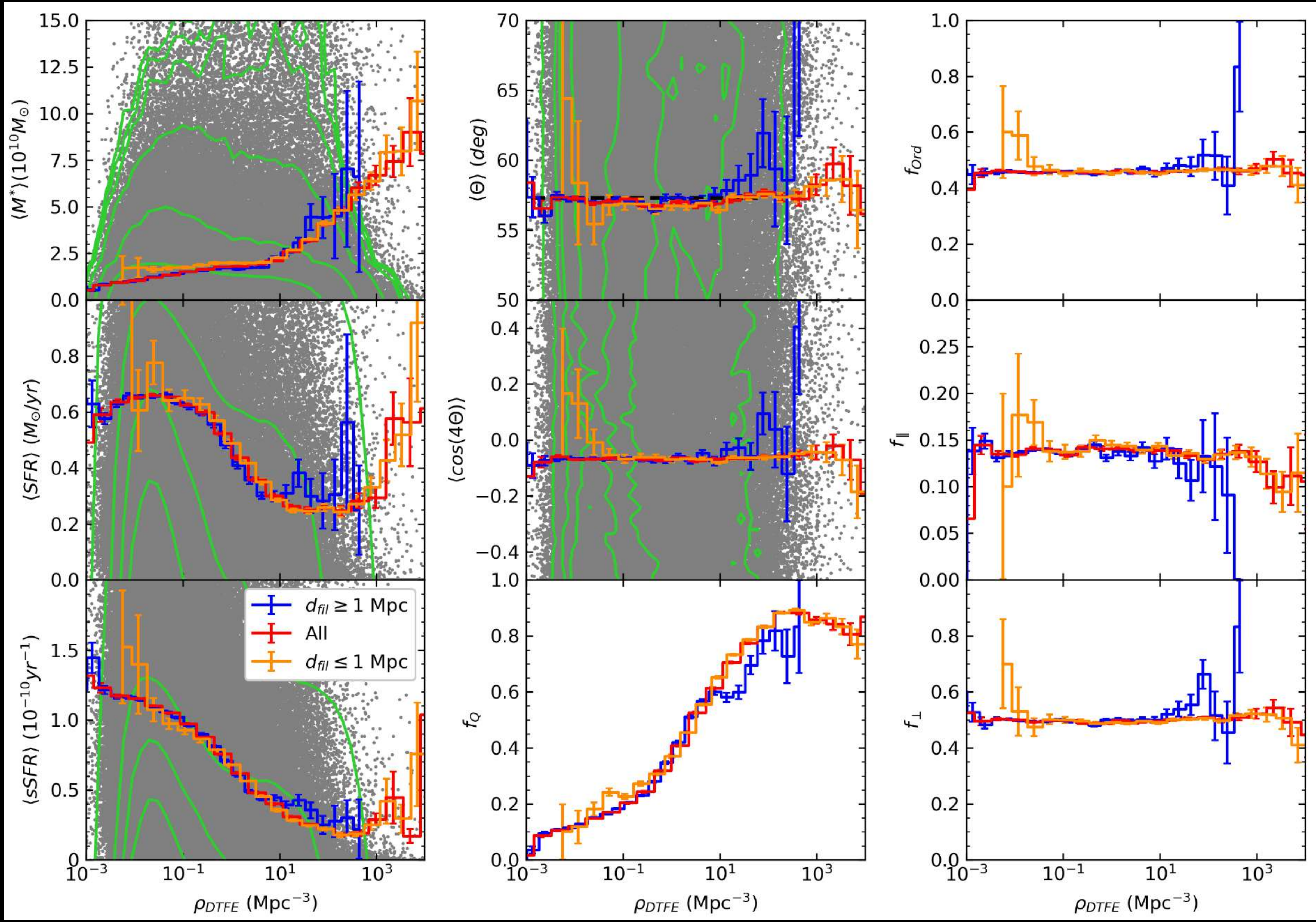
Results – High-spin galaxies



If only high-spin galaxies are considered, then at large distances from nodes following filaments and filaments $\cos(4\theta)$ varies as much as the fraction of quenched galaxies.

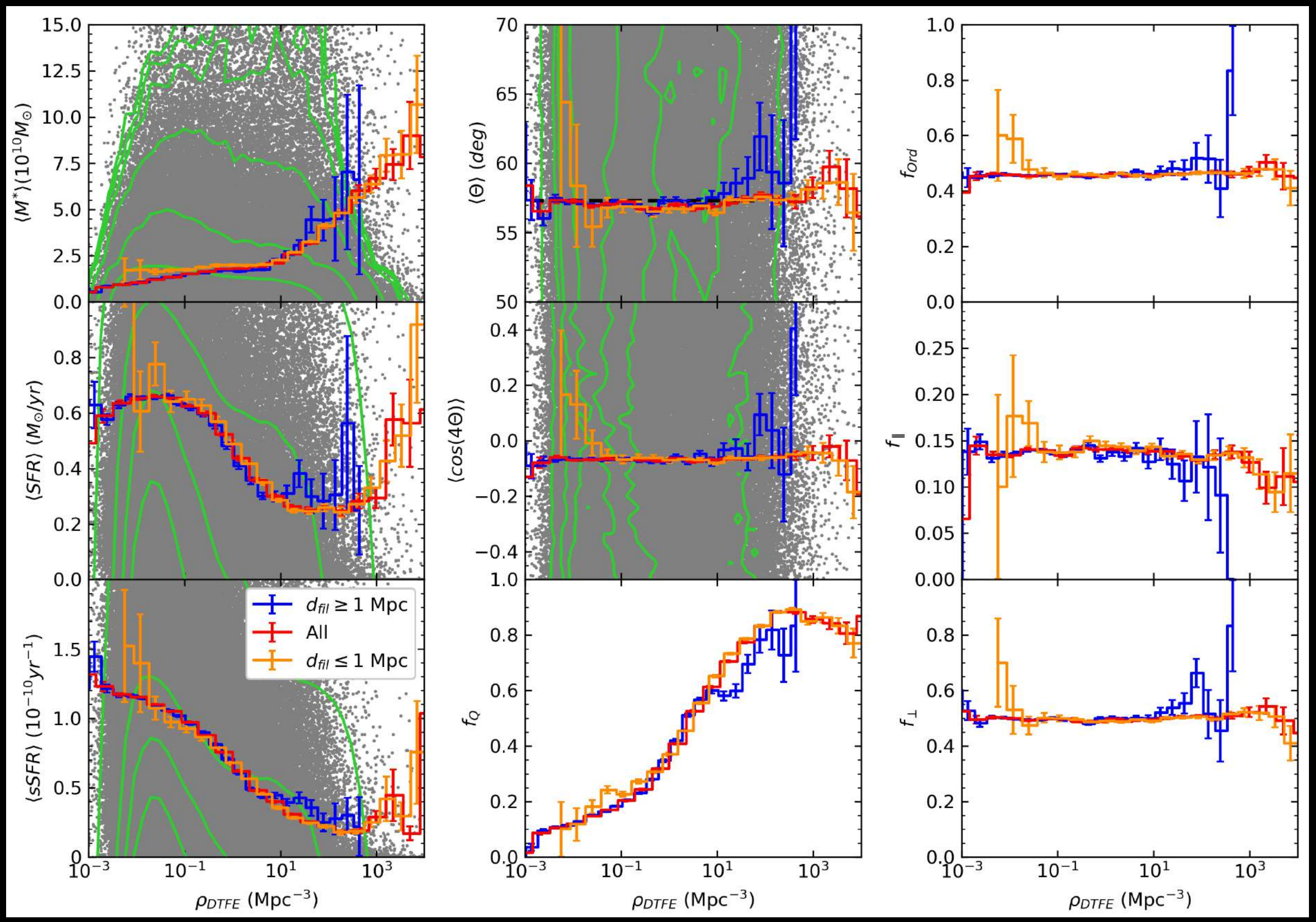
Malavasi et al. to be submitted

Relation with local density



Malavasi et al. to be submitted

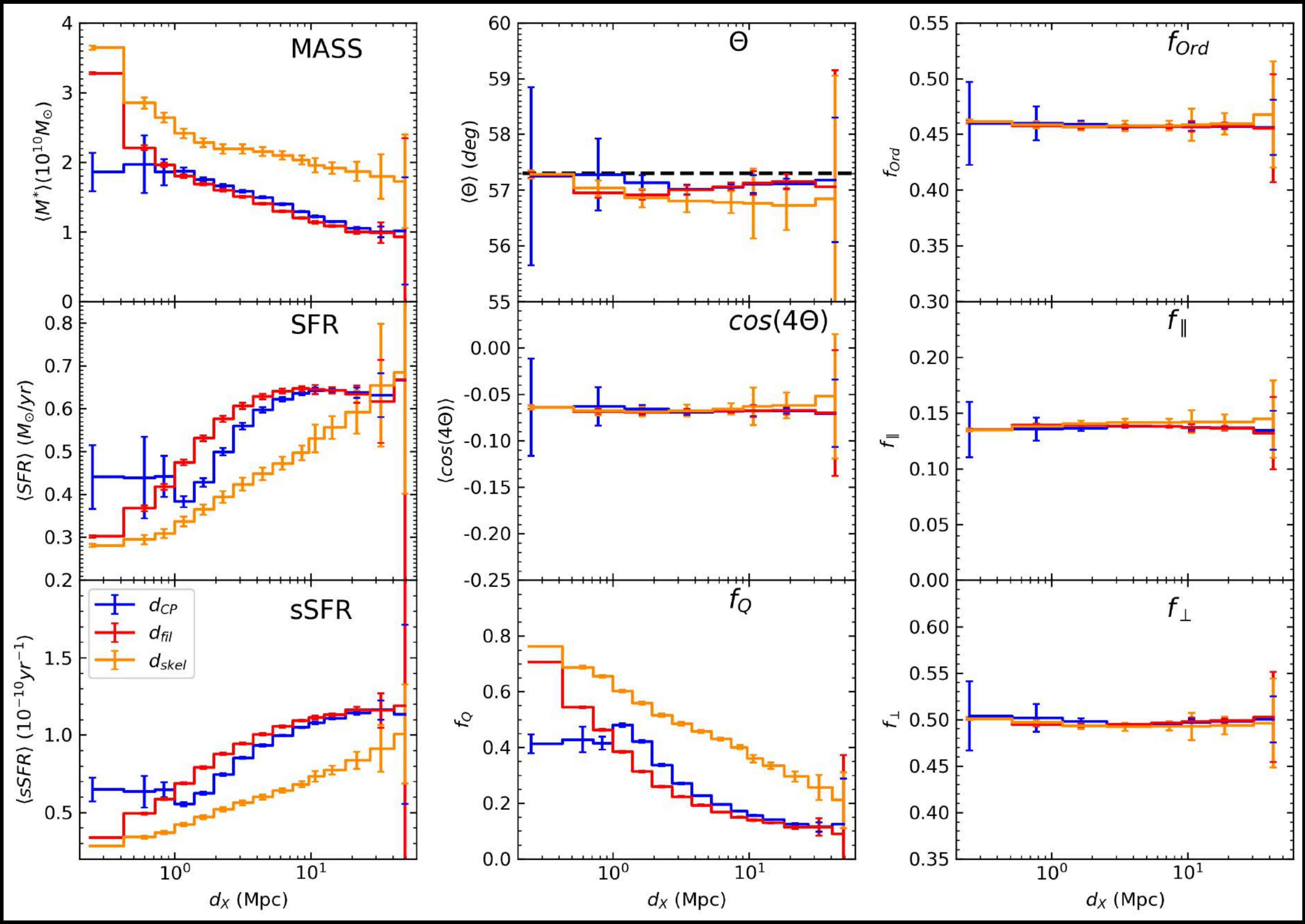
Relation with local density



- Quantities vary with respect to local density.
- We re-shuffled galaxy properties with respect to distances to structures within local density bins.
- We preserve the relation between local density and galaxy properties while cancelling the relation between galaxy properties and distance to structures.

Malavasi et al. to be submitted

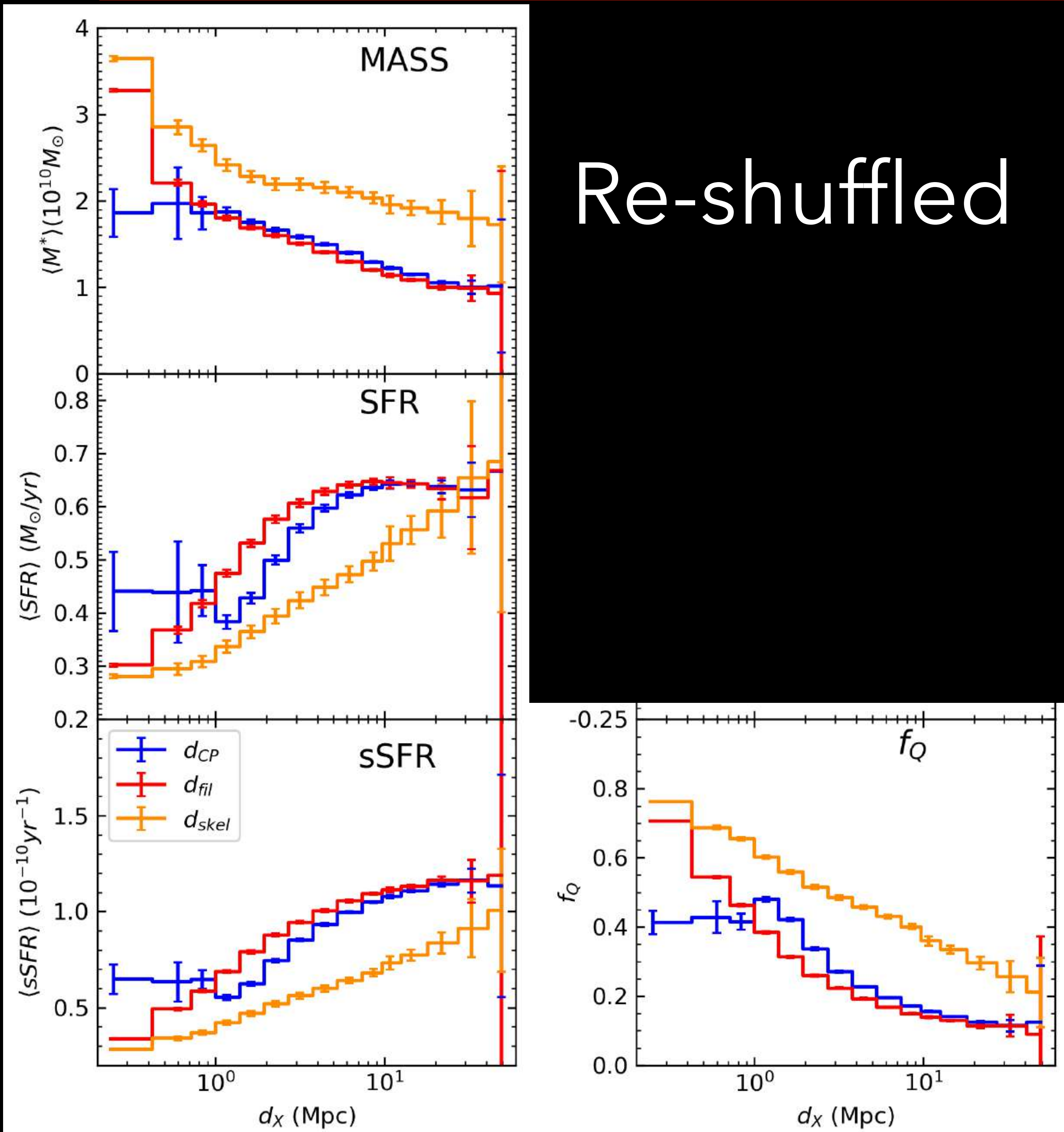
Results – Re-shuffled



Malavasi et al. to be submitted

RE-SHUFFLED VS. ORIGINAL

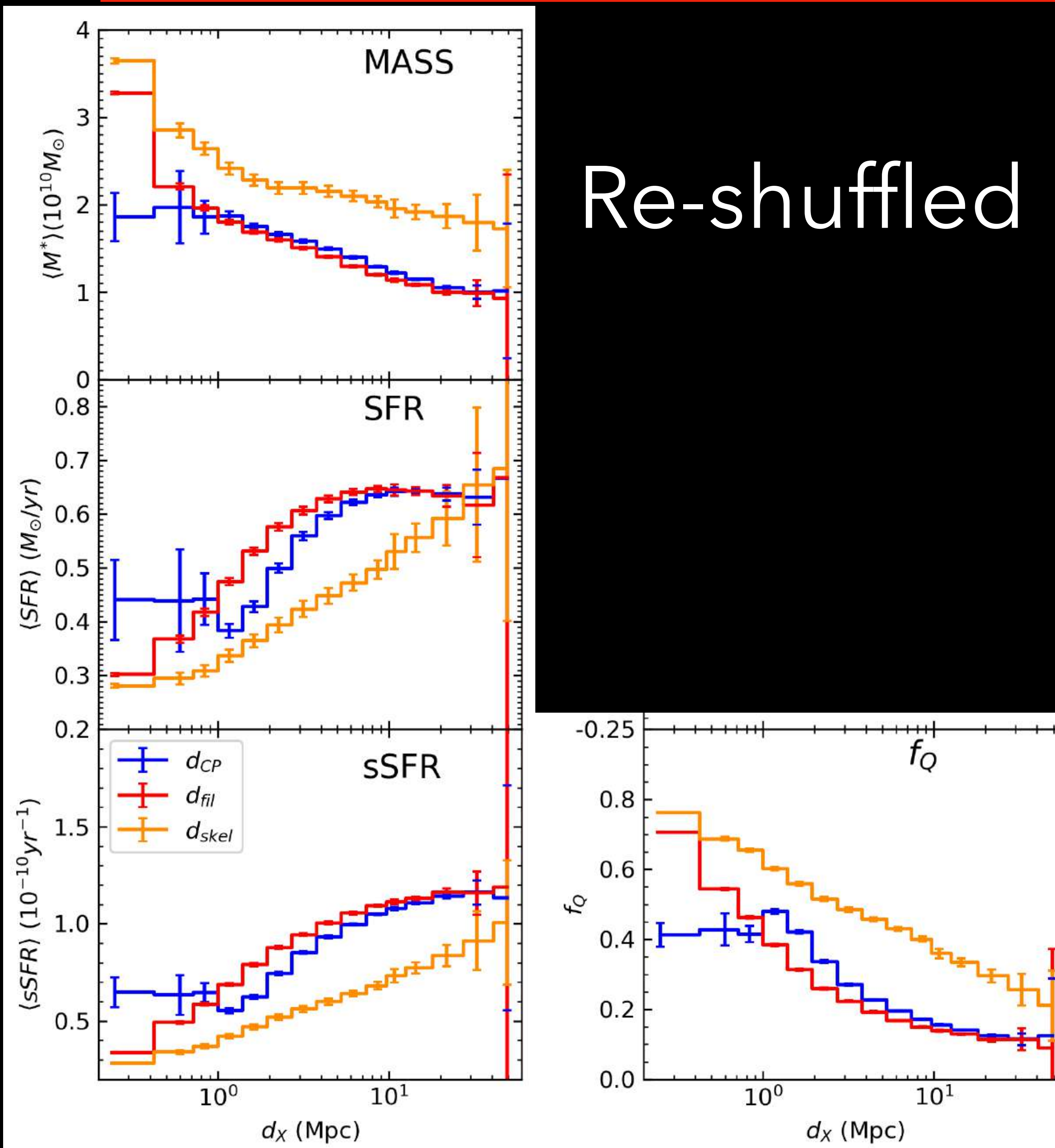
Re-shuffled

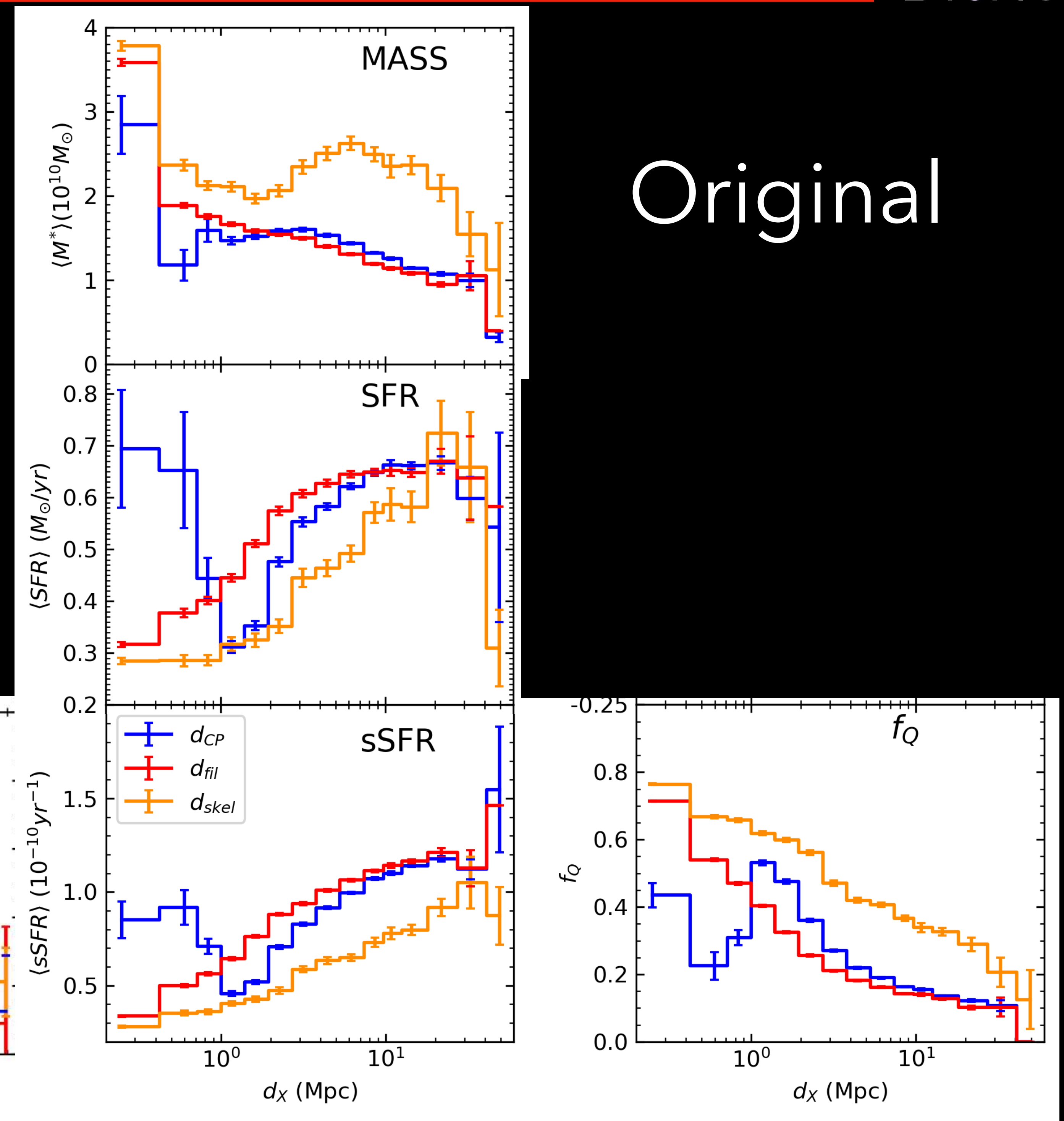


Malavasi et al. to be submitted

RE-SHUFFLED VS. ORIGINAL

BYOPIC

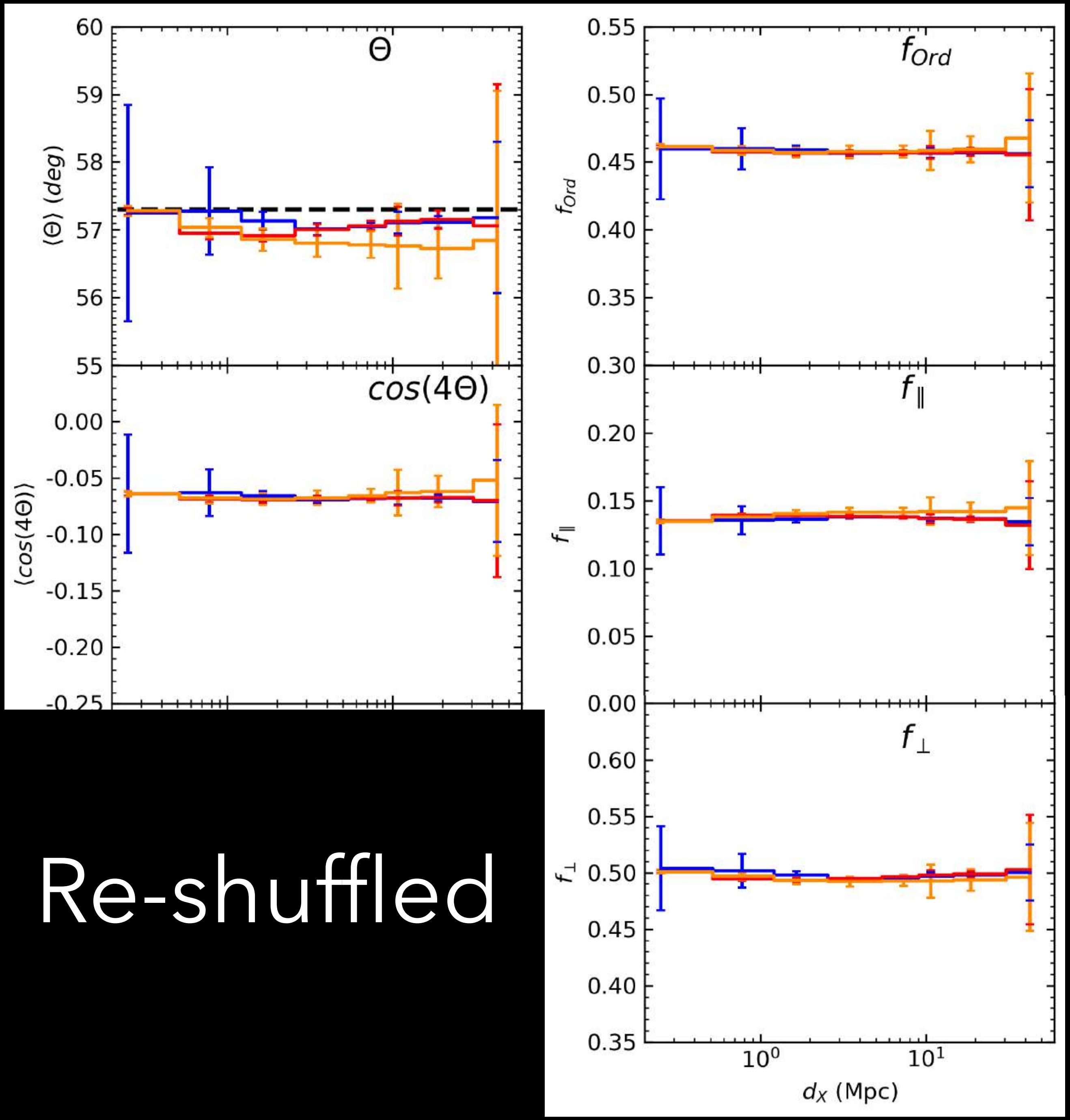




No change for Stellar Mass or SFR-related quantities.

Malavasi et al. to be submitted

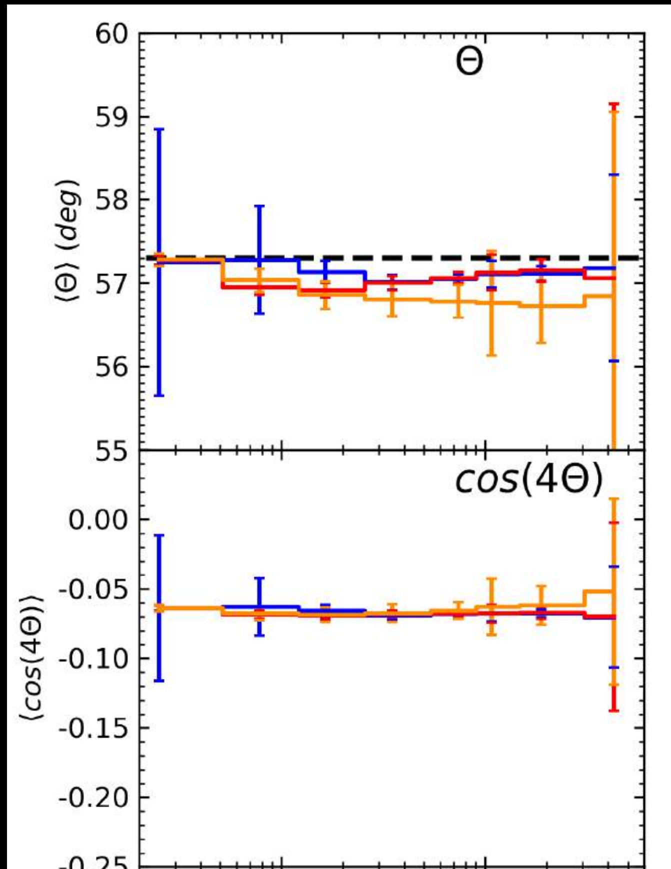
Re-shuffled vs. Original

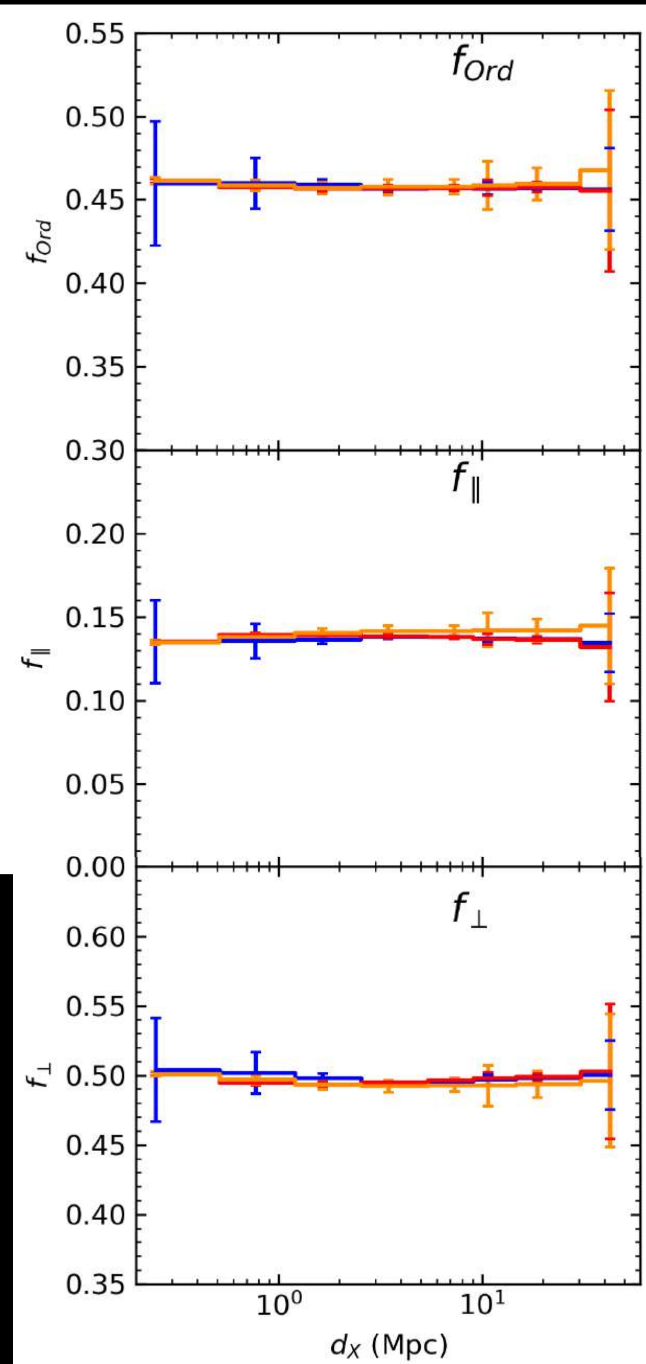


Re-shuffled

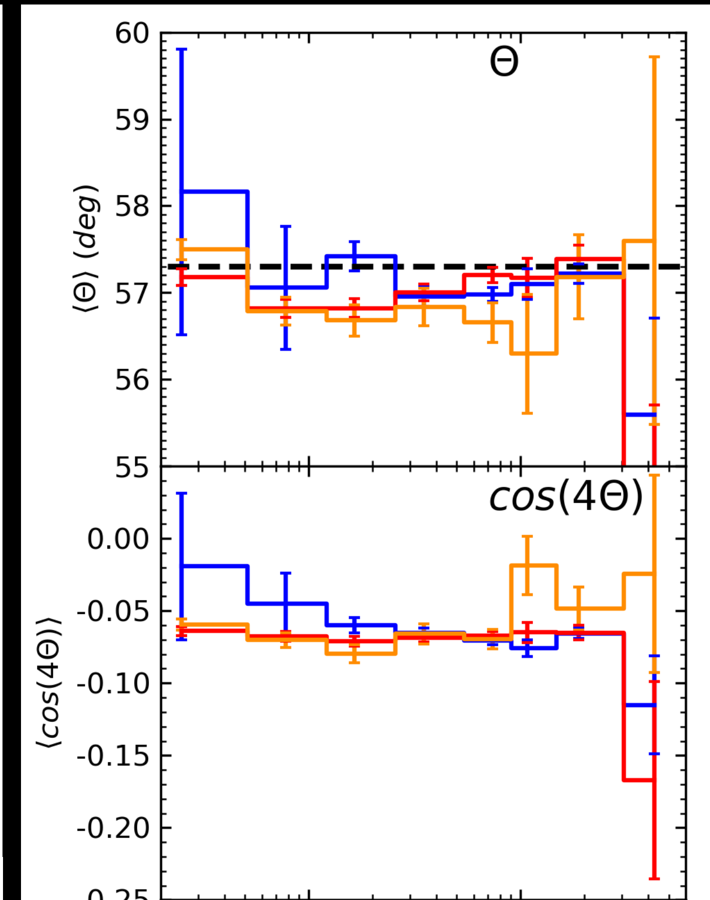
Malavasi et al. to be submitted

Re-shuffled vs. Original

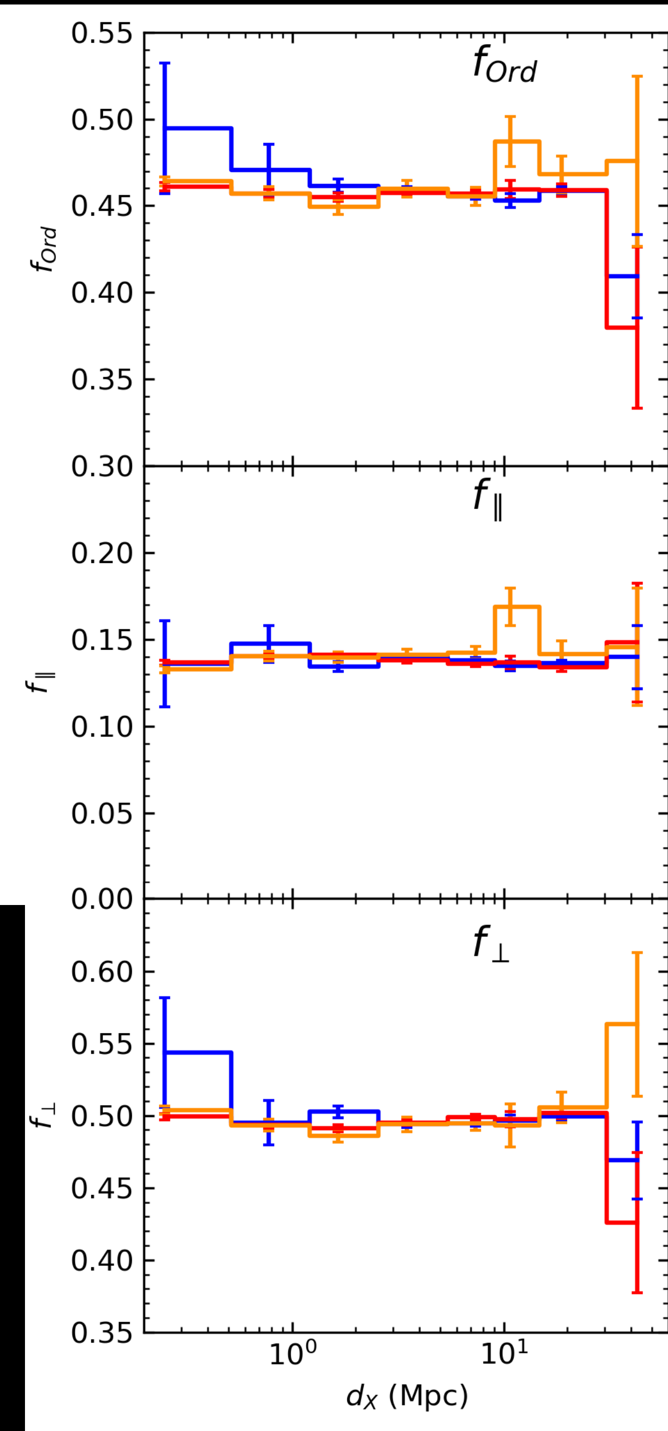




Re-shuffled



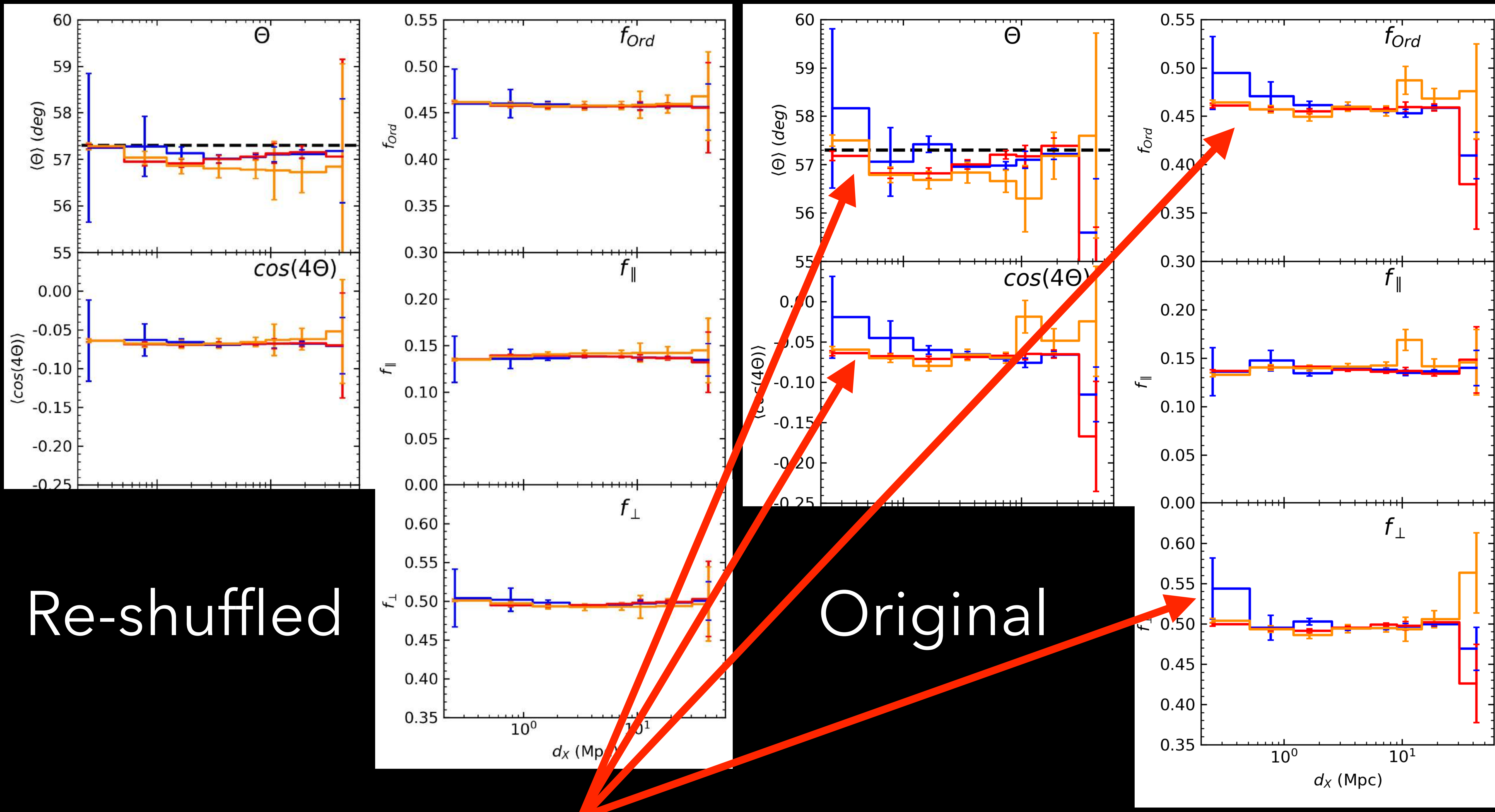
Original



The trends for θ and $\cos(4\theta)$ are reduced in the re-shuffled case. These quantities seem to be more sensitive to the structures than to local density.

Malavasi et al. to be submitted

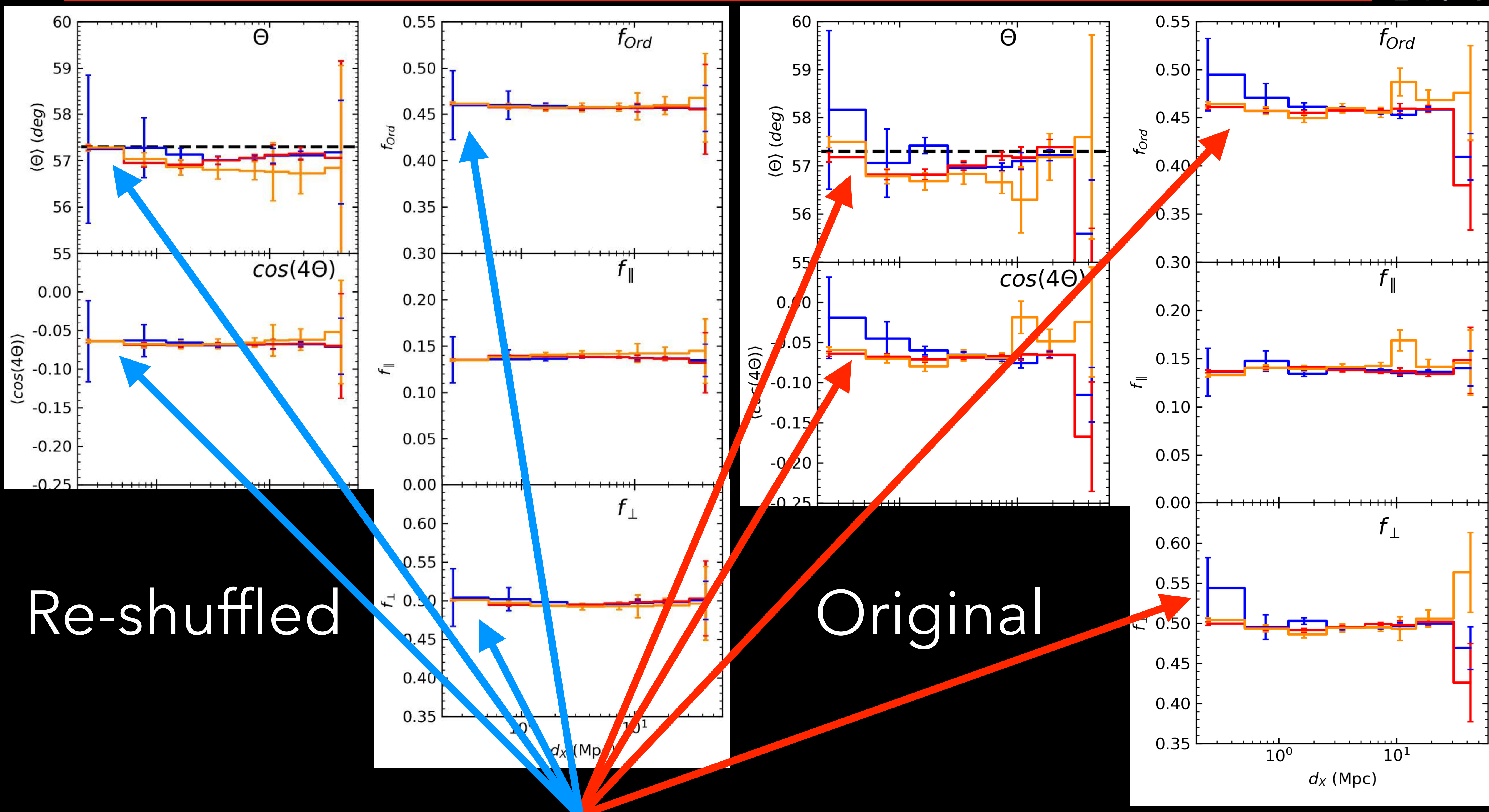
Re-shuffled vs. Original



The trends for θ and $\cos(4\theta)$ are reduced in the re-shuffled case. These quantities seem to be more sensitive to the structures than to local density.

Malavasi et al. to be submitted

Re-shuffled vs. Original



The trends for θ and $\cos(4\theta)$ are reduced in the re-shuffled case. These quantities seem to be more sensitive to the structures than to local density.

Malavasi et al. to be submitted

Conclusions

M*, SFR, and spin direction of galaxies are affected by cosmic structures throughout cosmic evolution.

In turn, galaxy properties can be used to better define the different types of structures.

- SFR-related quantities allow to distinguish the various structures better than other quantities.
- Spin-related quantities show very small trends with the distances to structures.
- There are indications for these trends to become stronger: if we consider the spin of the gas disk and if low-mass, fast-spinning galaxies are considered.
- Spin-related quantities are more sensitive to the structures of the cosmic web than to local density.

Malavasi et al. to be submitted