Spinning of galaxies in filaments

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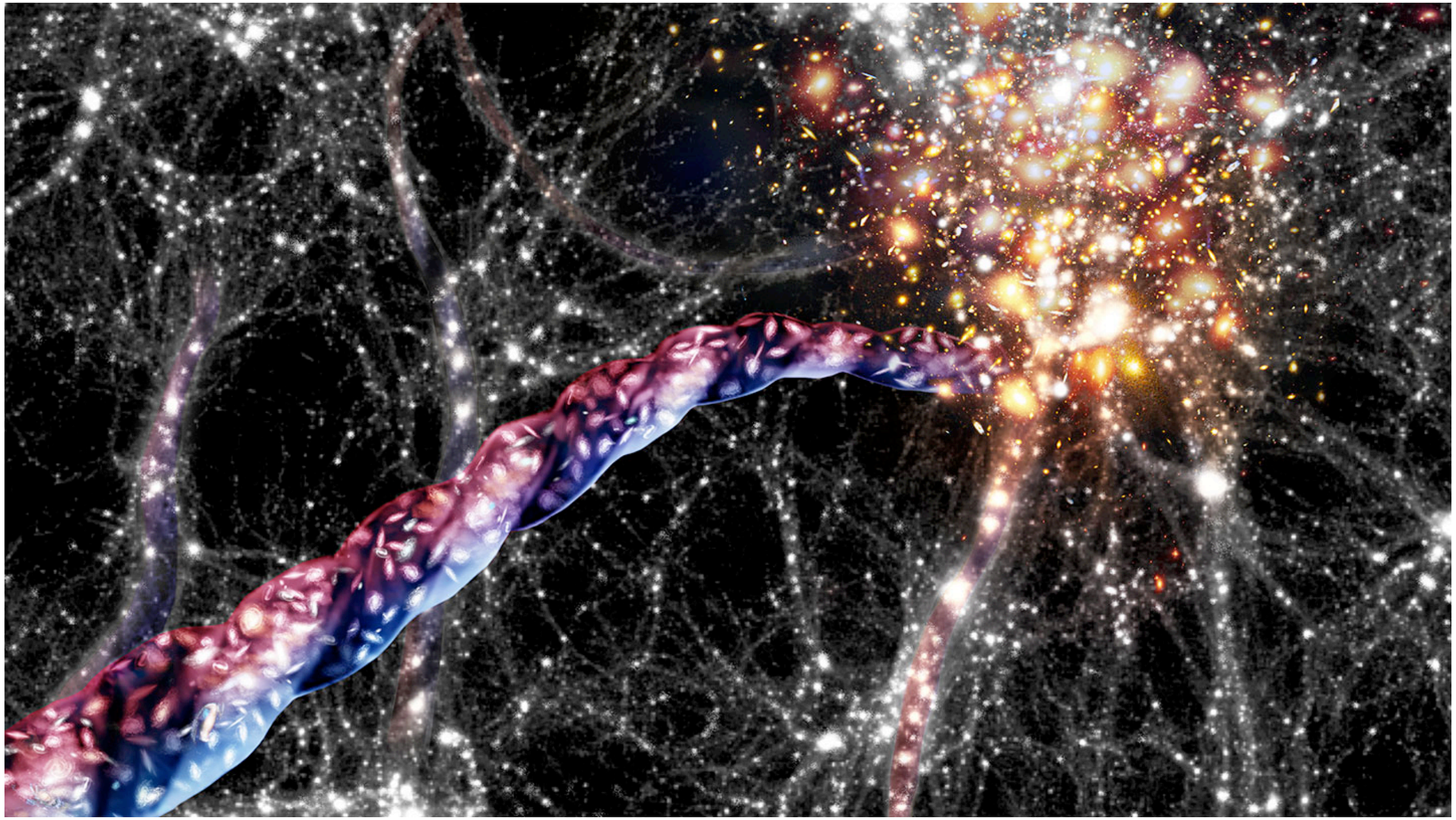
SAMI+Hector Busy Week 2022

Motivation

How do galaxies build up their spin in the cosmic web?



A. Khalatyan/J. Fohlmeister/AIP

Dark Matter Halos in the Cosmic Web

Alignment of the dark matter halo with respect to the filament is **mass-dependent**

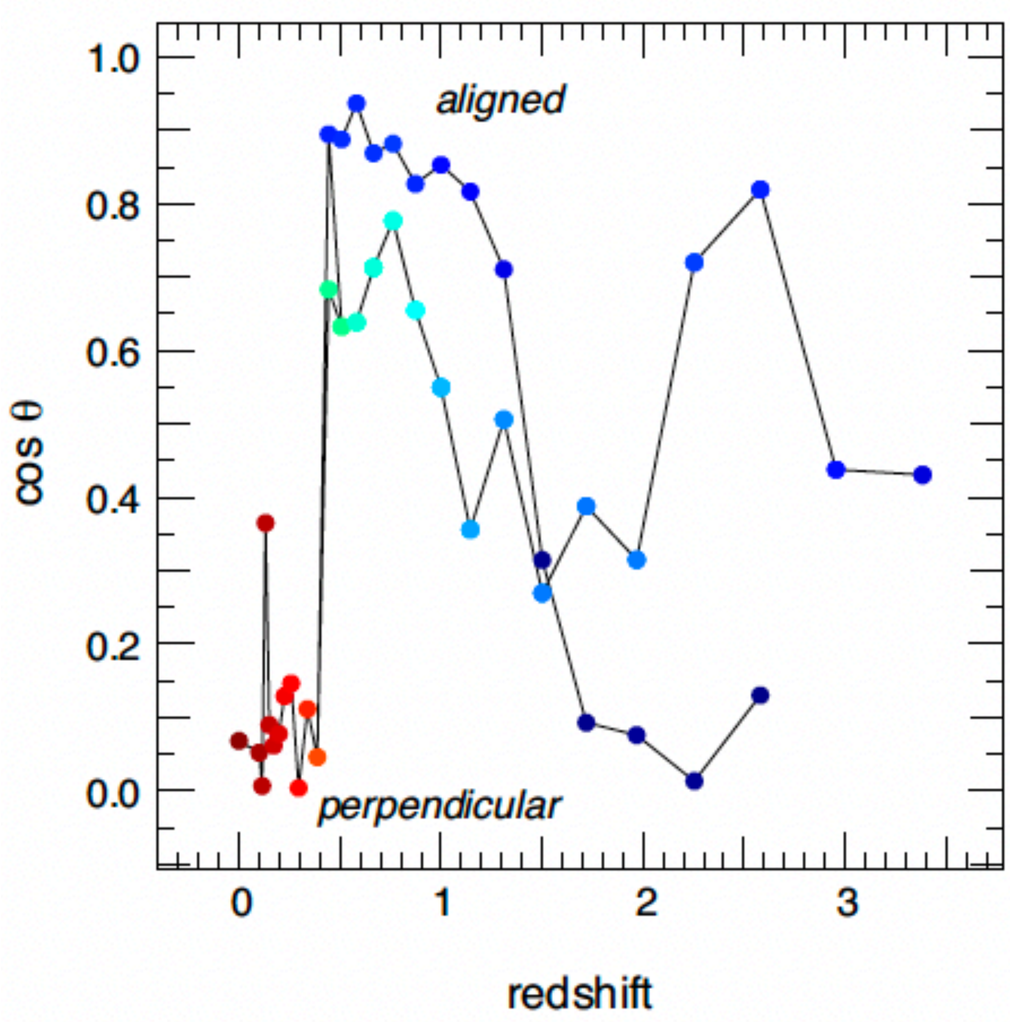
High-mass halos $\longrightarrow \perp$ alignement

Low-mass halos $\longrightarrow \parallel$ alignement

(Codis et al. 2012)

Dark Matter Halos in the Cosmic Web

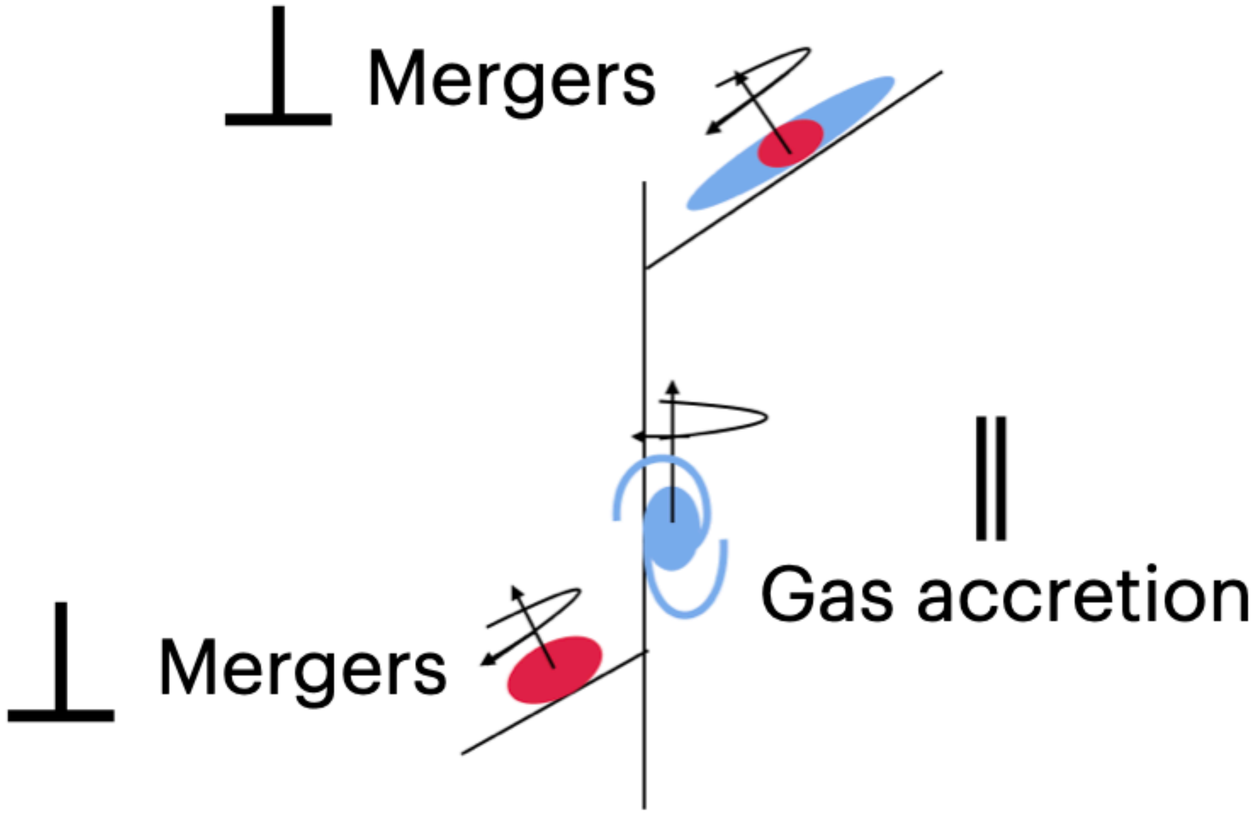
Alignment of the dark matter halo with respect to the filament is **redshift-dependent**



(Codis et al. 2012)

Adding Baryonic Matter

Similar **mass-dependency** for galaxies - with conflicting results in the literature



(Dubuois et al. 2014, Welker et al. 2014)

Observations

Memory of galaxy formation: **weak signal** - especially in the nearby Universe

Galaxy spin-filament alignments trends as a function of
morphology and stellar mass

Photometry: Tempel et al. 2013a,b

Observations

IFU - MaNGA: Krolewski et al. 2019, Kraljic et al. 2021

No trends as a function of stellar mass and contradicting results for S0 galaxies.

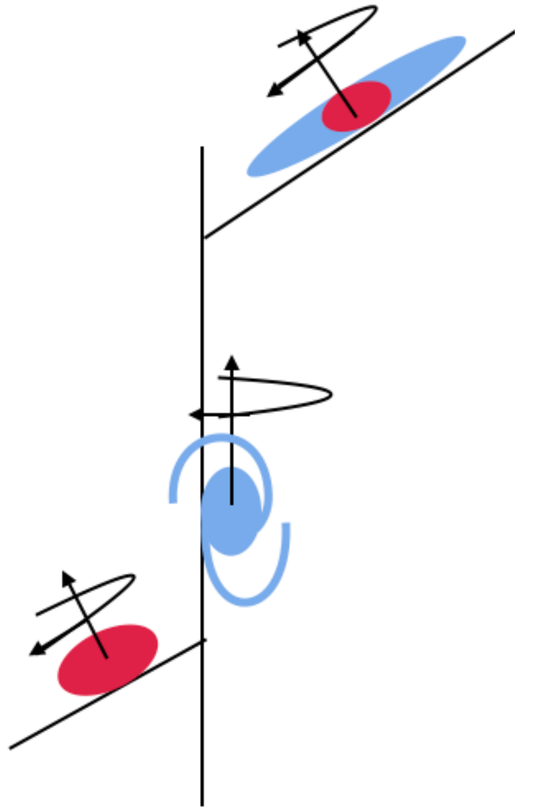
IFU - SAMI: Welker et al. 2020

First detection of the alignment of galaxy spins with filaments at≈ 2σ.

Barsanti, Colless, Welker et al. (2022)

What is the **primary galaxy parameter** of correlation with spin-filament alignments?

What can we tell about separate spin-filament alignments for **bulges and discs**?

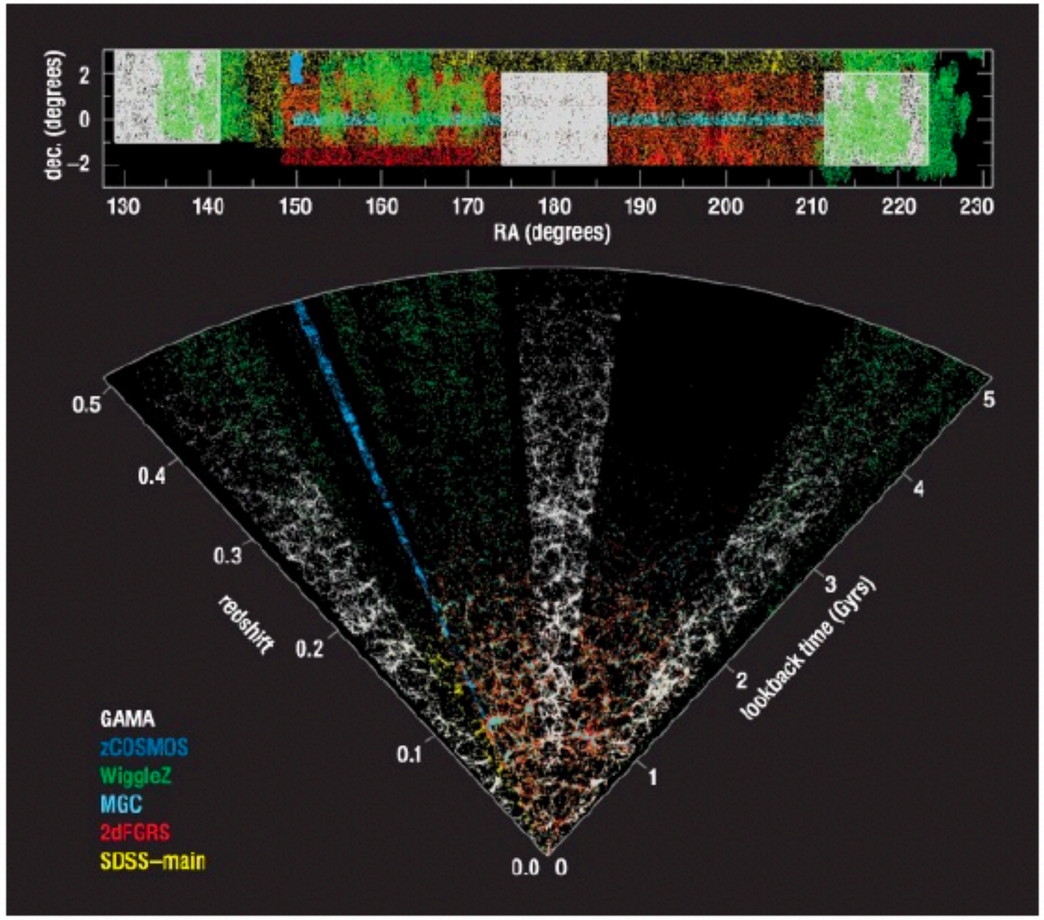


Insights on the formation of galaxies,
bulges and discs

The GAMA survey

(Driver et al. 2011, 2022)

Spectroscopic and photometric survey of ~300 000 galaxies at z<0.5



~36 000 galaxies at z<0.1

↓

reconstruct
cosmic filaments

Discrete Persistent Structure Extractor

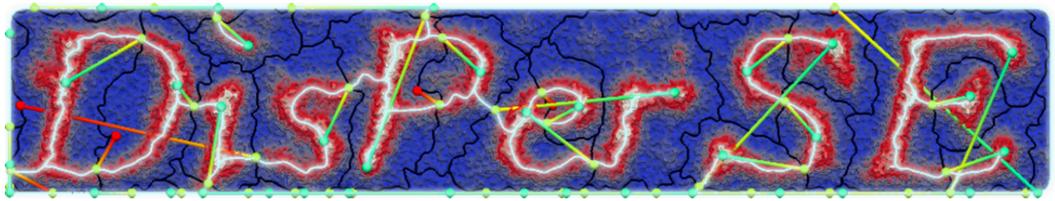
DisPerSE

Automatic identification of persistent structures
for cosmological and hopefully more useful applications.

- Sousbie (2011) a,b
- 3D topological features: no assumptions on the distribution
- Tessellation of space in **voids, walls and filaments**
- **Persistence** (i.e. significant) threshold: keep the most robust features against S/N

https://github.com/thierry-sousbie/DisPerSE

http://www2.iap.fr/users/sousbie/web/html/indexd41d.html?



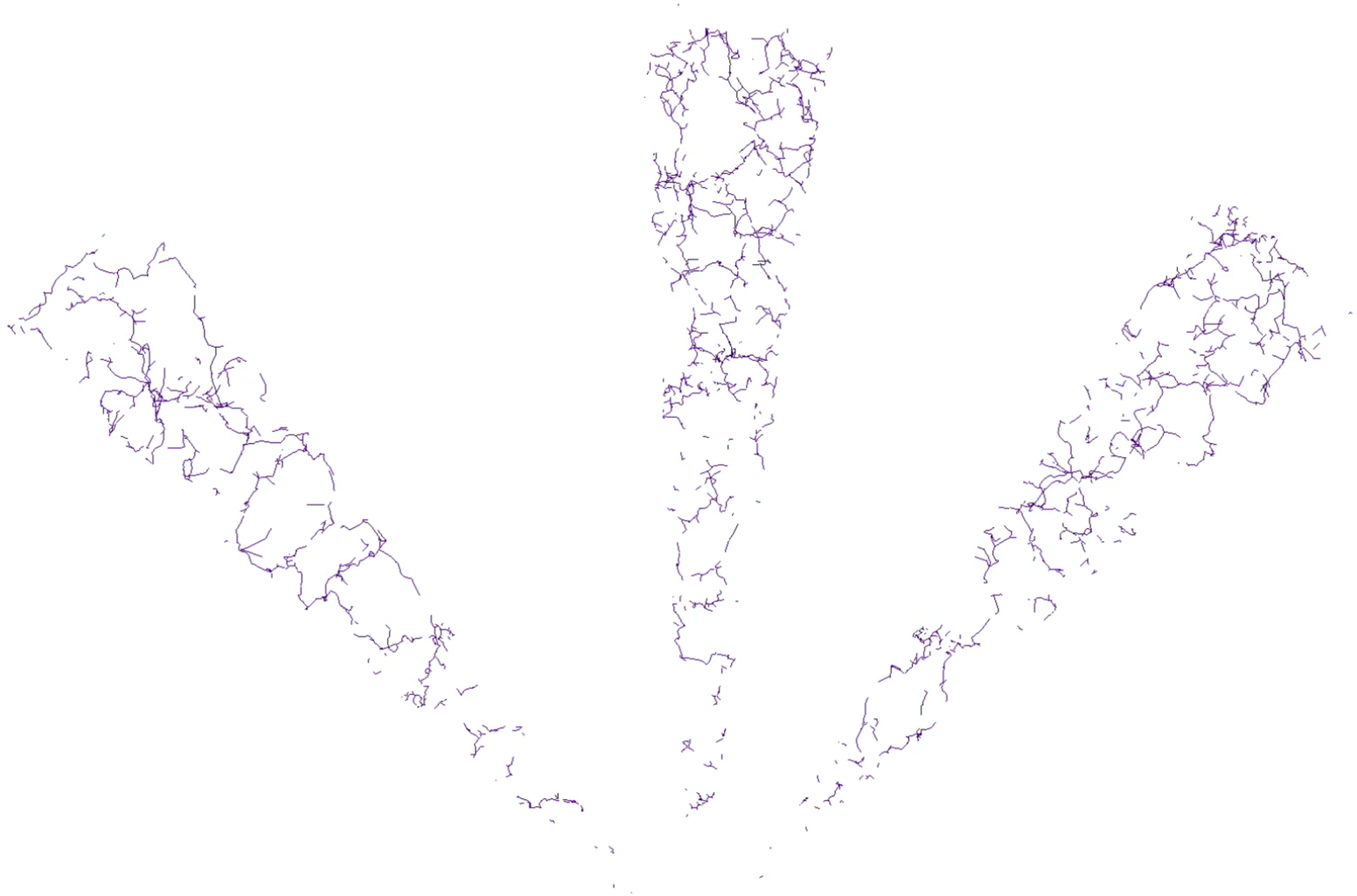
Delaunay Tessellation Field Estimator

GAMA G09, G12 and G15 regions

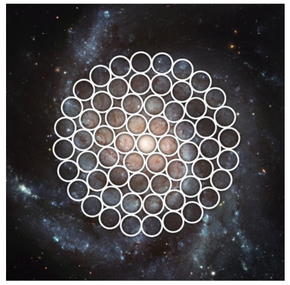
RA, Dec, Z of ~36 000 GAMA galaxies at z<0.1

Cosmic filaments

GAMA G09, G12 and G15 regions



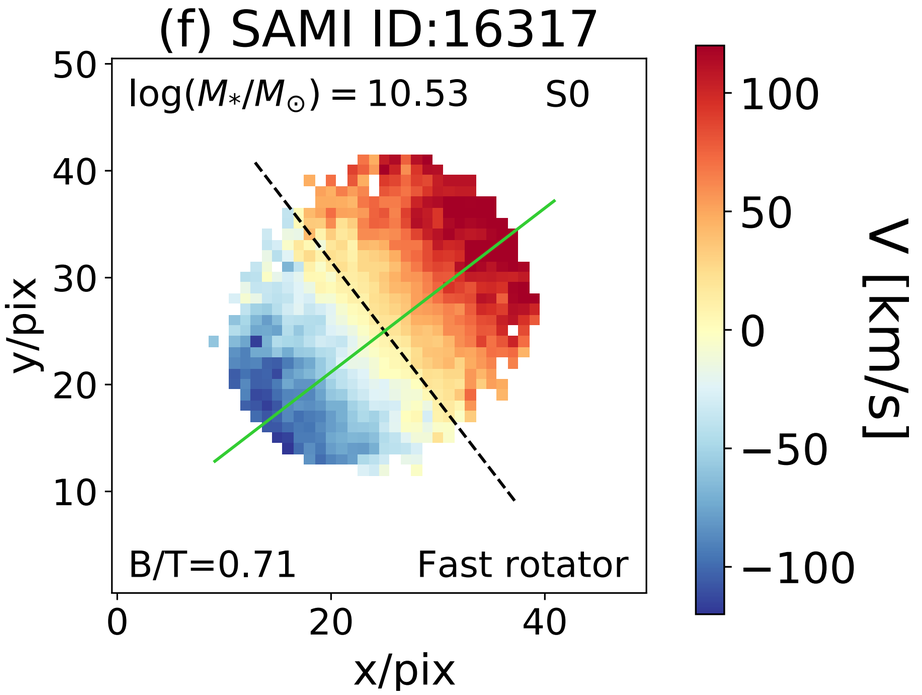
3D models on Sketchfab!



The SAMI survey

(Bryant et al. 2015; Croom et al. 2021)

We exploit **spatially-resolved stellar kinematics** to identify galaxy spin axes.

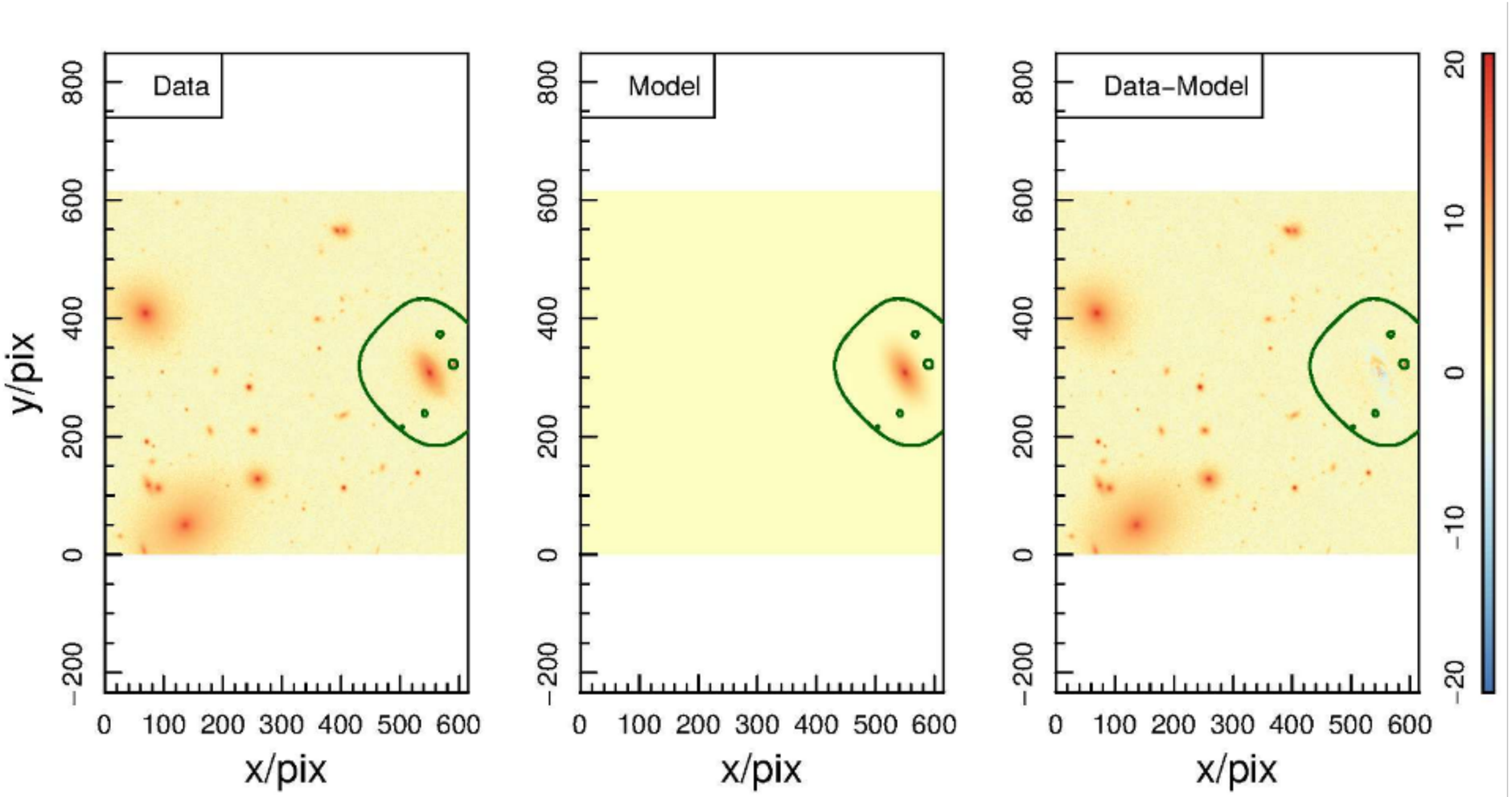


We study **spin-filament alignments of 1121 galaxies** as a function of their properties.

2D bulge/disc decompositions

Bulge/disc **photometric** decomposition

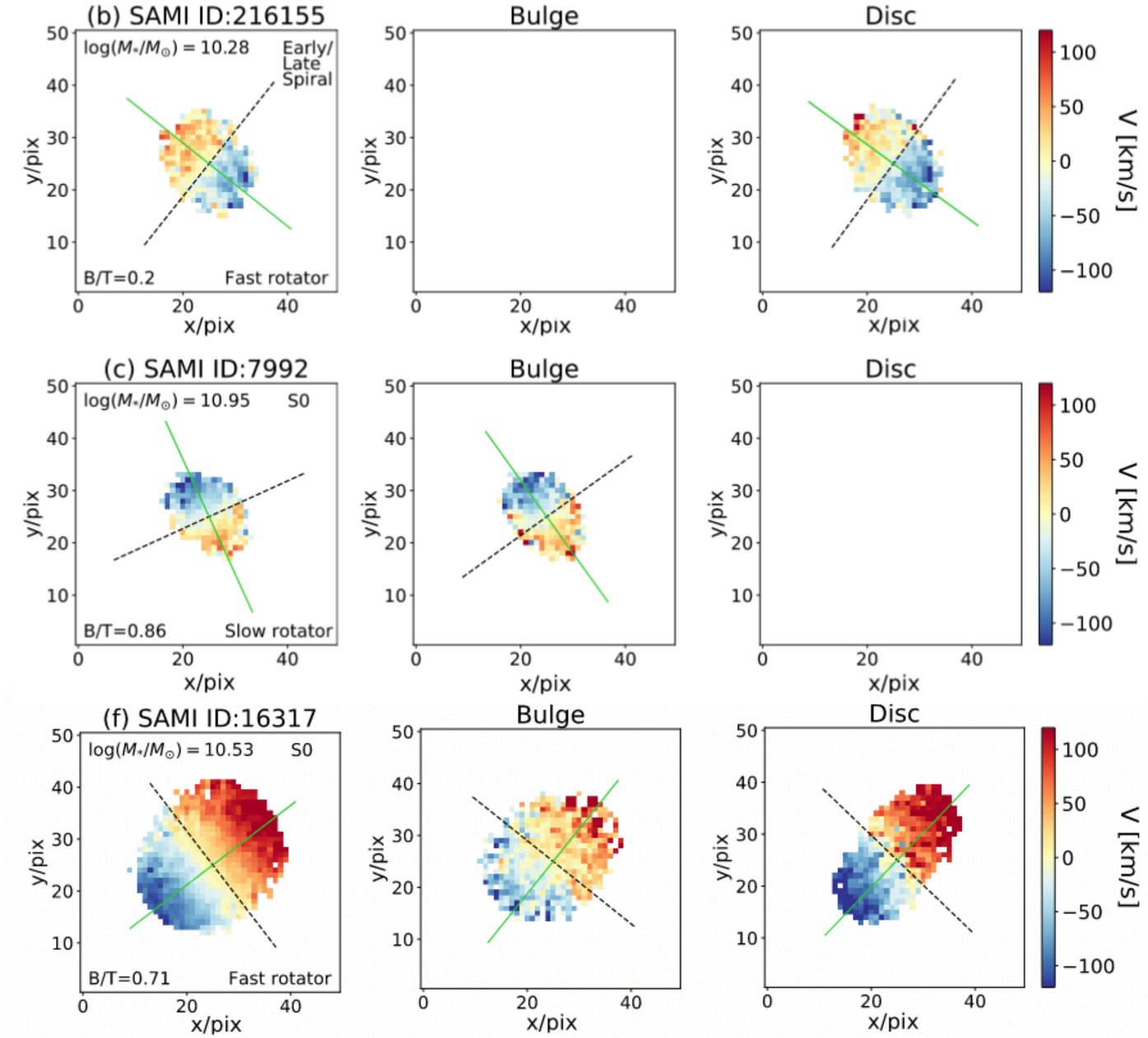
(Casura et al. 2022, Barsanti et al. 2021)



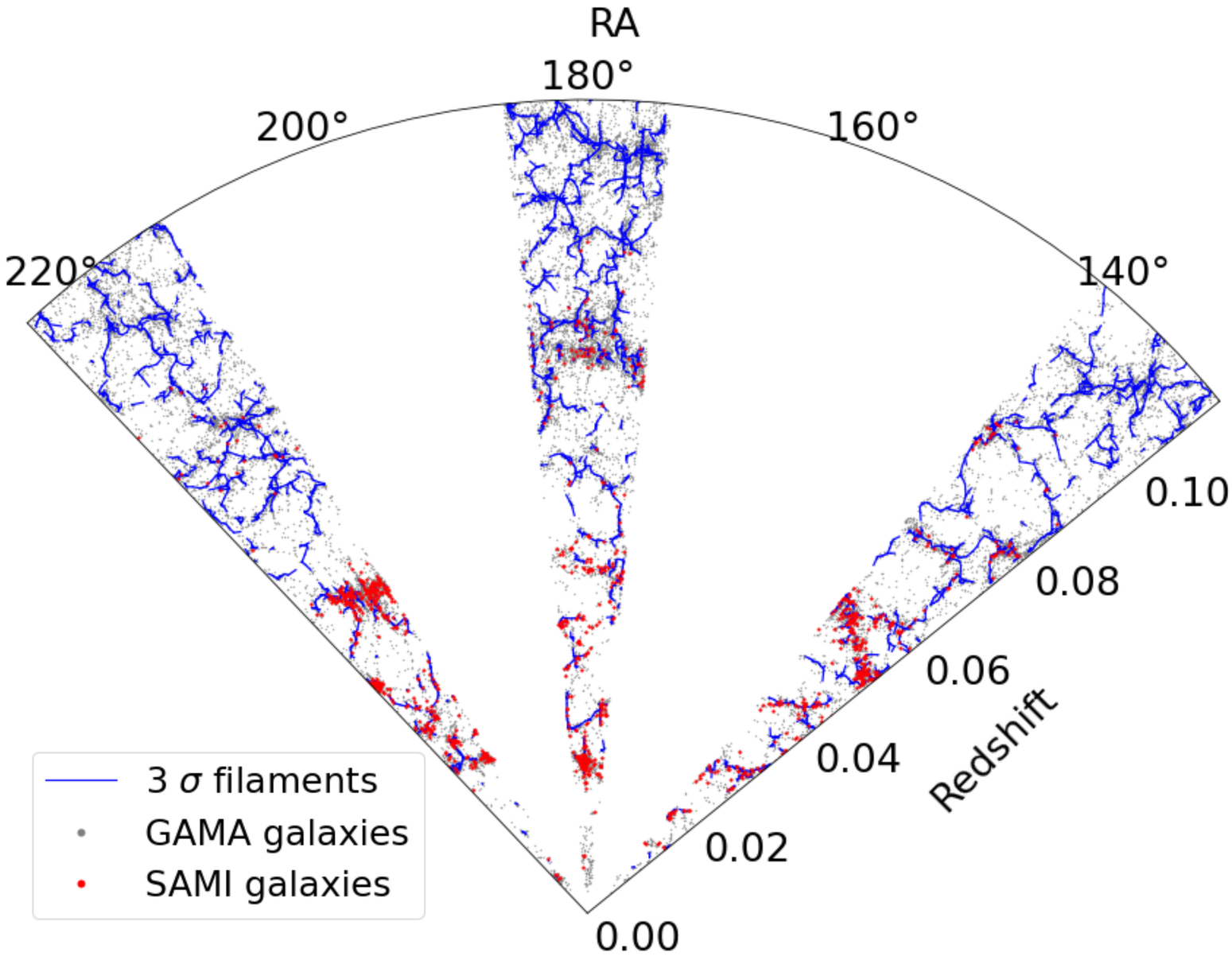
2D bulge/disc decompositions

Bulge/disc
kinematic
decomposition

(Oh, Colless, Barsanti et al. 2020)

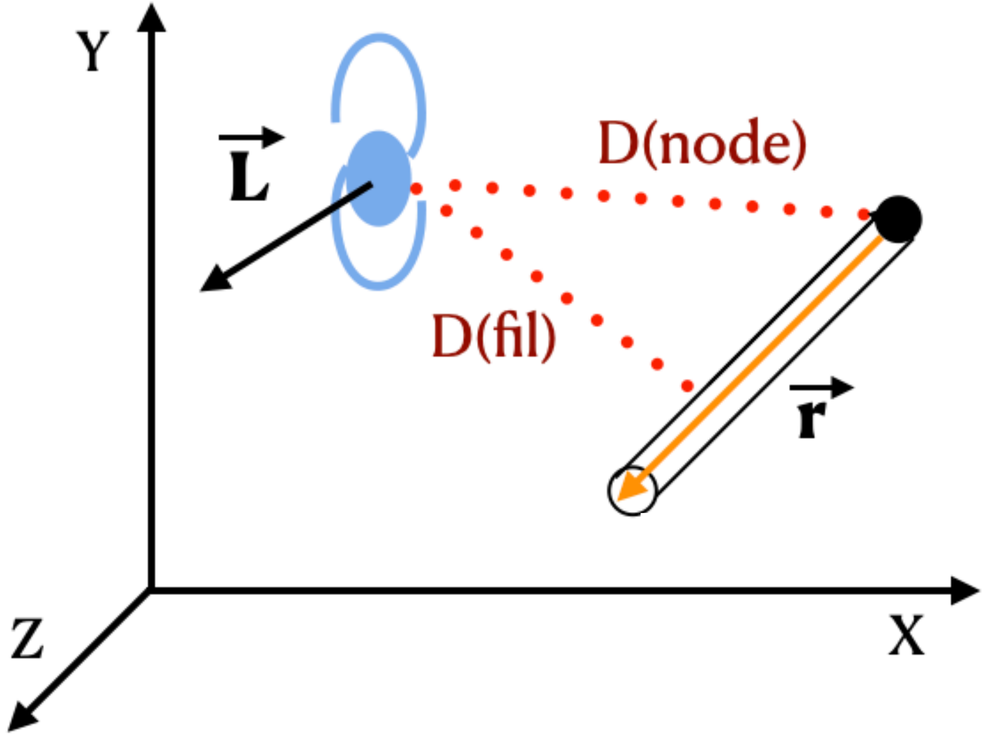


Filaments, GAMA and SAMI galaxies



Galaxy spin-filament angle

We assign each SAMI galaxy to the closest cosmic filament



3D angle

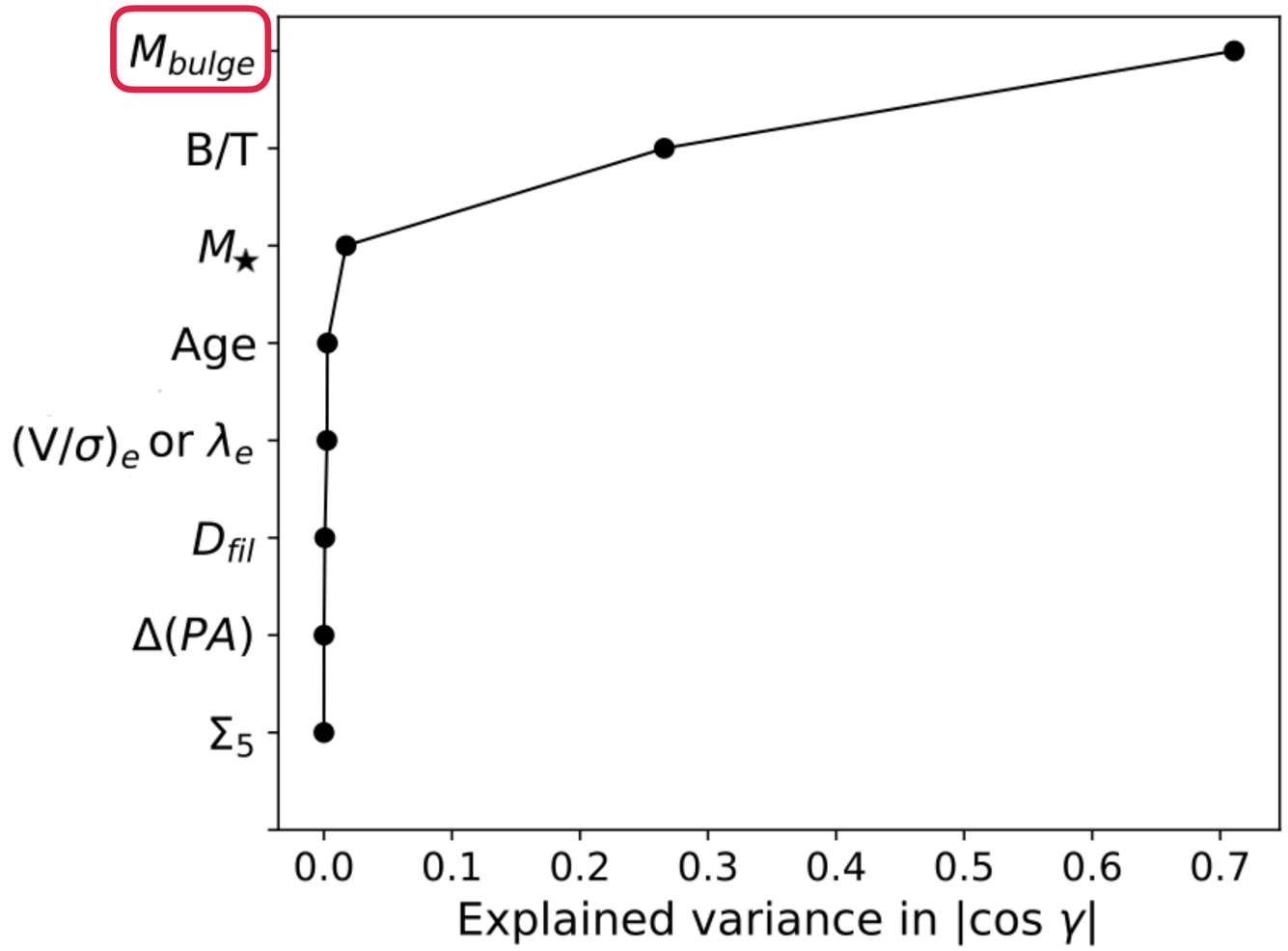
$$\cos(\gamma) = \left(\frac{\mathbf{L} \cdot \boldsymbol{r}}{|\mathbf{L}|\,|\boldsymbol{r}|} \right)$$

$|\cos(\gamma)| = 0 \longrightarrow \perp$ alignement

$|\cos(\gamma)| = 1 \longrightarrow \parallel$ alignement

Results

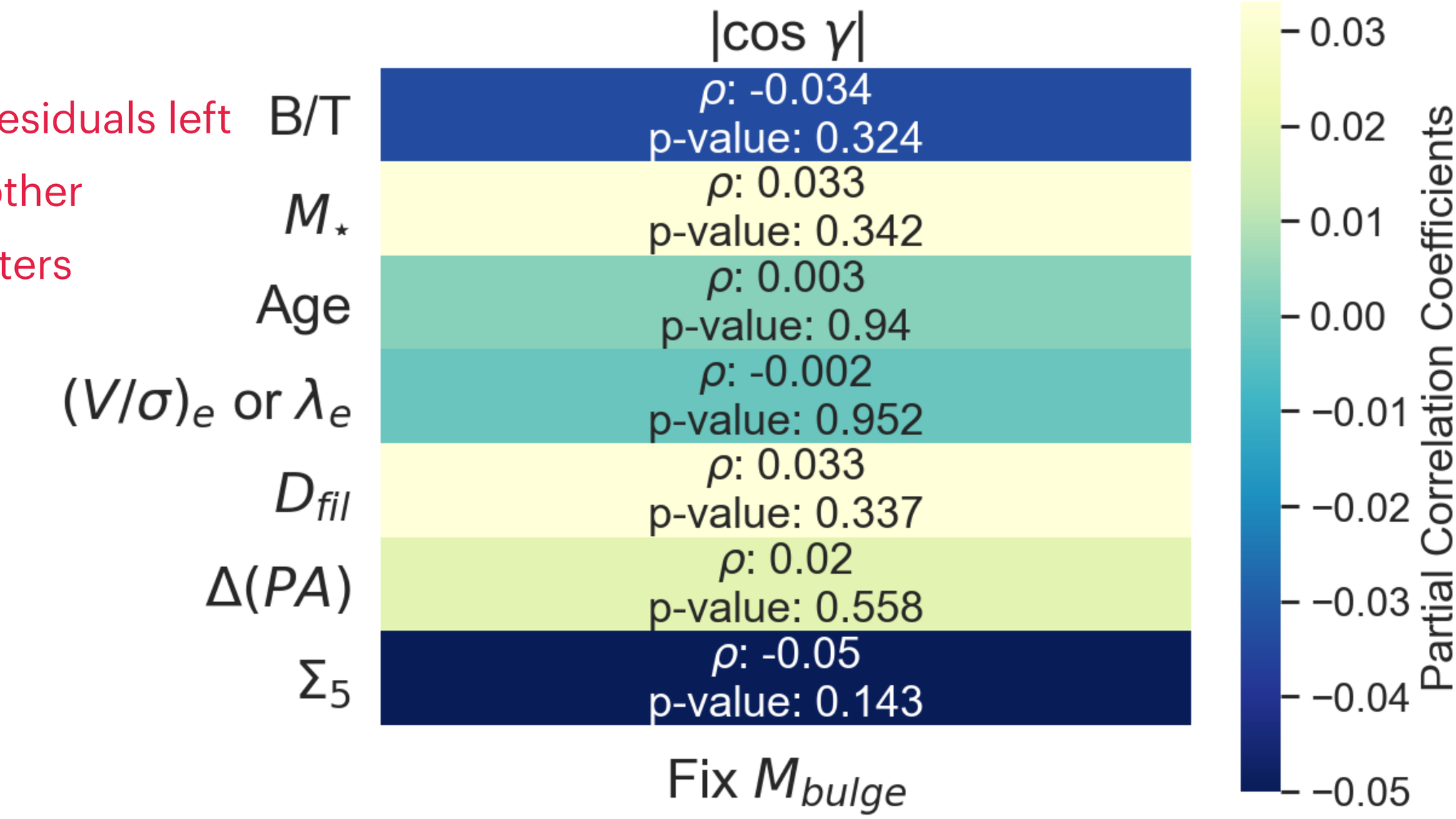
PLS method



~70% variance explained by Bulge Mass

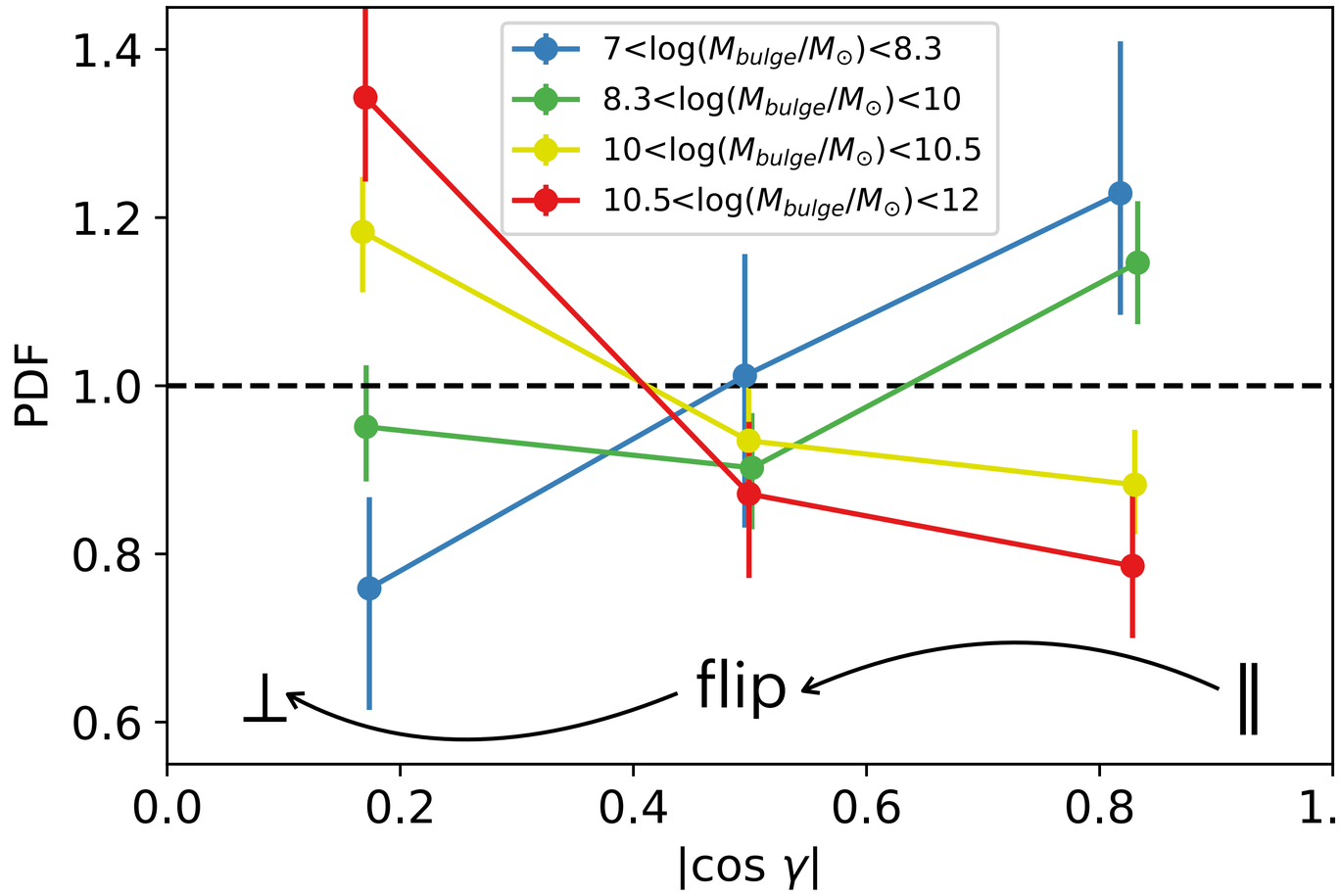
Results

No correlation residuals left for the other parameters



Accounting for the correlation with Bulge Mass

Bulge Mass is the primary parameter



Growth of the bulge

Mergers

flipping of spin-filament alignments

Galaxies with high bulge mass ⟶ ⊥ alignement

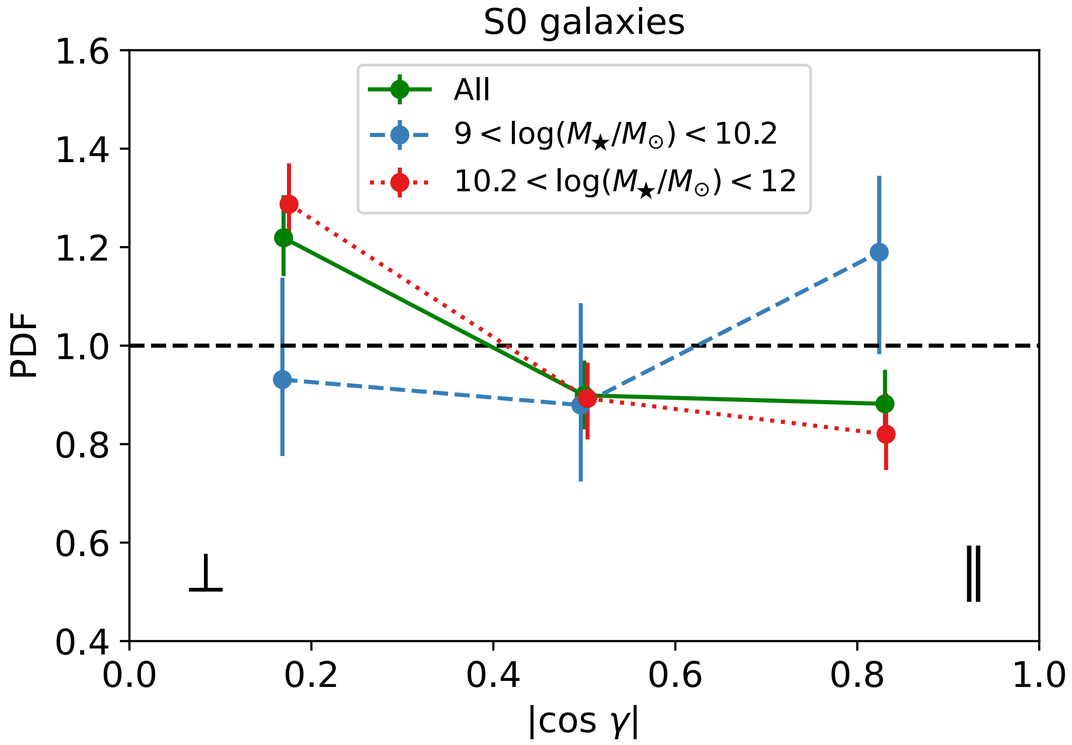
Galaxies with low bulge mass ⟶ ∥ alignement

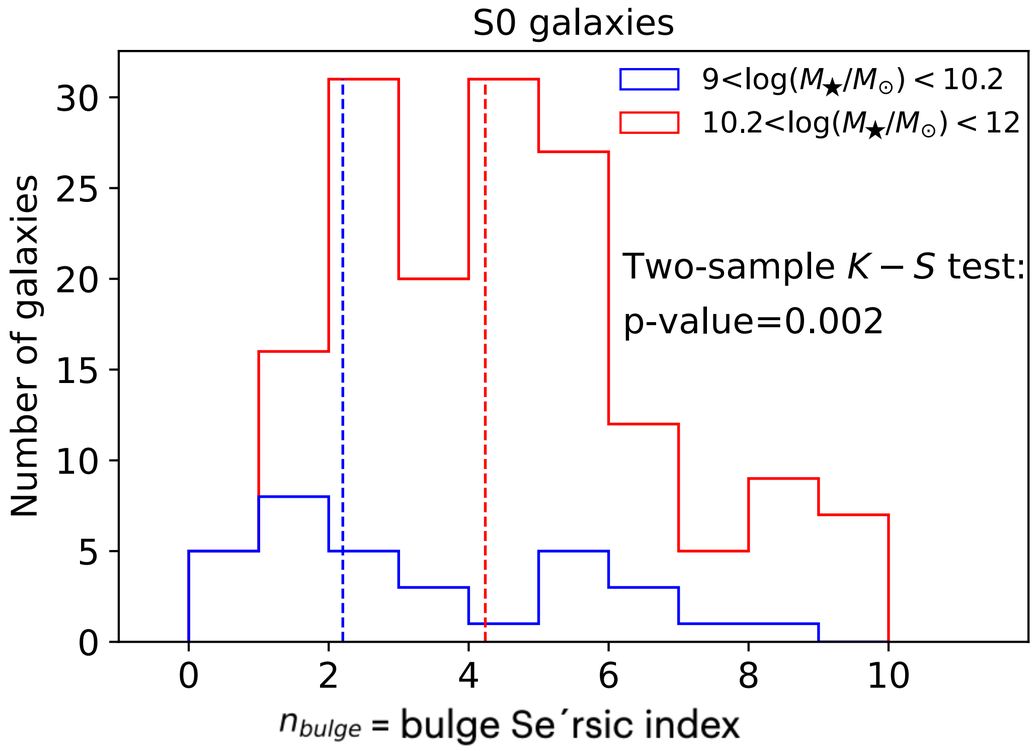
Significant tendencies

K-S test: p-values < 0.05

S0 galaxies

Visual morphology, fast rotators and photometric double-component

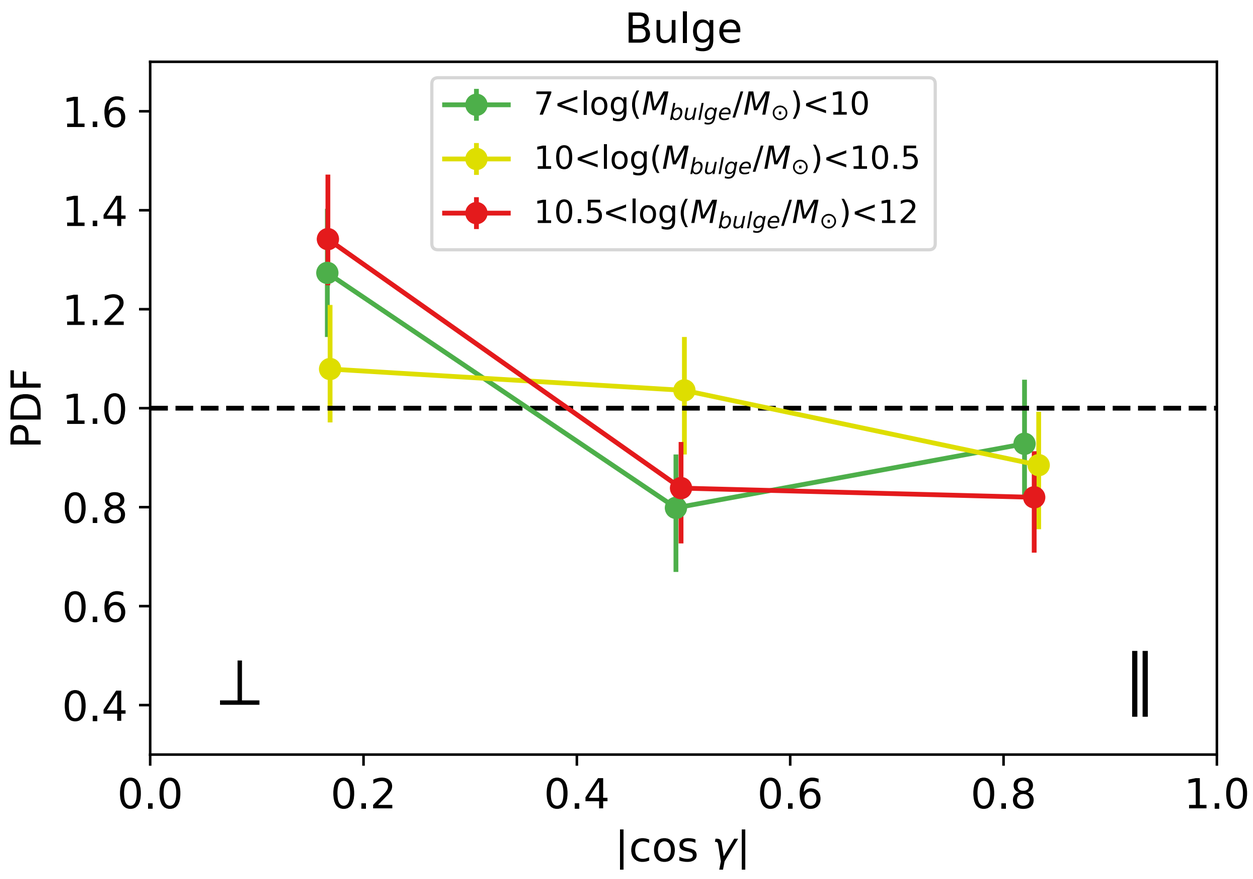


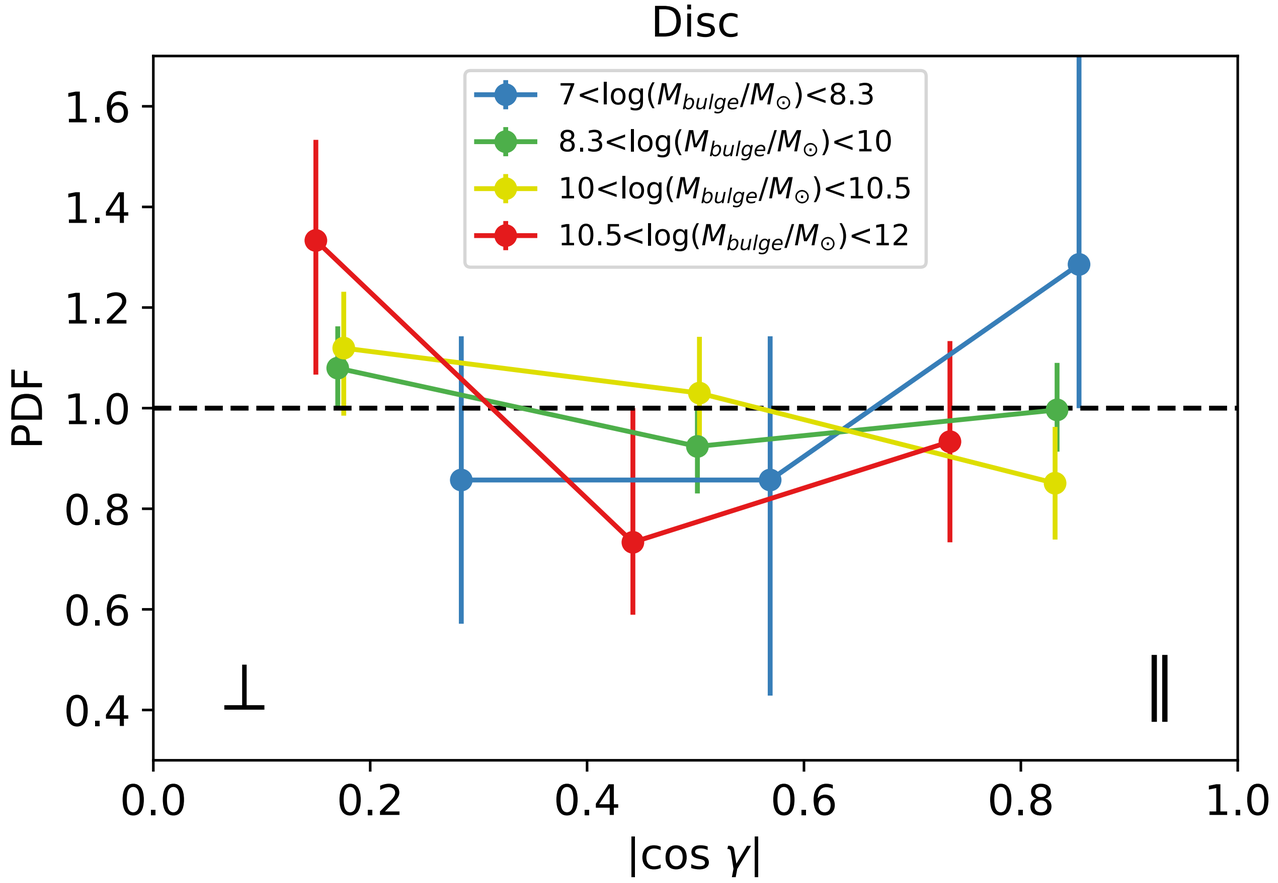


⊥ S0 galaxies ⟶ signal dominated by high-M★ galaxies ⟶ Mergers

⟶ uniform for low-M★ galaxies ⟶ Gas accreation / faded spirals?

Bulge/disc spin-filament alignments





Bulges ⟶ ⊥ alignement

Discs

high bulge mass ⟶ ⊥ alignement

low bulge mass ⟶ ∥ alignement

Mergers

Multiple channels of formation

ASTRO 3D

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Spin flips show how galaxies grow from the cosmic web

5 October, 2022

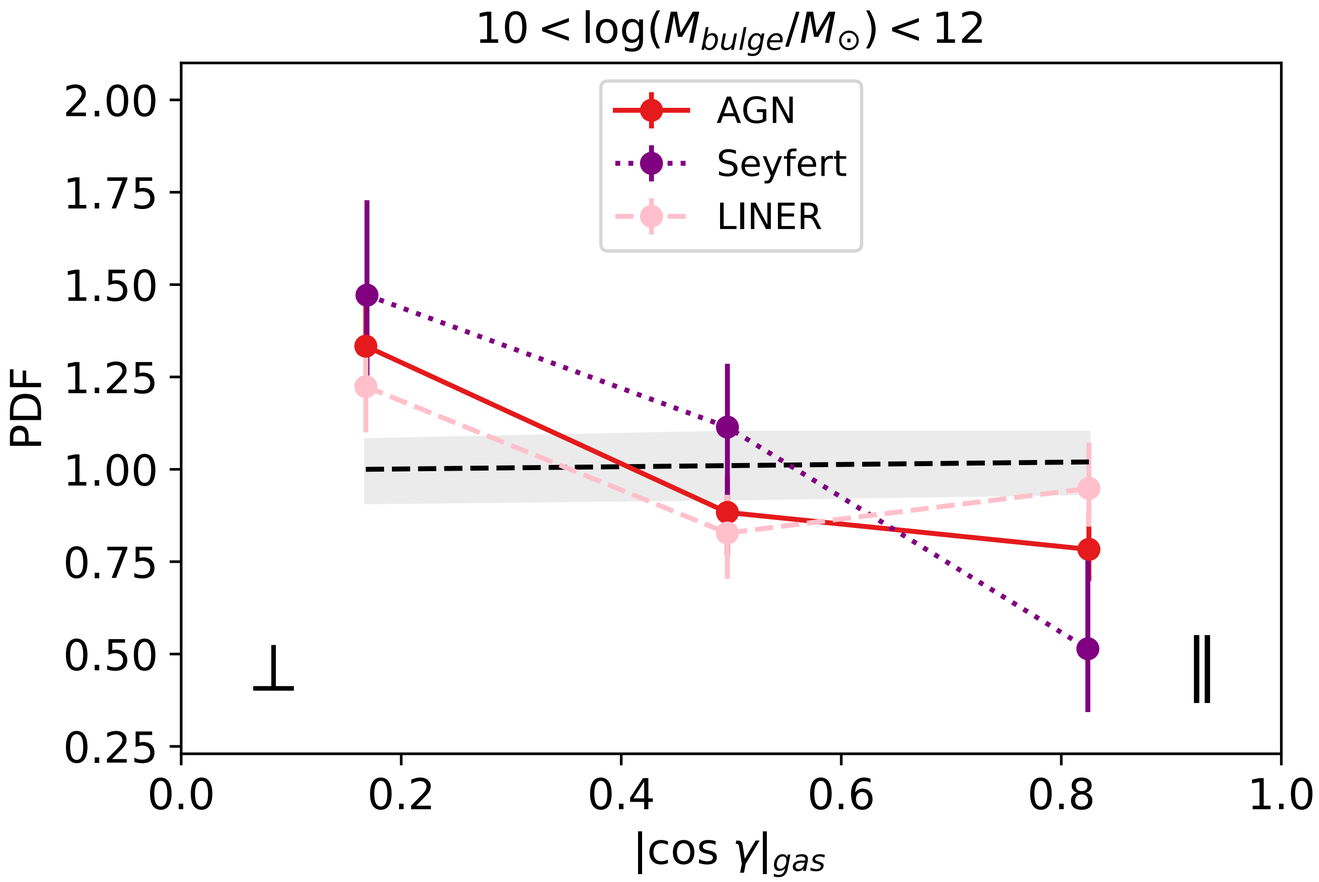
ARC Centre of Excellence for All Sky Astrophysics in Three Dimensions (ASTRO-3D)

The alignment between galaxy spins and the large-scale structure of the universe reveals the processes by which different components of galaxies form.

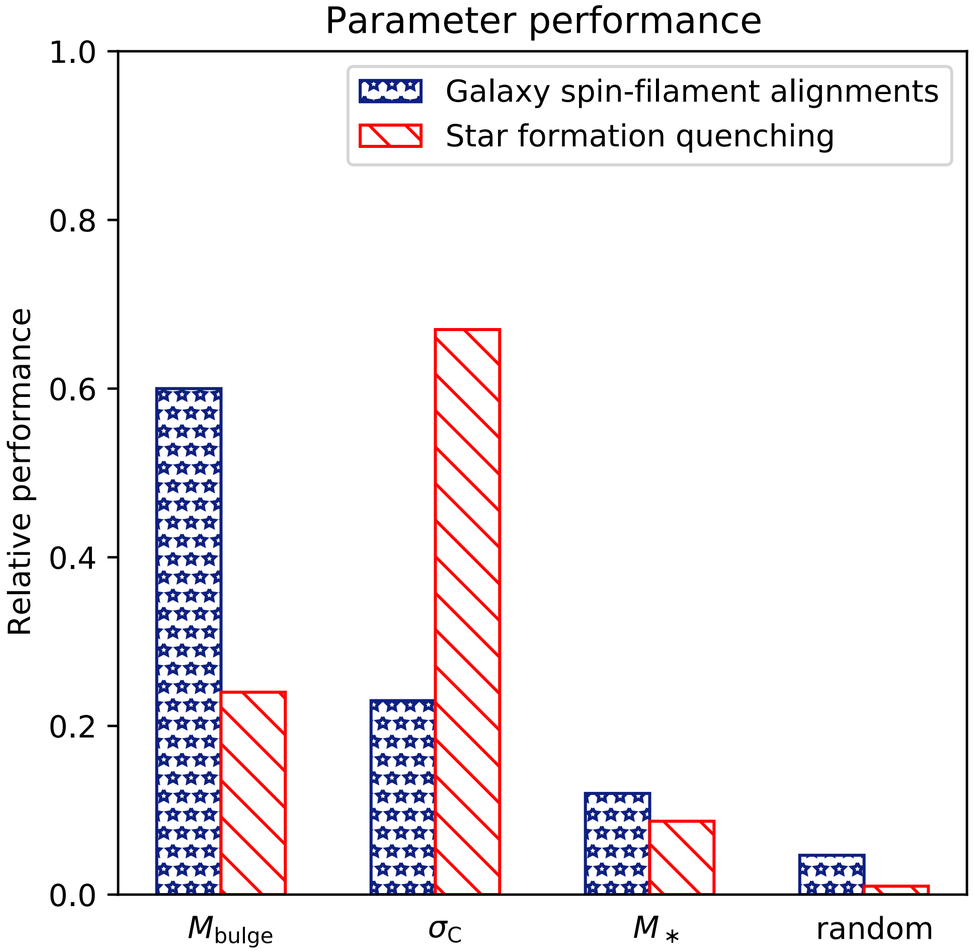
Work in progress

What is the role of **black hole activity** in galaxy spin-filament alignment?

instantaneous



integrated: RFclassifier



HECTOR Galaxy Survey

What is the role of the local **environment**?

Higher density regions: galaxy spins expected to have more perpendicular tendencies due to higher fraction of mergers (e.g., Welker et al. 2014)

Clusters: random orientation as they are regions where the flow of multiple filaments intersect.

Malavasi et al. 2021: no significant trend as a function of the local environment

HECTOR Galaxy Survey

What is the role of the local **environment**?

Cluster outskirts	⟷	Multivariate analysis of filaments Different galaxy populations
Outer regions of many galaxies	⟷	Mergers and disturbances
Low-mass galaxies	⟷	Mass-dependency
Larger galaxy sample	⟷	Significance of the signal