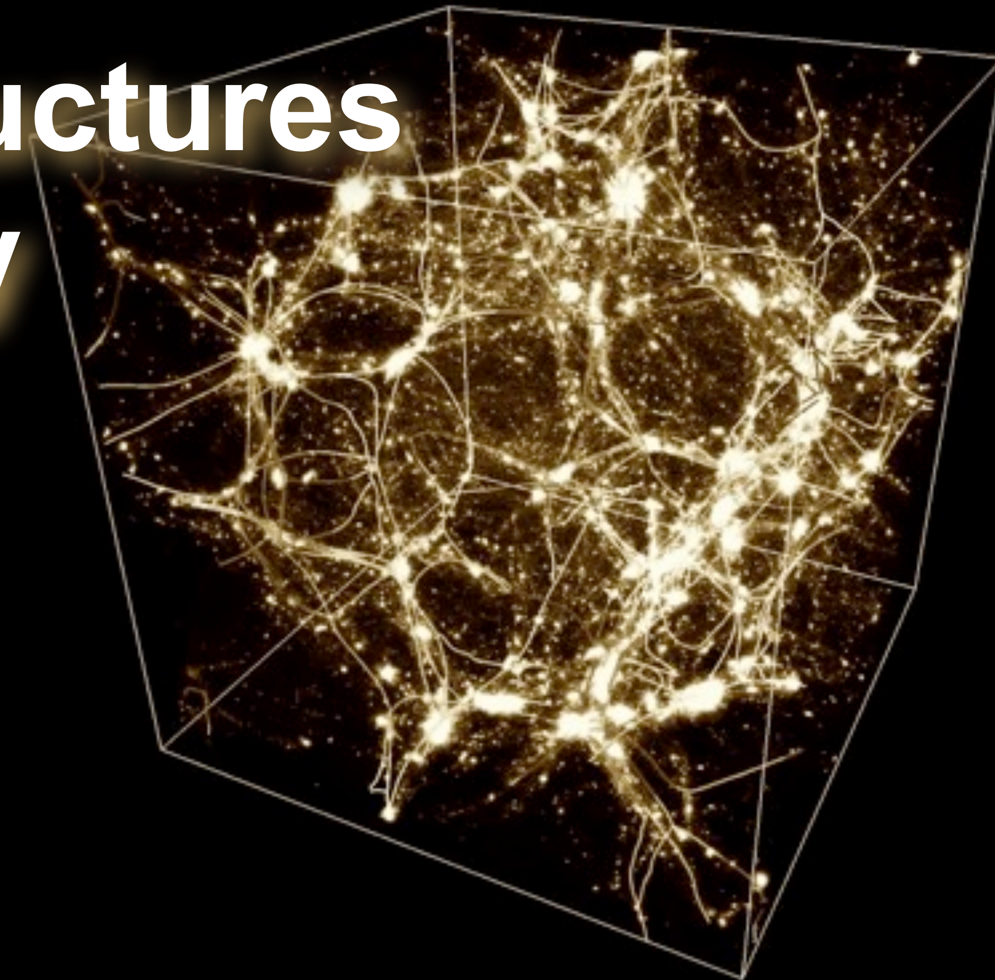
Connecting Large Scale Structures to Galaxy morphology



Can we quantify the impact of the cosmic web on the properties of galaxies **from first principles**?

cosmicorigin.org Spine

Christophe Pichon

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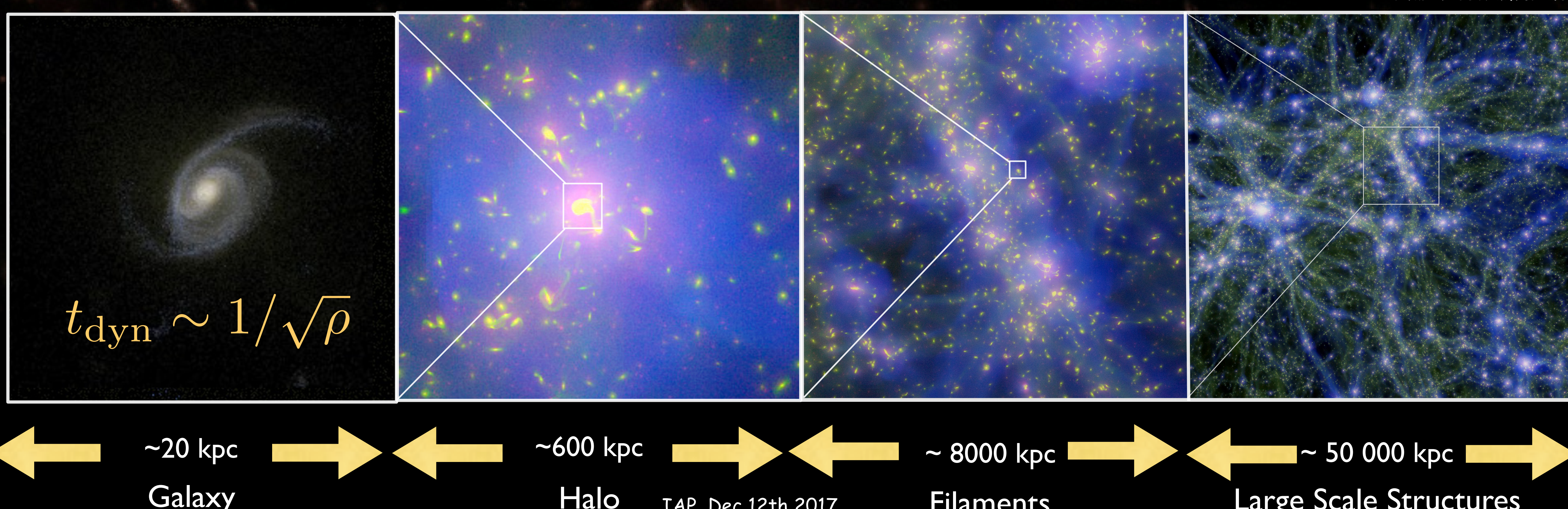
C. Laigle, C. Welker, K. Kraljic, C. Cadiou S. Codis, D. Pogosyan, J. Devriendt, Y Dubois, T. Kimm, H Hwang, S Arnouts

MareNostrum z=1.55



IAP Dec 12th 2017

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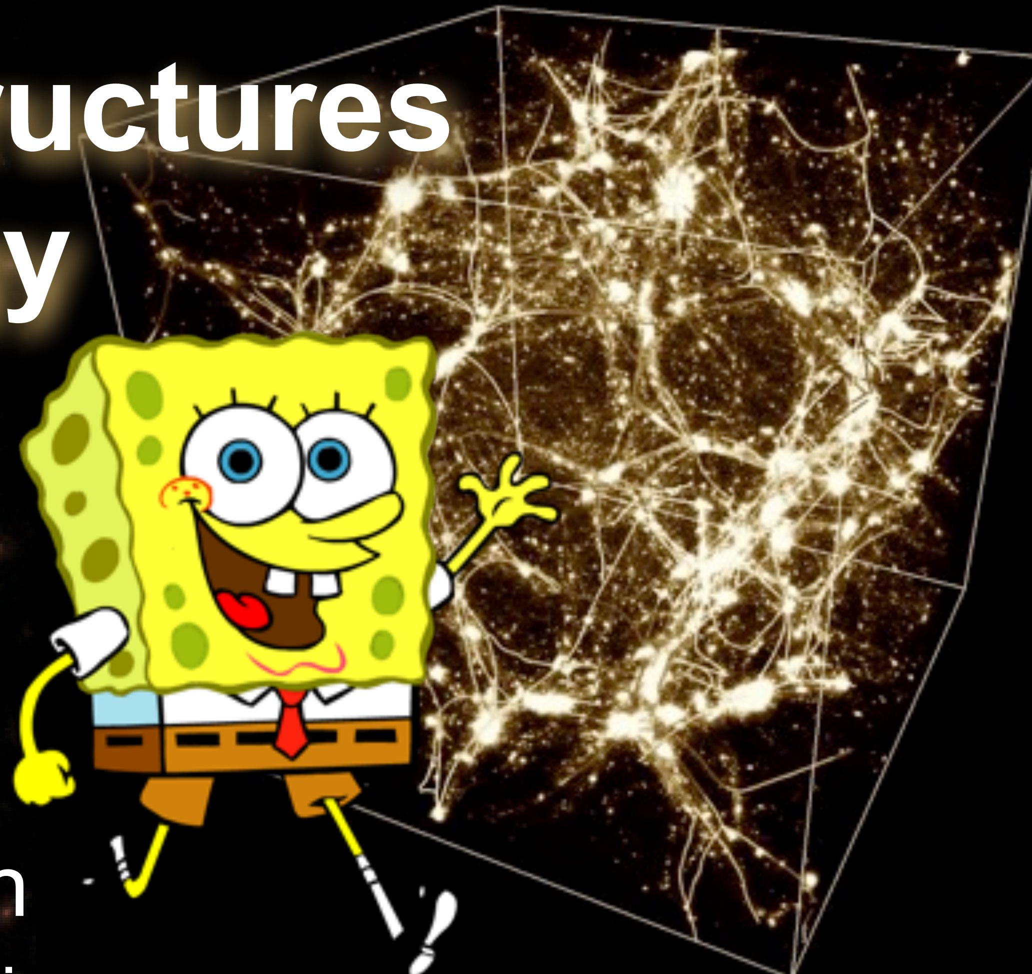

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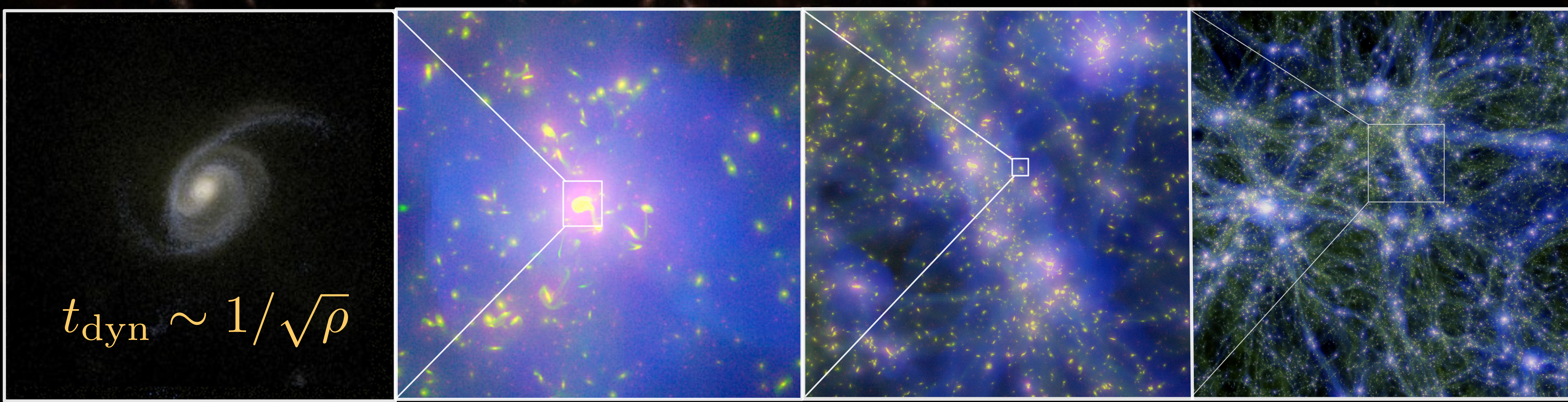

~20 kpc | ~600 kpc | ~ 8000 kpc | ~ 50 000 kpc

Galaxy | Halo | Filaments | Large Scale Structures

IAP Dec 12th 2017

Outline

- **How discs build up from persistent cosmic web?**
- **How galaxies's spin flip relative to filament? Why the transition mass? *Eulerian* view**
- **What is the corresponding Lagrangian theory?**

(c)Taysun Kimm +E. Pharabod

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Why do we care?

- *Weak lensing: intrinsic alignments*
- AM stratification drives **morphology**

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Galactic morphology is driven by AM acquisition through anisotropic secondary infall, coming from larger scales, which are less dense, hence more steady; baryonic flows provide the link.

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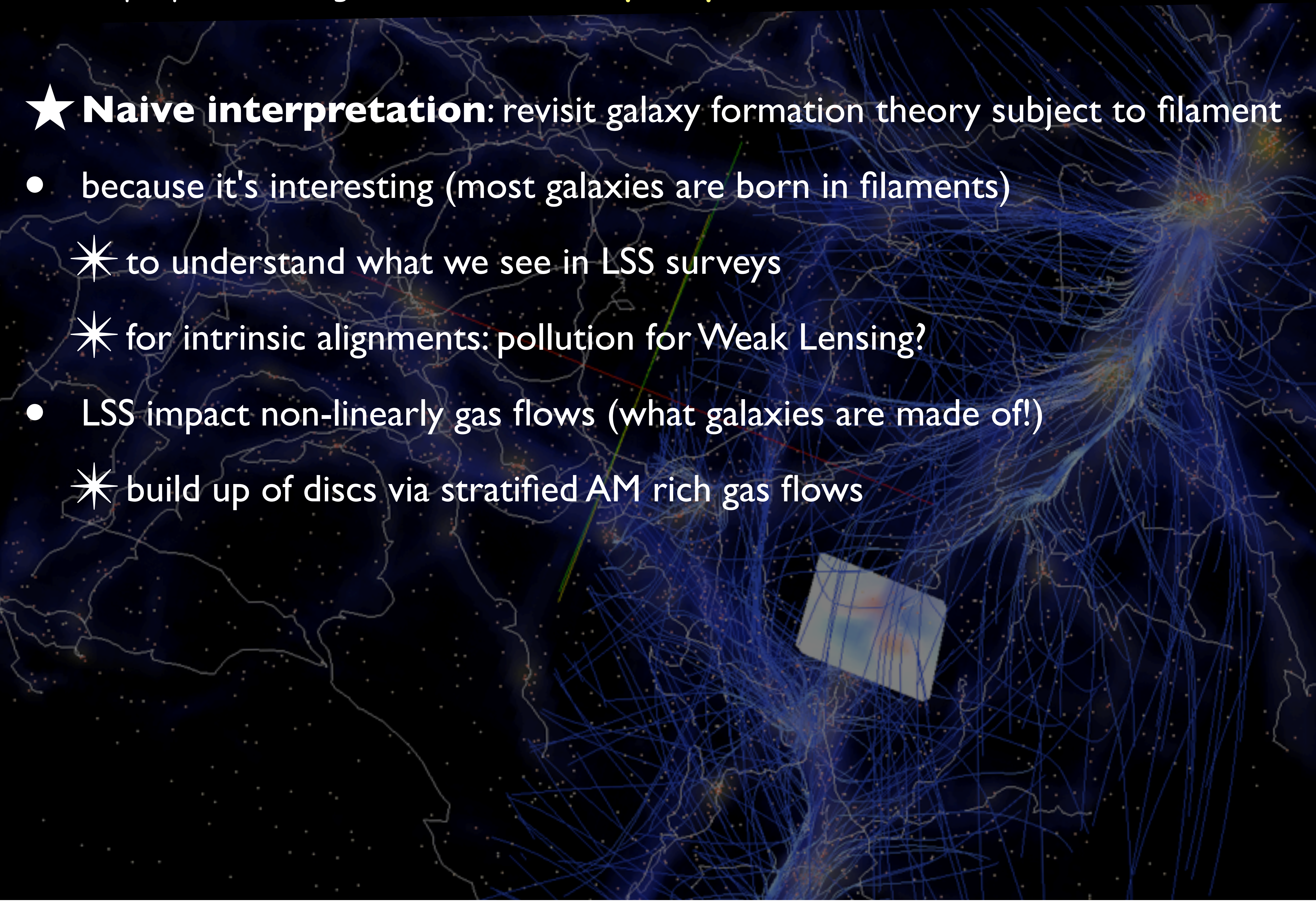
Galactic morphology is driven by AM acquisition through anisotropic secondary infall, coming from larger scales, which are less dense, hence more steady; baryonic flows provide the link.

- can be applied to galactic colours as well through extension of excursion set theory: secondary effect on accretion rate.

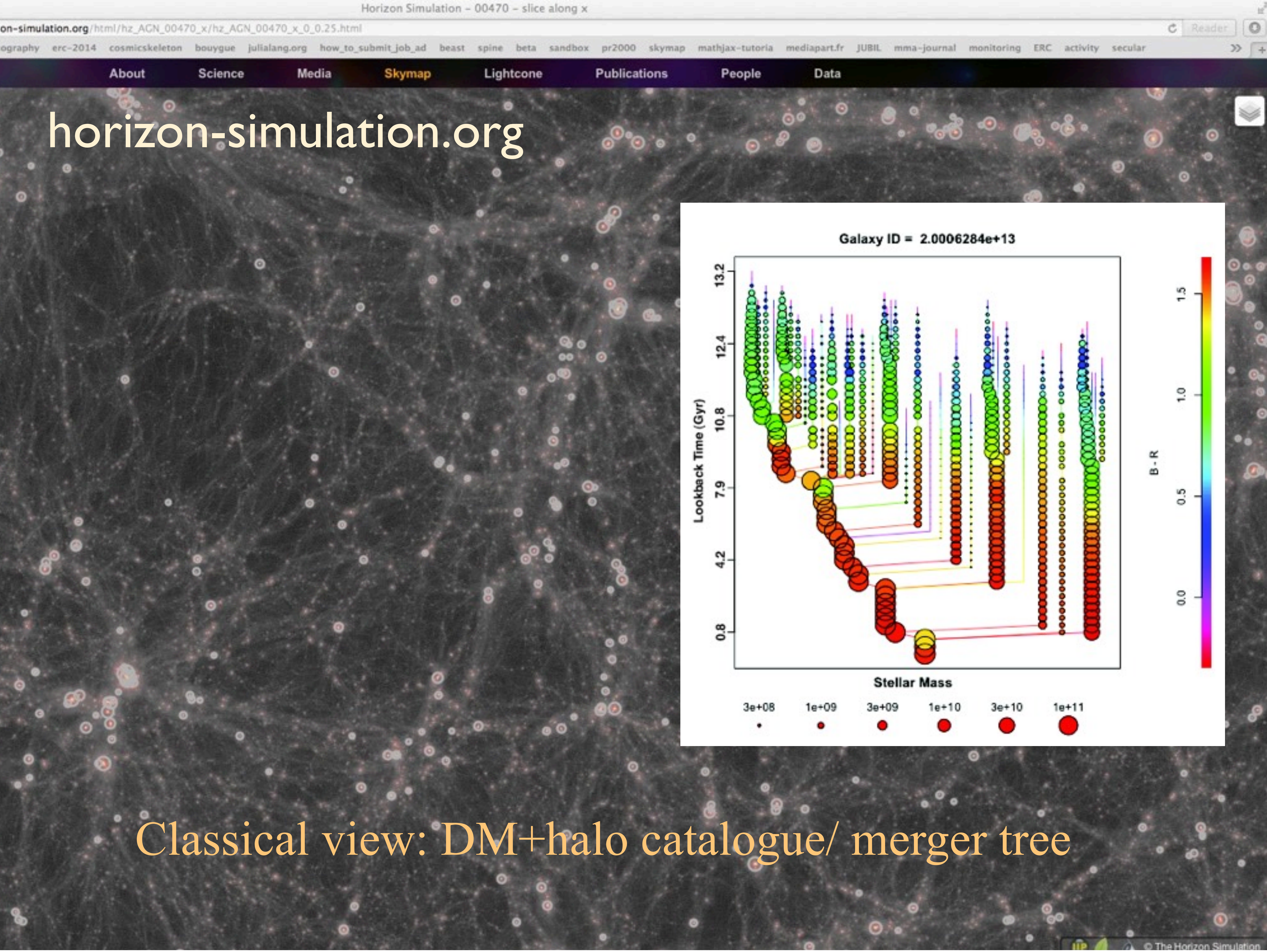
Can we **quantify** the impact of the cosmic web
on the properties of galaxies **from first principles**?

★ **Naive interpretation**: revisit galaxy formation theory subject to filament

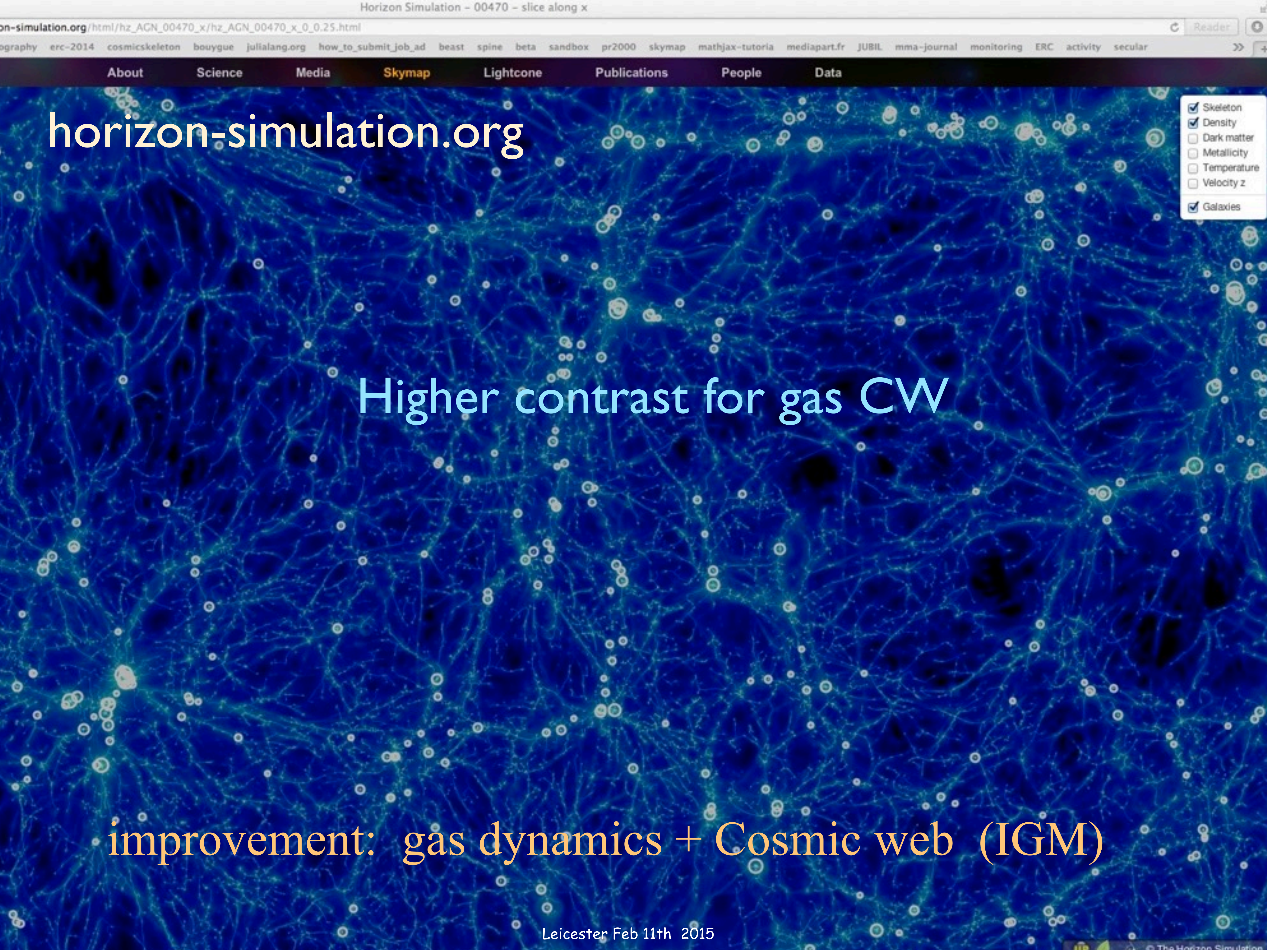
- because it's interesting (most galaxies are born in filaments)
  - ✳ to understand what we see in LSS surveys
  - ✳ for intrinsic alignments: pollution for Weak Lensing?
- LSS impact non-linearly gas flows (what galaxies are made of!)
  - ✳ build up of discs via stratified AM rich gas flows



horizon-simulation.org

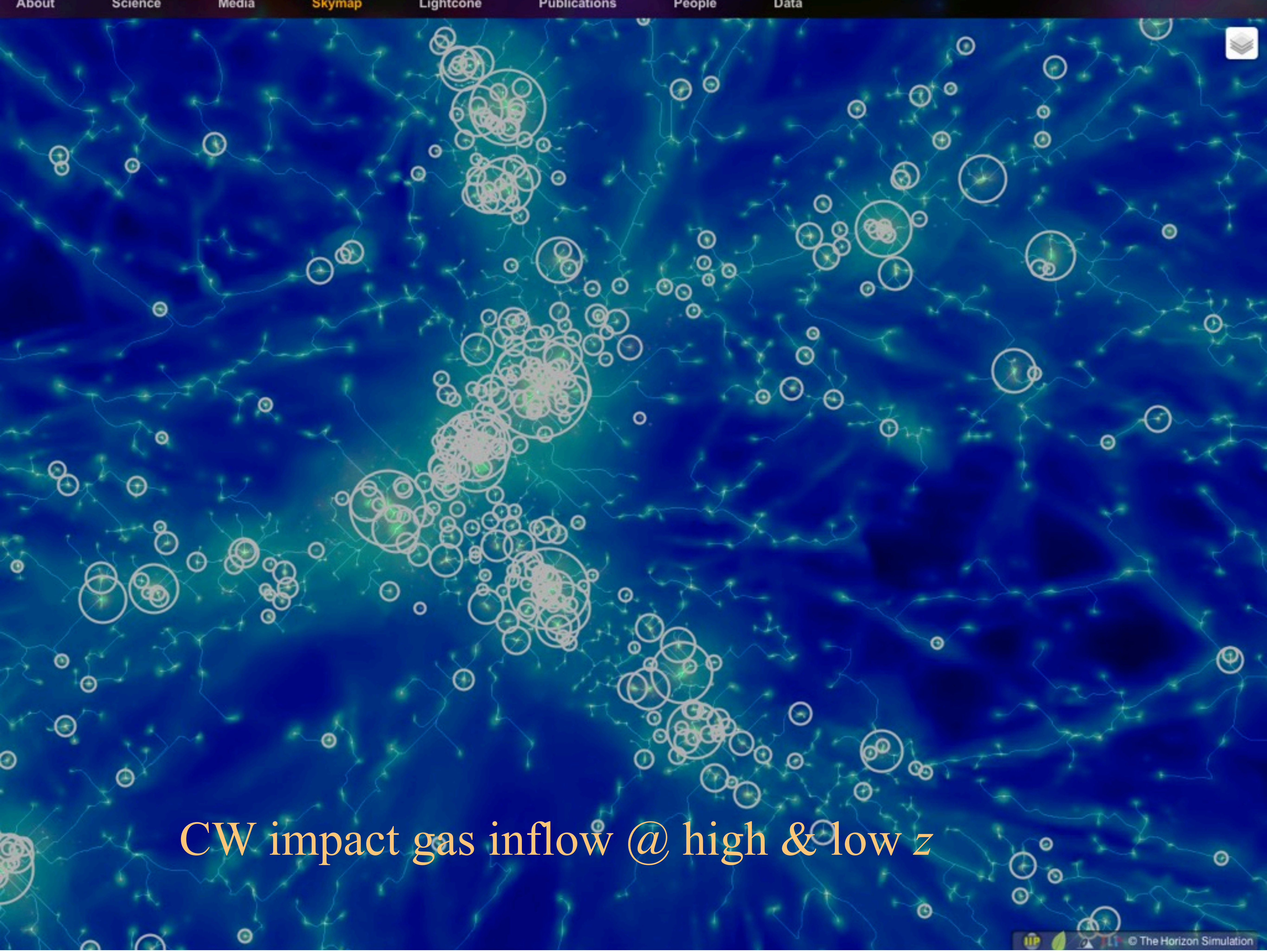


Classical view: DM+halo catalogue/ merger tree horizon-simulation.org

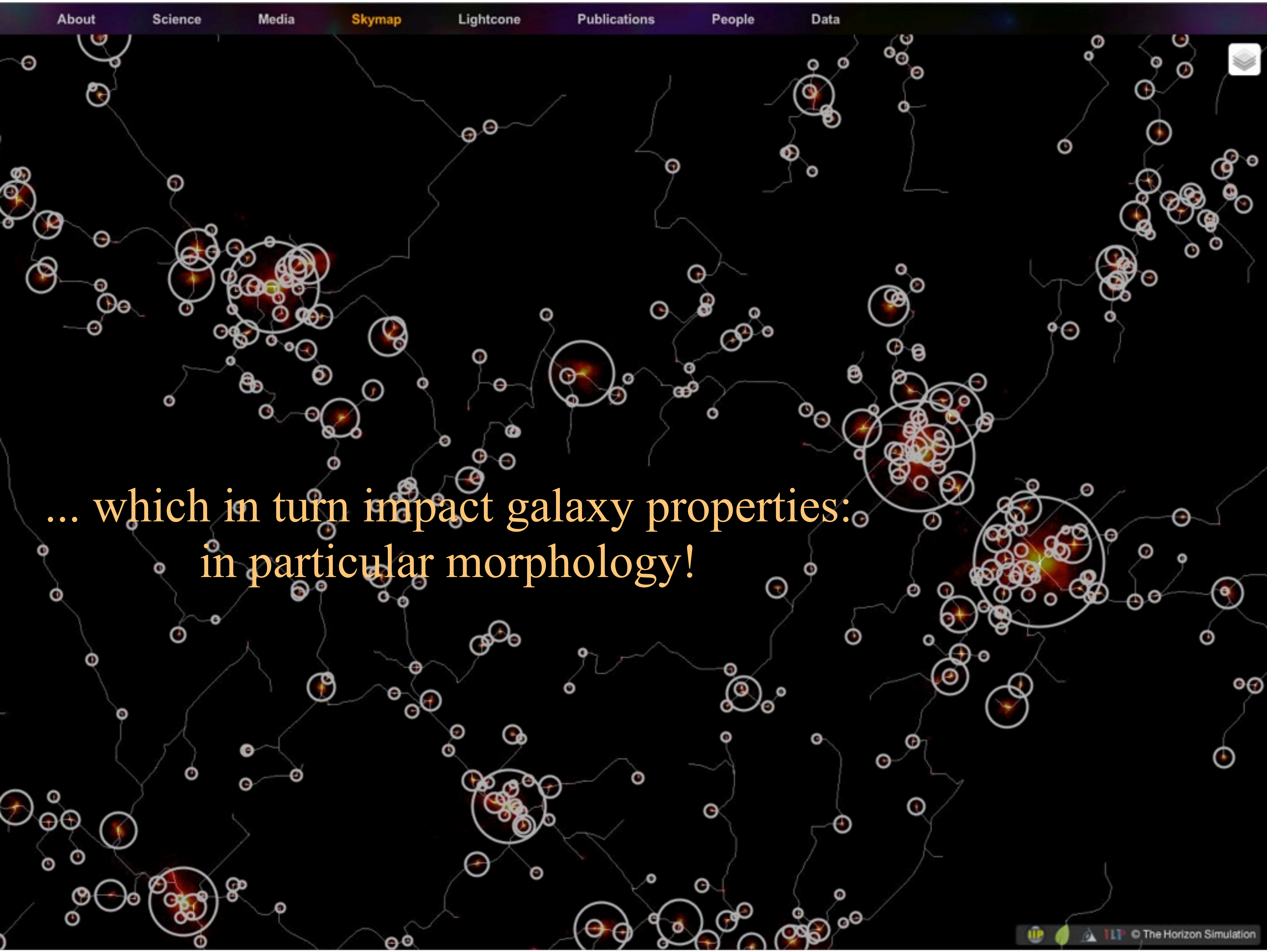


Higher contrast for gas CW

improvement: gas dynamics + Cosmic web (IGM)



CW impact gas inflow @ high & low z



... which in turn impact galaxy properties:
in particular morphology!

Can we **quantify** the impact of the cosmic web on the properties of galaxies **from first principles**?

★ **Revisit paradigm**: impact of large scale anisotropy on **statistics?**

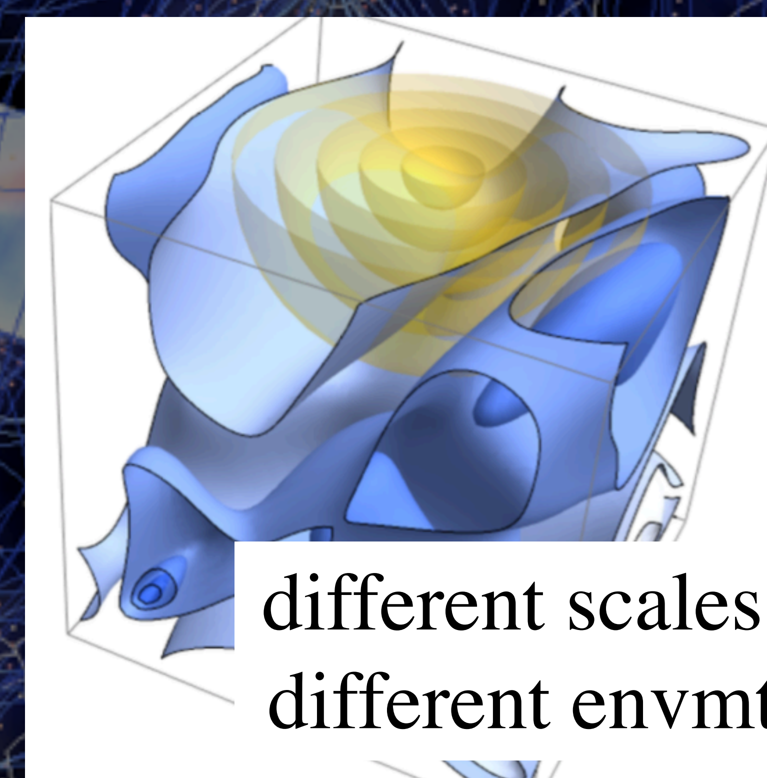
- Galaxy property driven by past lightcone of tidal tensor $\partial^2\psi/\partial x_i \partial x_j$
  non-linear evolution impacted by *scale coupling* / differential *time delays*

$$\langle f_{\rm NL}(IC)\rangle \neq f_{\rm NL}(\langle IC \rangle)$$

$$\langle f_{\rm NL}(IC)\rangle_{\theta,\phi} \neq f_{\rm NL}(\langle IC \rangle_{\theta,\phi})$$

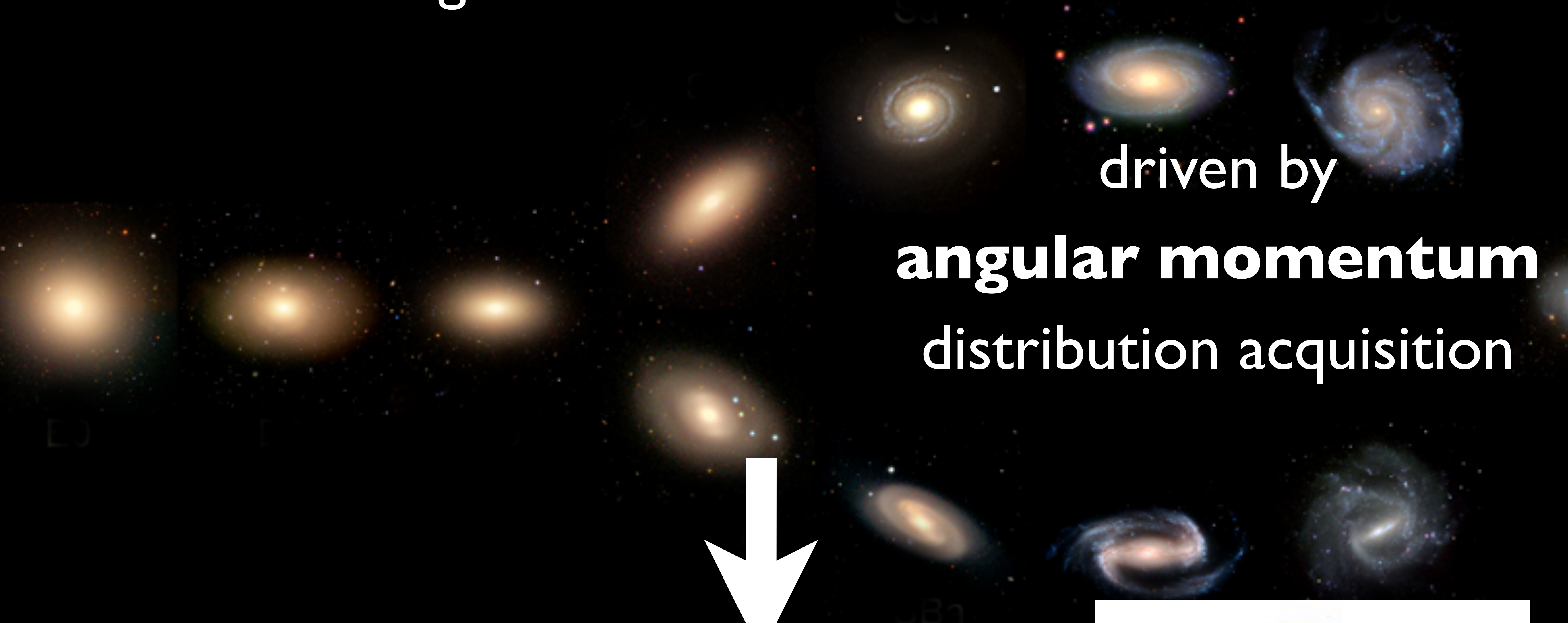
Spherical collapse does not capture filamentary tides...

Proto halo will be impacted by ***all*** *components of Tidal tensor (not just trace, also eigenvectors+other minors)*




Let's focus on morphology...

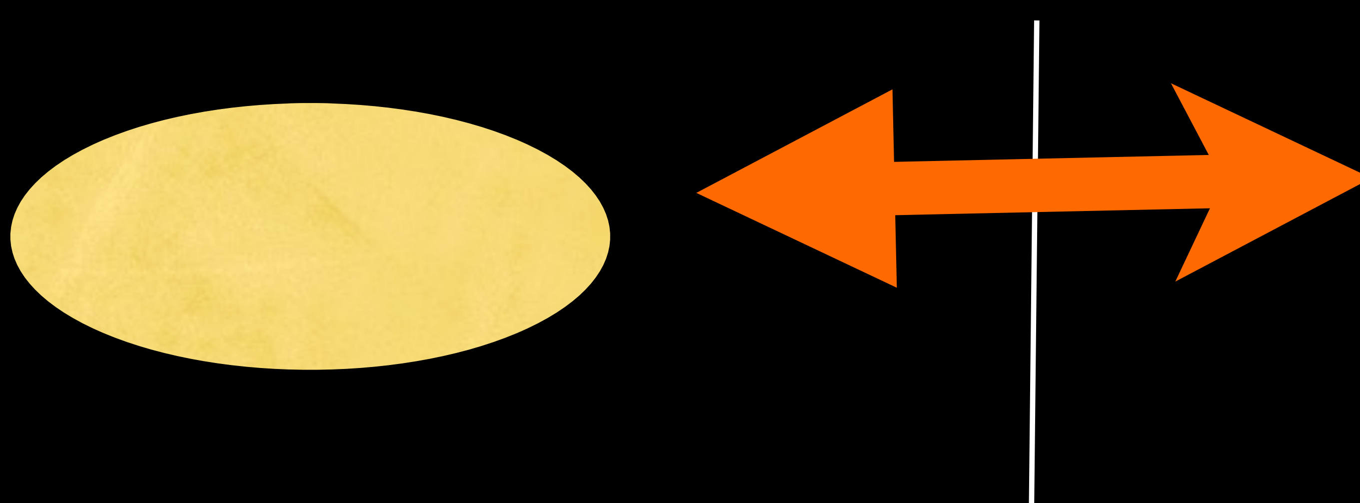
The Hubble diagram: a crude theorist's view



driven by

angular momentum

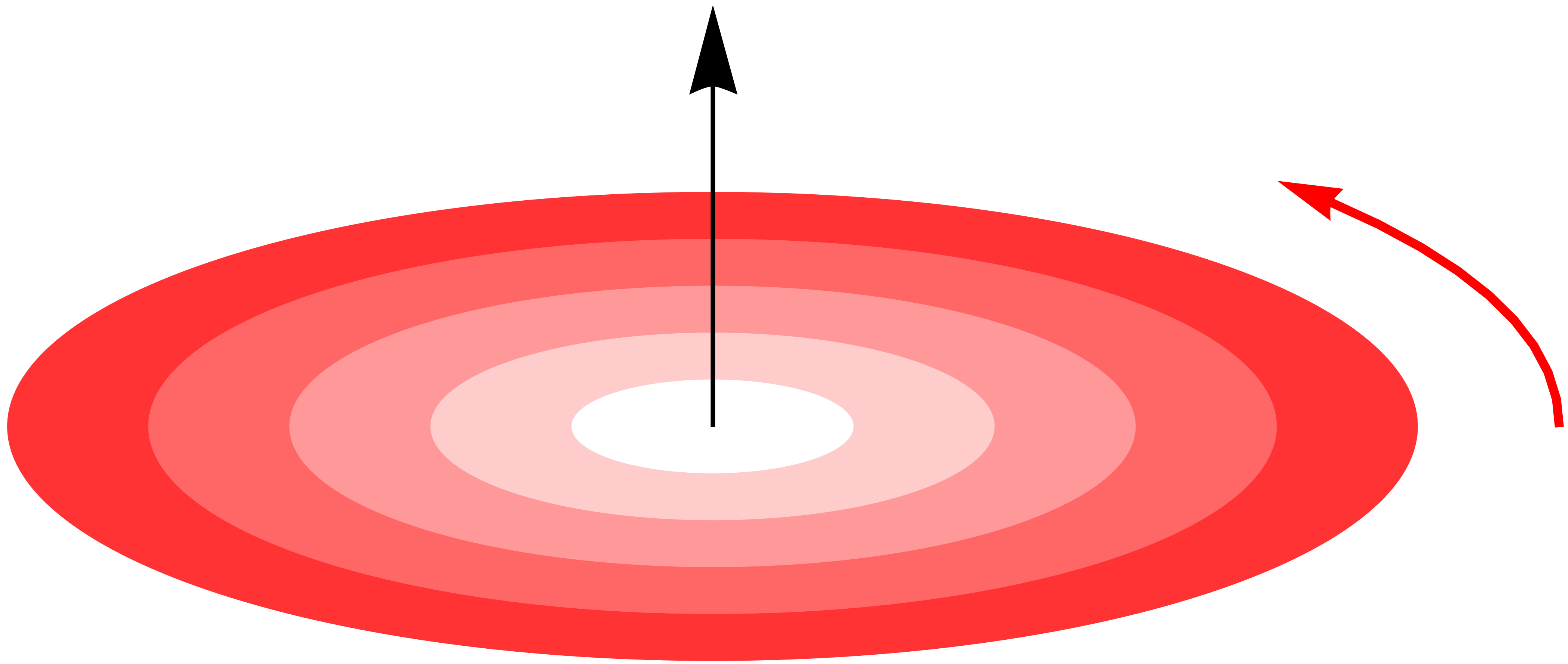
distribution acquisition



What drives coherent secondary infall?

Fact number one

“theoretically”, a galactic disc:



An ensemble of ring made of gas,

- turning around the same axis
- whose outer parts rotate with **more** angular momentum (flat rotation curve)

Fact number two

The *Virtual (dark matter)* universe

Voids become more void

Filaments drifts...

Log density

... and get **distorted**

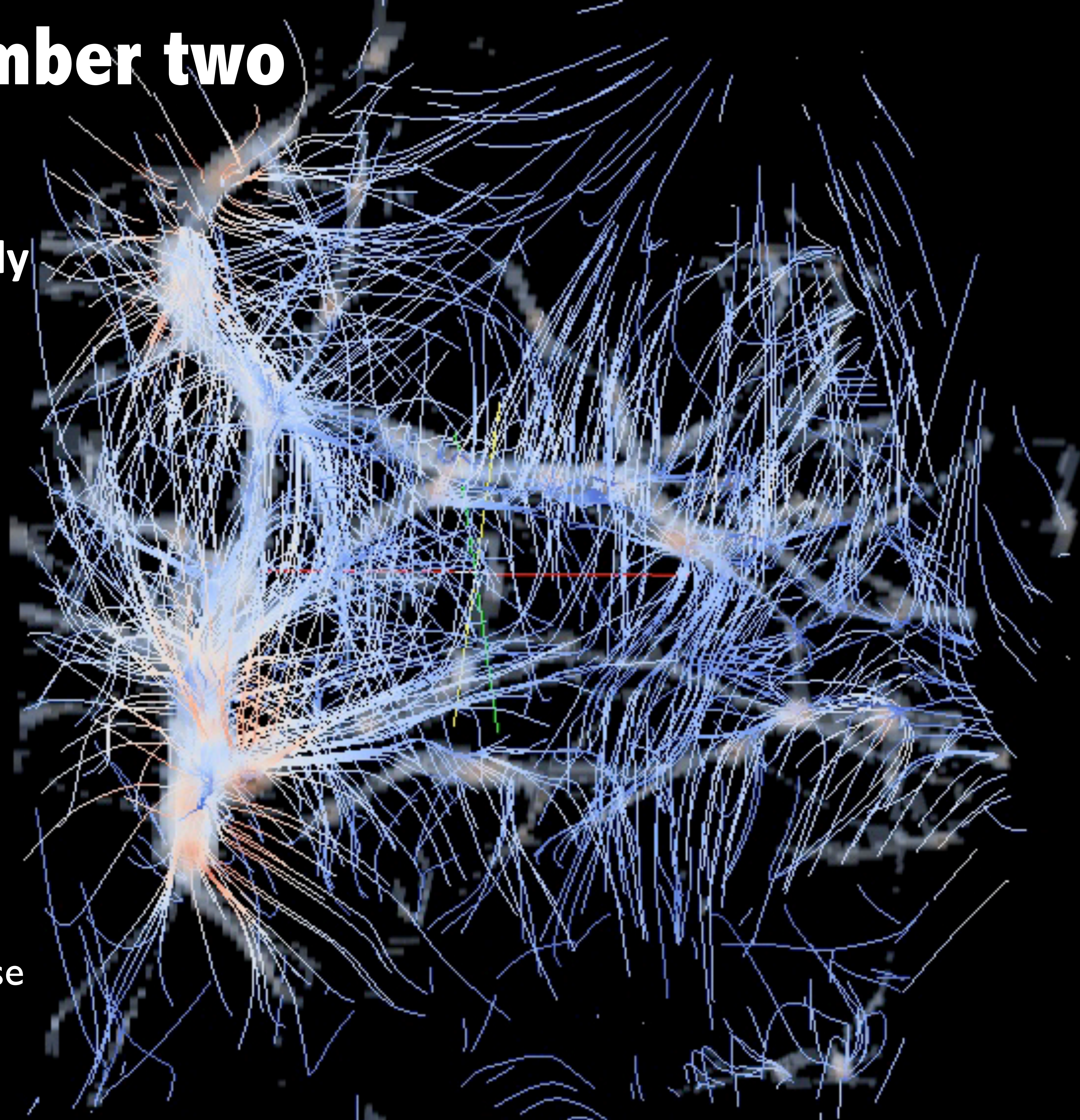
$t_{\rm dyn} \sim 1/\sqrt{\rho}$

not much happens on LS: which is good & expected

Fact number two

Peak attract

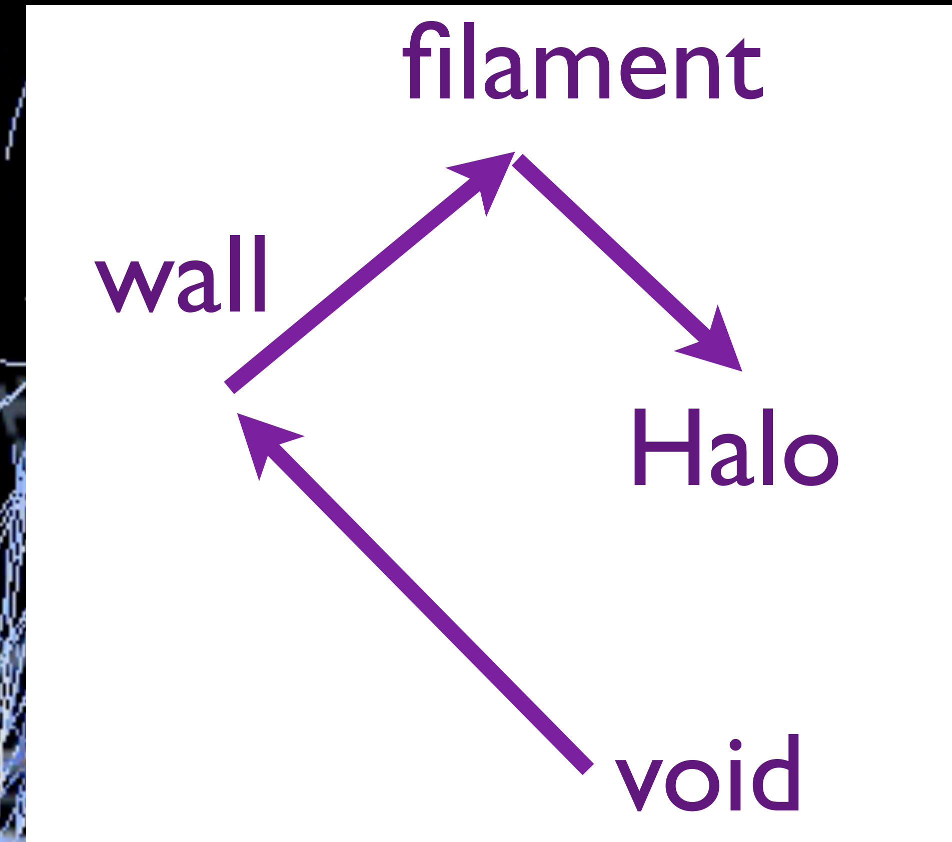
catastrophically



Velocity flow in
expanding universe

BUT surrounding void/wall repel (contrast<0) & contribute to secondary infall.

Fact number two



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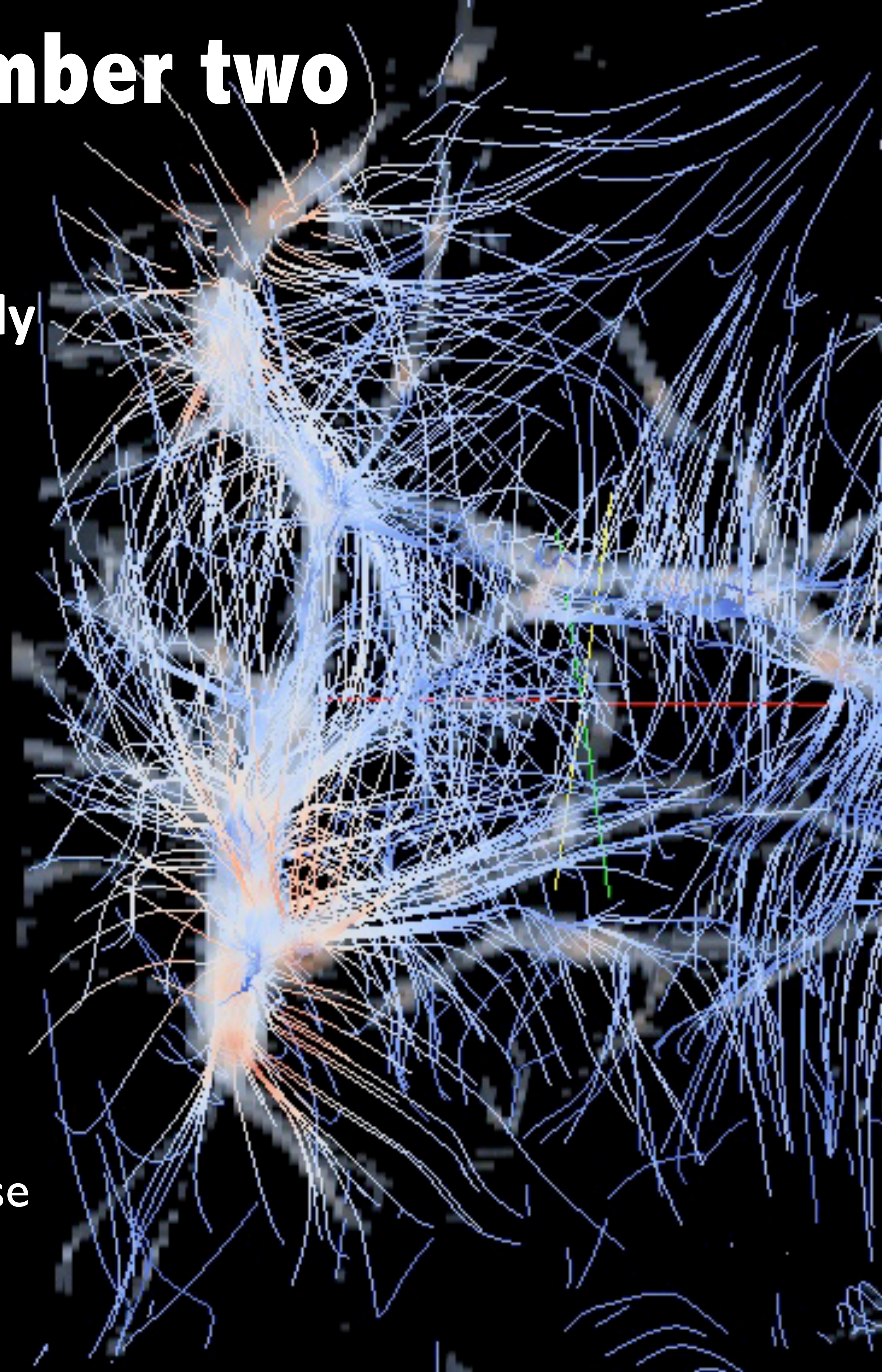

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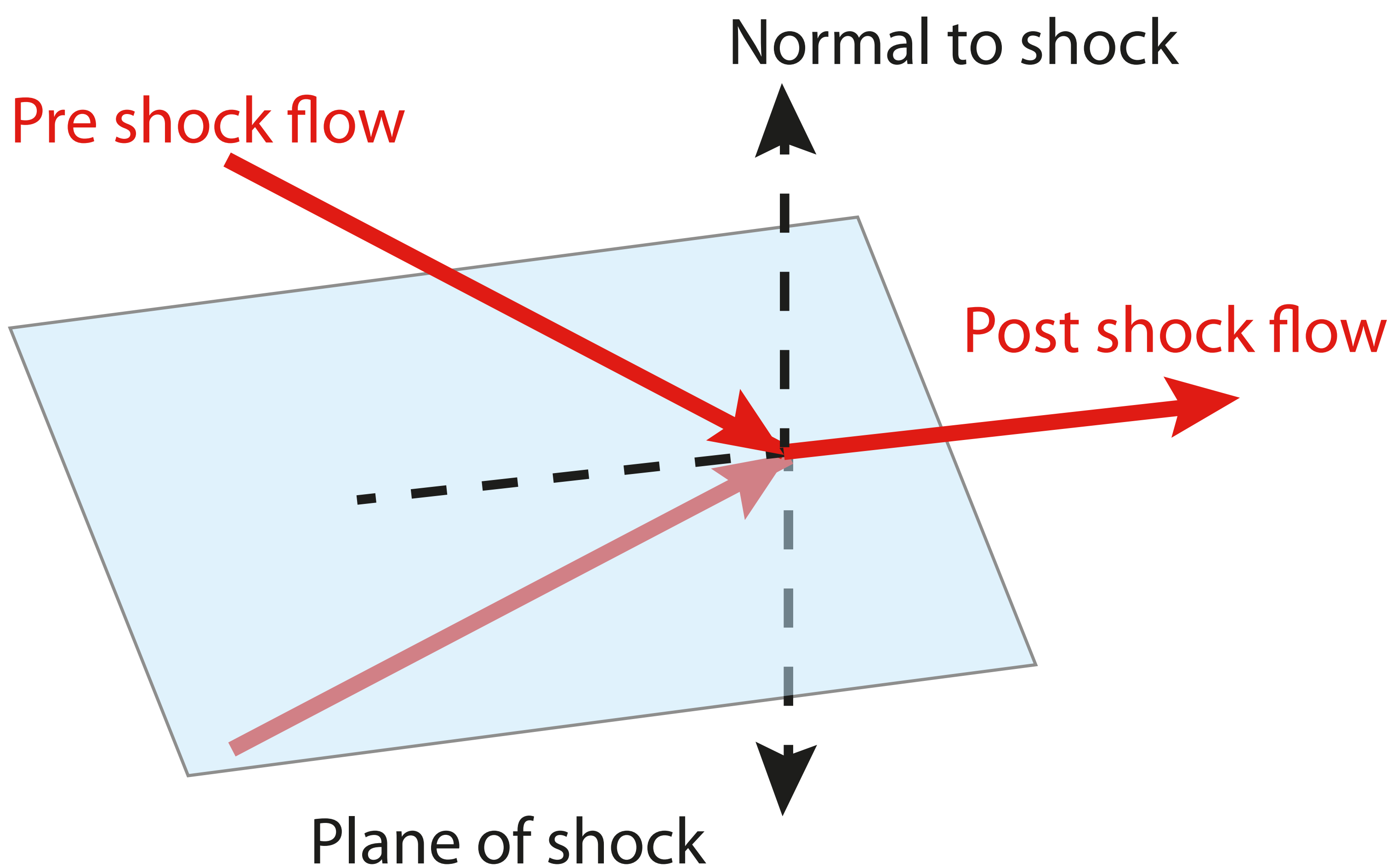
Fact number three

"theoretically", a shock:



Gas, unlike dark matters, shocks (iso-T) and

follows closely the cosmic web

→ **cosmic web is** important **for galaxy morphology**

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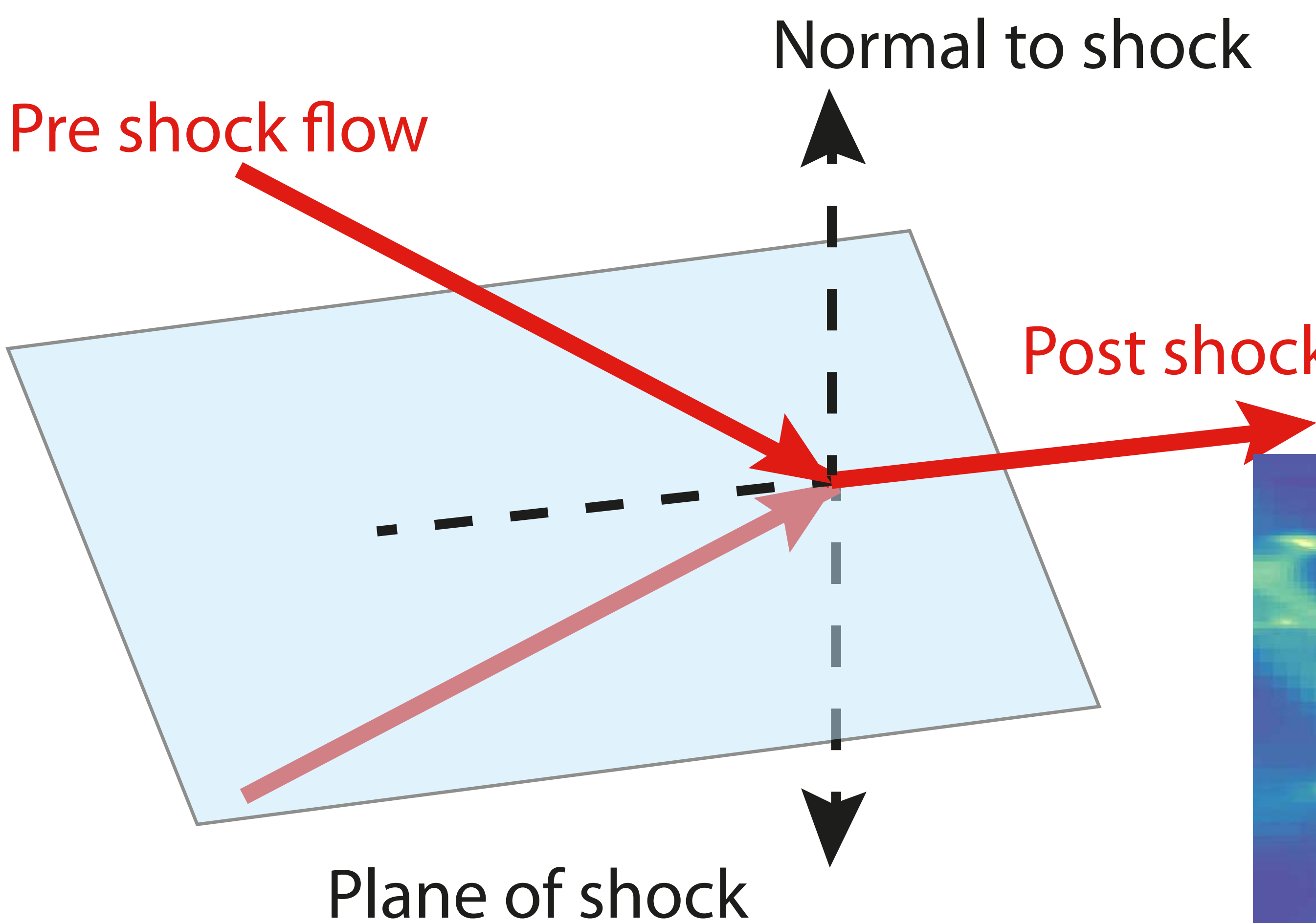

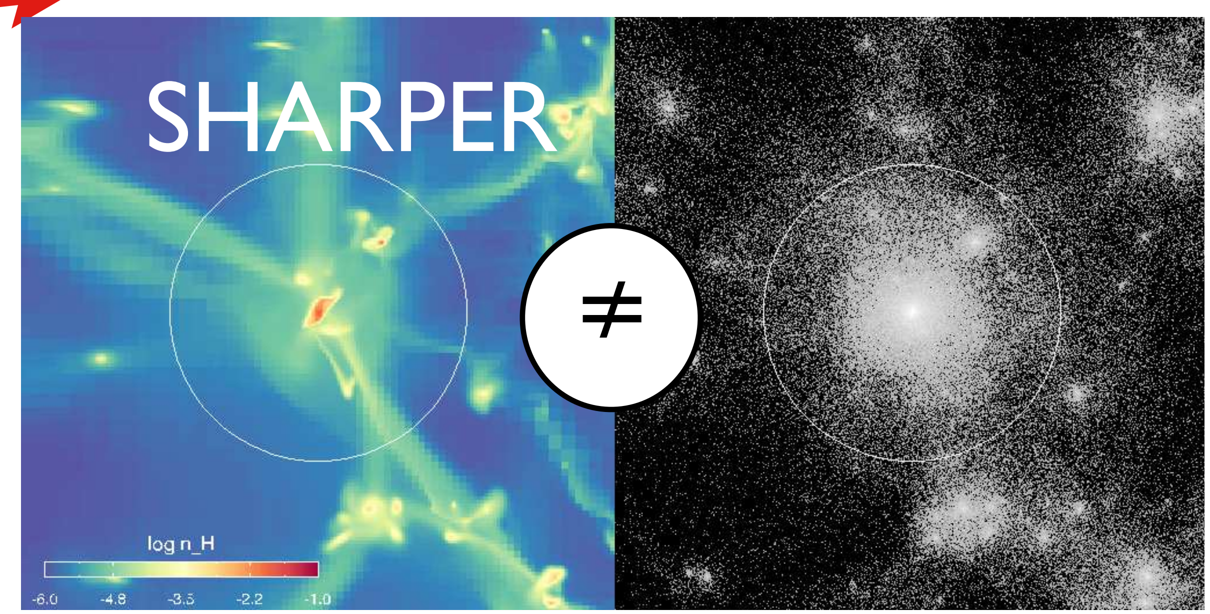

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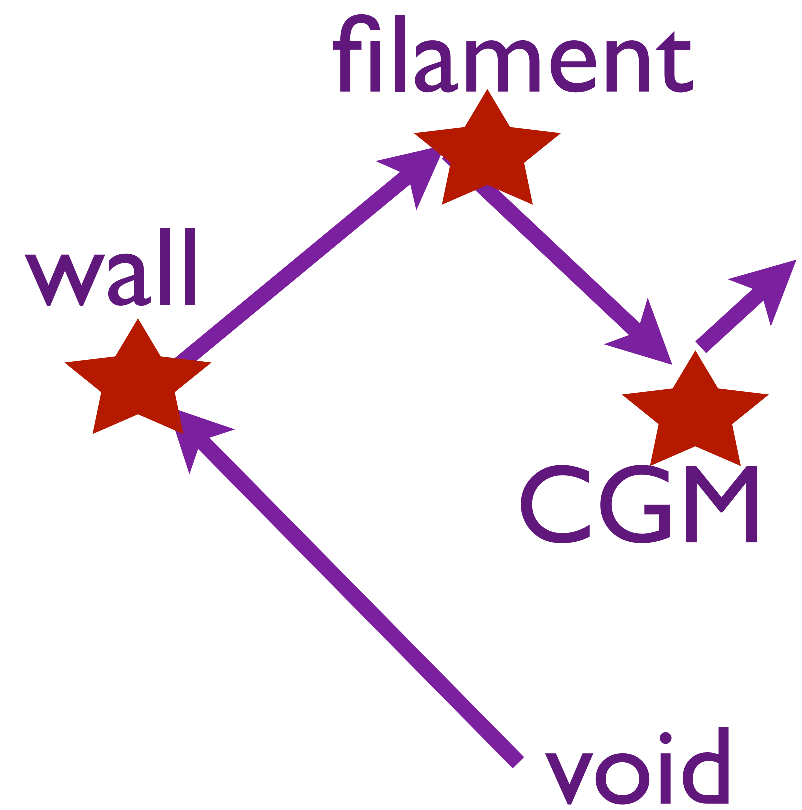

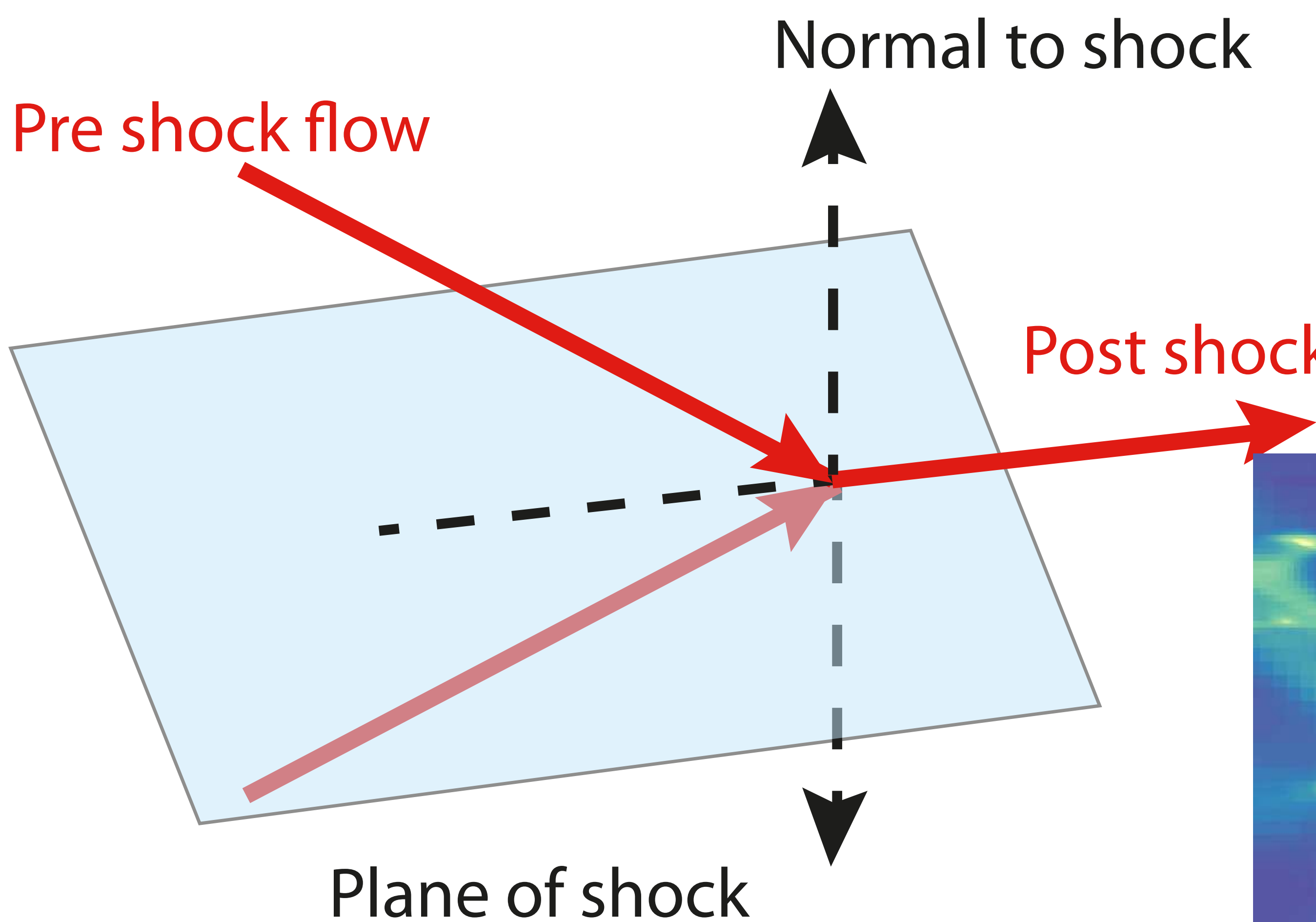

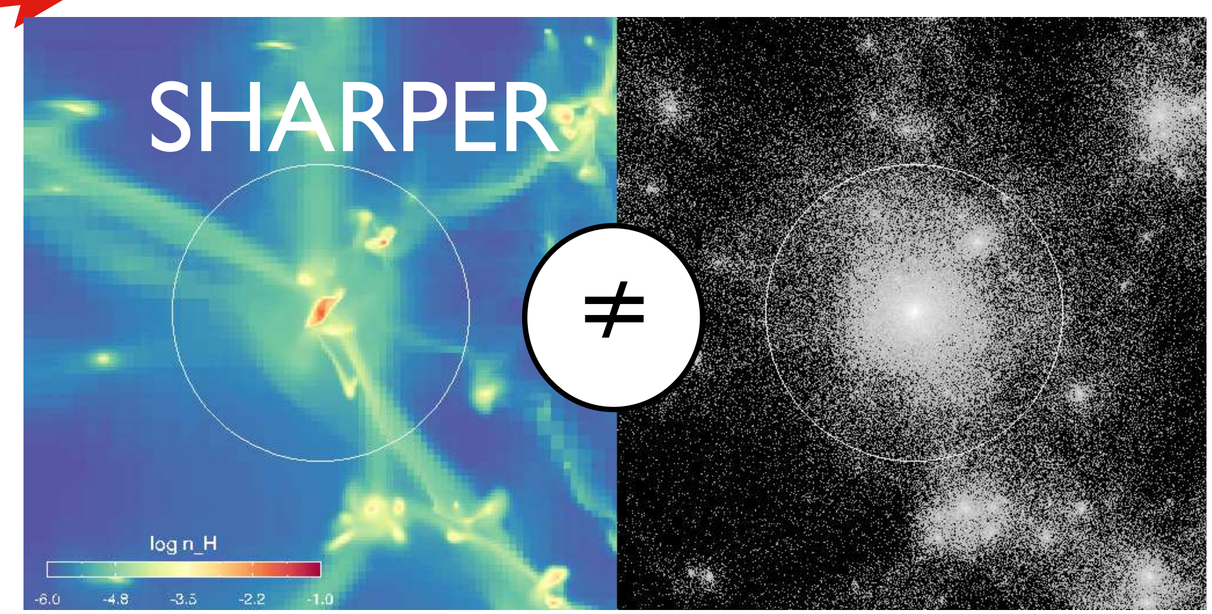

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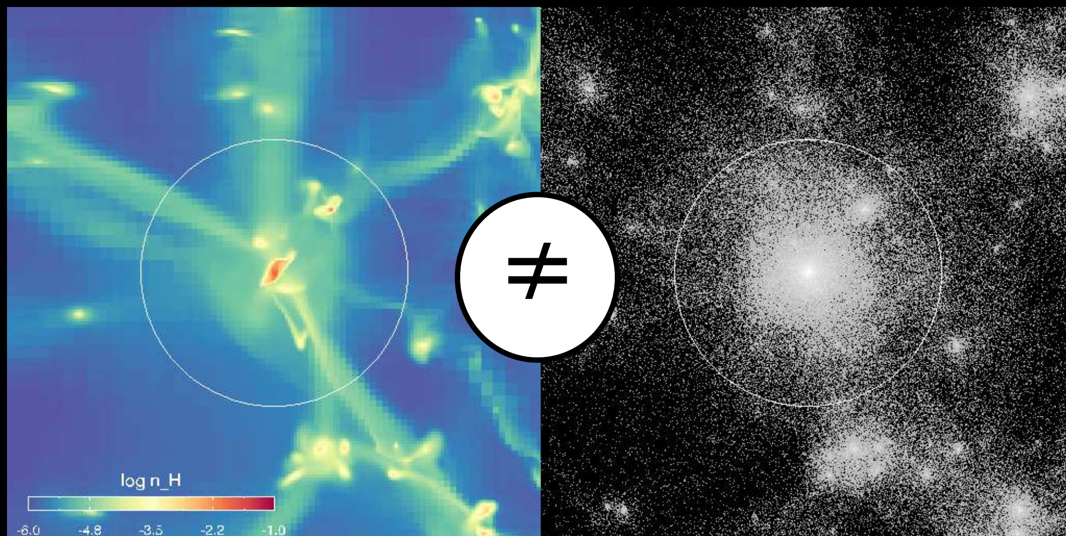
Fact number four

The *Virtual (hydrodynamical)* universe

z=99.00



Cosmic web SHARPER

2 kpc

Agertz et al. (2009)

we see cold flows + recurrent disk reformation
LSS drives secondary infall & SPIN ALIGNMENT

Context & clues

standard hierarchical clustering picture

halo rigging

aka completely useless (nautical) analogy that probably only the author understands

- ☑ disc must have a coherent stratified angular momentum
- ☑ surrounding void/wall repel (contrast<0) & contribute to secondary infall
- ☑ gas shocks isothermally during shell crossing, follows filaments closely
- ☑ galaxies form and evolve ***on*** the cosmic web

The proposition in one sentence

Disks (re)form because LSS are large *(dynamically young)* and *(partially)* an-isotropic :
they induce persistent angular momentum advection of cold gas along filaments which stratifies accordingly so as to (re)build discs continuously.

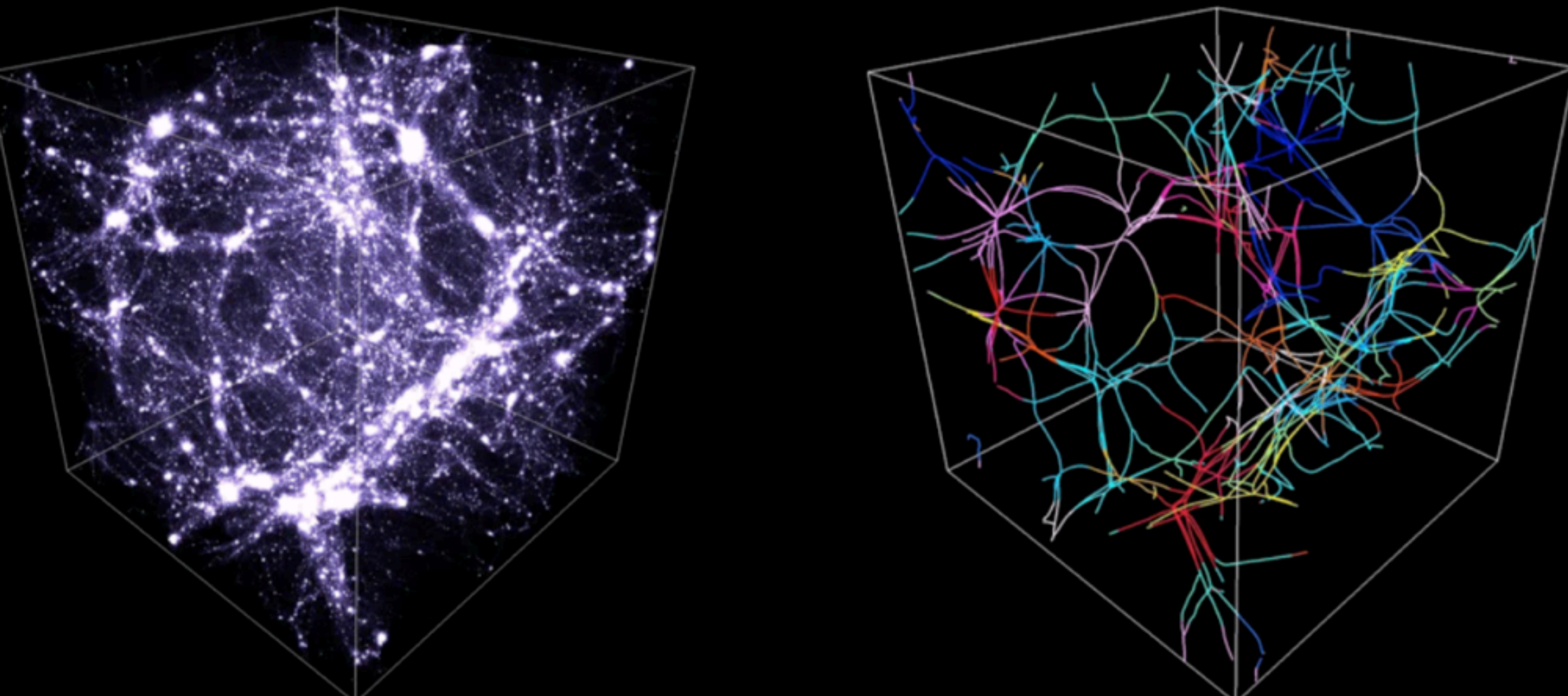
Clues from LSS

"Proof by halo centric environment"

a.k.a

proof by hypnosis,
fishy analogy &
mathematical jargon

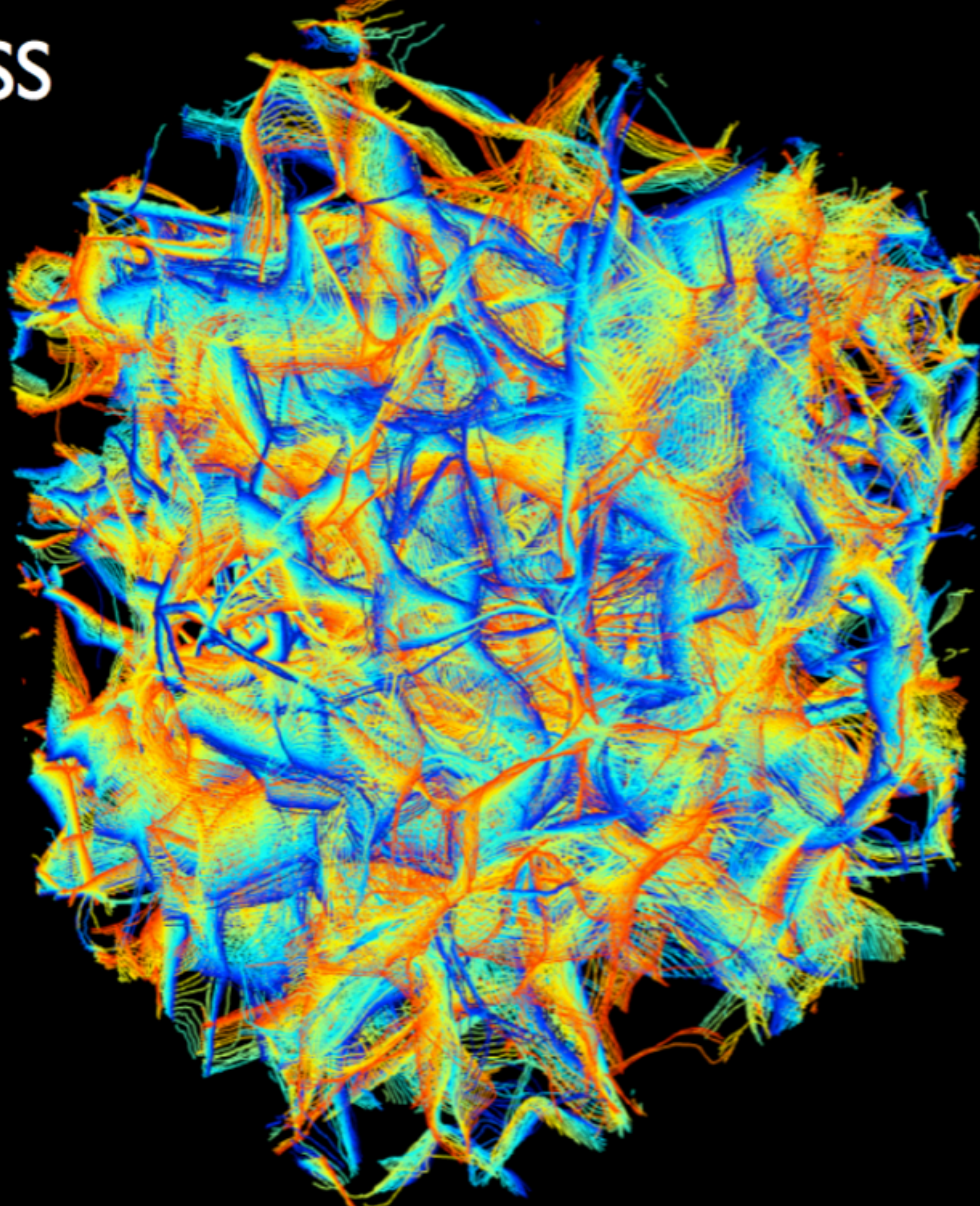
Skeleton of the LSS



traces filaments via crest lines of the density field

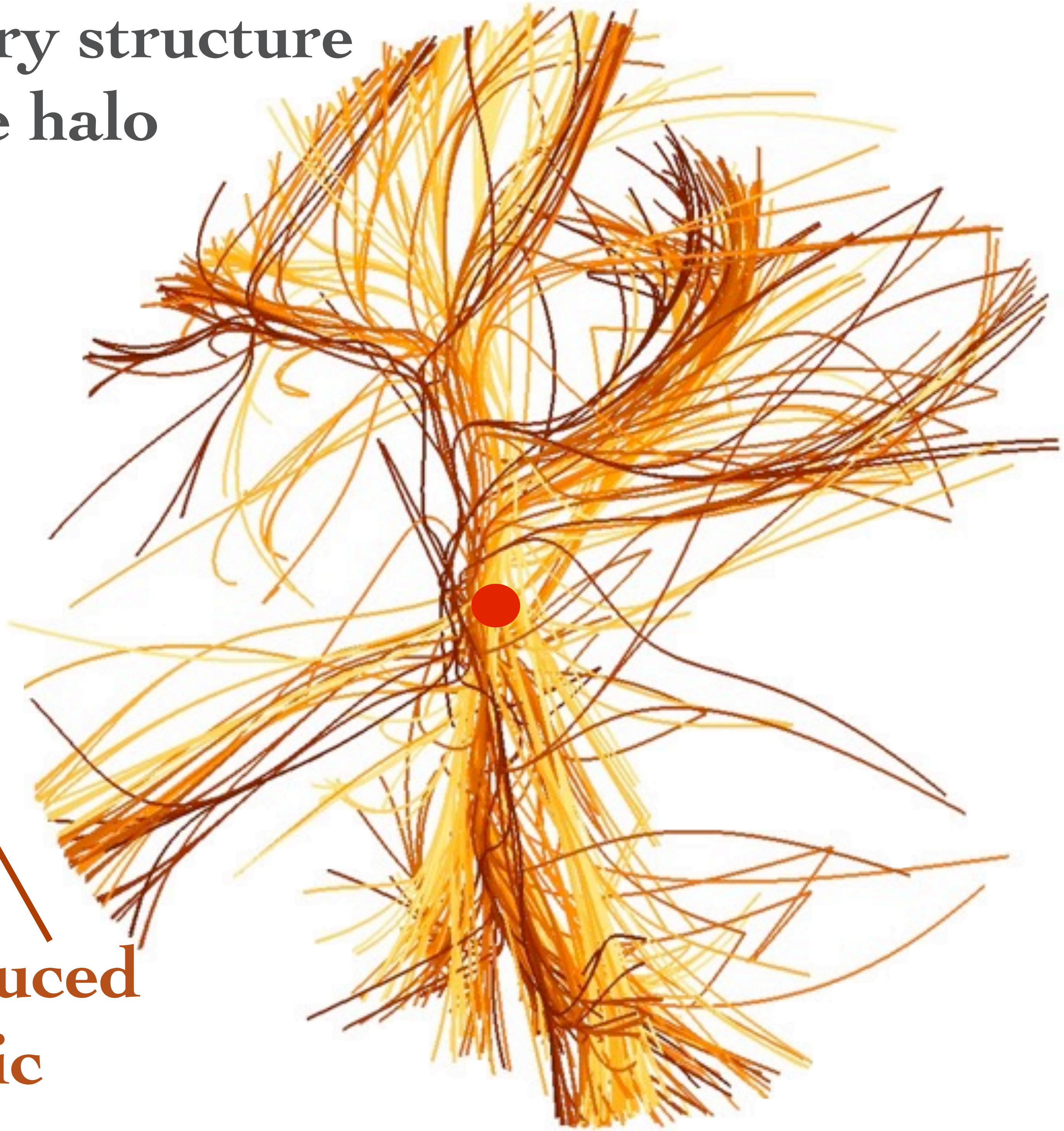
Time line of LSS

full history of universe
at once !



Drift of filaments

Time-line evolution of filamentary structure of one halo



void induced cosmic drift

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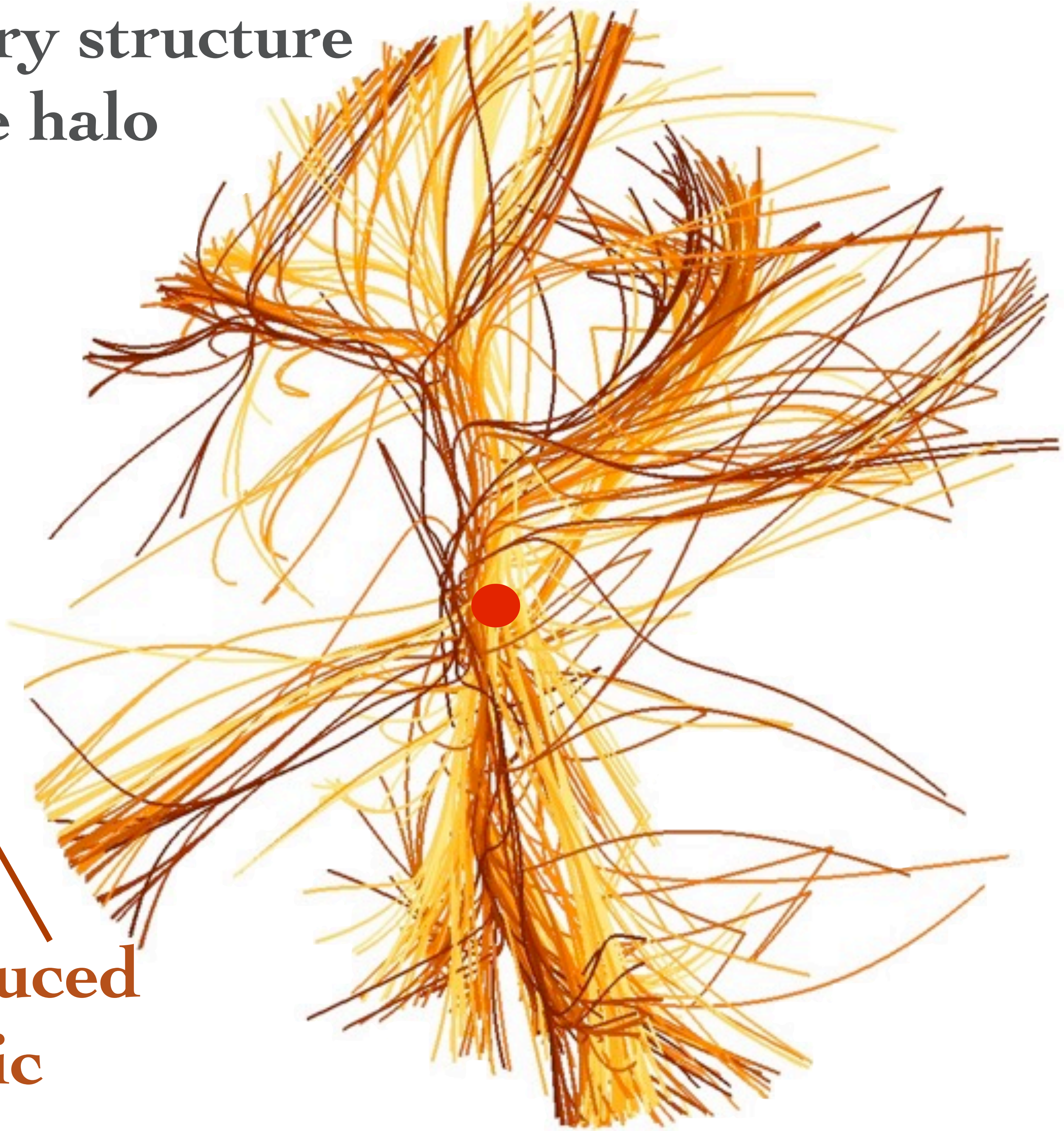

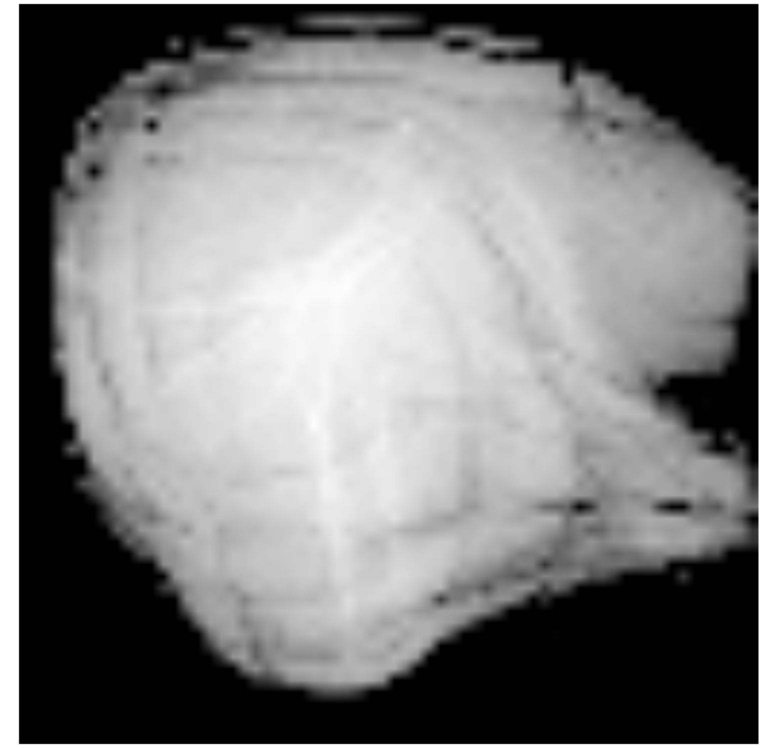

void induced cosmic drift

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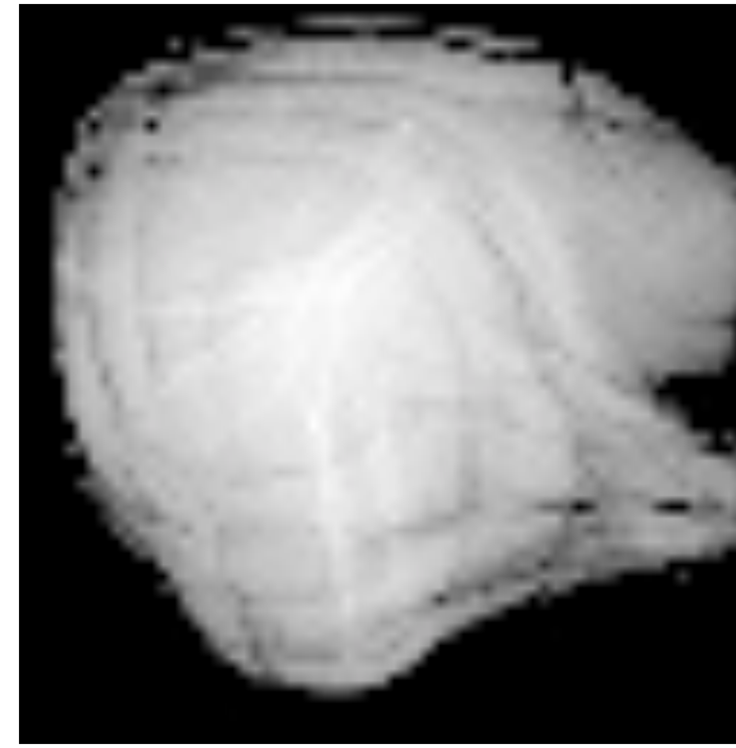

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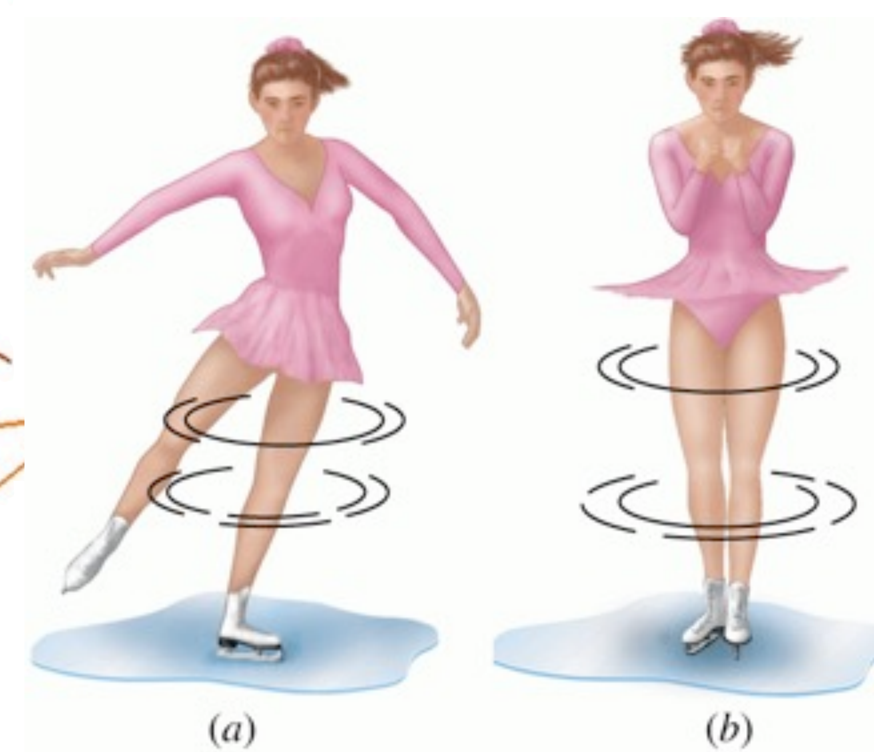
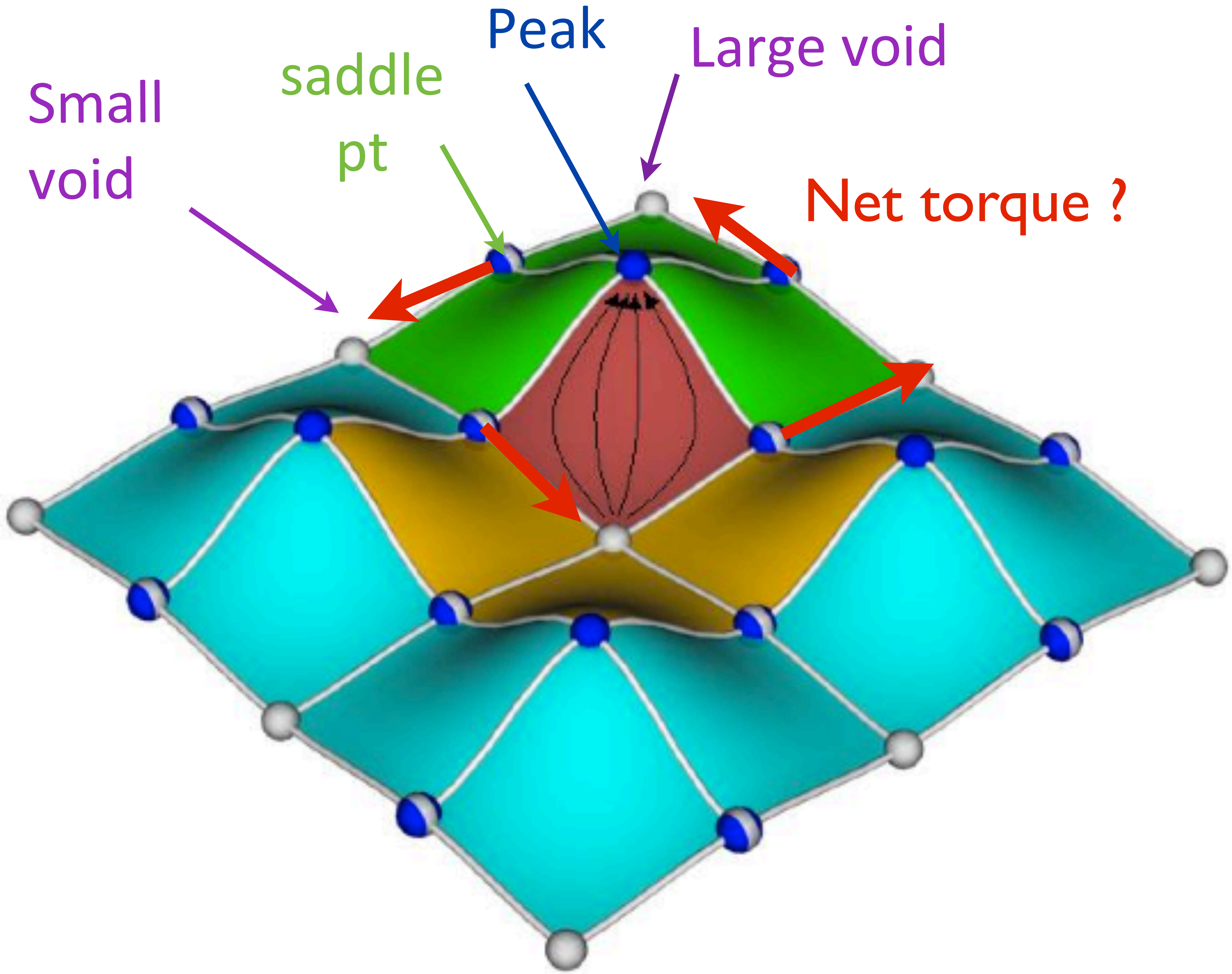


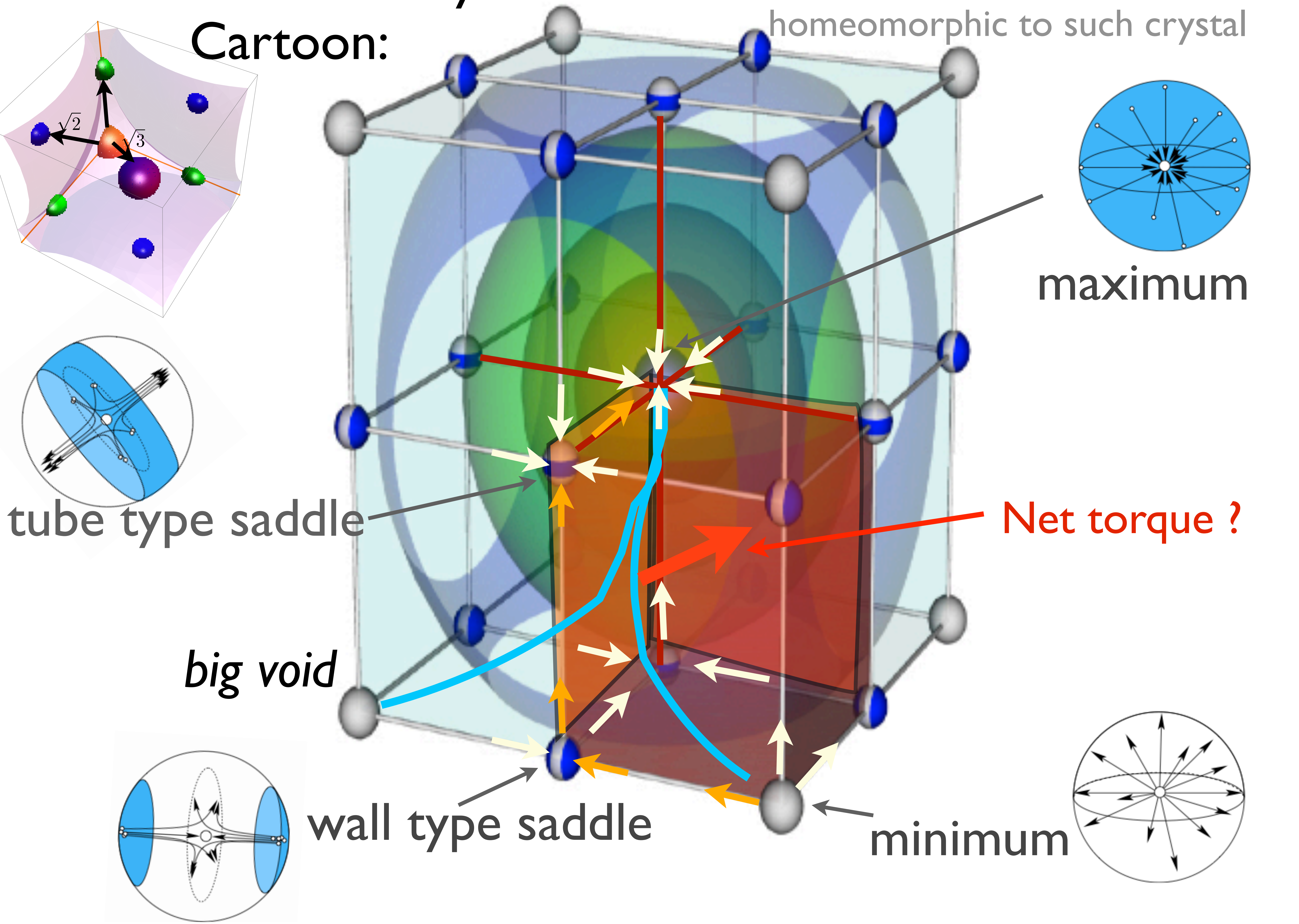
2D Cartoon of "ideal" cosmic environment :



Mean local cosmic initial condition
homeomorphic to such crystal

3D "ideal"cosmic crystal Cartoon:

Mean local cosmic initial condition homeomorphic to such crystal



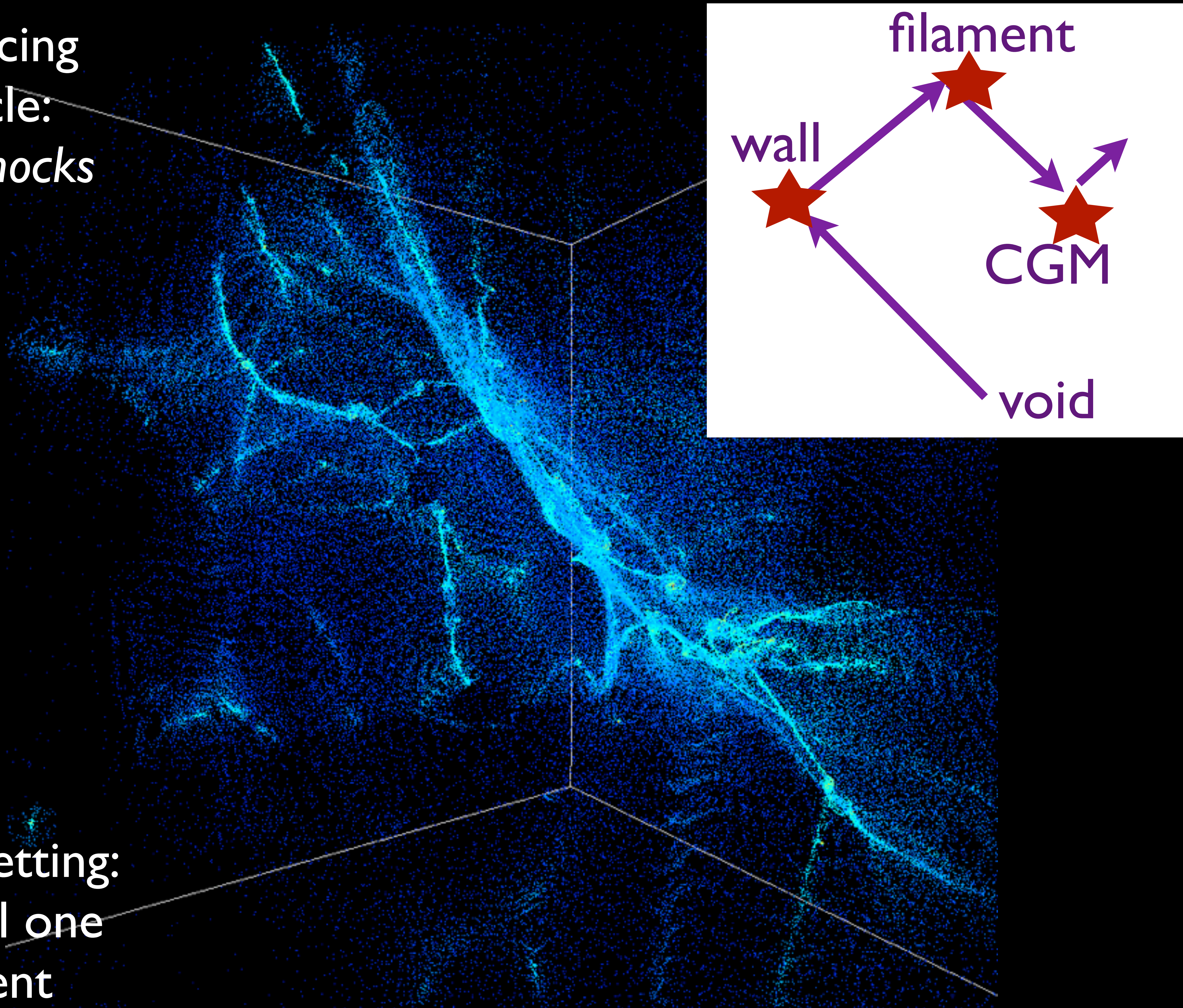
Do we see this?

"Proof" by visualisation of hydrodynamical simulation

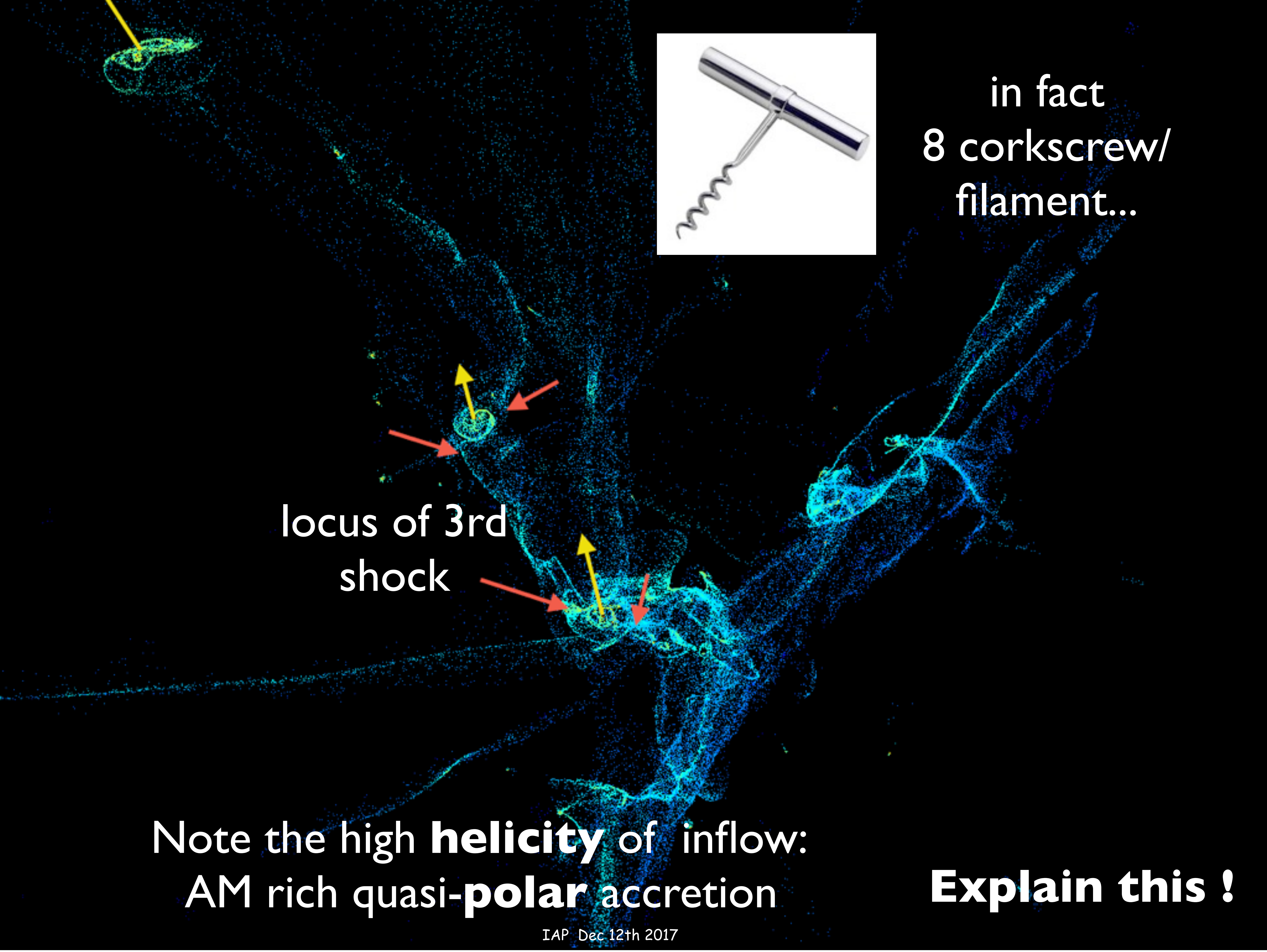
a.k.a

proof by pretty pictures

gas tracing particle: *follow shocks*



typical setting: one wall one filament



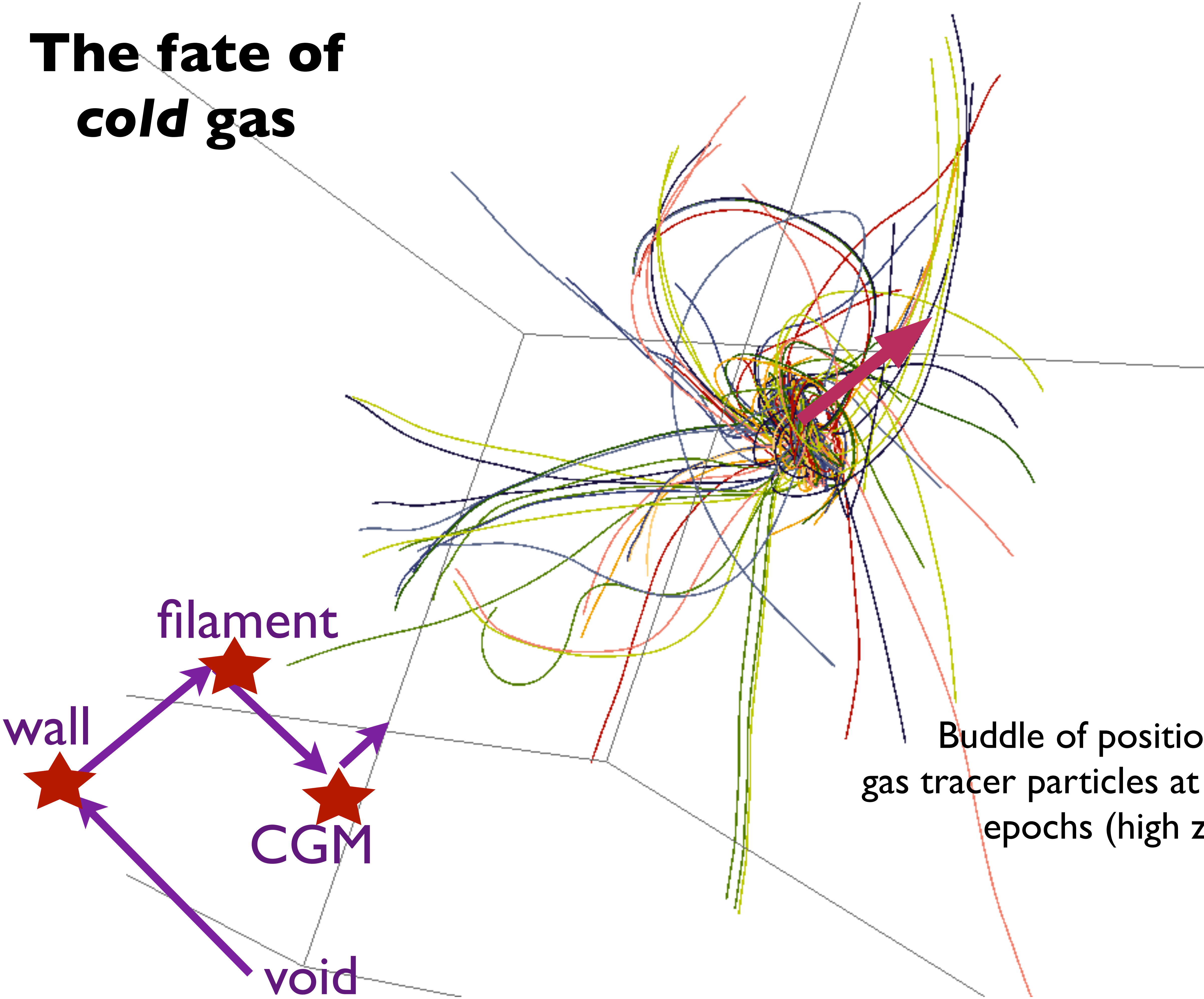
in fact
8 corkscrew/
filament...

locus of 3rd
shock

Note the high **helicity** of inflow:
AM rich quasi-**polar** accretion

Explain this !

The fate of *cold* gas



Buddle of position of
gas tracer particles at different
epochs (high z)

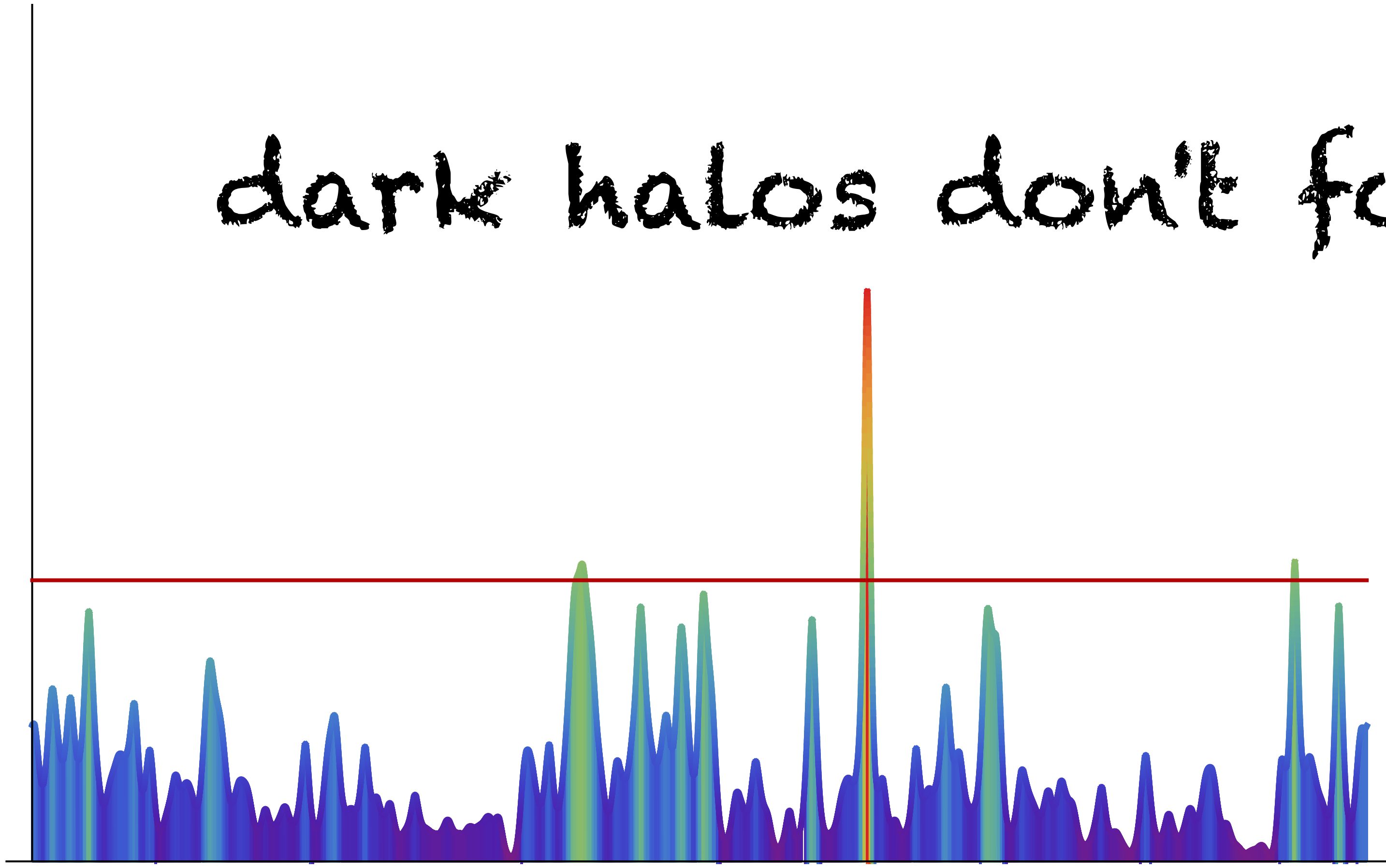
What's happening on larger scales?

How is the cosmic web woven?

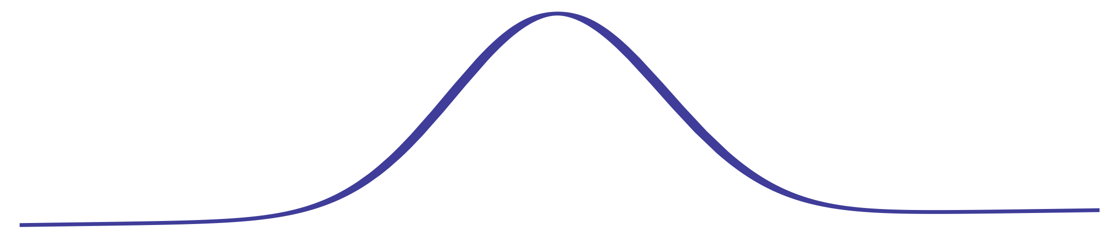
i.e Where do galaxies form in our Universe?

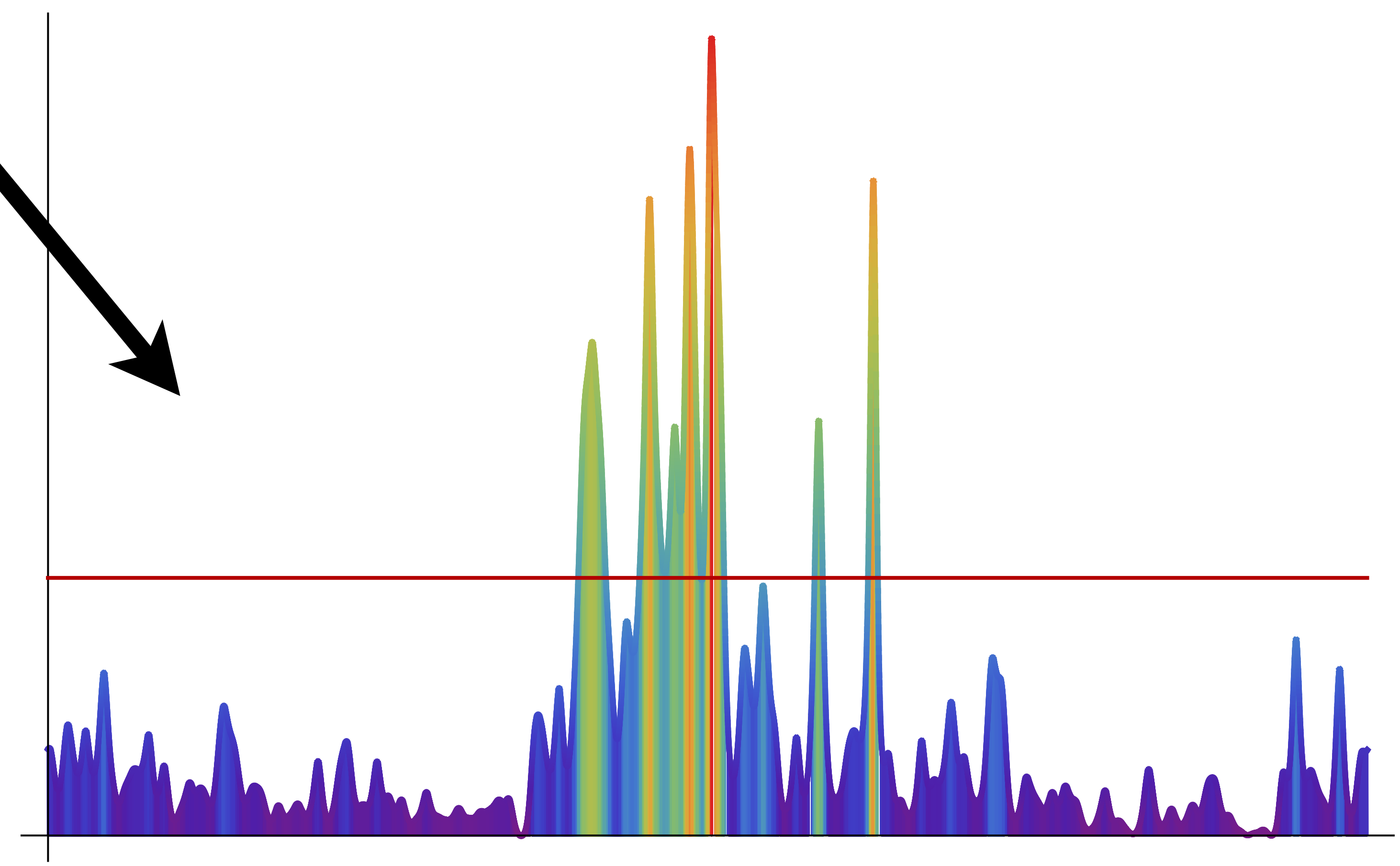
What are the dynamical implications?

dark halos don't form anywhere



+





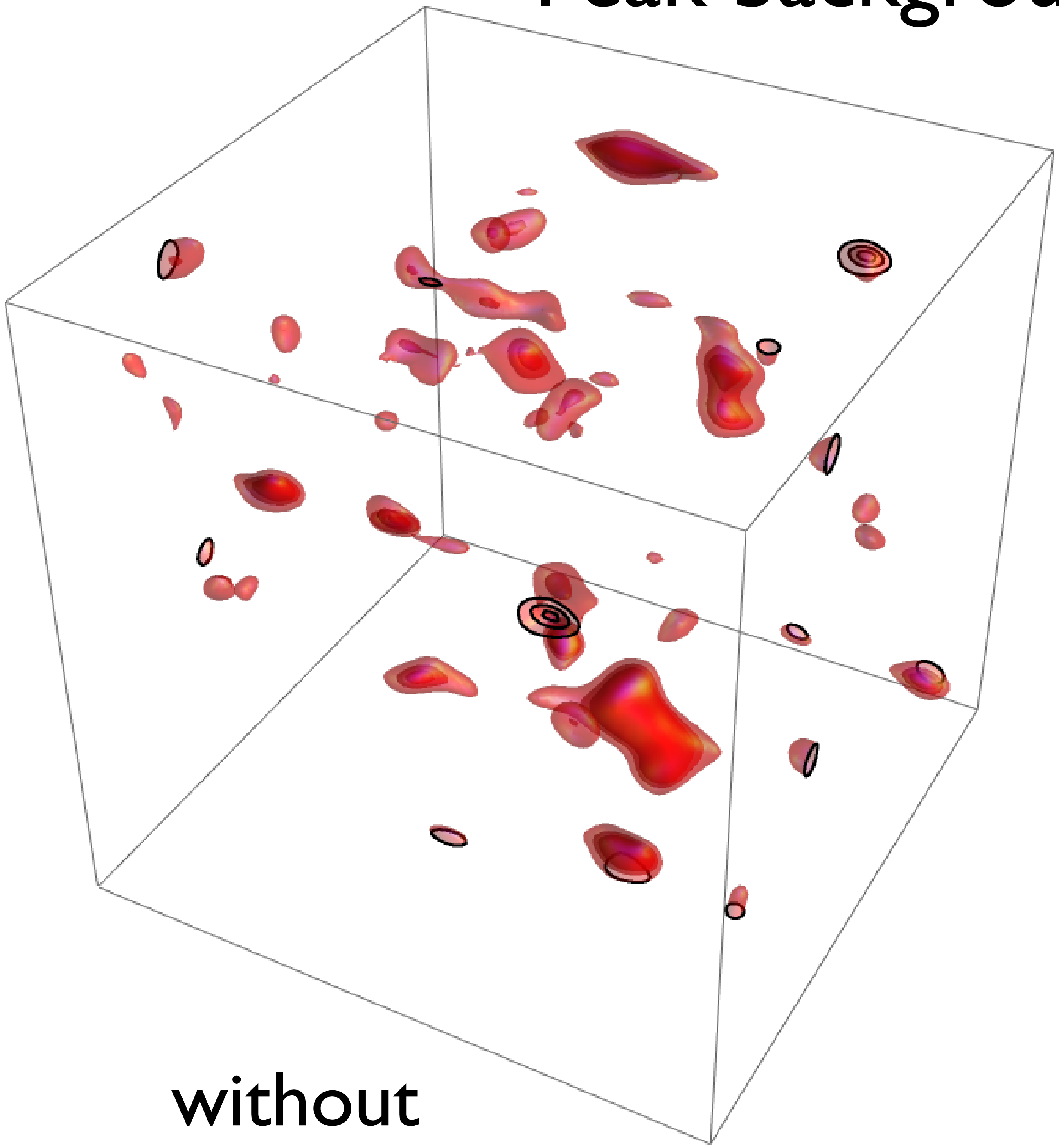
Peak background split

(PBS) in 1D

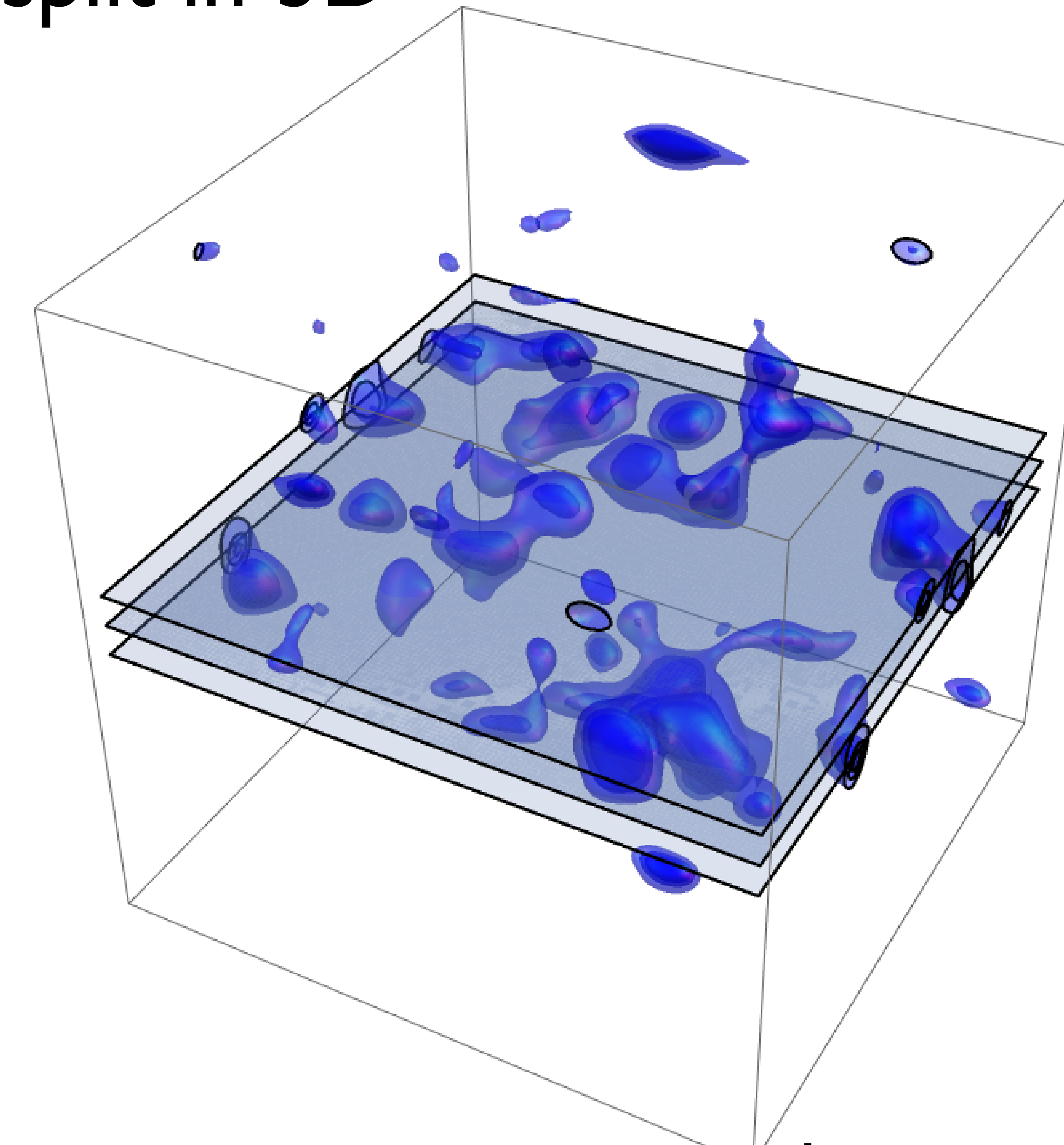
aka Kaiser Bias

NB: constraint shift mean and RMS!

Peak background split in 3D



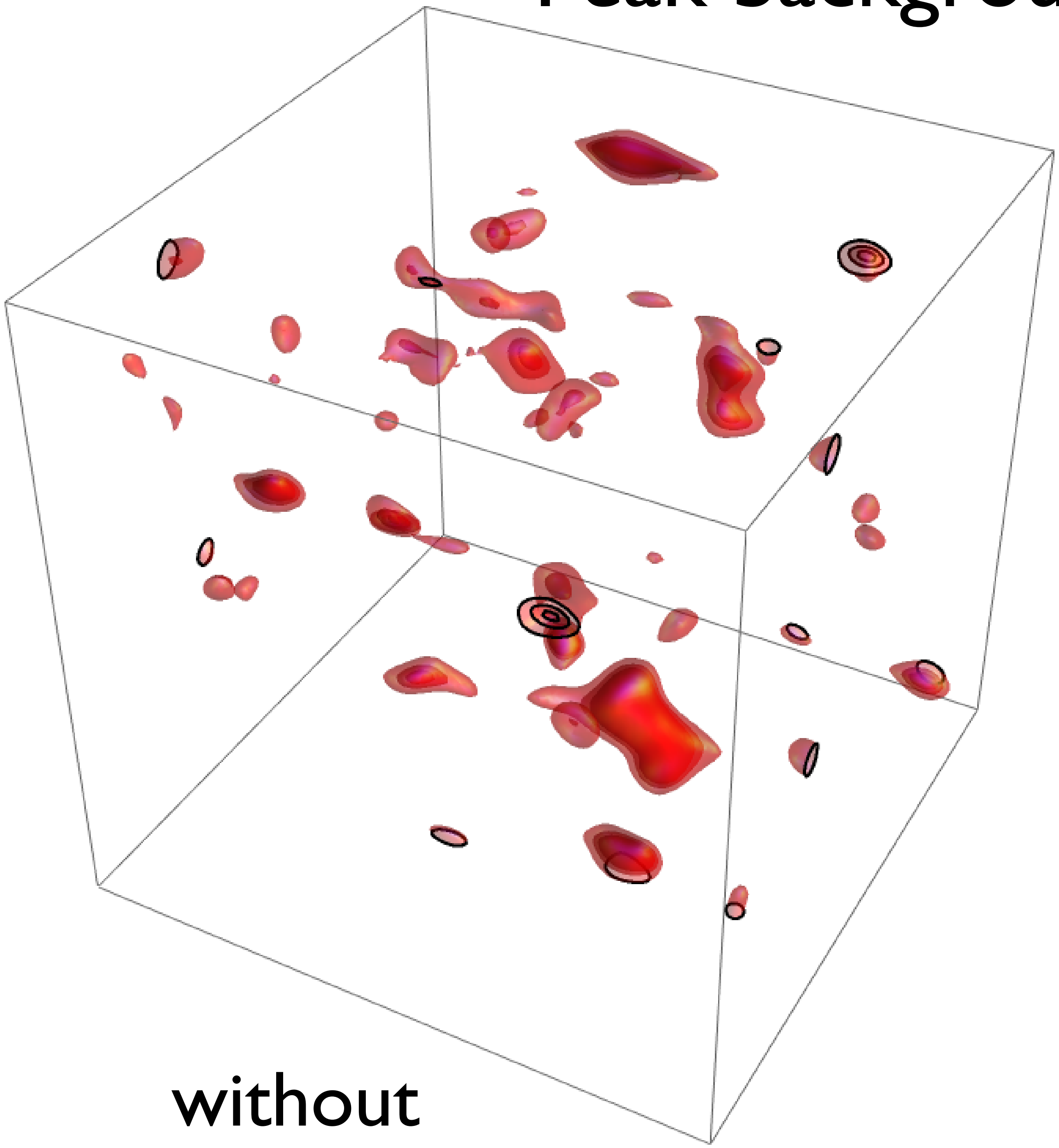
without
boost

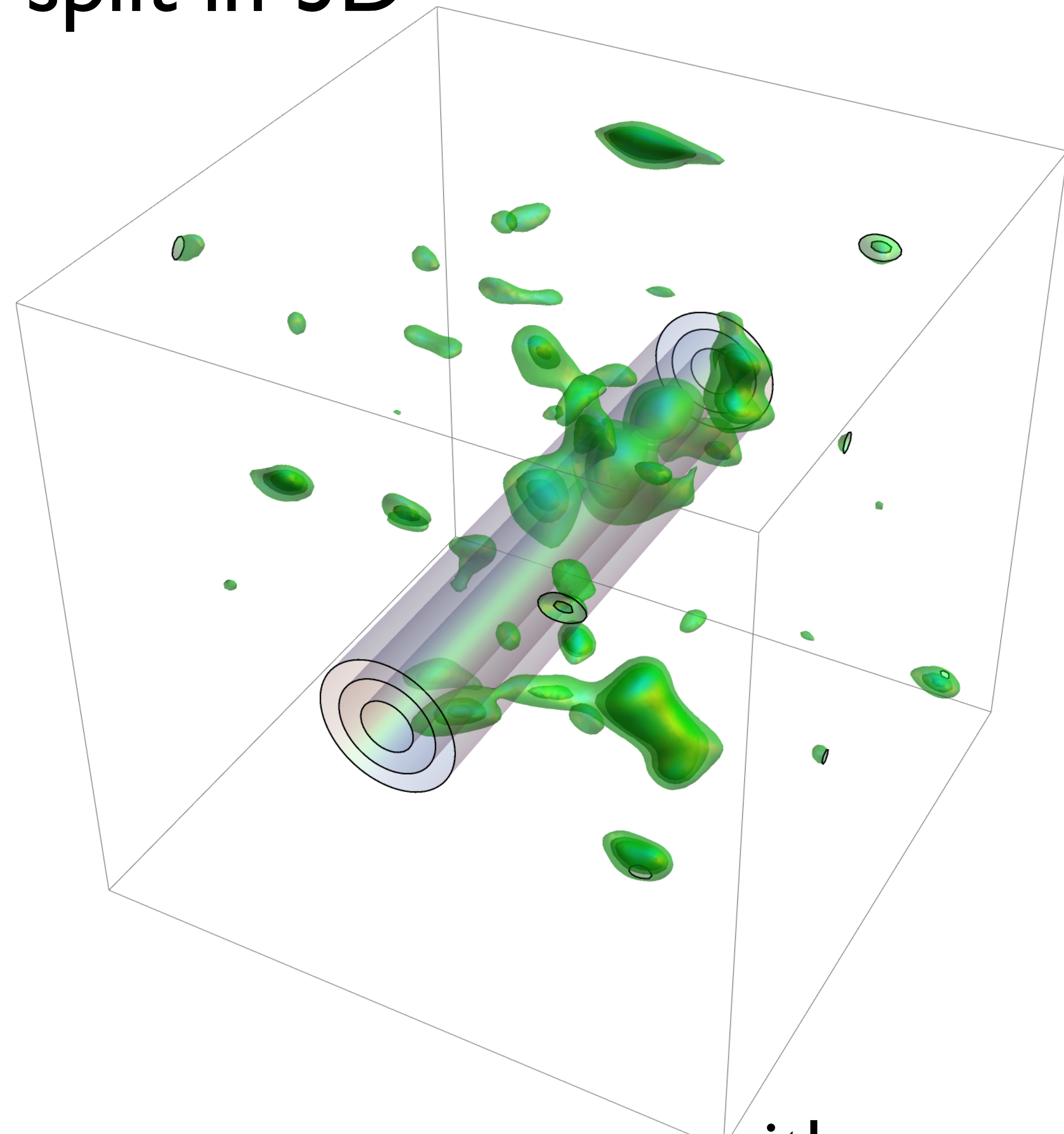


with
boost

Does this anisotropic biassing have a dynamical signature? *yes! in term of spin!*

Peak background split in 3D





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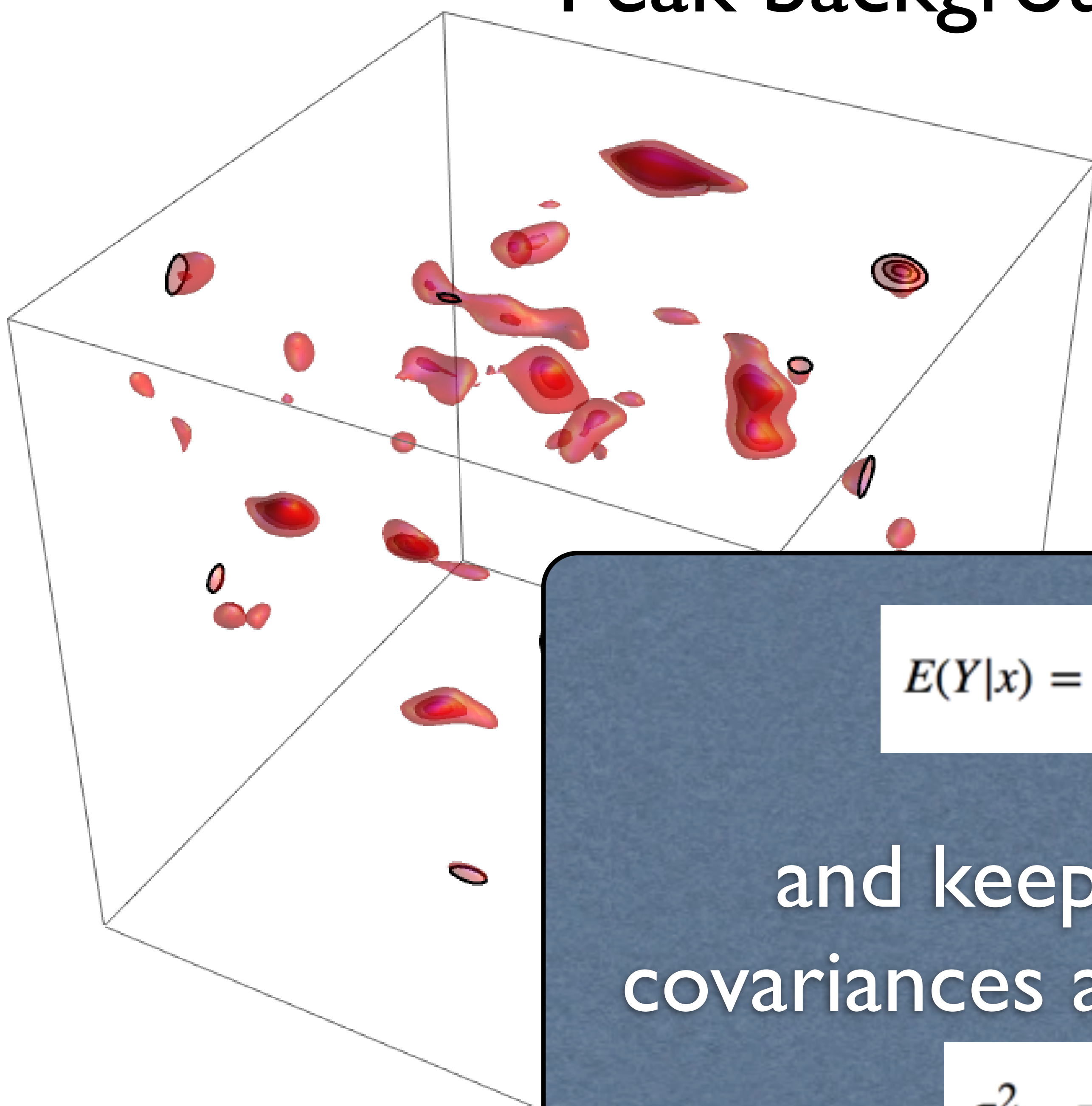


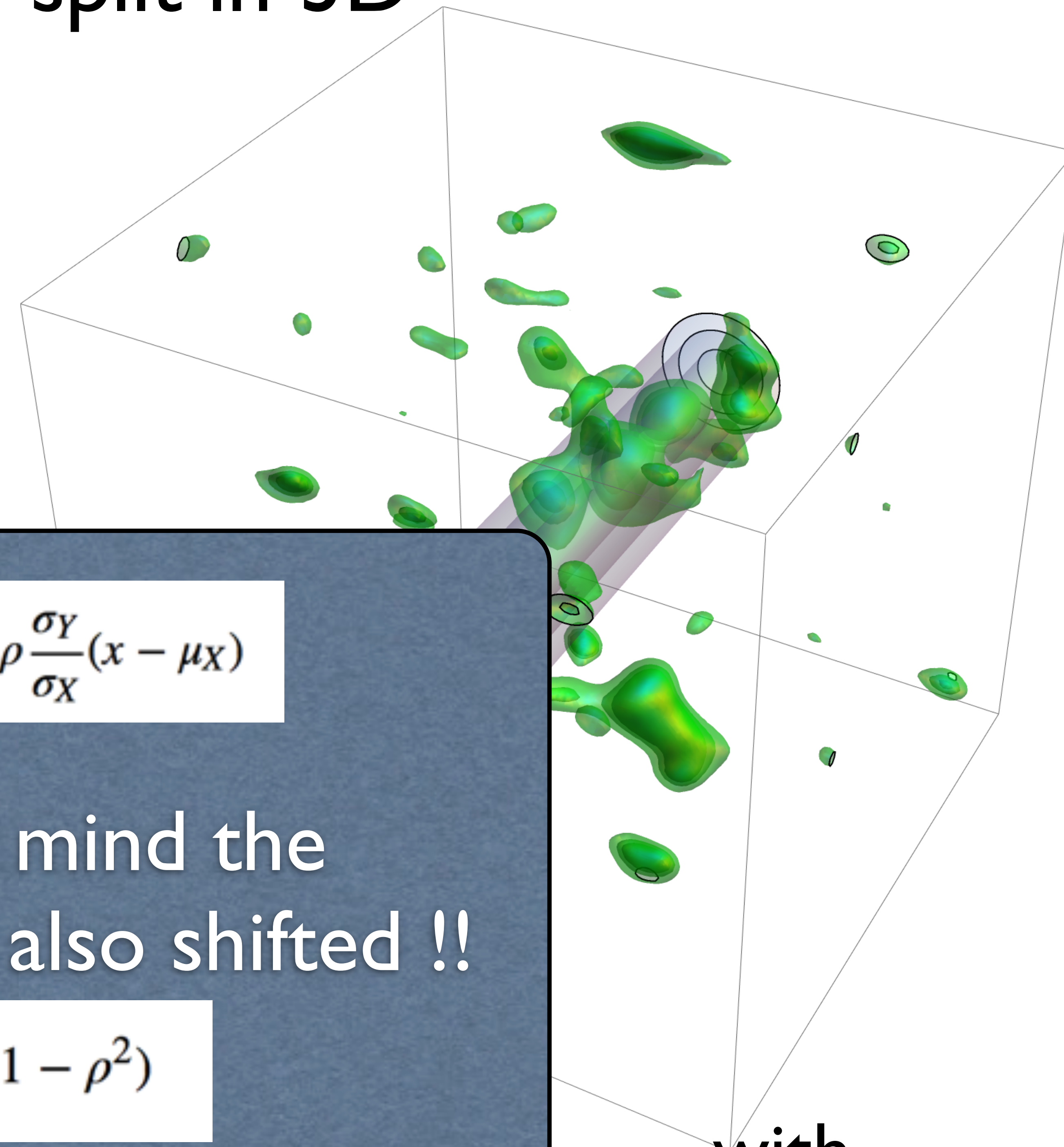
without boost

$$E(Y|x) = \mu_Y + \rho \frac{\sigma_Y}{\sigma_X}(x - \mu_X)$$

and keep in mind the covariances are also shifted !!

$$\sigma^2_{Y|X} = \sigma^2_Y(1 - \rho^2)$$

= *biased local clock* = *strength of environment*



with boost

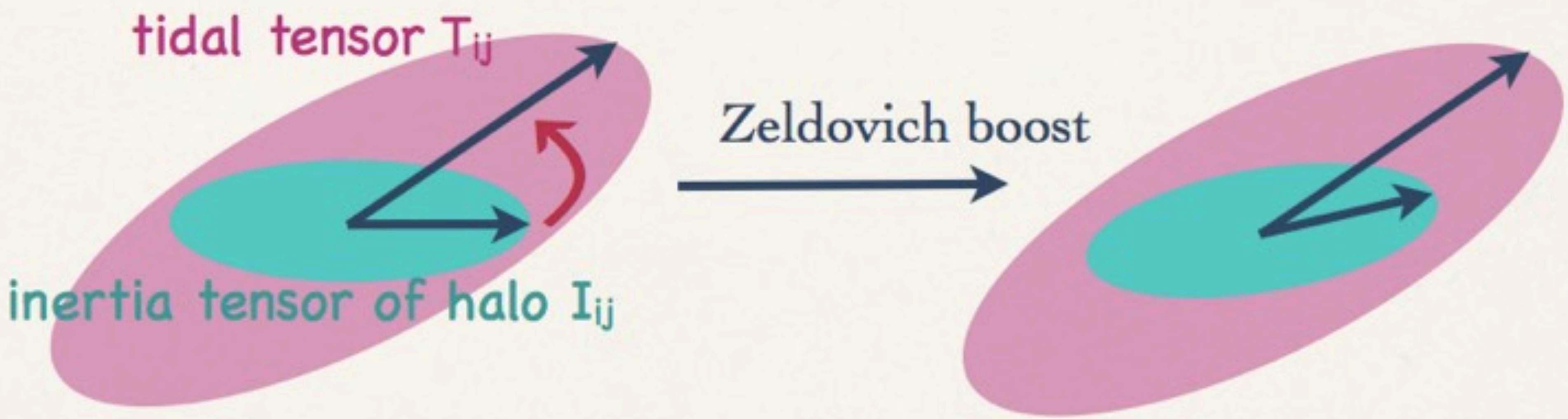
Does this anisotropic biassing have a dynamical signature? *yes! in term of spin!*

Tidal Torque Theory in one cartoon

Can we understand where spin and vorticity alignments come from?

-usual tidal torque theory

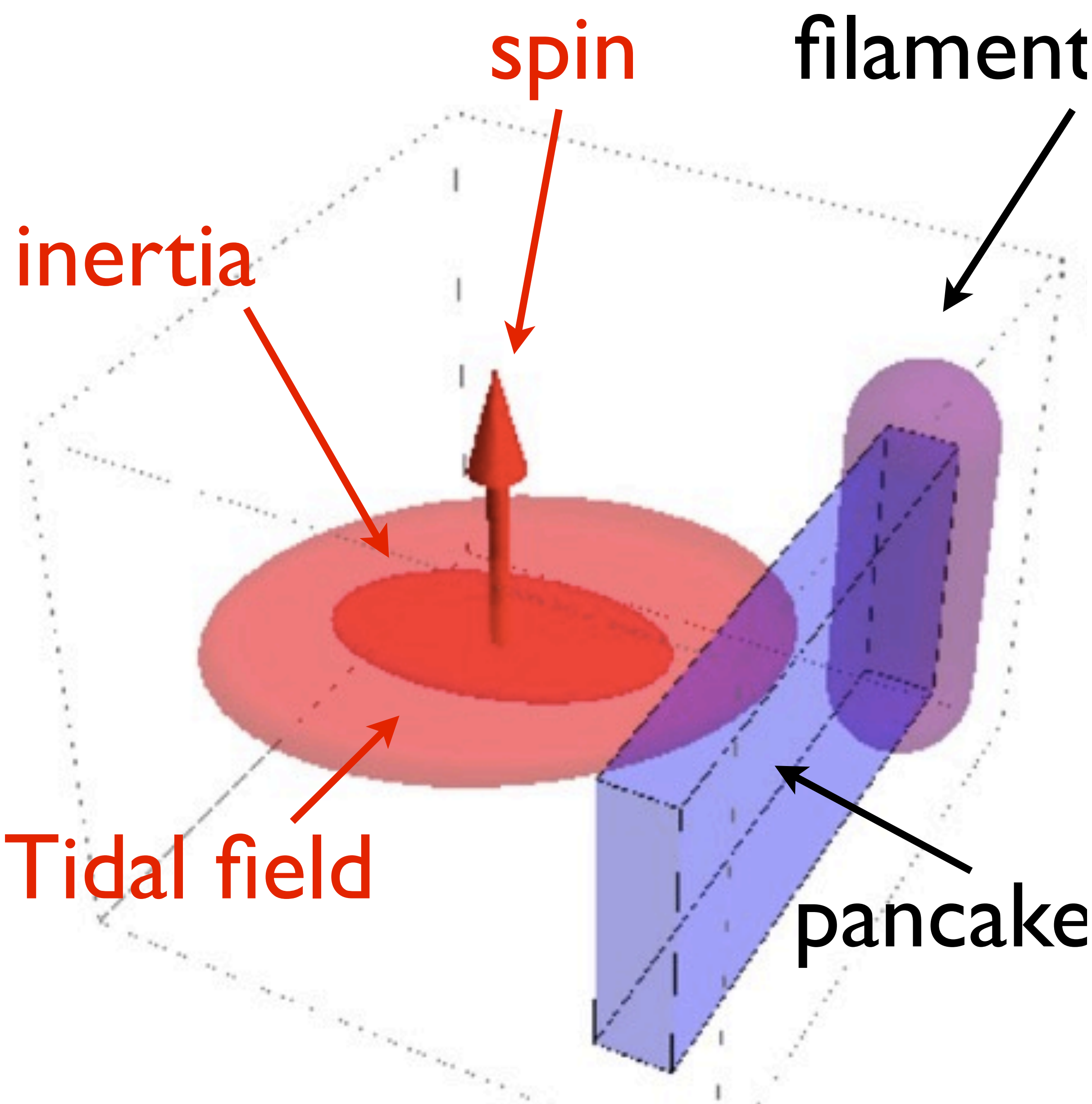
$$L_k = \varepsilon_{ijk} I_{li} T_{lj}$$



YES! via conditional TTT subject to CW

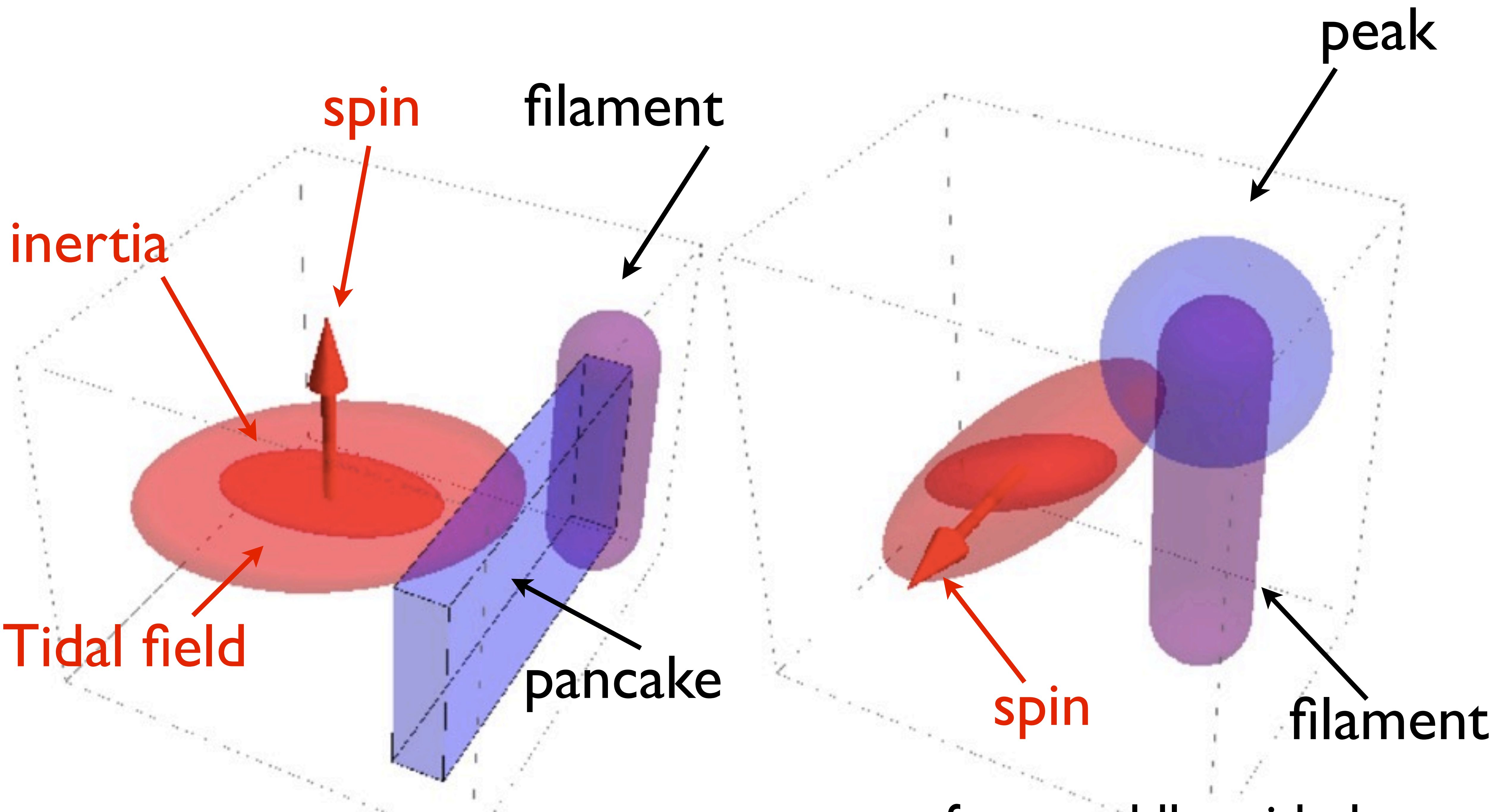
Et Voilà !

Tidal/Inertia mis-alignment



in saddle mid plane

Tidal/Inertia mis-alignment



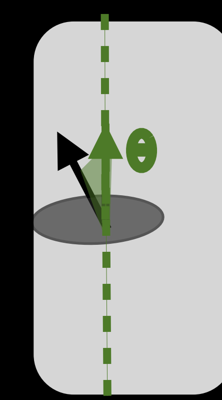
in saddle mid plane

away from saddle mid plane

Excess probability of alignment between the spins and their host filament

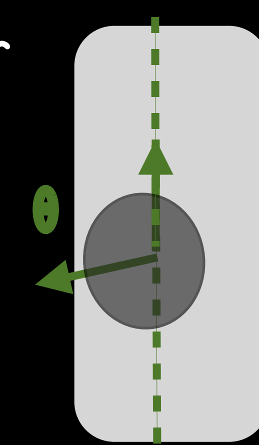
mass transition:

$$M_{\rm crit} = 4 \cdot 10^{12} M_\odot$$



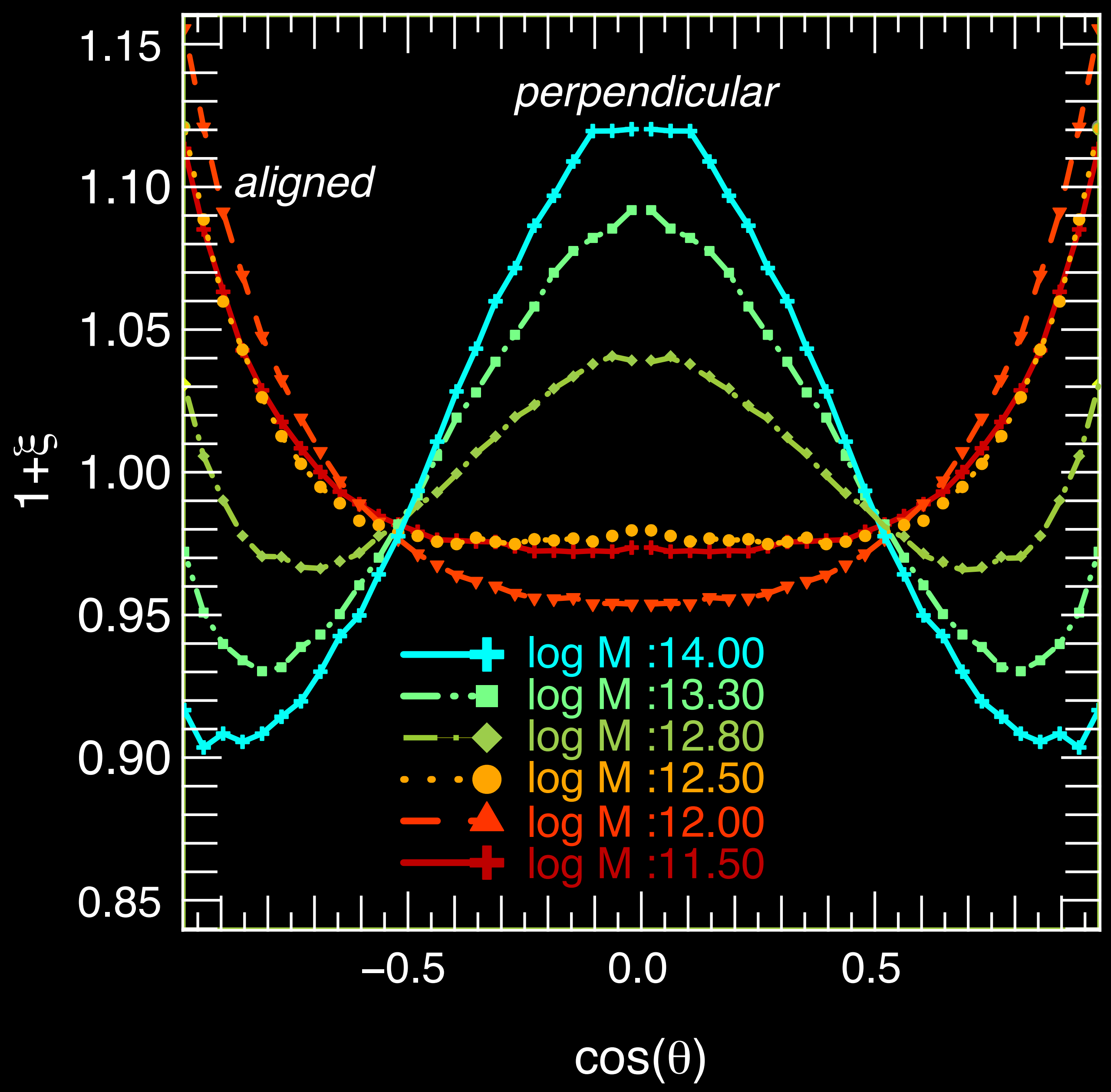
$M < M_{\rm crit}$: aligned

$M > M_{\rm crit}$: perpendicular



(Codis et al, 2012)

Excess probability of alignment between the spins and their host filament



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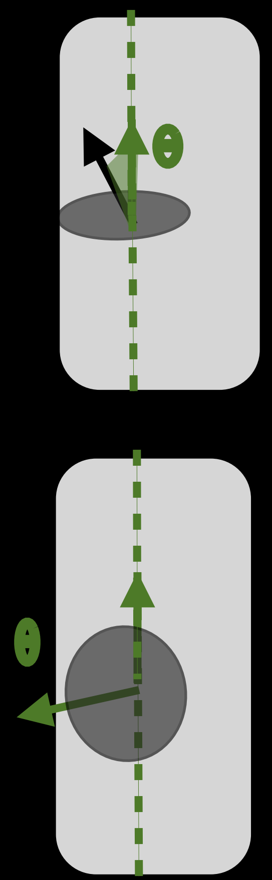
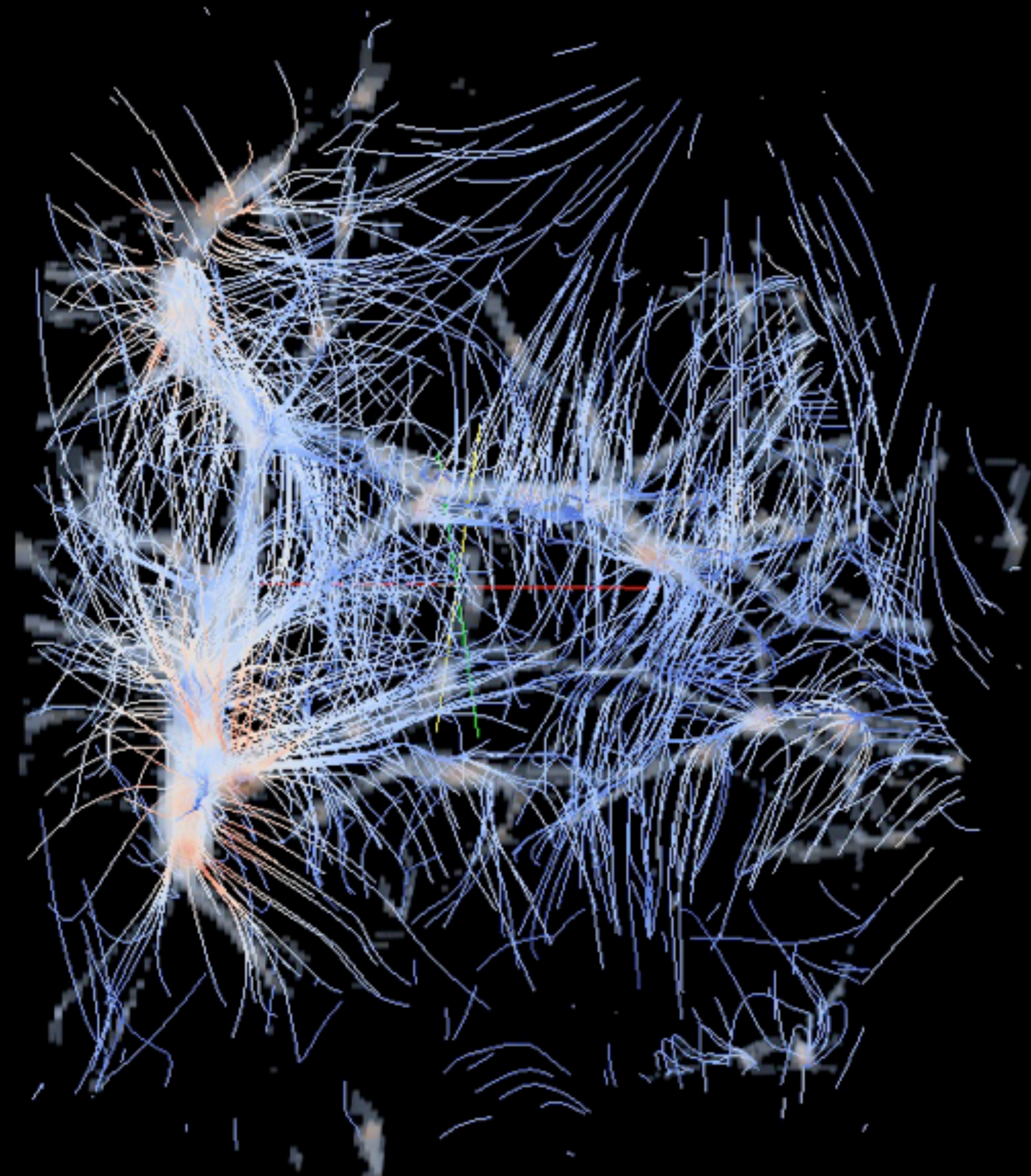


(Codis et al, 2012)

How does the formation of the filaments generate spin parallel to them?

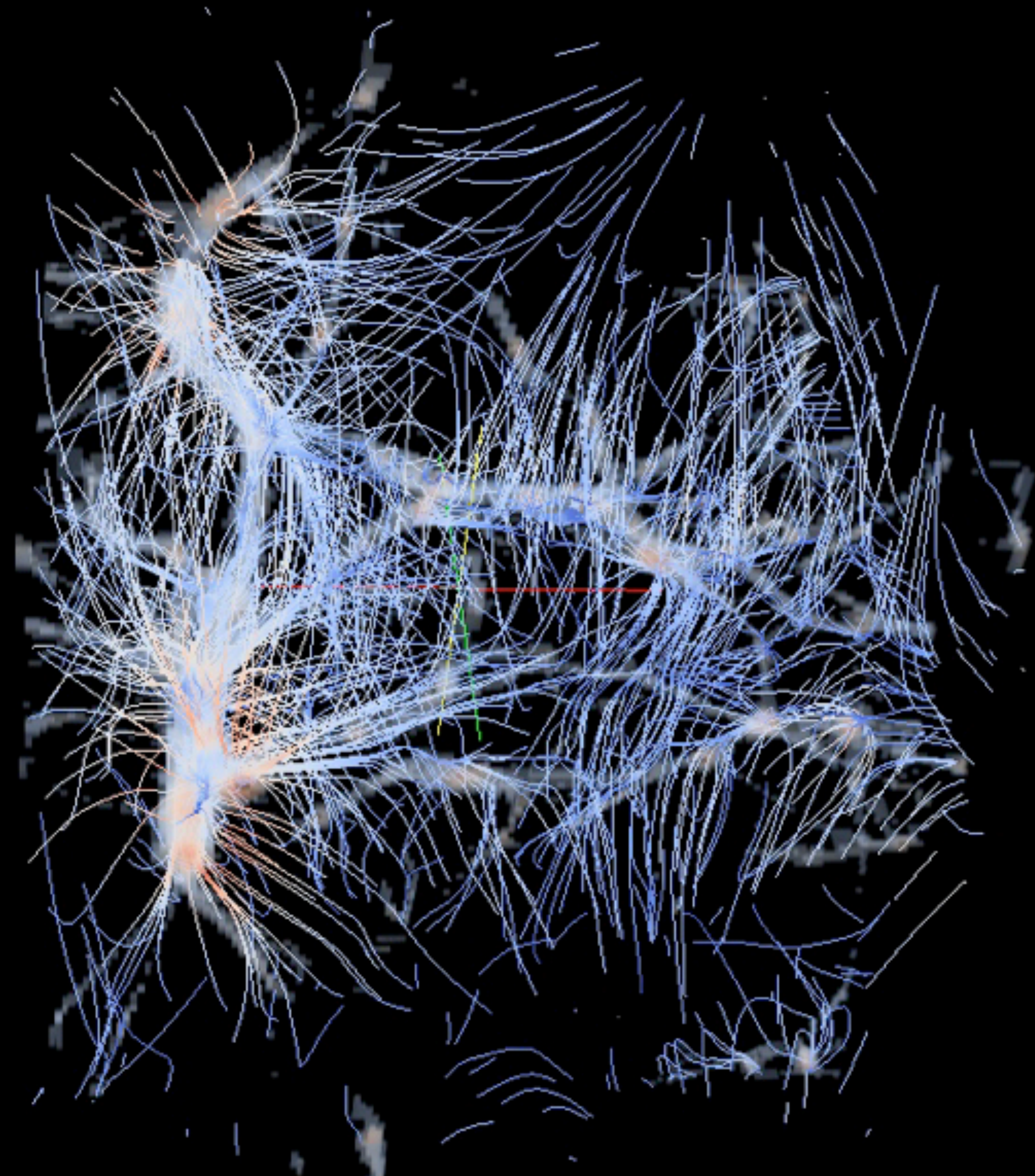
Voids/wall saddle repel...



How does the formation of the filaments generate spin parallel to them?

Voids/wall saddle repel...

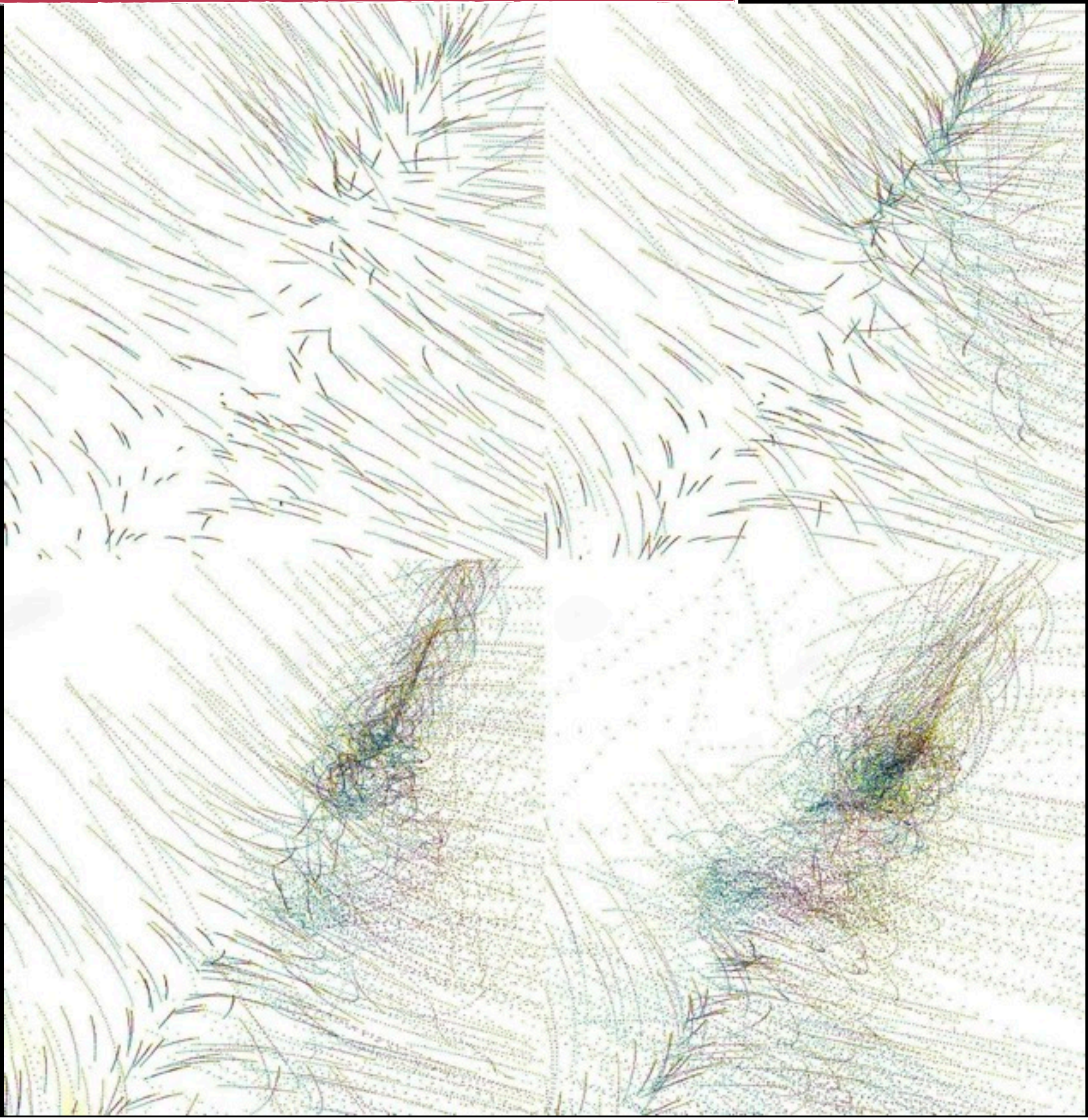
winding of walls into filaments



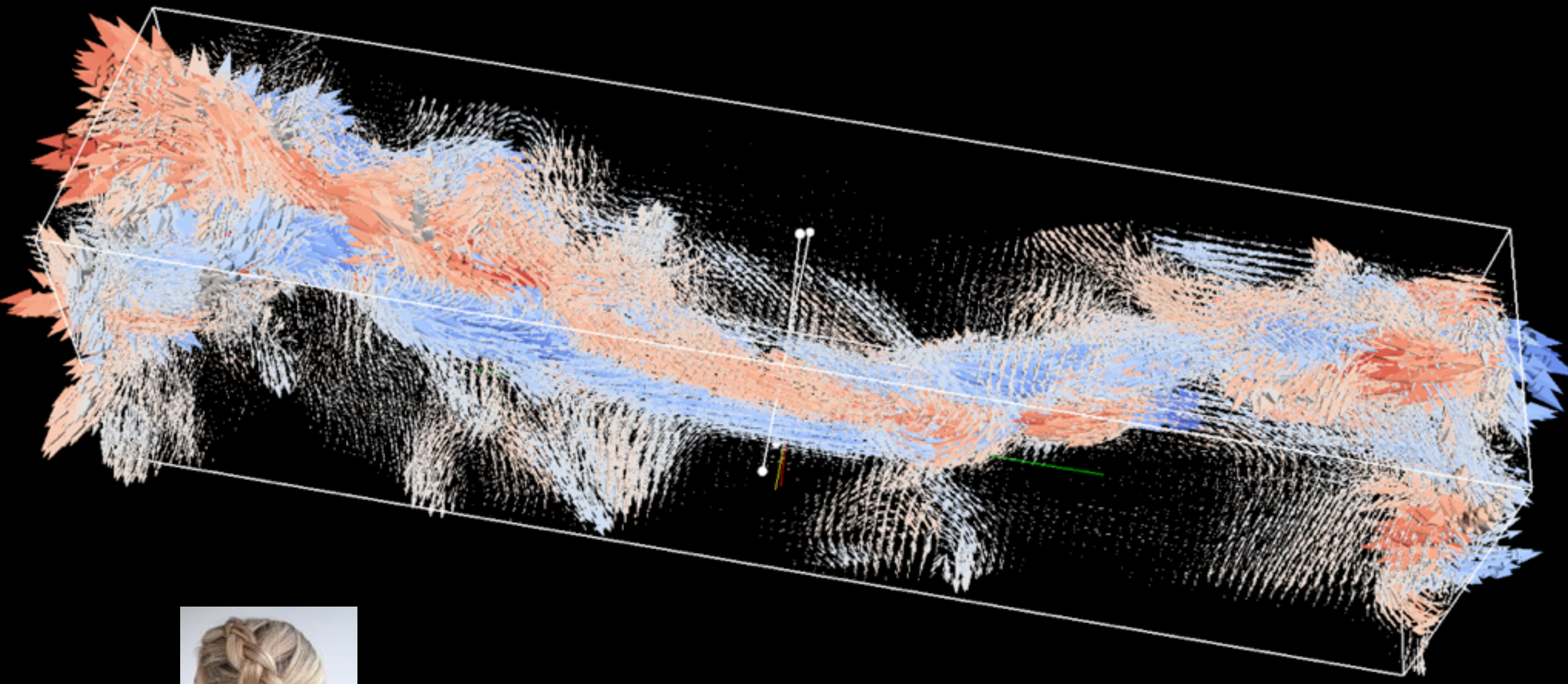
How does the formation of the filaments generate spin parallel to them?

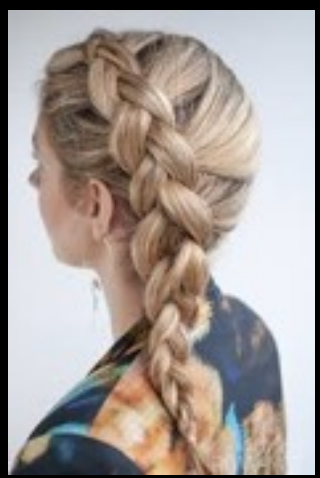
Voids/wall saddle repel...

winding of walls into filaments

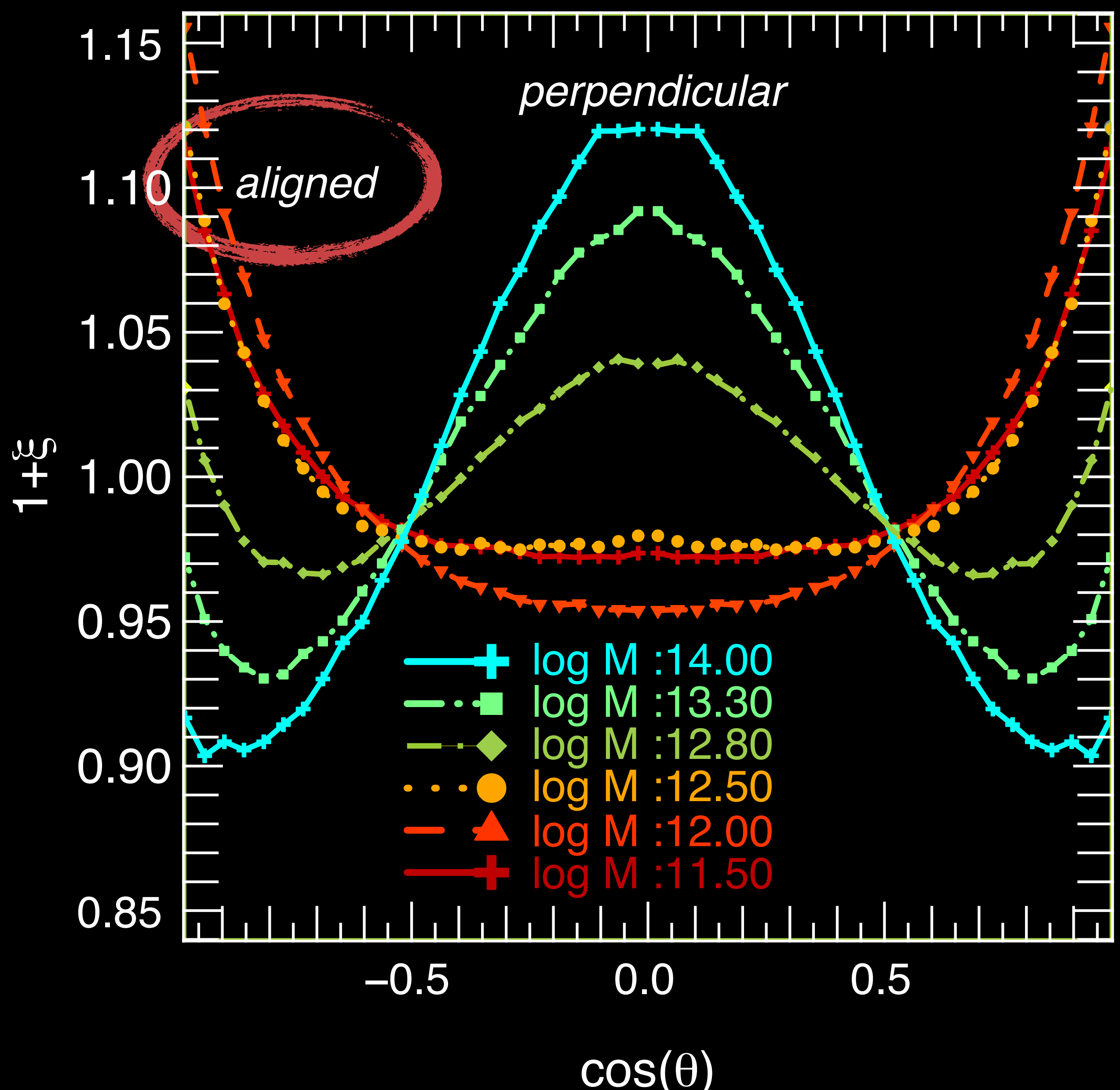


Alignement of vorticity with cosmic web





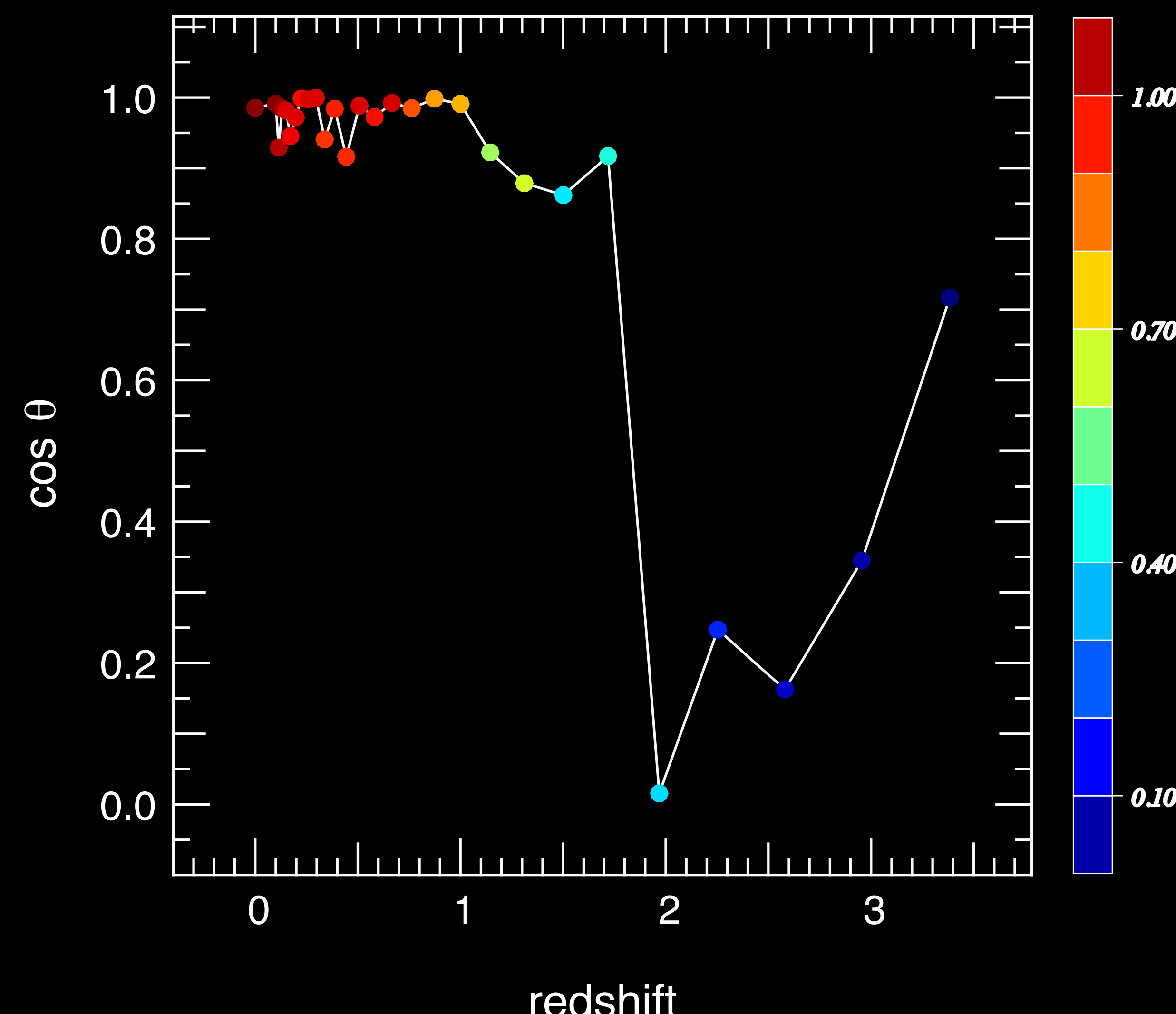
Low-mass haloes: $M < M_{\rm crit}$



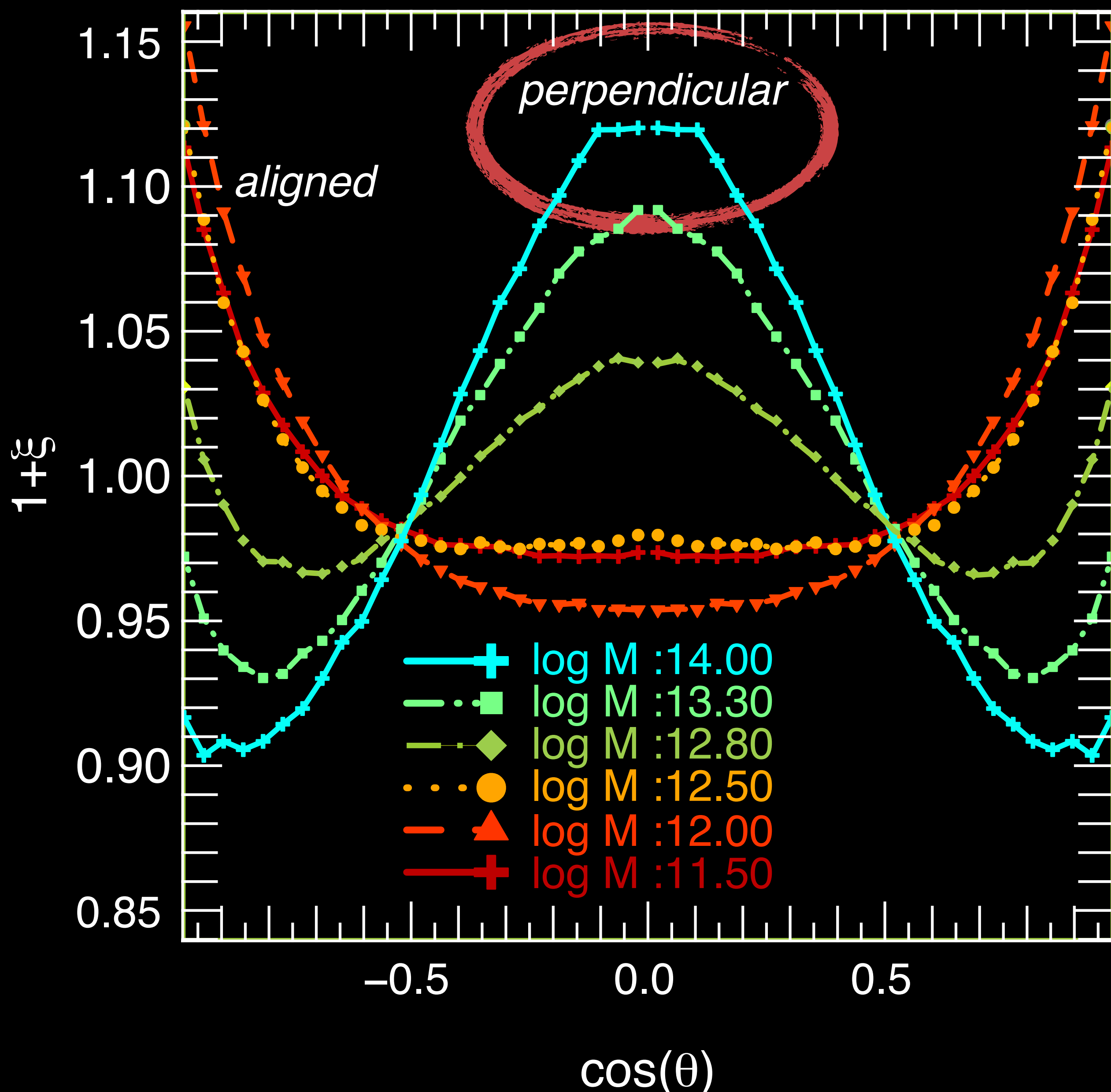
$$M_{\rm crit} = 4 \cdot 10^{12} M_\odot$$

-formed at high z during the formation within filaments

-no major merger but smooth accretion until z=0

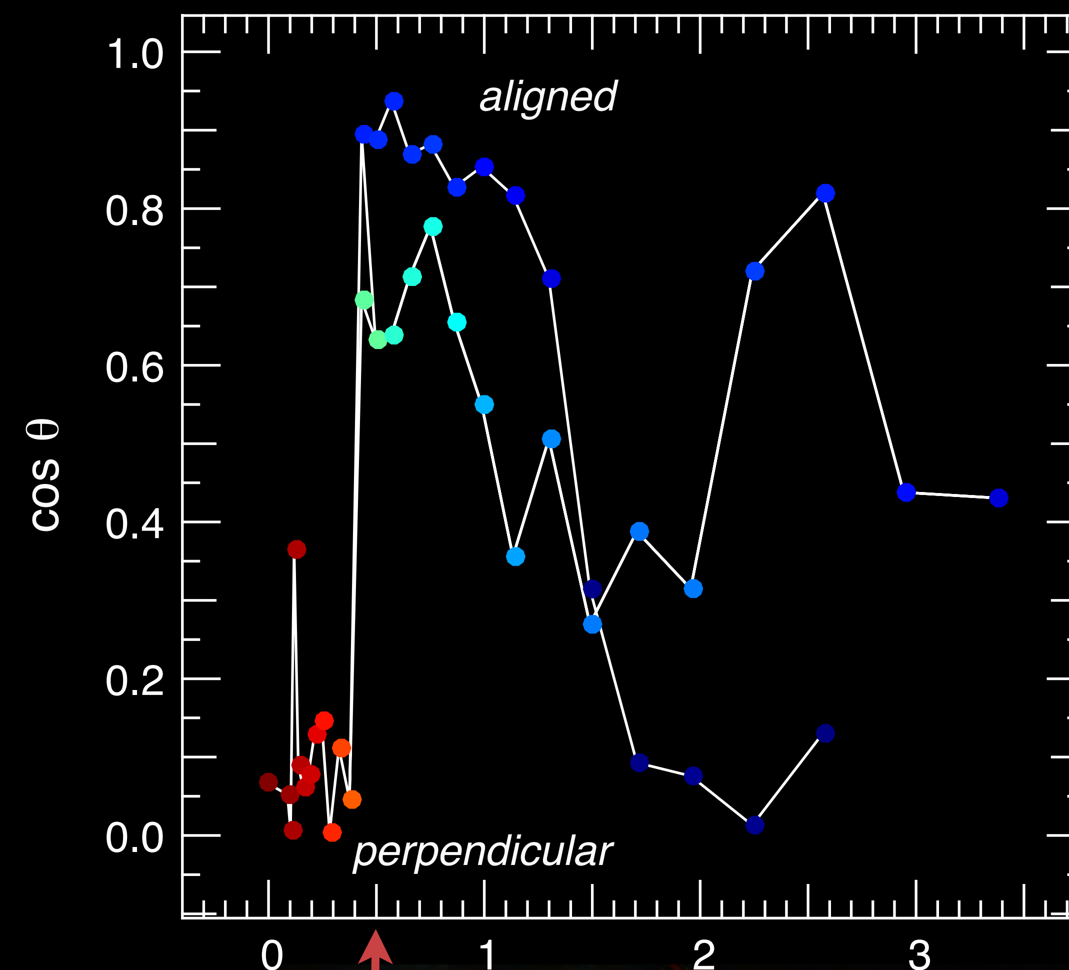


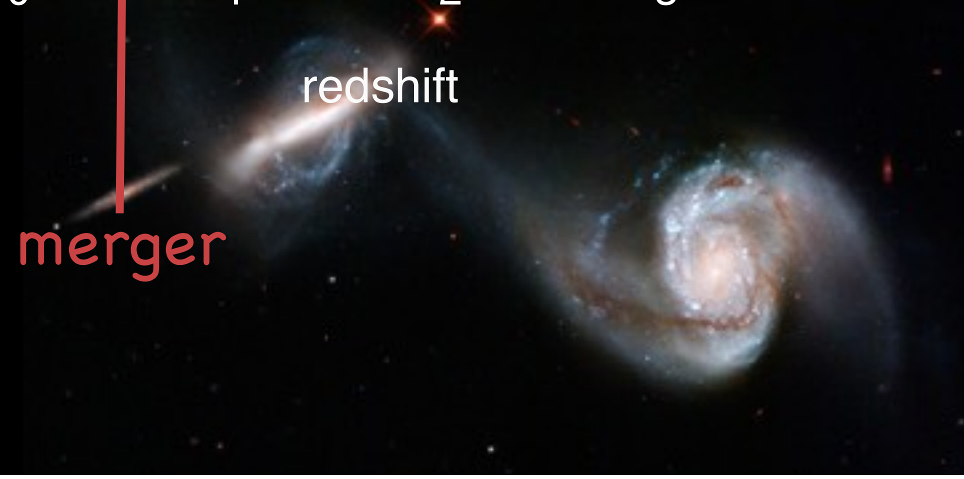
High-mass haloes: $M > M_{\rm crit}$



$$M_{\rm crit} = 4 \cdot 10^{12} M_{\odot}$$

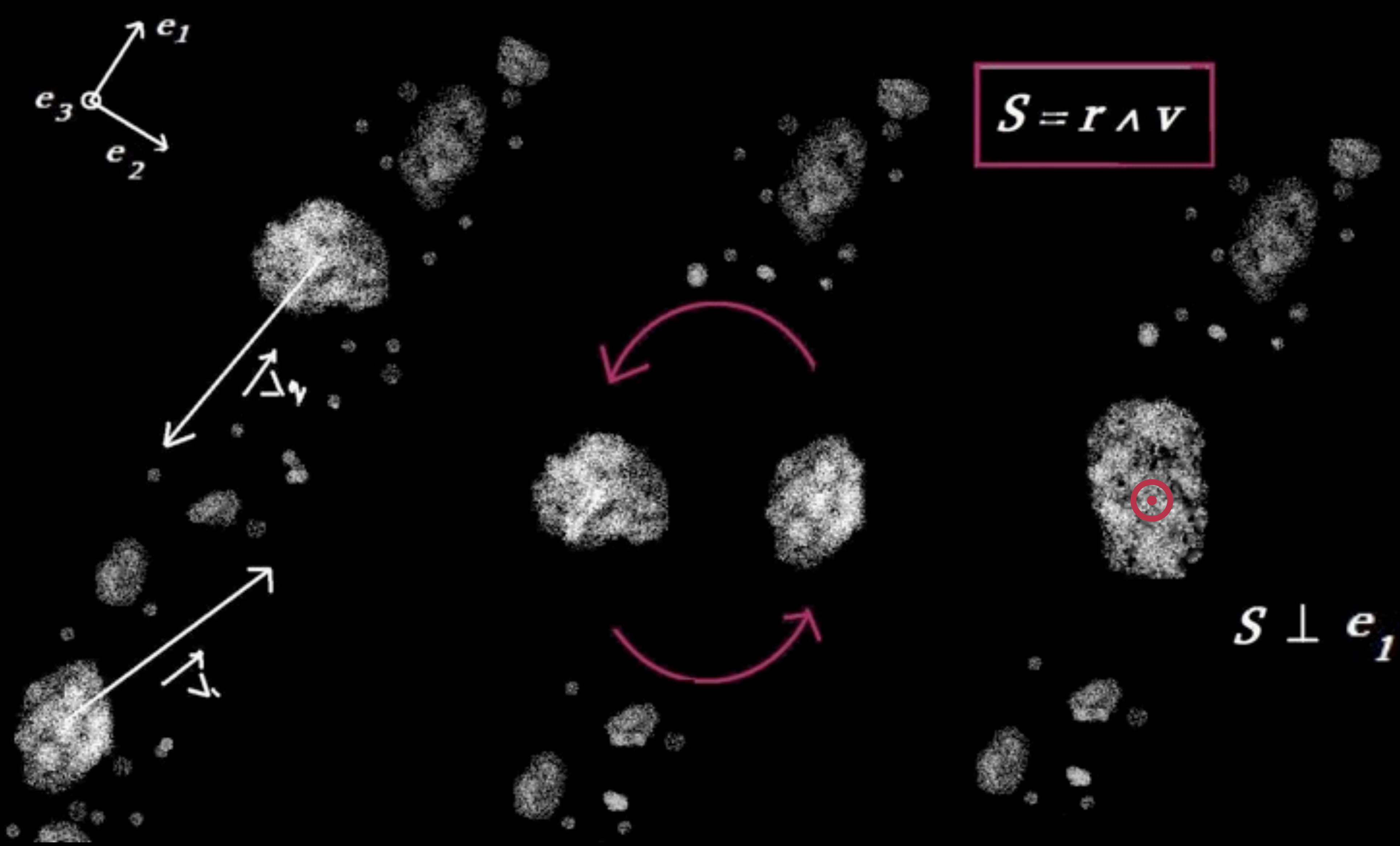
formed later by mergers inside the filaments





How do mergers along the filaments create spin perpendicular to them?

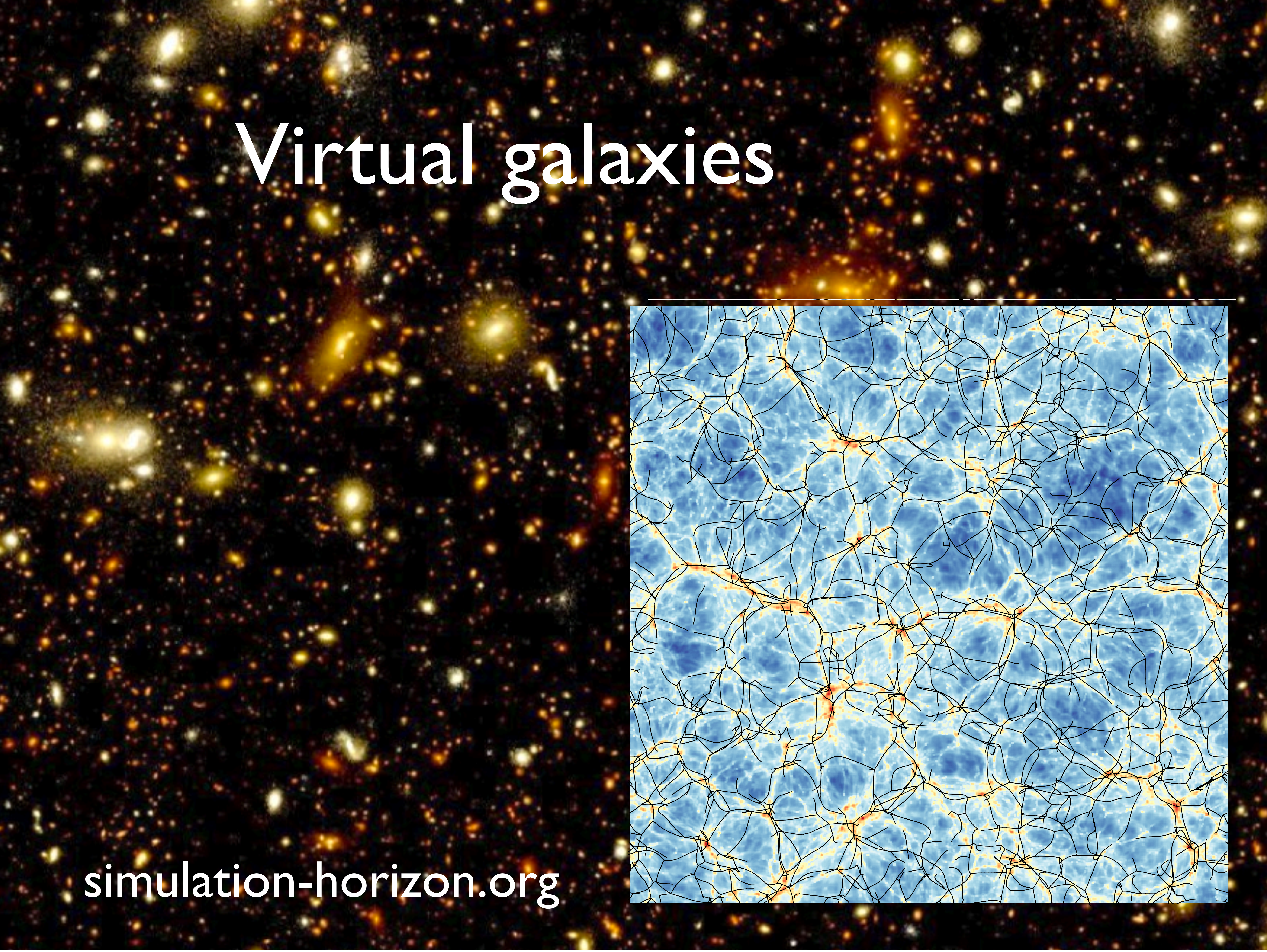
Halos catch up
with each other
along the filaments



What about galaxies?

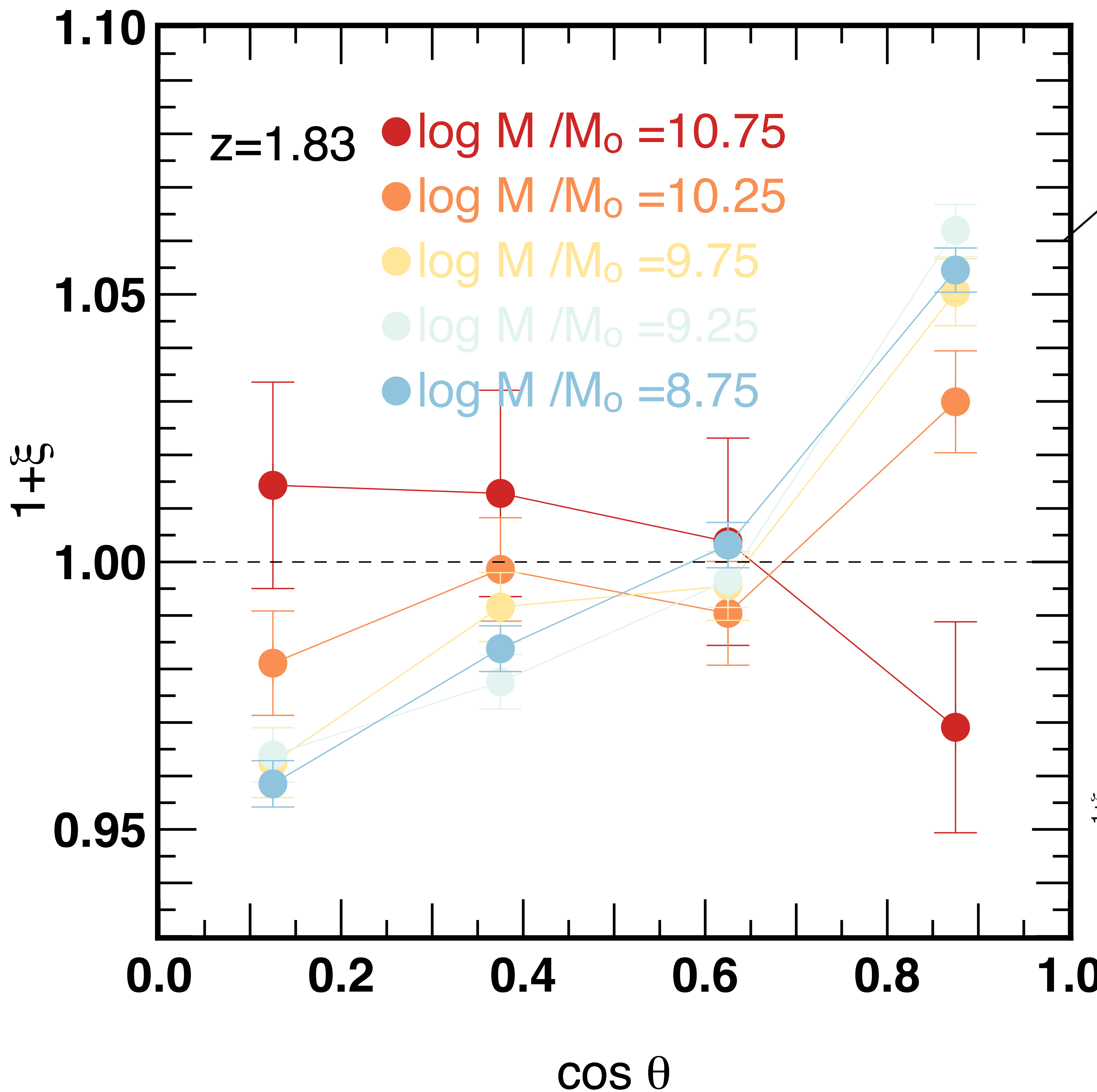
simulation-horizon.org

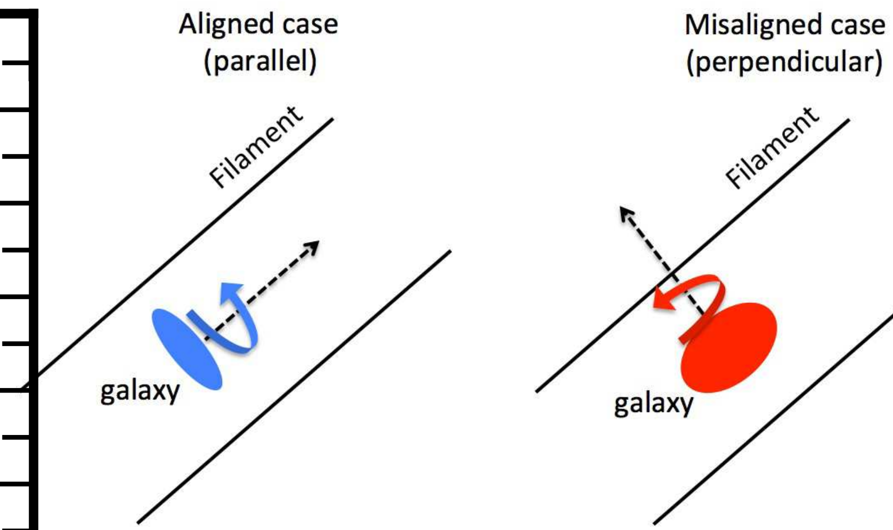
Virtual galaxies



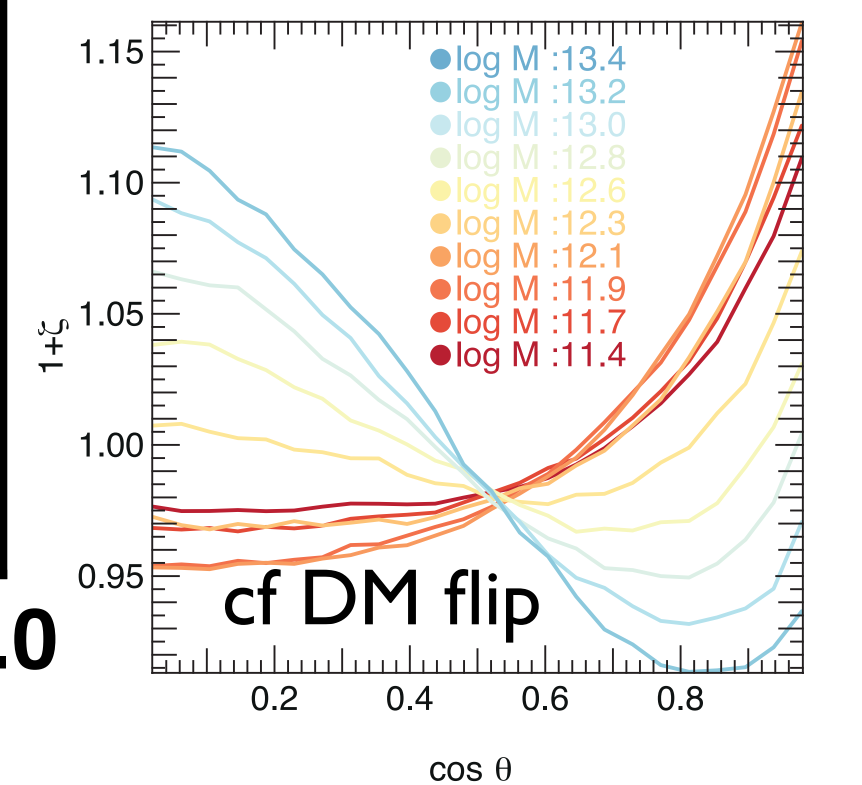
simulation-horizon.org

Filament-galactic spin & mass

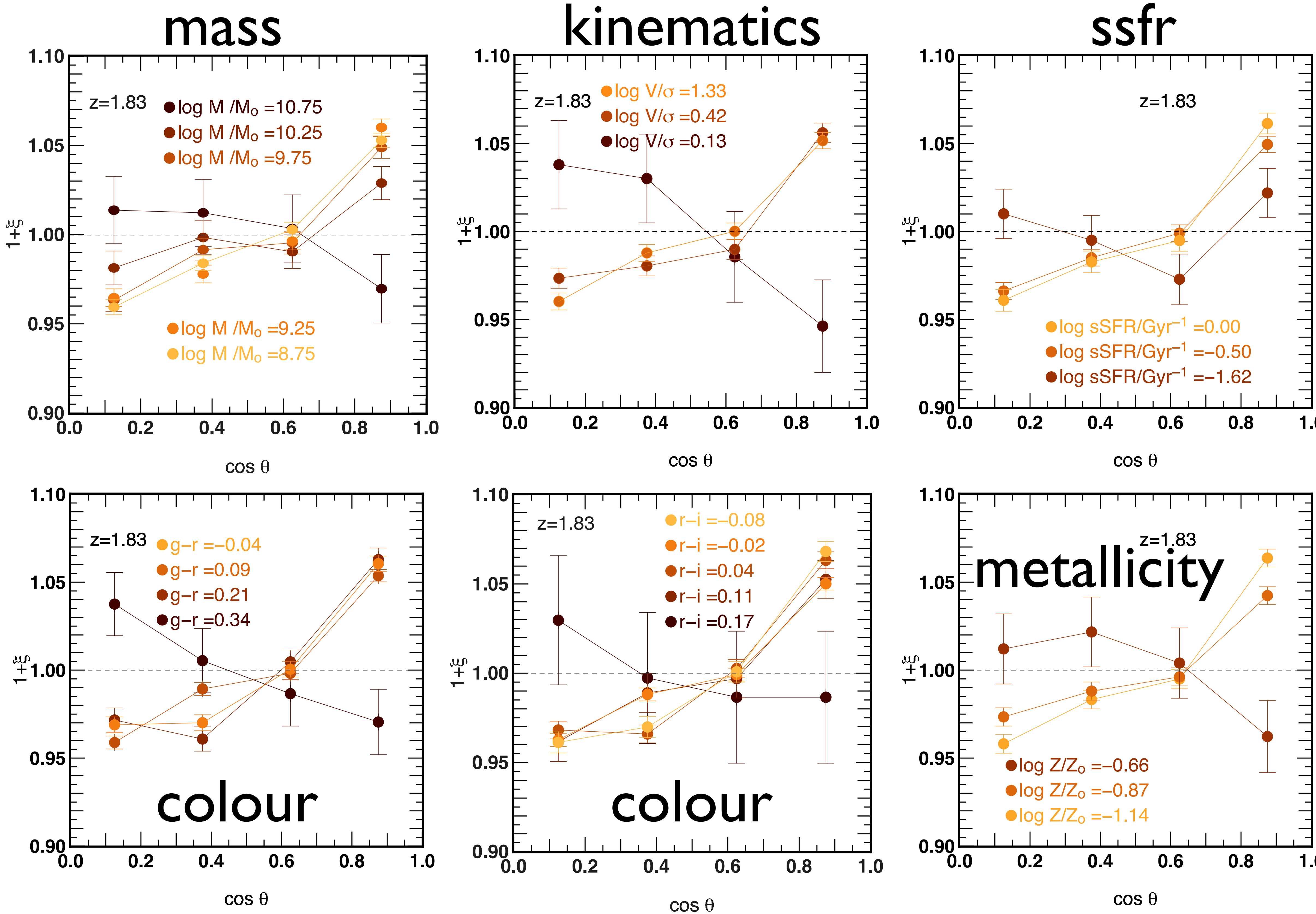




Signal stronger@low z

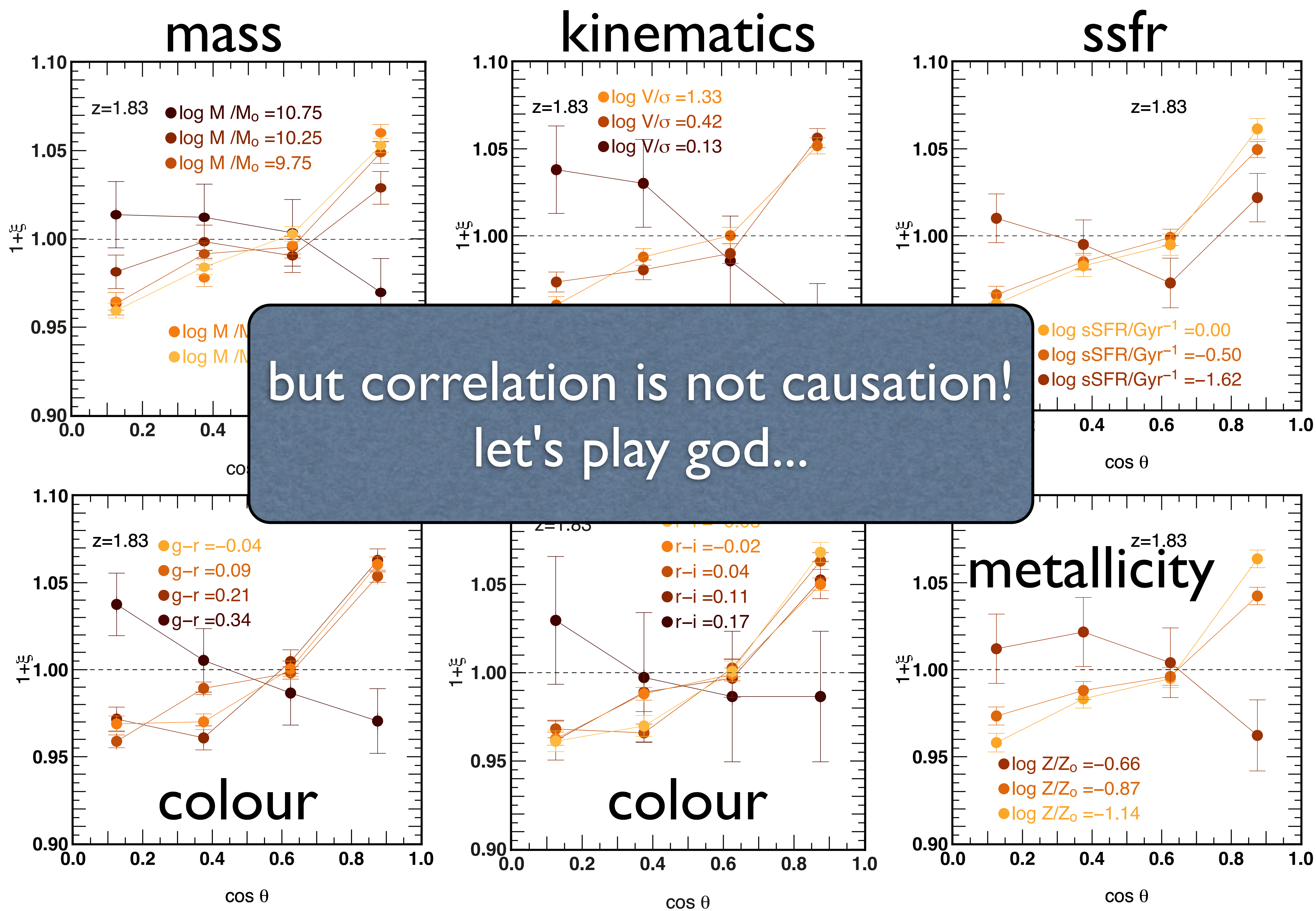


Can morphological/physical properties of galaxies trace spin flip?



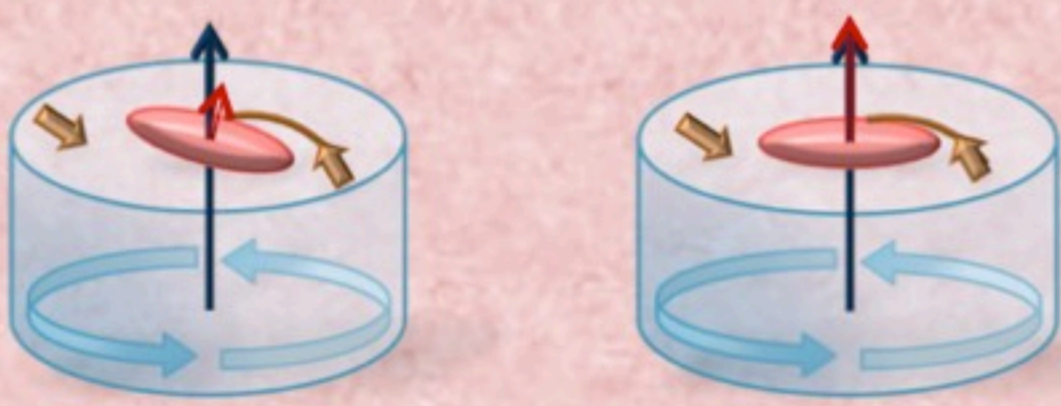
Tuesday, 12December, 17

Can morphological/physical properties of galaxies trace spin flip?

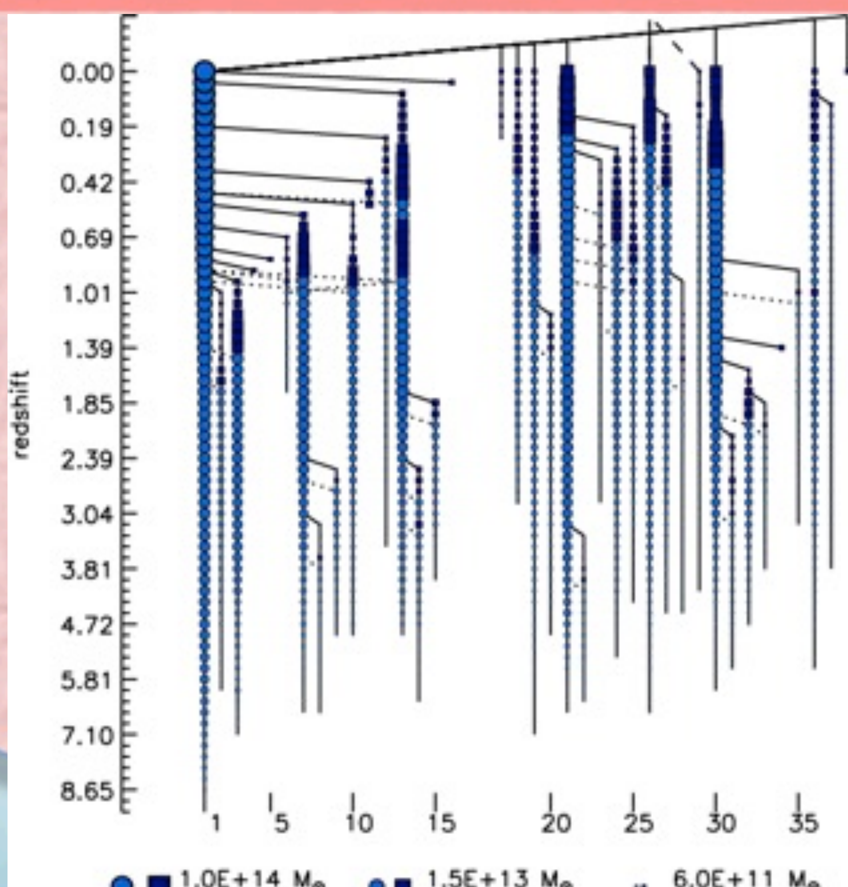


Lack of merger induce realigment

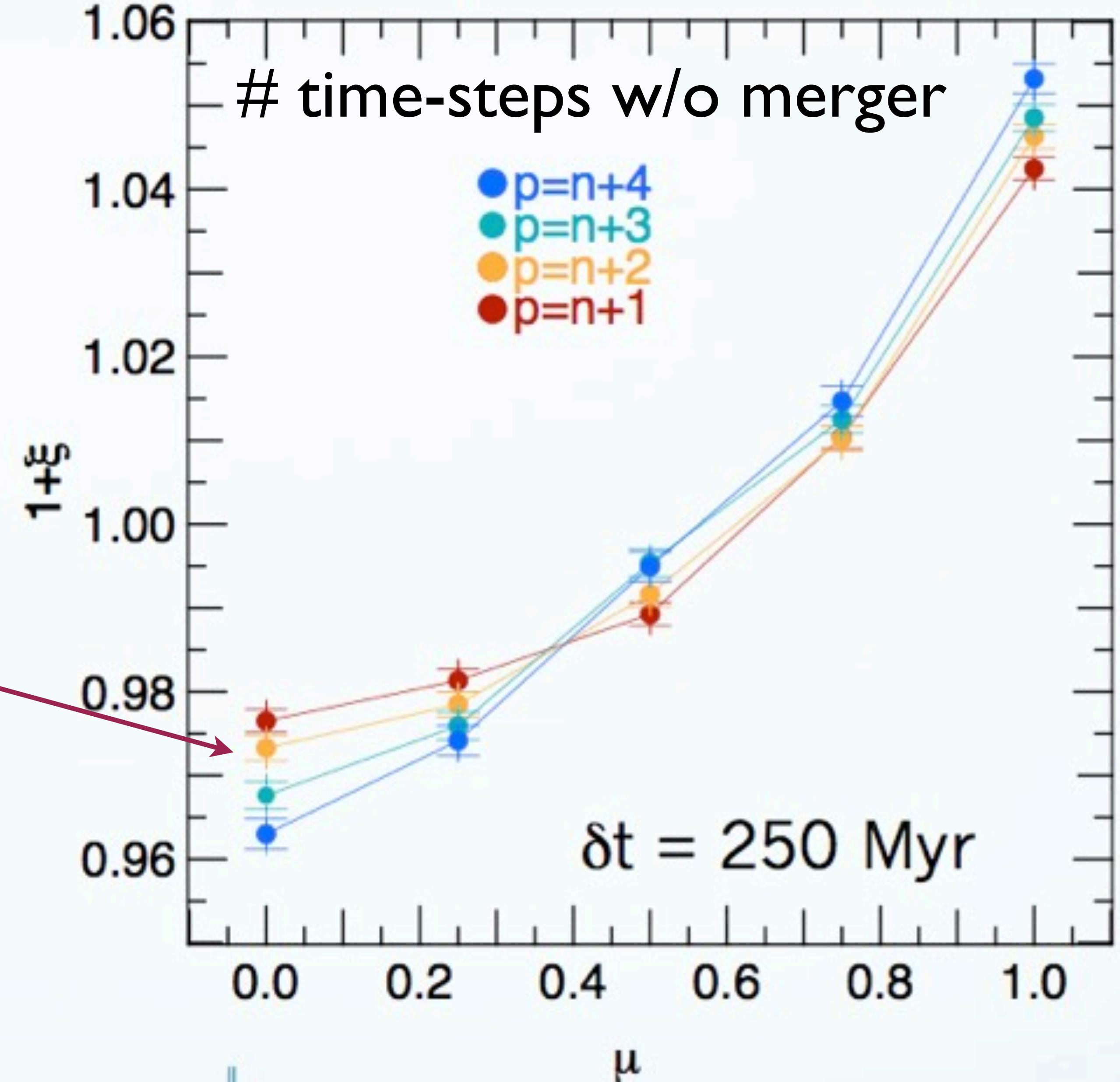
SMOOTH ACCRETION

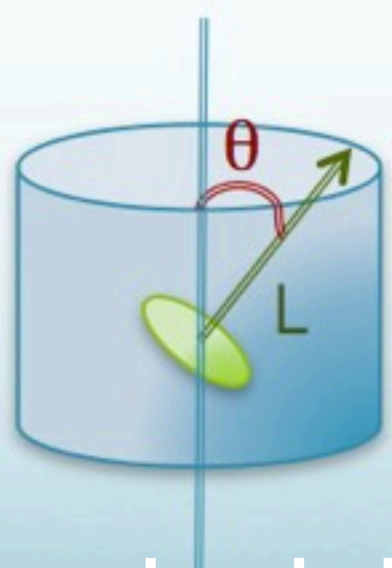


- Gas inflows (re)-align galaxies with their filament



PDF of μ over 4 timesteps δt



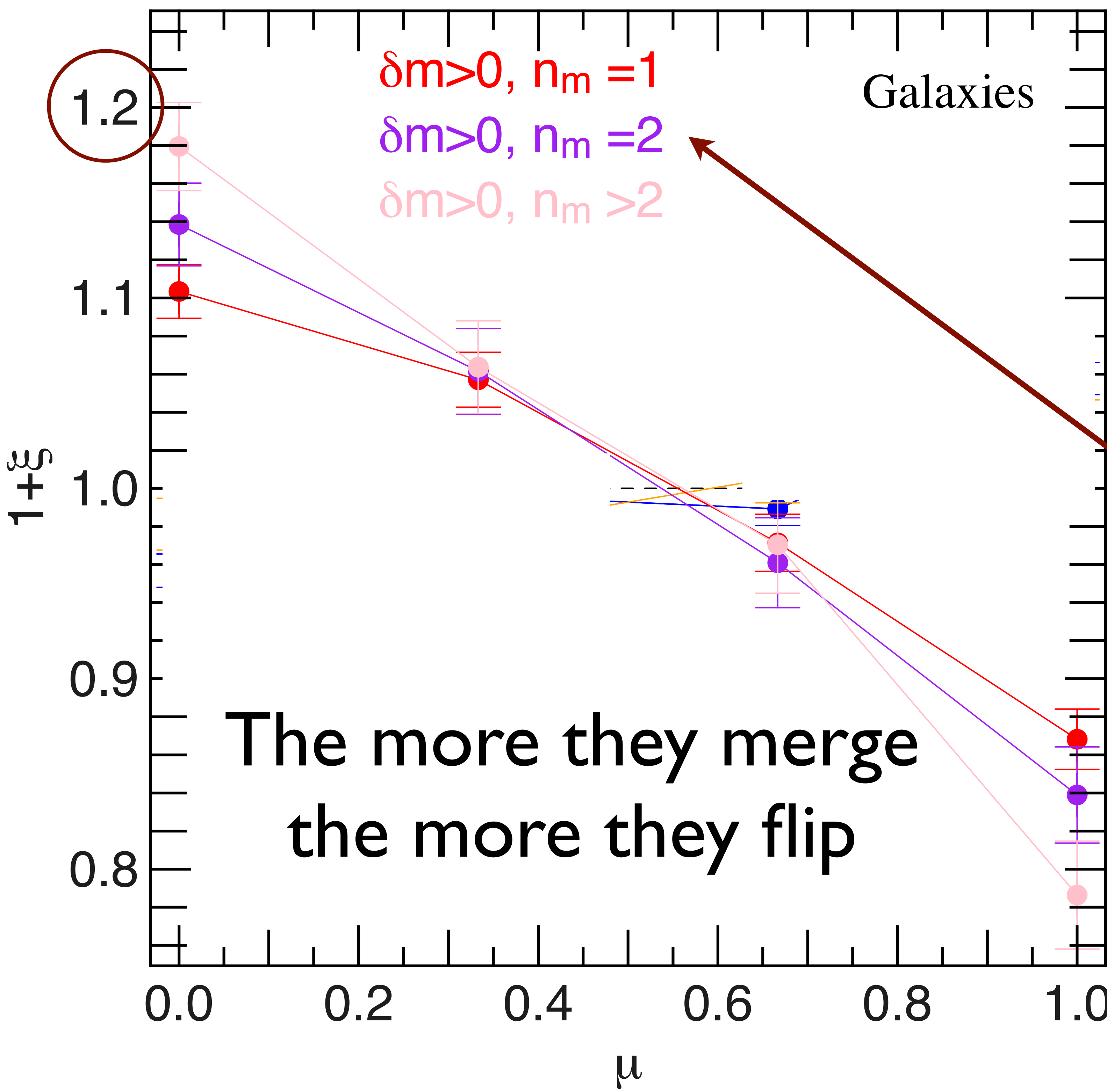


$\mu = |\cos(\theta)|$

- Spin-filament angle
- ξ : excess probability

no merger : orientation versus look-back time

What is the *physical* origin of spin flip?
high mass **galaxies** merge!



Transition mass
versus **merging rate**
for galaxies

stronger amplitude w/r mass

→

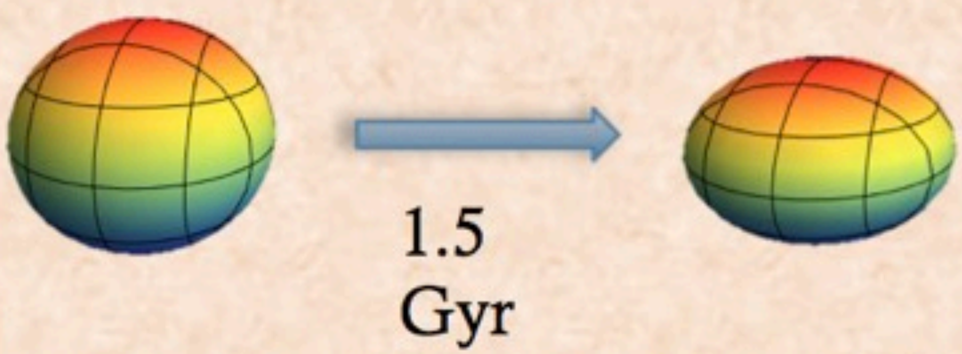
merger driver of flip

[2b]

Galactic morphologies: shape
Smooth accretion

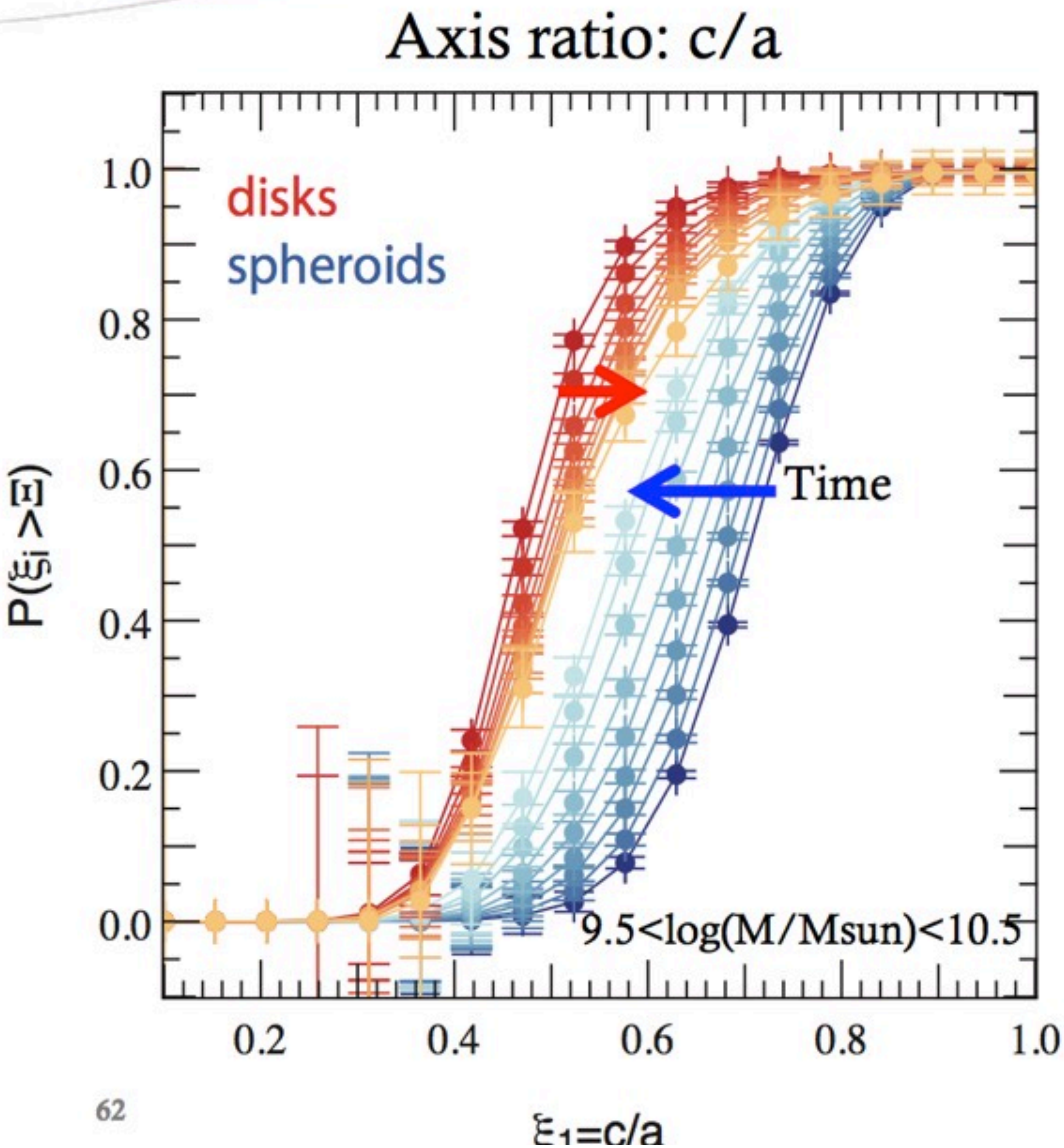
SMOOTH ACCRETION

- Gas inflows flatten galaxies over time along the filament direction



Dark to light: 1.5 Gyr

Cumulated probabilities of axis ratios ξ over a time step (250 Myr)



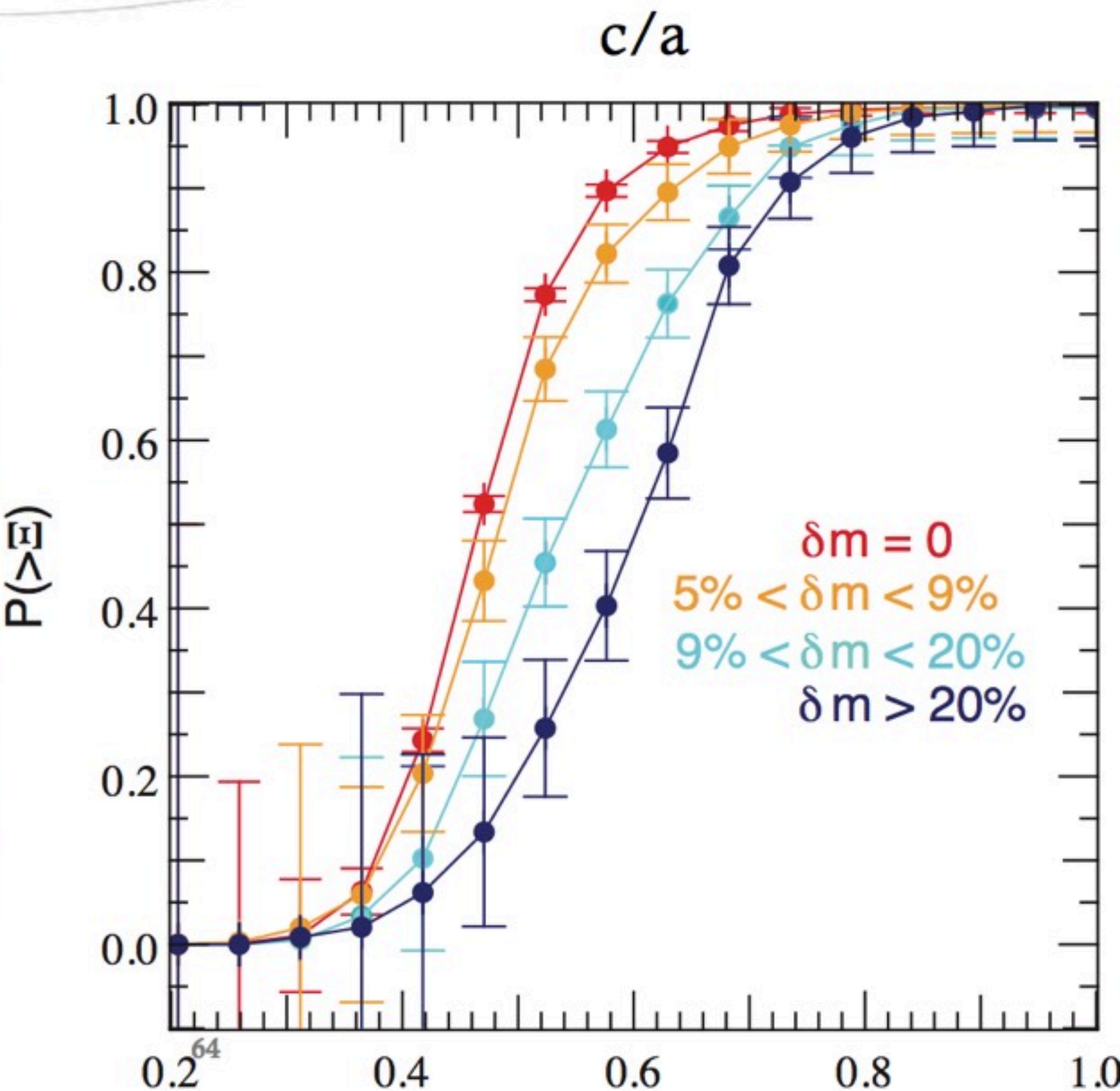
[2b]

Galactic morphologies: shape mergers

MERGERS

- Mergers turn disks into spheroids
- Even minor mergers can create spheroid remnants

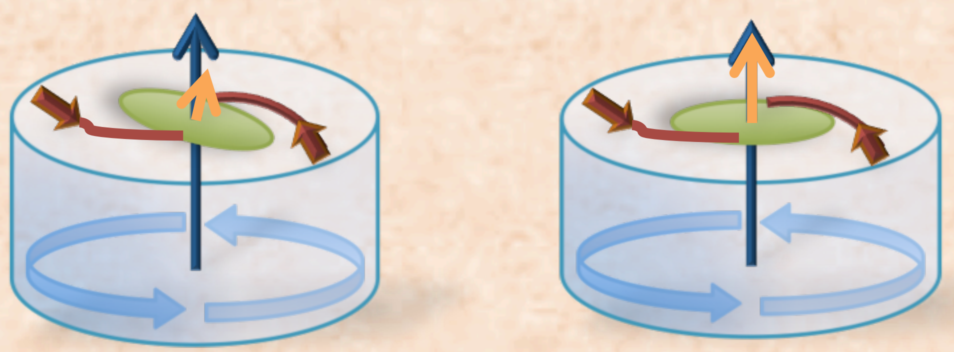
Cumulated probabilities of axis ratios ξ for mergers with different mass ratios over a time step (250 Myr)



Spin swing dynamics

Smooth accretion

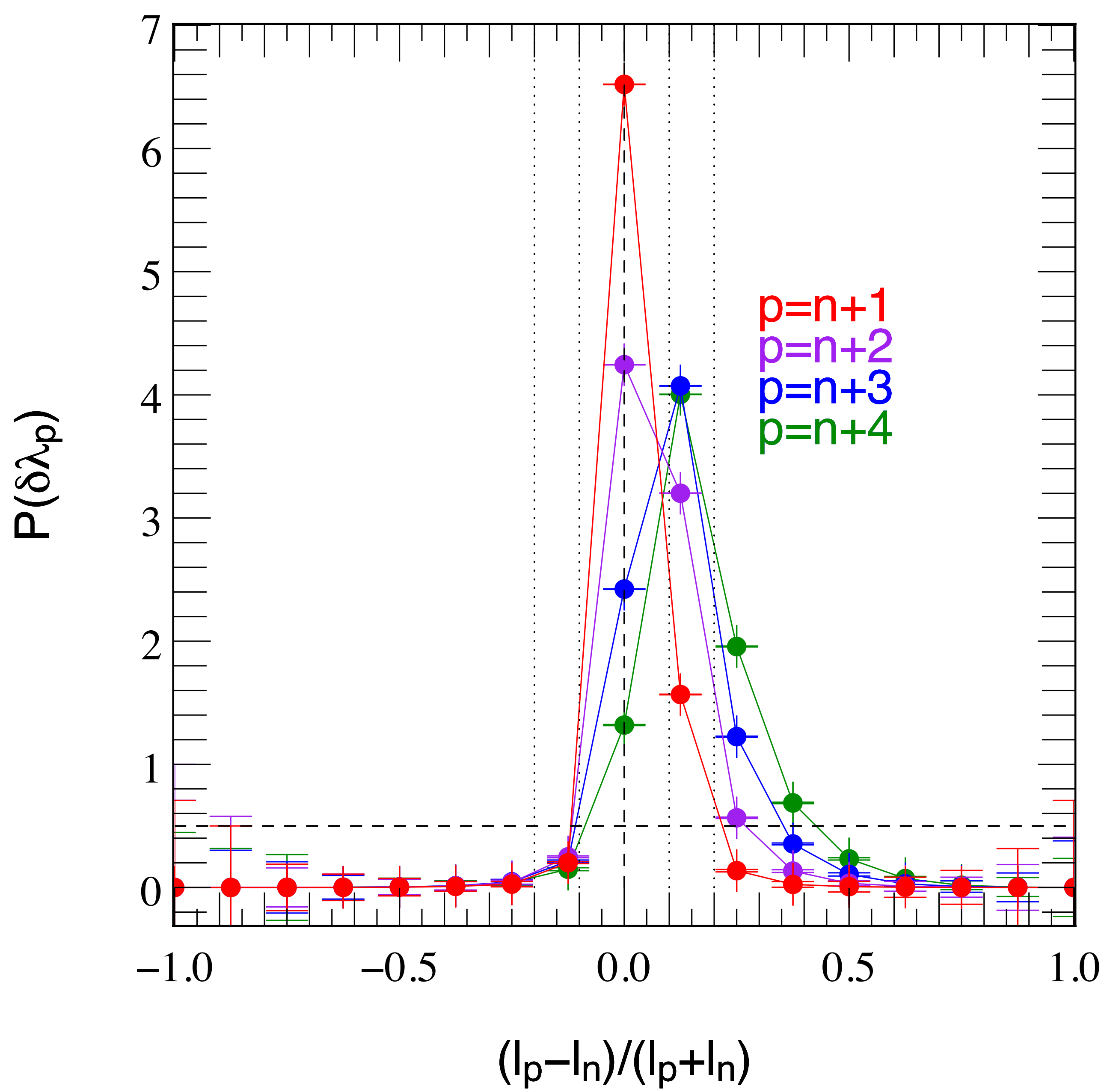
SMOOTH ACCRETION



- Gas inflows (re)-align galaxies with their filament
- Gas inflows build up the galactic spin

$$\delta\lambda(n+1) = \frac{L_{n+1} - L_n}{L_{n+1} + L_n}$$

PDF of δλ(p) for 4 different δt_p



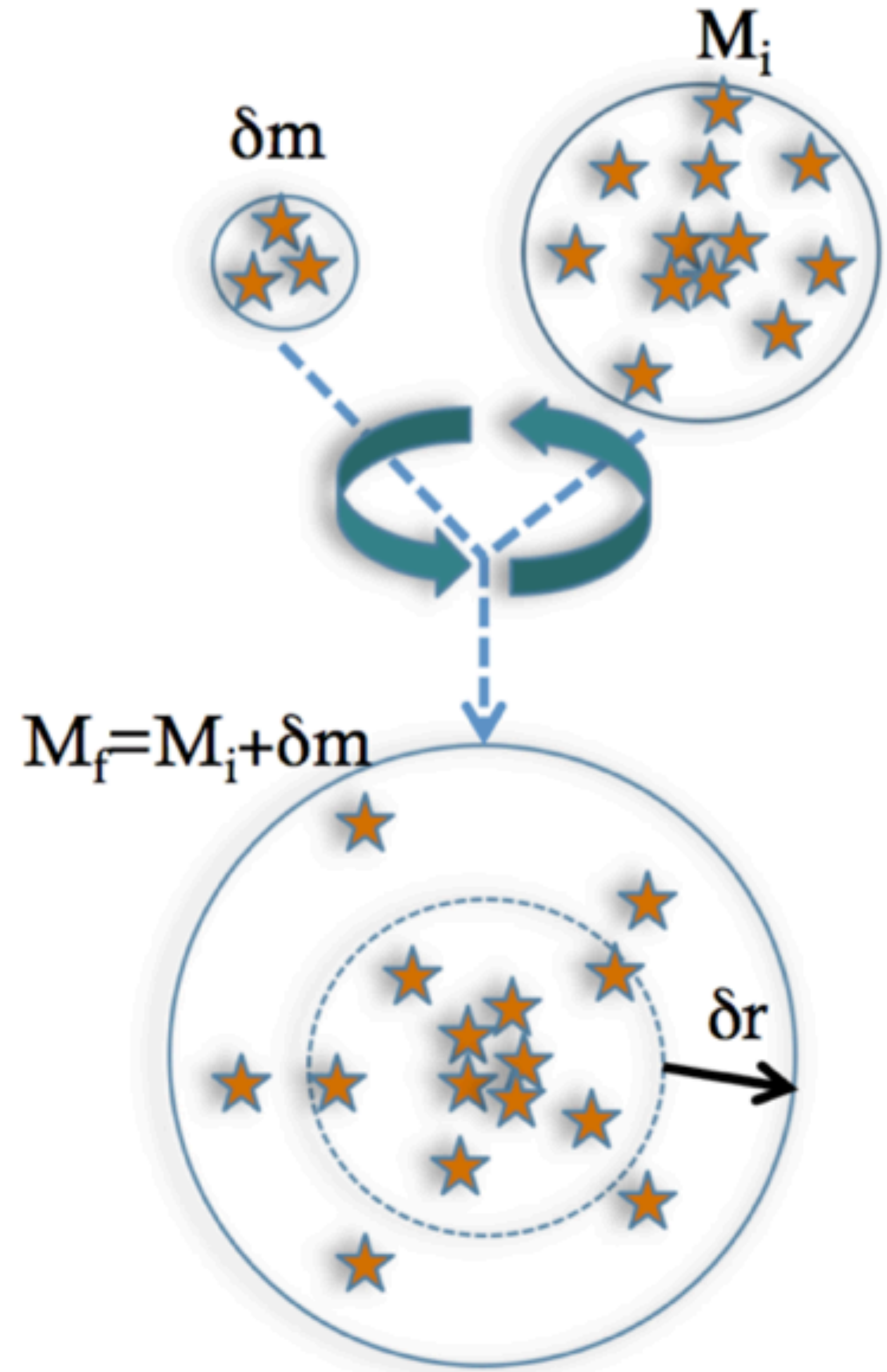
- δλ(p) : angular momentum contrast over timestep δt_p=(p-n)*δt

☛ Mergers grow galactic size much more efficiently than smooth accretion.

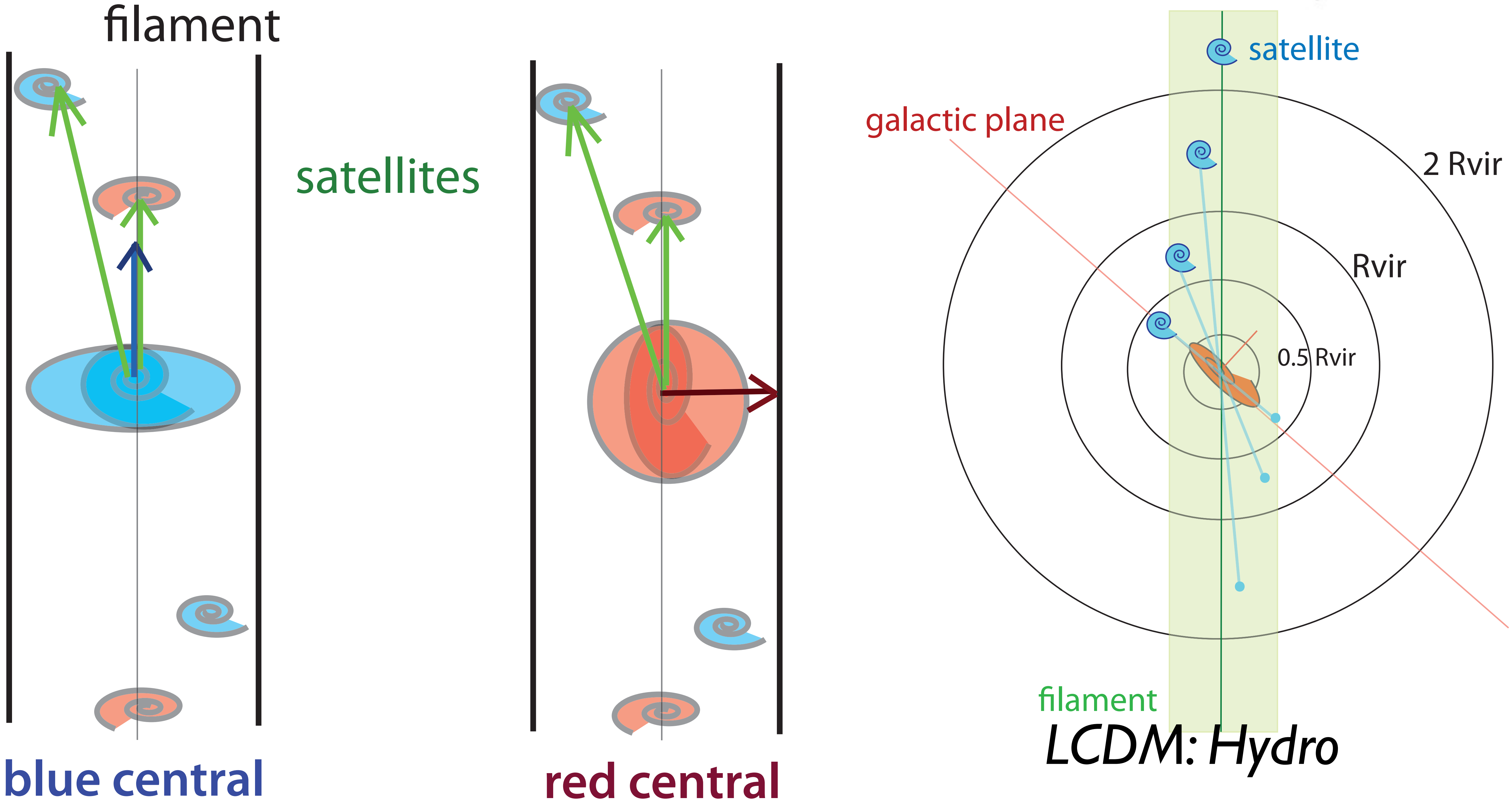
☛ Gas poor mergers trigger stronger increase in effective radius.

☛ **multiple minor merger** explains the loss of compacityt of spheroids at low redshift.

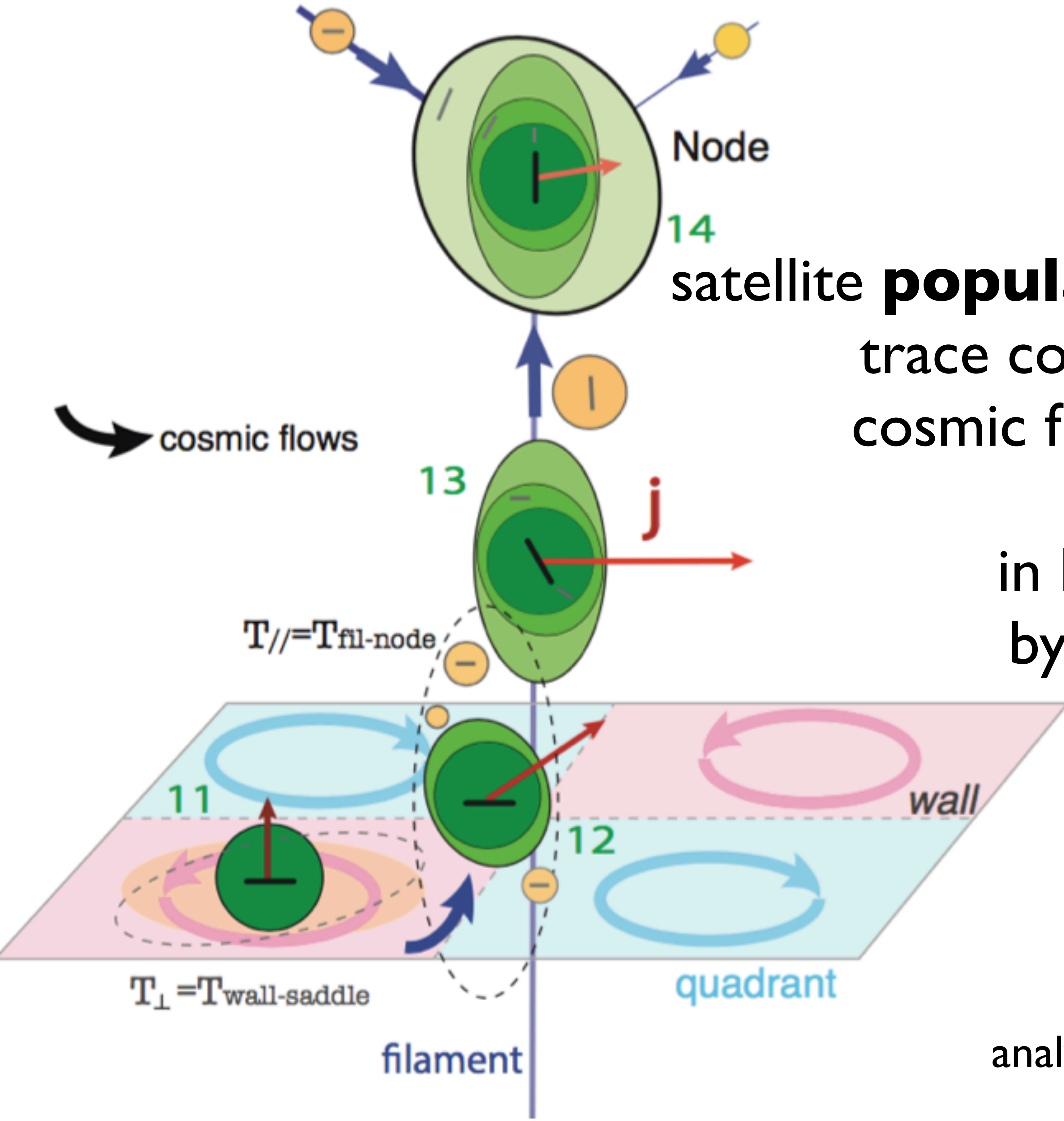
Angular momentum: hidden variable



Helicity rich satellite distribution consistent with filamentary polar accretion towards flipped central



Helicity rich satellite distribution consistent with filamentary polar accretion towards flipped central

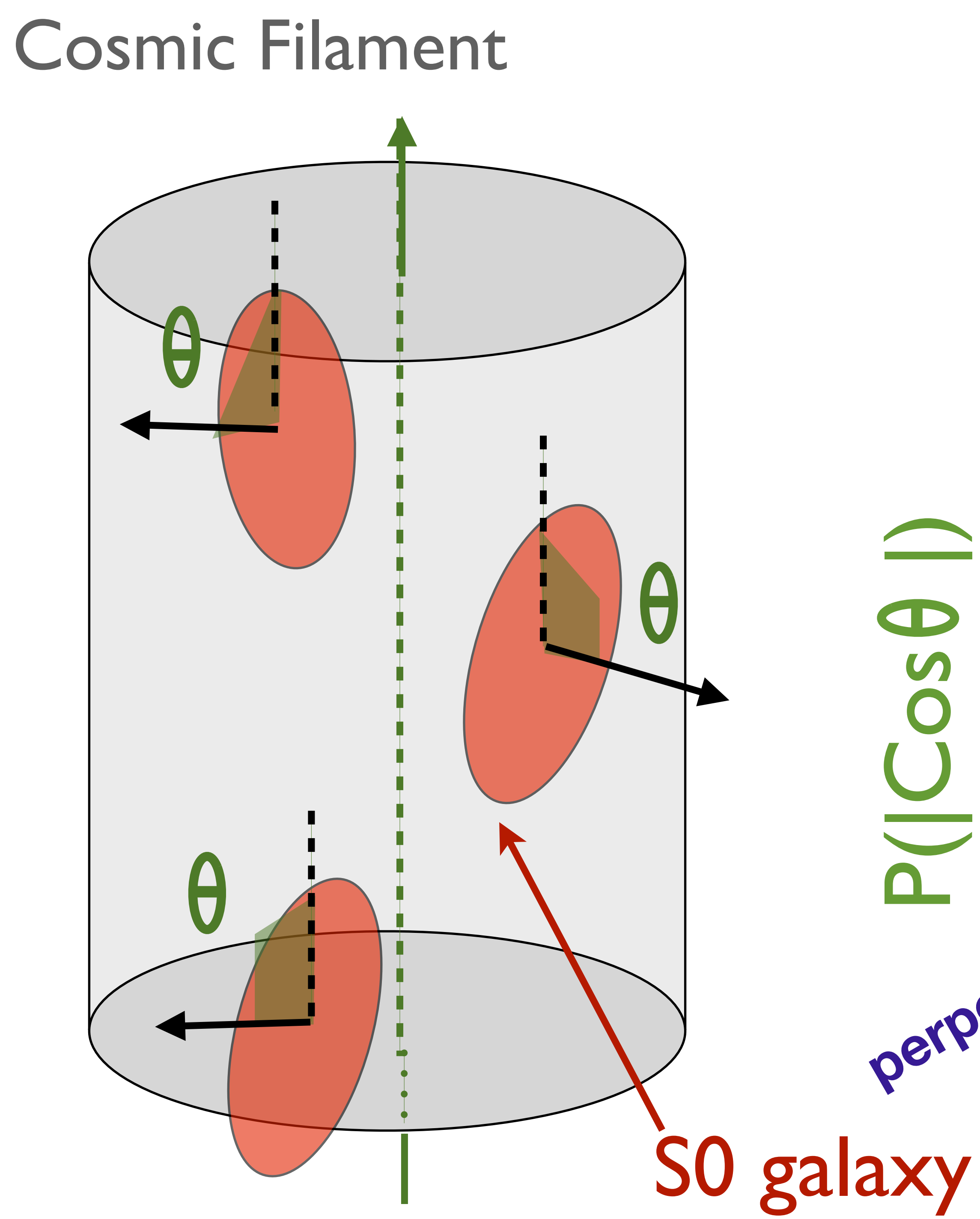


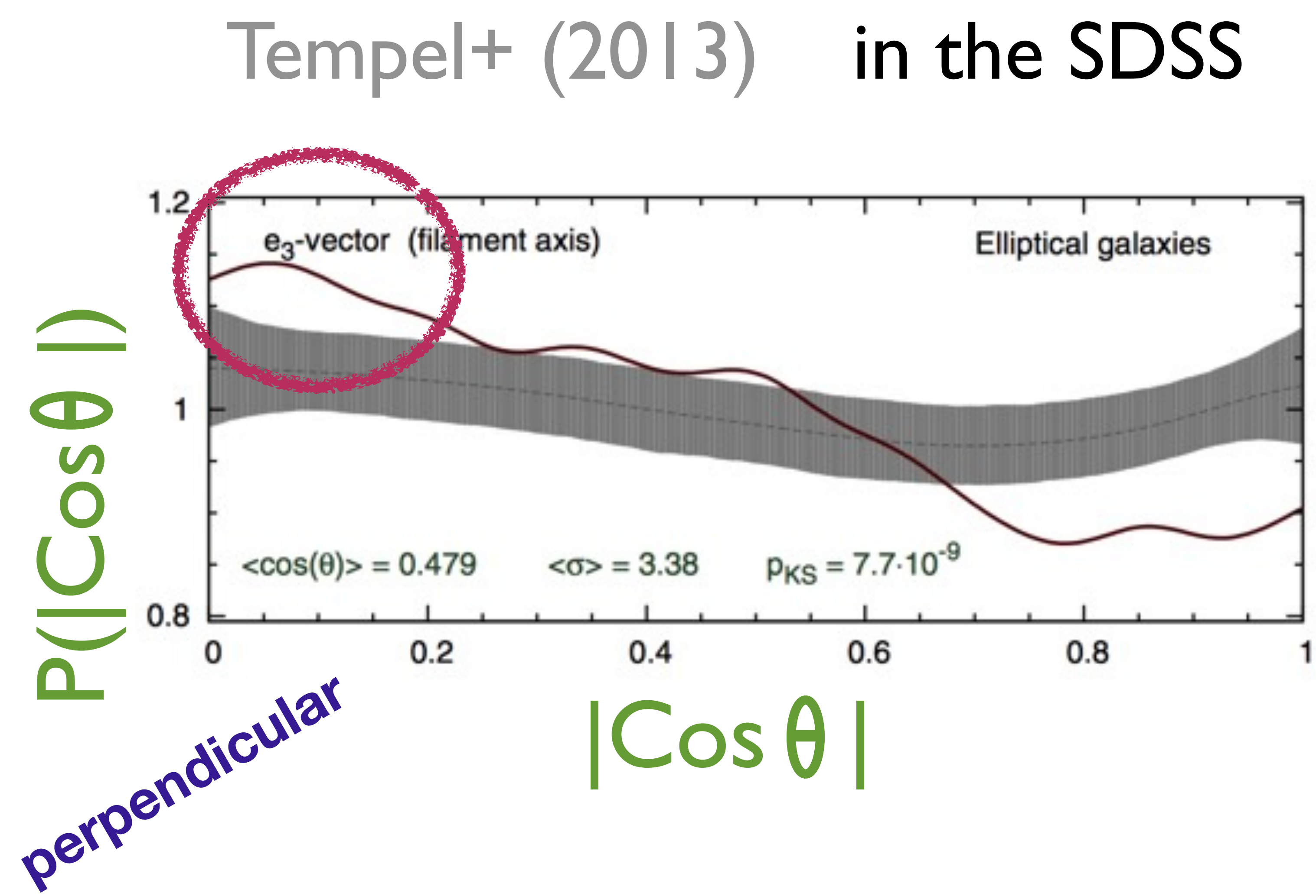
satellite **population** + halo **ellipticity**
trace competition between
cosmic flow and tides from
central,
in kinematic set
by cosmic web

analysis done at redshift zero

what about real galaxies?

Evidences of galaxy spin - filament alignment

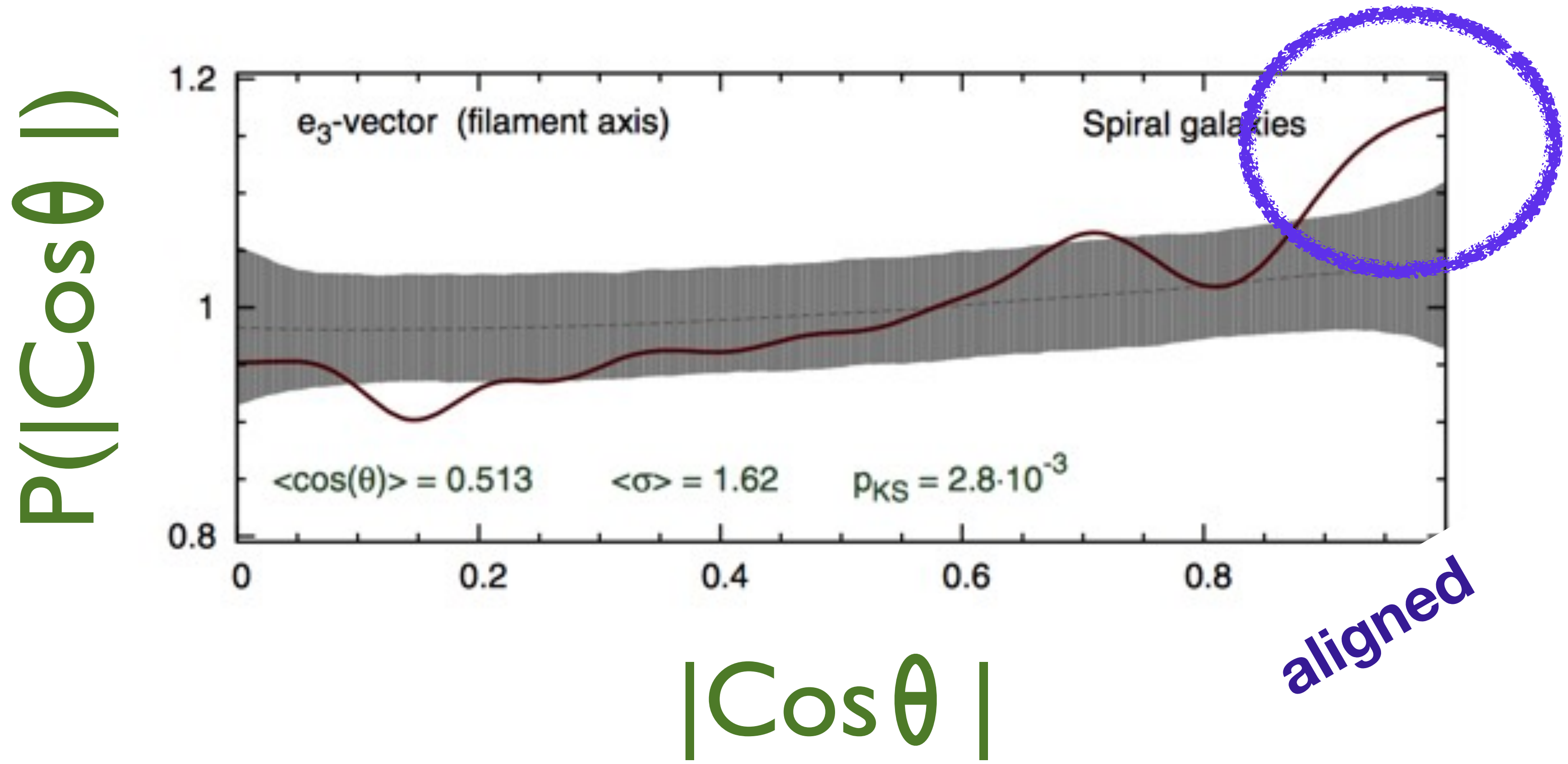


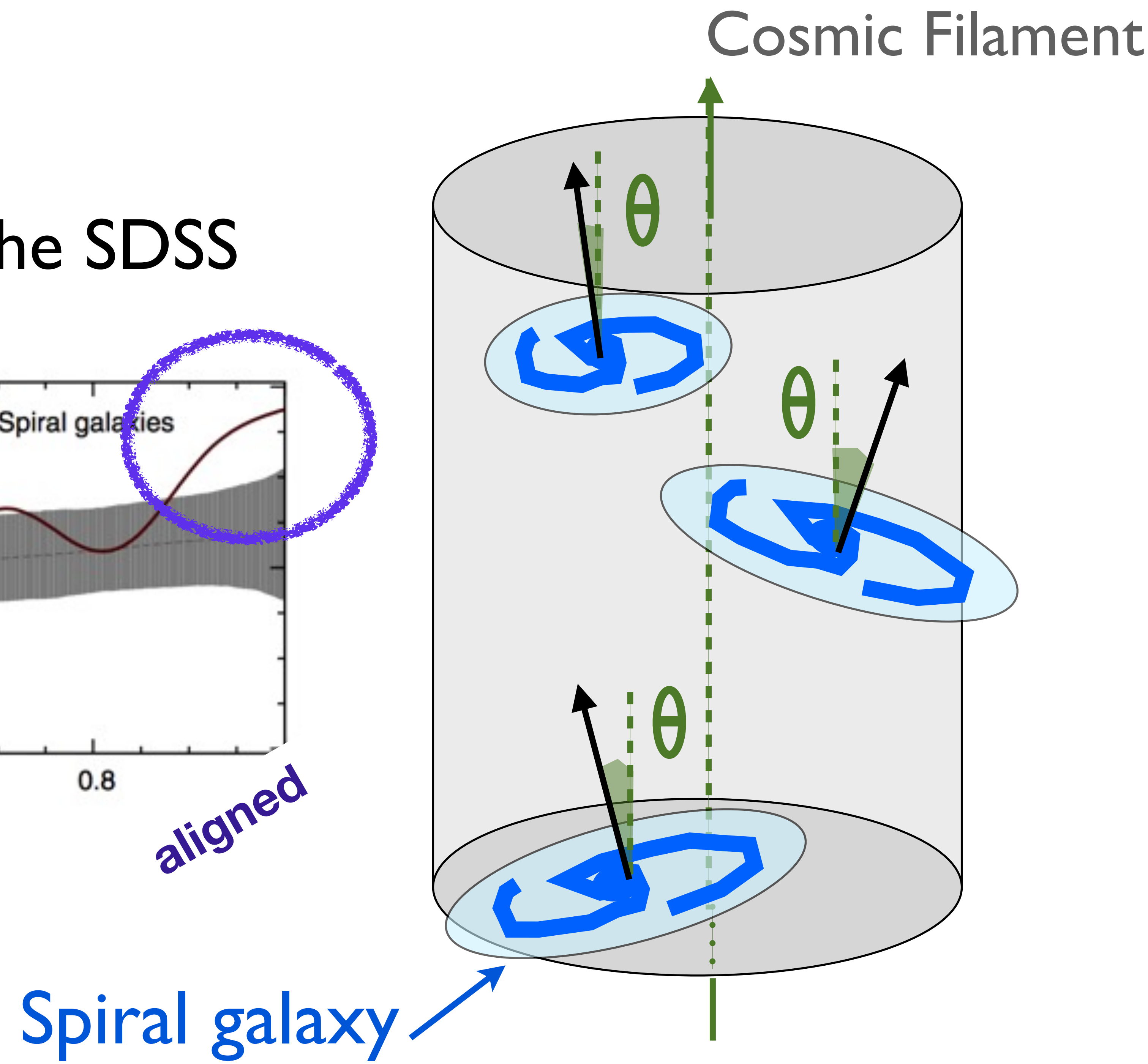


See also:
Aragon-Calvo+ 2007, Hahn+ 2007, Paz+ 2008, Zhang+ 2009, Codis+ 2012, Libeskind+ 2013, Aragon-Calvo 2013, Dubois+ 2014

Evidences of galaxy spin - filament alignment

Tempel+ (2013) in the SDSS





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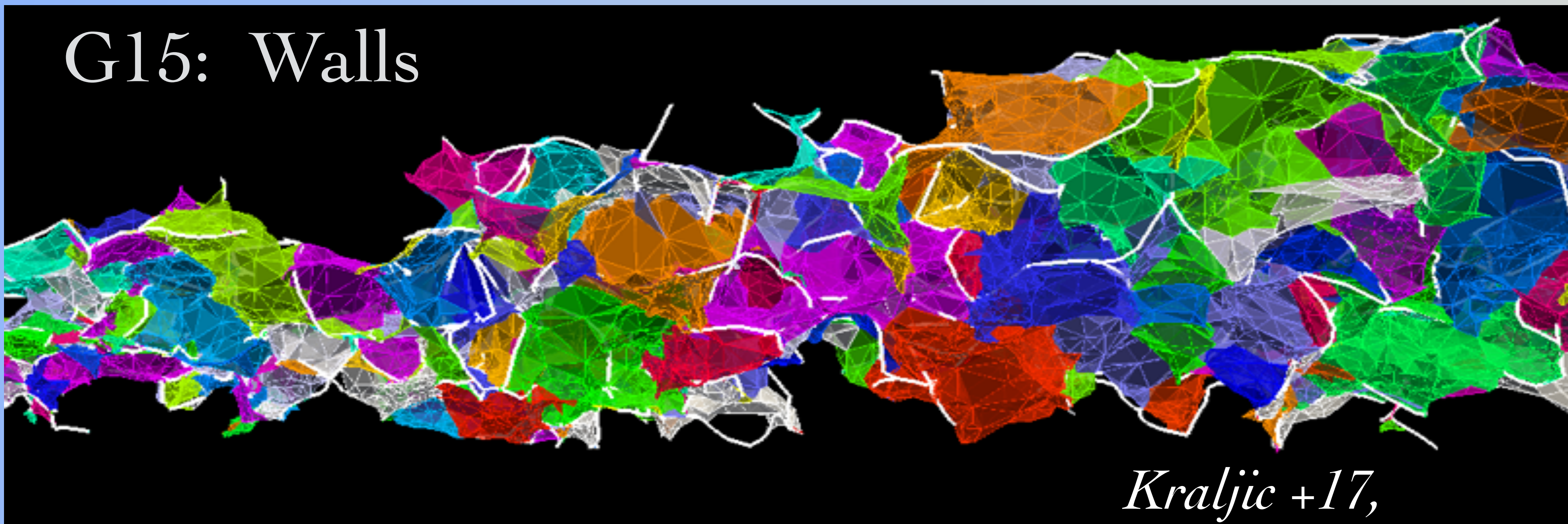
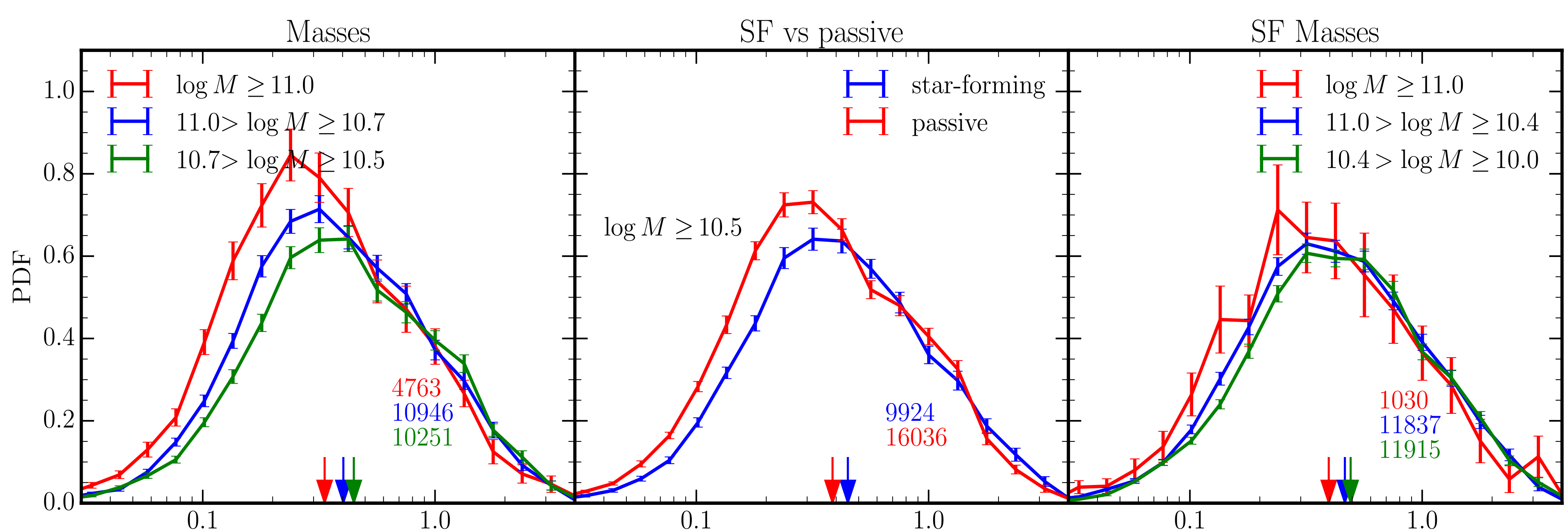
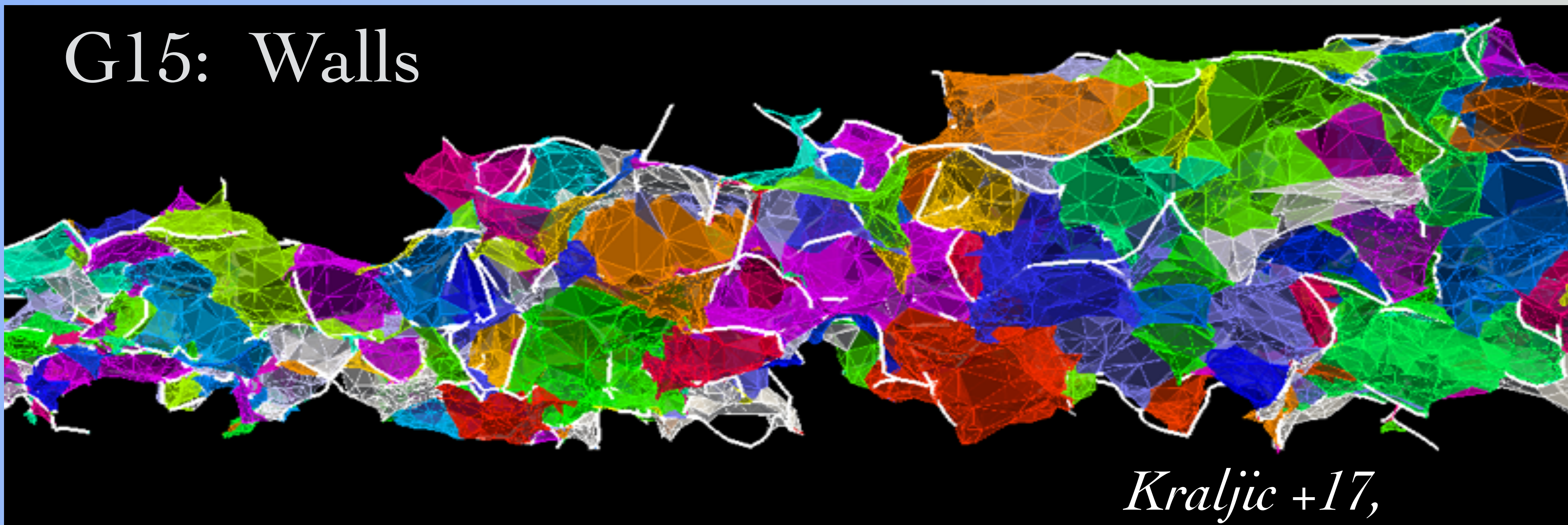
Influence of Cosmic Web : GAMA

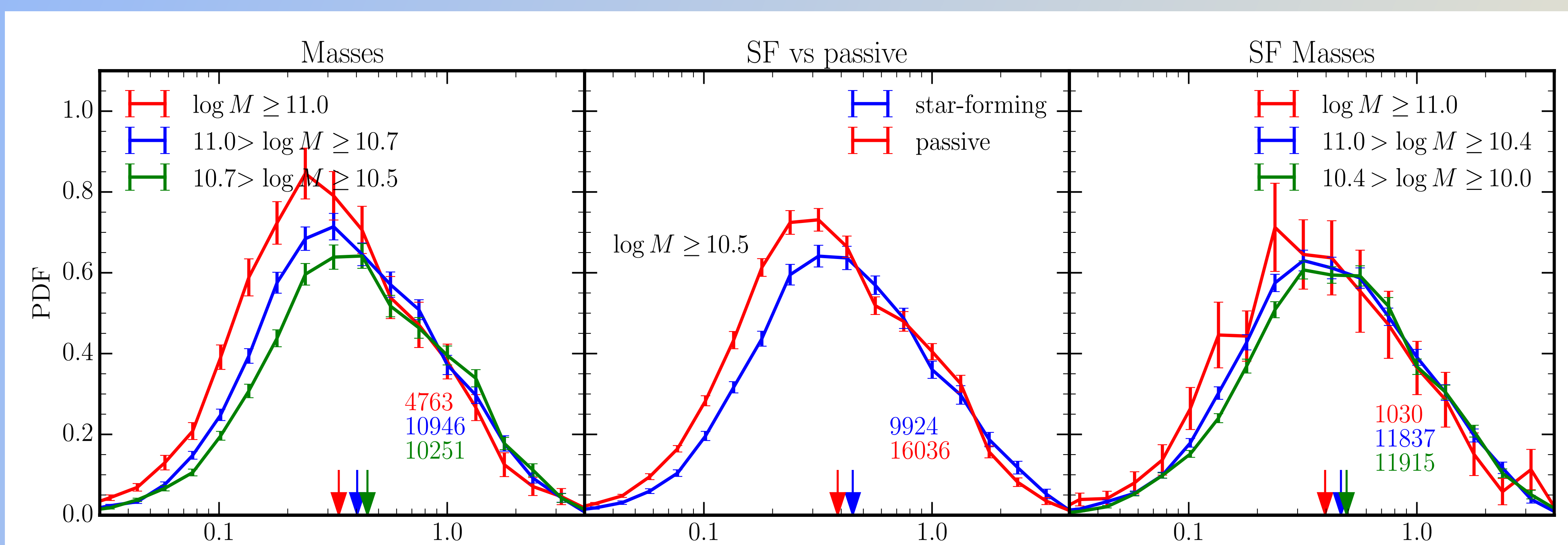




Distance to Walls

Influence of Cosmic Web : GAMA





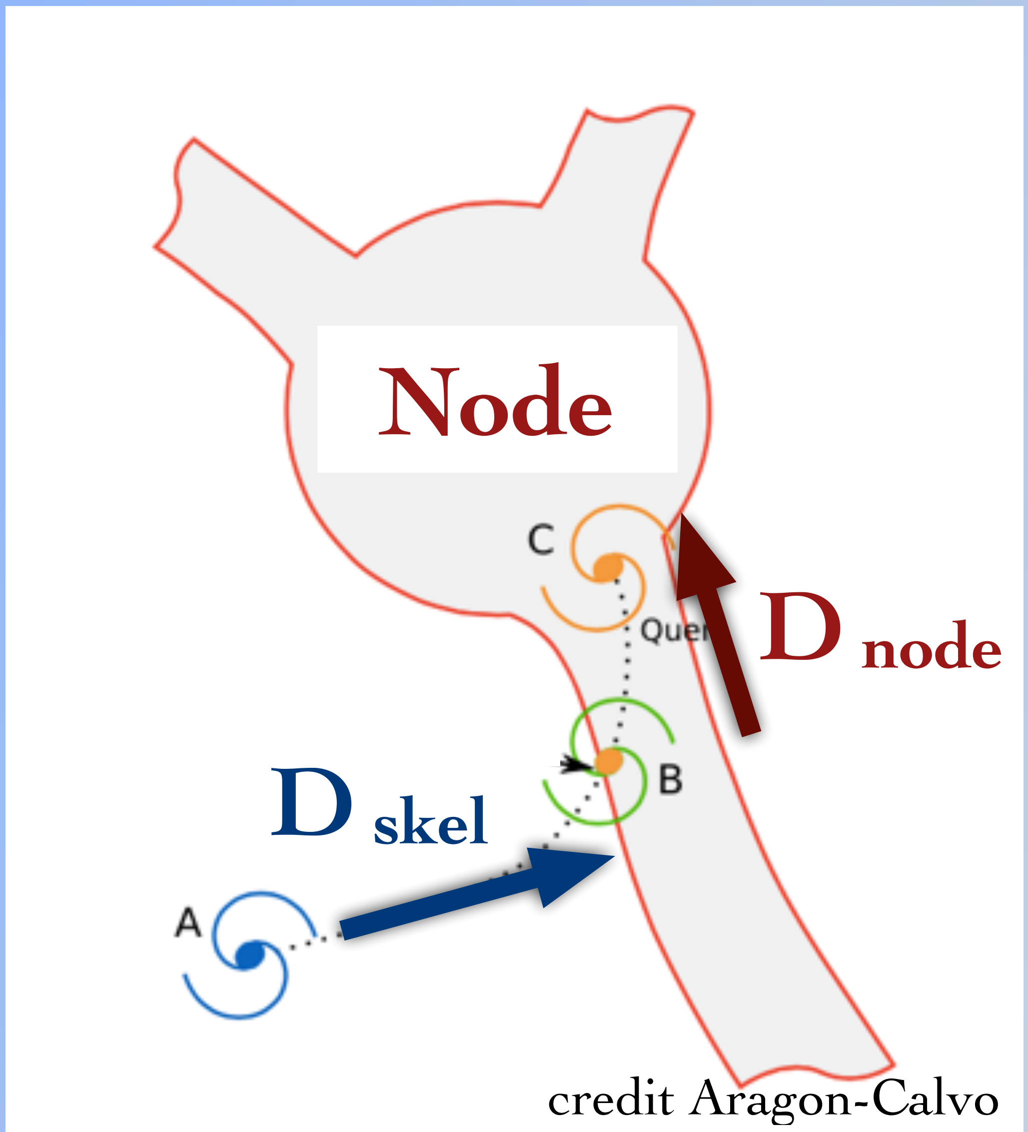
Distance to Walls

keep tuned on SAMI results

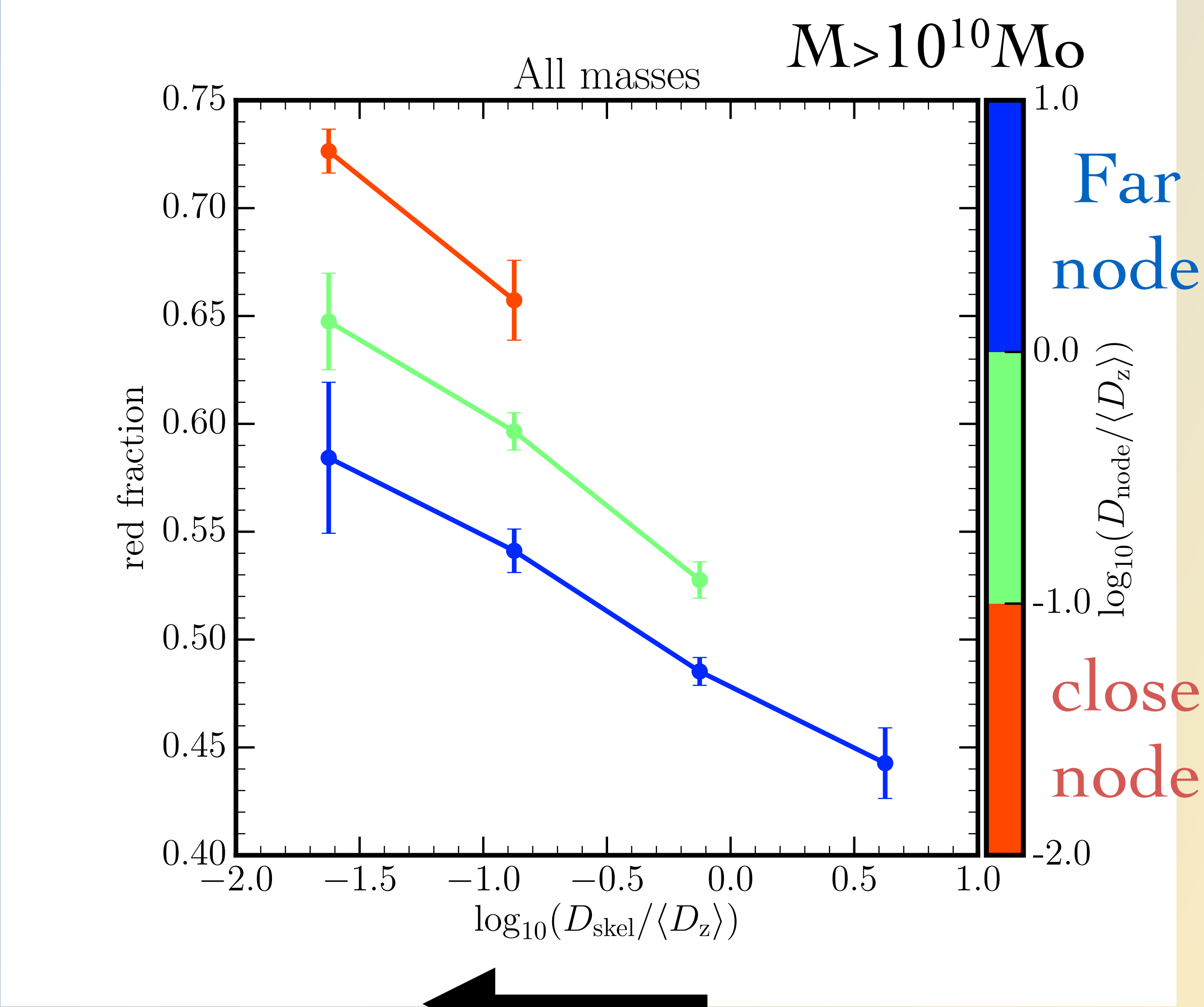
Influence of Cosmic Web : GAMA

Kraljic+17,

GAMA



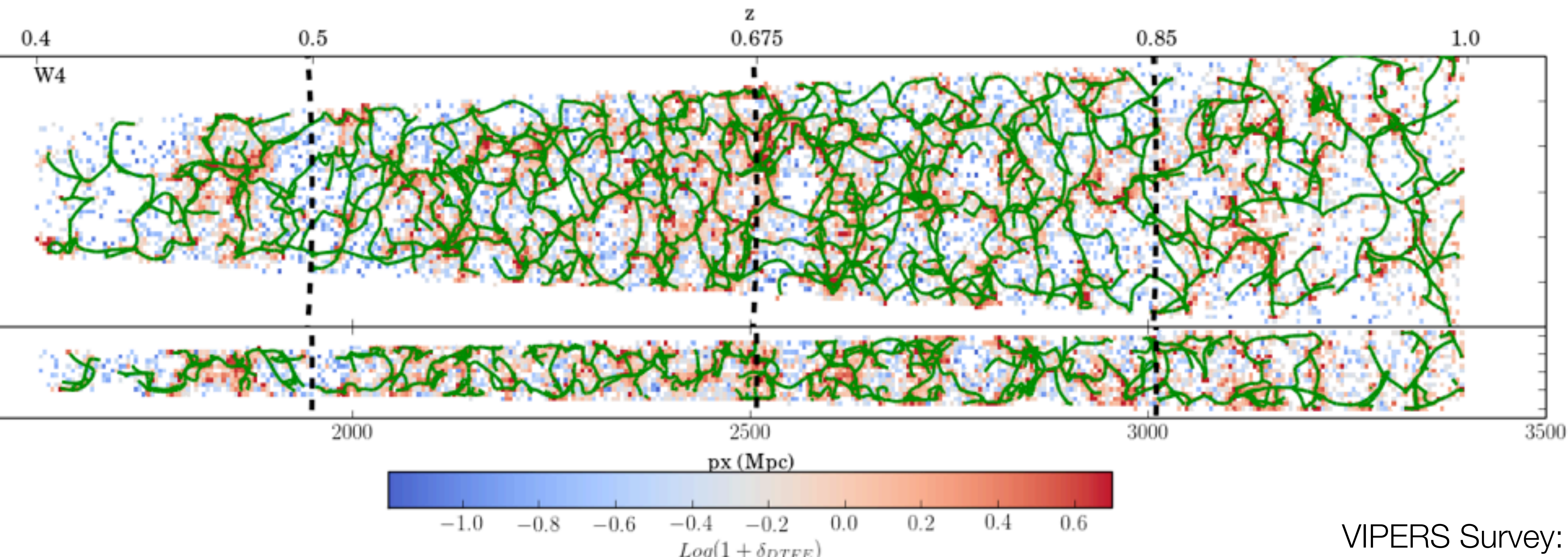
Red fraction [f=Q/(Q+SF)]



closer to filaments

Reconstructing the cosmic web: galaxy distribution

keleton extraction in VIPERS W1, 0.4<z<1, i_{AB}<22.5, scale of ~10cMpc (**Malavasi+16**)

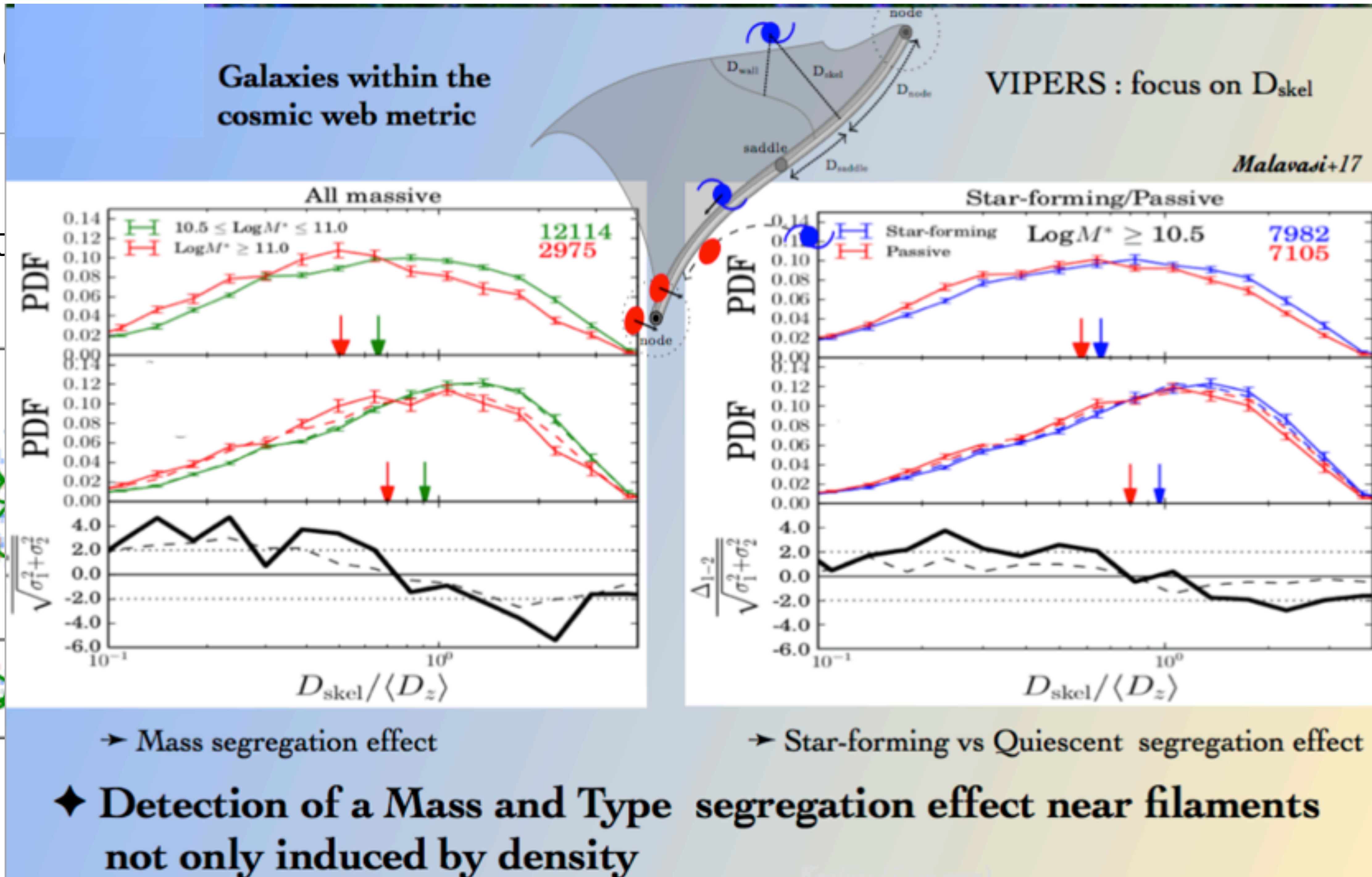


VIPERS Survey:
24 deg^2 on ESO VLT, 8m (see **Guzzo+14**)

influence of CW: vipers

Re ... ution

kelet ... vasi+16)



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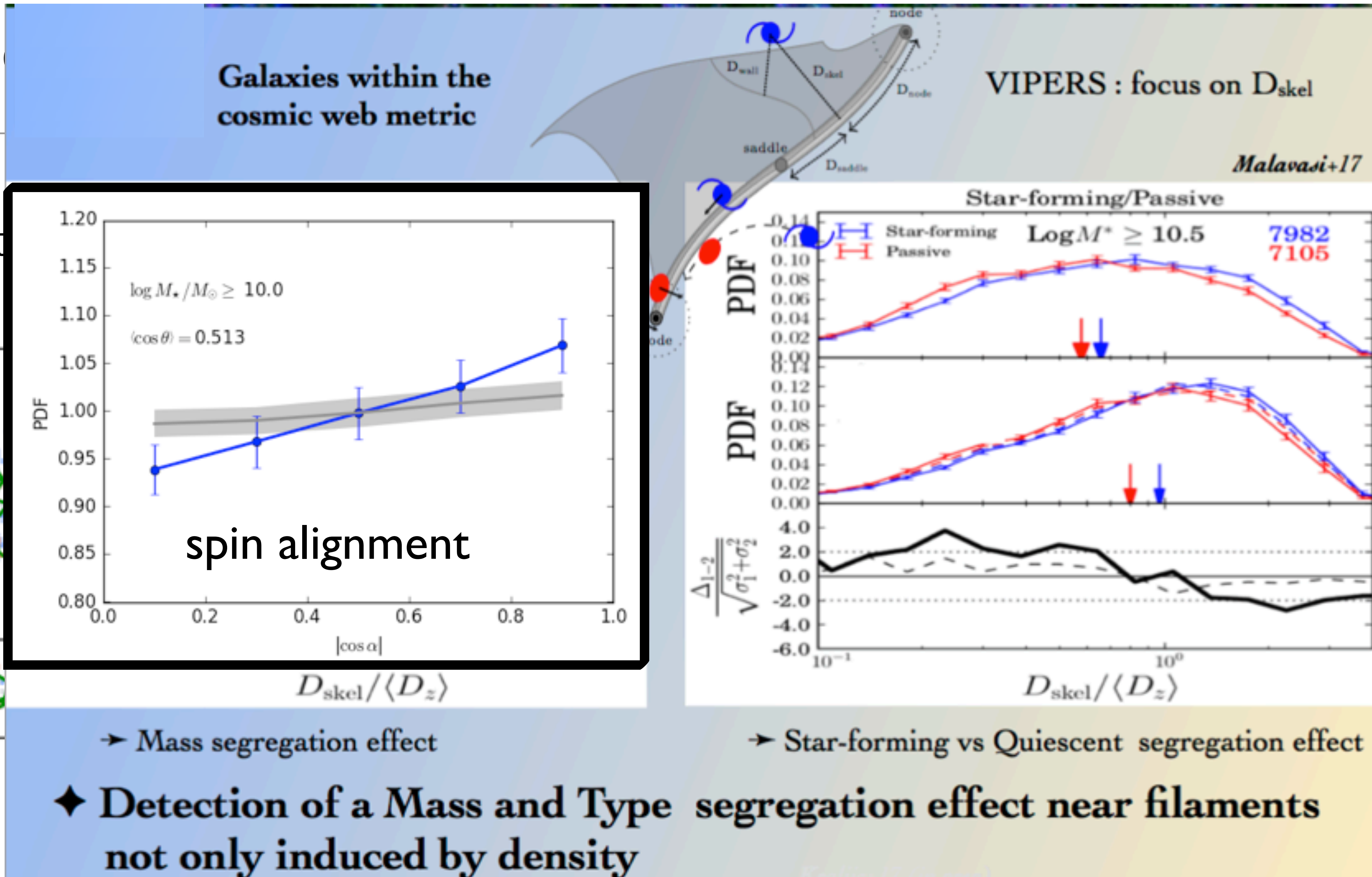
24 deg^2 on ESO VLT, 8m (see **Guzzo+14**)

influence of CW: vipers

Re ... ution

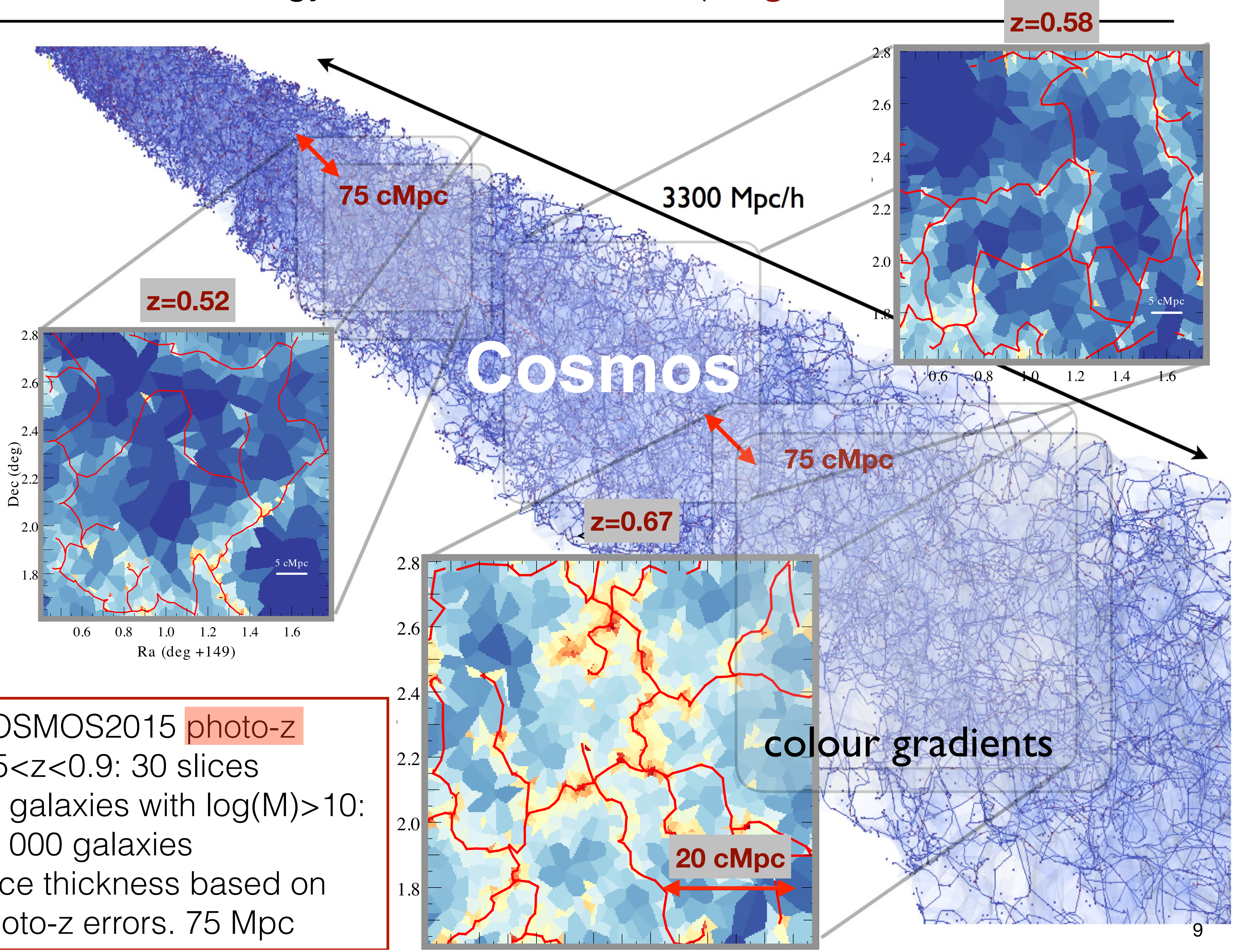
kelet ... vasi+16)



IPERS Survey:
24 deg^2 on ESO VLT, 8m (see **Guzzo+14**)

Influence of CW: cosmos

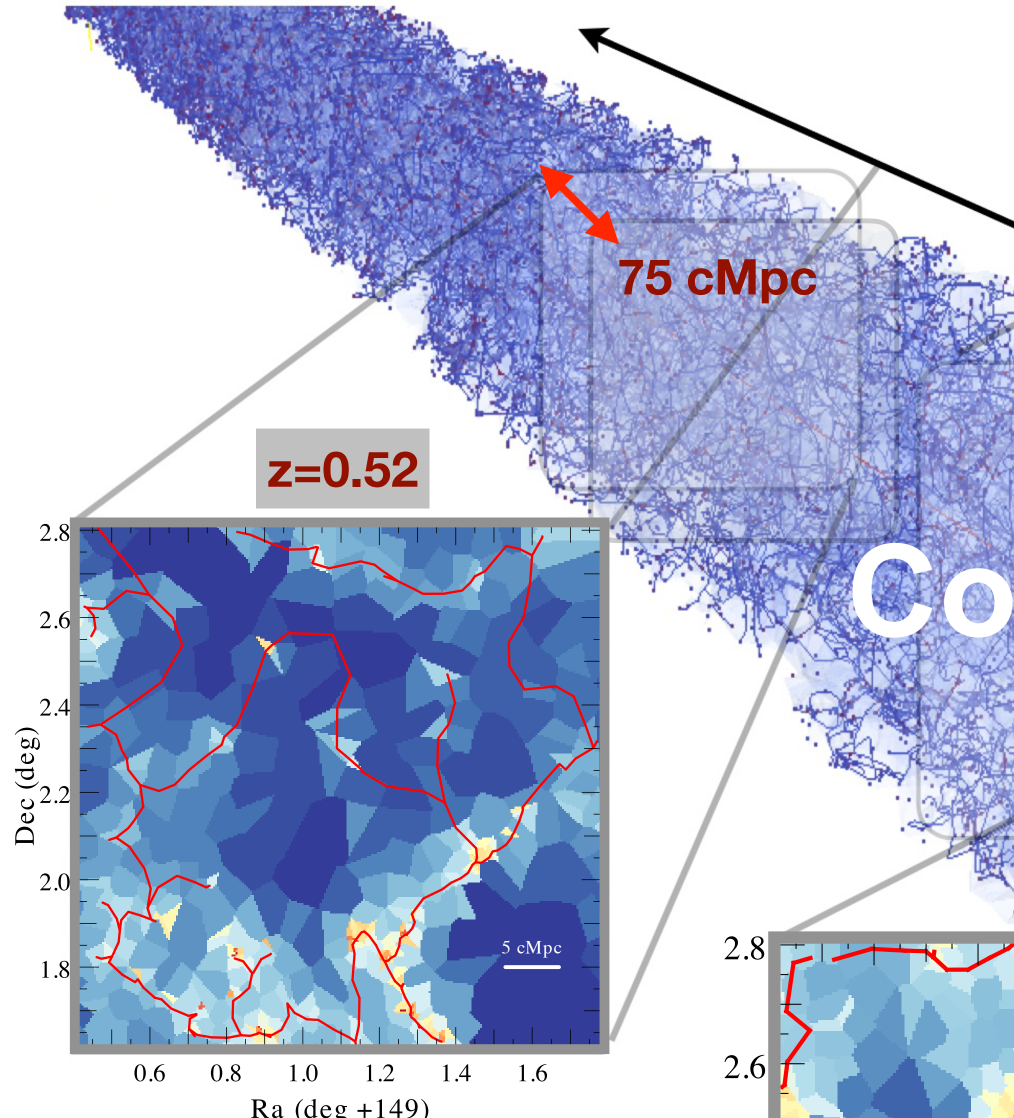
Our strategy with COSMOS2015 (**Laigle et al 2016**)

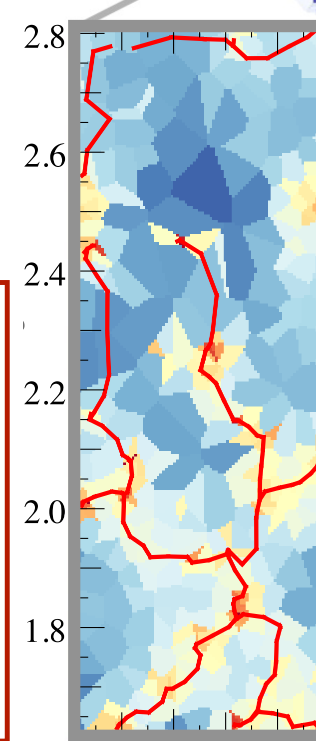


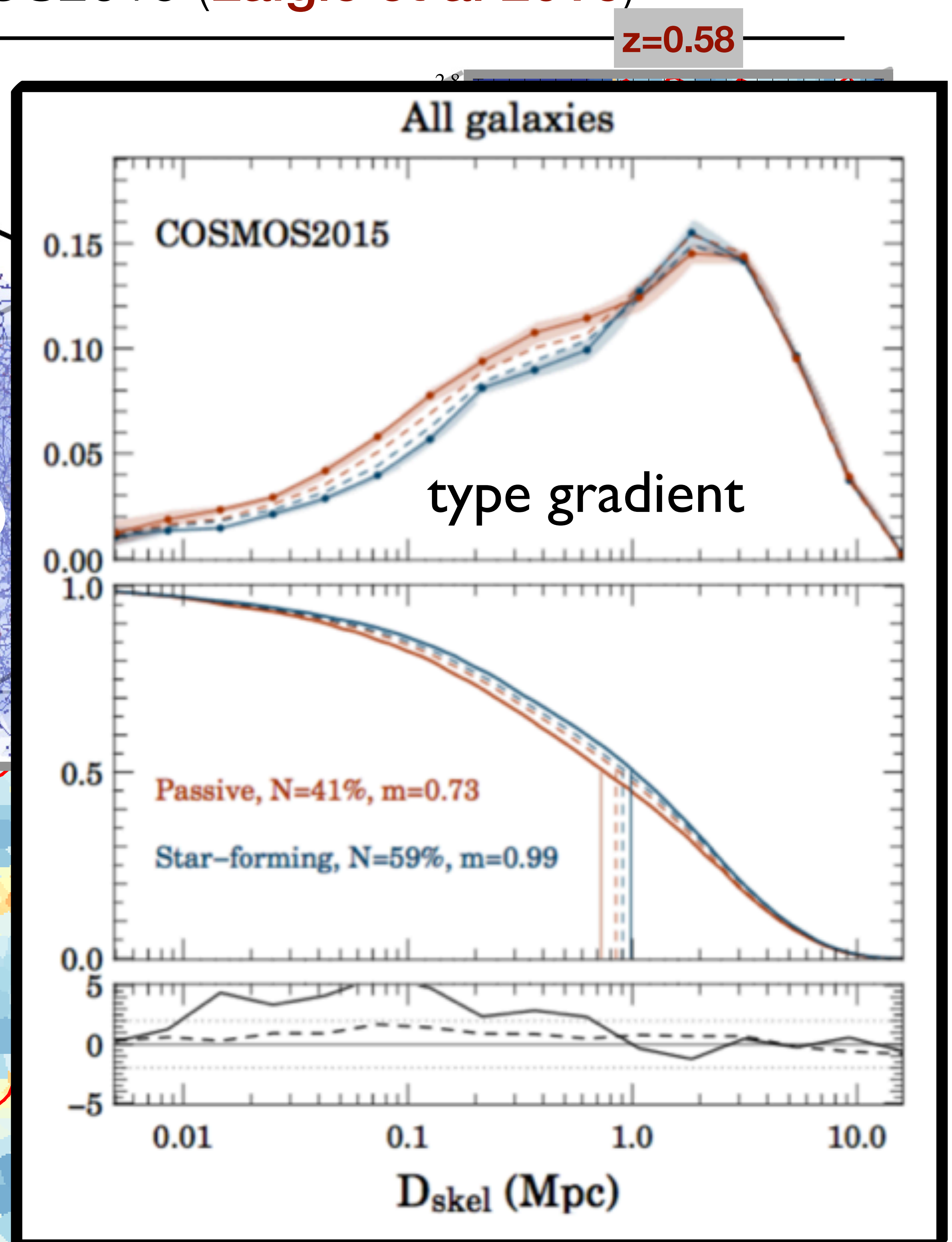
- COSMOS2015 photo-z
- 0.5<z<0.9: 30 slices
- All galaxies with log(M)>10: 30 000 galaxies
- Slice thickness based on photo-z errors. 75 Mpc

Influence of CW: cosmos

Our strategy with COSMOS2015 (**Laigle et al 2016**)







- COSMOS2015 photo-z
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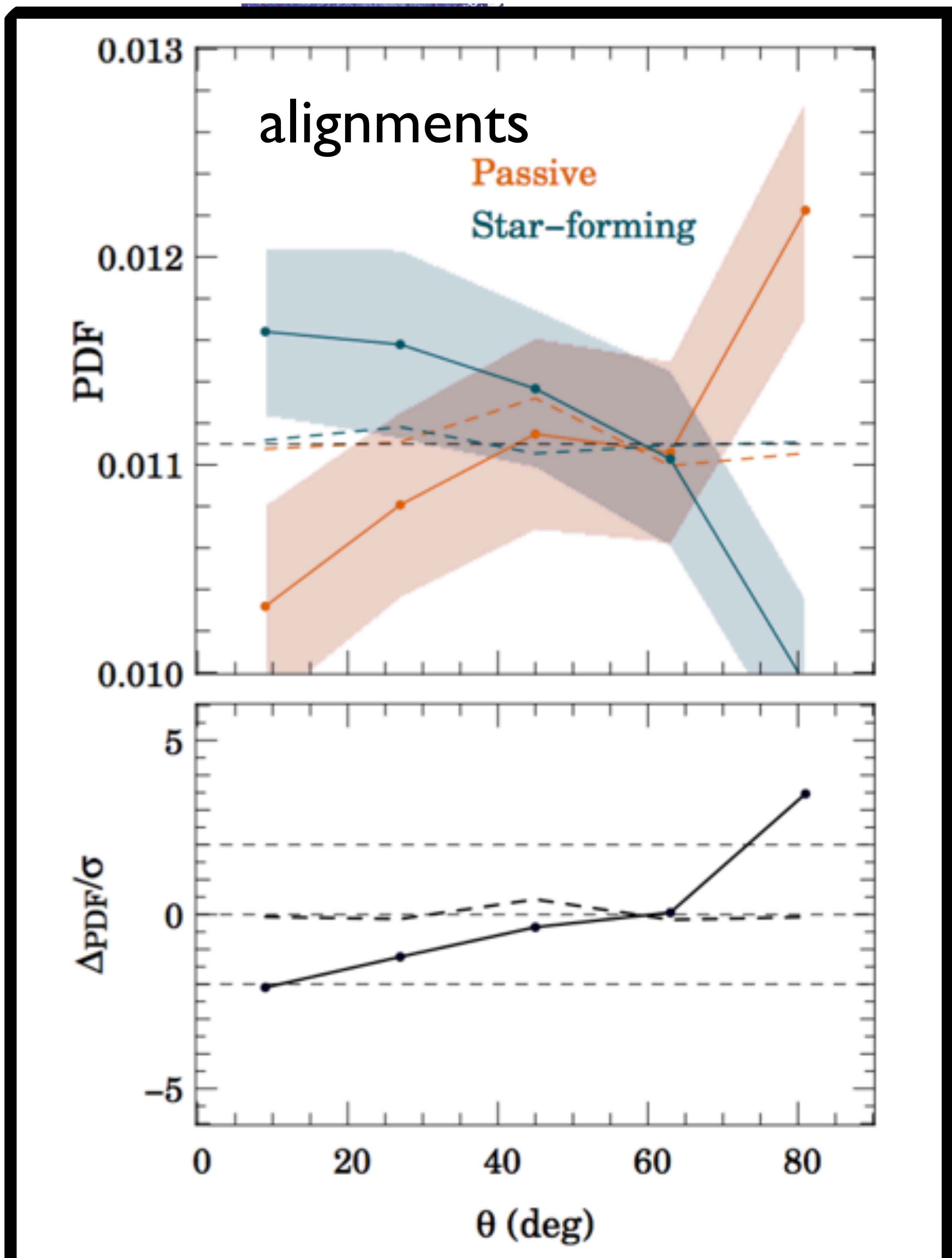
Influence of CW: cosmos

Our strategy with COSMOS2015 (**Laigle et al 2016**)

z=0.58



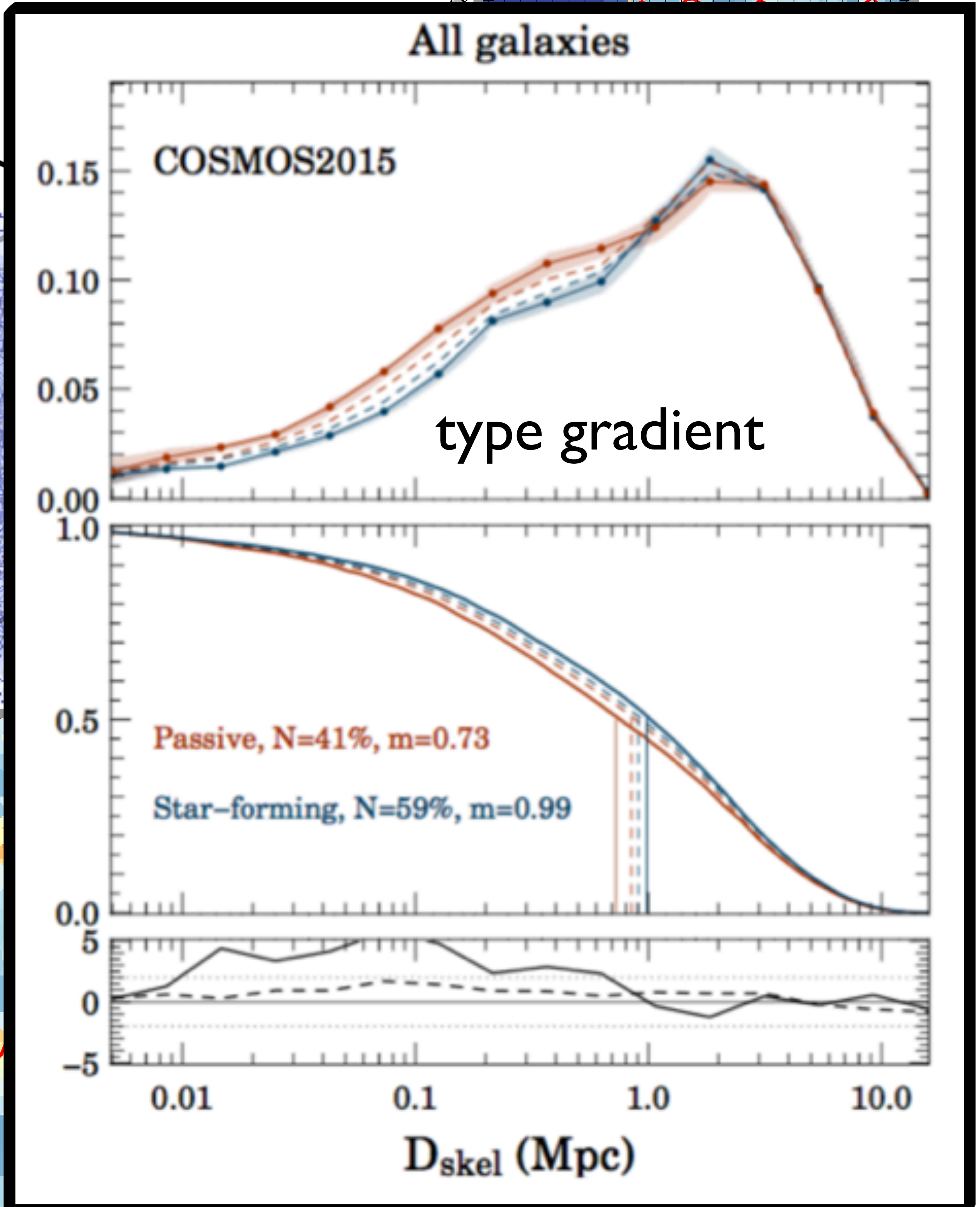
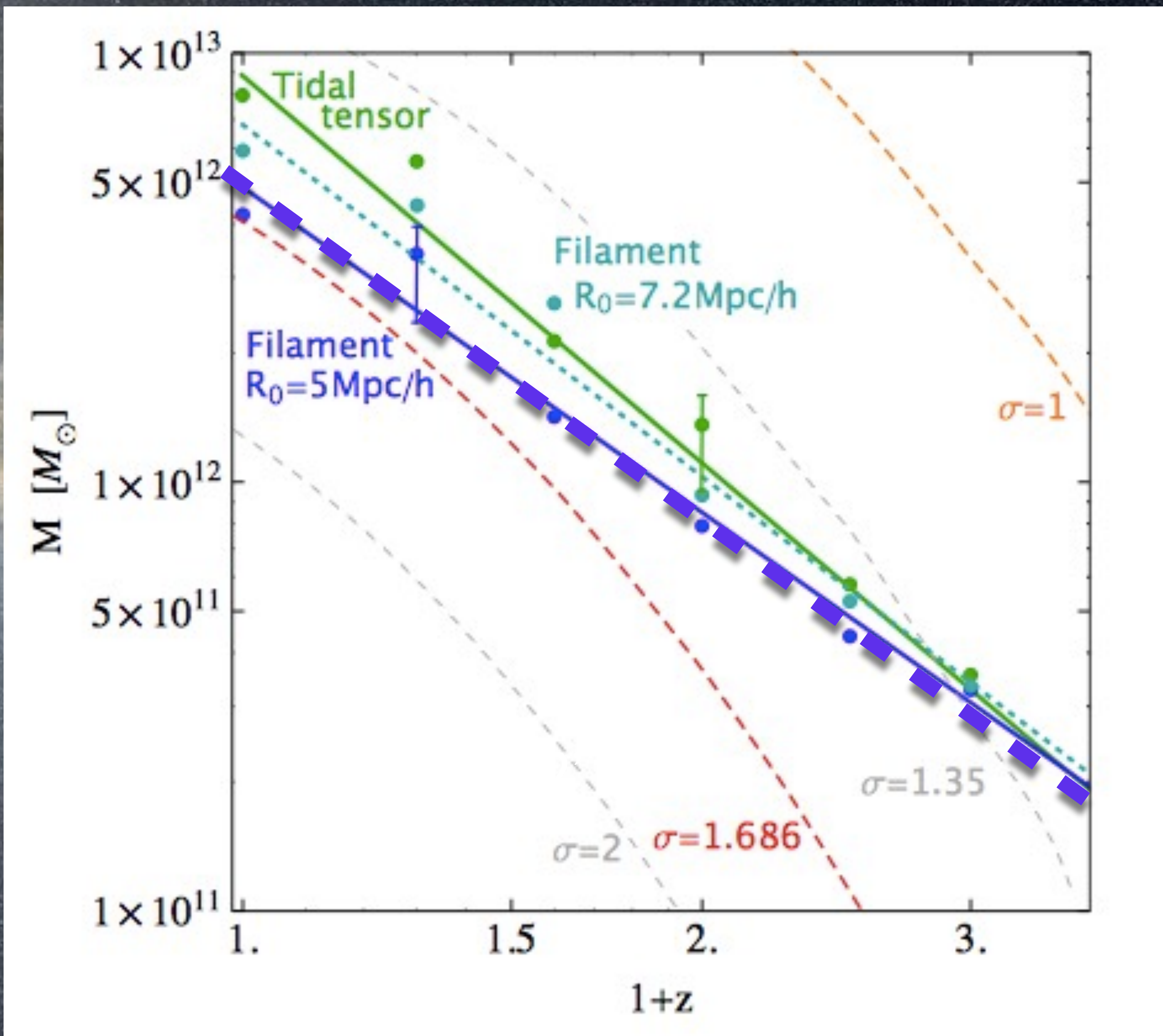
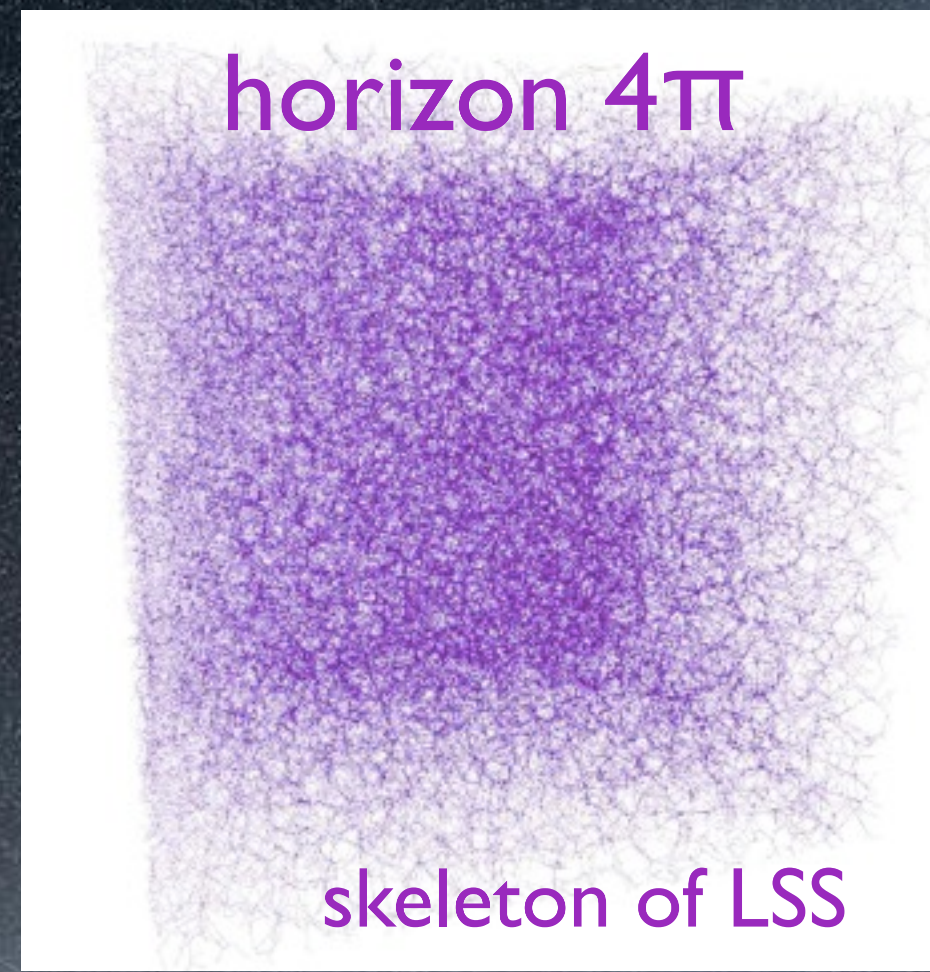


photo-z errors: 75 Mpc

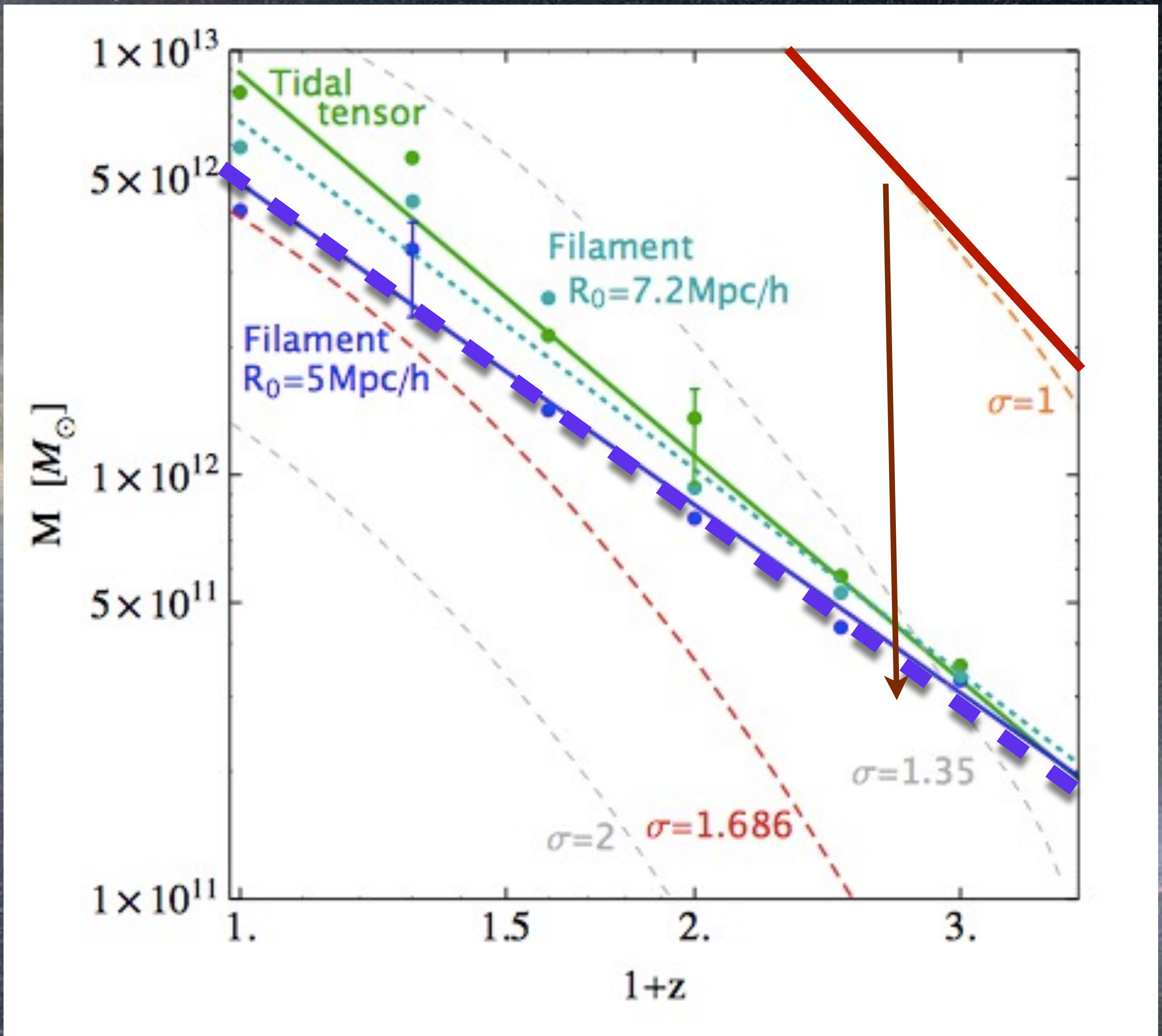
Explain transition mass?

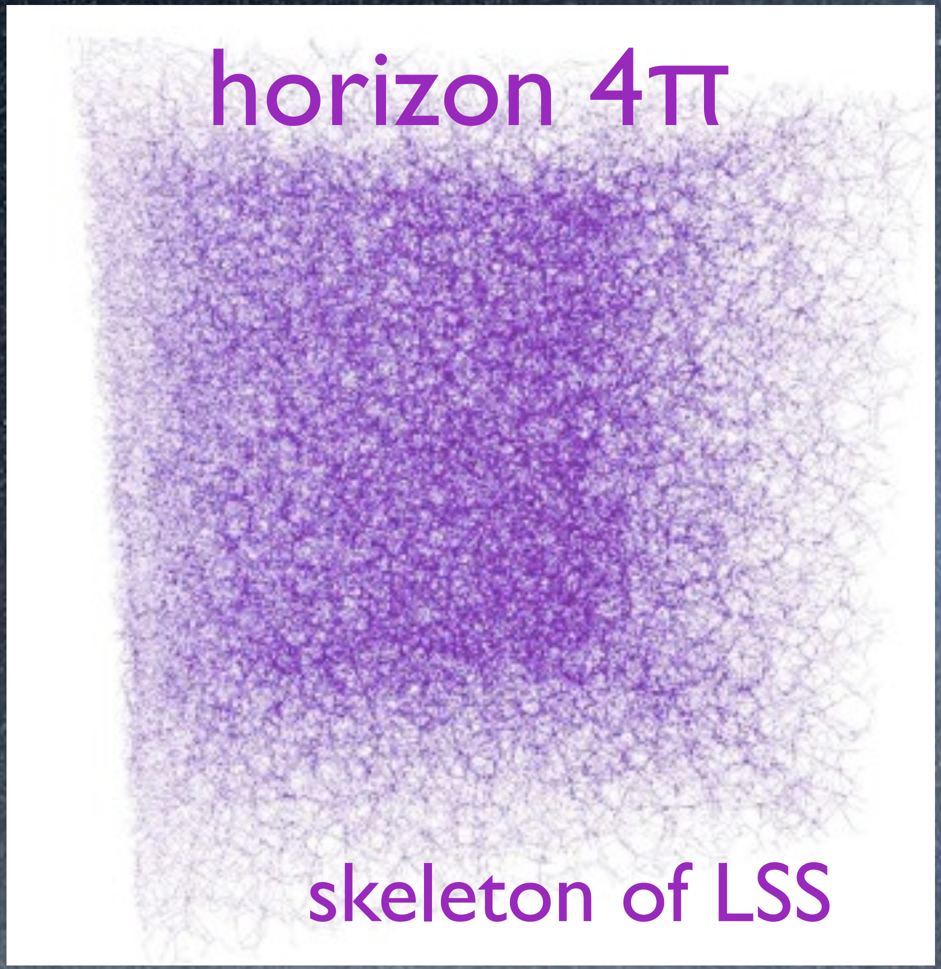




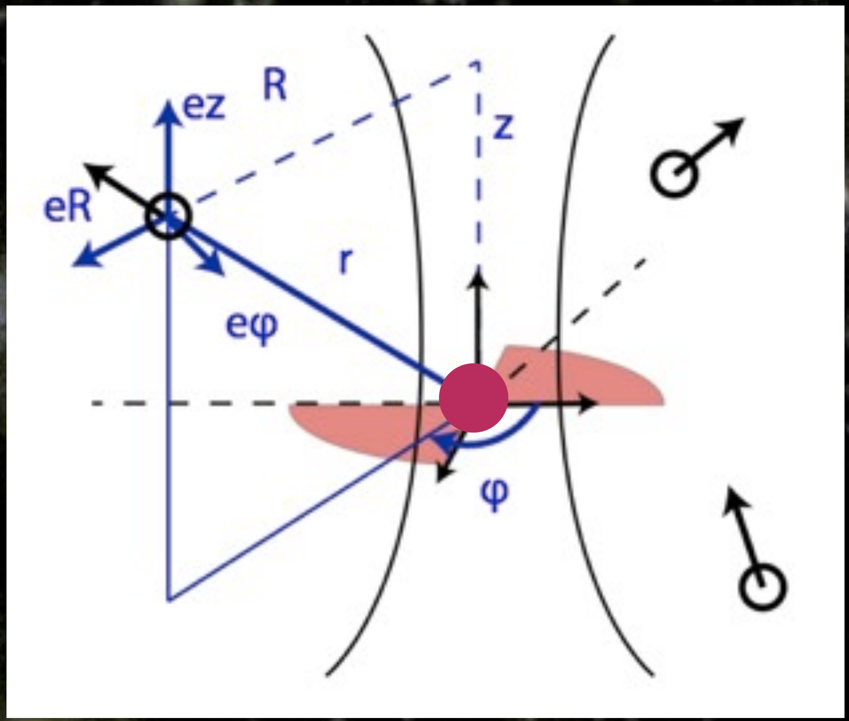
Explain transition mass?

Transition mass versus redshift: **what's wrong???**





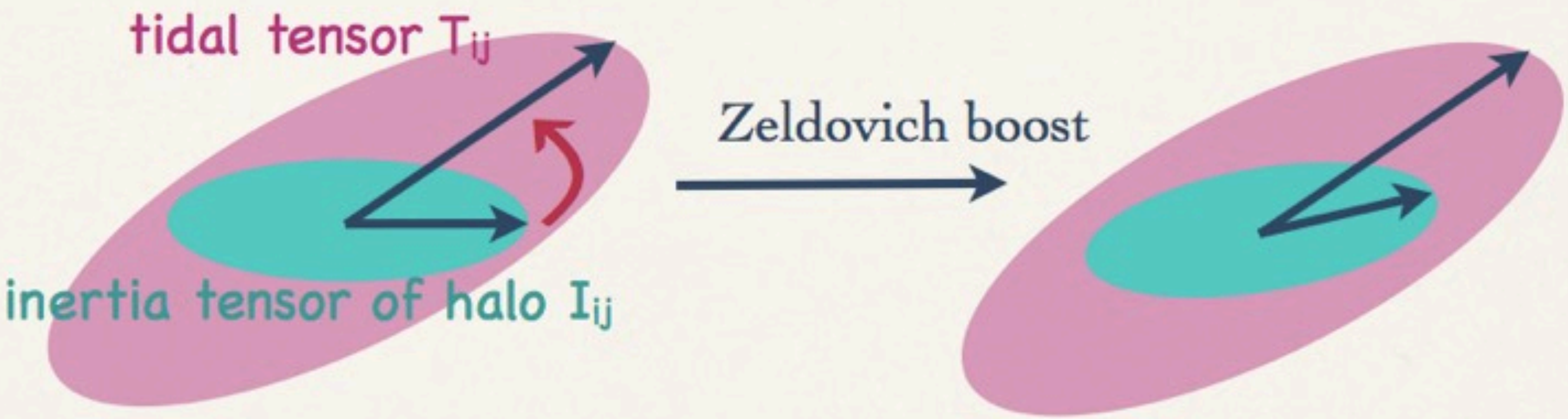
Tidal torque theory with a peak background split near a **saddle**



Can we understand where spin and vorticity alignments come from?

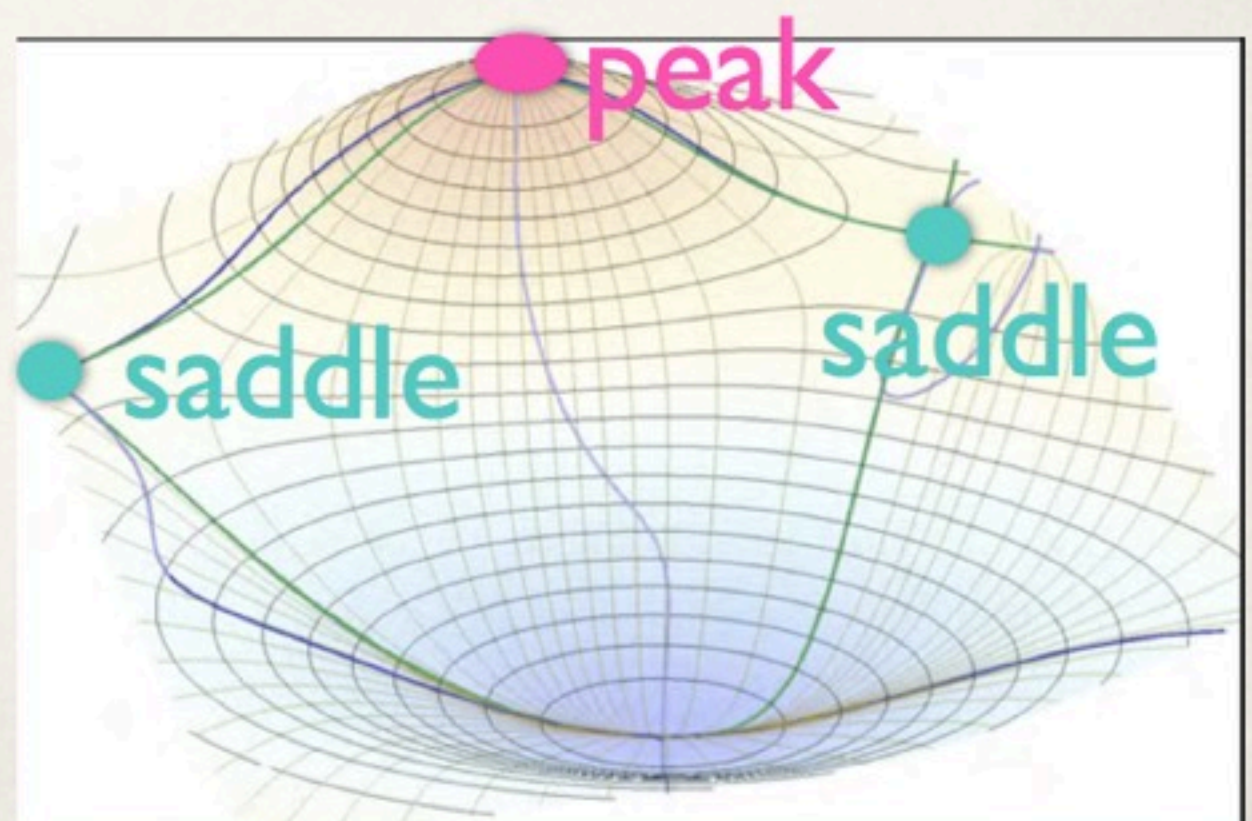
-usual tidal torque theory

$$L_k = \varepsilon_{ijk} I_{li} T_{lj}$$

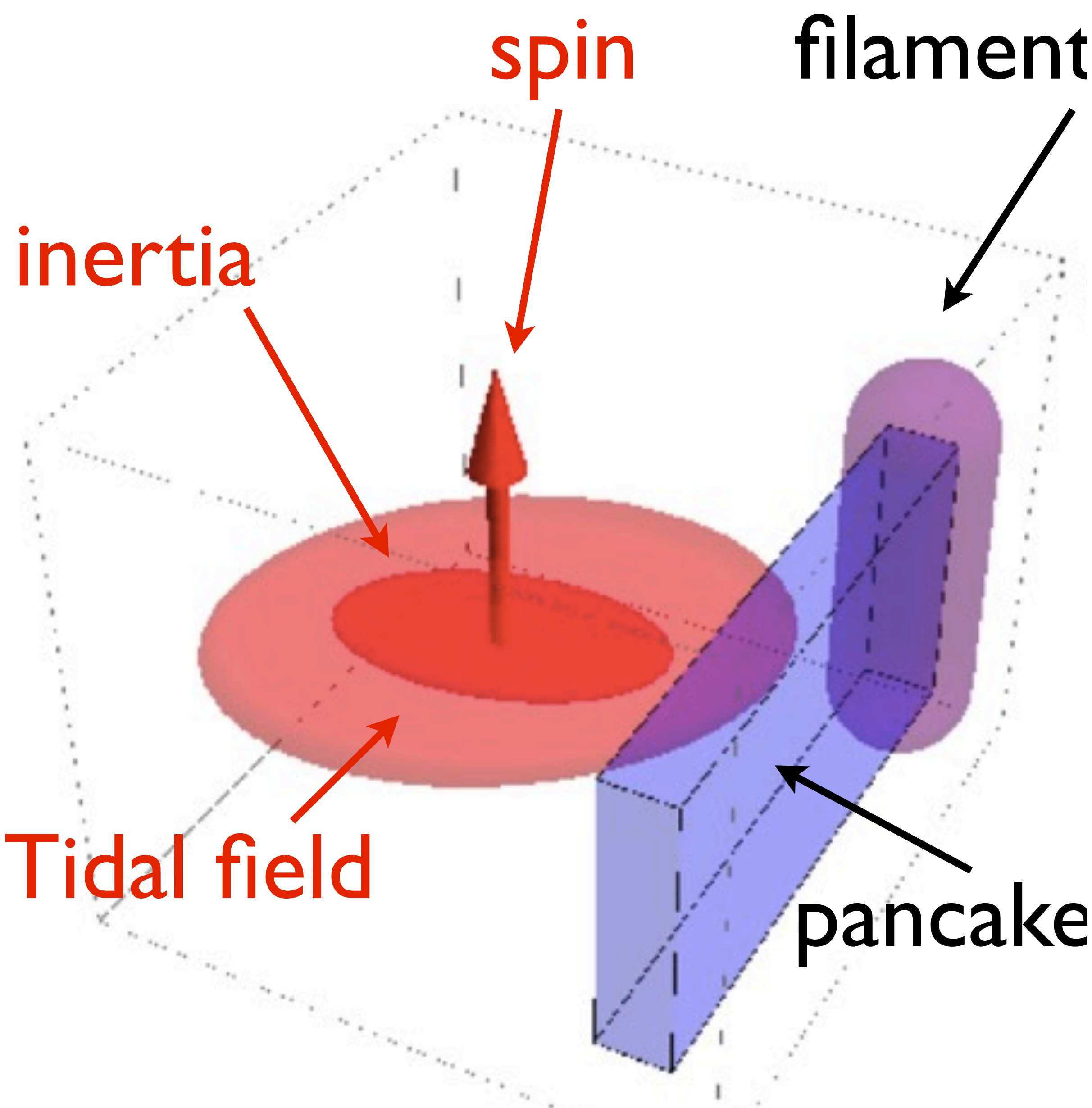


-anisotropy of the cosmic web:

surrounding of a saddle point with typical geometry

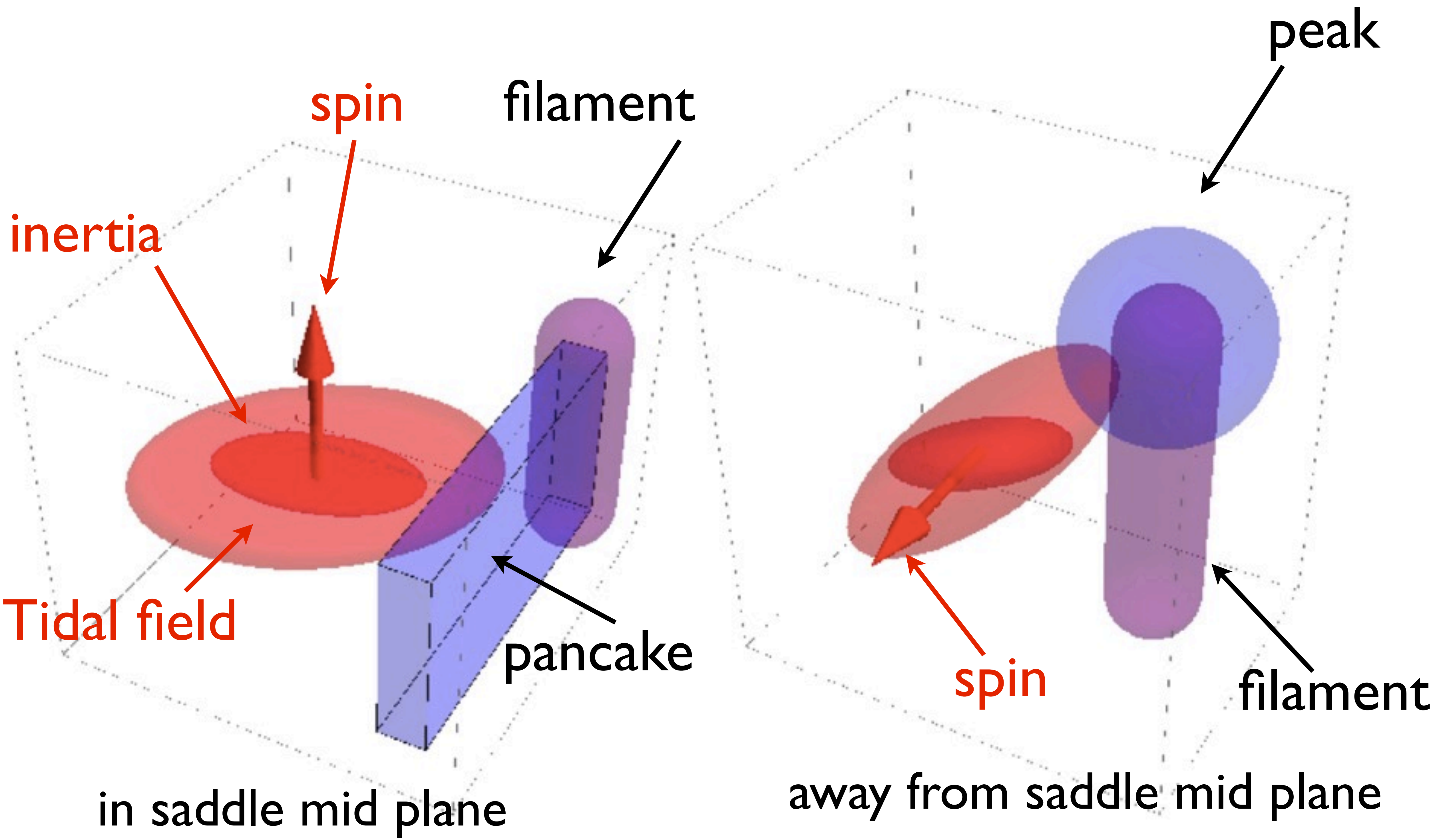


Tidal/Inertia mis-alignment

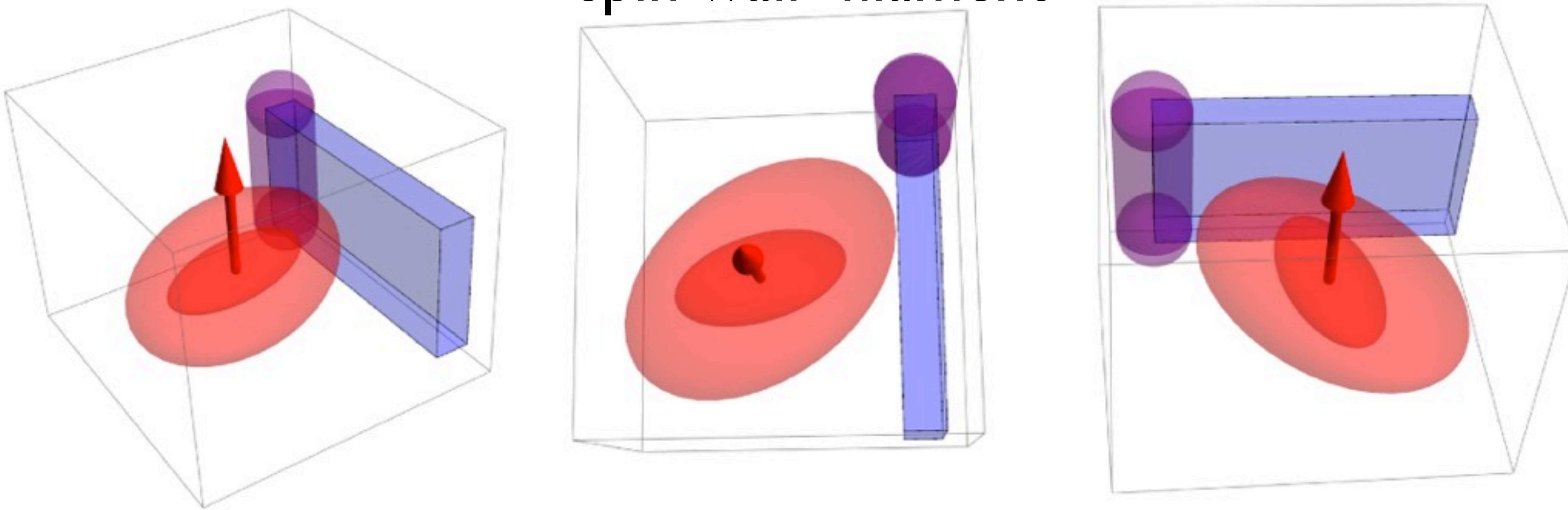


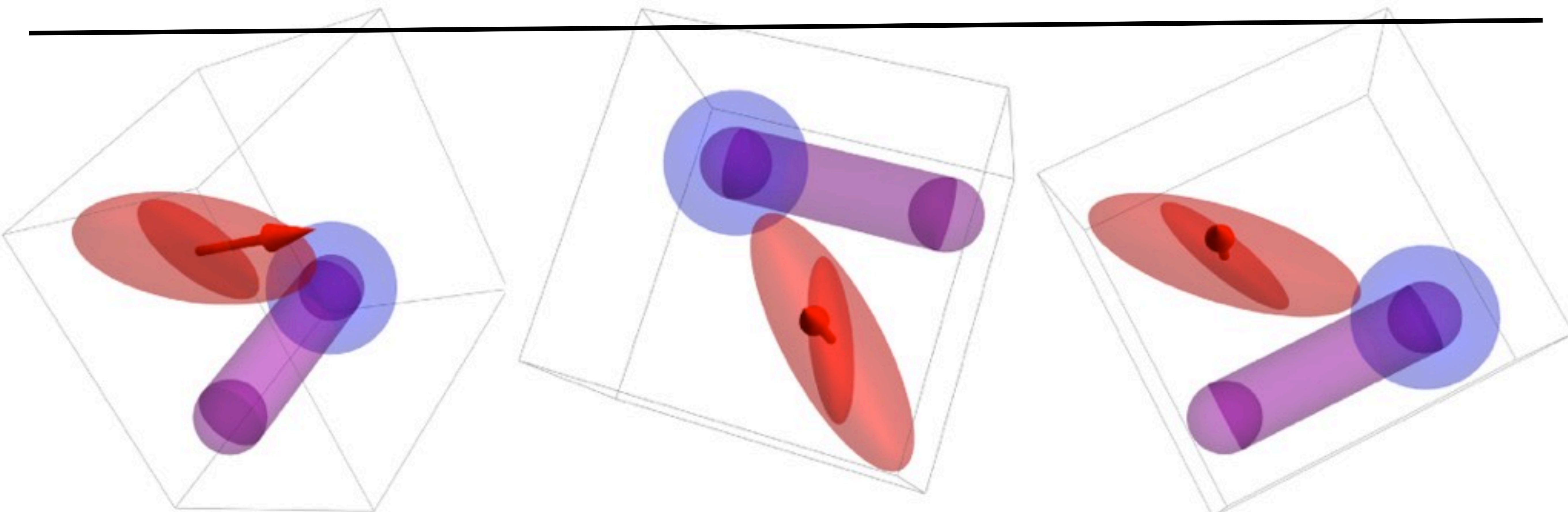
in saddle mid plane

Tidal/Inertia mis-alignment



spin wall -filament





spin filament-cluster

animation?

Spin structure near Saddle

$$L_k = \varepsilon_{ijk}\, I_{li}\, T_{lj}$$

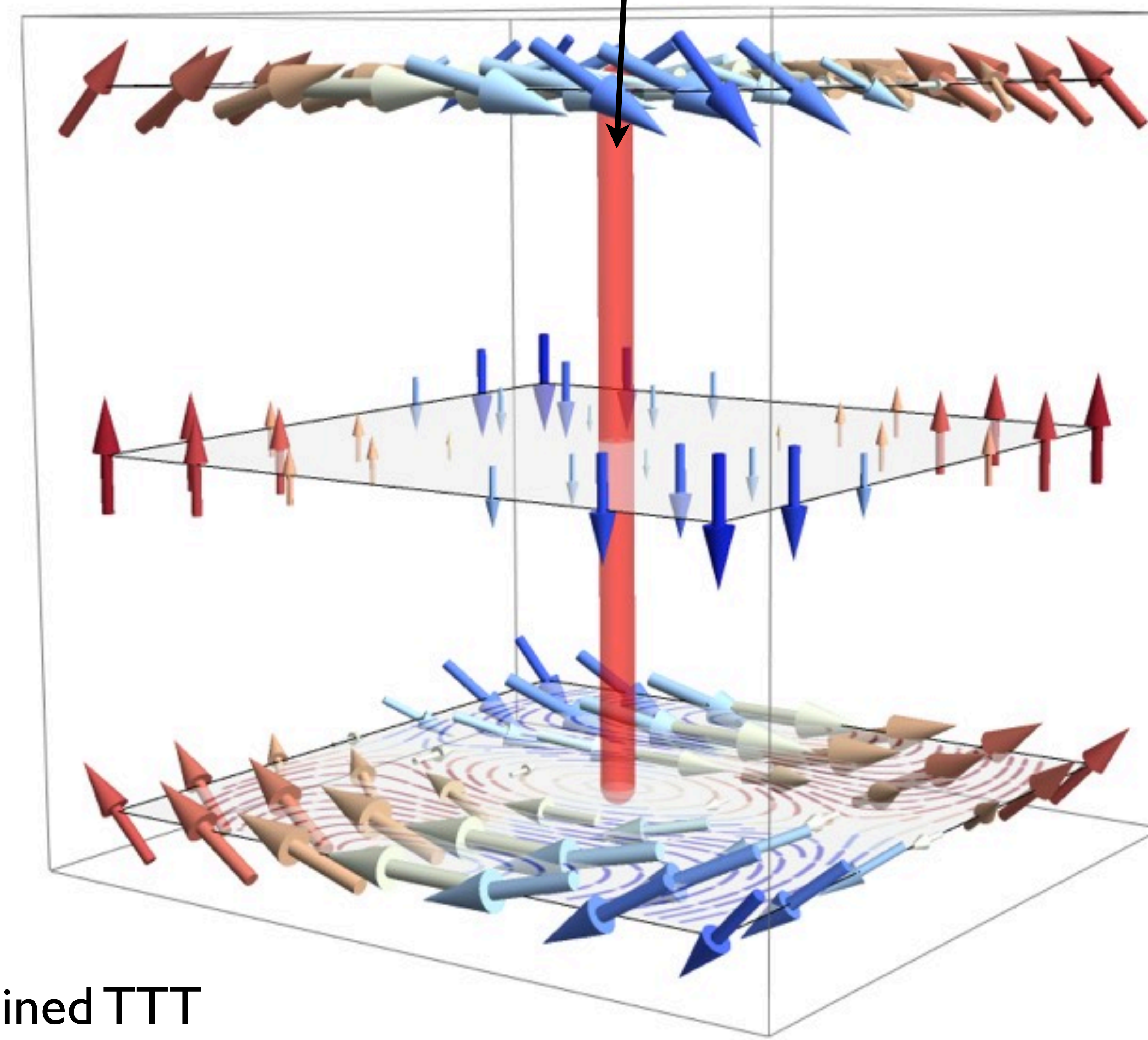
$$\approx \varepsilon_{ijk}\, H_{li}\, T_{lj}$$

Hessian

Tidal

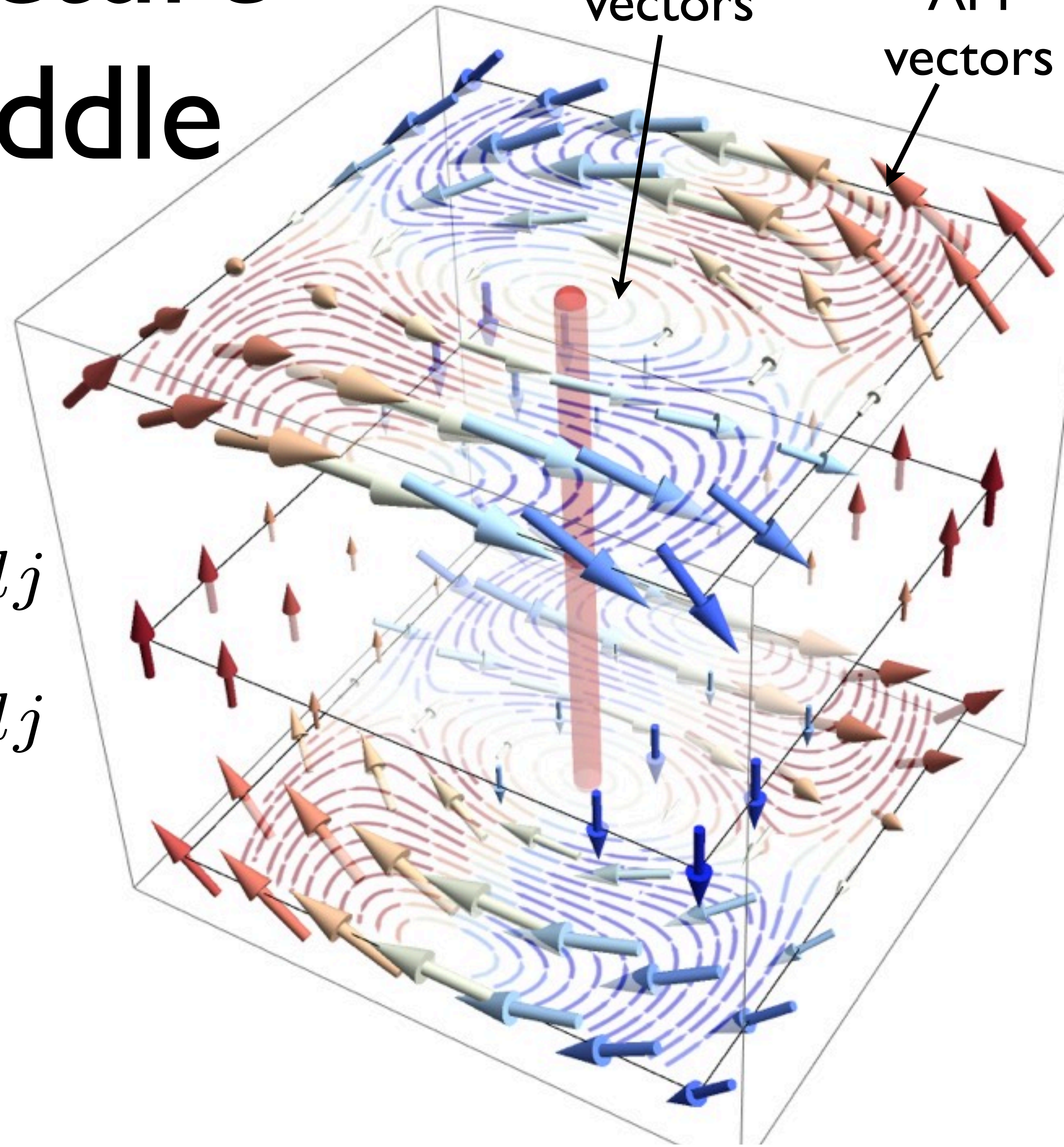
Flattened filament

AM vectors



Analytical result in constrained TTT

Spin structure near Saddle

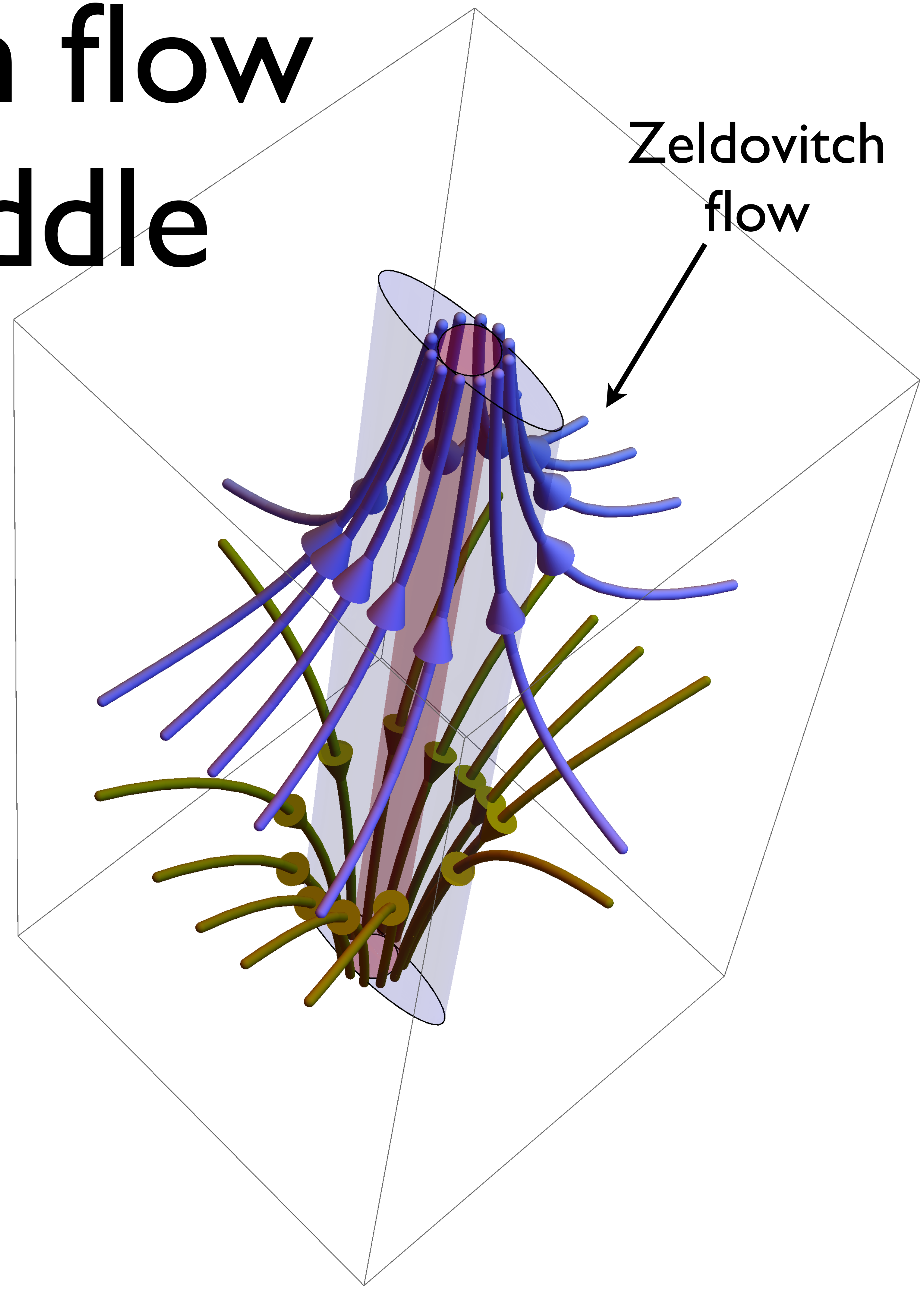


$$L_k = \varepsilon_{ijk}\, I_{li}\, T_{lj}$$
$$\approx \varepsilon_{ijk}\, H_{li}\, T_{lj}$$

Hessian

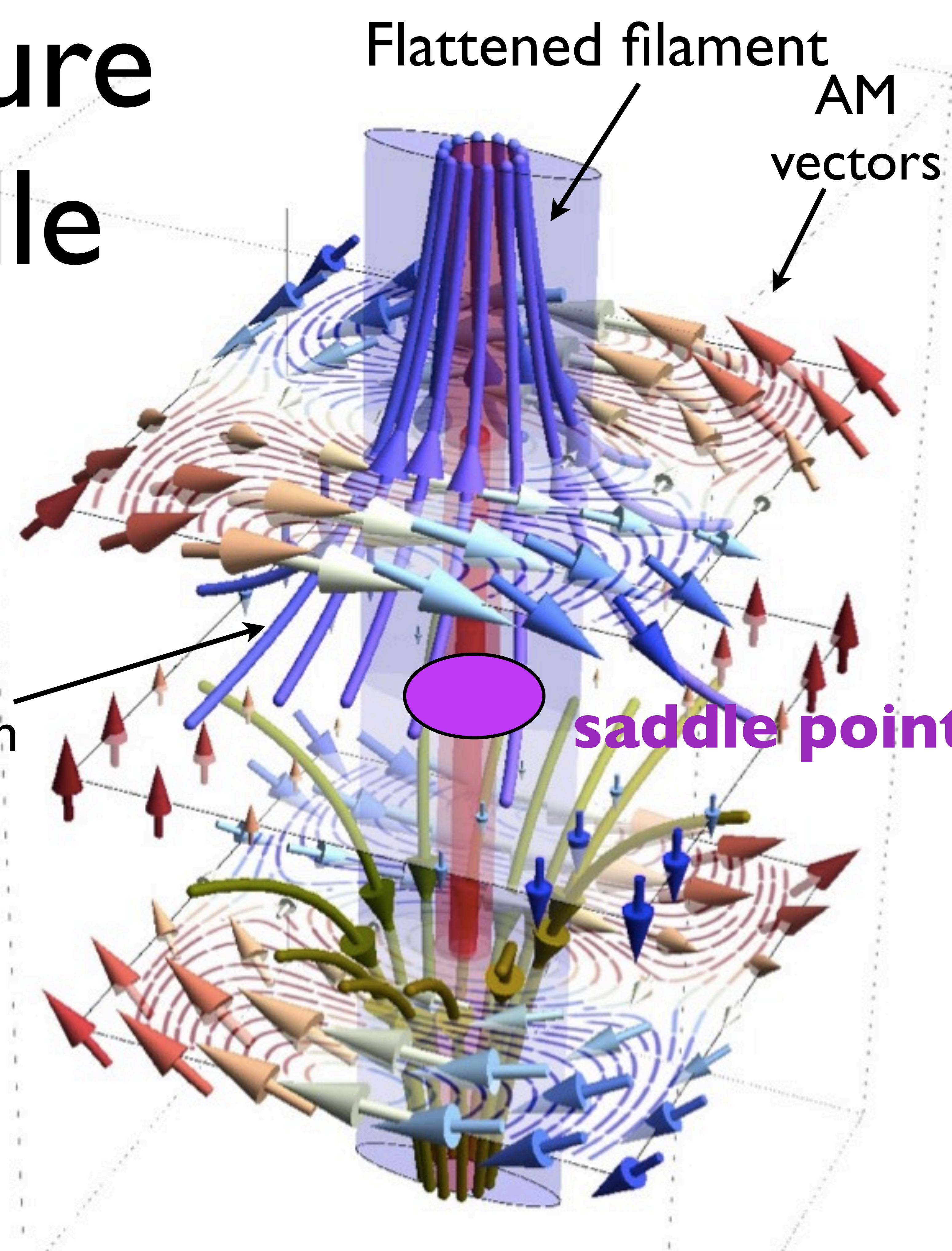
Tidal

Zeldovtich flow near Saddle



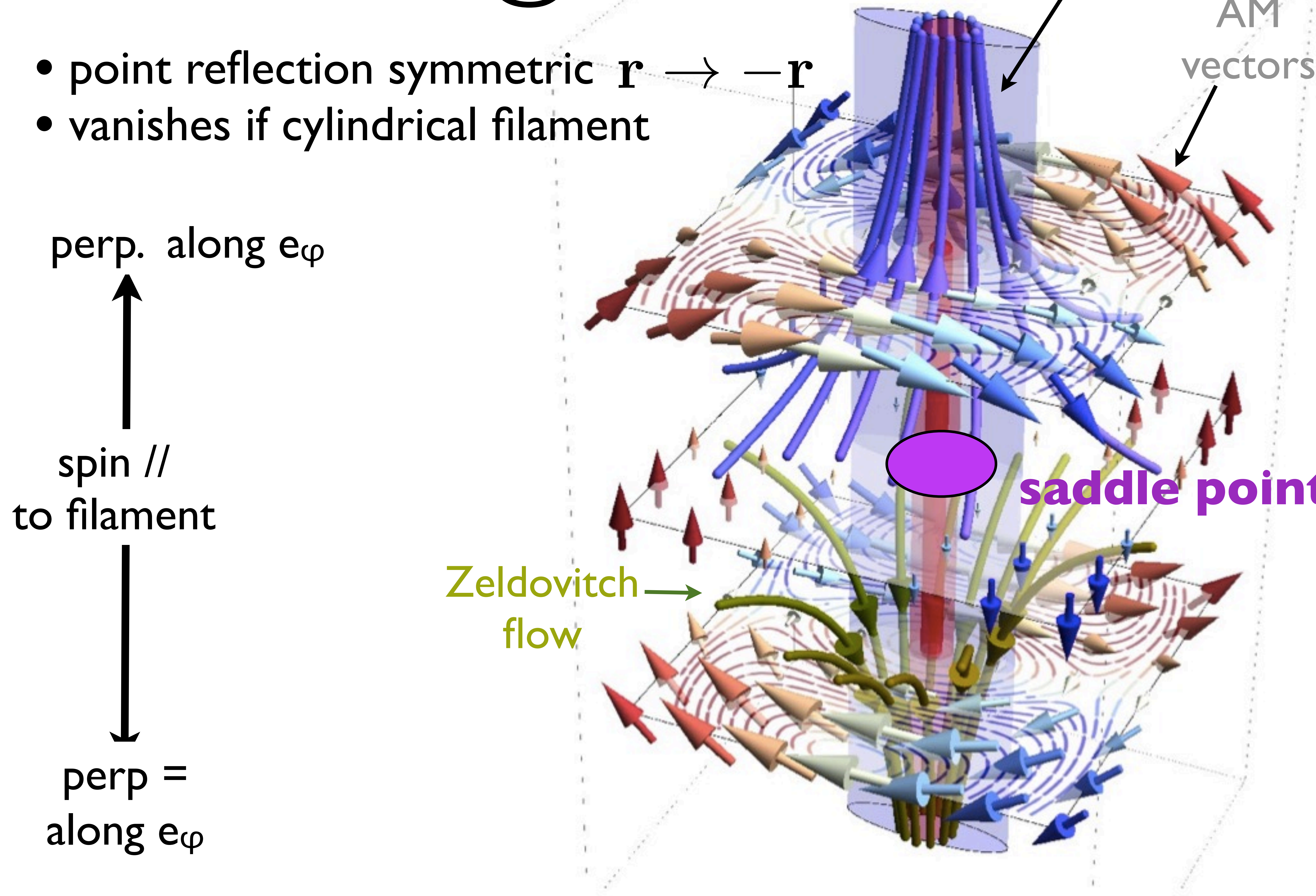
Spin structure near Saddle

$$L_k = \varepsilon_{ijk} I_{li} T_{lj}$$
$$\approx \varepsilon_{ijk} H_{li} T_{lj}$$



3D TTT@ saddle?

- point reflection symmetric $\mathbf{r} \to -\mathbf{r}$
- vanishes if cylindrical filament



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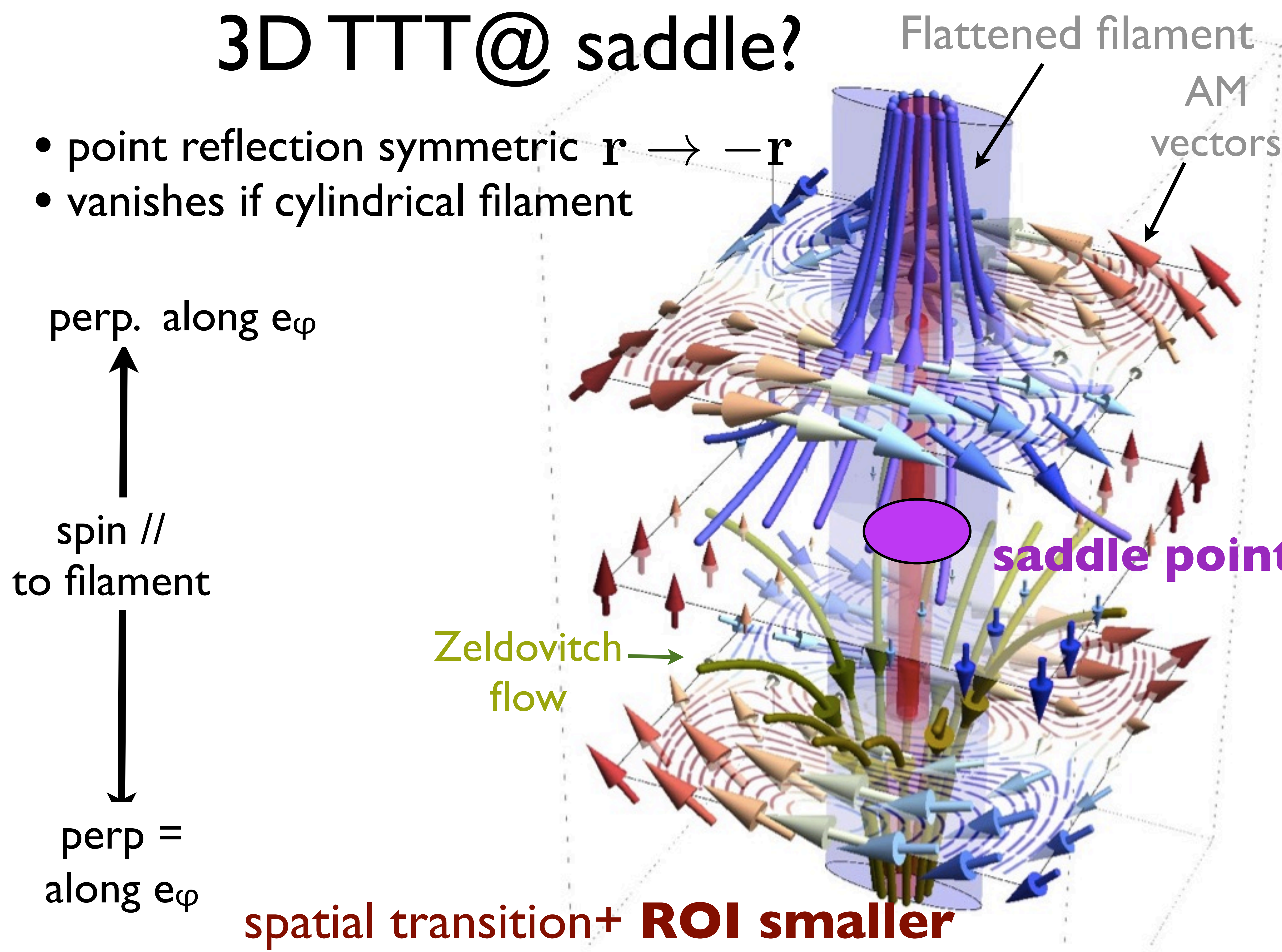
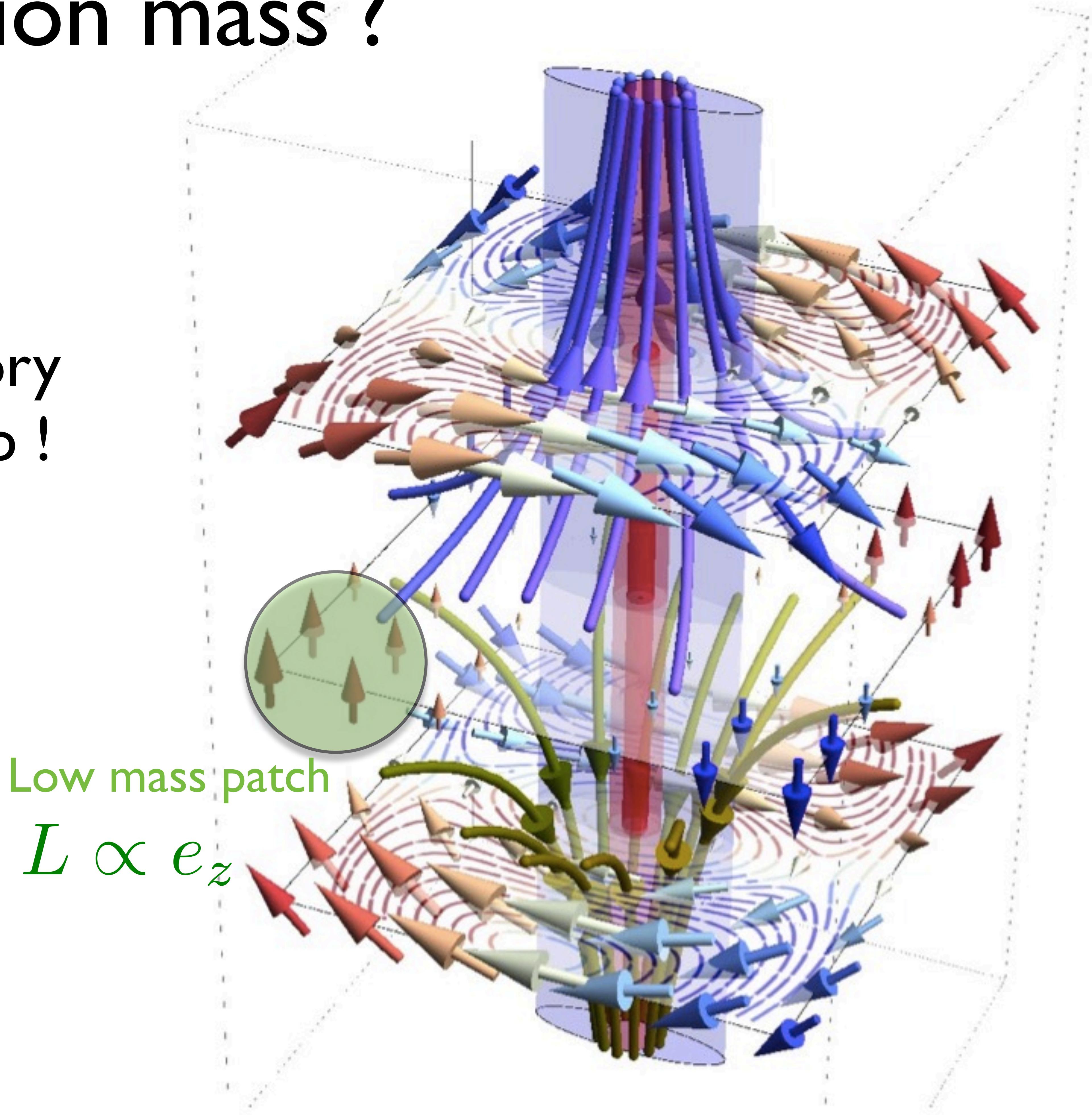


spatial transition+ **ROI smaller**

3D Transition mass ?

Lagrangian theory capture spin flip !

Transition mass associated with **size** of quadrant



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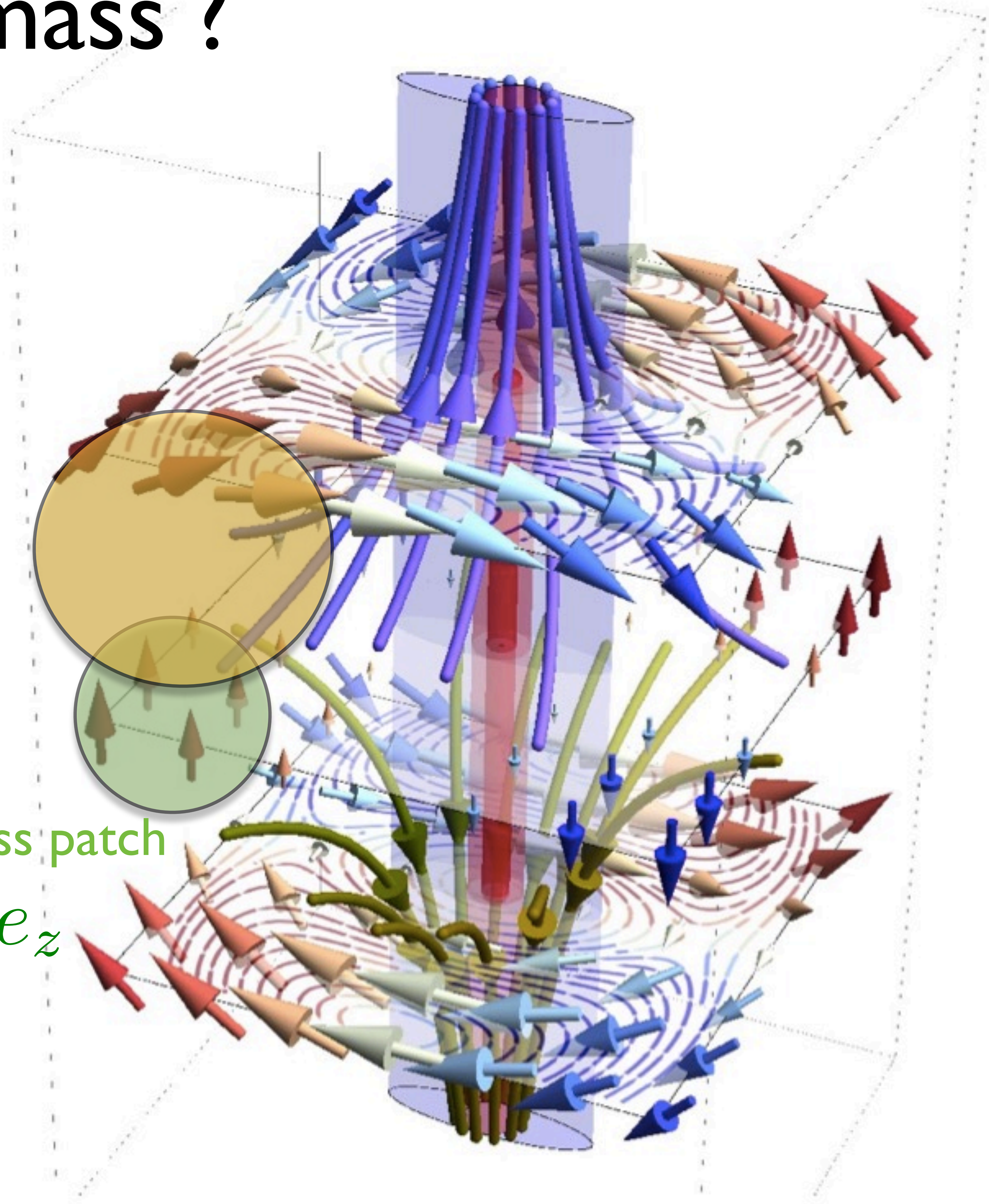


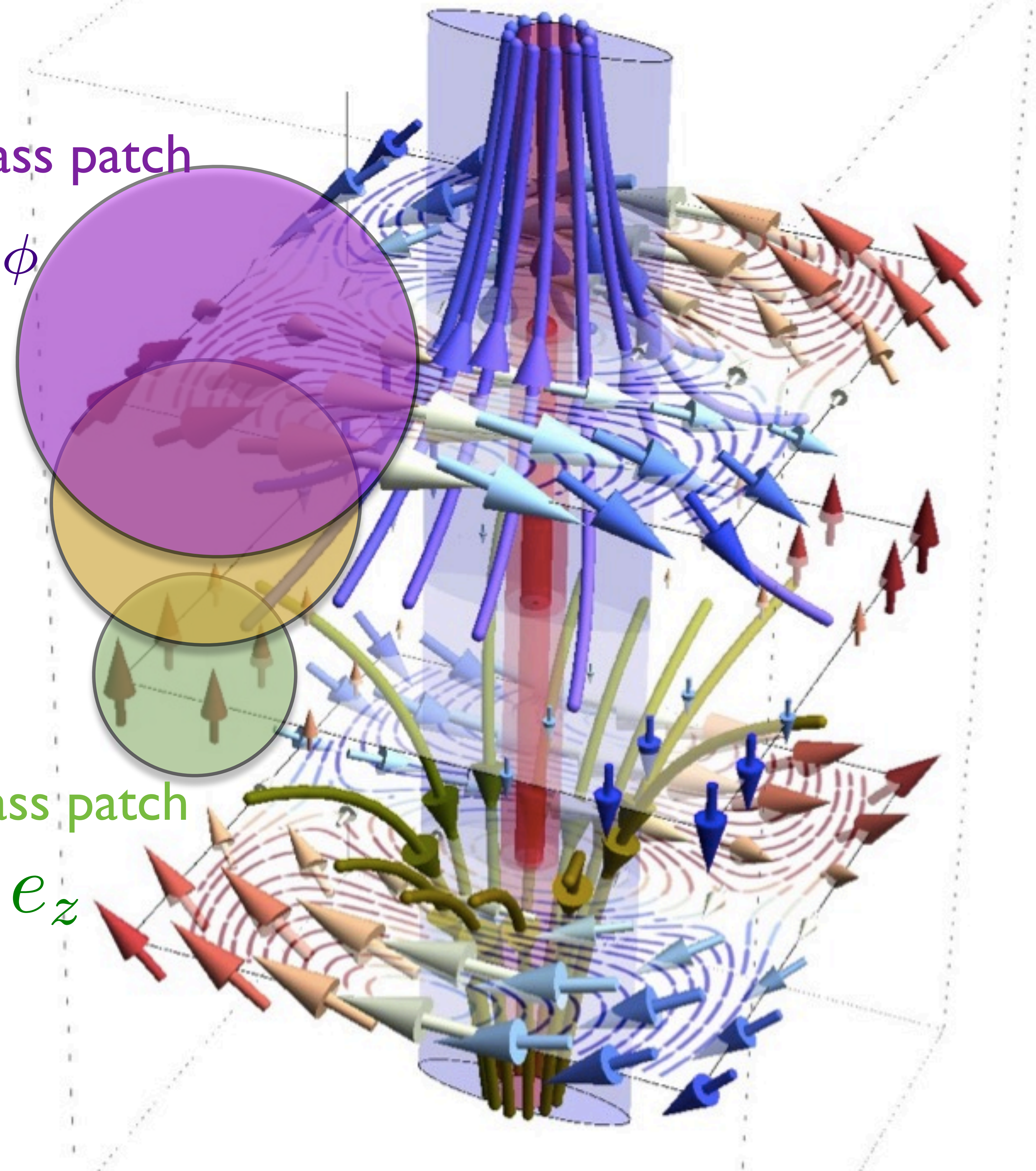
Low mass patch

$L \propto e_z$

3D Transition mass ?

Lagrangian theory capture spin flip !

Transition mass associated with **size** of quadrant



Geometry of the saddle provides **a natural 'metric'** (local frame as defined by Hessian @ saddle) relative to which **dynamical evolution** of DH is predicted.

Cloud in cloud effect

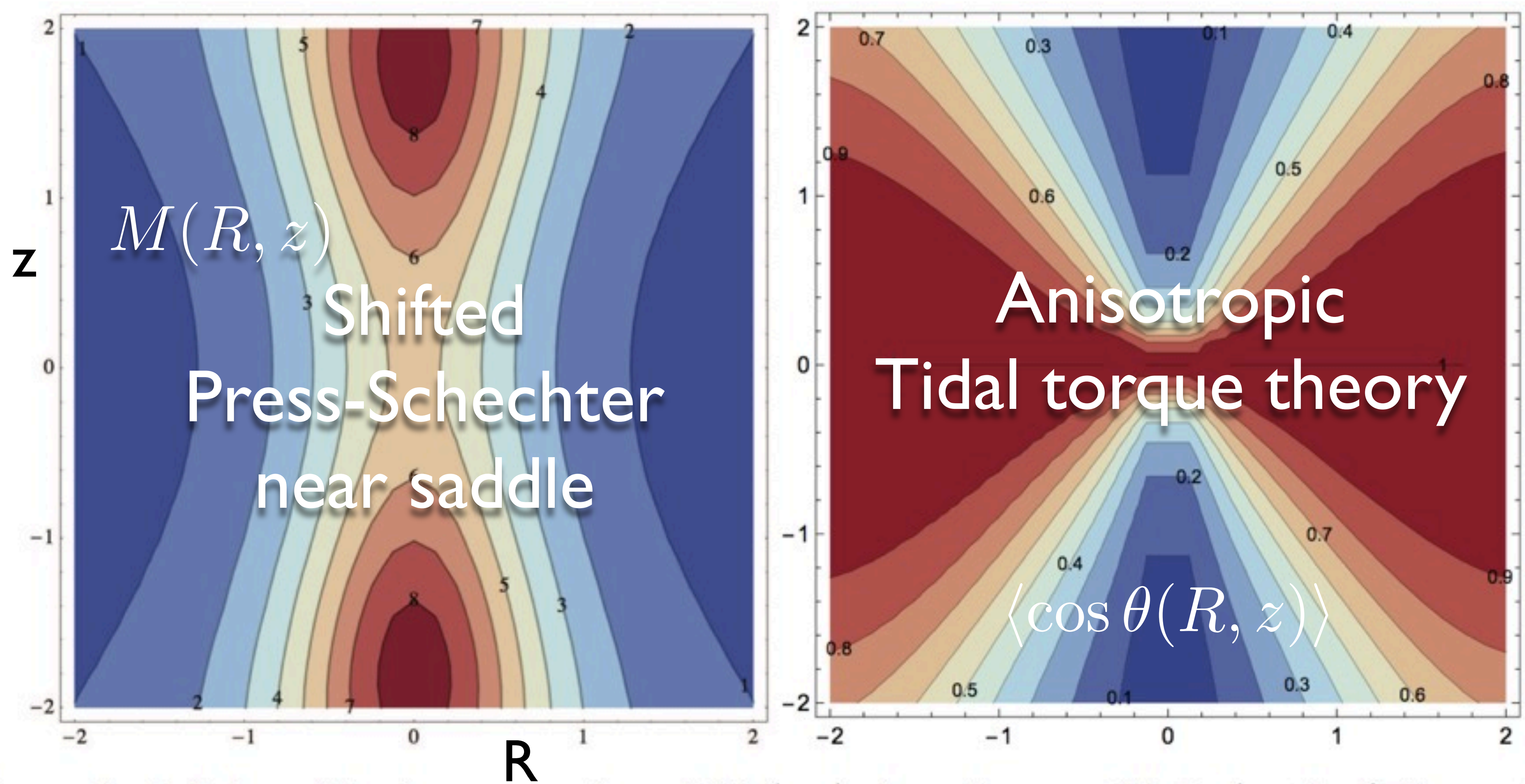
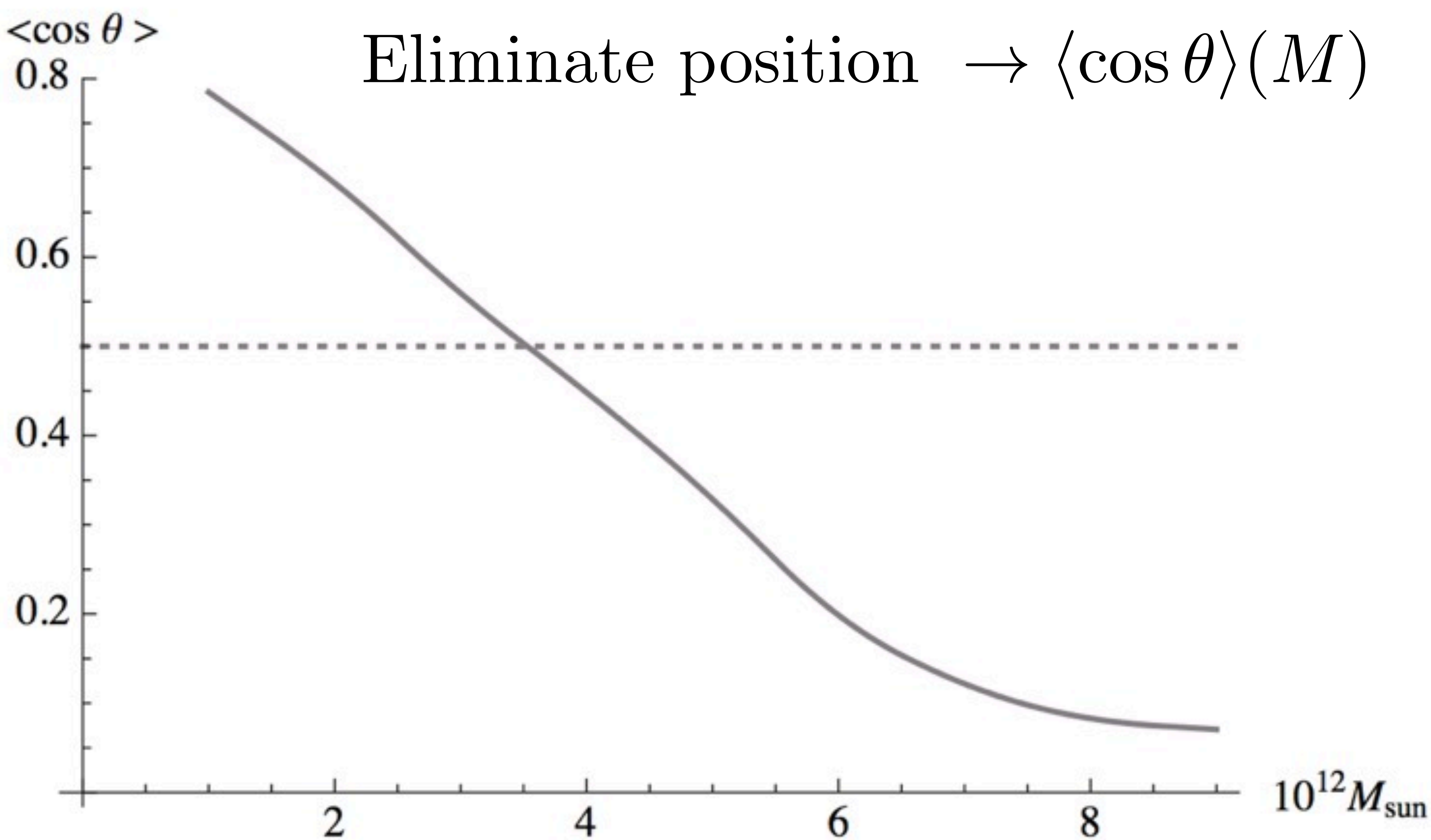


Figure 5. *Left:* logarithmic cross section of $M_p(r,z)$ along the most likely (vertical) filament (in units of $10^{12} M_\odot$). *Right:* corresponding cross section of $\langle\cos\hat{\theta}\,\rangle(r,z)$. The mass of halos increases towards the nodes, while the spin flips.

geometric split ⟶ mass split

Geometry of the saddle provides **a natural 'metric'** (local frame as defined by Hessian @ saddle) relative to which **dynamical evolution** of DH is predicted.

Cloud in cloud effect



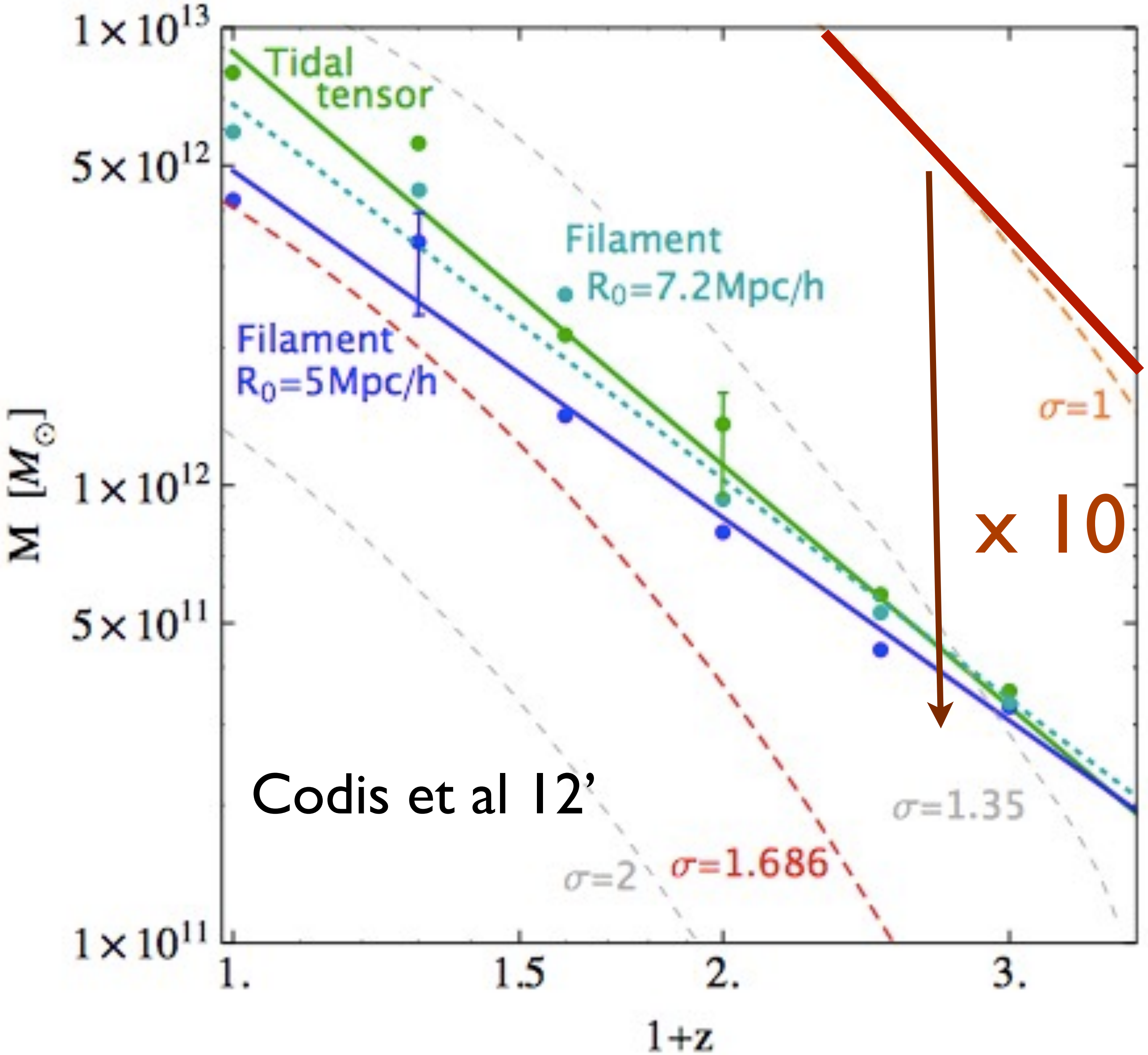
Eliminate position $\rightarrow \langle\cos\theta\rangle(M)$

Figure 6. Mean alignment between spin and filament as a function of mass for a filament smoothing scale of 5 Mpc/h. The spin flip transition mass is around $4\,10^{12}\,M_\odot$.

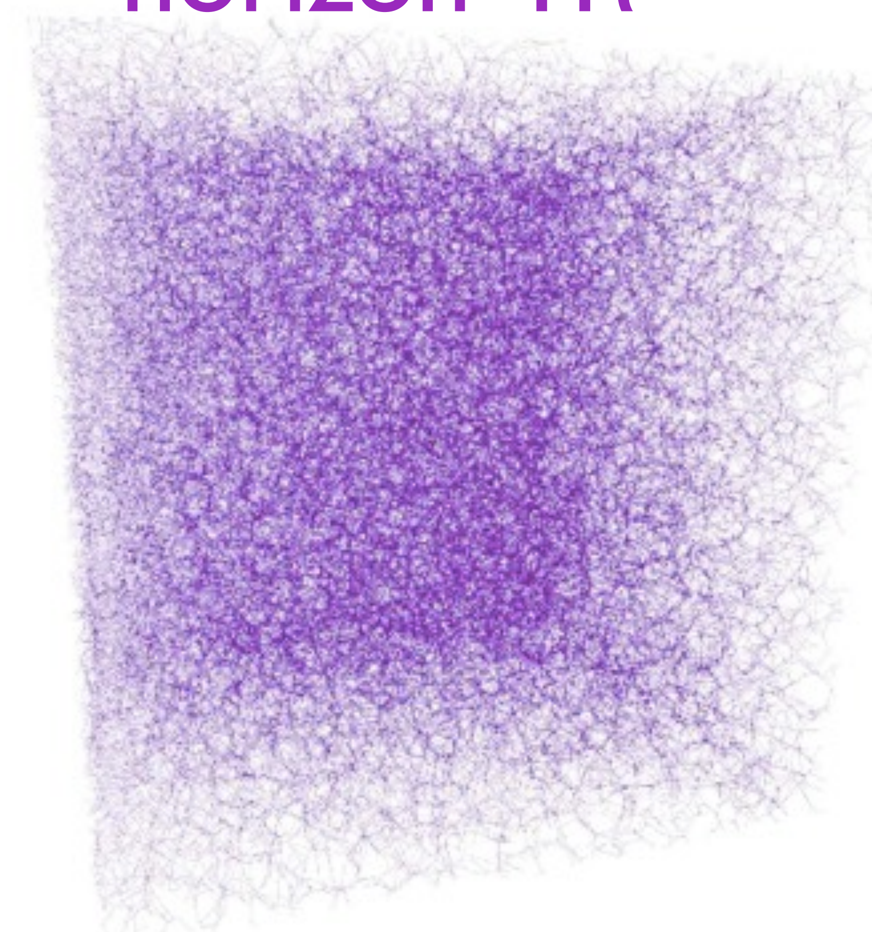
geometric split ⟶ mass split

Explain transition mass again!

Transition mass versus redshift



horizon 4π

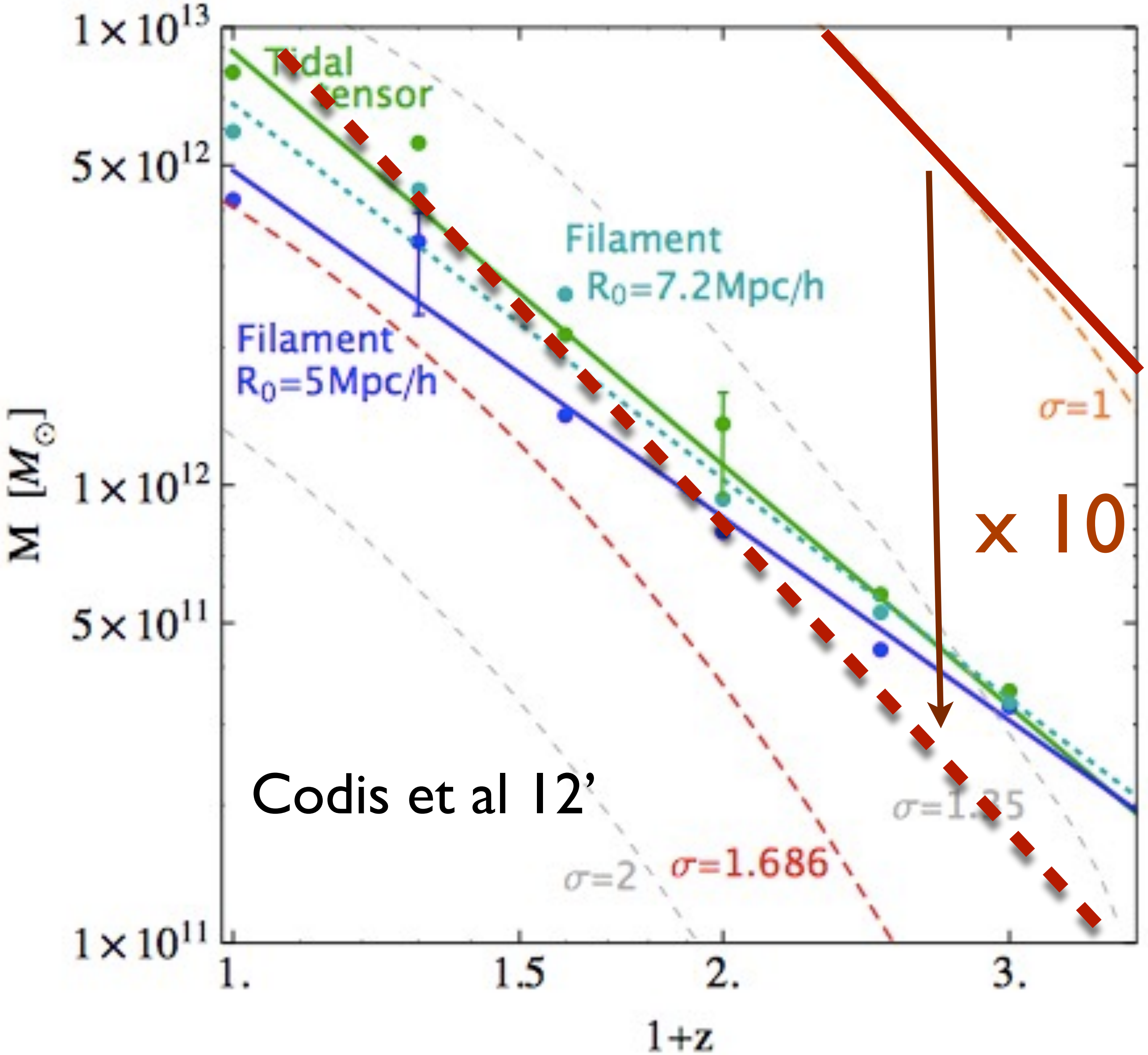


skeleton of LSS

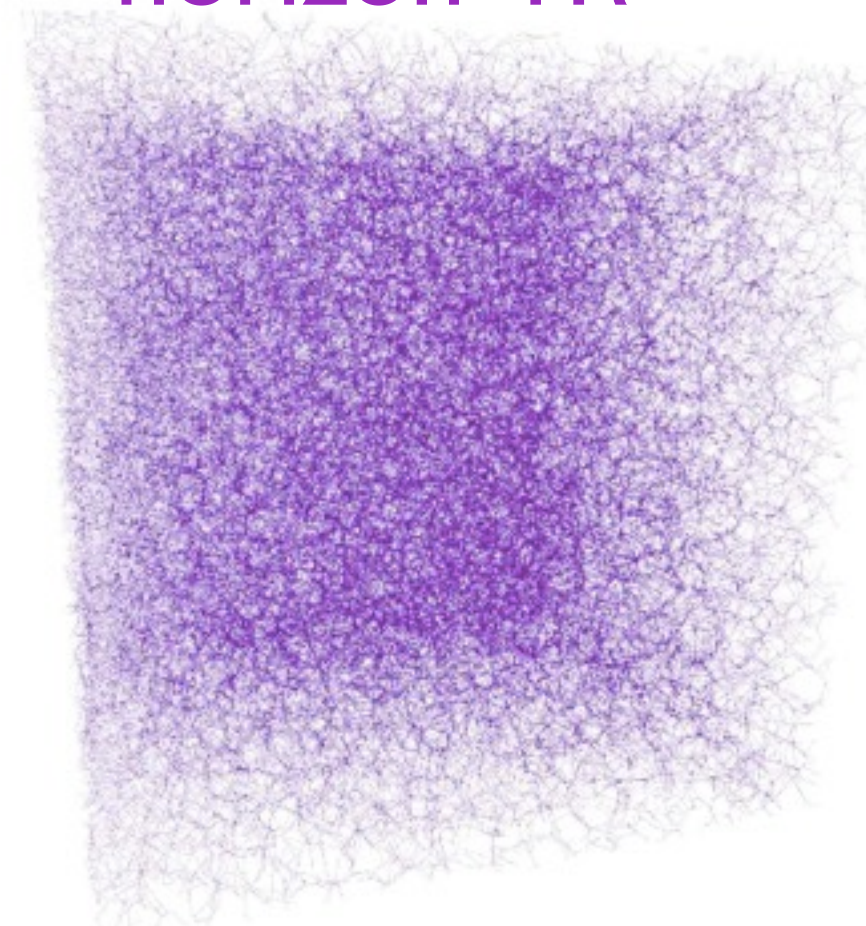
Only 2 ***ingredients***: a) spin is spin one b) filaments flattened

Explain transition mass again!

Transition mass versus redshift



horizon 4π



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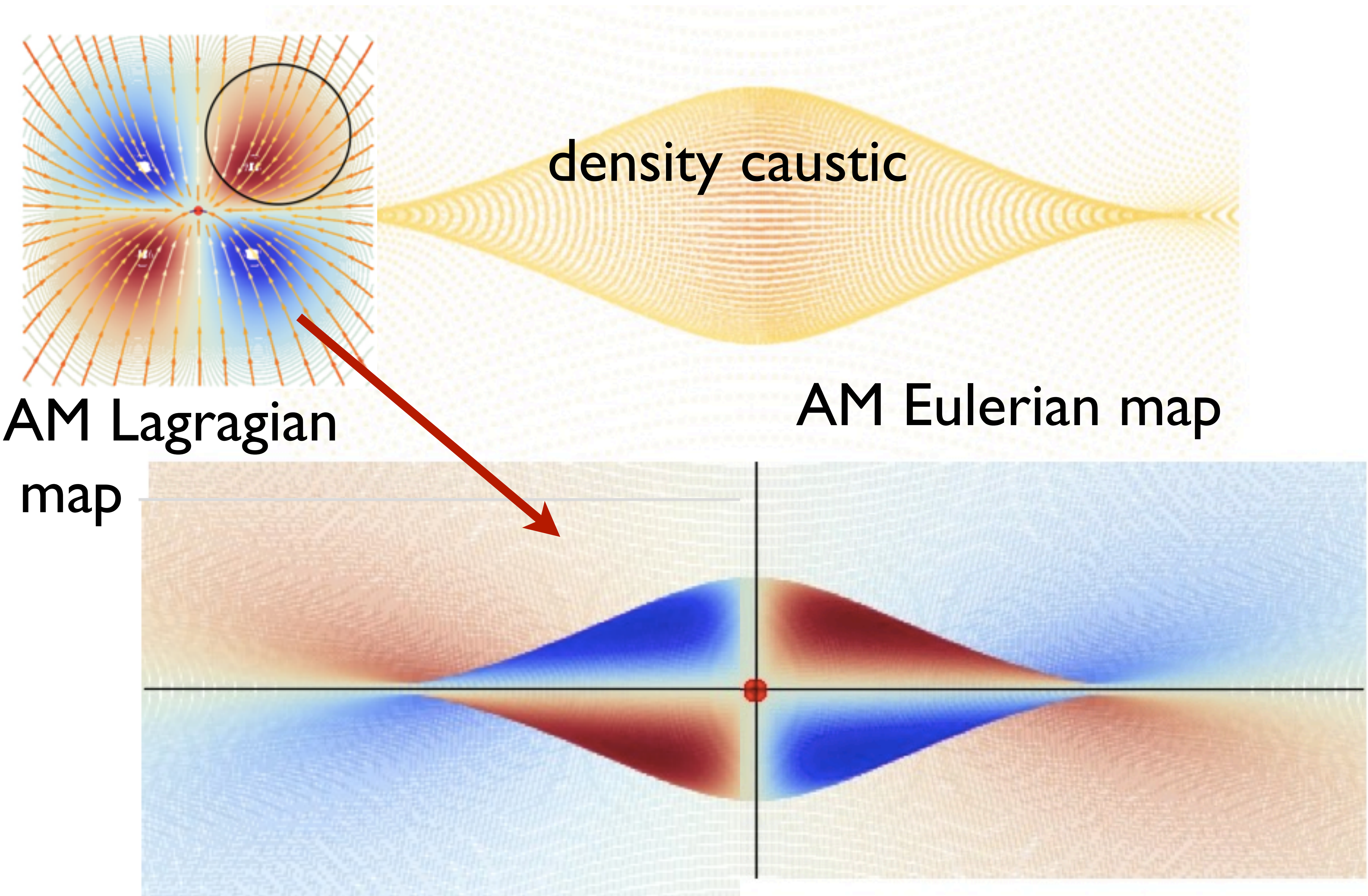
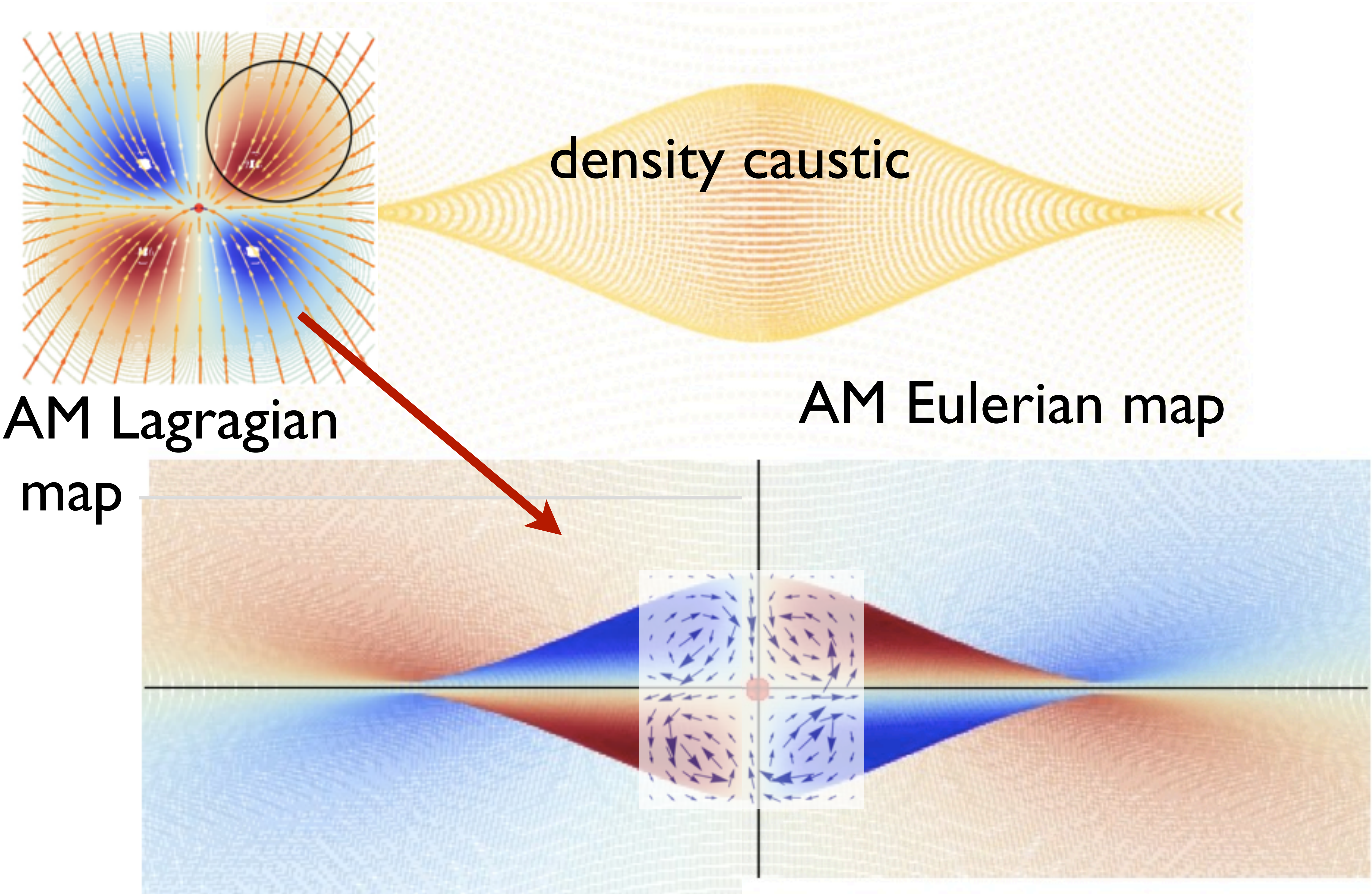
Link with Eulerian vorticity?



Link with Eulerian vorticity?

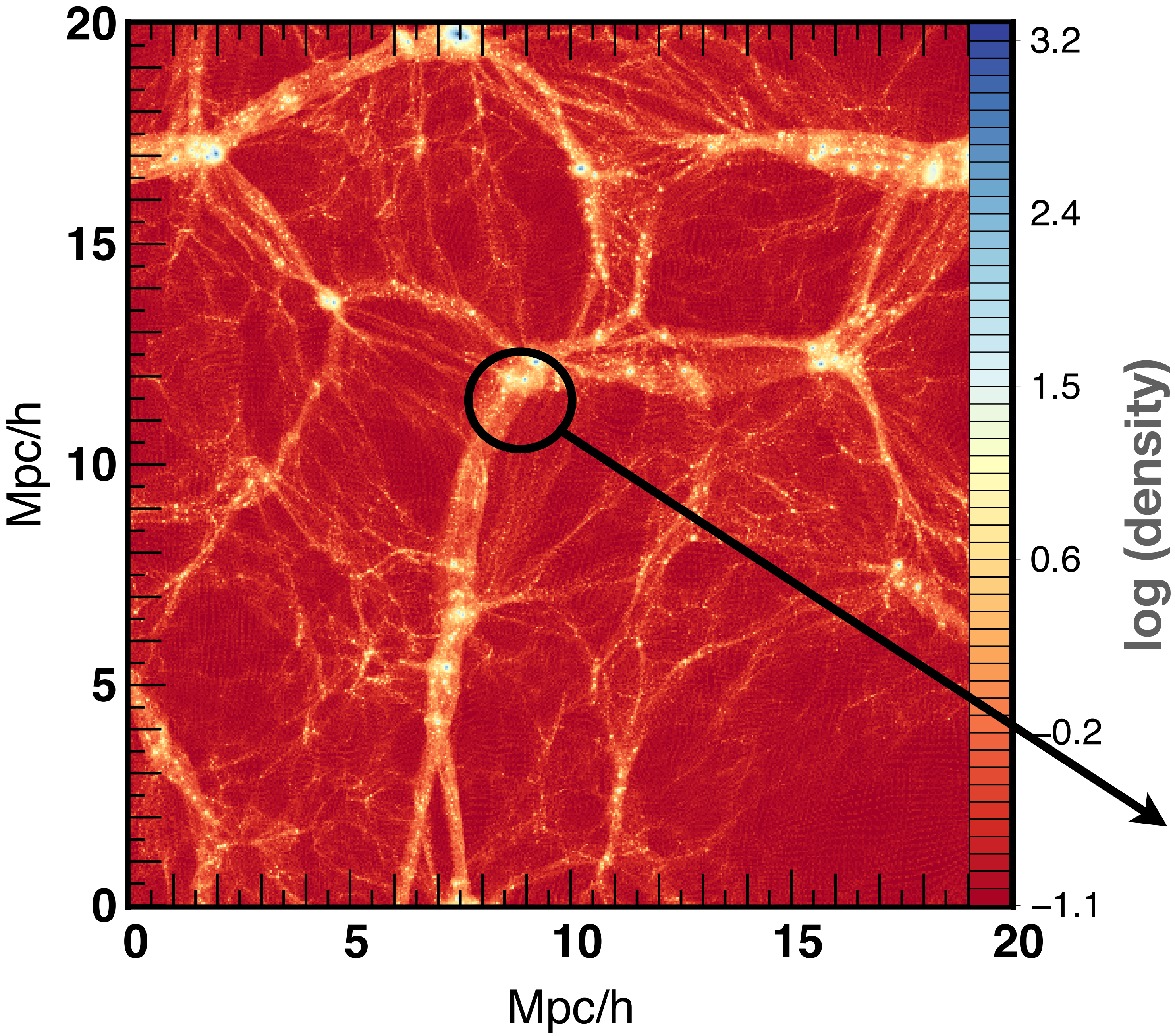


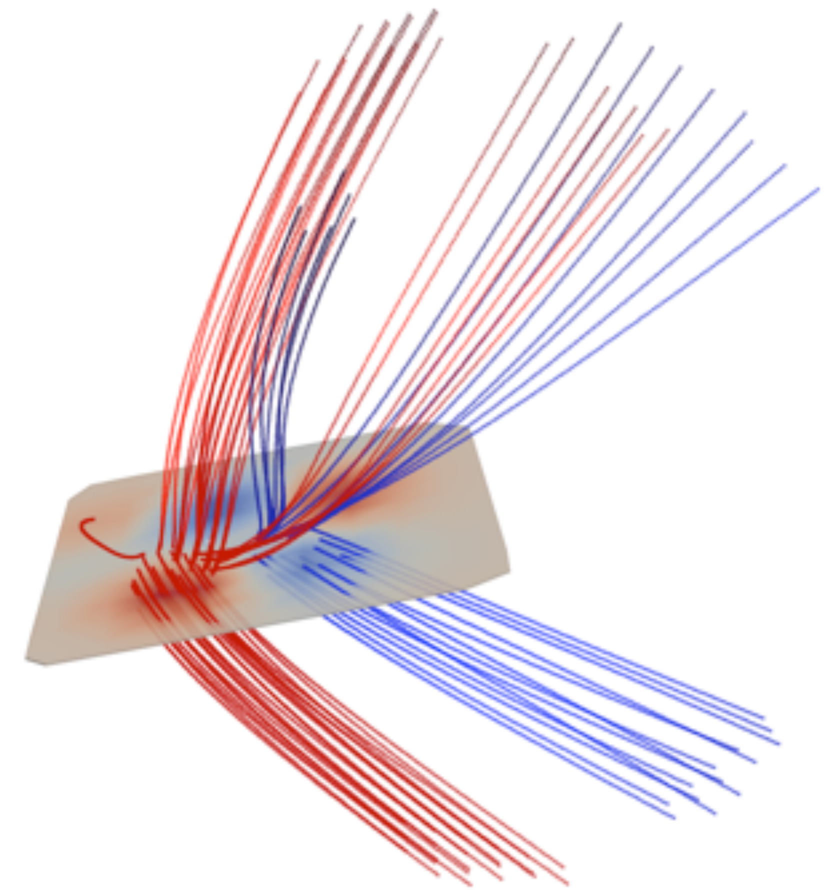
Growth of the large-scale structure

Laigle+15

Initial phase of structure formation: laminar and curl-free flows
This is no longer valid at the shell-crossing

Thin slice of a DM simulation at z=0





See also: **Pichon&Bernardeau+99, Pueblas&Scoccimarro+09 Hahn+14**

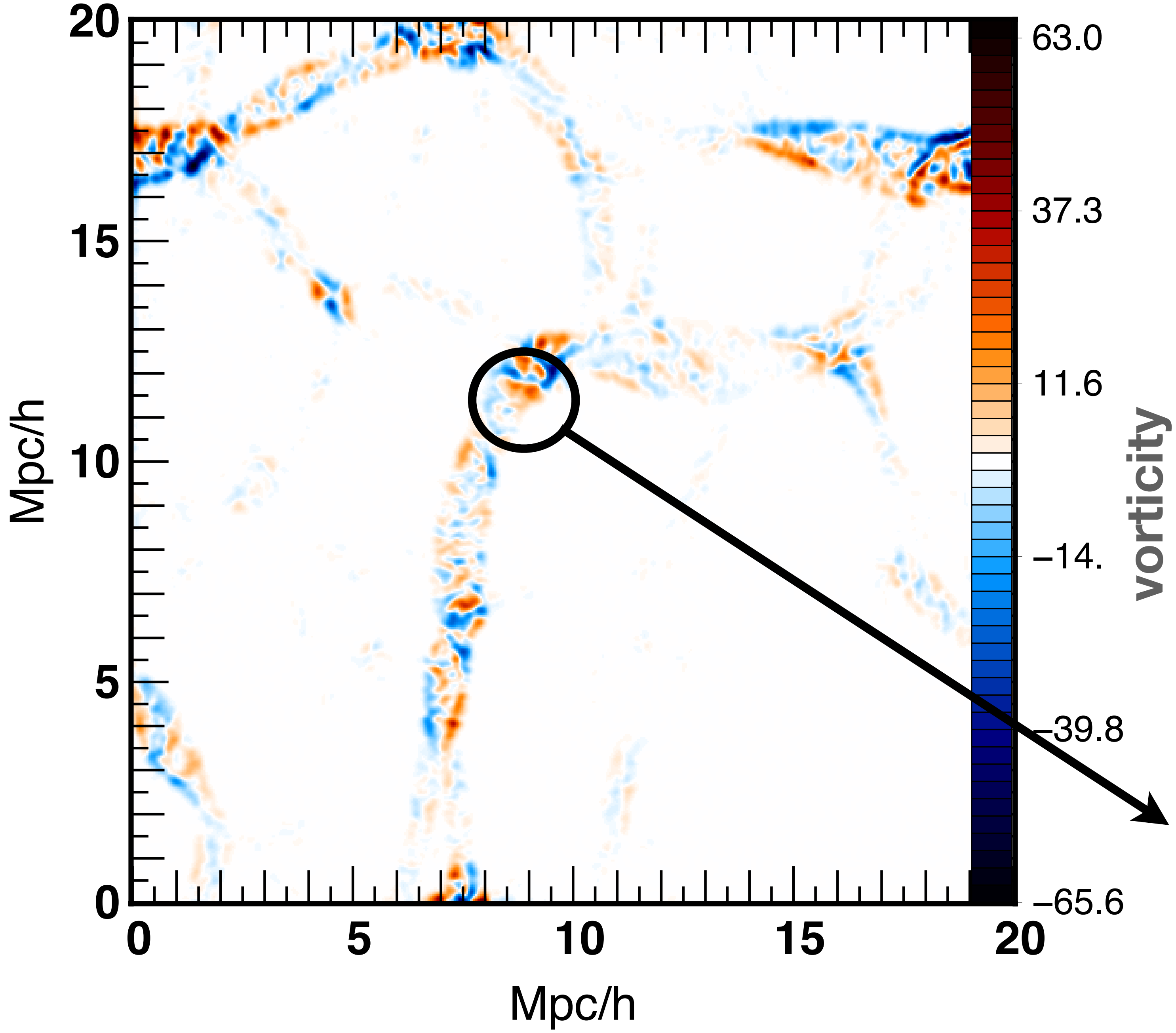
What happens when cosmic flows cross?

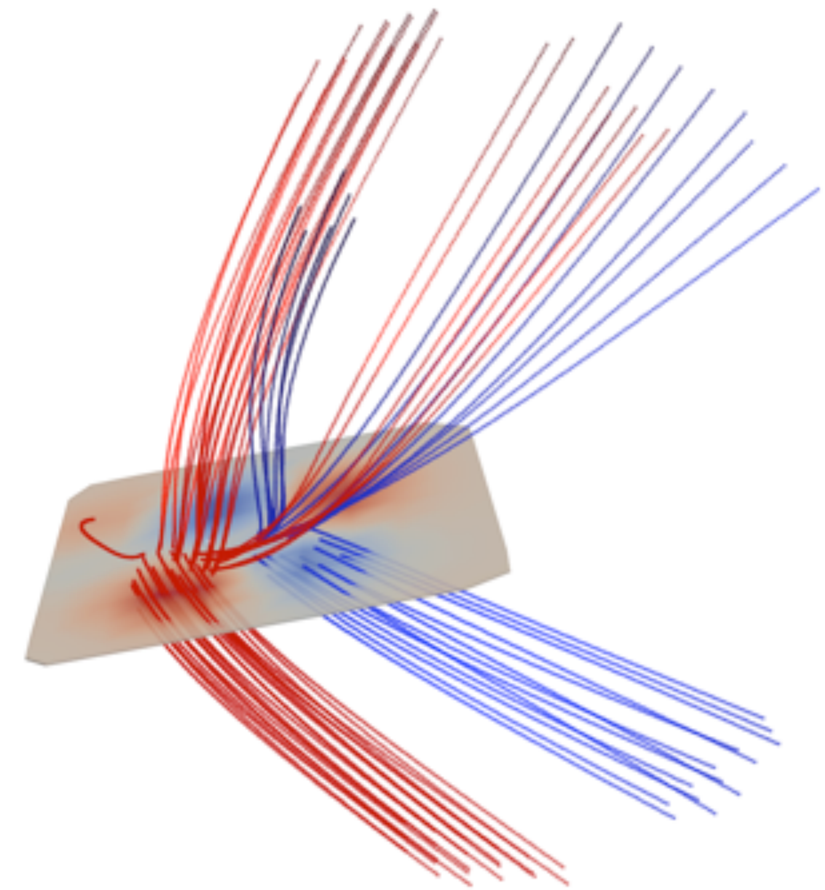
Vorticity generation

Laigle+15

Initial phase of structure formation: laminar and curl-free flows
This is no longer valid at the shell-crossing

Thin slice of a DM simulation at z=0

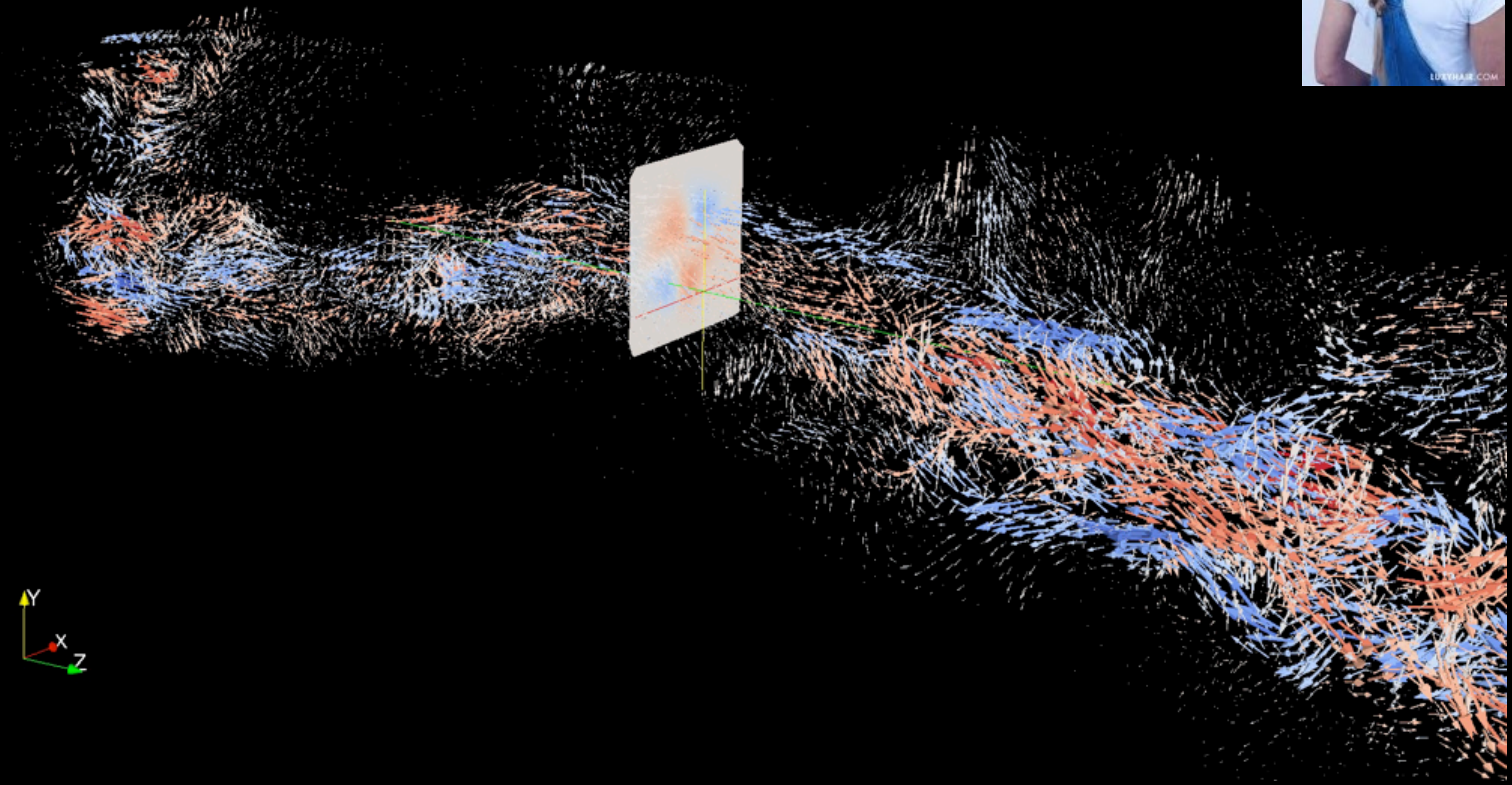




See also: **Pichon&Bernardeau+99, Pueblas&Scoccimarro+09 Hahn+14**

Vorticity is generated and confined within walls and filament

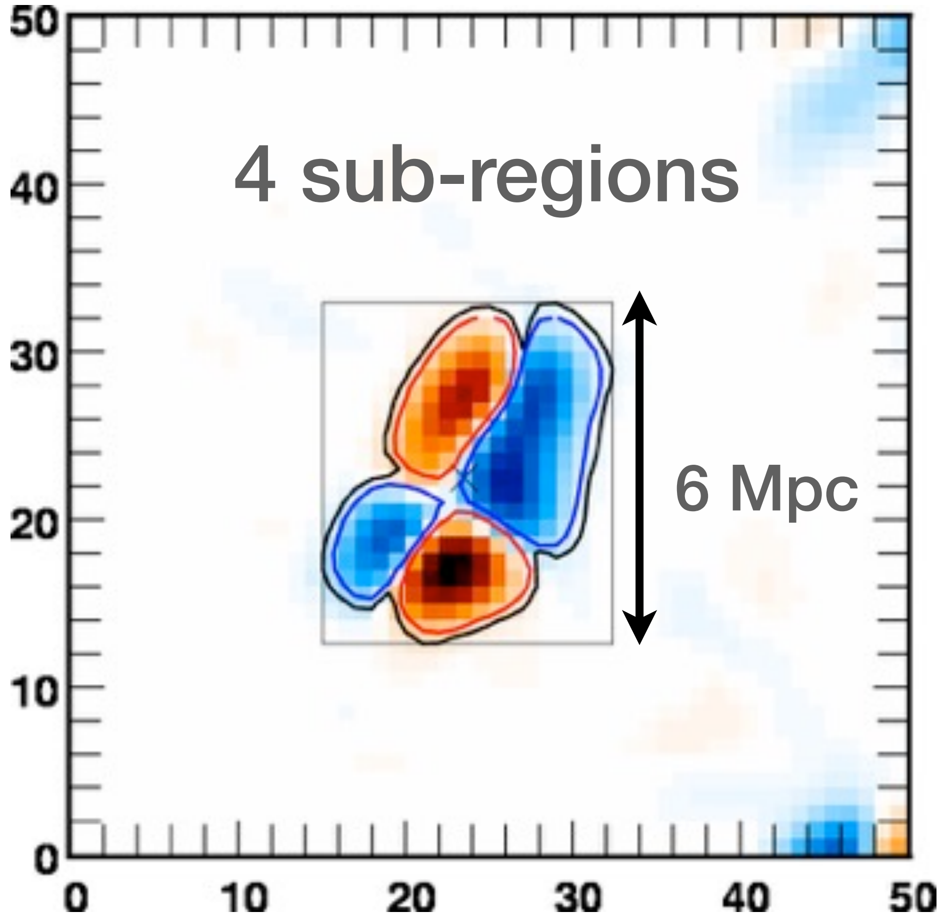
Alignement of vorticity with cosmic web

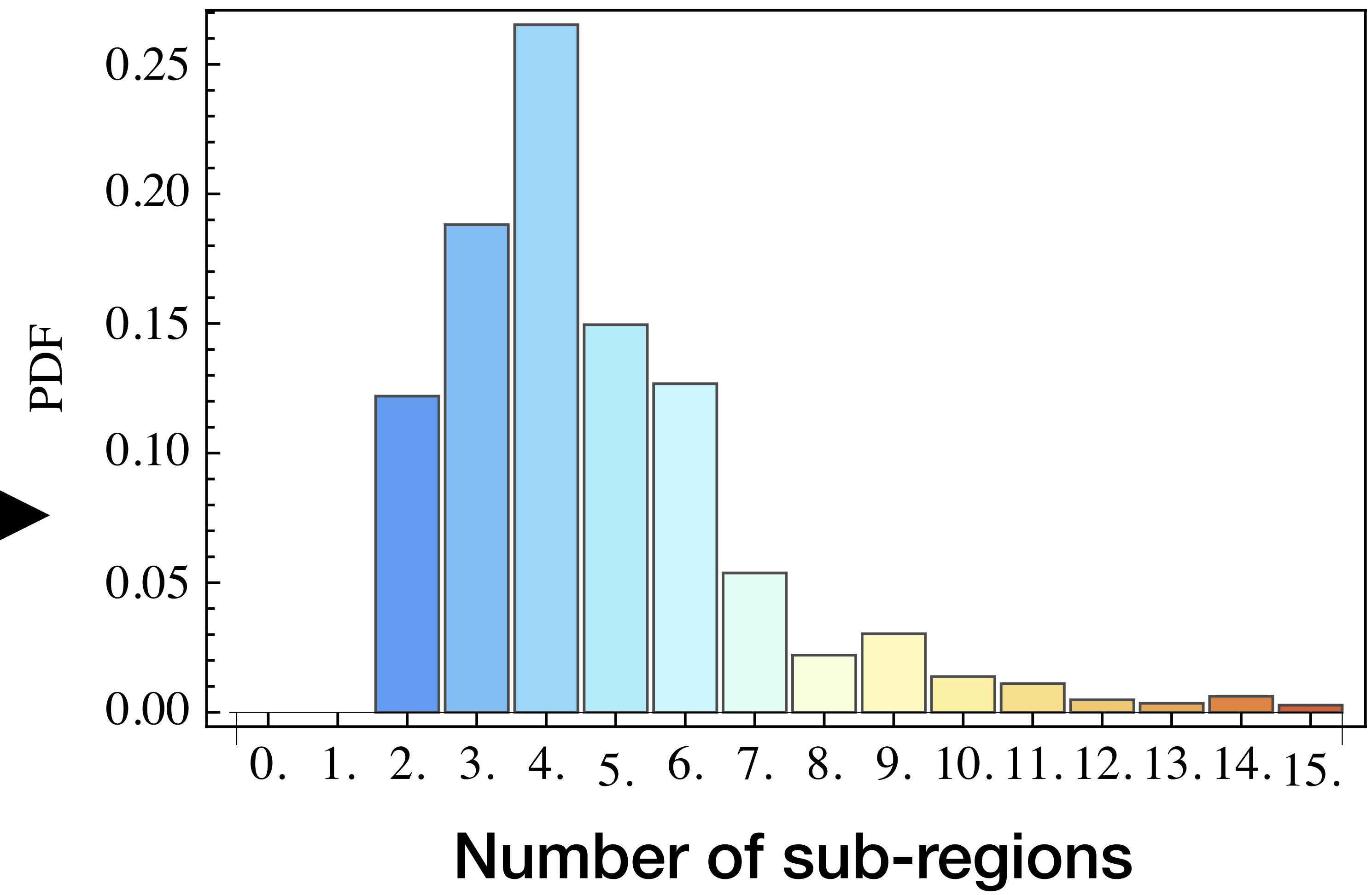


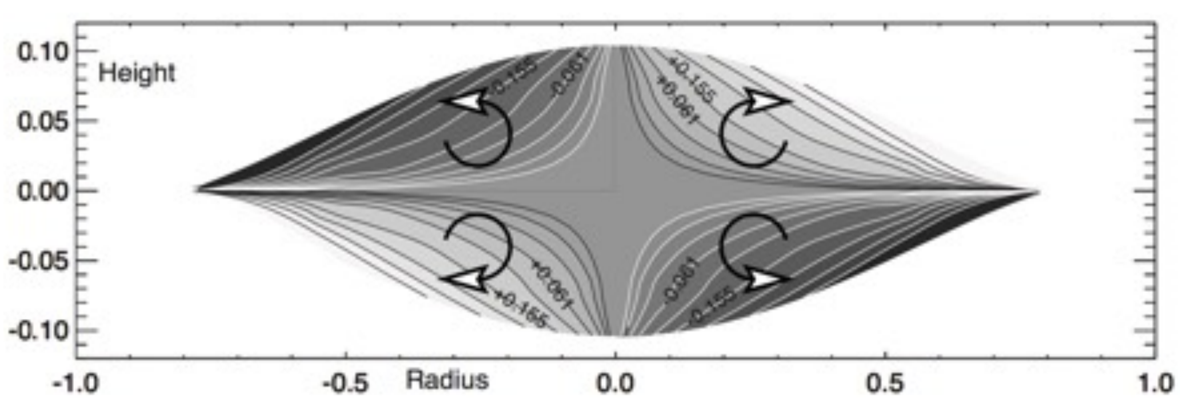
braids structure of vorticity.

Geometry of the vorticity cross-section

Laigle+15





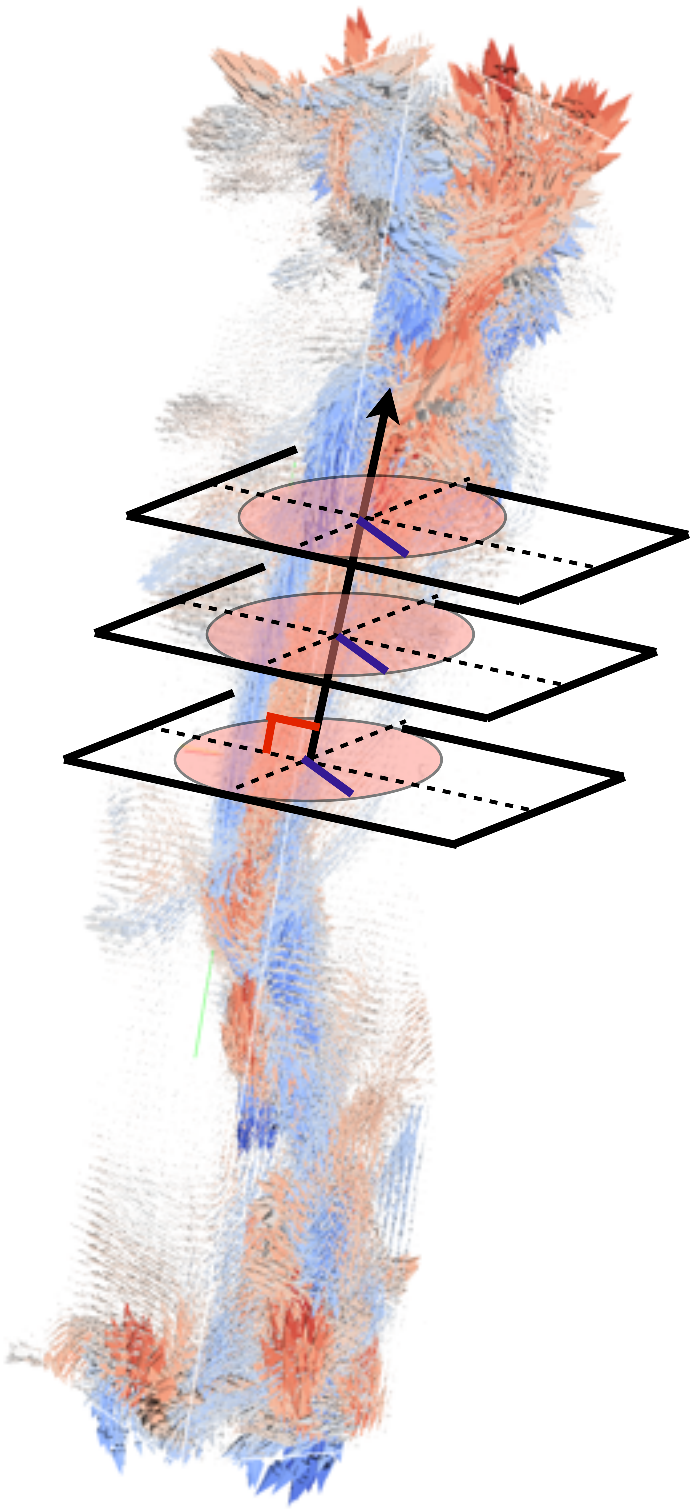


Theoretical prediction from Pichon & Bernardeau 1999

Cross-sections are typically divided in 4 quadrants

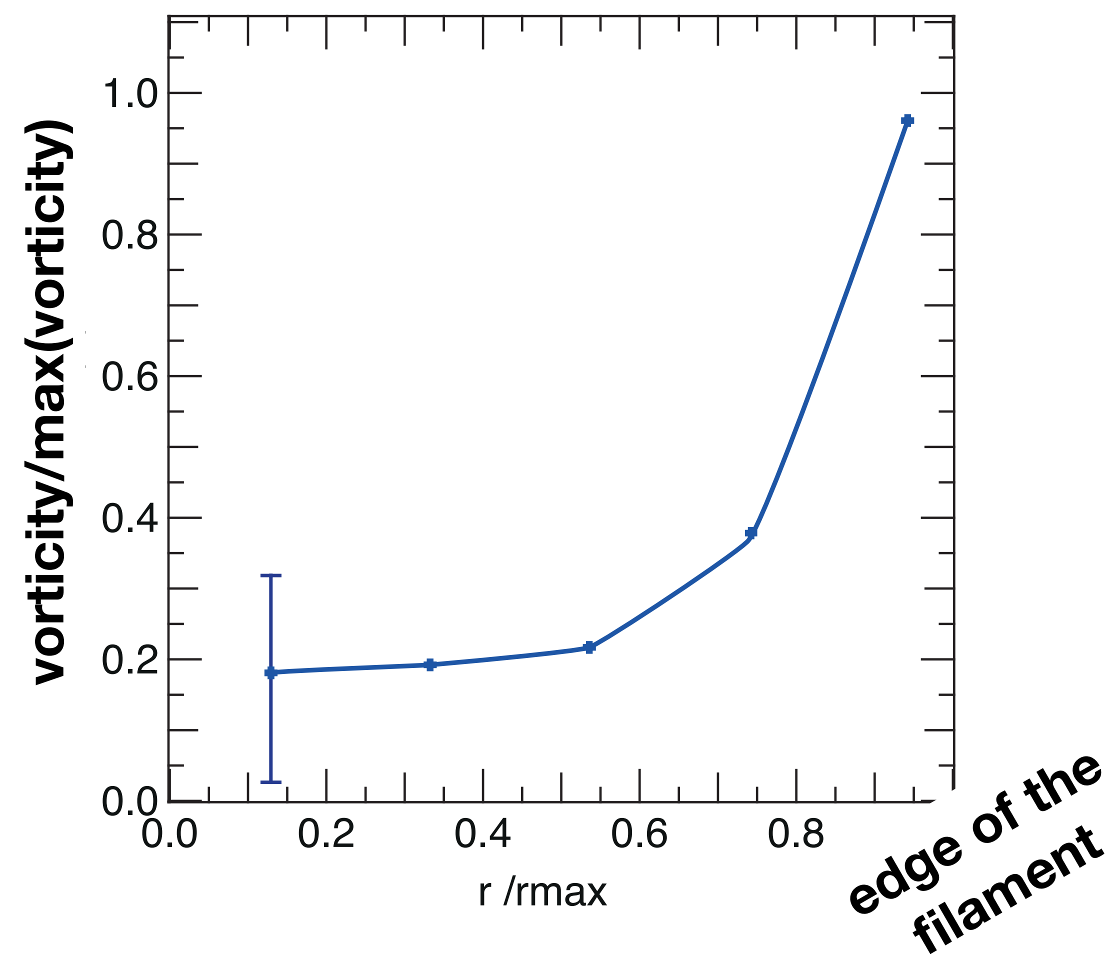
Geometry of the vorticity cross-section

Laigle+15



Vorticity vector field

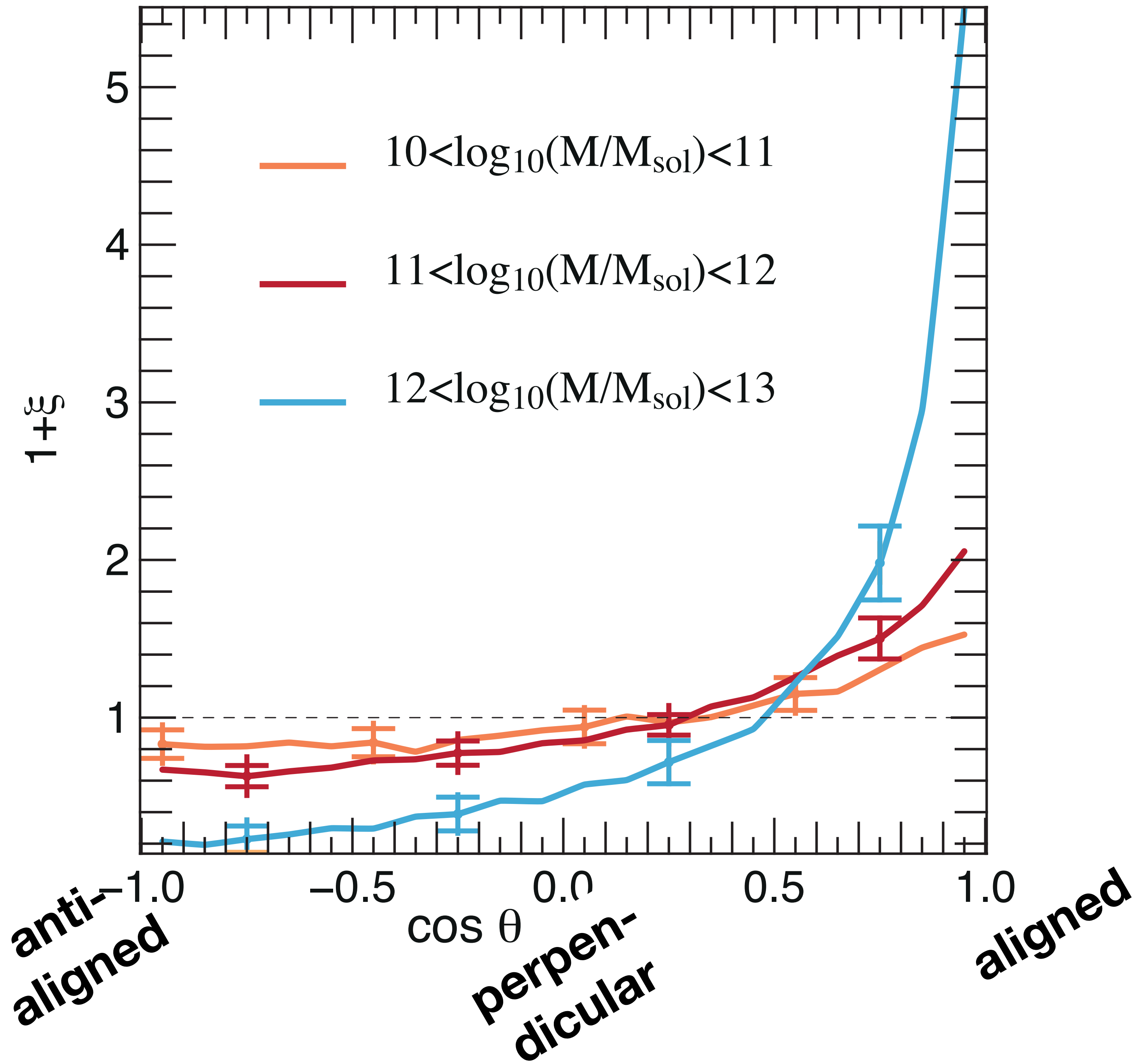
Stacked profile

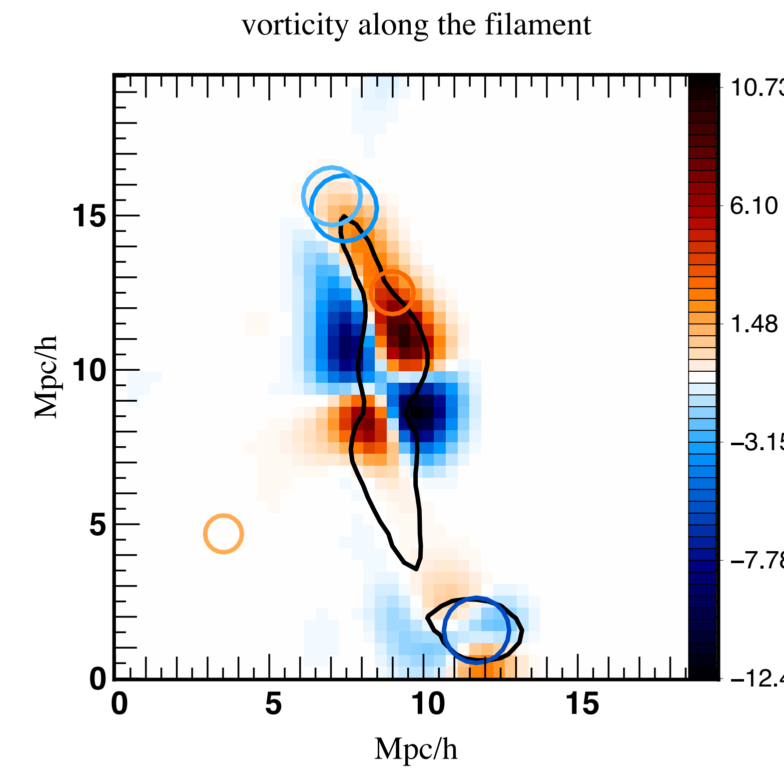


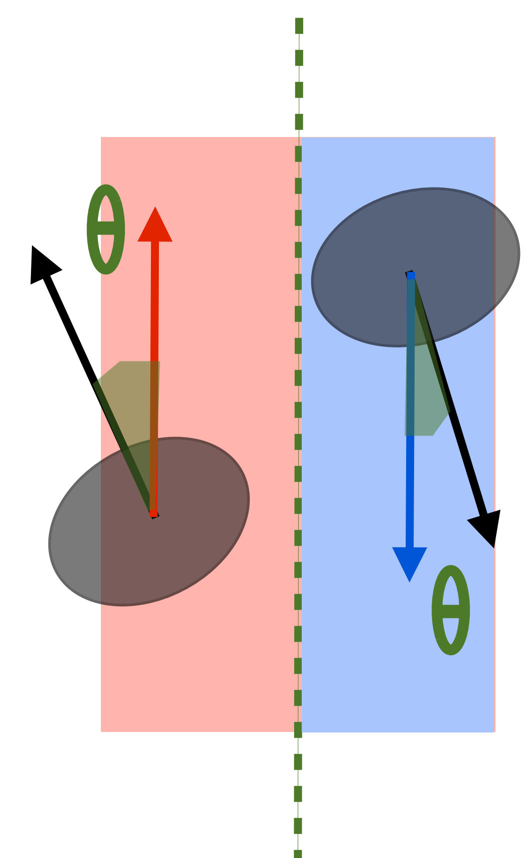
High vorticity regions are located at the edges of the filament

Halo spin-vorticity alignment

Laigle+15



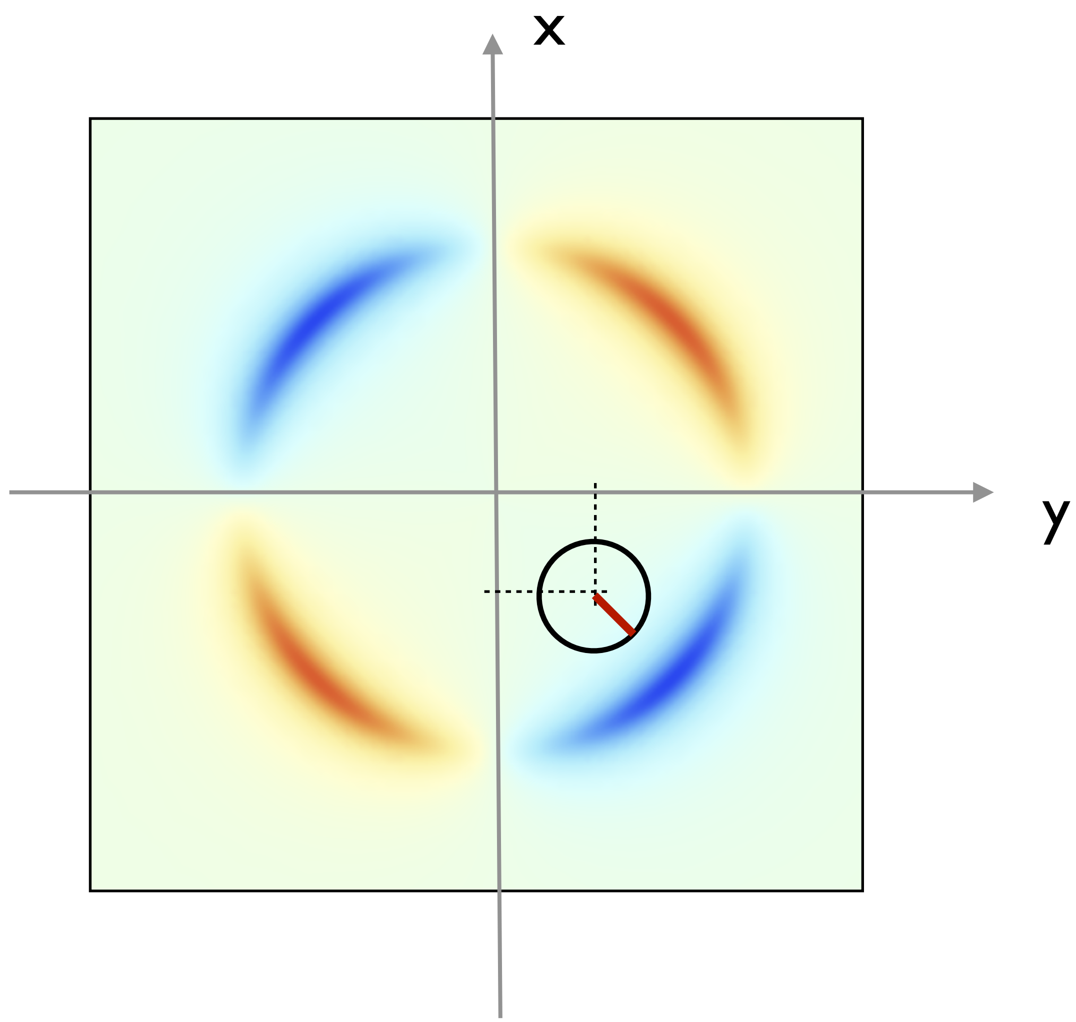


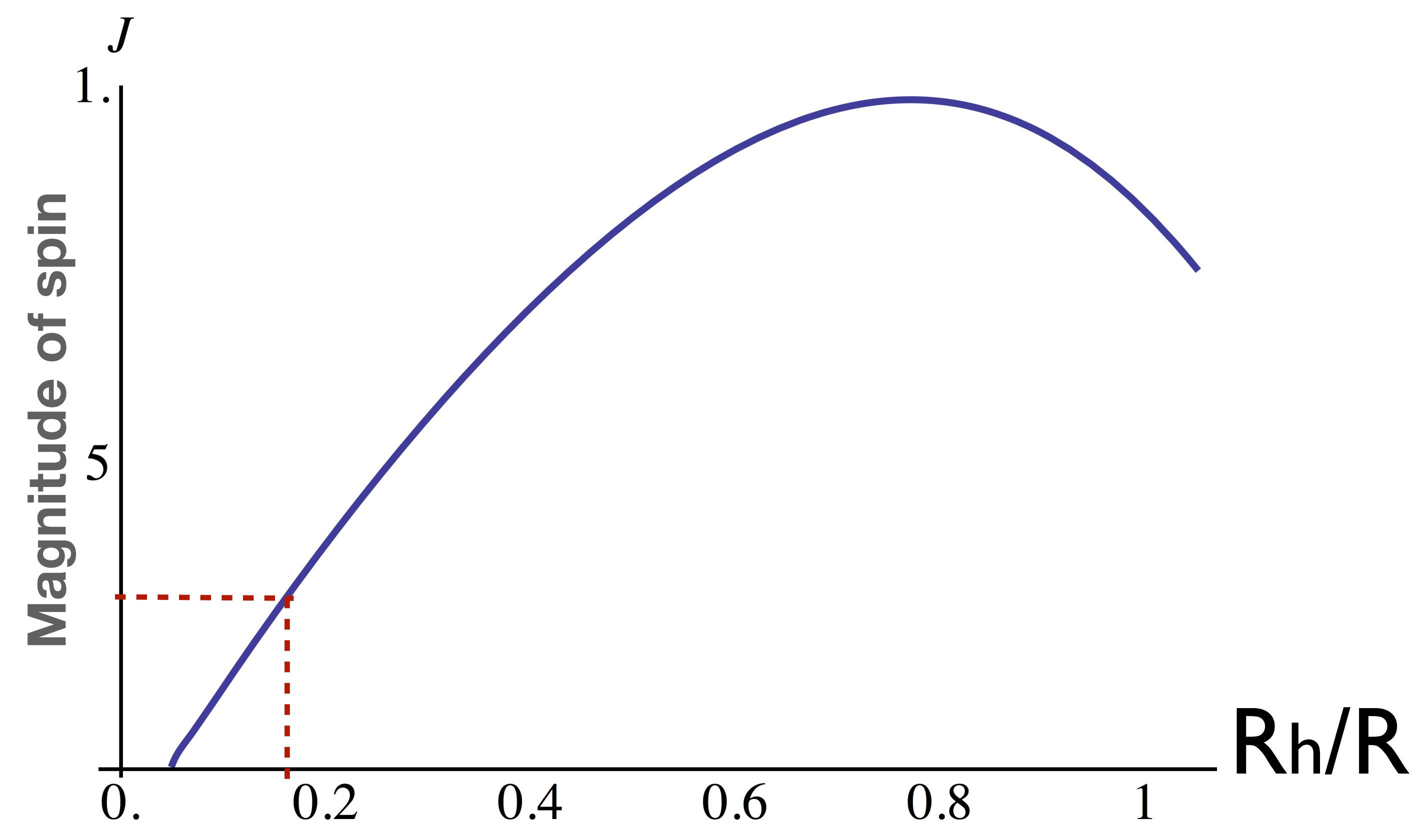


Halo spins are aligned with the vorticity in quadrants

Mass transition for spin alignment

Laigle+15



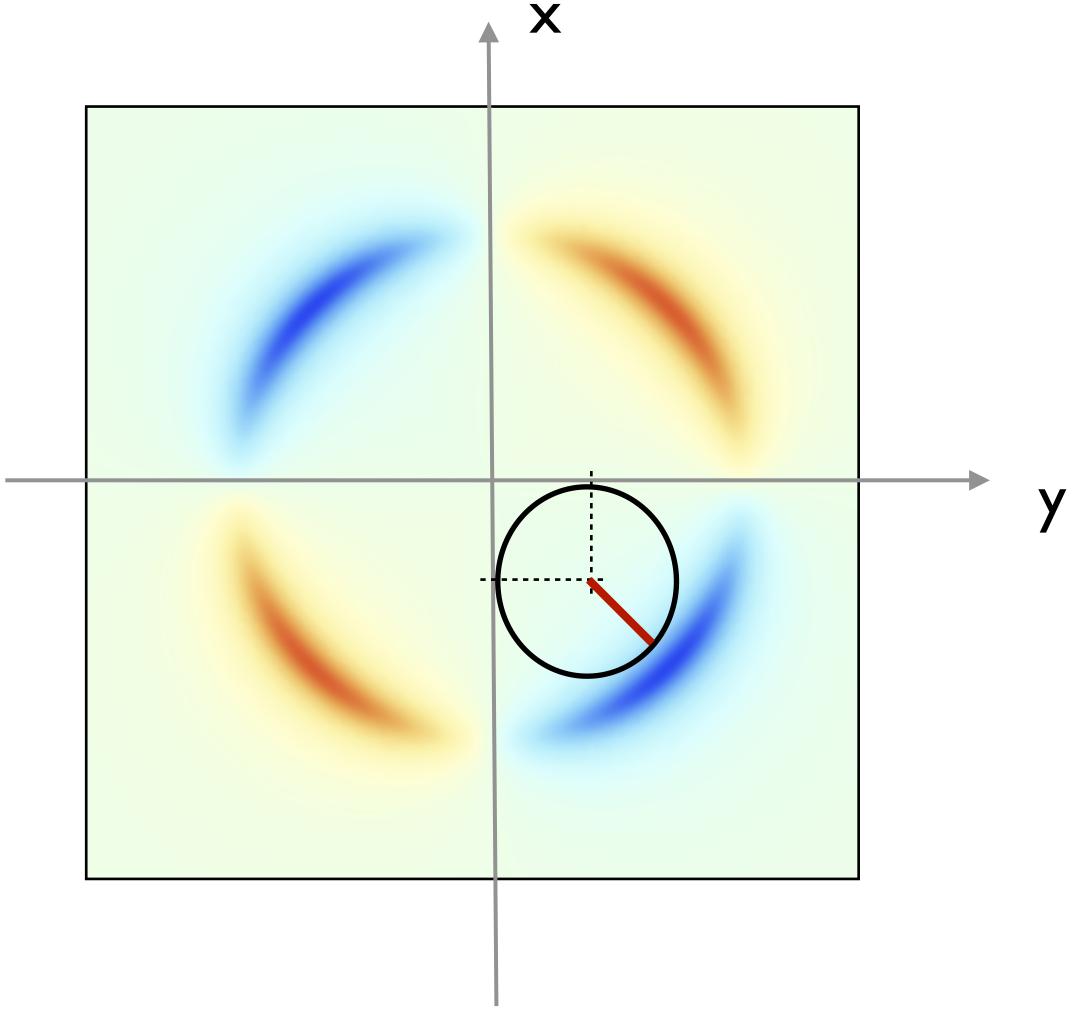


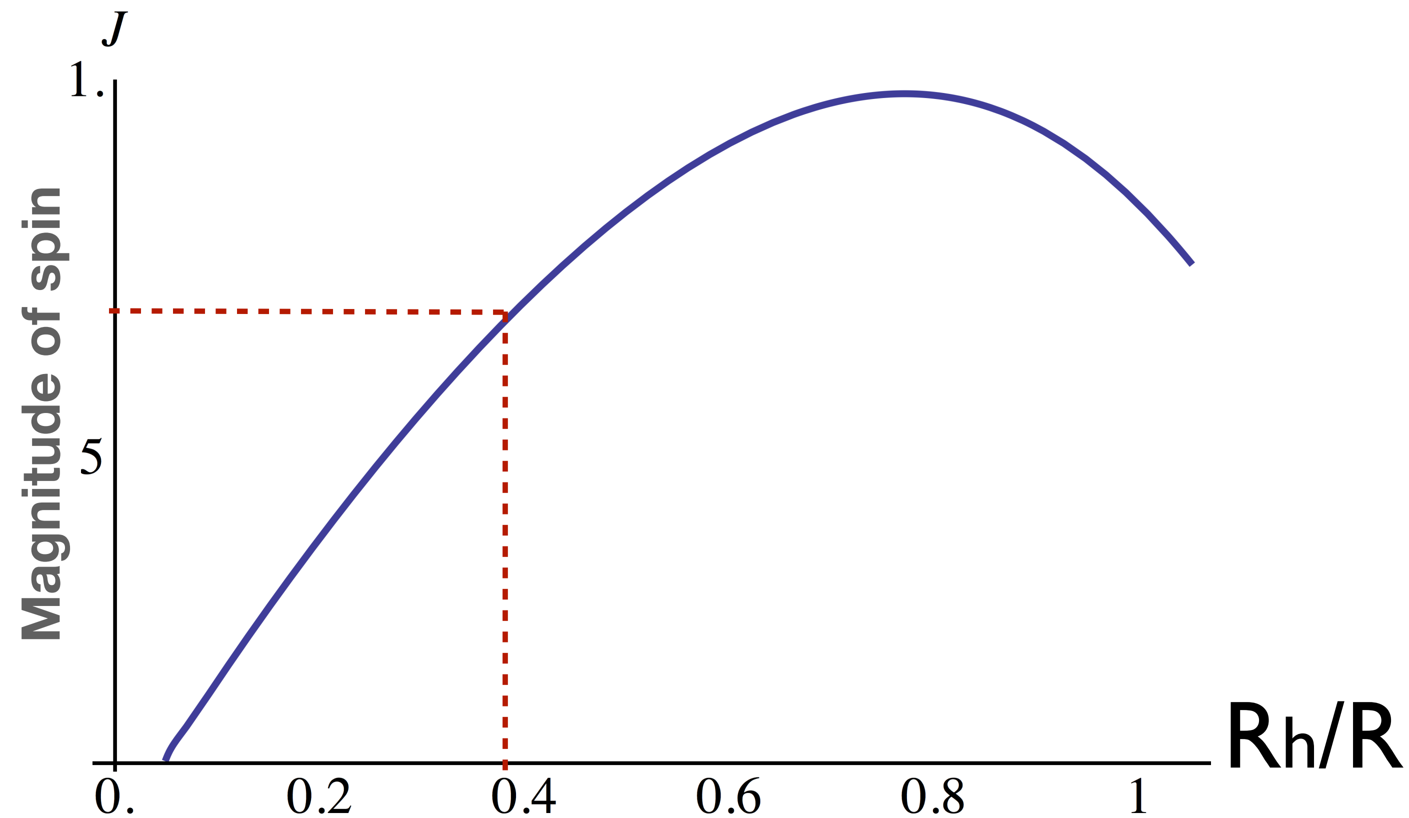
Idealized toy model: The position is fixed and the radius of the halo increases

Transition mass is correlated with the size of the quadrants

Mass transition for spin alignment

Laigle+15





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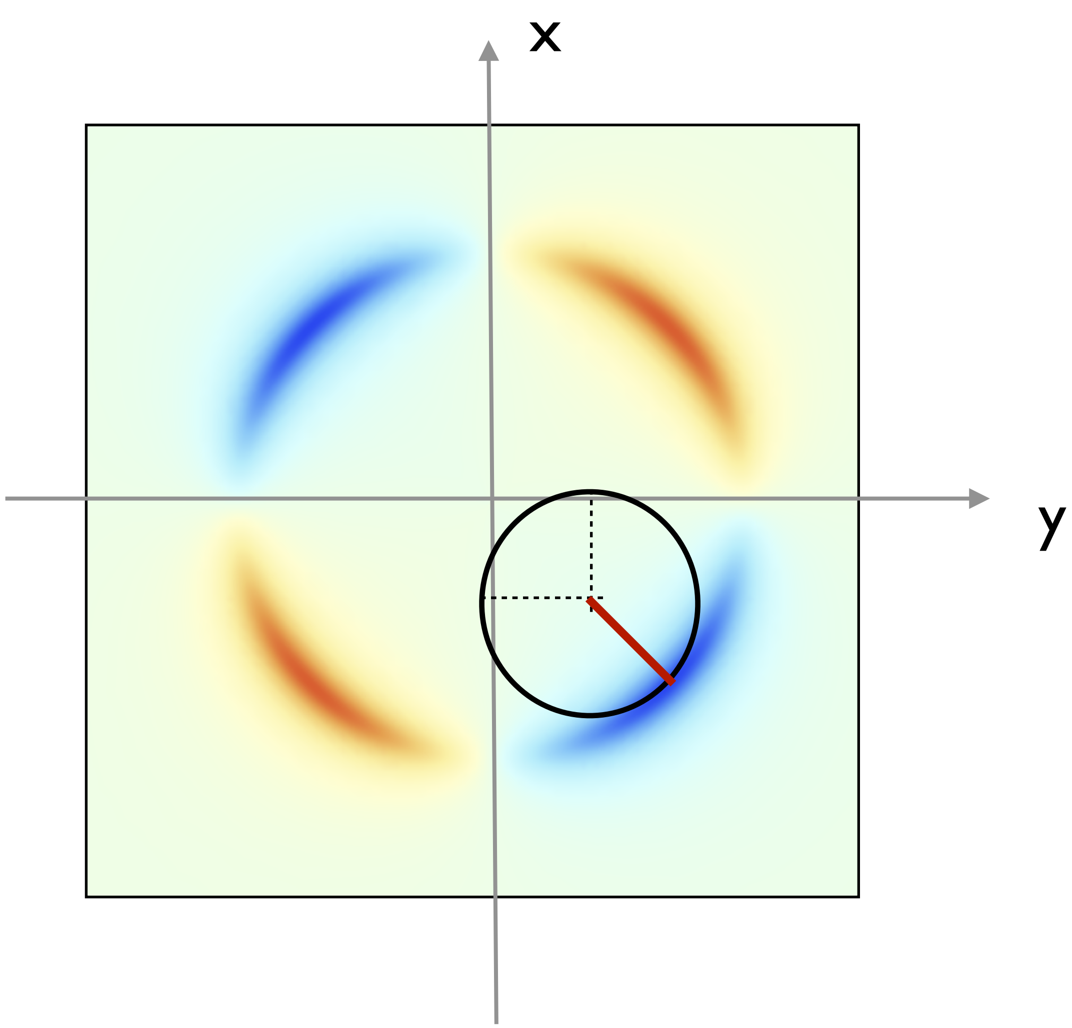

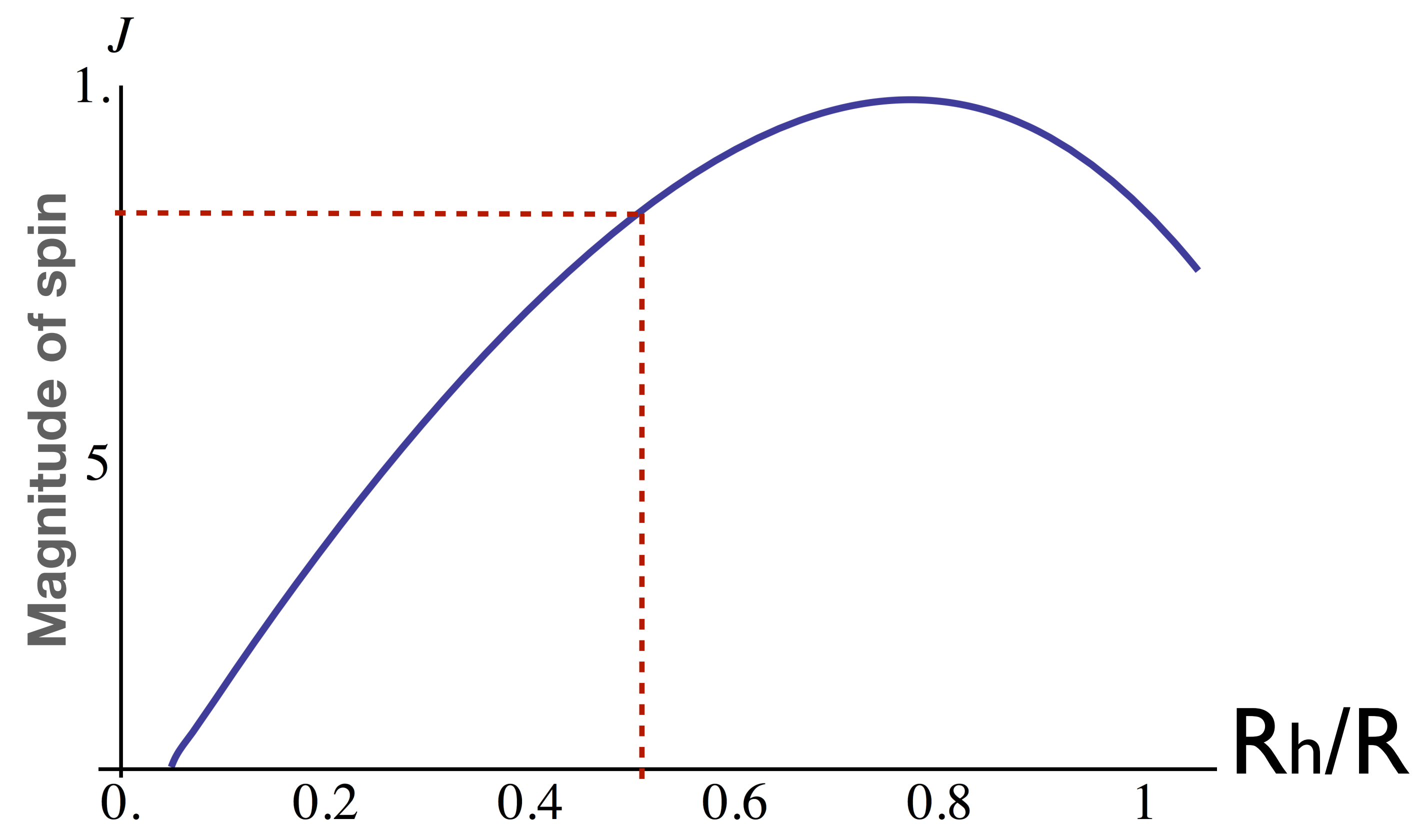

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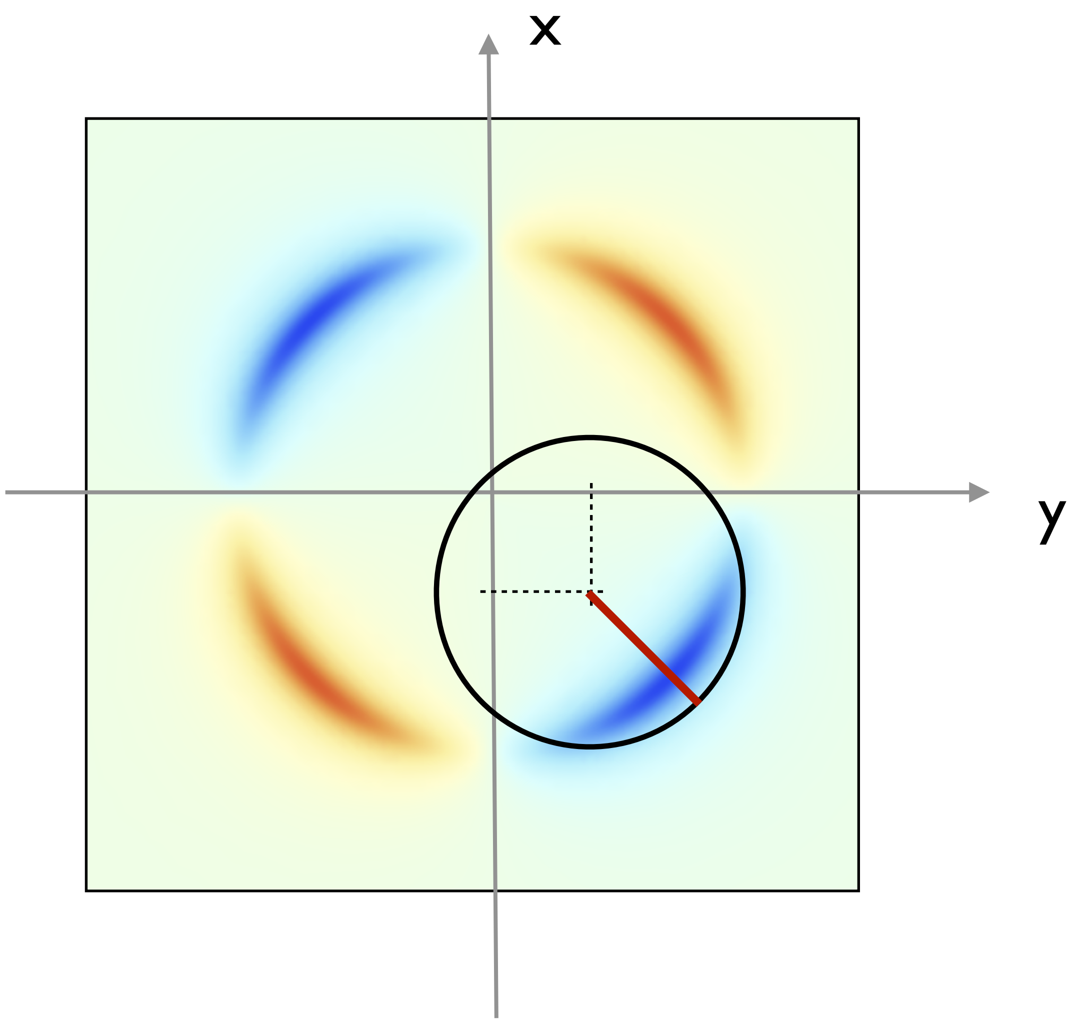

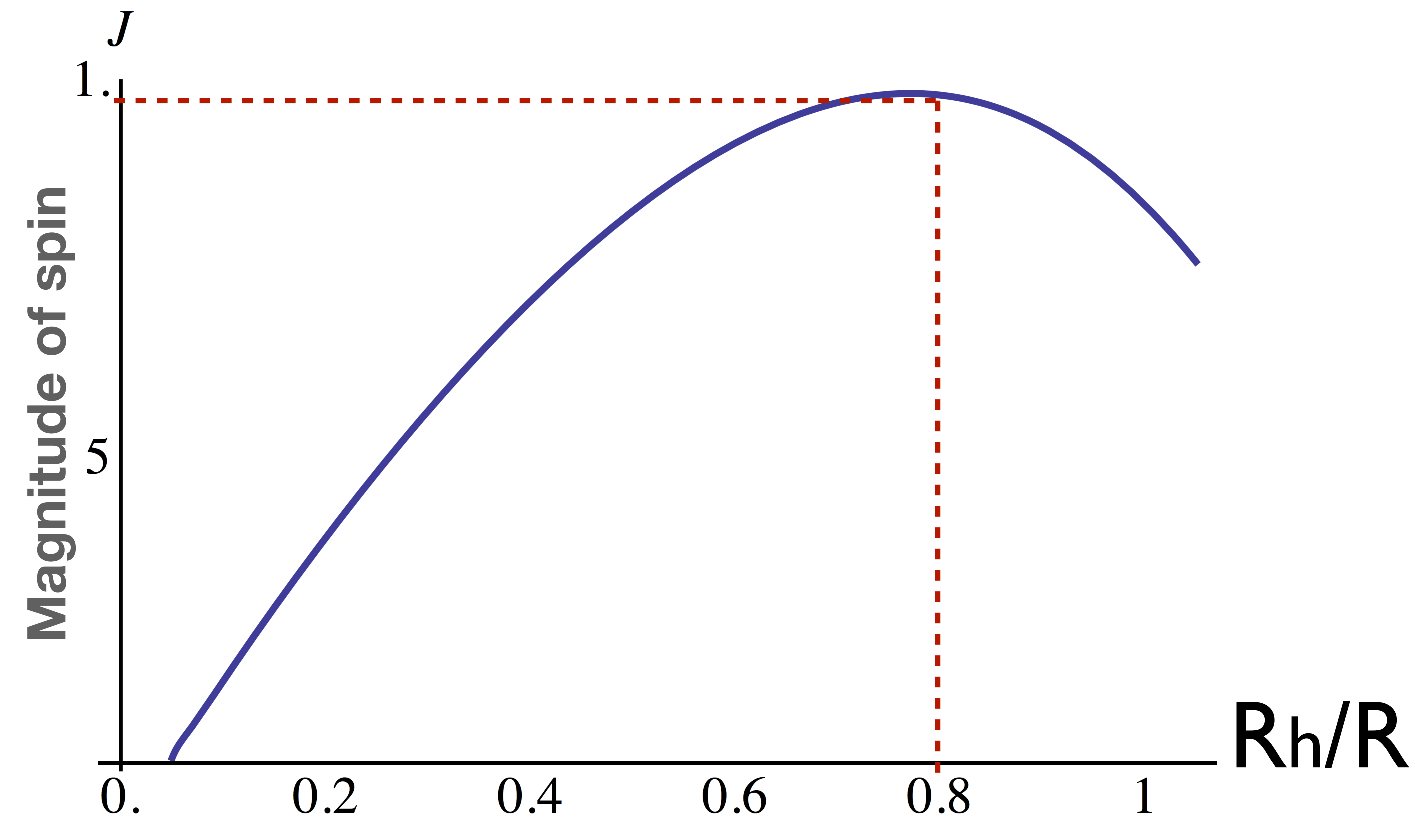

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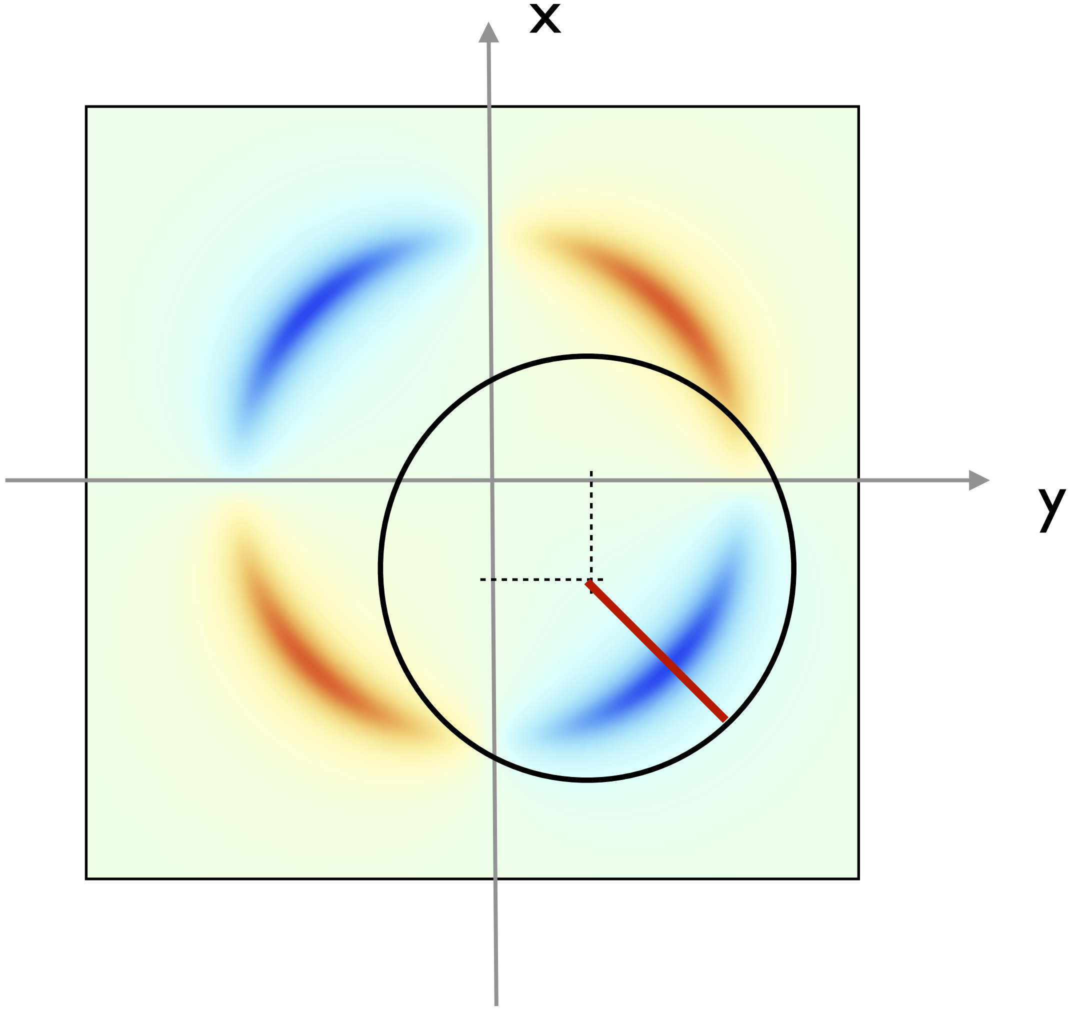

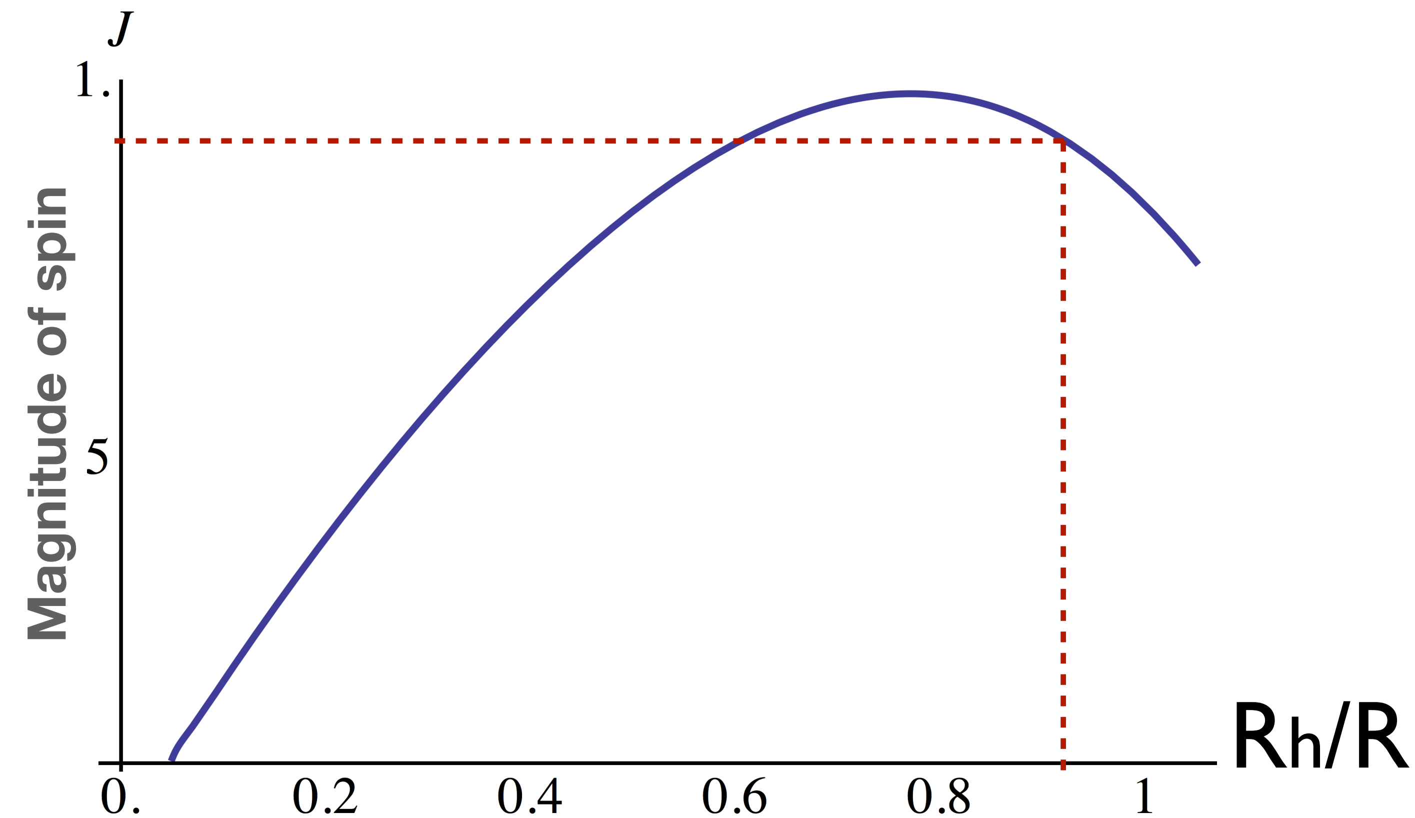

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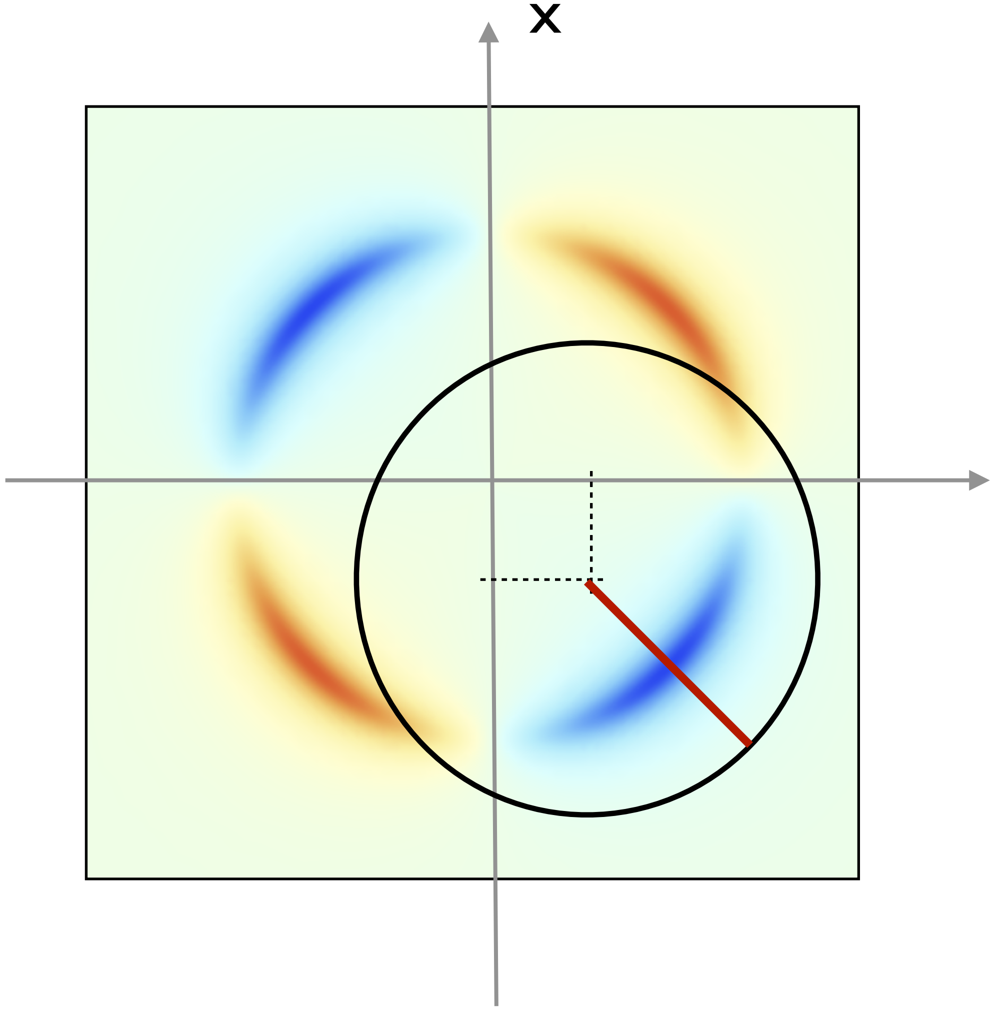

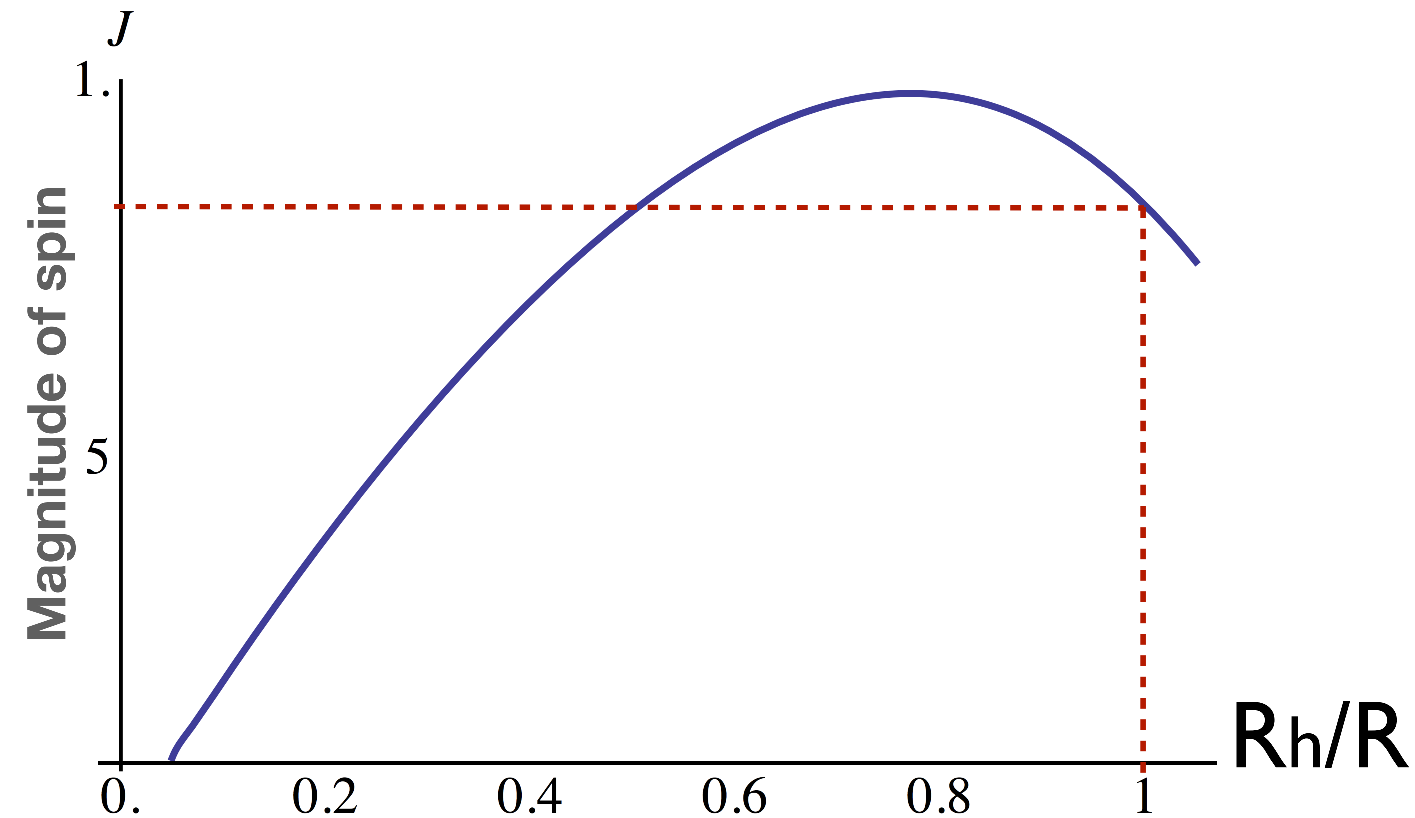

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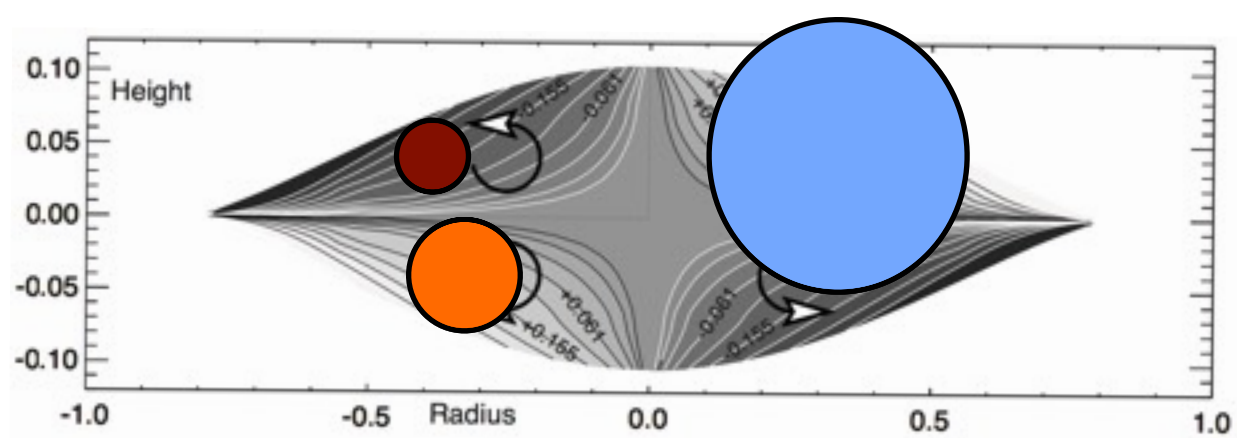
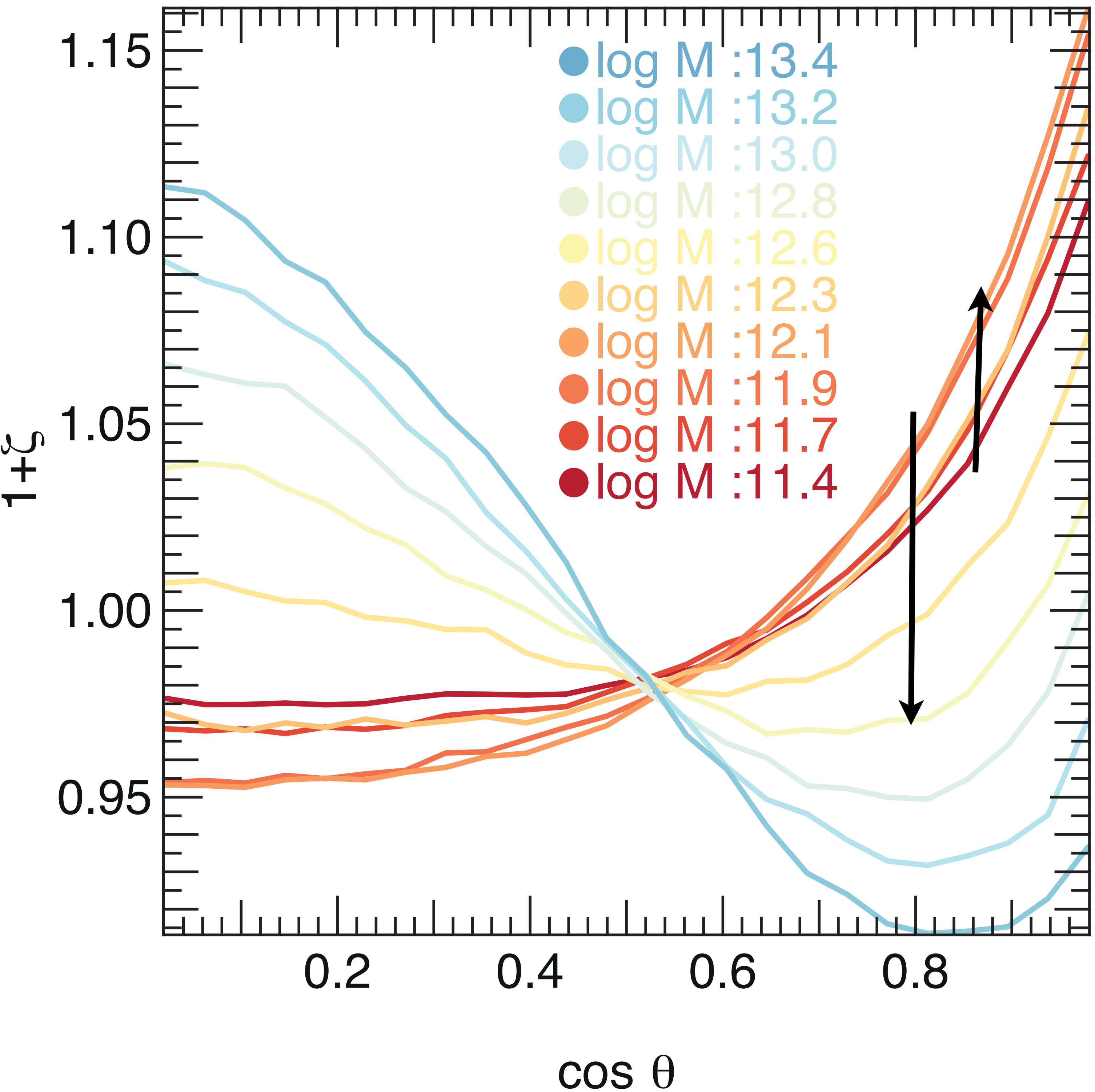
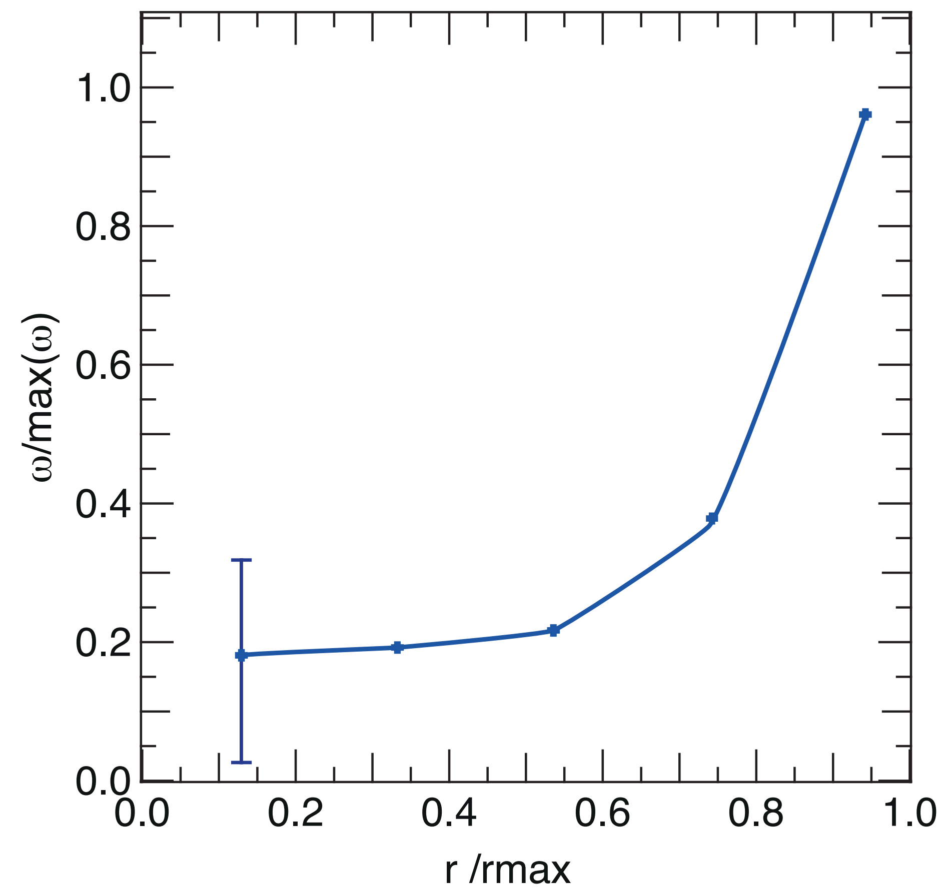


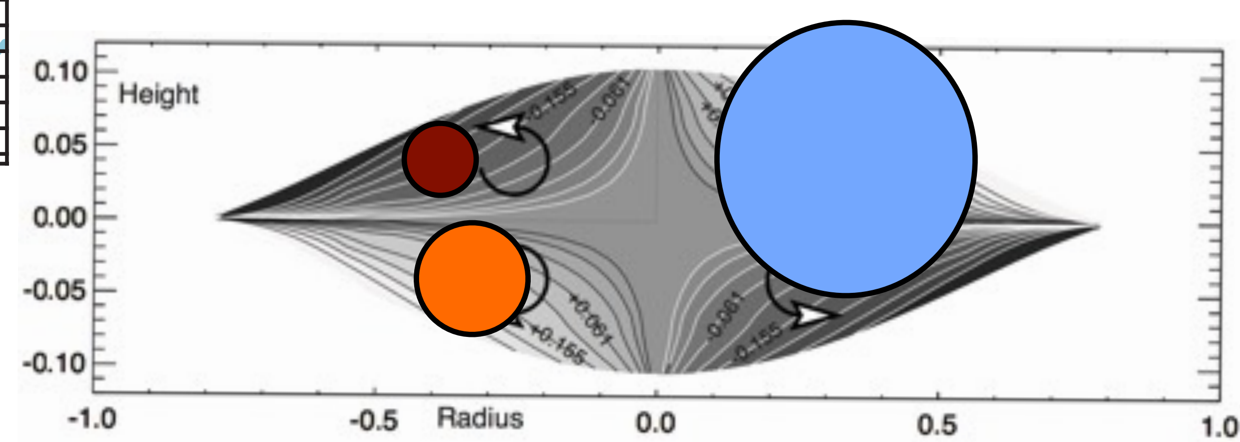
Revisit

Alignement of spin with cosmic web

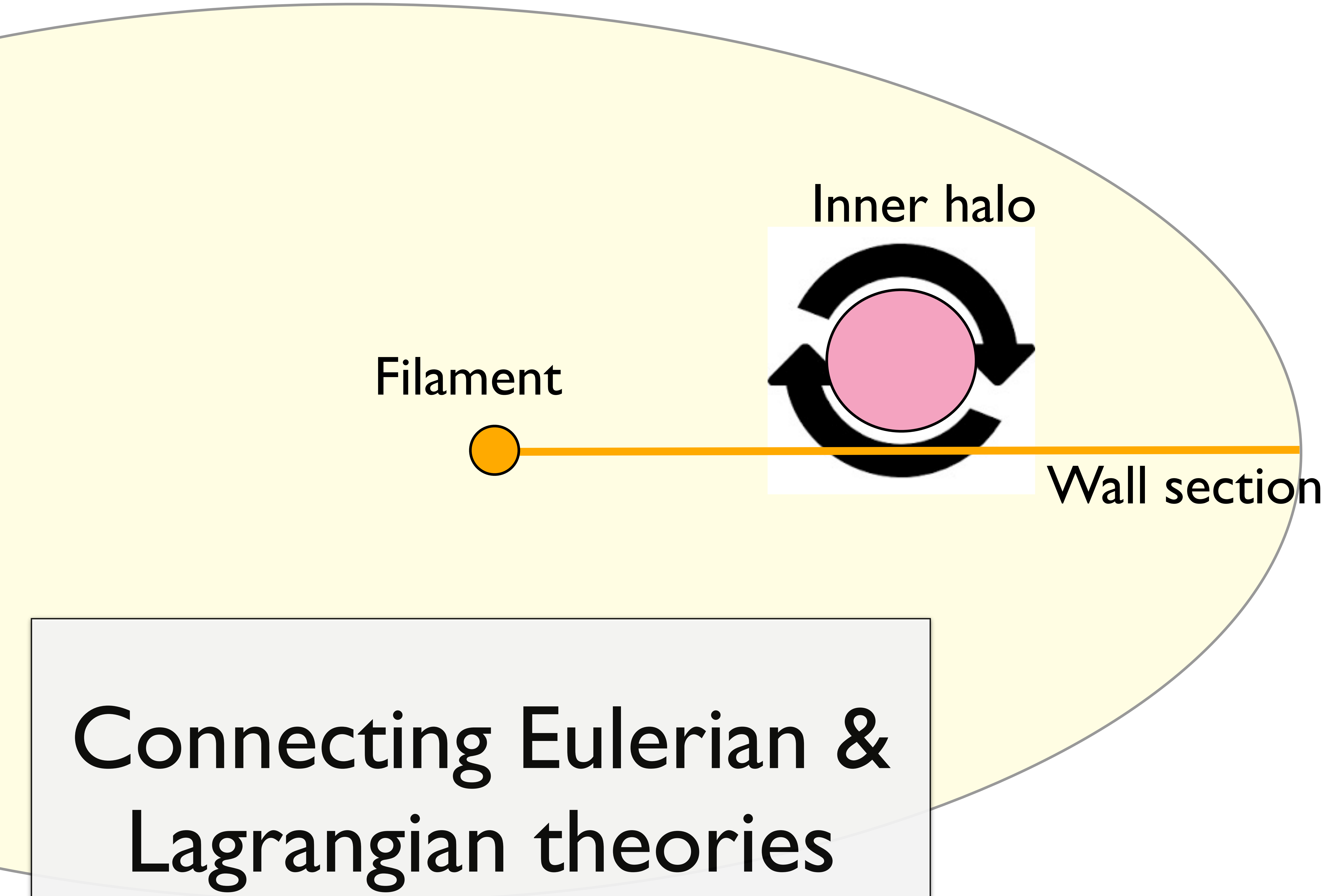
Spin alignment first INCREASES with mass



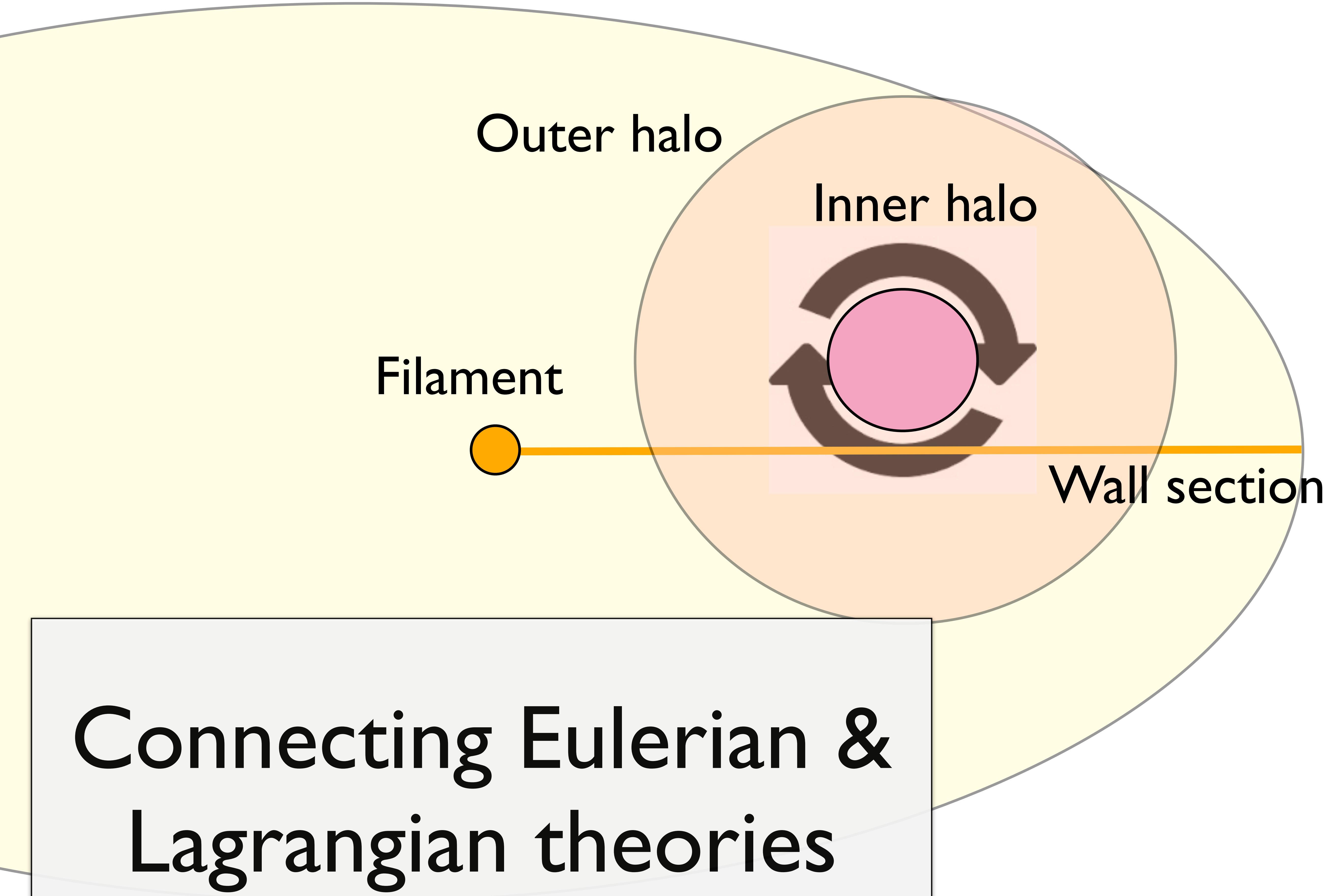




Spin flip imposed by caustic size



Connecting Eulerian & Lagrangian theories



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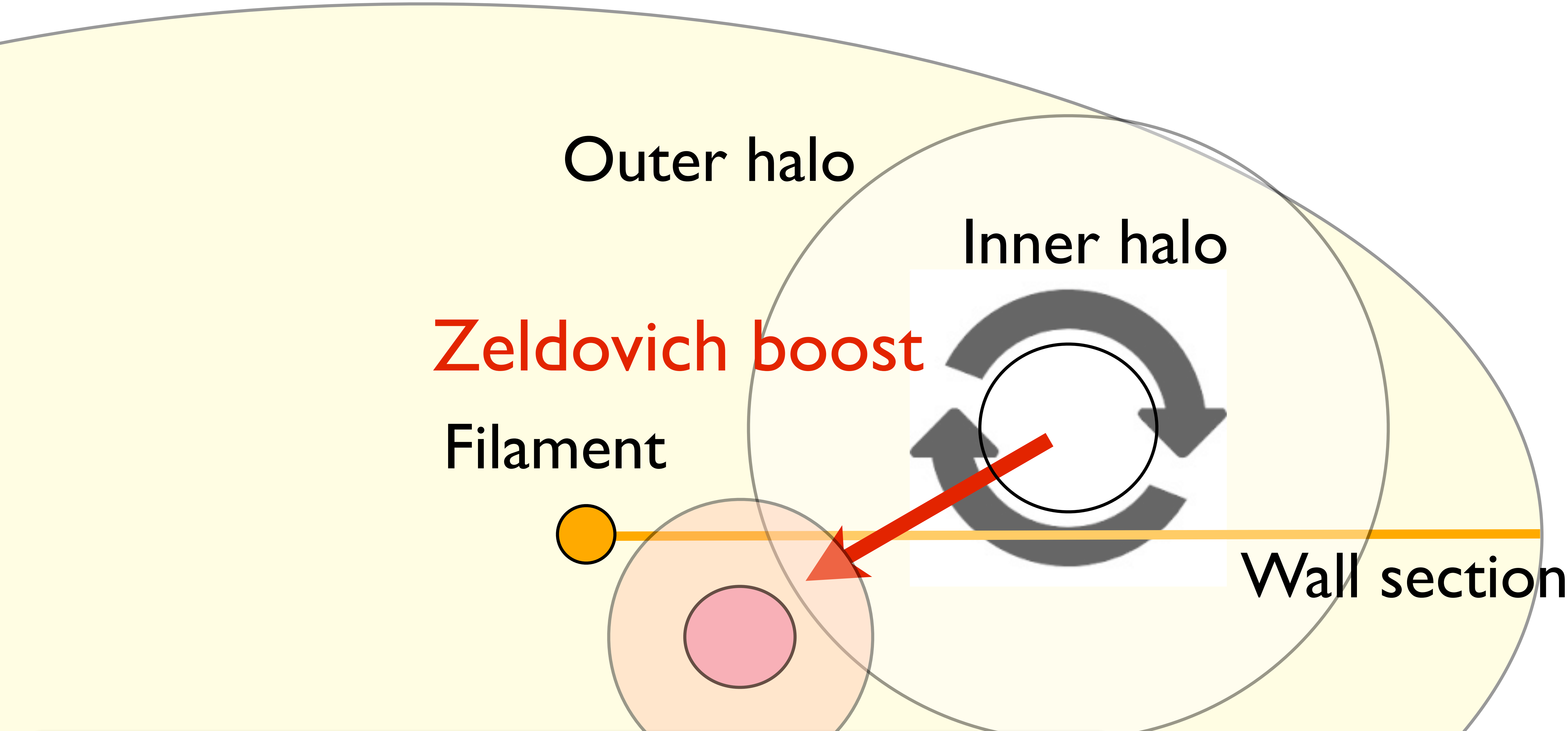

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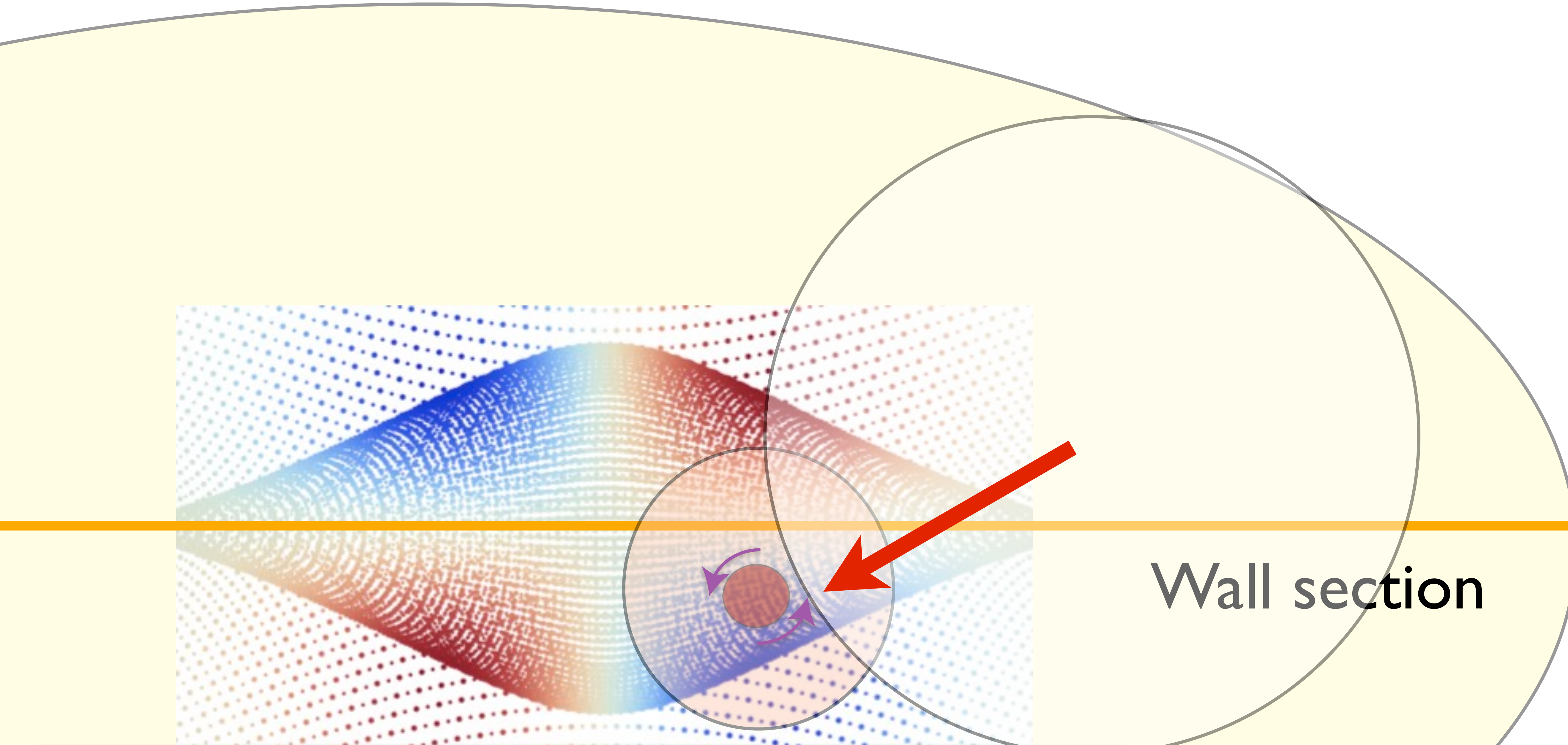

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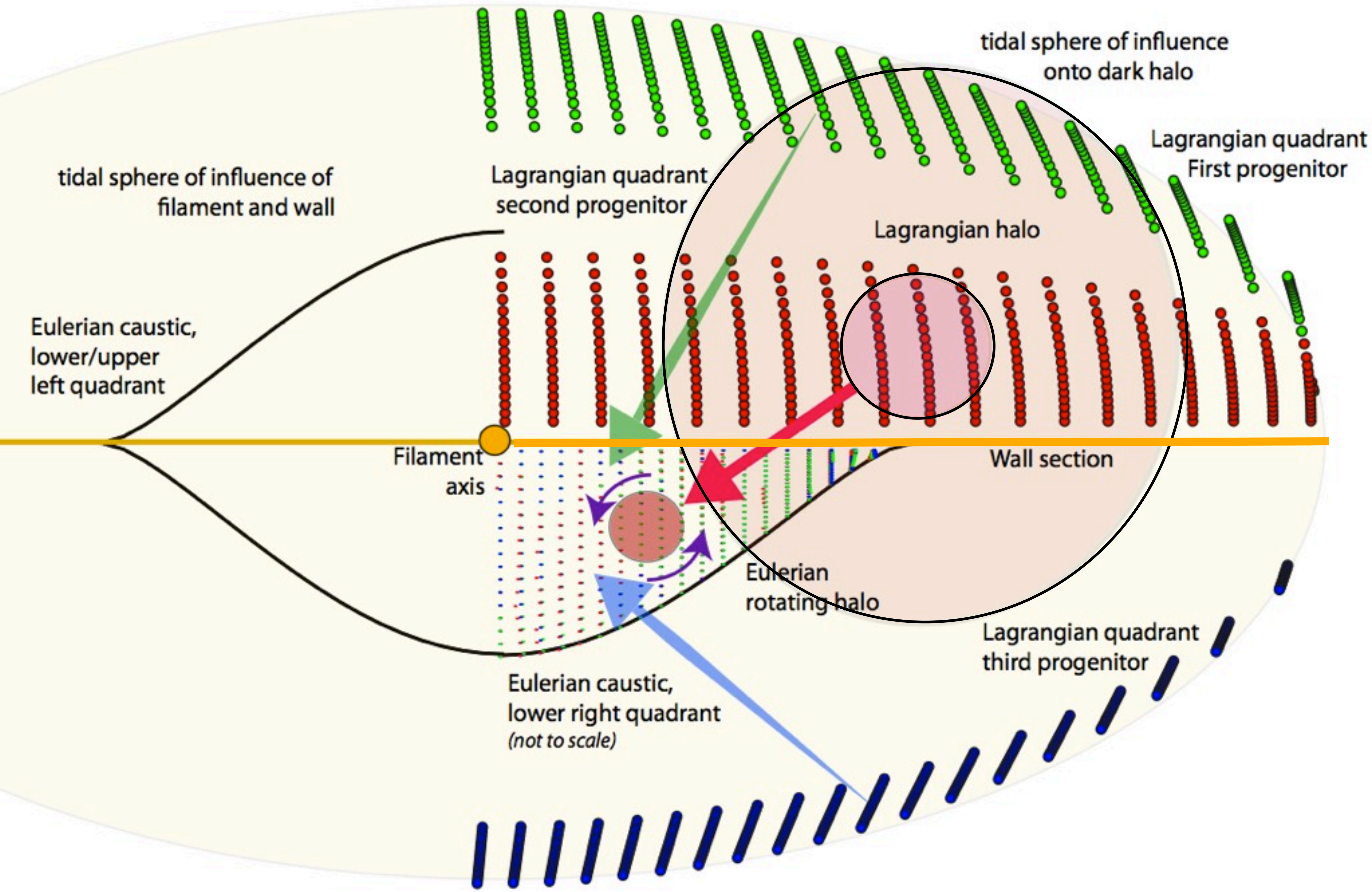
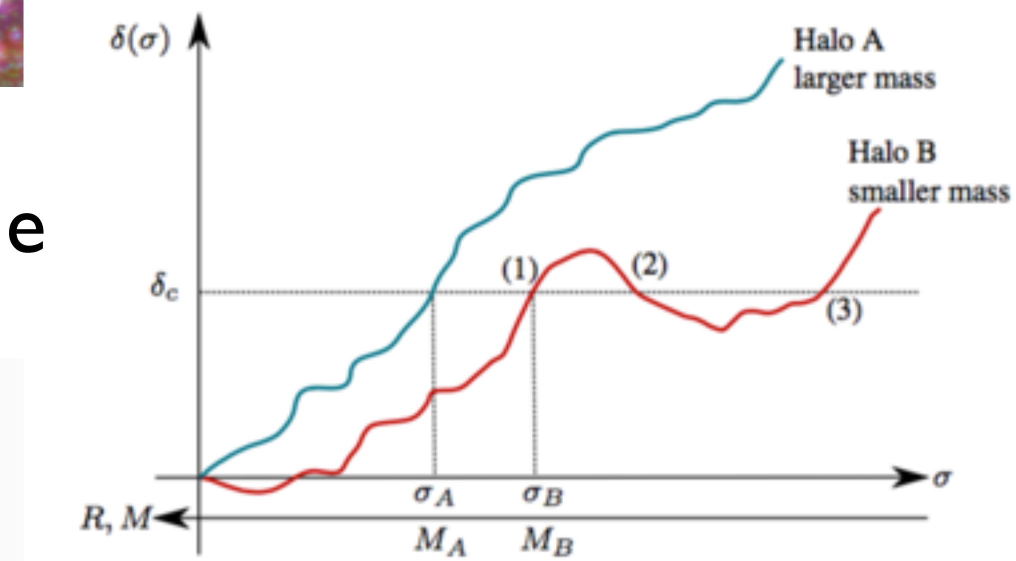

tidal sphere of influence
onto dark halo
Lagrangian quadrant
First progenitor
tidal sphere of influence of
filament and wall
Lagrangian quadrant
second progenitor
Lagrangian halo
Eulerian caustic,
lower/upper
left quadrant
Filament
axis
Wall section
Eulerian
rotating halo
Lagrangian quadrant
third progenitor
Eulerian caustic,
lower right quadrant
(not to scale)

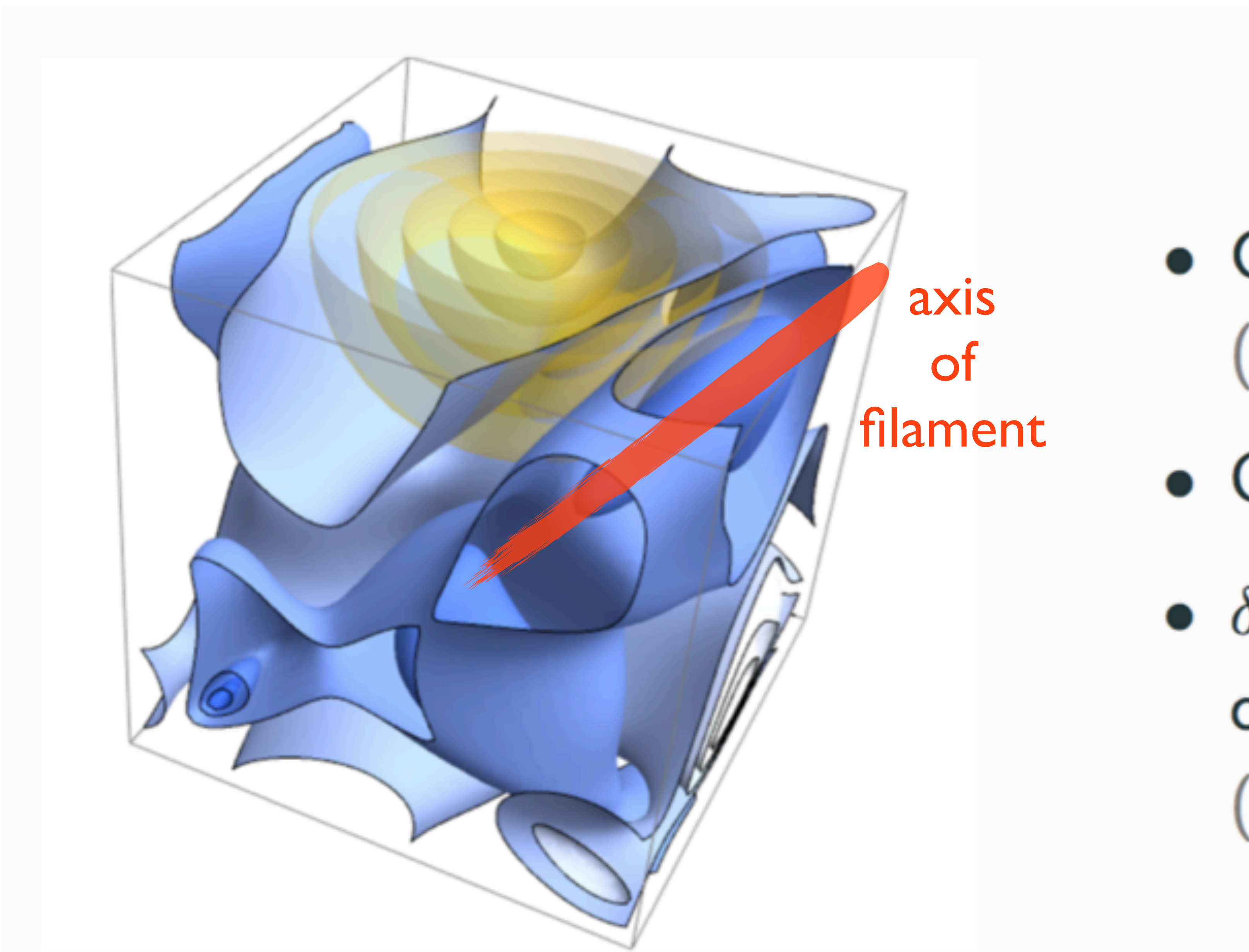

Let's now focus on colours...

Dark Matter Halos Assembly in the Frame of the Saddle Points of the Cosmic Web

or how does the cosmic web impacts assembly bias

Revisit (up crossing) excursion set theory / saddle





- Gaussian random field (initial conditions $\leftrightarrow$ CMB)
- Over-density $\delta \equiv \dfrac{\rho - \bar{\rho}}{\bar{\rho}}$
- $\delta = \delta_c / D(z) \Rightarrow$ spherical collapse at $z = 0$ (a DM halo will form)

Dark Matter Halos Assembly in the Frame of the Saddle Points of the Cosmic Web

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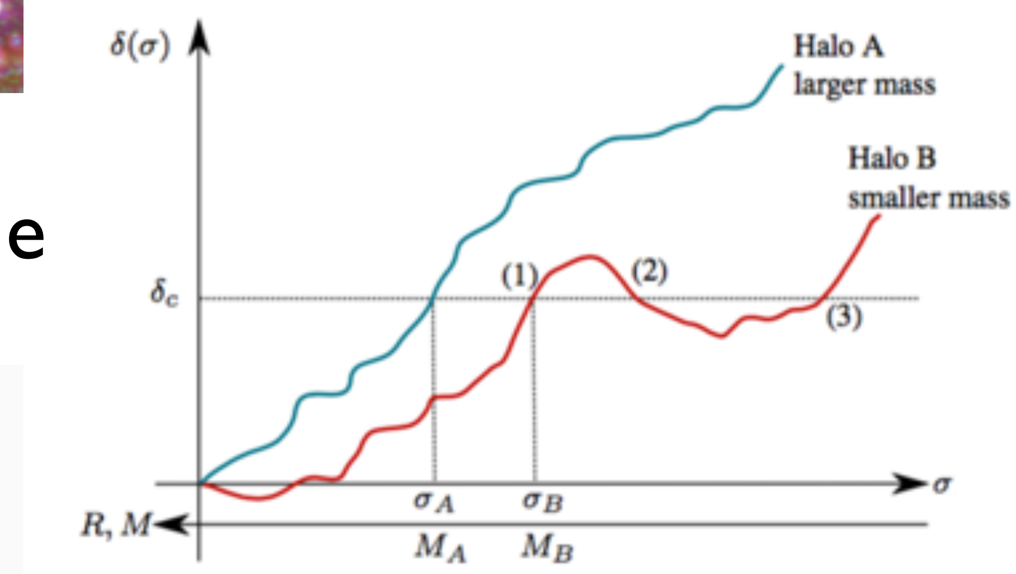

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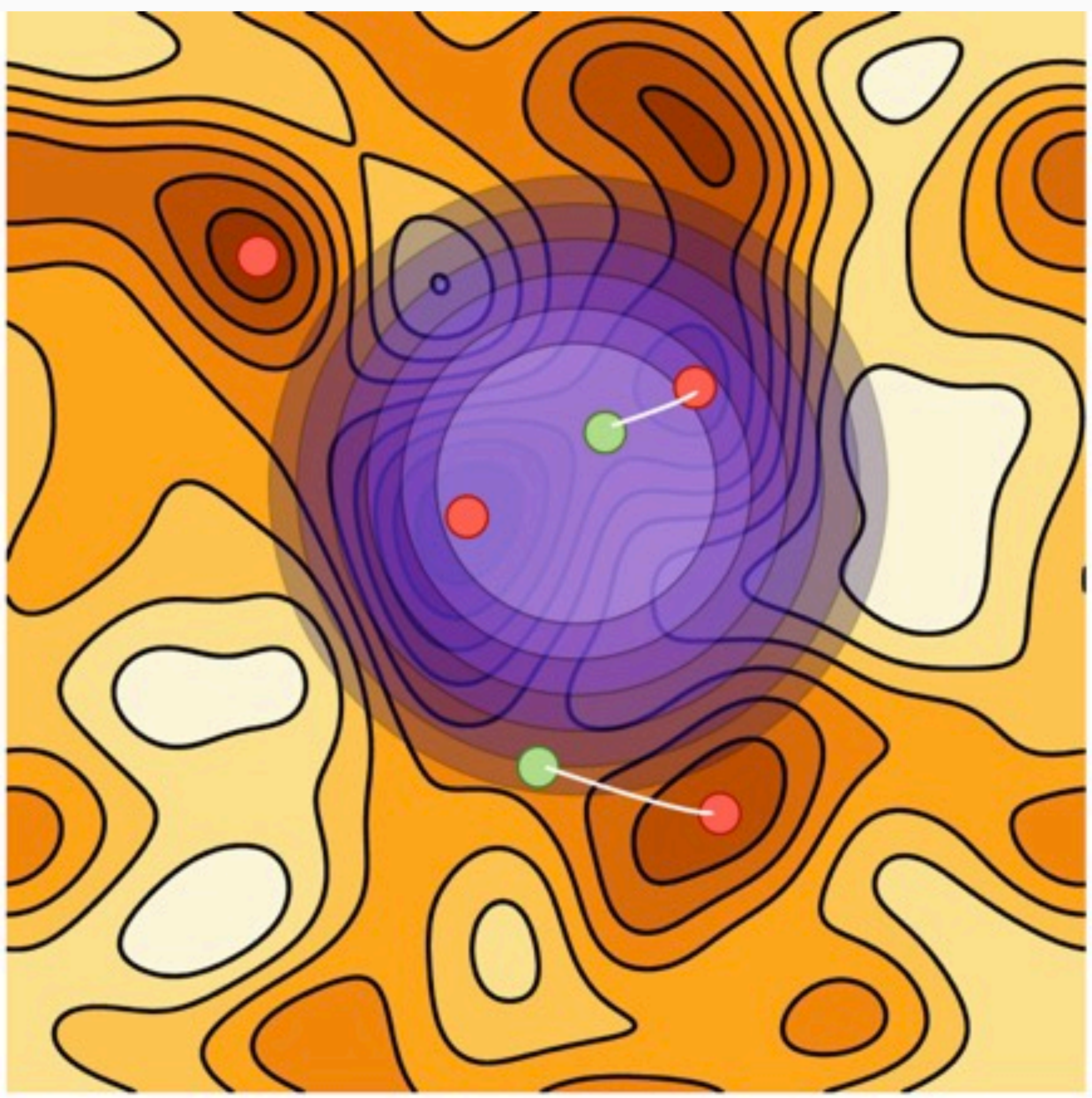

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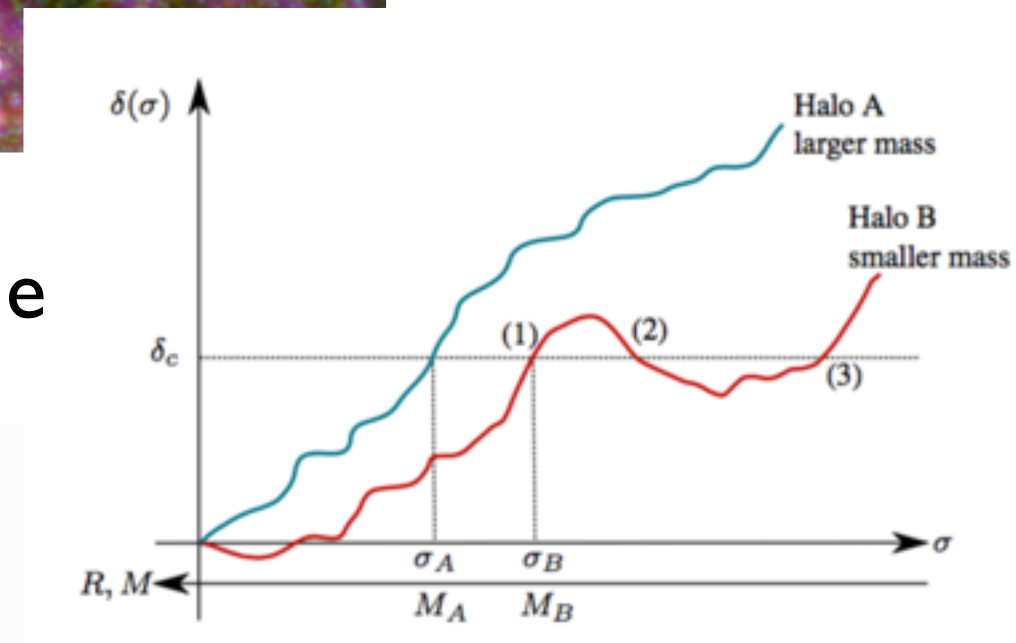
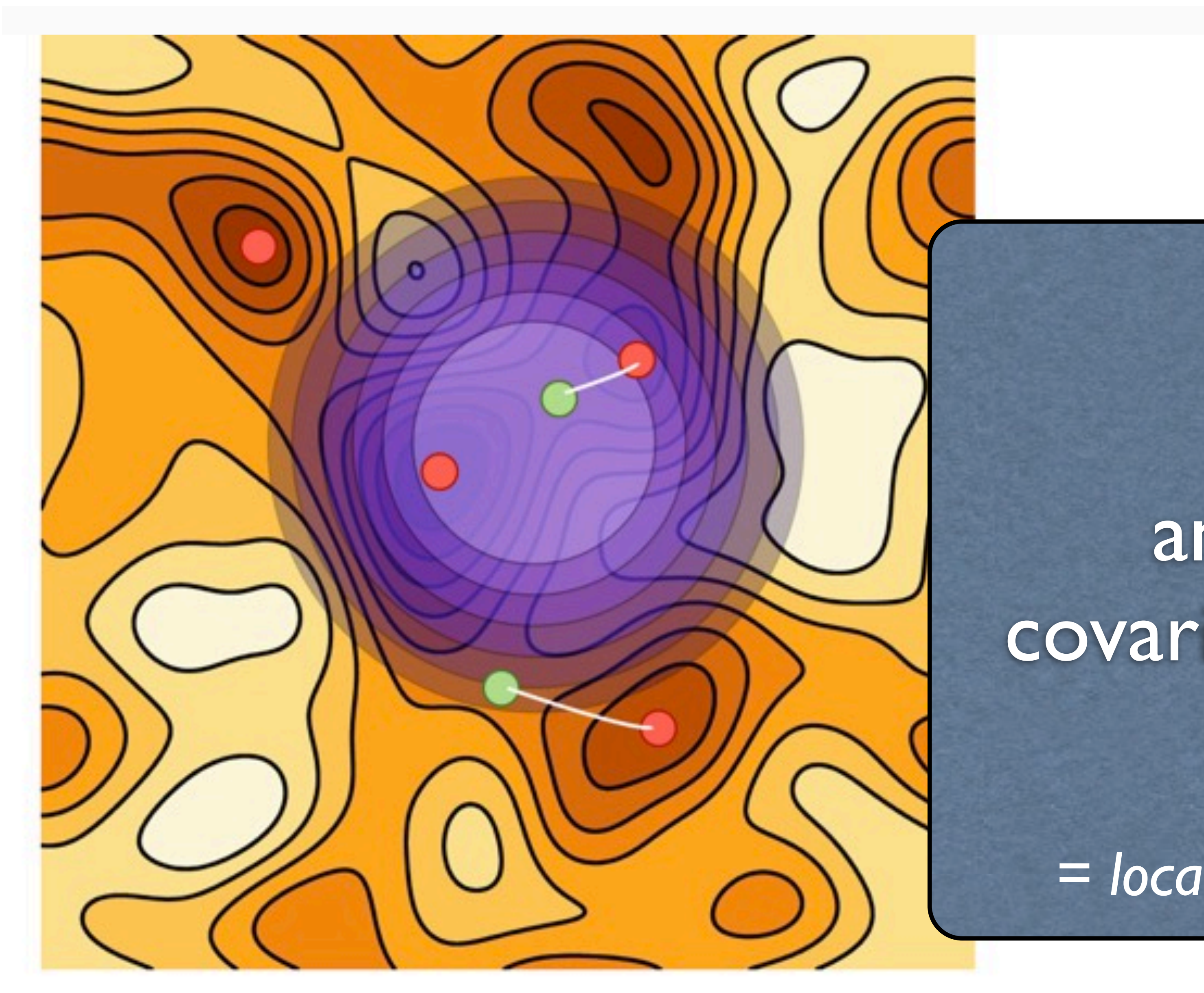


Revisit (up crossing) excursion set theory / saddle



$$E(Y|x) = \mu_Y + \rho \frac{\sigma_Y}{\sigma_X}(x - \mu_X)$$

and keep in mind the covariances are also shifted !!

$$\sigma^2_{Y|X} = \sigma^2_Y(1 - \rho^2)$$

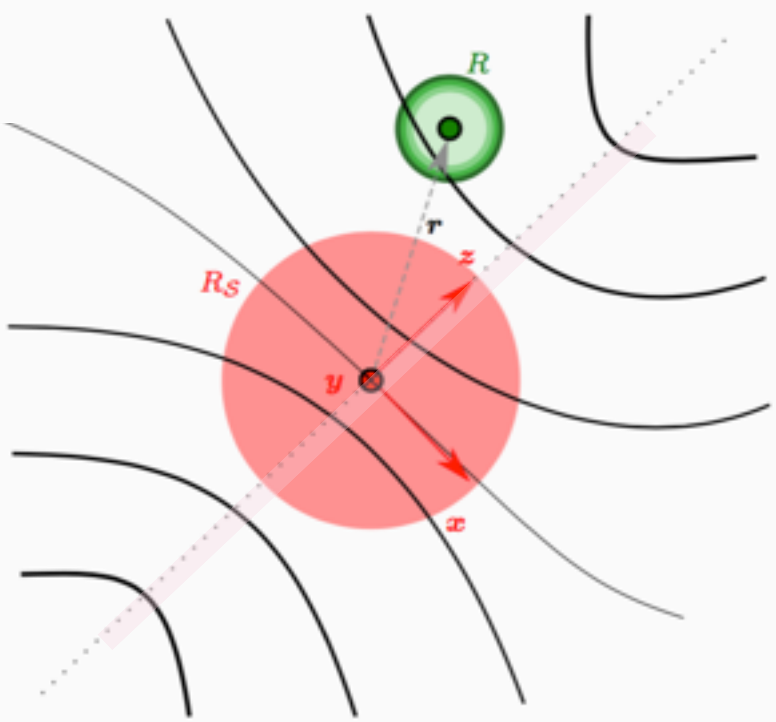
= *local clock* = *strength of environment*

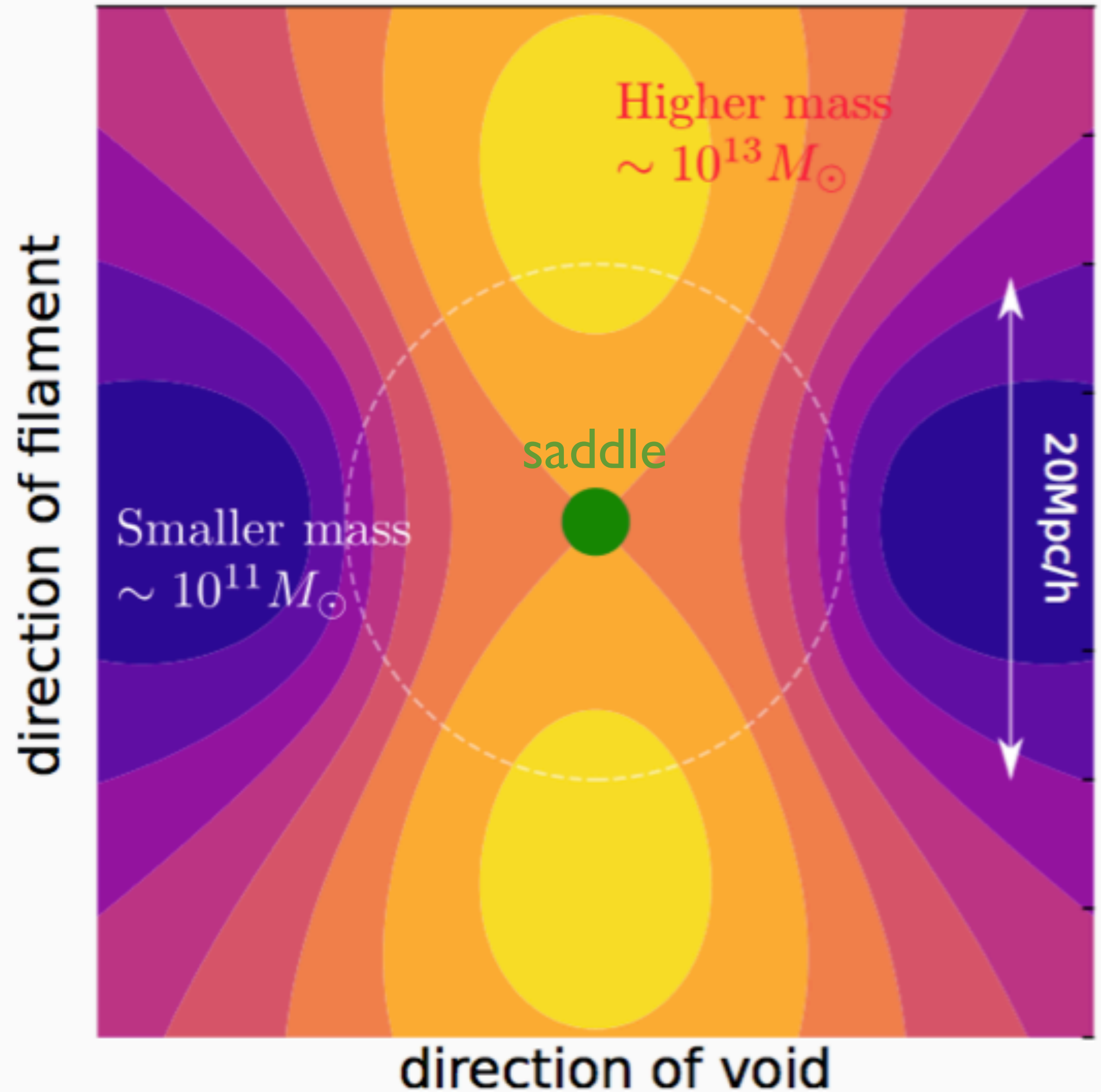
Typical mass in frame of saddle

extra degree of freedom, Q(θ,φ), provides a supplementary vector space

$$q_{ij} = \nabla_i \nabla_j \varphi$$

$$\mathcal{Q} = \sum_i \sum_j \frac{r_i \bar{q}_{ij} r_j}{\|\mathbf{r}\|^2}$$





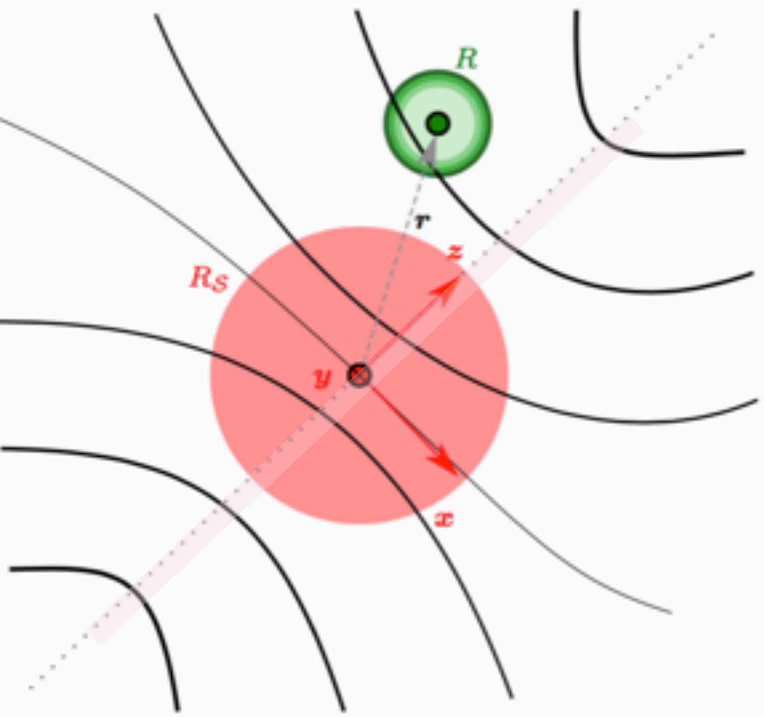
$$\Delta M_\star(\mathbf{r}) \propto \delta_S \xi_{20}(r) \mathcal{Q}$$

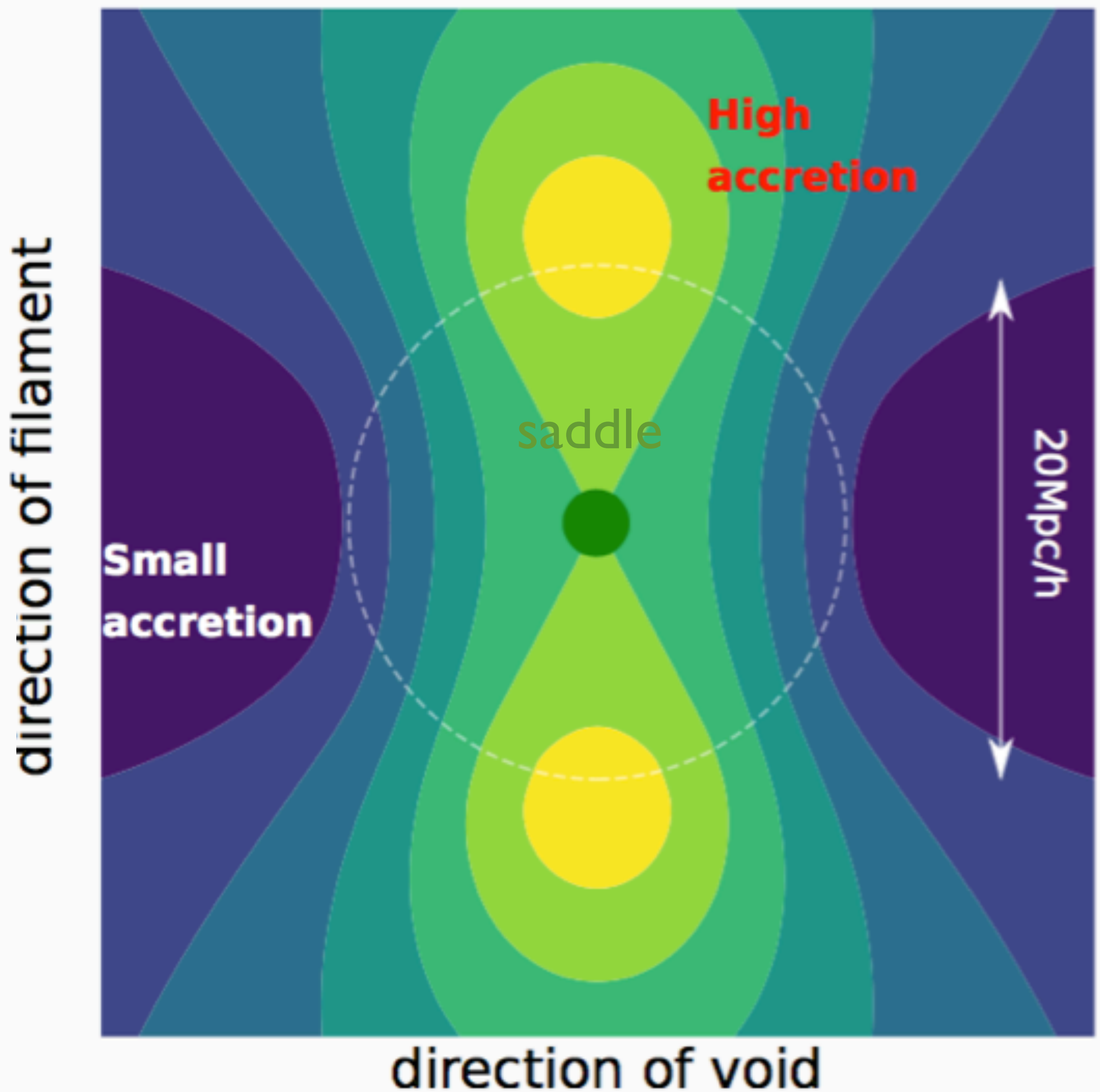
ξ_{20}: corr. density-tide

density

Accretion rate @ $\approx 3 \times 10^{11}\,\mathrm{M}_\odot$ & $z = 0$ in frame of saddle

$$\mathcal{P}(\delta, \partial_R \delta | \mathcal{S}addle)$$

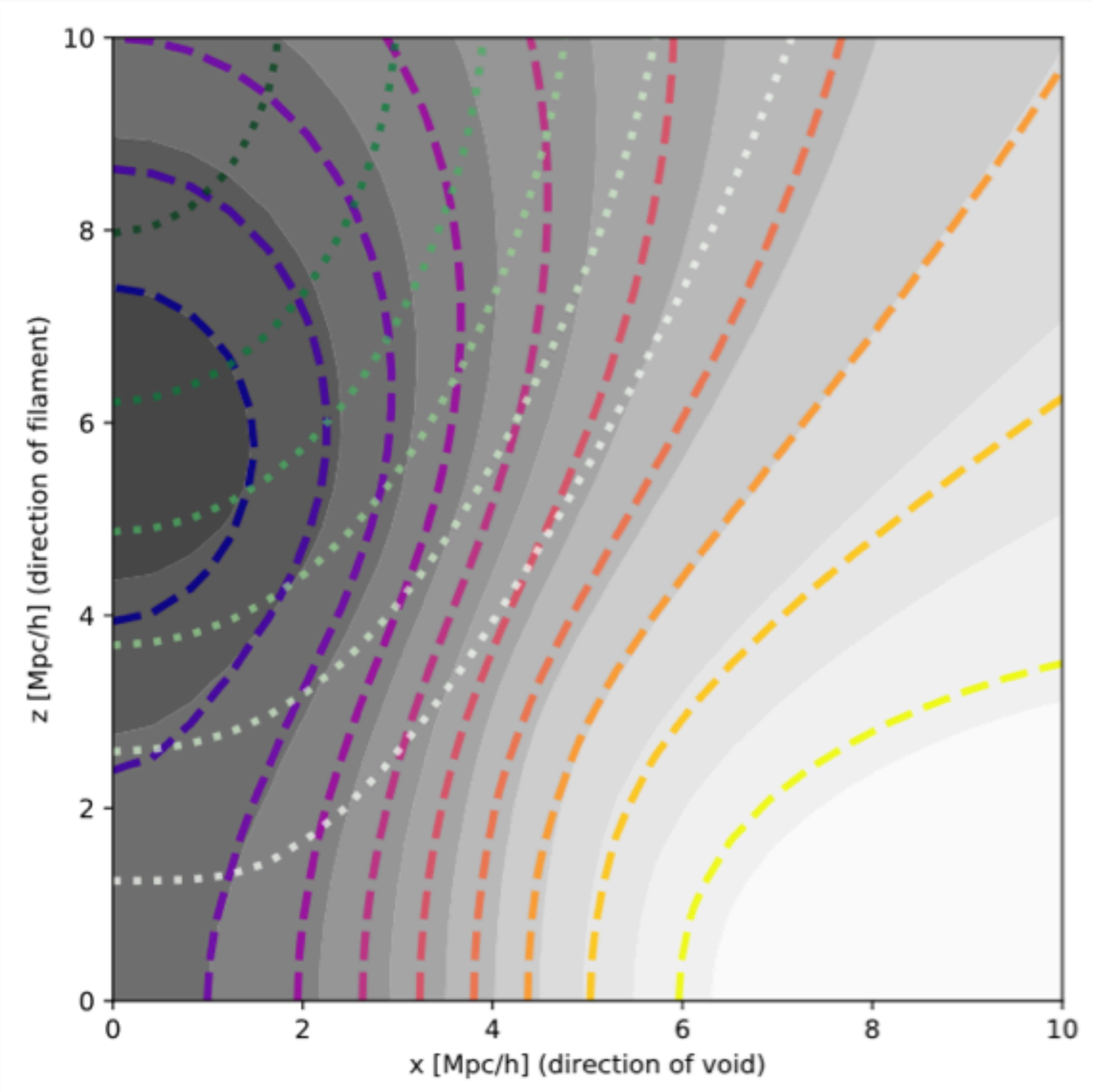




$$\Delta \dot{M}(\mathbf{r}) \propto \left[\xi'_{20} - \frac{\sigma - \xi'_I \xi_I}{\sigma^2 - \xi^2} \xi_{20} \right] \mathcal{Q}$$

ξ'_{20}: corr. slope-tide + variance of field

Gradient alignment in frame of saddle



cross product of normals

$$\left(\frac{\partial \dot{M}_\star}{\partial r}\frac{\partial M_\star}{\partial \mathcal{Q}} - \frac{\partial \dot{M}_\star}{\partial \mathcal{Q}}\frac{\partial M_\star}{\partial r}\right)\tilde{\nabla}\mathcal{Q}$$

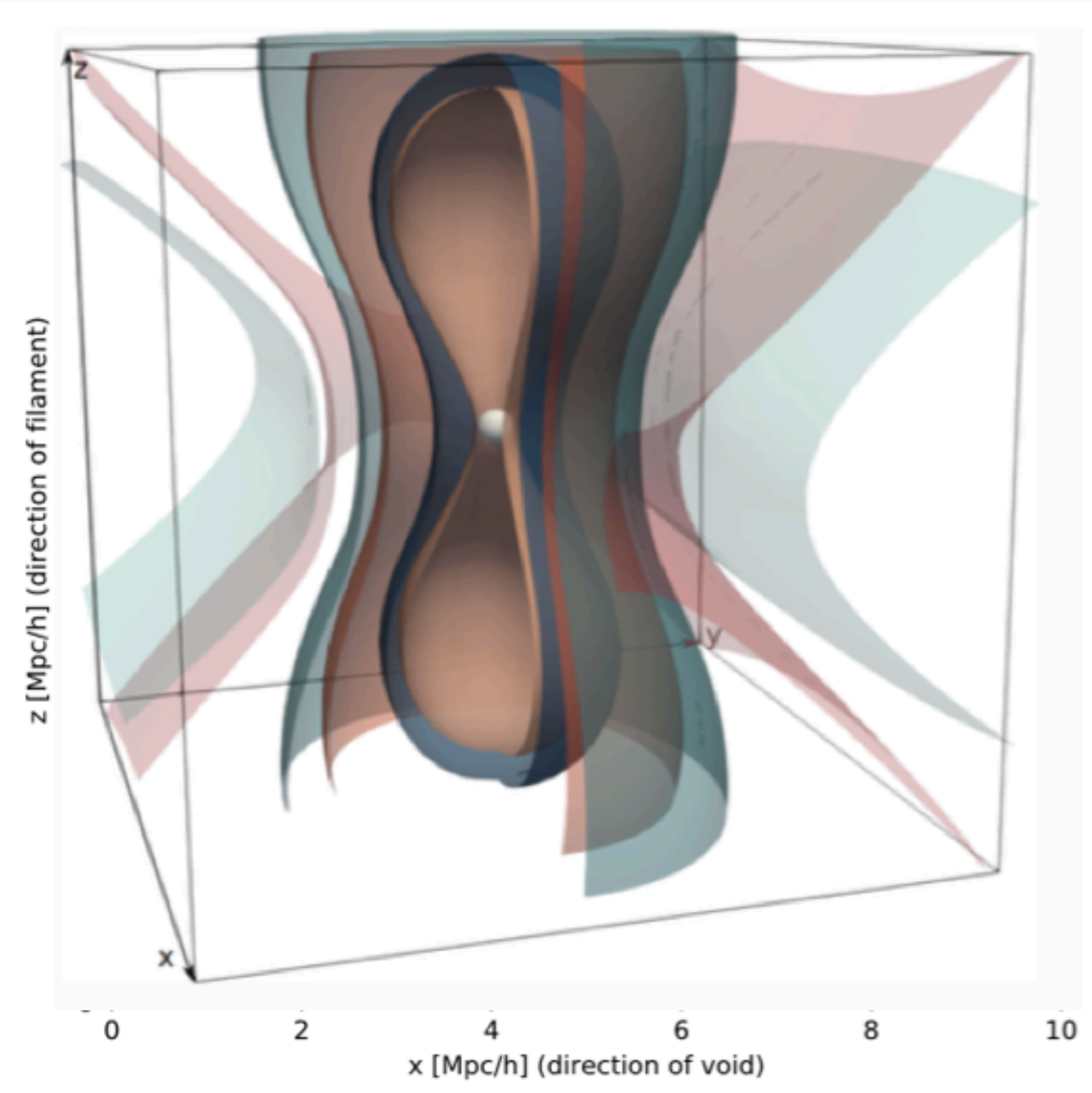
- background: ρ
- dotted M
- dashed $\dot{M}$

$\Rightarrow$ different gradients

accretion rate is not a function of mass and density alone

K. Kraljic, S. Arnouts, C. Pichon, C. Laigle, S. de la Torre, D.Vibert, C. Cadiou et al., MNRAS

Gradient alignment in frame of saddle



cross product of normals

$$\left(\frac{\partial \dot{M}_\star}{\partial r}\frac{\partial M_\star}{\partial \mathcal{Q}} - \frac{\partial \dot{M}_\star}{\partial \mathcal{Q}}\frac{\partial M_\star}{\partial r}\right)\tilde{\nabla}\mathcal{Q}$$

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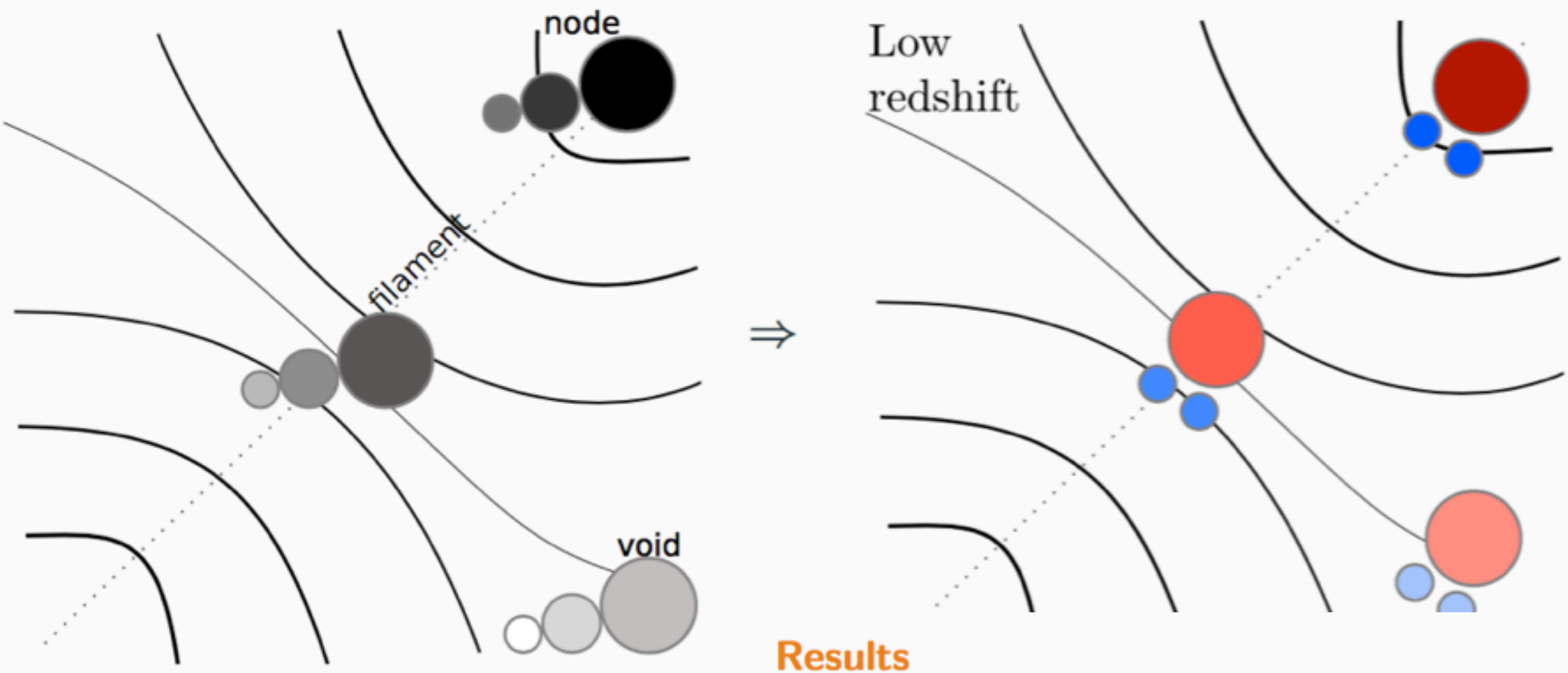
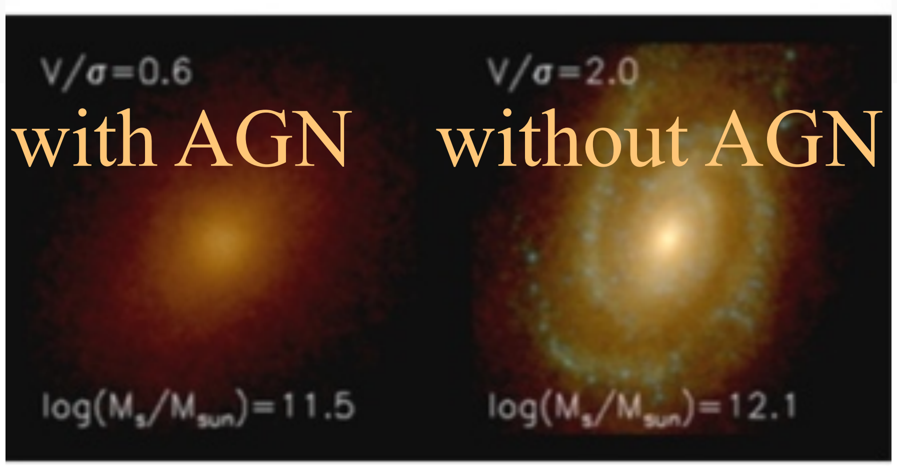
Effect of large scale





Results

- Different gradients for different quantities
- Effects beyond mass & local density
- DM halo in nodes (resp. filaments)
  - form later
  - accrete more
  - are more massive

  than in filaments (resp. voids)

Take home message...

- Morphology (= AM stratification) driven by LSS in cosmic web: it explains Es -> Sps where, how & why from **IC**s
- Signature in correlation between *spin* and *internal* kinematic structure of cosmic web on larger scales.
- Process driven by simple biassed clustering dynamics:

  - requires conditioning TTT to **saddles**: simple theory
  - can be expressed into an Eulerian theory via vorticity

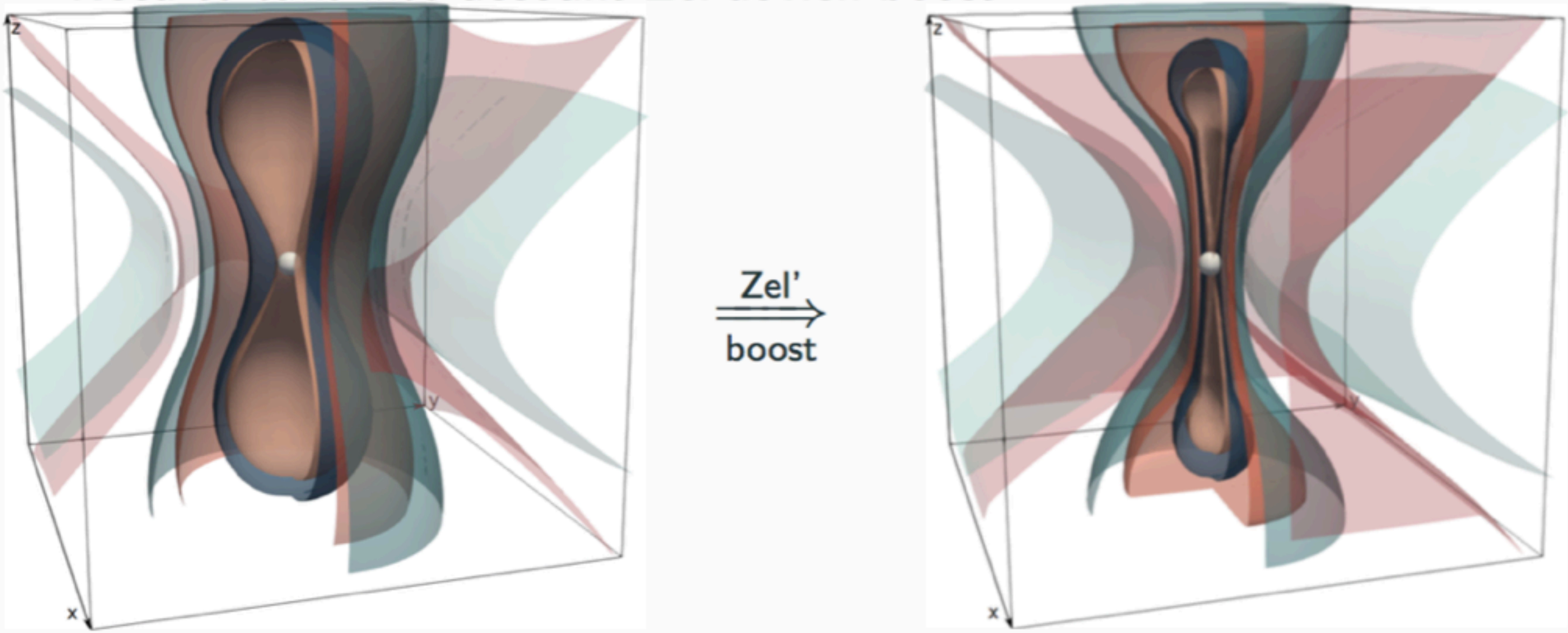
*Where **galaxies** form does matter, and can be traced back to ICs*
Flattened filaments generate point-reflection-symmetric AM/vorticity distribution: they induce the observed spin transition mass

- can be applied to galactic colours as well through extension of excursion set theory: secondary effect on accretion rate.

Merci !

Effect of Zel'dovich in frame of saddle

Need to take into account Zel'dovich-boost



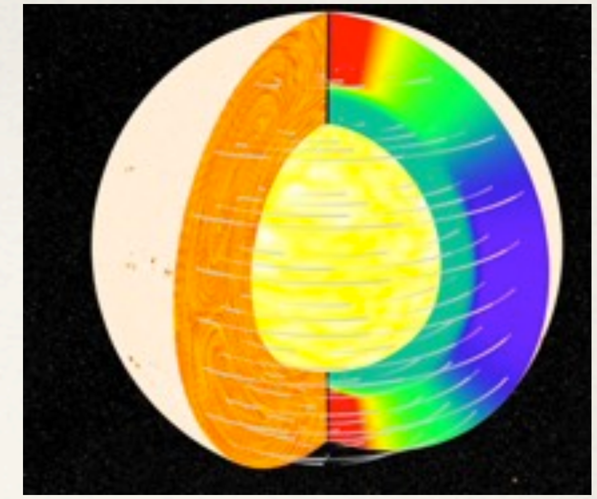
- gradients align
- information attenuated

isocontours of mass, density, accretion rate

Meridional maps:

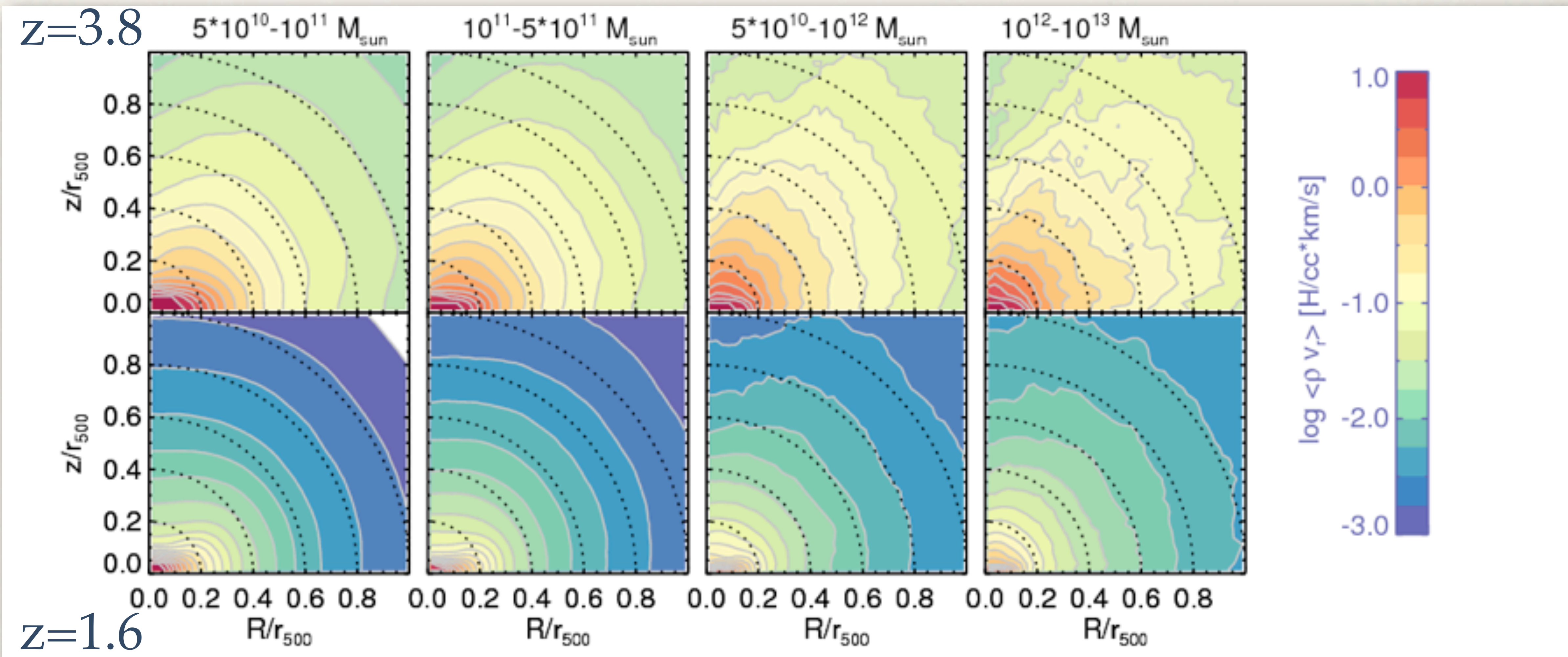
net gas mass flow

$$\langle \rho_{\mathrm{gas}} v_r \rangle$$



- meridional accretion @ all z & mass

Increasing redshift

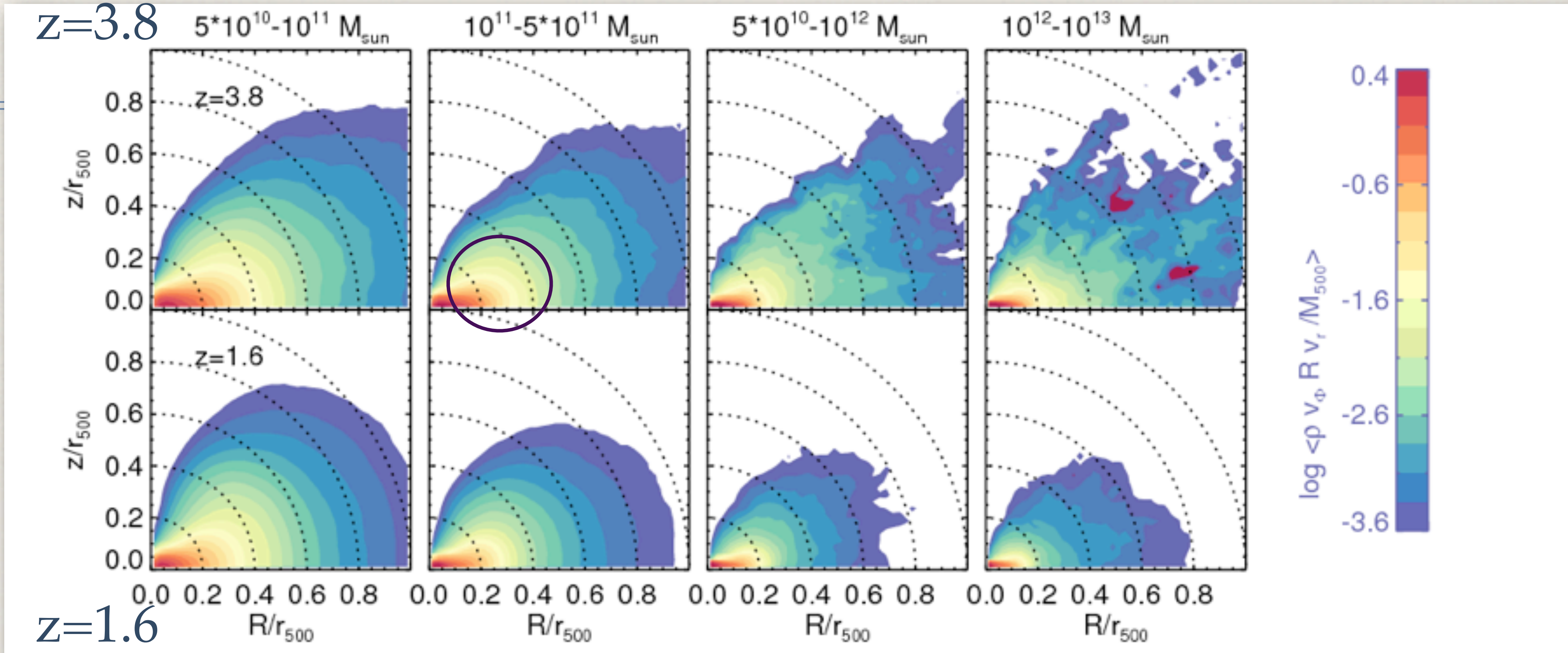


Increasing mass

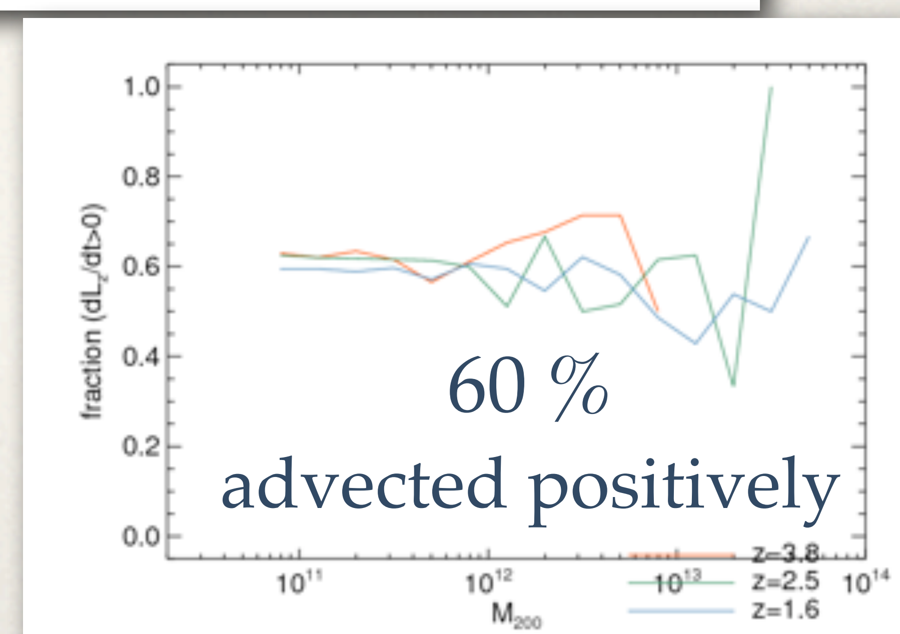
Meridional maps: advected momentum

$$\langle \rho_{\rm gas} L_z v_r \rangle$$

Increasing redshift



Increasing mass

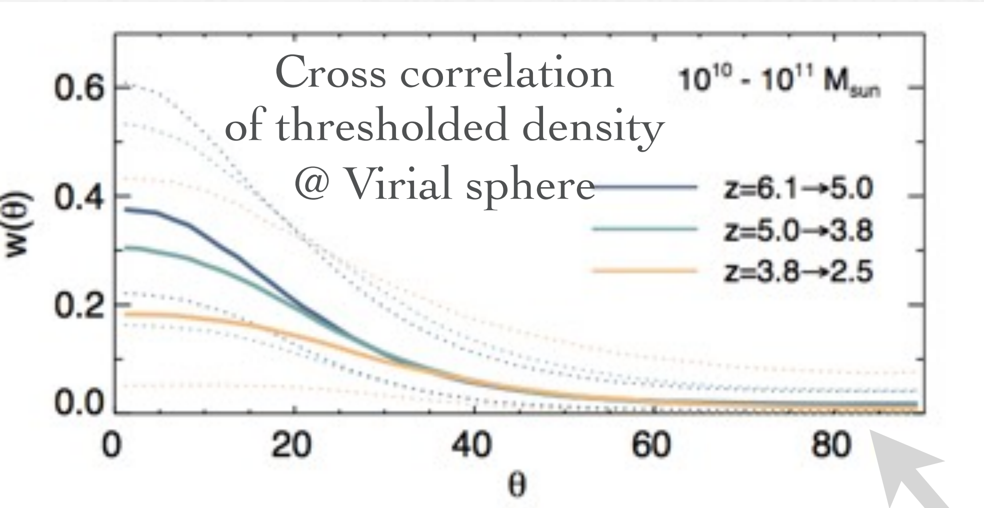


60 %
advected positively

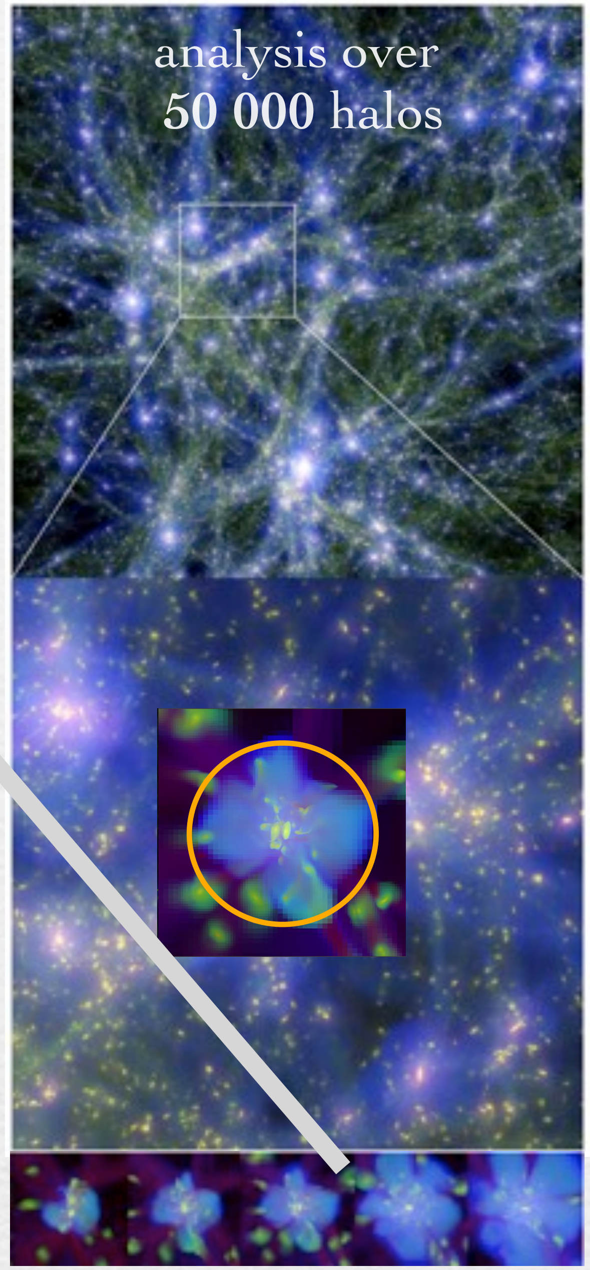
- significant L_z advected @ edge of disk

builds inside out ?

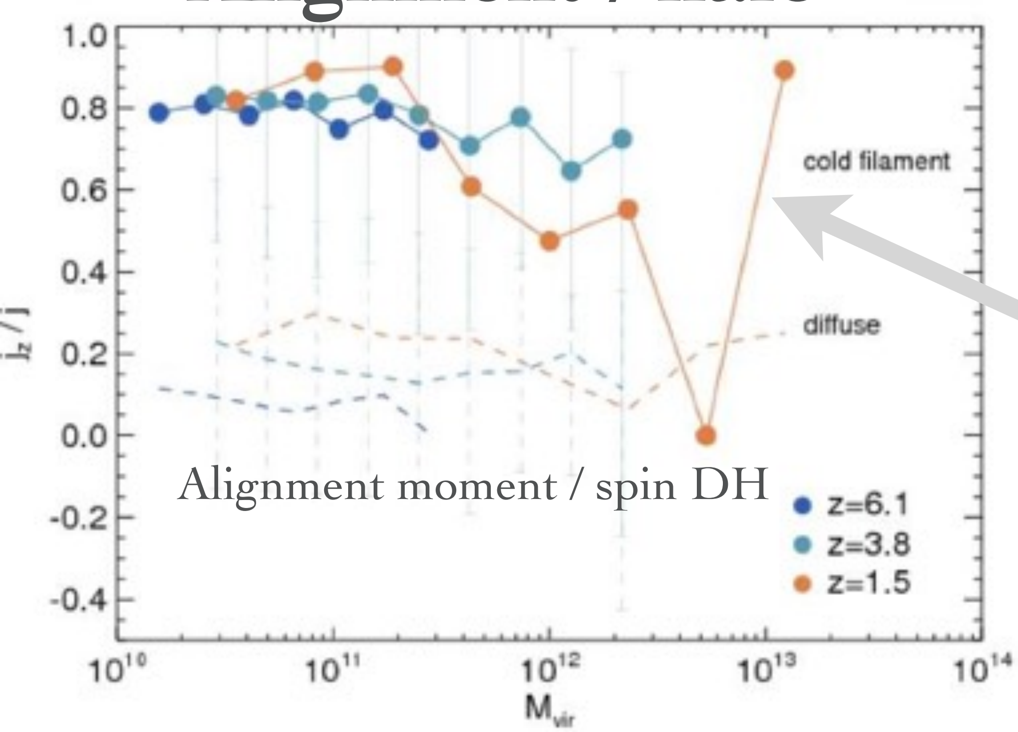
$$w(\theta) = \sum_{l,m}\langle a_{lm} b^*_{lm}\rangle P_l(\cos(\theta))/\sqrt{(\sum_{l,m}\langle|a_{lm}|^2\rangle \sum_{l,m}\langle|b_{lm}|^2\rangle)}\,,$$

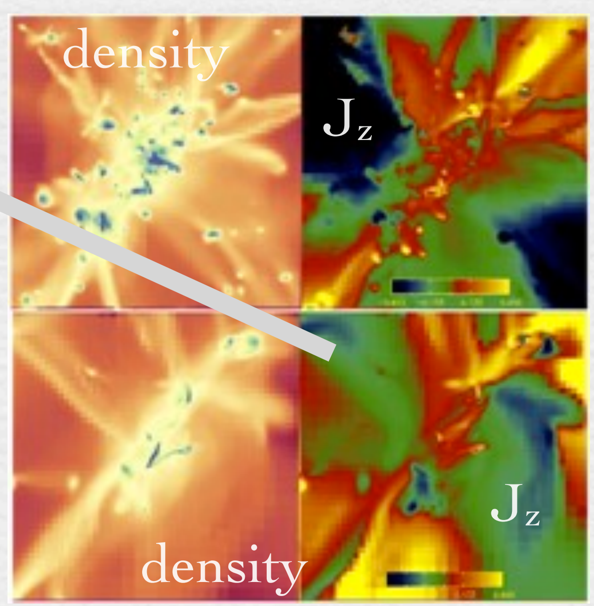


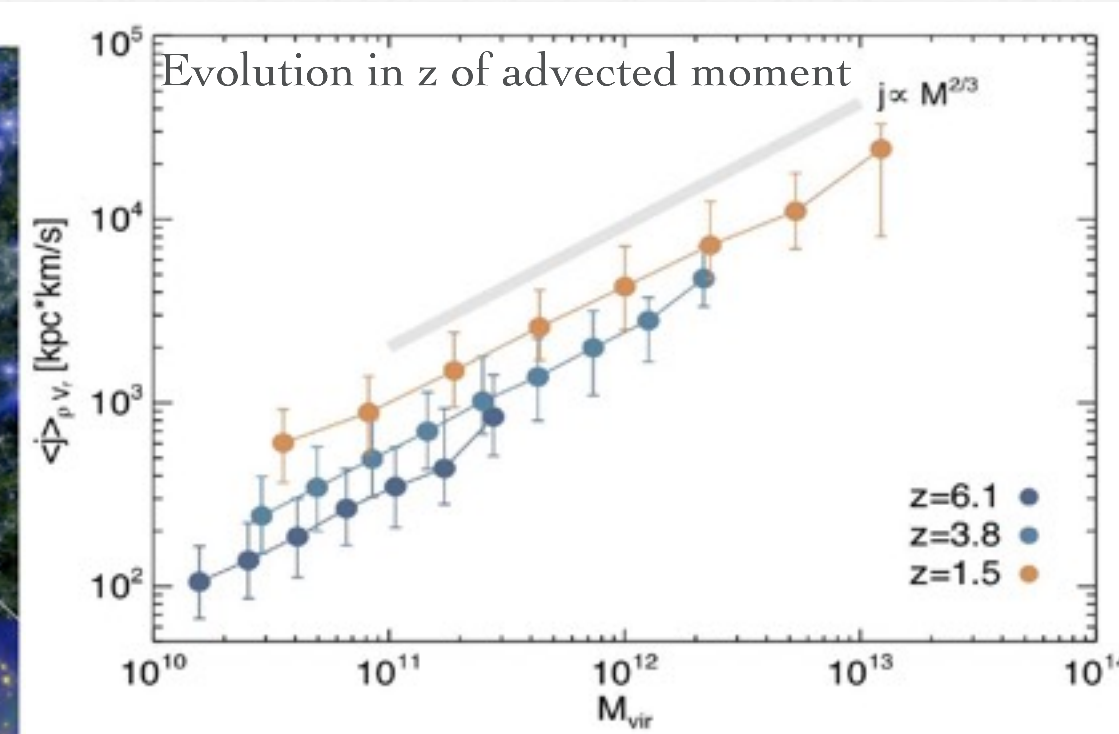
Filamentary Accretion: coherent orientation



Advected Ang Moment Alignment / halo







growth of |ang moment|

Coherent ang. moment orientation