Dark Halos Properties in the Frame of the Saddle

or how does the cosmic web impacts assembly bias

https://goo.gl/18oUAC

Marcello Musso, **Corentin Cadiou**, C. Pichon, S. Codis, K. Kraljic & Y. Dubois

Spine Meeting, Agay, September 21, 2017

Outline

Introduction

Describing filaments with saddle point

Effect on assembly history

- Typical mass
- Accretion rate
- Formation time

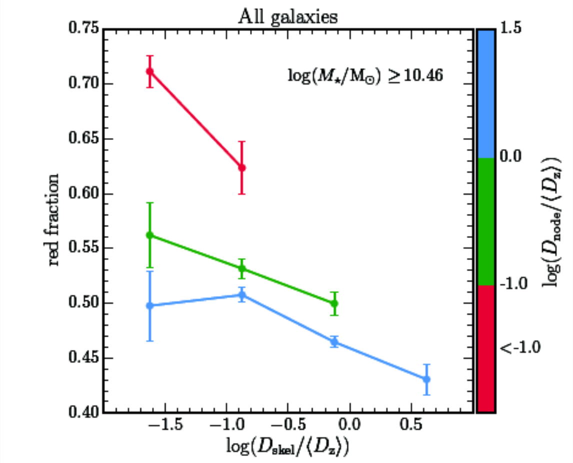
Expected observations?

Conclusion

https://goo.gl/18oUAC

Introduction

Observed gradients

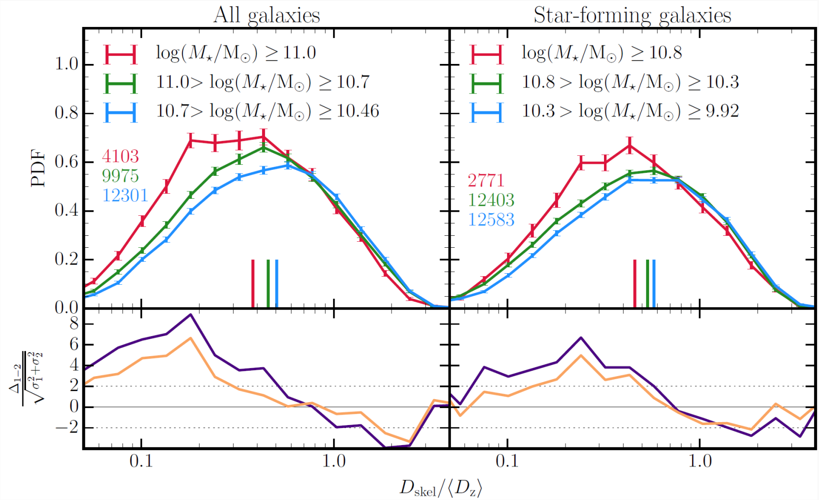


From void to filament
From filament to node
More massive, red and dead

Horizon-AGN + GAMA: K. Kraljic *et al*, submitted

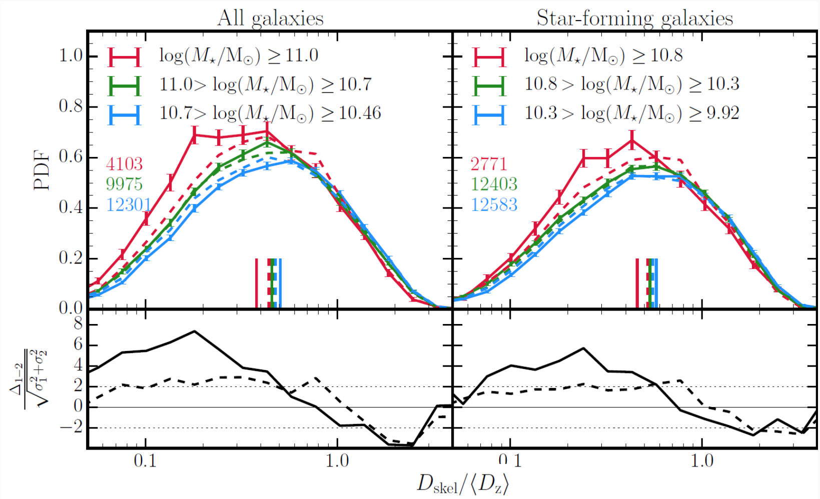
Advanced explanations

- Mass effect (not only)



Advanced explanations

- Mass effect (not only)
- Density effect (not only)



Need to take into account large-scale environment

Need to take into account large-scale environment

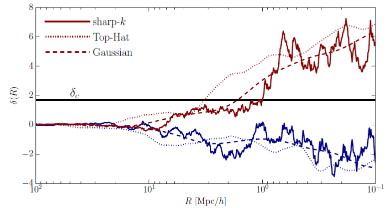
For 2nd order effects

Need to take into account large-scale environment

For 2nd order effects

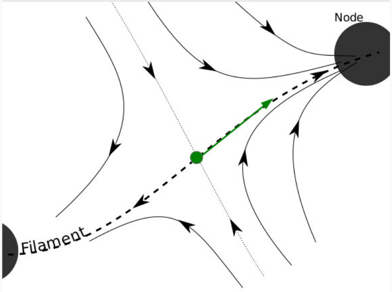
How?

Theoretical framework



Desjacques, Jeong, Smith 2016

+

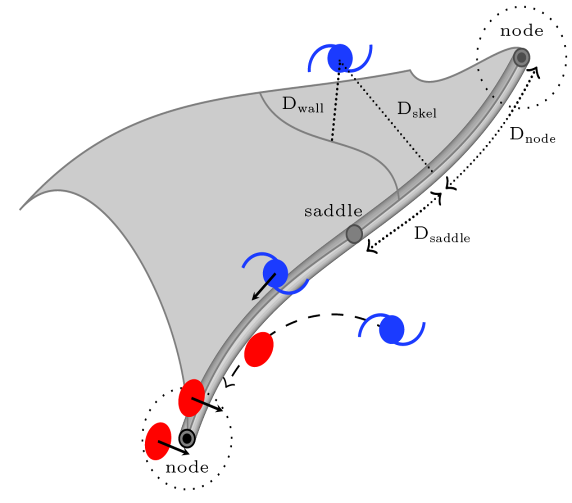


Use excursion set theory (Marcello's talk) in the frame of the cosmic web (this talk)

$\Rightarrow$ compute quantities constrained to their large scale environment

Describing filaments with saddle point

Google Maps in the cosmic web



K. Kraljic *et al*, submitted


Premia
Landschaftspark Binntal
Fiesch
Fieschertal
Termen
VALAIS

What's a saddle point?

Saddle point of ρ

- Direct access *via* number density, ...
- Probe scales $k^2 P(k)$ (small scale)

Saddle point of φ

- Access *via* e.g. grav. lensing
- Proba scales $P(k)$ (large scale)
- Theoretically tractable

How do we define it?

1. Critical point

$$\nabla\varphi \equiv -\mathbf{g}_{\mathcal{S}} = 0 \quad \text{no acceleration.}$$

2. Saddle point constrain (in frame of saddle point)

$$\nabla_i\nabla_j\varphi \equiv q_{ij} = \begin{pmatrix} q_{xx} & 0 & 0 \\ 0 & q_{yy} & 0 \\ 0 & 0 & q_{zz} \end{pmatrix} \quad \text{and} \quad q_{xx} < 0 < q_{yy} < q_{zz}.$$

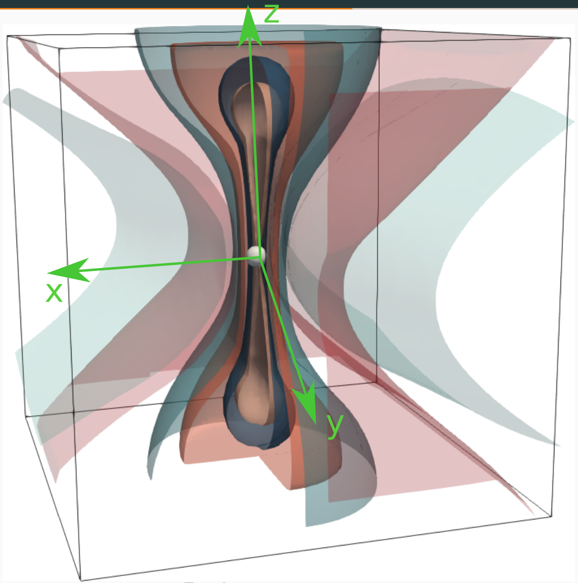
Physically: local maximum in y, z directions, local minimum in x direction.

3. Heigth of the saddle point

$$\delta_{\mathcal{S}} \equiv \frac{\rho - \bar{\rho}}{\bar{\rho}}$$

smoothed at scale $R_{\mathcal{S}}$.

Saddle Point Frame



3D density contours

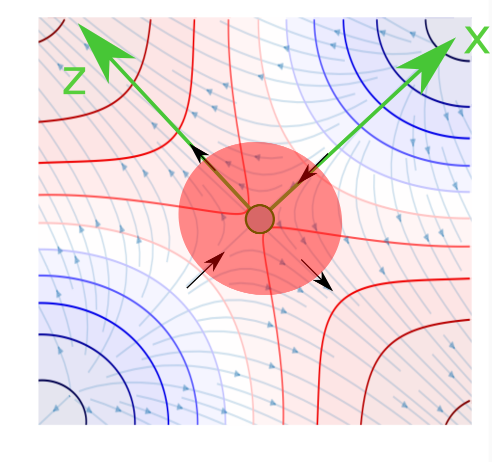
Directions

- x: toward void
- y: toward wall
- z: toward node

Filament

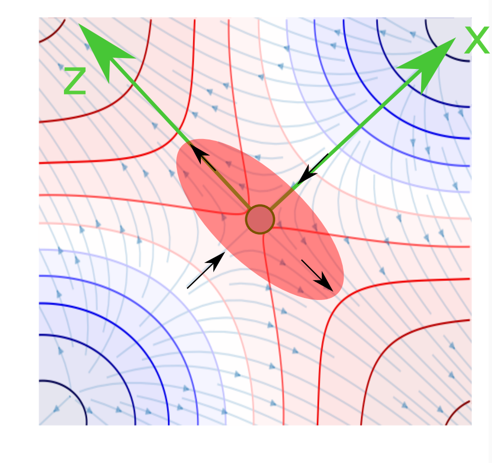
- x dir. collapsed (Zel'dovich)
- z dir. of filament

Flow Around Saddle Point



Saddle point is stationary (critical point of the “streamlines”)

Flow Around Saddle Point



Saddle point is stationary (critical point of the “streamlines”)

Description of the saddle point

Variables

- $R_\mathcal{S}$ the smoothing scale
- $\delta_\mathcal{S}$ the overdensity
- $\mathbf{g}_\mathcal{S}$ the acceleration
- q_{ij} (next slide)

Description of the saddle point

Variables

- $R_{\mathcal{S}}$ the smoothing scale
- $\delta_{\mathcal{S}}$ the overdensity
- $\mathbf{g}_{\mathcal{S}}$ the acceleration
- q_{ij} (next slide)

Values

- e.g. 10 Mpc/h
- ~ 1.2
- $(0, 0, 0)$
- q_{ij}

A few words about q_{ij}...

$$q_{ij} = \nabla_i \nabla_j \varphi \tag{1}$$

q_{ij} is a tensor of order 2 describing the *tides at the saddle point*.

A few words about q_{ij}...

$$q_{ij} = \nabla_i \nabla_j \varphi \sim -\nabla_i \nabla_j \delta \tag{1}$$

q_{ij} is a tensor of order 2 describing the *tides at the saddle point*.

Signature	**Type of point**
$+++$	peak
$-++$	filament-type saddle point
$--+$	wall-type saddle point
$---$	void

A few words about q_{ij}...

$$q_{ij} = \nabla_i \nabla_j \varphi \sim -\nabla_i \nabla_j \delta \qquad (1)$$

q_{ij} is a tensor of order 2 describing the *tides at the saddle point*.

Signature	**Type of point**
$+++$	peak
$-++$	filament-type saddle point
$--+$	wall-type saddle point
$---$	void

A few words about q_{ij}...

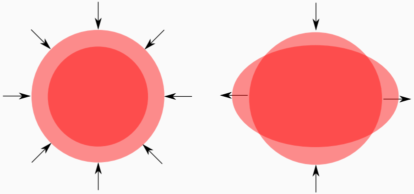
$$q_{ij} = \nabla_i \nabla_j \varphi \sim -\nabla_i \nabla_j \delta \quad (1)$$

q_{ij} is a tensor of order 2 describing the *tides at the saddle point*.

Signature	**Type of point**
$+++$	peak
$-++$	filament-type saddle point
$--+$	wall-type saddle point
$---$	void

A few words about q_{ij} [Stephane's slide]

$$q_{ij} = \underbrace{\frac{\delta_{\mathcal{S}}}{3}\begin{pmatrix}1 & & \\ & 1 & \\ & & 1\end{pmatrix}}_{\text{density}} + \underbrace{\begin{pmatrix}\bar{q}_{11} & \bar{q}_{12} & \bar{q}_{13} \\ & \bar{q}_{22} & \bar{q}_{23} \\ & & \bar{q}_{33}\end{pmatrix}}_{\text{tides}} \quad (2)$$

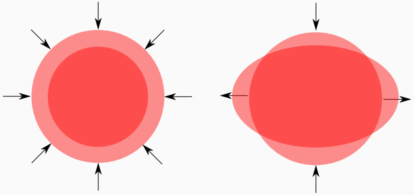


Information in $\mathrm{Tr}(q_{ij})$ ("diagonal" part)

$$\mathrm{Tr}(q_{ij}) = \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2}$$

A few words about q_{ij} [Stephane's slide]

$$q_{ij} = \underbrace{\frac{\delta_{\mathcal{S}}}{3}\begin{pmatrix}1 & & \\ & 1 & \\ & & 1\end{pmatrix}}_{\text{density}} + \underbrace{\begin{pmatrix}\bar{q}_{11} & \bar{q}_{12} & \bar{q}_{13} \\ & \bar{q}_{22} & \bar{q}_{23} \\ & & \bar{q}_{33}\end{pmatrix}}_{\text{tides}} \tag{2}$$

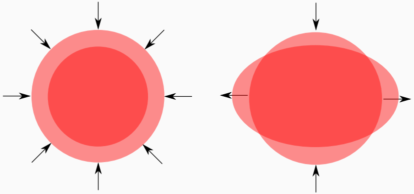


Information in $\mathrm{Tr}(q_{ij})$ ("diagonal" part)

$$\mathrm{Tr}(q_{ij}) = \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2} = \Delta \varphi$$

A few words about q_{ij} [Stephane's slide]

$$q_{ij} = \underbrace{\frac{\delta_{\mathcal{S}}}{3}\begin{pmatrix}1 & & \\ & 1 & \\ & & 1\end{pmatrix}}_{\text{density}} + \underbrace{\begin{pmatrix}\bar{q}_{11} & \bar{q}_{12} & \bar{q}_{13} \\ & \bar{q}_{22} & \bar{q}_{23} \\ & & \bar{q}_{33}\end{pmatrix}}_{\text{tides}} \tag{2}$$

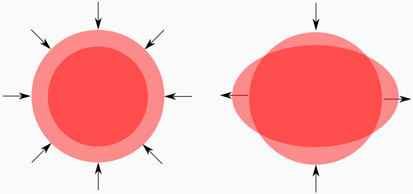


Information in $\mathrm{Tr}(q_{ij})$ ("diagonal" part)

$$\mathrm{Tr}(q_{ij}) = \frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial y^2} + \frac{\partial^2\varphi}{\partial z^2} = \Delta\varphi = \underbrace{4\pi\bar{\rho}G(1+\delta_{\mathcal{S}})}_{\text{Poisson equation}}$$

A few words about q_{ij} [Stephane's slide]

$$q_{ij} = \underbrace{\frac{\delta_{\mathcal{S}}}{3}\begin{pmatrix}1 & & \\ & 1 & \\ & & 1\end{pmatrix}}_{\text{density}} + \underbrace{\begin{pmatrix}\bar{q}_{11} & \bar{q}_{12} & \bar{q}_{13} \\ & \bar{q}_{22} & \bar{q}_{23} \\ & & \bar{q}_{33}\end{pmatrix}}_{\text{tides}} \quad (2)$$



Information in $\mathrm{Tr}(q_{ij})$ ("diagonal" part)

$$\mathrm{Tr}(q_{ij}) = \frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial y^2} + \frac{\partial^2\varphi}{\partial z^2} = \Delta\varphi = \underbrace{4\pi\bar{\rho}G(1+\delta_{\mathcal{S}})}_{\text{Poisson equation}}$$

A few words about q_{ij}... [continued]

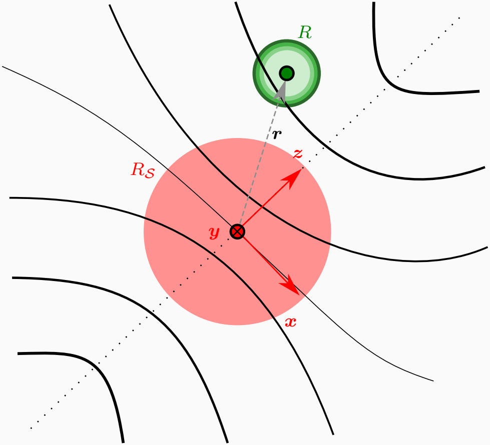
$$\bar{q}_{ij} \equiv \text{traceless part of } q_{ij} = q_{ij} - \frac{\delta_{\mathcal{S}}}{3}\mathbb{I}_{ij} \tag{3}$$

Why do we care about $\bar{q}_{ij}$?

- contains *geometric* information
- no information on *local density*
- probe for LSS

$\Rightarrow$ from theory: seem like good way to measure large scale environment

Saddle point frame



- Distance $\mathbf{r} = (r_x, r_y, r_z)$ from saddle point
- Scale $R \sim 1\,\mathrm{Mpc/h} \ll R_{\mathcal{S}}$

Angular variable

$$\mathcal{Q} = \sum_i \sum_j \frac{r_i \bar{q}_{ij} r_j}{\|\mathbf{r}\|^2} \tag{4}$$

- Filament: $\mathcal{Q} = \bar{q}_{zz} \sim 1$
- Void: $\mathcal{Q} = \bar{q}_{xx} \sim -1$

Angular variable

$$\mathcal{Q} = \sum_i \sum_j \frac{r_i \bar{q}_{ij} r_j}{\|\mathbf{r}\|^2} \tag{4}$$

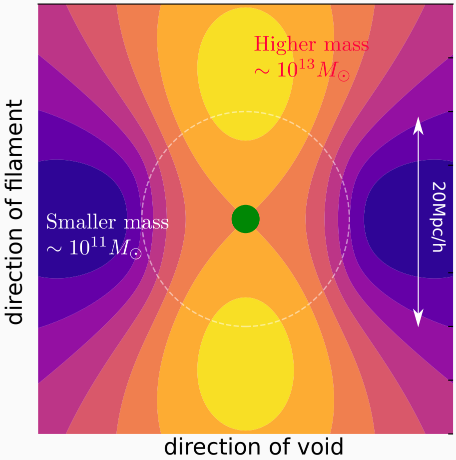
- Filament: $\mathcal{Q} = \bar{q}_{zz} \sim 1$
- Void: $\mathcal{Q} = \bar{q}_{xx} \sim -1$

In practice: all results are functions of r and $\mathcal{Q}$.

$\mathcal{Q}$ is *the* variable encoding **anisotropic** environmental effects

Effect on assembly history

Typical mass

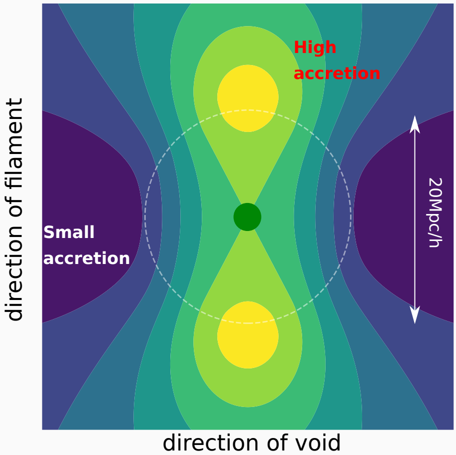


$$\Delta M_\star(\mathbf{r}) \propto \delta_{\mathcal{S}} \xi_{20}(r) \mathcal{Q}$$

ξ_{20}: corr. density-tide + density

MM, CC *et al.*, submitted

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

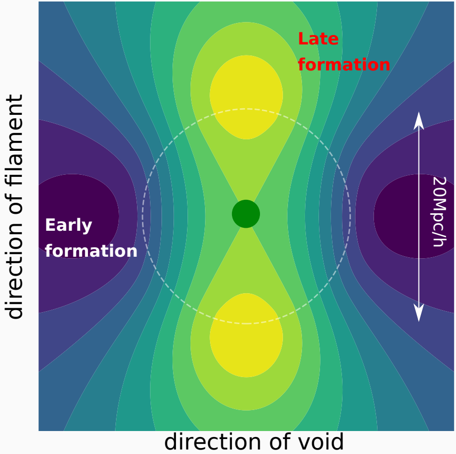


$$\Delta \dot{M}(\mathbf{r}) \propto \left[\xi'_{20} - \frac{\sigma - \xi'_I \xi_I}{\sigma^2 - \xi^2}\xi_{20}\right]\mathcal{Q}$$

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

MM, CC *et al.*, submitted

Formation time @ $\approx 3 \times 10^{11}\,\mathrm{M}_\odot$ & $z = 0$



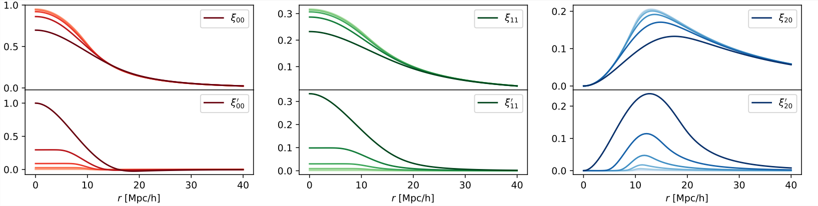
$$\Delta z_\star(\mathbf{r}) \propto M\xi_{20}(r)\mathcal{Q}$$

higher mass: later formation time

MM, CC *et al.*, submitted

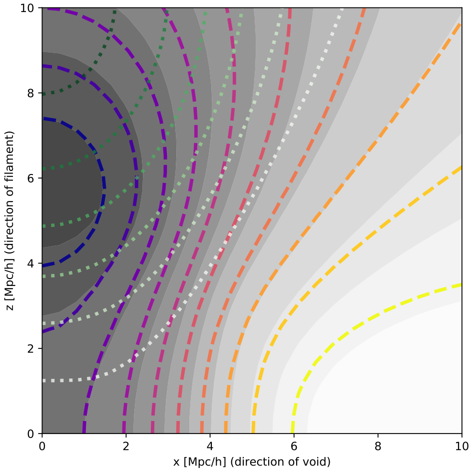
ξ functions

$\xi_{00} \propto \langle \delta \delta_{\mathcal{S}} \rangle$ $\xi_{11} \propto \langle \delta g_i \rangle$ $\xi_{20} \propto \langle \delta \bar{q}_{ij} \rangle$



$\xi'_{00} \propto \langle \delta' \delta_{\mathcal{S}} \rangle$ $\xi'_{11} \propto \langle \delta' g_i \rangle$ $\xi'_{20} \propto \langle \delta' \bar{q}_{ij} \rangle$

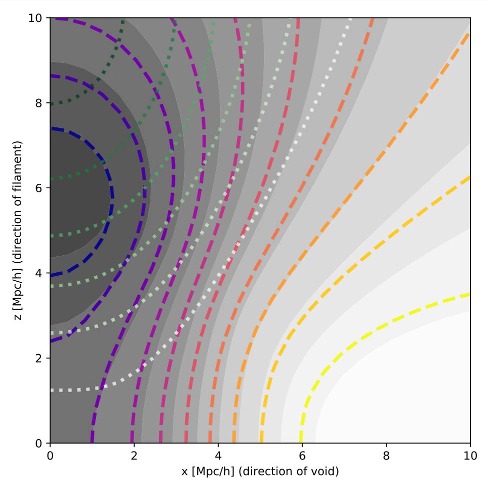
Gradient alignment



K. Kraljic *et al*, submitted

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

Gradient alignment



K. Kraljic *et al*, submitted

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

$\Rightarrow$ different gradients

(Temporary) conclusions

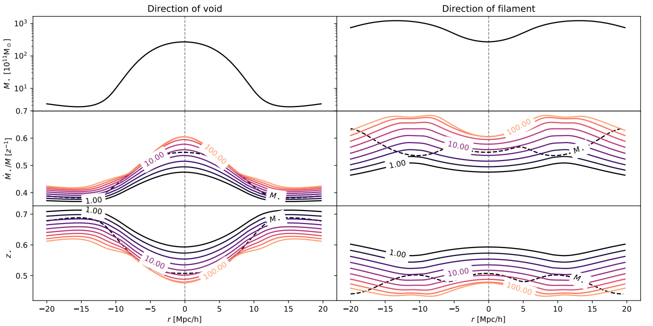
Halos in nodes . . .

- form later,
- are accreting more,
- typically more massive,

compared to those in filaments (and same from voids to filaments).

In agreement with results from n-body simulations + hint for different assembly w.r.t. cosmic web.

Quantitative results



Voids to filaments

- $M \times 10^2$
- $\dot{M}/M + 30\%$
- $z_f - 15\%$

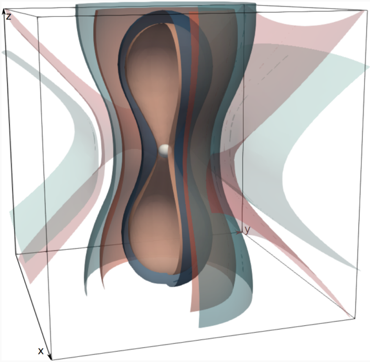
Filaments to nodes

- $M \times 5$
- $\dot{M}/M + 10\%$
- $z_f - 5\%$

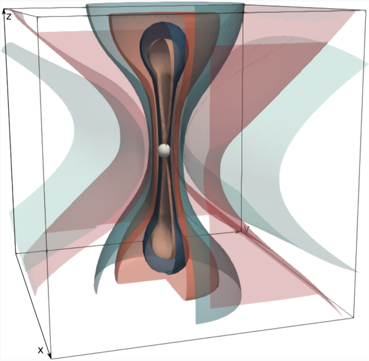
Expected observations?

Effect of Zel'dovich

Need to take into account Zel'dovich-boost

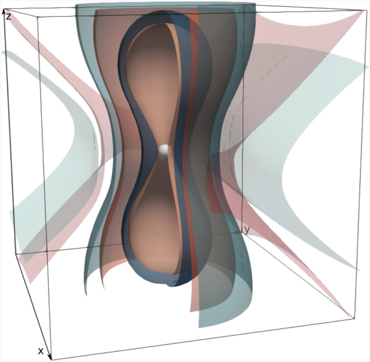


$\xrightarrow[\text{boost}]{\text{Zel'}}$

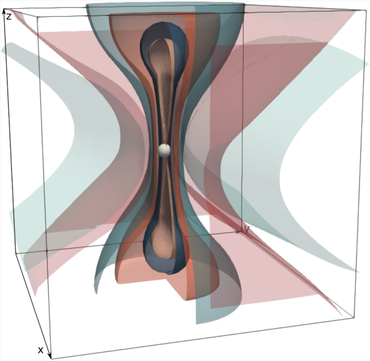


Effect of Zel'dovich

Need to take into account Zel'dovich-boost



$\xrightarrow[\text{boost}]{\text{Zel'}}$



- gradients align
- information attenuated

Conclusion

Conclusion

Results

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

  than in filaments (voids)

Questions

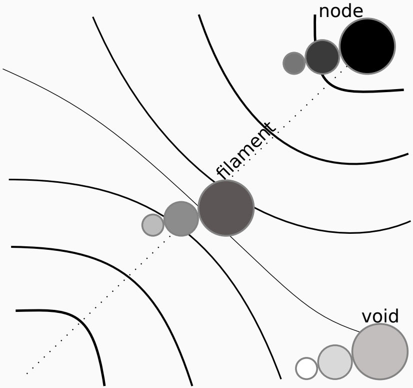
- Link between DM and baryons?
- Influence of SN/AGN feedback on the picture?
- Build more proxies (e.g. concentration)?

Thank you!

Thank you!

and read M. Musso, C. Cadiou et al, 2017!

Effect of large scale



⇒