Anisotropic satellite accretion onto the Local Group with HESTIA in the context of the cosmic web

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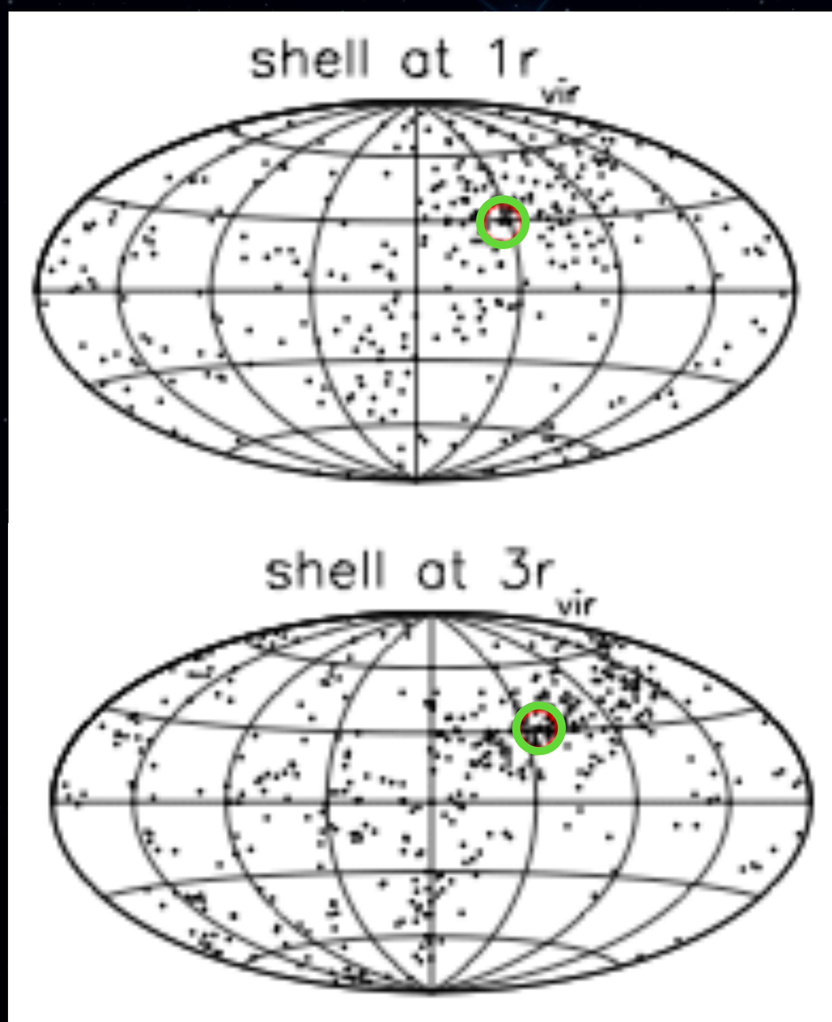
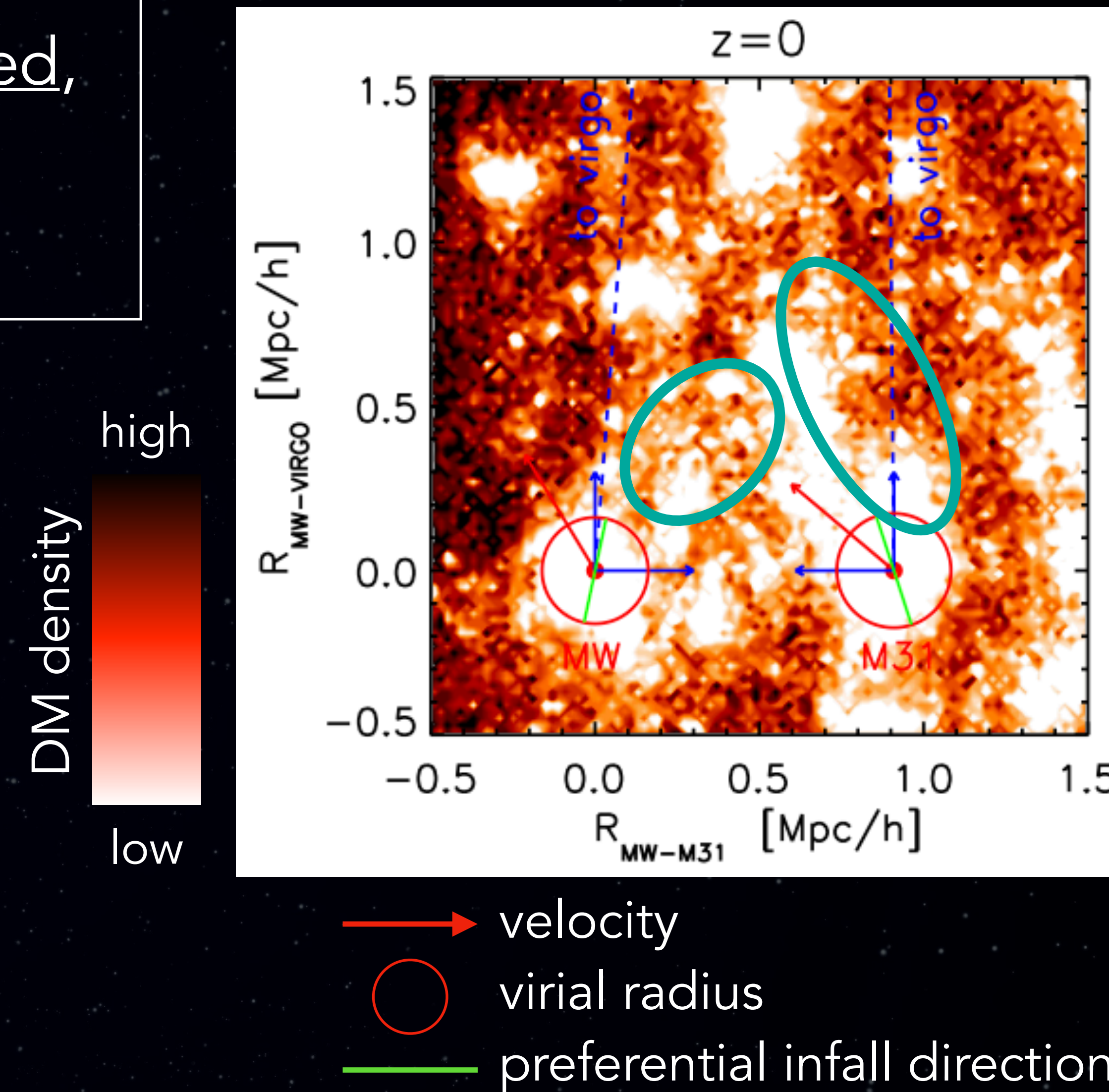
Preferred direction of accretion in the LG

Satellite infall points not uniformly distributed, highly clustered in a patch of the sky: preferred direction?



Libeskind et al. (2011)

CLUES simulation (see Libeskind et al. 2010)



Green lines aligned in same direction as filamentary like high density region

The Cosmic Web

Frame of reference within which we can define infall and assembly of matter → Identify preferred directions in the Universe

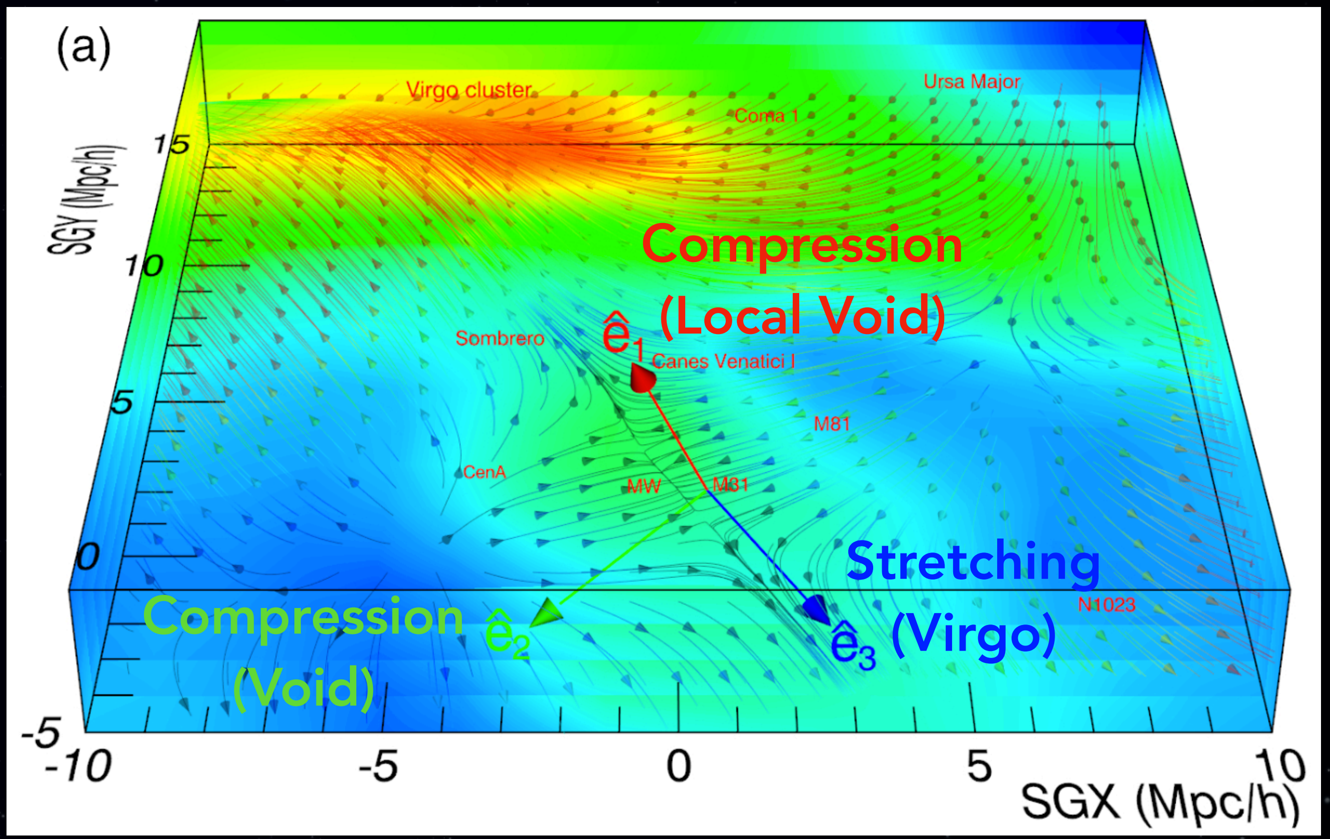
Shear eigenframe at LG location:
Eigenvectors $\vec{e}_1$, $\vec{e}_2$, $\vec{e}_3$

Axis of fastest collapse ($\vec{e}_1$)

Axis of slowest collapse ($\vec{e}_3$)

Question:
Are the preferred directions of accretion in the Local Group co-incident with the local cosmic web?

Libeskind et al. (2015)



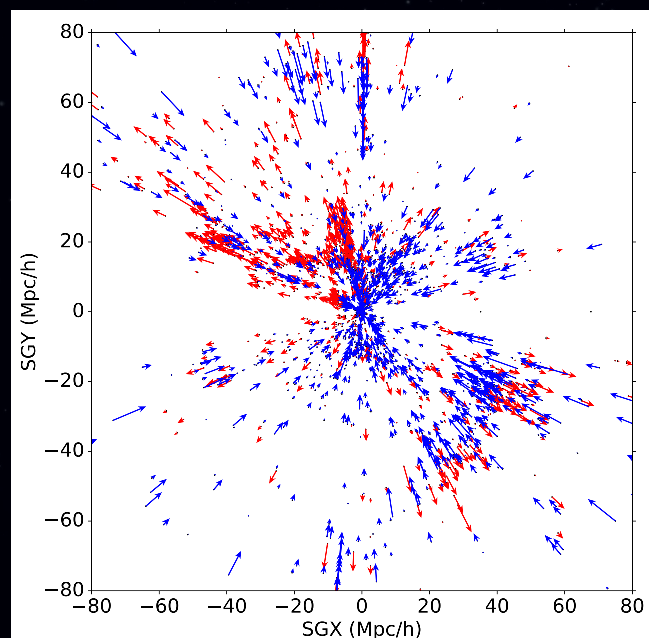
Overdensity and velocity field reconstructed from Cosmicflows-2

HESTIA: simulations of the Local Group

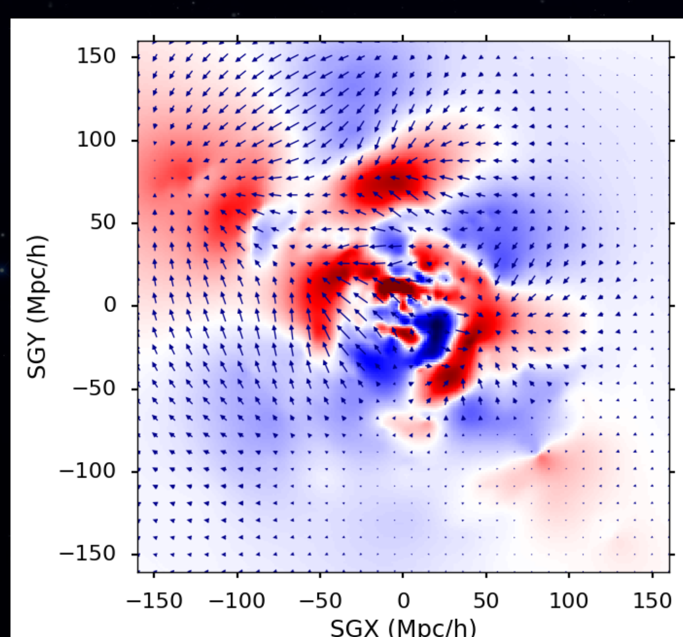
Initial Conditions ⟶ 3 high-resolution simulations of the LG:

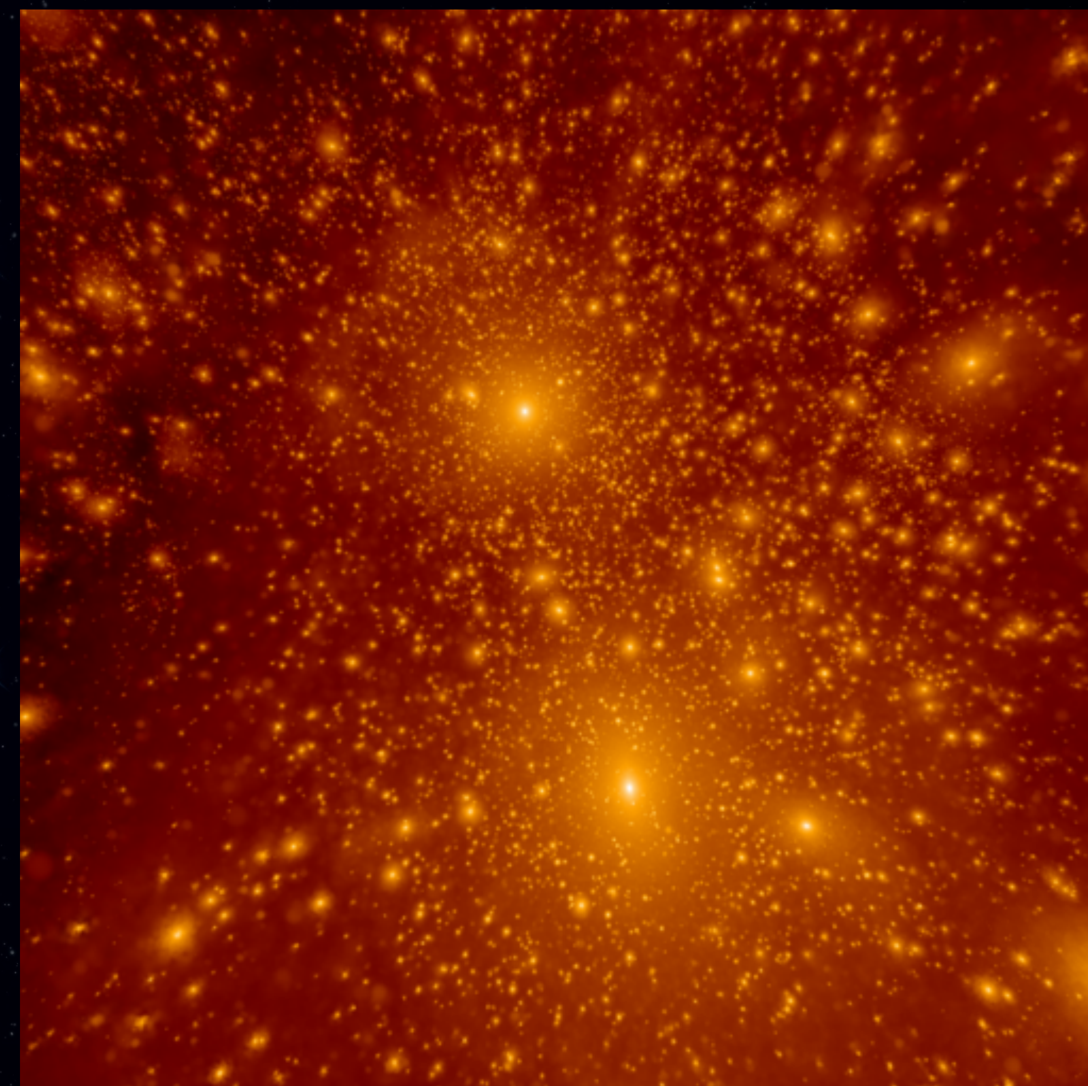
09_18 17_11 37_11

Cosmicflows-2 catalog:
$v_{pec} = cz - H_0 d$



WF reconstruction:
3D overdensity and velocity fields

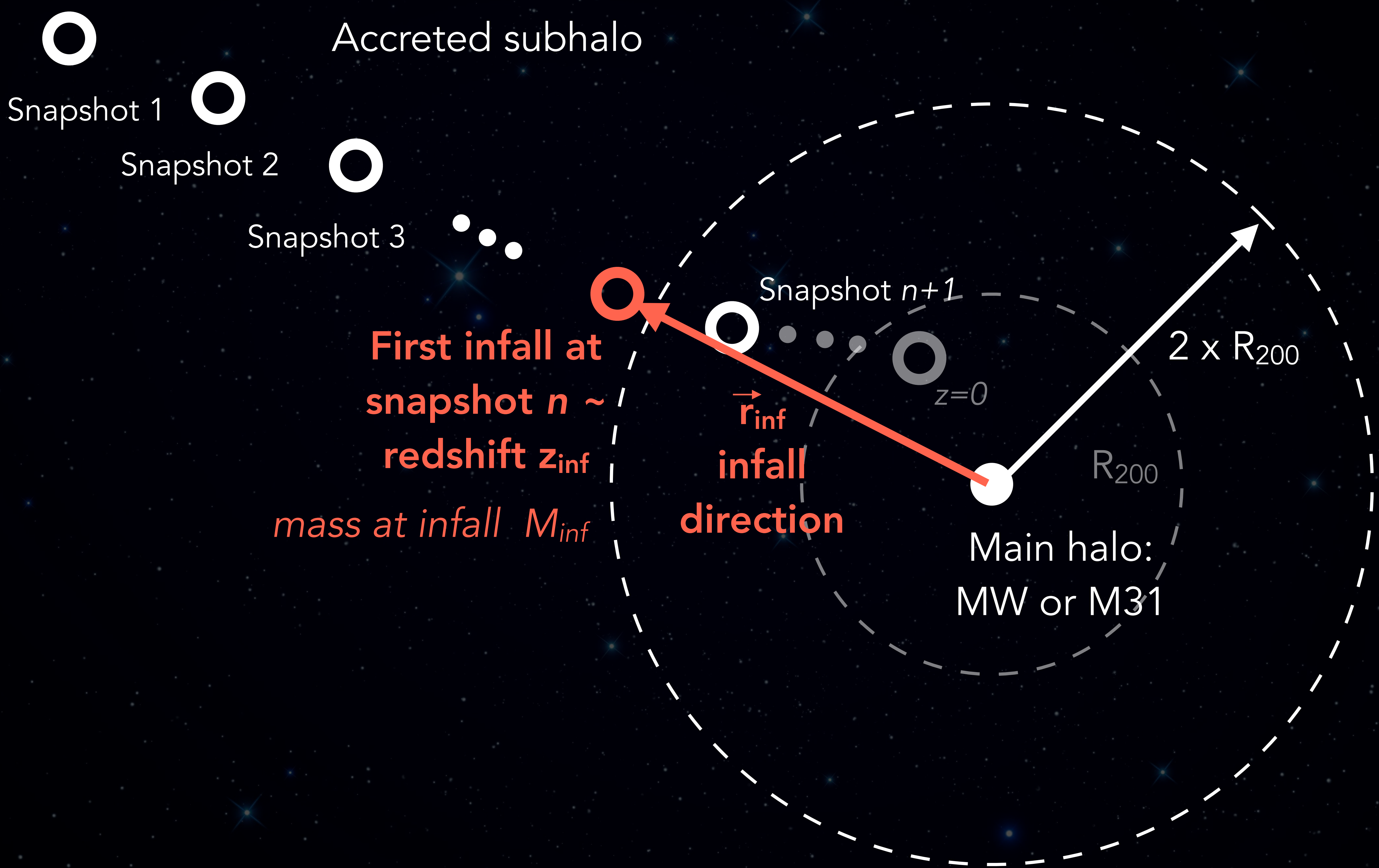




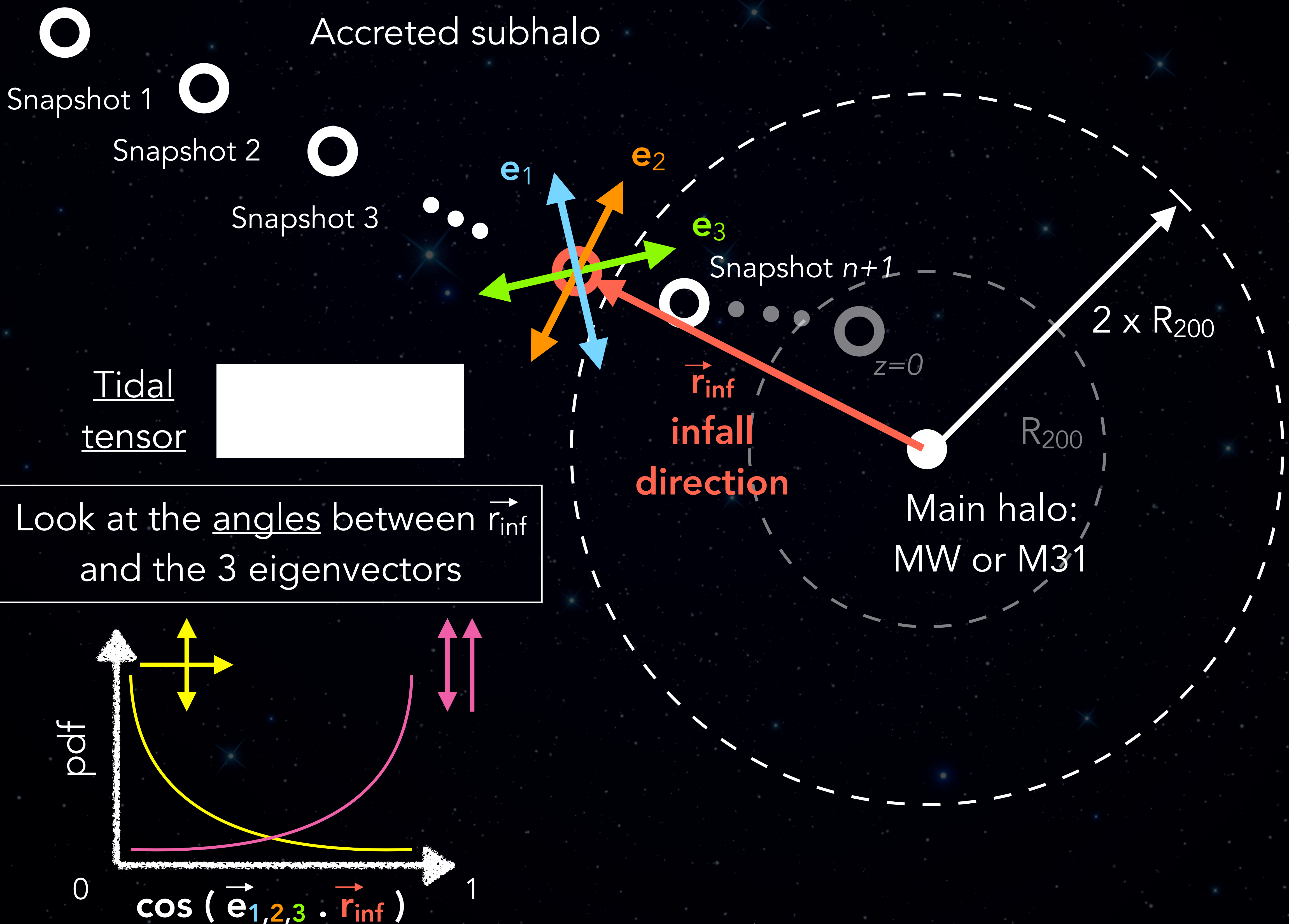
Libeskind et al. (2020)

DM density
17_11 high-res simulation at z=0

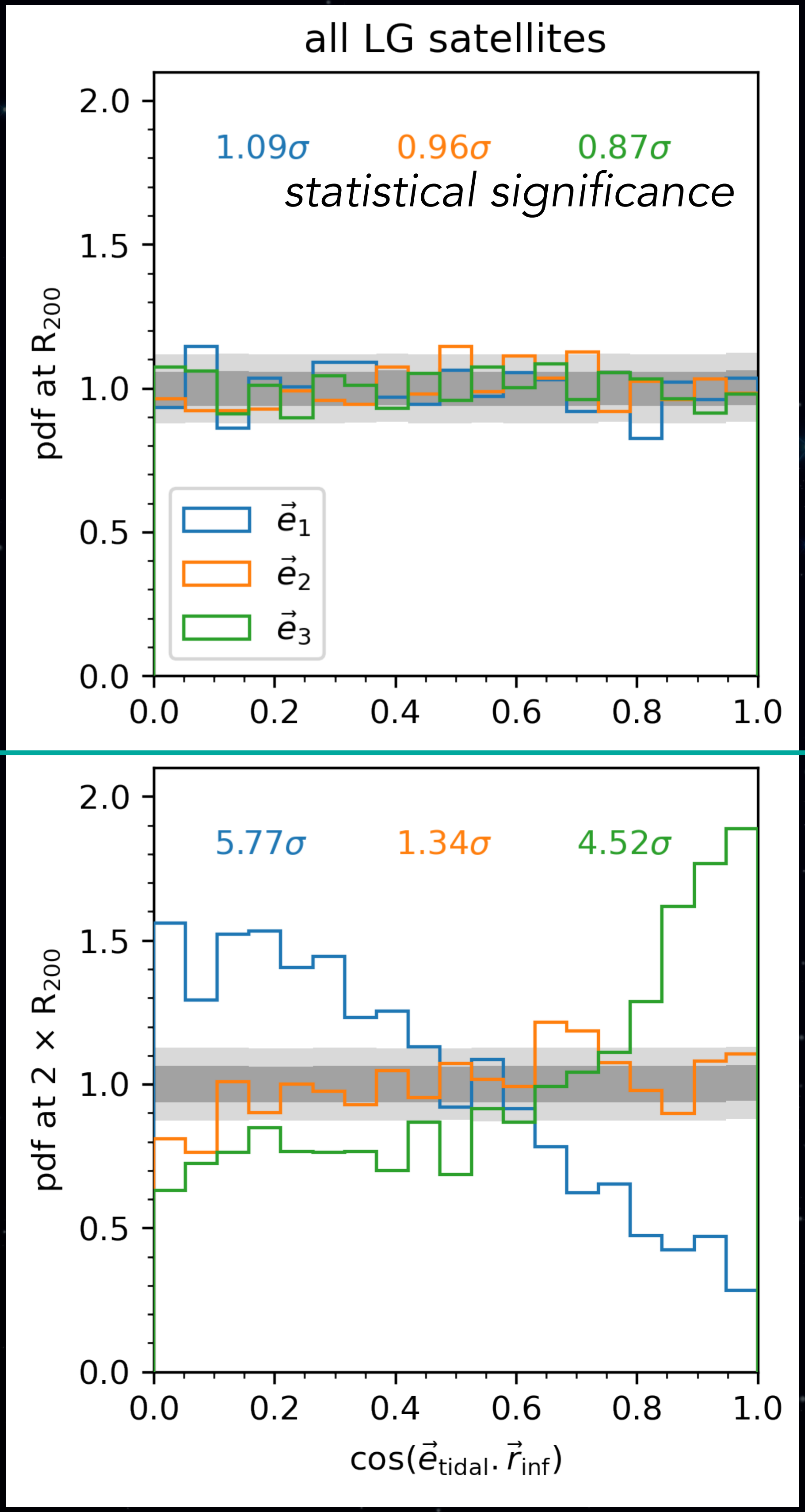
Identifying accreted satellite galaxies



Identifying accreted satellite galaxies



Preferred direction of accretion and the cosmic web



Dupuy et al. (2022)

R_{200}

$2 \times R_{200}$

orthogonal ⟷ *aligned*

Distribution of $\cos(\vec{r}_{inf} \cdot \vec{e}_{1,2,3})$

No significant alignment (non-linear dynamics)

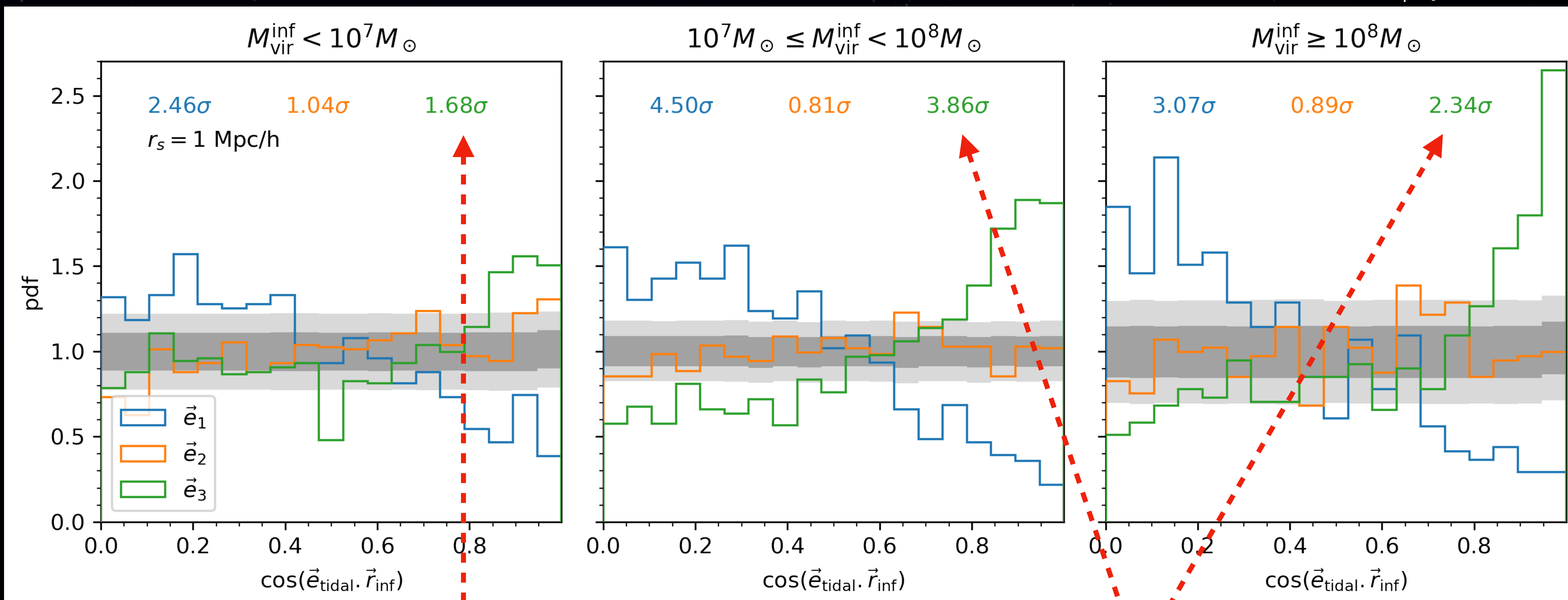
Quasi-linear regime: strong alignment with $\vec{e}_3$

Mass, redshift dependency?

Preferred direction of accretion and the cosmic web

Mass of subhalo at time of accretion divided in 3 bins:

Dupuy et al. (2022)

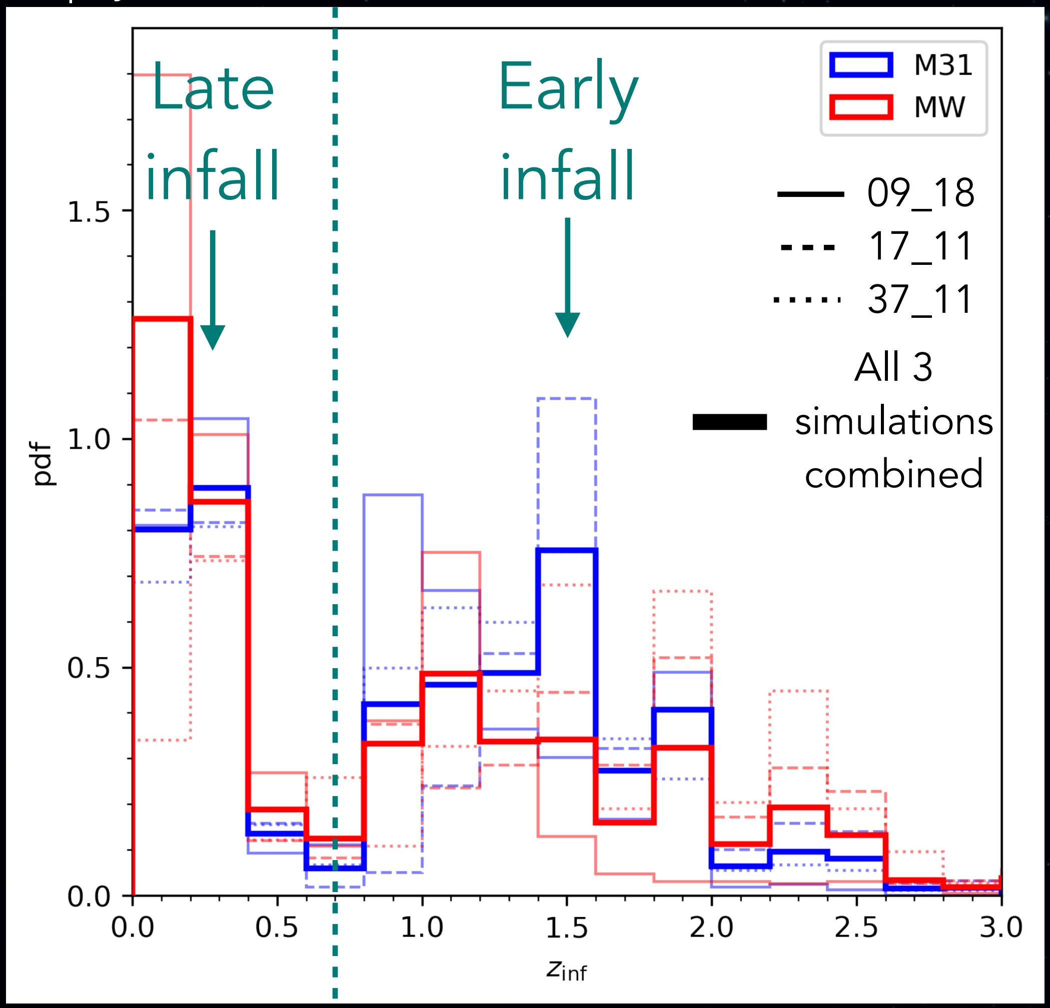


Low infall masses:
weaker signal

More massive haloes:
stronger signal

Preferred direction of accretion and the cosmic web

Dupuy et al. (2022)

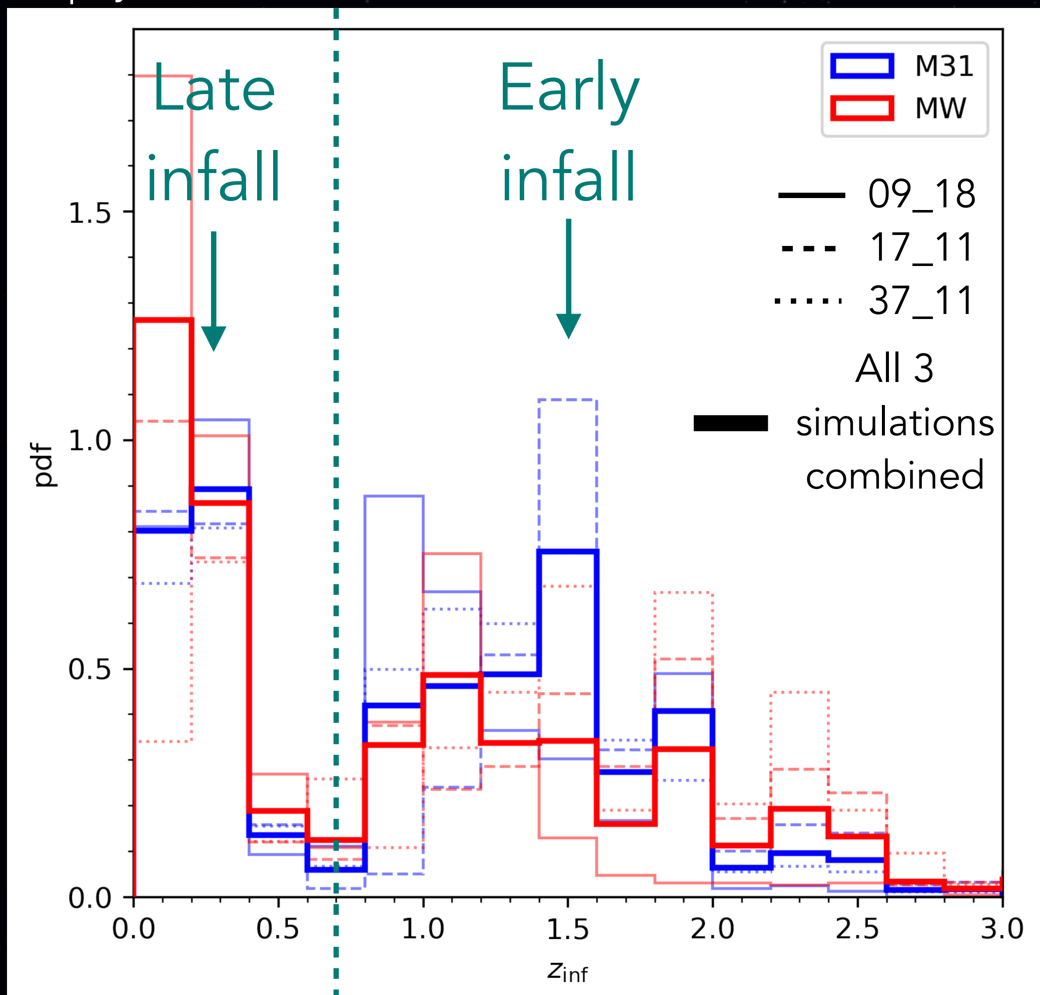


Two eras in accretion history:

before and after $z_{inf} = 0.7$

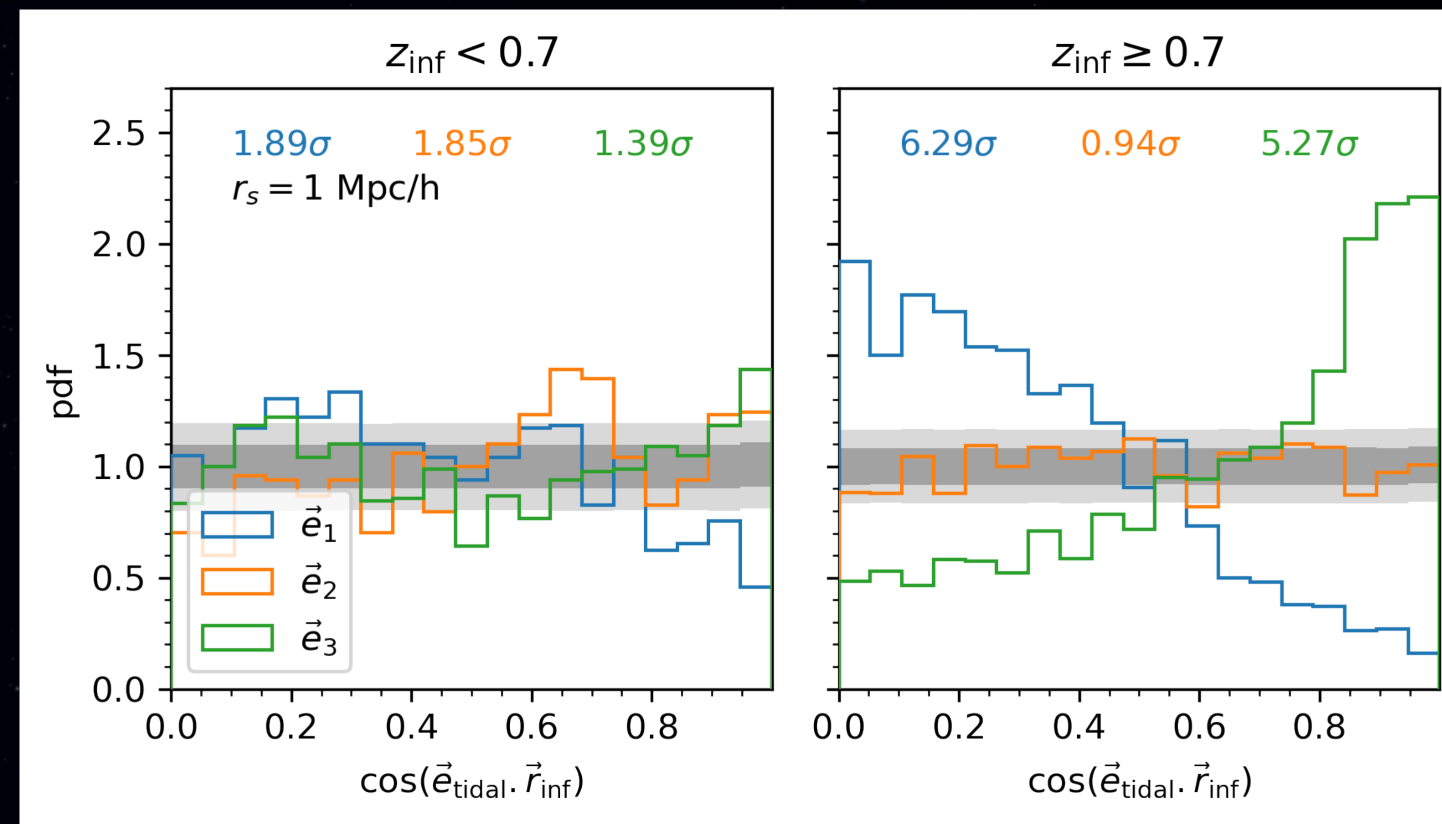
Preferred direction of accretion and the cosmic web

Dupuy et al. (2022)



Two eras in accretion history: before and after $z_{inf} = 0.7$

Late infall   Early infall

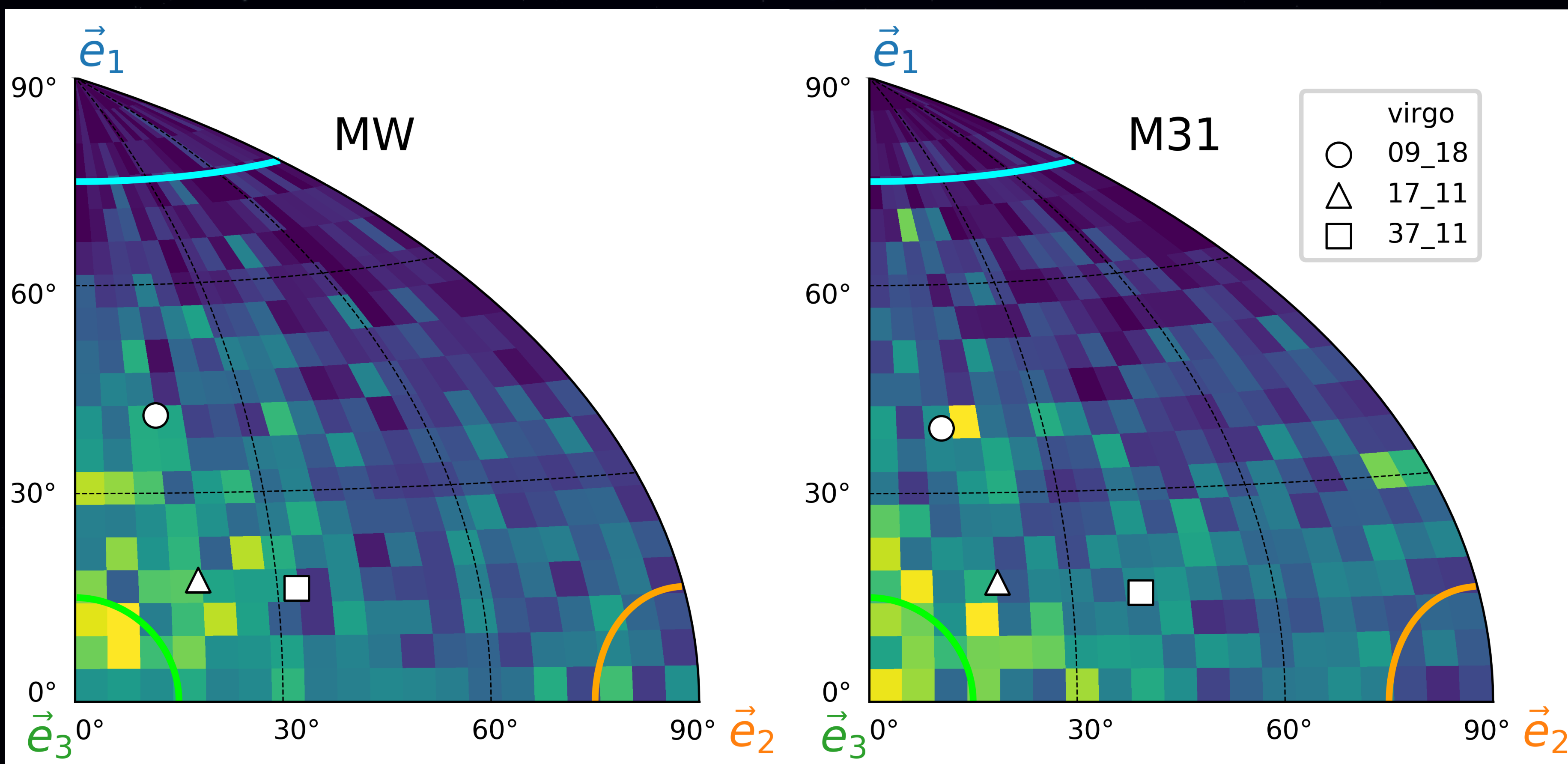


Dupuy et al. (2022)

Alignment with $\vec{e_3}$ dominated by **early infall (z>0.7)**

Closer look at the main haloes: MW and M31

Dupuy et al. (2022)



Projected virial sphere at 2 x R_{200}: only one octant as eigenvectors are non-directional

Density of entry points:

High number of entry points

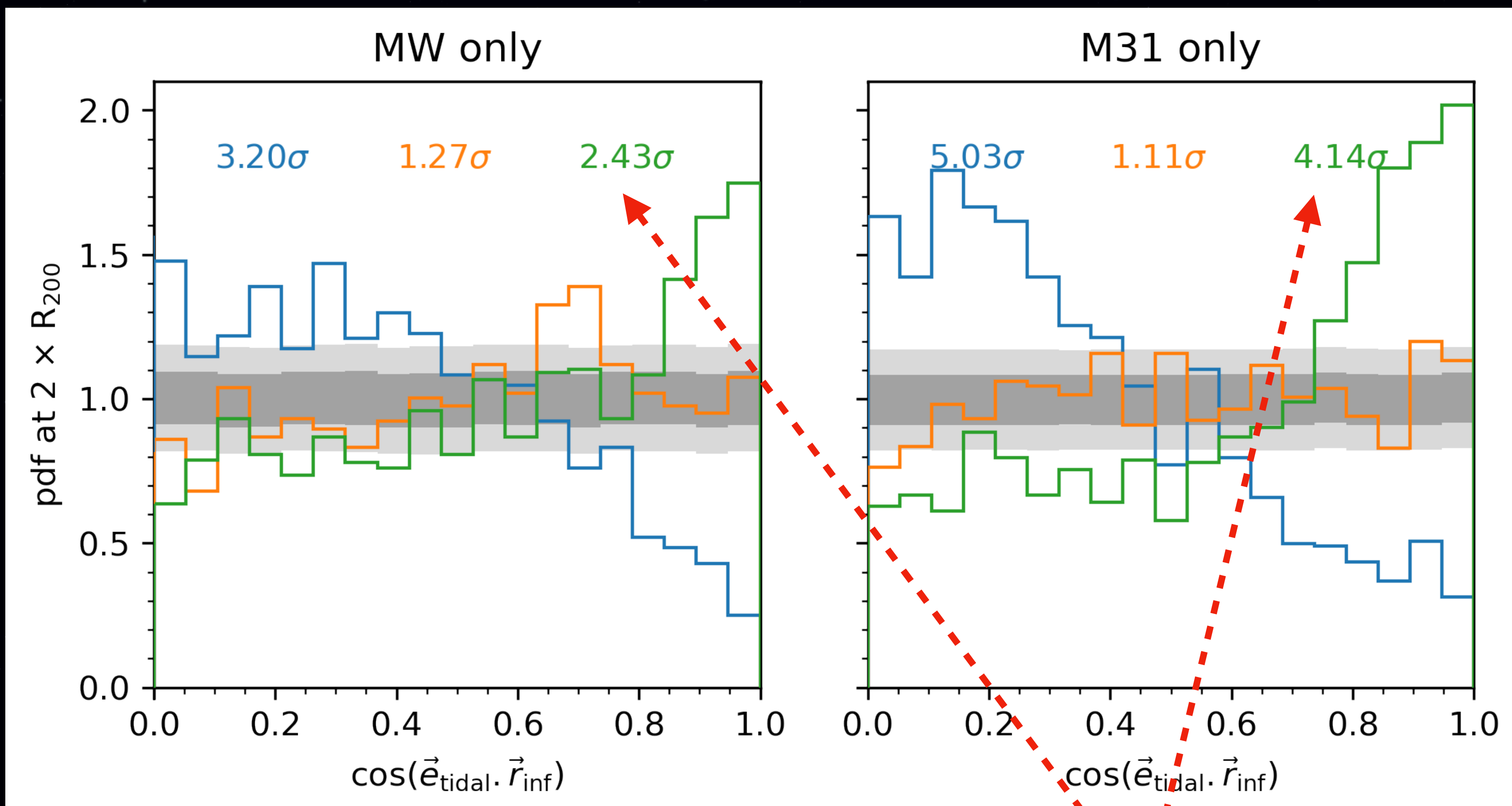
Low number of entry points

Infall aligned with $\vec{e}_3$

Different trend between MW and M31?

Closer look at the main haloes: MW and M31

Distribution of $\cos(\vec{\mathbf{r}}_{\mathbf{inf}} \, . \, \vec{\mathbf{e}}_{\mathbf{1,2,3}})$ at 2 x R_{200}



Dupuy et al. (2022)

M31 defined as the most massive halo in HESTIA

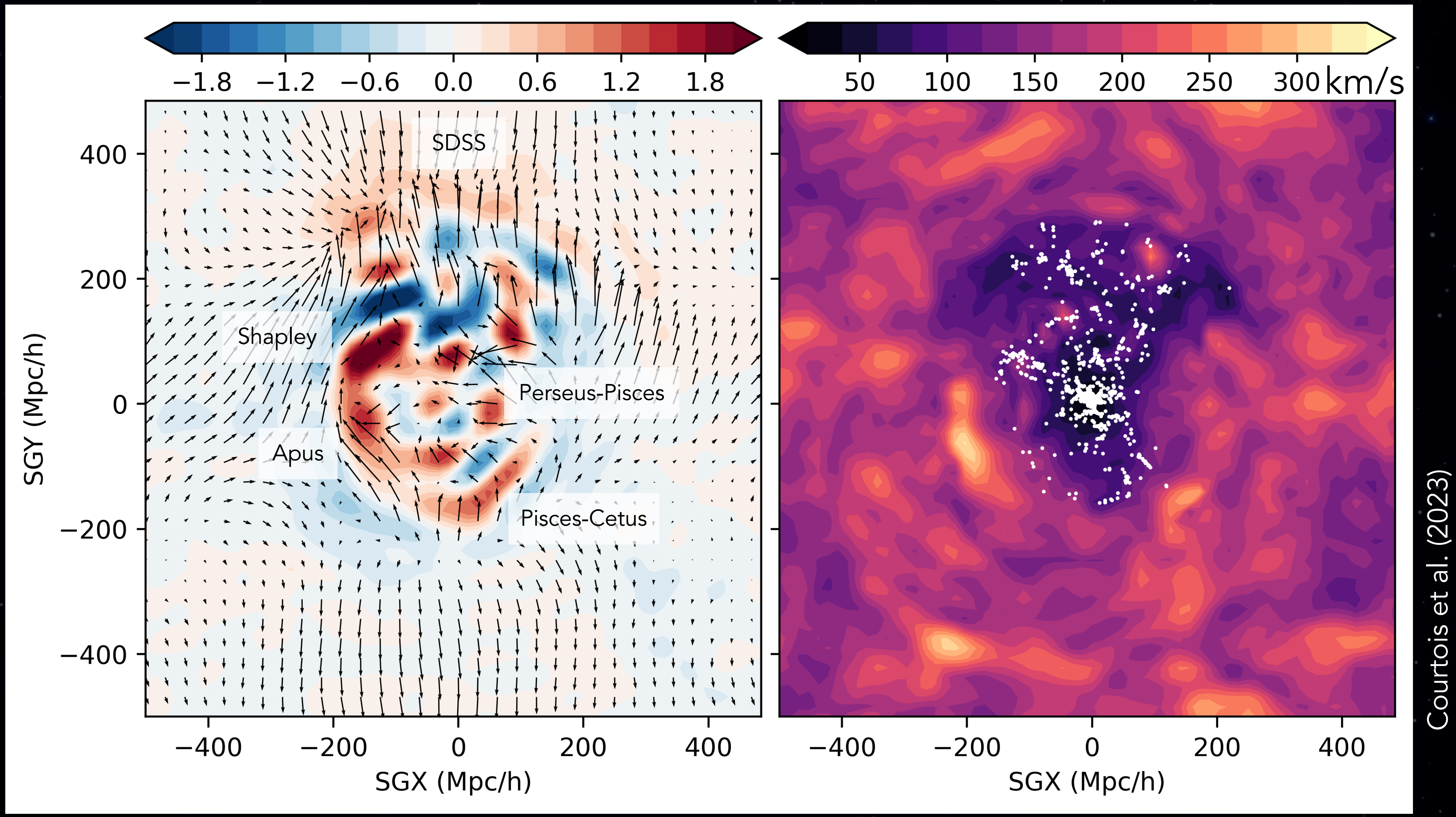
~1.7 times higher for M31

Gravity in the local universe with Cosmicflows-4

Collaborators: Helene Courtois (IP2I), Daniel Guinet (IP2I)

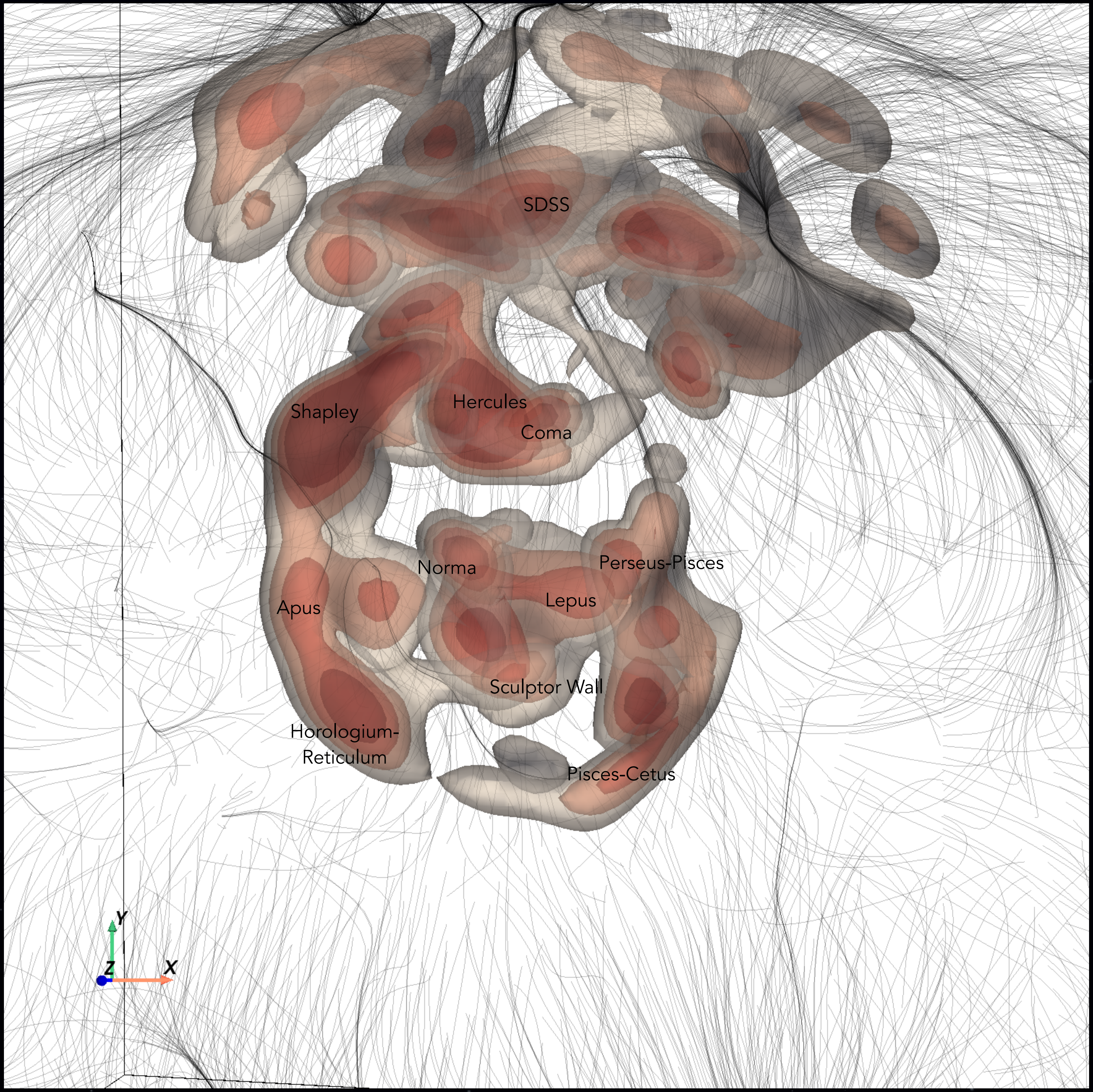
Reconstructed overdensity/velocity fields from CF4 galaxies

Overdensity (and velocity as arrows) Standard deviation on the velocity



Reconstructed with a Hamiltonian-Monte-Carlo algorithm (extension of Graziani et al. 2019)

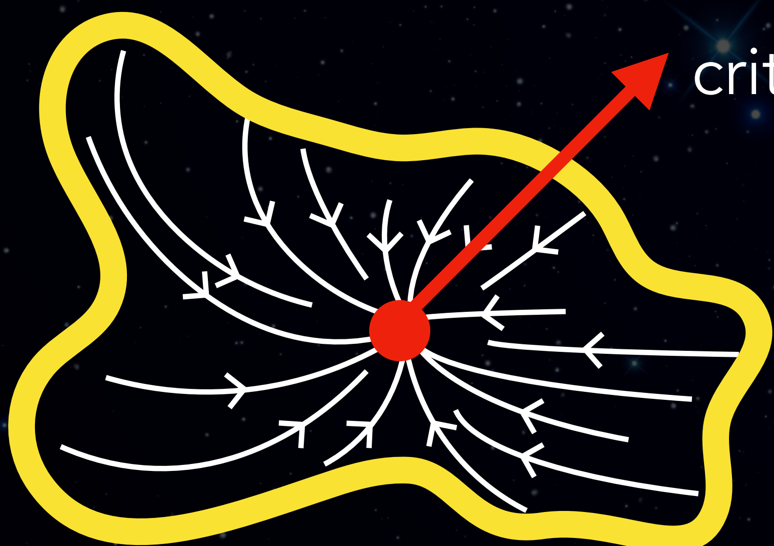
Gravity in the local universe with CF4



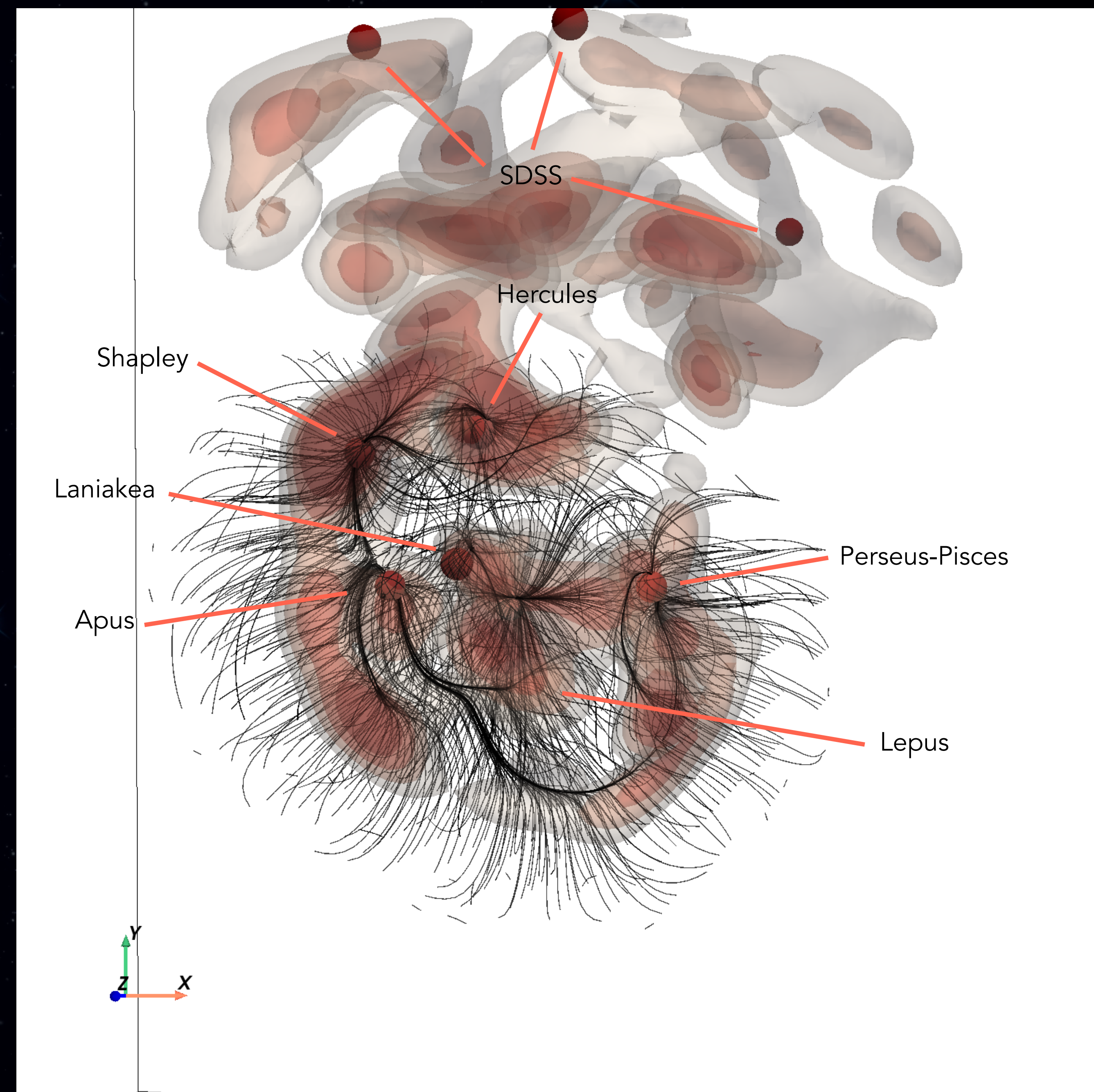
Gravity in the local universe with CF4

Look for basins of attraction

Attractors:
critical points of v



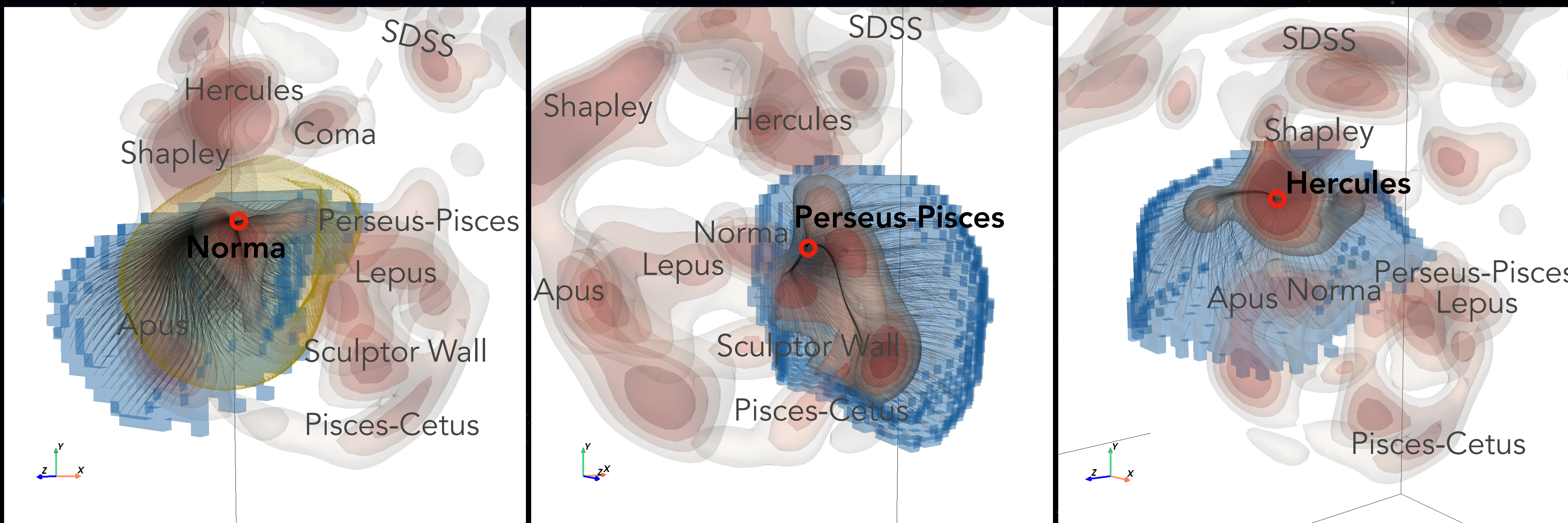
Streamline:



Gravity in the local universe with CF4

CF4 volume: 1.9 x 10^6 $(Mpc/h)^3$

CF2 volume: 2.3 x 10^6 $(Mpc/h)^3$



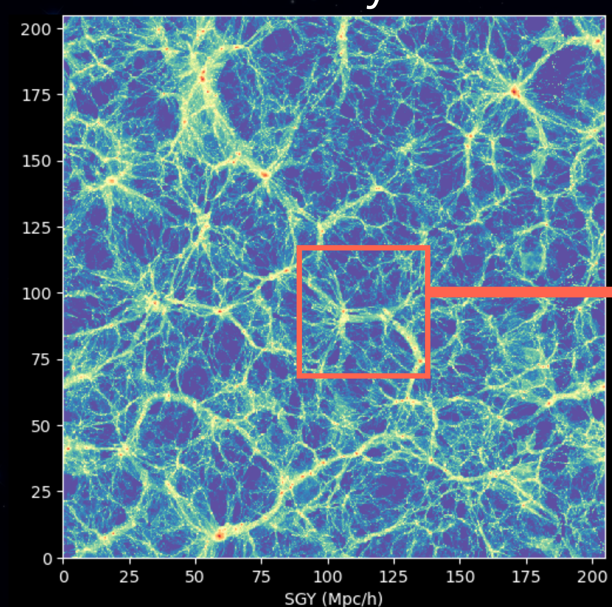
Laniakea **Perseus-Pisces** **Hercules**

Reconstructing the local dark matter map from Cosmicflows-4 with deep learning

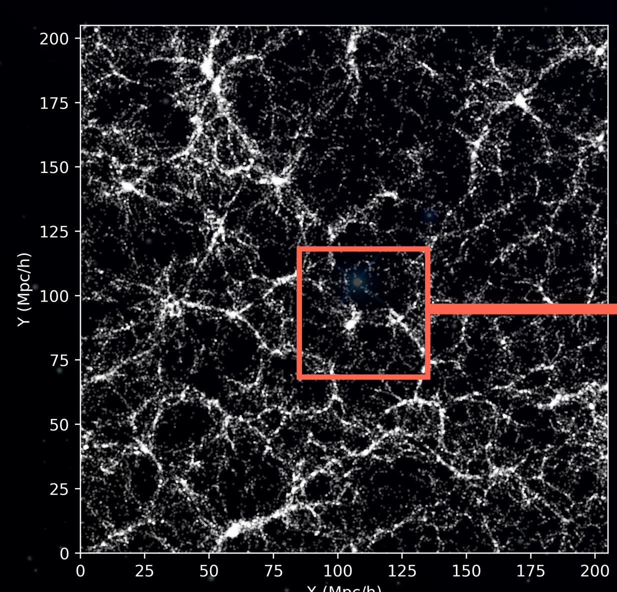
Collaborators: Donghui Jeong (PSU), Sungwook Hong (KASI), Hoseong Hwang (SNU), Juhan Kim (KIAS)

Training with Illustris TNG300 simulation

DM density field



Galaxy catalog



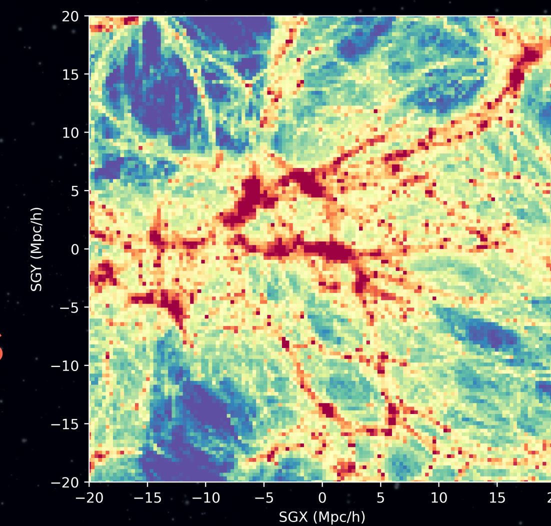
128^3 40 Mpc/h cubes around MW like galaxies

 # training samples: 10629

 # validation samples: 1256

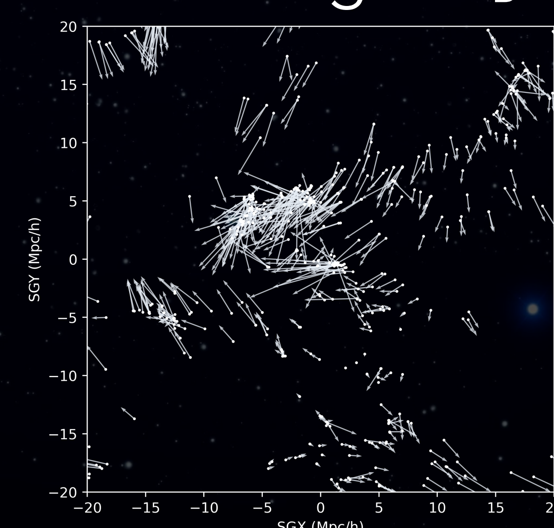
Output layer

"True" DM density field



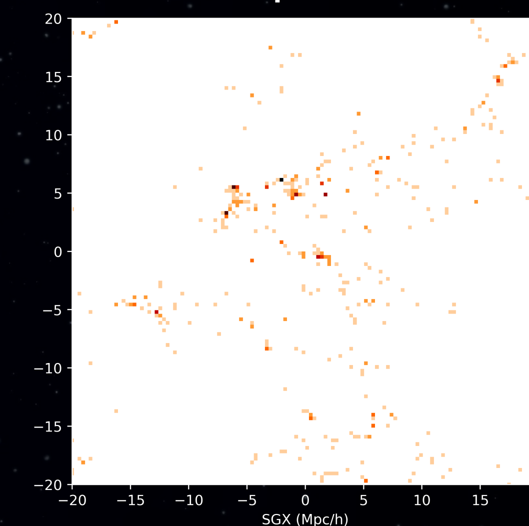
Mock "observations"

ZOA cut |b|<10 deg +M_B cut

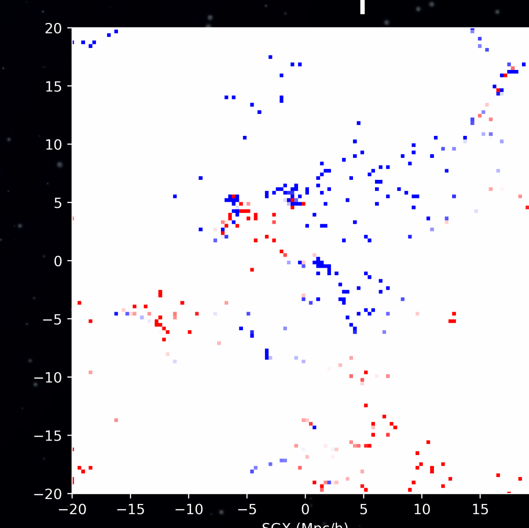


2 channel input layer

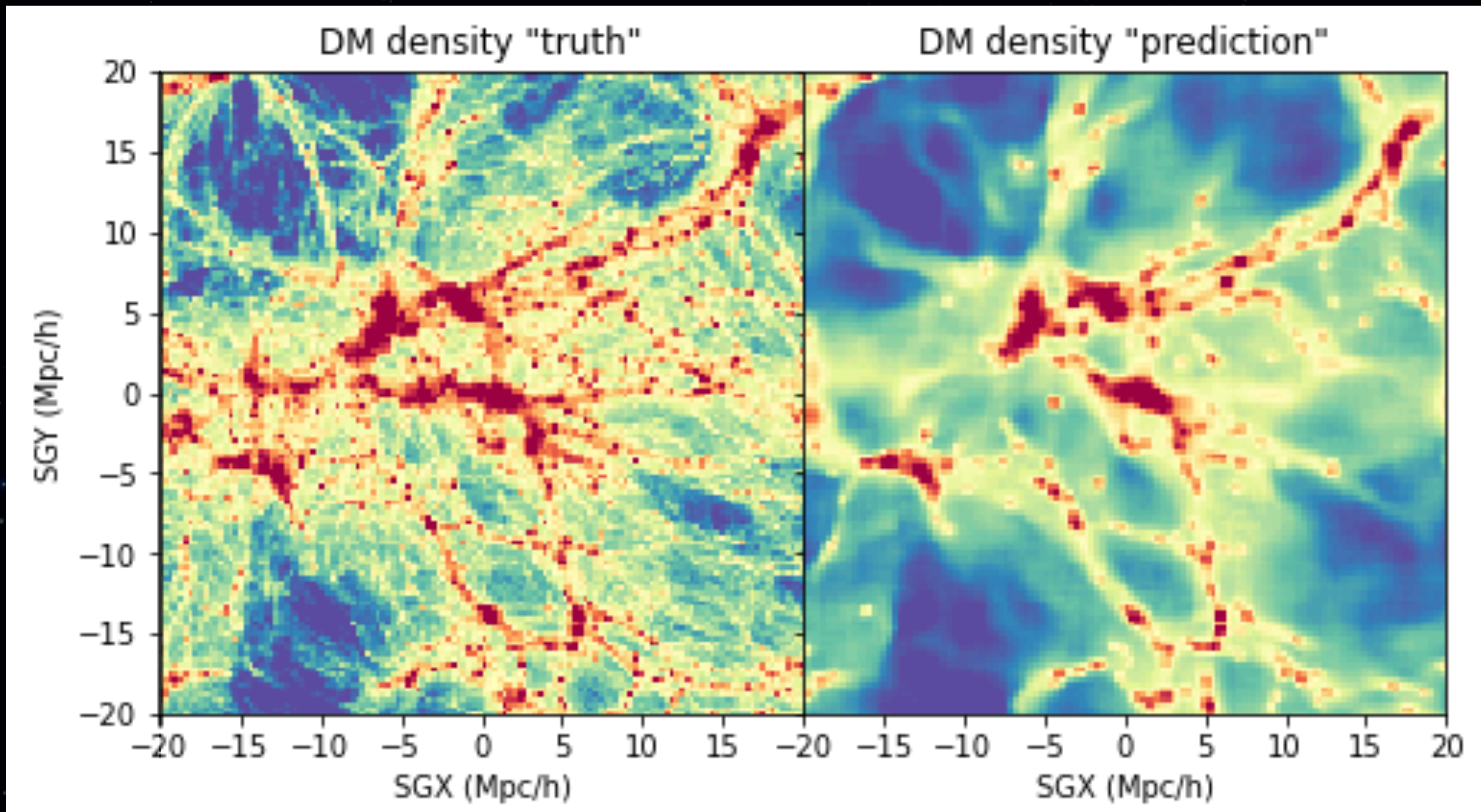
Galaxy positions



Radial vpec



Local DM map from CF4 with deep learning



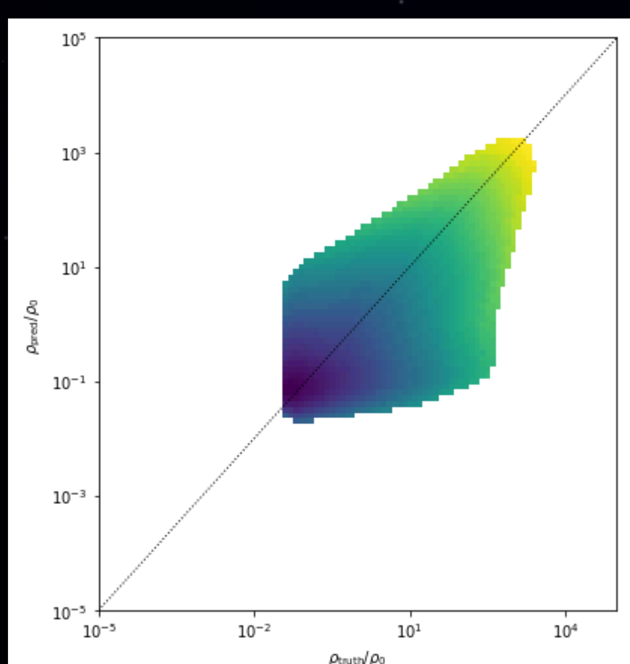
Model trained with TNG300

Convolutional neural network

$$\mathcal{L}_{\mathrm{TNG300}} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{1}{5}\log_{10}\left(\frac{\rho_i^{\mathrm{pred}}}{\rho_i^{\mathrm{truth}}}\right)\right]^2$$

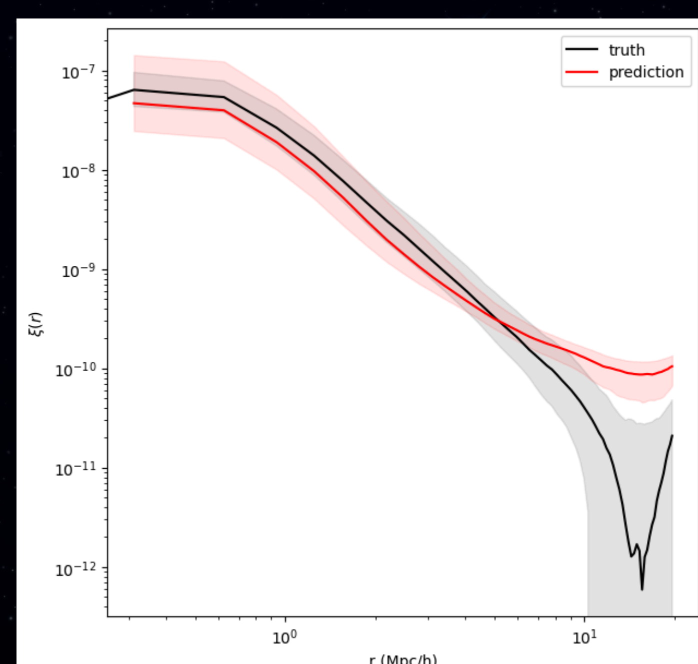
Cell by cell comparison

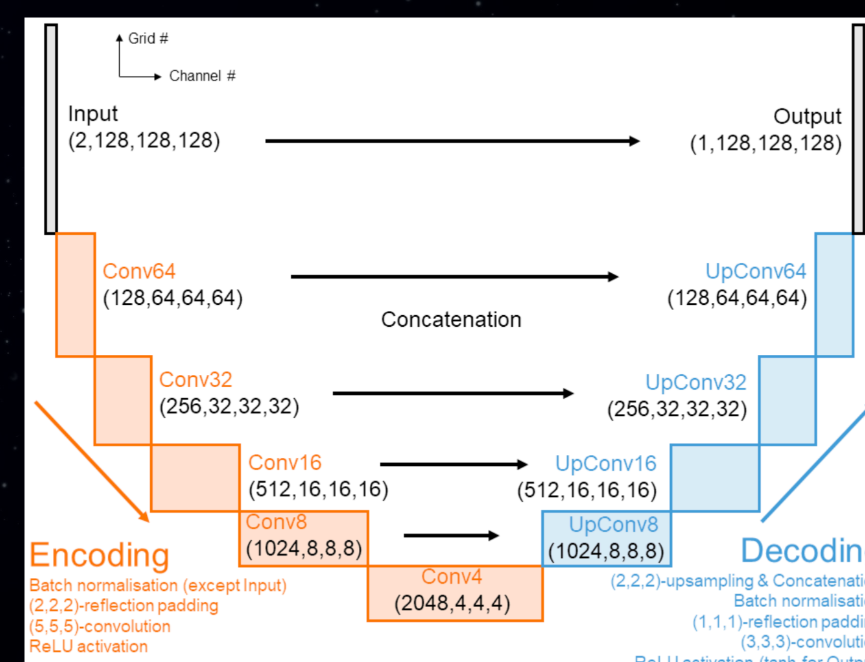
Predicted DM density



True DM density

2point correlation function

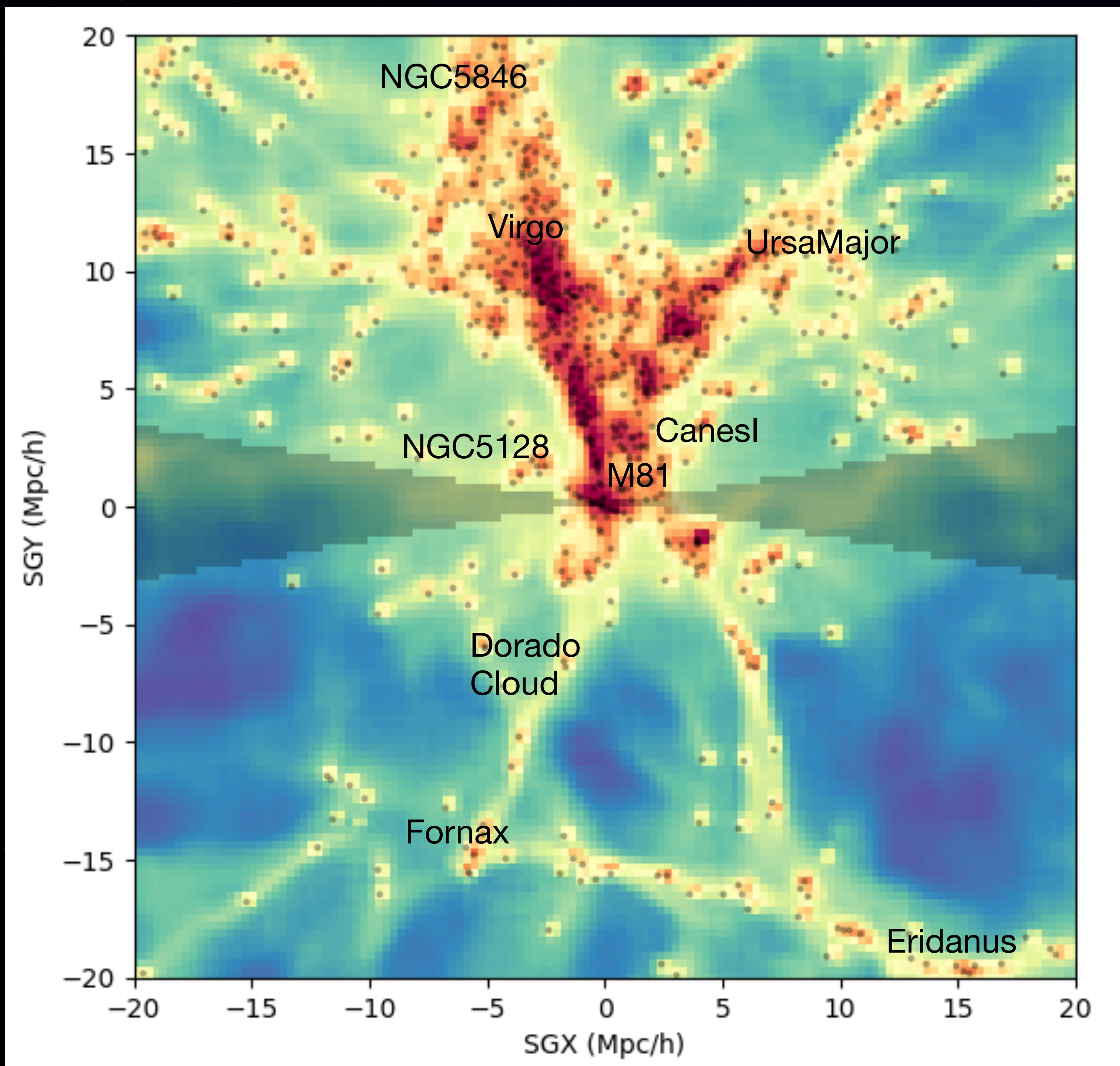




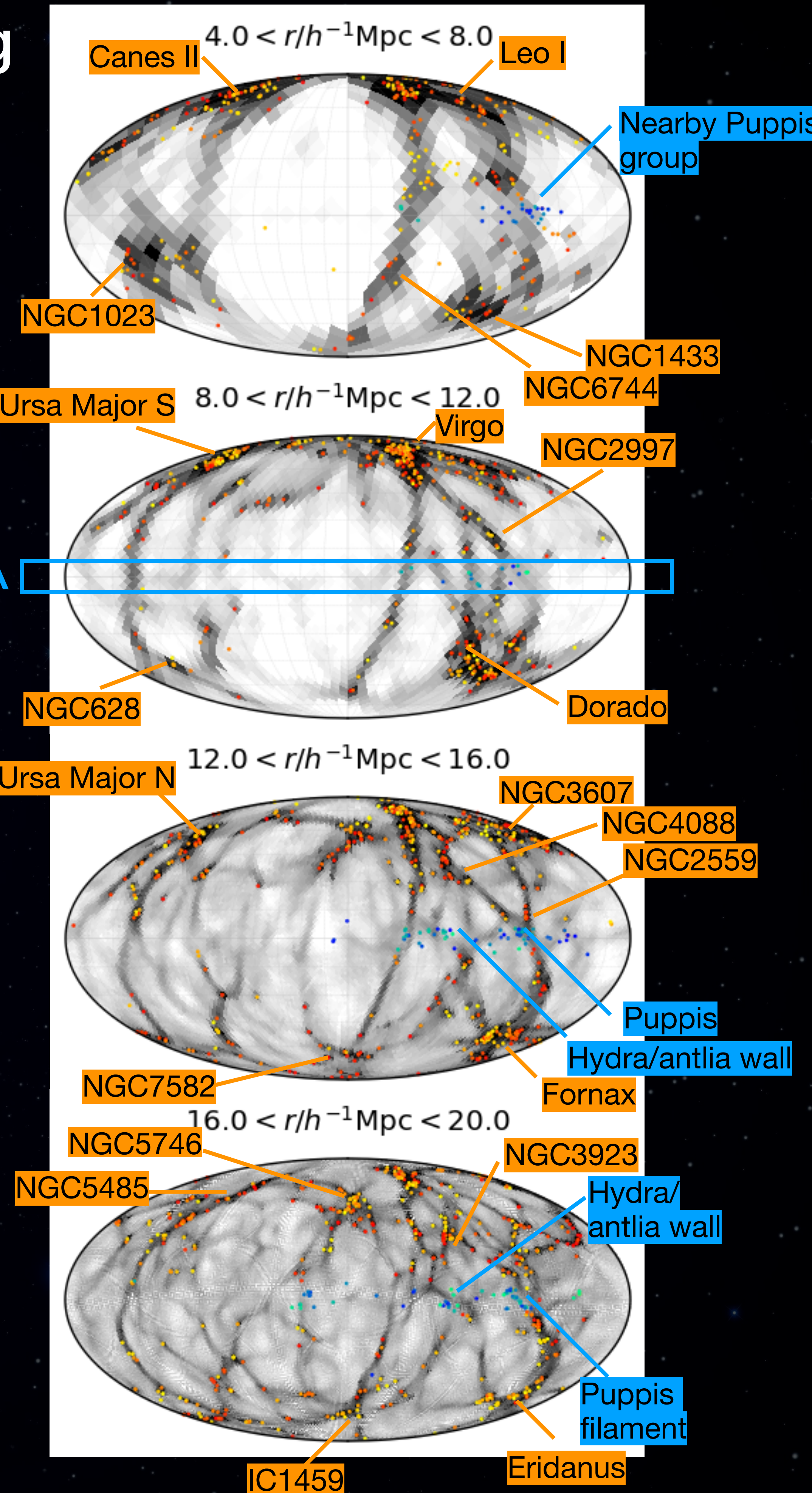
Local DM map from CF4 with deep learning

TNG300 model applied to CF4

Sky map in galactic coordinates
- CF4 galaxies
- ZOA galaxies (2MRS ZOA+ Parkes HI ZOA)



SGZ = 0 Mpc/h



Summary

Anisotropic satellite accretion with HESTIA

- Two eras in Local Group accretion history: early (before z=0.7) and late (after z=0.7) infall

What happens to LG around z=0.7?

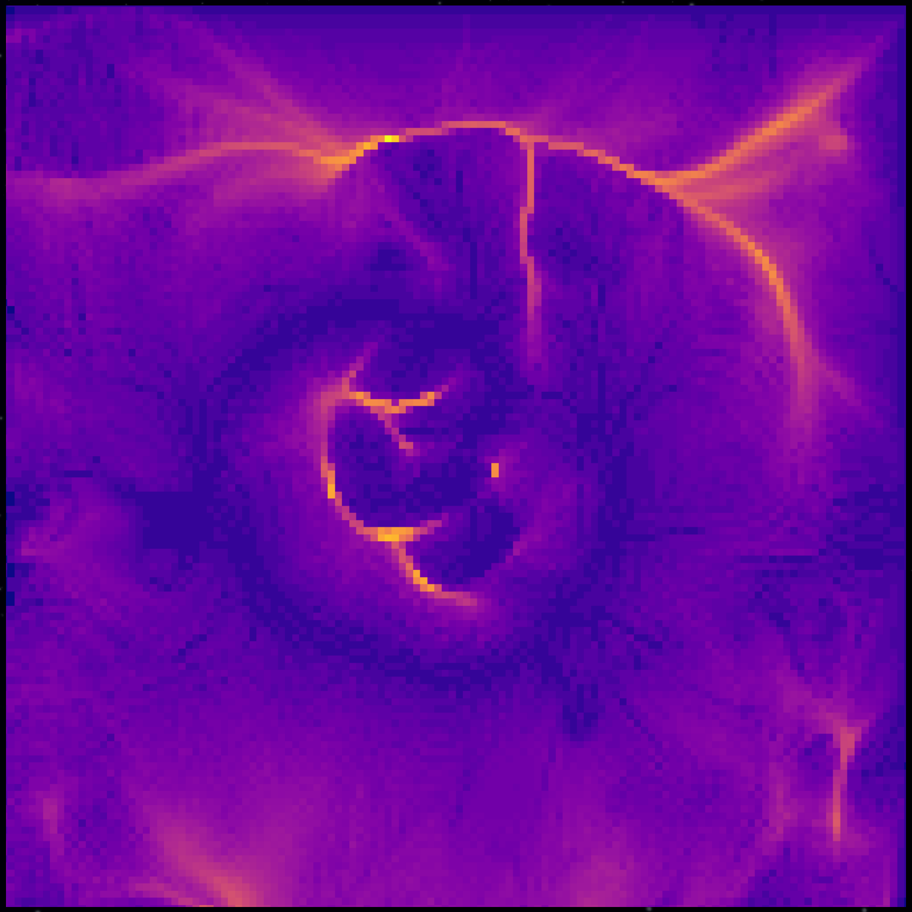
- At 2 x R_{200} (probing transition from NL to QL regimes): **infall direction strongly aligned with $\vec{e}_3$**

Mass being fed into LG may come from local filament also aligned with $\vec{e}_3$

Reconstructing DM map with deep learning

Reconstructed the high-resolution DM map up to 20 Mpc/h from the Cosmicflows-4 peculiar velocities

Extend training to larger grid to include full catalog and explore distant structures



Gravity in the local universe with CF4

Identified basins of attraction within the Cosmicflows-4 reconstructed velocity field with segmentation

Also look at basins of repulsion / repellers: Dipole Repeller, Cold Spot Repeller…