Bayesian inference and cosmic web classification

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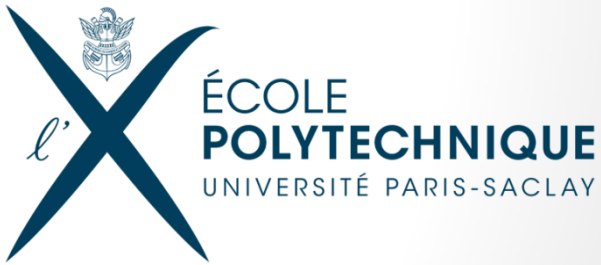
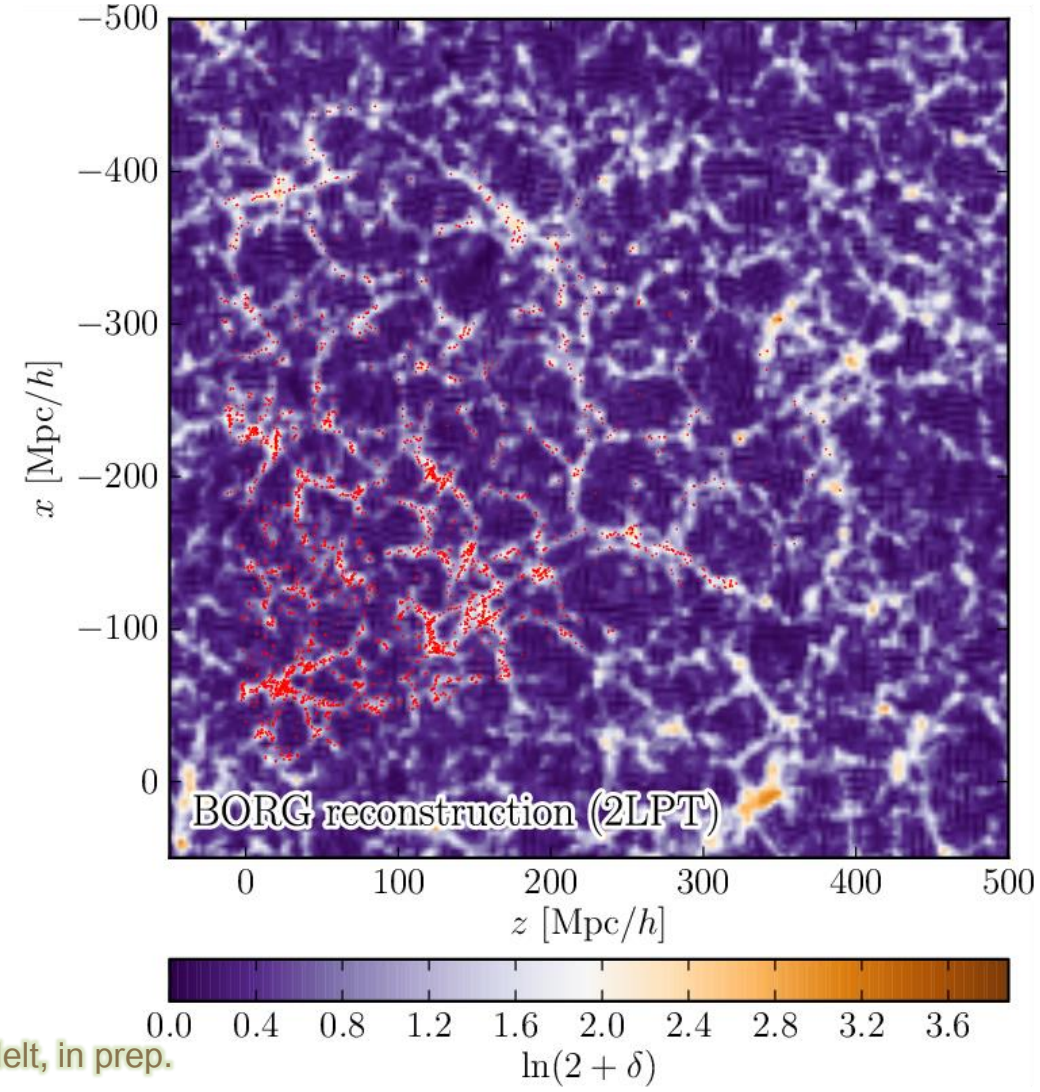


In collaboration with:

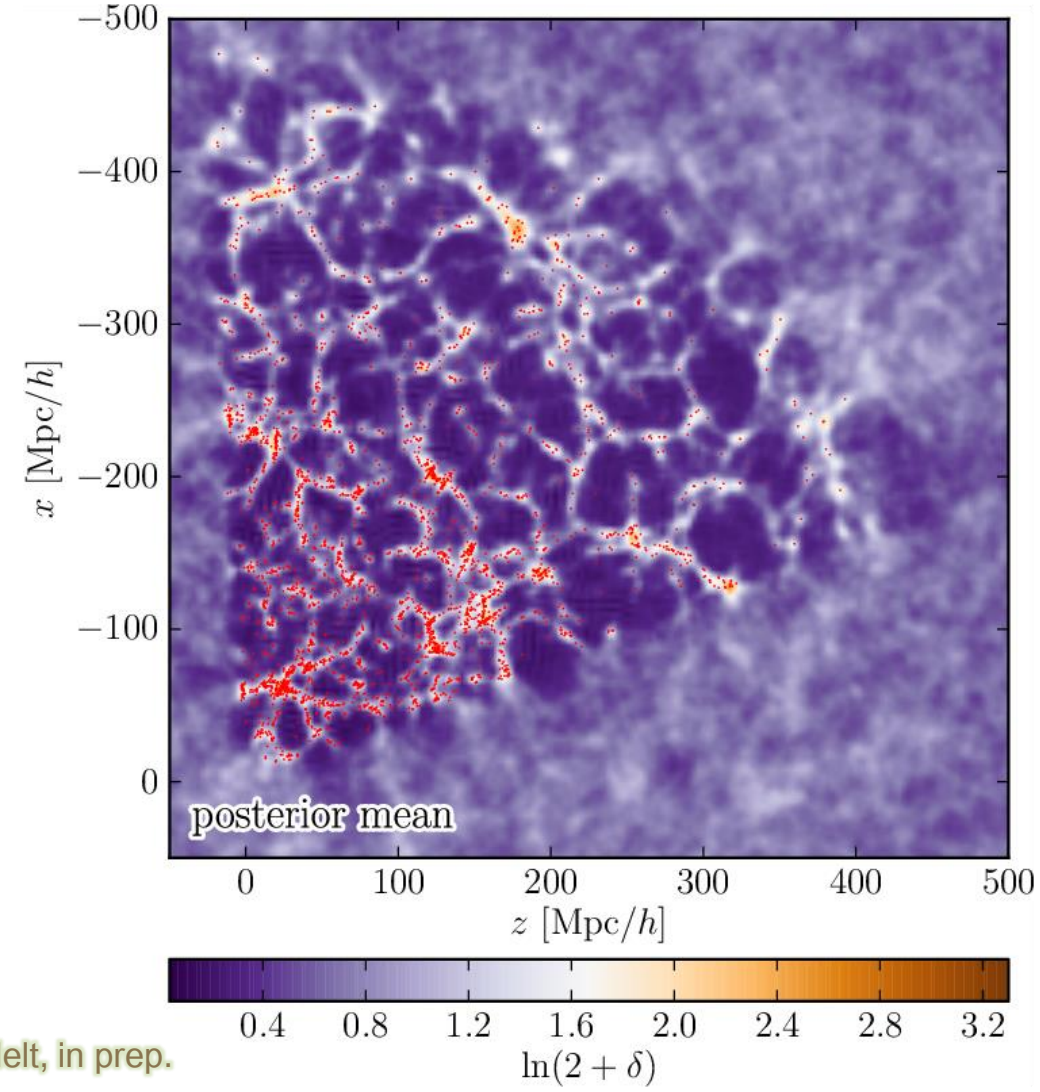
Jacopo Chevallard (U. São Paulo), Nico Hamaus (IAP), Jens Jasche (IAP), Emilio Romano-Díaz (U. Bonn), Paul M. Sutter (IAP/Ohio State U.), Benjamin Wandelt (IAP/U. Illinois)

Previously…



Jasche, FL & Wandelt, in prep.

Previously…



Jasche, FL & Wandelt, in prep.

Classifications of the cosmic web

Static

- Identification based on the density of tracers
- On an object basis

FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

(for voids)

Dynamic

- Identification based on tidal shear analysis
- On a voxel basis

FL, Jasche, Chevallard & Wandelt, in prep.

Tidal shear analysis

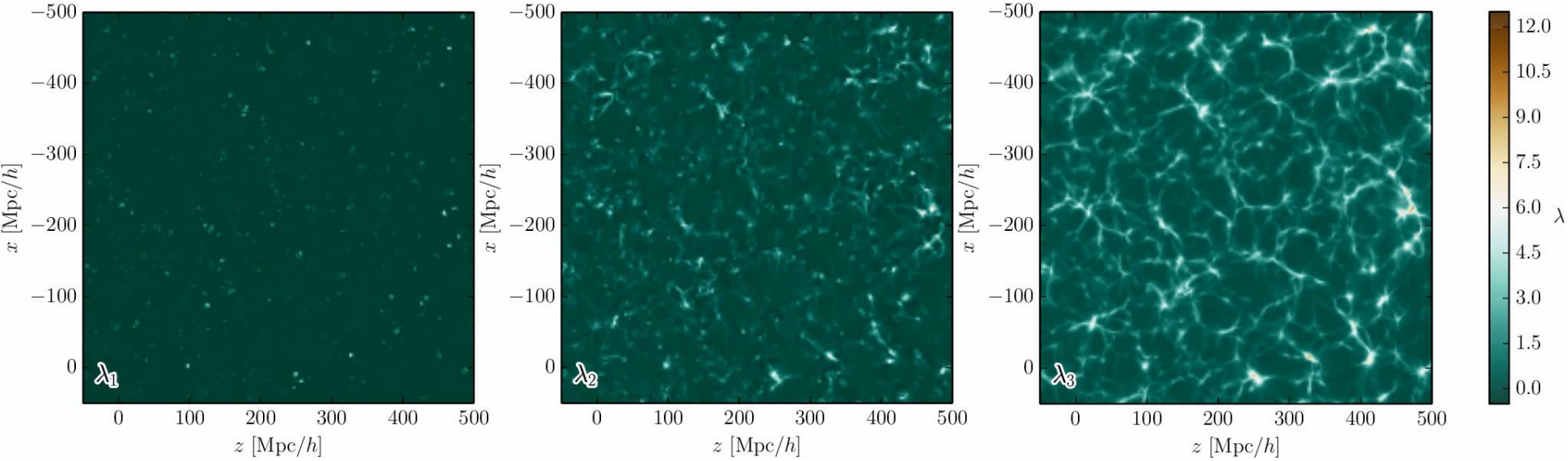
- $\lambda_1, \lambda_2, \lambda_3$: eigenvalues of the tidal field tensor, the Hessian of the gravitational potential: $T_{ij} = \partial_i \partial_j \Phi$

  - Voids: $\lambda_1, \lambda_2, \lambda_3 < 0$
  - Sheets: $\lambda_1 > 0$ and $\lambda_2, \lambda_3 < 0$
  - Filaments: $\lambda_1, \lambda_2 > 0$ and $\lambda_3 < 0$
  - Clusters: $\lambda_1, \lambda_2, \lambda_3 > 0$

Hahn, Porciani, Carollo & Dekel, 2006, arXiv:astro-ph/0610280

- Outline:
  - I. Dynamic structures inferred by BORG
  - II. Non-linear constrained realizations of the Sloan volume
  - III. Dark matter voids in the SDSS

Tidal shear inferred by BORG



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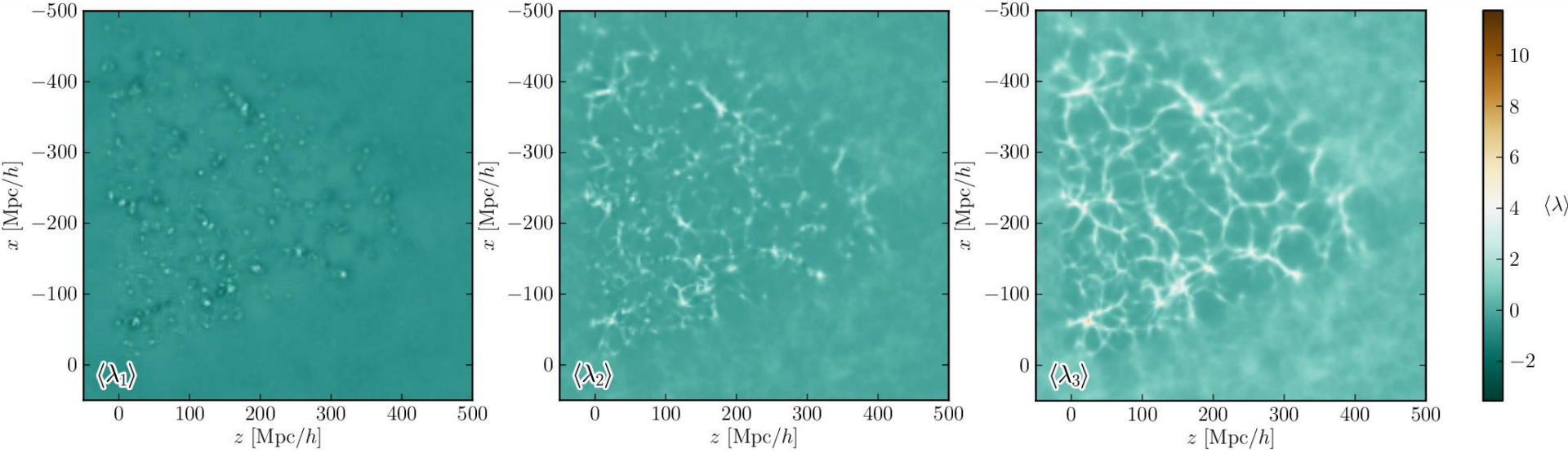

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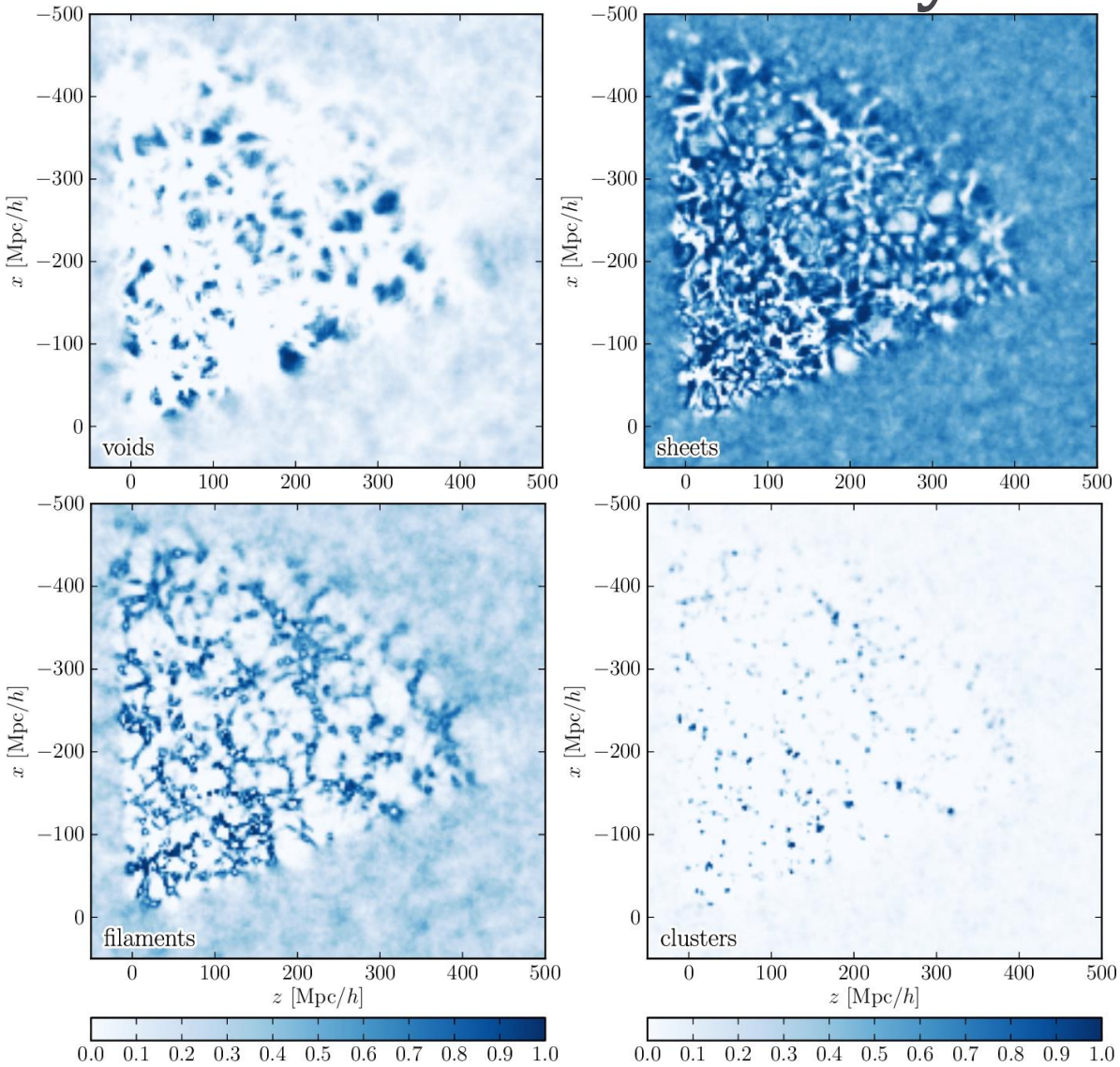
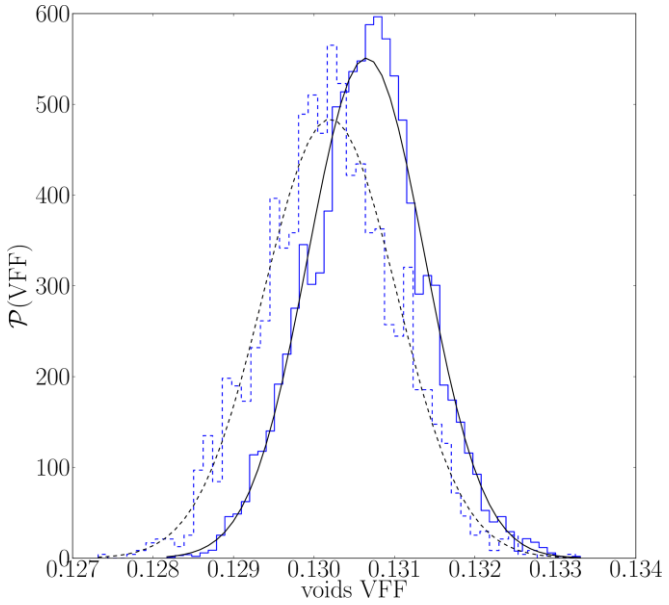
Dynamic structures inferred by BORG



Volume and Mass filling fractions

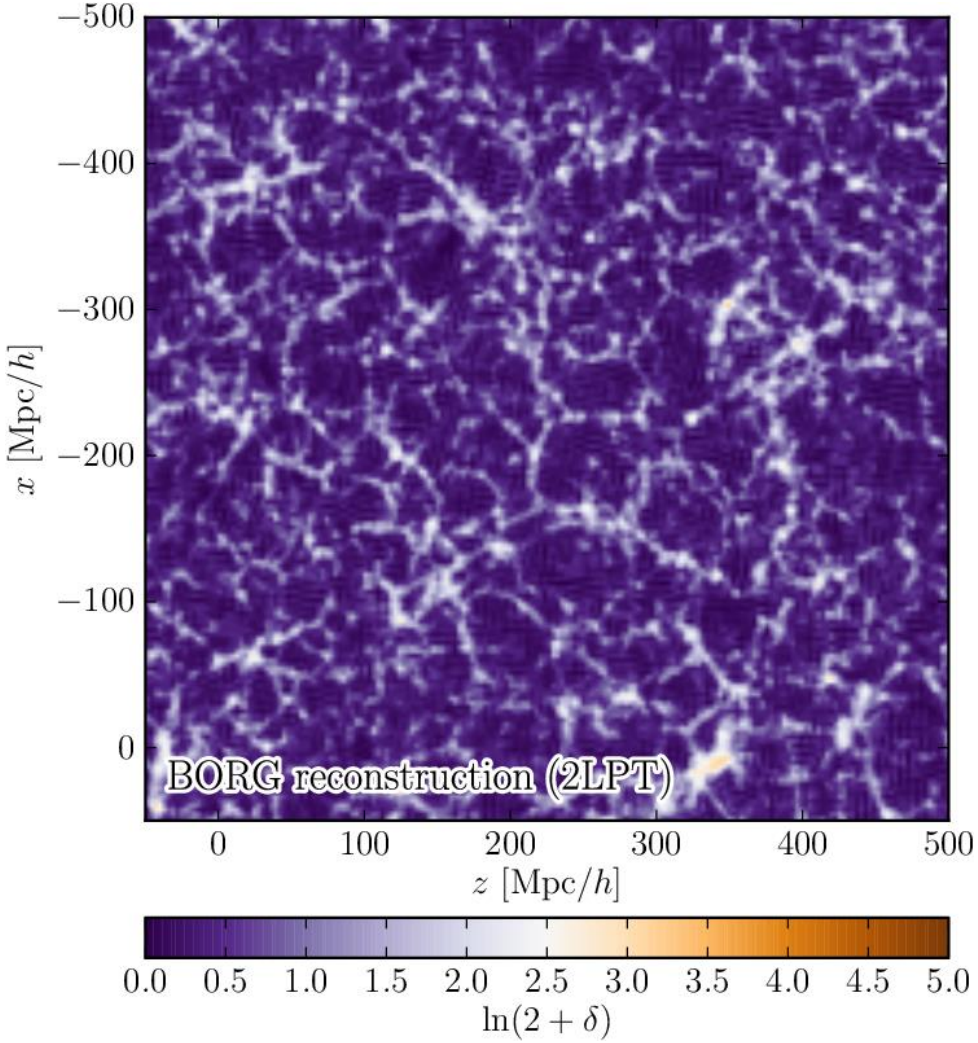
Structure type	$\mu_{\rm VFF}$	$\sigma_{\rm VFF}$	$\mu_{\rm VFF}$	$\sigma_{\rm VFF}$
	Initial conditions ($z = 1000$)			
	BORG samples		Unconstrained 2LPT	
Void	0.07550	1.6791×10^{-3}	0.07989	1.4830×10^{-3}
Sheet	0.41182	3.0739×10^{-3}	0.42018	2.5812×10^{-3}
Filament	0.42787	2.9295×10^{-3}	0.42008	2.5918×10^{-3}
Halo	0.08481	1.8245×10^{-3}	0.07985	1.4697×10^{-3}
	Final conditions ($z = 0$)			
	BORG samples		Unconstrained 2LPT	
Void	0.11211	6.6627×10^{-3}	0.13032	6.8015×10^{-3}
Sheet	0.53195	1.3806×10^{-3}	0.54273	2.2572×10^{-3}
Filament	0.31703	6.4430×10^{-3}	0.29733	5.8562×10^{-3}
Halo	0.03890	1.0625×10^{-3}	0.02962	7.7642×10^{-3}

Structure type	$\mu_{\rm MFF}$	$\sigma_{\rm MFF}$	$\mu_{\rm MFF}$	$\sigma_{\rm MFF}$
	Initial conditions ($z = 1000$)			
	BORG samples		Unconstrained 2LPT	
Void	0.07526	1.6734×10^{-3}	0.07963	1.4785×10^{-3}
Sheet	0.41164	3.0751×10^{-3}	0.42002	2.5816×10^{-3}
Filament	0.42803	2.9277×10^{-3}	0.42025	2.5904×10^{-3}
Halo	0.08508	1.8311×10^{-3}	0.08011	1.4749×10^{-3}
	Final conditions ($z = 0$)			
	BORG samples		Unconstrained 2LPT	
Void	0.03644	2.8585×10^{-3}	0.03913	1.4669×10^{-3}
Sheet	0.33573	5.2606×10^{-3}	0.34070	2.5190×10^{-3}
Filament	0.48757	5.1458×10^{-3}	0.48267	2.5181×10^{-3}
Halo	0.14027	3.0501×10^{-3}	0.13750	1.6489×10^{-3}



FL, Jasche, Chevallard & Wandelt, in prep.

Data-constrained non-linear realizations



Jasche, FL, Romano-Diaz & Wandelt, in prep.

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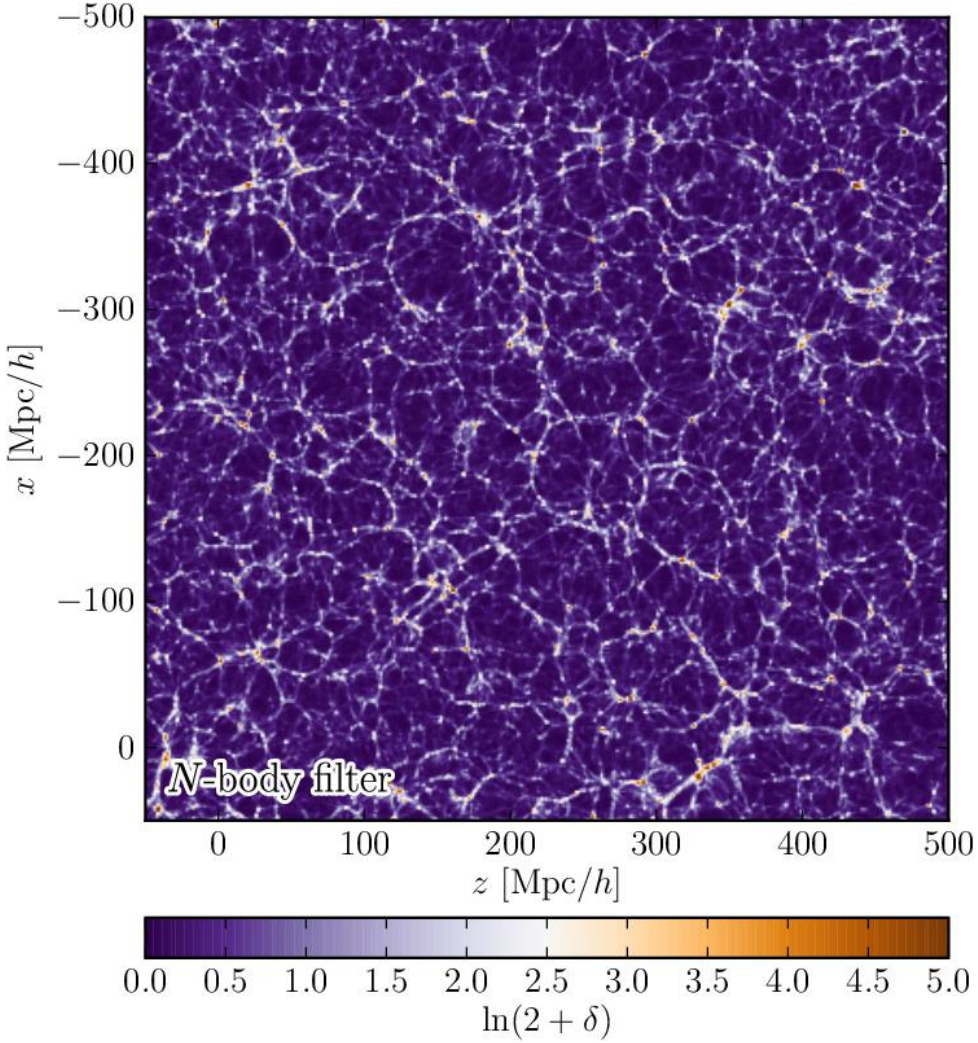

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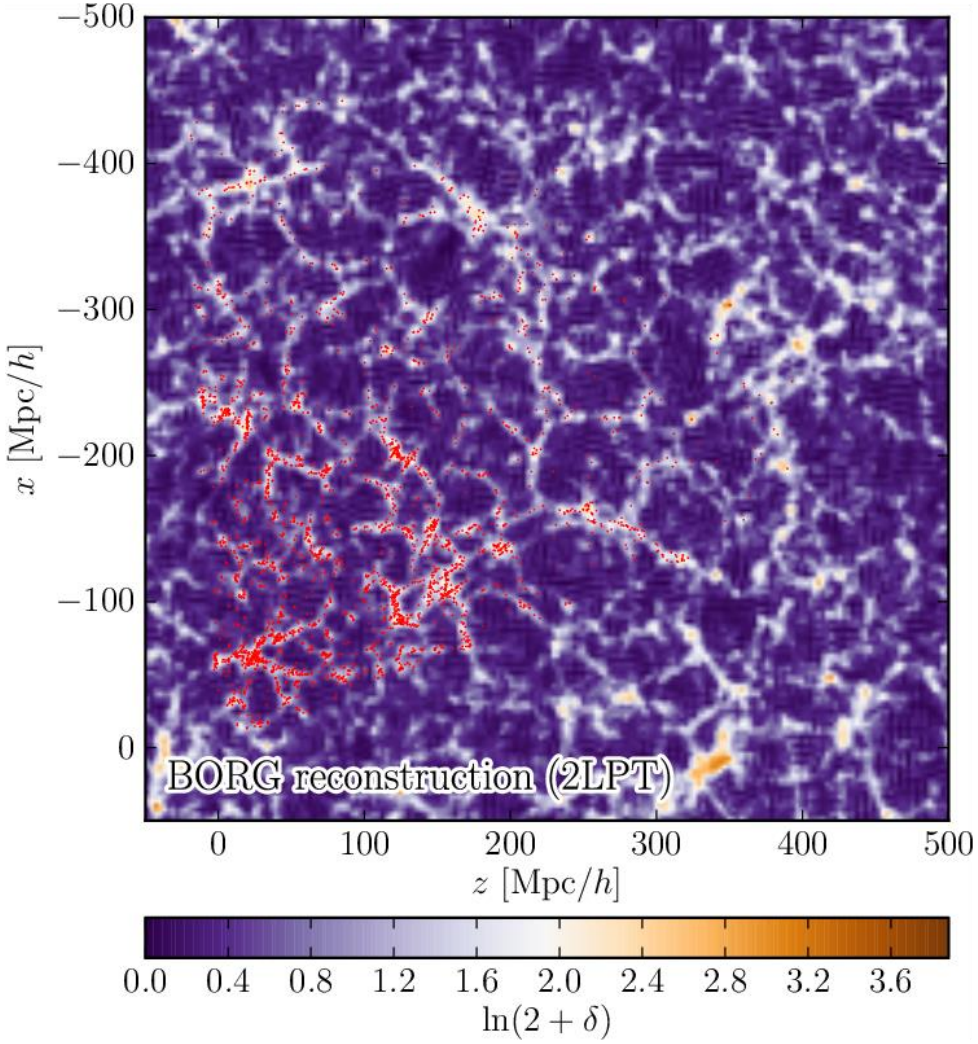

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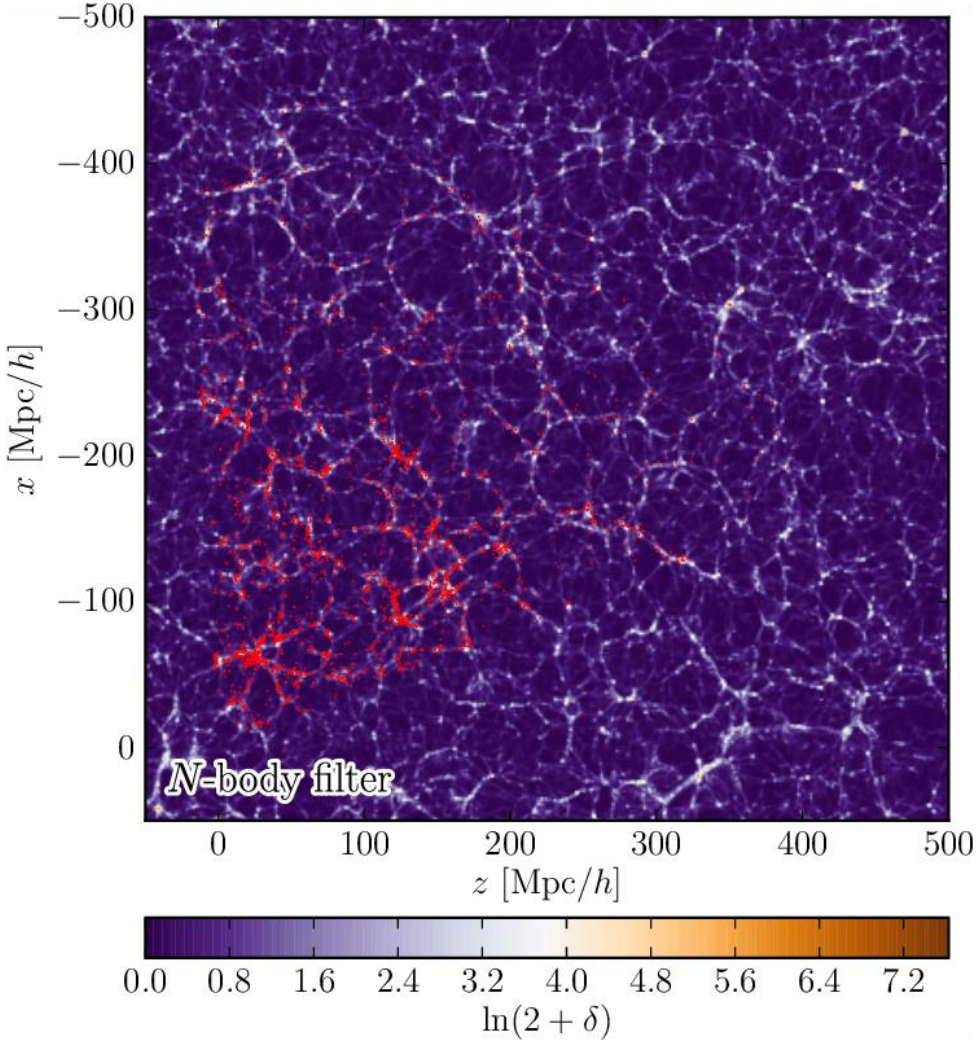
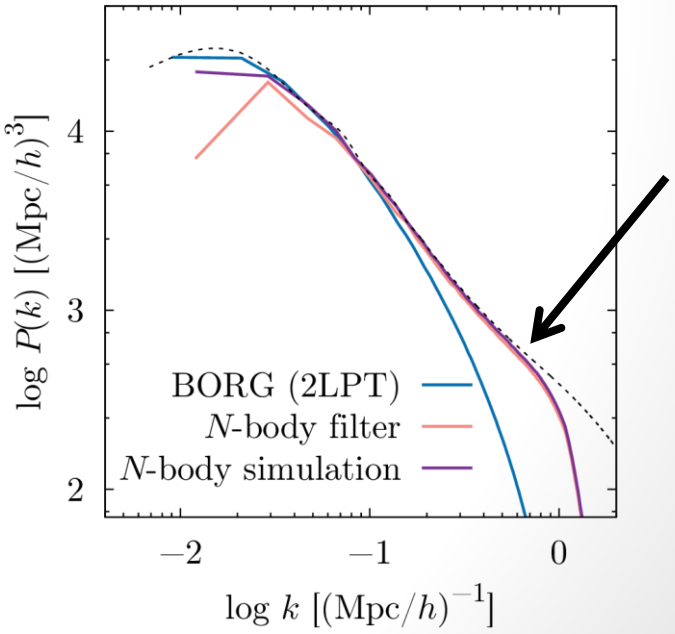


Jasche, FL, Romano-Diaz & Wandelt, in prep.

Data-constrained non-linear realizations

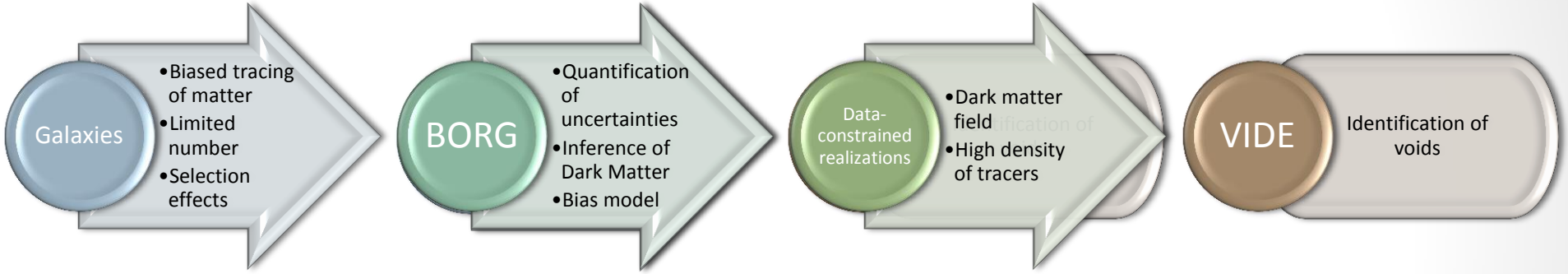
- A dynamic physical model naturally introduces some correlations between the constrained and unconstrained parts
- Constrained resimulations act as hypothesis generating machines, whose predictions can be tested with complementary observations in the actual sky.
- With a full N-body simulation, we address the non-linear regime of structure formation!



Jasche, FL, Romano-Diaz & Wandelt, in prep.

Dark matter voids in the SDSS

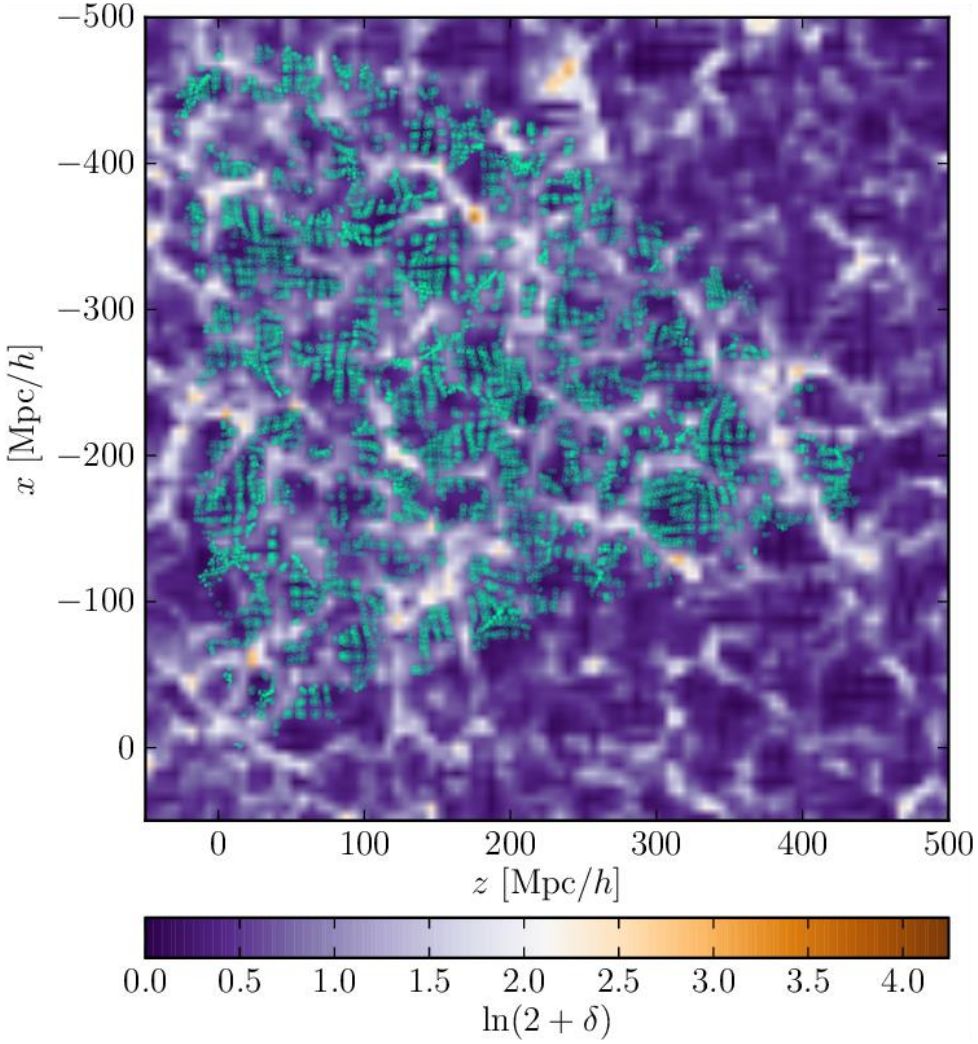
- How?



- Why? What is made possible by our technology:
  - Bias. Voids are defined in the dark matter distribution, not in galaxies.
  - Shot noise. Galaxies sparsely sample the dark matter distribution. We get 10x more dark matter voids than galaxy voids.

FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

Dark matter voids in the SDSS



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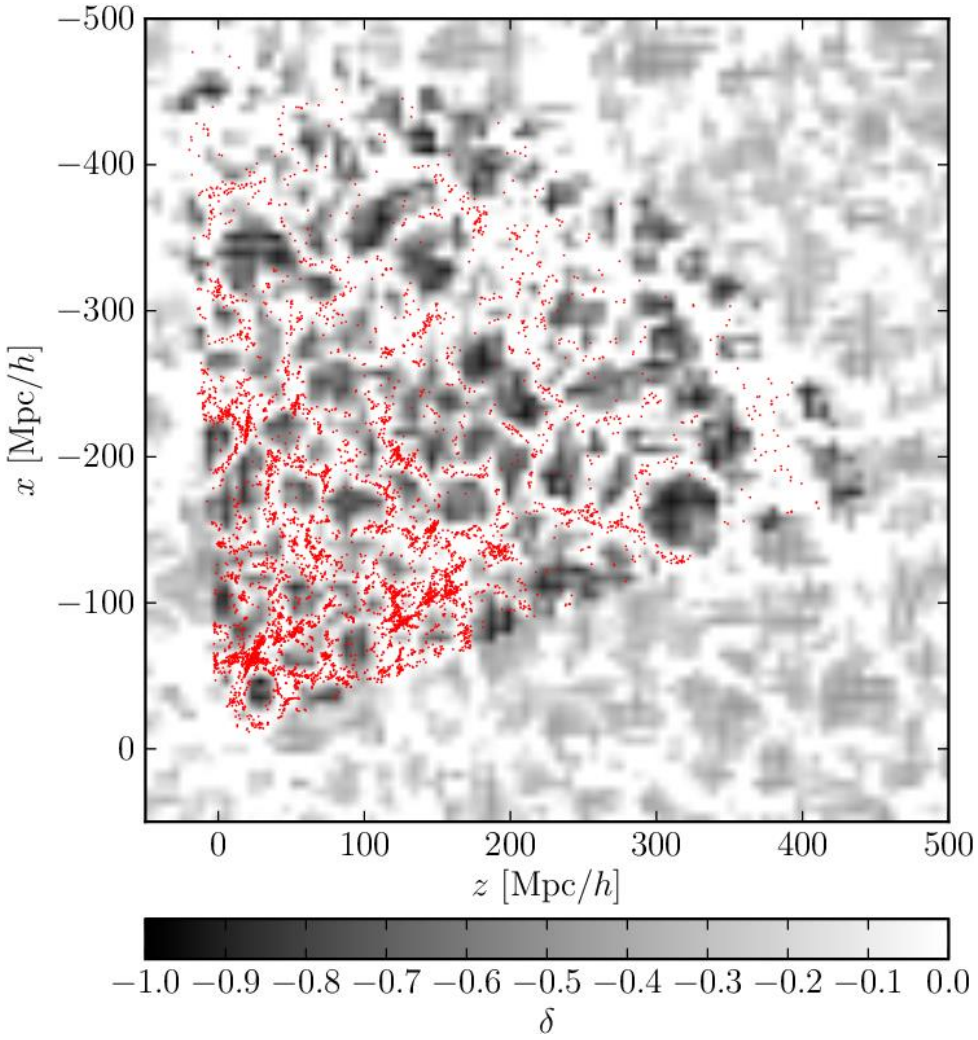
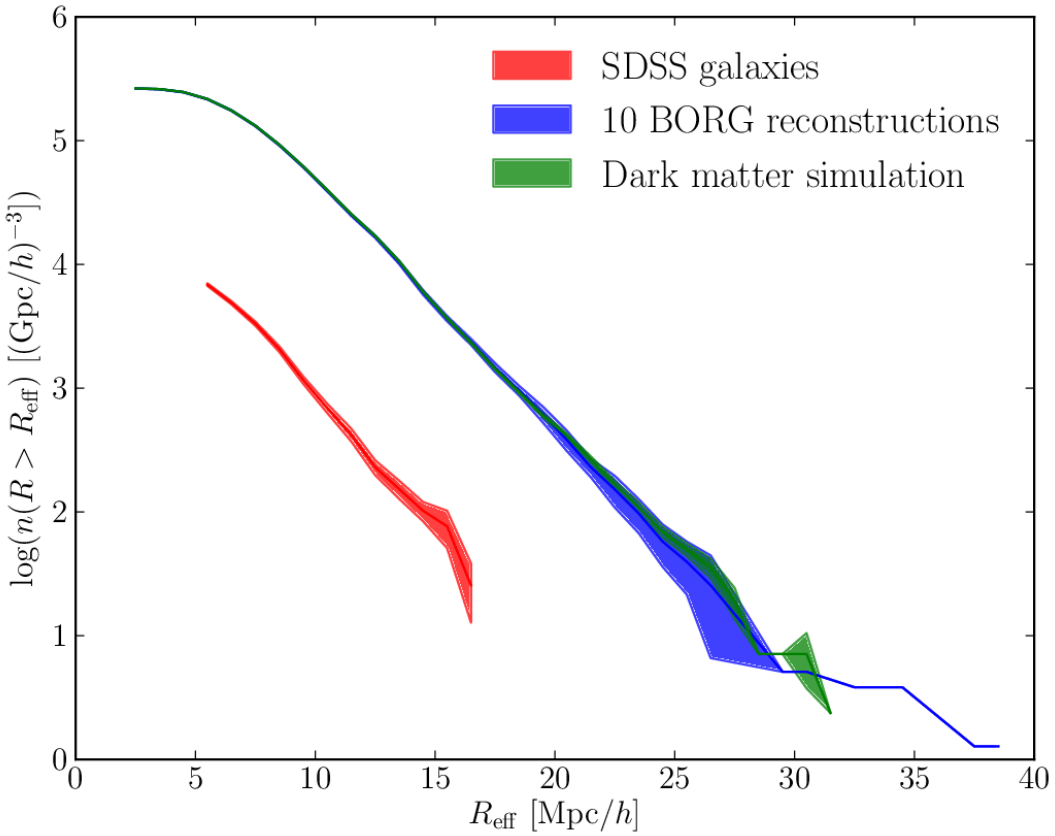


FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

Properties of dark matter voids

- For usual void statistics, results are consistent with *N*-body simulations.



void number count

FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

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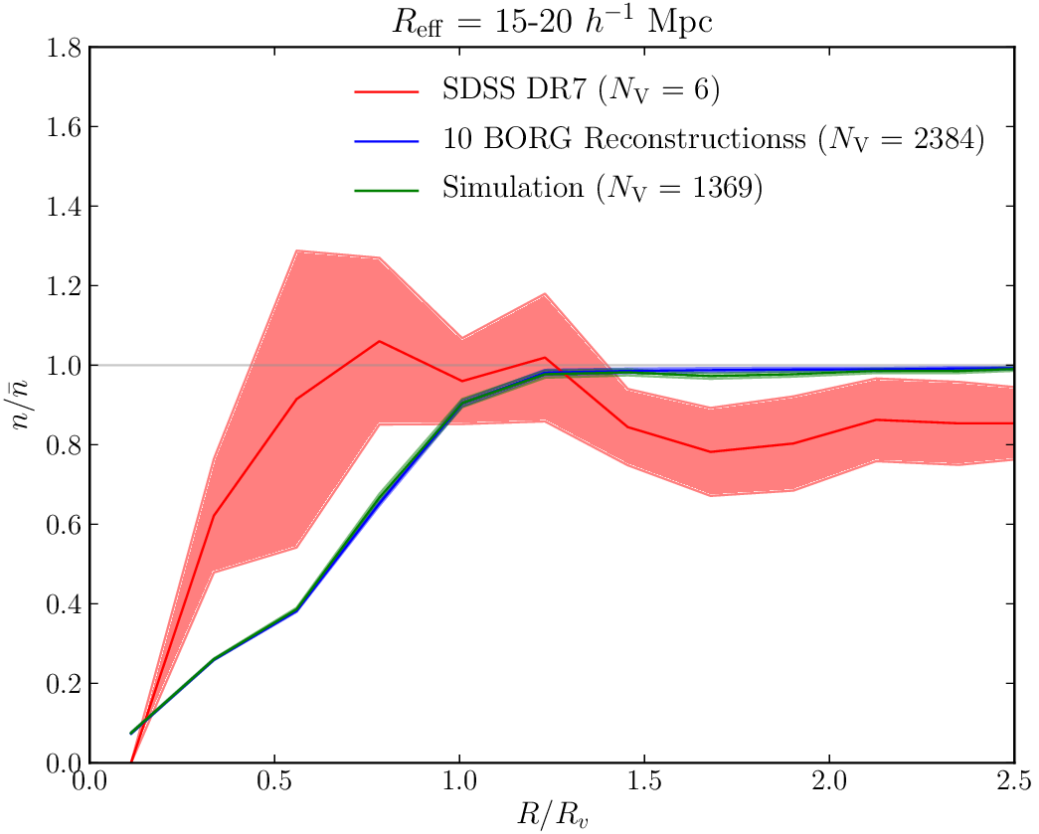

void density profile

FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

Properties of dark matter voids

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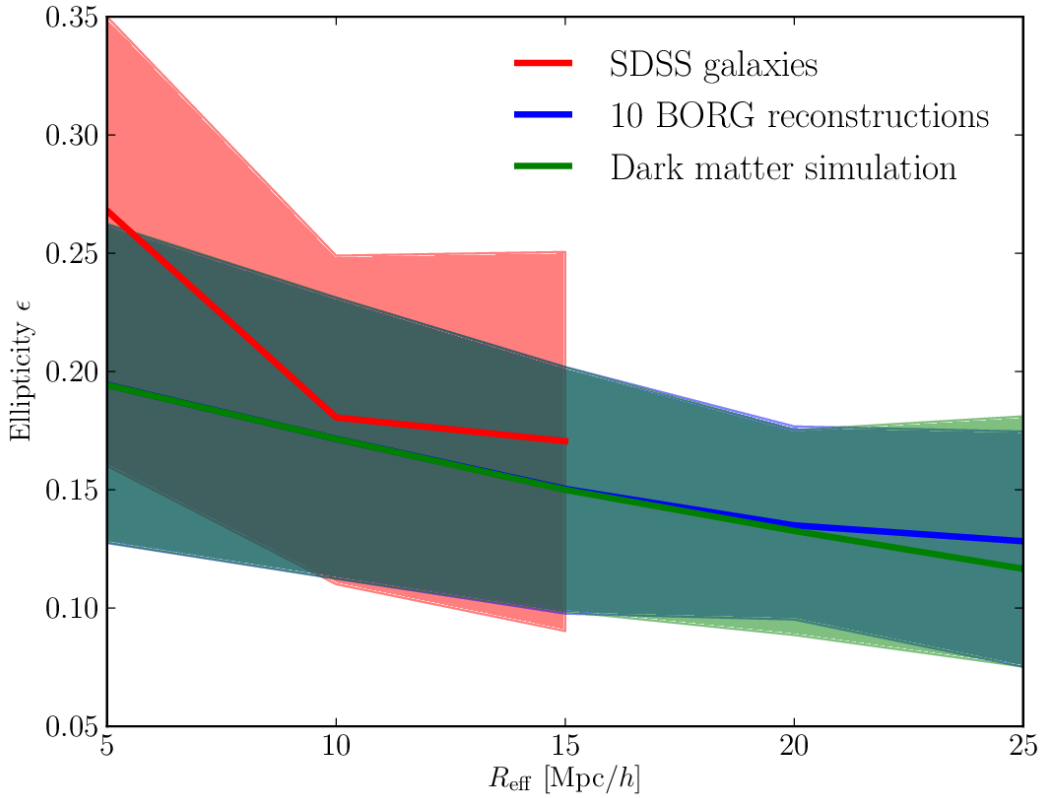
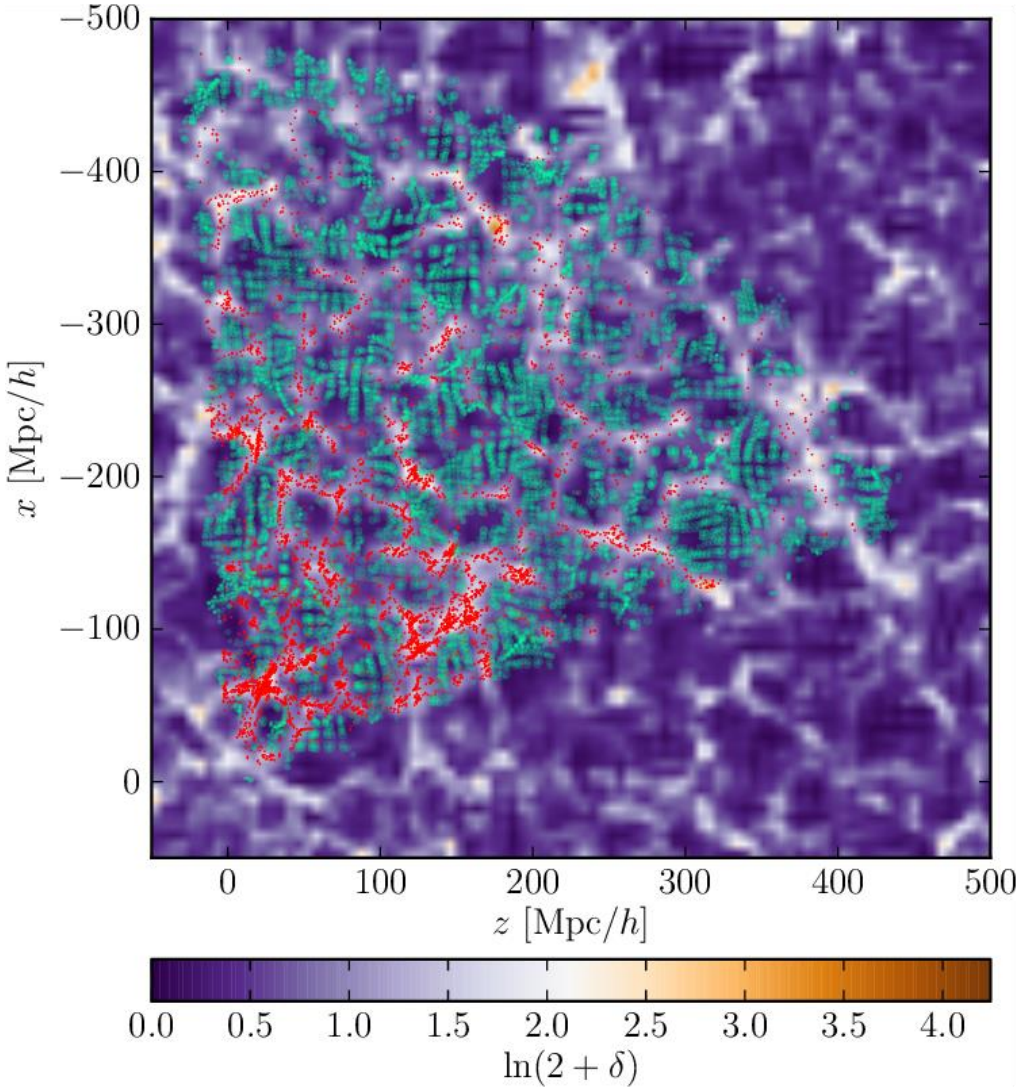


void ellipticities

FL, Jasche, Sutter, Hamaus & Wandelt, in prep.

Putting all together…



Static and dynamic structures