

# Sondes de l'énergie sombre: Conditions initiales, champs de vitesse et test d'expansion

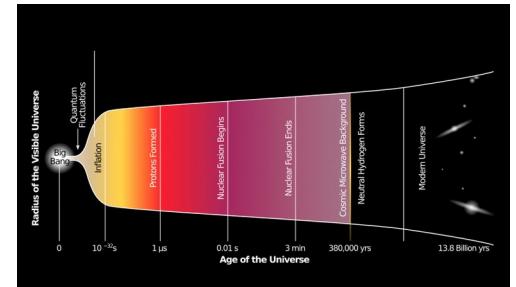
Guilhem Lavaux (IAP/CNRS)  
for the Aquila Consortium



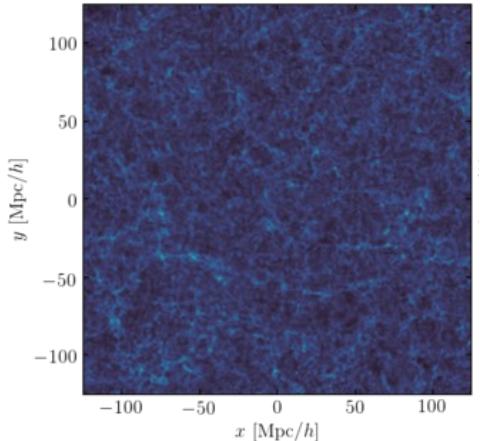
May 7<sup>th</sup> 2019

# List of direct probes of concern here

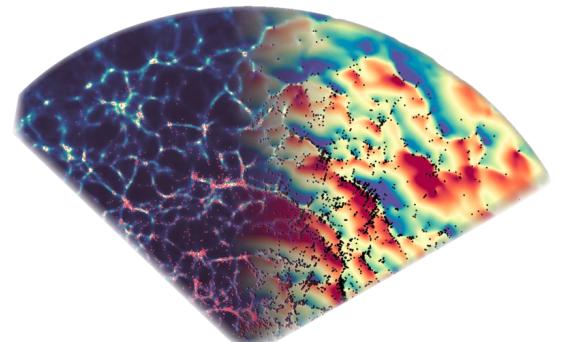
Expansion test (a.k.a. Alcock/Paczynski test)



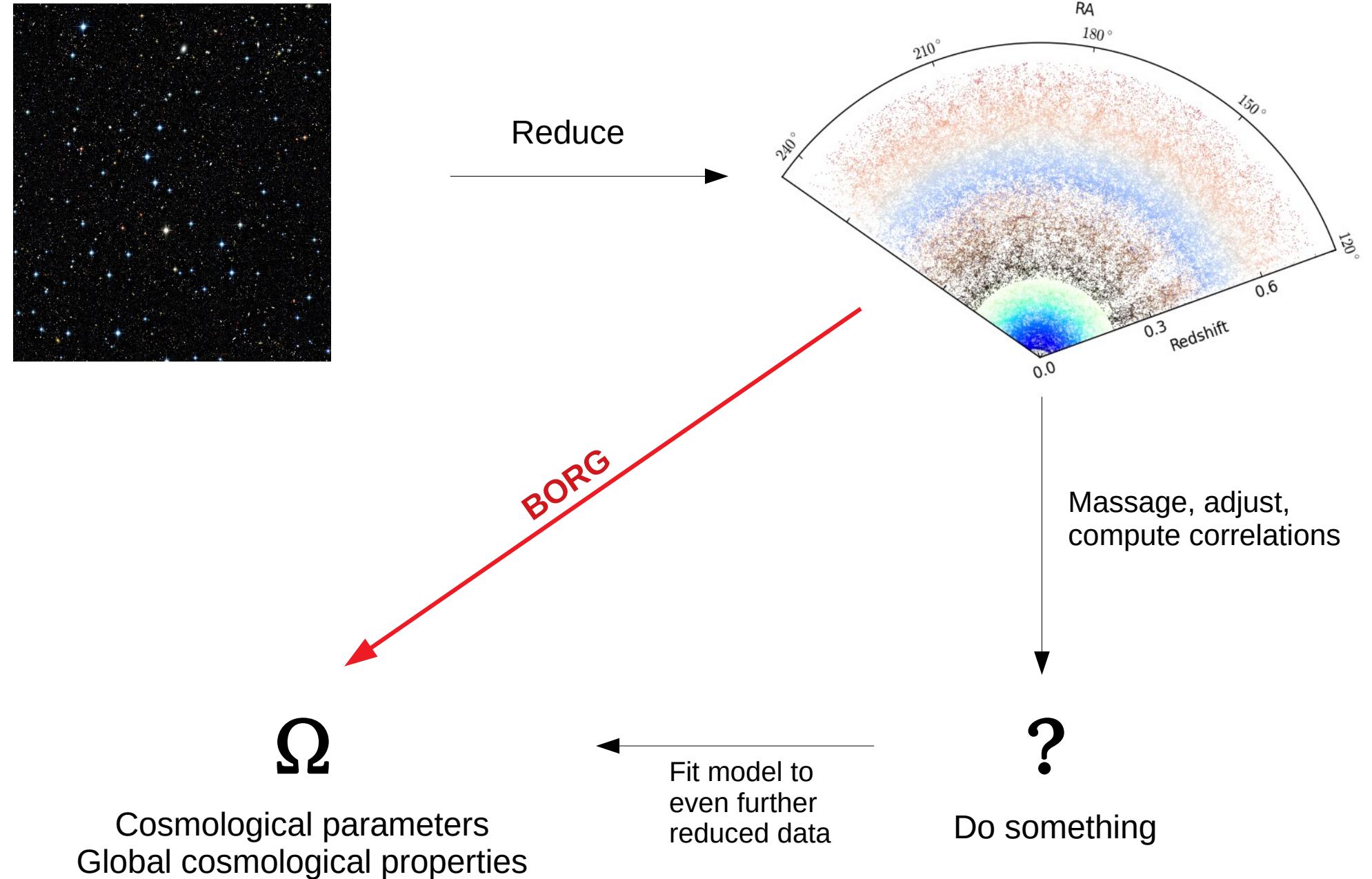
Primordial power spectrum / Large scale structures



Velocity field at late time / Growth rate



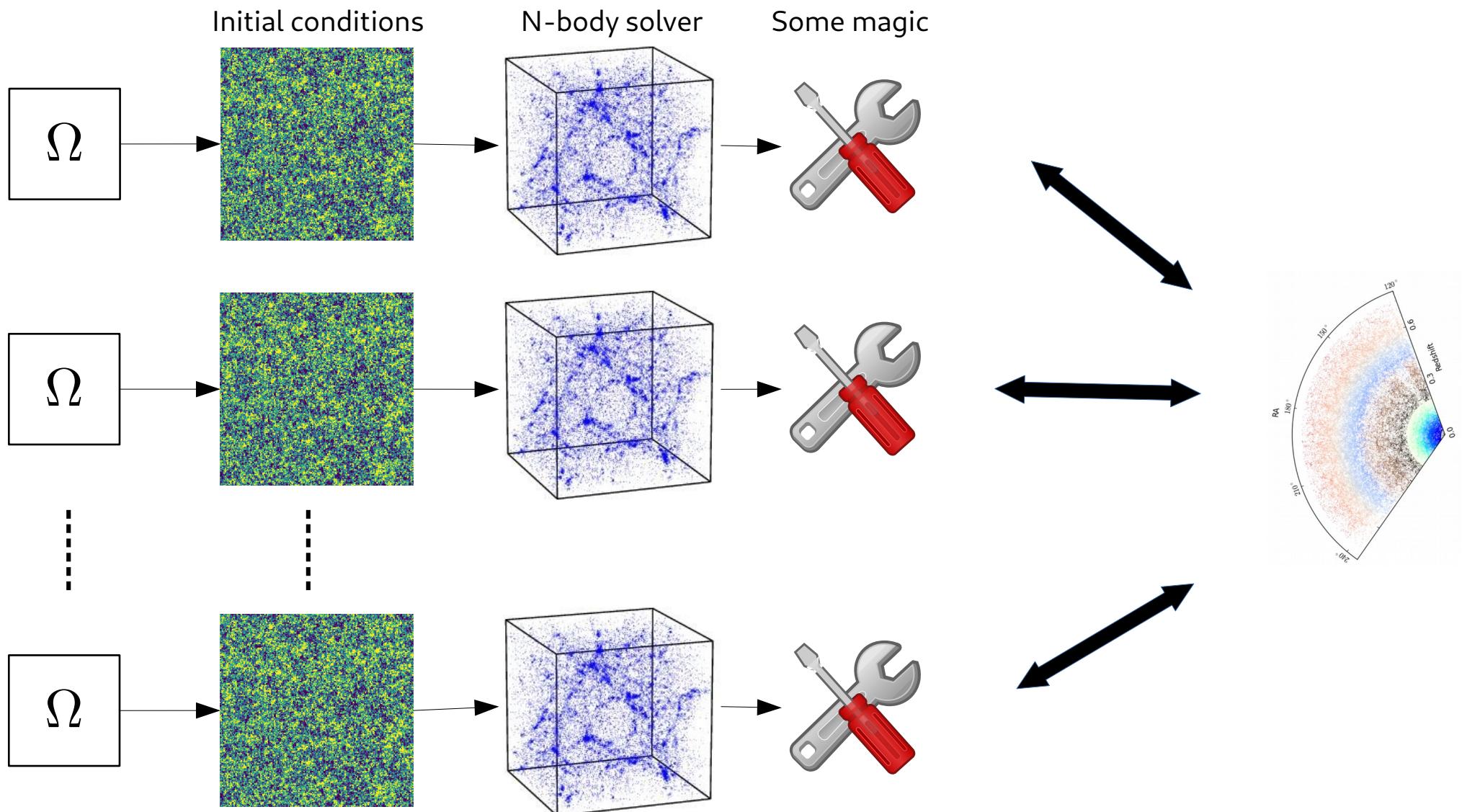
# Overall procedure for cosmology and LSS





The BORG cube

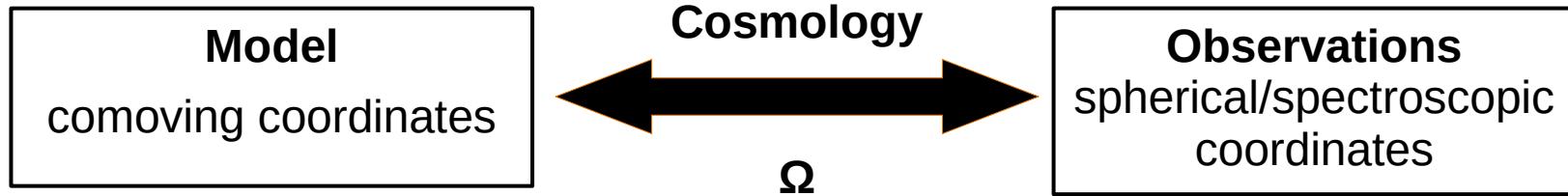
# The BORG scheme



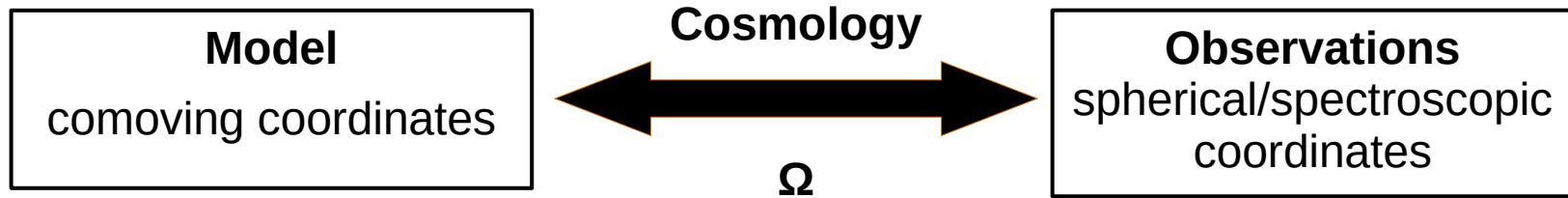
## Expansion test for DE



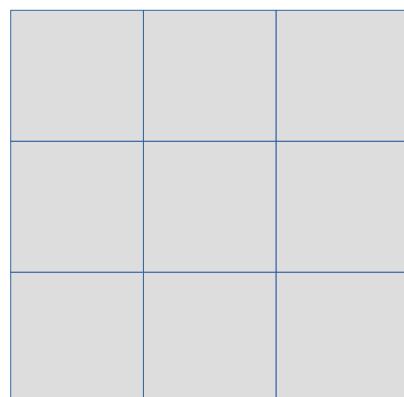
# Use expansion of Universe (A/P)



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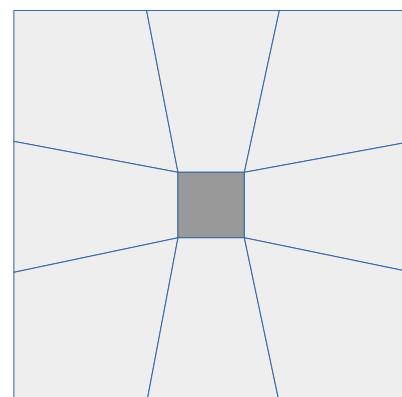


Added in BORG as density remapping:



Comoving  
coordinates

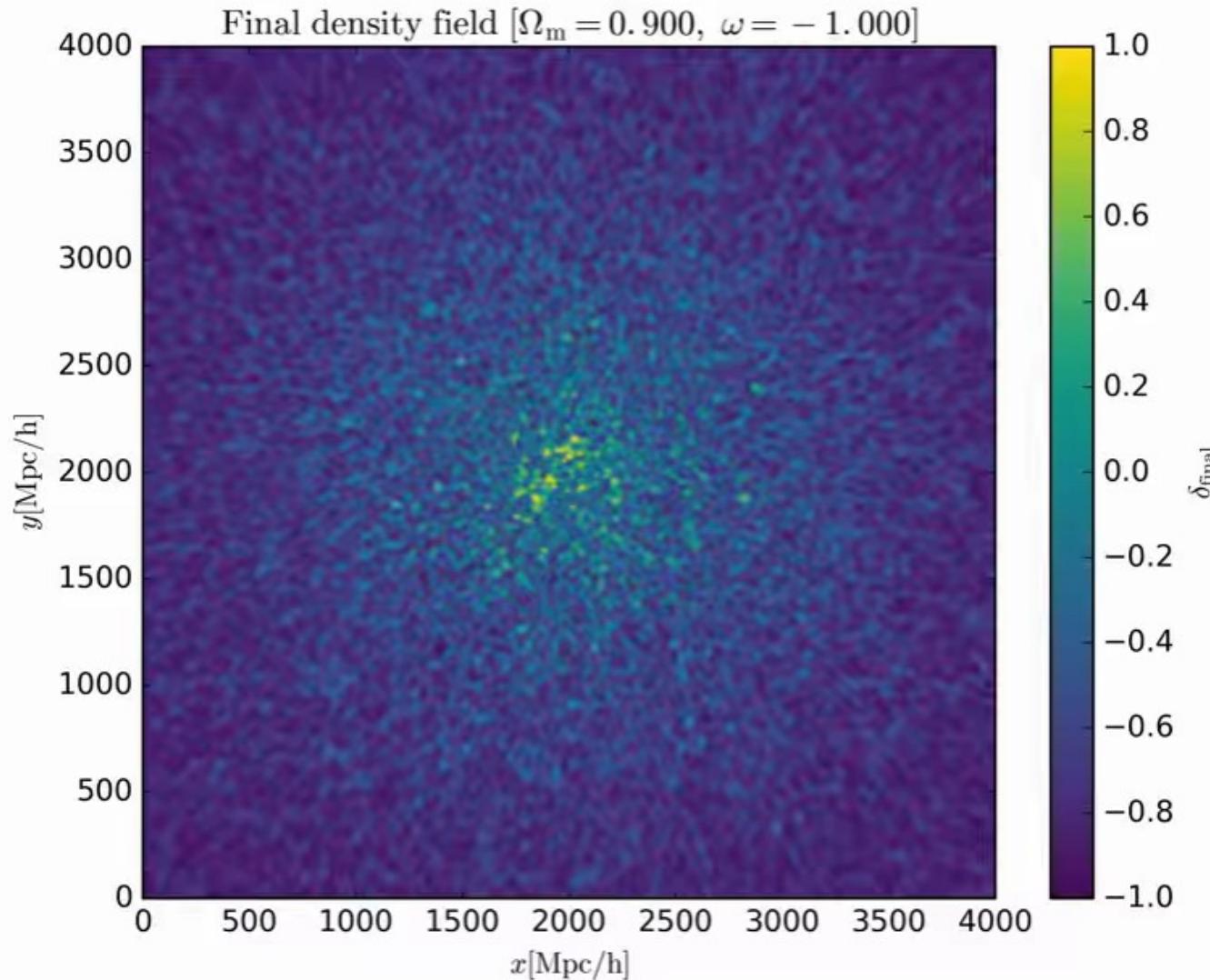
$$\vec{x}$$



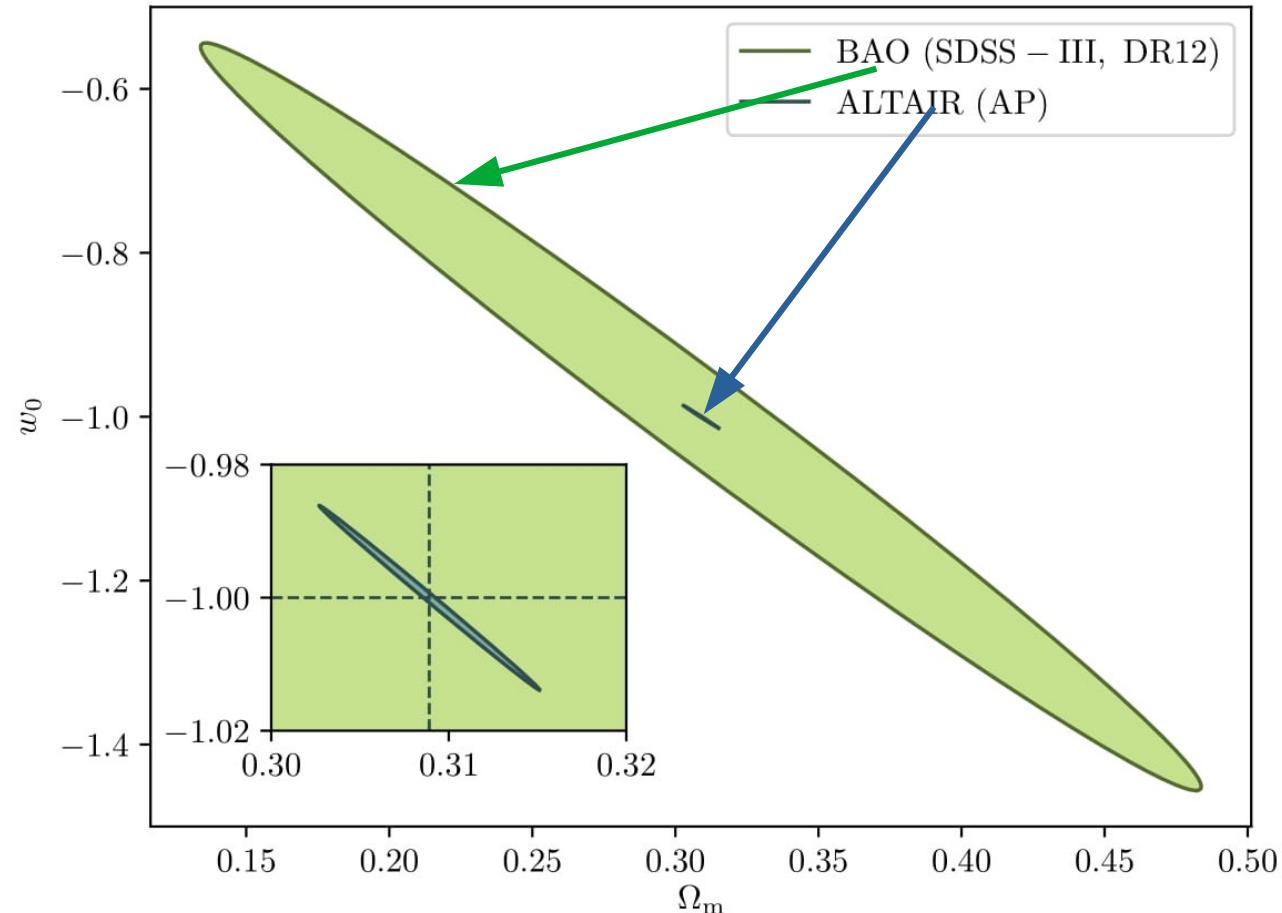
Scaled redshift  
coordinates

$$\vec{z}_i = \frac{c}{H_0} z_i \hat{u}_i$$

# A/P: dependence on cosmology



# A/P: mock test



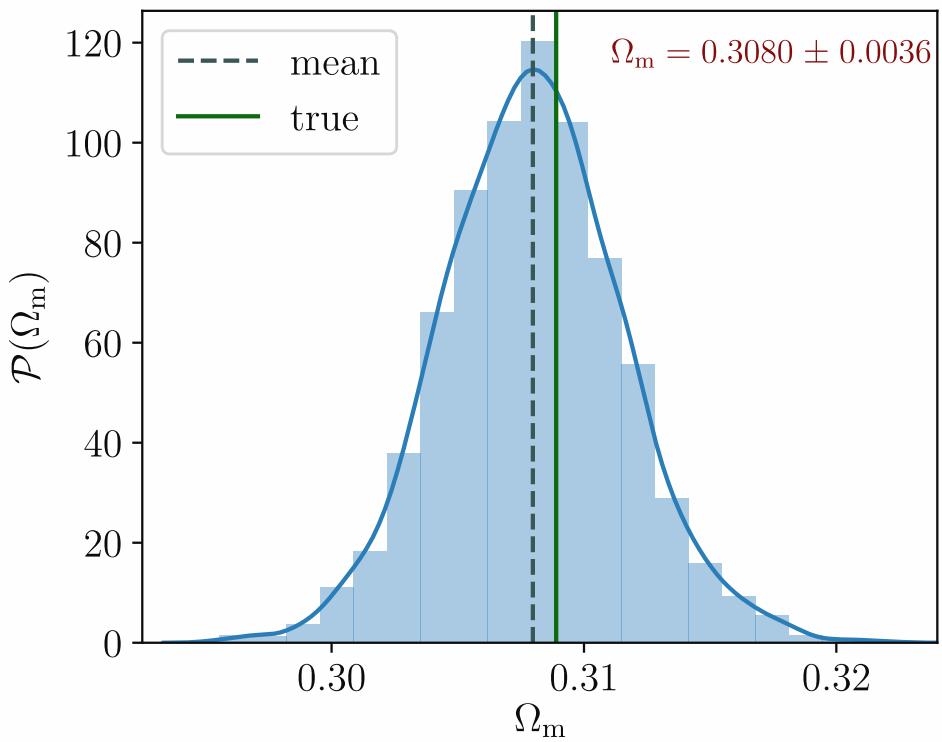
Source of additional information:  
complete use of all the modes, and high order statistics (paper in preparation).

# A/P: mock test

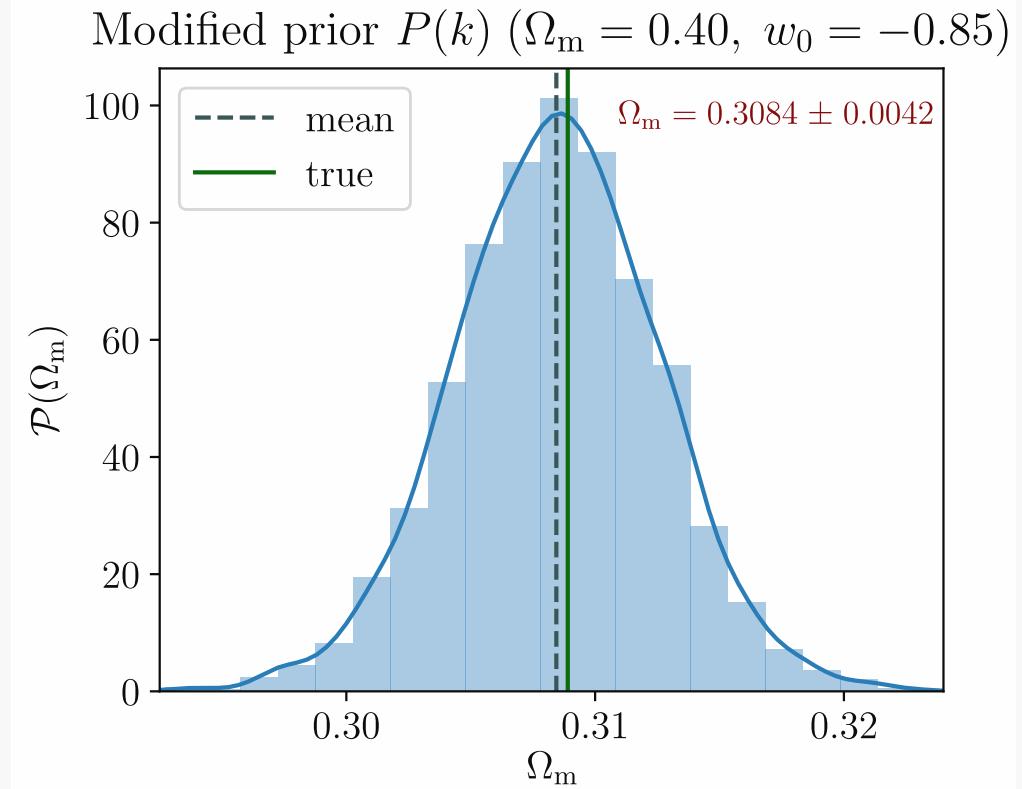


Constraints resilient to isotropic prior biases

## Good prior



## Bad prior



Test with peculiar velocities for DE





# Distance data/velocity inference

Cosmic flows from observed distances

$$cz \simeq H d + v_r$$

Spectroscopic redshift

Supernovae Ia  
Tully-Fisher  
Fundamental plane  
...



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Cosmic flows from observed distances

$$cz \simeq H d + v_r$$

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...

## Model include:

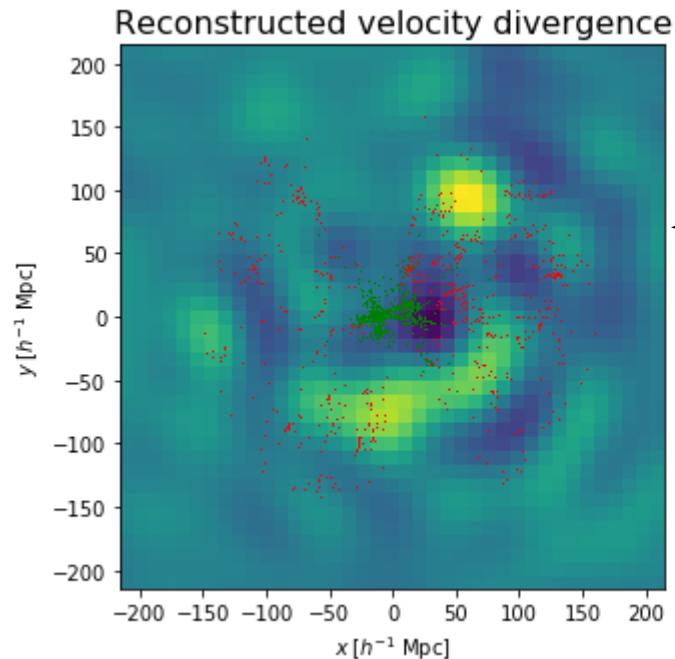
- flexible distance prior
- redshift cut selection
- mixture error distribution
- Gaussian random field cosmic velocity field
- zero point calibration

Stochastic velocity model

$$\vec{v} \propto f(\Omega_m, \Omega_\Lambda, w, \dots) \vec{\nabla} \Delta^{-1} \delta$$

Application: 6dFv + Spitzer data (from CosmicFlows 3 database, Tully et al. 2016)

# VIRBIUS2: inferred maps



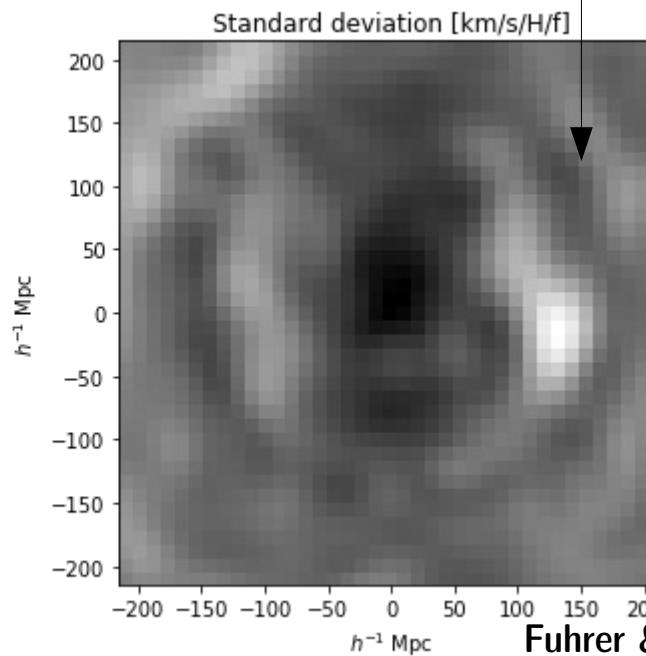
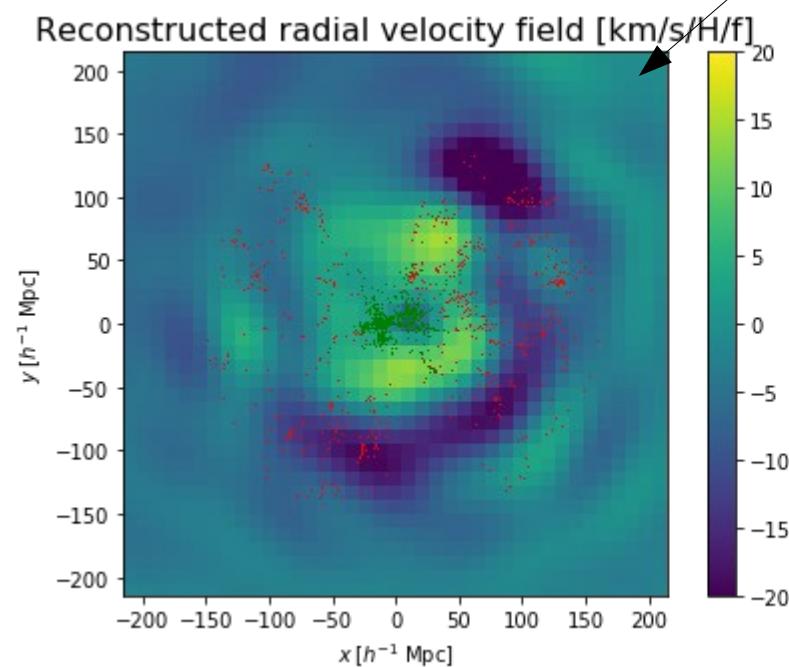
6dFv

Spitzer

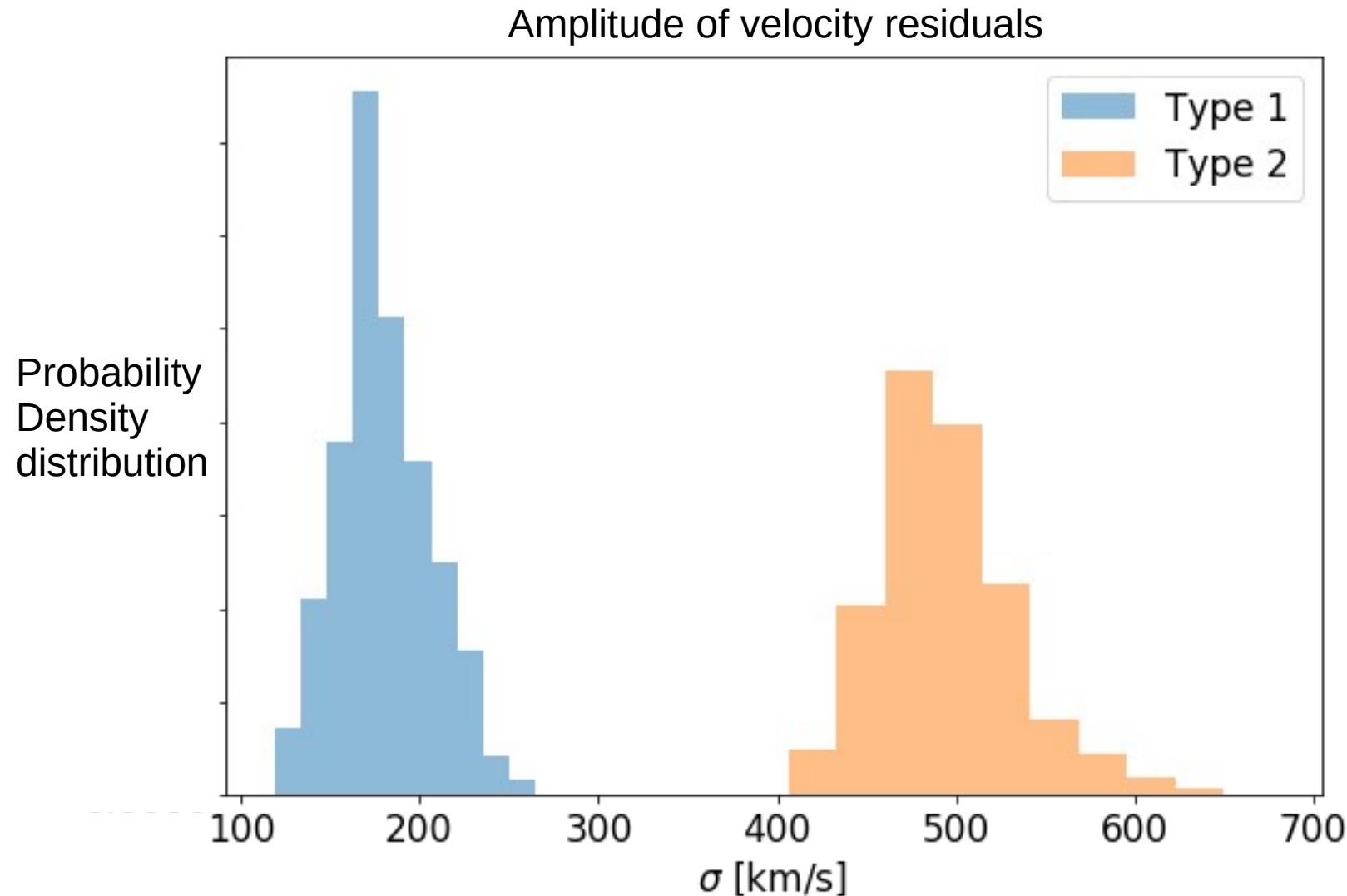
~Density

Mean radial velocity

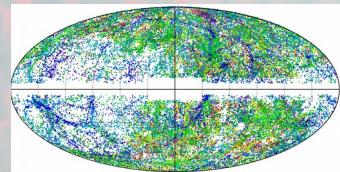
Estimated error



# VIRBIUS2: mixture error distribution

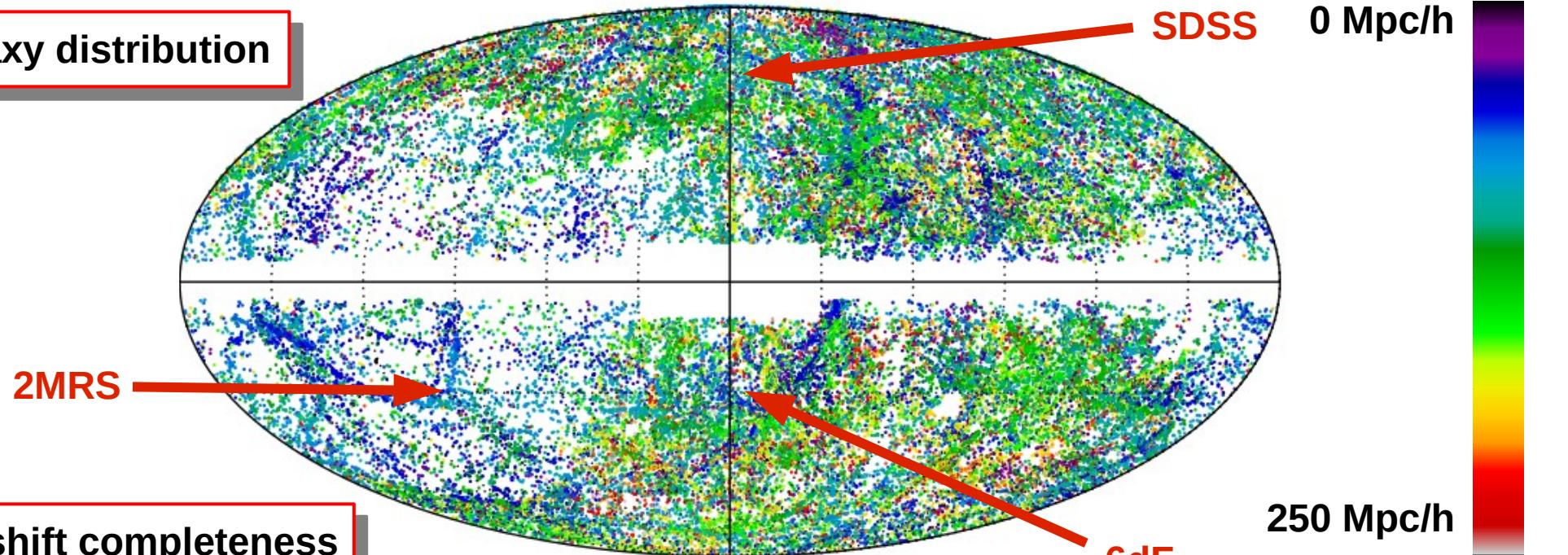


**BORG data application:  
2M++, “small scale” modeling**



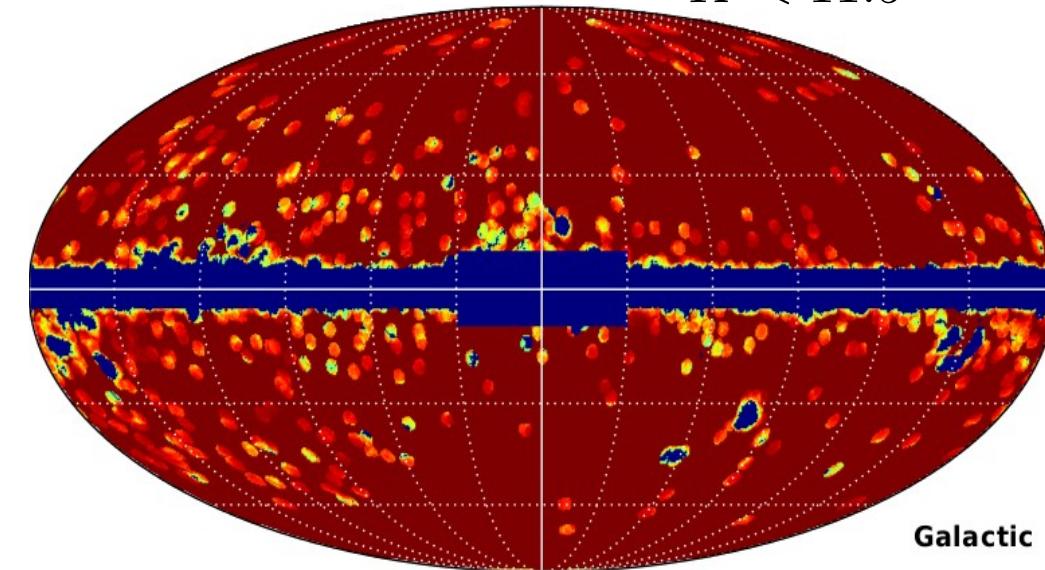
# The 2M++ galaxy compilation

Galaxy distribution



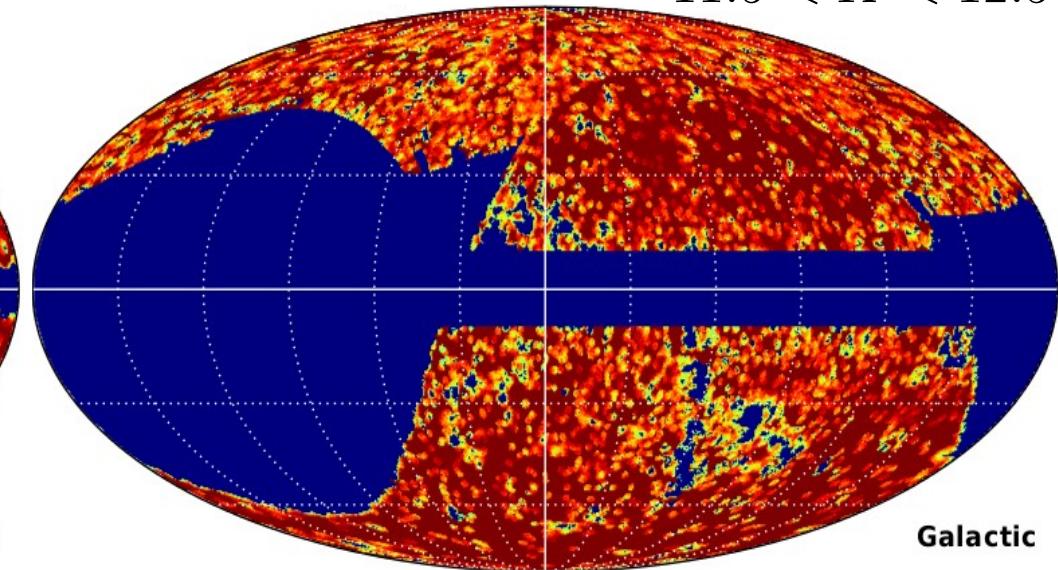
Redshift completeness

$K < 11.5$



Galactic

~70 000 galaxies

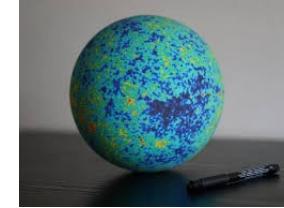


Galactic

Lavaux & Hudson (MNRAS, 2011)

# The model

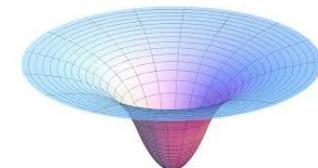
$\Lambda$ CDM Universe with Planck+15 cosmological parameters



Box of  $(677.7 \text{ Mpc}/h)^3$   
 $256^3$  initial condition elements  
 $512^3$  particles



Particle mesh solver  
Redshift space distortions derived from particle simulations

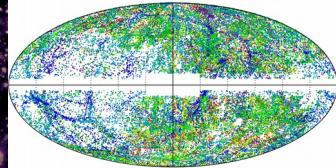


Bias model:  $\rho_g \propto \rho_m^\alpha \exp\left(-(\rho_m/\rho_0)^{-\epsilon}\right)$

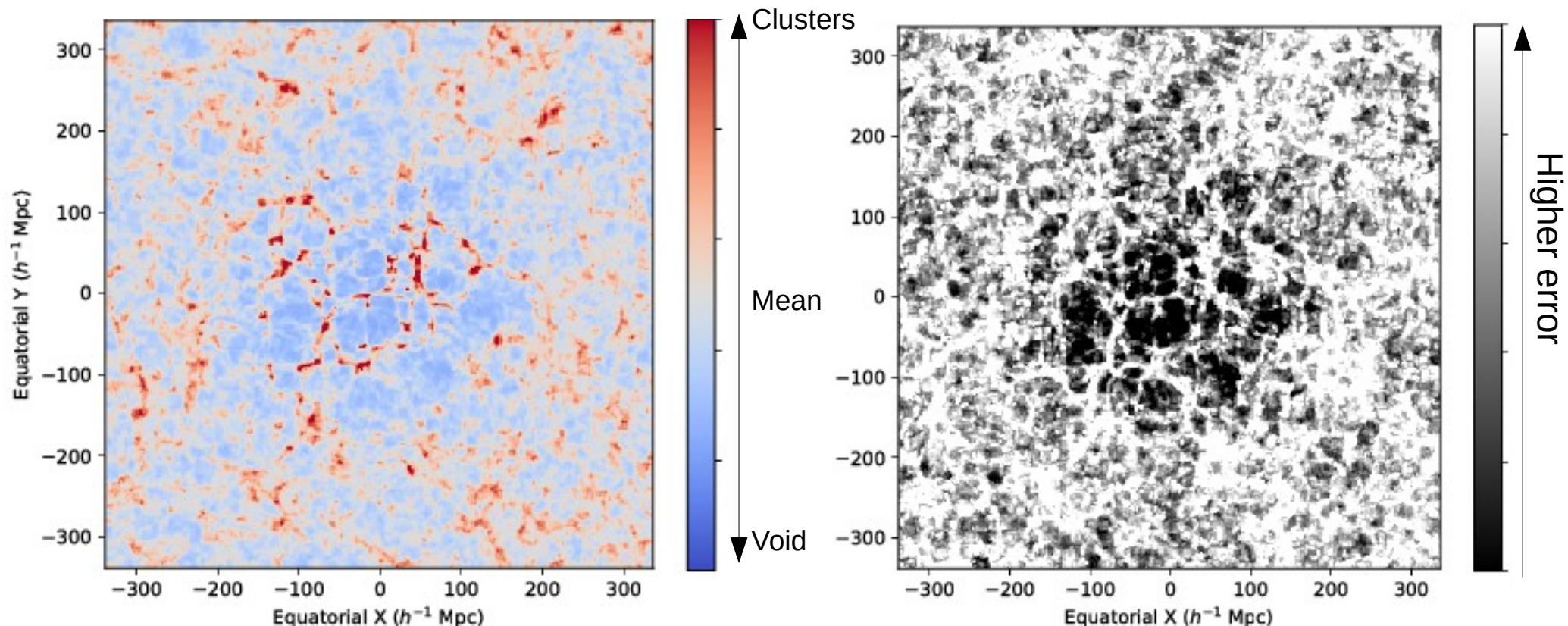
Selection derived from Schechter luminosity function



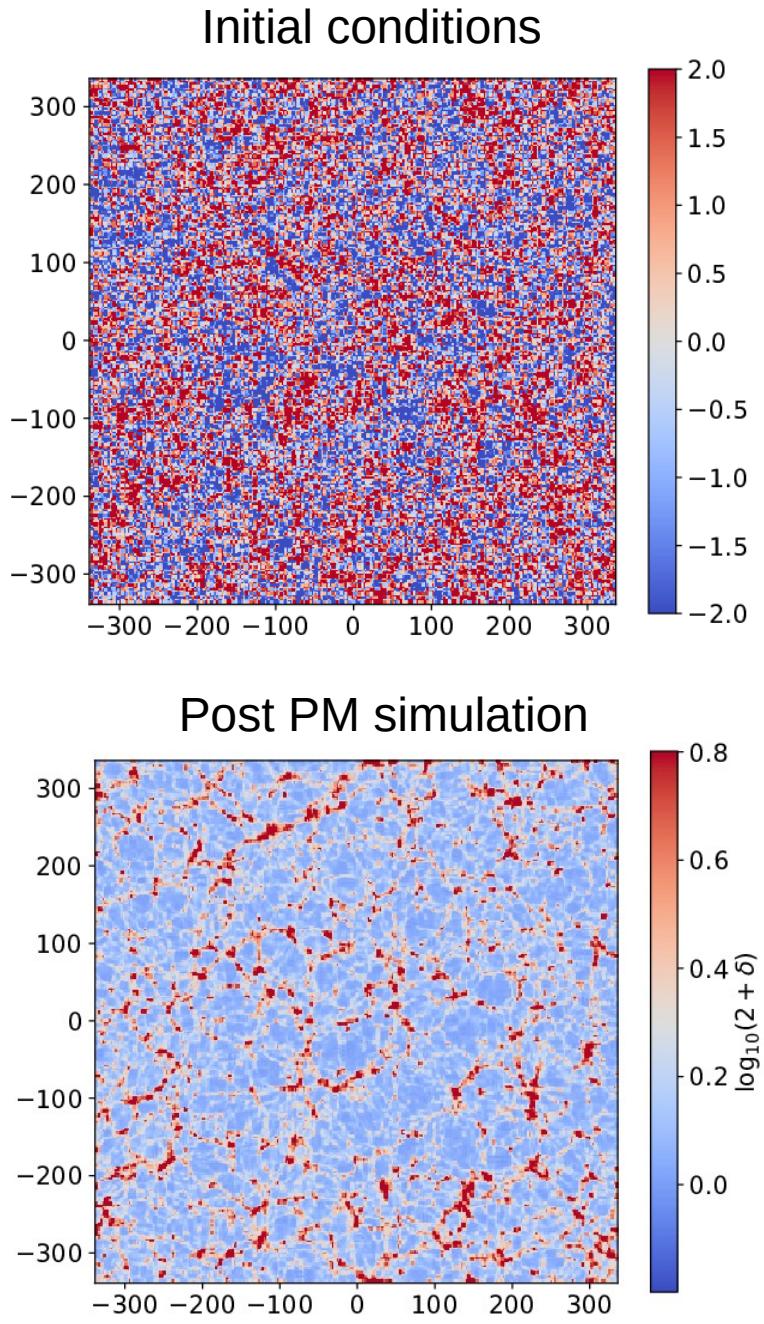
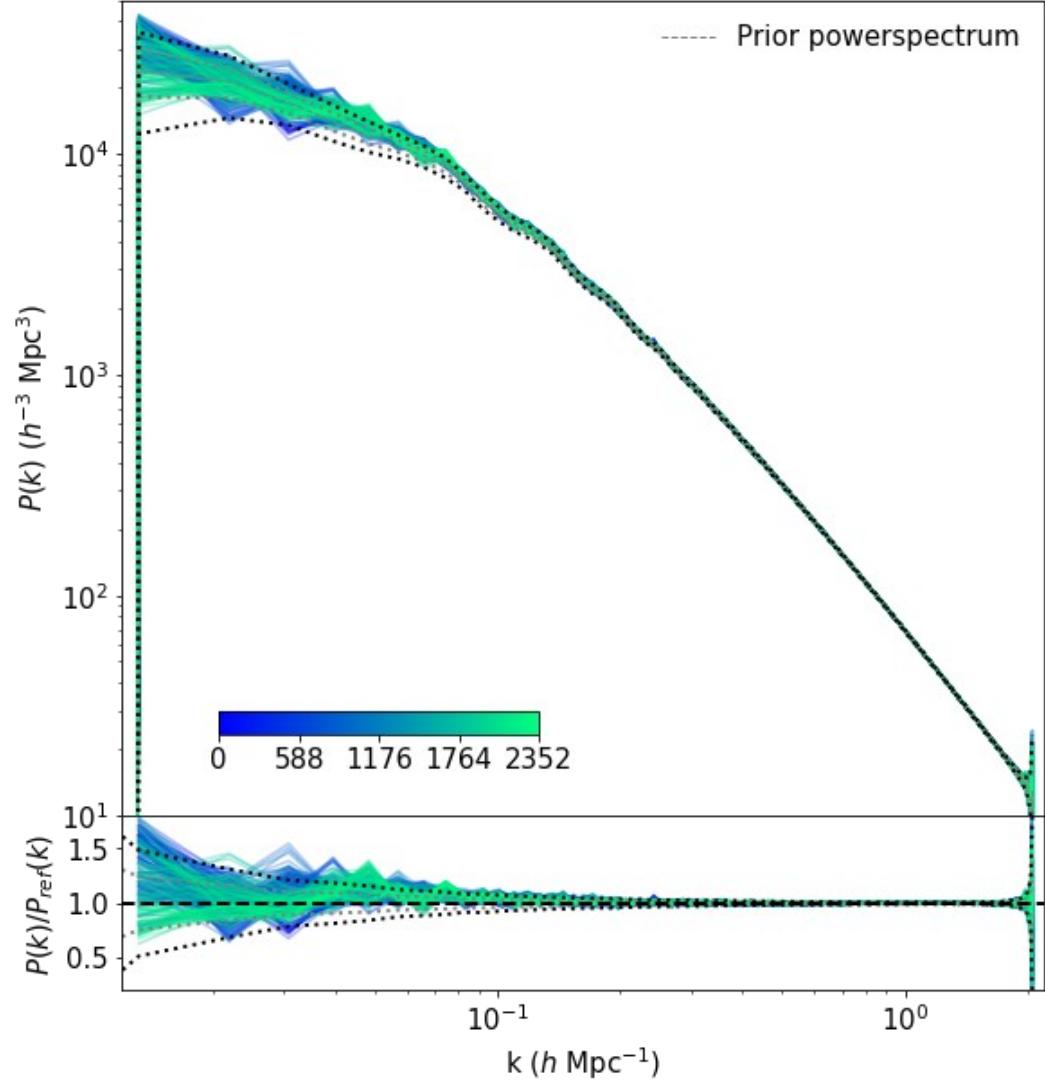
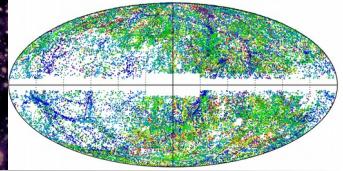
# Inferred density fields



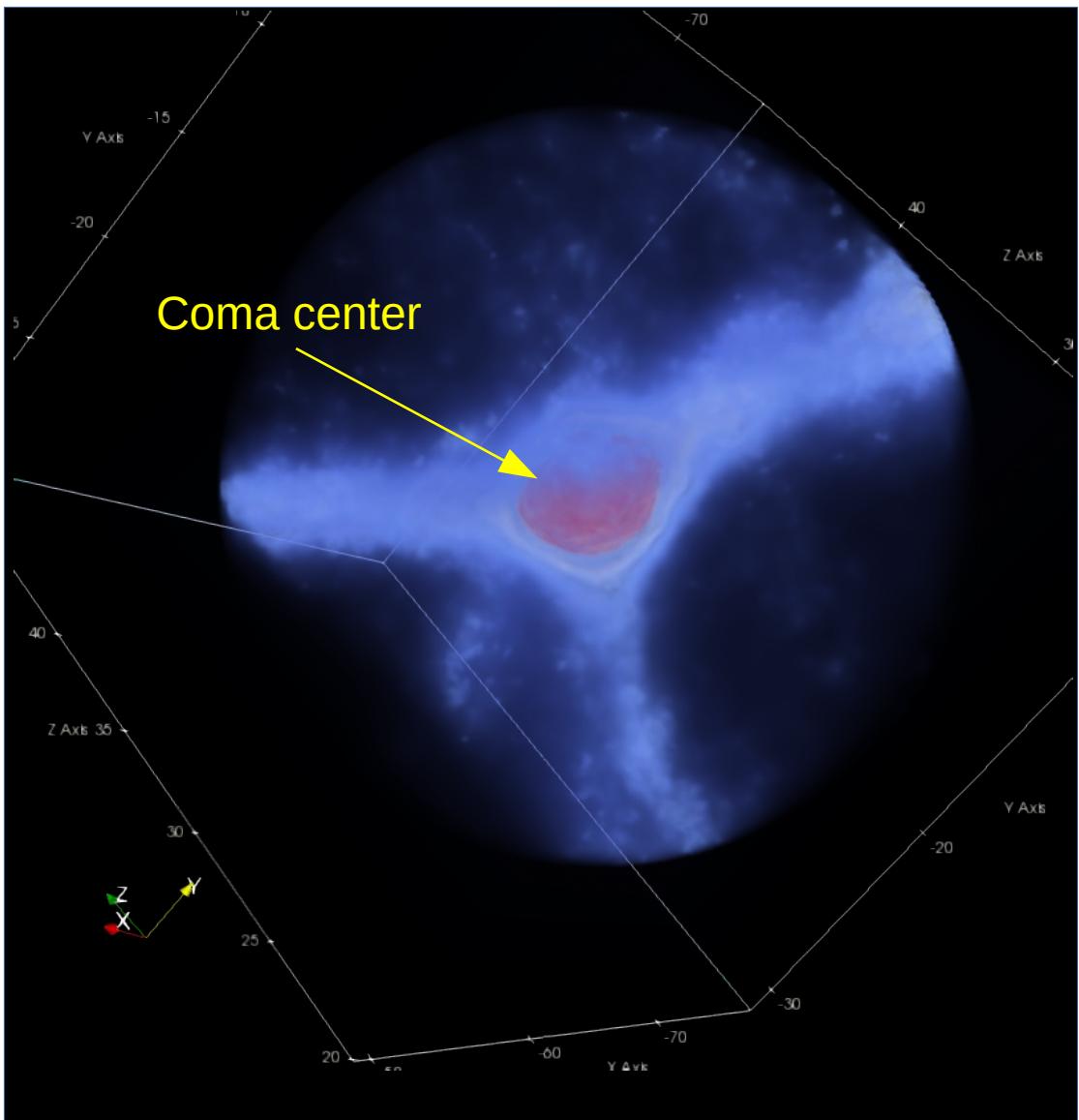
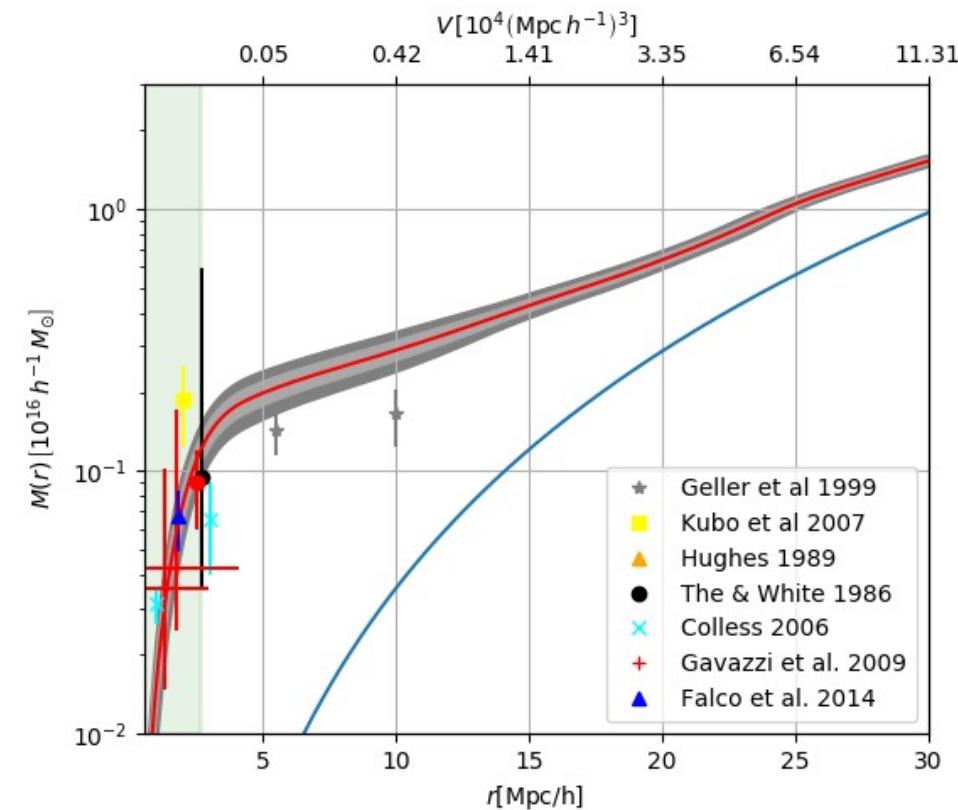
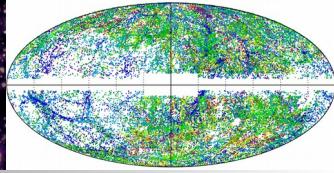
Ensemble average density fields at  $z=0$



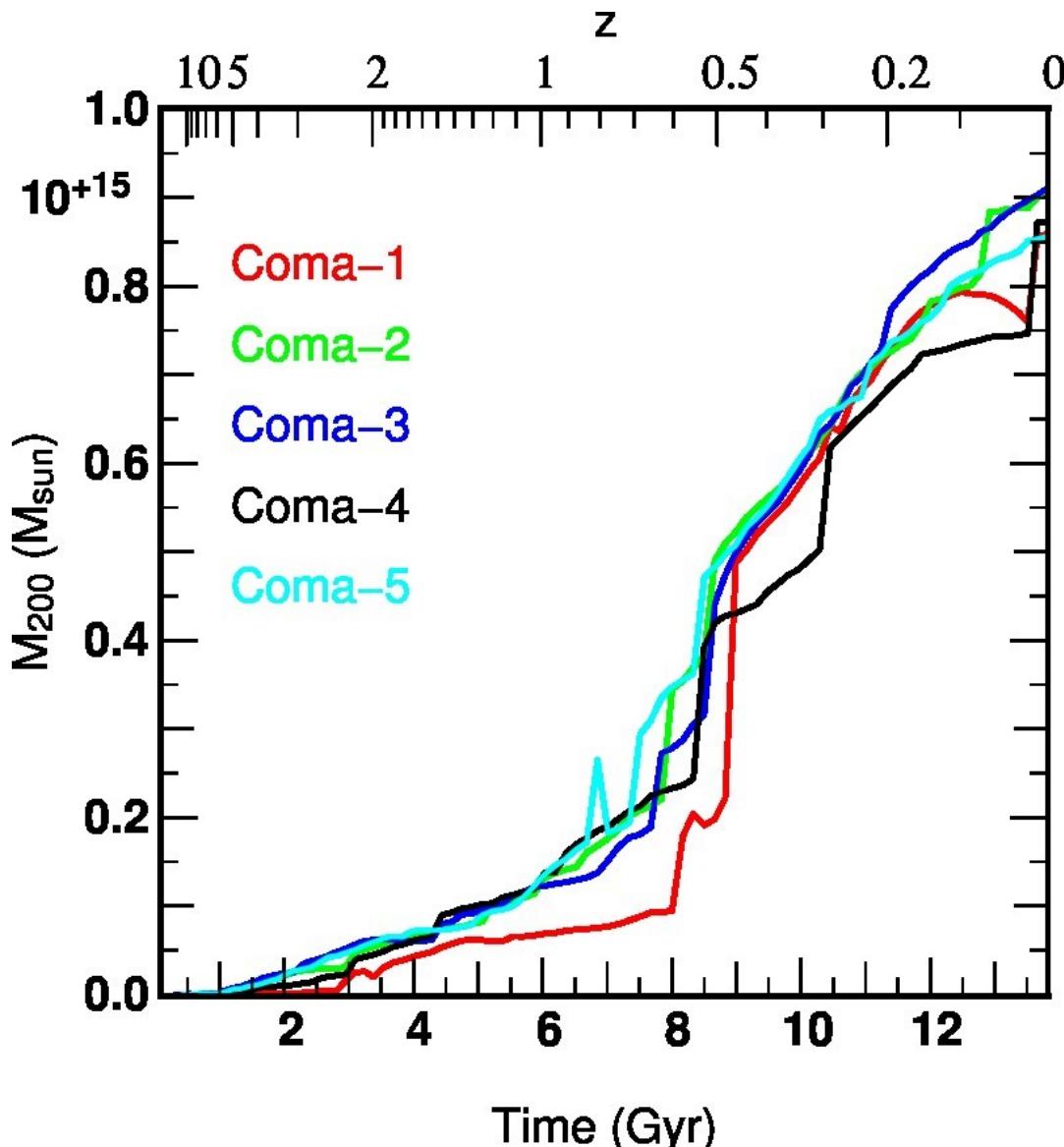
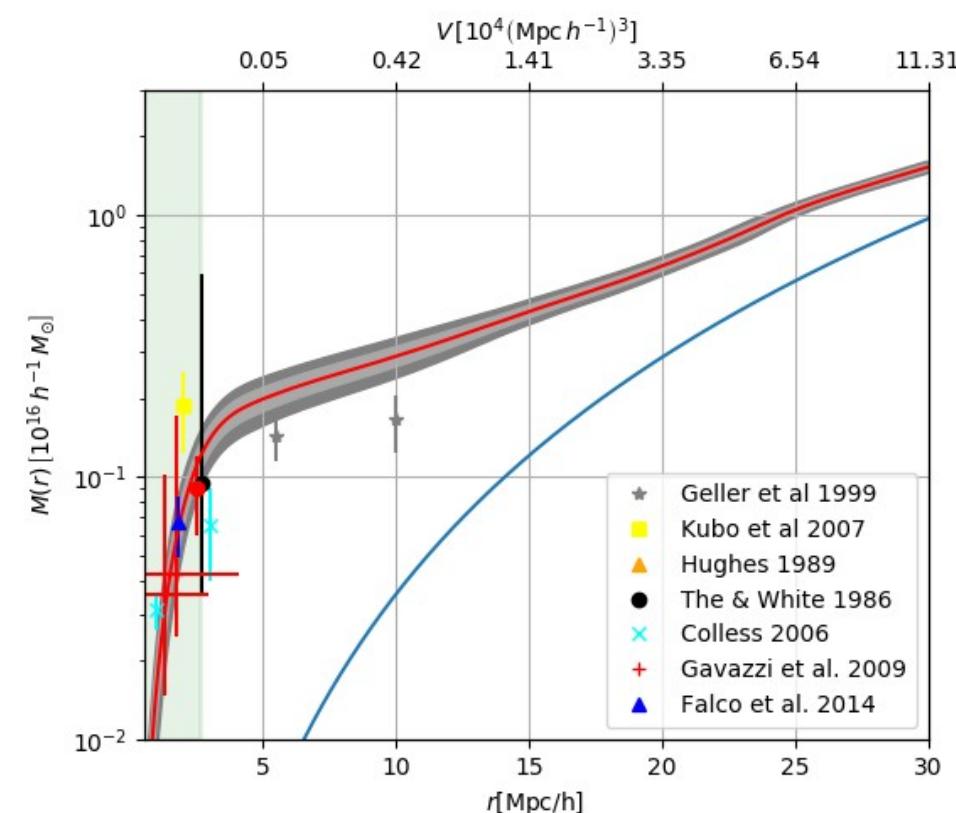
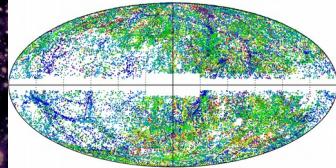
# Initial condition powerspectrum



# Coma dynamical properties



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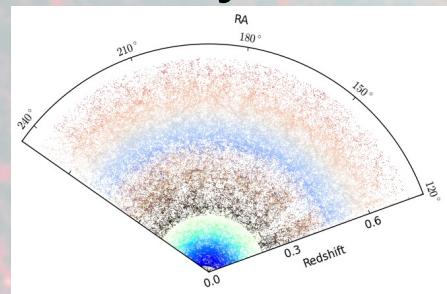


Zoom simulation on Coma  
(~250 Mpart in zoom)

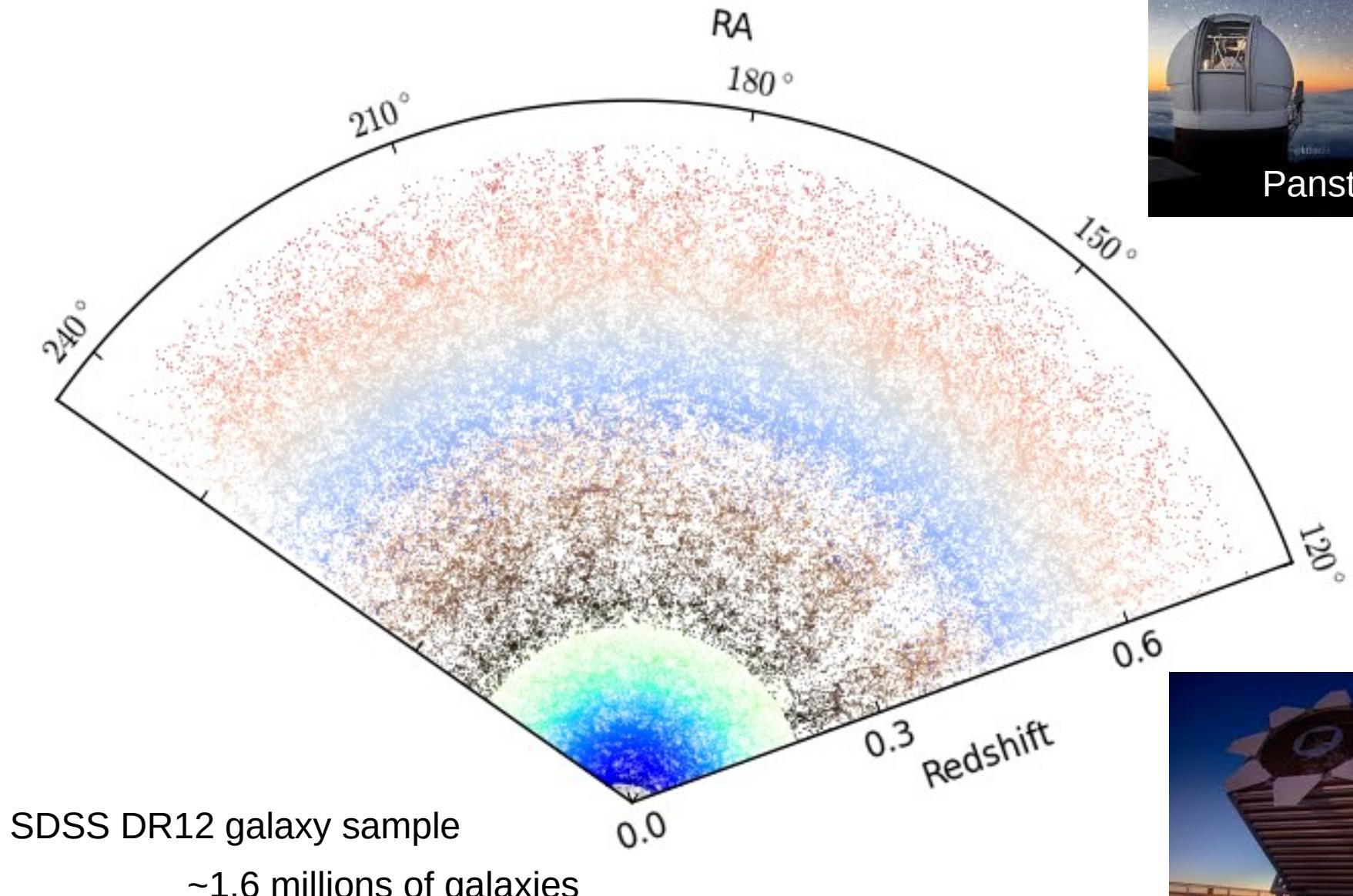
$4 \times 10^7 h^{-1} M_{\odot}/\text{part}$

# BORG data application: SDSS III / BOSS

## Large scale and systematic cleanings

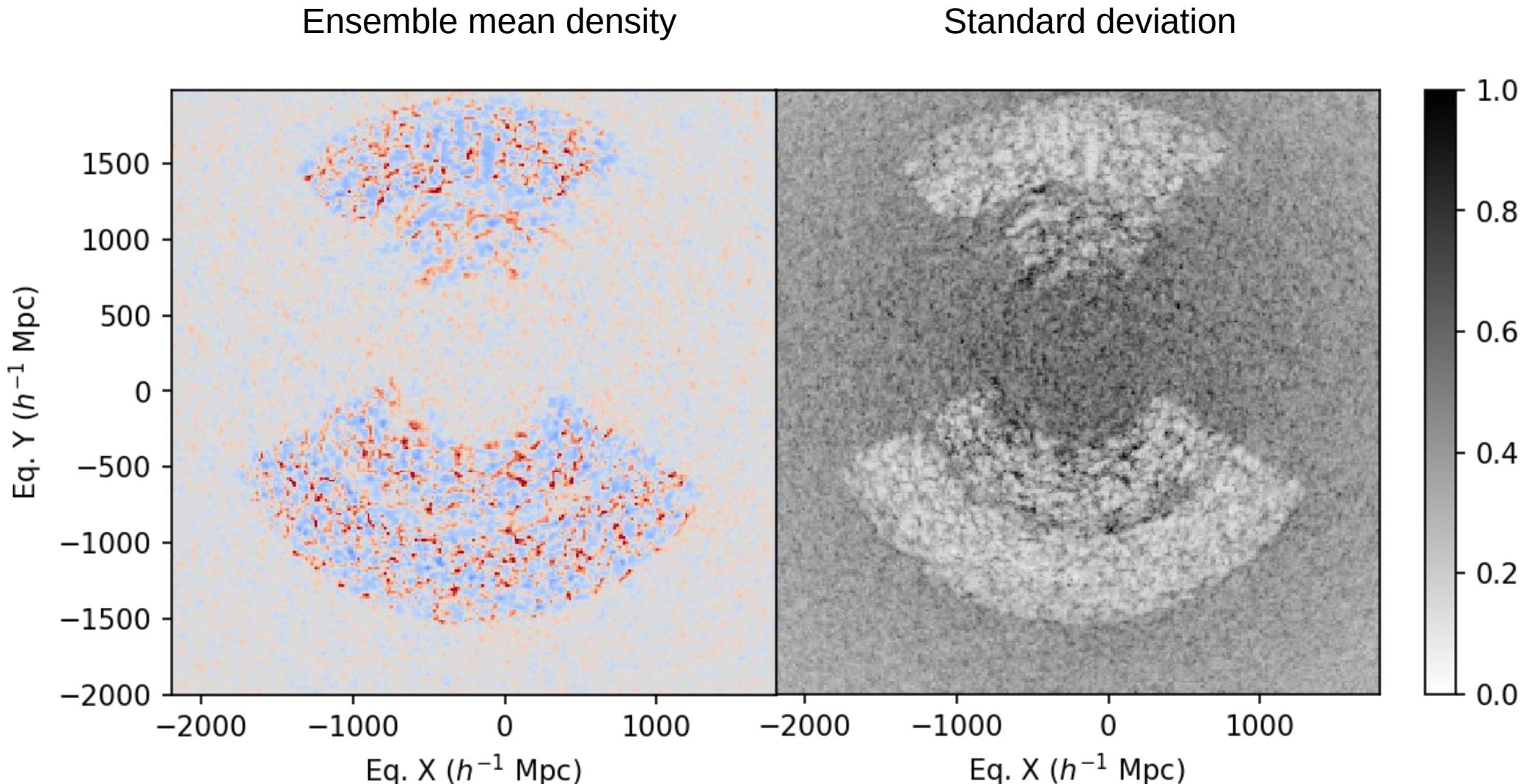


# SDSS3 data



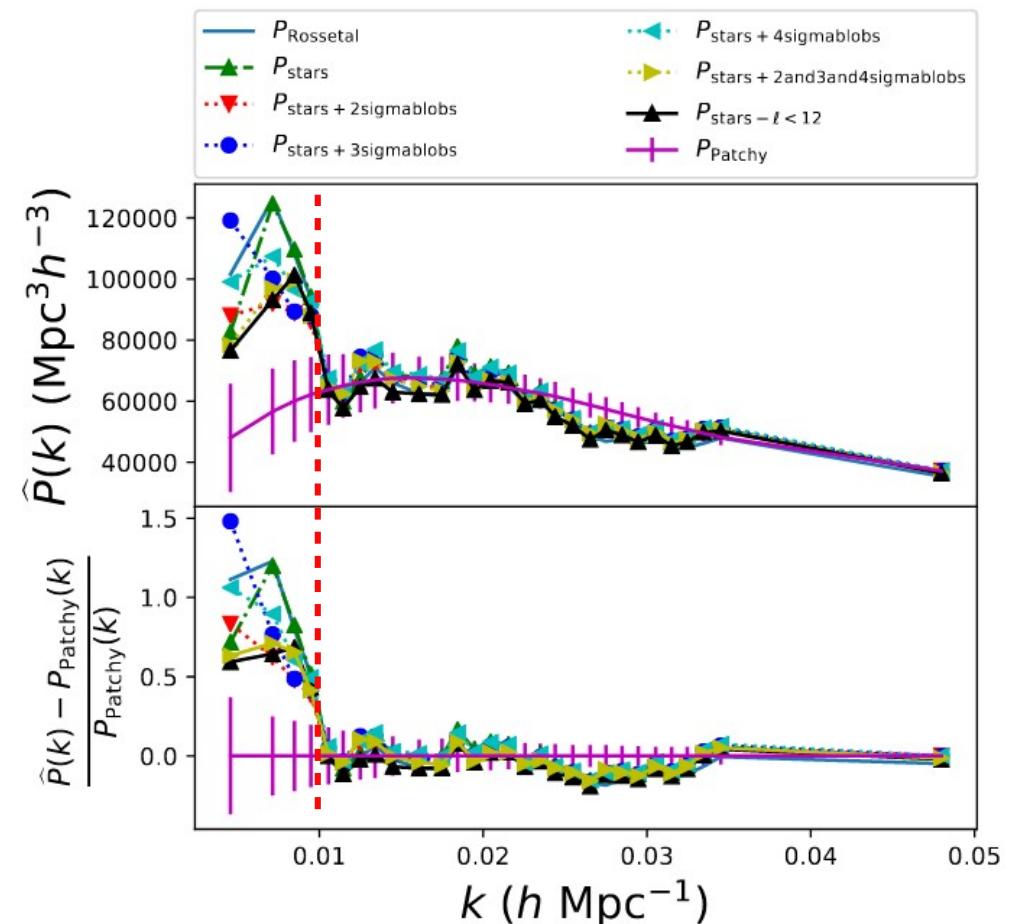
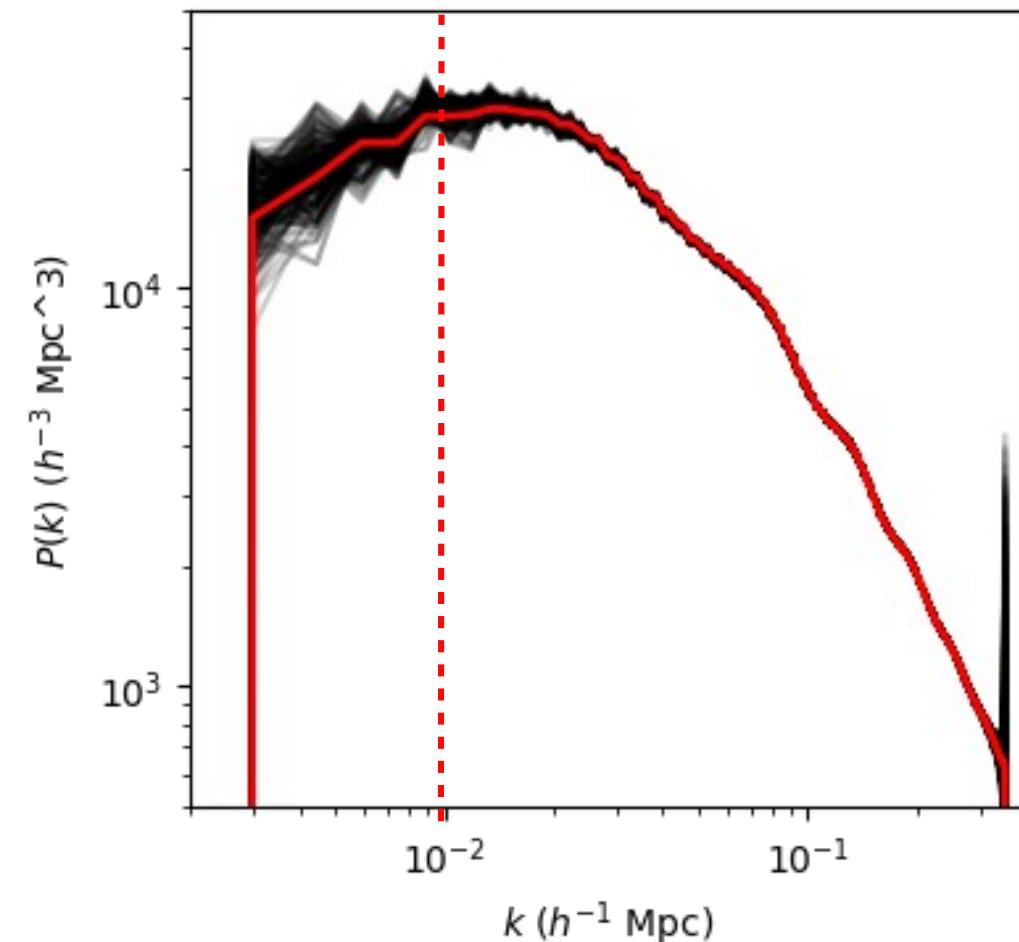
# Inference results: density and $P(k)$

Preliminary



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Preliminary



# Application to CMB lensing

Preliminary

Estimated error from  
MCMC

Convergence

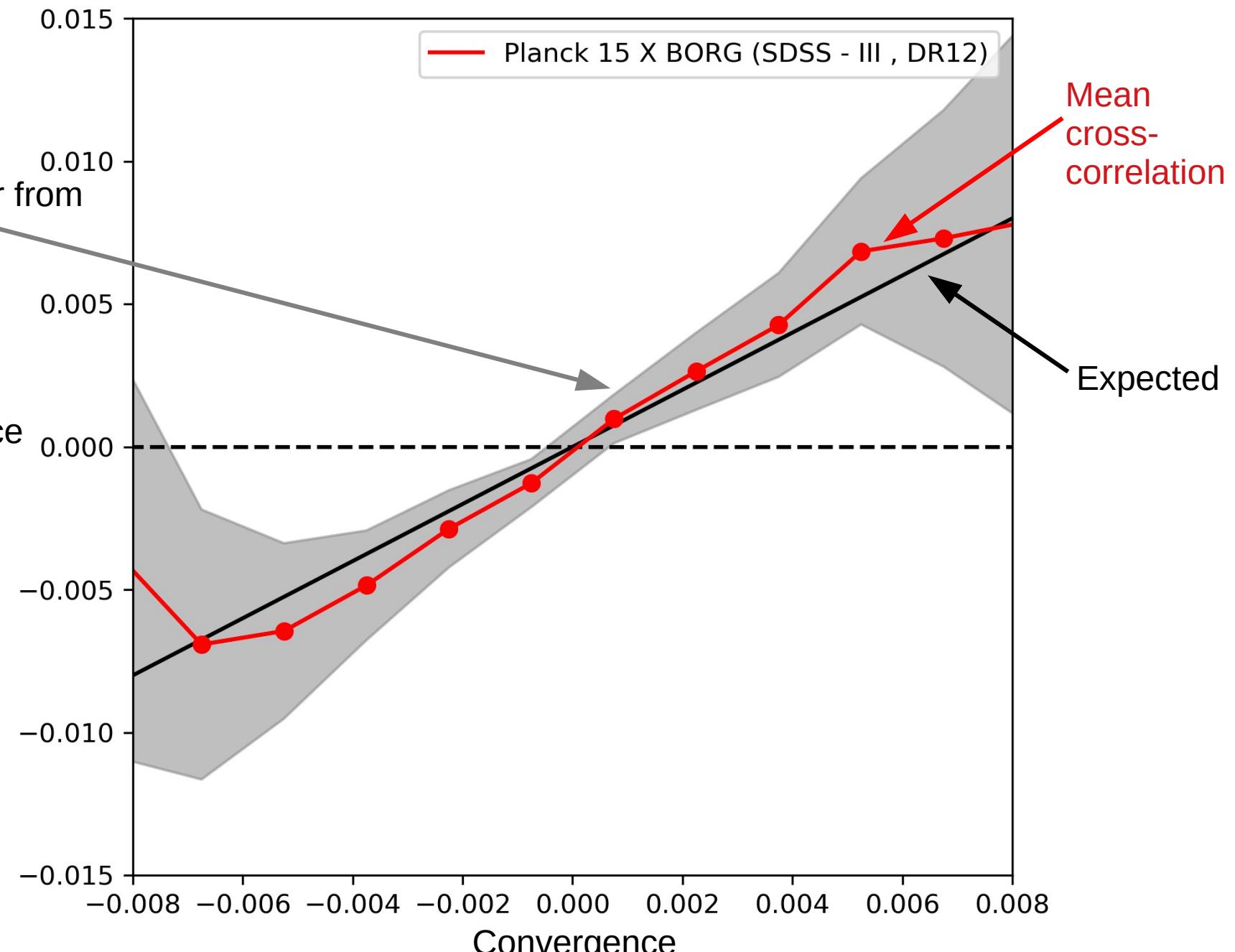
$K_{\text{Planck}}$

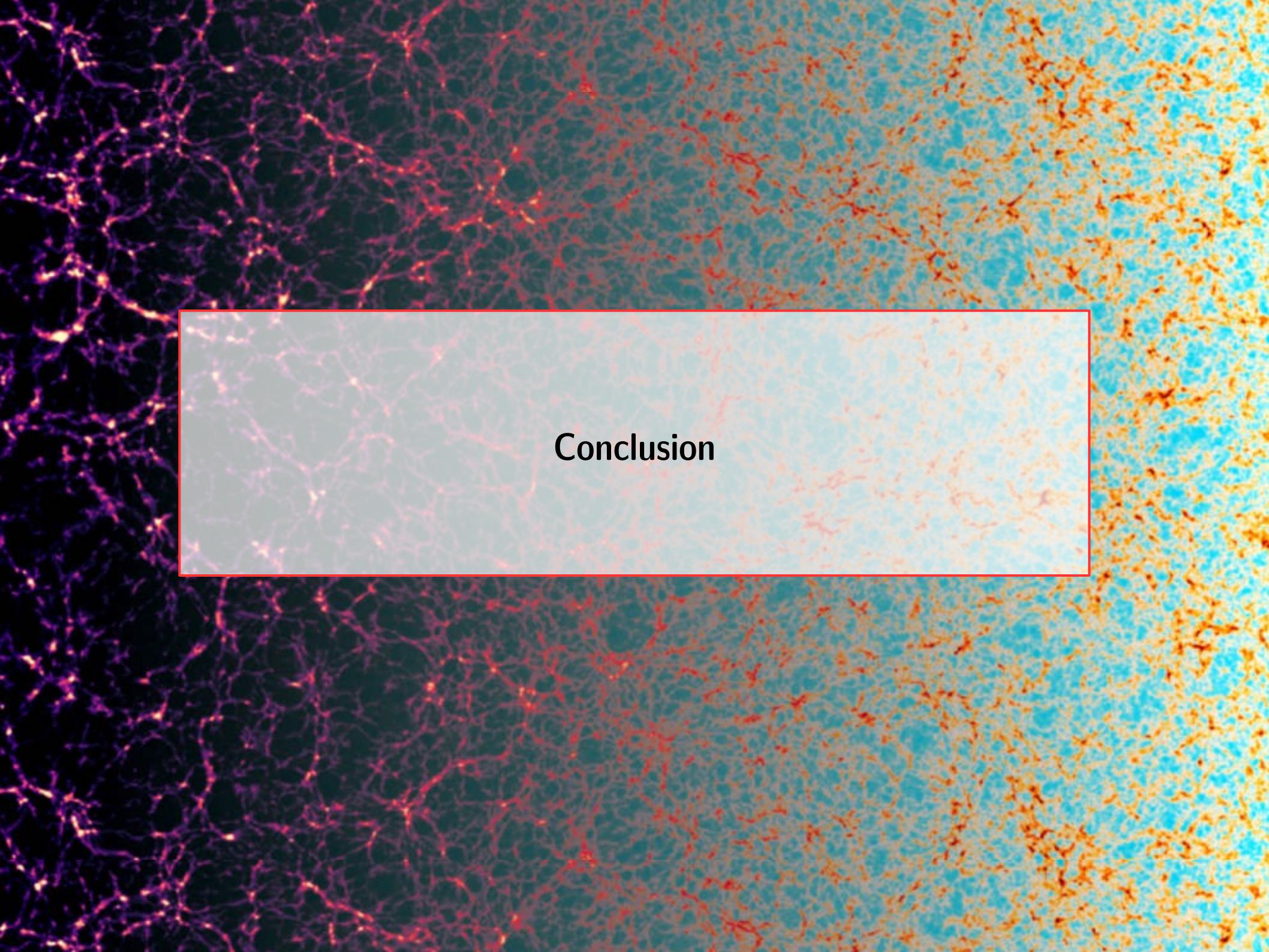
Planck 15 X BORG (SDSS - III , DR12)

Mean  
cross-  
correlation

Expected

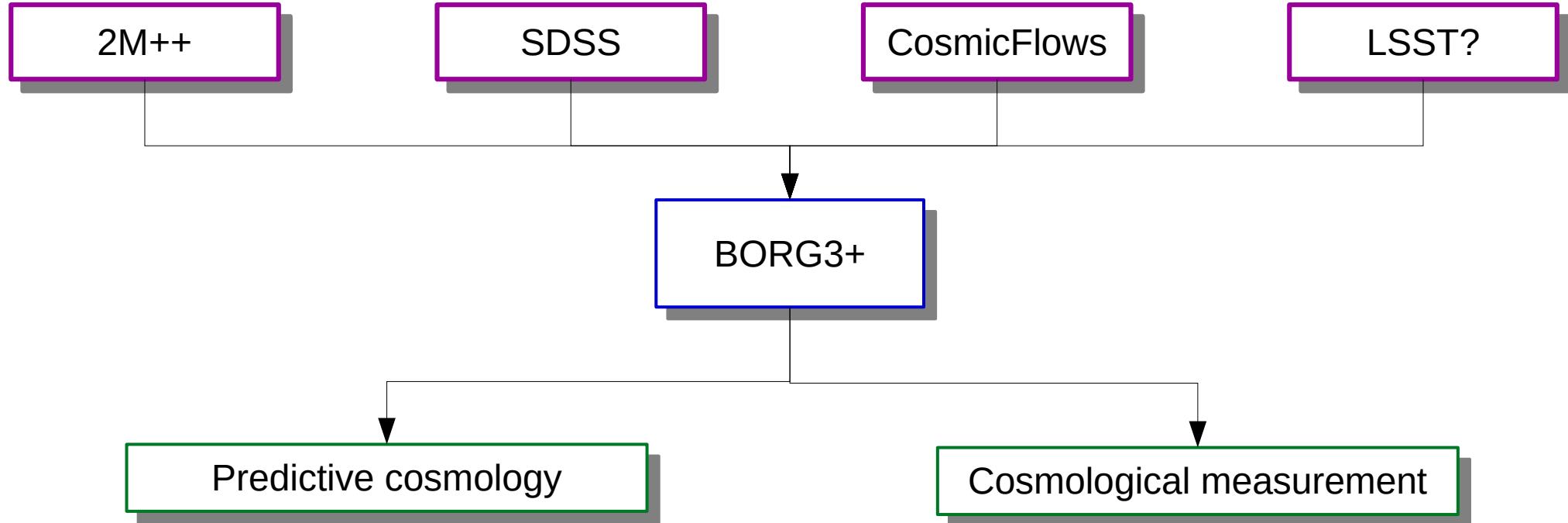
$K_{\text{BORG / CMASS}}$





## Conclusion

# Conclusion: great future



- Velocity field
- X-ray cluster emission
- Kinetic Sunyaev Zel'dovich
- Rees-Sciama
- Dark matter ?

- Cosmic expansion
- Power spectrum (and governing parameters)
- Gaussianity tests of initial conditions
- Direct probe of dynamics