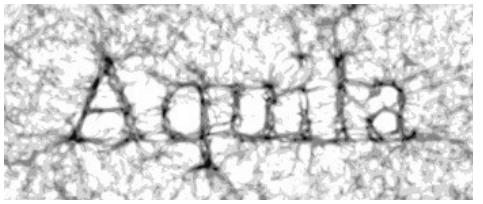
Imperial College London

ICIC Imperial Centre for Inference & Cosmology



Inferring the dynamical growth of structures at high-redshift

Natalia Porqueres

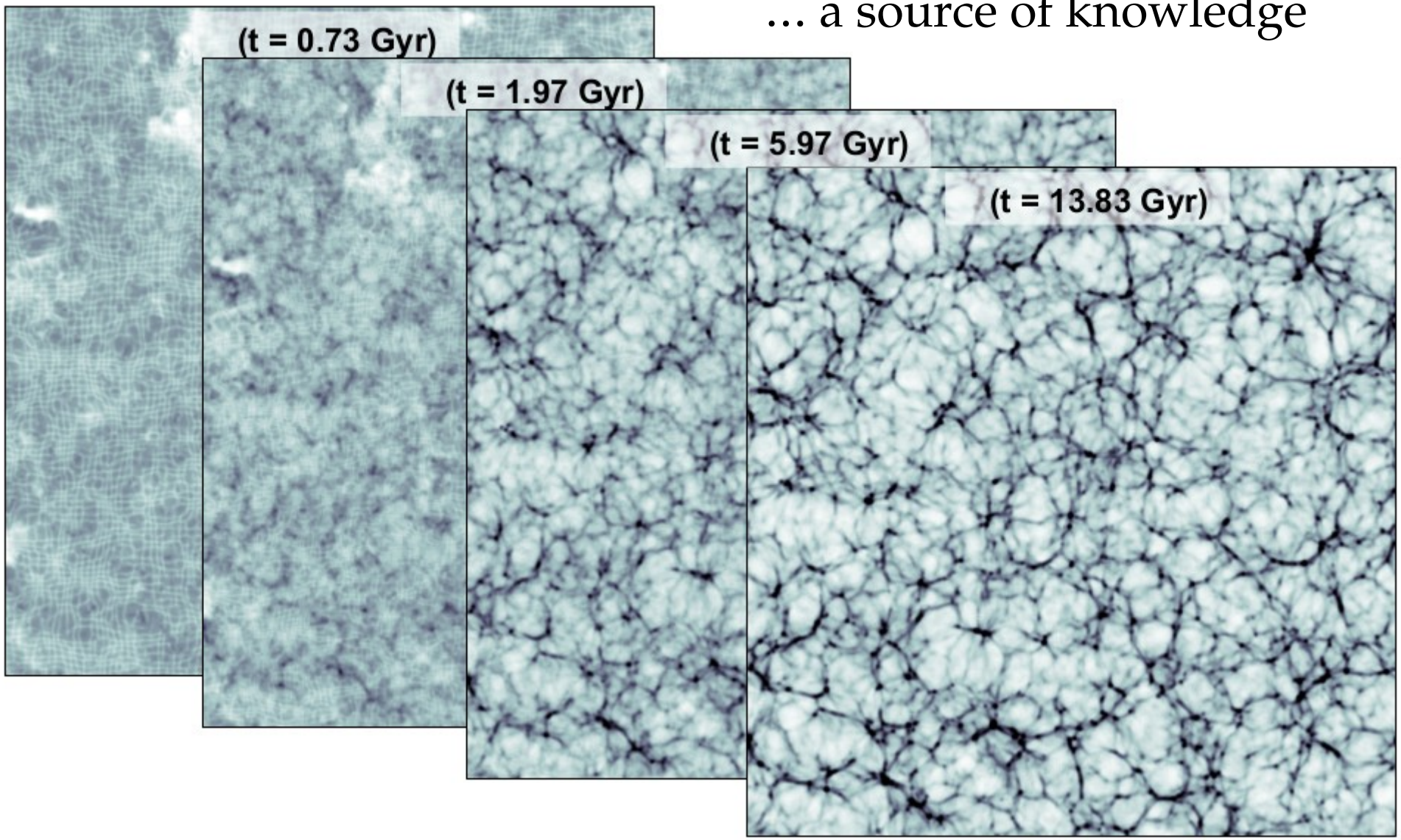
Jens Jasche, Guilhem Lavaux, Torsten Enßlin

Observatoire de la Côte d'Azur

25.02.20

The large-scale structure

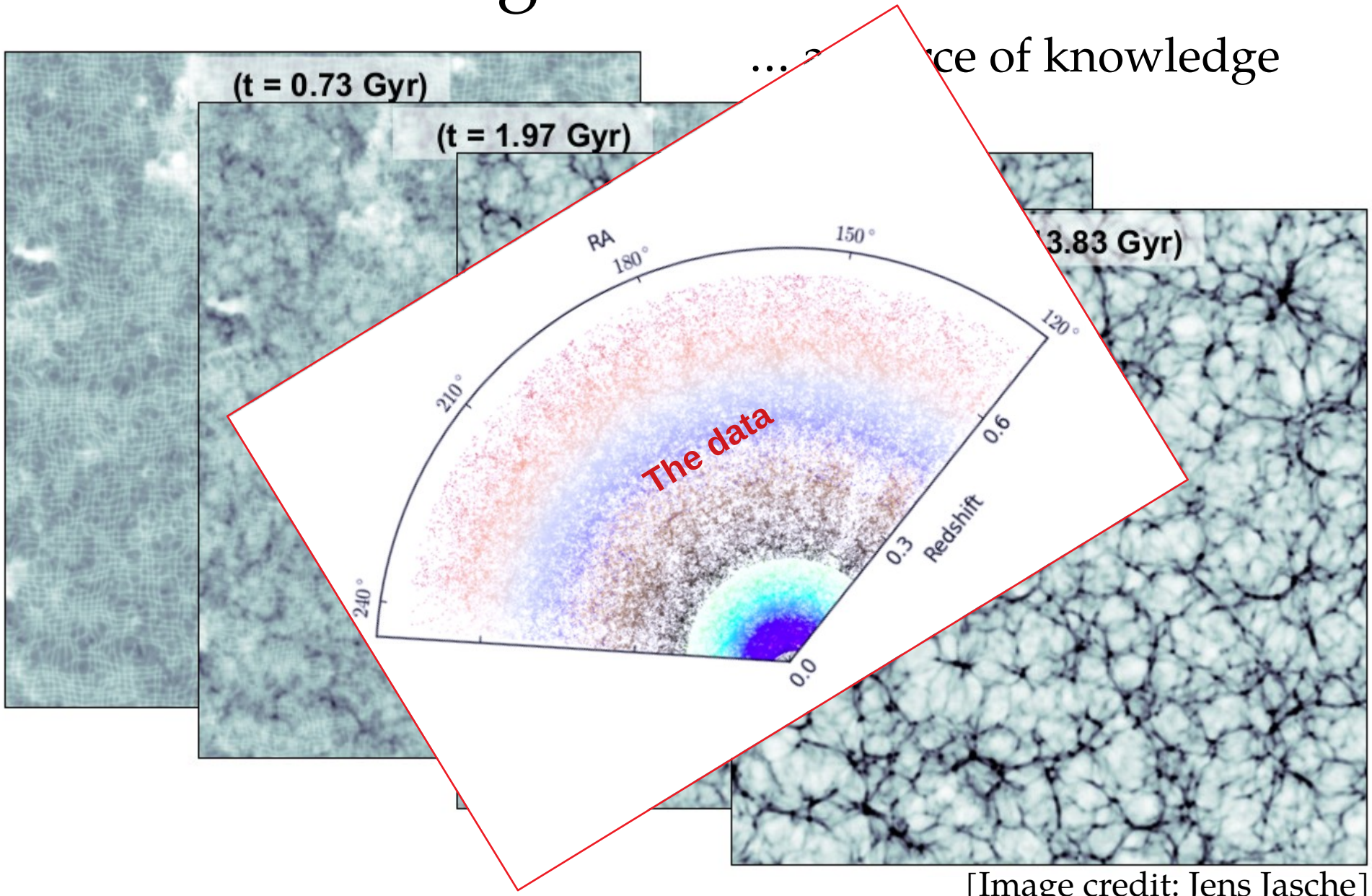
… a source of knowledge



[Image credit: Jens Jasche]

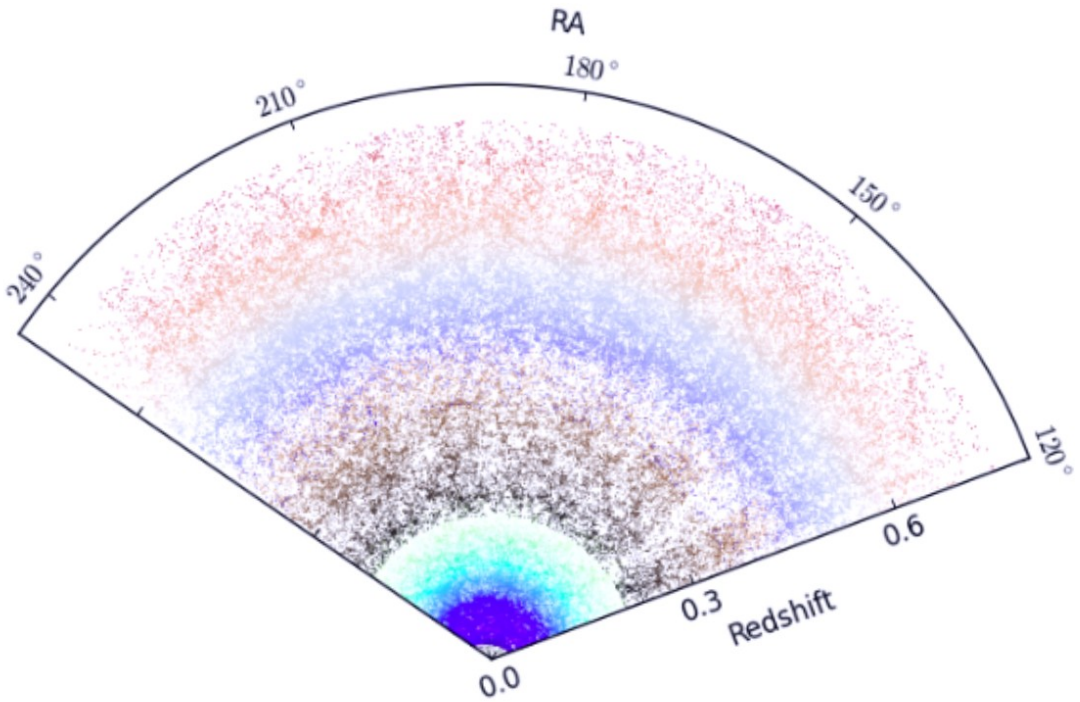
The large-scale structure

… a source of knowledge



[Image credit: Jens Jasche]

From data to cosmology



incomplete noise

no unique recovery of LSS

Statistics!

$$P(\delta|d) = \frac{P(d|\delta)P(\delta)}{P(d)}$$

Ω

cosmology

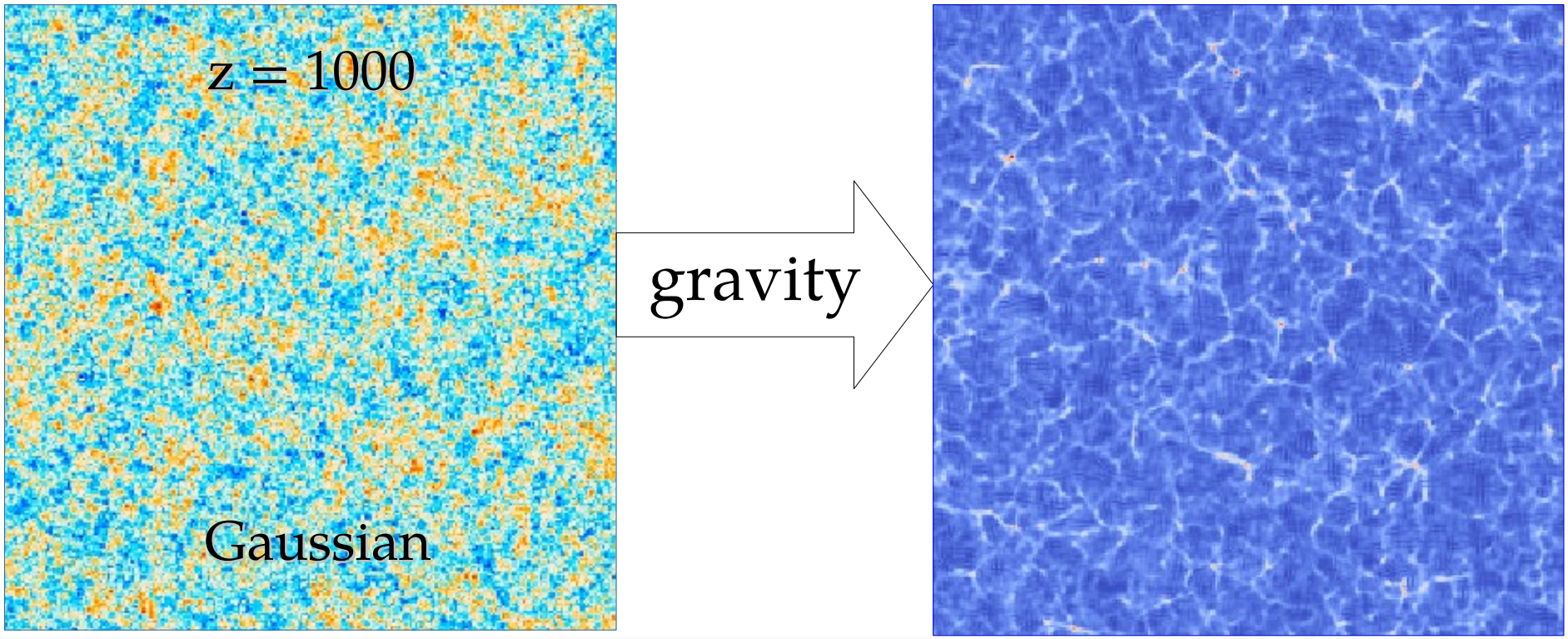
The BORG framework

[Jasche & Wandelt 2012]

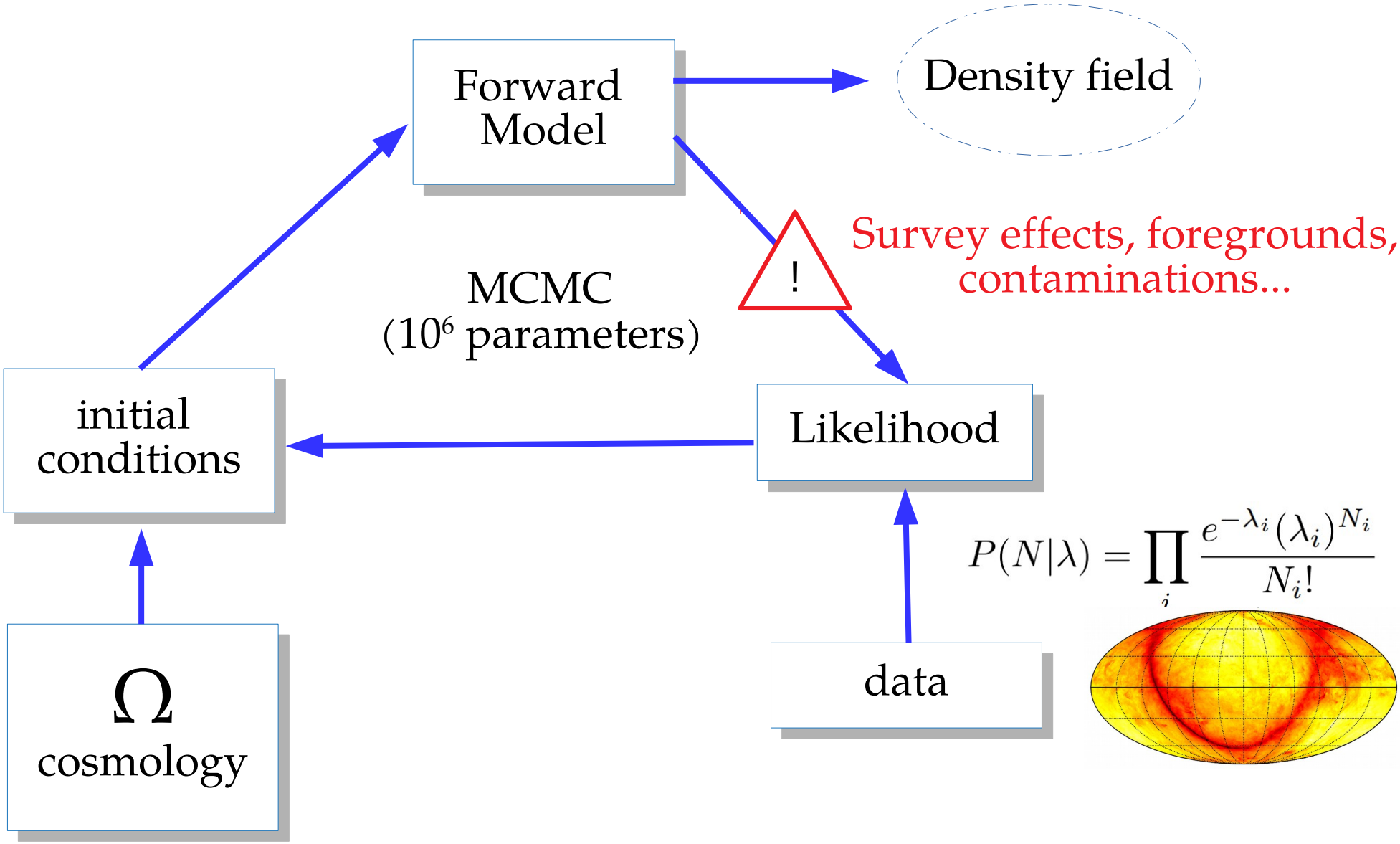
$$P(\delta|d) \propto P(d|\delta)P(\delta)$$

likelihood prior

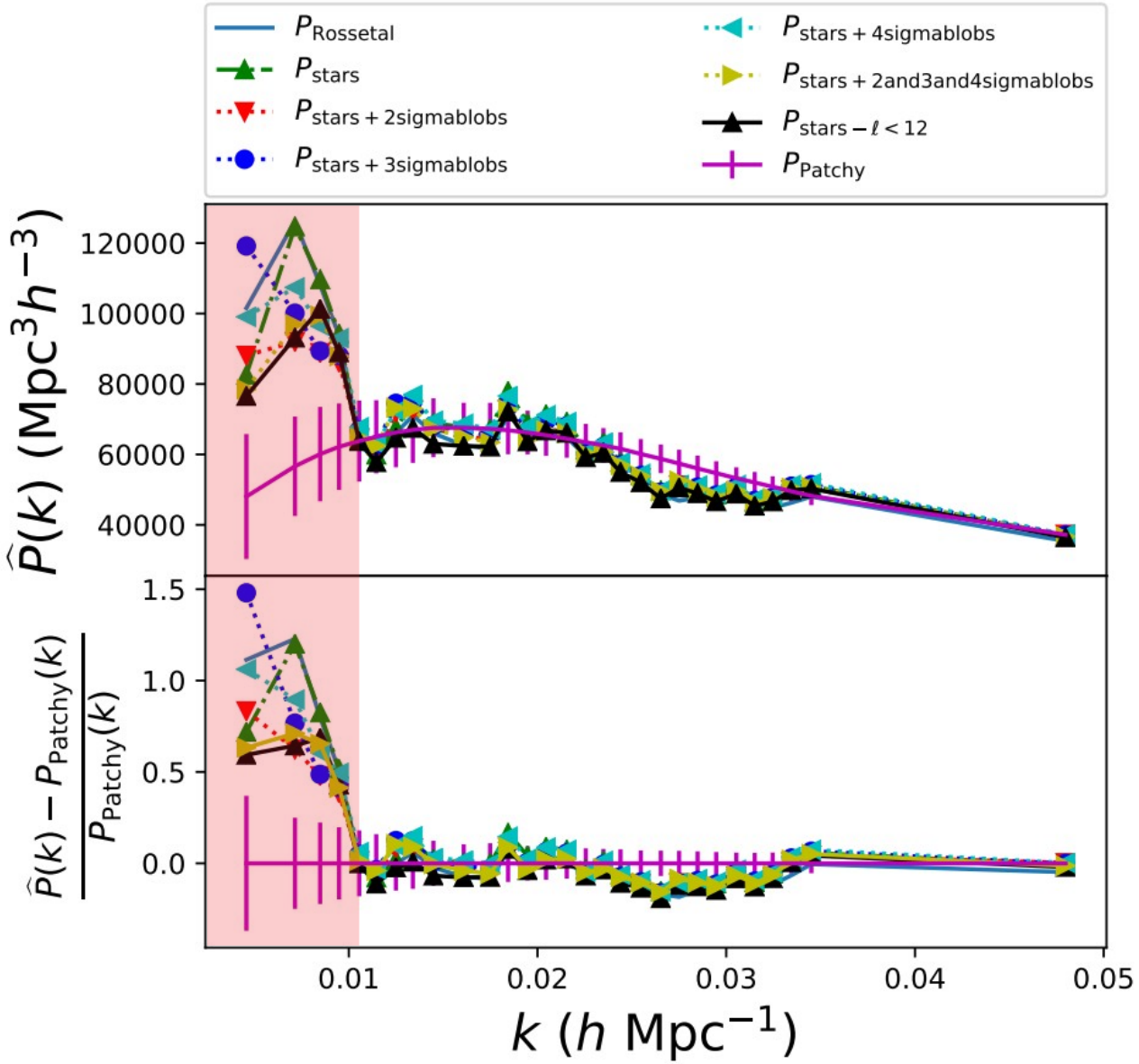
$$\propto P(d|\delta) \underbrace{P(\delta|\delta_0)}_{\delta^D(\delta-\mathcal{F}(\delta_0))} \underbrace{P(\delta_0)}_{G(0,S)}$$



The inference chain

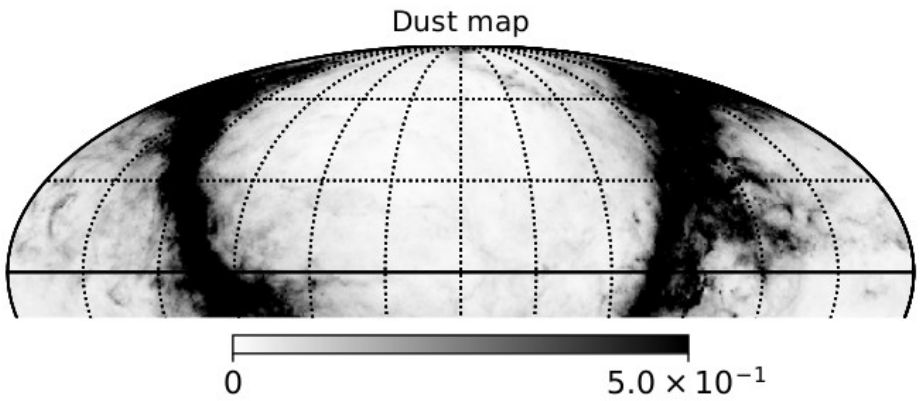


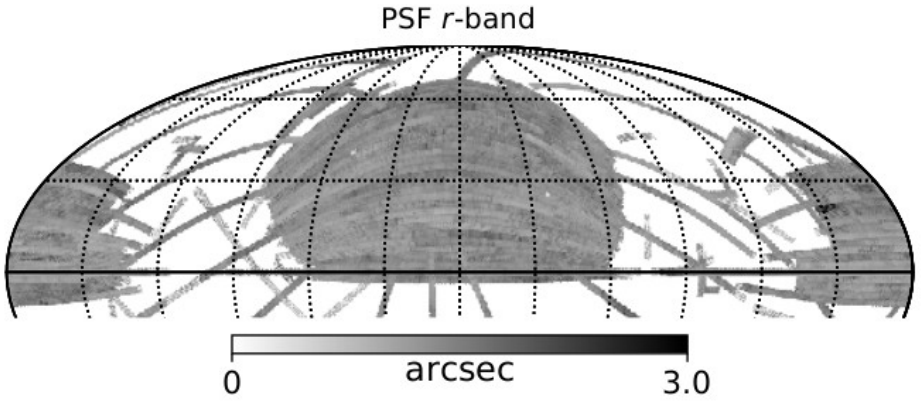
Effect of contaminations

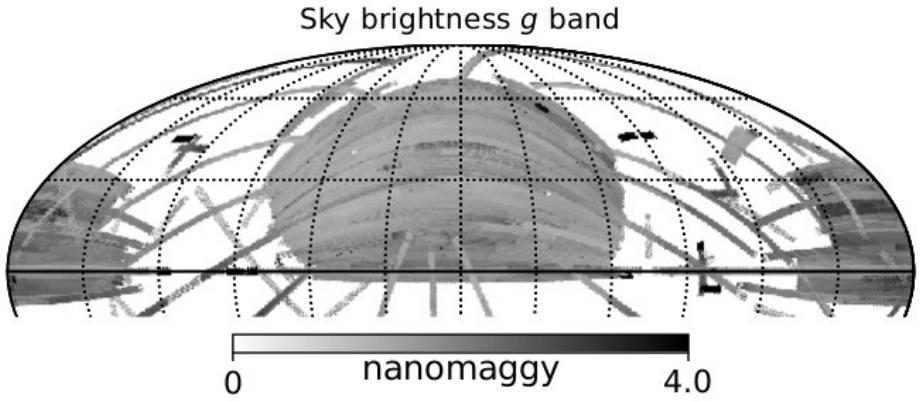


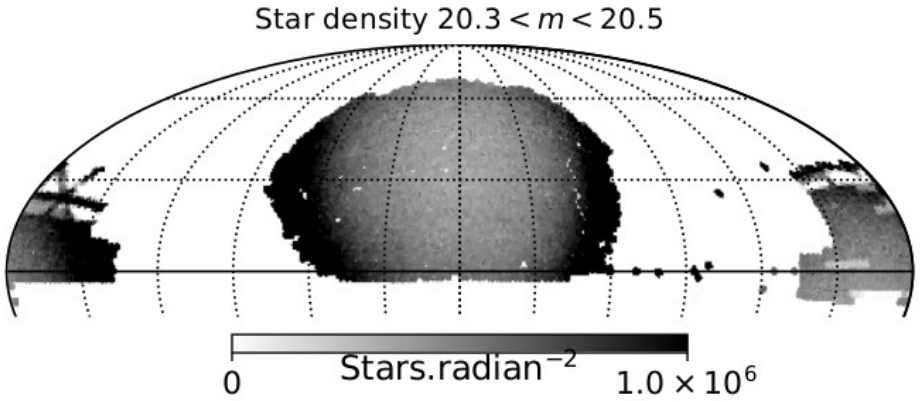
[Kalus, Percival et al 2018]

Foreground templates









[Lavaux, Jasche, Leclercq 2019]

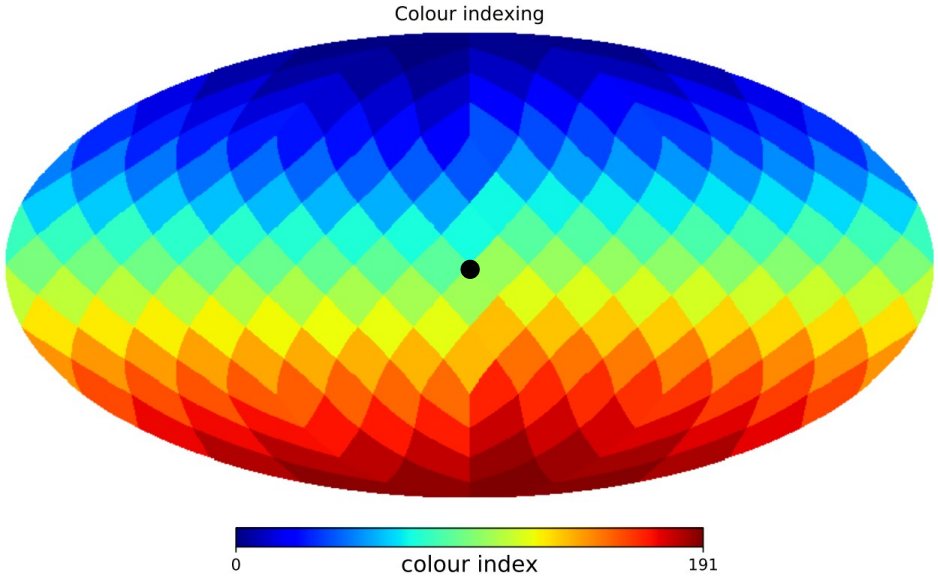
Unknown systematics?

Robust Likelihood

[Porqueres et al. 2019]

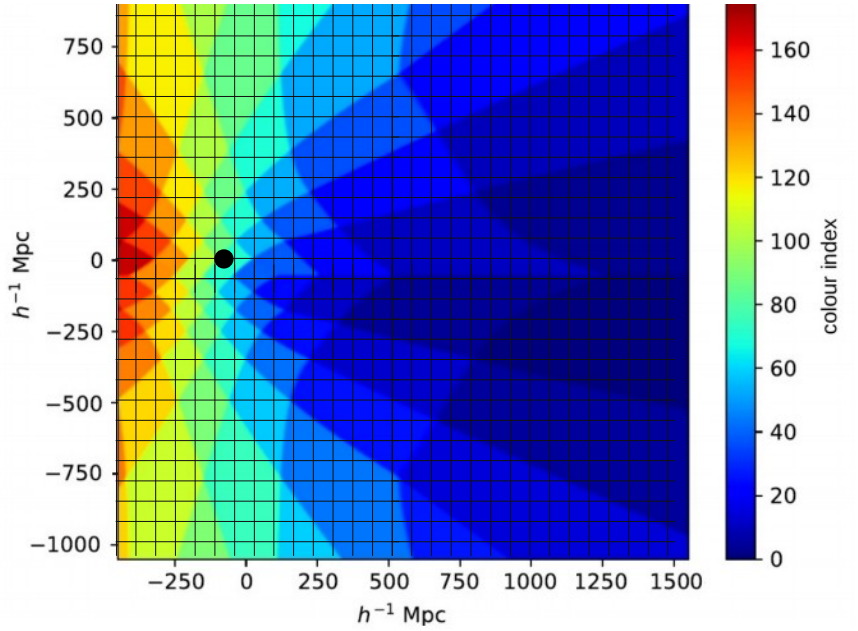
$$\lambda_c = A_c \bar{\lambda}_c$$

$$P(N|\lambda) = \prod_i \frac{e^{-\lambda_i} (\lambda_i)^{N_i}}{N_i!}$$

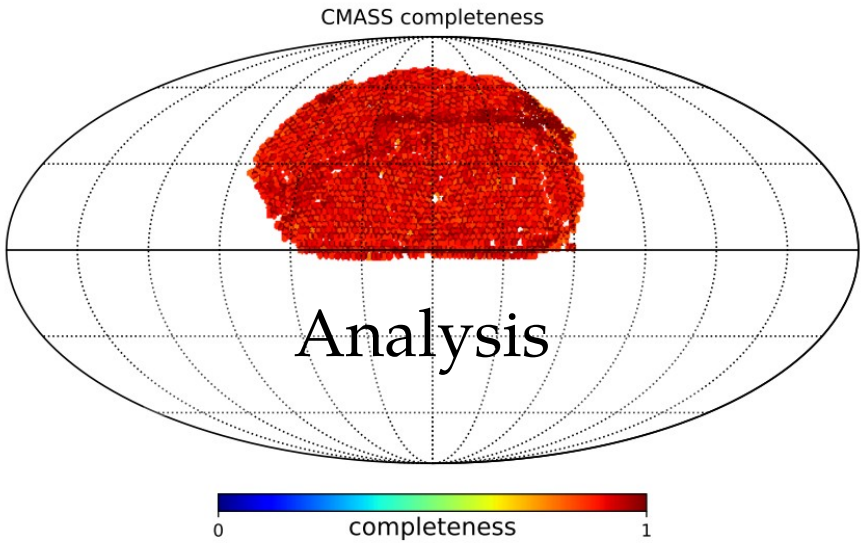


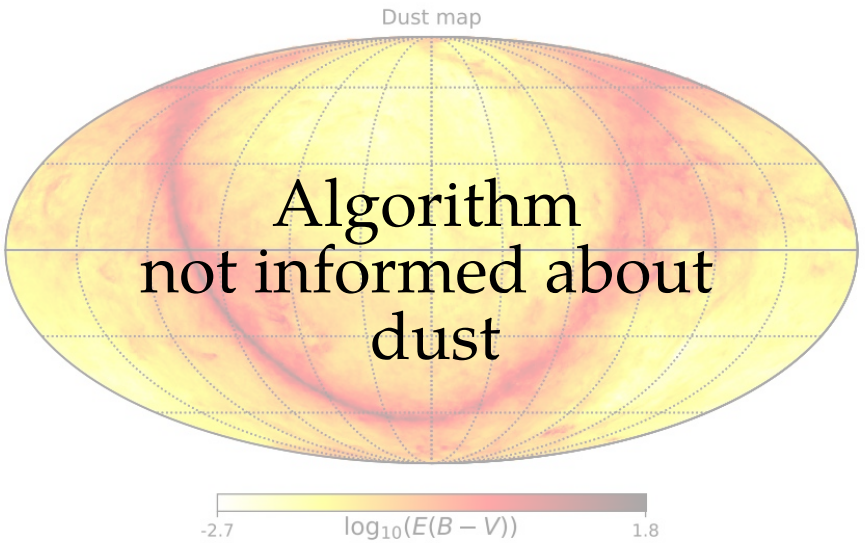
Marginalizing over A:

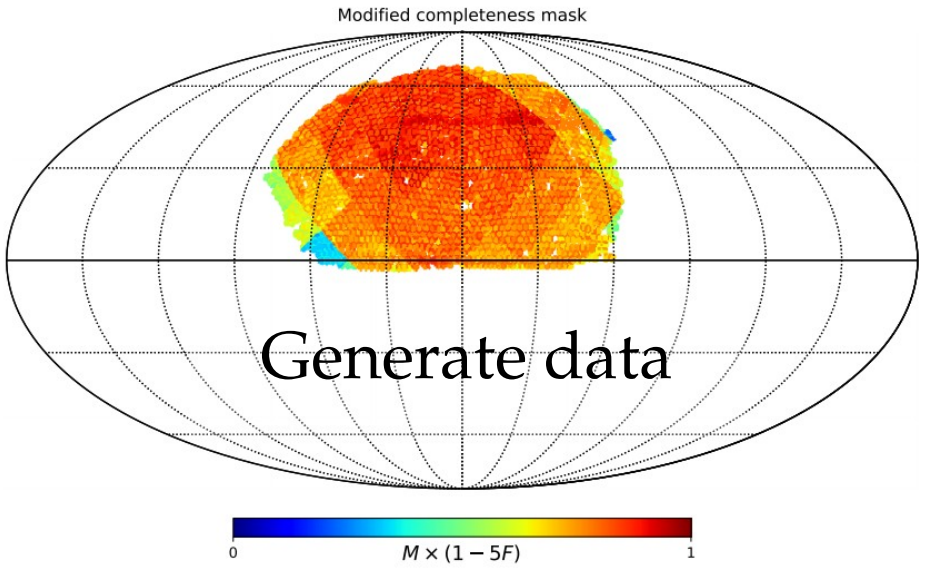
$$P(N|\lambda) \propto \prod_c \prod_{i \in \mathcal{A}_c} \left(\frac{\lambda_i}{\sum_{j \in \mathcal{A}_c} \lambda_j} \right)^{N_i}$$



Contaminated mock data

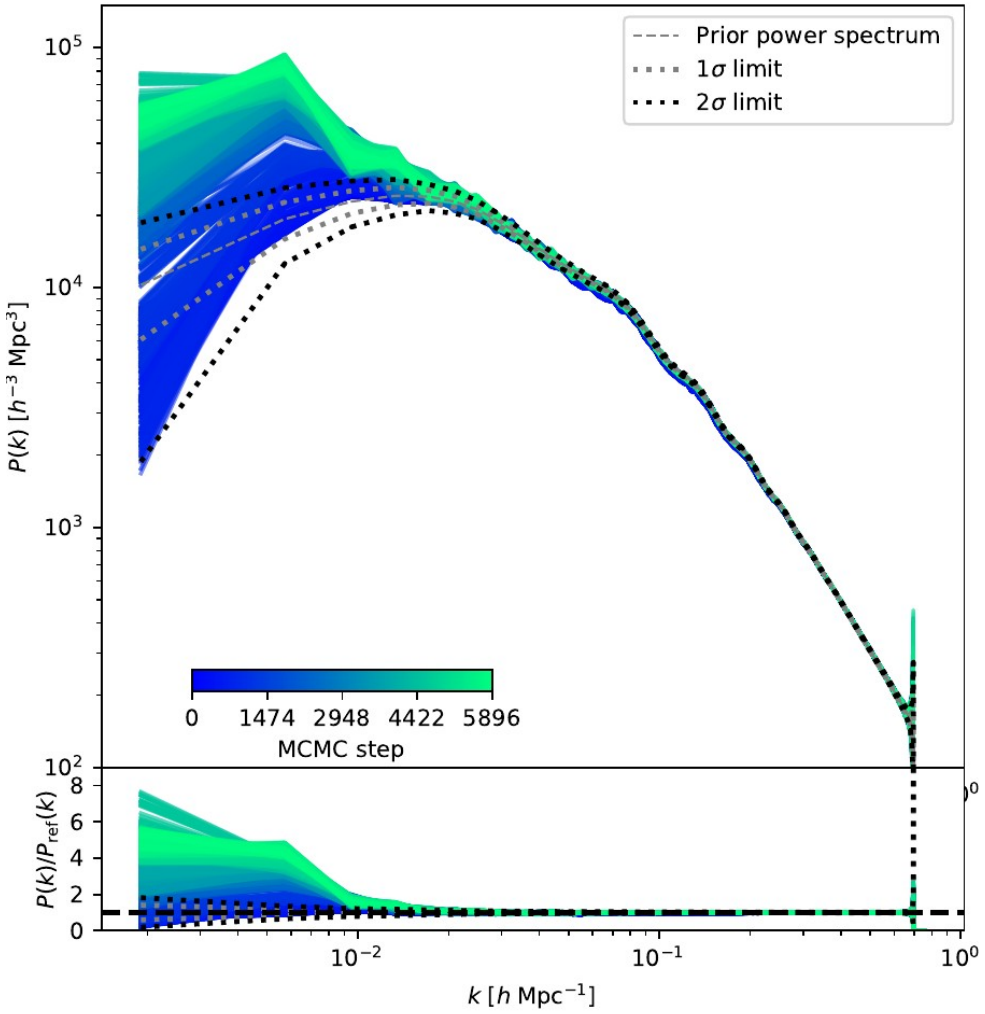




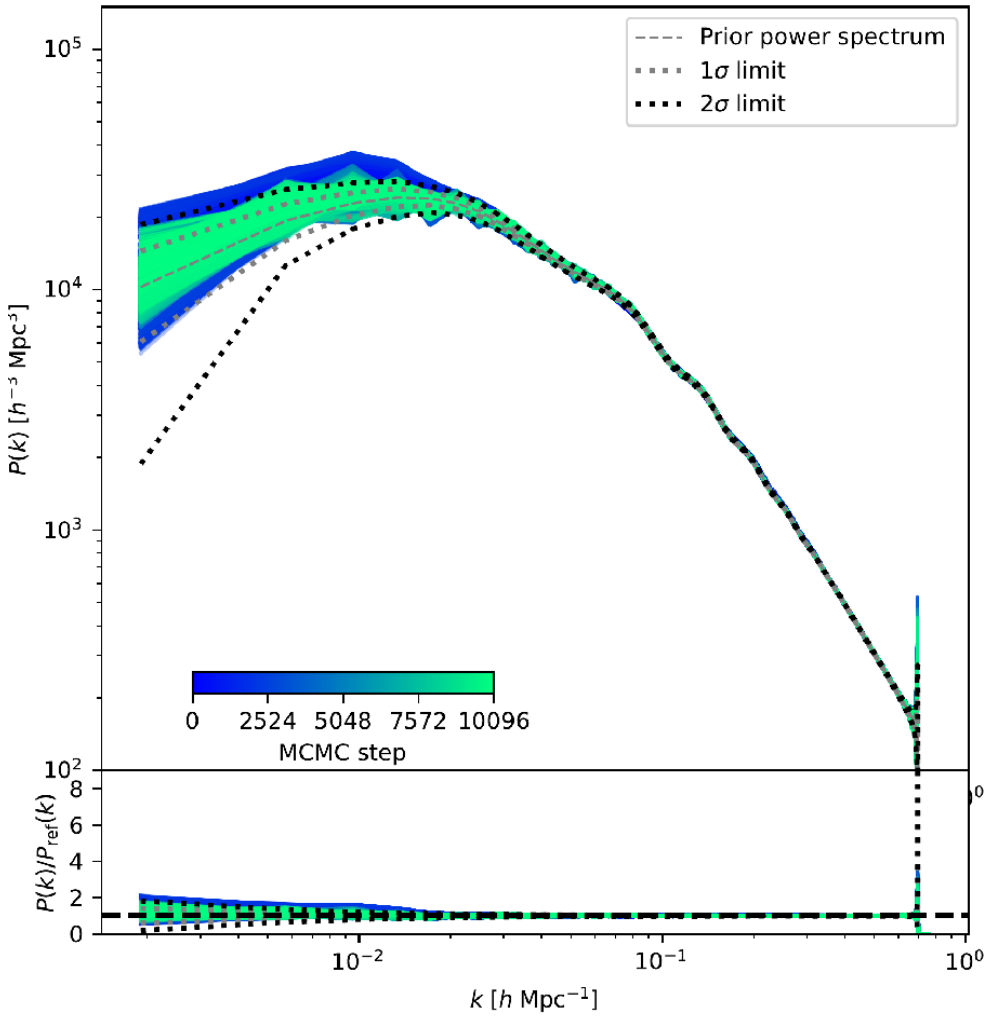


Poisson vs Robust likelihood

[Porqueres et al. 2019]

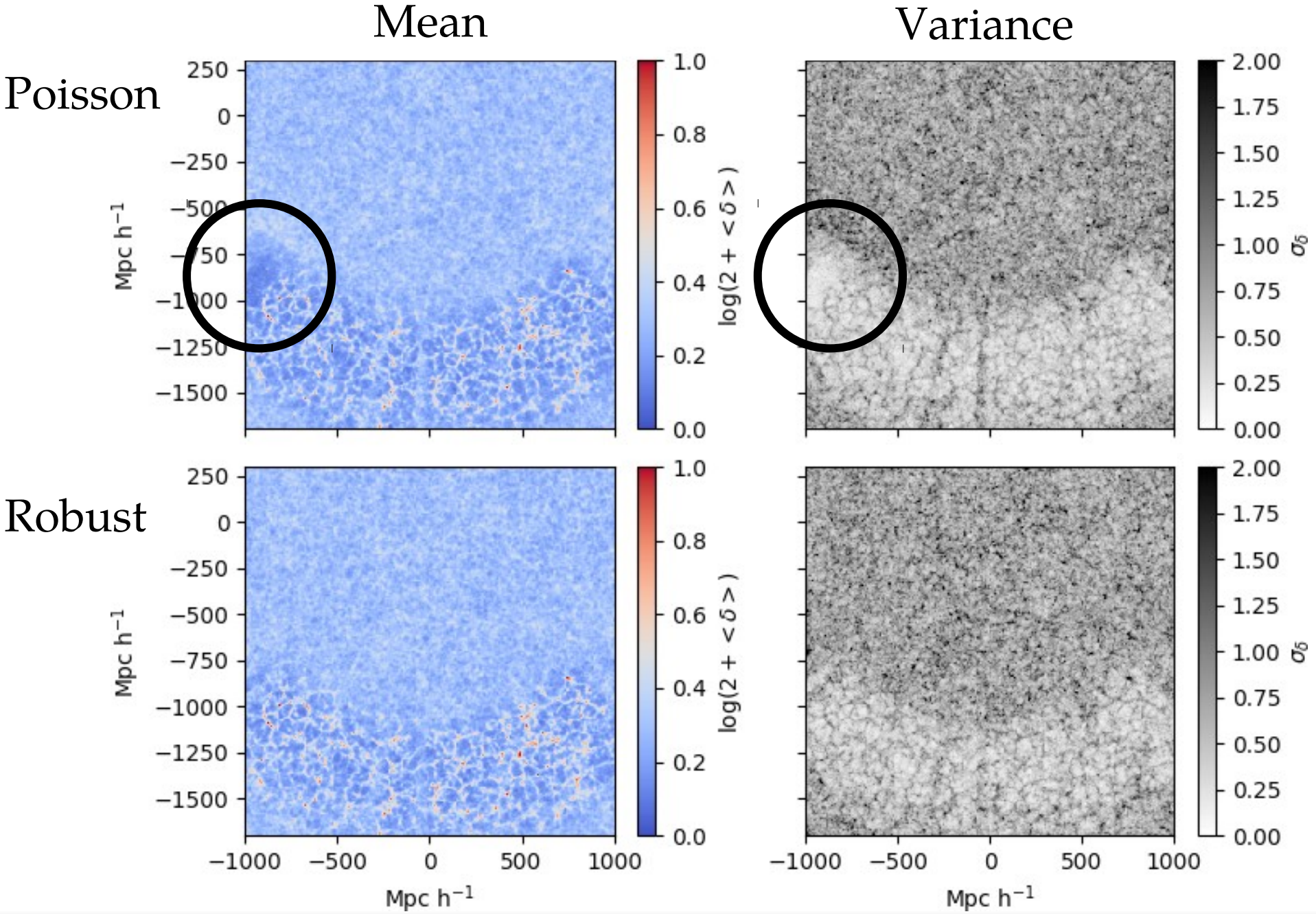


Poisson

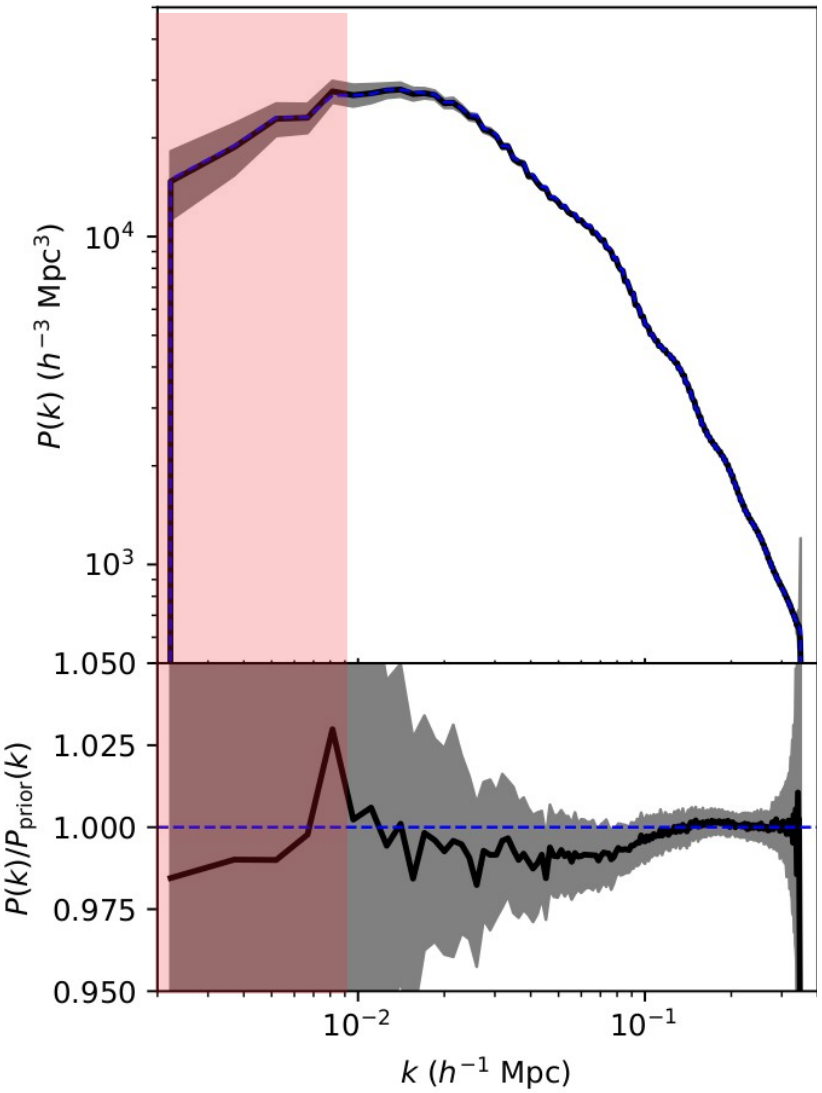


Robust

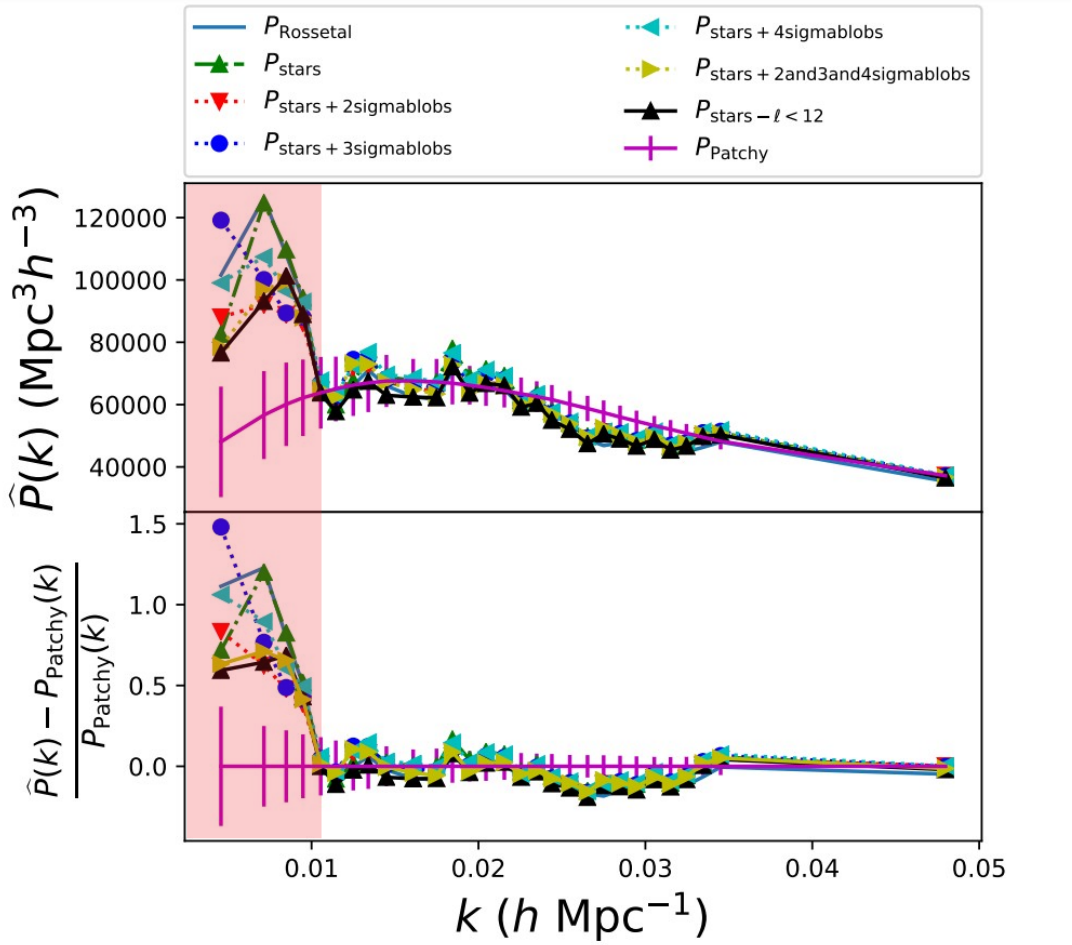
Poisson vs Robust likelihood



Robust likelihood and BOSS real data

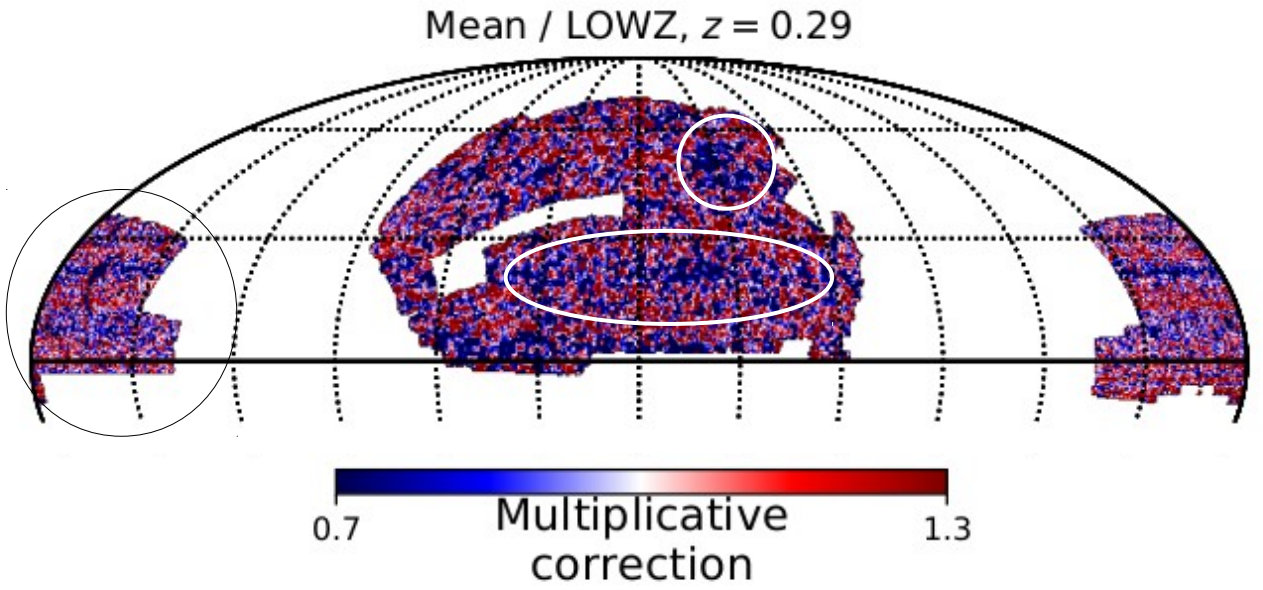


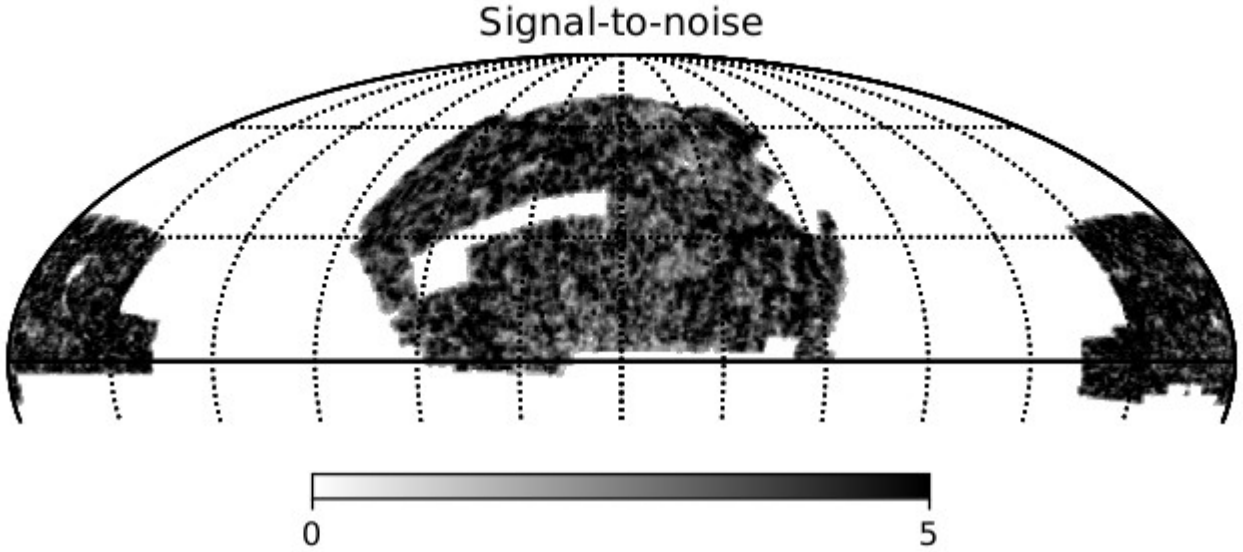
[Lavaux, Jasche, Leclercq 2019]



[Kalus, Percival et al 2018]

Templates of unknown foregrounds





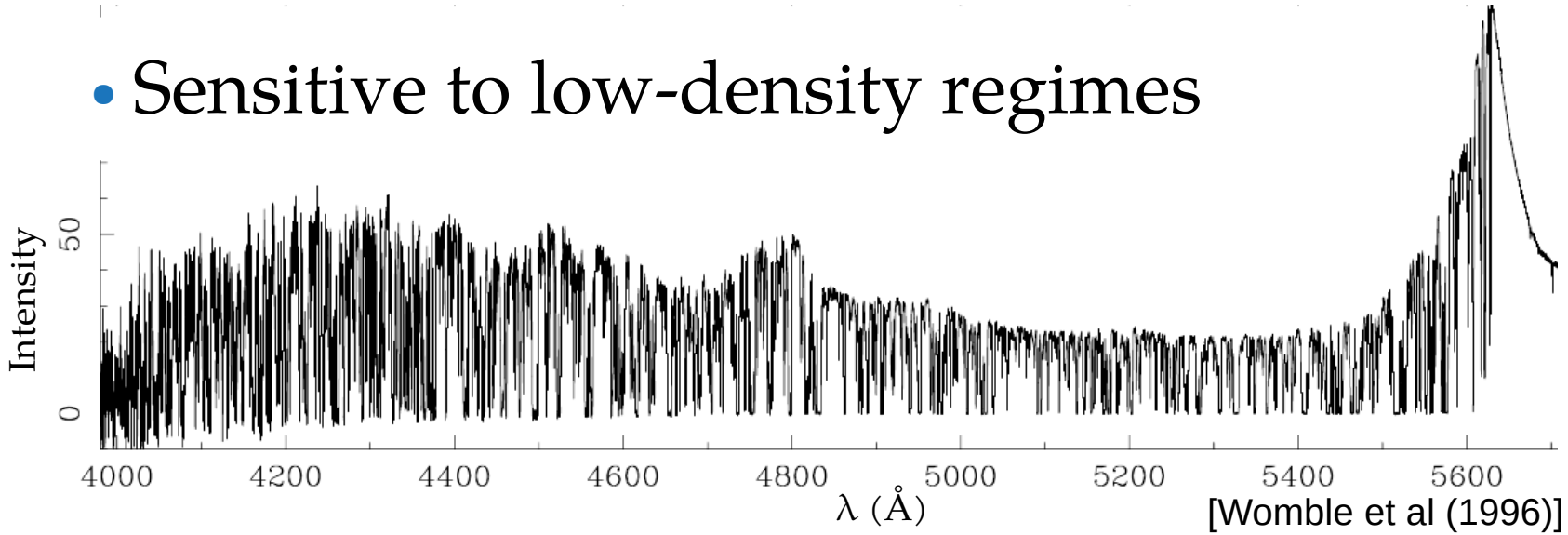
[Lavaux, Jasche, Leclercq 2019]

The Lyman-α forest:

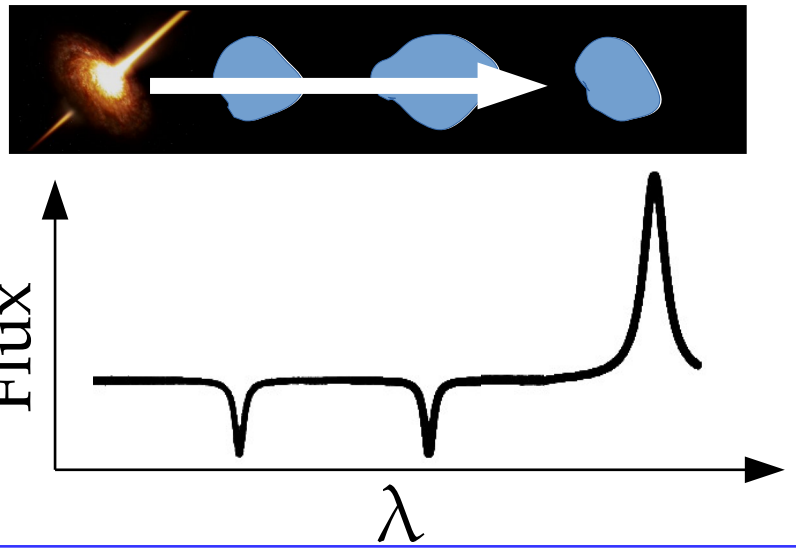
A complementary source of information

The Lyman-α forest

- High-resolution (Mpc) along the line of sight
- Sensitive to low-density regimes



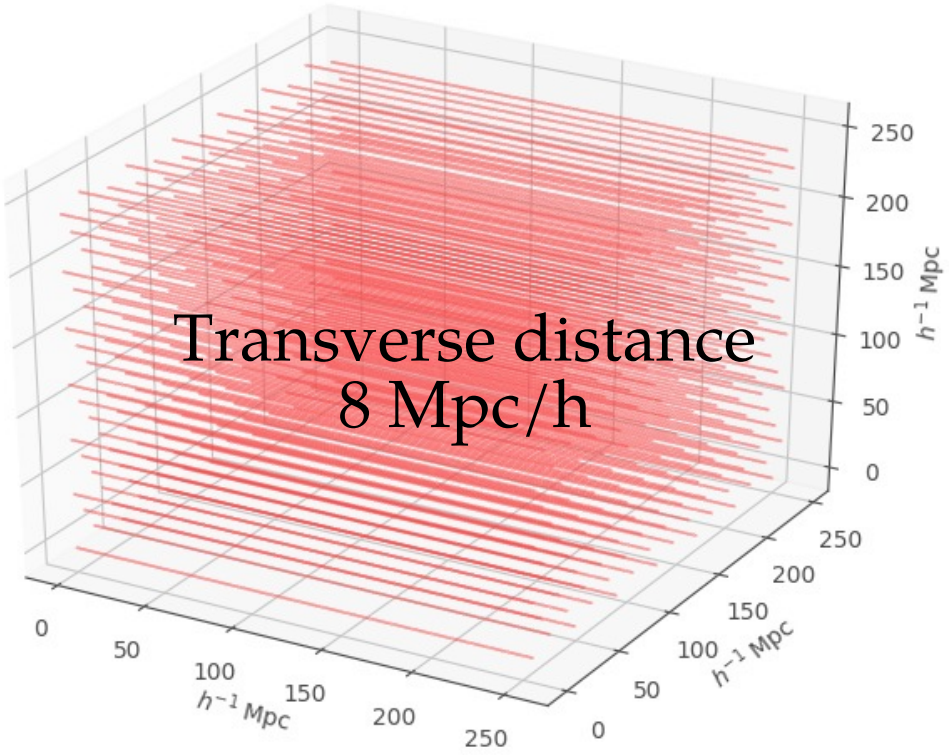
[Womble et al (1996)]

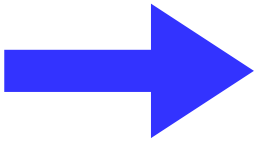


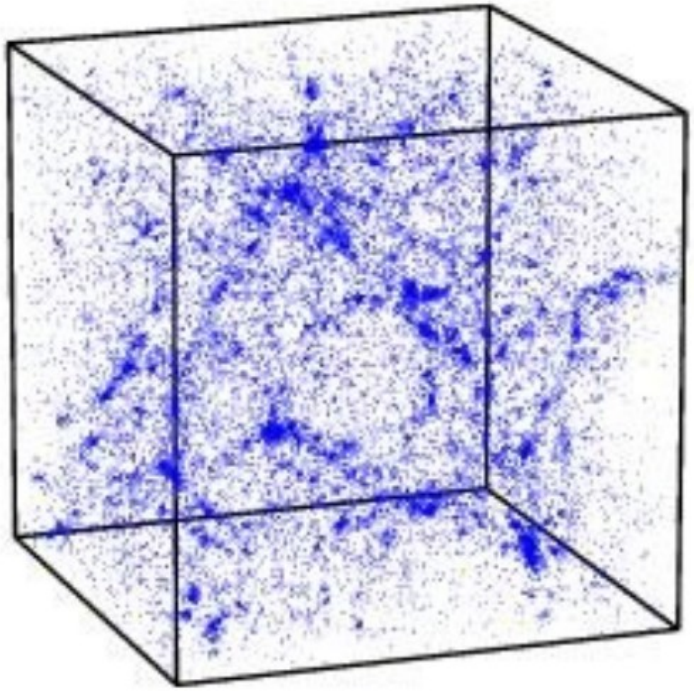
Challenges:

- Non-gaussianity of data
- Interpolate between lines of sight

From 1D to 3D



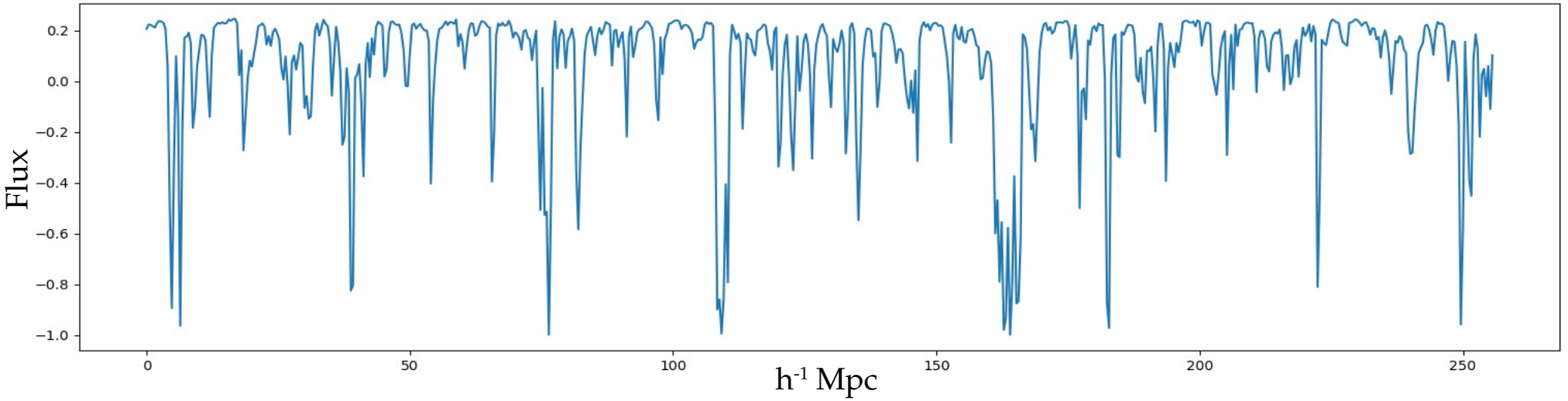




Statistics!

$$P(\delta|F) = \frac{P(F|\delta)P(\delta)}{P(F)}$$

Data model

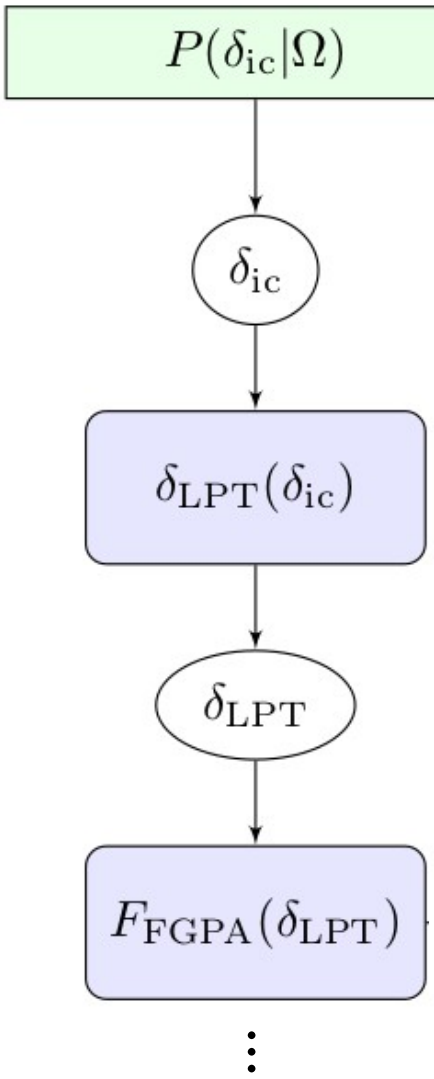


Likelihood

$$-\log P(F|\delta) = \frac{\left(F - \exp[-A(1+\delta)^{\beta}]\right)^2}{2\sigma^2}$$

Sampling density and astrophysical parameters

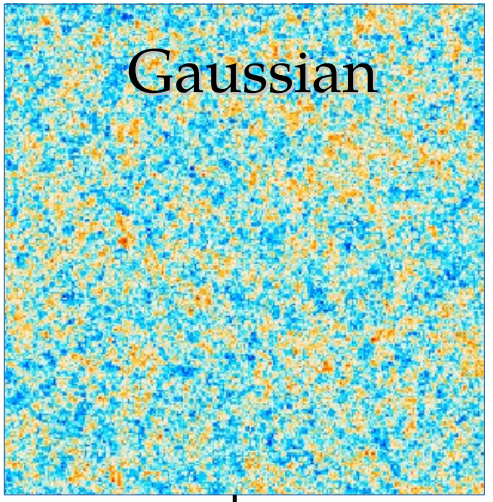
The BORG framework



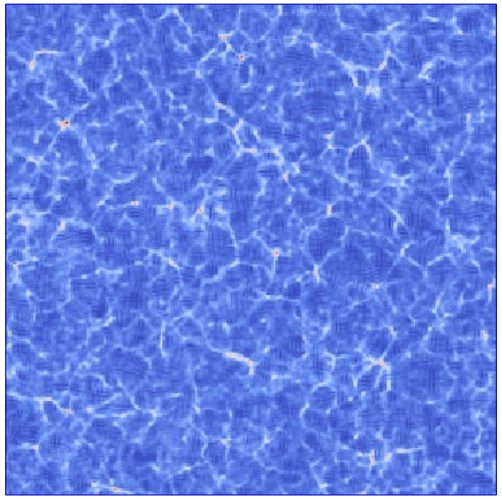
Gaussian prior

Forward model
- LPT
- PM
- QLPT (Uhlemann+ 2018)

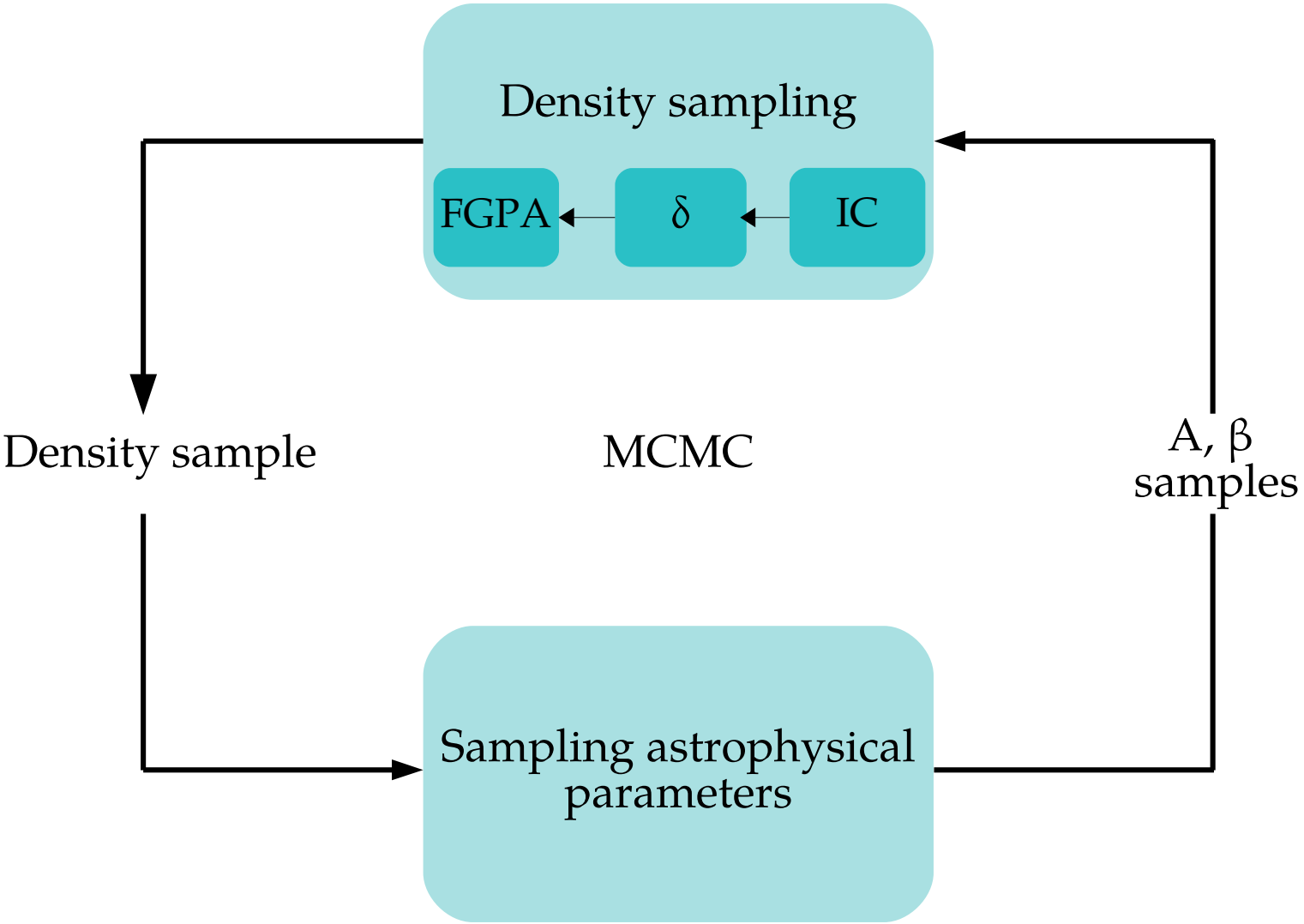
Likelihood



gravity



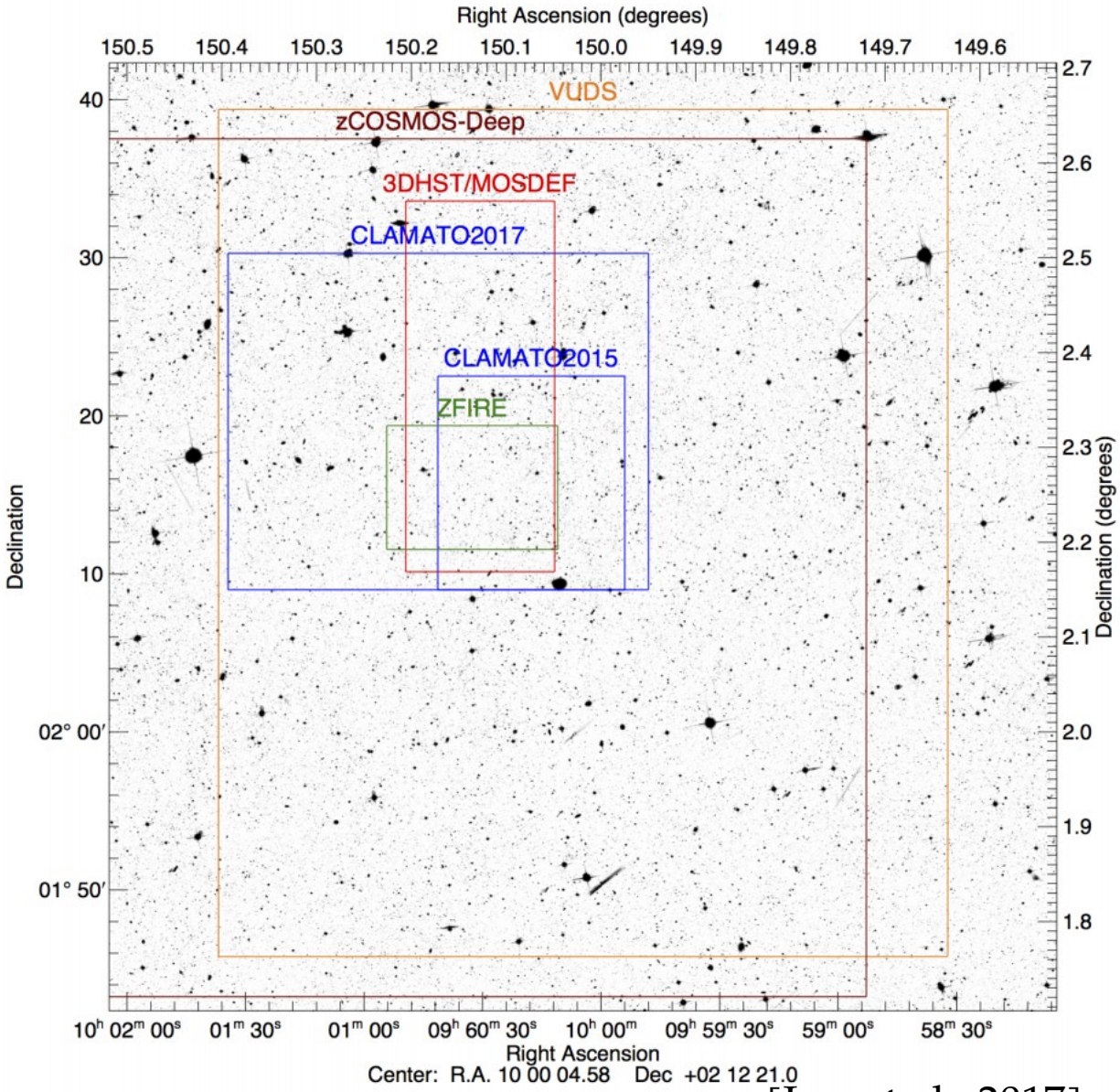
Statistical modular framework



Testing with mock CLAMATO data

Small sky area (0.8 deg^2)

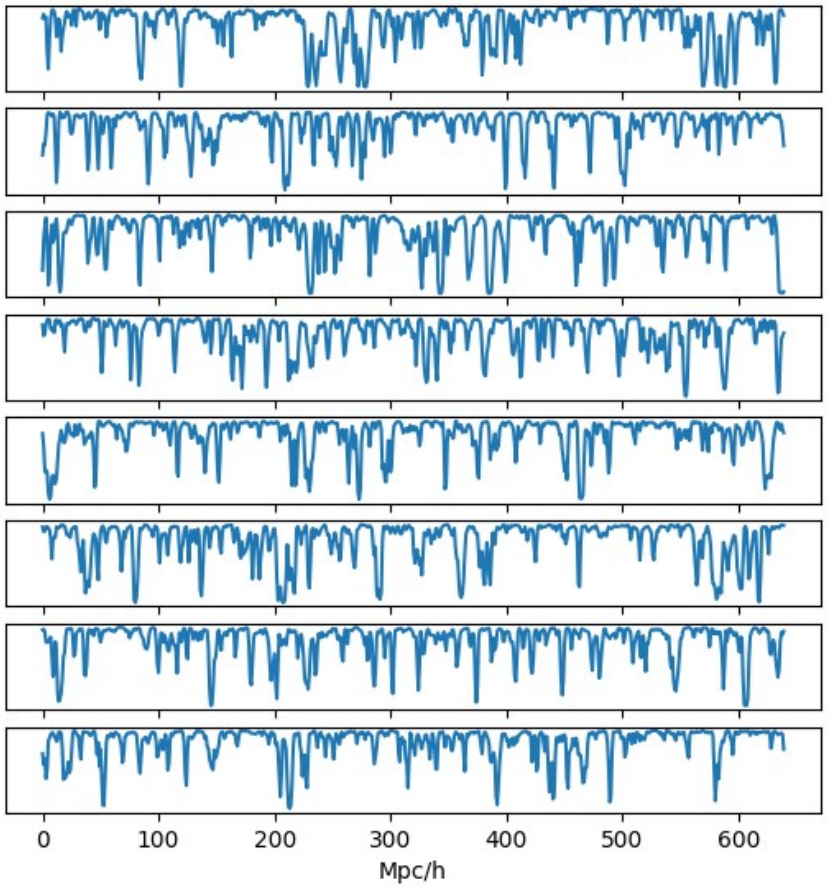
High density of los
(more than 400 spectra)



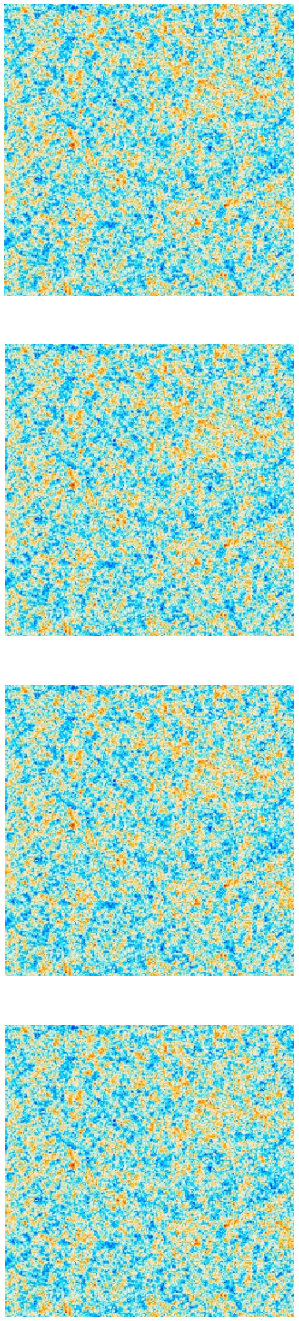
[Lee et al. 2017]

Inference of DM density

simulated QSO spectra

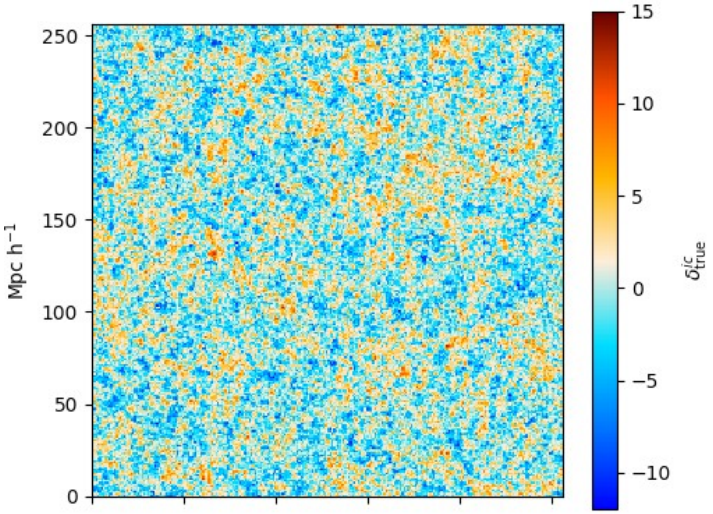


BORG

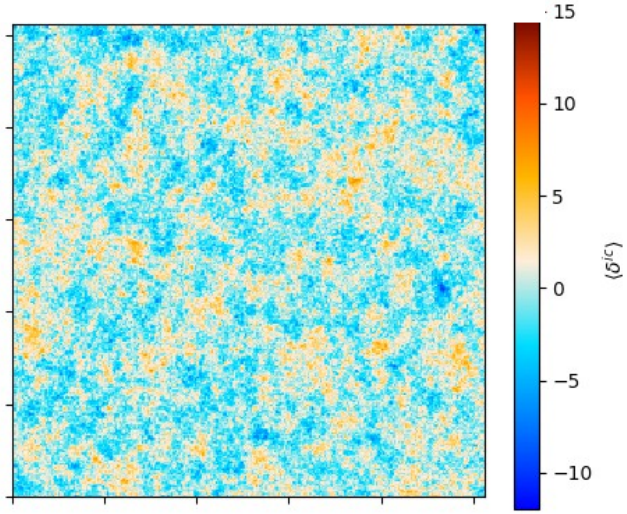


L = 256 Mpc/h
resolution 1 Mpc/h

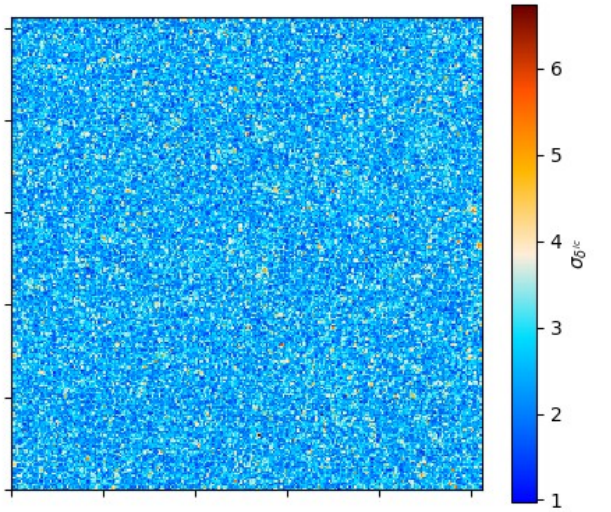
True initial conditions



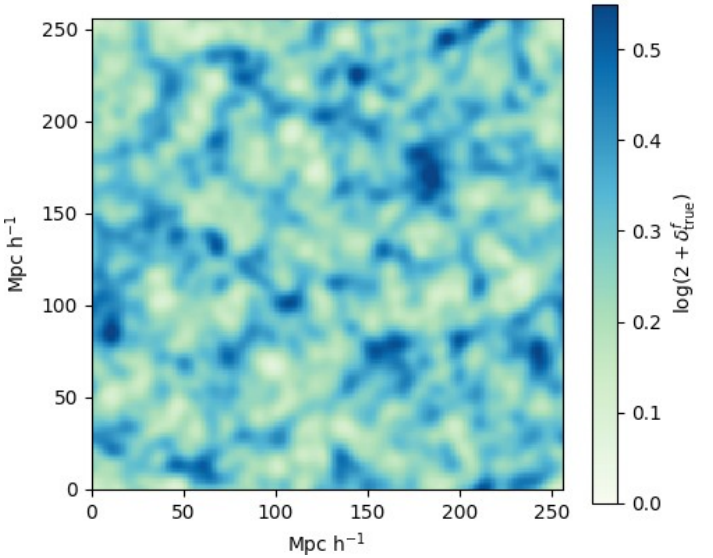
Mean initial conditions



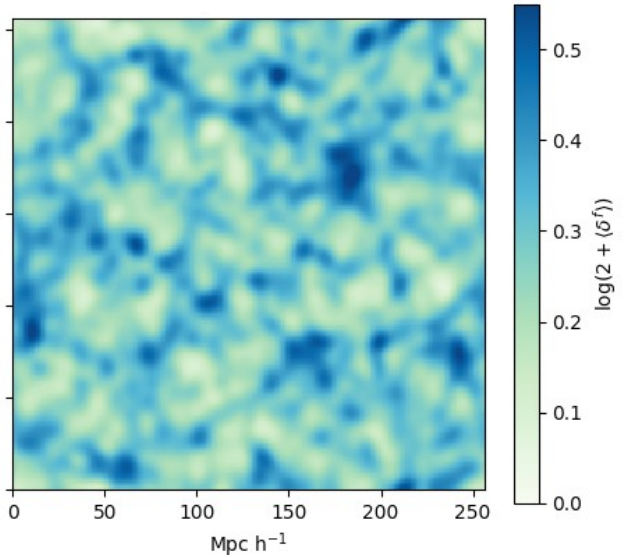
Variance initial conditions



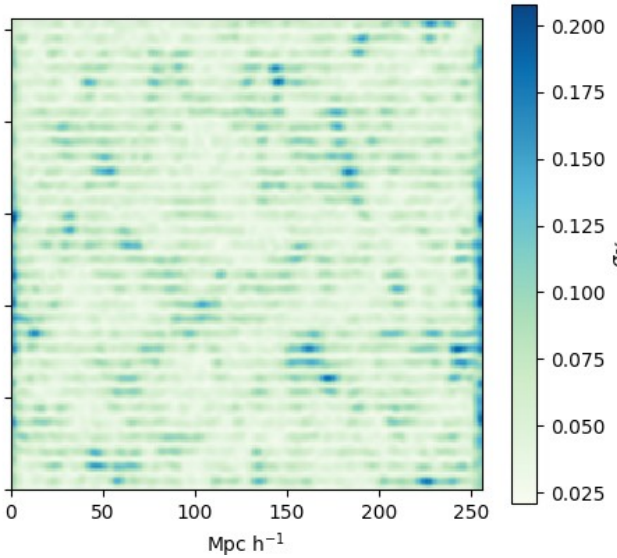
True density



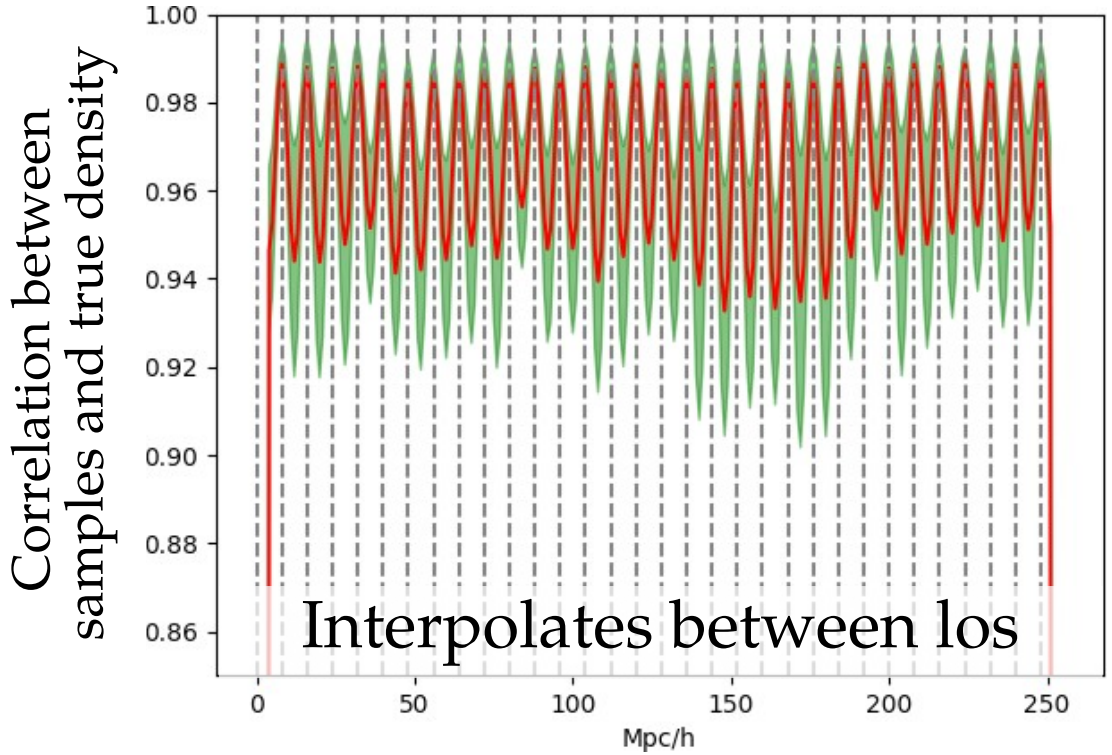
Mean density

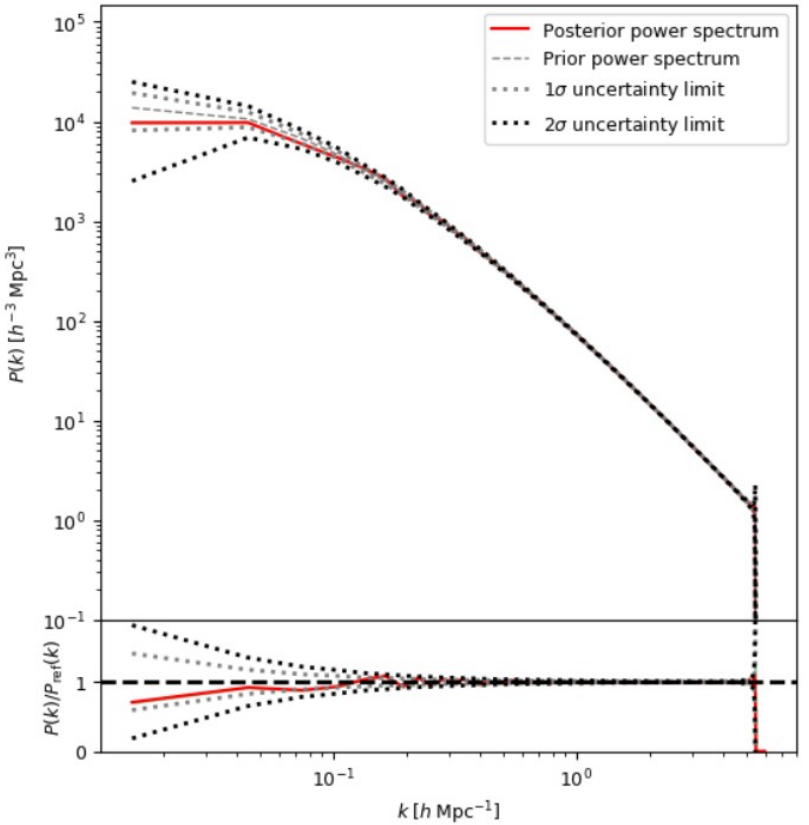


Variance density



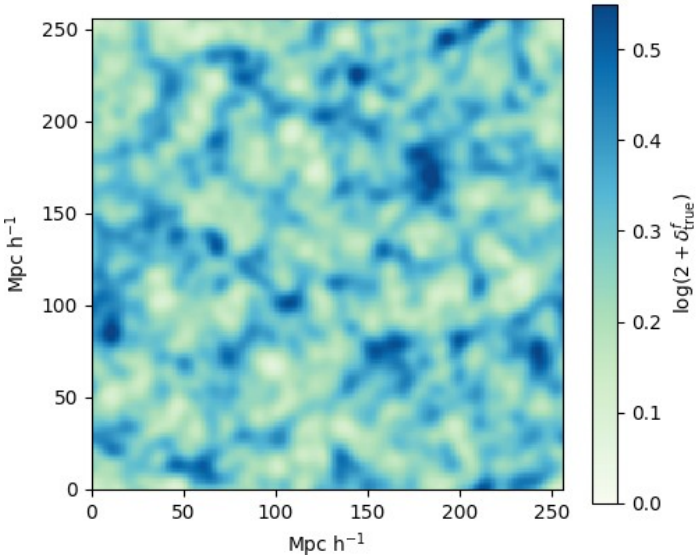
[Porqueres et al. 2019]

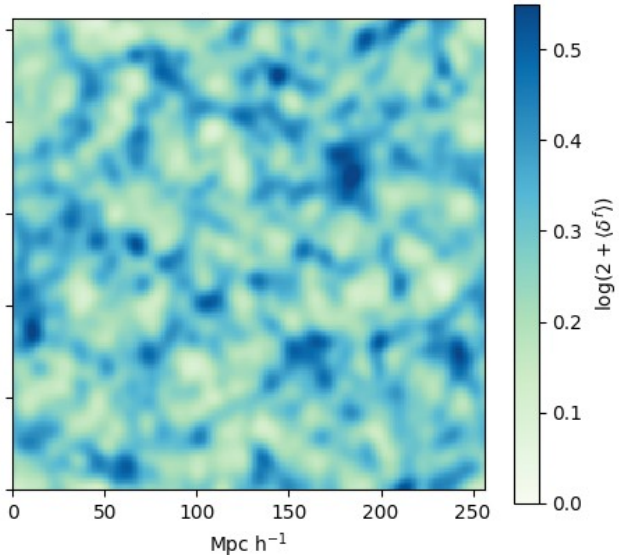


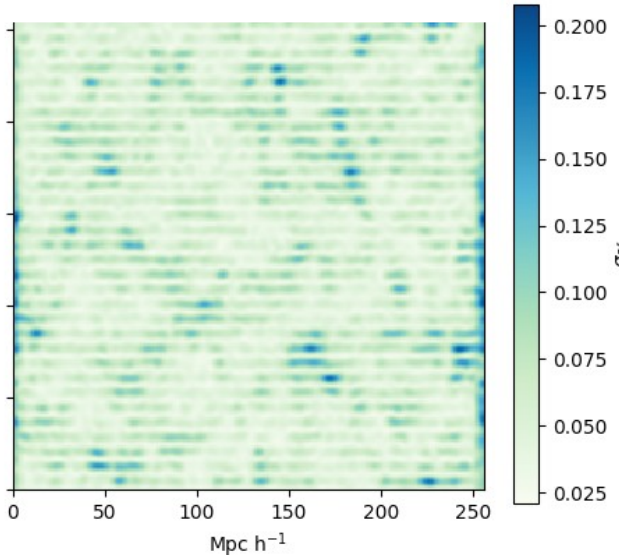


True density

Mean density

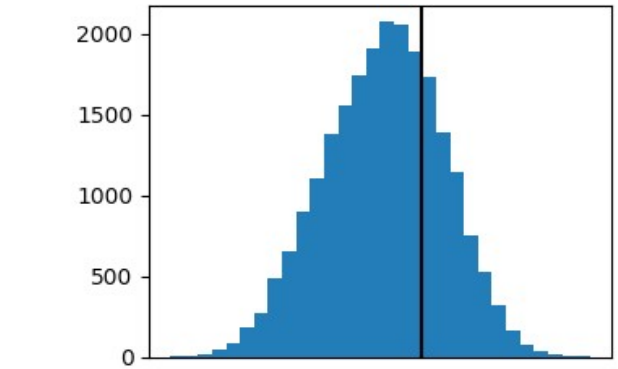




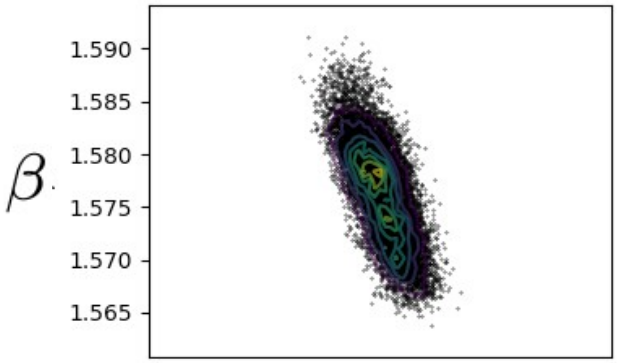


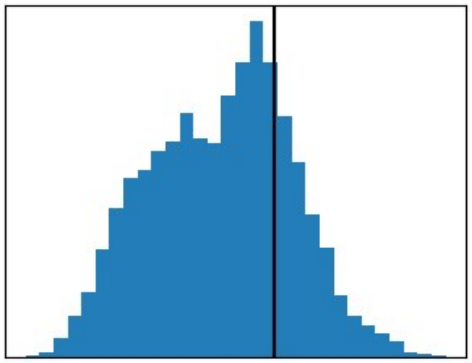
[Porqueres et al. 2019]

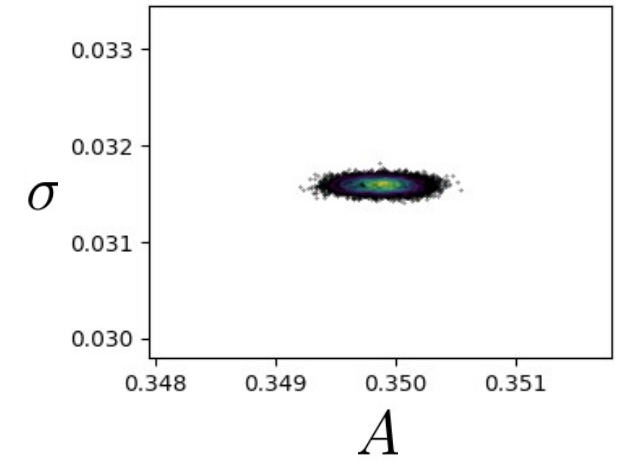
Astrophysical parameters

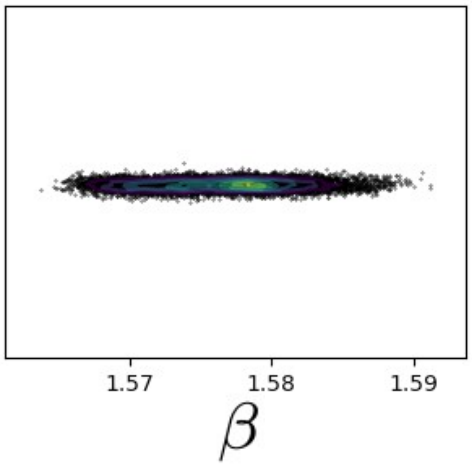


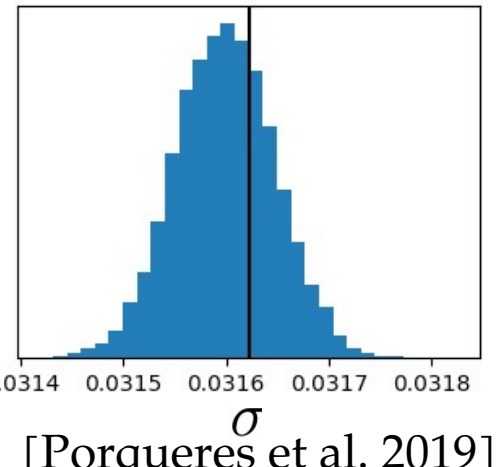
$$-\log P(F|\delta) = \frac{\left(F - \exp[-A(1+\delta)^{\beta}]\right)^2}{2\sigma^2}$$





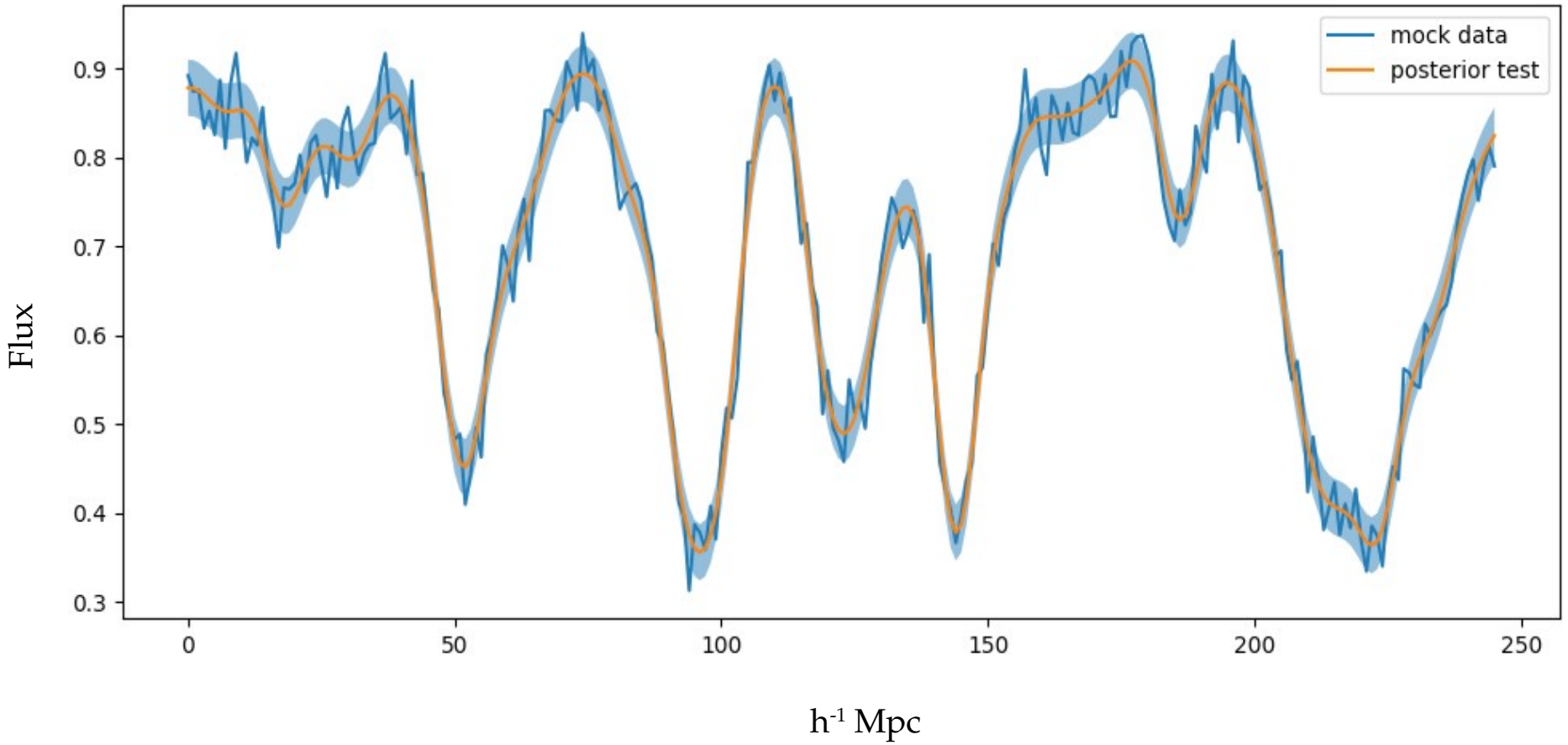






[Porqueres et al. 2019]

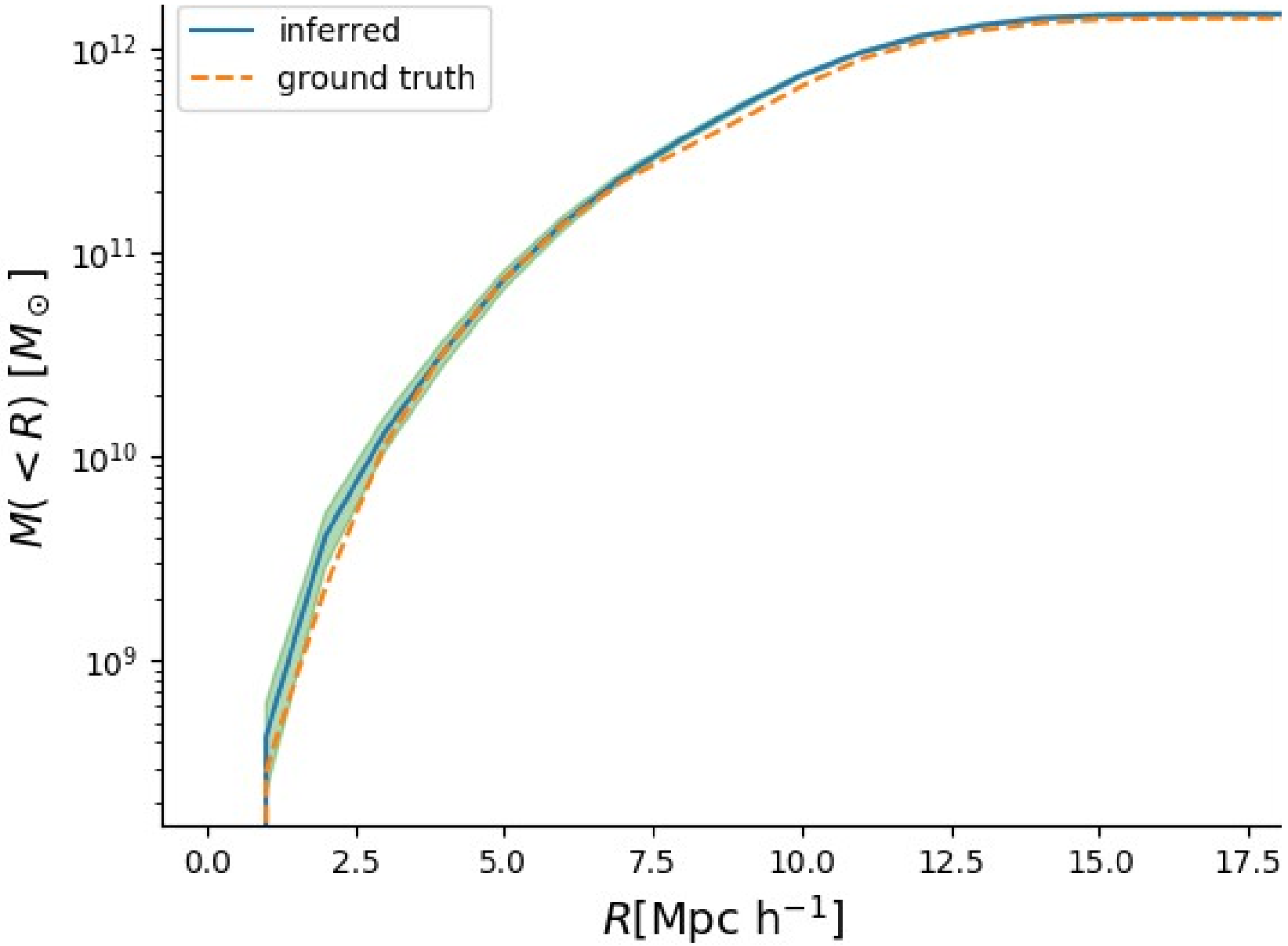
Posterior predictive test



[Porqueres et al. 2019]

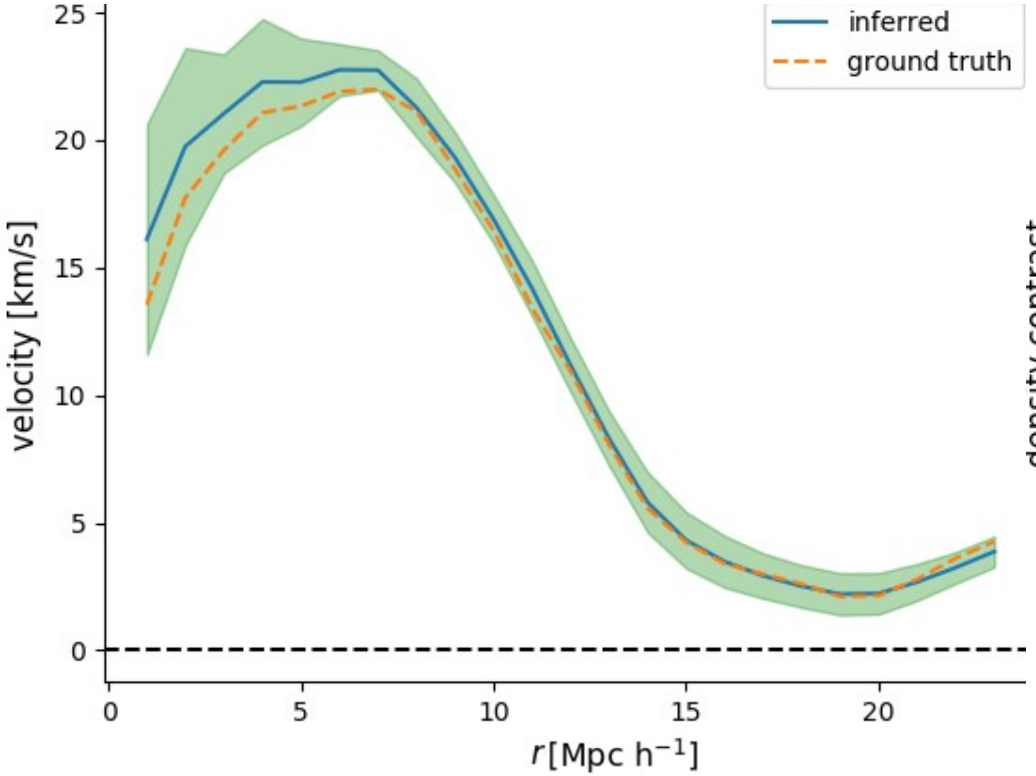
What physics can we do with this method?

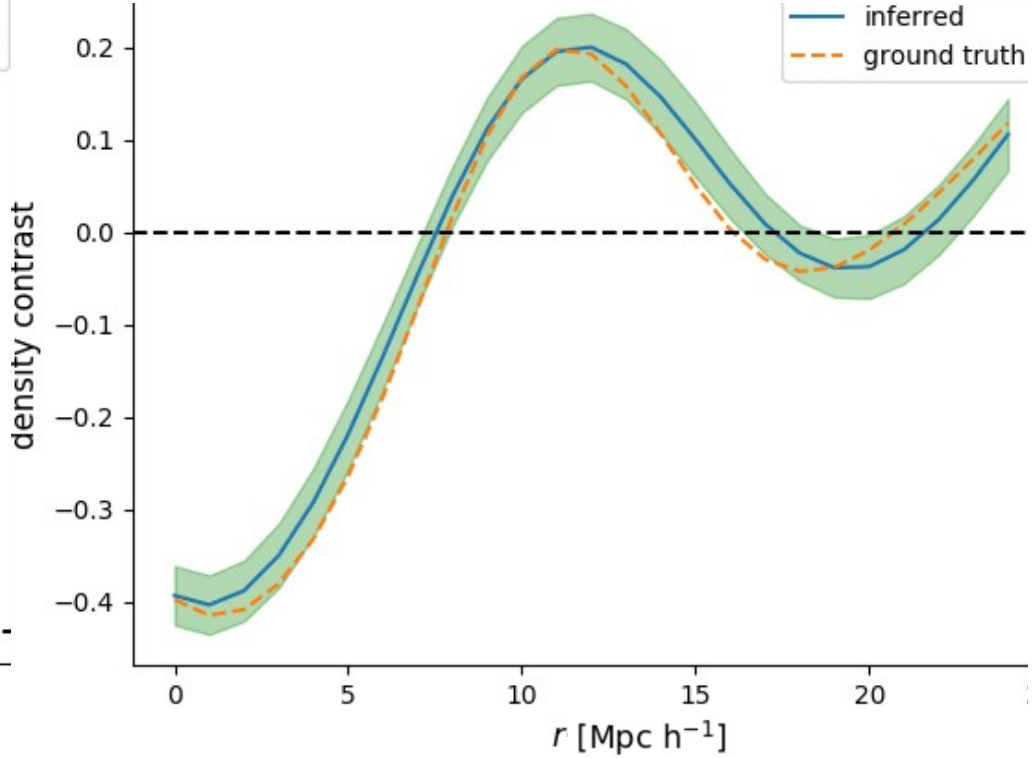
Cluster mass profile



[Porqueres et al. 2019]

Void profiles



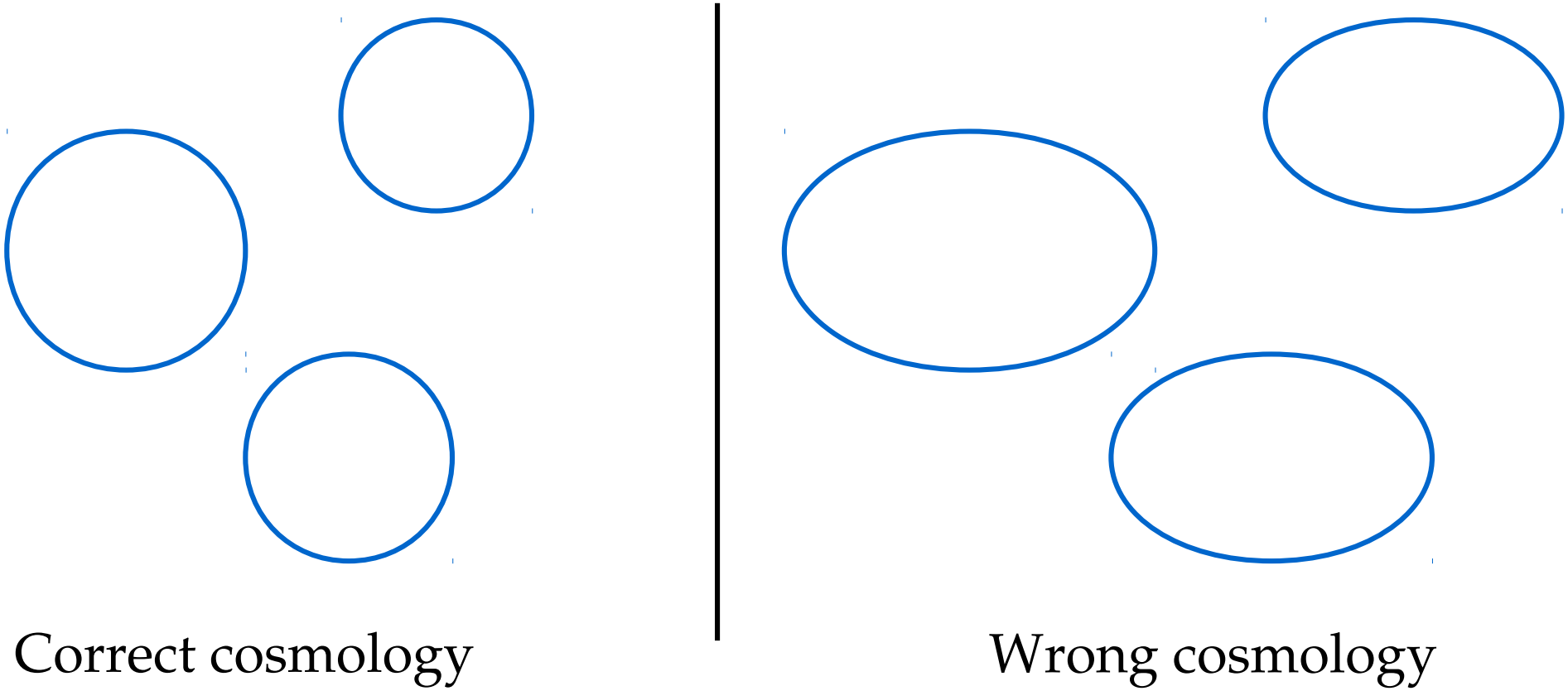


[Porqueres et al. 2019]

Alcock-Paczynski test

Isotropy of the Universe

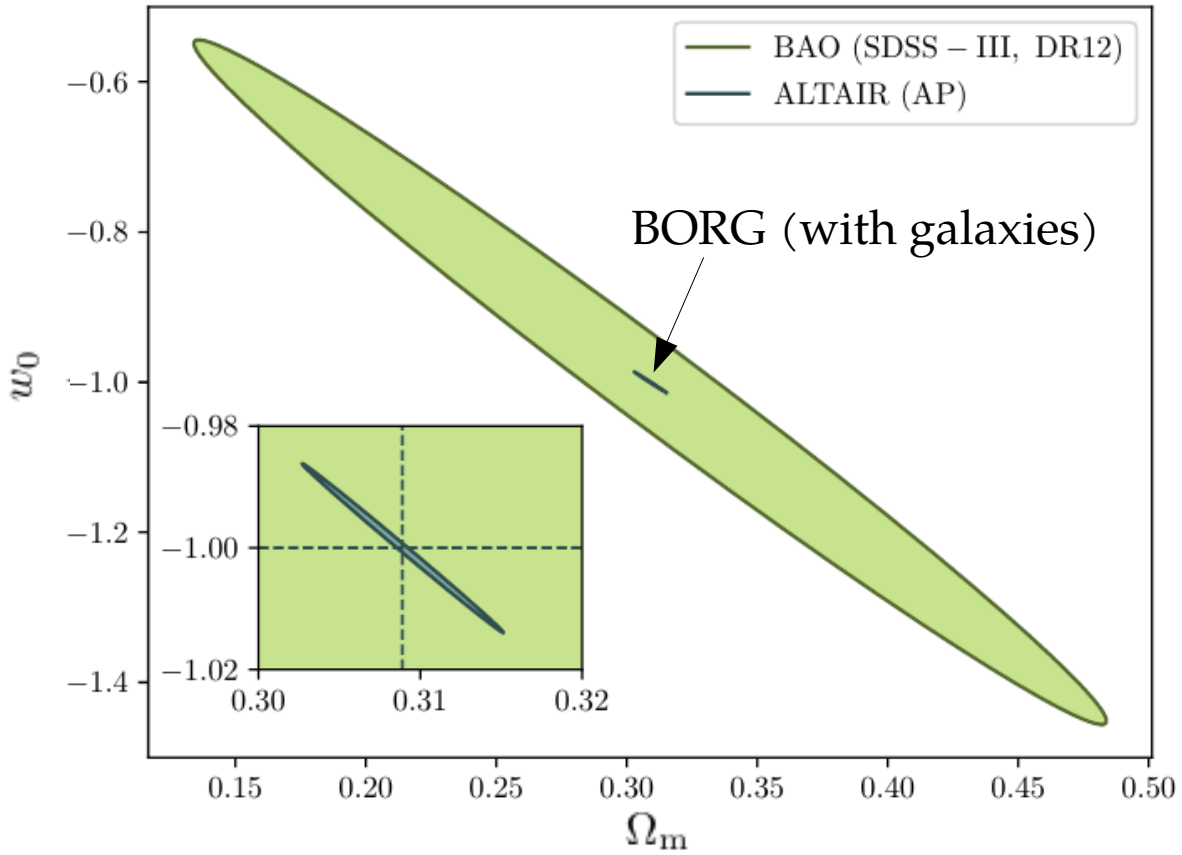
Constrain $d(z, \Omega)$ relation



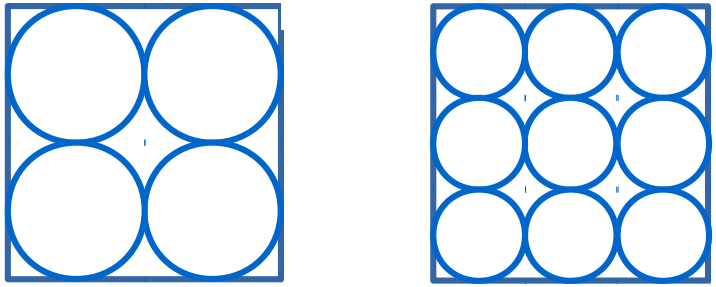
Correct cosmology

Wrong cosmology

Cosmological parameters



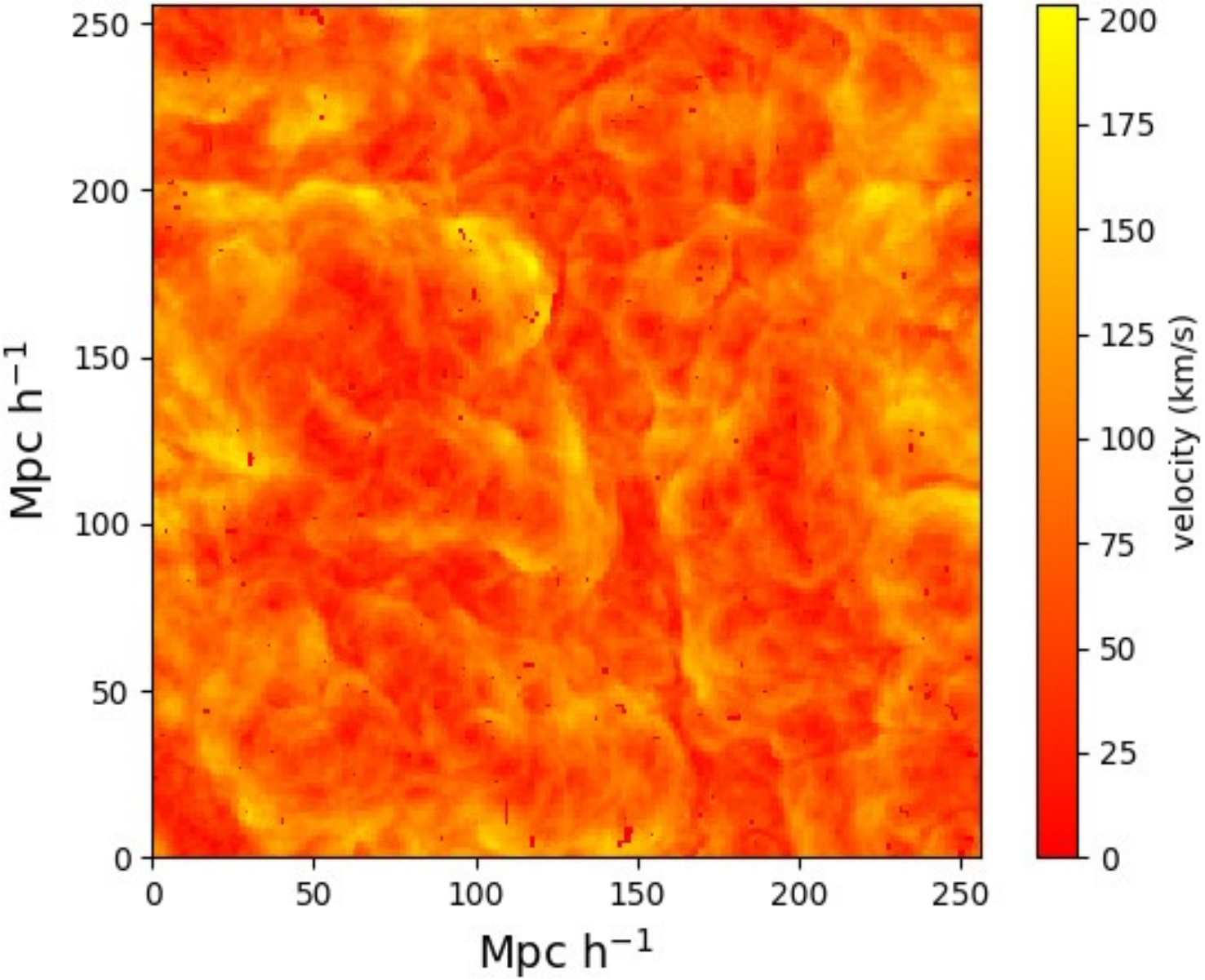
[Ramanah et al. 2018]



BAO
150 Mpc

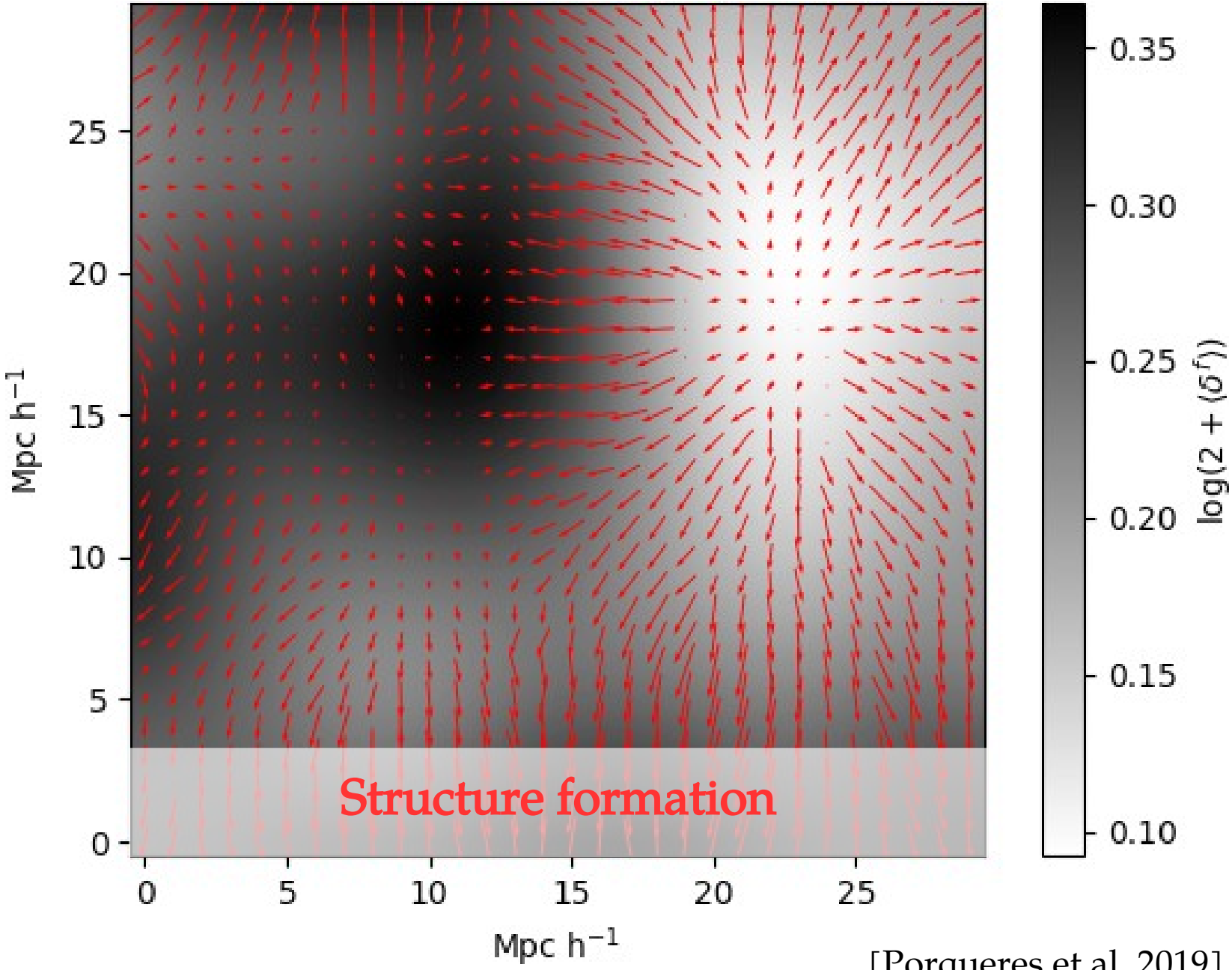
AP test
Smaller scales

Velocity field at z>2



[Porqueres et al. 2019]

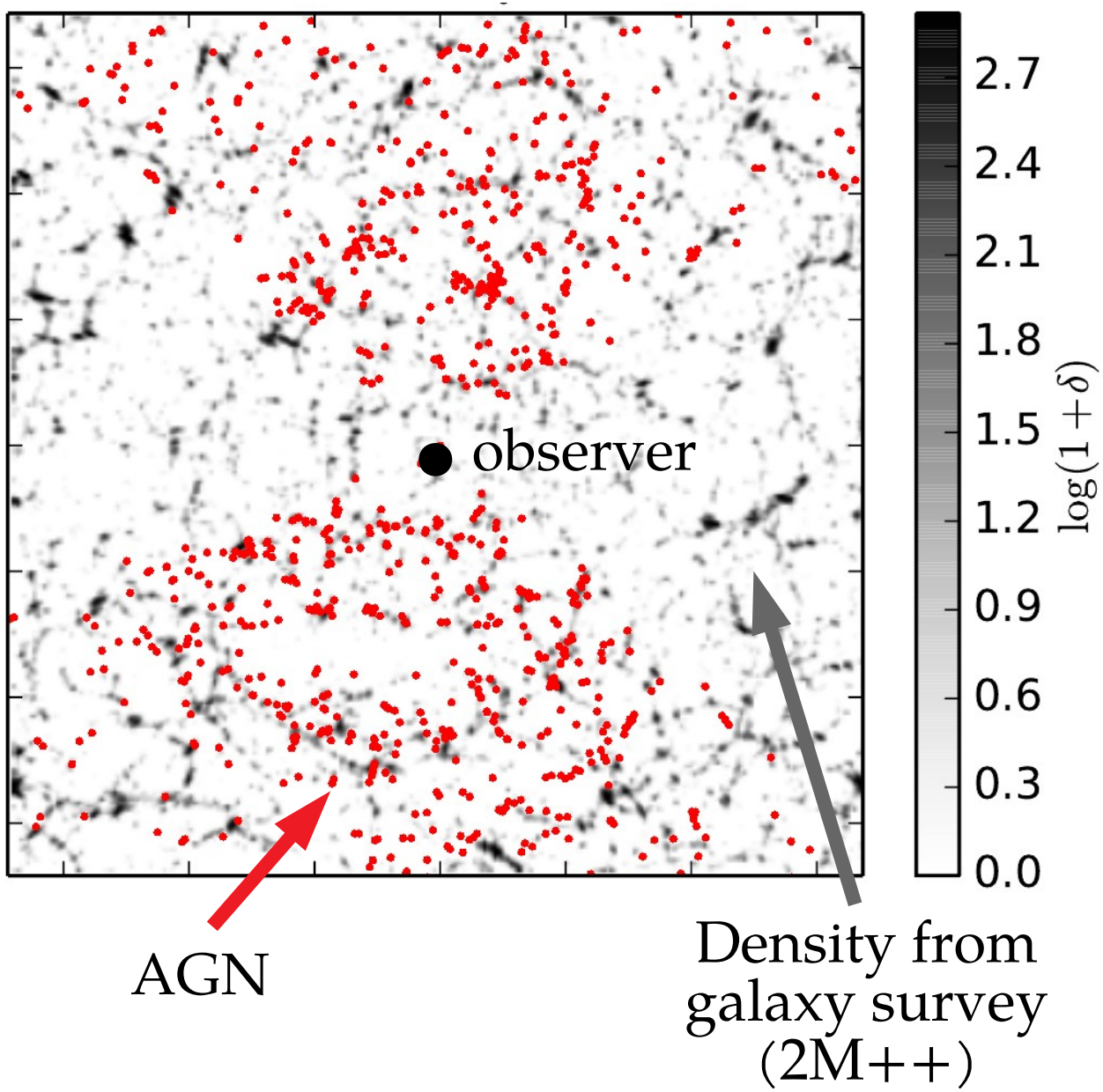
Matter flow

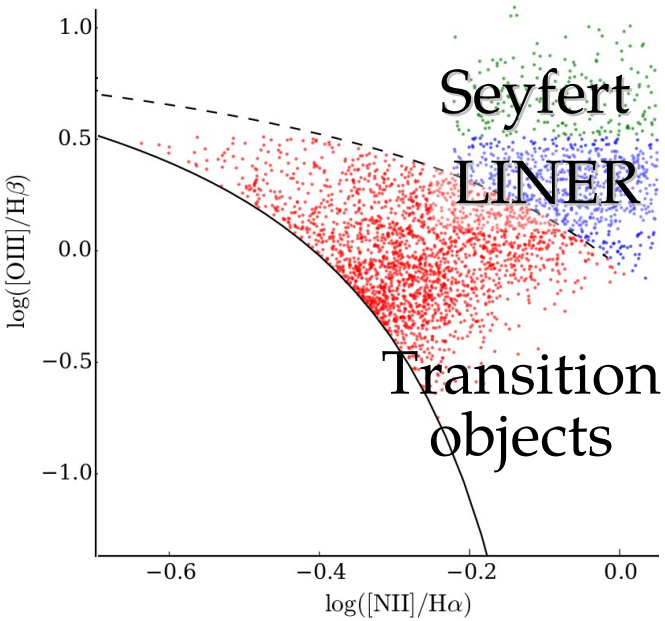


[Porqueres et al. 2019]

LSS effect on AGN evolution

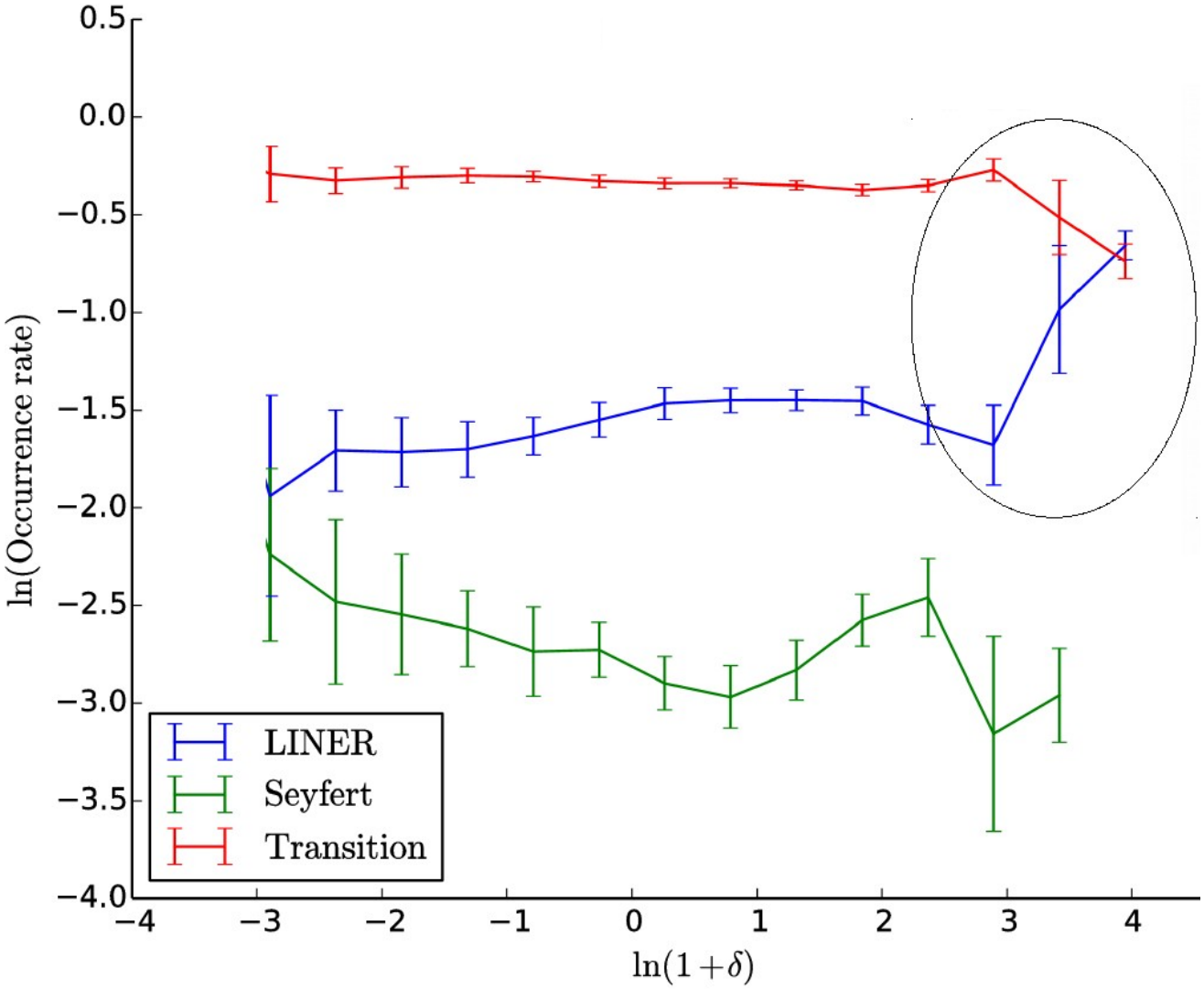
[Porqueres et al. 2017]

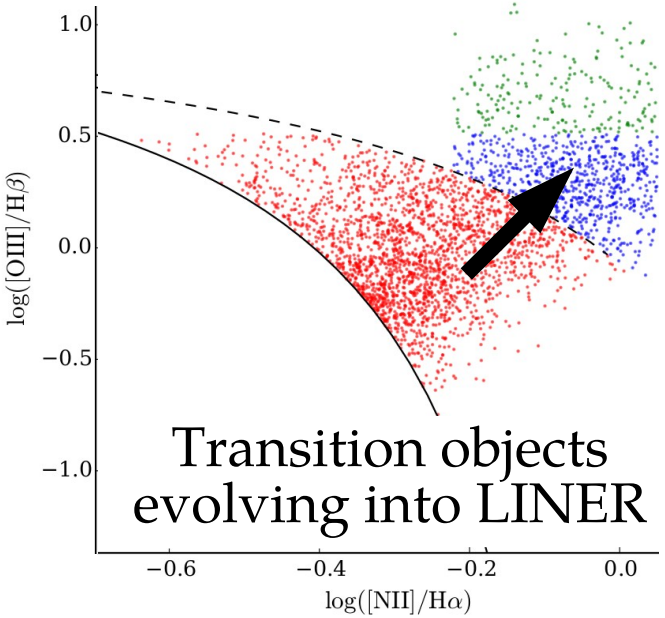


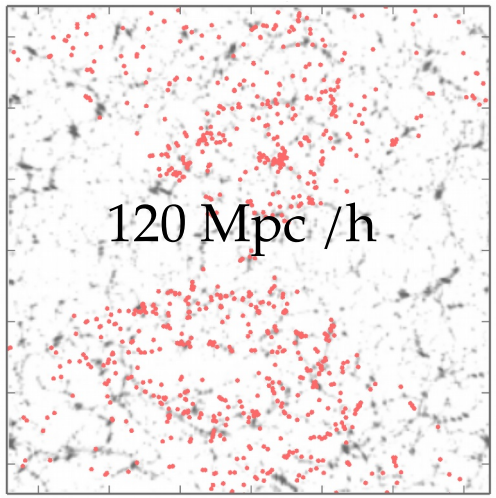


LSS effect on AGN evolution

[Porqueres et al. 2017]

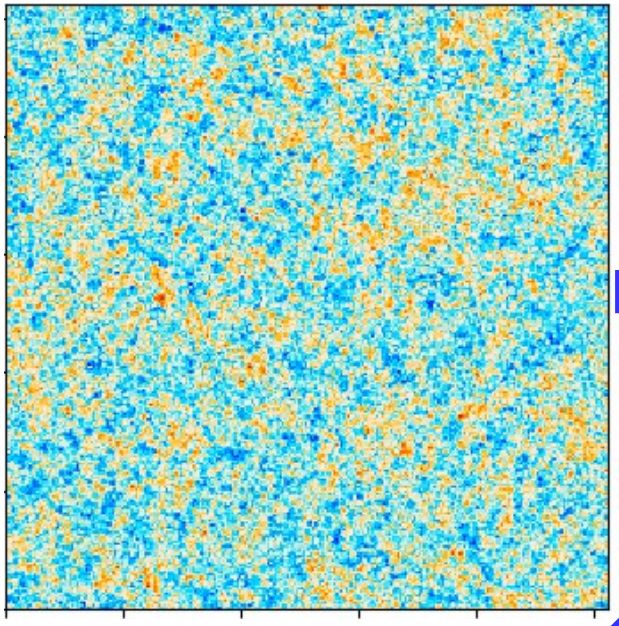






Constrained simulations

BORG initial conditions



Resimulation of Coma cluster (pure DM)

[G. Lavaux, S. Peirani, J. Jasche]

Hydrosimulations to study the physics of gas

Summary

- BORG provides a consistent picture of the cosmic dynamics. It can analyse different types of data: galaxies or Ly-α forest.
- 3D analysis of high-z density field is feasible from a set of 1D lines of sight.
- Physical parameters inference from the Ly-α forest: matter distribution inferred jointly with physical state of neutral hydrogen.
- Matter distribution and velocity fields can be used for
    - Cosmology: cluster and void profiles
    - Test structure and galaxy formation models