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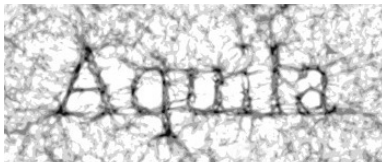


Lifting weak lensing degeneracies with a field-based likelihood

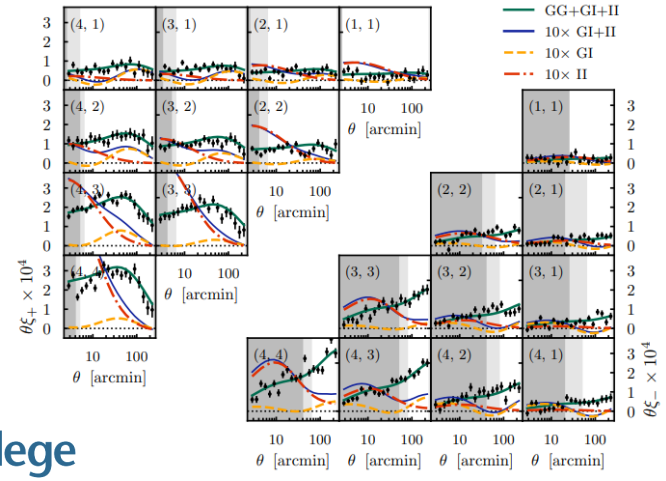
Natalia Porqueres

with Alan Heavens, Daniel Mortlock & Guilhem Lavaux

Cosmology from home – July 2022

The standard approach to WL analysis

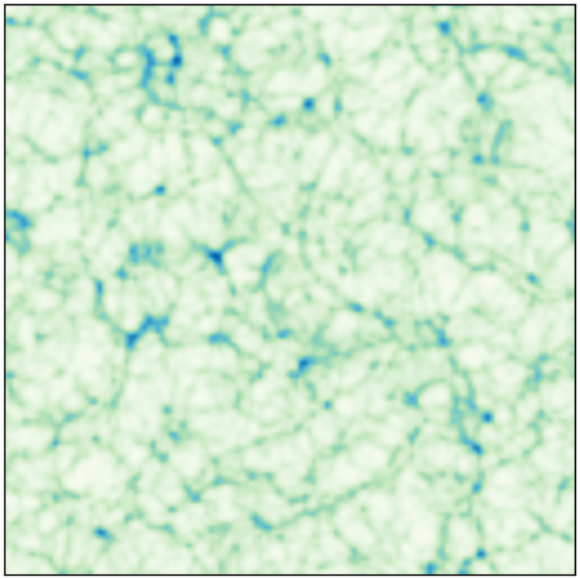
Summarise

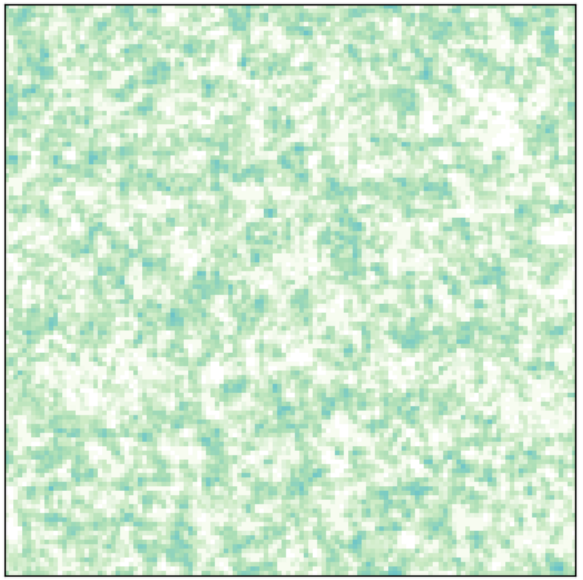


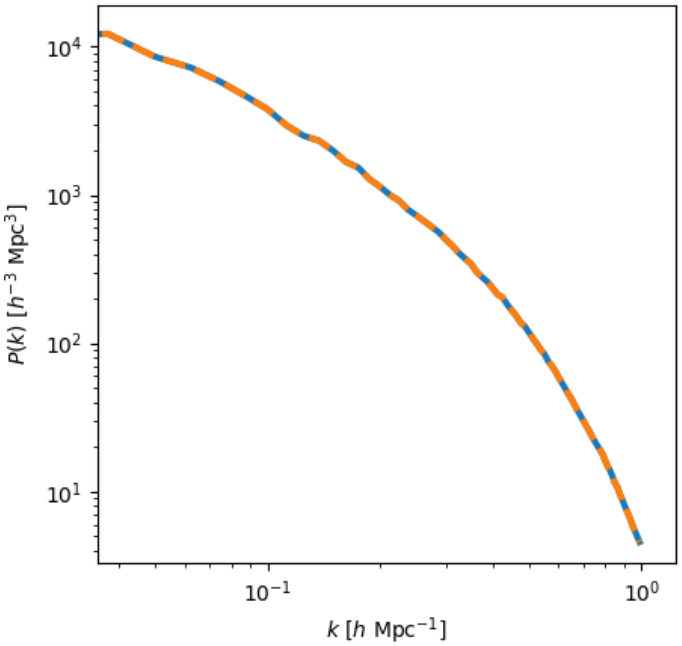
Does this capture all the information?

Why a field-based approach?

The standard approach misses information!



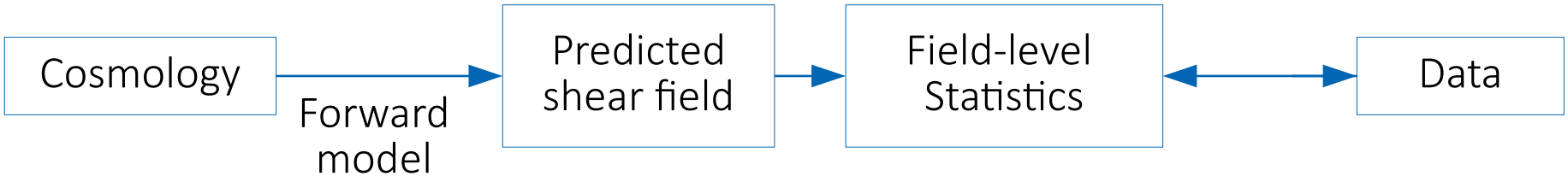




- Higher-order statistics: what are the sampling distributions? And covariance matrix?

- Field-based approach without data compression of the pixelised shear.

Field-level approach

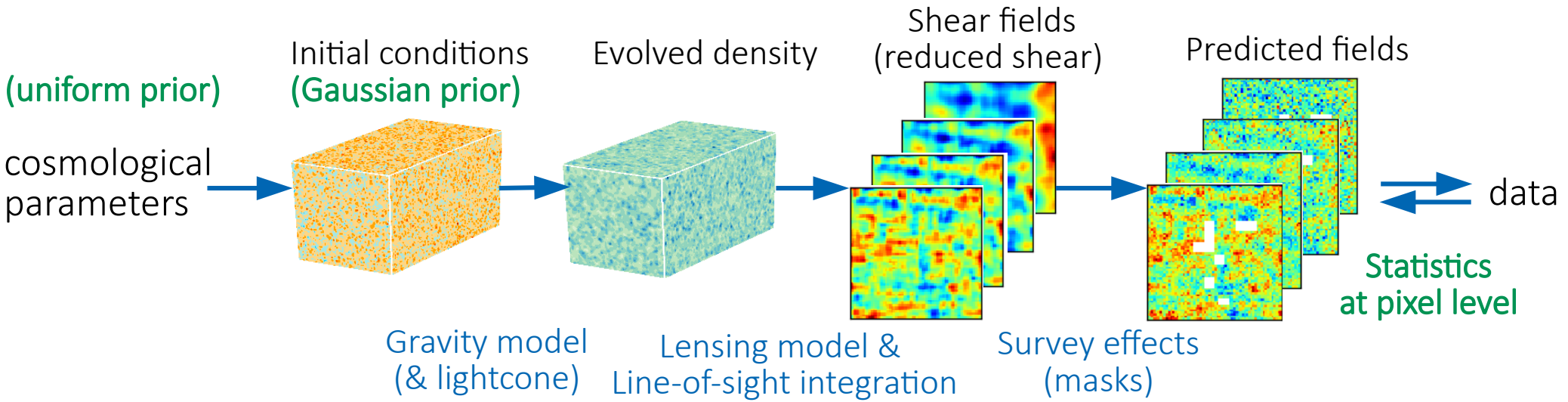


Statistics pixel by pixel can access all the information

Probabilistic forward model → Simulations are constrained by the data

BORG framework: gravity model

Forward model of BORG-WL



Sensitivity to cosmology:
- Initial matter power spectrum
- Growth of structures
- Geometry

Likelihood:

$$-\log P(\hat{\gamma}_1, \hat{\gamma}_2 | \gamma_1, \gamma_2) = \sum_b \sum_{mn} \frac{(\gamma^b_{1,mn} - \hat{\gamma}^b_{1,mn})^2 + (\gamma^b_{2,mn} - \hat{\gamma}^b_{2,mn})^2}{2\sigma^2_{mn}}$$

Assumes Gaussian noise in pixelised shear field

Doesn't need covariance matrix! $\sigma^2_{mn} = \sigma^2_\epsilon / N_{\rm sources}$

Getting the full posterior distribution

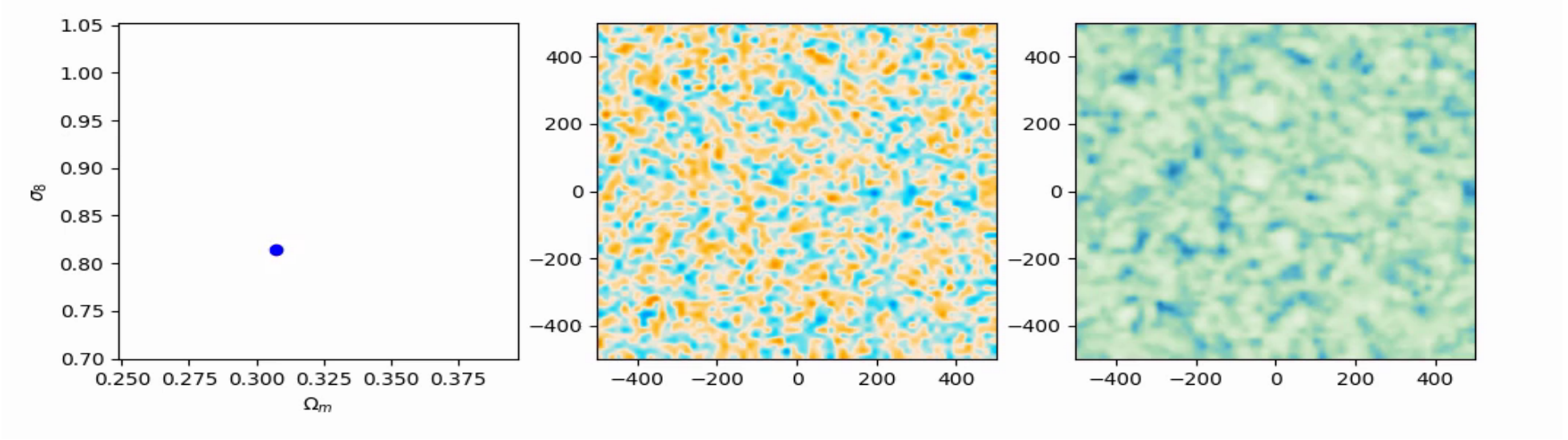
$$P(\theta, \delta^{\rm ic}|\hat{\gamma}) \propto P(\hat{\gamma}|\gamma) P(\gamma|\delta^{\rm ic}) P(\delta^{\rm ic}|\theta) P(\theta)$$

posterior likelihood prior

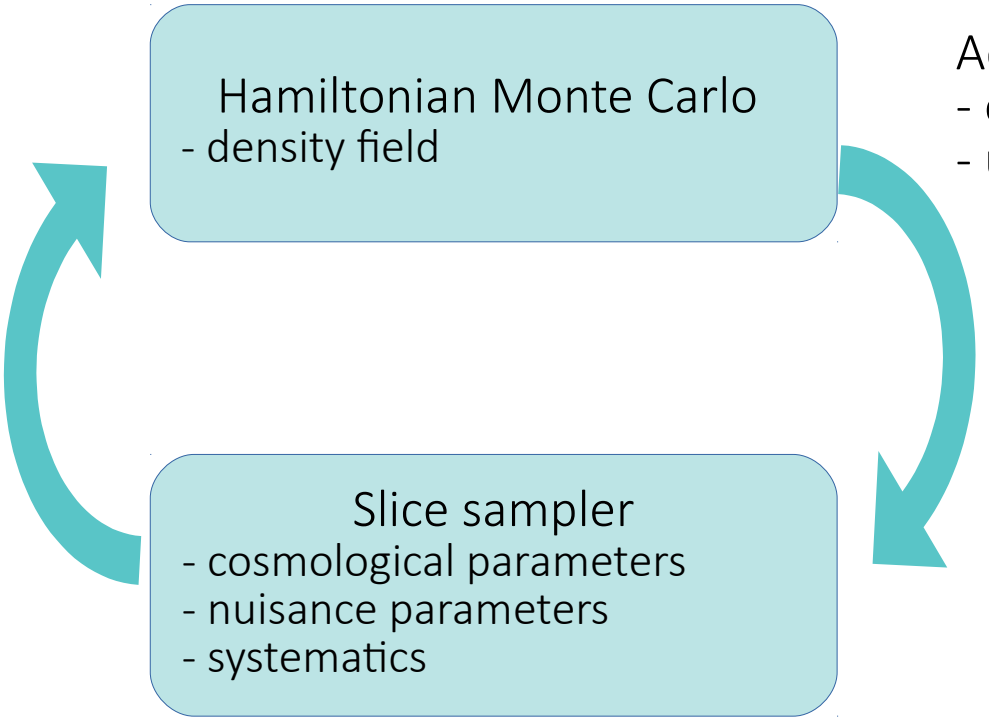
$$\delta^D(\gamma - \mathcal{F}(\delta^{\rm ic})) \quad G(0, S(\theta))$$

forward model prior

10^7 parameters!



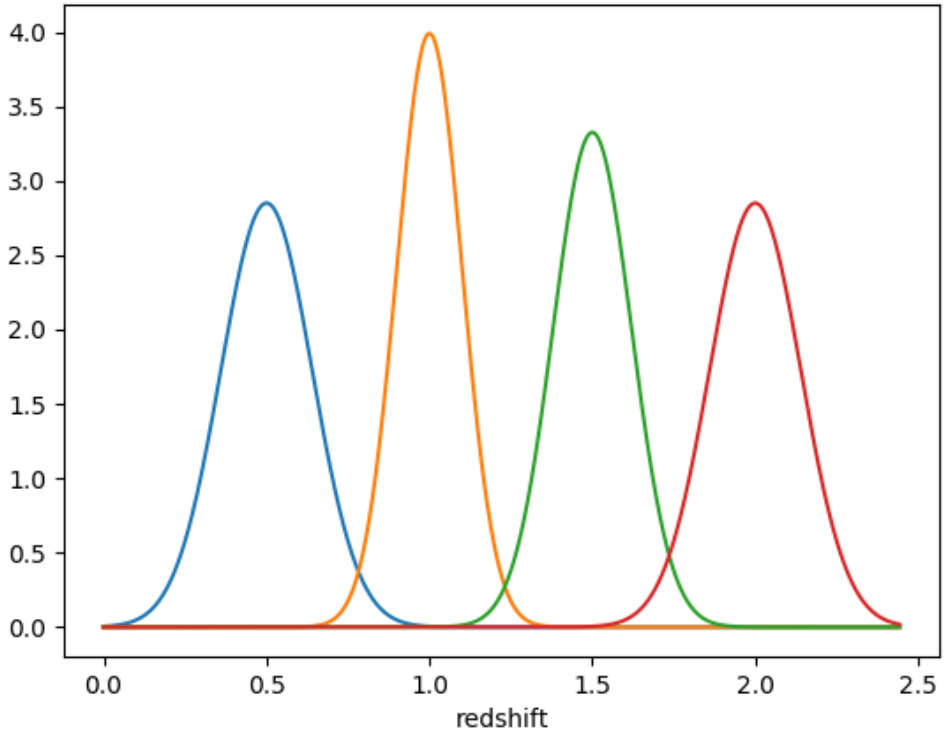
Sampling efficiently in a high-dimensional space

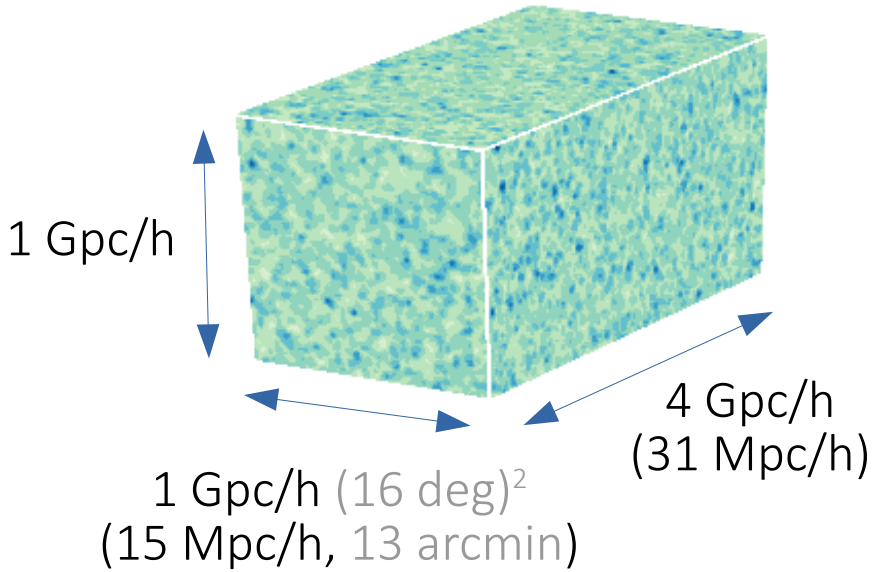


Addresses curse of dimensionality by
- exploiting information in gradients
- using conserved quantities

Simulated data

Tomographic bins



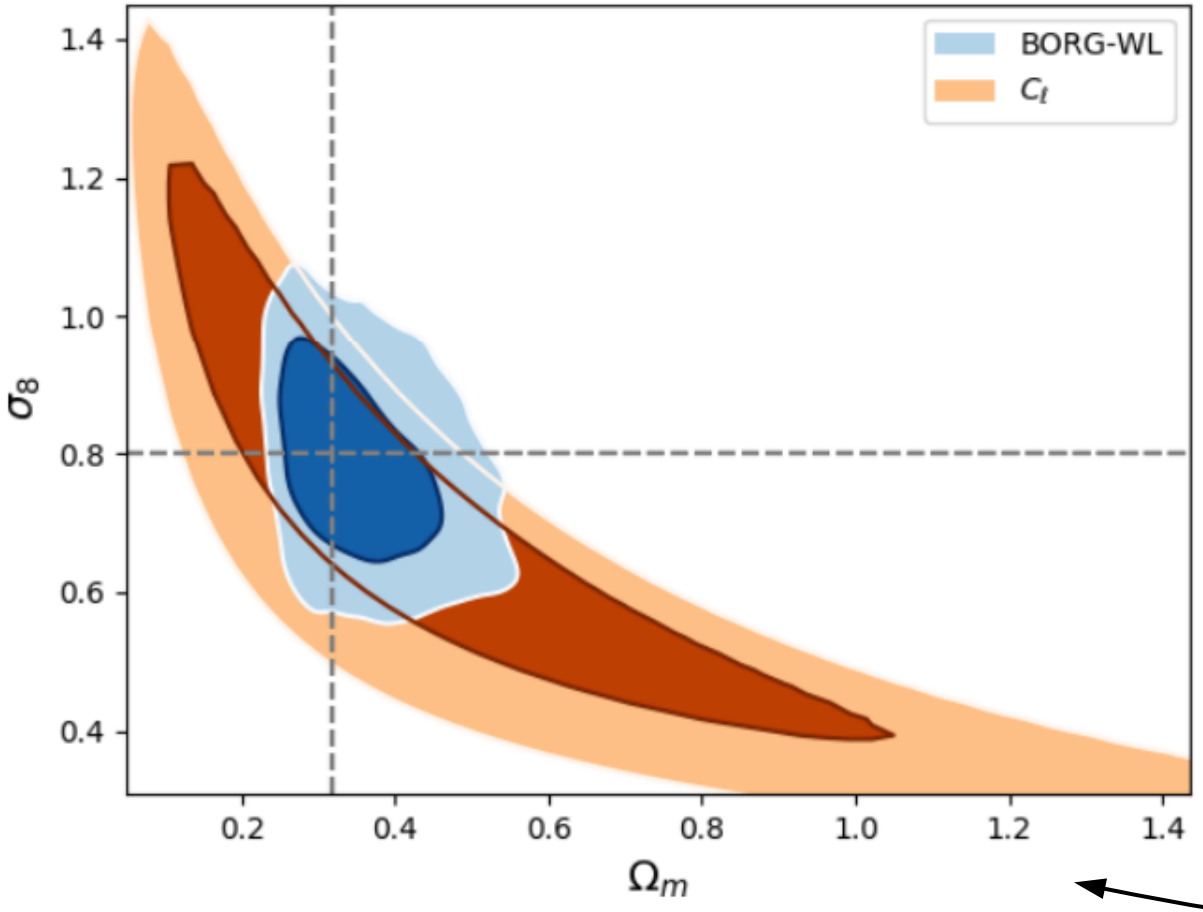


Gaussian pixel-noise corresponding to 30 sources per square arcmin

Gravity model for this experiment LPT (but PM is also available in BORG)

Comparison of cosmology constraints

marginal error
3 times smaller



(1 Gpc/h)^2, 4Gpc/h
(16 deg)^2, 13 arcmin
LPT

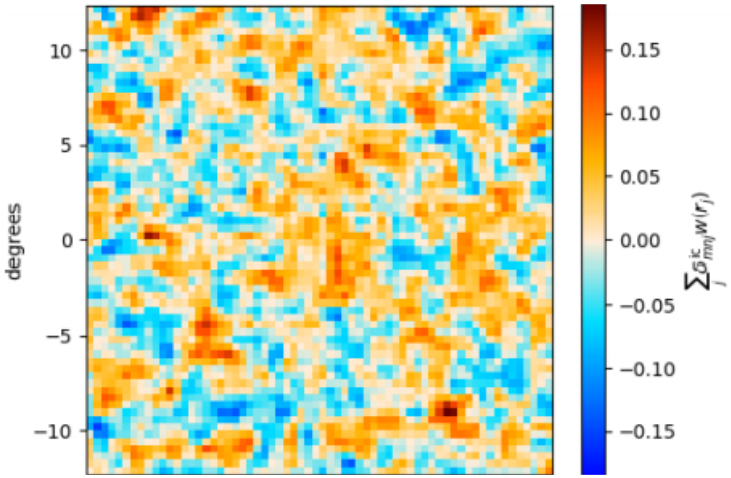
marginal error
5 times smaller

Field-level approach **lifts degeneracy** by extracting more information from the data

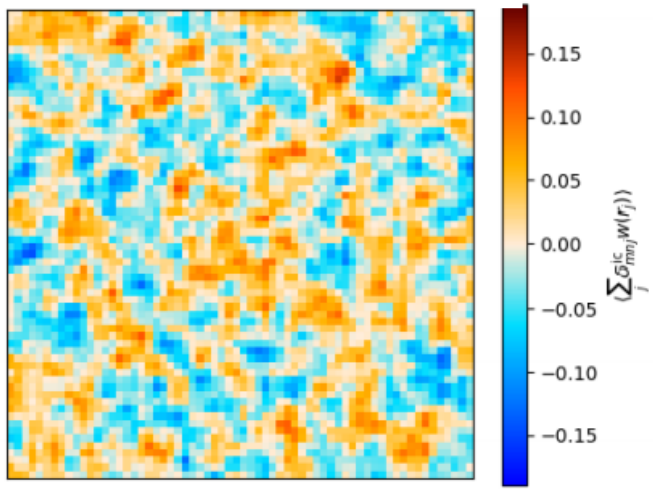
NP, Heavens+ 2022

Projection of inferred density fields

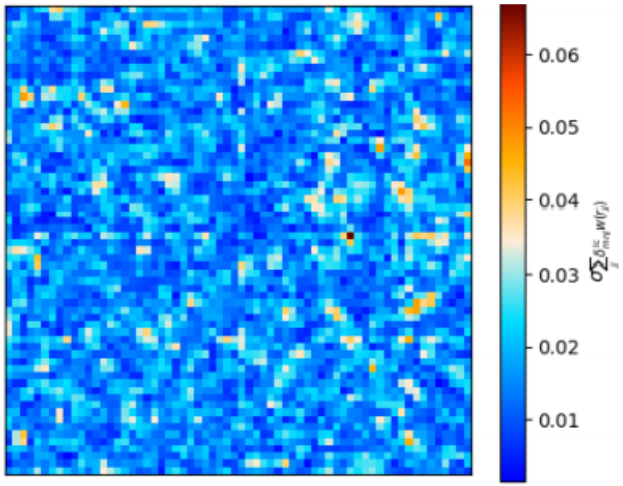
True initial conditions



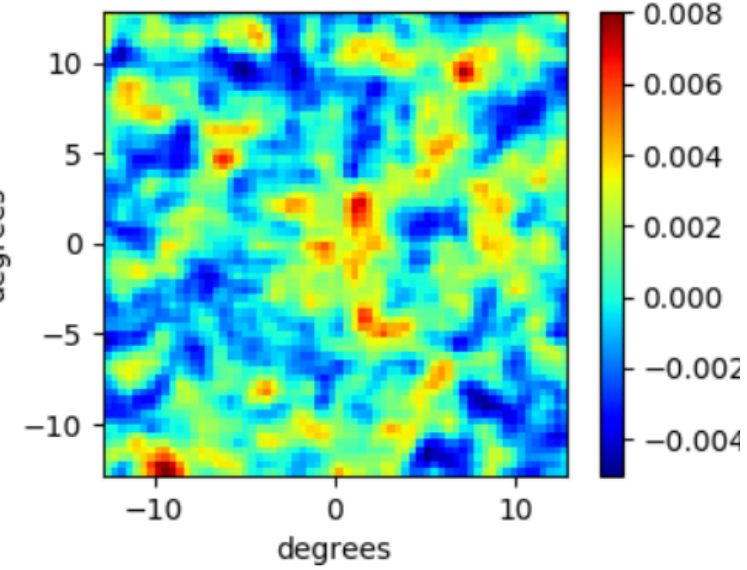
Mean initial conditions



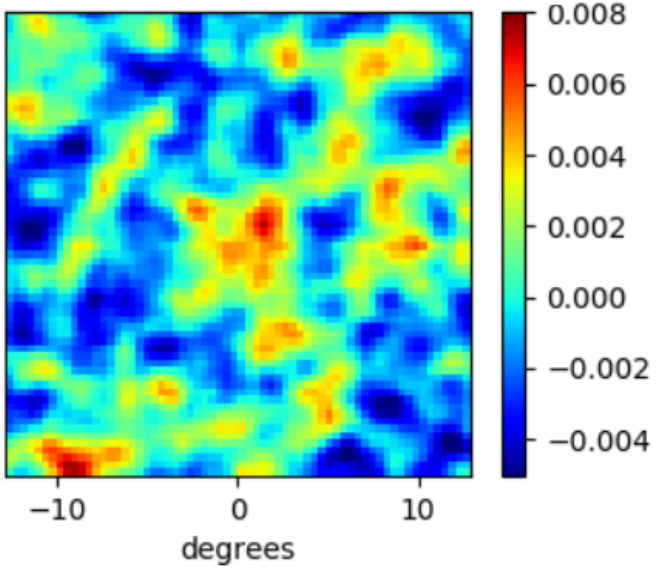
Standard deviation



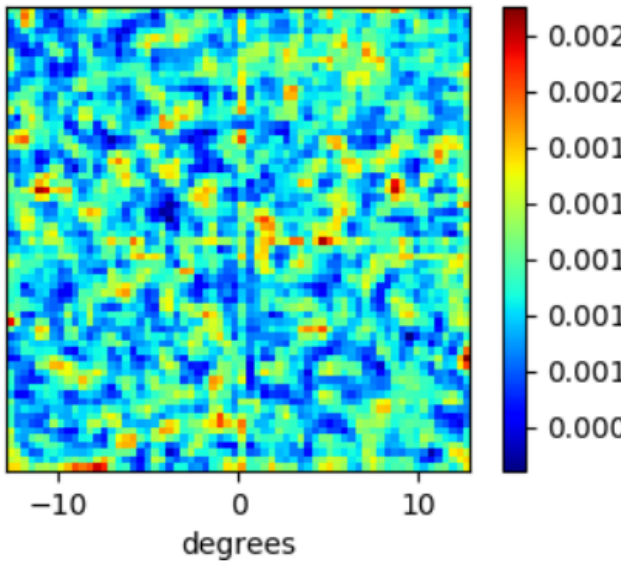
True convergence



Mean convergence



Standard deviation



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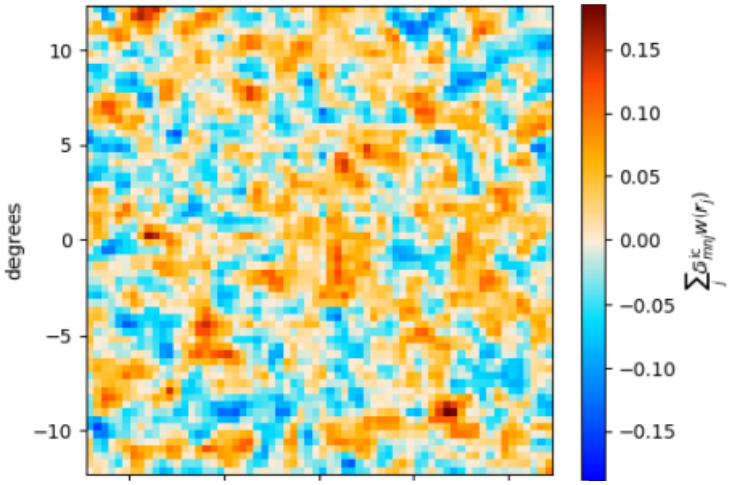
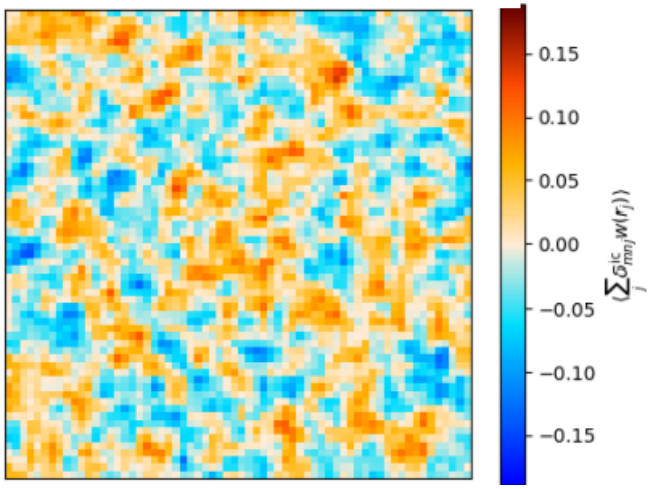
Projection of inferred density fields

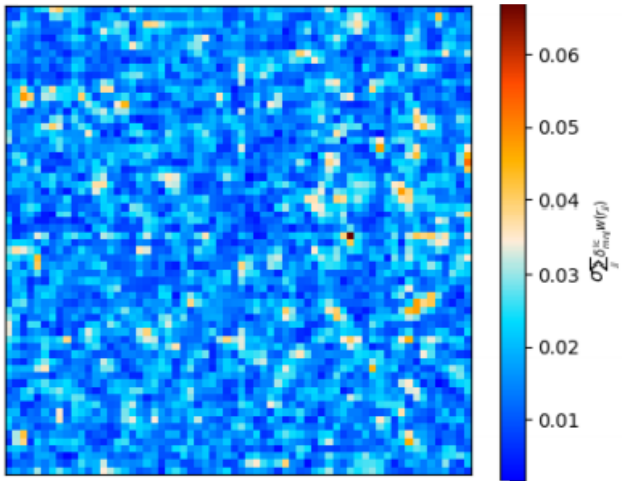
True initial conditions



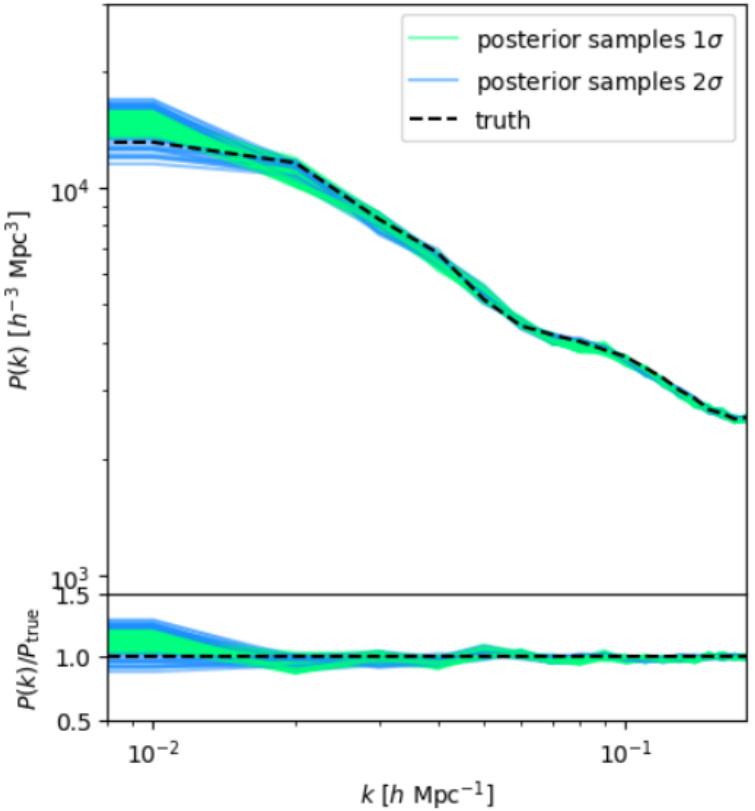
Mean initial conditions



Standard deviation



Initial matter power spectrum (3D)



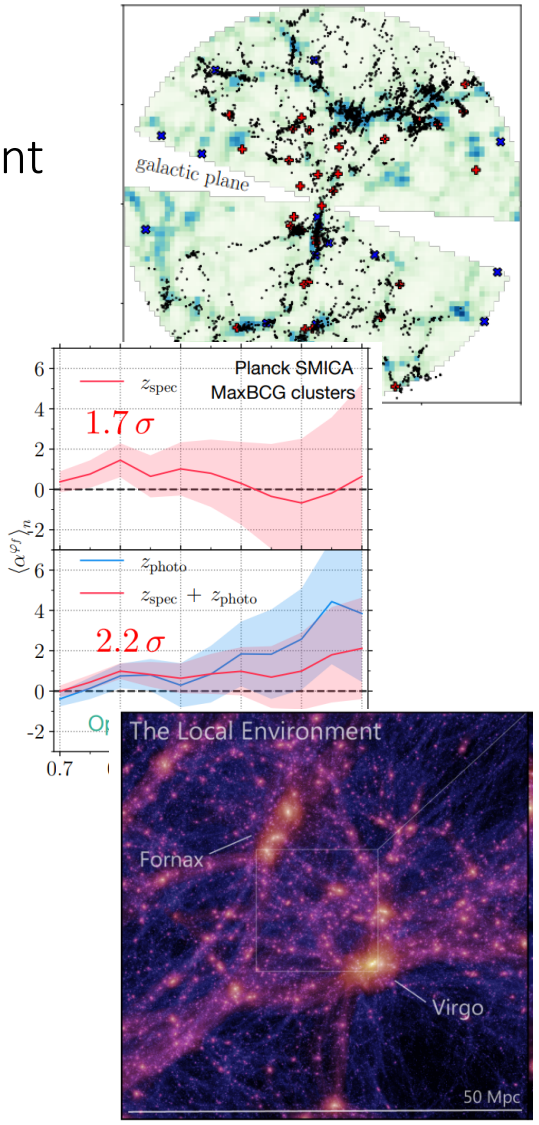
Why should we care about the density fields?

We can do physics

- Galaxy or SN environment
(Porqueres et al. 2017)
(Tsaprazi et al. 2021)

- kSZ effect
(Nguyen et al 2020)

- Constrained simulations
(McAlpine et al 2022)

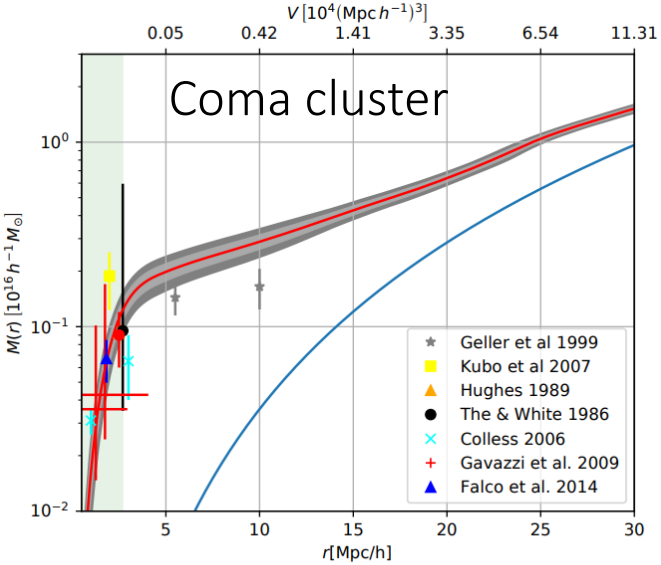


… and also powerful tests

- do we get the clusters we know they are there?

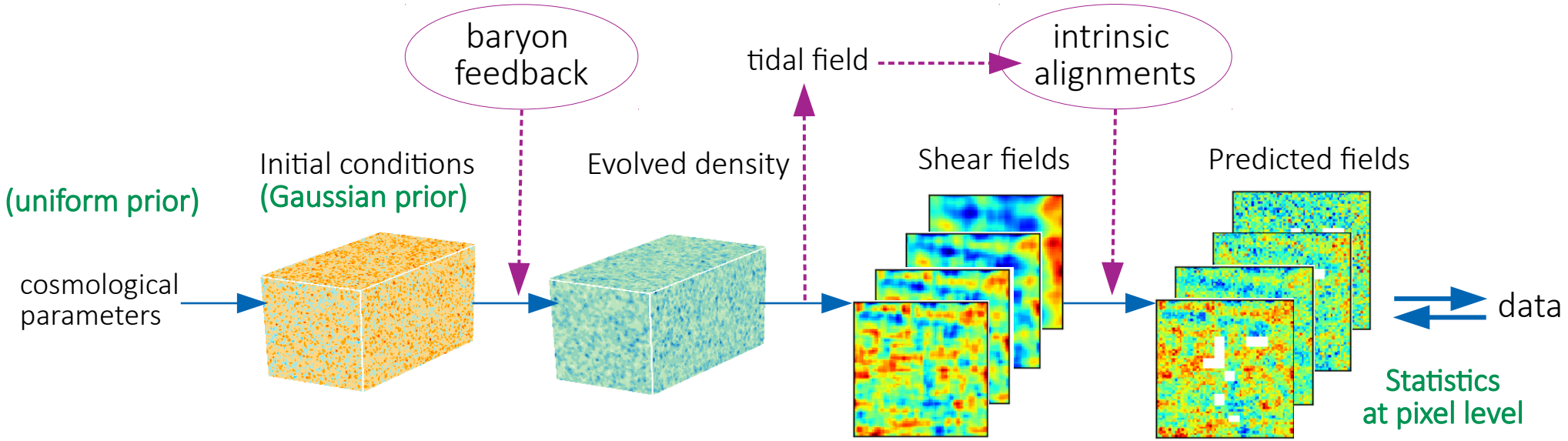
- do we get the expected mass profiles?

- are the inferred IC compatible with CMB observations?



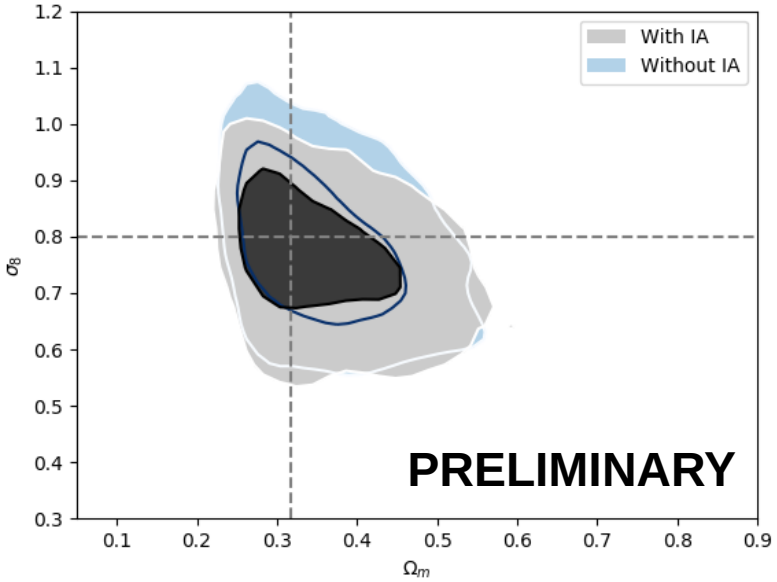
Jasche & Lavaux 2019

Control of systematics (work in progress)

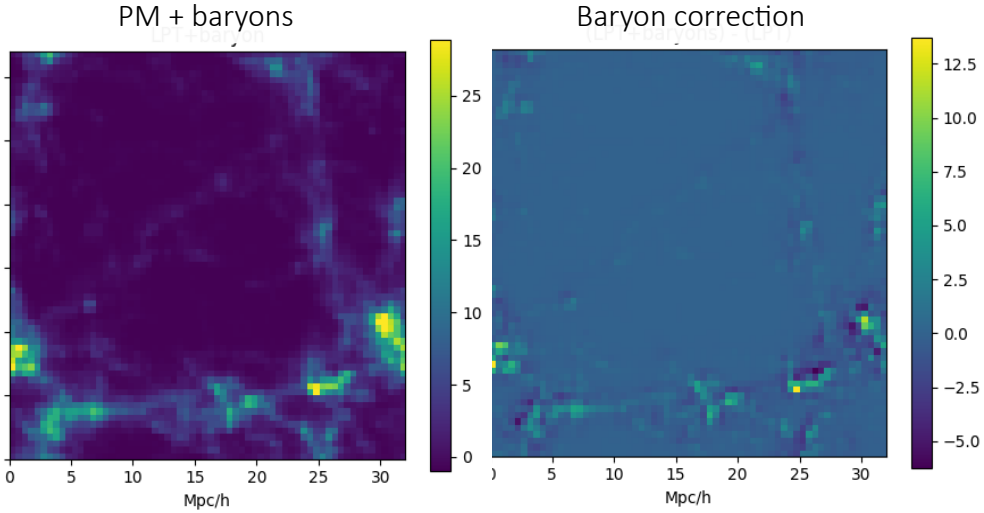


We can use **physical models of systematics** rather than effective models

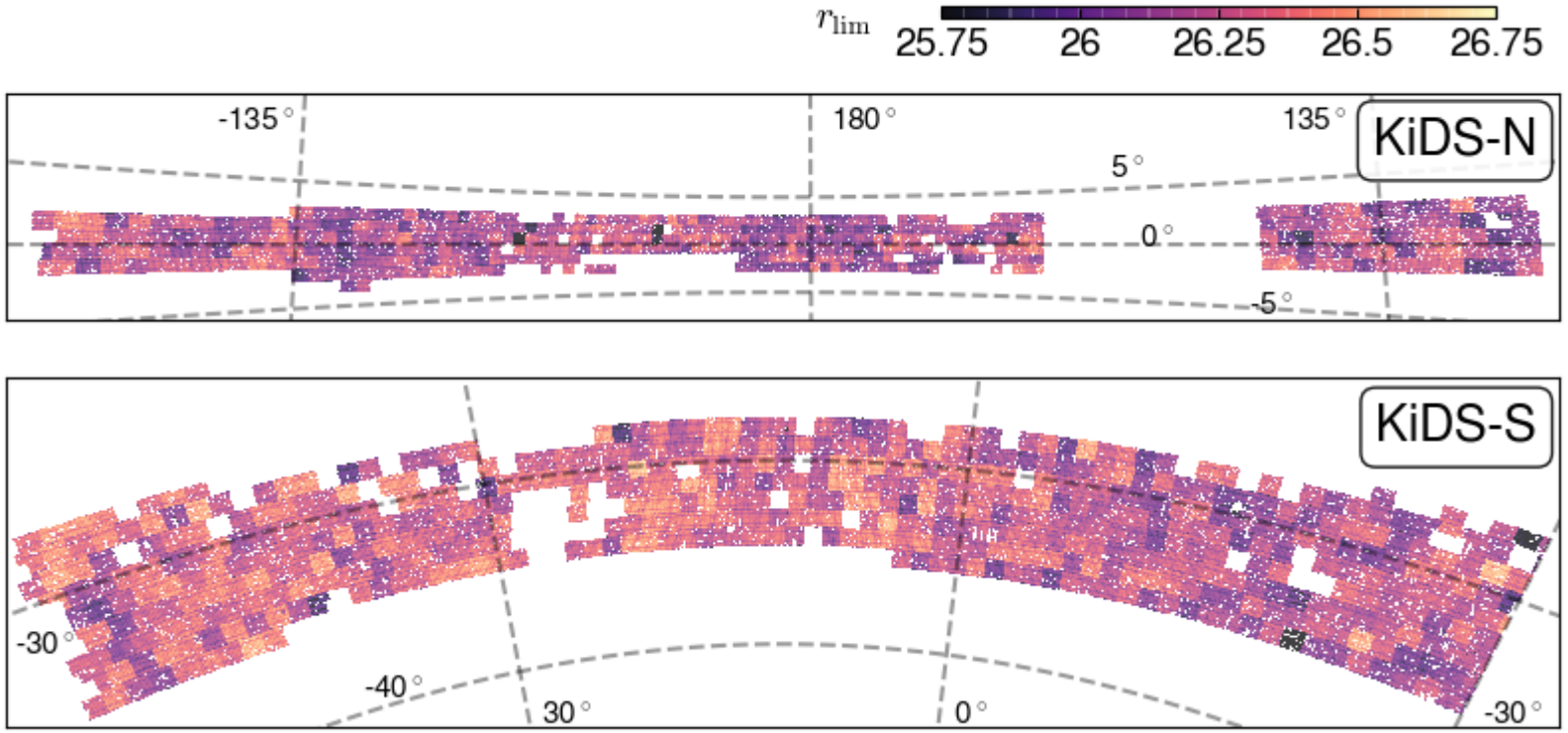
IA: NLA, TATT



Baryons: Dai et al 2018



Survey systematics



Joachimi+ 2020

- Variable depth

- Variable seeing (PSF)

- Variation in source galaxy and redshift distribution

Summary and outlook

- There is more information in the data that the 2-point summary statistics do not capture.
- Field-based approach lifts degeneracy and reduces marginal error up to a factor of 5.
- What's next?
  First real data analysis with BORG-WL