Initial Density Field Reconstructions with COSMIC BIRTH

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(Paco)

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Outline

- Presenting COSMIC BIRTH to you
- Application to BOSS survey
- Application to COSMOS field surveys
- Summary

COSMIC BIRTH

- Fresh out of the oven (COSMological Initial Conditions from Reconstructions with THeoretical models)

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COSMIC BIRTH: Efficient Bayesian Inference of the Evolving Cosmic Web from Galaxy Surveys

Francisco-Shu Kitaura[1,2⋆], Metin Ata[3], Sergio A. Rodríguez-Torres[1,2], Mónica Hernández-Sánchez[1,2], A. Balaguera-Antolínez[1,2] and Gustavo Yepes[4,5]

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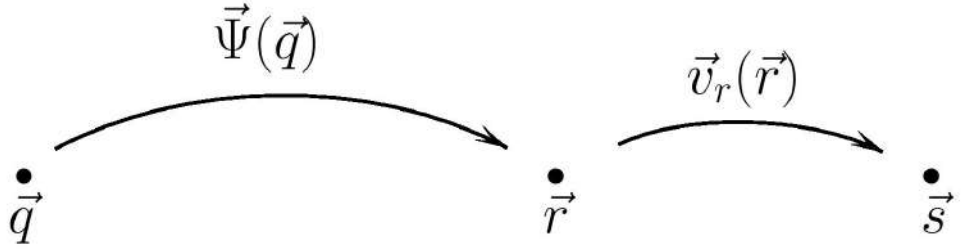
COSMIC BIRTH

- Constrain the initial density fields given a set of observed tracer positions iteratively $\vec{q} = \vec{s} - \vec{\Psi}(\vec{q}) - \vec{v}_r(\vec{q})$ (Also see Elucid talk)
- General idea: sample from $\mathcal{P}(\delta(\vec{q})|\delta(\vec{s}))$



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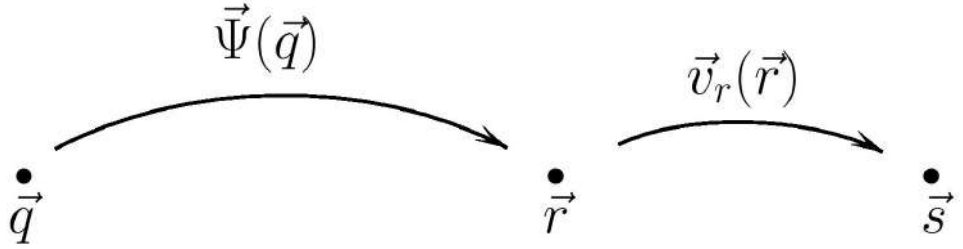
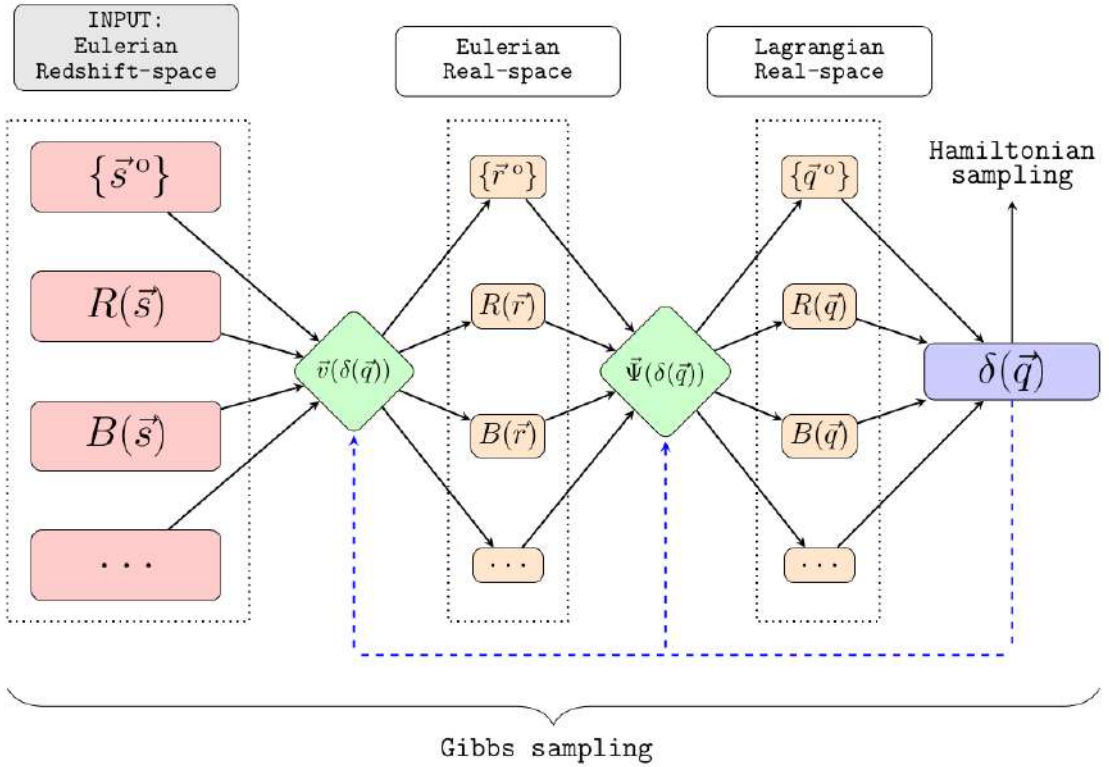


- Problem: Mapping of $\vec{s}$ and $\vec{q}$ requires to include a structure formation model, displacement field $\vec{\Psi}(\vec{q})$ must be part of the sampling process

- This is computationally very expansive

COSMIC BIRTH

- Approach of BIRTH:
  - Move back all tracers to initial Lagrangian positions and sample the Gaussian field $\delta(\vec{q})$
  - Nested Gibbs sampling scheme to forward model
    - Peculiar velocities,
    - Displacements,
    - Responds function of the survey,
    - Bias parameters,
    - …
- Advantage: Sampling of the density field independent of structure formation model!



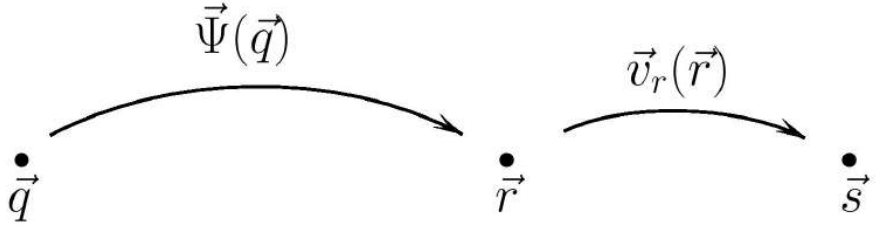
COSMIC BIRTH

- In a first step we assume the data is in Lagrangian real-space at high redshift:

$$\delta(q) \curvearrowleft \mathscr{P}\left(\delta(q)|\{q\},\{b\},\{R\}\right)$$

- In a second step: forward modelling to obtain $\vec{s}$:

$$\{q\} \curvearrowleft \mathscr{P}\left(\{q\}|\{s^o\},\delta(q),\mathcal{M}\right)$$



- Optional, Likelihood comparison: $s \longleftrightarrow s^o$

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  - Density sampling is done with a Hamiltonian MC (HMC)

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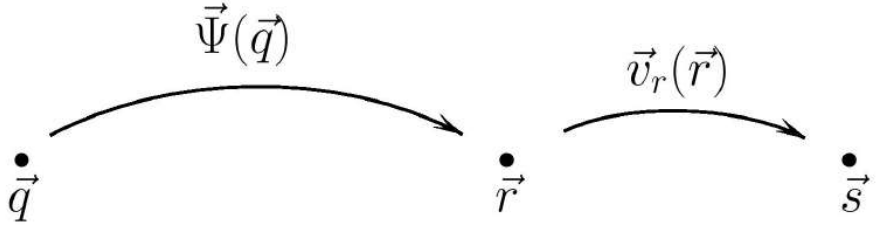

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COSMIC BIRTH

- New developments to make the HMC more efficient:
  - Higher order leapfrog integrations schemes (Mónica Hernández-Sánchez et al. in prep)

$$T_\epsilon = T_p(\epsilon/2) T_q(\epsilon) T_p(\epsilon/2)$$

$$T_{n+2}((2i-s)\epsilon) = T_n(\epsilon)^i T_n(-s\epsilon) T_n(\epsilon)^i$$

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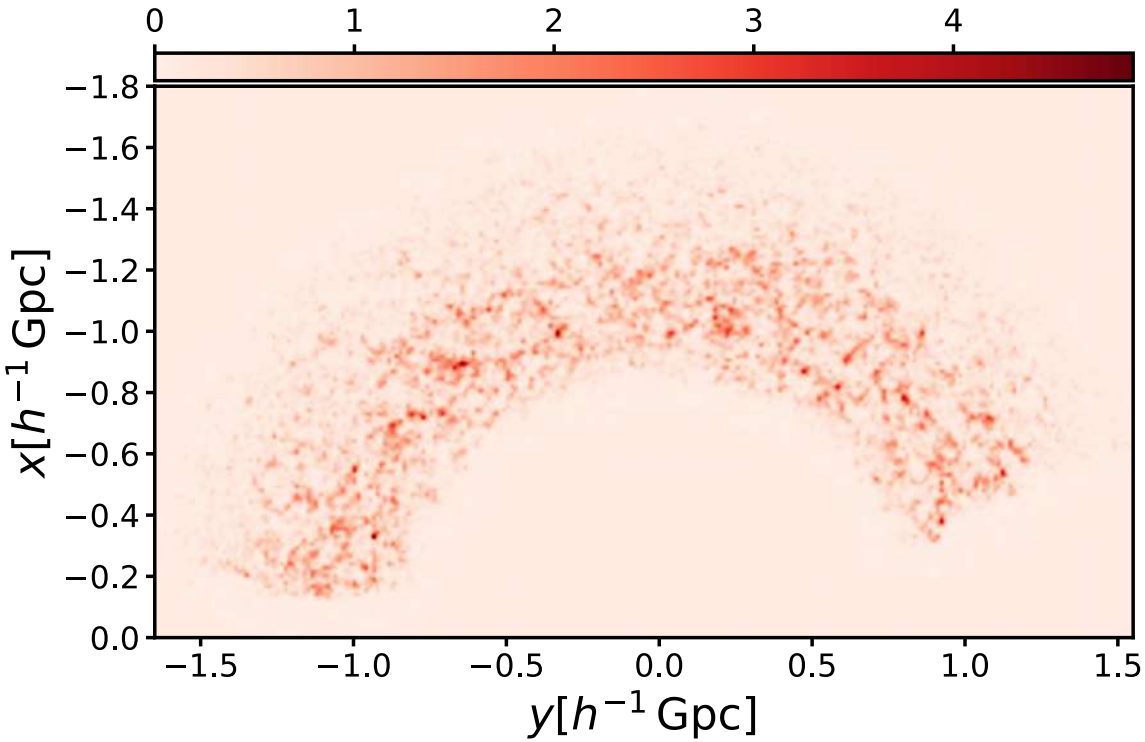
  - Non-diagonal mass matrix **M** including information of the prior and the likelihood for the Hamiltonian Equations of motion

$$\frac{dq_i}{dt} = \frac{\partial H}{\partial p_i} = M^{-1} p_i$$

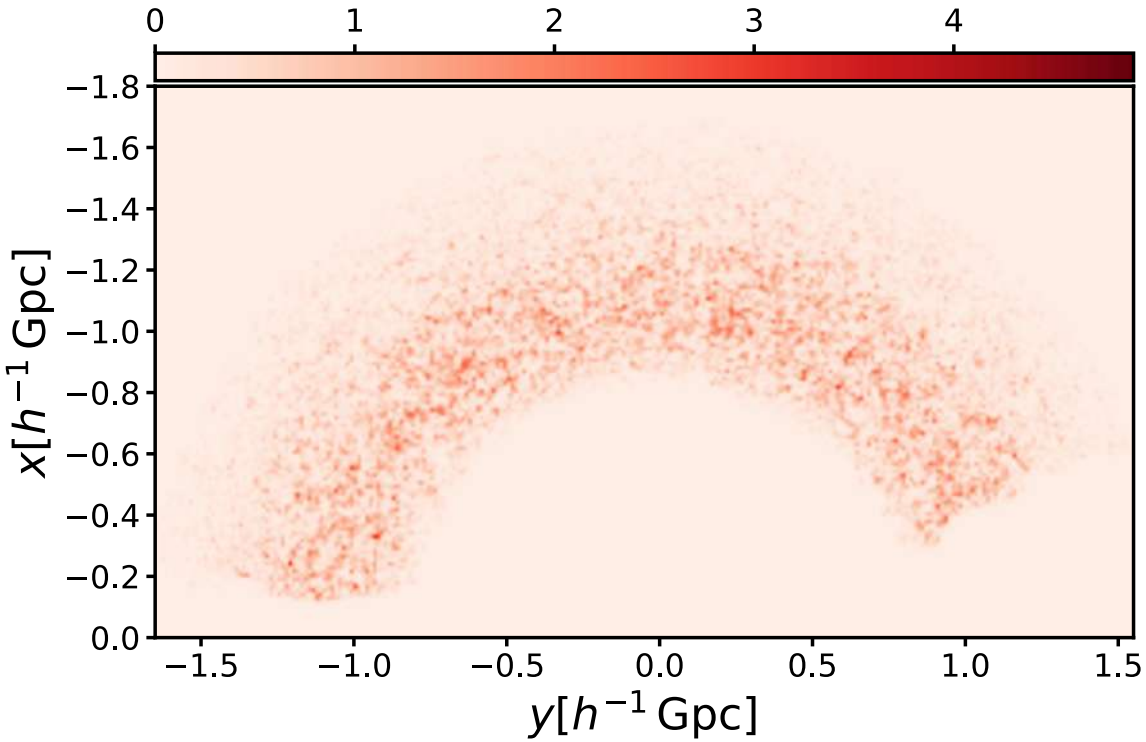
$$\frac{dp_i}{dt} = -\frac{\partial H}{\partial q_i} = -\frac{\partial U}{\partial q_i}$$

BIRTH with BOSS CMASS

Eulerian tracers:



Lagrangian tracers:



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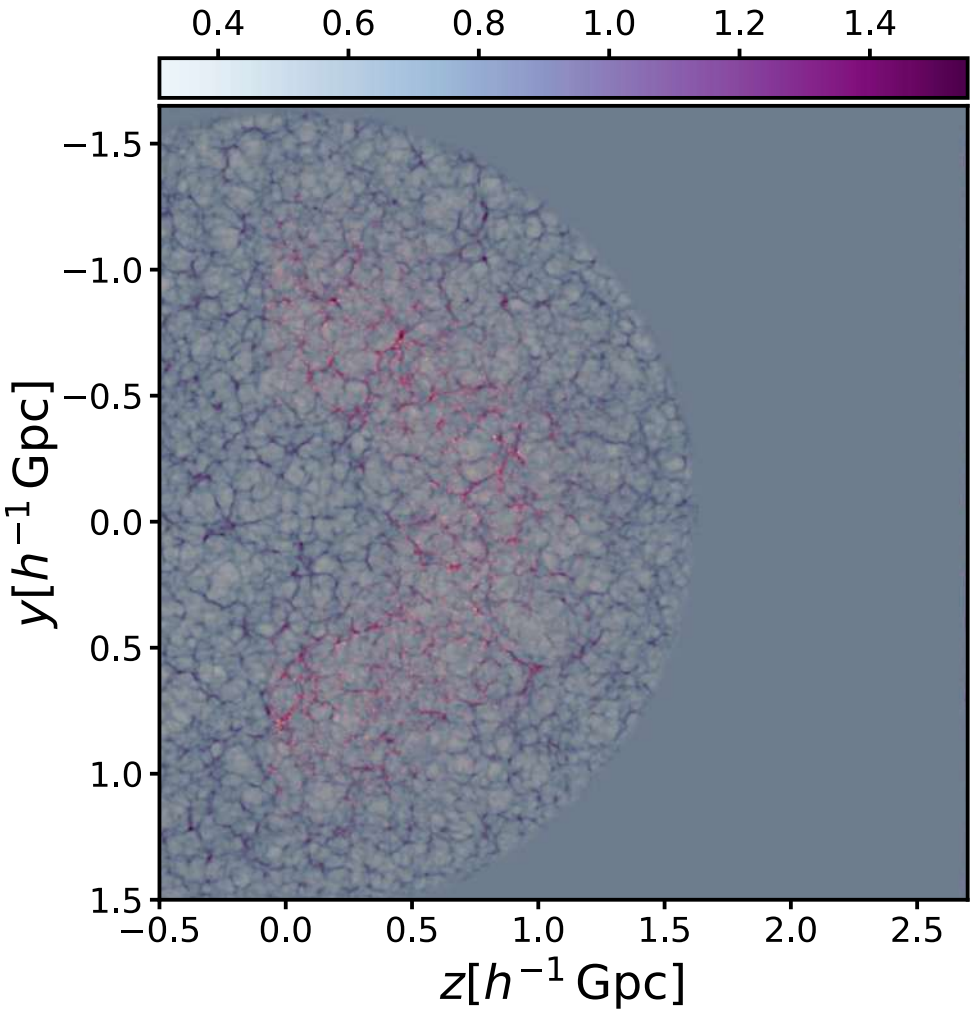

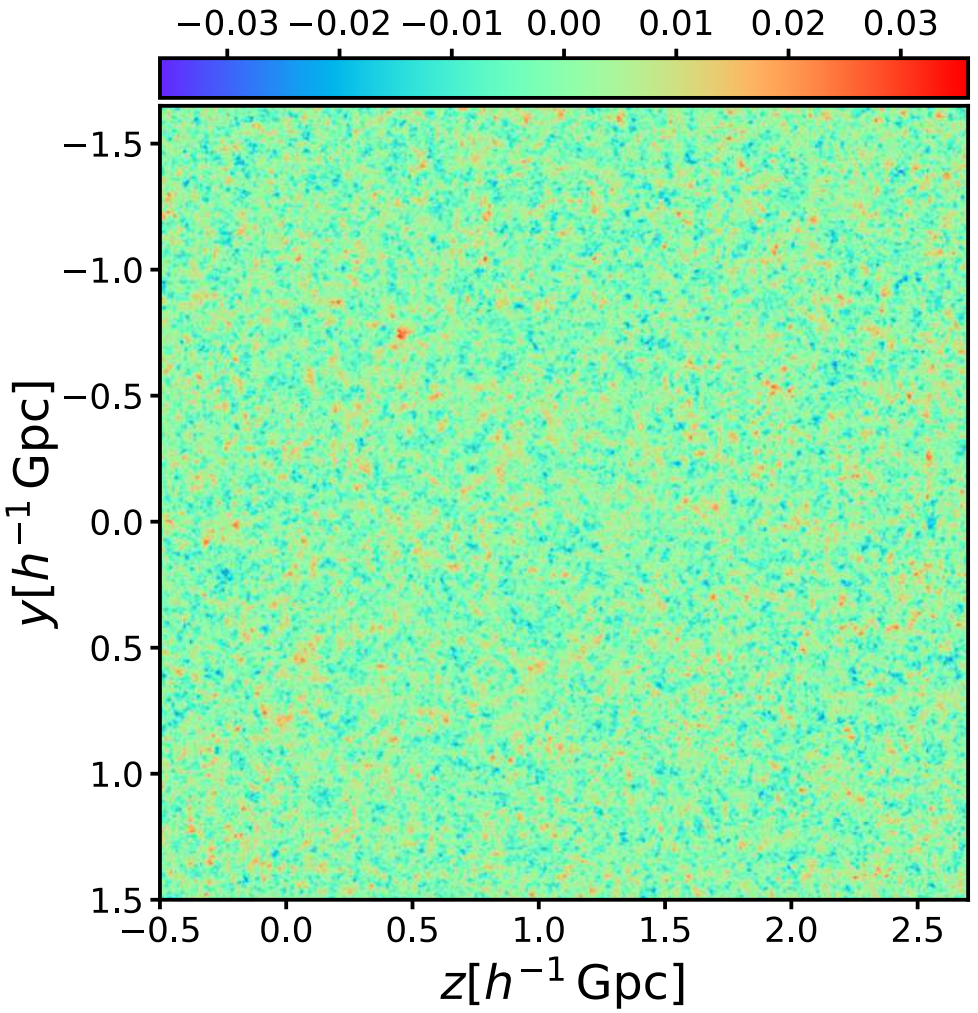

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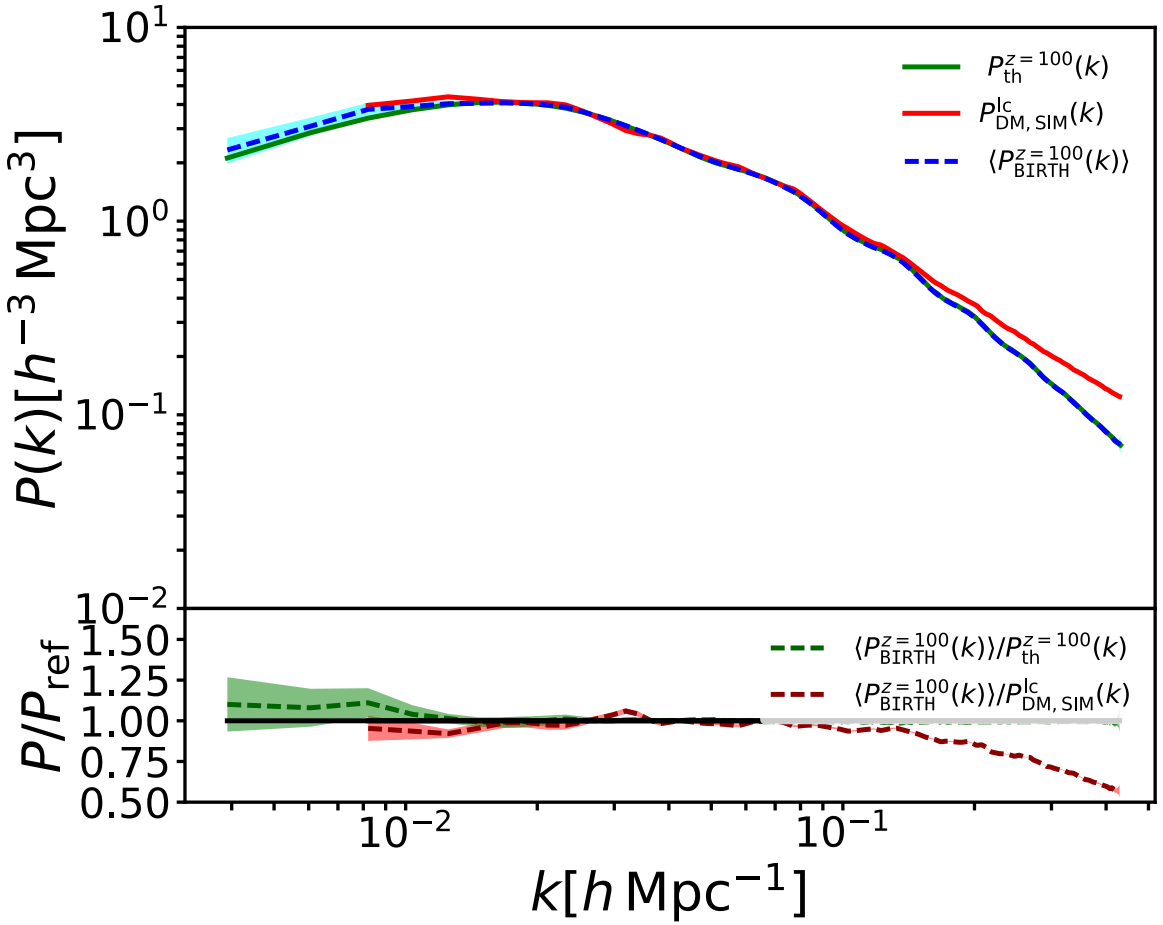

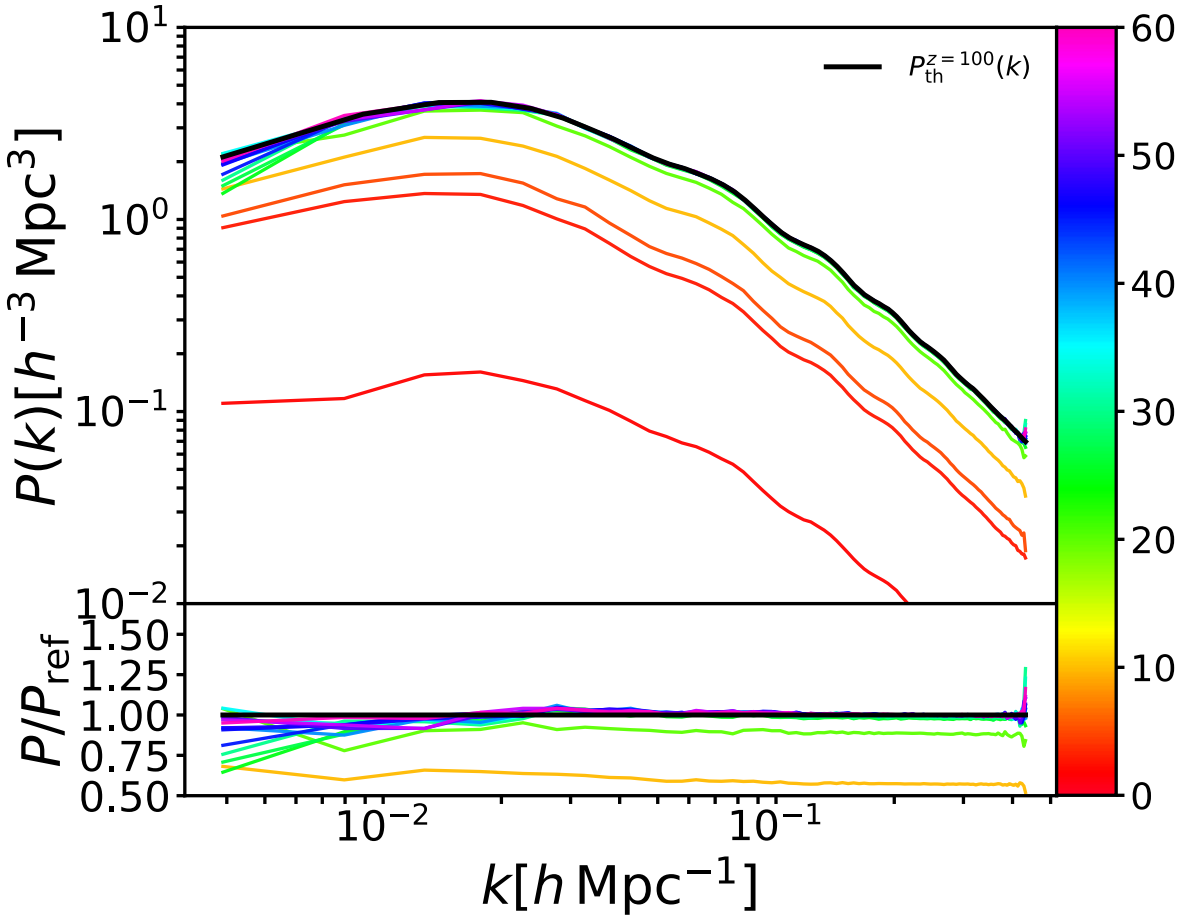

BIRTH with COSMOS field surveys

- Why the COSMOS field?

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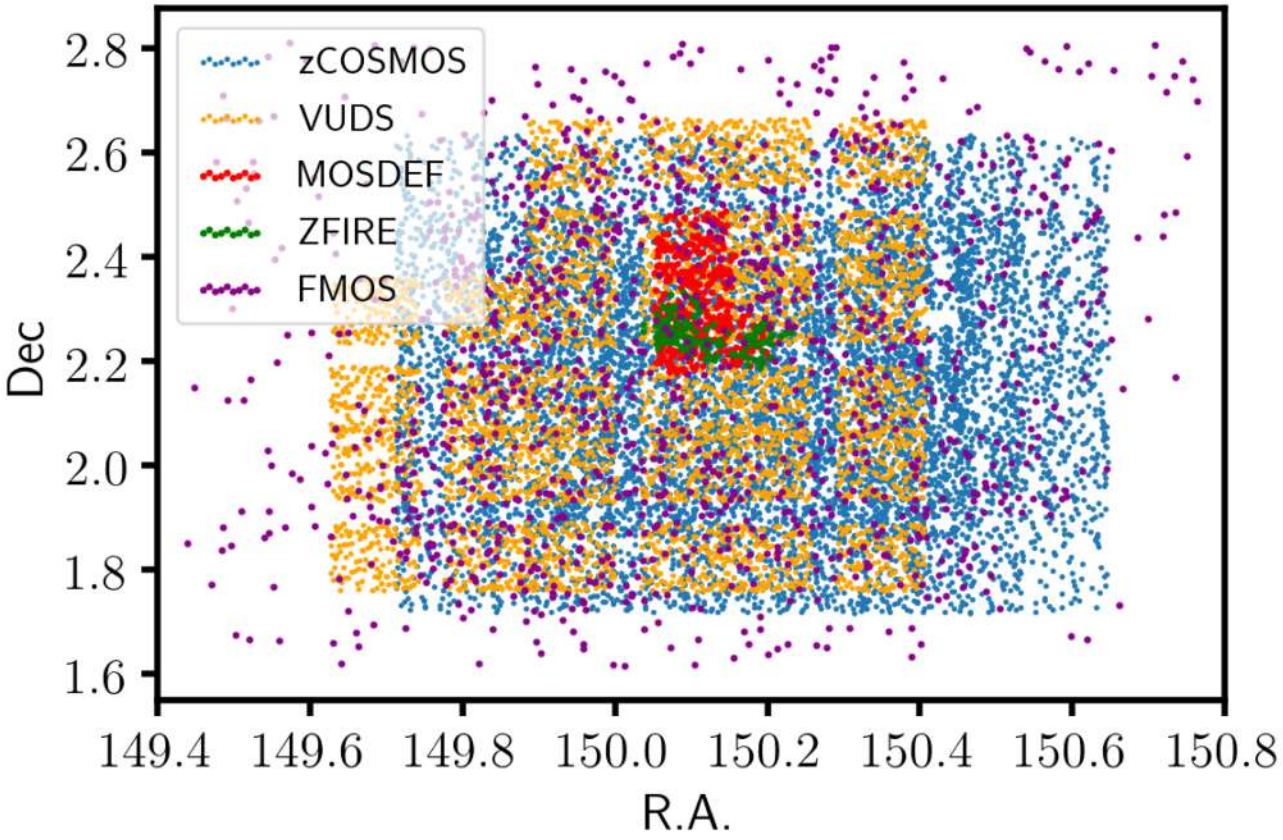
  - It's deep
- Highest redshift galaxy surveys on the market probing peak of star formation epoch ($1.6 > z > 3.2$)
  - Combine 5 different surveys, different
    - Number densities
    - Survey geometries
    - Selection functions
    - Biases



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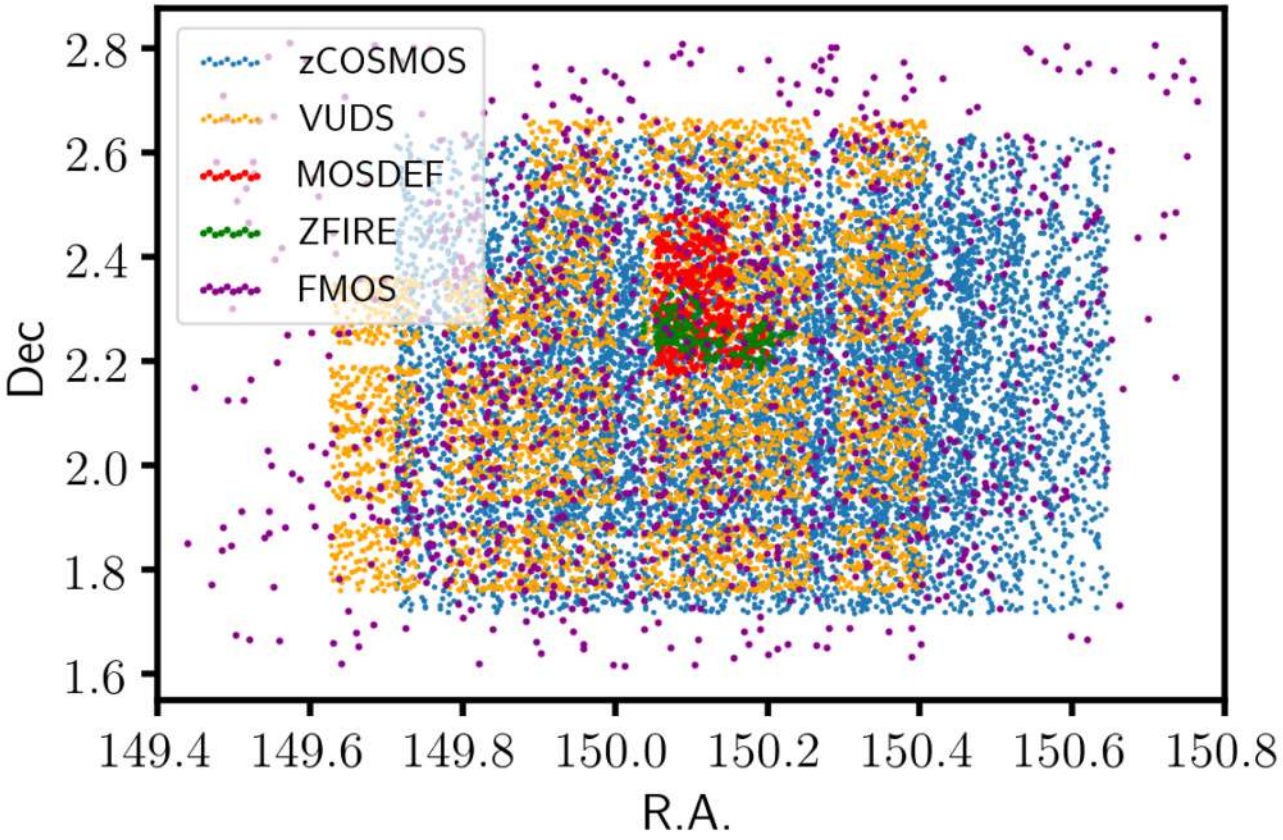
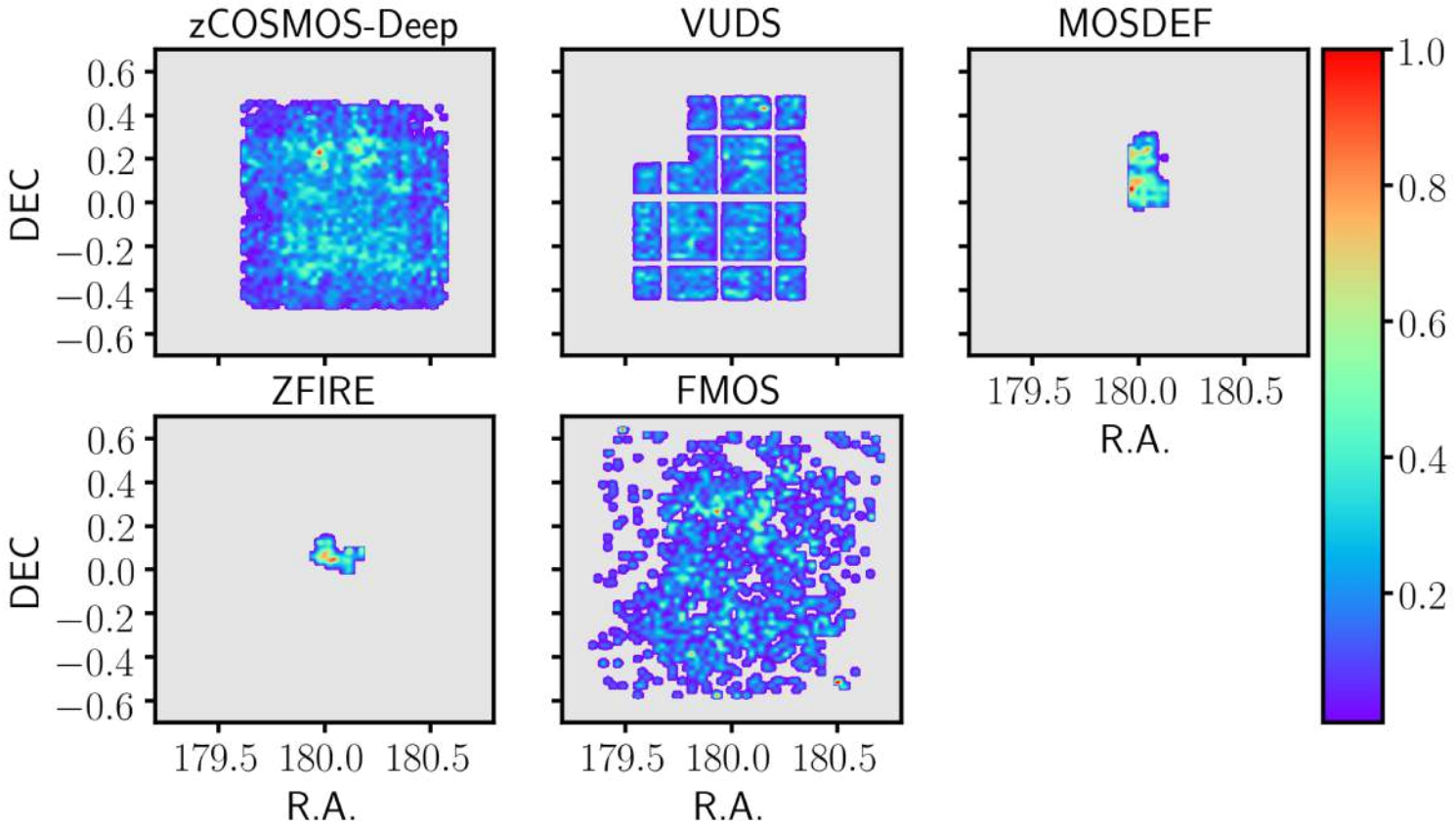


- First application of a Bayesian multi-tracer reconstruction on a light-cone (Ata et al in prep)

BIRTH with COSMOS field surveys

- Building the selection function from scratch



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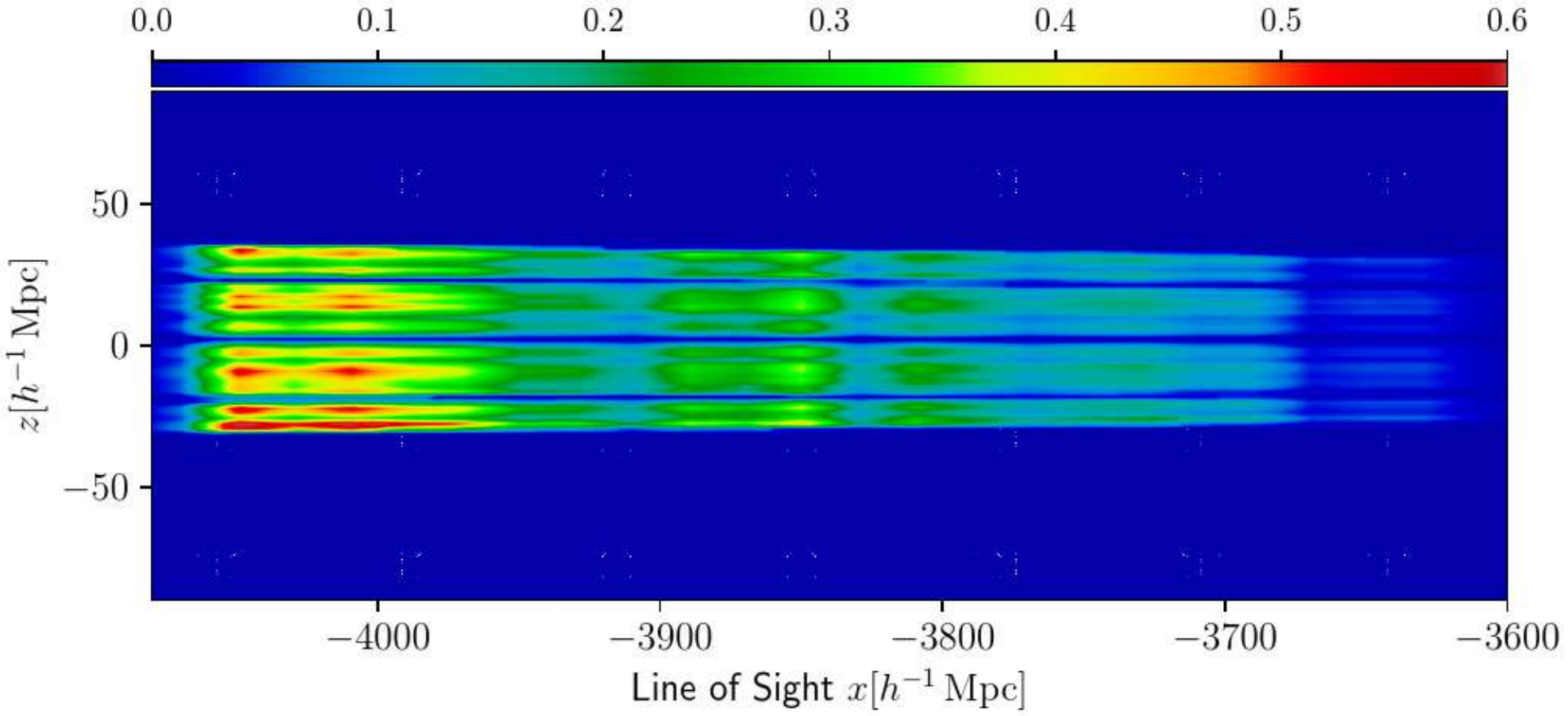

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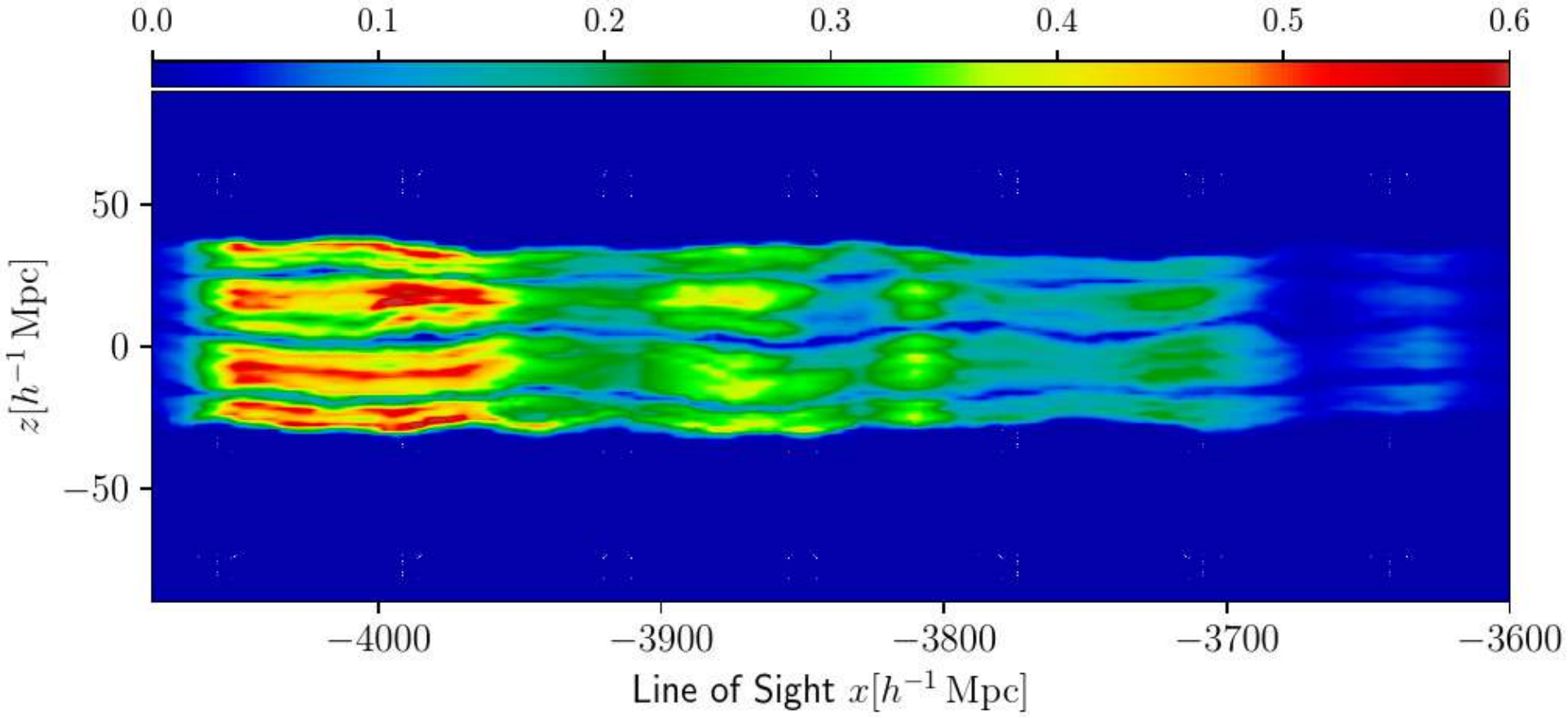

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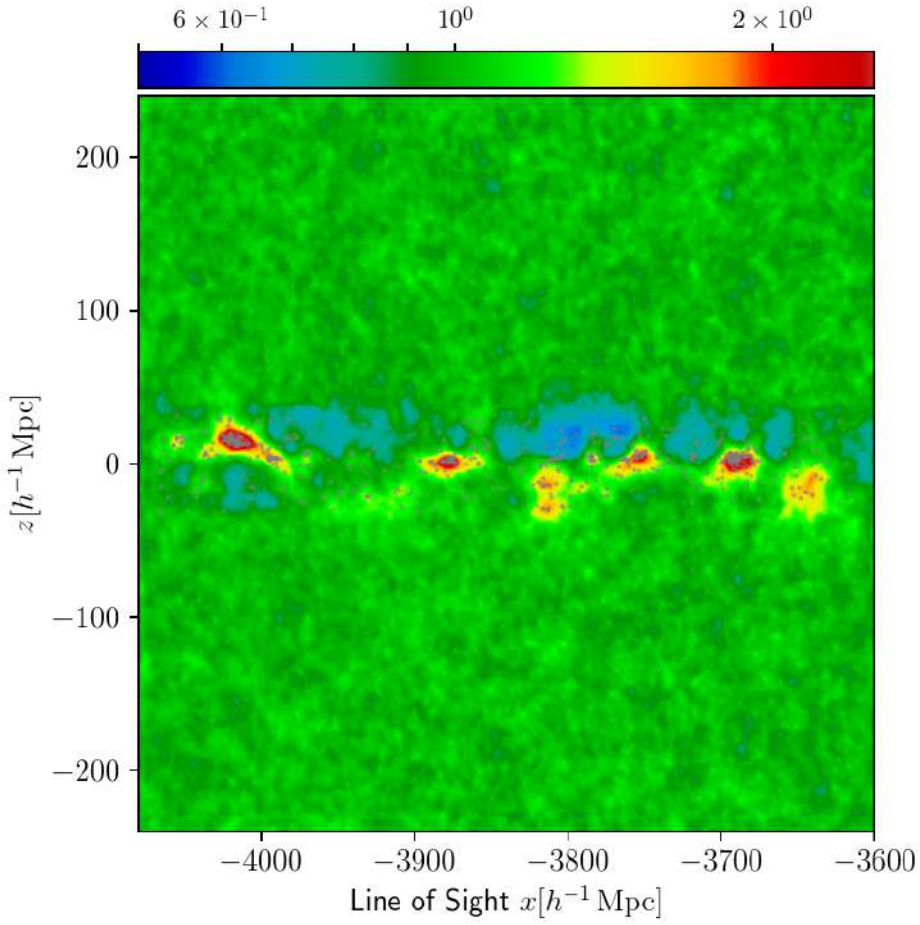

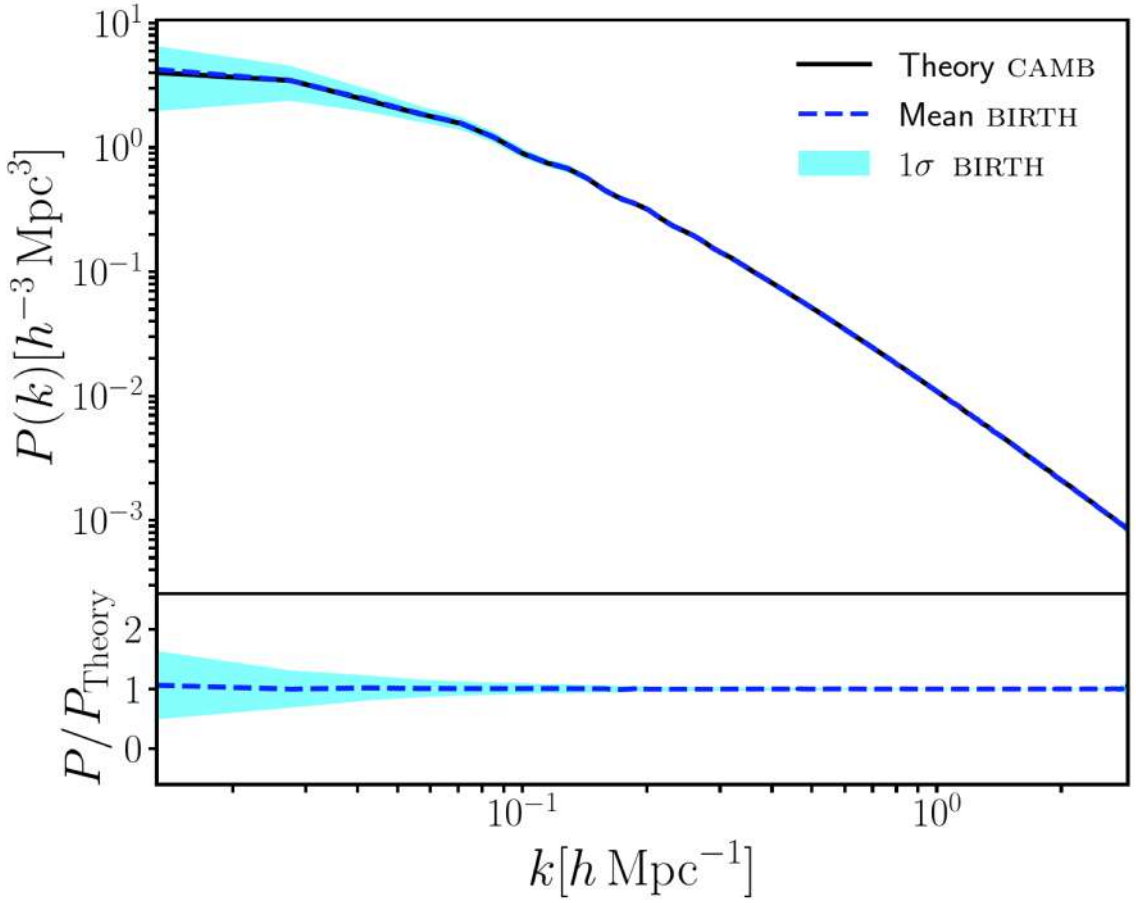

Summary

- COSMIC BIRTH novel tool to reconstruct initial condition from galaxy surveys
- This approach does not sample need to include the structure formation model within the density sampling step
- Applied to BOSS wide field survey & deep surveys in the COSMOS field
- Future Projects:
  - Compare with IGM tomography (K.G. Lee in prep)
  - Constrained simulations of high redshift proto-clusters (Ata et al in prep)

Thanks

- My favorites
  - Jianbing 煎餅
  - Lamb skewers 新疆烤串