

Cosmology from Field Level, Forward Modeling: an EFT approach

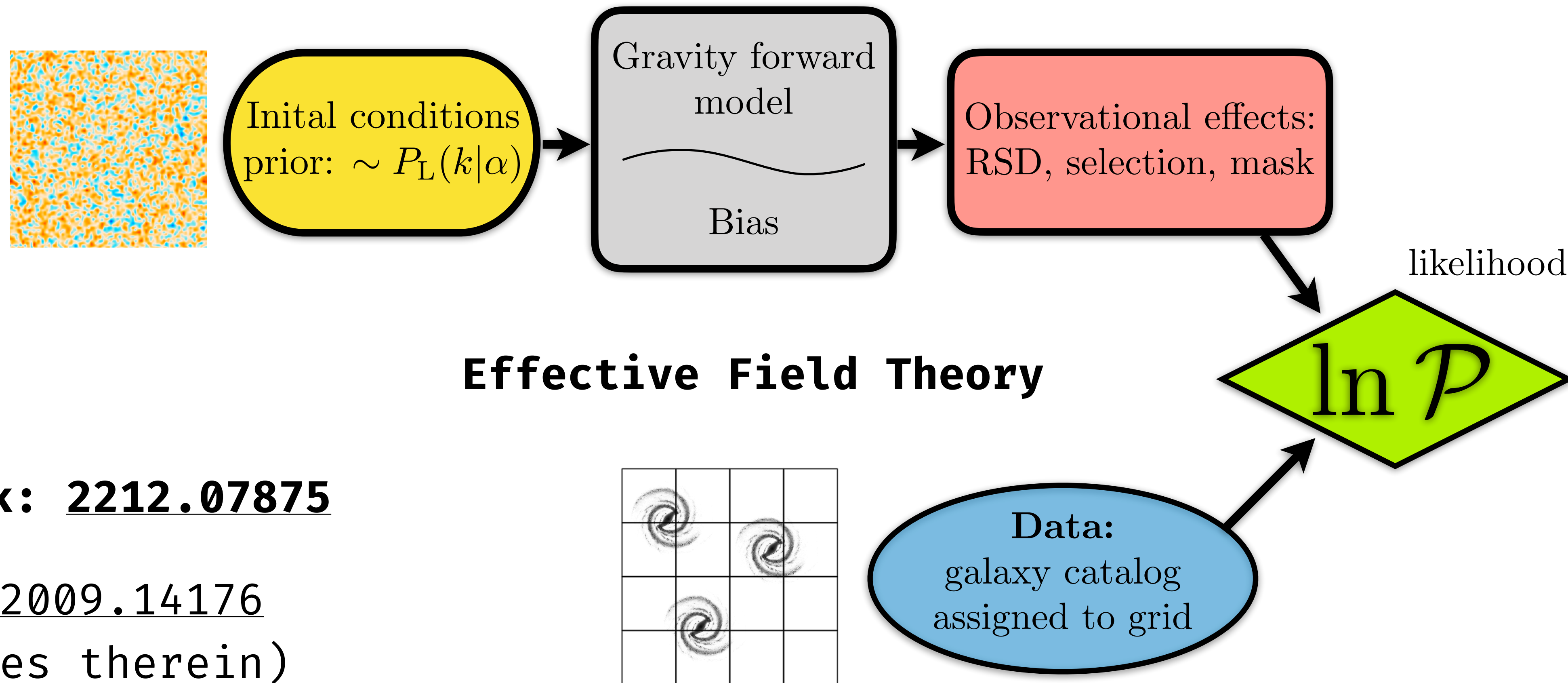
(Nhat-)Minh Nguyen

Leinweber Center for Theoretical Physics

University of Michigan

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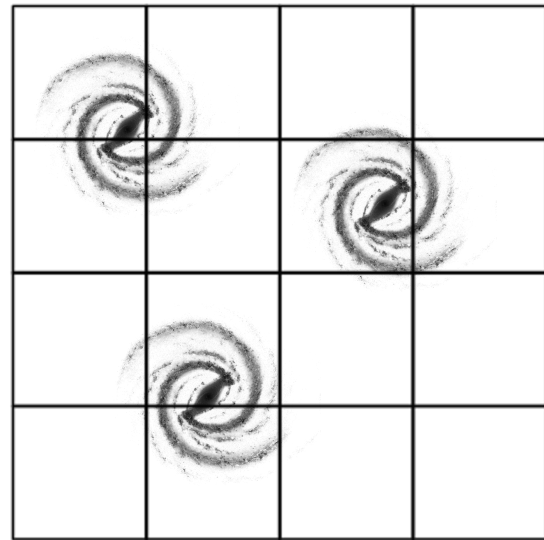
Cosmology from Field Level, Forward Modeling: Basics



Latest work: [2212.07875](#)

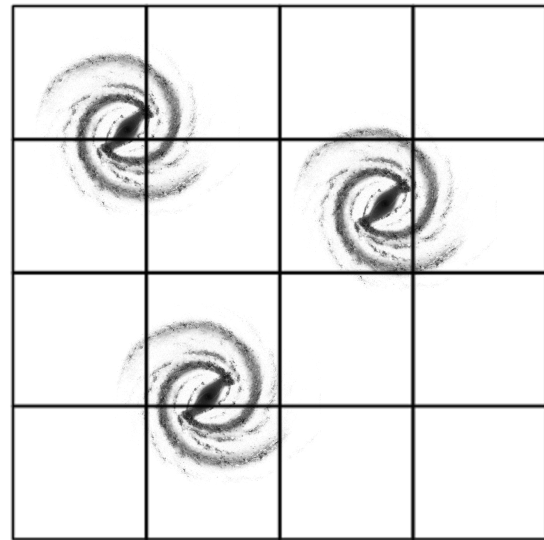
See also: [2009.14176](#)
(& references therein)

3 Cosmology from Field Level, Forward Modeling: Motivation



Why data vector $\sim 10^6$ dimensions?

4 Cosmology from Field Level, Forward Modeling: Motivation



Why data vector $\sim 10^6$ dimensions?

More and better information

Improve cosmological constraint

Better density ~~reconstruction~~ inference

5 Cosmology from Field Level, Forward Modeling: Inference scheme

Code:

BORG

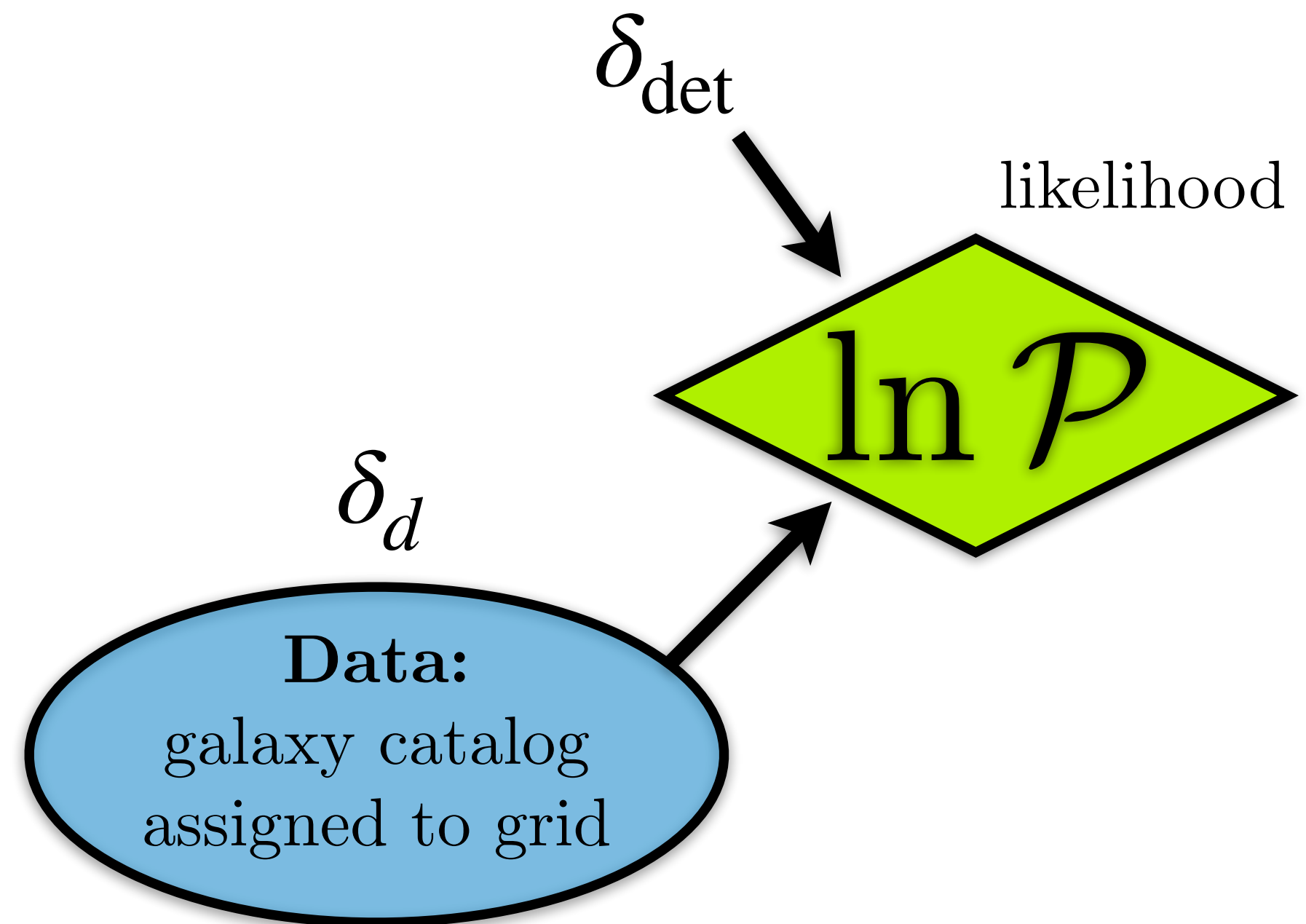
ELUCID

LEFTfield

pmwd

The field-level LSS posterior

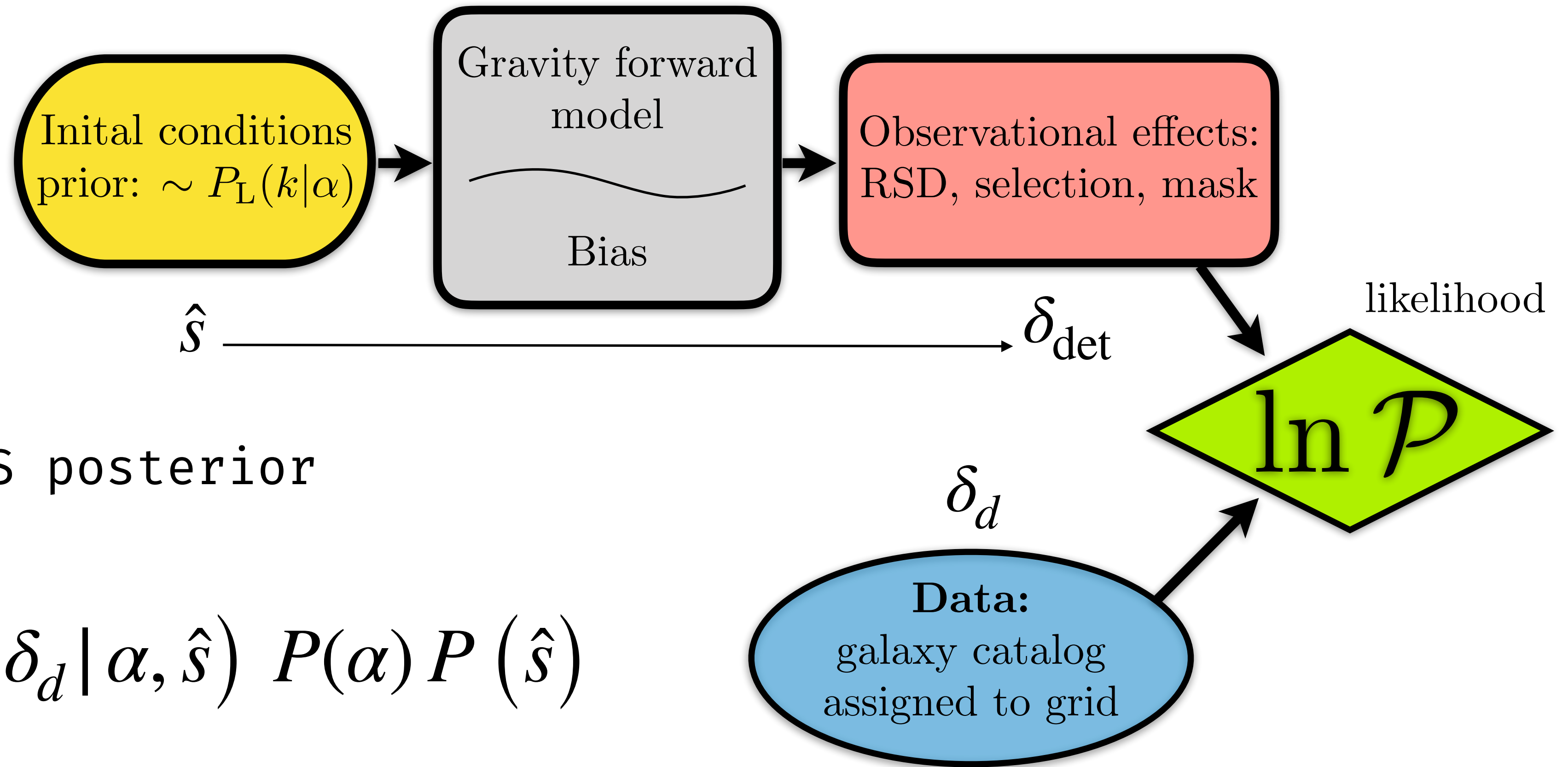
$$P(\alpha | \delta_d) = \int_{\delta_{\text{det}}} P(\delta_d | \alpha, \delta_{\text{det}}) P(\alpha) P(\delta_{\text{det}})$$



6 Cosmology from Field Level, Forward Modeling: Inference scheme

Code:

BORG
ELUCID
LEFTfield
pmwd



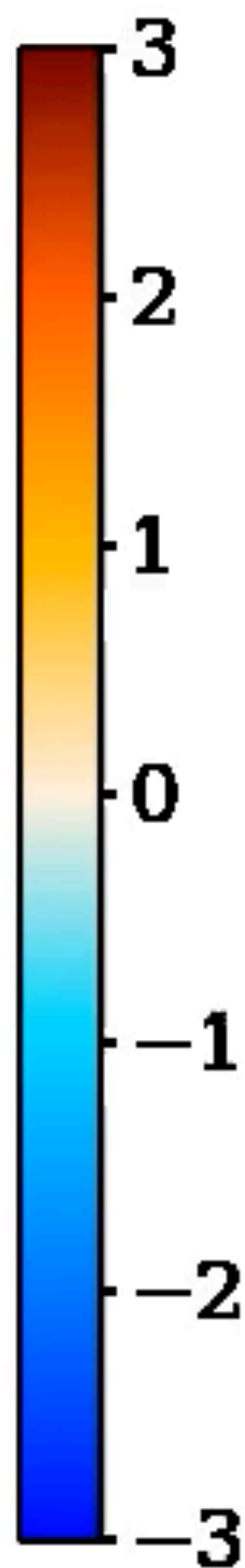
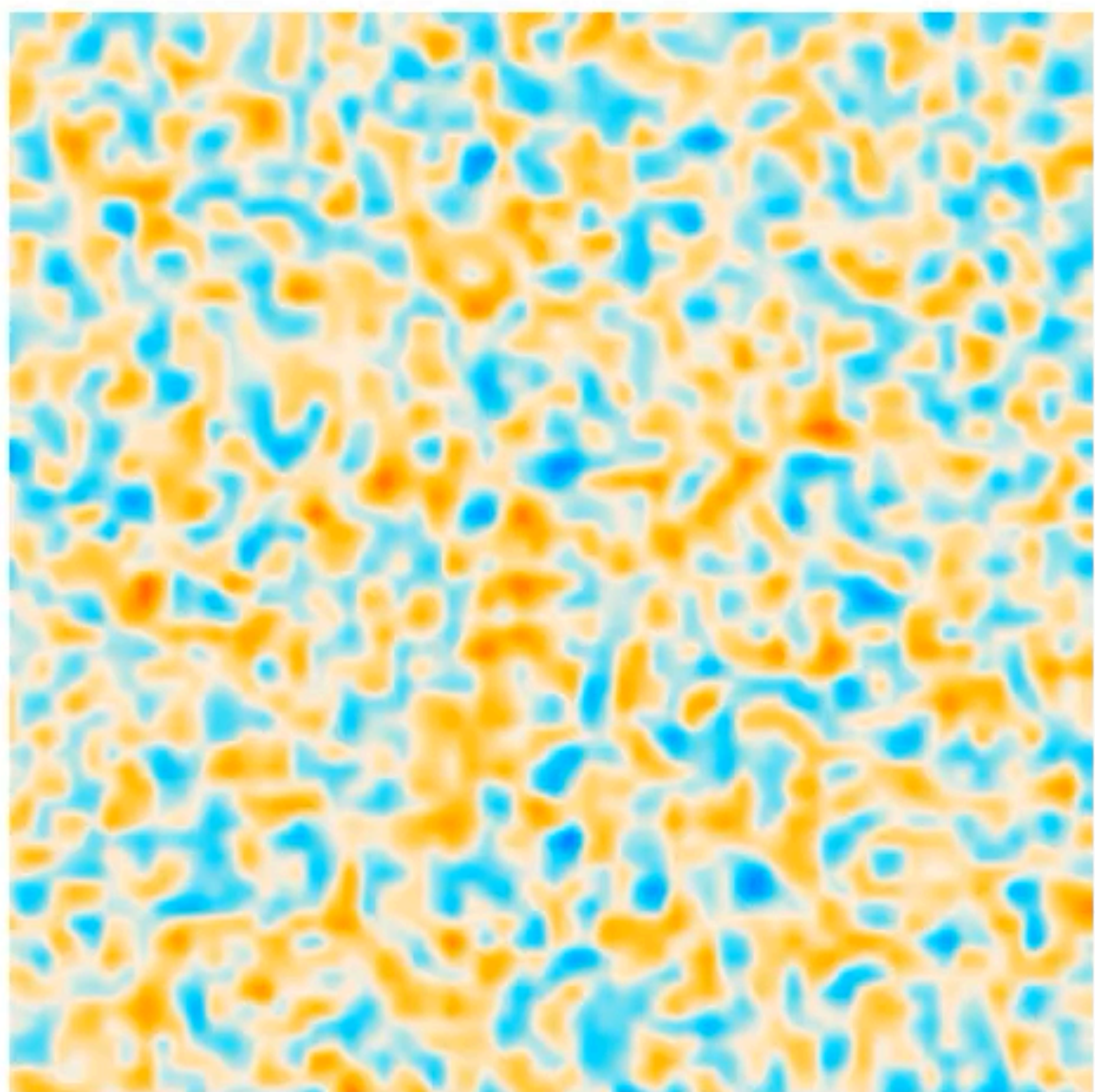
The field-level LSS posterior

$$P(\alpha | \delta_d) = \int_{\hat{s}} P(\delta_d | \alpha, \hat{s}) P(\alpha) P(\hat{s})$$

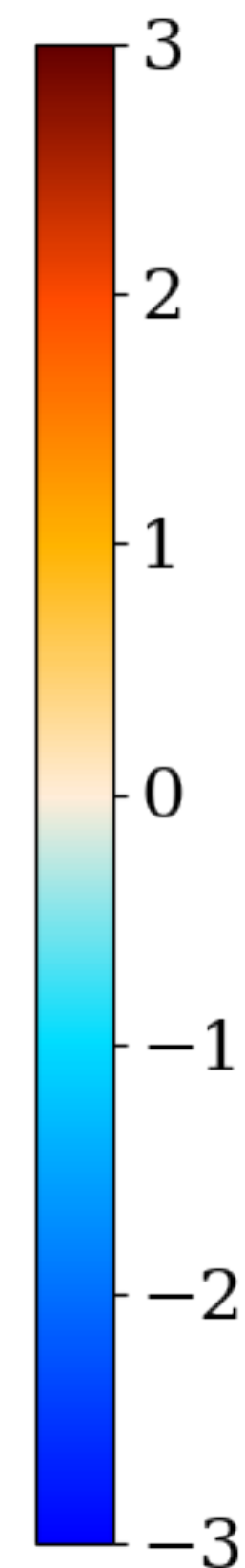
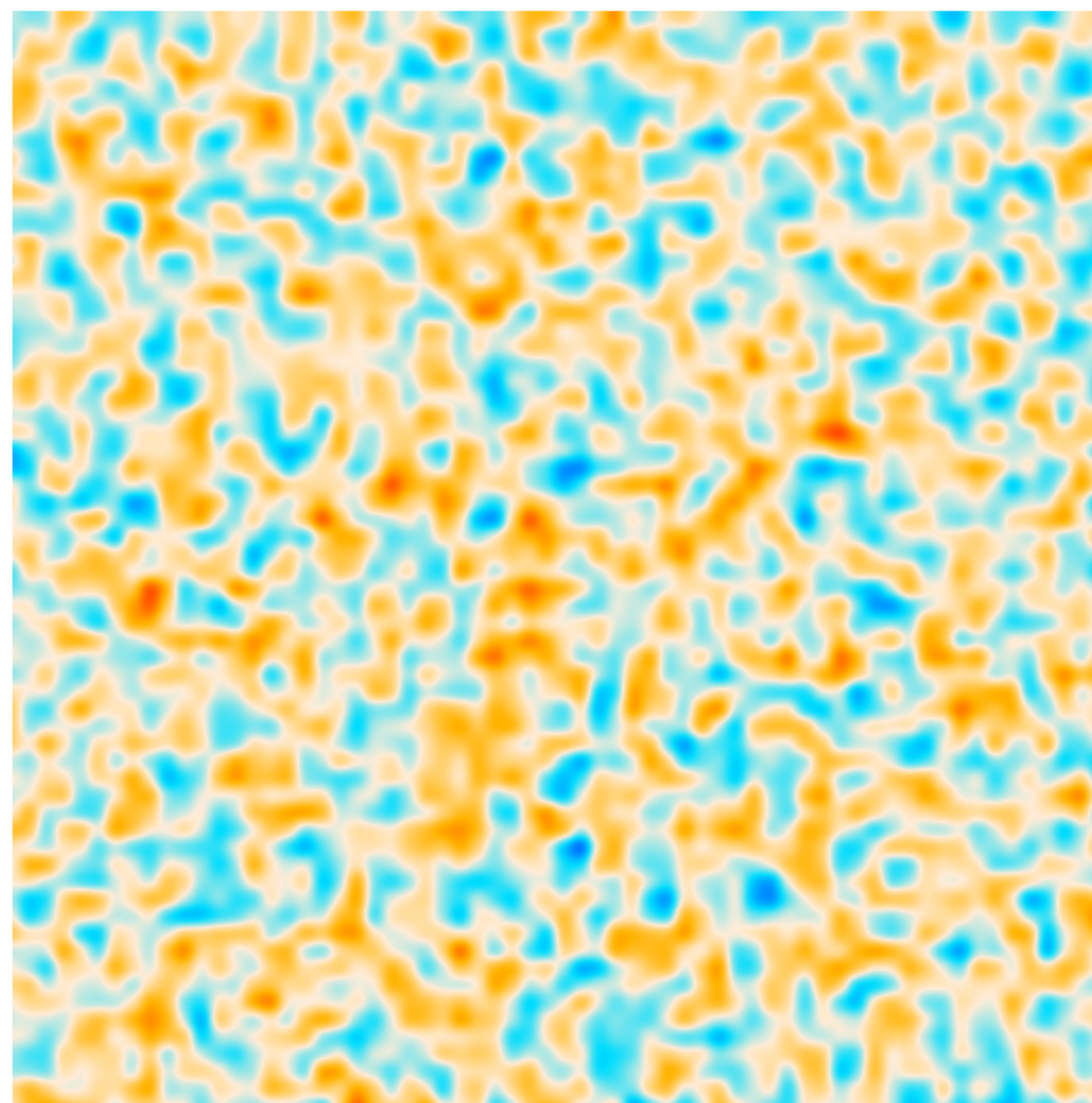
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Cosmology from Field Level, Forward Modeling: Phase sampling - example

$$\hat{s}(\mathbf{x})$$

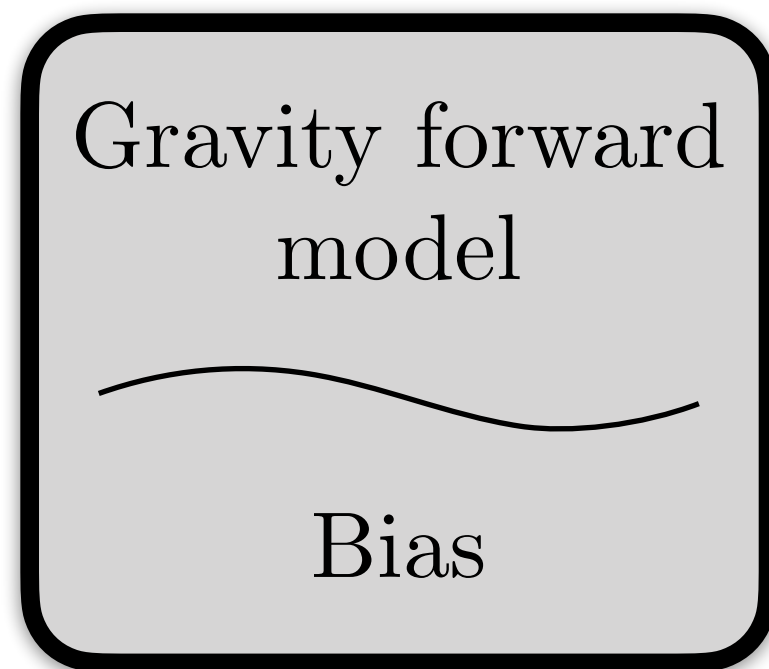


$$\hat{s}_{\text{true}}(\mathbf{x})$$



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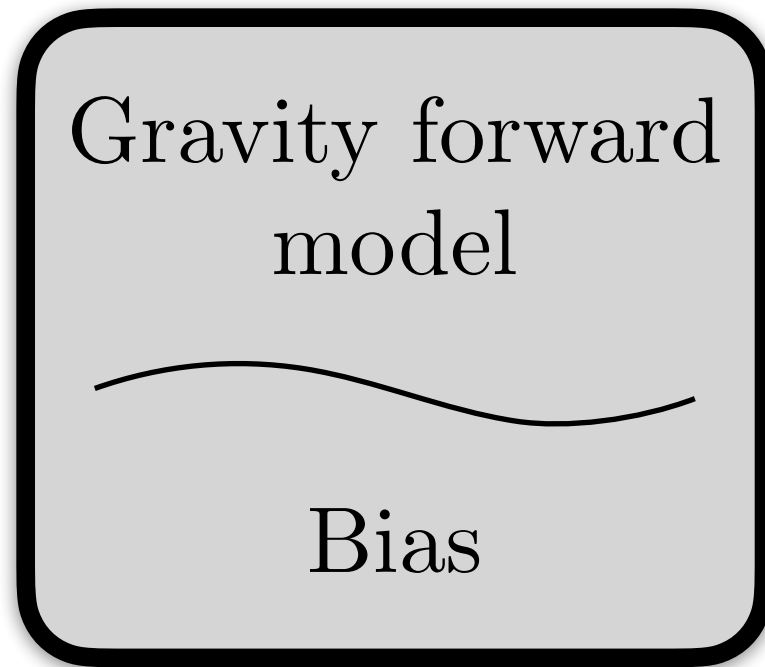
Cosmology from Field Level, Forward Modeling: Effective Field Theory



Why EFT?

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Cosmology from Field Level, Forward Modeling: Effective Field Theory



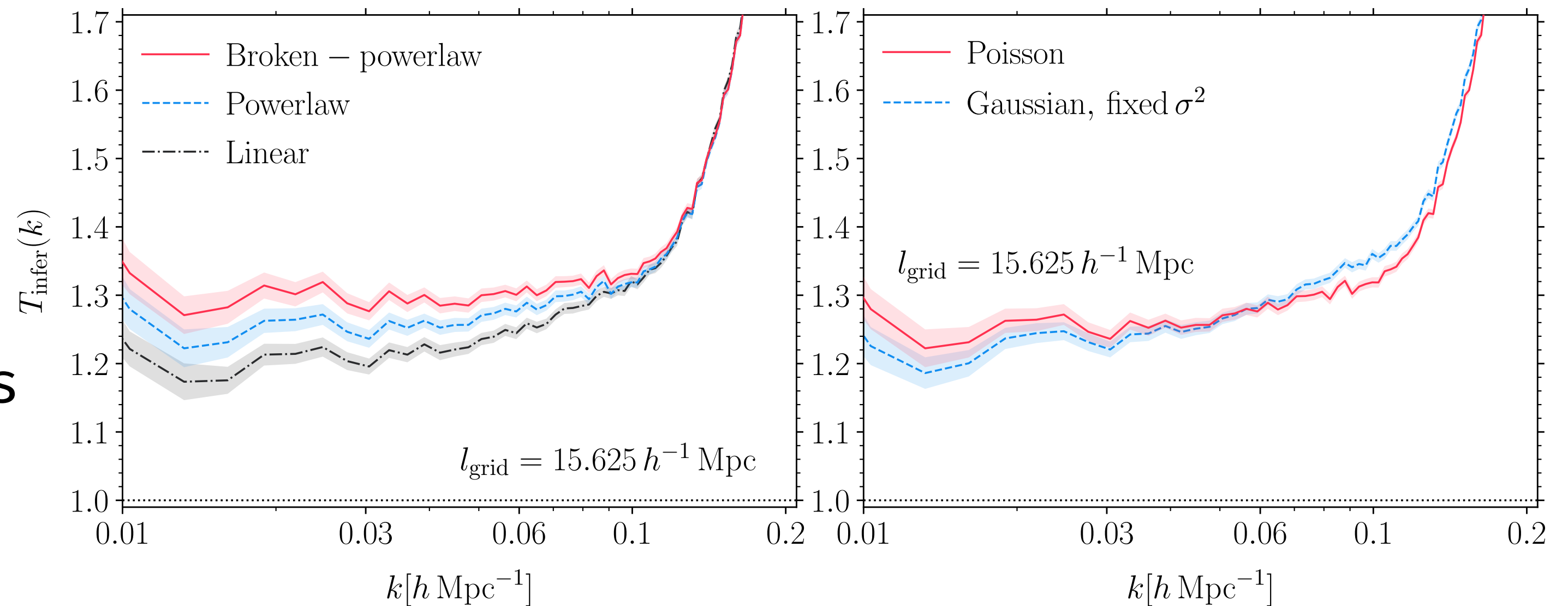
Why EFT?

N-body halos from gravity-only sims

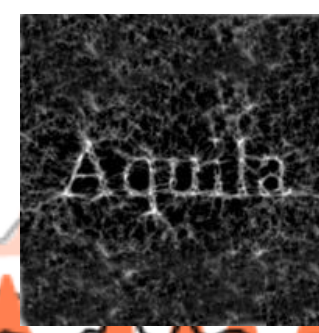
Phenomenological galaxy bias model

Solid theoretical footing

Strict control of coupling modes



MN+, 2011.06587



10 Cosmology from Field Level, Forward Modeling:
EFT of matter

(e.g. [1310.2920](#))

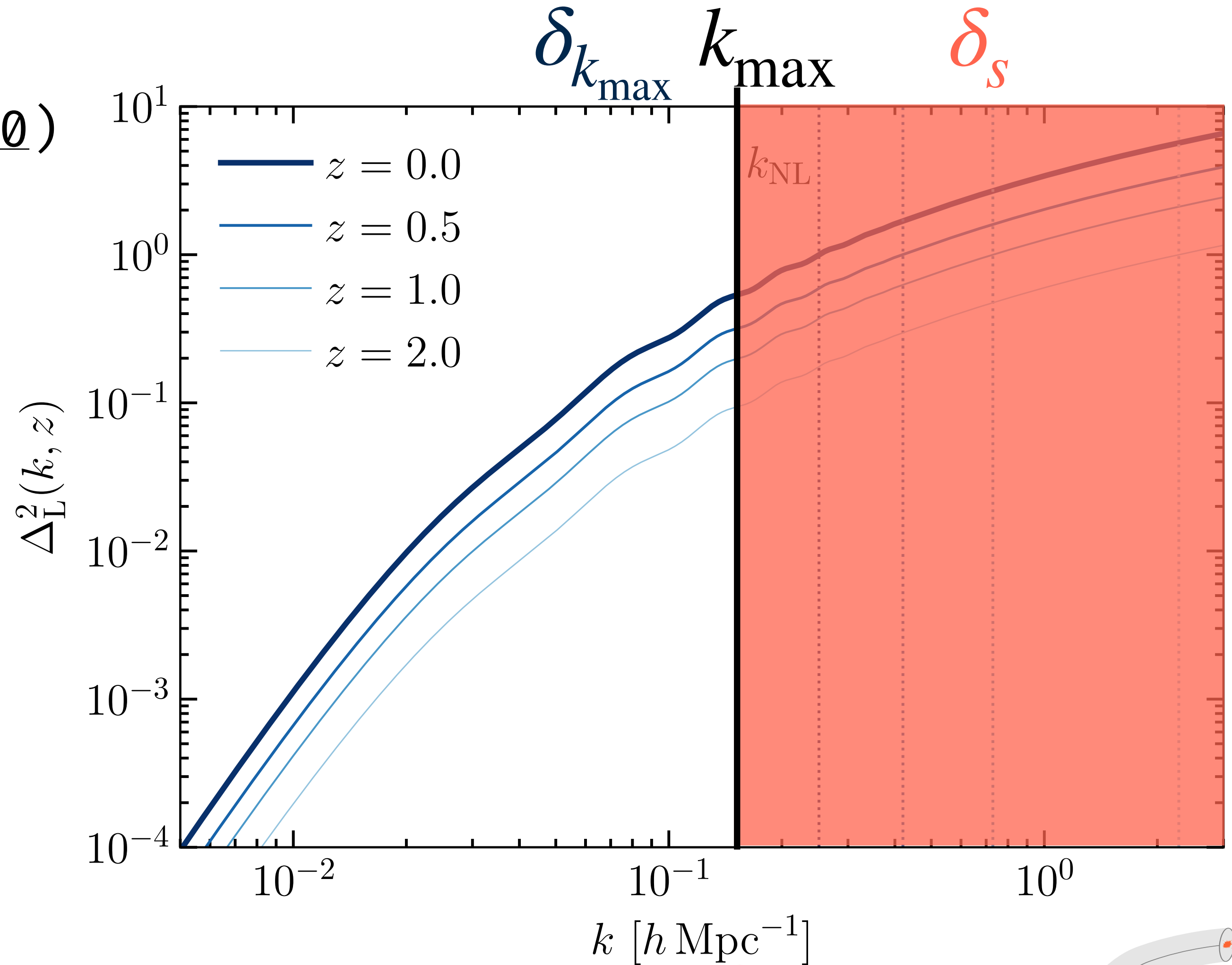
Motive: trust theory up to k_{\max}

Procedure:

Split initial conditions

$$\delta \equiv \frac{\rho - \bar{\rho}}{\bar{\rho}} - 1 = \delta_{k_{\max}} + \delta_s$$

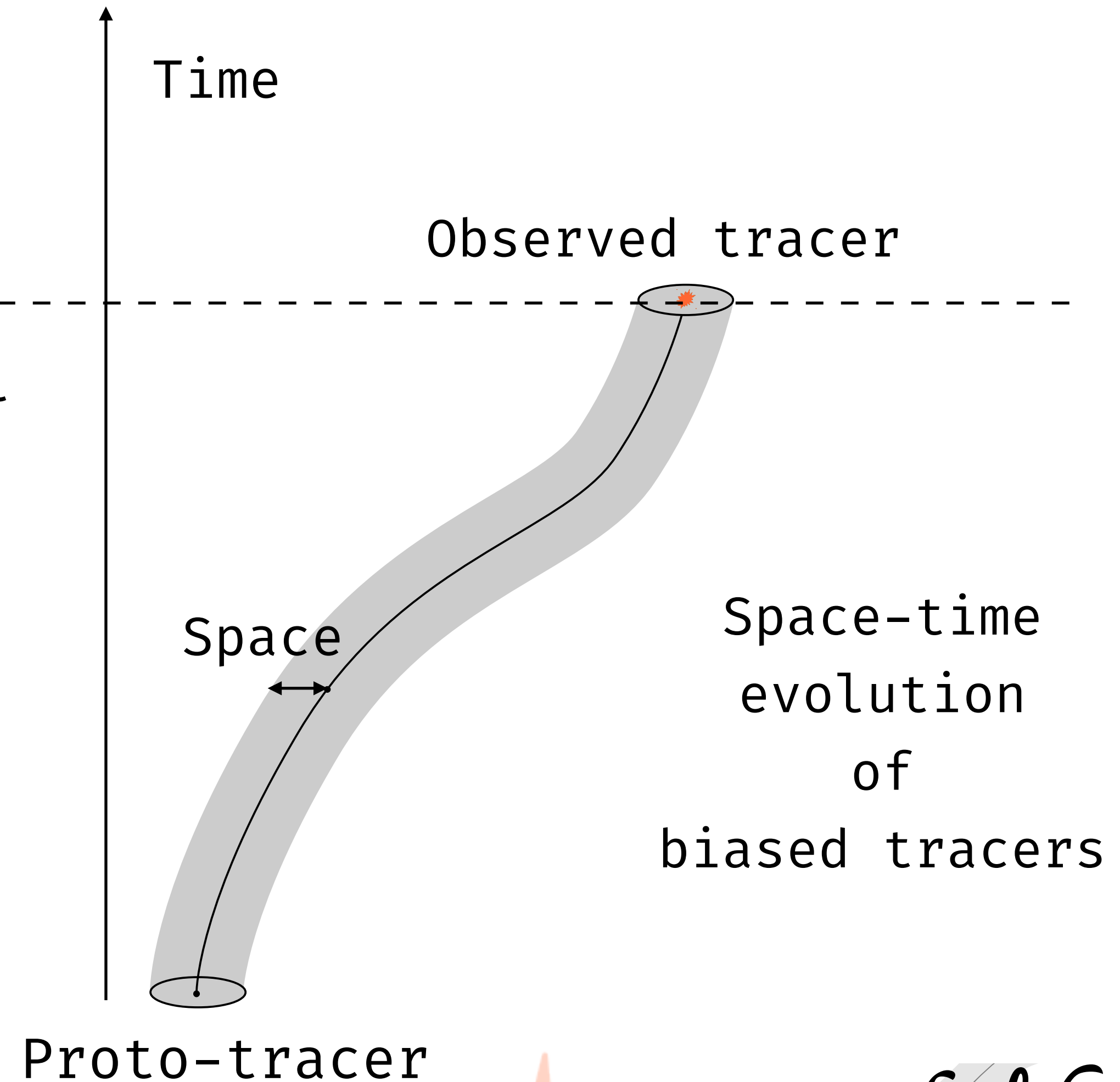
Marginalize over δ_s



11 Cosmology from Field Level, Forward Modeling:
EFT of biased tracers

Tracer bias expansion
$$\delta_{d,k_{\max}} = \sum_0 \overbrace{b_0 O}^{\delta_{\text{det},k_{\max}}} + \epsilon$$

Insight: tracer formation is spatially local



12 Cosmology from Field Level, Forward Modeling:
EFT of biased tracers

Tracer bias expansion
$$\delta_{d,k_{\max}} = \sum_0 \overbrace{b_0 O}^{\delta_{\text{det},k_{\max}}} + \epsilon$$

Insight: tracer formation is spatially local

large-scale perturbations

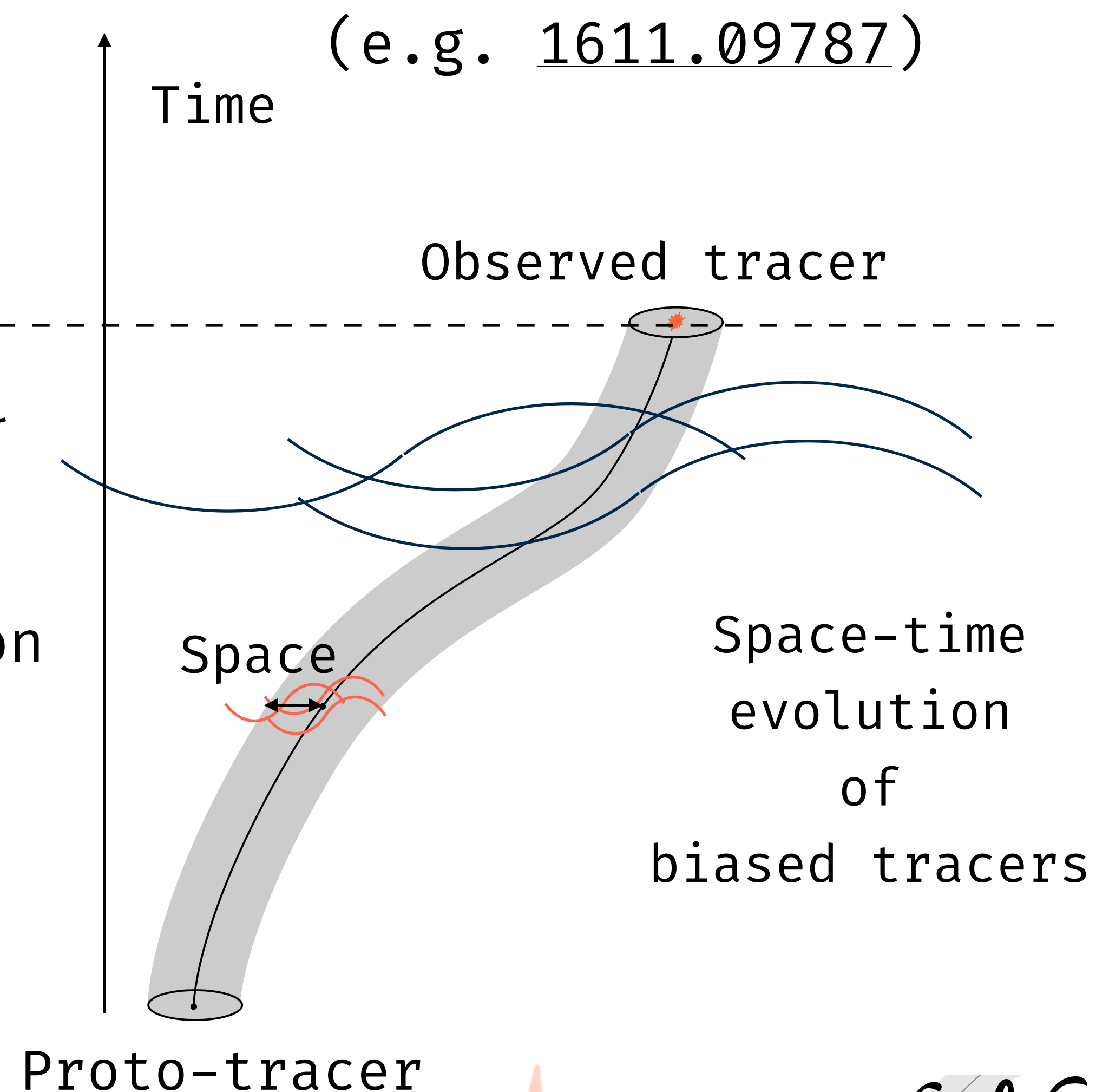
deterministic, local-time expansion

$O \sim$ only density and tidal fields

small-scale perturbations

stochastic field

$\epsilon \sim$ Gaussian, white spectrum



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$$\delta_{d,k_{\max}} = \sum_0 \overbrace{b_0 O}^{\delta_{\text{det},k_{\max}}} + \epsilon$$

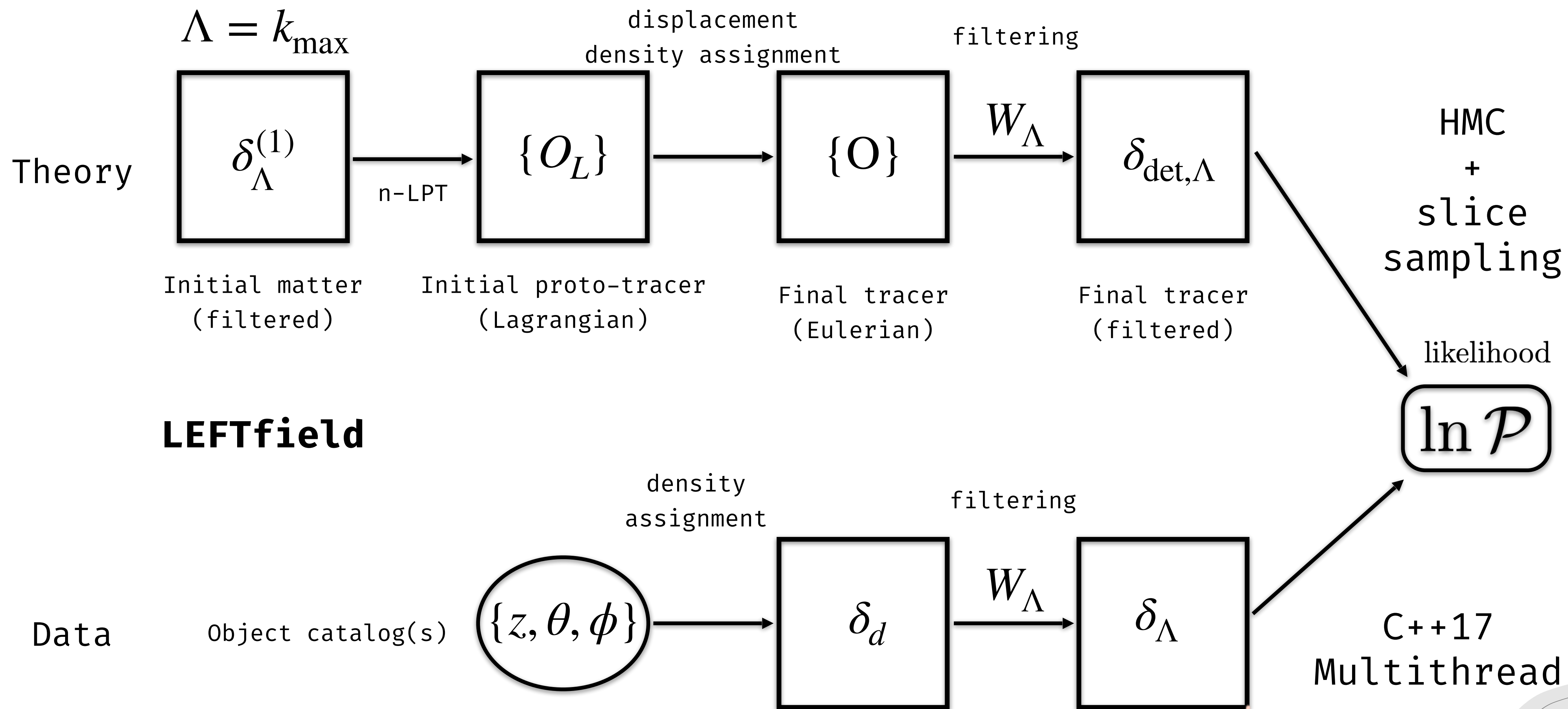
Analytical marginalization over ϵ

$$\ln \mathcal{L} \left(\delta_{d,k_{\max}} \middle| \alpha, \hat{s}, \{b_0\}, \sigma_\epsilon \right) = -\frac{1}{2} \sum_{k \neq 0}^{k_{\max}} \left[\ln 2\pi\sigma_\epsilon^2 + \frac{1}{\sigma_\epsilon^2} \left| \delta_{d,\Lambda}(\mathbf{k}) - \delta_{\text{det},\Lambda}[\alpha, \hat{s}, \{b_0\}](\mathbf{k}) \right|^2 \right]$$

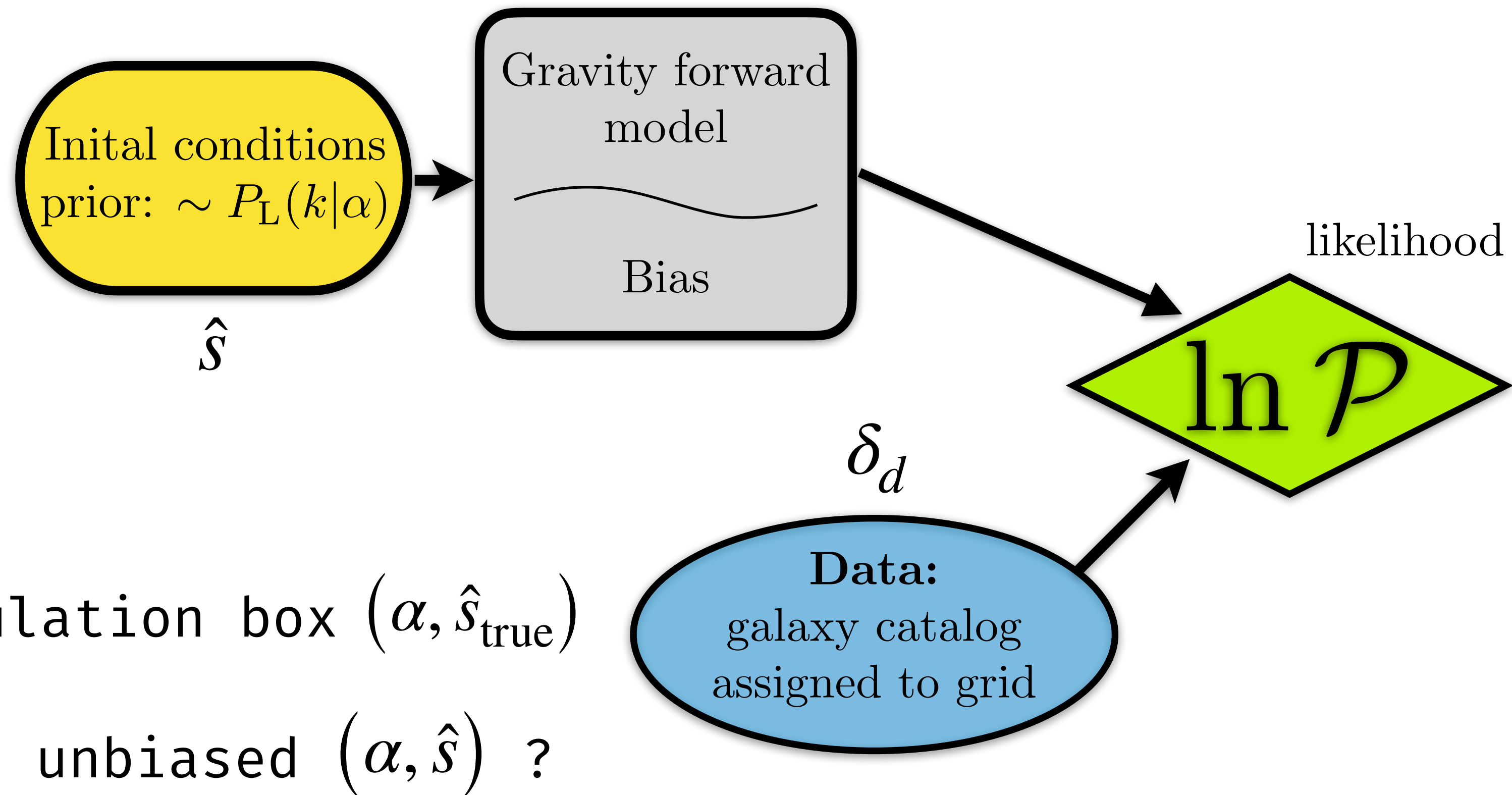
σ_ϵ to be inferred from data itself

Cabass, Schmidt [1909.04022](#)

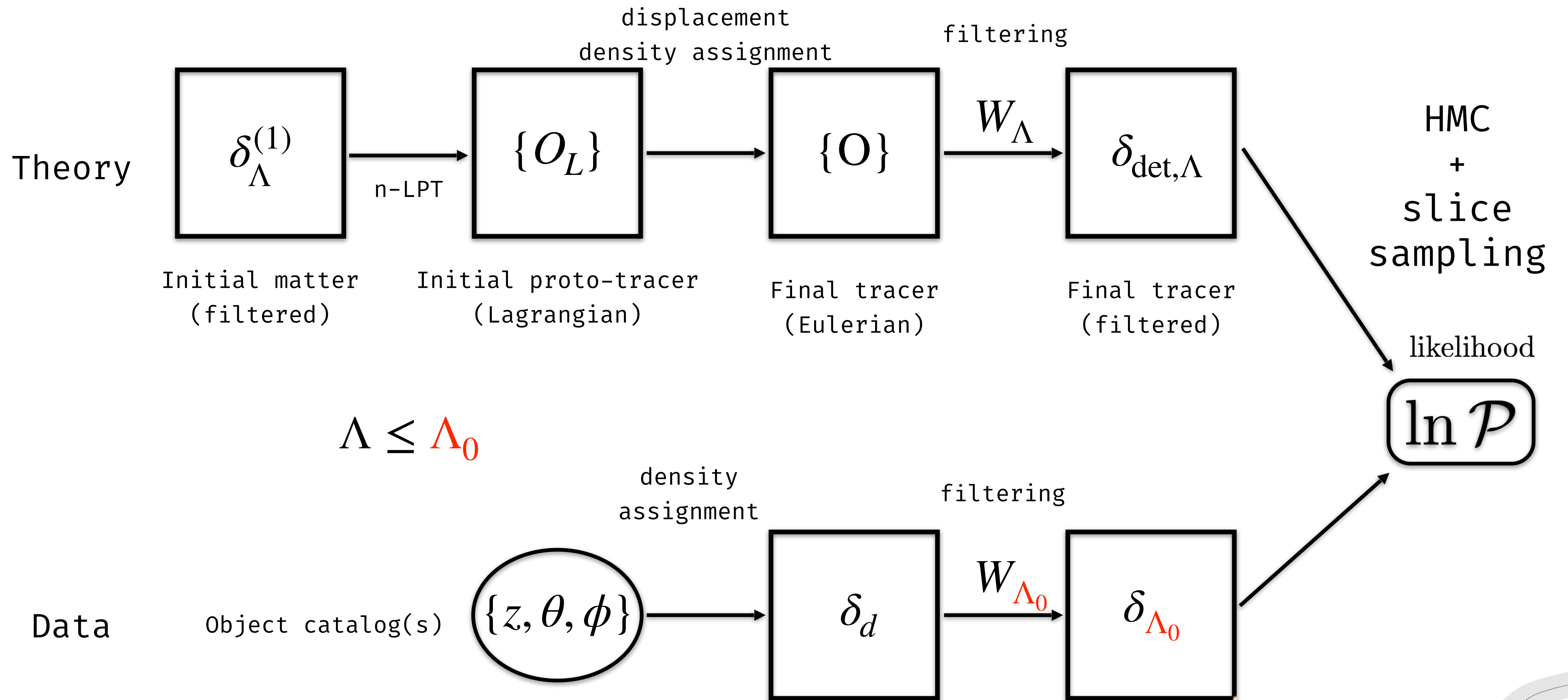
Cosmology from Field Level, Forward Modeling: LEFTfield



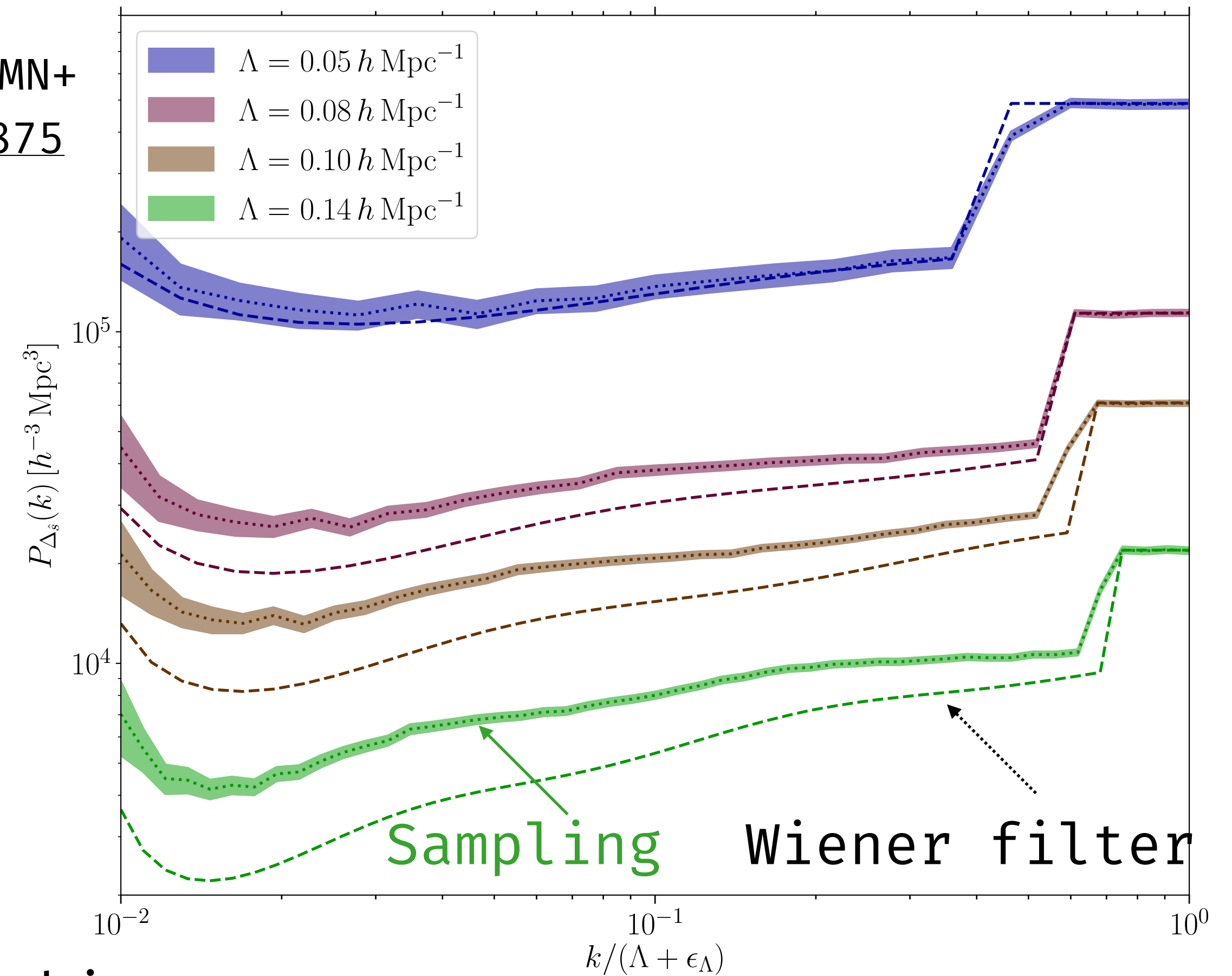
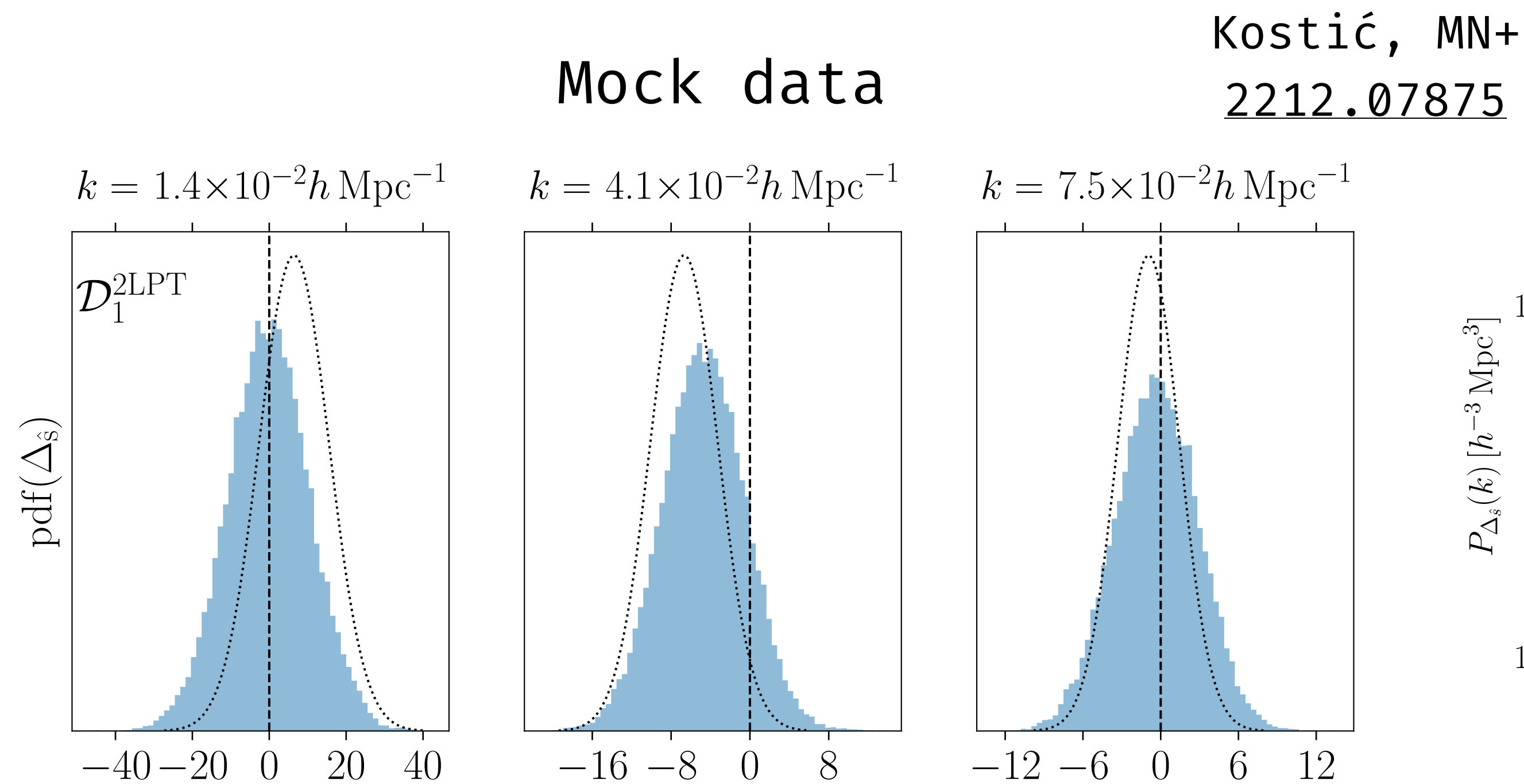
Cosmology from Field Level, Forward Modeling: Applications



Cosmology from Field Level, Forward Modeling: EFT mocks w/ cutoff mismatch



Cosmology from Field Level, Forward Modeling: EFT mocks w/ cutoff mismatch



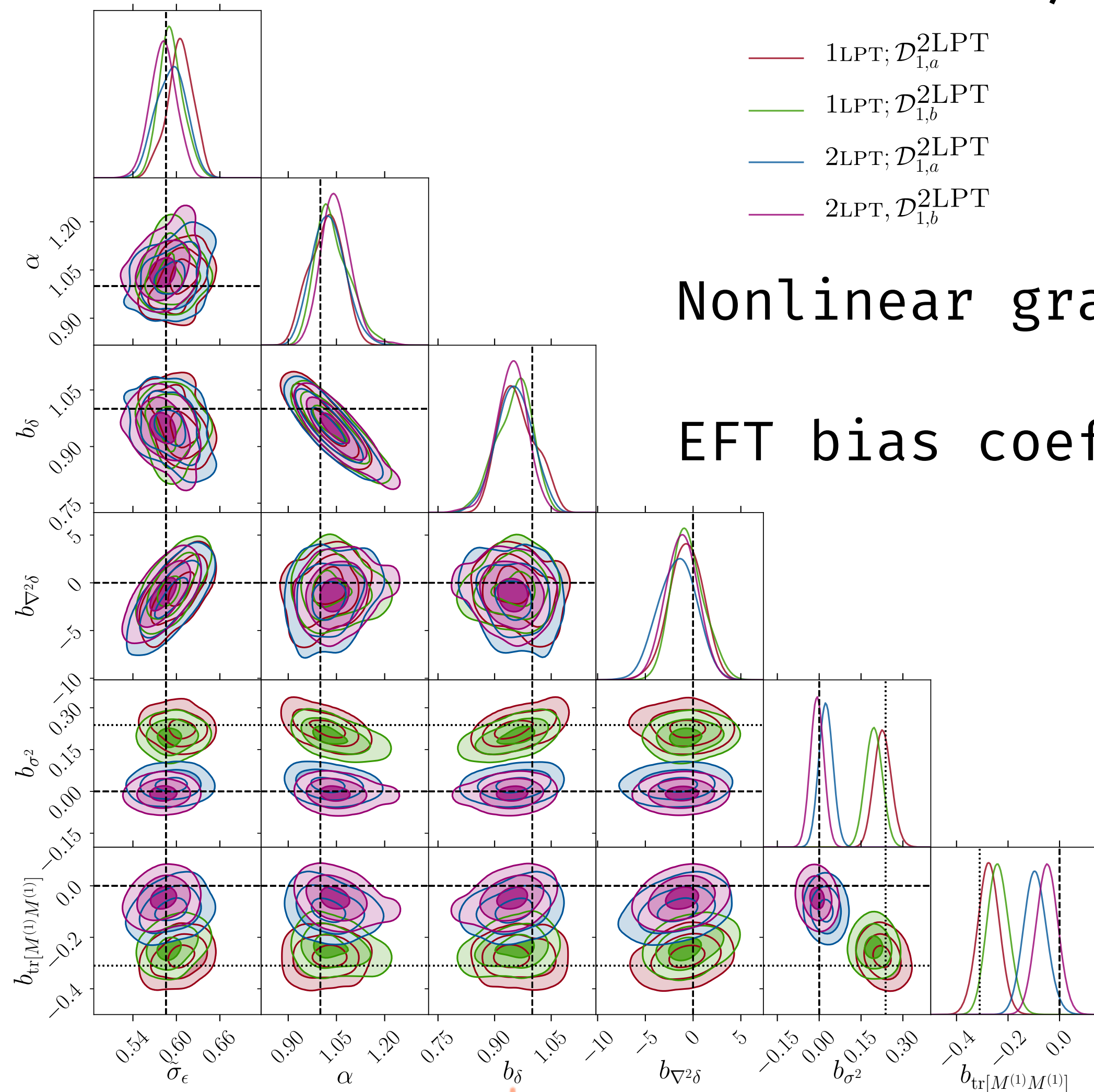
Nonlinear corrections matter even without bias

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Cosmology from Field Level, Forward Modeling:

Mock data

EFT mocks w/ cutoff mismatch



Nonlinear gravity, linear galaxy bias

EFT bias coefficients properly absorb mis-specification
in models of gravity

Kostić, MN+
[2212.07875](https://arxiv.org/abs/2212.07875)

19 Cosmology from Field Level, Forward Modeling: Mock data EFT mocks w/ cutoff mismatch

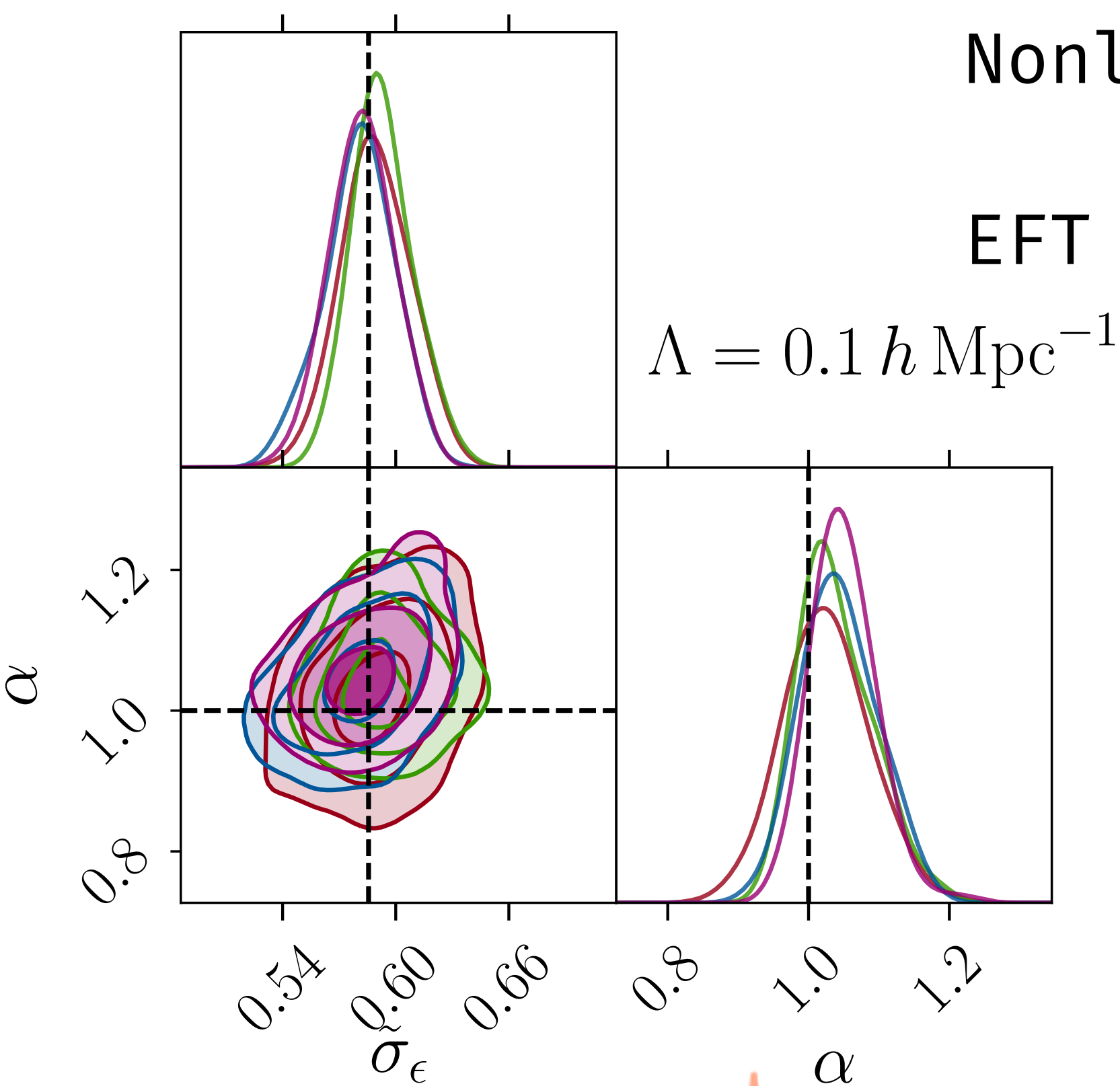
- 1LPT; $\mathcal{D}_{1,a}^{2LPT}$
- 1LPT; $\mathcal{D}_{1,b}^{2LPT}$
- 2LPT; $\mathcal{D}_{1,a}^{2LPT}$
- 2LPT; $\mathcal{D}_{1,b}^{2LPT}$

Nonlinear gravity, linear galaxy bias

EFT bias coefficients properly absorb mis-specification
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$$\Lambda = 0.1 h \text{ Mpc}^{-1}$$

68%-CL constraint on $\alpha \sim 0.04$

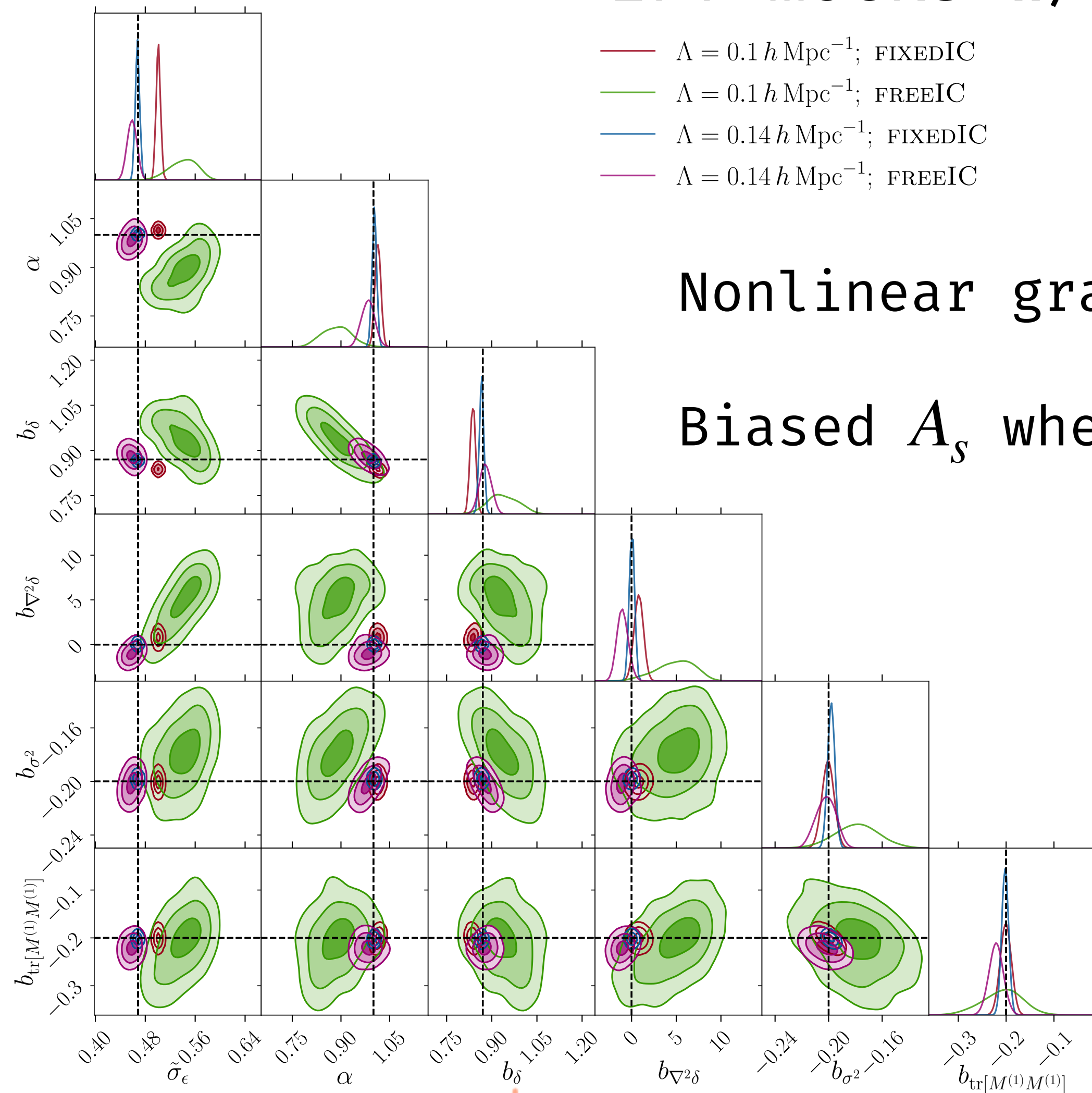


Kostić, MN+
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Cosmology from Field Level, Forward Modeling:

Mock data

EFT mocks w/ cutoff mismatch



Nonlinear gravity, nonlinear galaxy bias

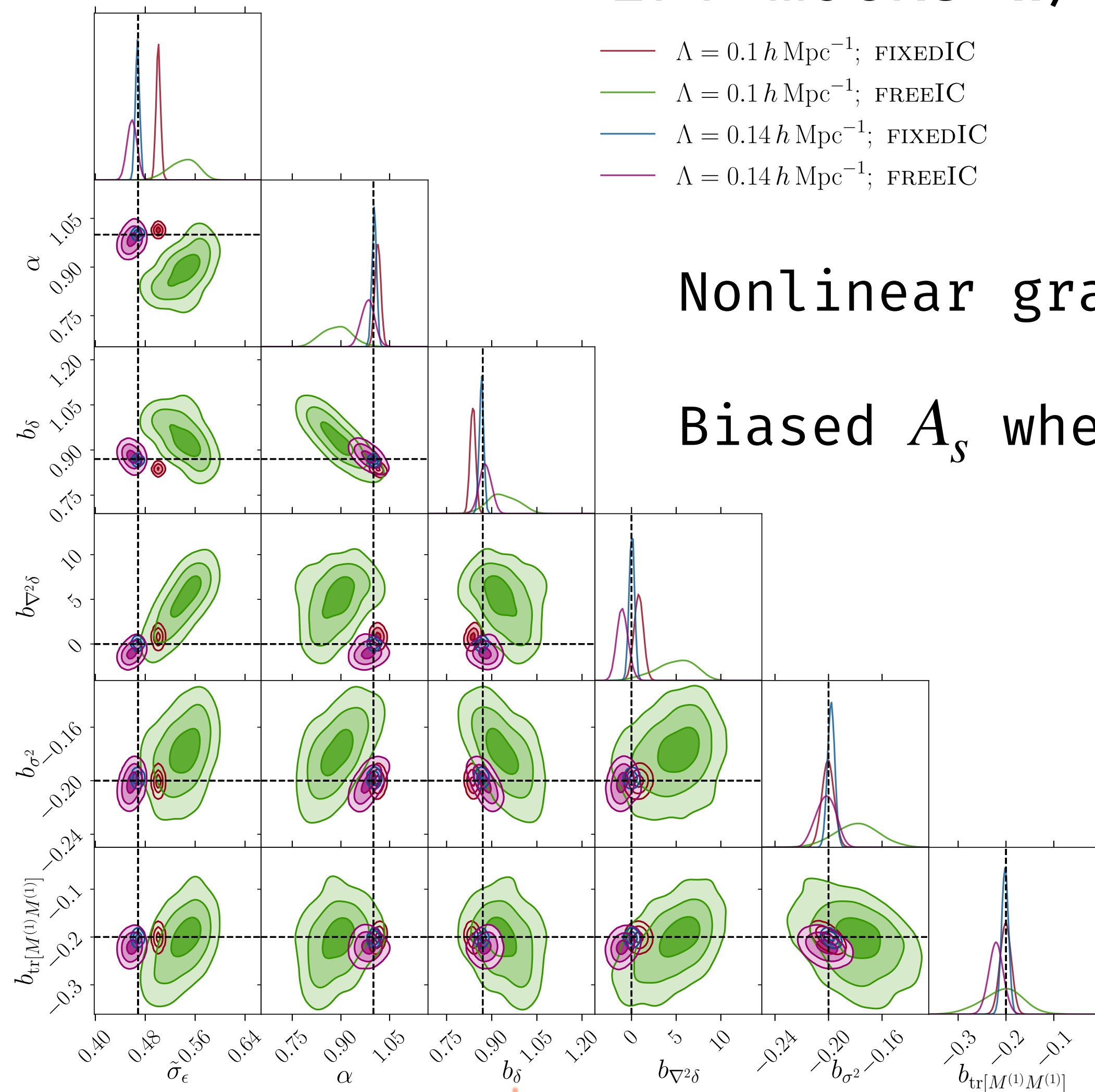
Biased A_s when nonlinear bias is involved

Kostić, MN+
2212.07875

Cosmology from Field Level, Forward Modeling:

Mock data

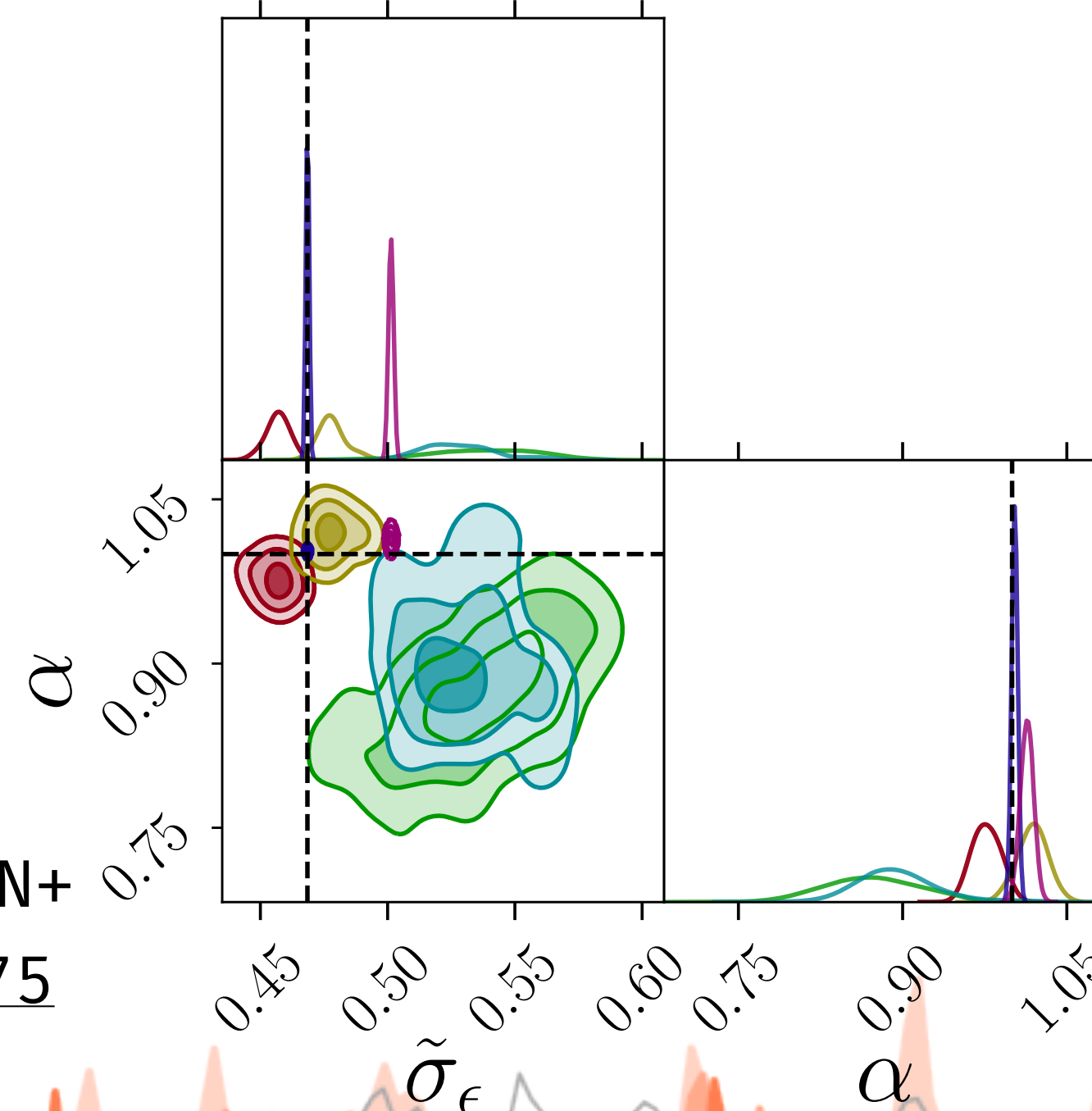
EFT mocks w/ cutoff mismatch



Nonlinear gravity, nonlinear galaxy bias

Biased A_s when nonlinear bias is involved

Kostić, MN+
2212.07875



22 Cosmology from Field Level, Forward Modeling: Summary

More and better information

Optimal cosmological inference

Proper density inference

Coming soon: New probes (galaxy momentum, intrinsic shape,...)

LEFTfield will be publicly available

Stay tuned!