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Single frequency CMB B-mode inference with realistic foregrounds from a single training image

Niall Jeffrey

François Boulanger, Benjamin Wandelt,
Bruno Regaldo-Saint Blancard, Erwan Allys, François Levrier

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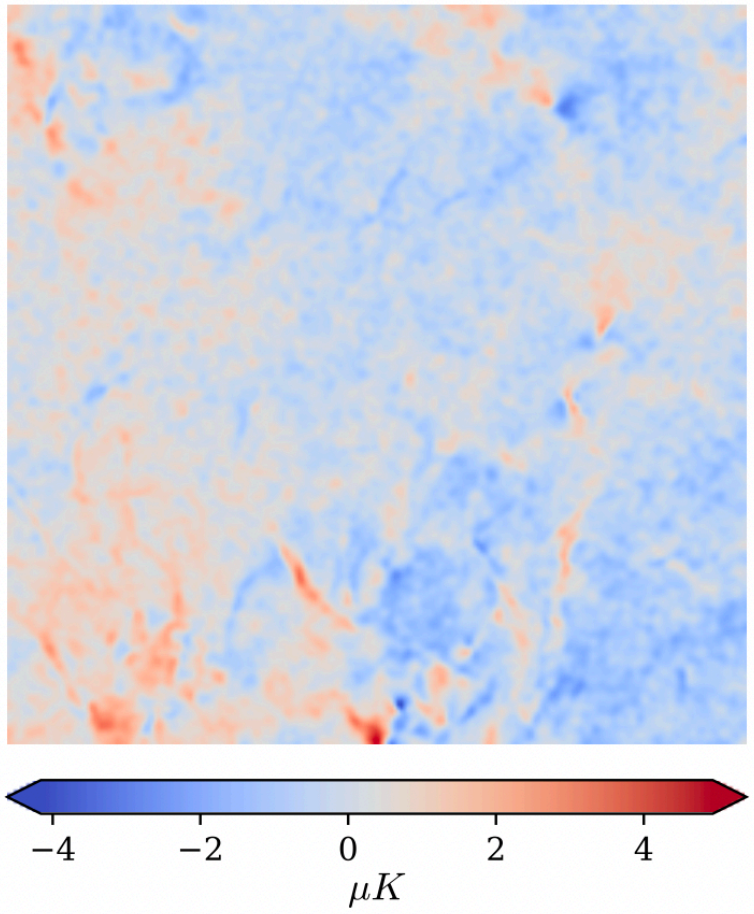
B-mode inference

B-mode data



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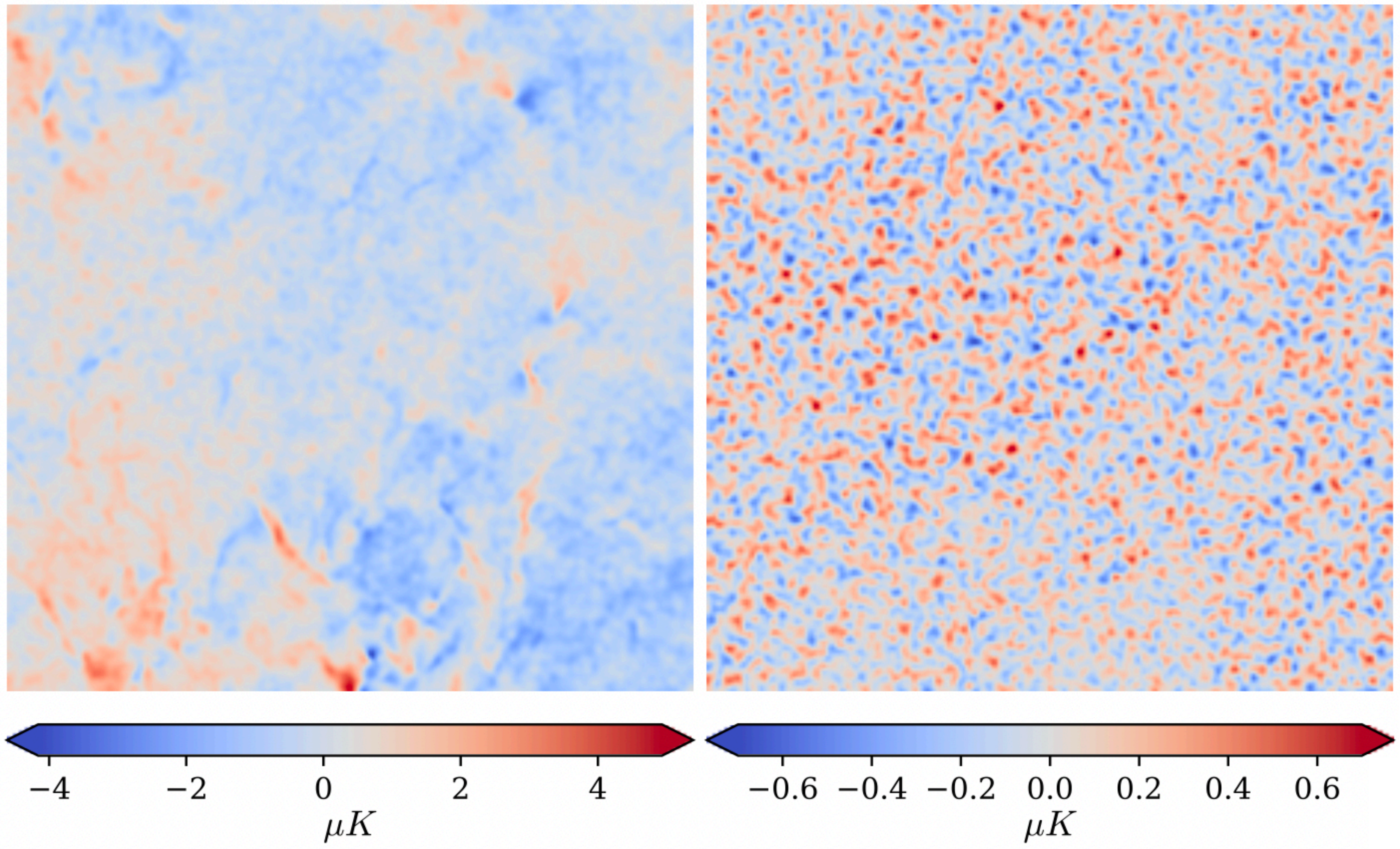
B-mode inference

B-mode data

Posterior mean



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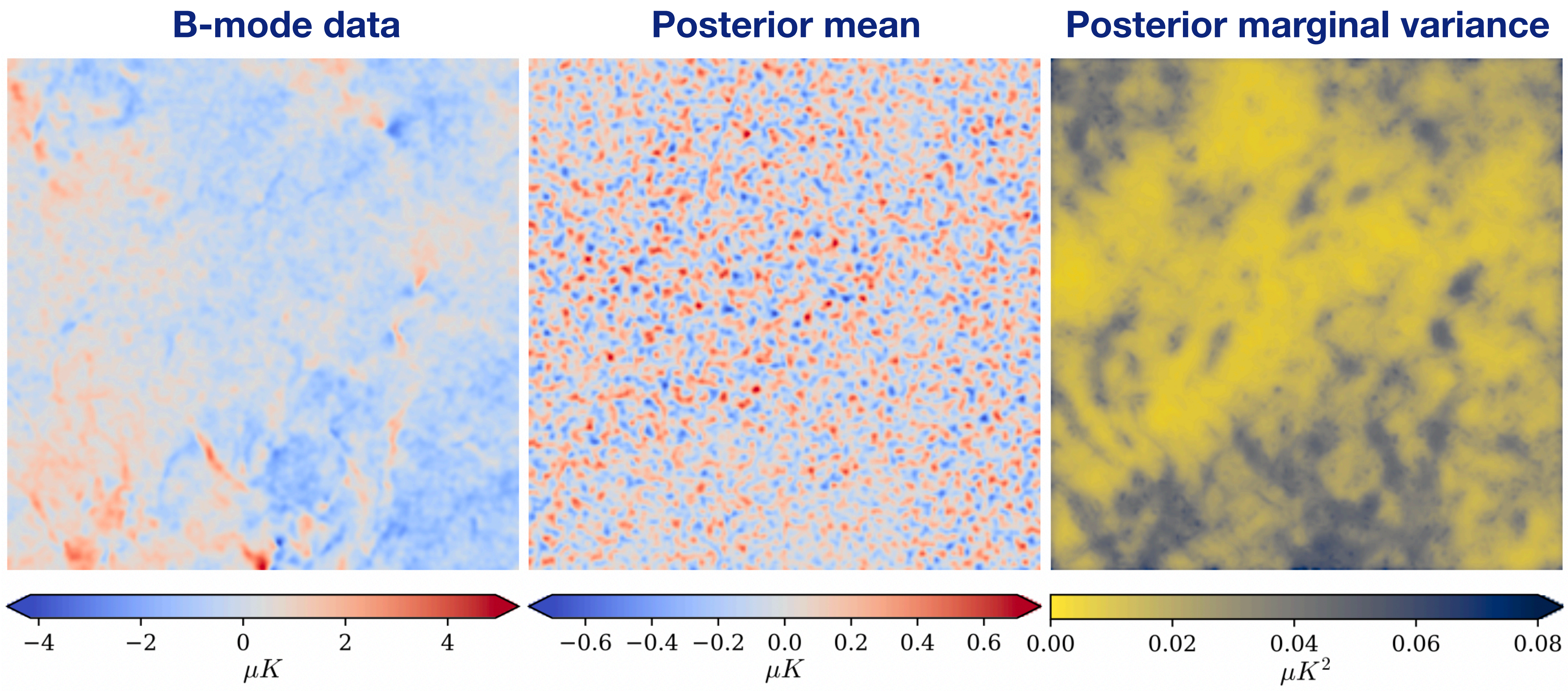

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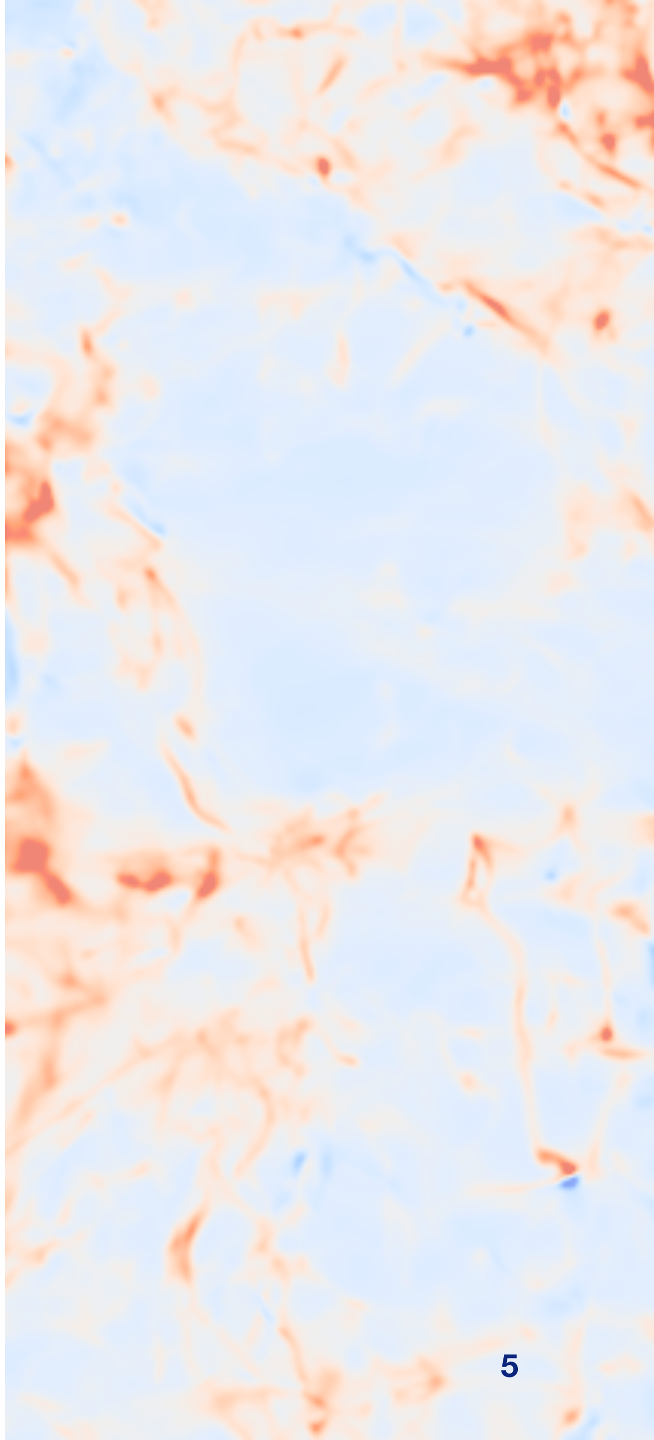
Outline

1. ***High-dimensional likelihood-free inference***

2. ***Realistic forward model***

3. ***Posterior validation***



01

High-dimensional likelihood-free:
Moment Networks

Parameter inference

1. Possible “data” $\mathbf{d}$

2. Unknown parameters: $\mathbf{s}$ signal

$$p(\mathbf{s}\,|\,\mathbf{d}) \propto p(\mathbf{d}\,|\,\mathbf{s})\; p(\mathbf{s})$$

Likelihood-free inference

$$\{\mathbf{d}_i, \mathbf{s}_i\}$$

I. $\mathbf{d}_i$ are simulated data vector summary statistics (inc. noise)

II. Draw $\mathbf{d}_i$ from the distribution $p(\mathbf{d} \mid \mathbf{s}_i)$ by running a simulation

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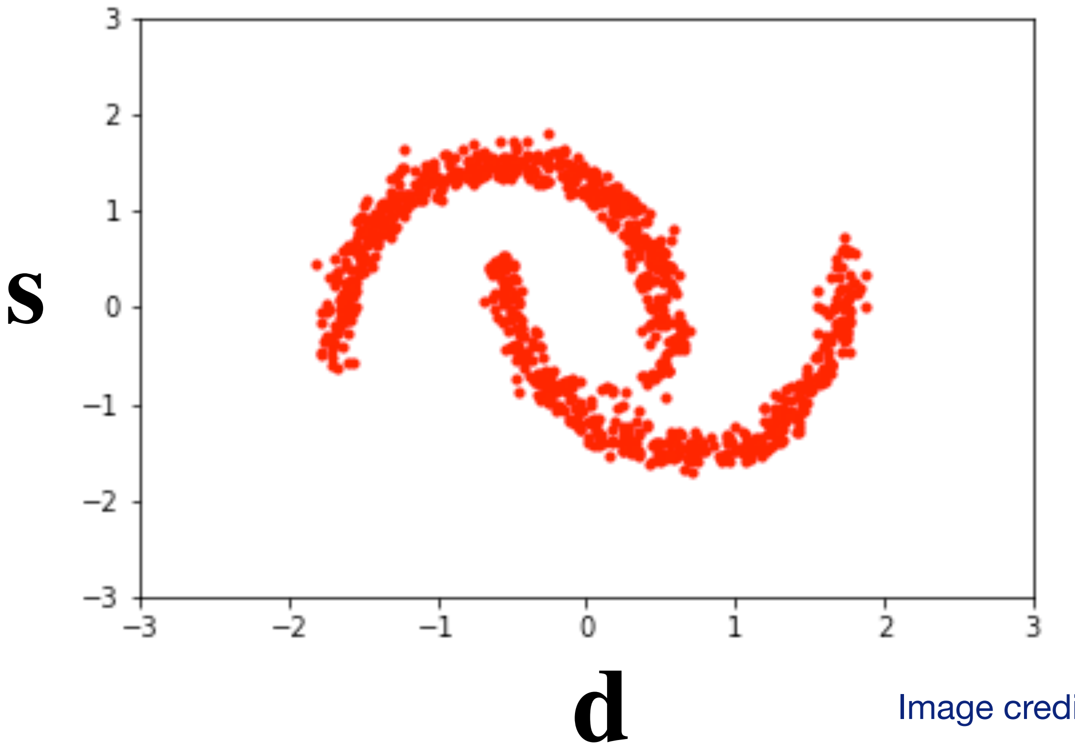

Image credit: Eric Jang

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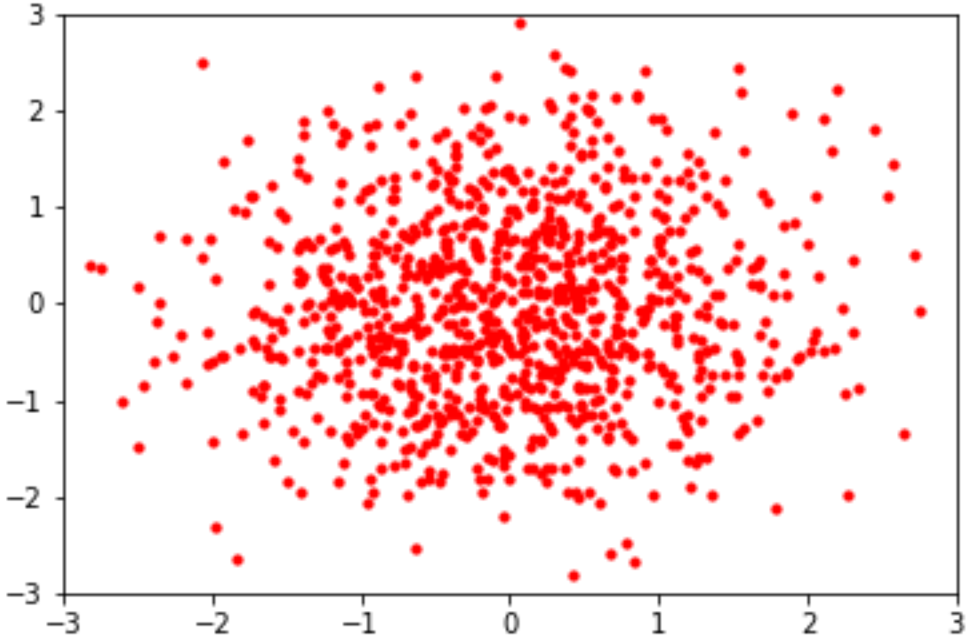
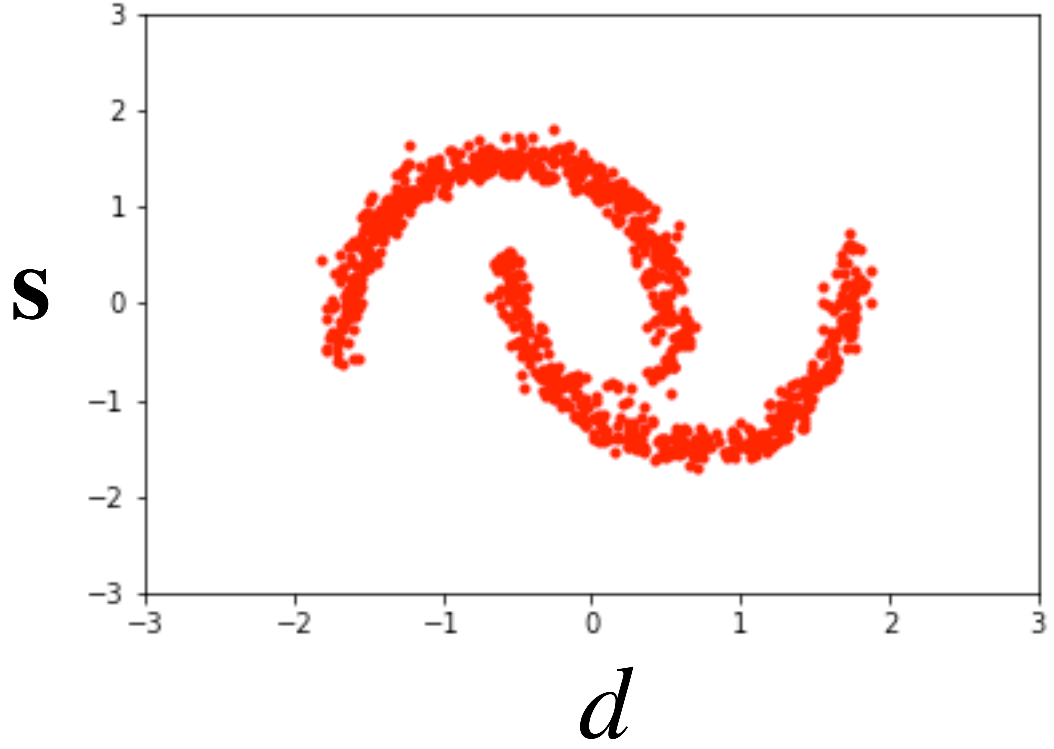
Normalizing flow

Neural density estimation method





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Moment Network:

Side-step density estimation for likelihood-free inference

NJ & Wandelt 2011.05991

Moment Network:
Side-step density estimation for likelihood-free inference

NJ & Wandelt 2011.05991

I. Hierarchy of Networks

II. Optimization objective use square loss

$$J_0 = \int ||\boldsymbol{s} - \mathcal{F}(\boldsymbol{d})||^2 p(\boldsymbol{d}, \boldsymbol{s})\, \mathrm{d}\boldsymbol{d}\, \mathrm{d}\boldsymbol{s}$$

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Moment Network:
Side-step density estimation for likelihood-free inference

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$$J_1 = \int ||(\boldsymbol{s} - \mathcal{F}_{\text{fixed}}(\boldsymbol{d}))^2 - \mathcal{G}(\boldsymbol{d})||^2 p(\boldsymbol{d}, \boldsymbol{s})\ \mathrm{d}\boldsymbol{d}\ \mathrm{d}\boldsymbol{s}$$

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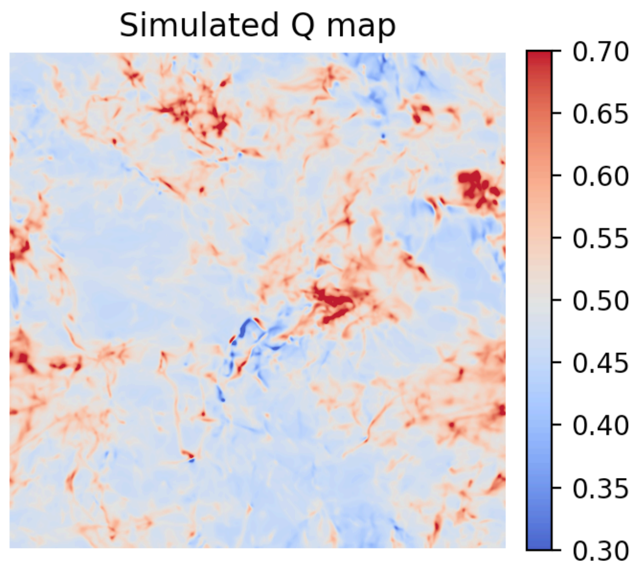
02

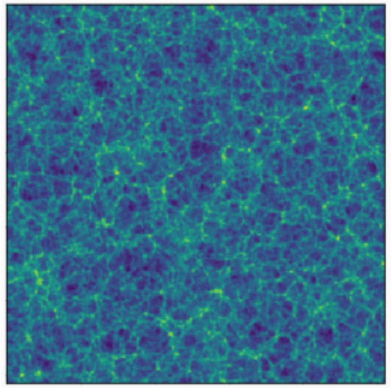
Forward model &
B-mode inference

Generative model for data?

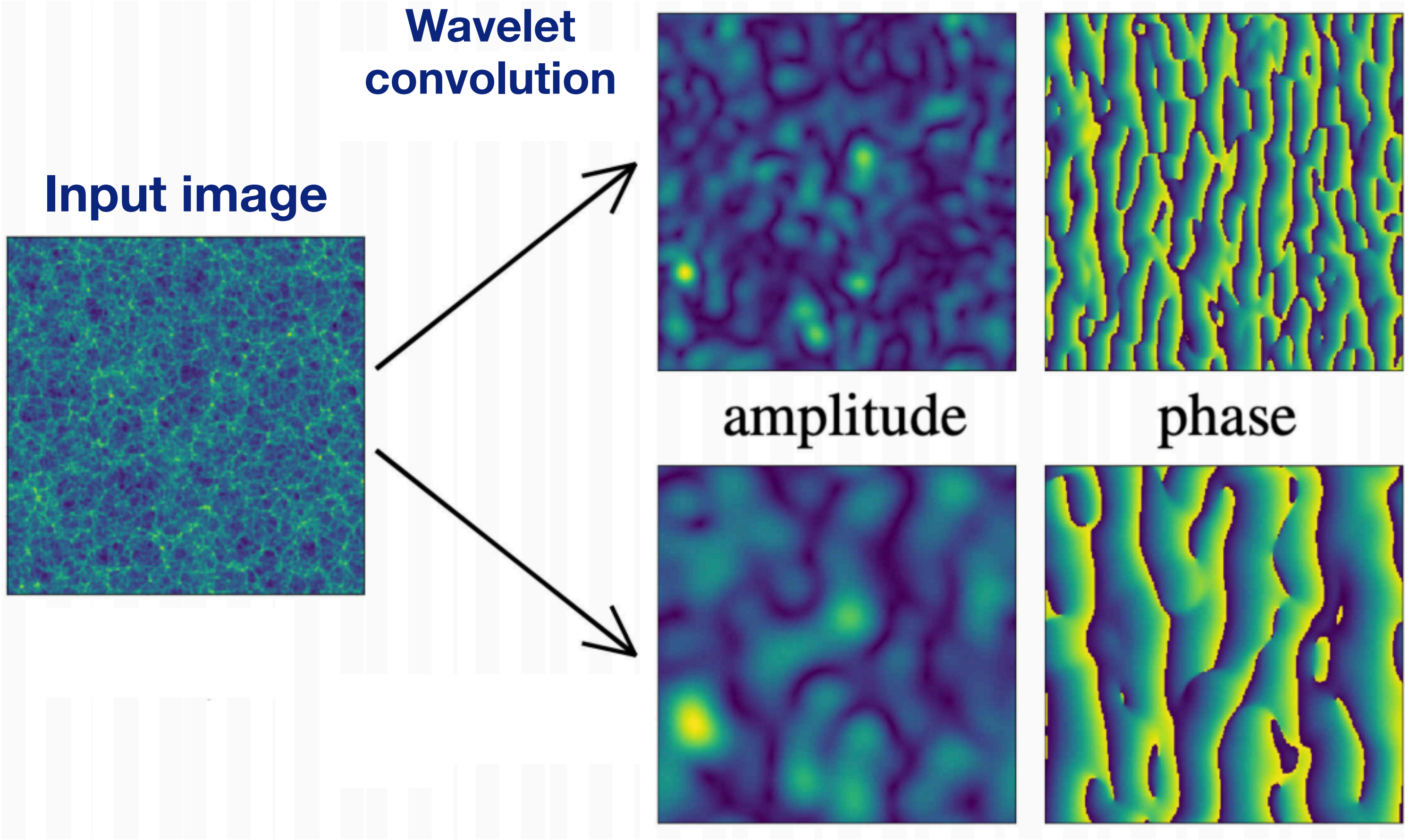


Wavelet Phase Harmonics

Input image

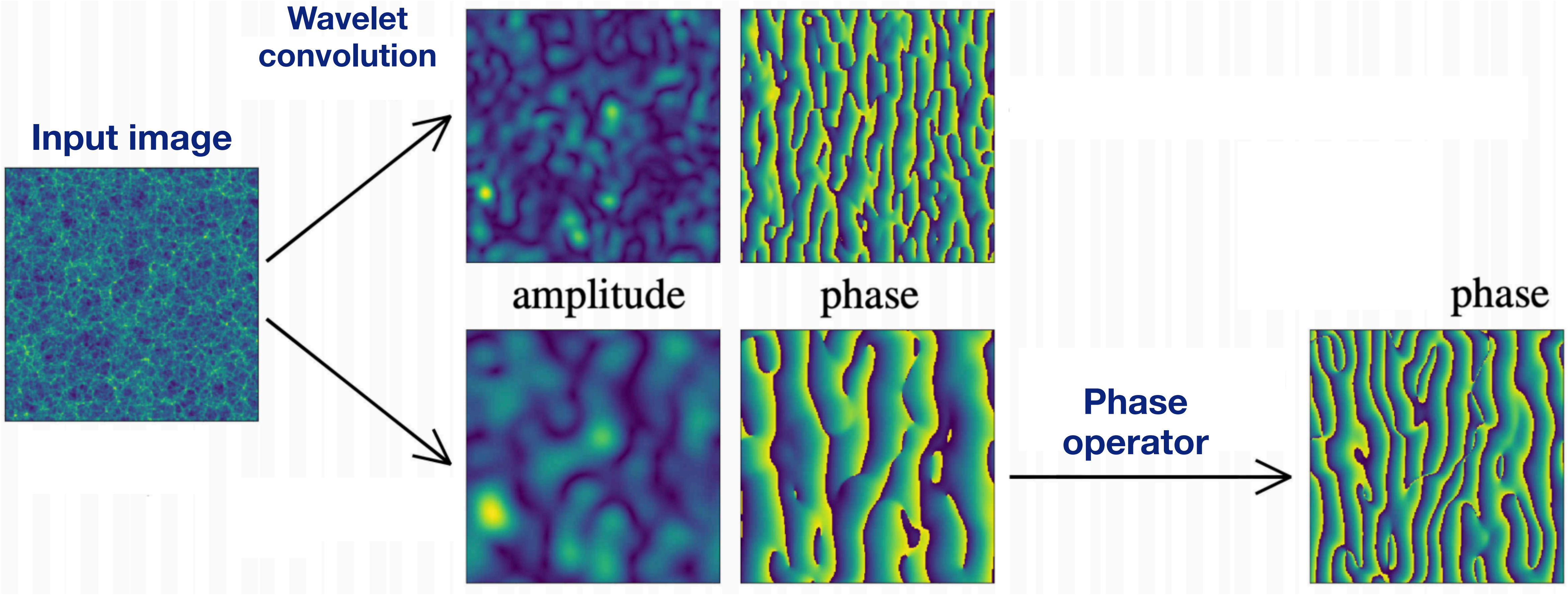


Wavelet Phase Harmonics



(adapted from Allys++ 2006.06298)

Wavelet Phase Harmonics



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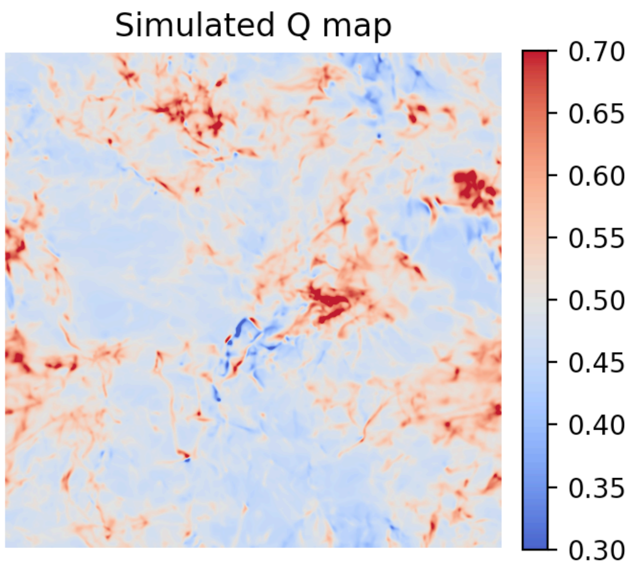
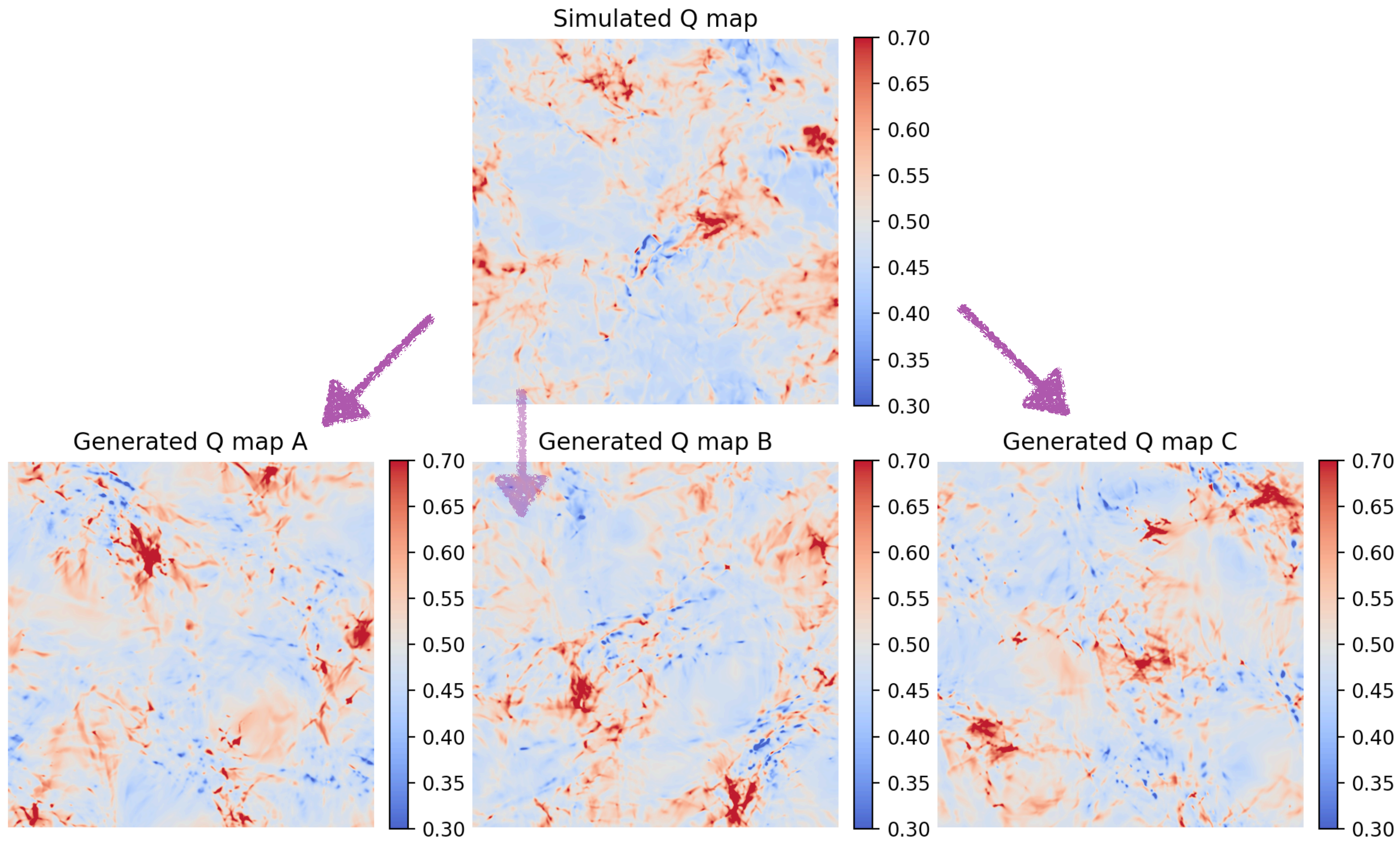
Generative model for data



Generative model for data



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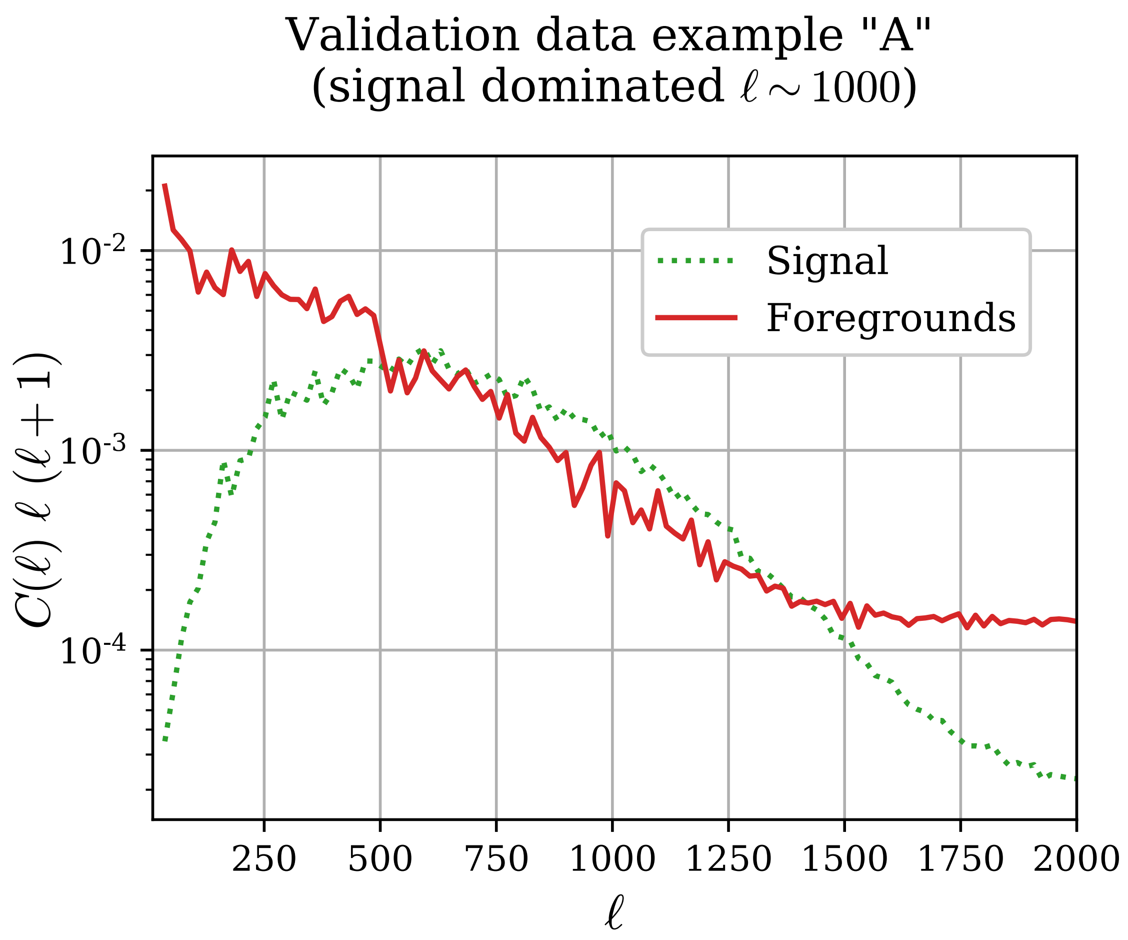
Model parameters from prior



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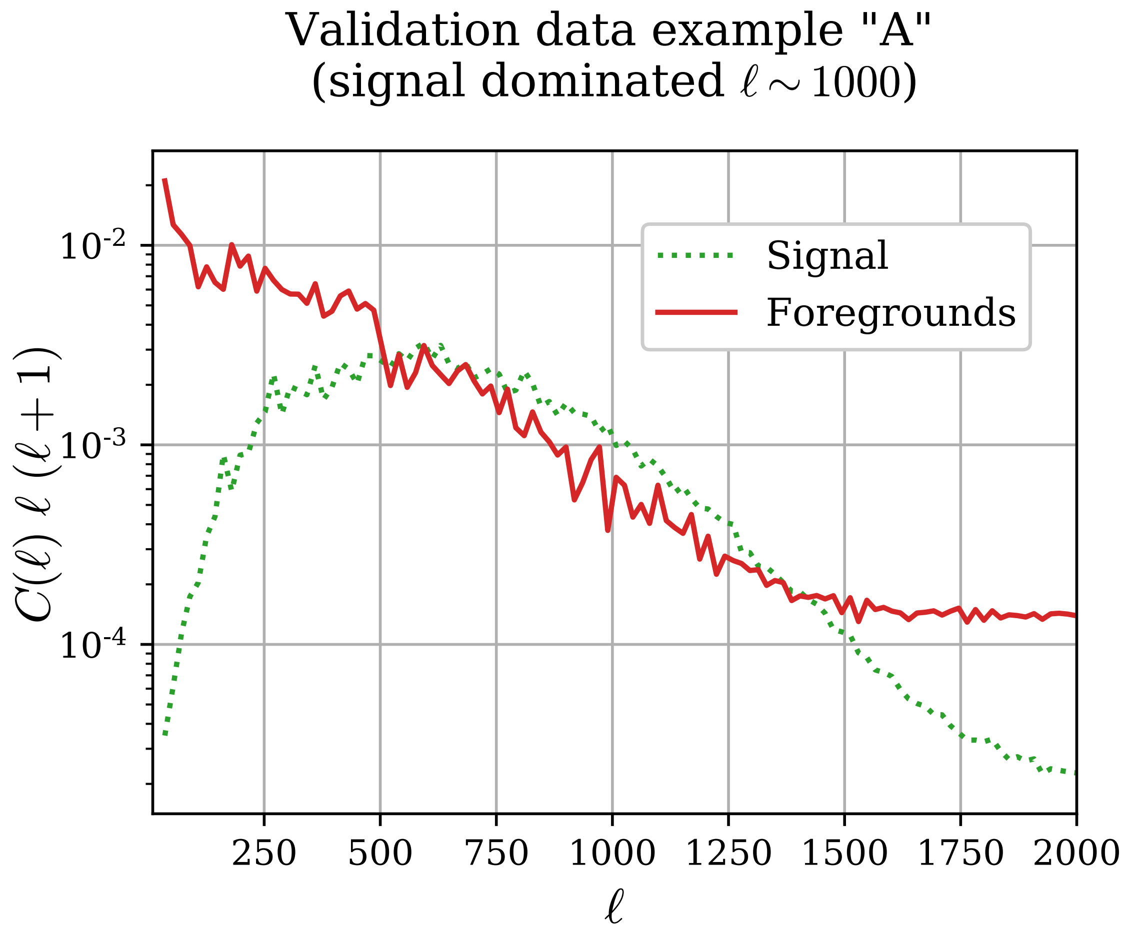

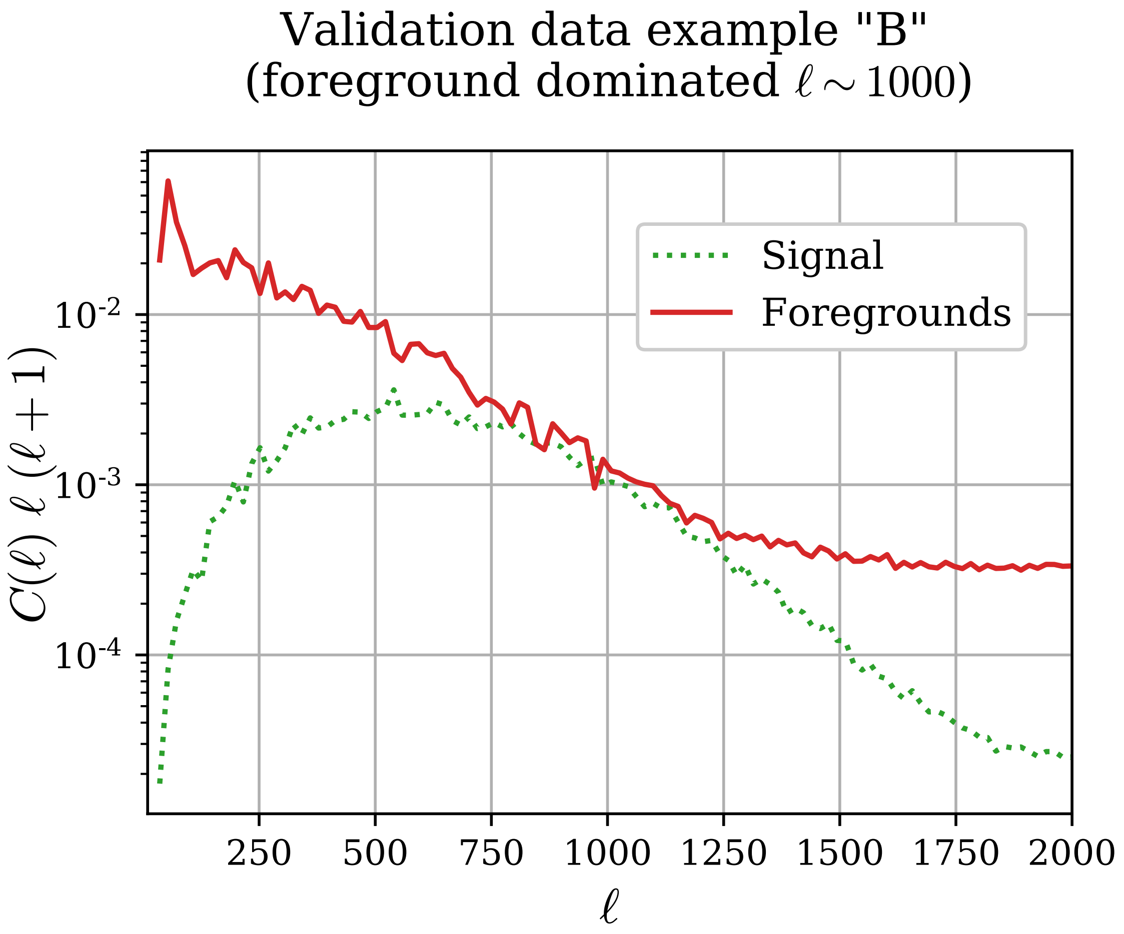

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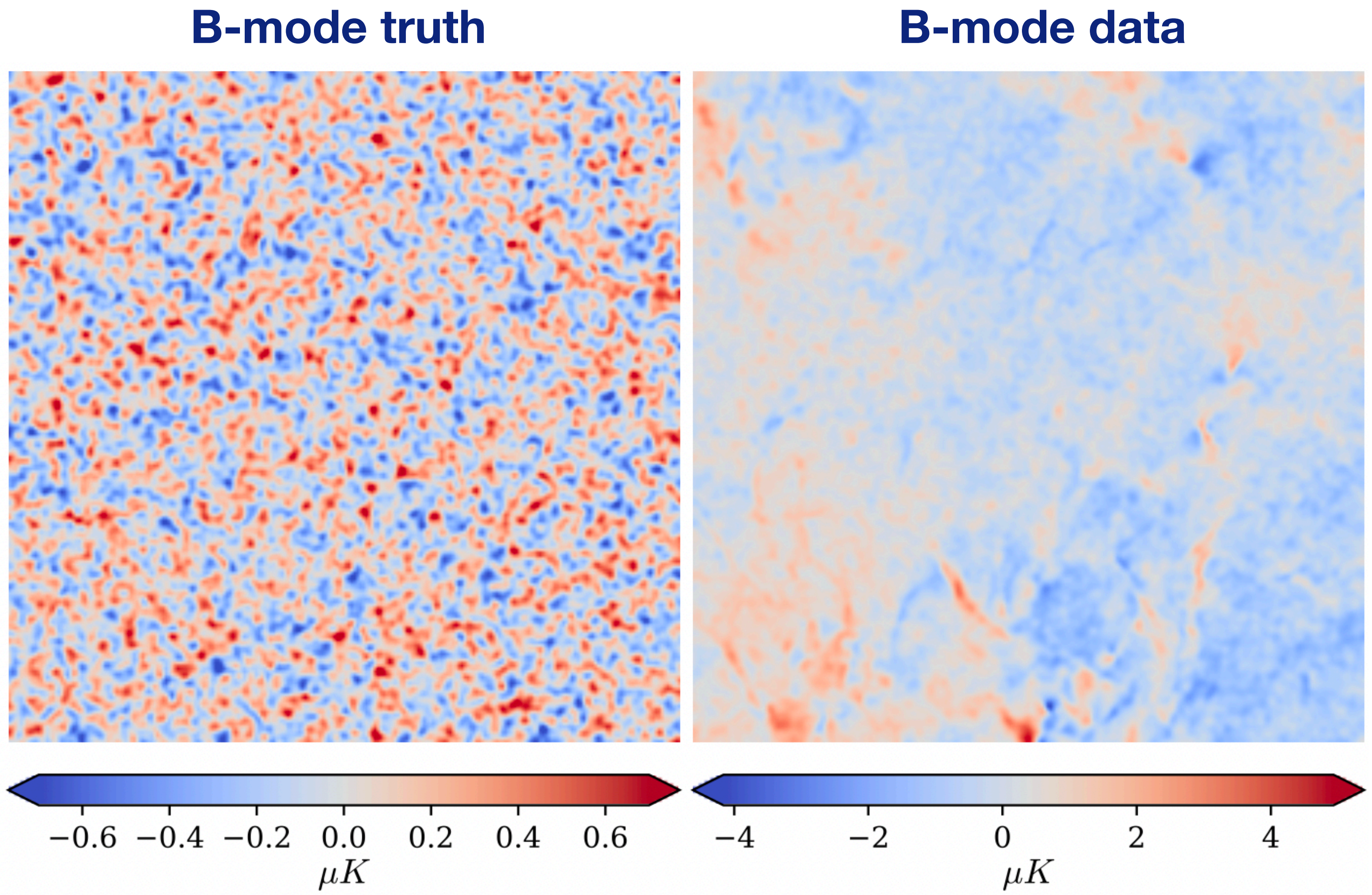
B-mode inference



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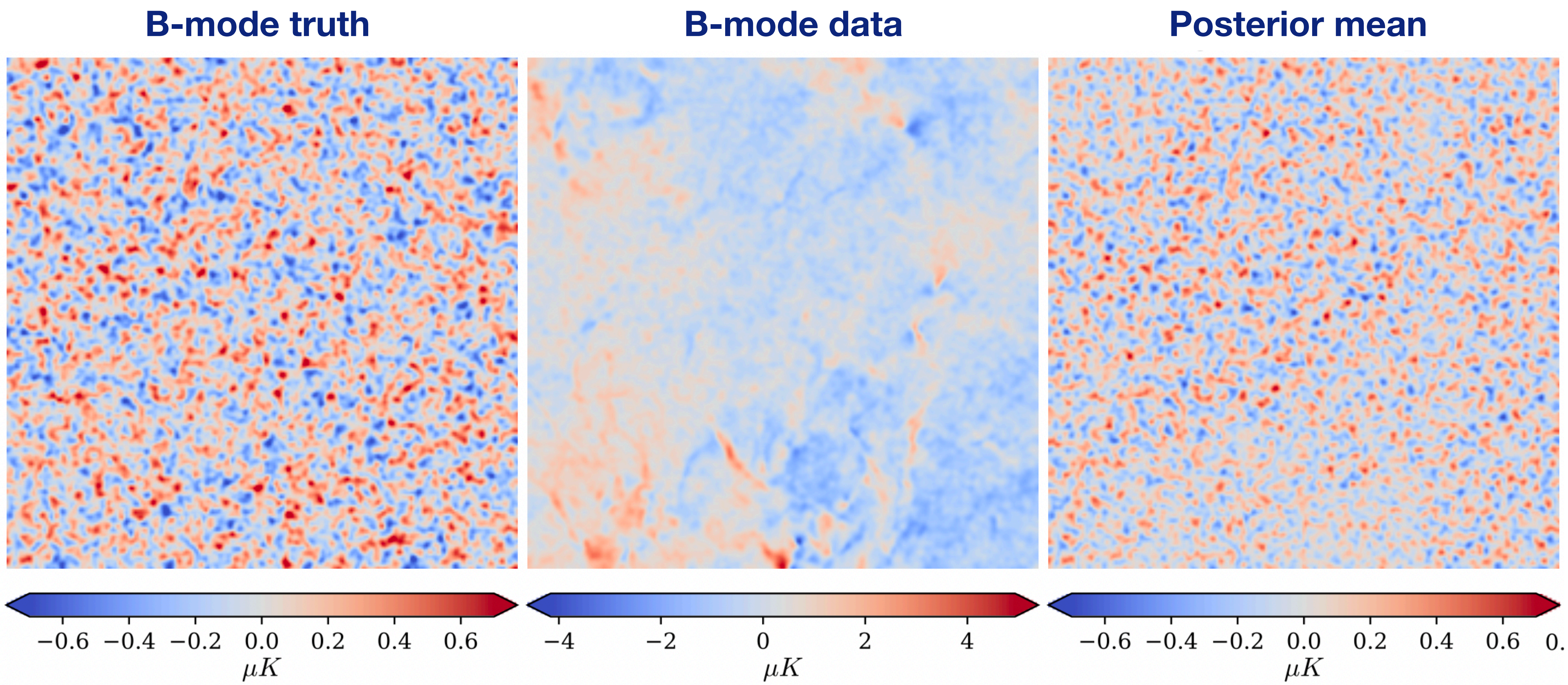
B-mode inference



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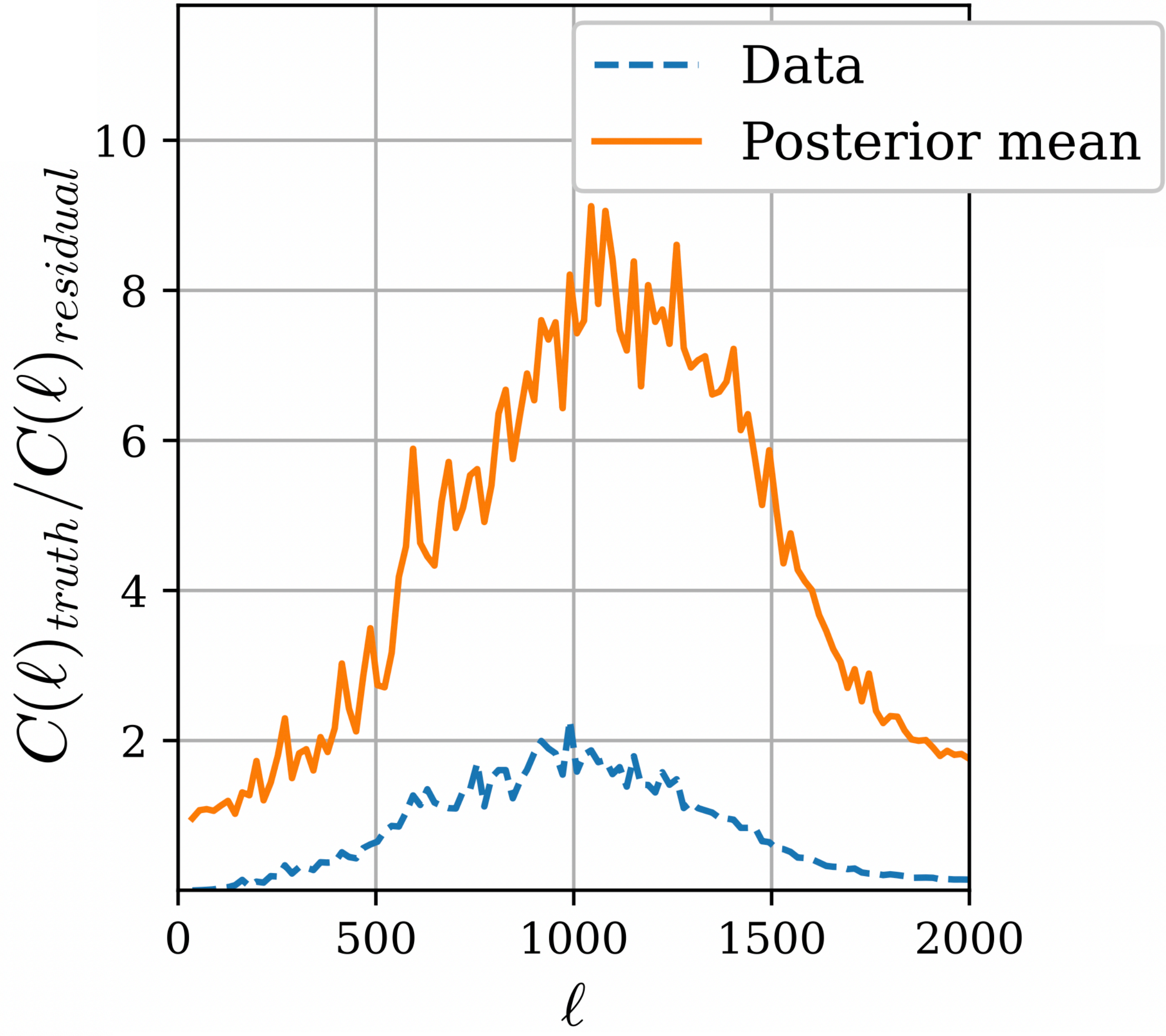
Recovered "signal-to-noise"



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03

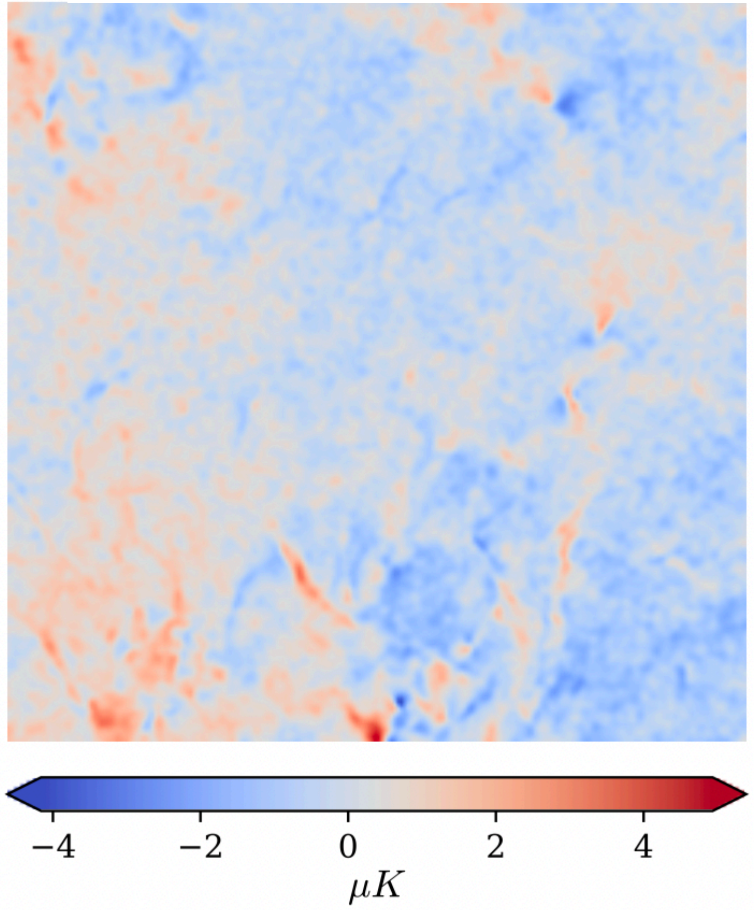
Posterior validation

How can we test the posterior?

What does the “wrong” answer look like…

Naive Gaussian model:

B-mode data



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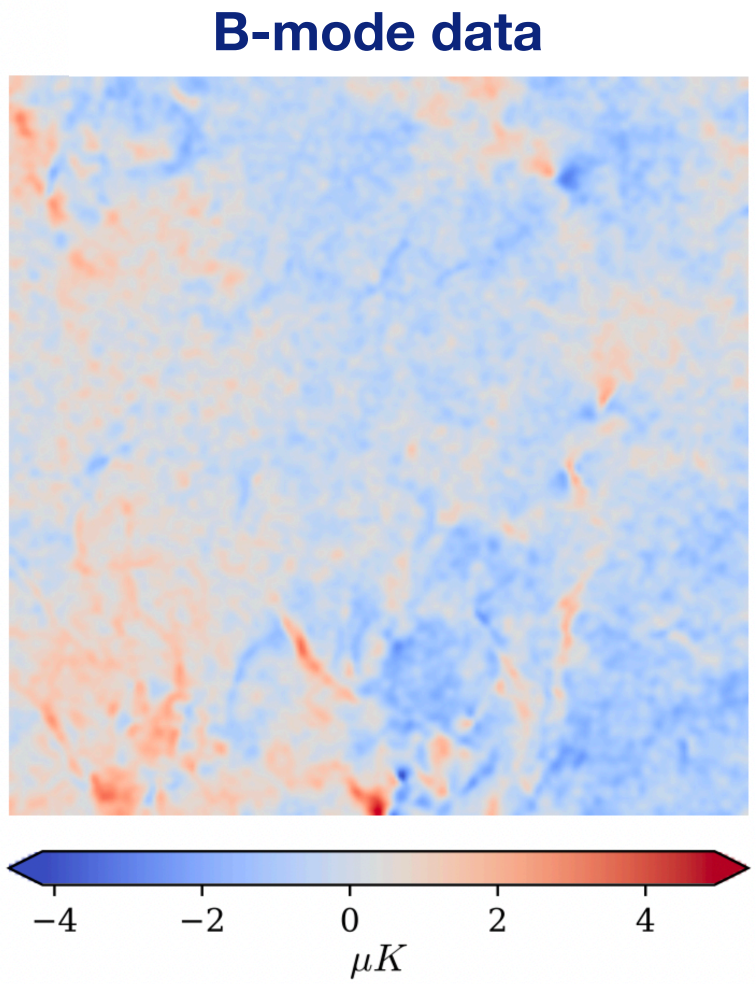
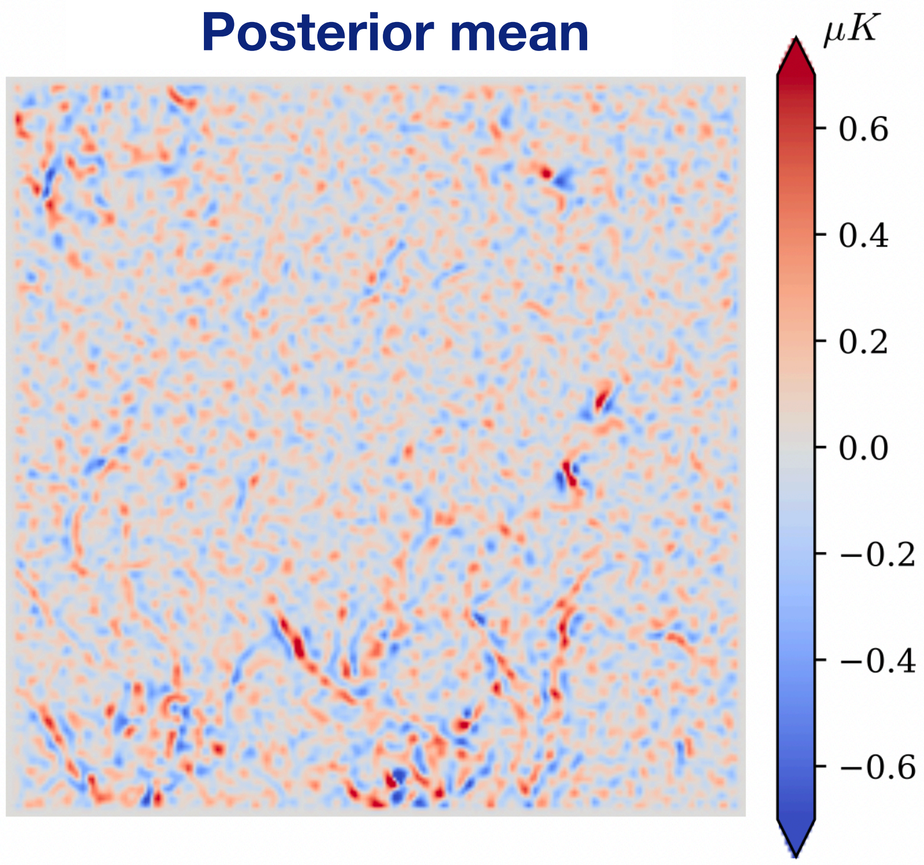
Naive Gaussian model:





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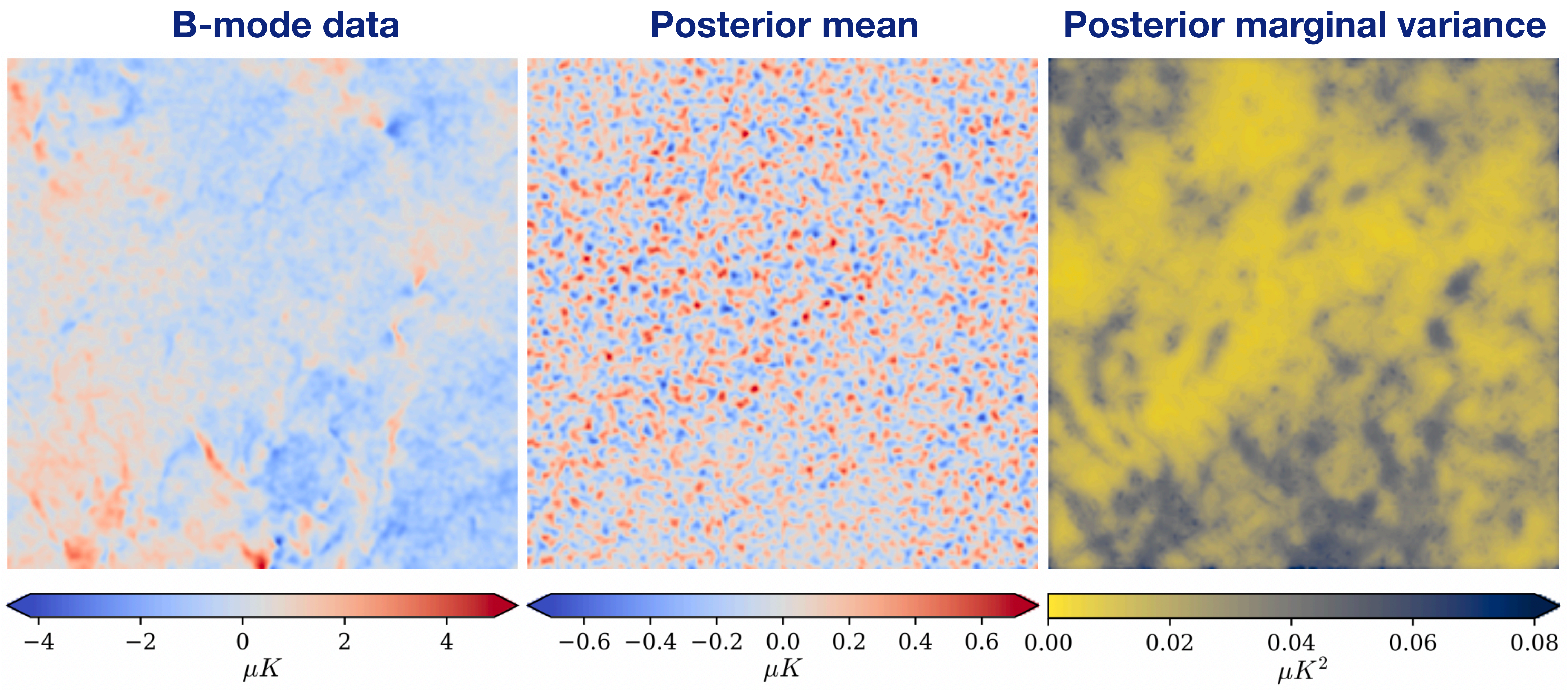
Validation of posterior



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Rescaled residuals

$$(\mu_B - s_B)/\sigma_B$$

POSTERIOR MEAN

TRUE PIXEL VALUE

POSTERIOR VARIANCE

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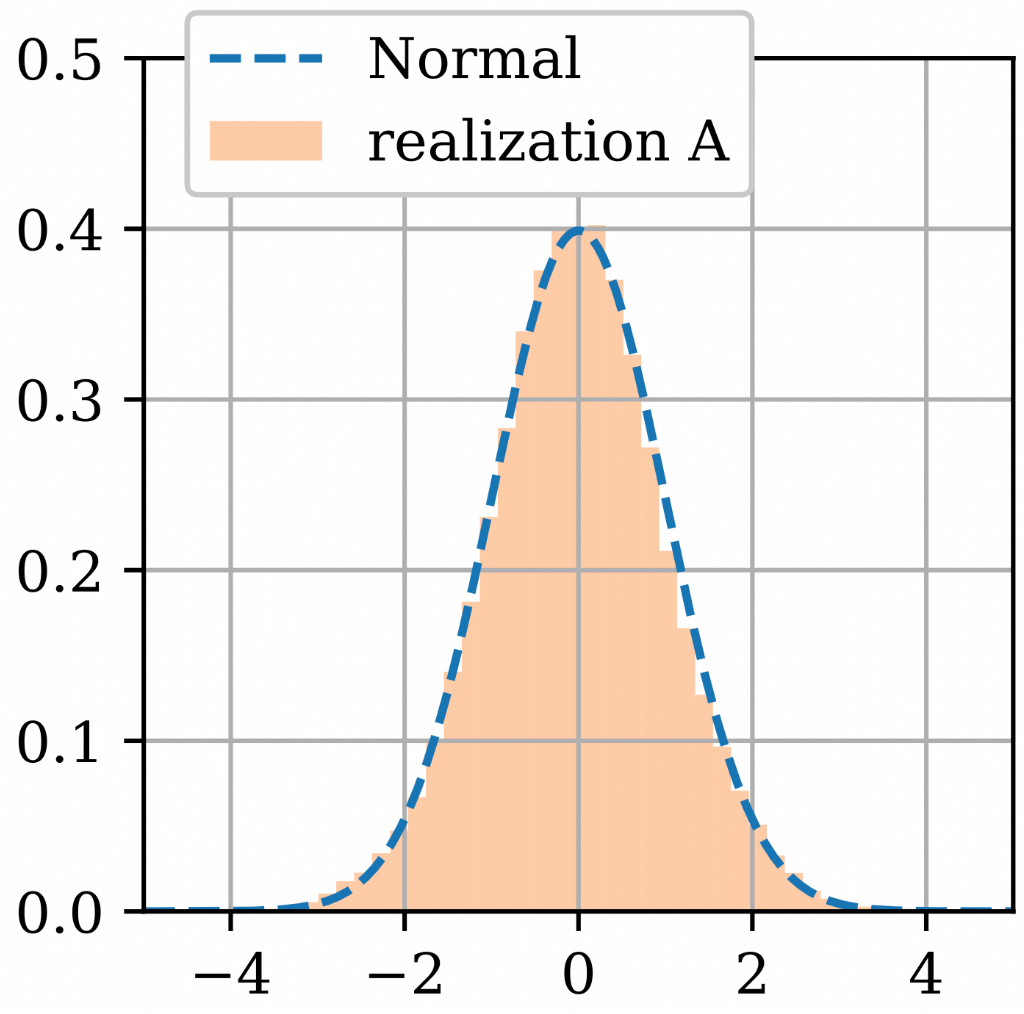
Rescaled residuals



$$(\mu_B - s_B)/\sigma_B$$

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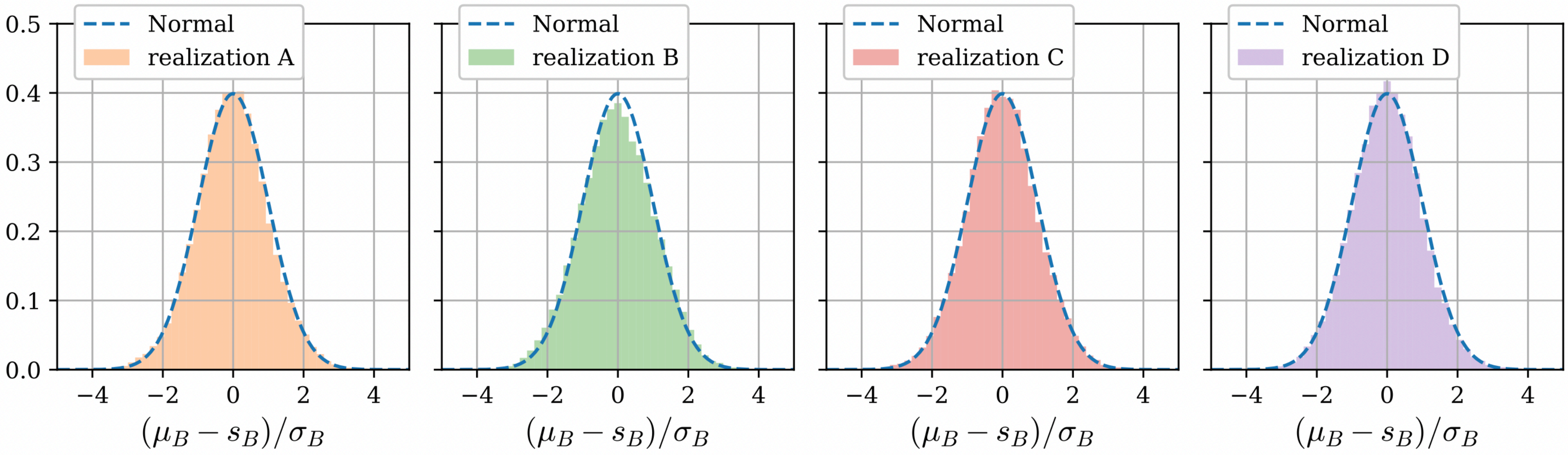
Posterior estimates are excellent:



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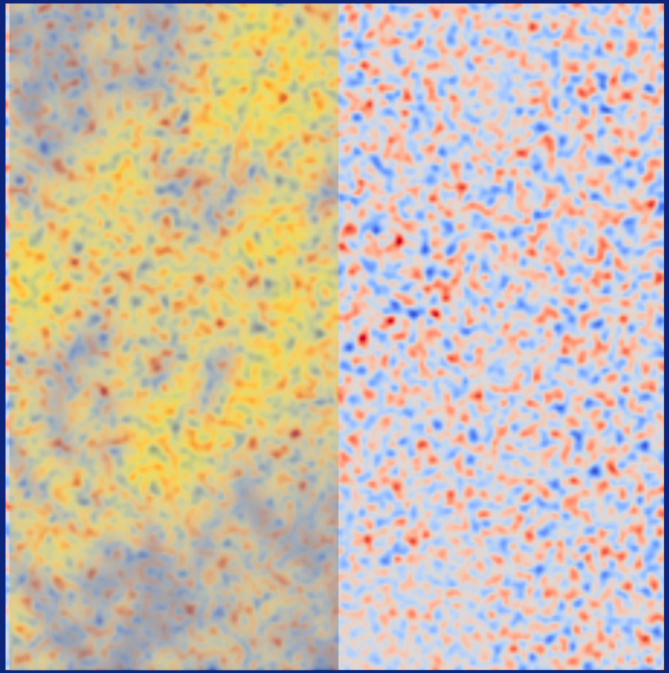
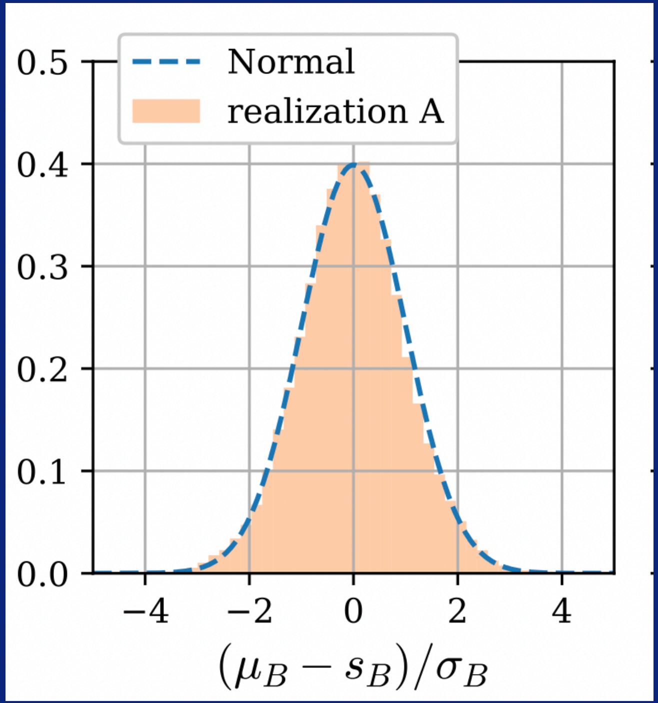


Merci !



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