



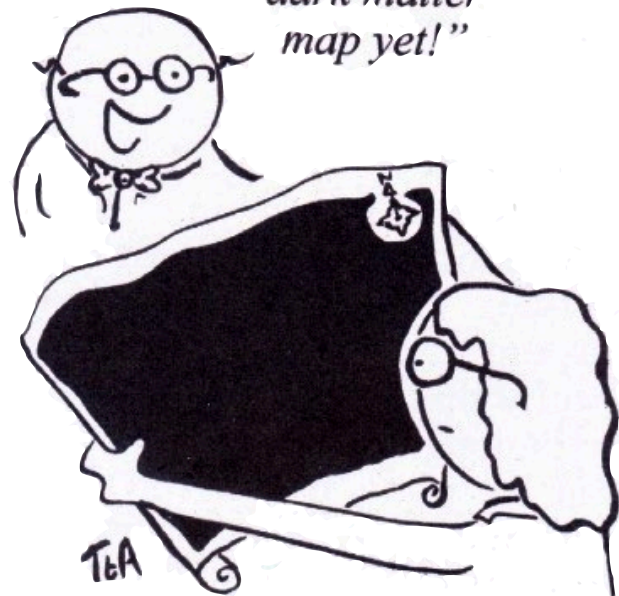
UCL

Dark Energy Survey Year 3 results: simulation-based inference with weak-lensing maps

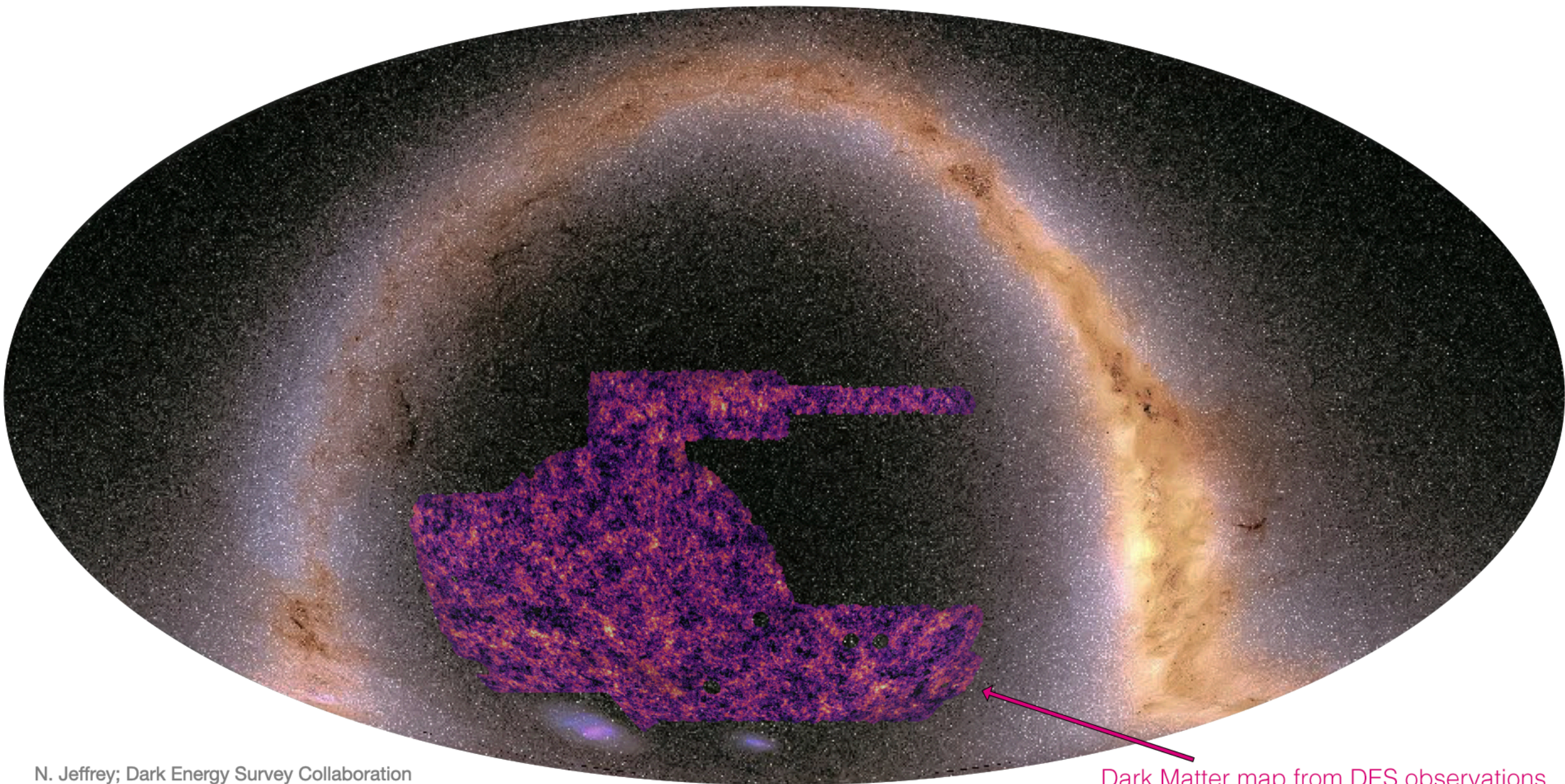
Niall Jeffrey

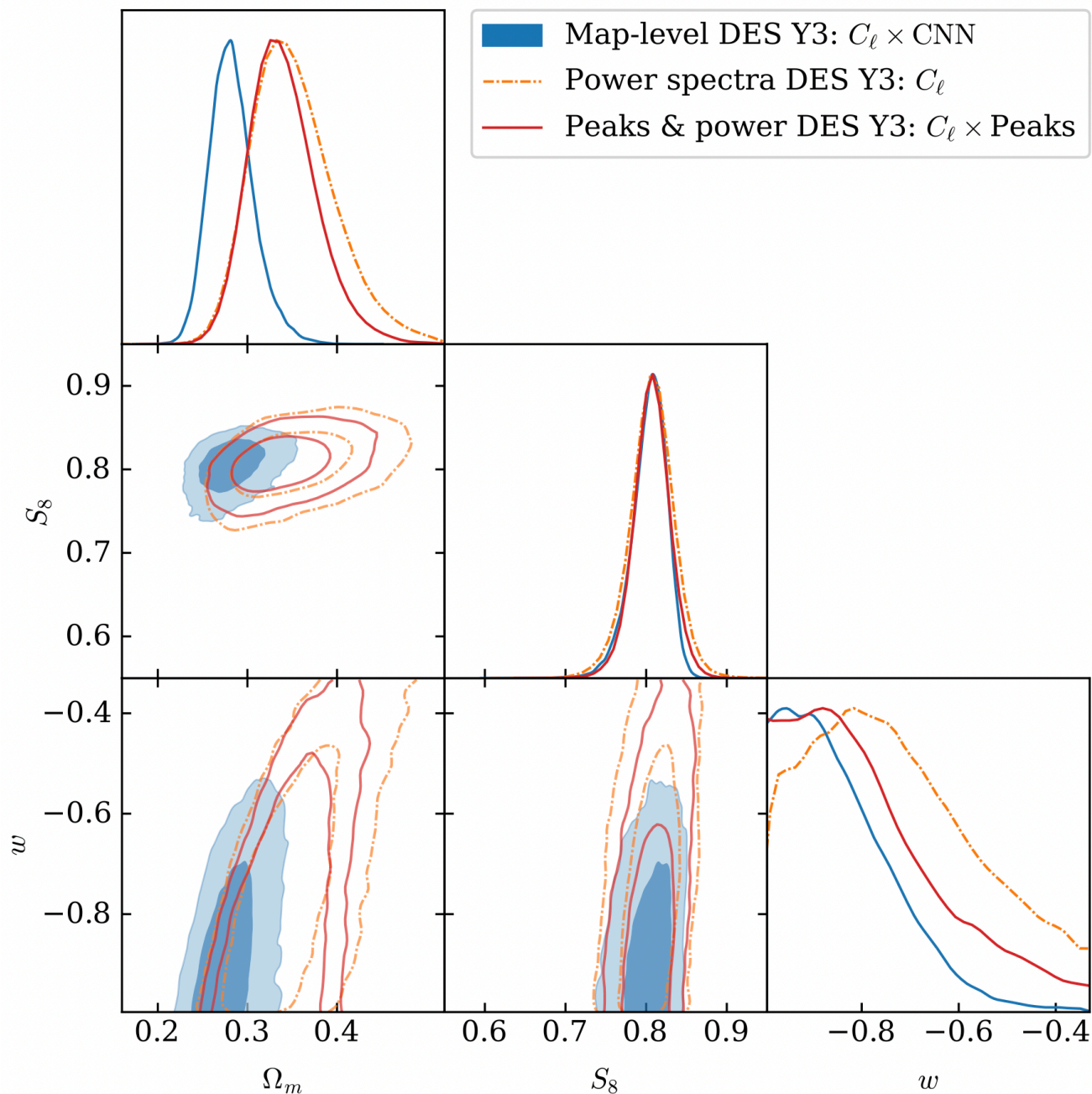
he/him, n.jeffrey@ucl.ac.uk

*"It's our most
comprehensive
dark matter
map yet!"*



<https://arxiv.org/abs/2403.02314>; NJ et al. DES Collaboration





Precision

+

Accuracy

Outline

1. Simulation-based inference
2. Modelling with the Gower St Simulations
3. Results — how do I know this is right?

1. Simulation-based inference

Astrophysics and Cosmology: questions

S_8 ?

Λ ?


H_0 ?

galaxy evolution


Astrophysics and Cosmology: data

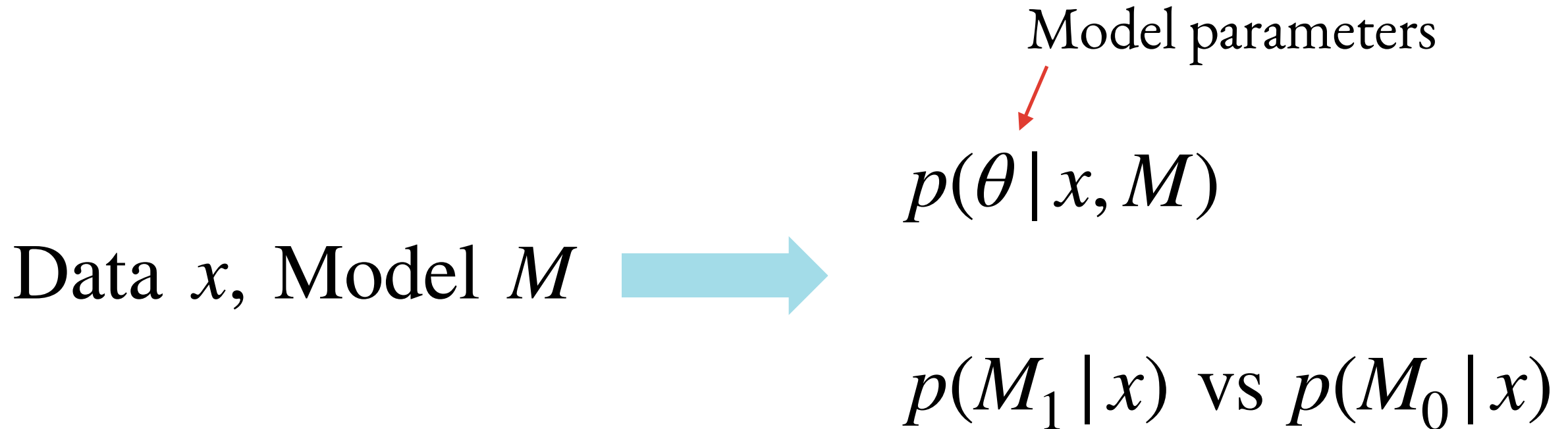
Data x , Model M 

Data x , Model M 

Model parameters

 $p(\theta | x, M)$

Data x , Model M 

Model parameters

 $p(\theta | x, M)$
 $p(M_1 | x)$ vs $p(M_0 | x)$



Parameter inference:

“Likelihood”



$$p(\theta | x, M) \propto p(x | \theta, M) p(\theta | M)$$

Likelihood-free inference

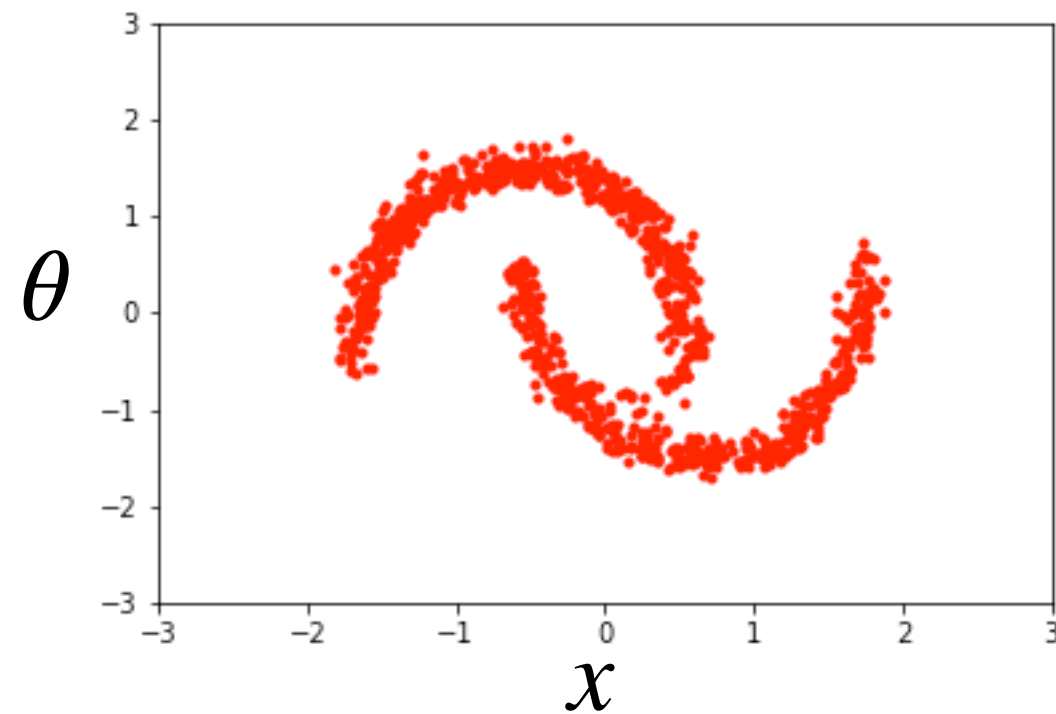
$$p(x | \theta) ?$$

Draw x_i from the distribution $p(x | \theta_i)$ by running a simulation:

$$\{x_i, \theta_i\}$$

$$p(x | \theta) ?$$

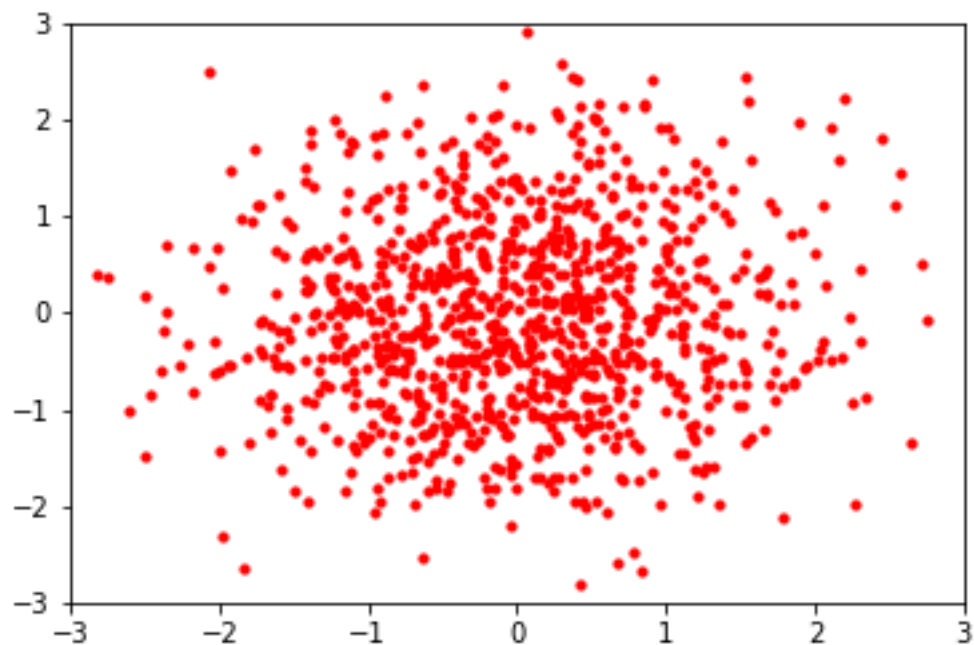
Image credit: Eric Jang



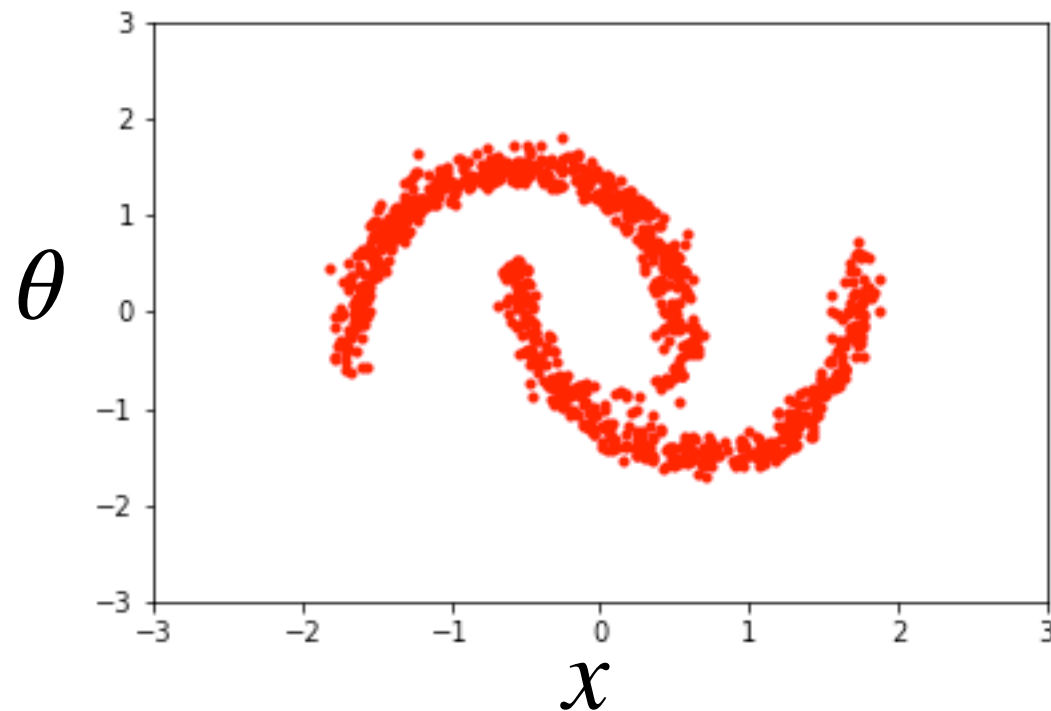
Simulated data

e.g. DELFI: Alsing et al. 1903.00007

$$p(x | \theta) ?$$



Normalising Flow



Simulated data

Simulation-based inference in astrophysics

1. Simulate mock data
2. Compress mock data (optional)
3. Estimate likelihood or posterior
4. Evaluate for observed data

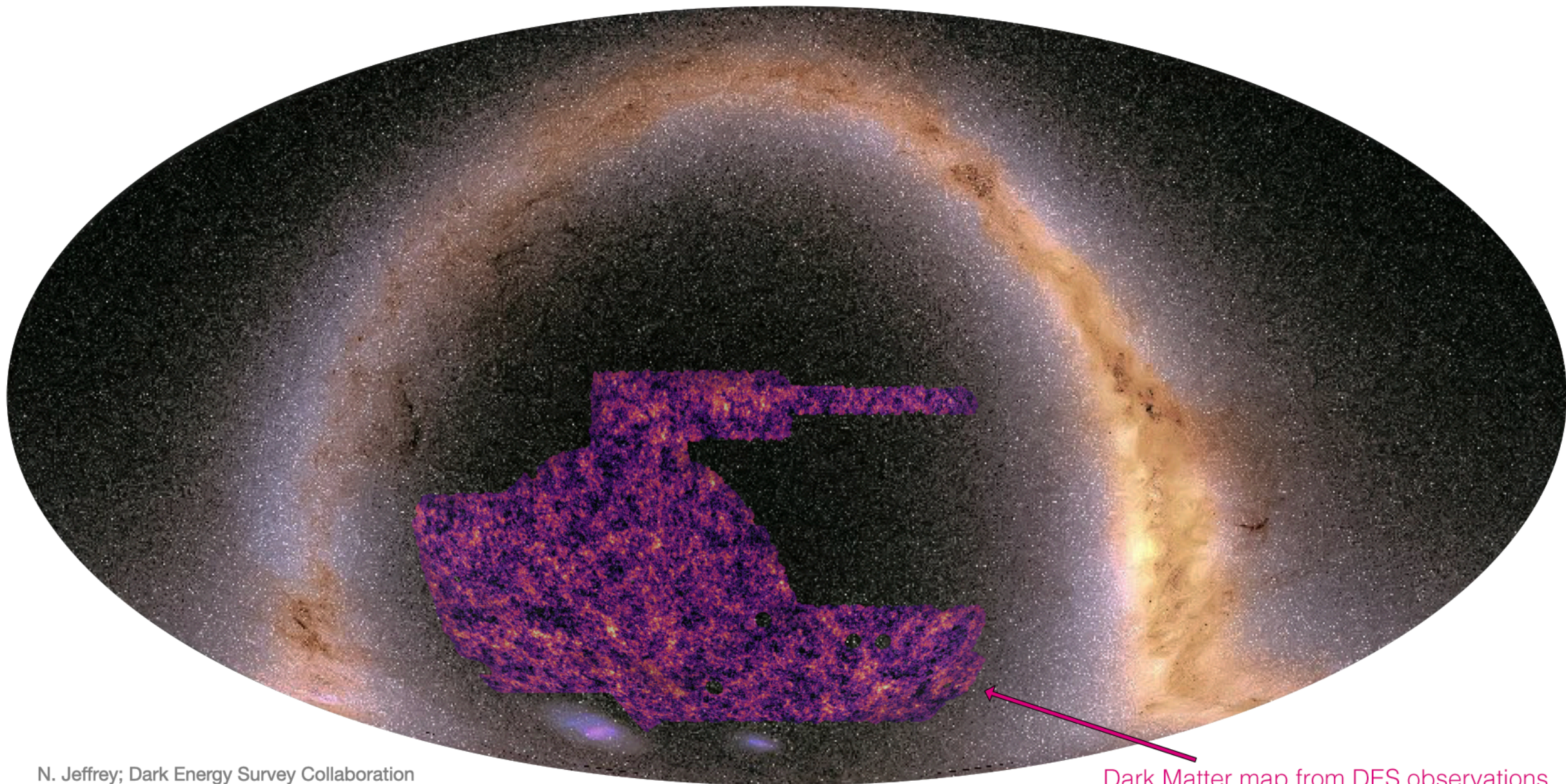
2. Forward-modelling with the Gower Street simulations

Accuracy

Realistic forward modelling
+
Simulation-based inference

Precision

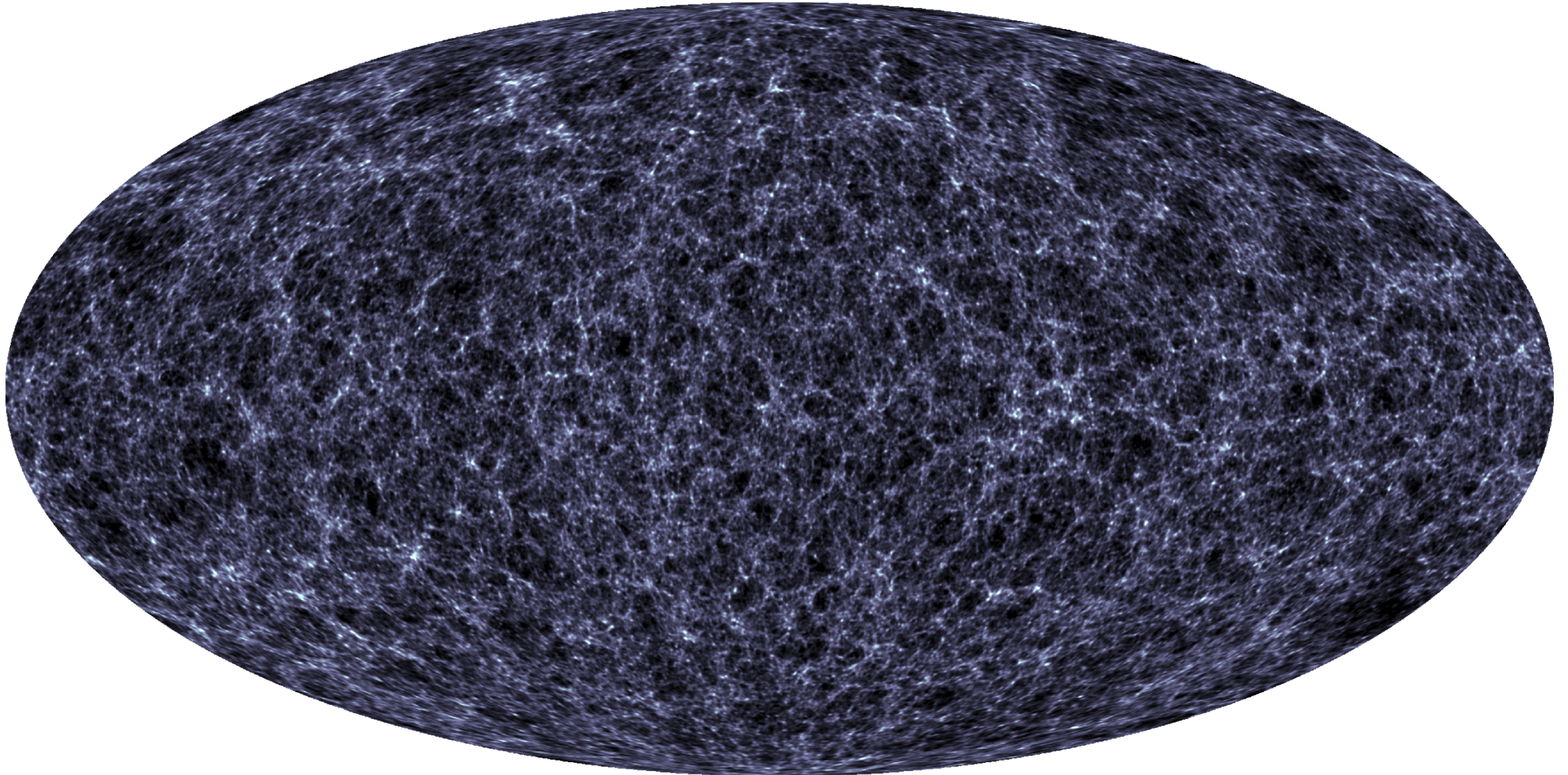
Beyond standard statistics
(e.g. power spectra)



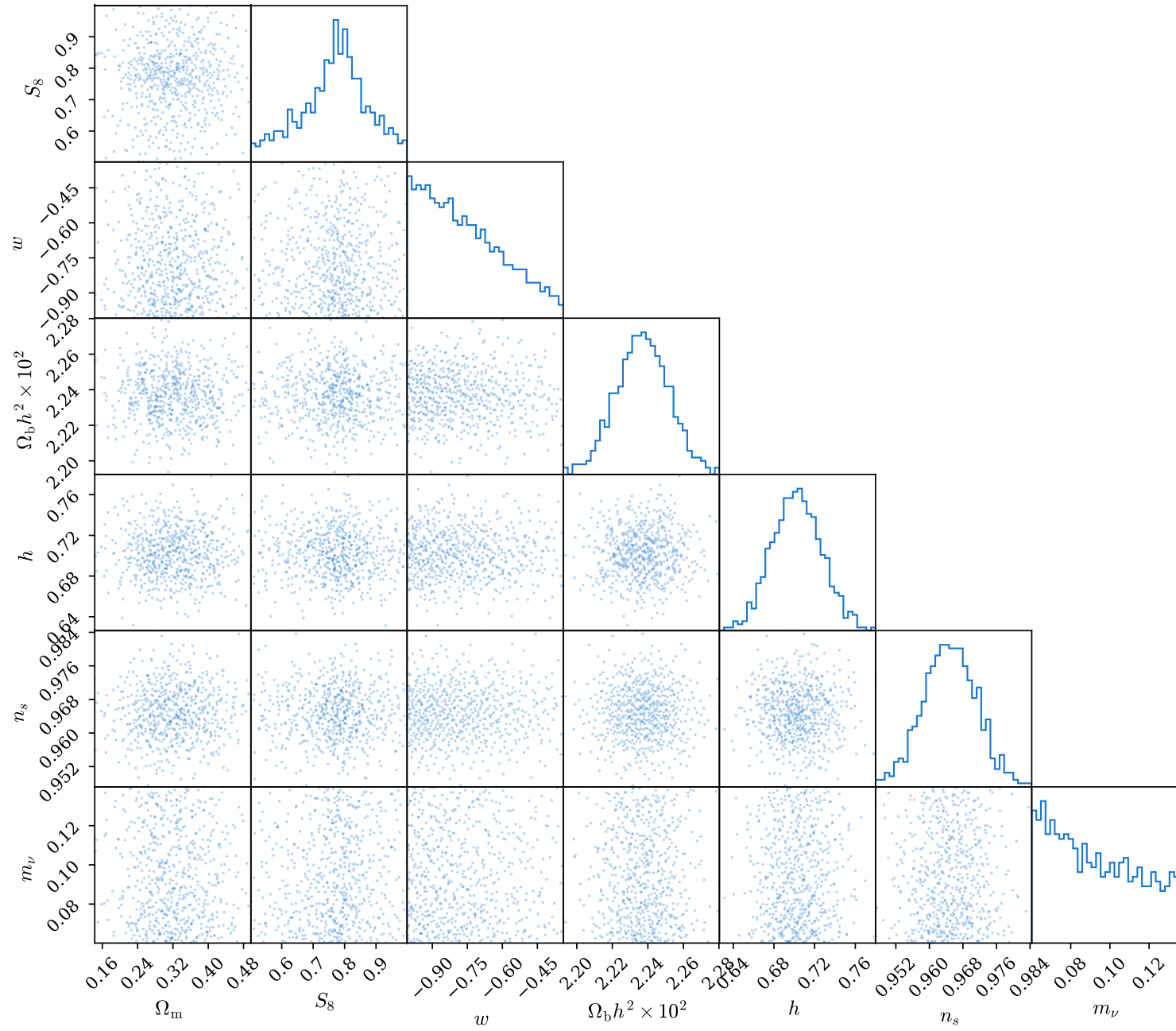
N. Jeffrey; Dark Energy Survey Collaboration

Dark Matter map from DES observations

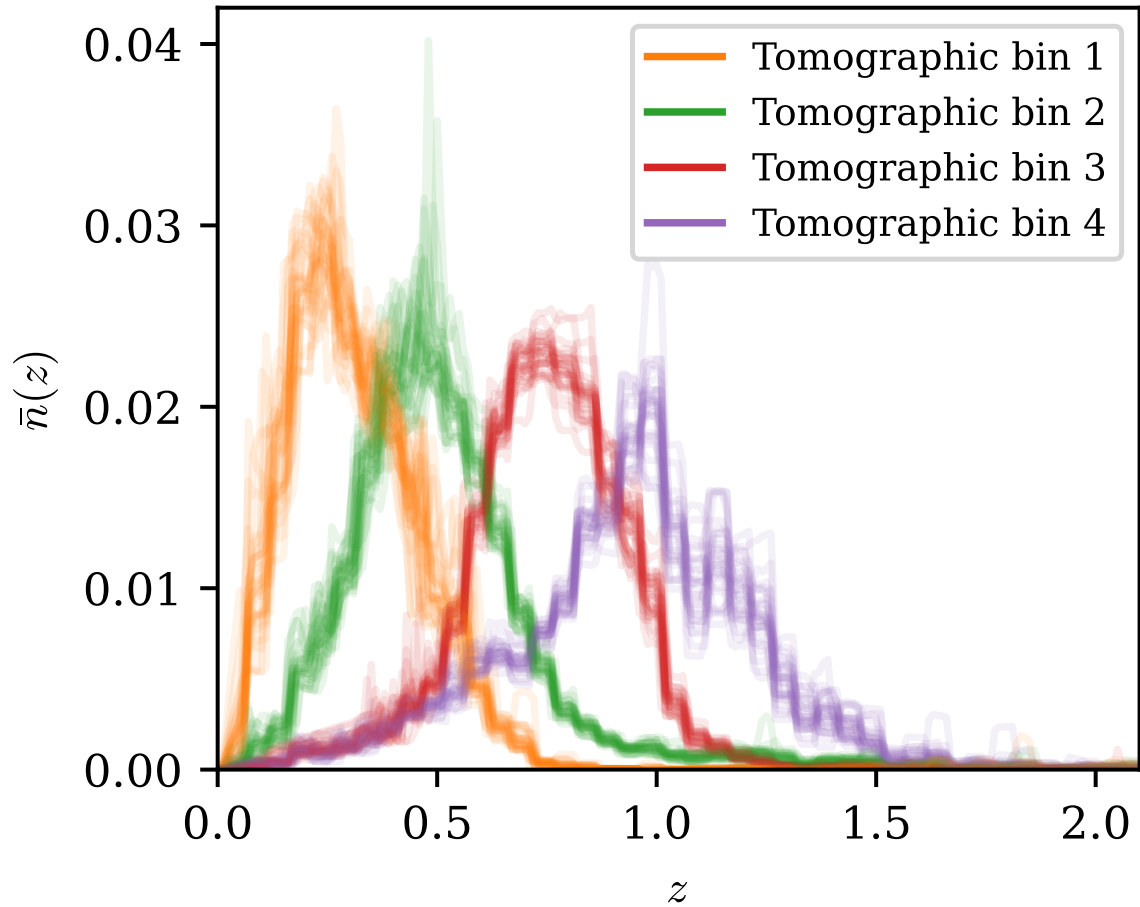
$\ln(\delta + 1)$



Gower St Simulations: parameter values



Samples from $p(\bar{n}(z)|x_{\text{phot}})$



Intrinsic alignments

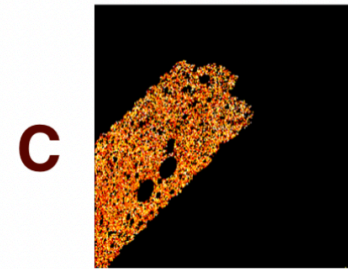
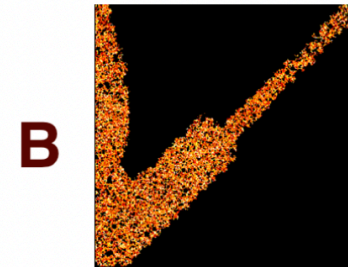
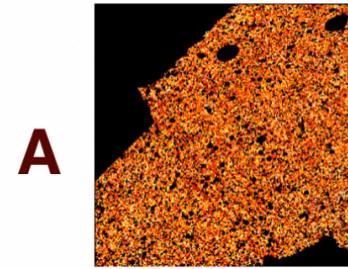
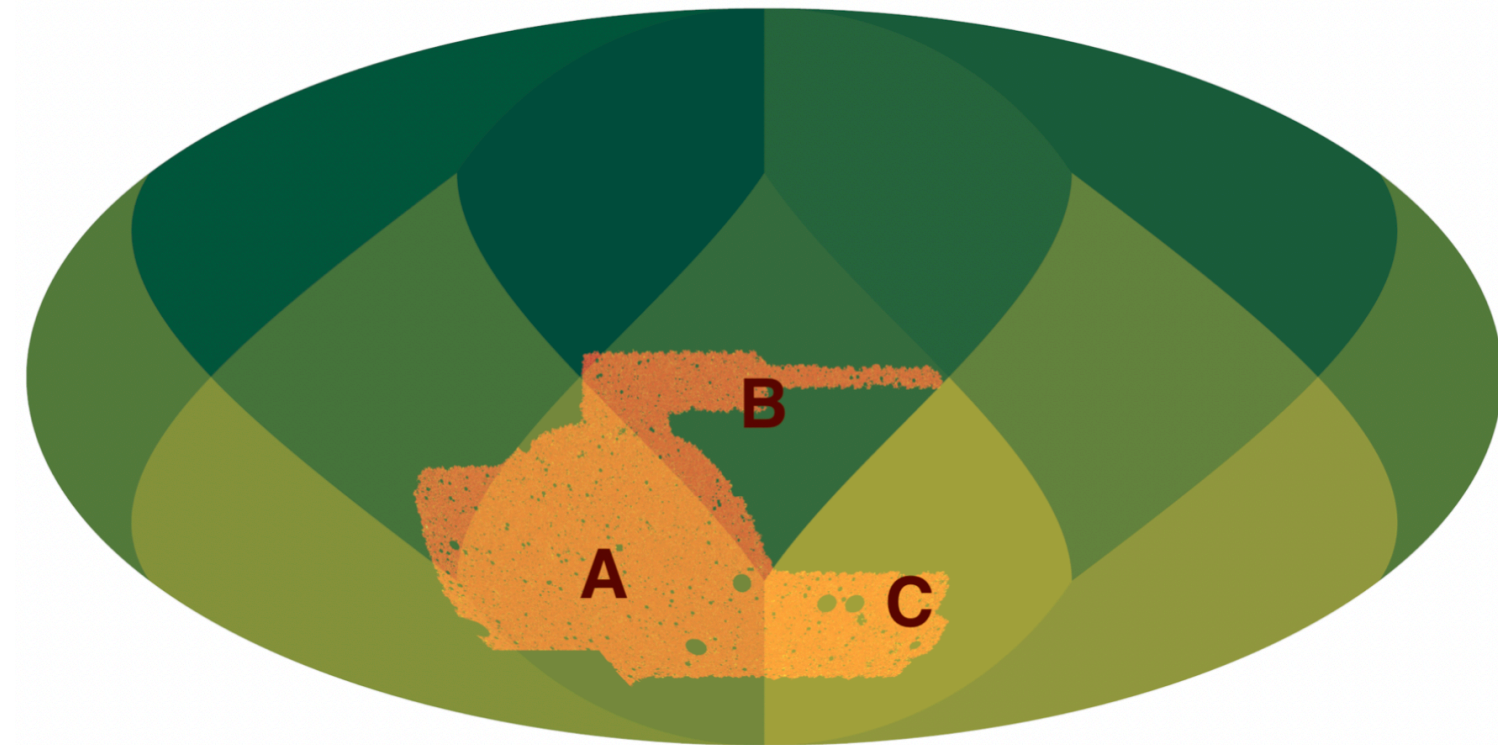
3. Results —

and how do we know this is right?

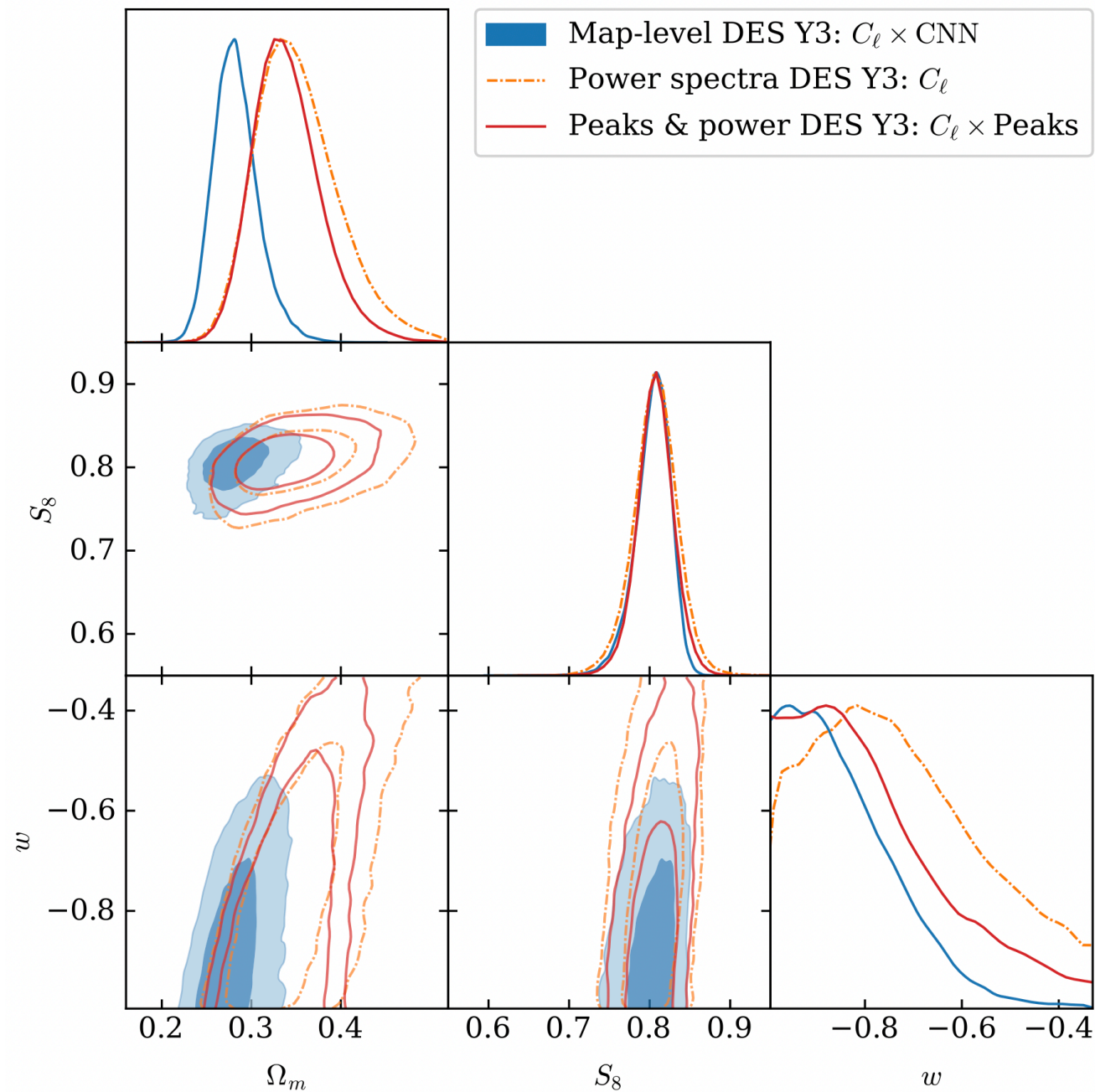
Observables (summary statistics)

1. Power spectrum: 2-point correlation
2. Peak counts: counting number matter peaks
3. Map-level compression

Extracting cosmology directly from the dark matter map

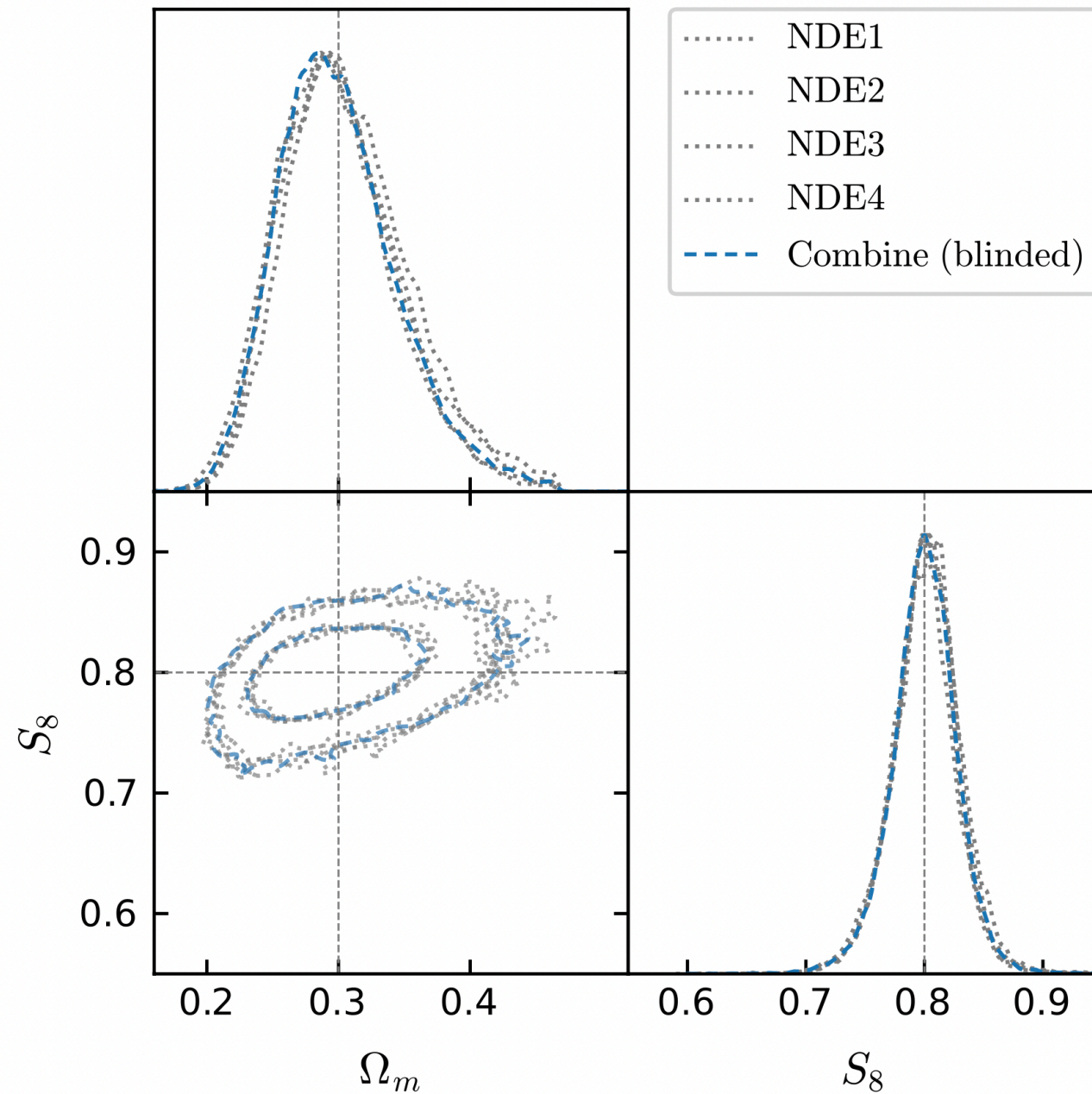


Neural
compression

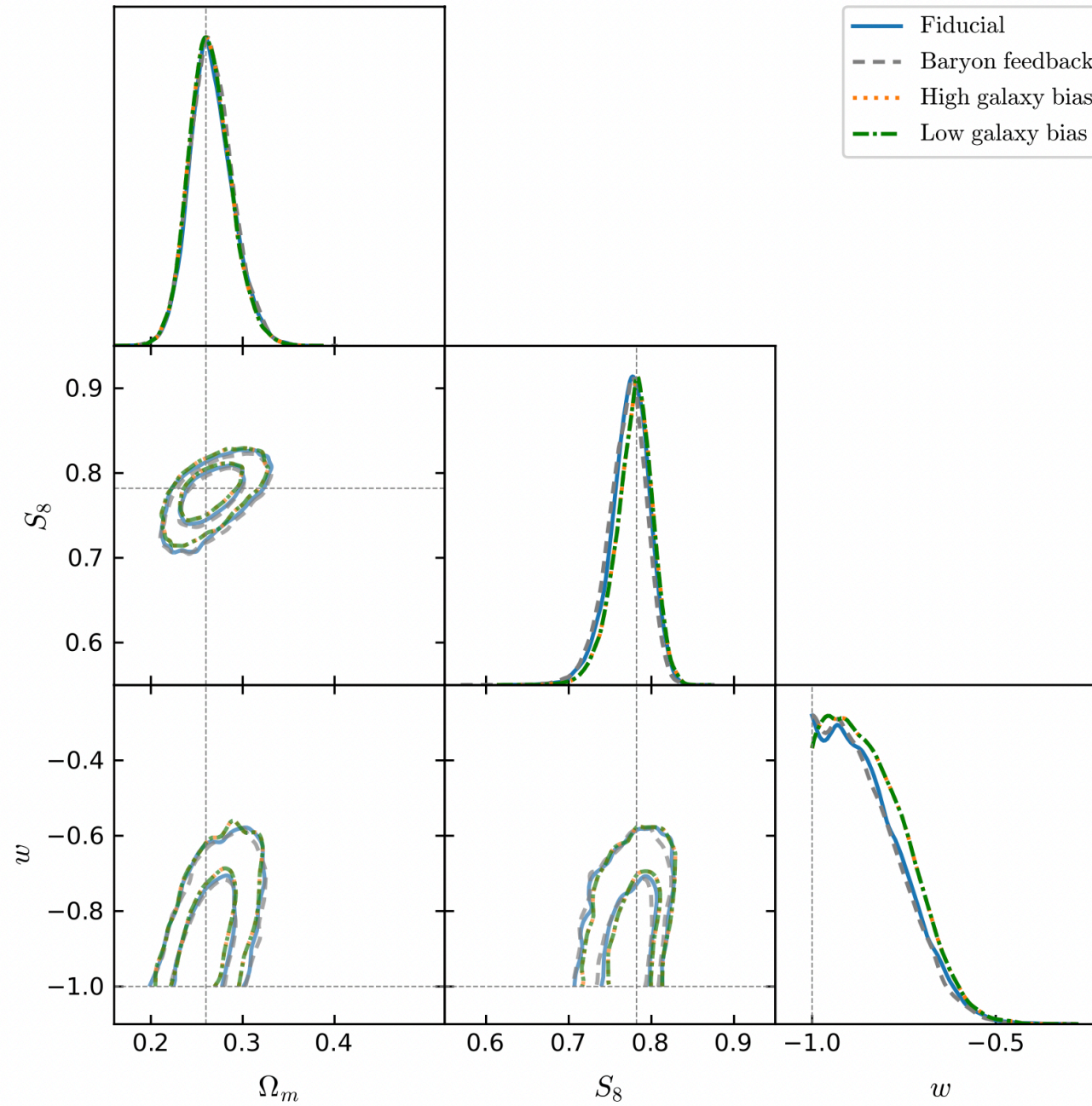


How do I know this is right?

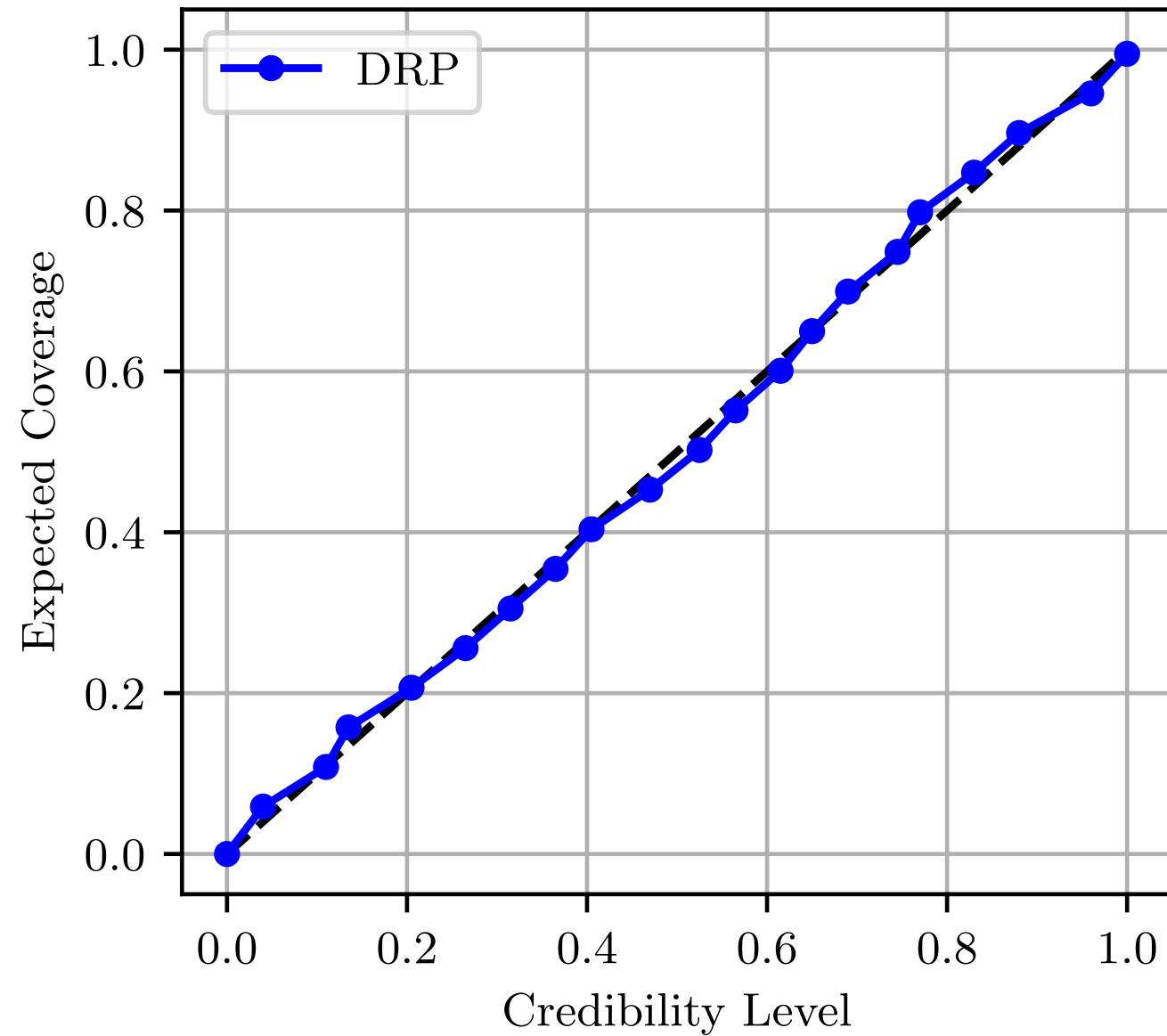
How do I know this is right?



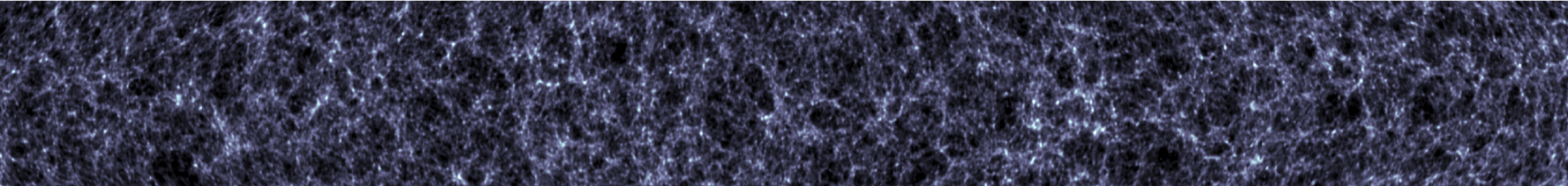
Injecting systematic error



How do I know this is right?



- New simulation-based inference results improve:
 - Accuracy — permits realistic data modelling and novel validation
 - Precision — this is the most constraining weak lensing analysis to date
- Future of reliable & more precise cosmology
- Gower Street simulations are now available

A visualization of the cosmic web, showing a dense network of dark matter filaments and galaxy clusters in shades of blue and purple.

New DES results: <https://arxiv.org/abs/2403.02314>; **NJ** et al. DES Collaboration
+ if you are interested in model comparison: <https://arxiv.org/abs/2305.11241> **NJ** & Wandelt