PAINTING BARYONS ON DARK MATTER

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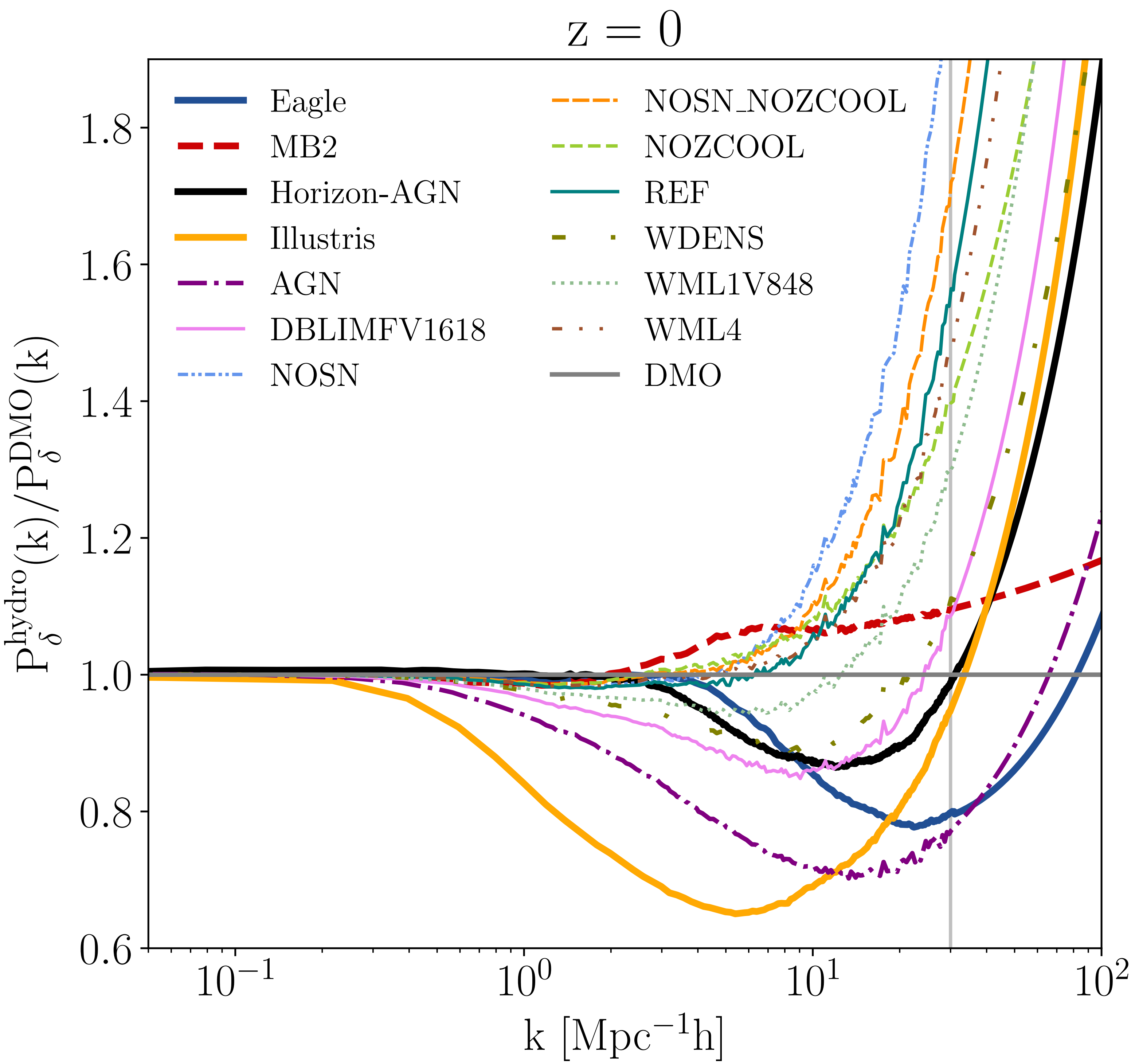
Weak lensing

Weak lensing probes the total matter distribution

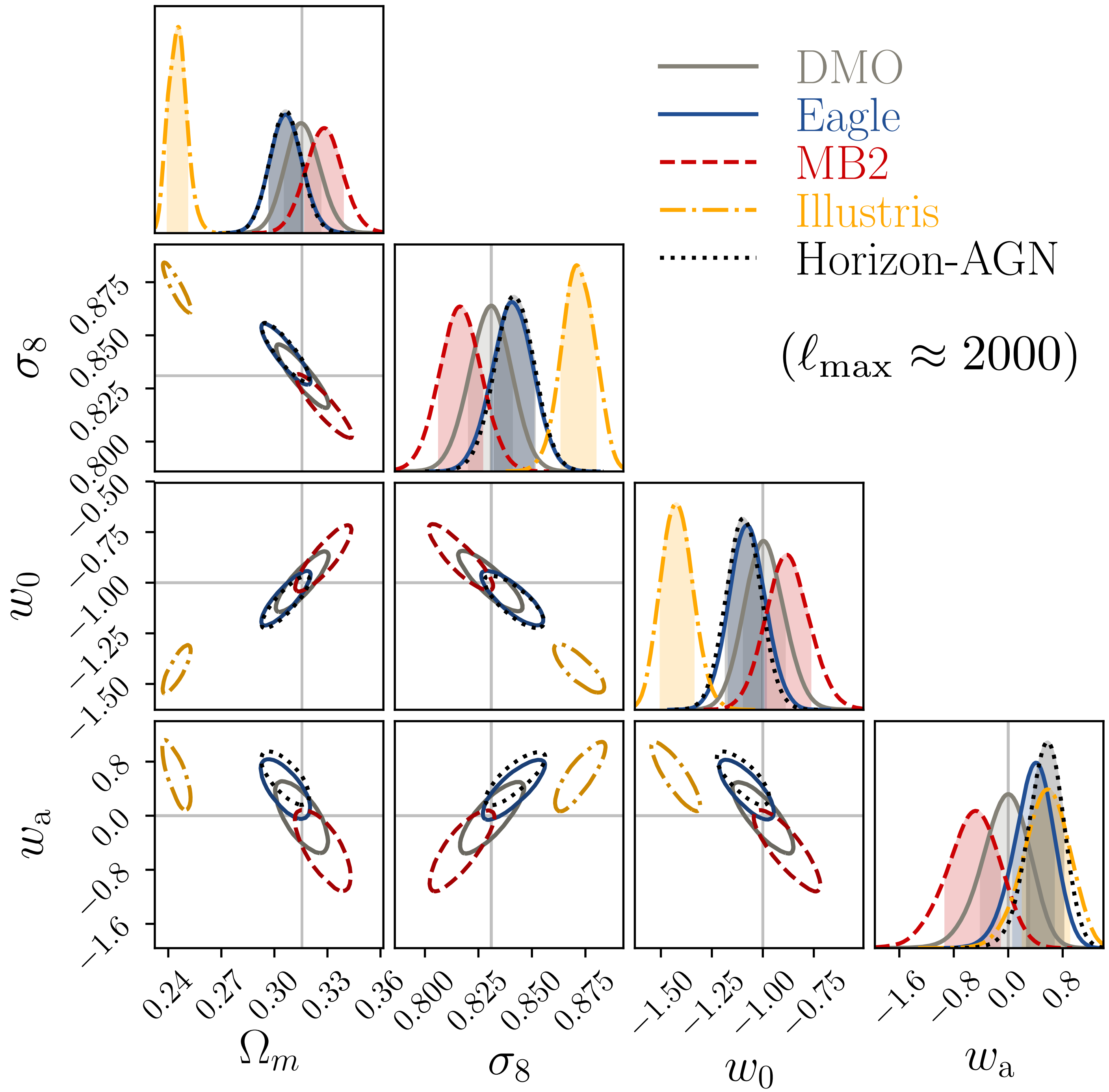
- $\sim$80% of matter is dark matter
- If we want to constrain LCDM, we need to understand the other 20%
- Baryons are complicated!

Effect of baryons on the matter power spectrum



Huang+ 2018

Effect on cosmological parameters



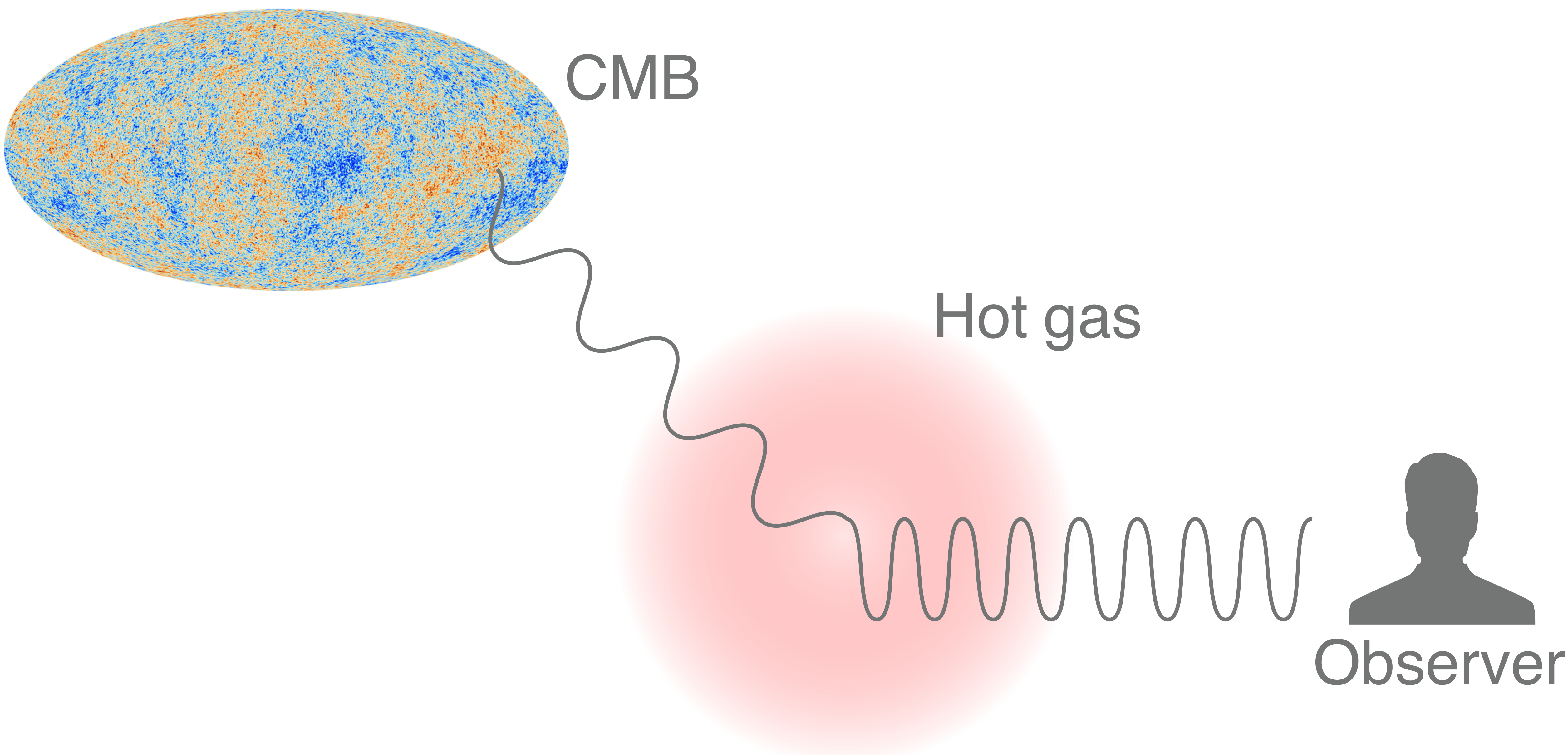
Huang+ 2018

Effect on cosmological parameters

Account for baryons

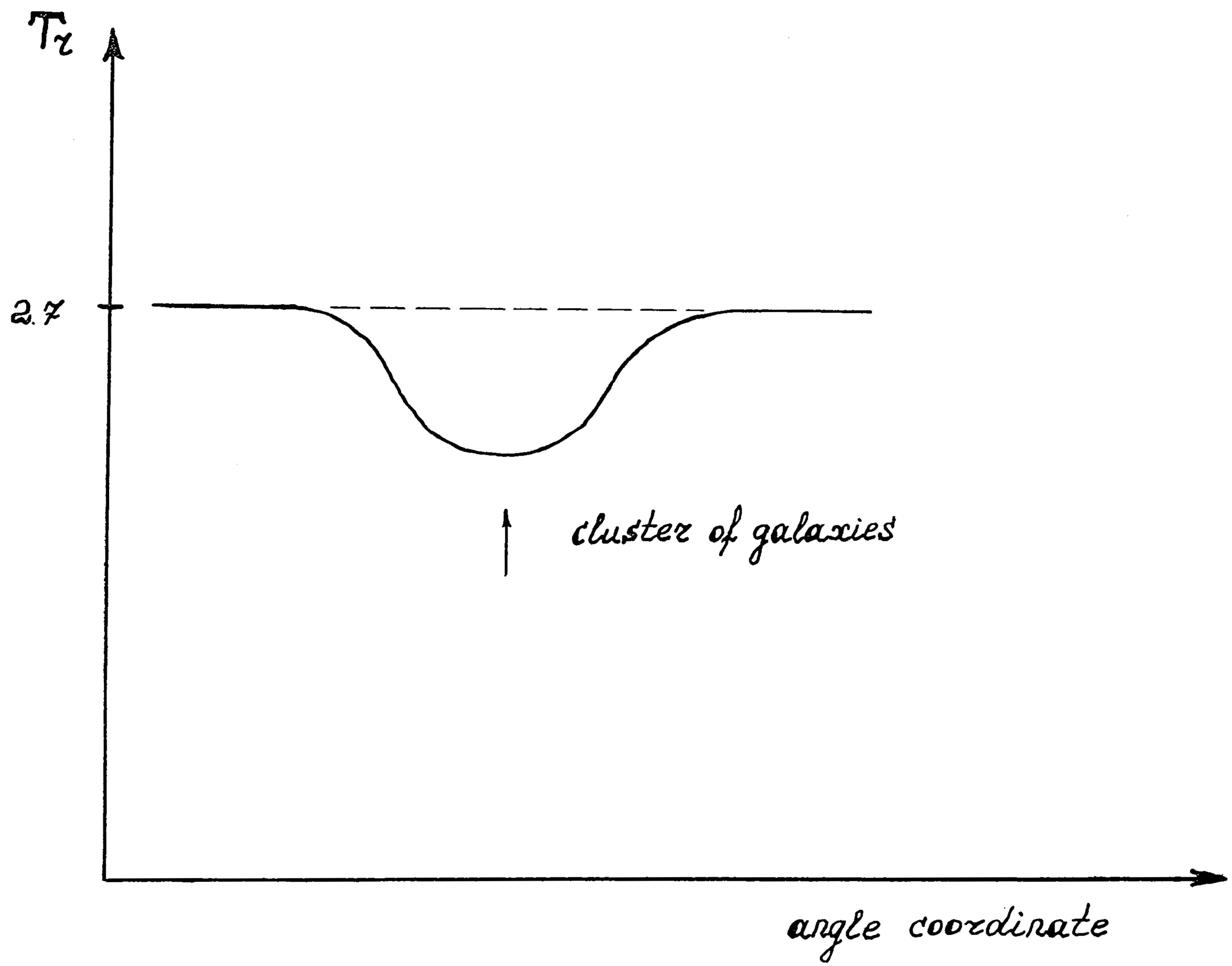
- Model
- Marginalise
- Need priors
  - Need observations

Thermal Sunyaev-Zel'dovich Effect



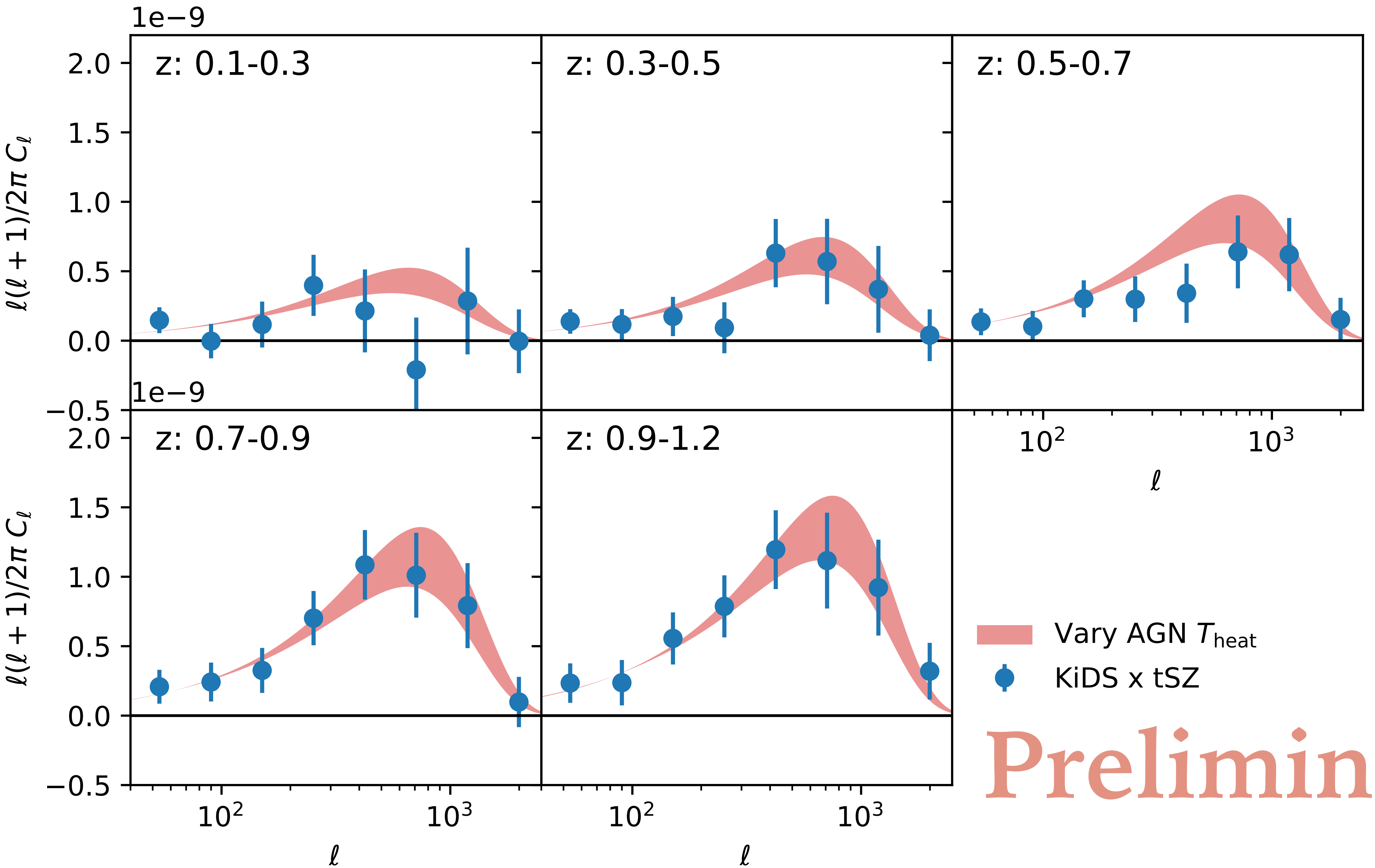
tSZ effect

“Shadow” on the CMB



Sunyaev, Zel’dovich 1972

Cross-correlate tSZ with lensing

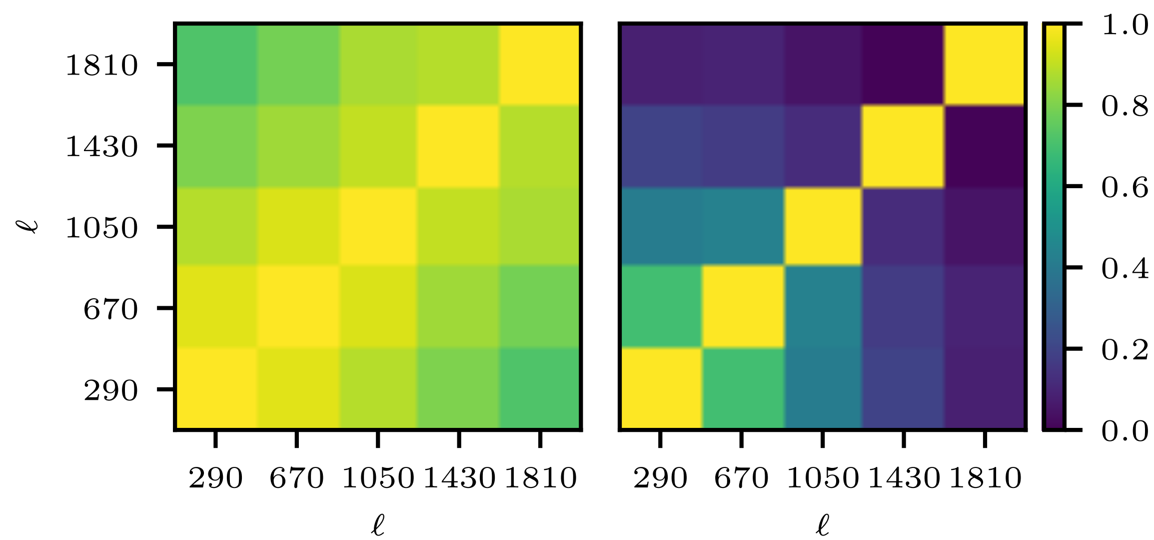


Preliminary!

Covariances

Analytic

- ➤ Gaussian insufficient
- ➤ Modelling uncertain



Simulations

- ➤ Know anyone with 10^3 lensing + tSZ lightcones?

Internal

- ➤ Non-trivial to do correctly

Covariances

Analytic

- Gaussian insufficient
- Modelling uncertain

Simulations

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- Might work but WIP

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Simulation data

SLICS

- N-body simulation
- 505 Mpc/h box size
- $\sim$1000 independent volumes

BAHAMAS

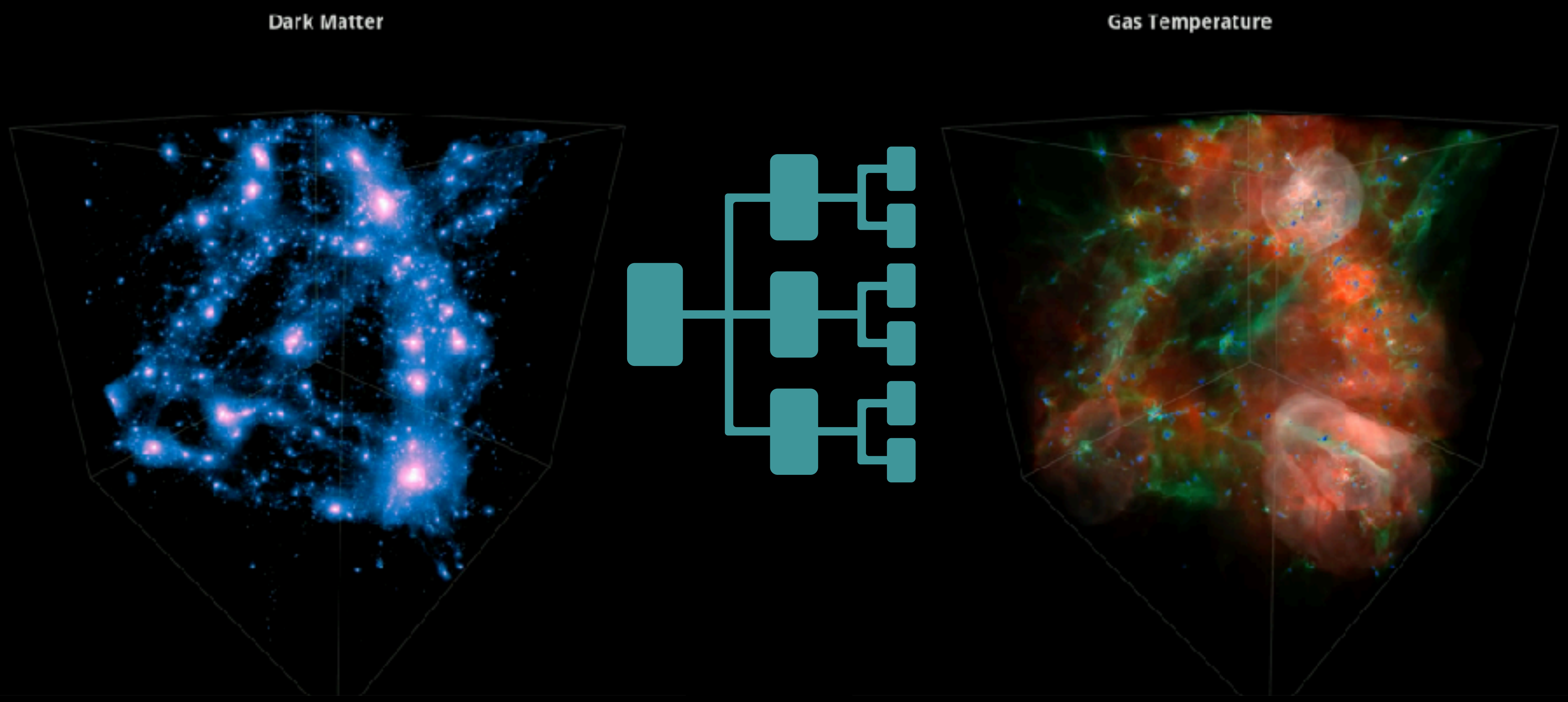
- Hydrodynamical simulation
- 400 Mpc/h box size
- 3 independent volumes

Why are hydro sims hard?

Feedback couples large and small scales

- Simulating large and small scales at the same time is hard
- (for lensing) we don't care about the small scales
- "small scales":
  - Galaxy properties
  - SFR
  - etc

Use machine learning?



Vogelsberger+2004

Karras+2018

Karras+ 2018

Zhu+2017

Generative models

Conditional variational auto-encoder (CVAE)

- Probabilistic description
- Easy to train
- Can predict variance of output

Generative adversarial network (GAN)

- Tends to give better results
- Training is harder; often unstable

Conditional Variational Auto-Encoder (CVAE)

Sample x, given y:

- $x \sim p_\theta(x|y)$
- E.g., x is pressure, y is dark matter

Introduce latent variable z

- $p_\theta(x|y) = \int \mathrm{d}z\ p_\theta(x, z|y) = \int \mathrm{d}z\ p_\theta(x|y, z)p(z)$
- Infinite mixture model

Conditional Variational Auto-Encoder (CVAE)

Approximate prior on z

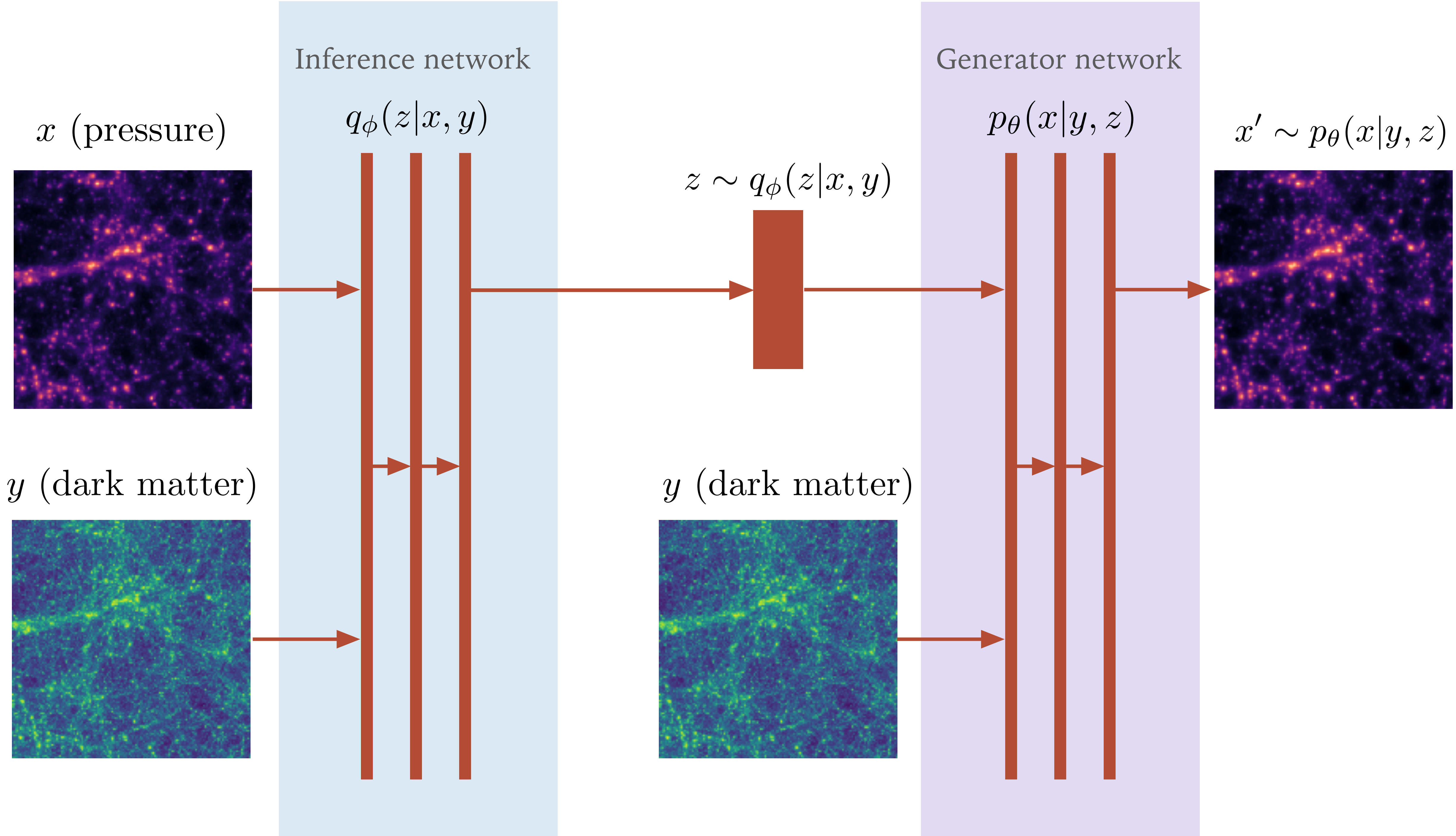
- $q_\phi(z|x,y) \approx p(z)$

Variational lower bound

- $$\log p_\theta(x|y) \geq \underbrace{-\mathbb{D}_{KL}(q_\phi(z|x,y)||p(z))}_{\text{KL-term}} + \underbrace{\mathbb{E}_{z\sim q_\phi(z|x,y)}[\log p_\theta(x|y,z)]}_{\text{Reconstruction loss}}$$

- $p_\theta(x|y,z)$ and $q_\phi(z|x,y)$ can be expressed as neural networks
- Can be efficiently optimised

Conditional Variational Auto-Encoder (CVAE)



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BAHAMAS

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Simulation data

SLICS

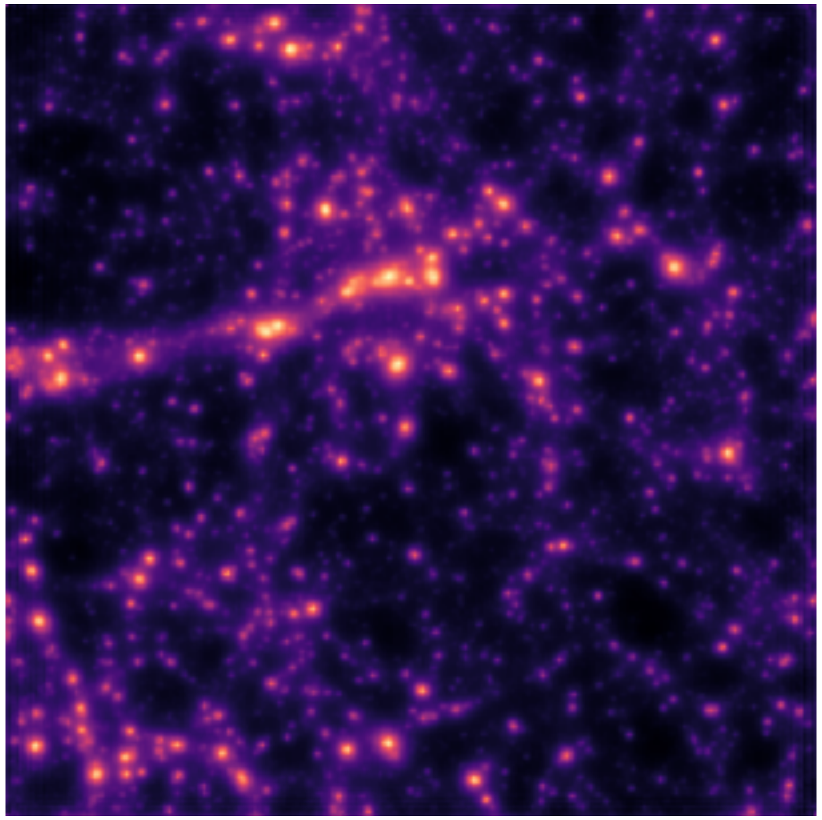
- No particle snapshots
- Mass sheets corresponding to 252 Mpc/h thick slices
- Not a problem; lensing and tSZ are projected quantities

BAHAMAS

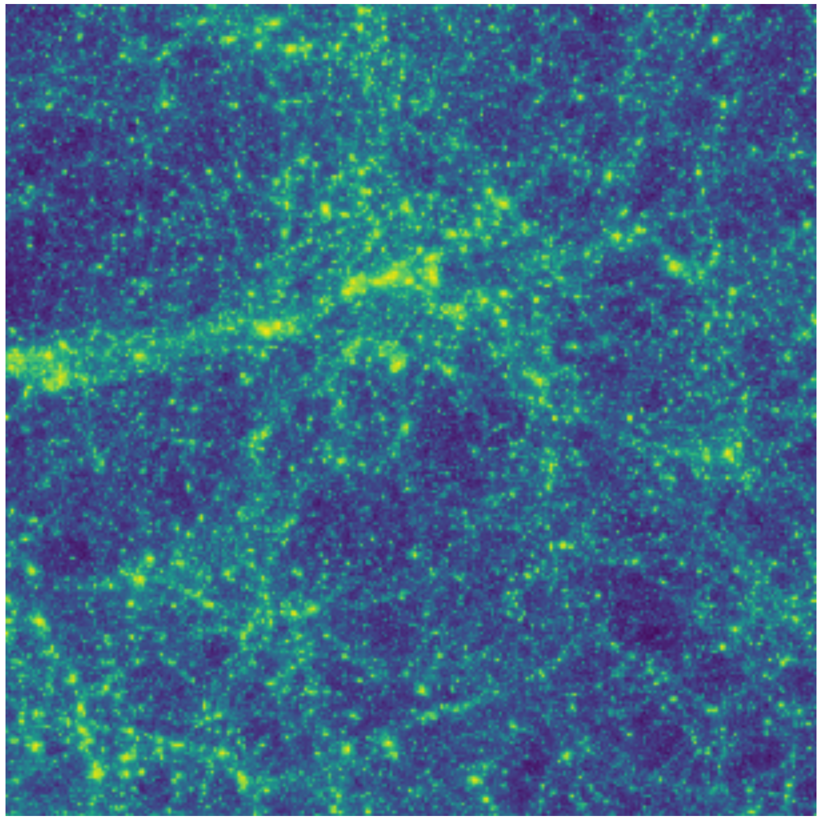
- Create 250 Mpc/h thick slices
- Form combinations of 150 Mpc/h and 100 Mpc/h slices
- 16 tiles per slice
  - ~50k combinations per redshift

Results

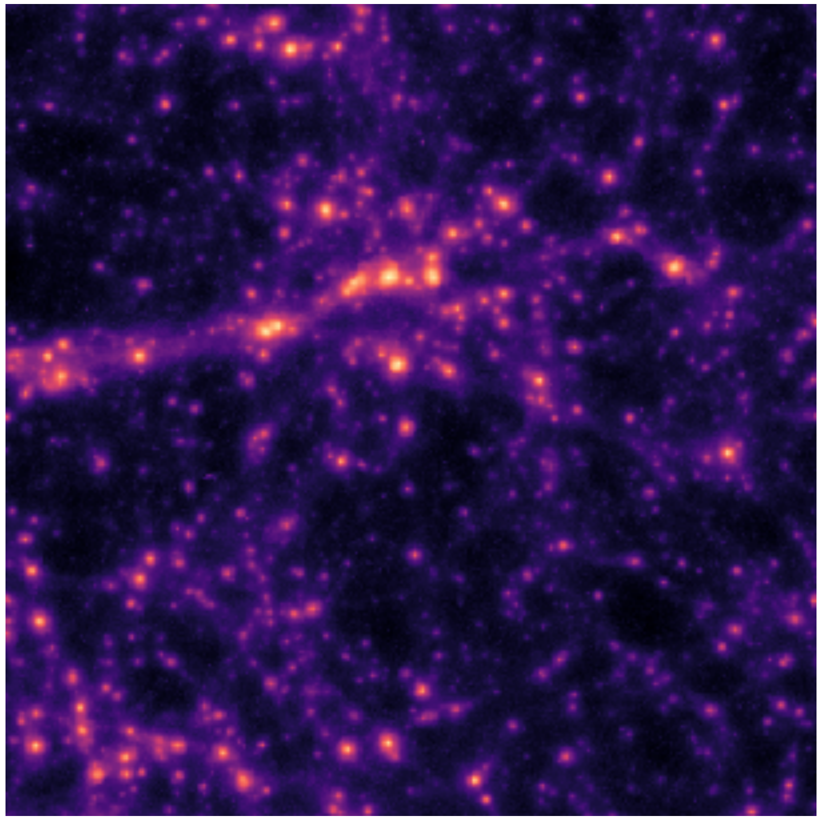
Pressure (fake)



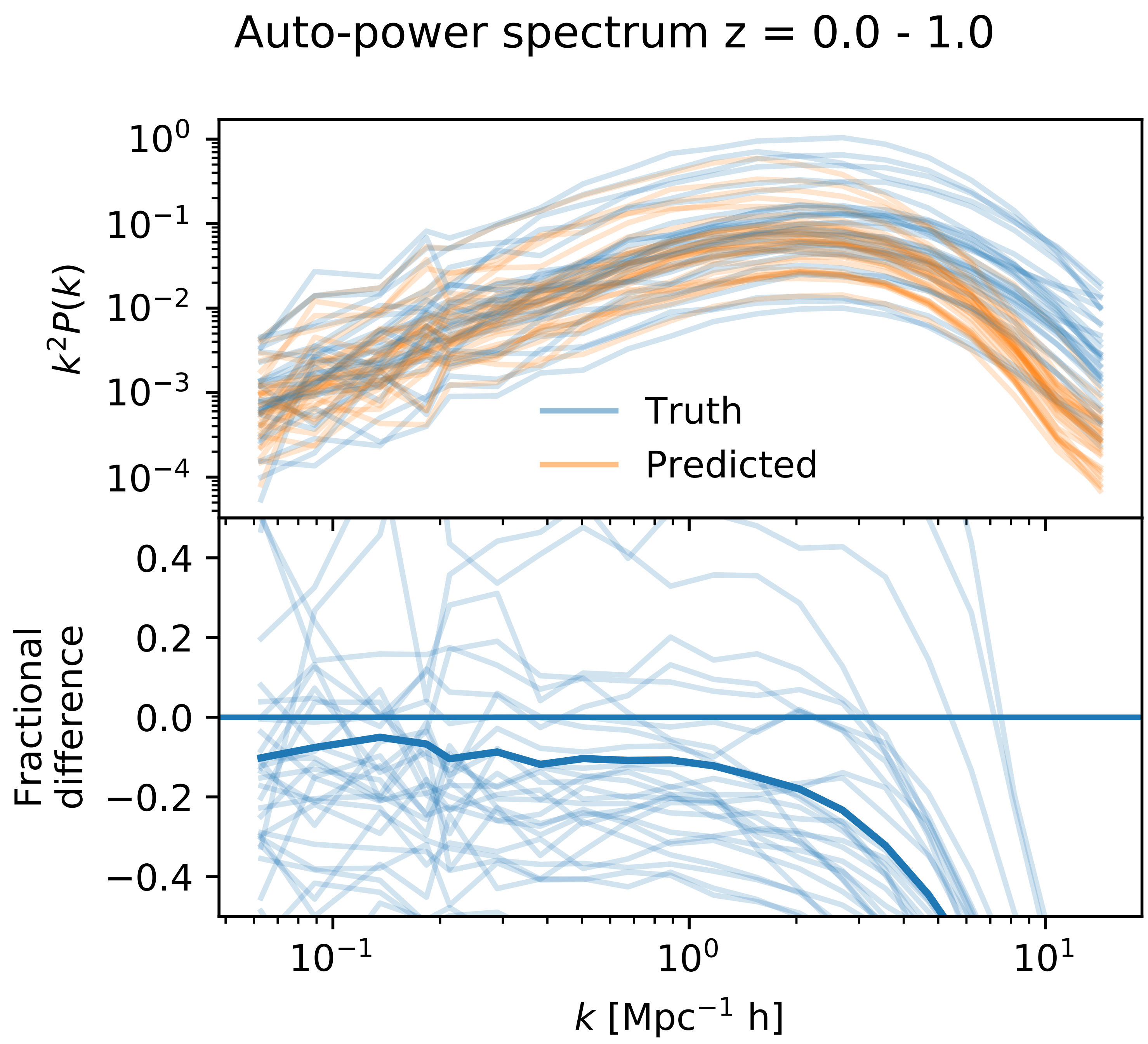
Dark matter (input)



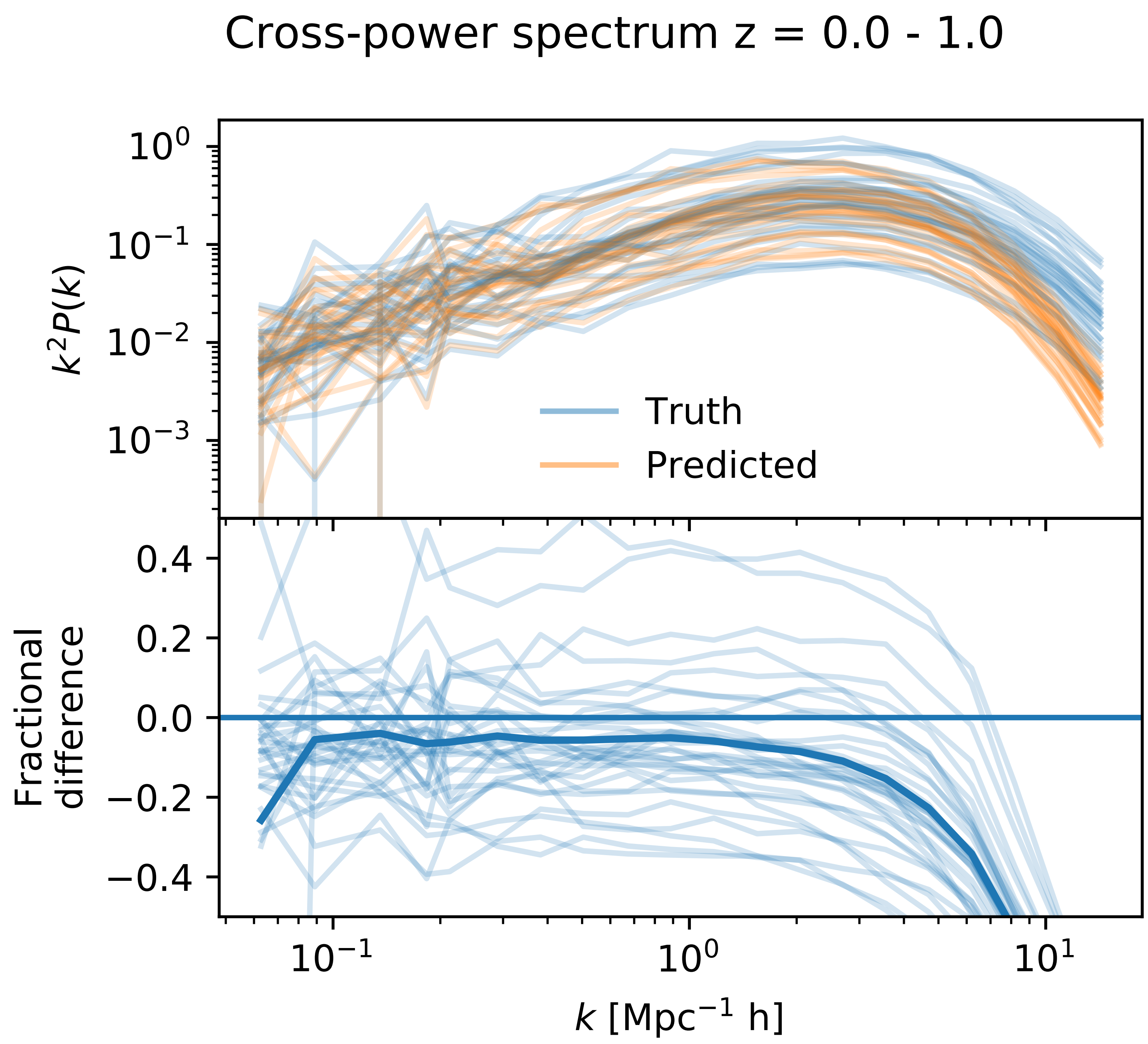
Pressure (truth)



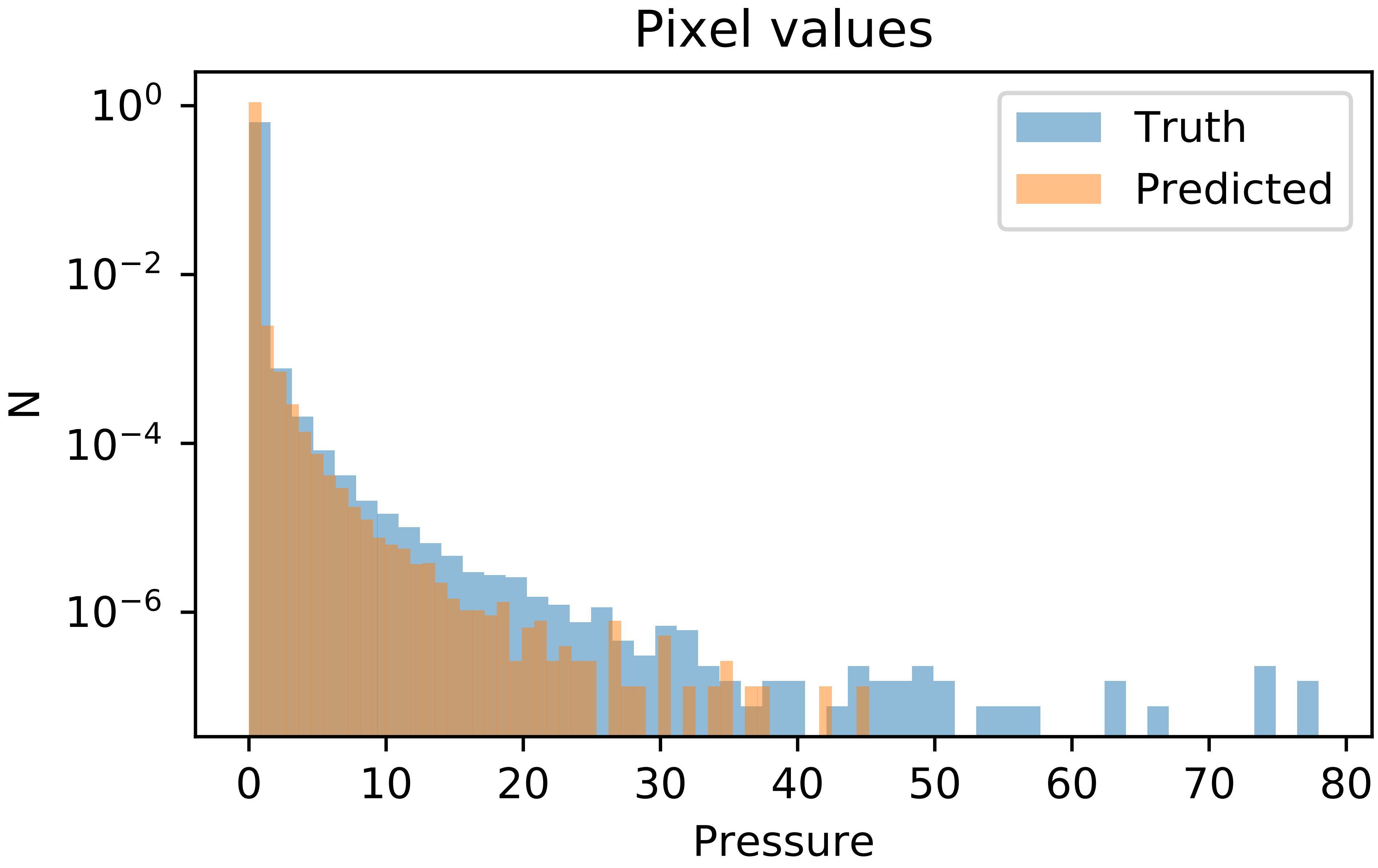
Auto-power spectra



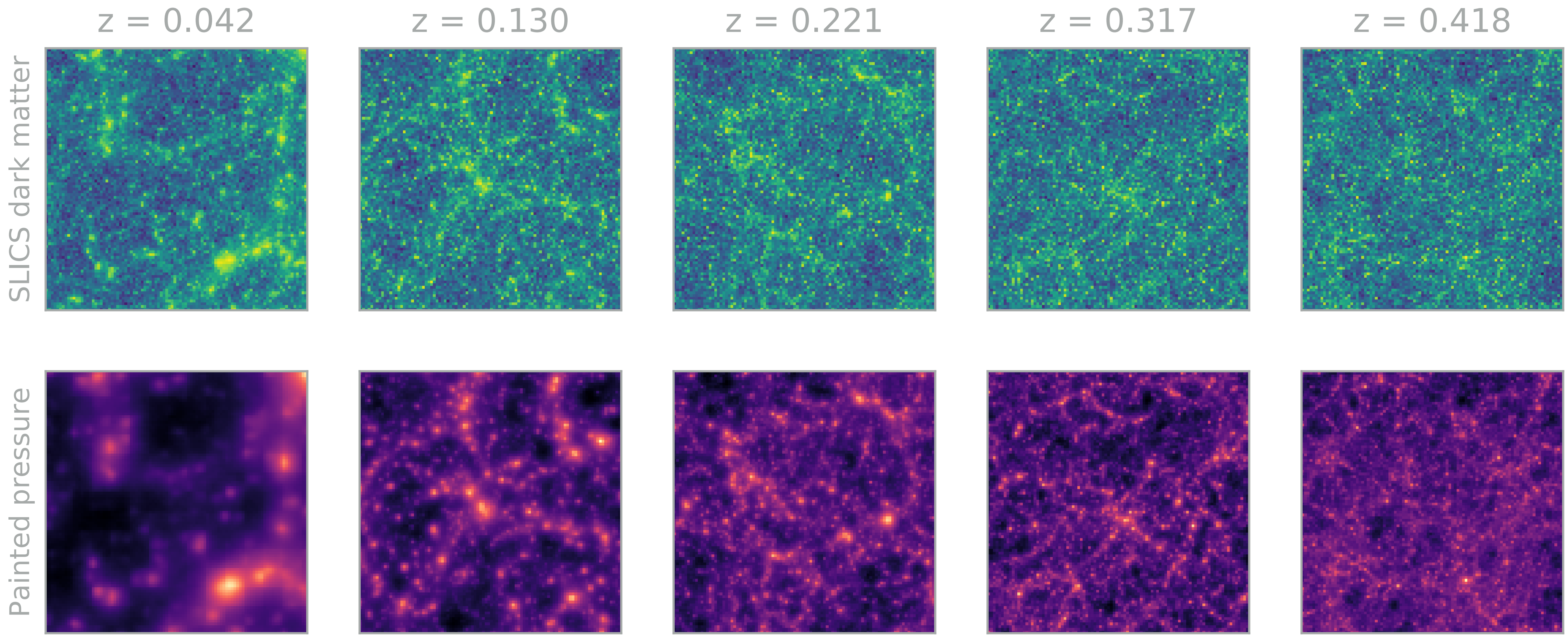
Cross-power spectra



Pixel distribution

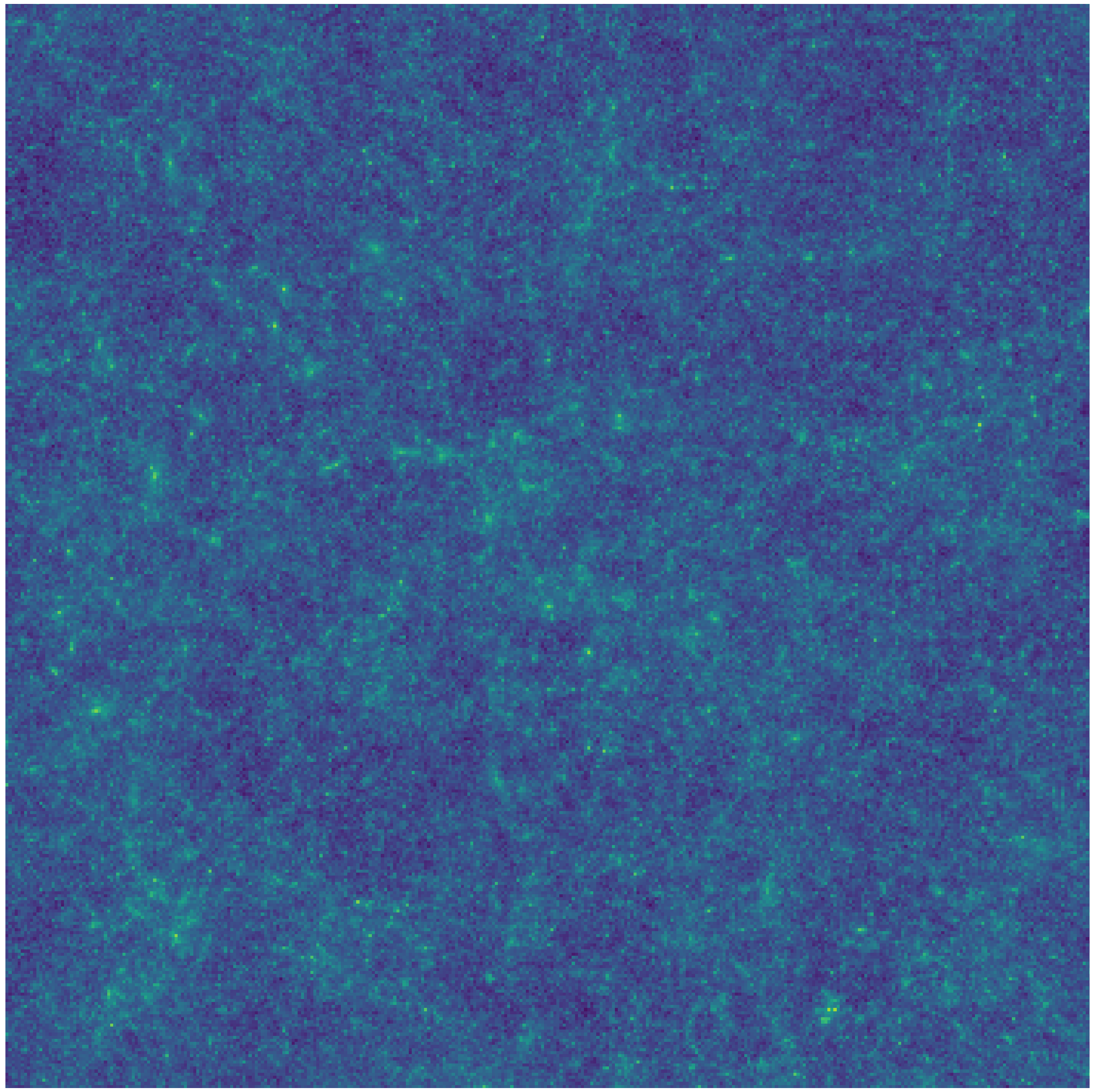


Paint on SLICS

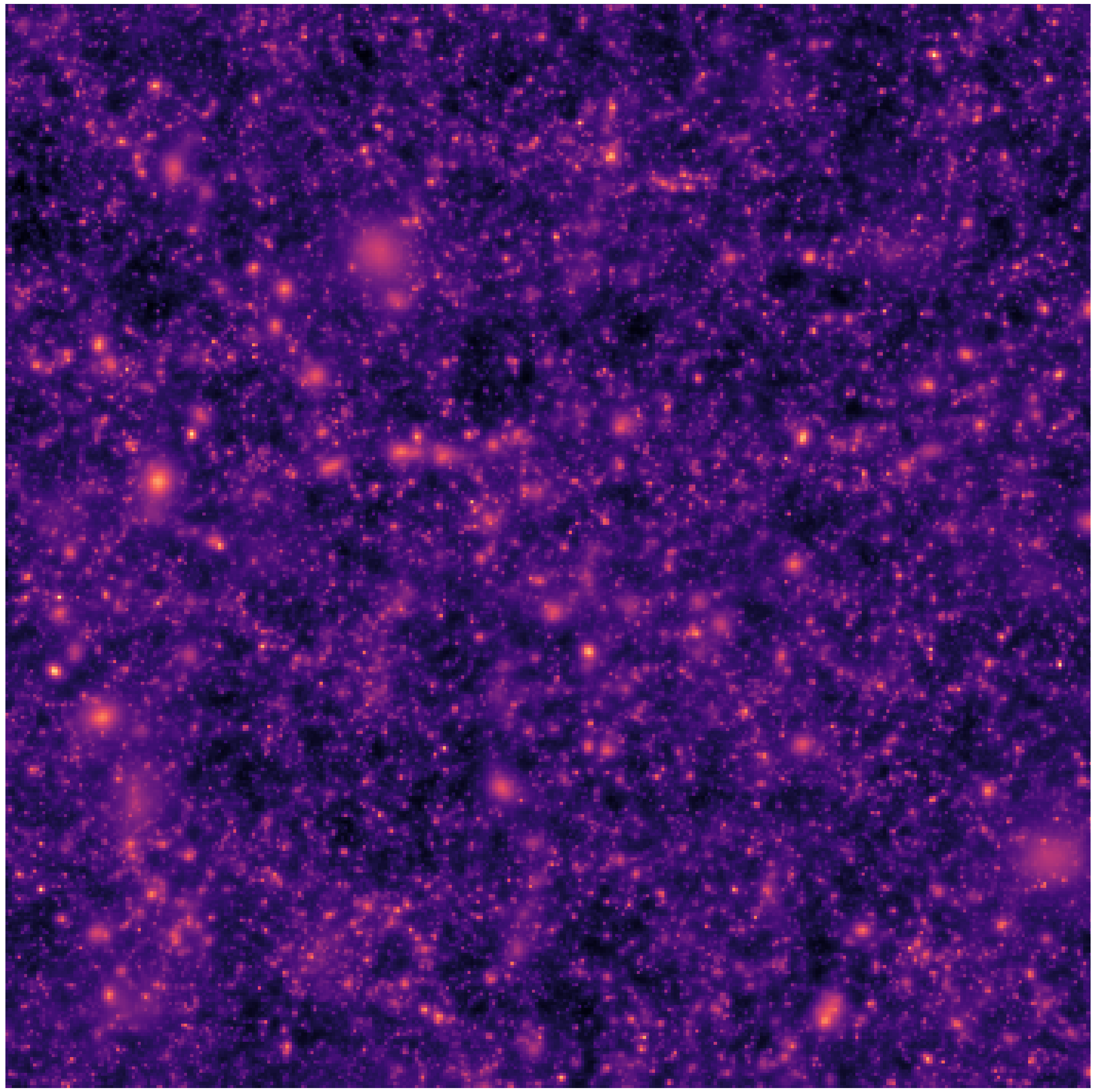


Convergence vs Compton-y

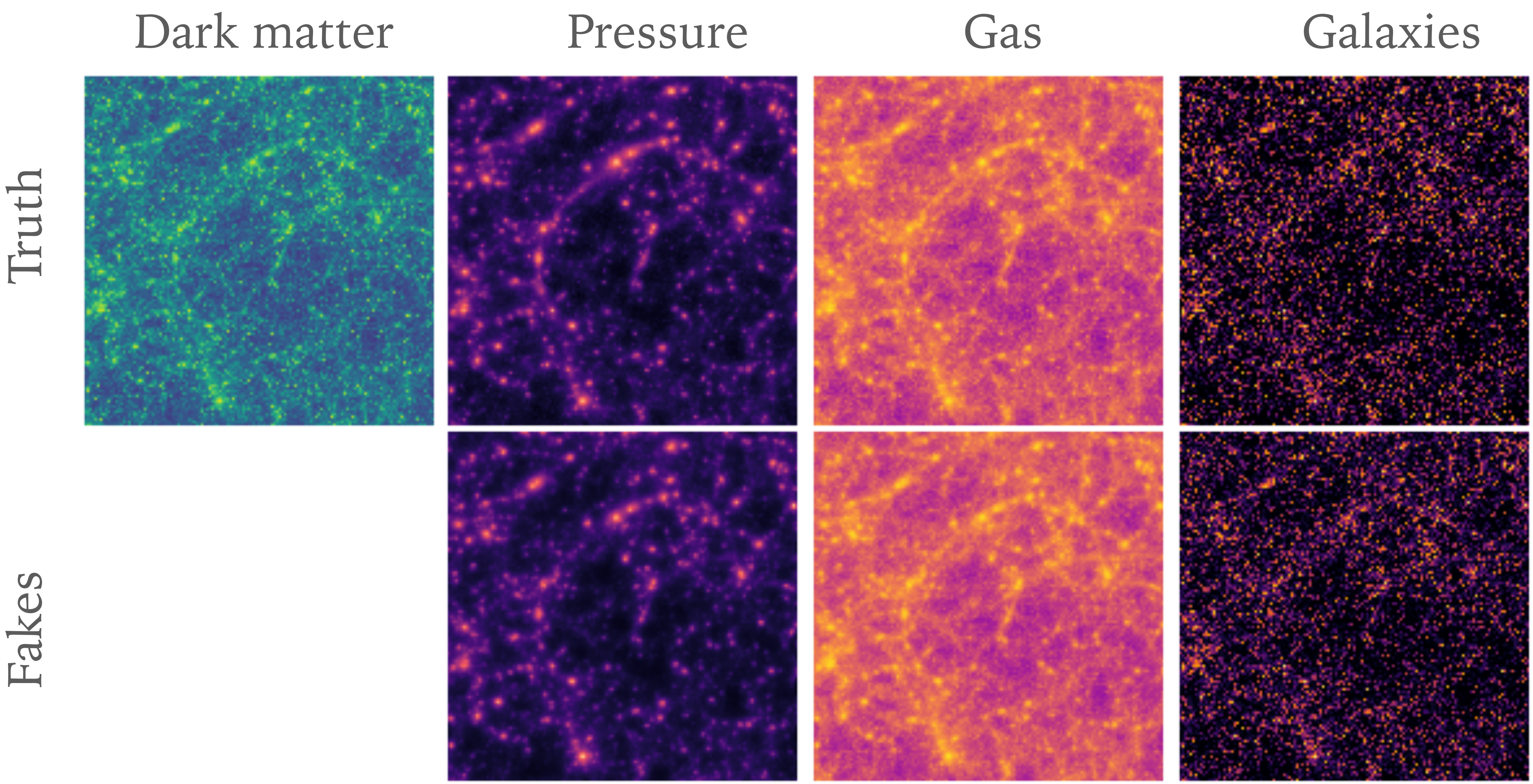
Convergence κ, KiDS-450 $n(z)$



Compton y



Paint baryons on dark matter



Summary

Deep generative models are powerful tools to bridge the gap between N-body and hydrosims

Even simple models give promising results

More sophisticated models (e.g., GANs) WIP, stay tuned!

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