



**UNIVERSITÄT
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ZUKUNFT
SEIT 1386

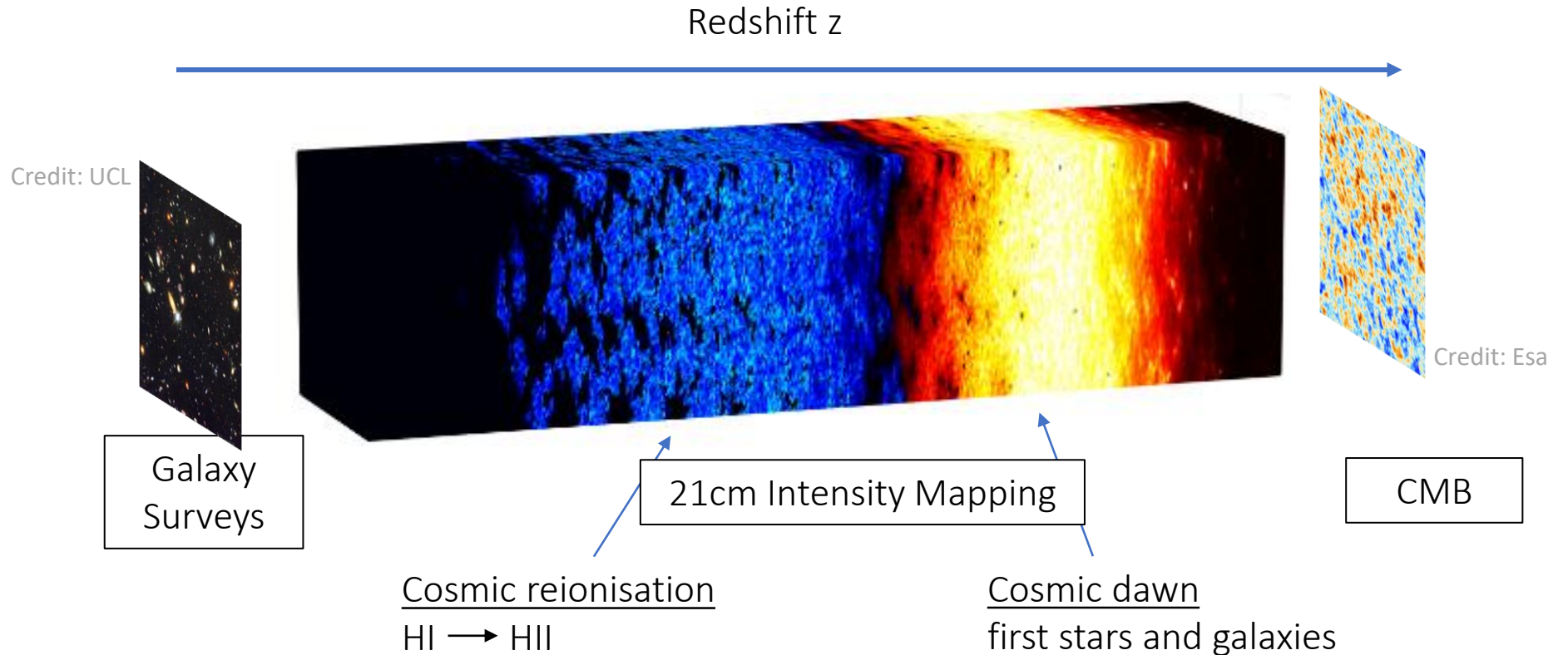
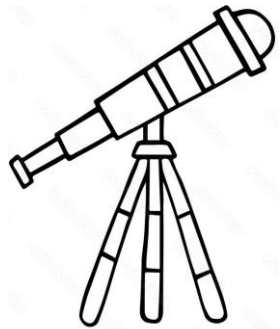
Bayesian Insights into the high-redshift Universe with 21cmPIE-cINN

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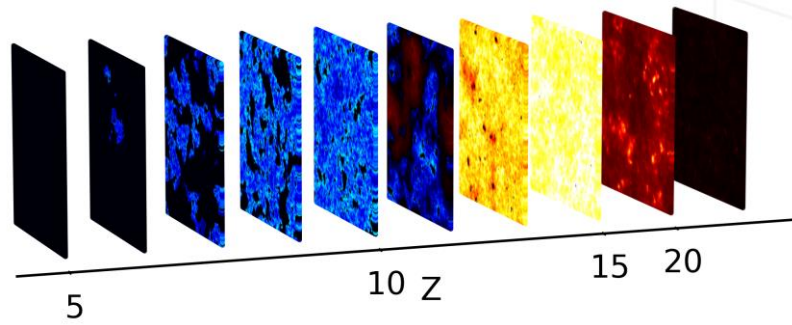
ML4Jets2023 – Desy, Hamburg 08.11.2023

21cm Cosmology

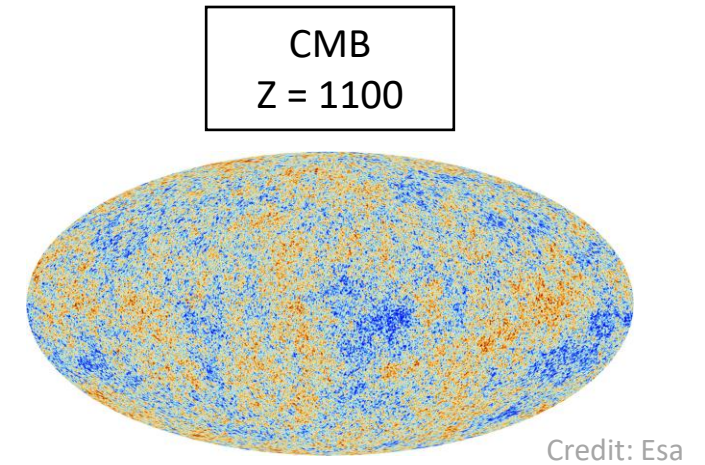
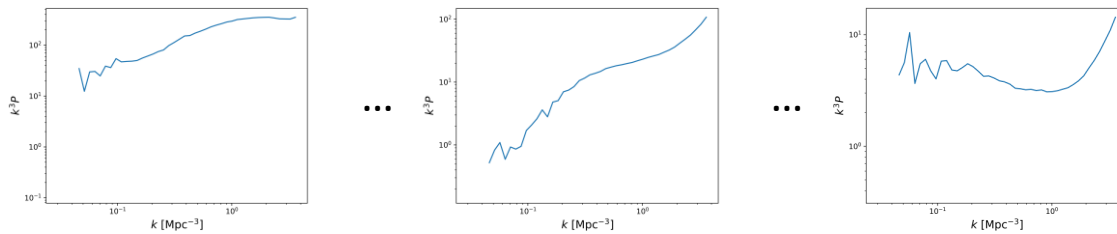


21cm Intensity Mapping

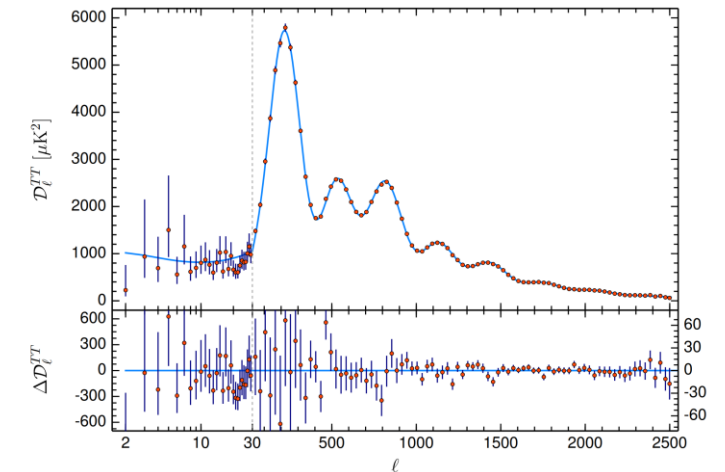
21cm lightcone:
2D spatial + 1D frequency



2D Powerspectrum
for each z-slice

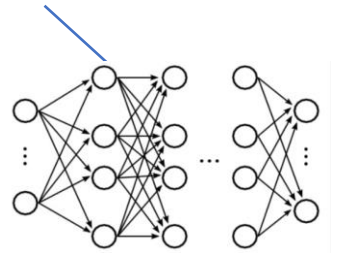
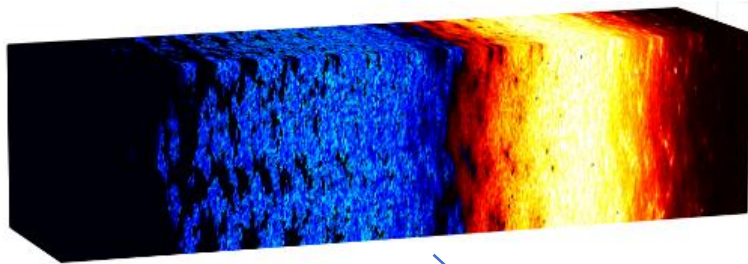


Powerspectrum

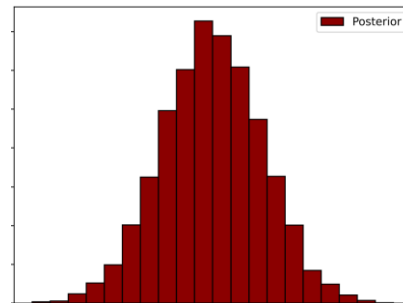


21cm Intensity Mapping

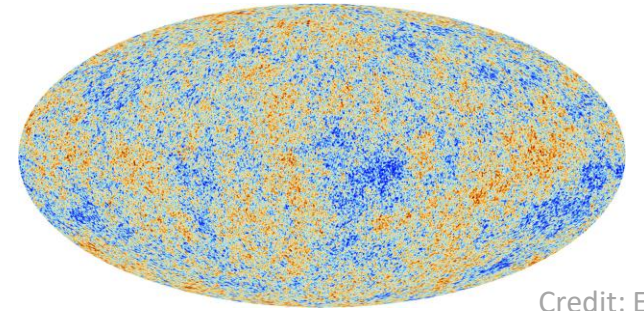
21cm lightcone:
2D spatial + 1D frequency



- However, want
- non linearities
 - fast Inference
 - no hand-crafted summary statistic
 - ...

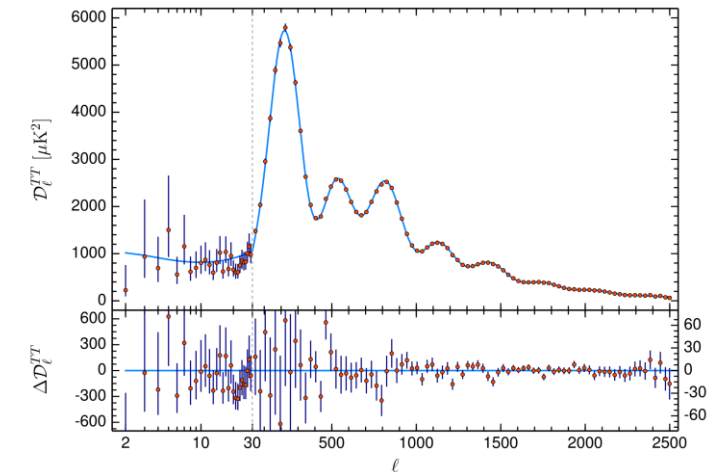


CMB
 $Z = 1100$

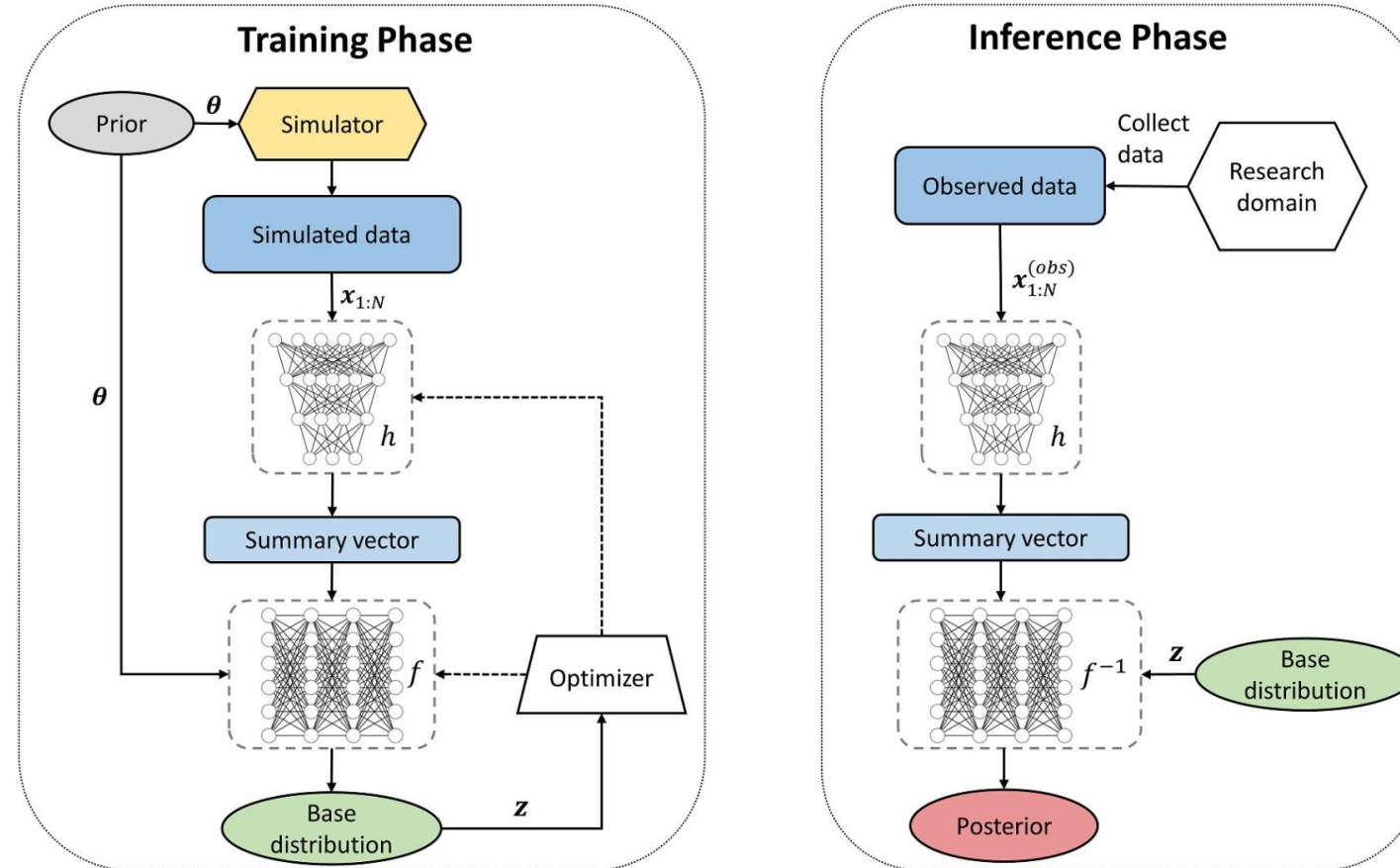


Credit: Esa

↓ Powerspectrum

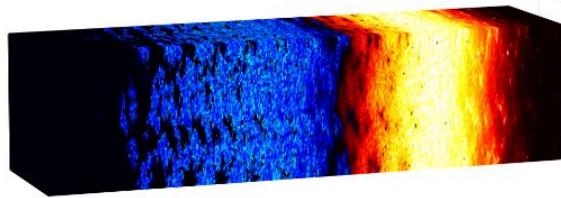


Simulation based Inference

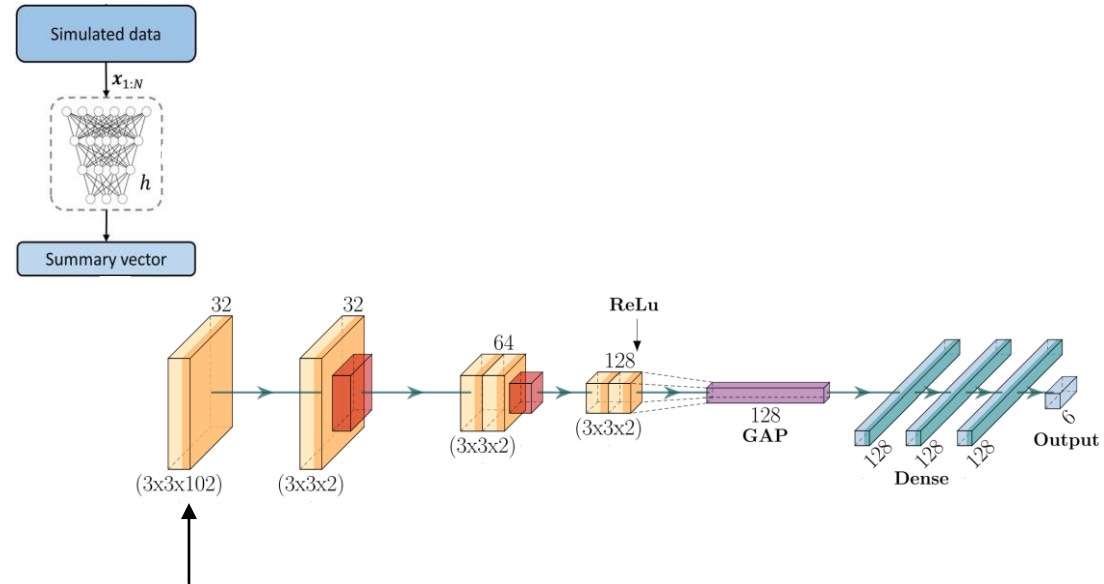


Dataset and Architecture

Summary Network: 3D CNN

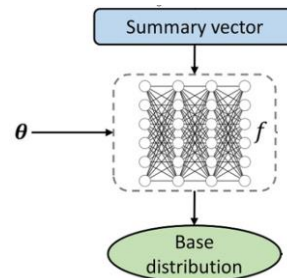


5000 LC with dimensions (140x140x2350)



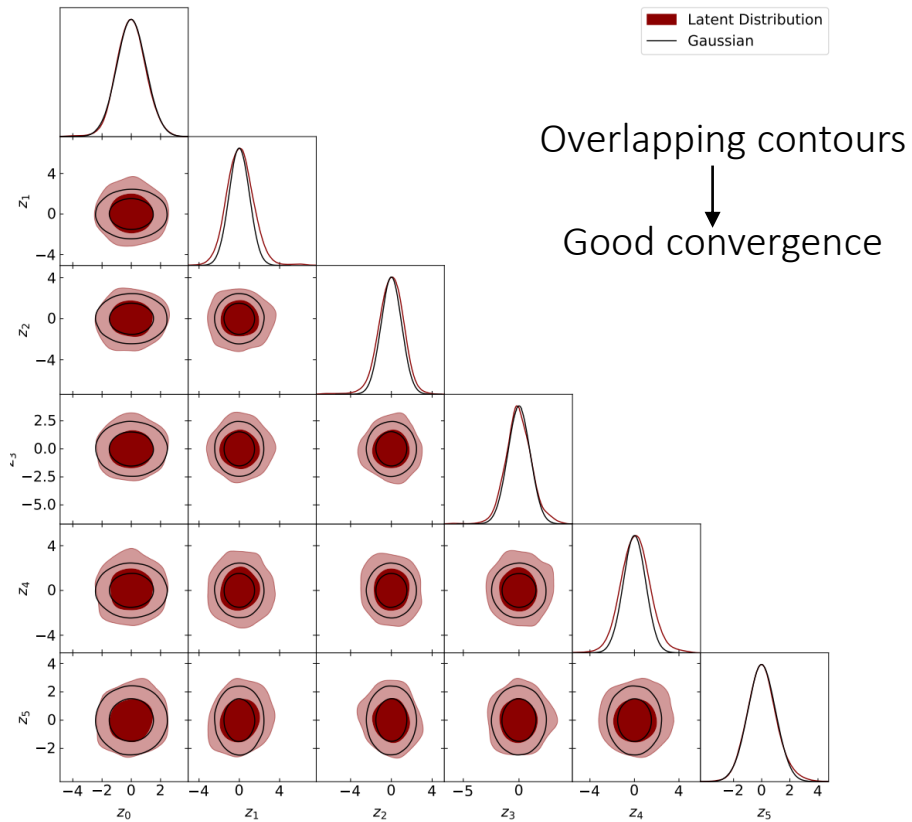
Highly asymmetric filter, to capture asymmetric fluctuations

Invertible Network: cINN

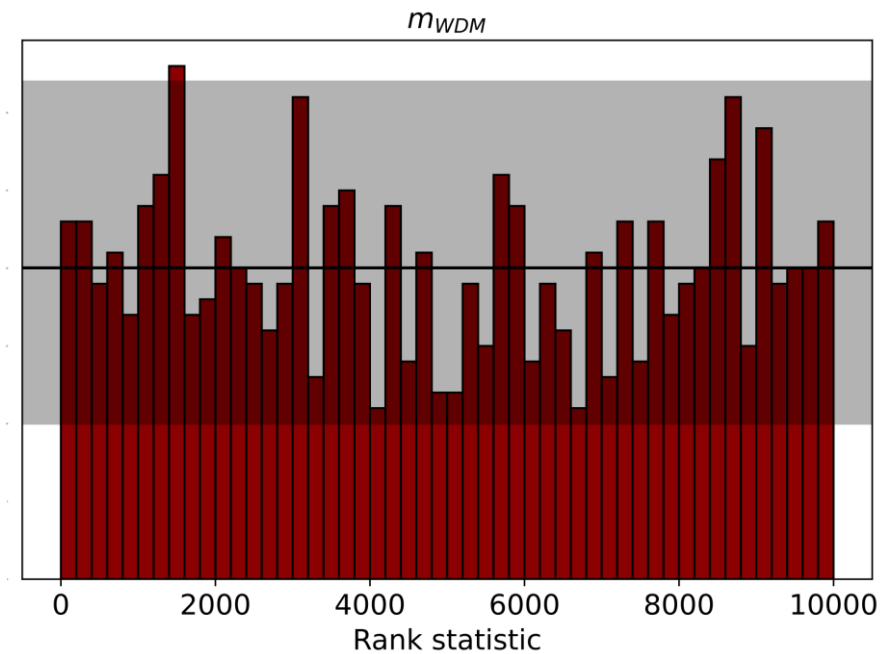


Performance Validation – Consistency Checks

Latent Space examination



Simulation based Calibration



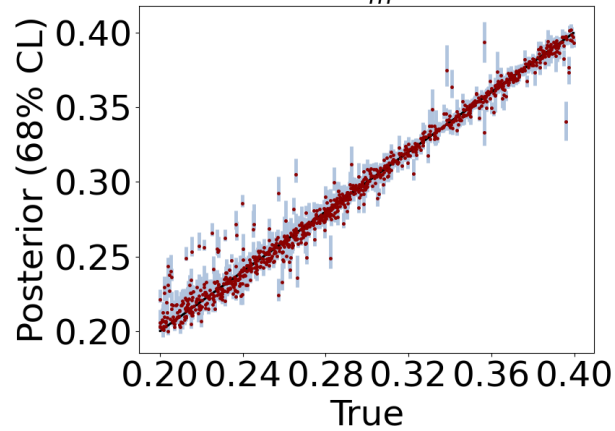
Uniform distribution → self consistent sampling

Performance Validation – Parameter Recovery

Direct Inference from simulated 3D cubes → Check Posterior vs. True label

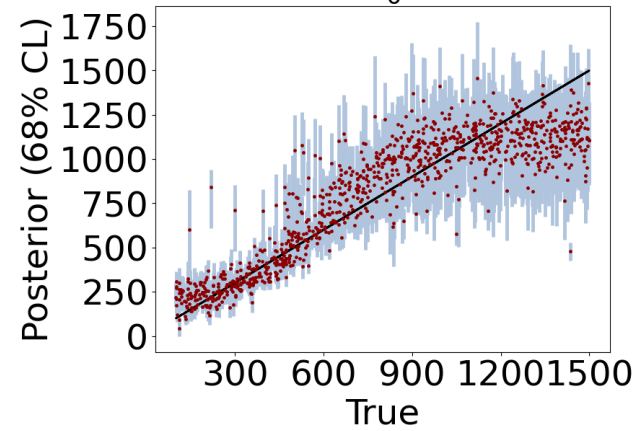
Cosmology

Ω_m



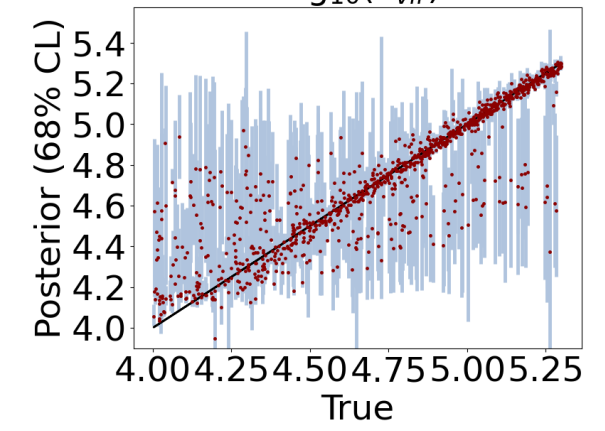
Reionization

E_0

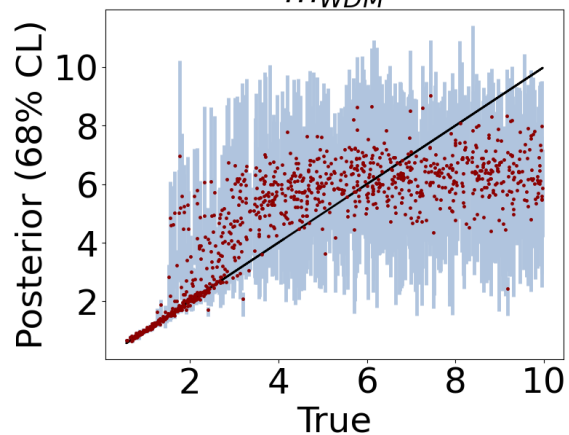


Cosmic Dawn

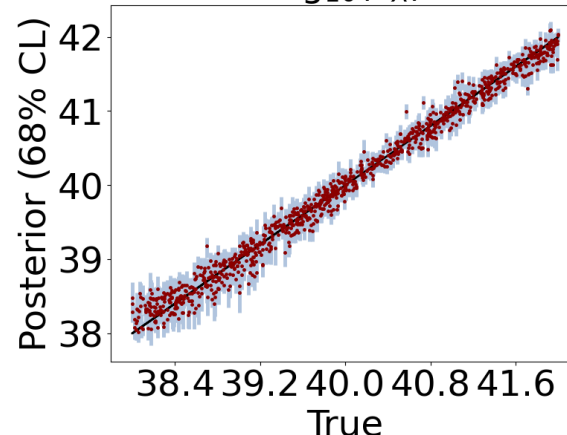
$\log_{10}(T_{vir})$



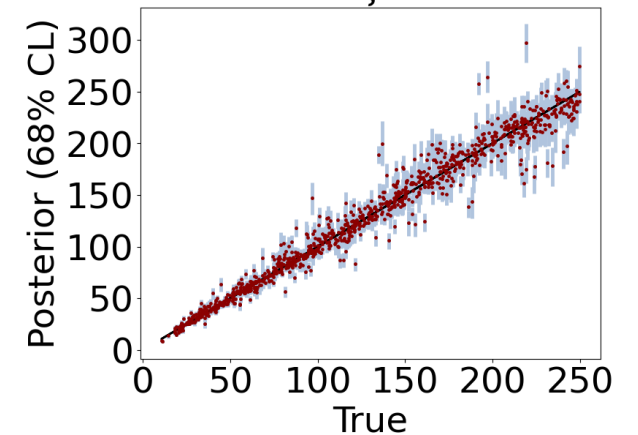
m_{WDM}



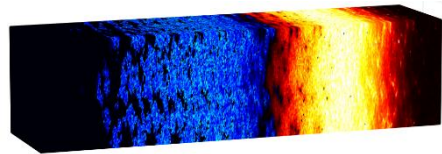
$\log_{10}(L_X)$



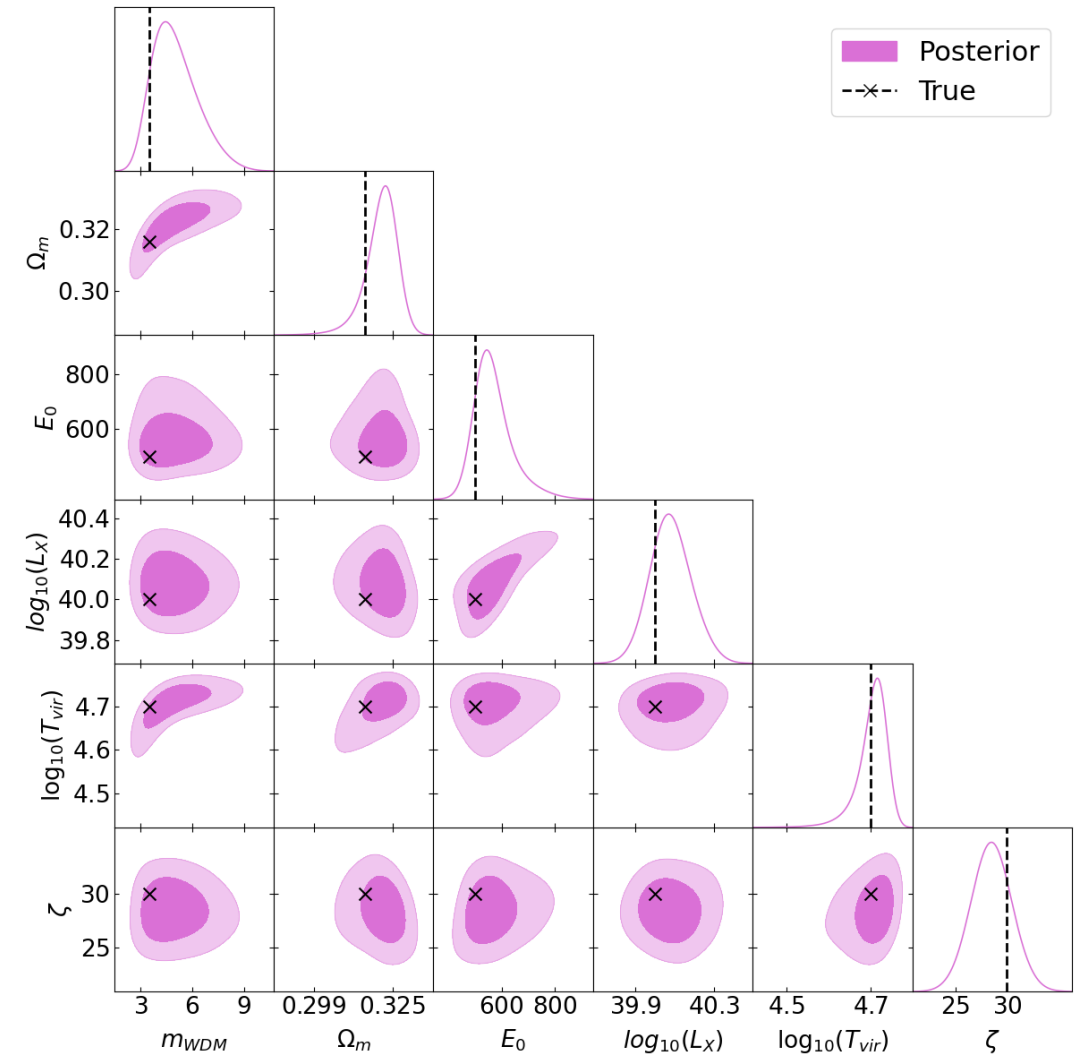
ζ



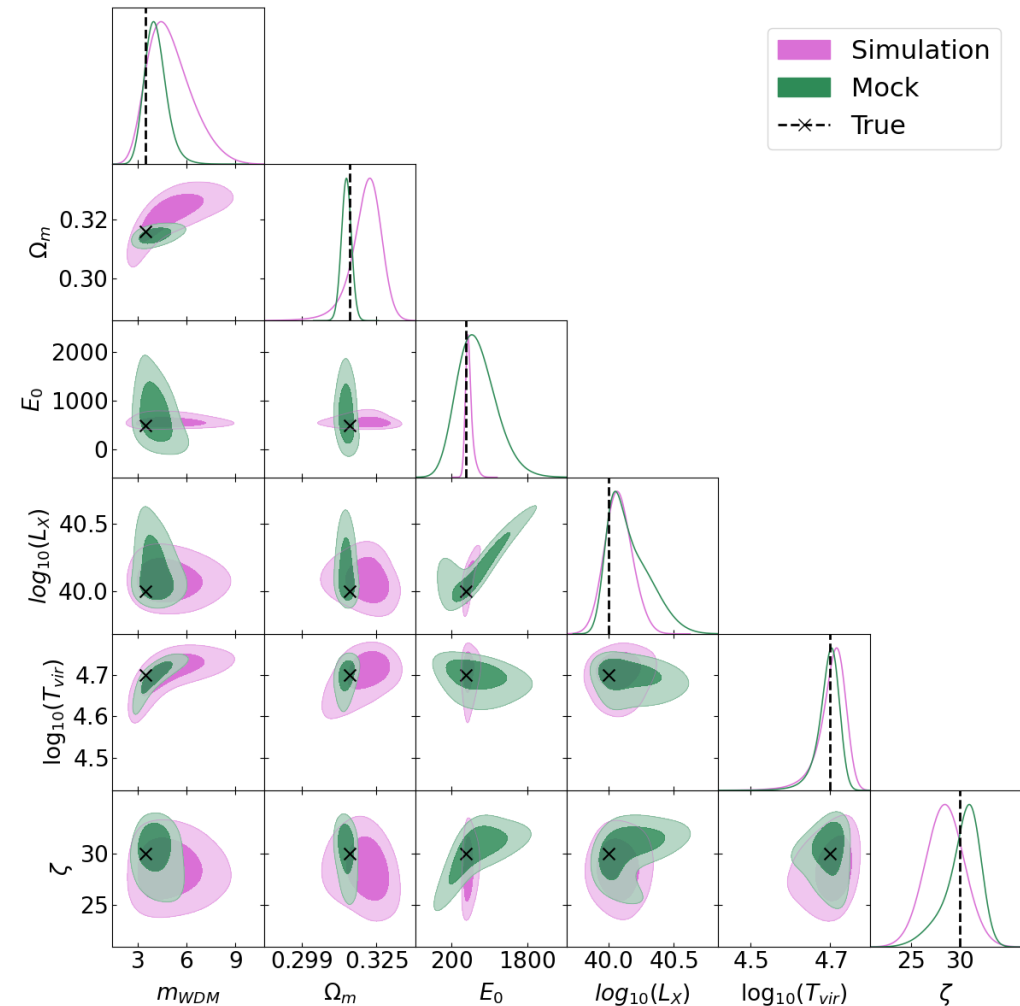
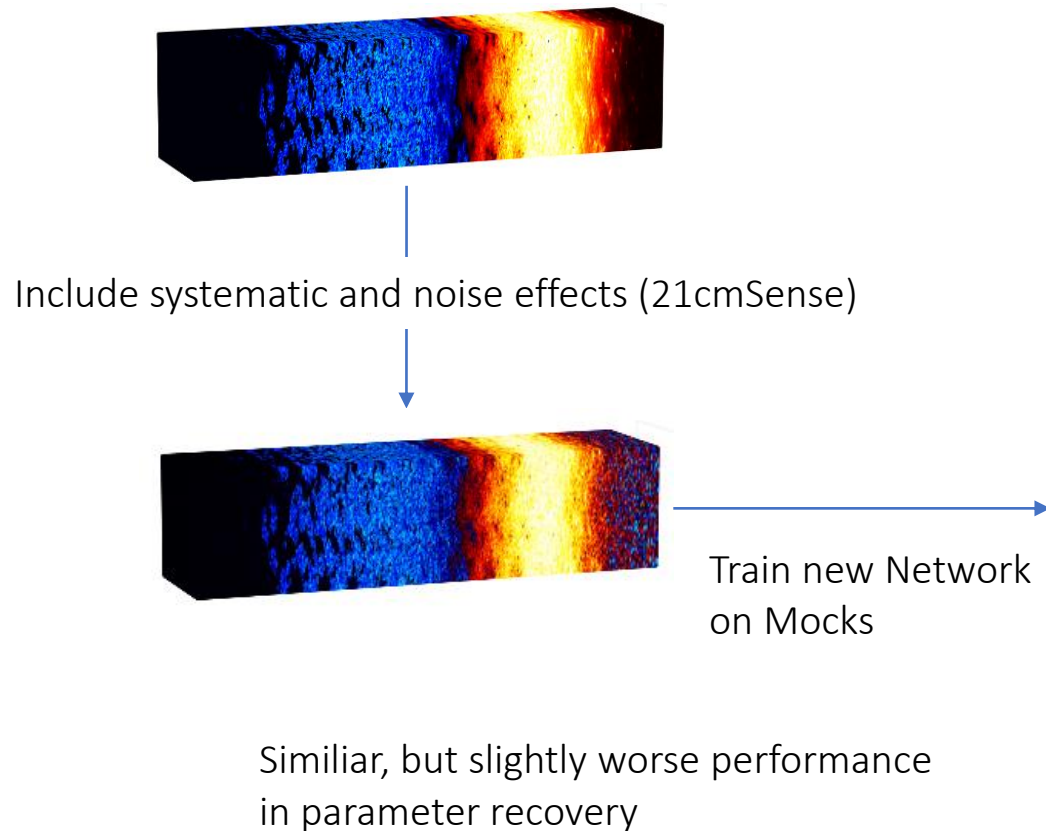
Fast Inference from 3D tomographic cubes



21cmPIE-cINN



Adding noise with Mock observations



Summary

- 21cm Data can jointly constrain Cosmology, Reionization and Cosmic Dawn
- No need for hand-crafted summary statistics
- ML gives fast and precise Inference

