NN-based inference of the optical depth to reionization τ from Planck maps[1]

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Background

- The optical depth to reionization, τ, is the least constrained ΛCDM parameter. To date, its most precise value stems from large-scale EE cross power spectra (XCL) from *Planck's* high-frequency instrument (HFI).
- *Planck* HFI maps contain hard-to-model non-Gaussian systematic residuals. Robust XCL methods, using simulations to build an empirical likelihood, yield $\tau = 0.0566^{+0.053}_{-0.062}$ (68% CL).[2]
- We present the first likelihood-free τ inference from polarized *Planck* HFI maps fully based on neural networks (NNs).

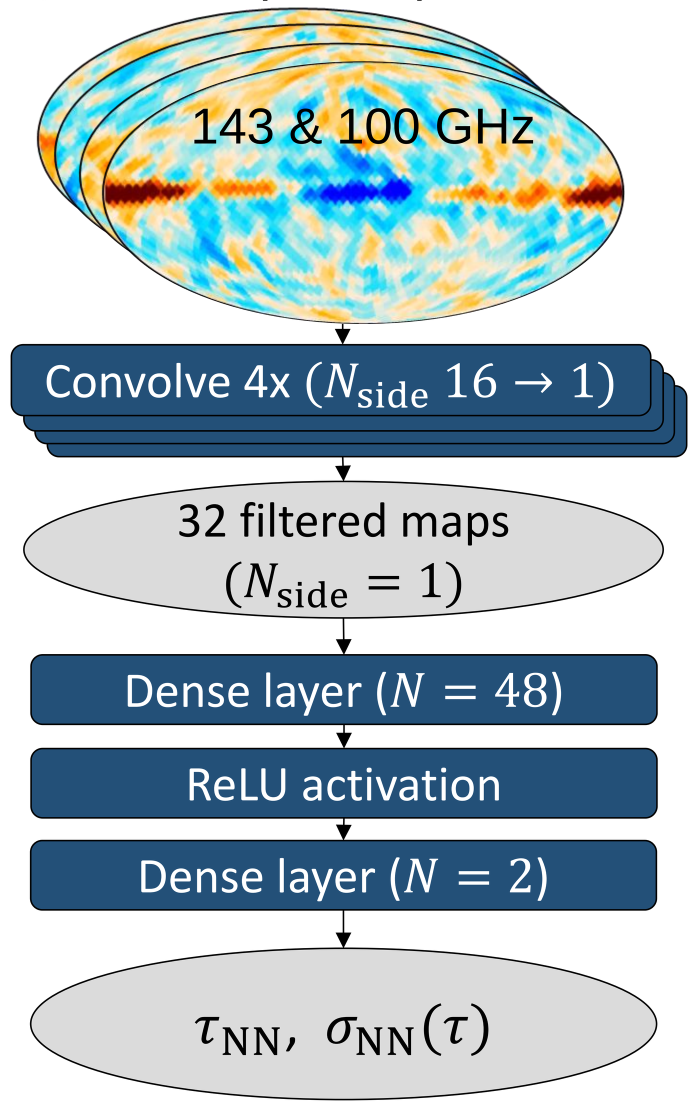

Fig. 1. Schematic of the convolutional dense neural net used in this work.

Method: CNNs

- Convolutional neural nets (CNNs) do not need analytical modeling and can be trained on multi-channel sims.
- We train, test, and validate NN models on Gaussian or *Planck* SRoll2[3] sky sims (CMB, noise, systematics).
- Infer value of τ directly from Stokes Q and U maps at ~4° pixel resolution, convolving first-neighbor pixels on the sphere using the *NNhealpix* code.[4]

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Results

Simulations

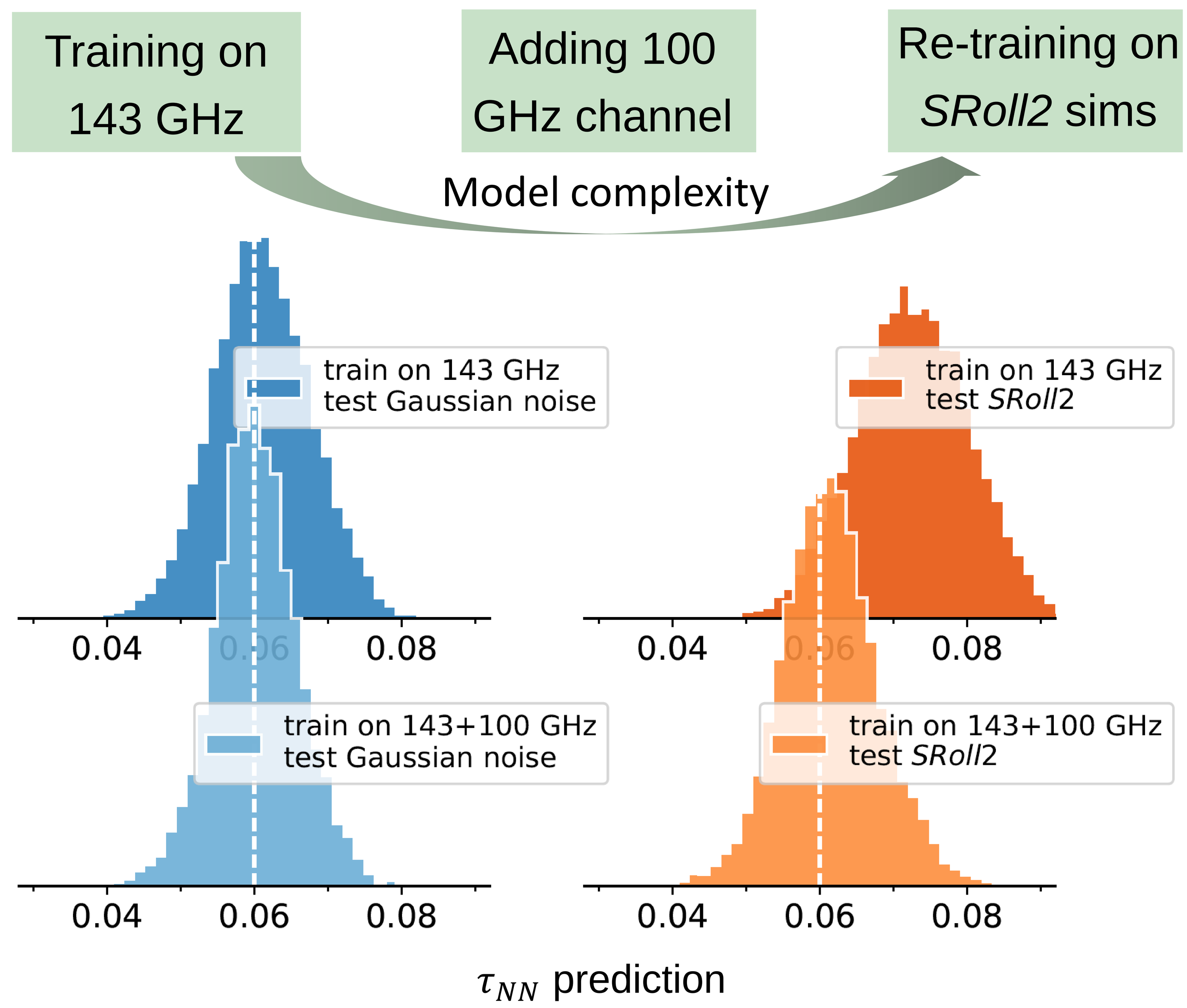

Fig. 2. Predictions from 10^4 simulations with input τ = 0.06, of CMB with Gaussian noise (left panels) or CMB with *SRoll2* noise + systematics (right panels). CNN models are trained on CMB + Gaussian noise on one (top) or two frequency channels (bottom).

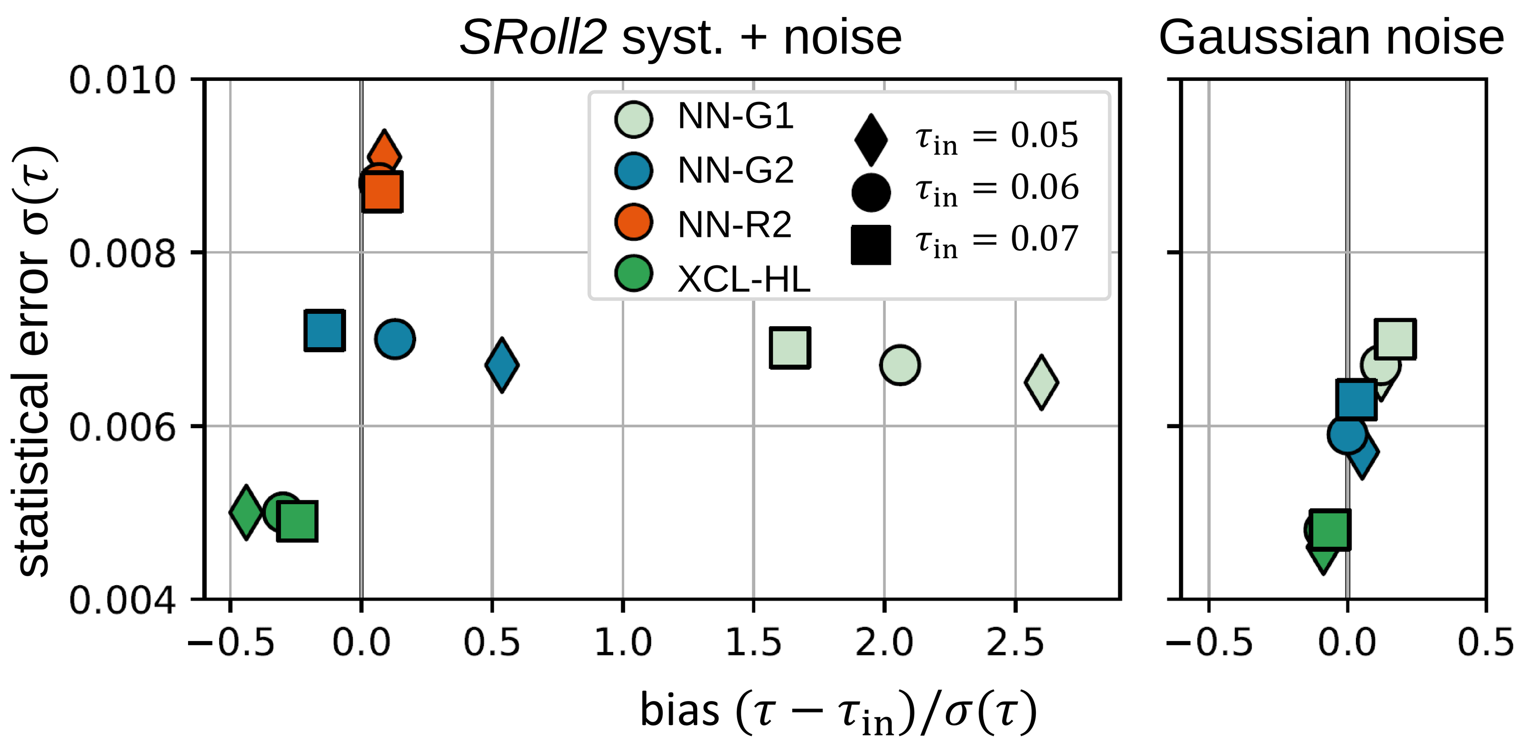

Fig. 3. Prediction bias and statistical error from sims as in Fig. 2, with different input τ values. CNN models are trained on 1 or 2 channels of Gaussian noise (teal, blue) or retrained on SRoll2 sims (orange). For comparison, we show results from the Hamimeche-Lewis (HL) XCL likelihood (green).

Planck data

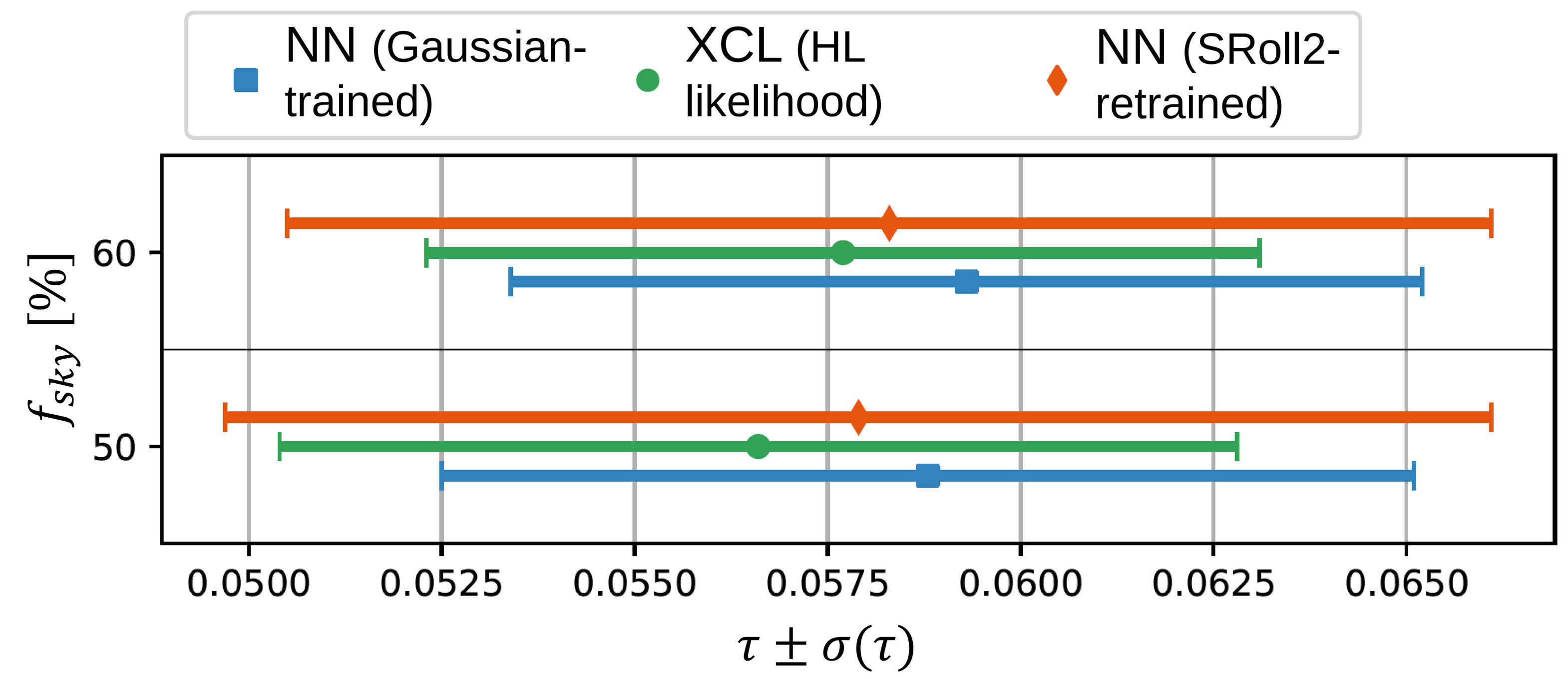

Fig. 4. Results for τ from Planck SRoll2 data, using the standard 50% sky mask or a 60% mask for comparison. Considered are the Gaussian NN, the retrained NN and the HL likelihood.

Conclusions

- On Planck data, we obtain $\tau_{NN} = 0.0579 \pm 0.0082$ (68% CL), compatible with current XCL results but with a ~ 30% larger uncertainty.[1]
- NNs effectively combine information from two channels, reducing impact of noise and systematics without need of explicit modeling.
- While this work does not improve $\sigma(\tau)$, it is the first robust NN-based inference on real CMB data.
- Promising tool for complementary analysis of near-future CMB experiments, *e.g.*, B-mode searches.

References

1 Kevin Wolz et al. 2023, submitted to A&A, arxiv:2301.09634
2 Luca Pagano et al. 2020, A&A, doi:201936630
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