

Maria Goes NIFTy

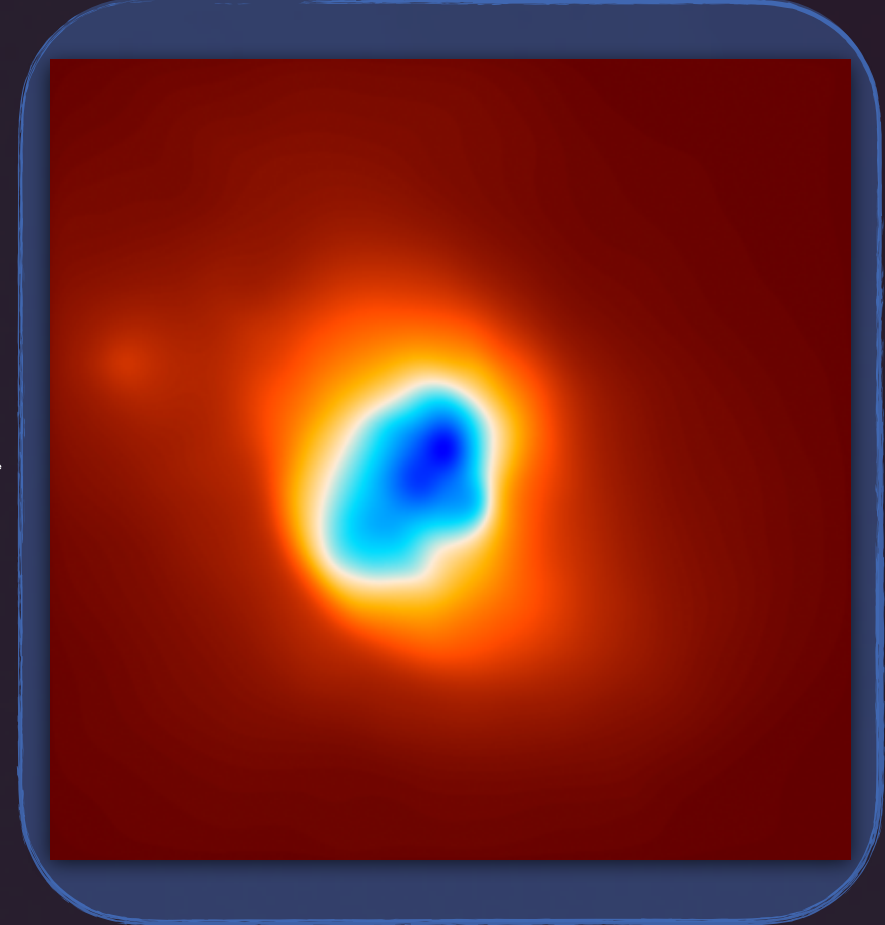
Simulation, Gaussian Process-Based Reconstruction and Denoising of (Sub-)Millimetre Single-Dish Telescope Data

J. Würzinger, J. van Marrewijk, T.W. Morris, R. Fuchs, T. Mroczkowski, L. Heinrich

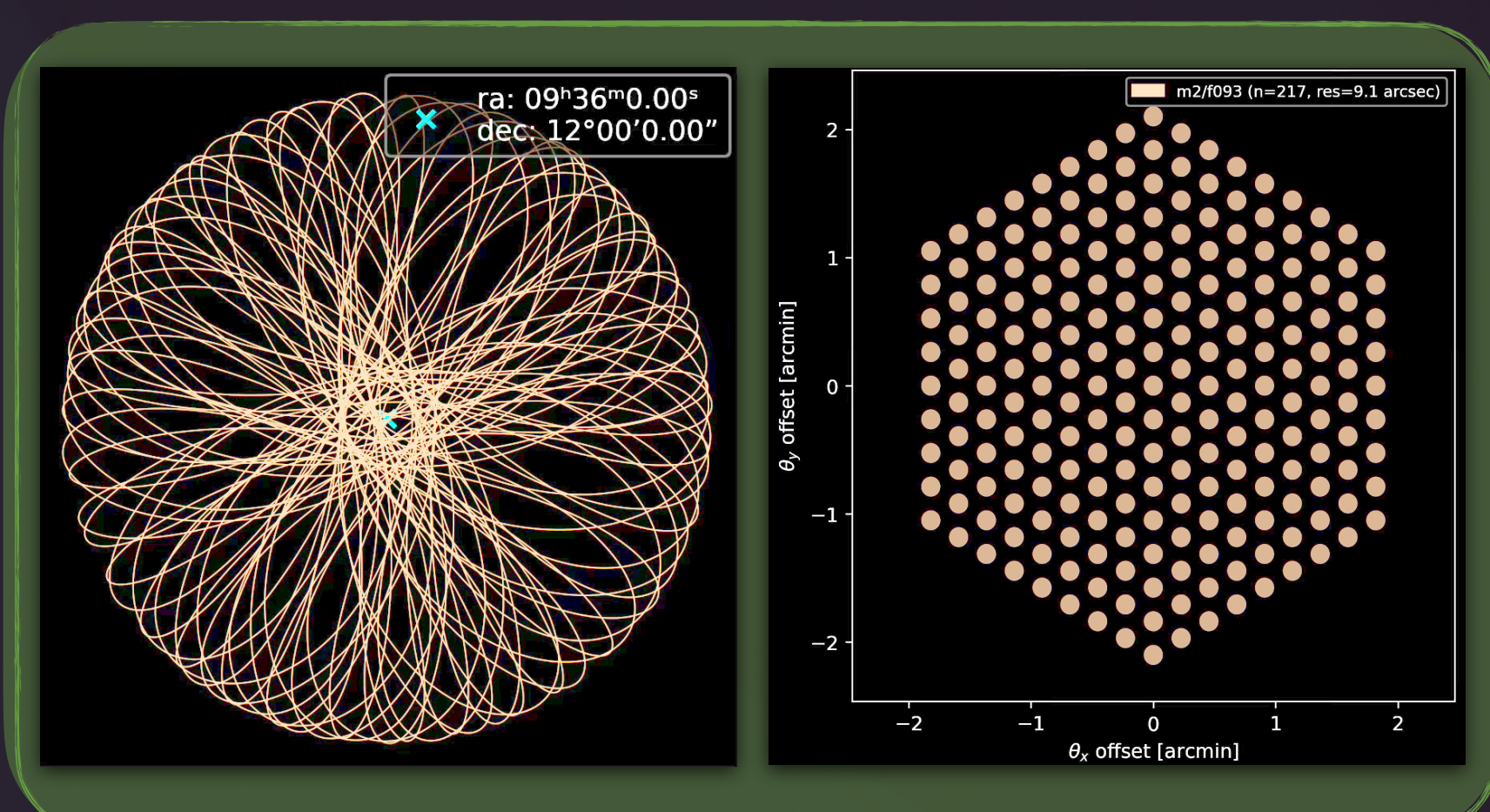
Maria [1]

A novel simulator for forecasting single-dish (sub-)mm observations
 “Maria blows the stars around and sends the clouds a-flying”
 - Alan J. Turner

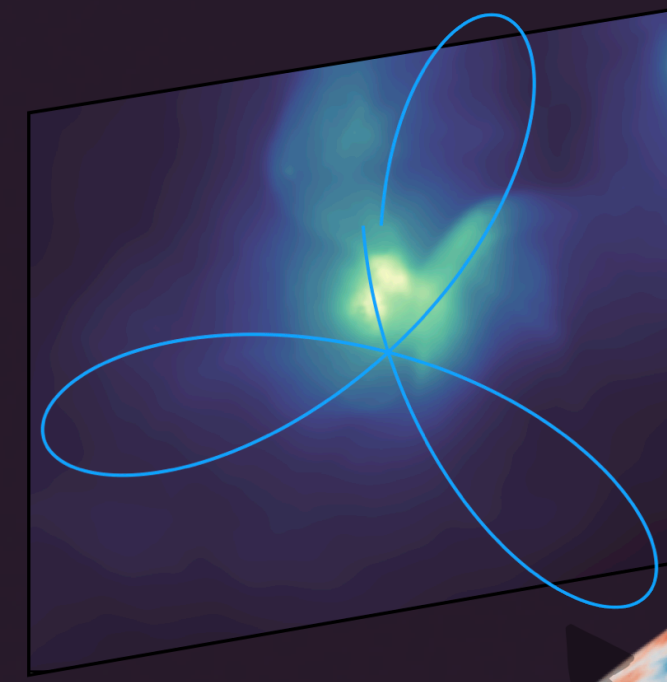
Input Map



Instrument: MUSTANG-2

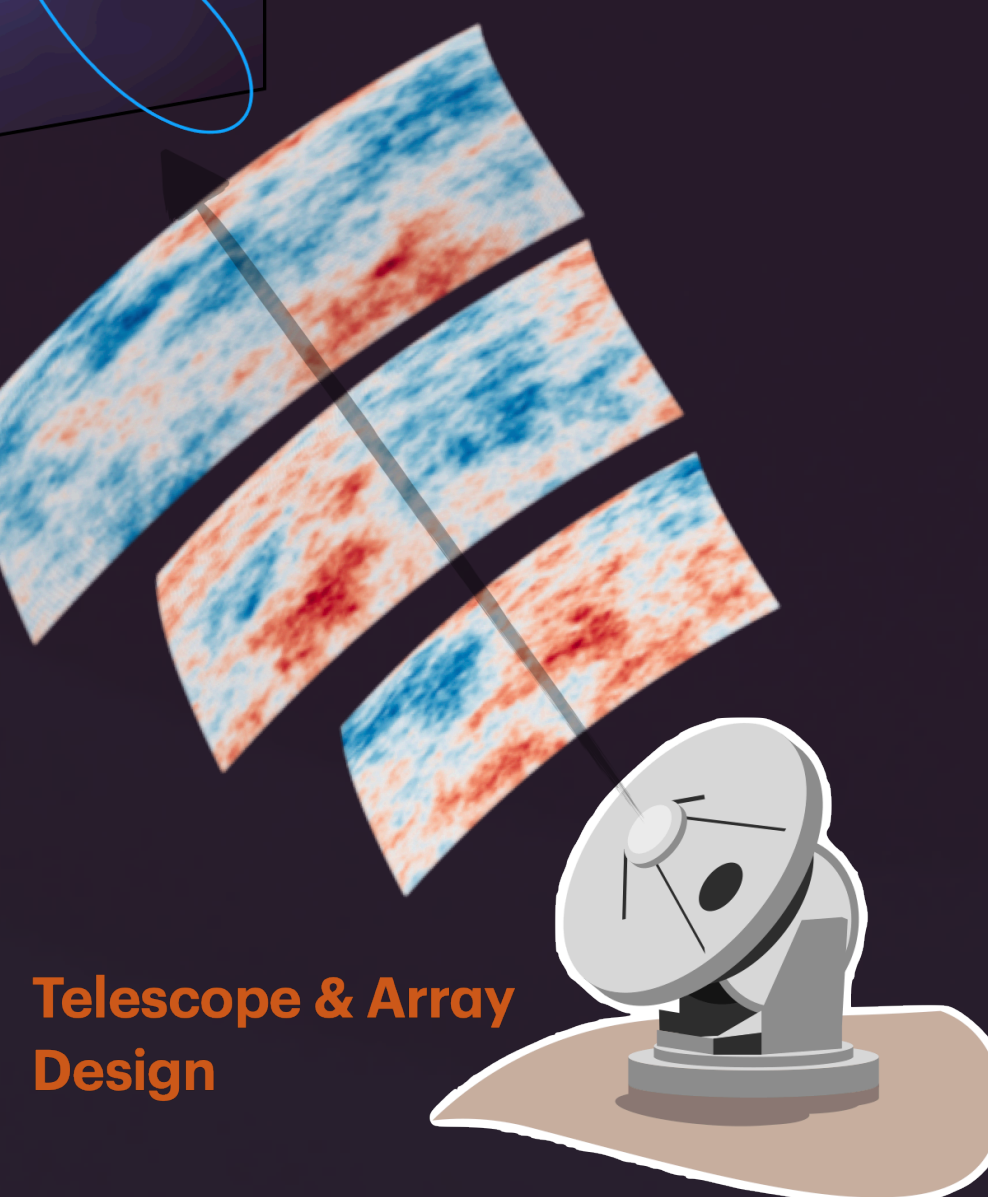


Input Sky



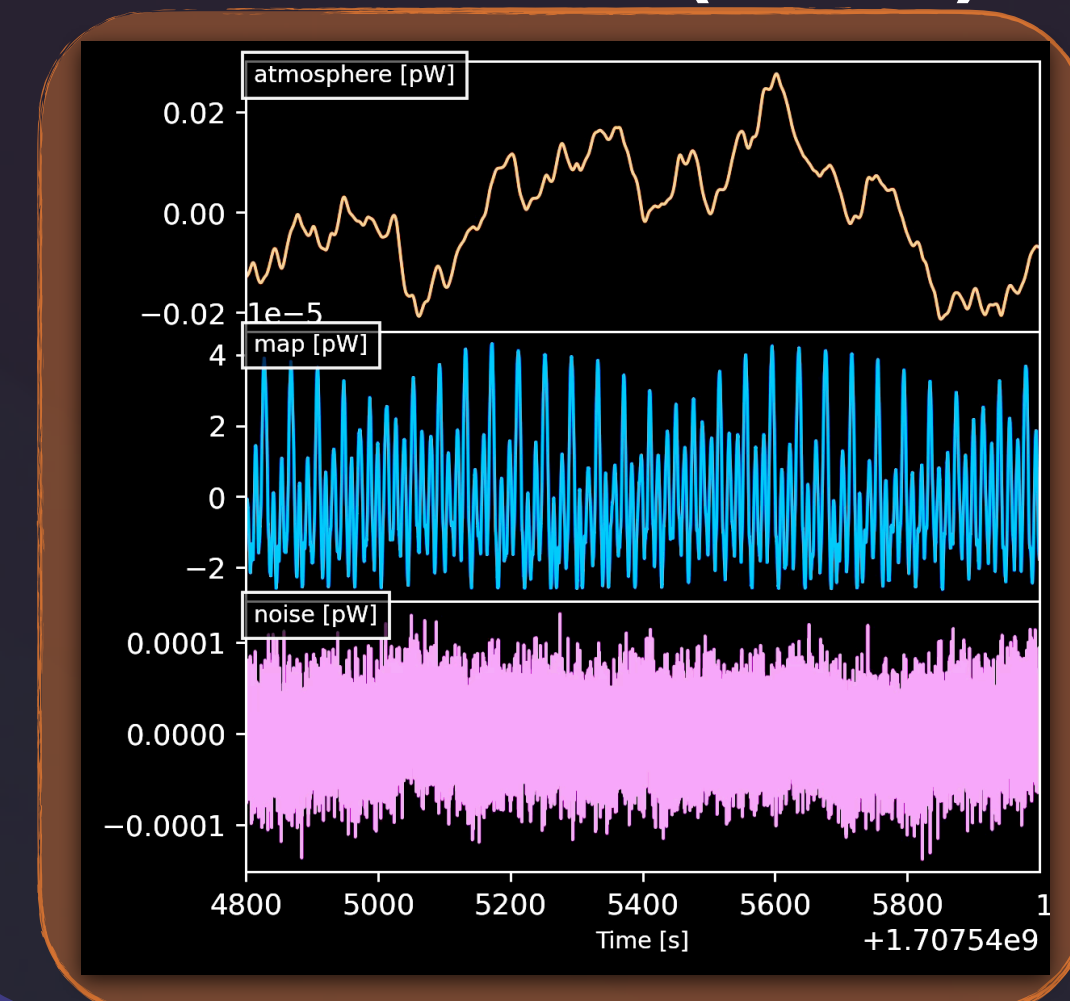
Scanning strategy

Simulated Evolving Atmosphere



Telescope & Array Design

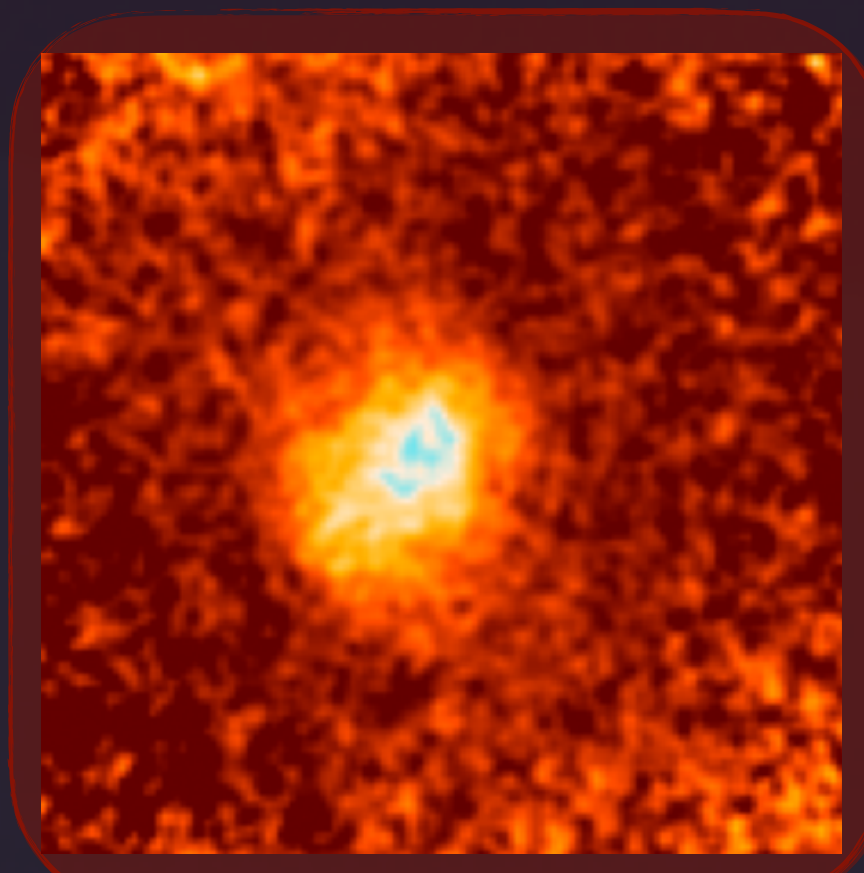
Time series (TODs)



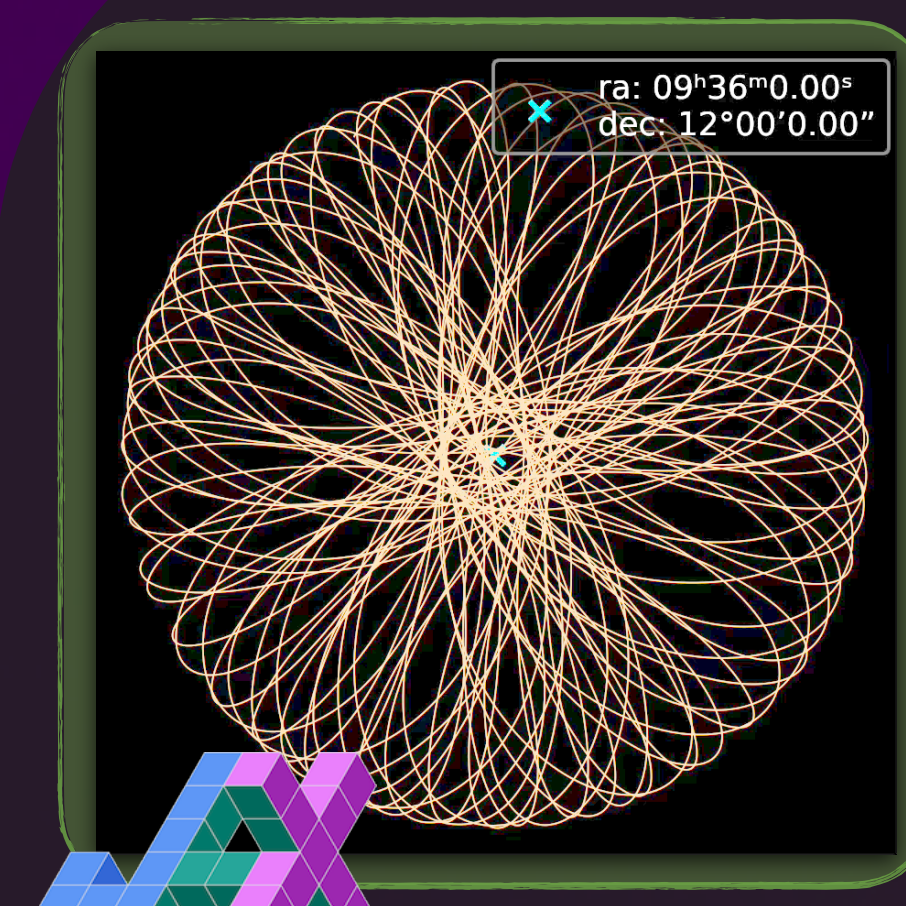
Reconstruction

“Map Making”

Reconstructed Map

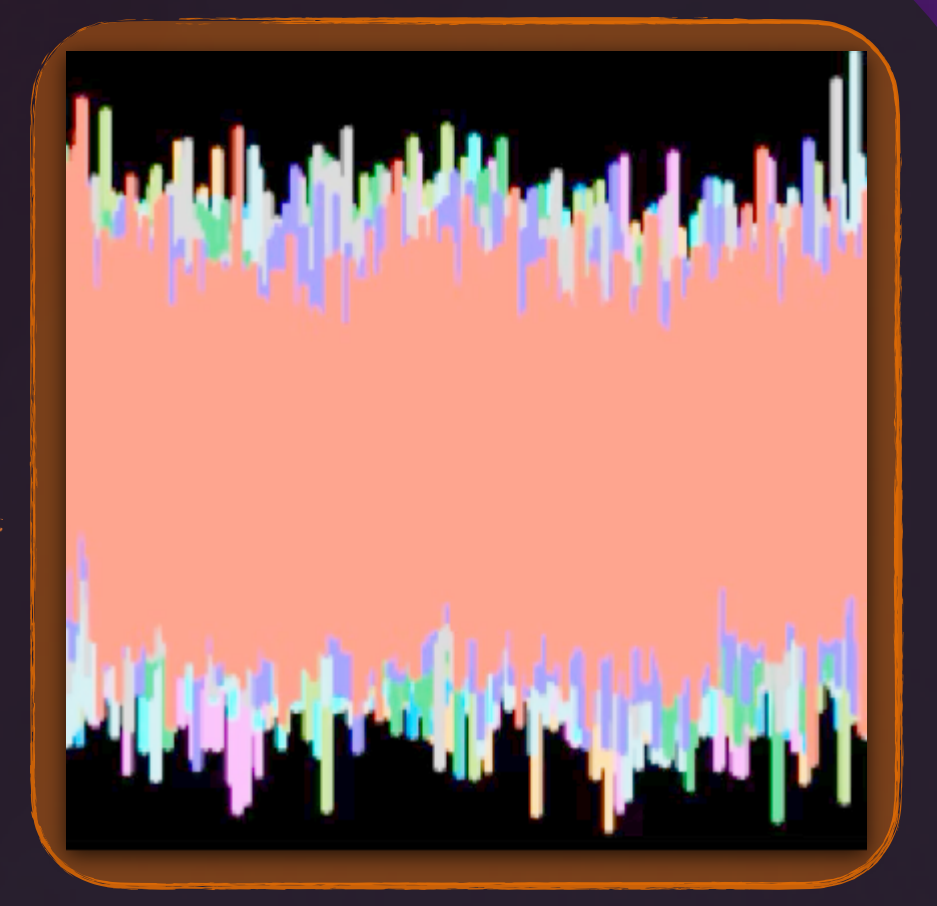


Forward Model

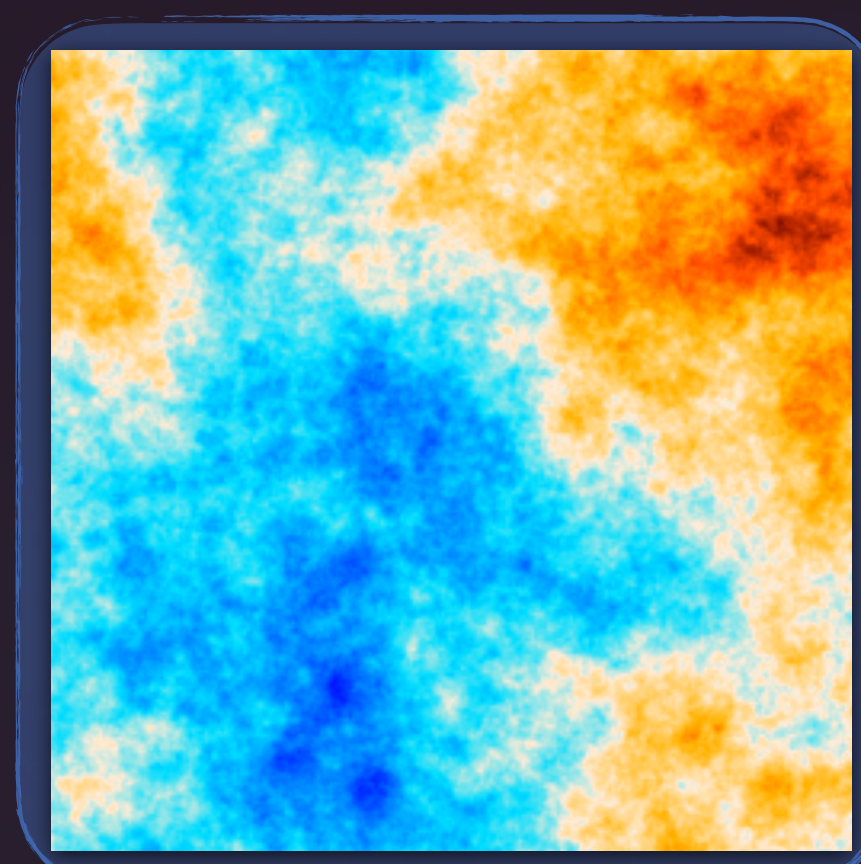


NIFTy [2]

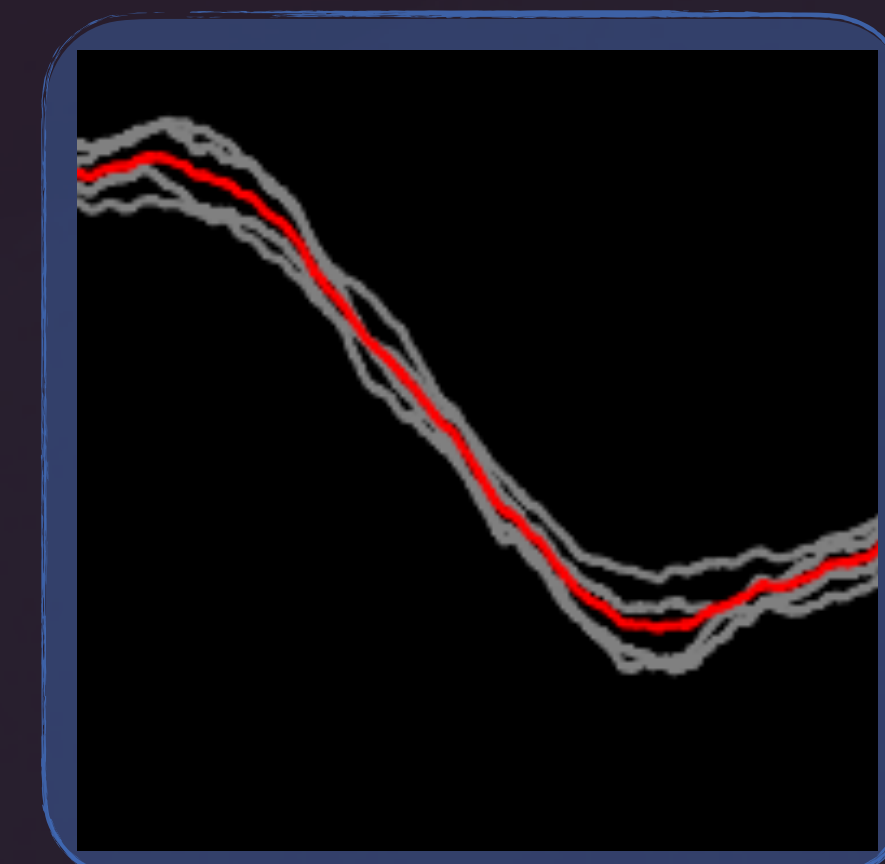
White Noise



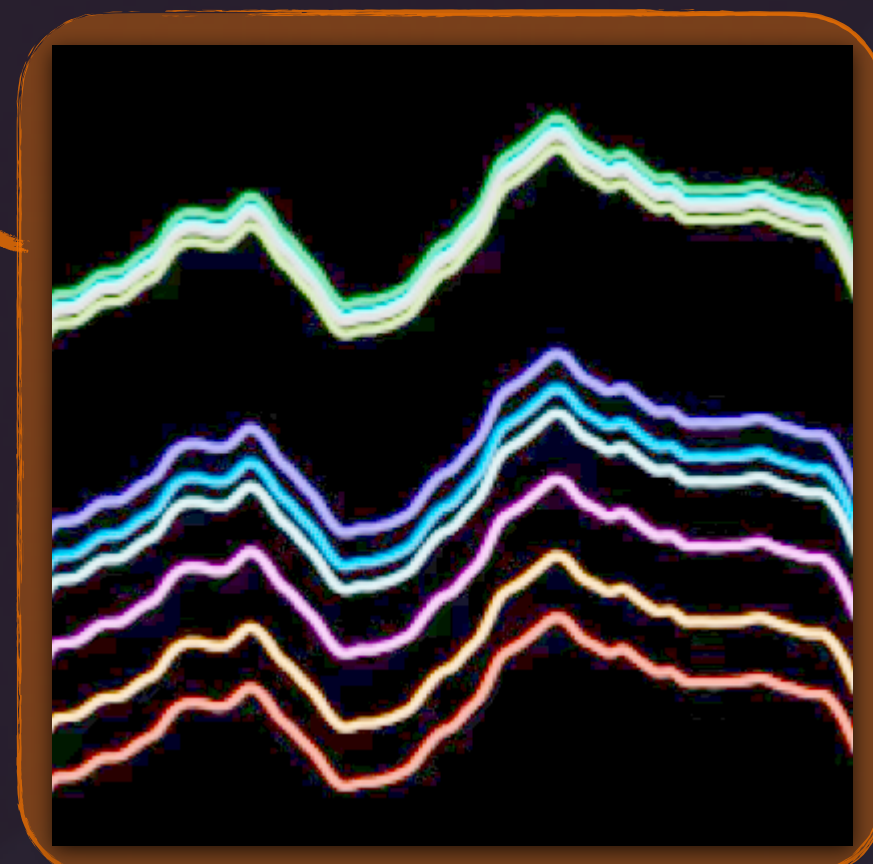
$$R(s, t) + a(t) + n = d(t)$$



2D map GP $\mathcal{G}(x, y)$



1D atmos. GP $\mathcal{G}(t)$



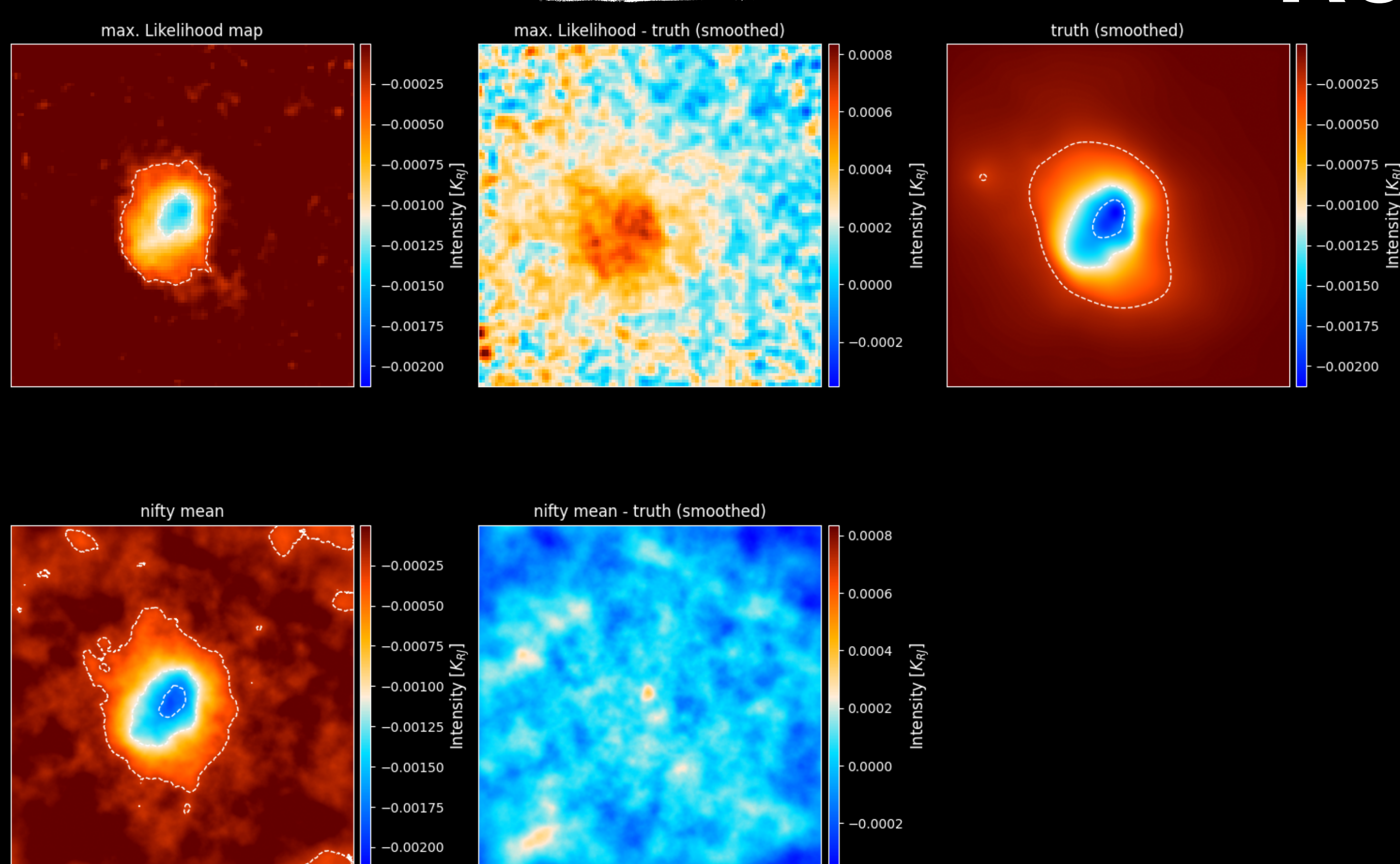
Predicted Data

Gradients $\vec{\nabla}$

Where is the ✨ Magic ✨?

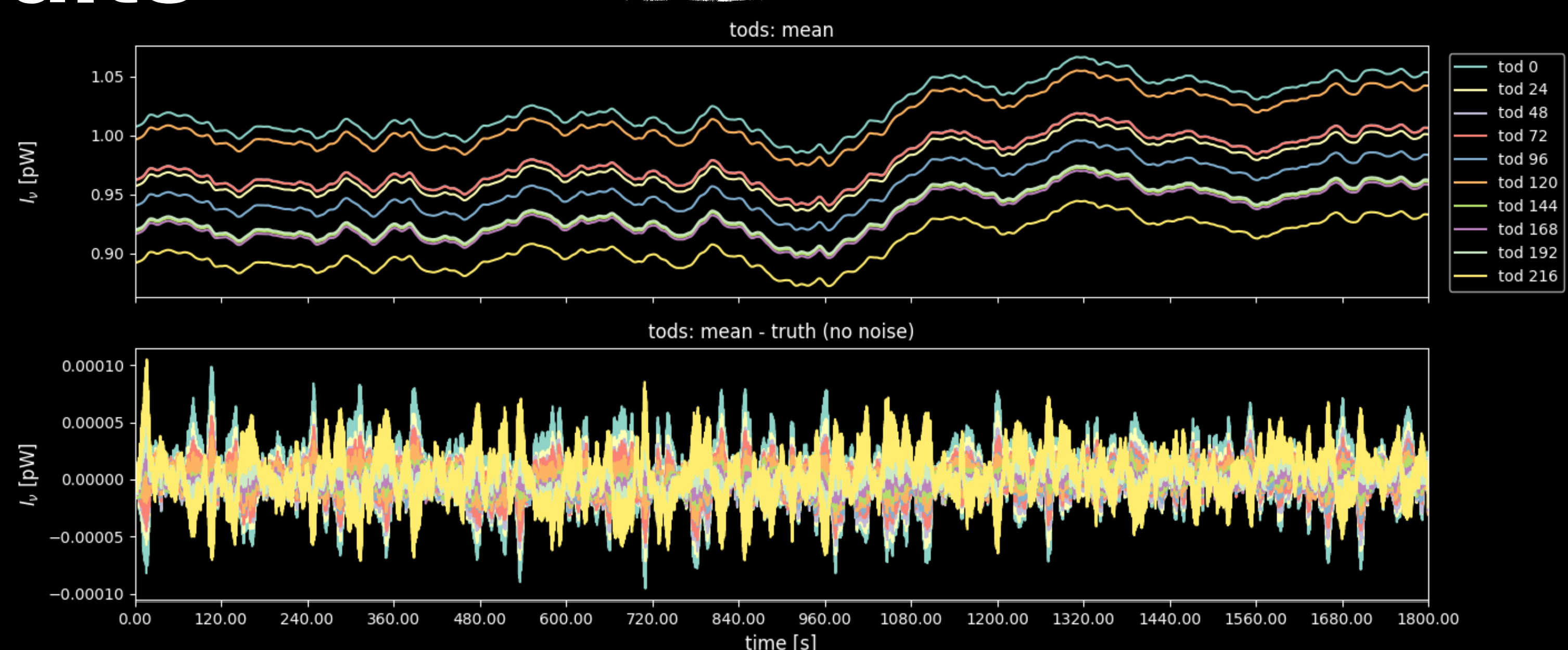
1. Correlated Field Model $\mathcal{G} = \mathcal{F}\sqrt{\mathcal{P}}\xi$
2. Variational Inference (Samples & Uncertainties)
3. Information Field Theory: Powerful statistics framework
Fisher information & non-linear transformation of posterior
4. JAX-ed Forward Model: Incorporate physics knowledge about the system

Map Reconstruction

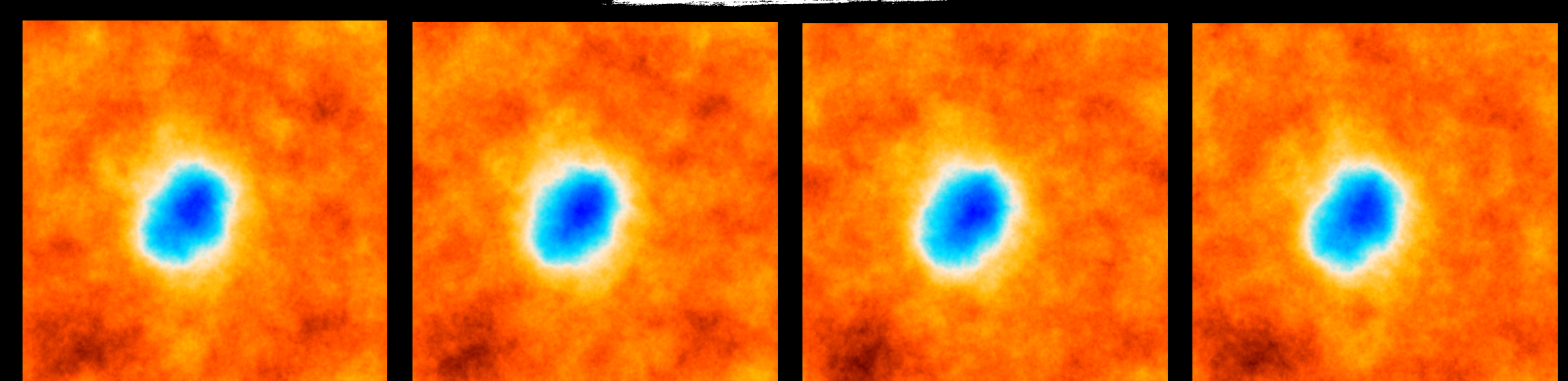


Results

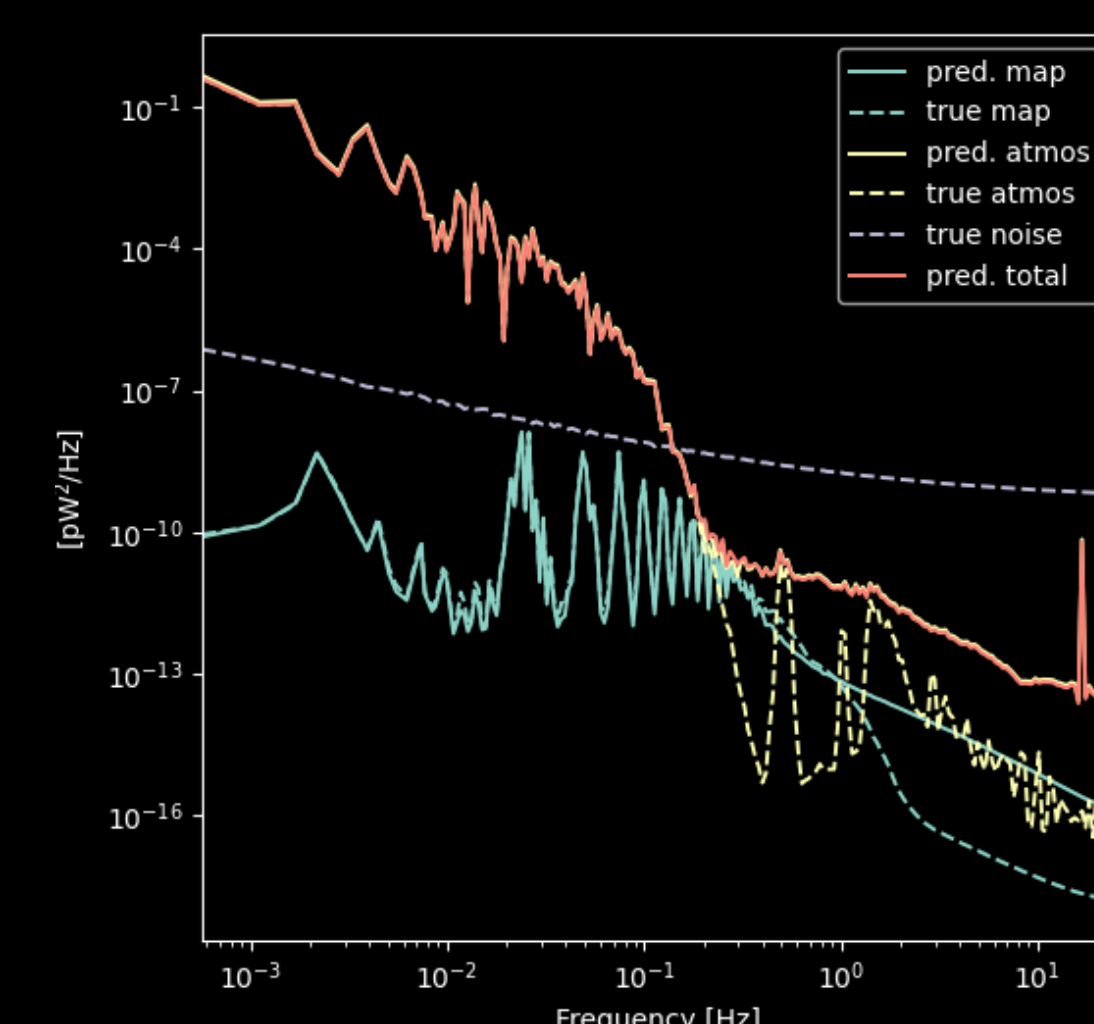
Atmosphere Reconstruction



Draw Samples



Powerspectrum



Open Items

- Scale up: 217 → ~300,000 detectors
- Reconstruction on real MUSTANG-2 data
- Expand to: multi-frequency, add $1/f$ noise, CMB reco, point sources, interferometry

Better Reco than State-of-the-Art!

	NIFTy	Minkasi [3]
Resolution	1,000 x 1,000	200 x 200
Max. Residual	4E-04 (20%)	8E-04 (40%)
Avg. Residual	2E-06	2E-04
Samples	✓	✗
Unc.	✓	✗
Atmos. Reco	✓	✗

Try the code!



[1] Maria, arXiv:2402.10731

[2] NIFTy, arXiv:2402.16883

[3] Minkasi, Jon Sievers et al. (in prep.)

<https://github.com/sievers/minkasi>