Accelerating High-Dimensional Cosmological Inference with COSMOPOWER

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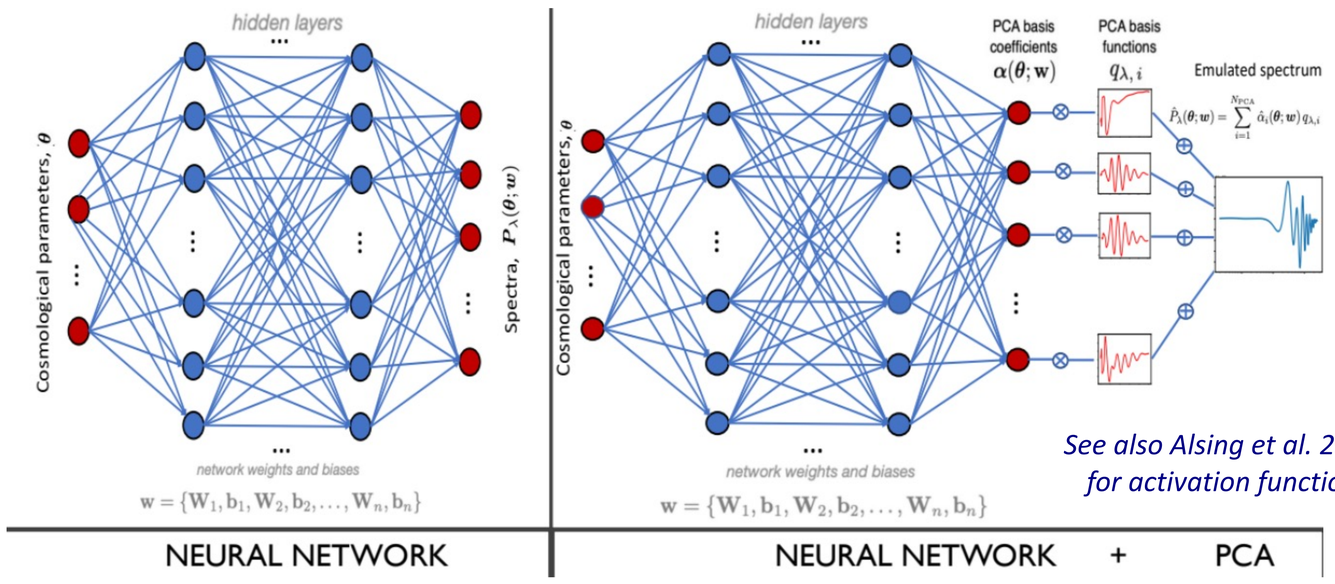
1. COSMOPOWER

- Neural network emulating CMB & matter power spectra from Boltzmann codes
- It can either learn to emulate spectra from parameters directly (left image) or PCA coefficients of the spectra from the parameters (right image)

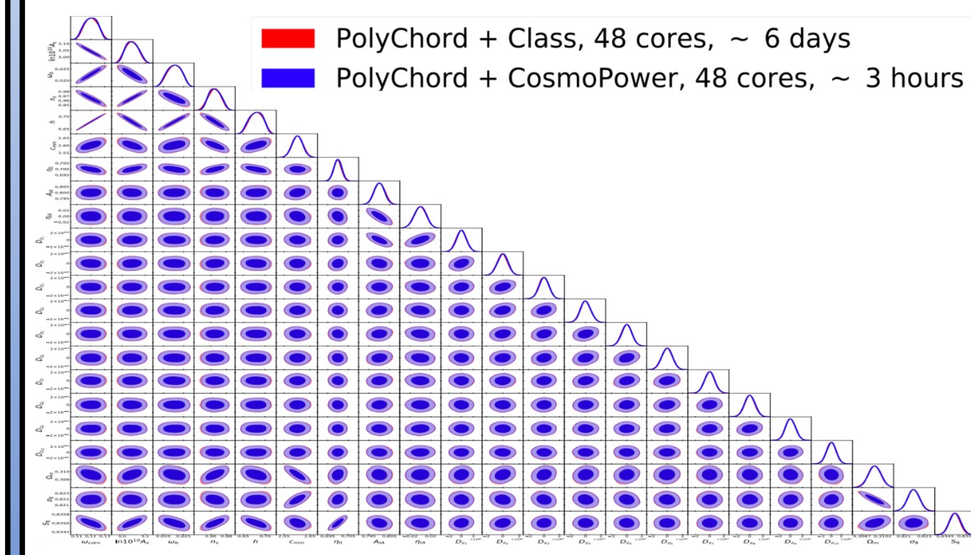
Spurio Mancini + 2022



See also Alsing et al. 2020 for activation function

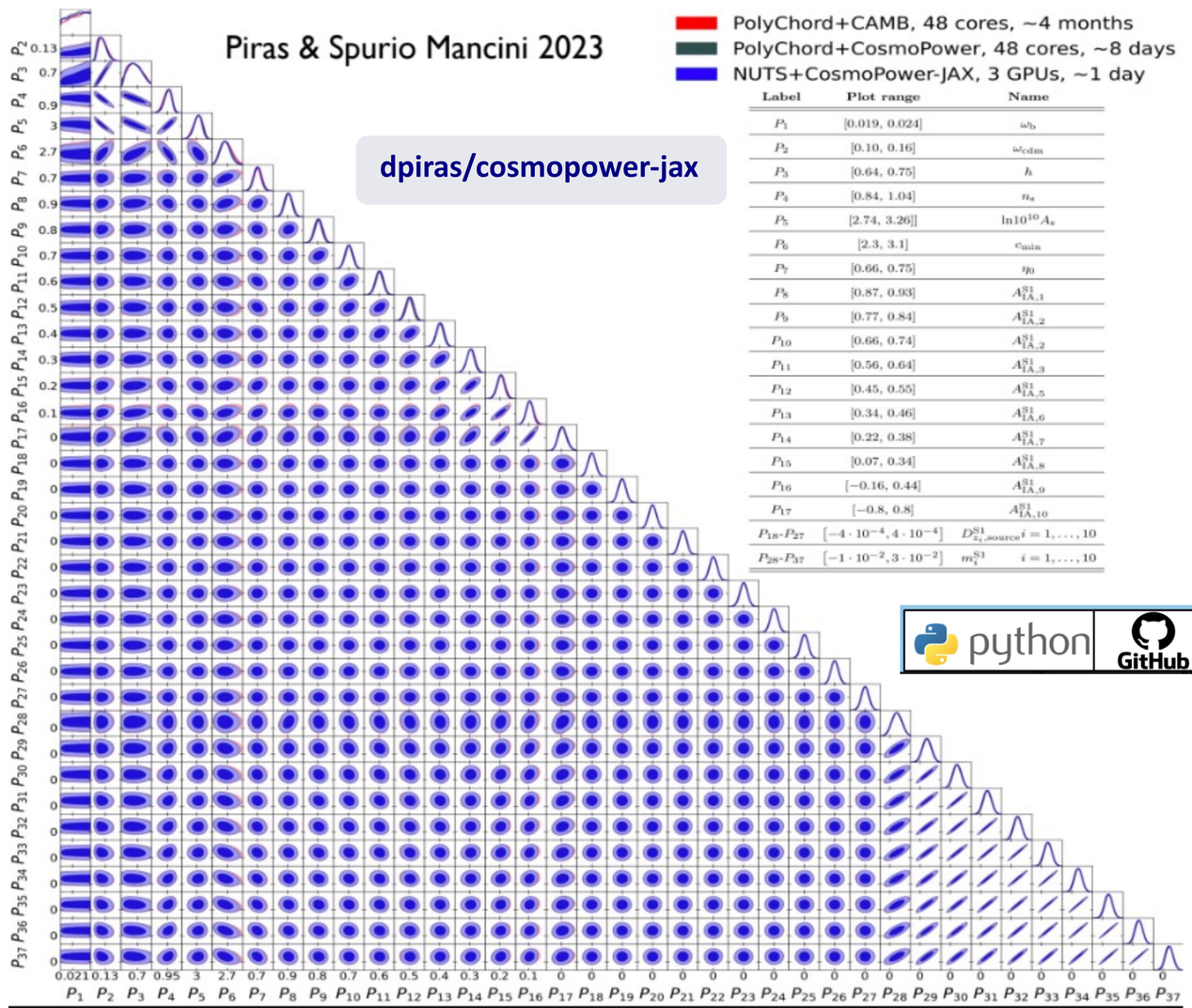
alessiospuriomancini/cosmopower

2. Inference Acceleration



- Replacing the Boltzmann code with COSMOPOWER in the likelihood function leads to massive acceleration
- This is shown here for a Cosmic Shear Survey with Stage IV configurations

3. Fully-differentiable inference pipeline



dpiras/cosmopower-jax

Label	Plot range	Name
P_1	$[0.019, 0.024]$	ω_b
P_2	$[0.10, 0.16]$	ω_{cdm}
P_3	$[0.64, 0.75]$	h
P_4	$[0.84, 1.04]$	n_s
P_5	$[2.74, 3.26]$	$\ln 10^{10} A_s$
P_6	$[2.3, 3.1]$	c_{min}
P_7	$[0.66, 0.75]$	η_0
P_8	$[0.87, 0.93]$	$A_{IA,1}^{S1}$
P_9	$[0.77, 0.84]$	$A_{IA,2}^{S1}$
P_{10}	$[0.66, 0.74]$	$A_{IA,2}^{S1}$
P_{11}	$[0.56, 0.64]$	$A_{IA,3}^{S1}$
P_{12}	$[0.45, 0.55]$	$A_{IA,5}^{S1}$
P_{13}	$[0.34, 0.46]$	$A_{IA,6}^{S1}$
P_{14}	$[0.22, 0.38]$	$A_{IA,7}^{S1}$
P_{15}	$[0.07, 0.34]$	$A_{IA,8}^{S1}$
P_{16}	$[-0.16, 0.44]$	$A_{IA,9}^{S1}$
P_{17}	$[-0.8, 0.8]$	$A_{IA,10}^{S1}$
P_{18}-P_{27}	$[-4 \cdot 10^{-4}, 4 \cdot 10^{-4}]$	$D_{z_i,source}^{S1}$ $i = 1, \ldots, 10$
P_{28}-P_{37}	$[-1 \cdot 10^{-2}, 3 \cdot 10^{-2}]$	m_i^{S1} $i = 1, \ldots, 10$

- COSMOPOWER-JAX = JAX-based version of COSMOPOWER
- Provides efficient & accurate derivatives of power spectra with respect to cosmological parameters
- Coupled with JAX-COSMO (Campagne et al. 2023) can write fully differentiable, GPU-accelerated pipelines for inference with NUTS, scaling up to very large parameter spaces
- Can also obtain model comparison using HARMONIC (Polanska et al. 2024; see Alicja Polanska's talk)

4. Future of cosmological likelihood-based inference

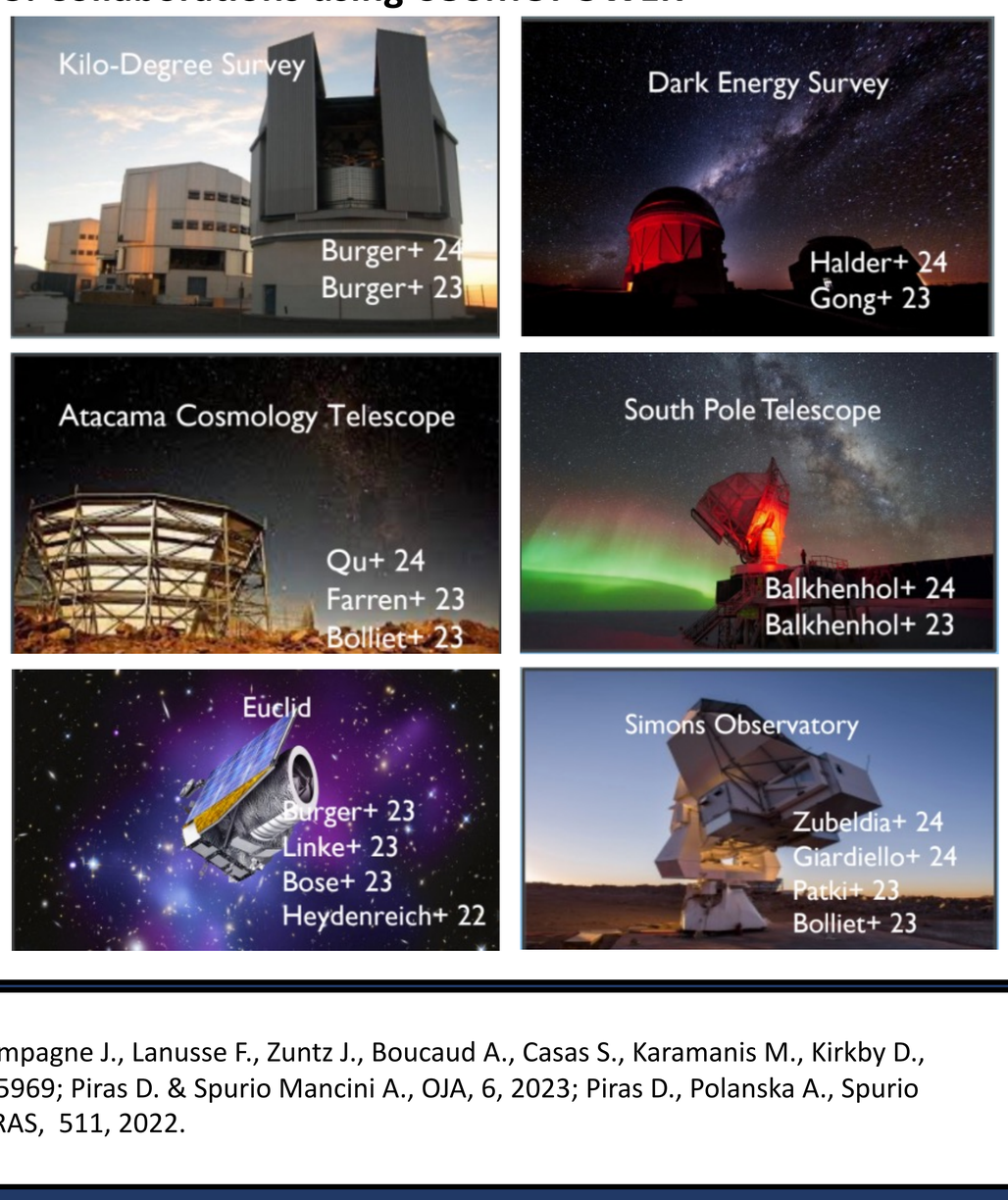
- Parameter estimation with a fully differentiable pipeline & model selection decoupled from sampling

Cosmic shear for Stage IV survey (37 / 39 parameters) LCDM vs w0waCDM
Our estimate: $\log \mathrm{BF} = 1.53 \pm 0.07$ (2 days + 12min on 12 GPUs) Nested sampling: $\log \mathrm{BF} = 0.78 \pm 0.79$ (8 months on 48 CPUs)

3x2pt for 3 Stage IV surveys (157 / 159 parameters) LCDM vs w0waCDM
Our estimate: $\log \mathrm{BF} = 1.9^{+0.7}_{-0.5}$ (8 days on 24 GPUs) Nested sampling: Estimated computation time ~ 12 years

Piras et al. 2024

5. Collaborations using COSMOPOWER



Key References

Alsing J., Peiris H., Leja J., Hahn C., Tojeiro R., Mortlock D., Leistedt. B., Johnson B., Conroy C., ApJS, 249, 2020; Campagne J., Lanusse F., Zuntz J., Boucaud A., Casas S., Karamanis M., Kirkby D., Lanzieri D., Li Y., Peel A., OJA, 6, 2023; Polanska A., Price M., Piras D., Spurio Mancini A., McEwen J., arXiv:2405.05969; Piras D. & Spurio Mancini A., OJA, 6, 2023; Piras D., Polanska A., Spurio Mancini A., Price M., McEwen J., OJA, 7, 2024; Spurio Mancini A., Piras D., Alsing J. Joachimi B., Hobson M., MNRAS, 511, 2022.