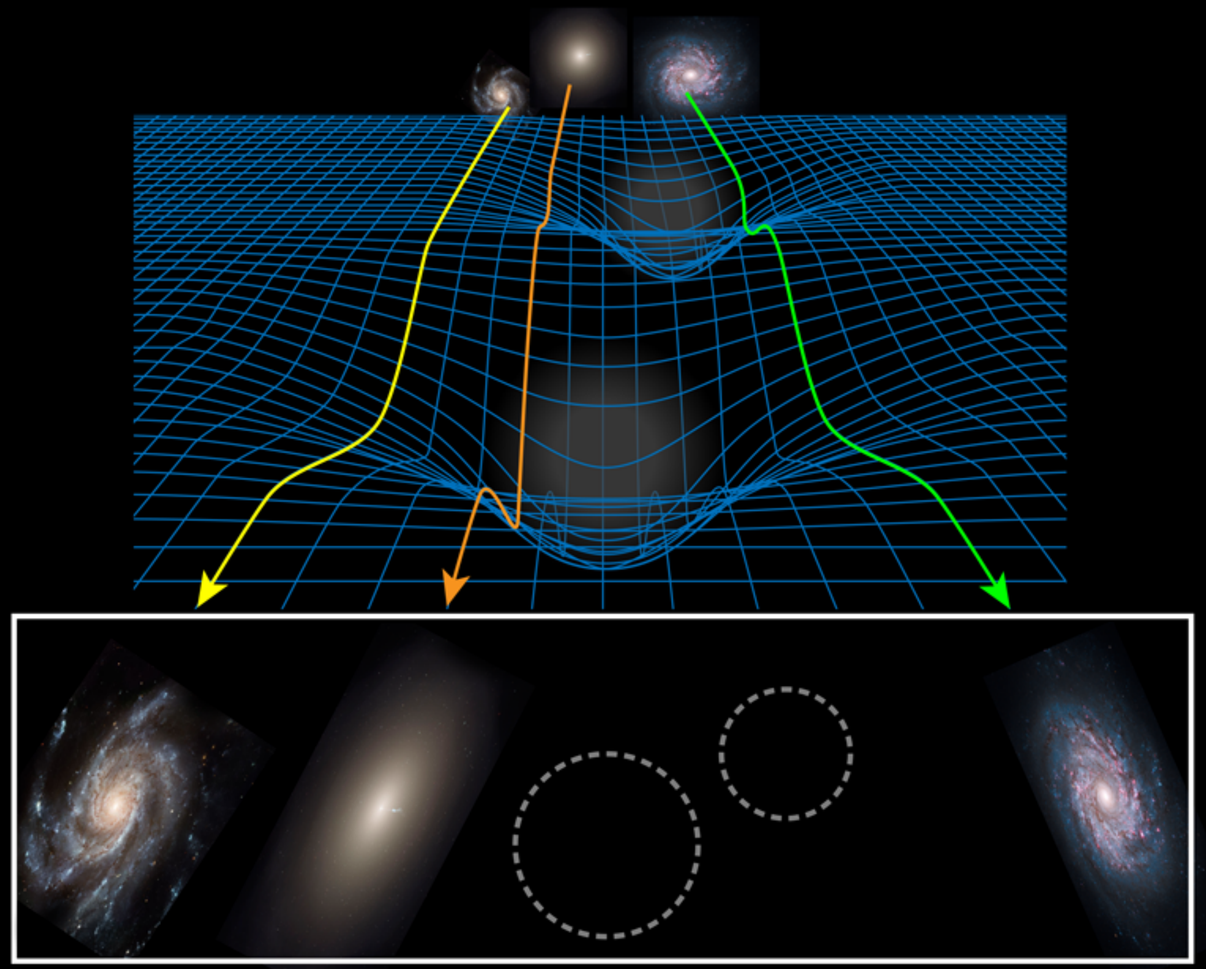
Weak Lensing ML Uncertainty Competition

FAIR Universe

Overview

Weak gravitational lensing

- The gravity of matter warps the surrounding space-time and causes distortions in the observed shapes of the background galaxies.
- Powerful probe of the matter distribution in our universe from coherent patterns of galaxy shapes.
- Numerous current and upcoming WL surveys: DES, HSC, Euclid, Rubin LSST, Roman, etc.
- Traditional analysis based on two-point correlation functions can only capture limited amount of information from the weak lensing data (2D fields similar to images).
- **AI/ML-based approaches could capture more information hidden in higher-order correlations!**
  WE NEED YOU!



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Competition tasks

The competition tasks will be structured into **2 phases**:

- **Phase 1: Cosmological Parameter Estimation**

  Participants will develop models that:

  - Accurately infer cosmological parameters (Ω_m, S_8) from the weak lensing image data.
  - Quantify uncertainties via the 68% confidence intervals of the parameters of interest (Ω_m, S_8).

- **Phase 2: Out-of-Distribution Detection**

  Some test data will be generated with different physical models (OoD), leading to some distribution shifts with respect to the test data in Phase 1. Participants will develop models that:

  - Identify test data samples inconsistent with the training distribution (OoD detection).
  - Provide probability estimates indicating data conformity to training distributions.

Scoring metrics

KL divergence between the true Gaussian-like posterior distribution and the Gaussian with the predicted mean and standard deviation:

$$\text{score}_{\text{inference}} = -\frac{1}{N_{\text{test}}} \sum_{i=0}^{N_{\text{test}}} \left\{ \frac{\left(\hat{\Omega}_m - \Omega_m^{\text{truth}}\right)^2}{\hat{\sigma}_{\Omega_m}^2} + \frac{\left(\hat{S}_8 - S_8^{\text{truth}}\right)^2}{\hat{\sigma}_{S_8}^2} + \log\left(\hat{\sigma}_{\Omega_m}^2\right) + \log\left(\hat{\sigma}_{S_8}^2\right) + \lambda \left[\left(\hat{\Omega}_m - \Omega_m^{\text{truth}}\right)^2 + \left(\hat{S}_8 - S_8^{\text{truth}}\right)^2 \right] \right\}$$

$\lambda \equiv 10^3$: penalty factor for bad point estimates

Binary cross-entropy:

$$\text{score}_{\text{OoD}} = \frac{1}{N_{\text{test}}} \sum_{i=0}^{N_{\text{test}}} \left(y_i \log\left(p_i\right) + \left(1 - y_i\right) \log\left(1 - p_i\right)\right)$$

where $y_i = 1$ if the dataset is InD; $y_i = 0$ if the dataset is OoD, and p_i is the probability estimates predicted by the model.

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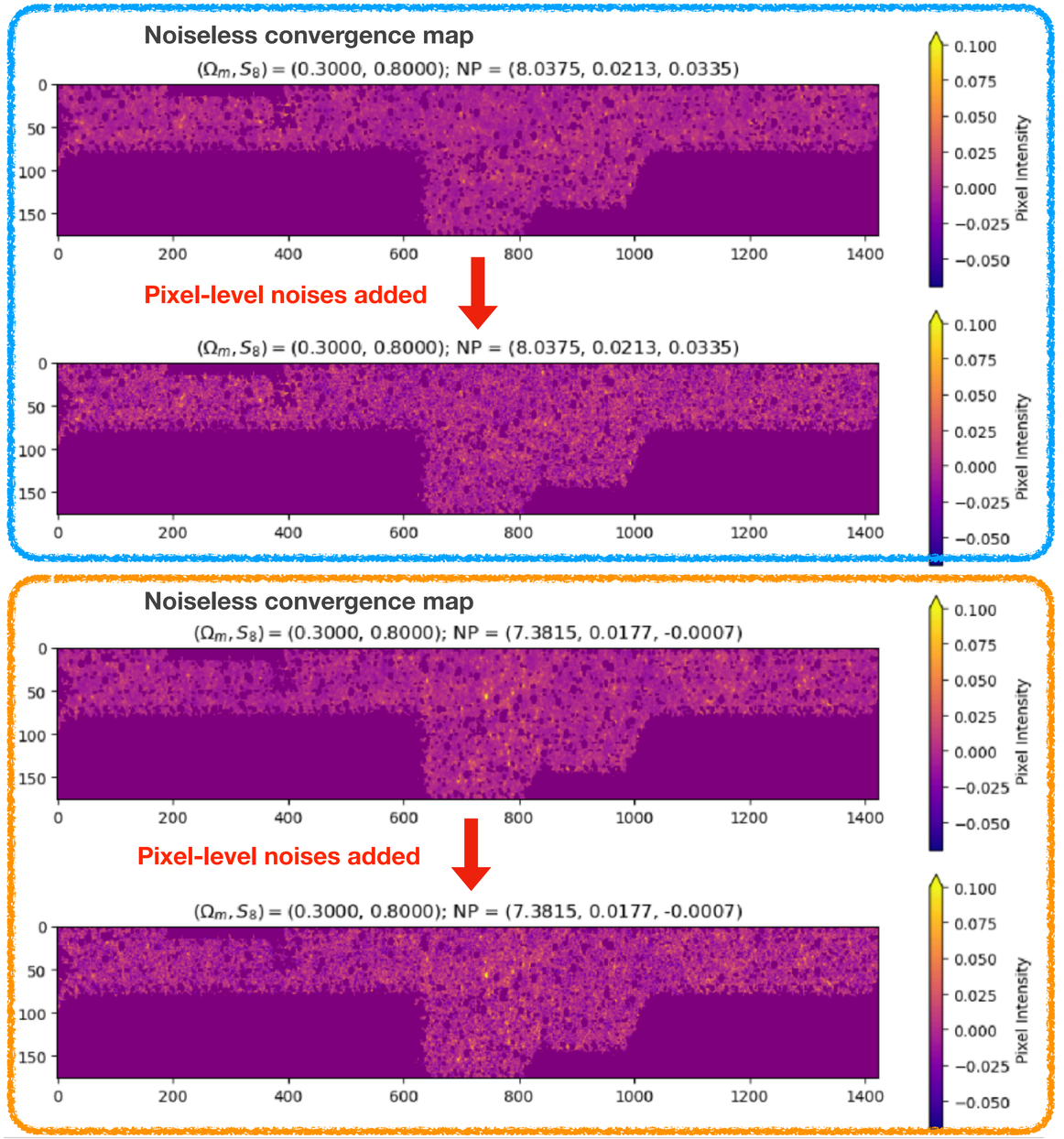
Dataset

- Mock galaxy catalogs predicted with N-body simulations and lens algorithms at 101 cosmological parameters (Ω_m, S_8)
- Pixelized 2D weak lensing images: convergence maps
- The model must take into account the systematic uncertainties from **4 realistic systematic effects**:
  (1) 2 baryonic effect uncertainties
  (2) 1 photometric redshift uncertainty
  (3) Pixel-level noises

Same cosmology, different systematics



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Phase 1 Dataset

The participants will be provide with:

- **Public training set:**
  - Image data; shape = (101, 256, 1424, 176)
  - Label shape = (101, 256, 5)

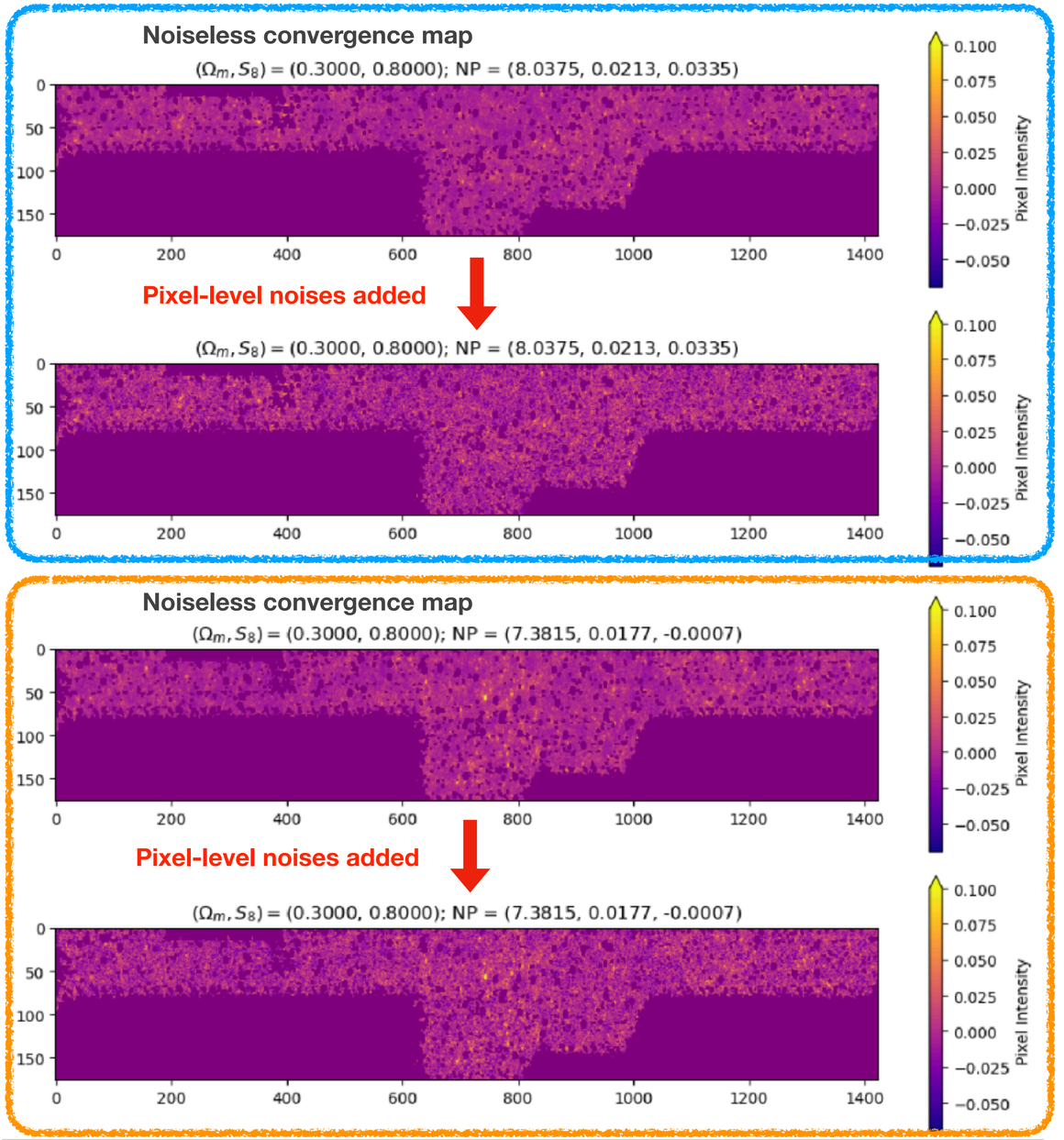
    101 = Realizations of cosmological models; each characterized with 2 parameters of interest (Ω_m, S_8)

    256 = Realizations of 3 nuisance parameters for systematics (1) and (2)

    (1424, 176) = Image dimension

    5 = 2 parameters of interest (Ω_m, S_8) + 3 nuisance parameters for systematics (1) and (2)

  - **The provided training set is noiseless.** Participants can generate pixel-level noise (3) to augment their training data using a simple function we provide



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Phase 1 Dataset

The participants will be provide with:

- **Public test set:**
  - Image data; shape = (4000, 1424, 176)

    4000 = Number of test images

    (1424, 176) = Image dimension

  - The test images are generated with random cosmological parameters, random nuisance parameters, and random pixel-level noises.

Phase 1 Evaluation

The true parameters $(\Omega_{\mathrm{m}}^{\mathrm{truth}}, \mathrm{S}_8^{\mathrm{truth}})$ of the public test set are unknown to the participants.

Participants will submit predictions of

- **Cosmological parameters** $(\hat{\Omega}_{\mathrm{m}}, \hat{\mathrm{S}}_8)$
- **Their uncertainties** $(\hat{\sigma}_{\Omega_{\mathrm{m}}}, \hat{\sigma}_{\mathrm{S}_8})$

to Codabench, our competition platform.

The model performance will then be evaluated with the hidden ground truth based on our scoring metrics.

The competition Codabench page will be available soon.

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Status and timeline

- This challenge has been accepted as one of the ***NeurIPS 2025 competitions***.

Envisioned competition schedule		
Competition Phase	**Date**	**Description**
Phase 1	Aug – Early Nov 2025 Early Nov – Mid Nov 2025 Mid Nov 2025	Open submissions Evaluating top submissions on hidden dataset Announcement of winners
Phase 2	Sep – Mid Dec 2025 Mid Dec 2025 – Jan 2026 Jan 2026	Open submissions Evaluating top submissions on hidden dataset Announcement of winners
NeurIPS 2025	Early Dec 2025	Winners will be invited to our workshop

- **Coming soon!** Please keep following our updates on the FAIR Universe website: https://fair-universe.lbl.gov/.

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