PISCO : A Deep Learning Method for Shear Calibration

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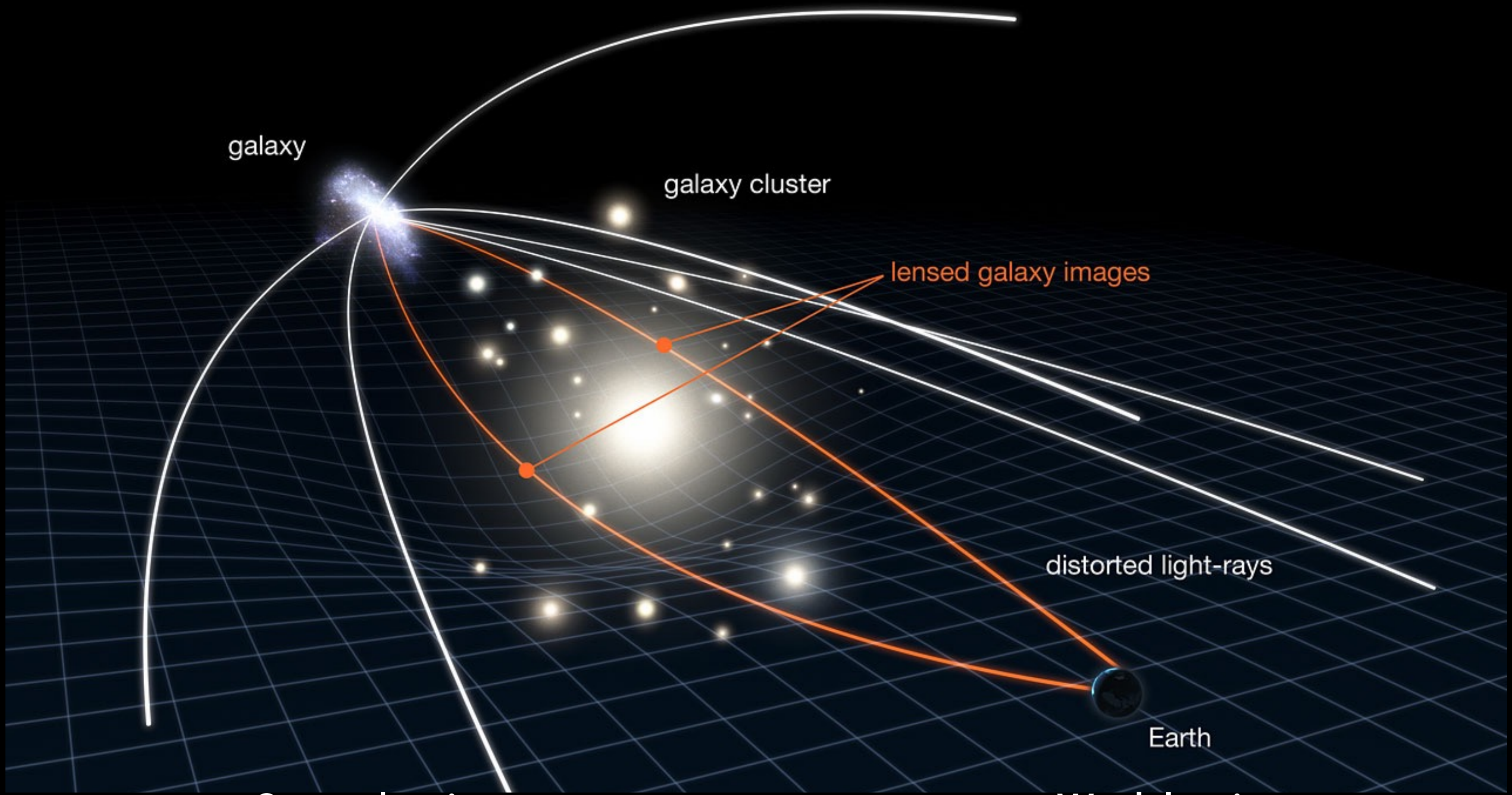
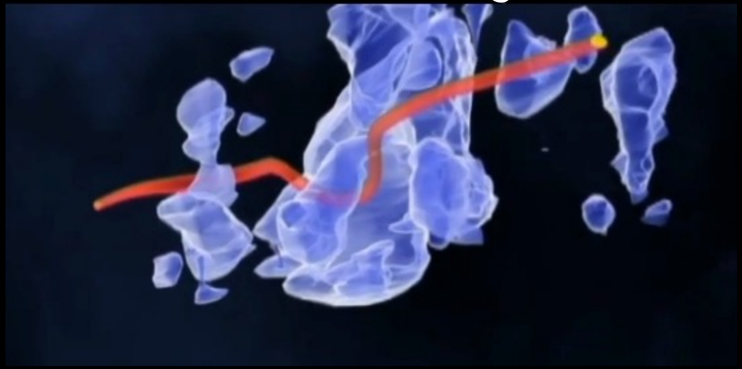
GRAVITATIONAL LENSING



Strong lensing

Strong effects visible by eyes

Weak lensing

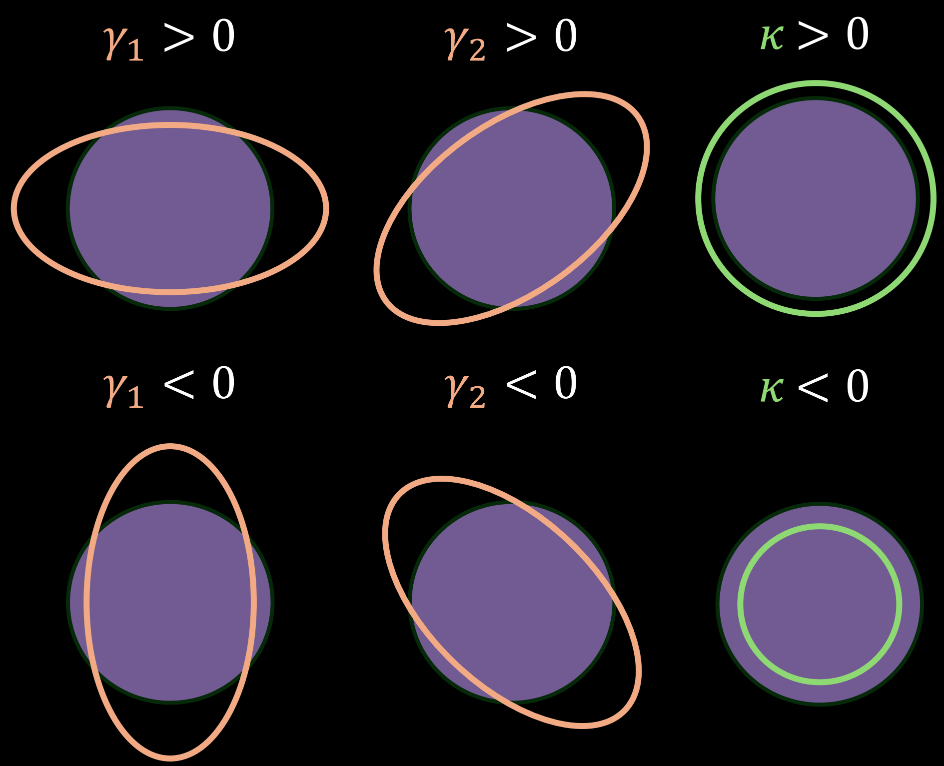


Subtle effects measured by statistics

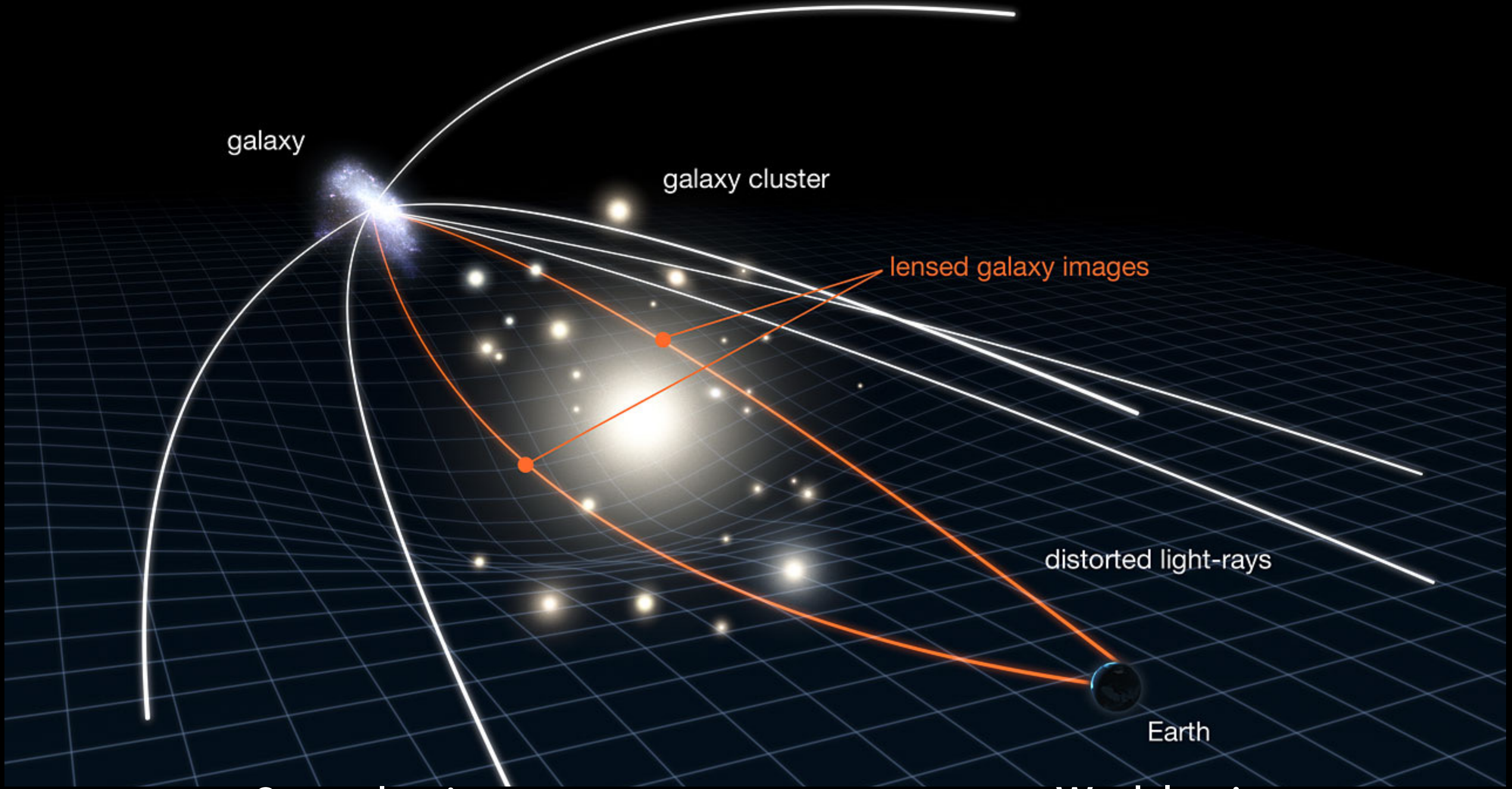
- Foreground massive object deviates the light from a background object

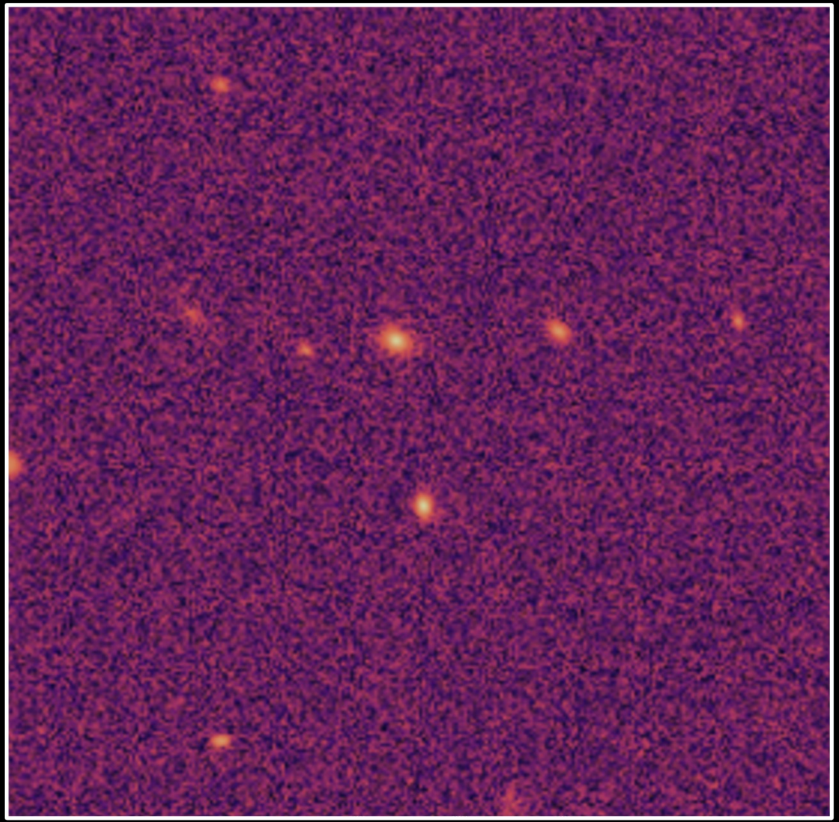
Observable effects

γ shear : anisotropic stretching
κ convergence : isotropic magnification



GRAVITATIONAL LENSING

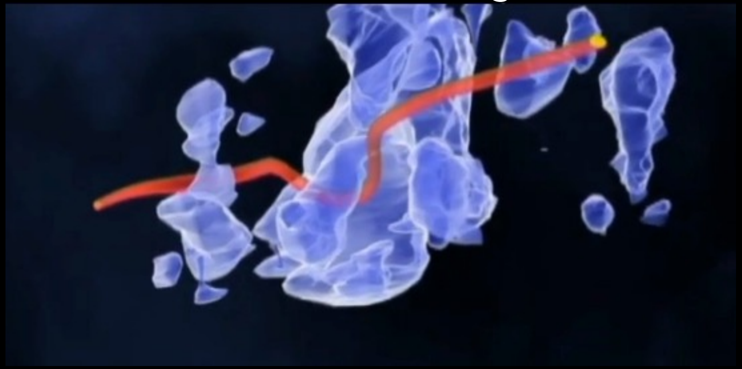




Strong lensing

Strong effects visible by eyes

Weak lensing



Subtle effects measured by statistics

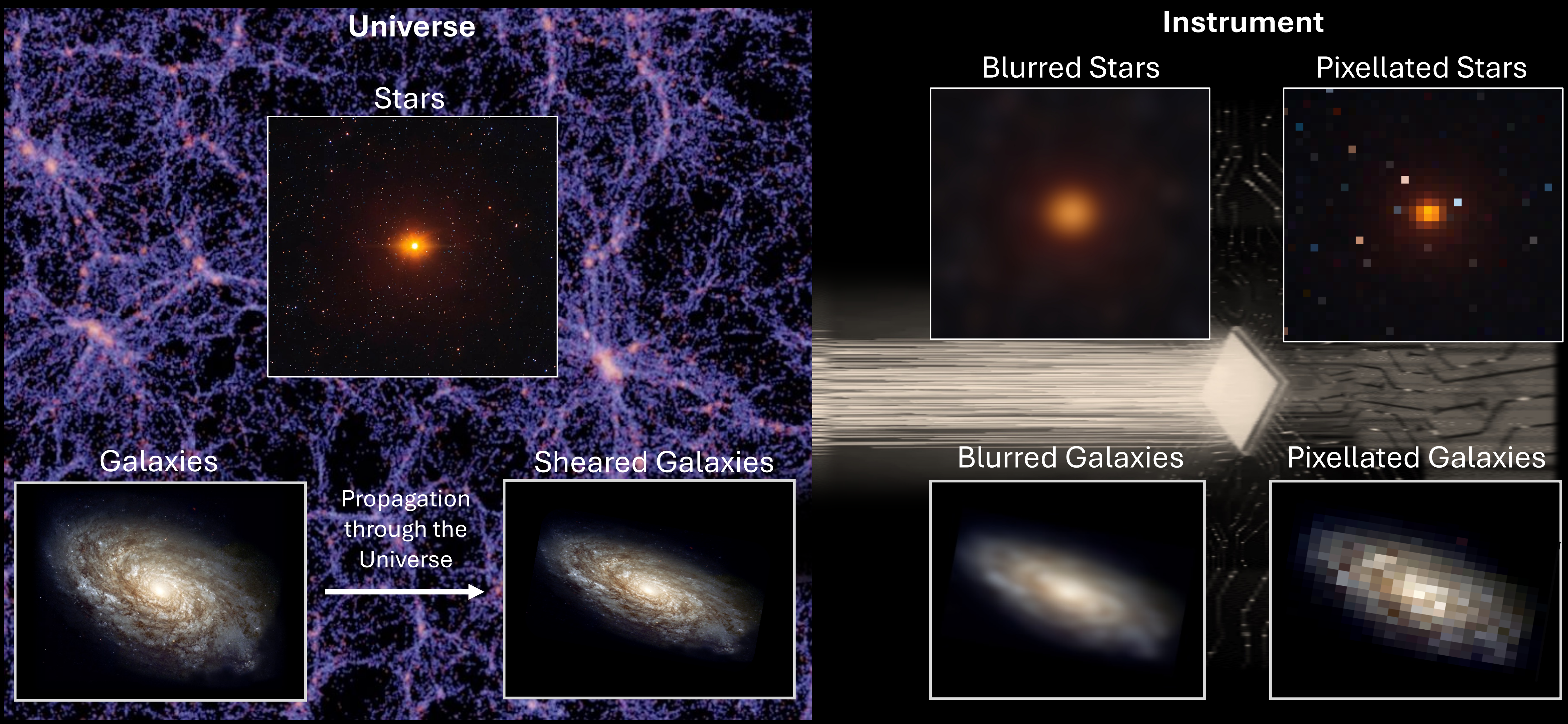
- Ellipticity measured in an image :

$$e_{observed} = e_{intrinsic} + \gamma$$

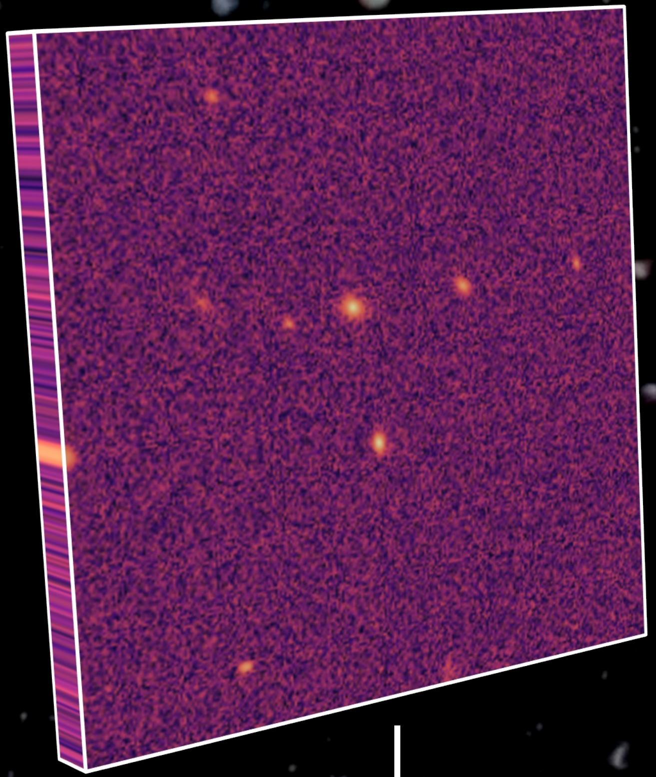
- Intrinsic ellipticity random distribution : $< e_{intrinsic} > \sim 0$

$$< e_{observed} > \sim < \gamma >$$

The Shear measurement challenge



PISCO (PIxelS to COsmology) project



(γ_1, γ_2) → (Ω_m, σ_8)

Pixels to Shear

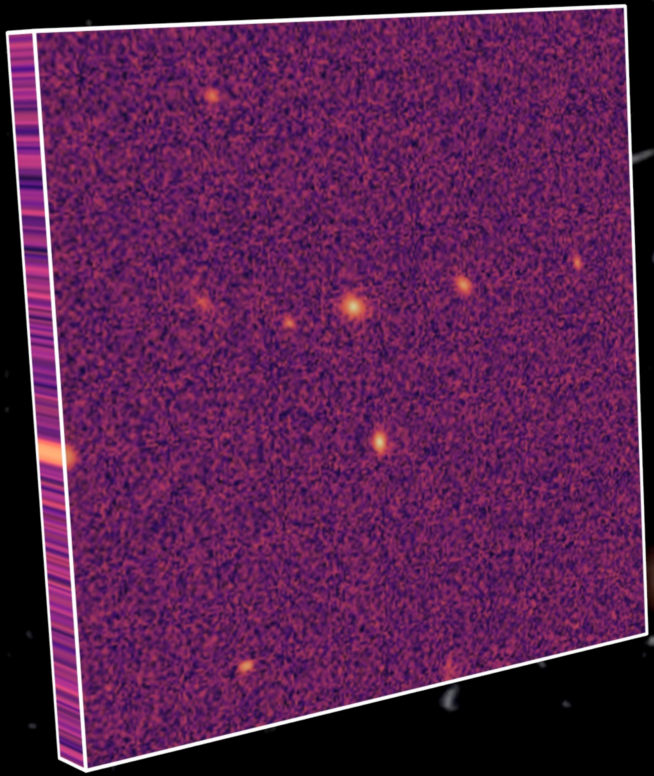
Shear to Cosmology

Pixels to Cosmology

OVERVIEW OF THIS WORK

1st step of PISCO project

Input



Simulated Image

Deep learning →

Output

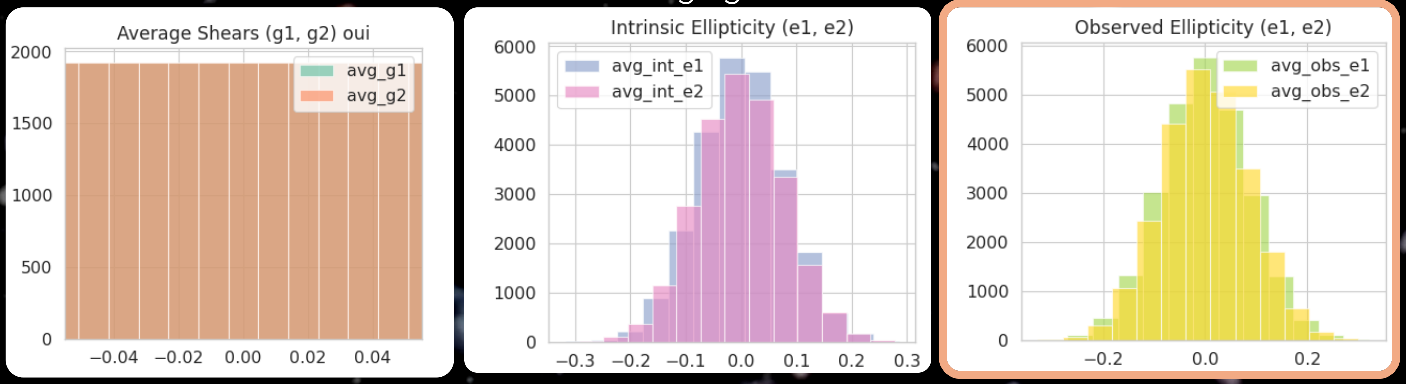
Average ellipticity/shear of all galaxies in an image

The model will predict the average ellipticity of all galaxies in the image, and **not** the ellipticity of individual galaxies

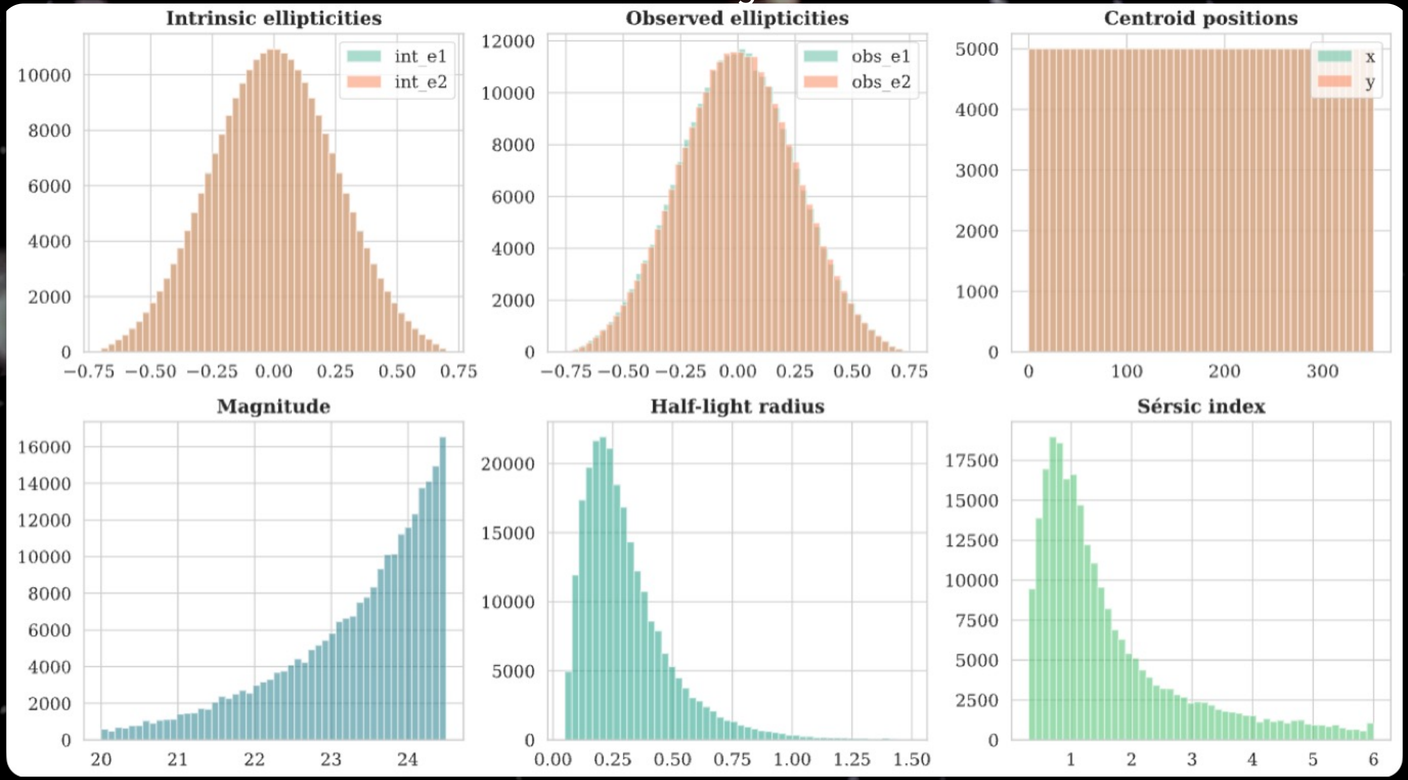
DATABASE

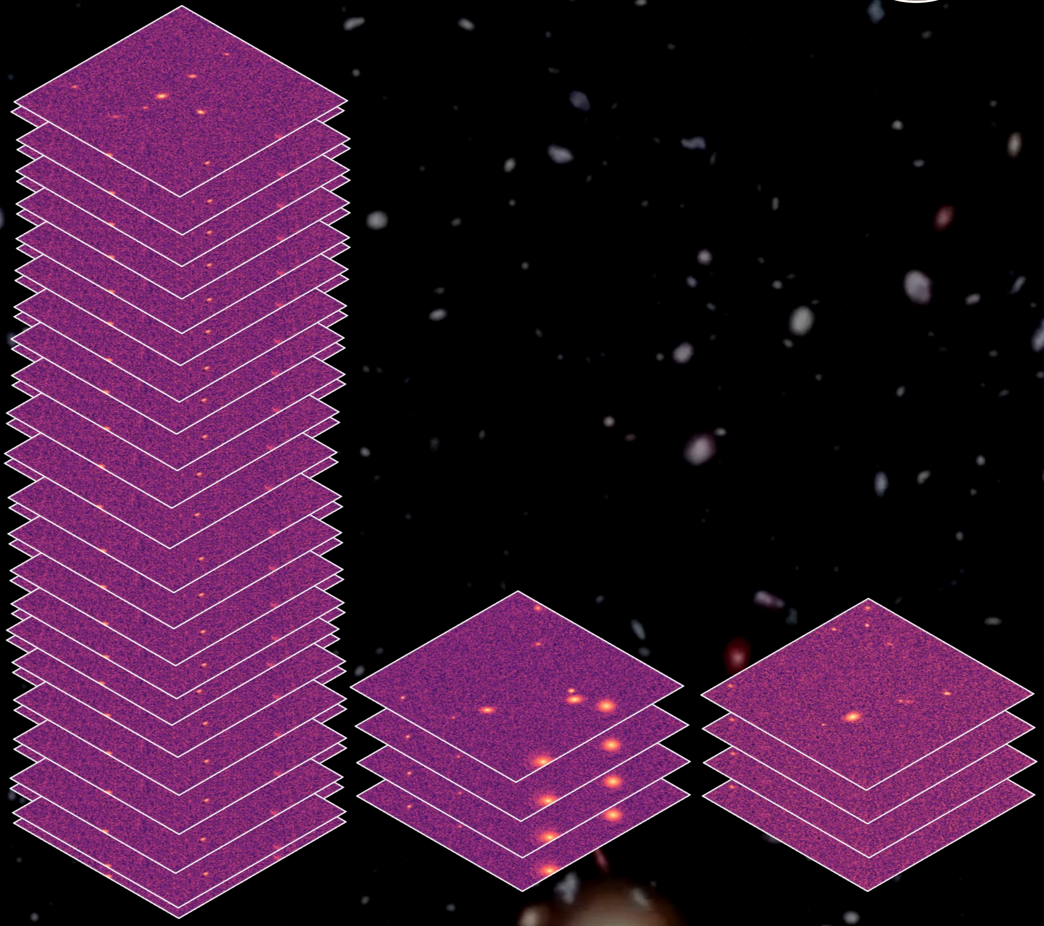
Simulations with Galsim

Average galaxies



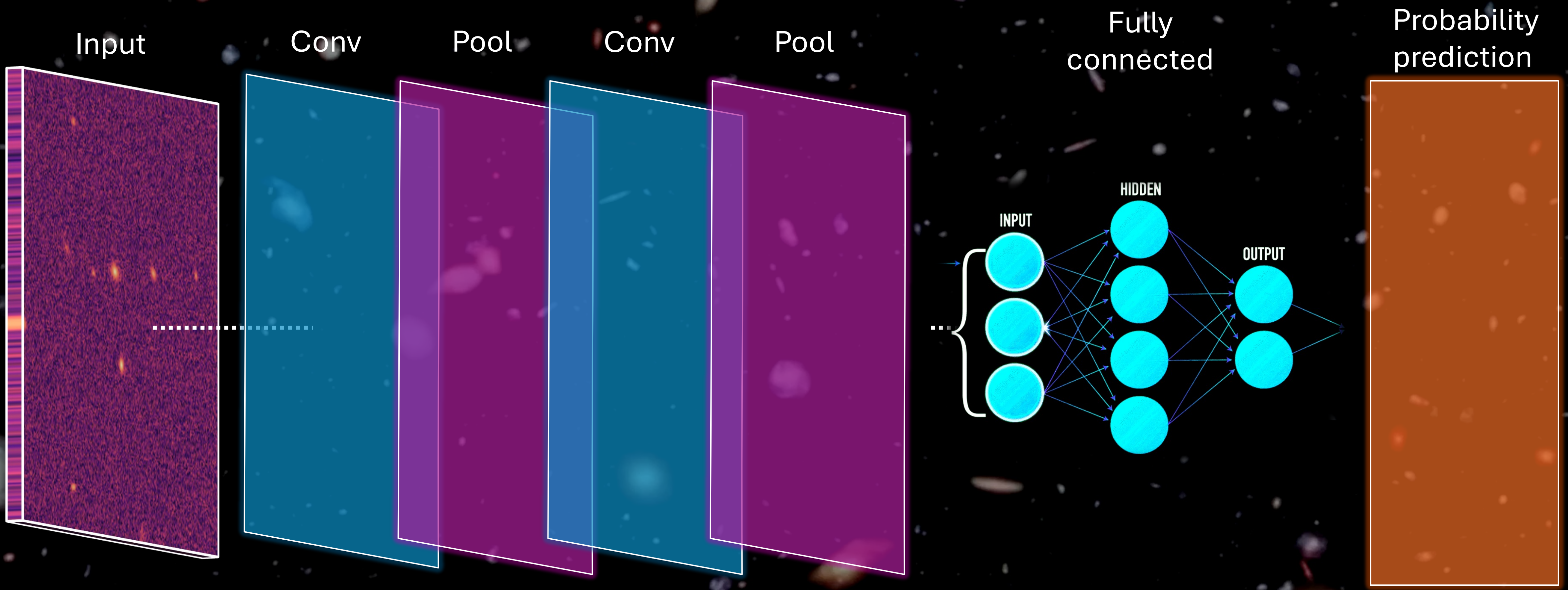
Individual galaxies



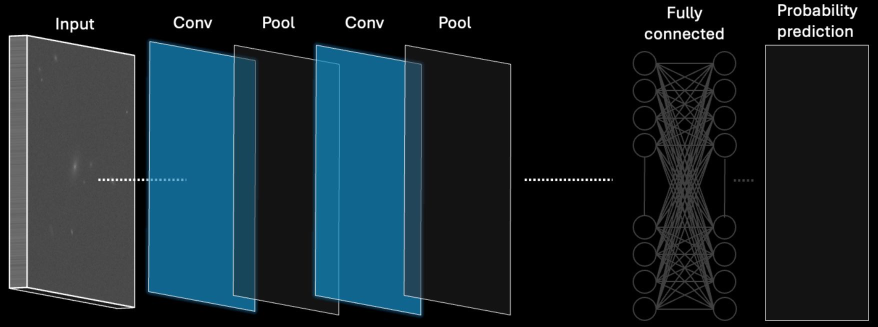


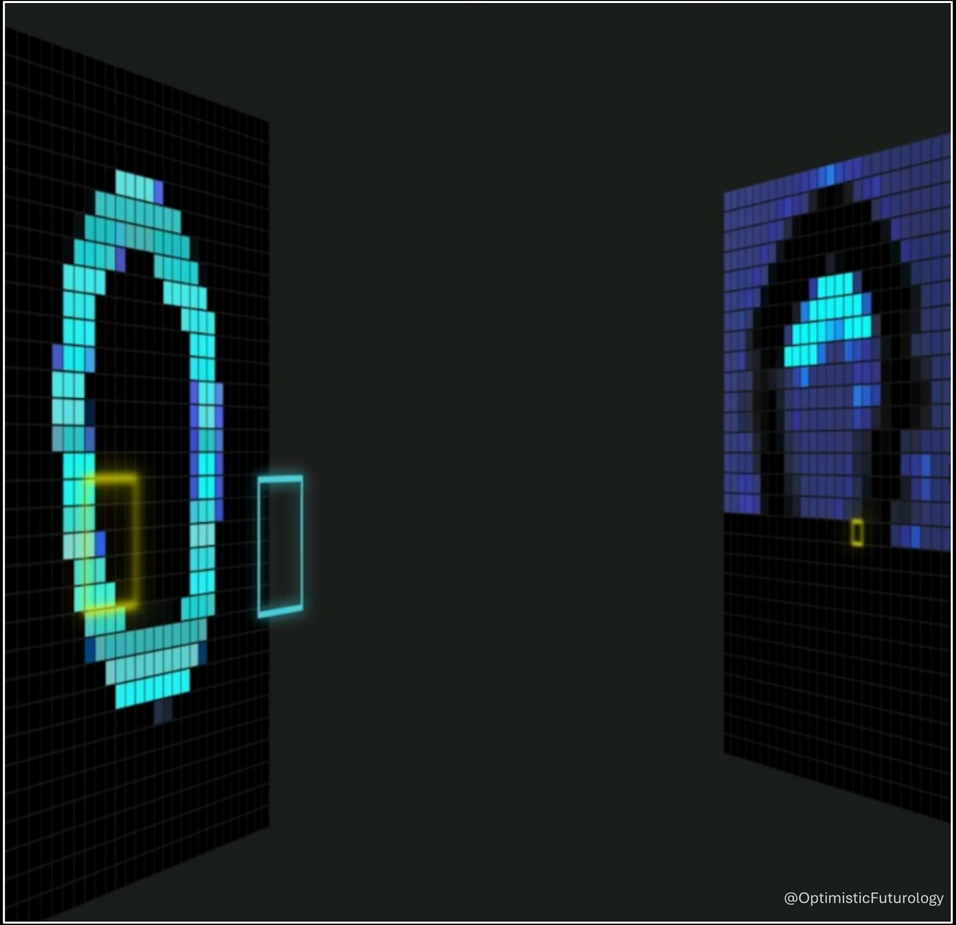
80% training + 10% validation + 10% test

CONVOLUTIONAL NEURAL NETWORK (CNN)



CONVOLUTIONAL LAYER

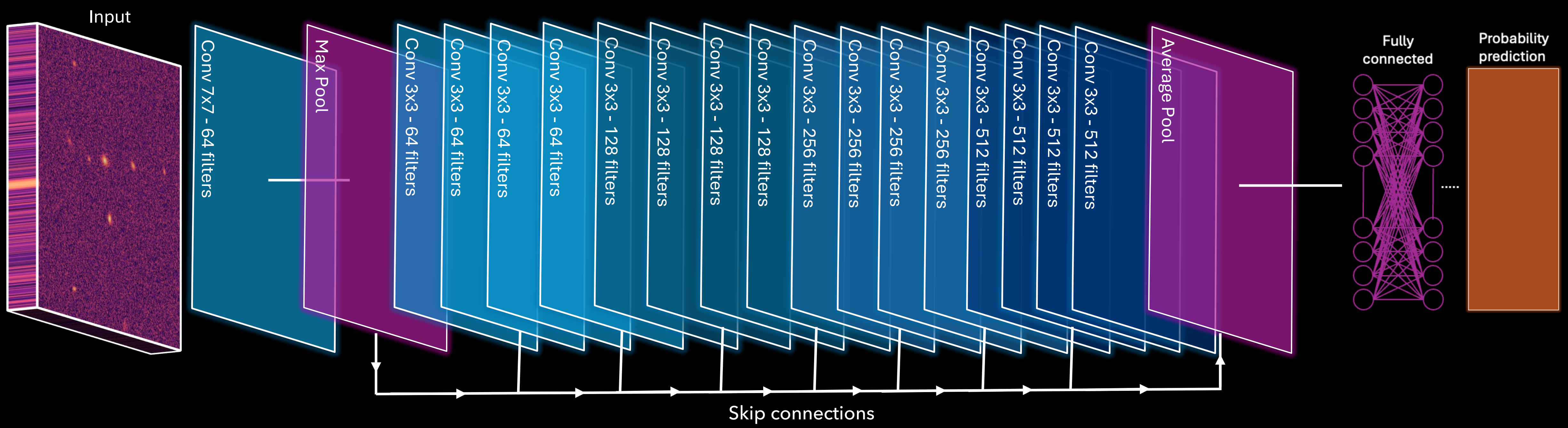




Features maps

- **Kernel/Filter** : matrix smaller than the input which slides over the input image to extract features.

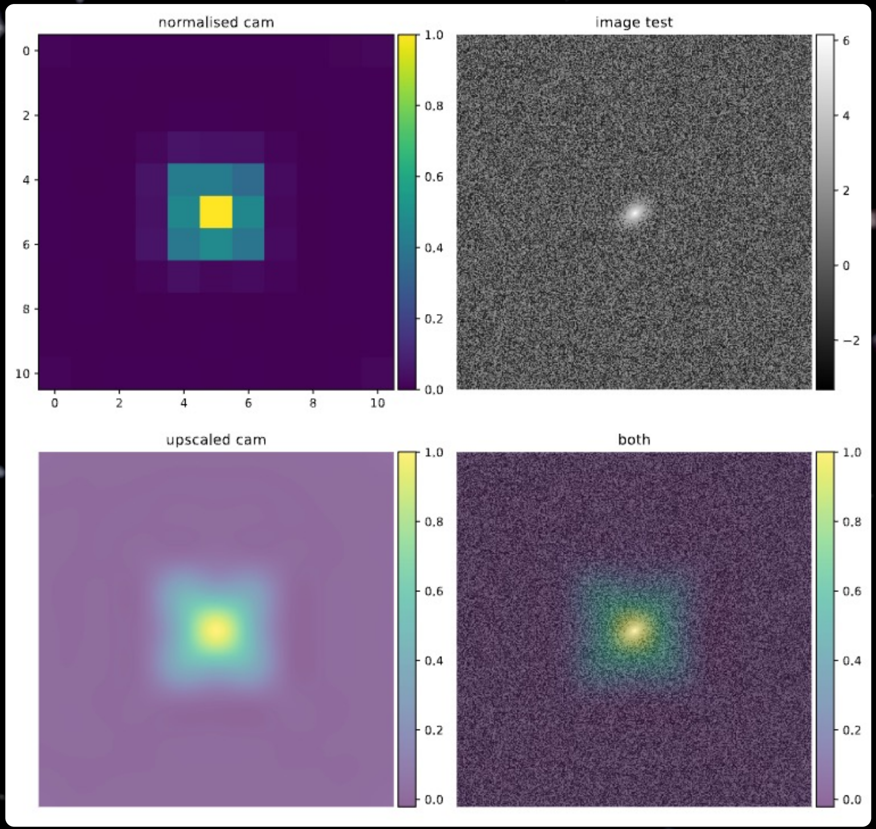
RESNET
RESNET 18



- Prediction compared to the real value with the **loss function**
- Gradient of the loss is computed and backpropagate through the network
- Resnet contains **skip connection layers** which enables to train deep model with a lot of layers
  → Avoid "*vanishing gradient*"

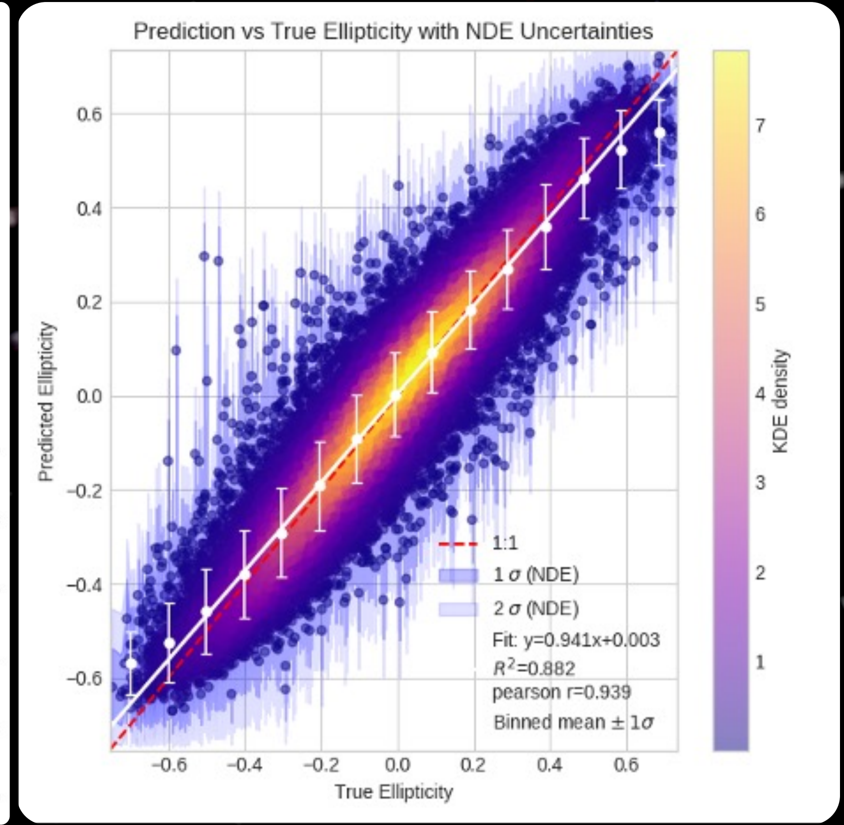
Case 1 : 1 galaxy per image

Gradcam

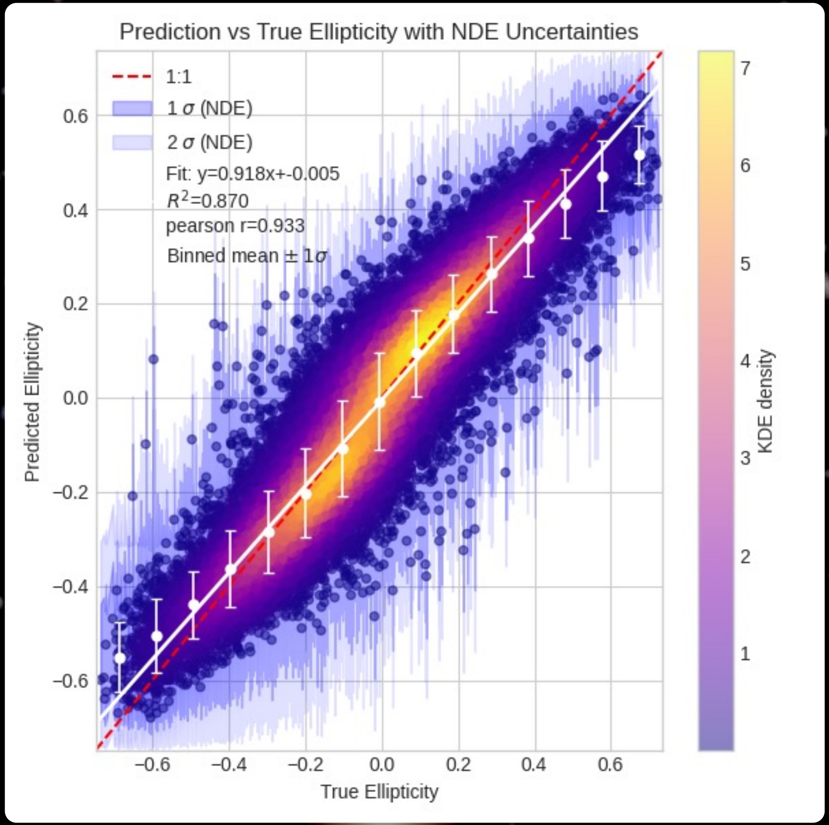


CNN Predicted Ellipticity vs True Ellipticity

$\langle e_1 \rangle$



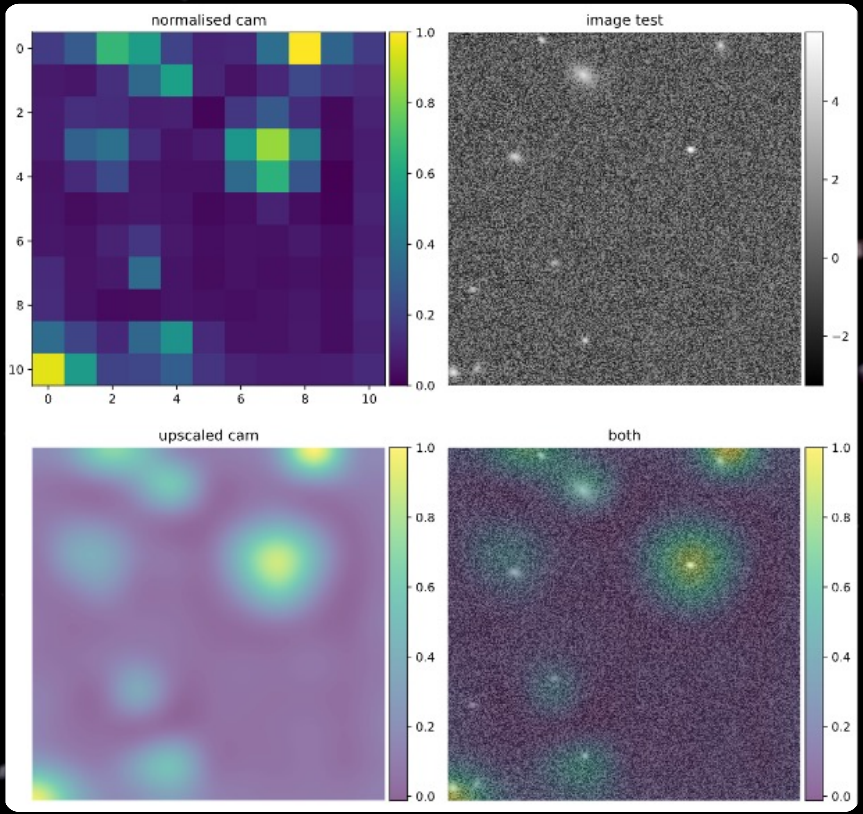
$\langle e_2 \rangle$



Accurate ellipticity prediction

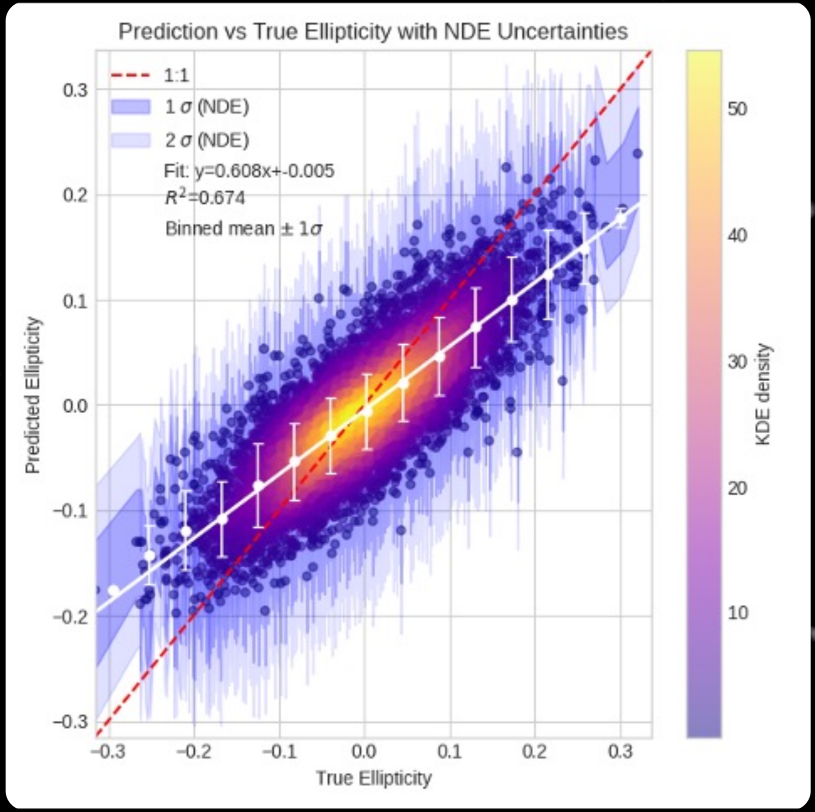
Case 2 : 10 galaxies per image

Gradcam

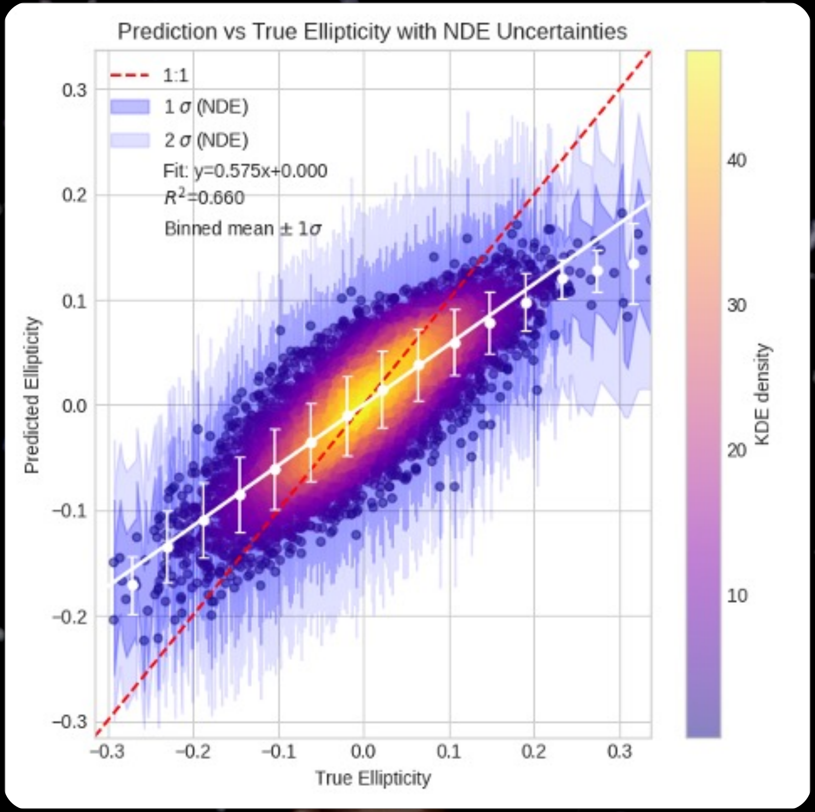


CNN Predicted Ellipticity vs True Ellipticity

$\langle e_1 \rangle$



$\langle e_2 \rangle$



Increased bias in ellipticity prediction

Residuals plots

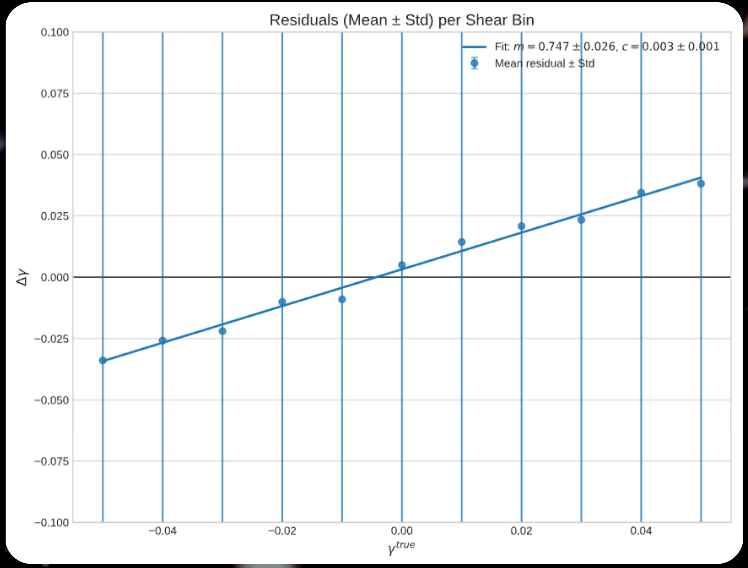
Multiplicative and additive bias

$\gamma_{1,2}^{obs} - \gamma_{1,2}^{true} = m\gamma_{1,2}^{true} + c$

$\langle e_1 \rangle$ | $\langle e_2 \rangle$

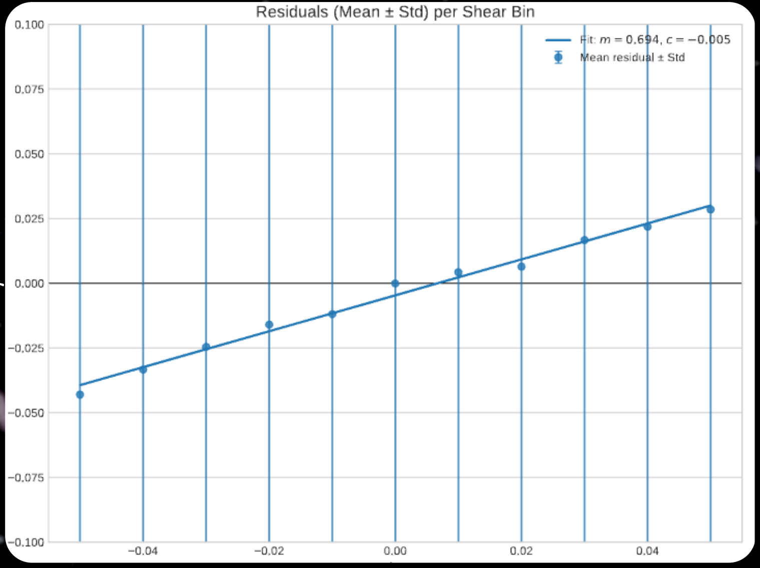
1 galaxy per image

$\varepsilon^{obs} - \gamma^{true}$



γ^{true}

$\varepsilon^{obs} - \gamma^{true}$



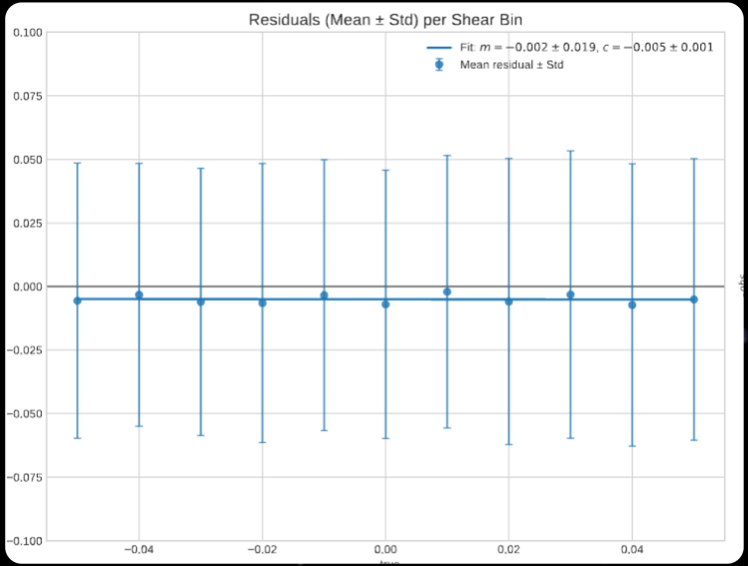
γ^{true}

Very bad multiplicative bias :(

Euclid requirements : $m < 10^{-3}$ et $c < 10^{-4}$

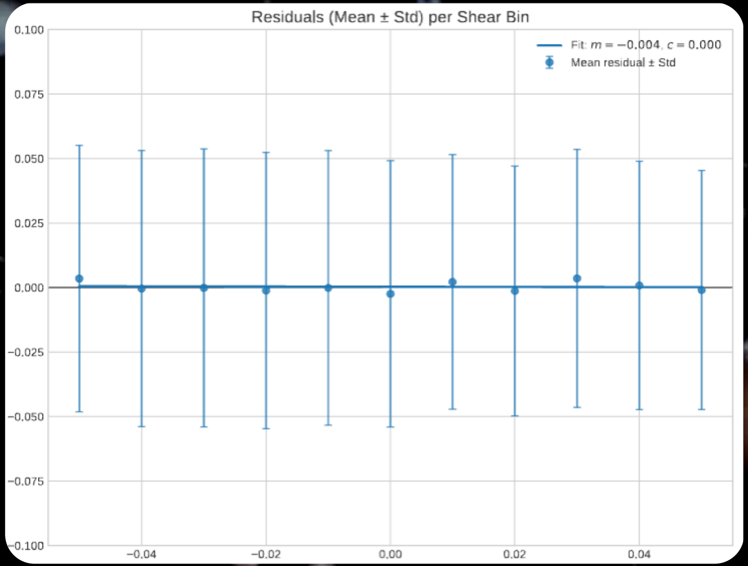
10 galaxies per image

$\varepsilon^{obs} - \gamma^{true}$



γ^{true}

$\varepsilon^{obs} - \gamma^{true}$

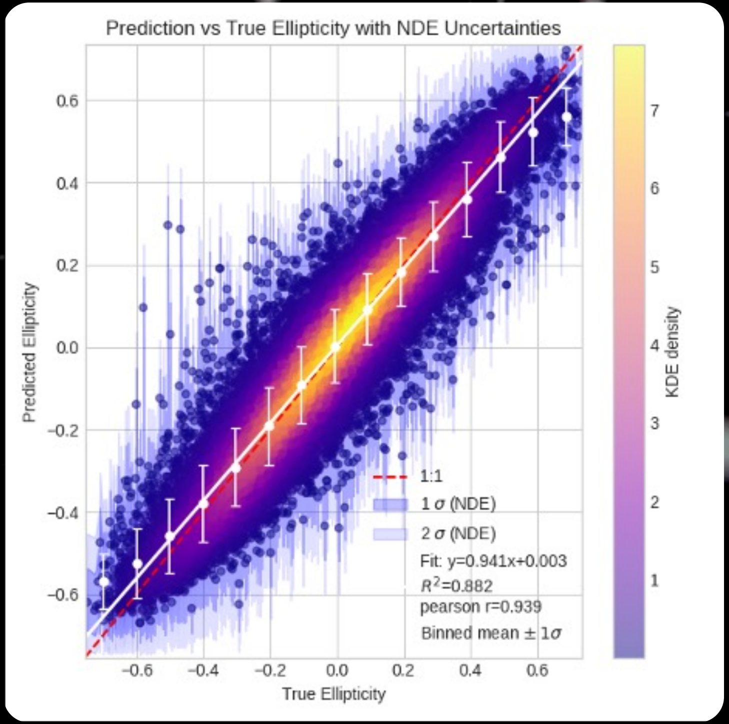


γ^{true}

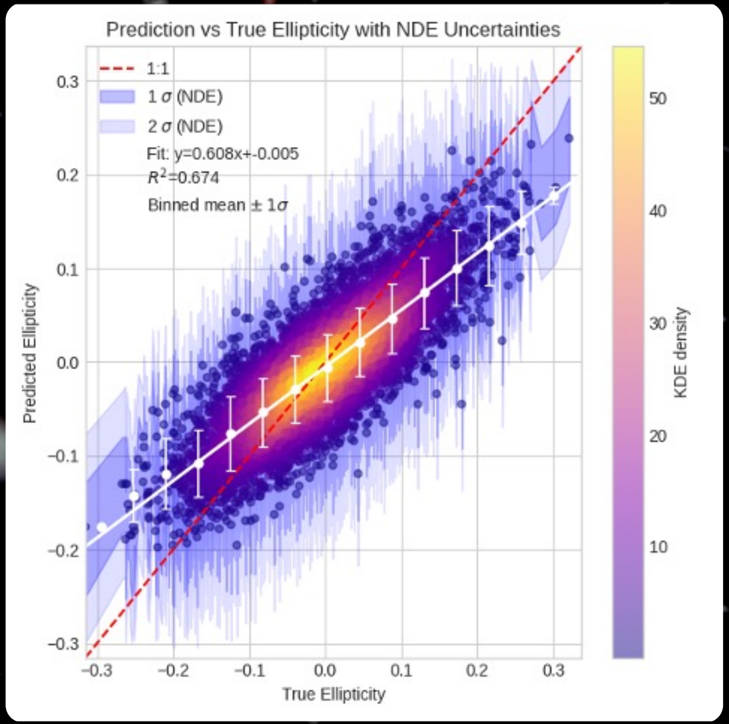
Multiplicative bias m $\sim 10^{-3}$ for the two components

Impact of Shape Noise

$\langle e_1 \rangle$



1 galaxy per image

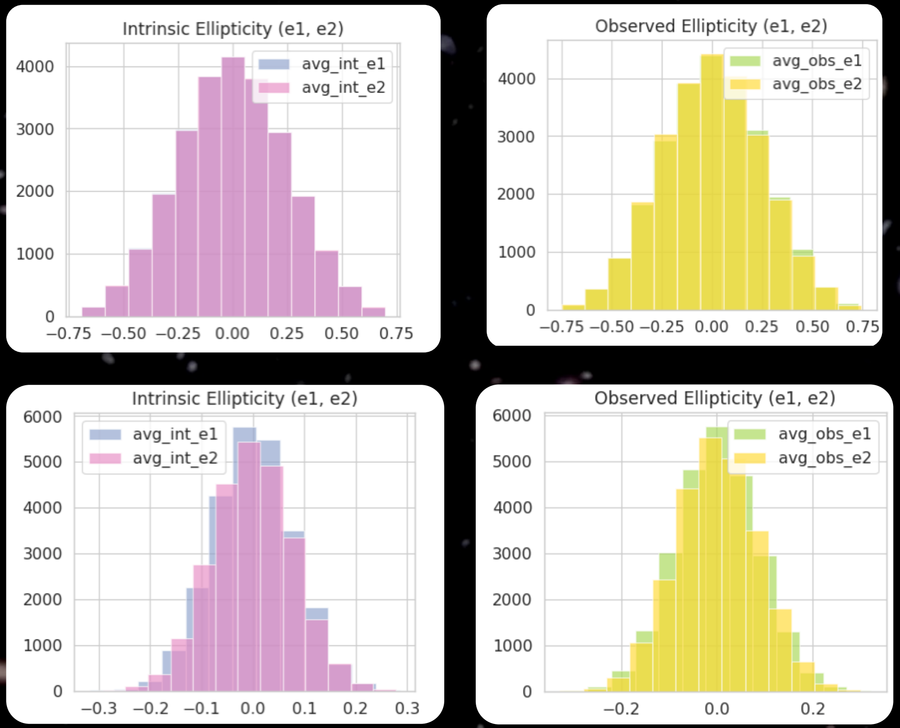


10 galaxies per image

1 galaxy per image

σ = 0.26

σ = 0.08



10 galaxies per image

Averaging 10 galaxies = reducing shape noise

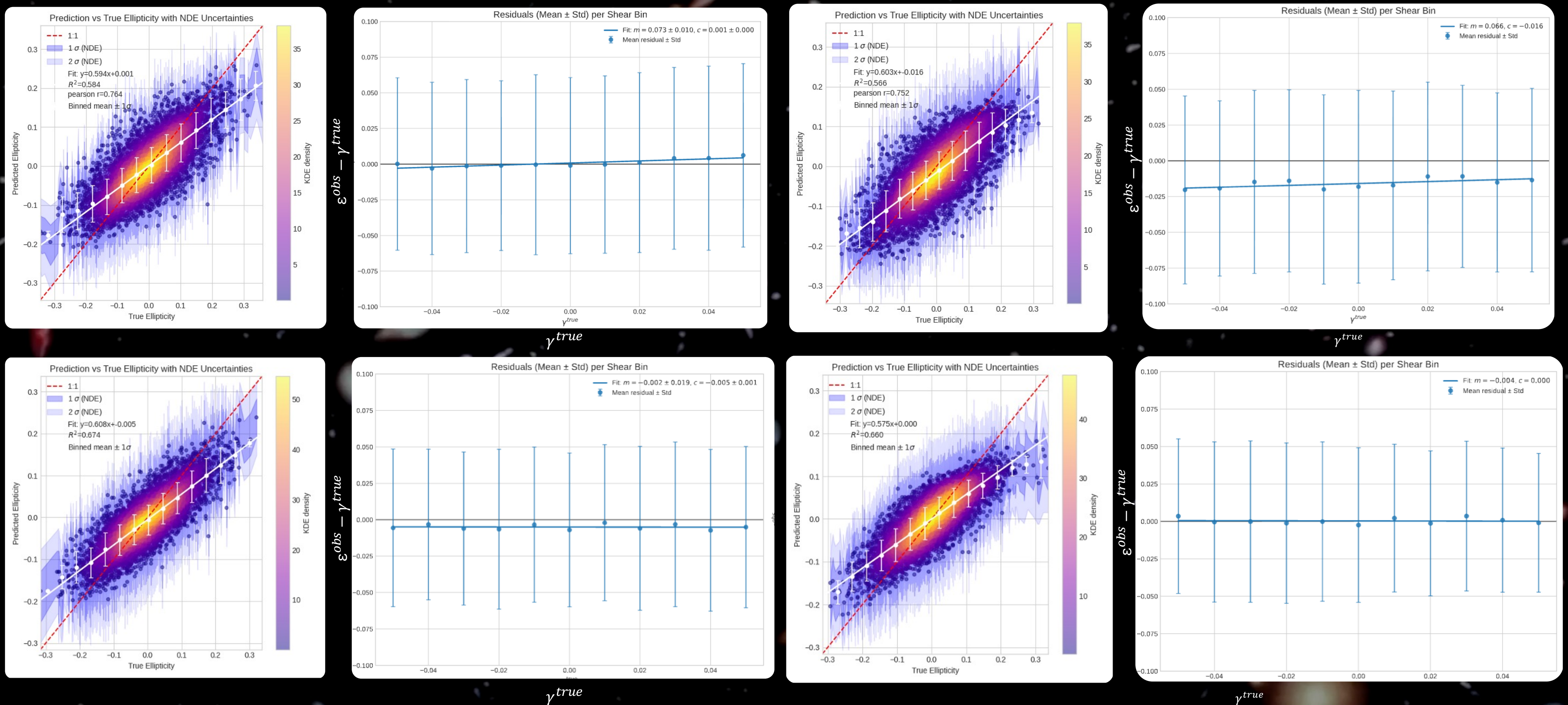
Impact of Shape Noise

$\langle e_1 \rangle$ $\langle e_2 \rangle$

1 galaxy per image

σ = 0.08

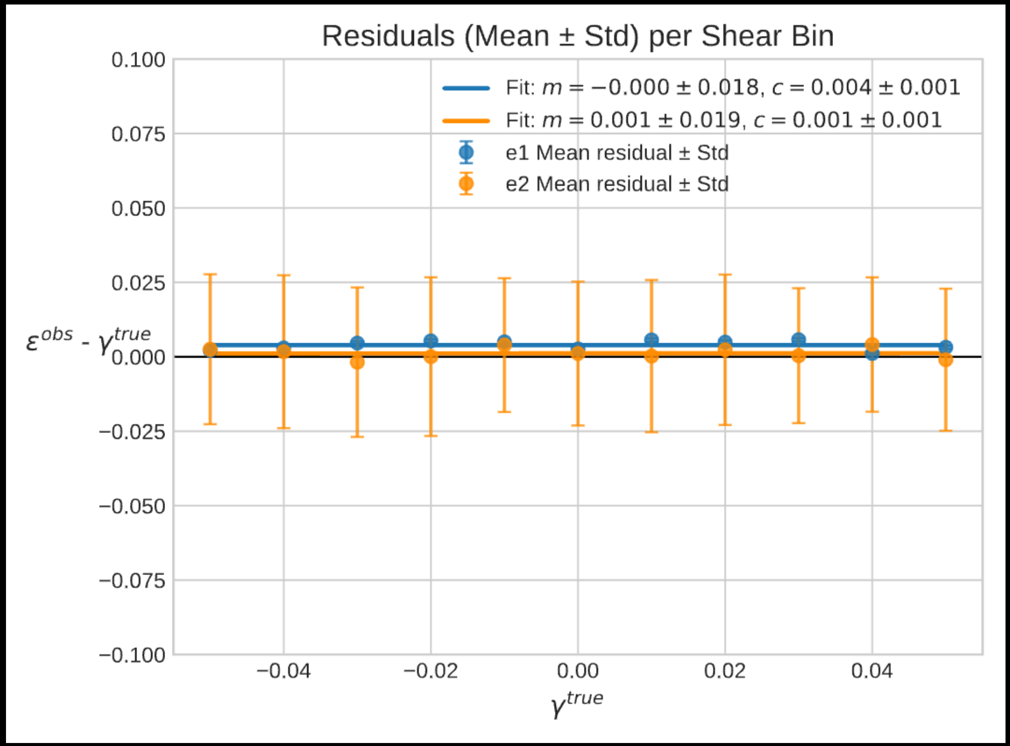
10 galaxies per image

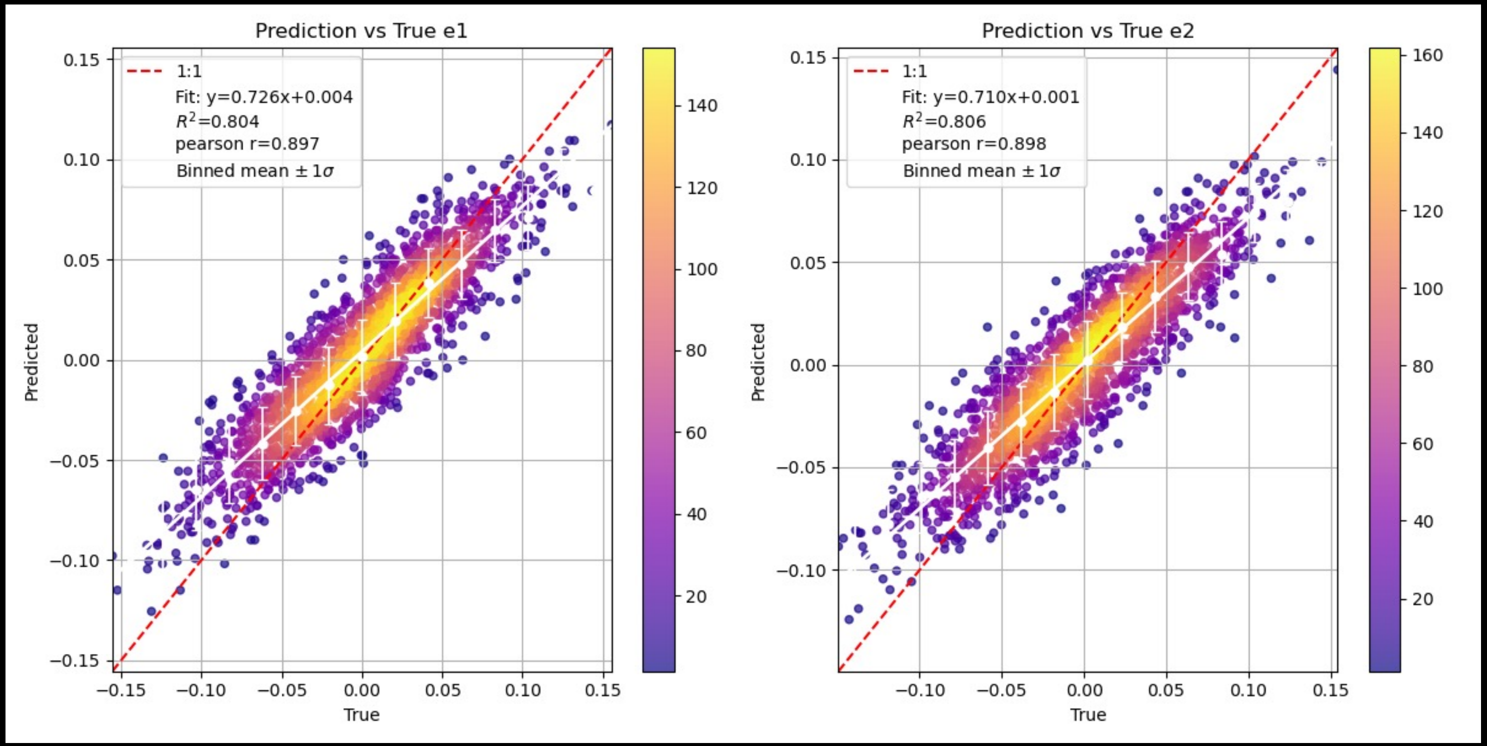


Same behavior between the two for the same label distribution
→ Good shear prediction but biased ellipticity prediction

Impact of Shape Noise

Test on 40 galaxies per images

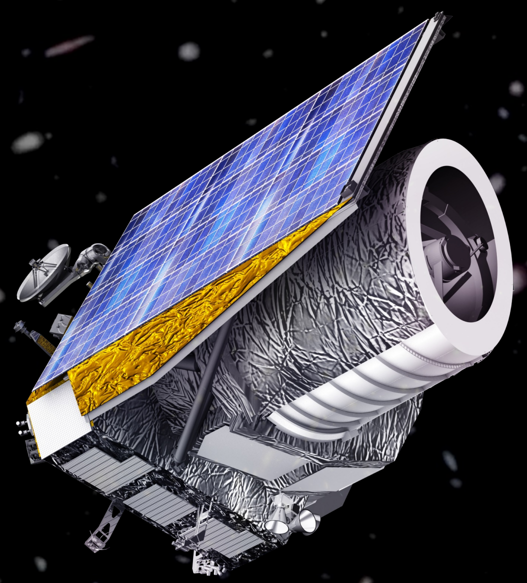




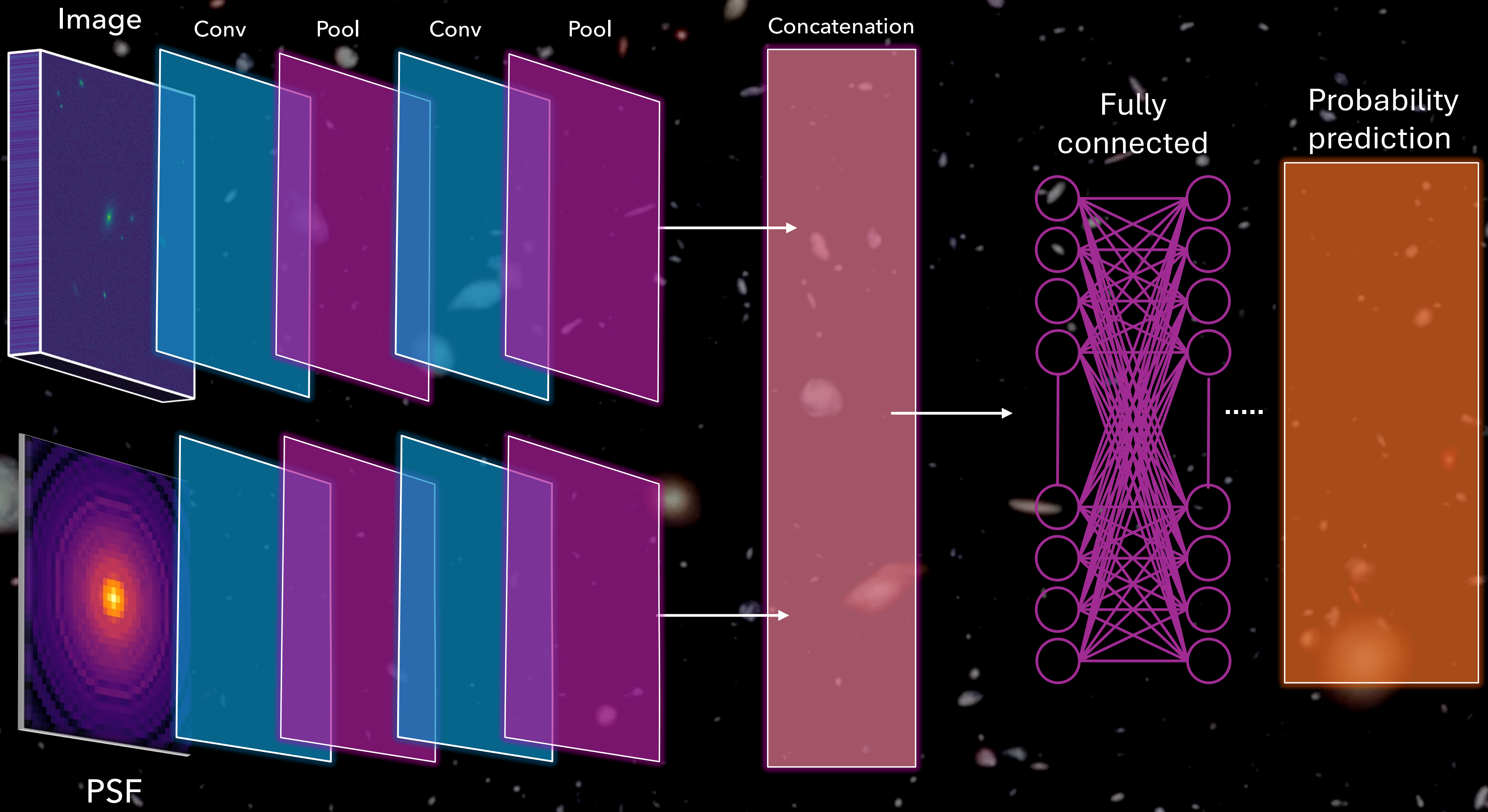
Multiplicative bias m $\sim 10^{-3}$ for the two components even one at m $\sim 10^{-4}$!

Perspectives and evolution

- Finishing the test of the shape noise impact
- Comparison with Sextractor
- Detection bias test with SNR variation
- Blending test
- Realistic galaxies implementation with COSMOS catalog
- Using Euclid data to test the model



PSF features

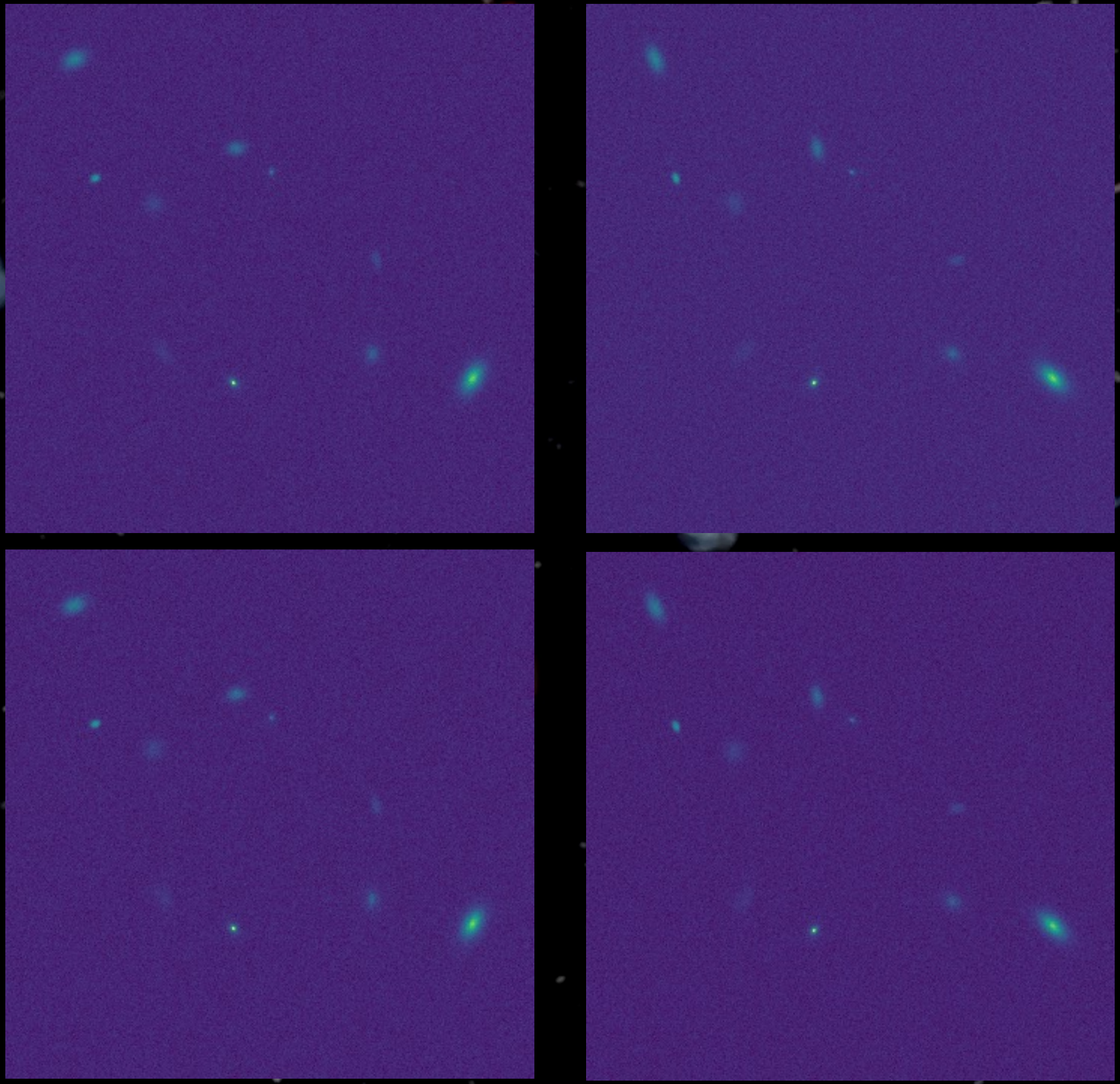


Shape and Pixel Noise Cancellation Database

No Rotation | Rotation 90 °

Add Noise

Substract Noise



- Intrinsic shapes of galaxies orthogonal but same shear

→ during training helps to isolate the true lensing signal

- help reduce the number of samples needed to achieve a given statistical precision