APC, CNRS, FRANCE

Google

MADNESS

Maximum-A-posteriori solution with Deep generative NEtworks for Source Separation

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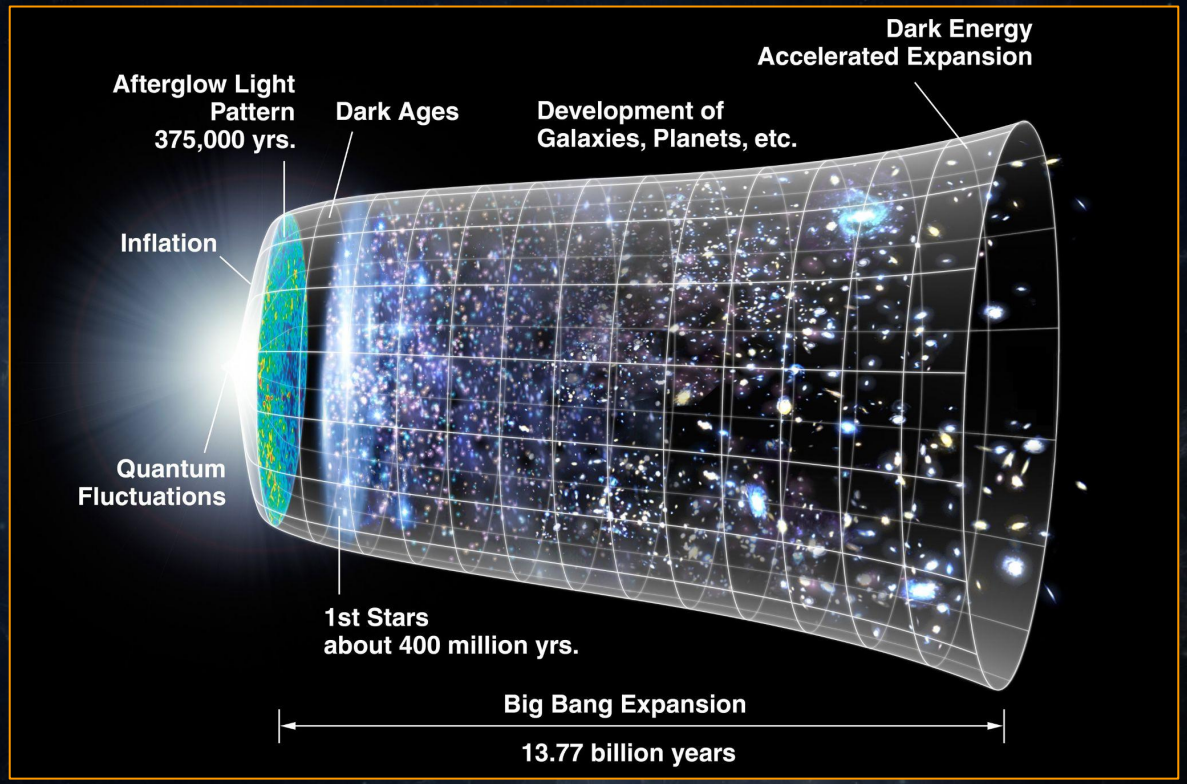
ENS | PSL

Dark Energy



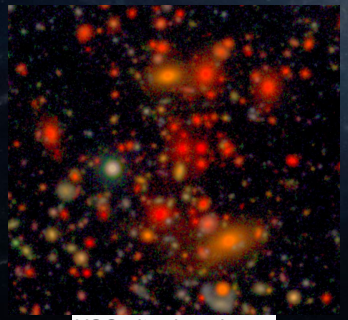
Credits: NASA/WMAP Science Team

Surveys and Challenges

Large survey of Space and Time (LSST) at Vera Rubin Observatory:

- Ground-based
- constrain Dark Energy
- 3.2 billion pixel camera
- 6 observation bands in visible range

more depth + area of coverage ⇒ More statistics!



HSC ultradeep image

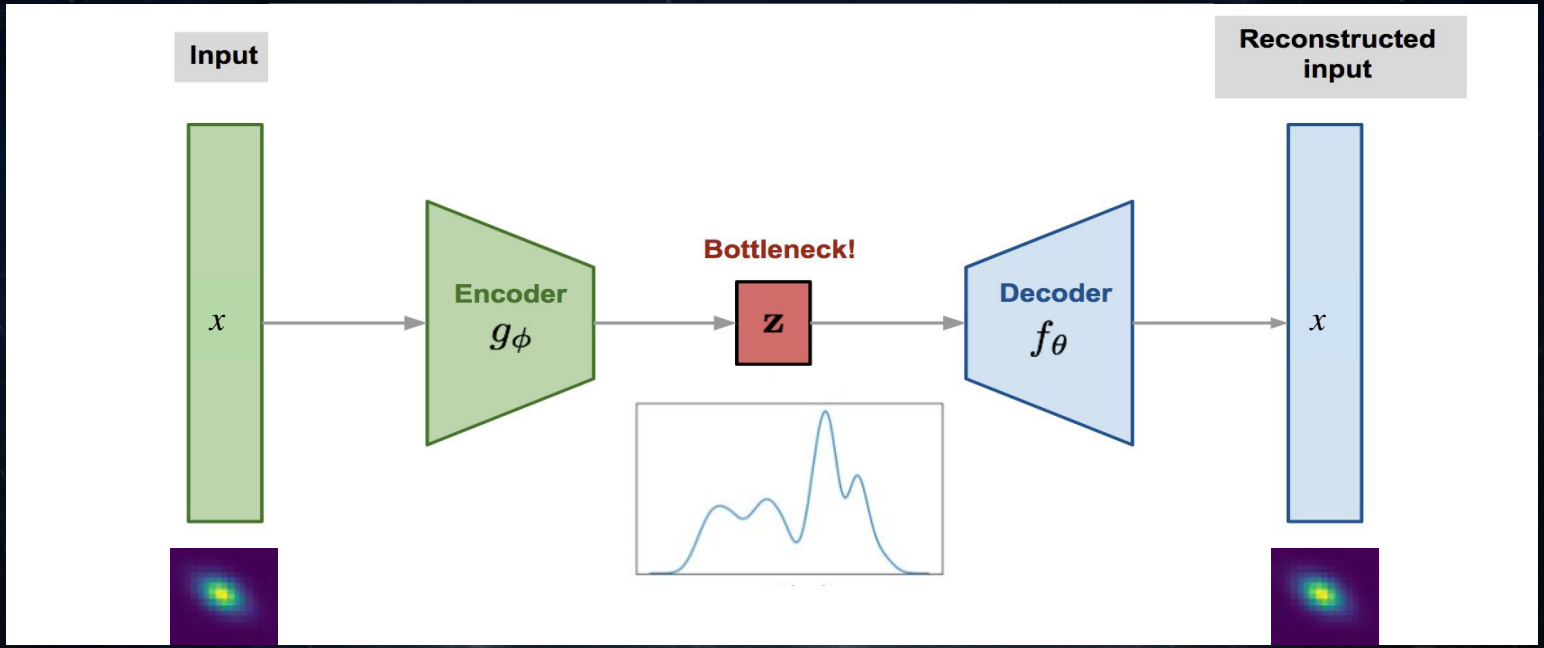
greater depth means more complex data!

~ Galaxies (60% in LSST) are expected to overlap (blending) in images due to increased depth

Why AI for deblending?

- Large data [billions of galaxies]
- Exploit advances in the field of image processing
- predict complex galaxy shapes
- Multi-band, multi-instrumental approach

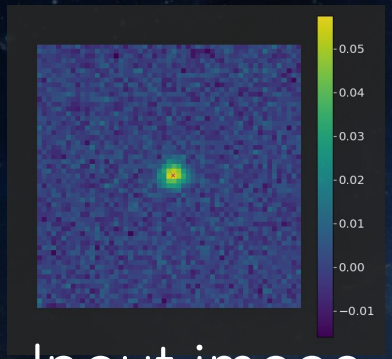
Train VAE as generative model



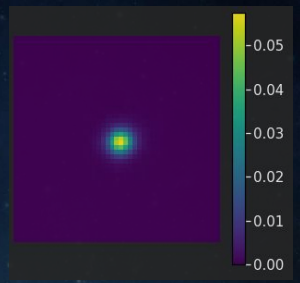
For example: Lanusse et al (arXiv:2008.03833)
Arcelin et al (arXiv:2005.12039)

The VAE creates an underlying distribution from which galaxies are drawn!

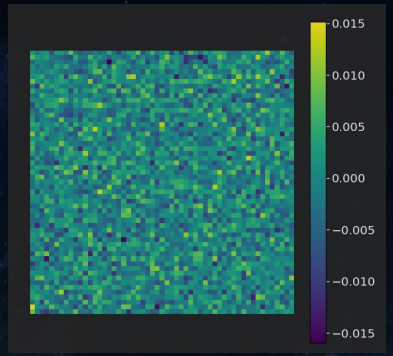
Denoising (Single source)



Input image (y)



Predicted image (x)



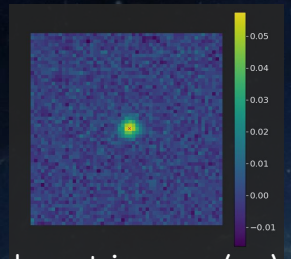
Residual (y-x)

$$x^* = \arg\min_x -\log p(y|x) - \log p(x)$$

$$x^* = \arg\min_x \frac{||\, y - x \,||^2}{2\sigma^2_{noise}} - \log p(x)$$

Where, x^* is the maximum a posteriori probability (MAP) estimate

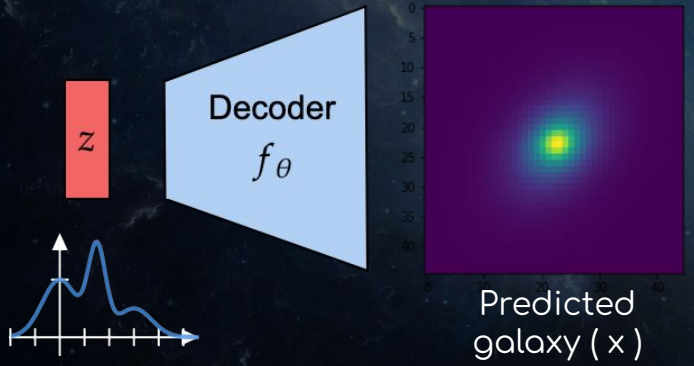
MAP estimate in latent space



Input image (y)

$$x^* = \arg\min_x - \frac{|| y - x ||^2}{2\sigma^2_{noise}} - \log p(x)$$

Going to the latent space

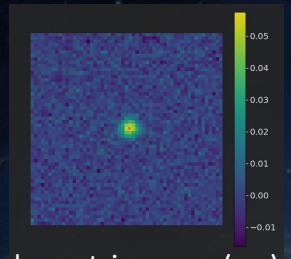


Predicted galaxy (x)

$$z^* = \arg\min_z \frac{|| y - f_\theta(z) ||^2}{2\sigma^2_{noise}} - \log p(z)$$

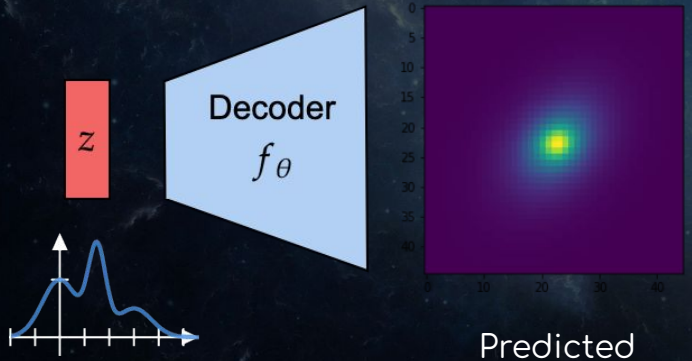
Where, z^* is the maximum a posteriori probability estimate in the latent space

Minimization



Input image (y)

- Start with random z
- Do gradient descent in the latent space to minimize the objective function



Predicted galaxy (x)

$$z^* = \arg\min_z \frac{|| y - f_\theta(z) ||^2}{2\sigma^2_{noise}} - \log p(z)$$

Where, z^* is the maximum a posteriori probability estimate in the latent space

Deblending (Multiple sources)

$$Z = \{z_i \mid z_i \text{ being the latent space representation of } i^{th} \text{ galaxy}\}$$

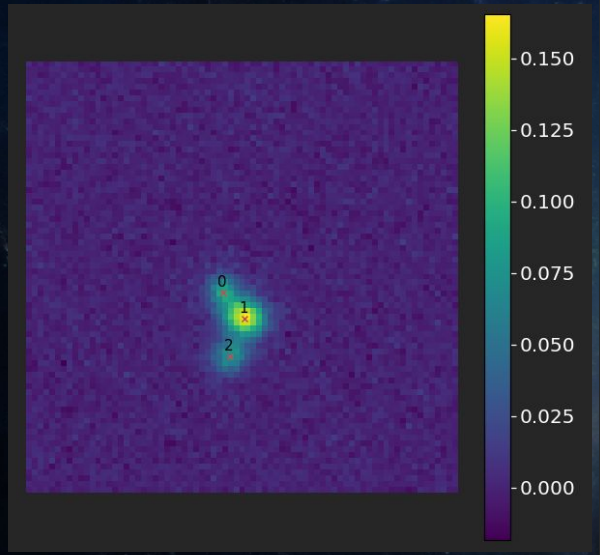
$$Z^* = \arg\min_Z \; -\log p(y|Z) - \log p(Z)$$

Reconstructed field

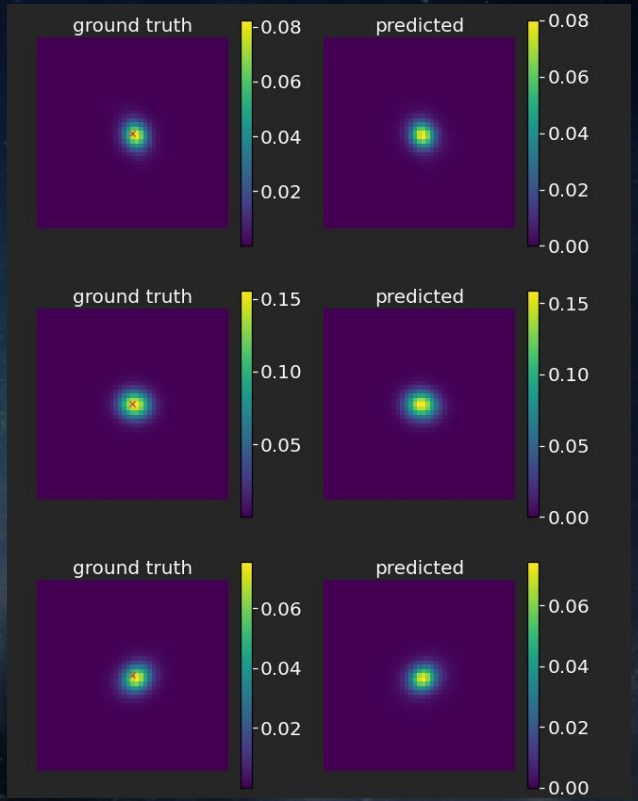
Probability that predictions are galaxies!

$$Z^* = \arg\min_Z \frac{|| y - \sum_i f_\theta(z_i) ||^2}{2\sigma^2_{noise}} - \sum_i \log p(z_i)$$

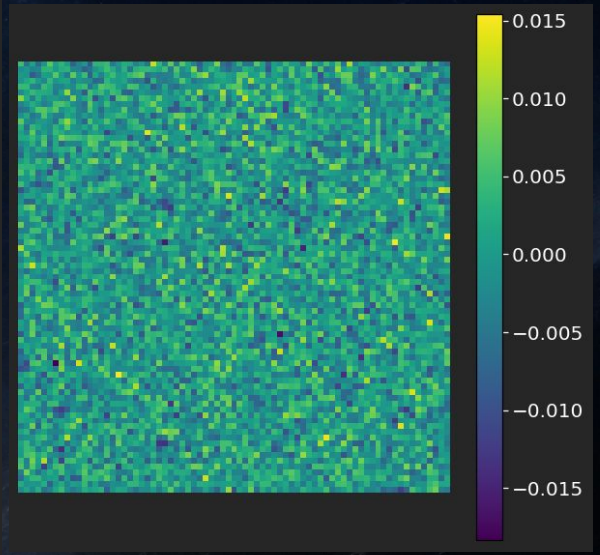
Deblending Example



Input image

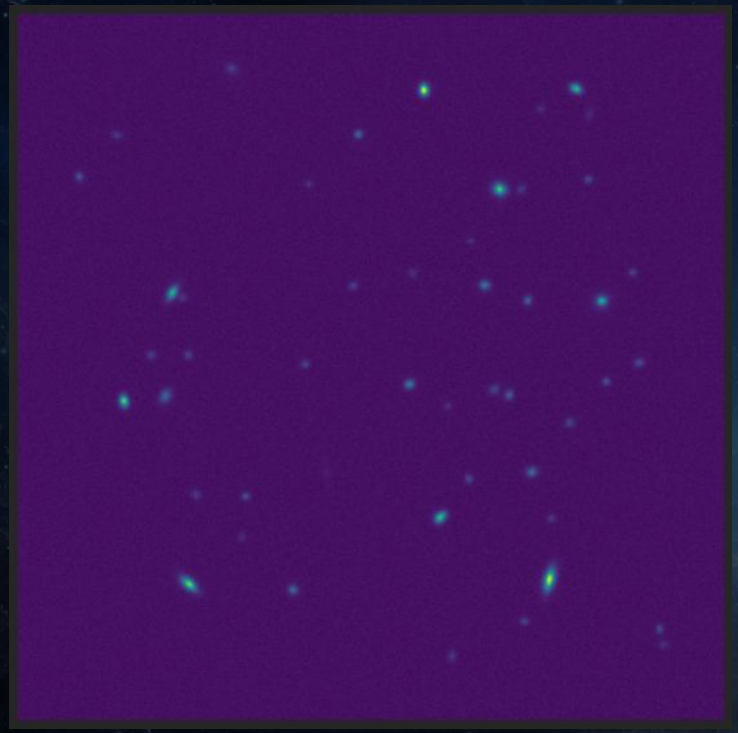


Predictions

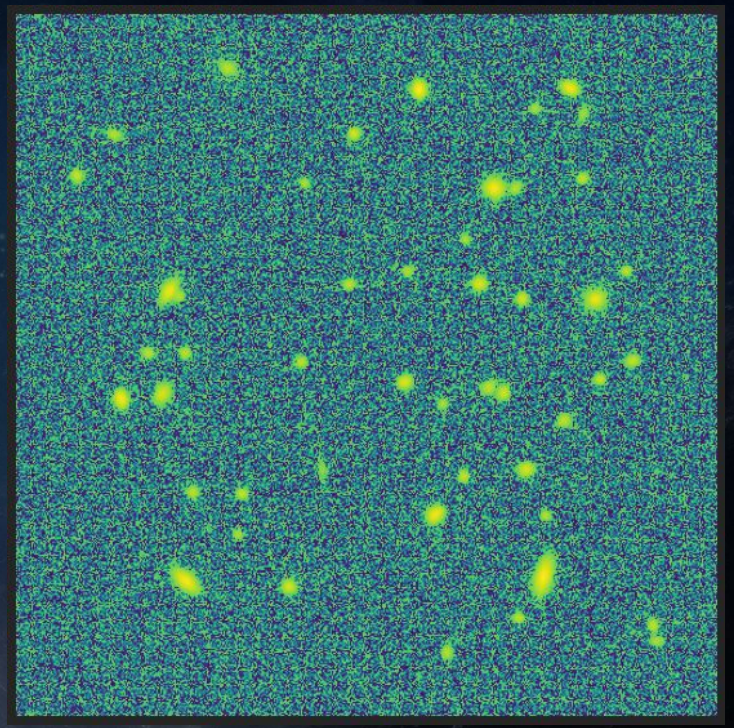


Residual image
(input - predictions)

Moving to a larger field...

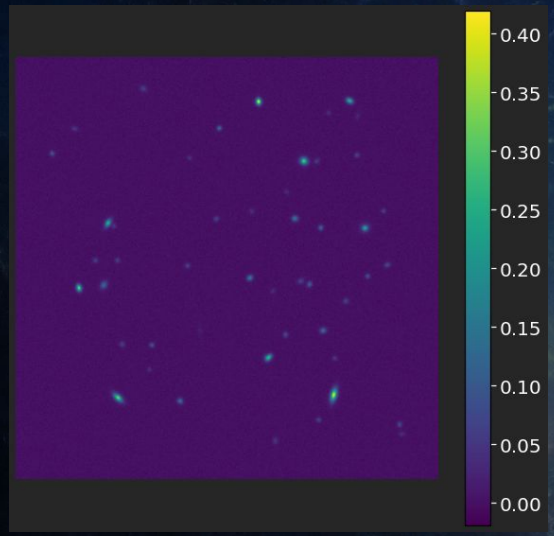


Input field

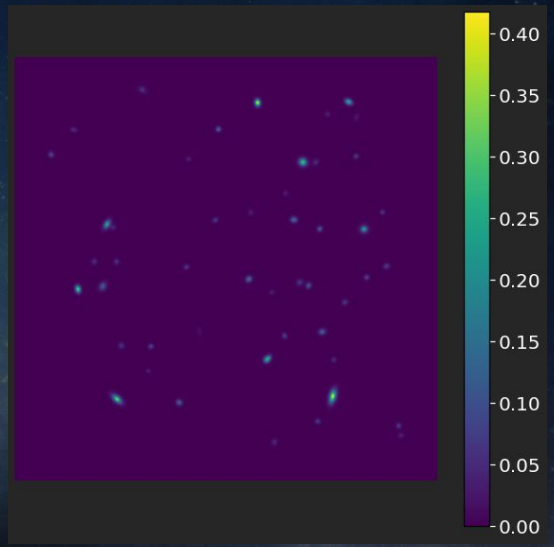


Sinh^{-1} (Input field)

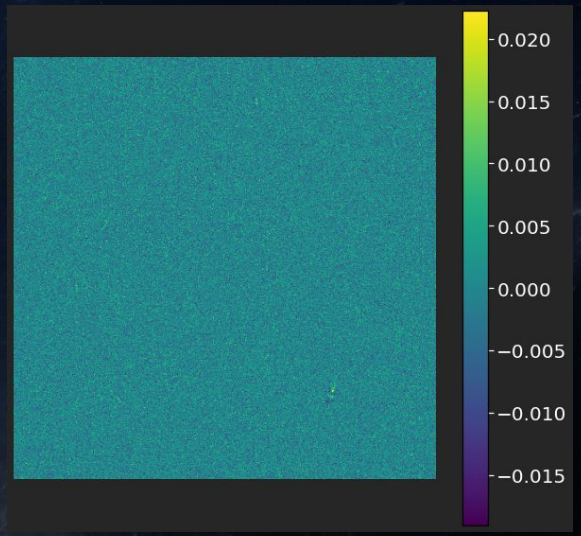
Moving to a larger field...



Input field



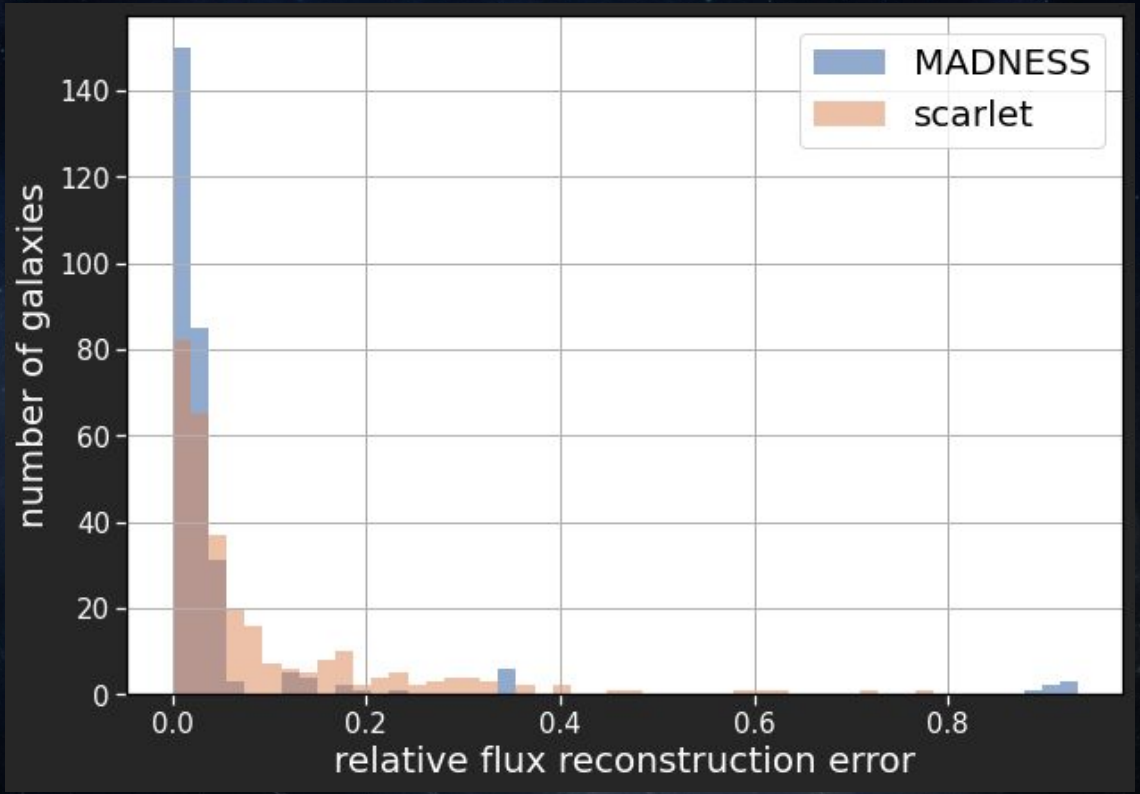
predicted field



residual field
(Input - predicted)

Preliminary results*

Compare with scarlet



Preliminary results*

Conclusion and Future work

- Encouraging initial results!
- Time to get back to the basics (network architecture, loss function...)
- Choose metrics to evaluate the deblending results. (Flux reconstruction, SSIM...)
- Real data?

Thank you!