Deblending galaxies with Variational Autoencoder:
a multi-bands, multi-instruments analysis

(*Arcelin, Doux, Roucelle, Aubourg*)

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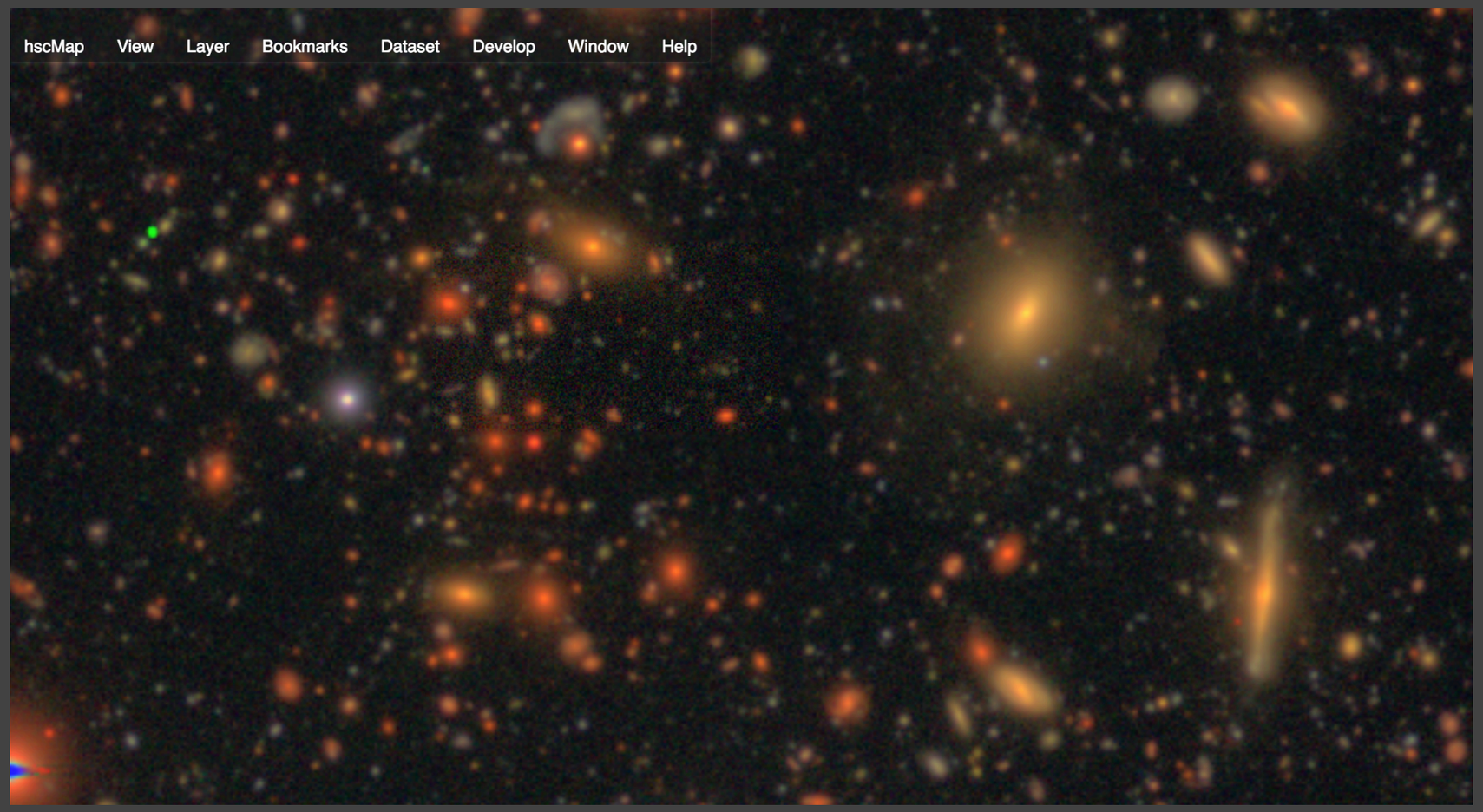
LSST France - Juin 2019

LSST Data

- Will look a lot like HSC data (hsc-release.mtk.nao.ac.jp/hscMap2/)

- For HSC 58% of the detected objects are identified as blended*

- Systematic in shear measurement



From Cyrille Doux
(LSST Europe, 14 Juin 2018)

* Bosch et al. (2017)

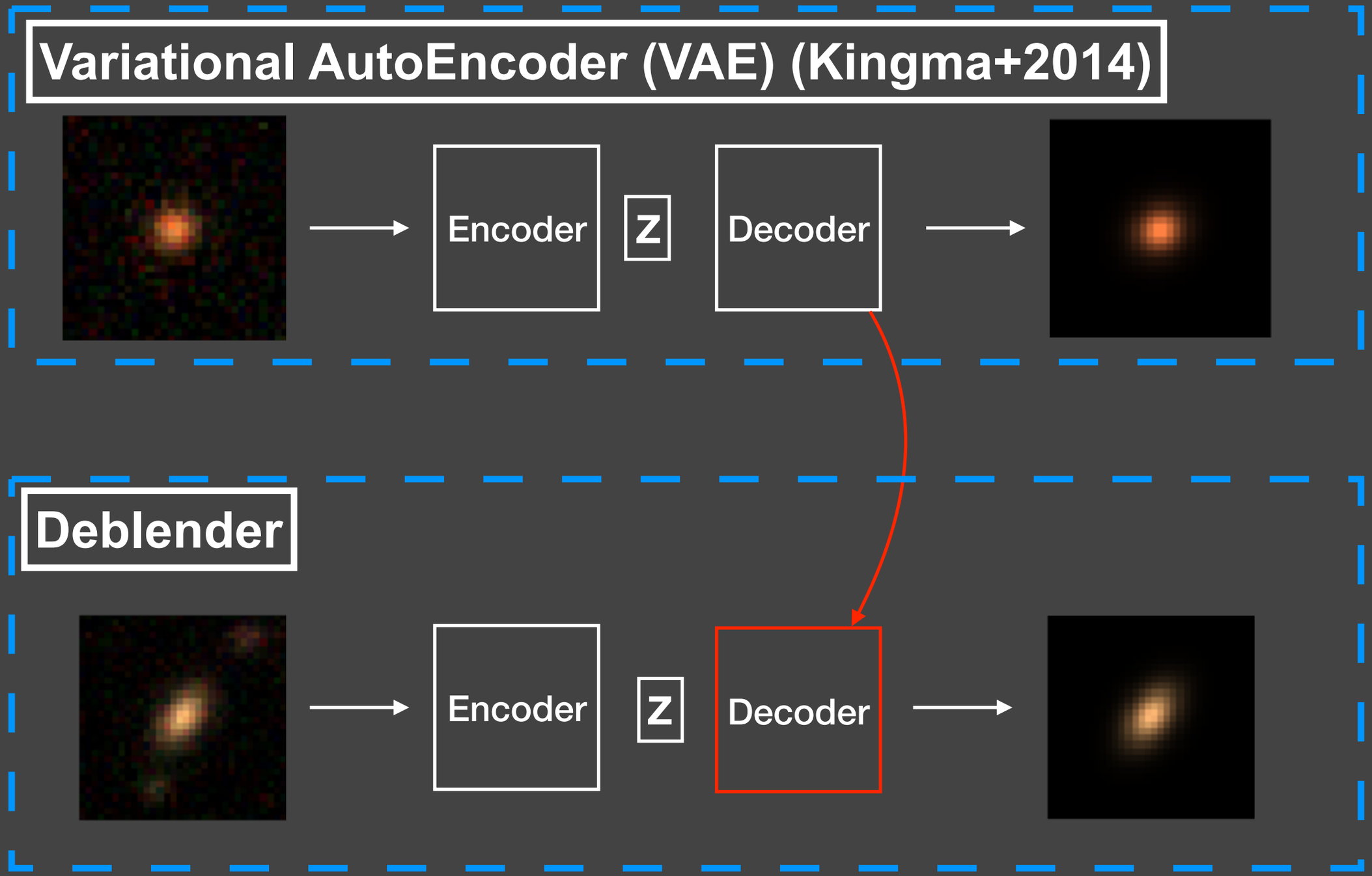
Goals and motivation

- Create a model for galaxy images from the data → Generative model

- Bayesian approach → Variational AutoEncoder

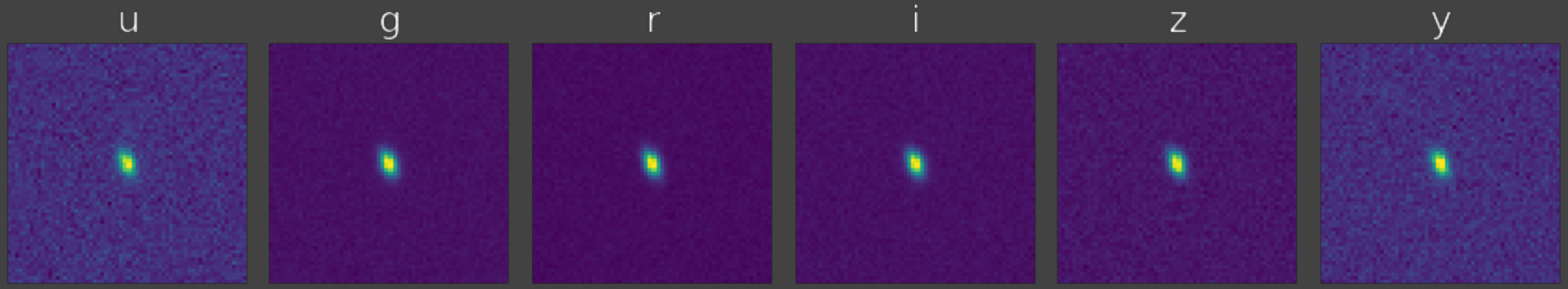
- Accurate reproduction of relevant weak lensing parameters → Shape and flux reproduction

Machine learning for deblending

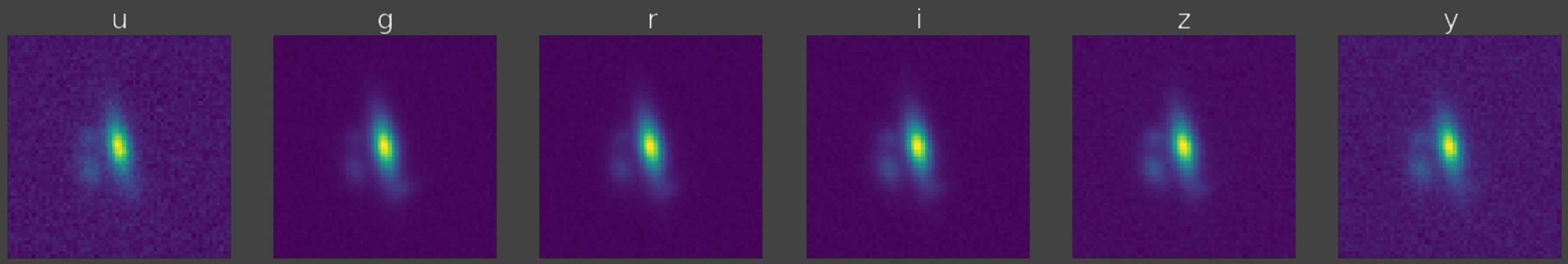


Training sample

- With GalSim from COSMOS catalog: 6 LSST pass-band filters
  - 200k galaxies for the VAE



  - 200k blends of galaxies for the deblender



Training

- 3 steps:

    1) Train VAE on noiseless images of single galaxy

    2) Train on noisy images of single galaxy

    3) Train on noisy images of blended galaxies

- 3 cases:

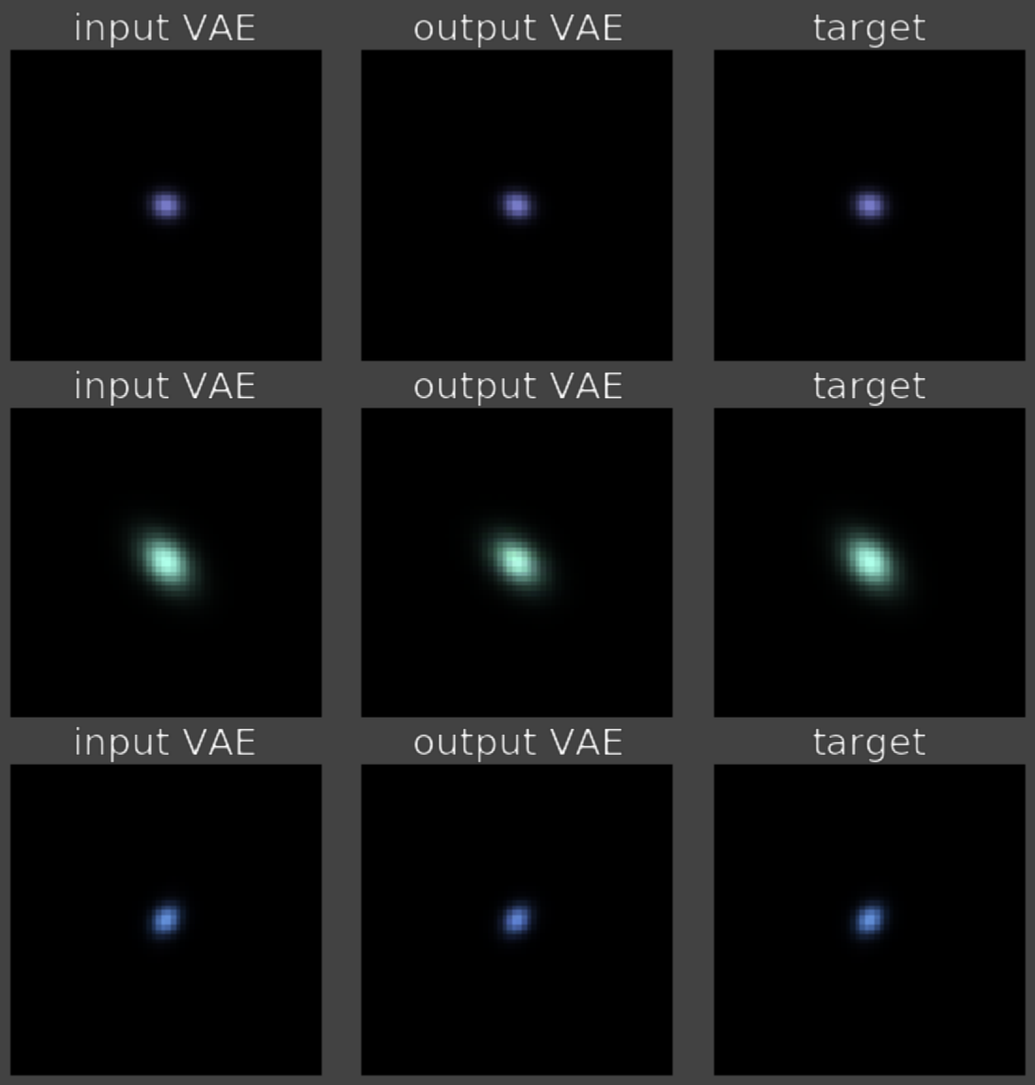
    1) Train on images composed of only ***R band-pass filter***

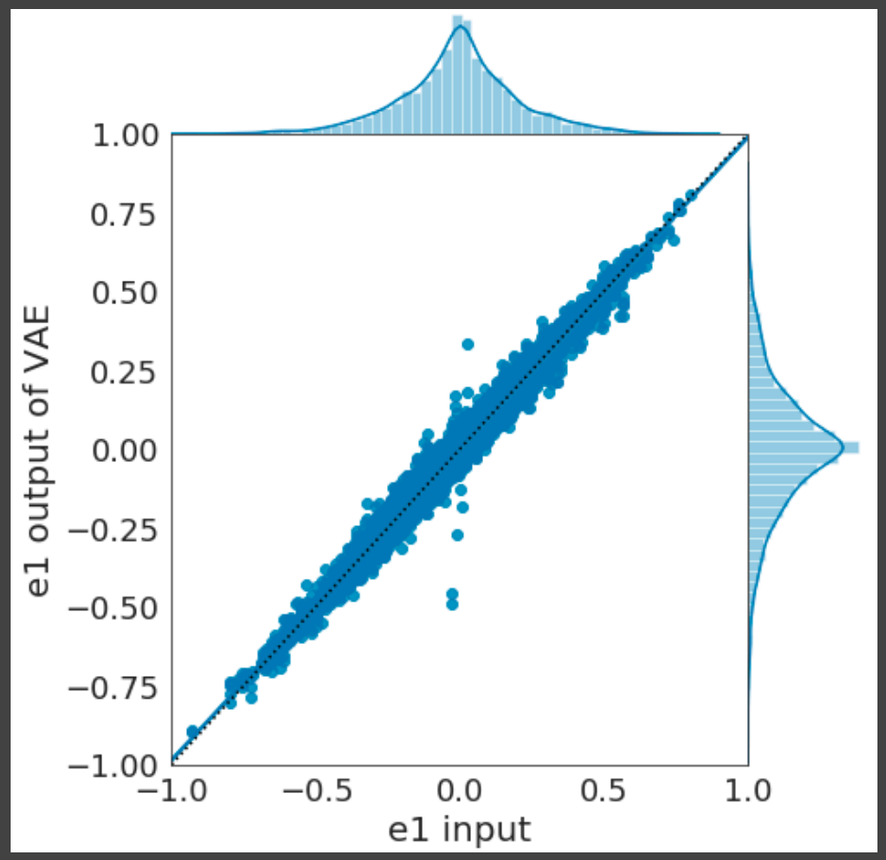
    2) Train on images composed of the ***6 LSST band-pass filters***

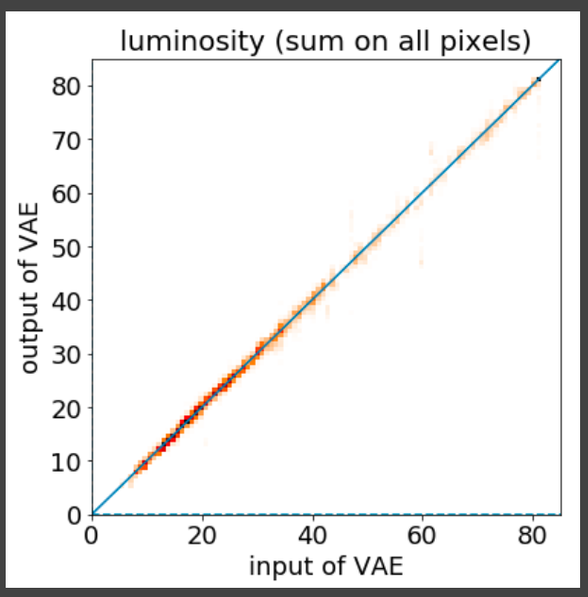
    3) Train on images composed of the ***6 LSST band-pass filters + the 4 Euclid band-pass filters***

Tests

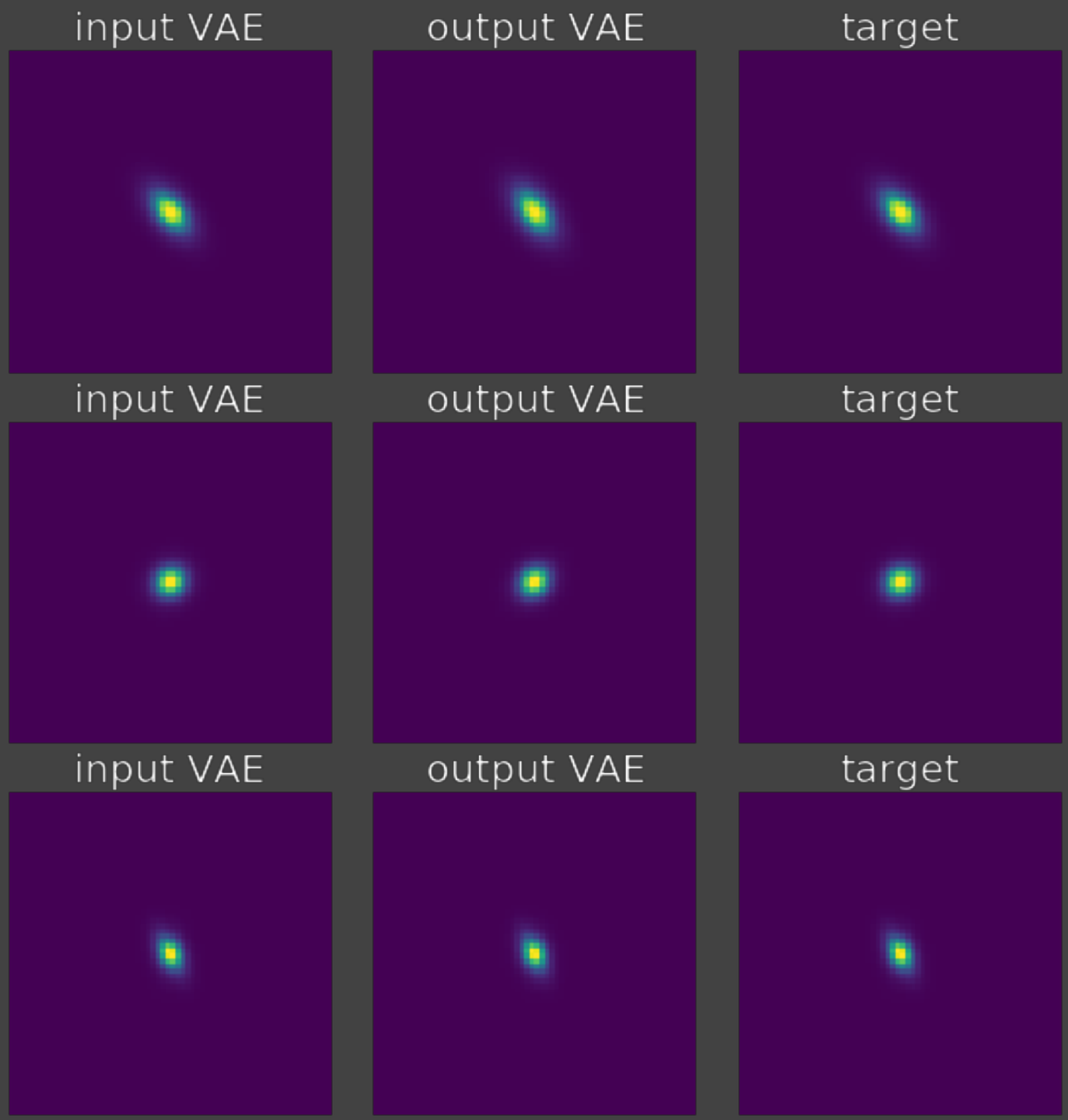
- Visual inspection
- Reproduction of shapes/fluxes



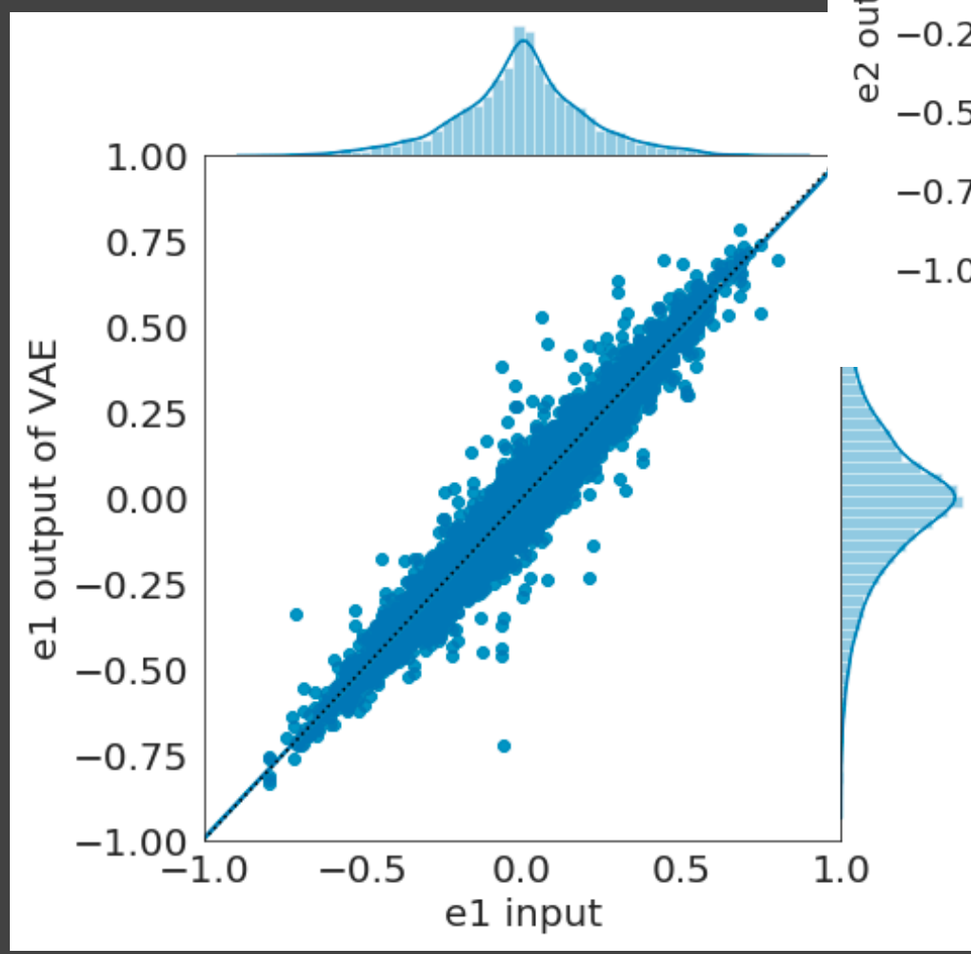


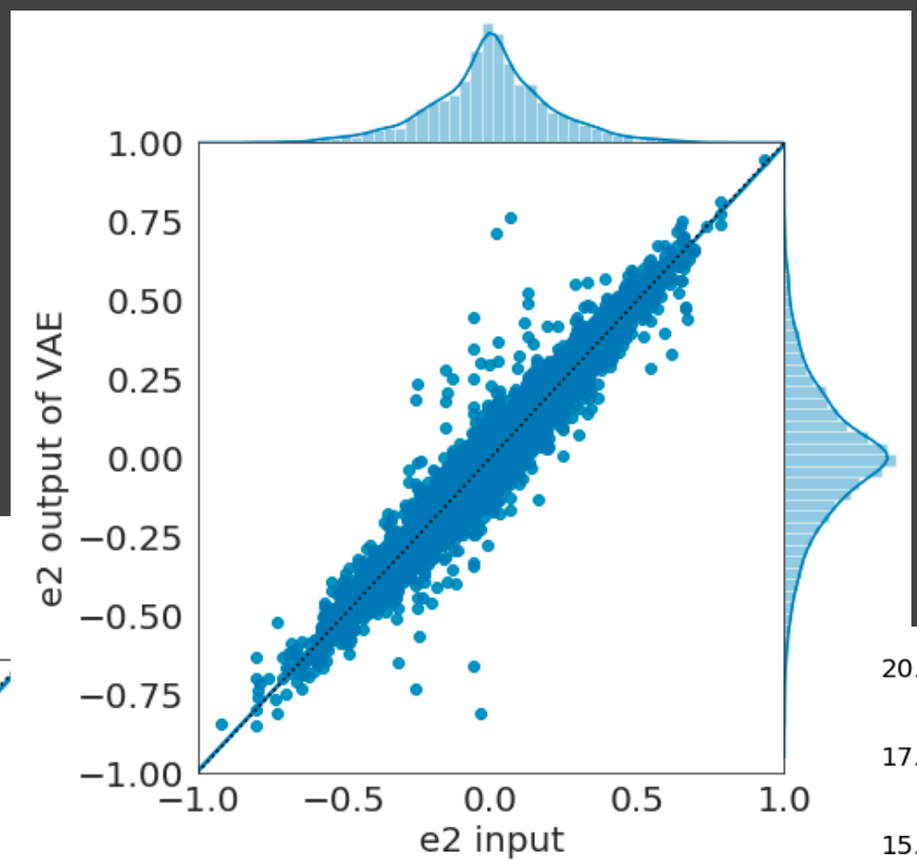


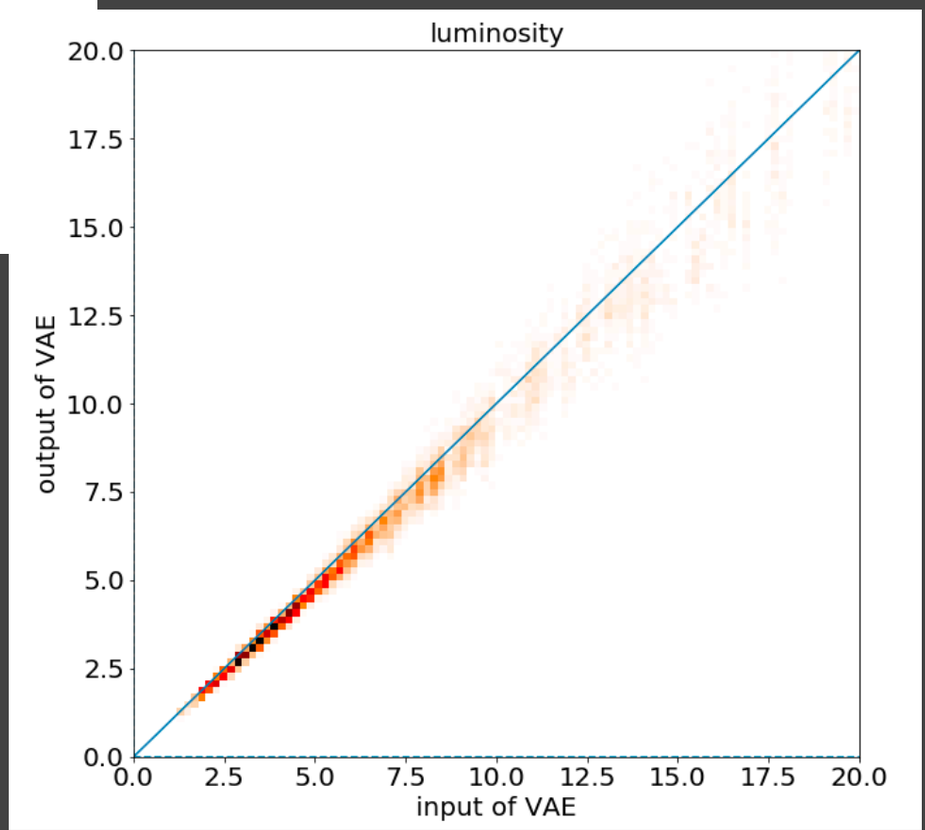
VAE: R band-pass filter



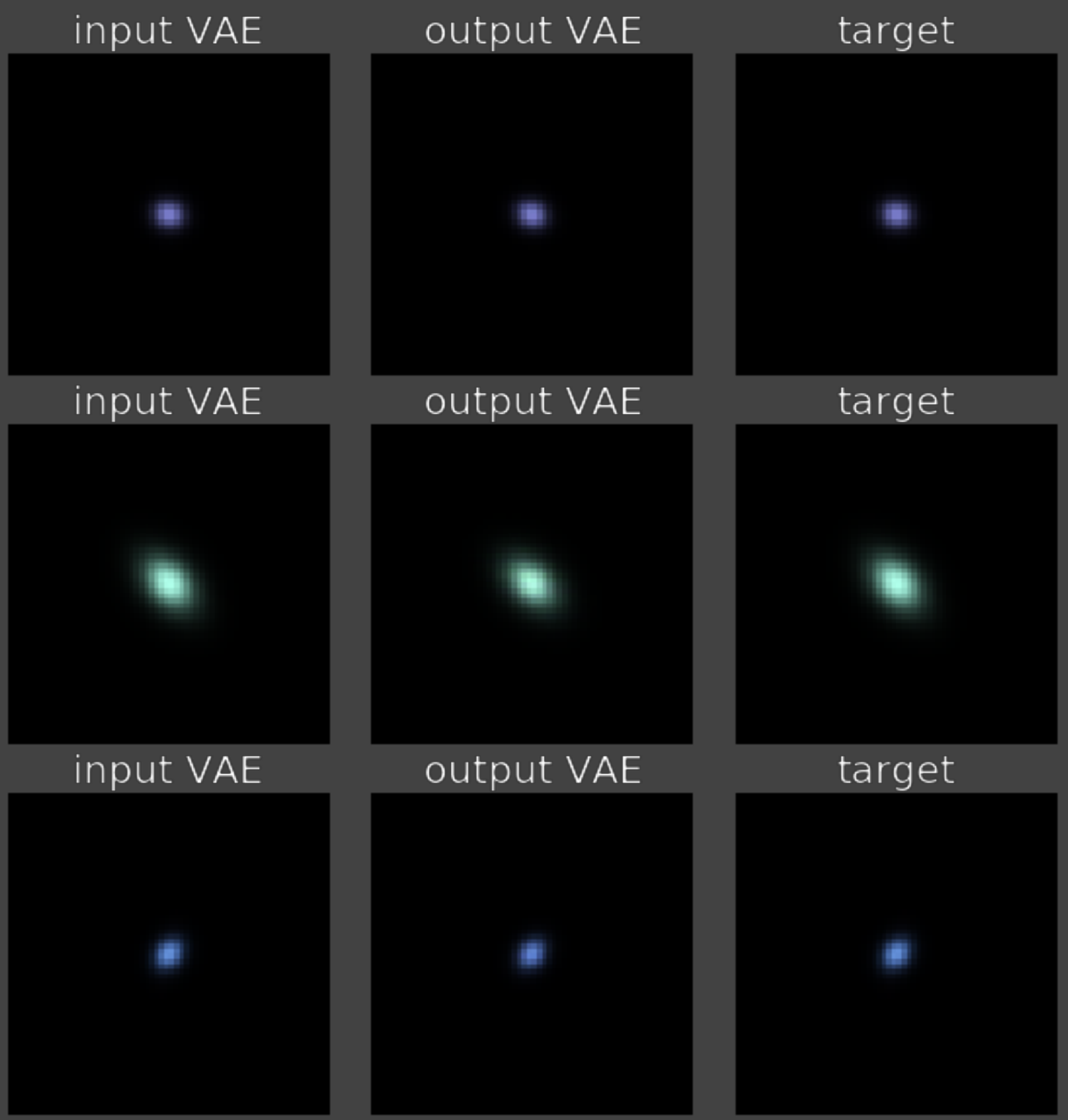
VAE: with LSST R band-pass filter







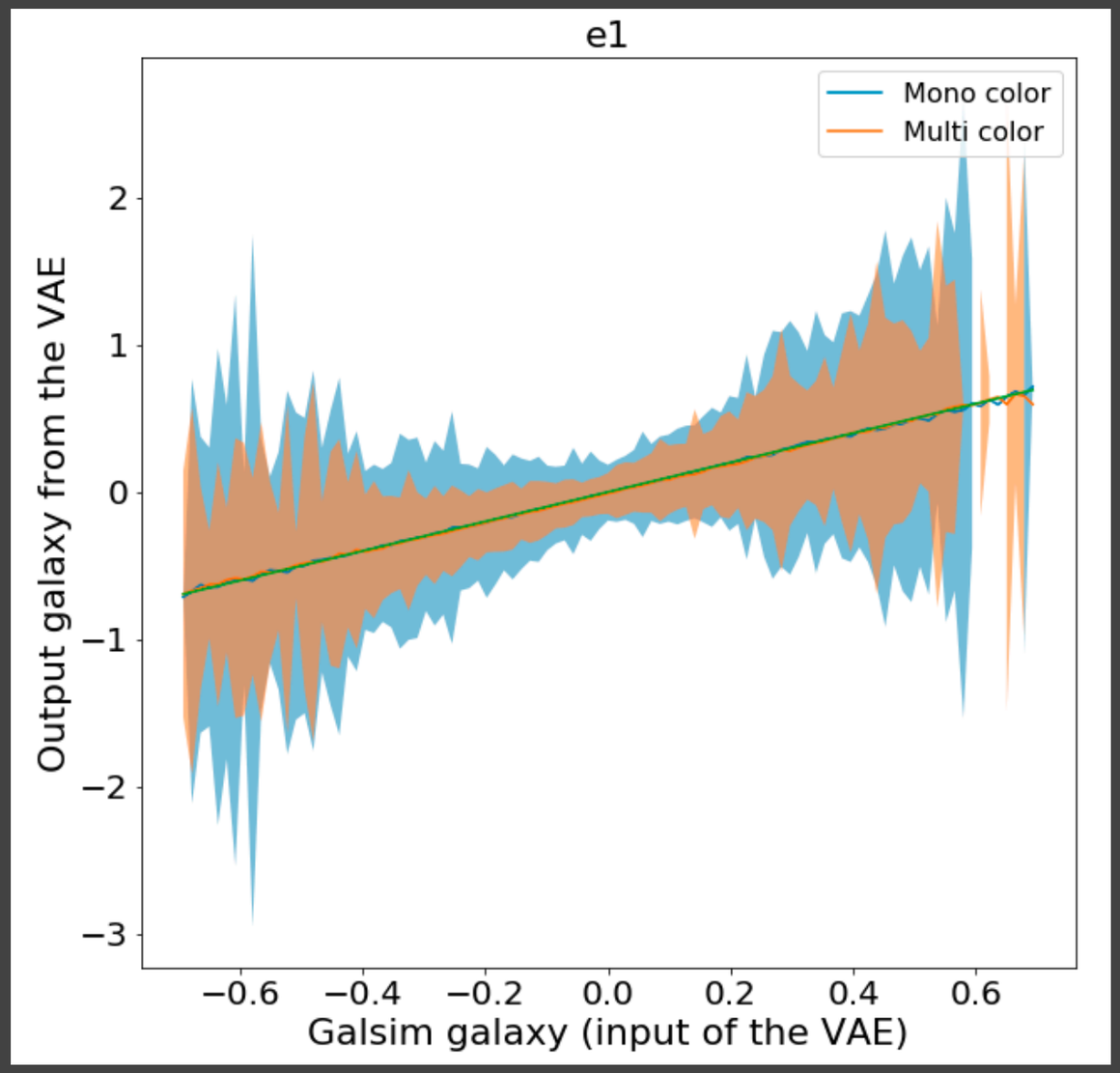
VAE: 6 LSST band-pass filters

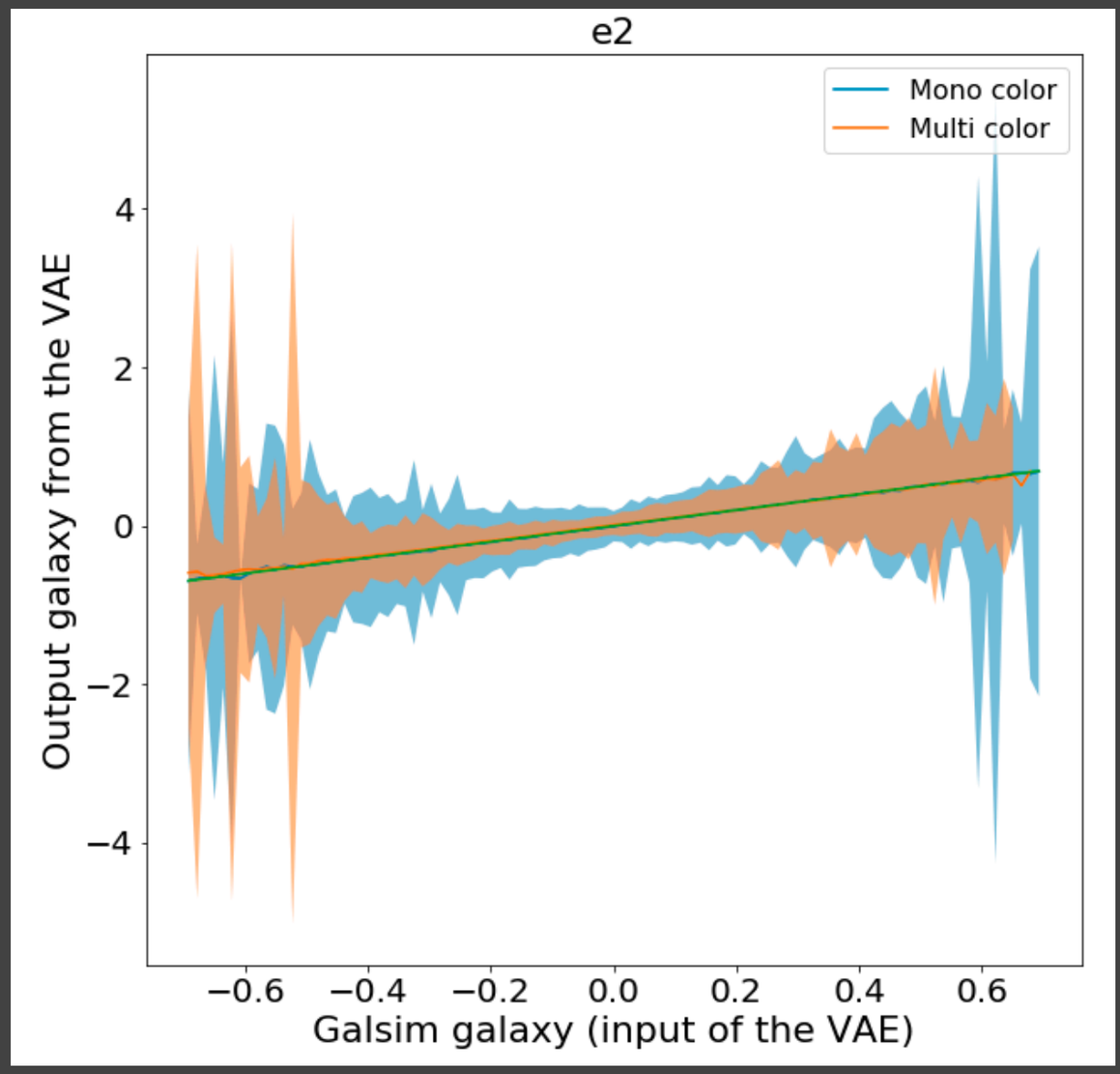


VAE

mono-wavelength/multi-wavelengths comparison

- 6 passbands of LSST (comparison done on r band)



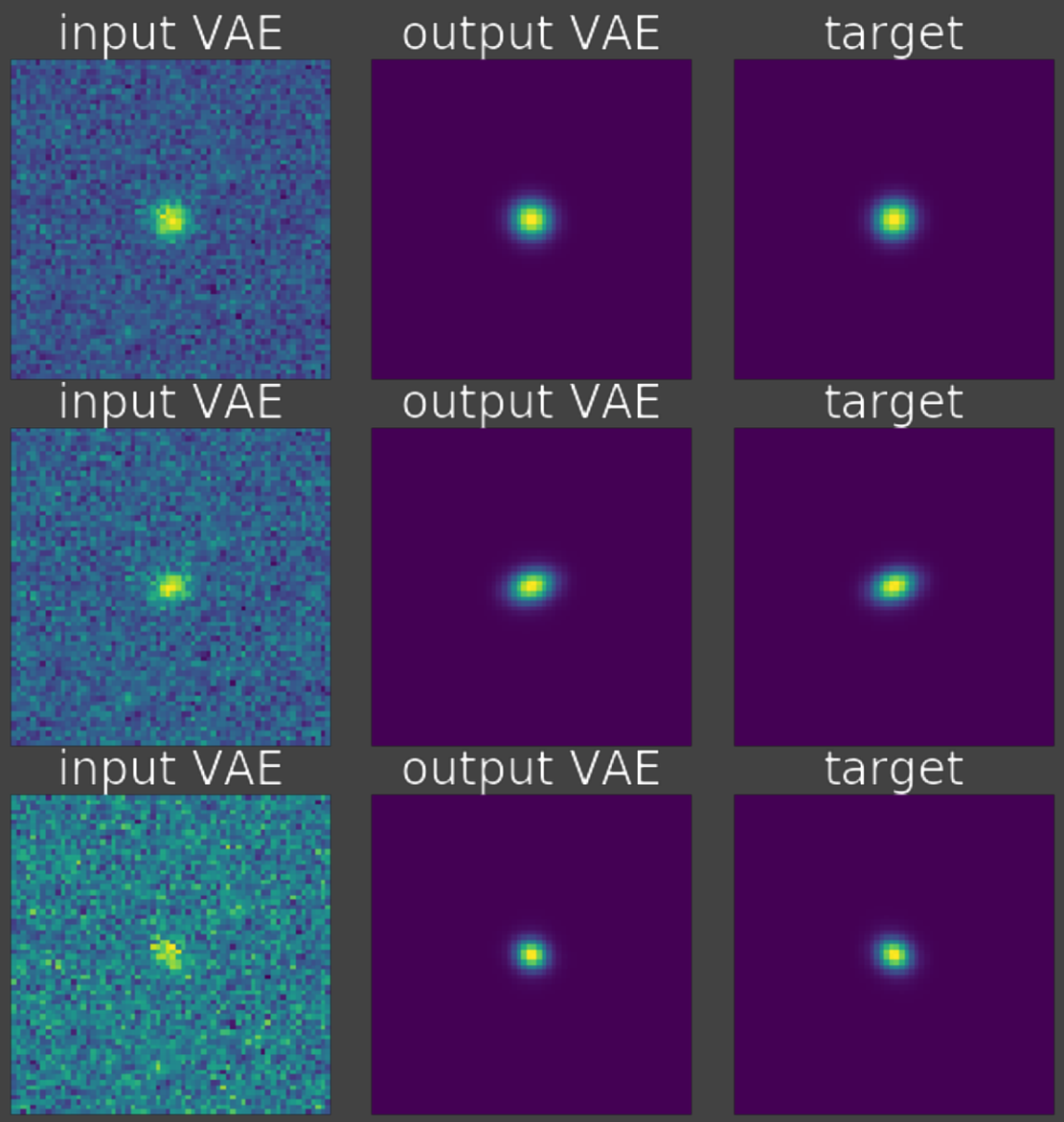


➡ VAE gives better results using 6 bands rather than one

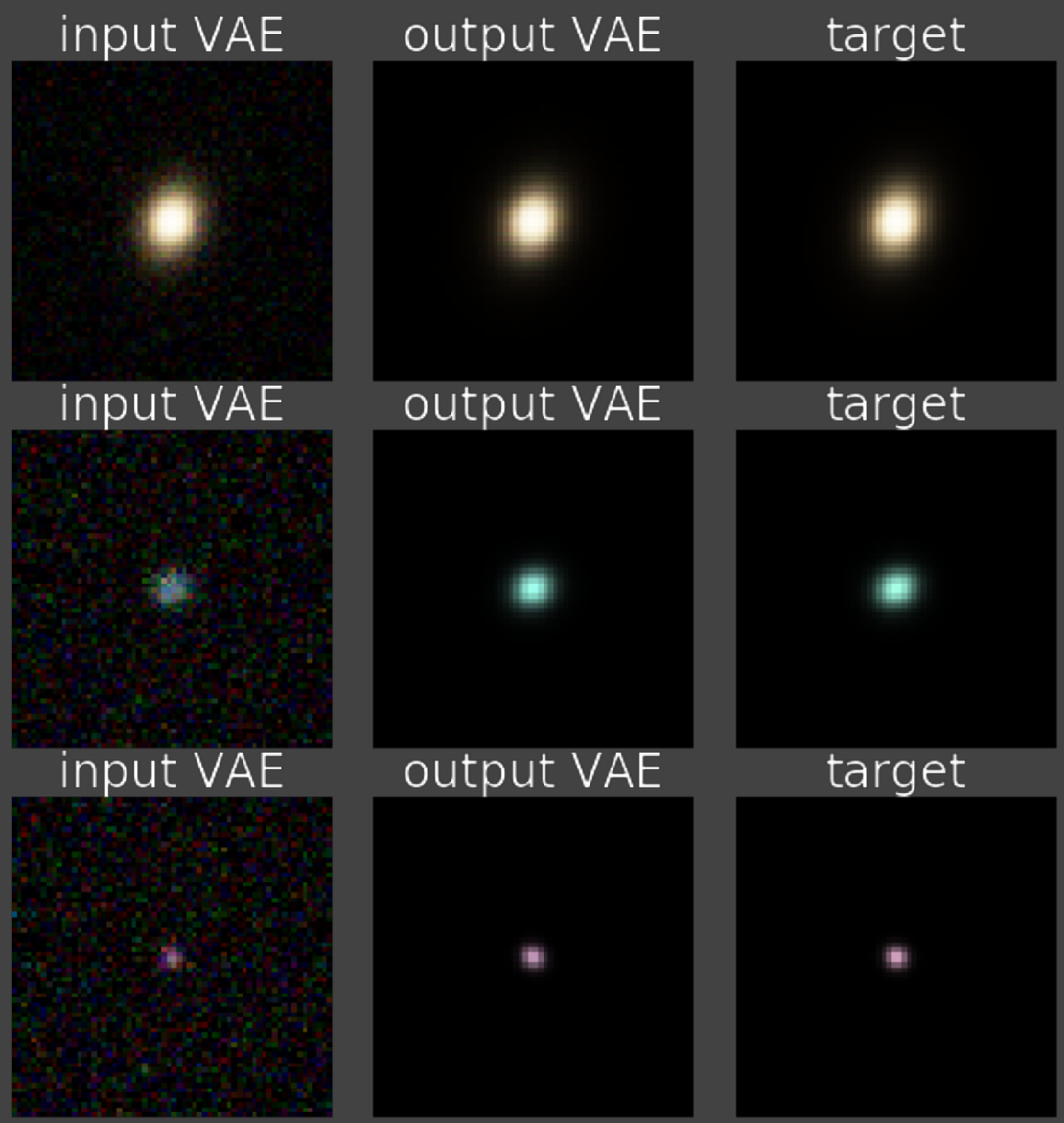
VAE: noisy images

- Poissonian noise added

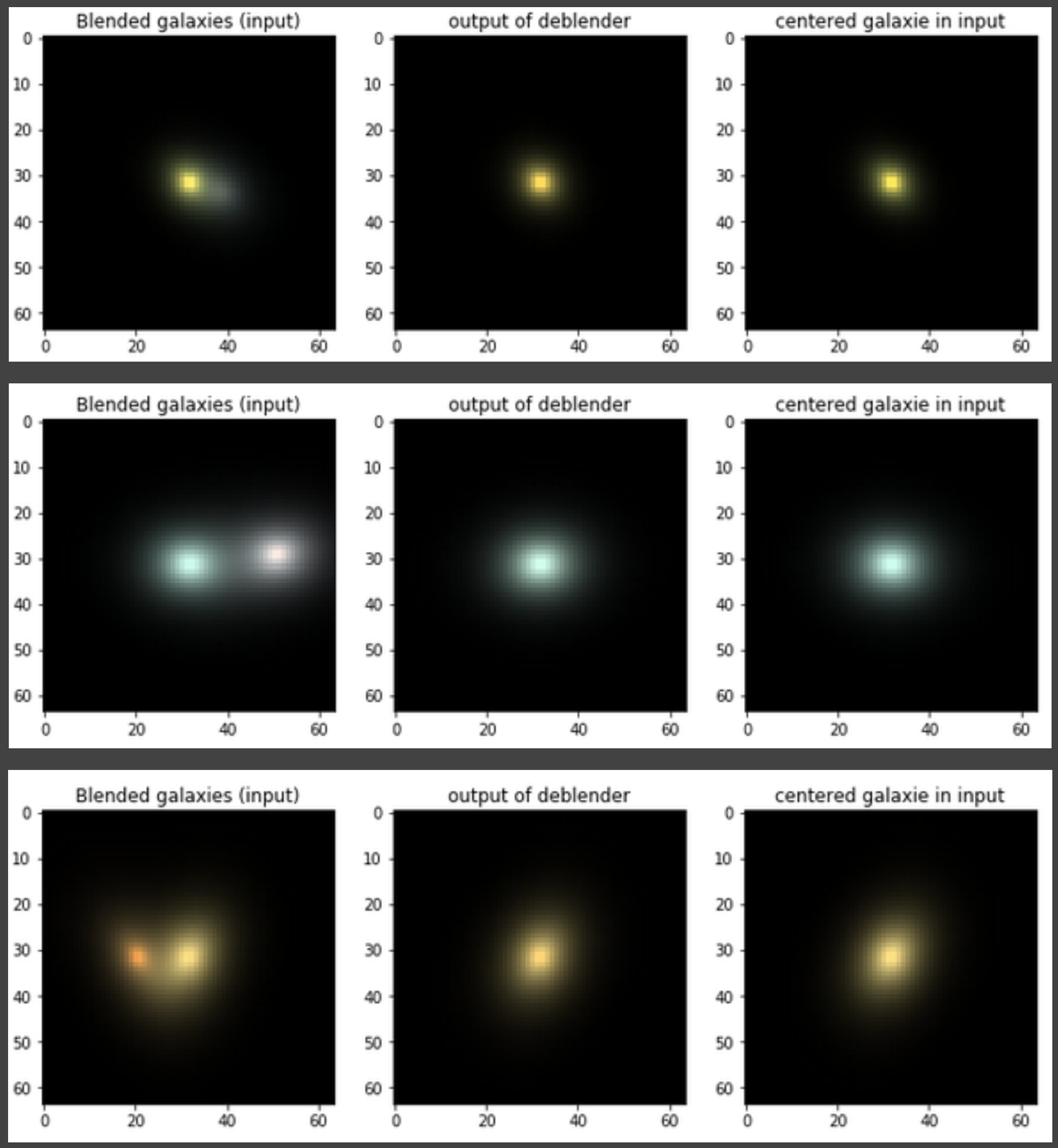
Only R pass-band filter images



6 LSST pass-band filters images

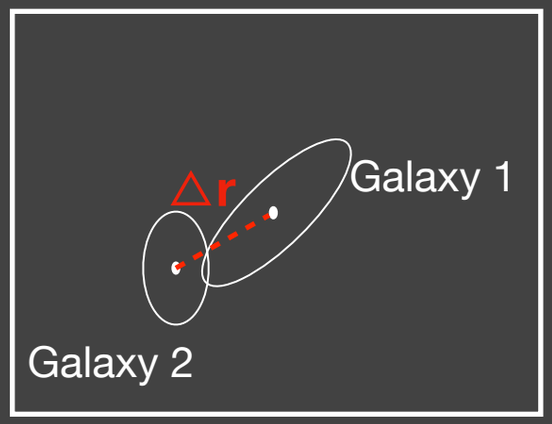


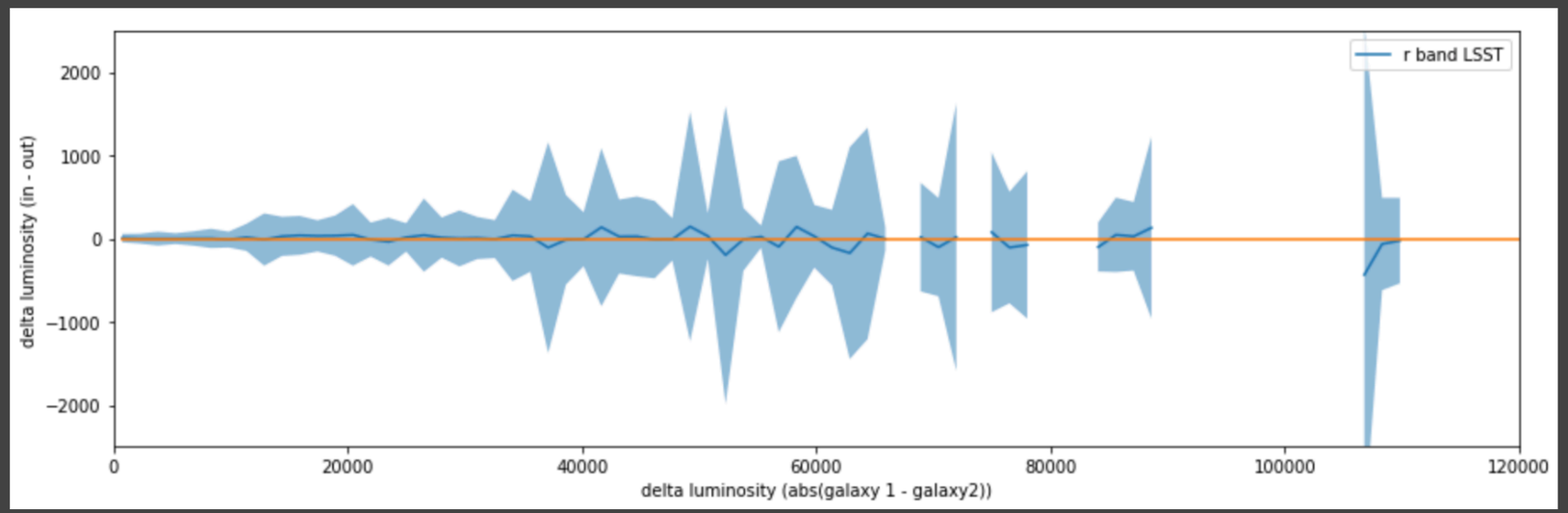
Deblender : preliminary results

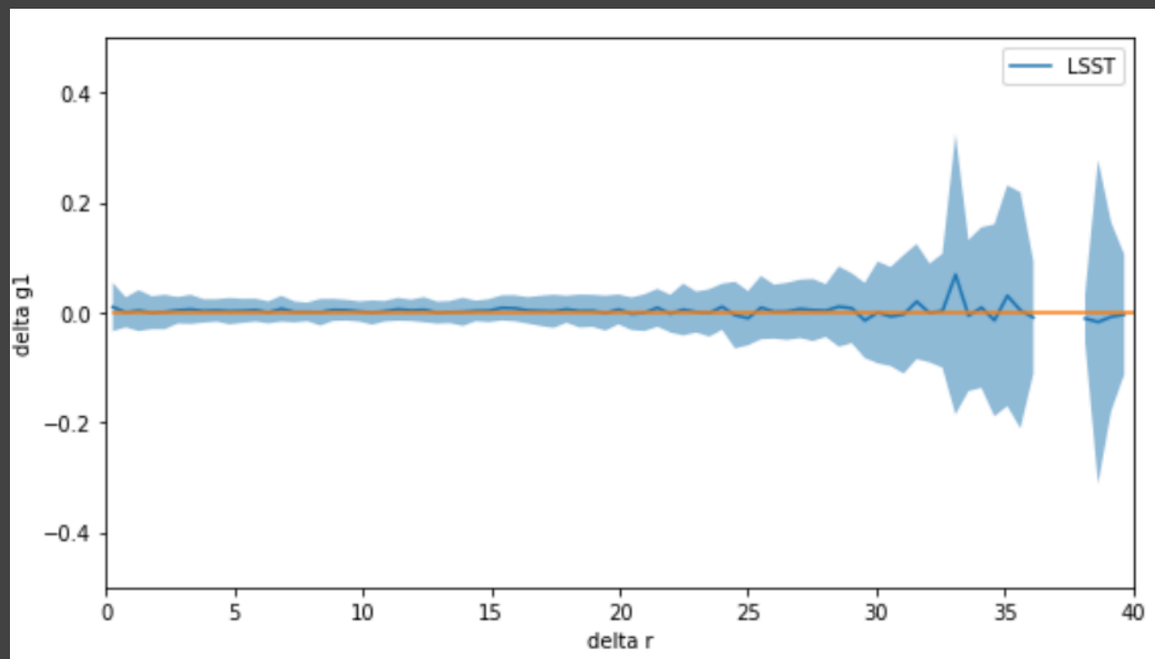


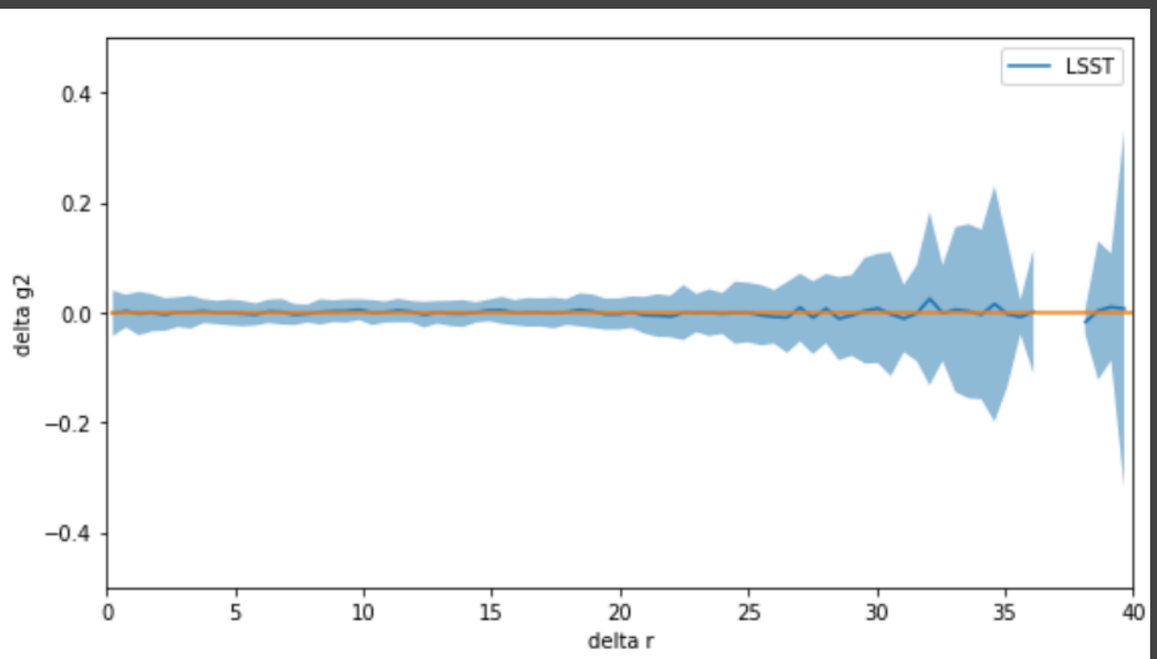
Deblender : preliminary results

shape and luminosity reproduction









LSST+Euclid Data

- Why using Euclid data:
  - ✓ Adding infrared bands (x3)
  - ✓ Adding a wide optical band
  - ✓ Different PSF

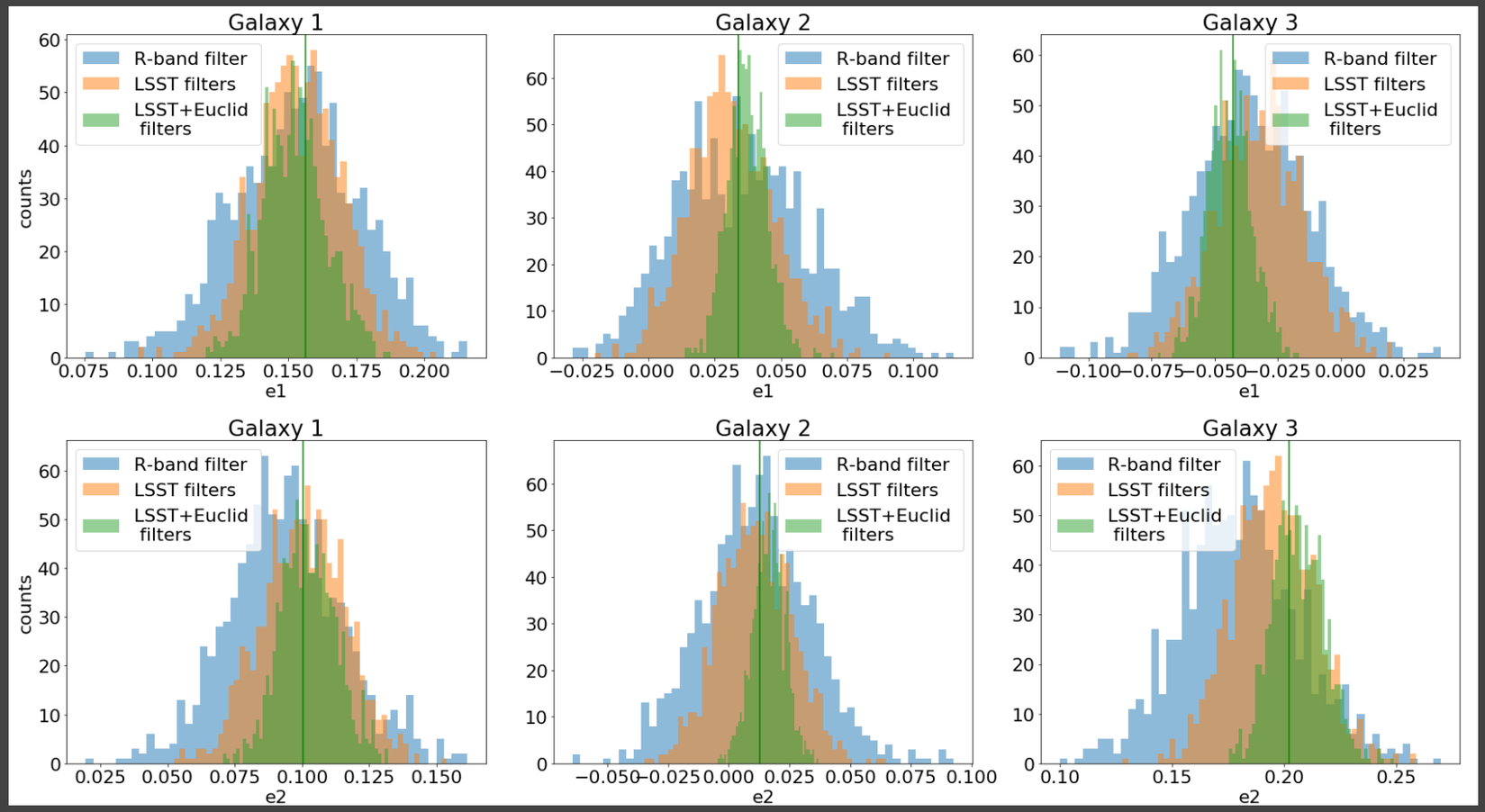
DES data - Peter Melchior’s slides

CLASH WFC3/IR data - Peter Melchior’s slides

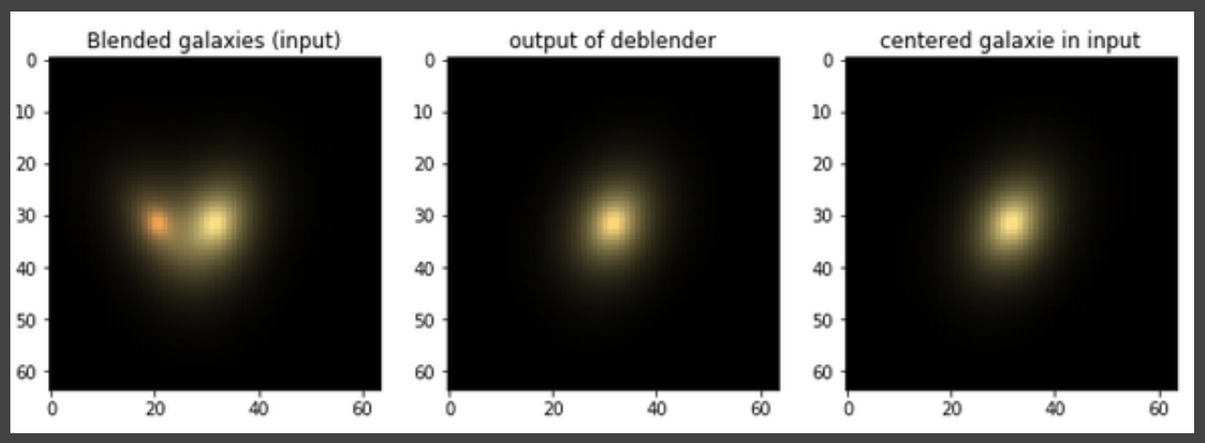
LSST + Euclid : preliminary results

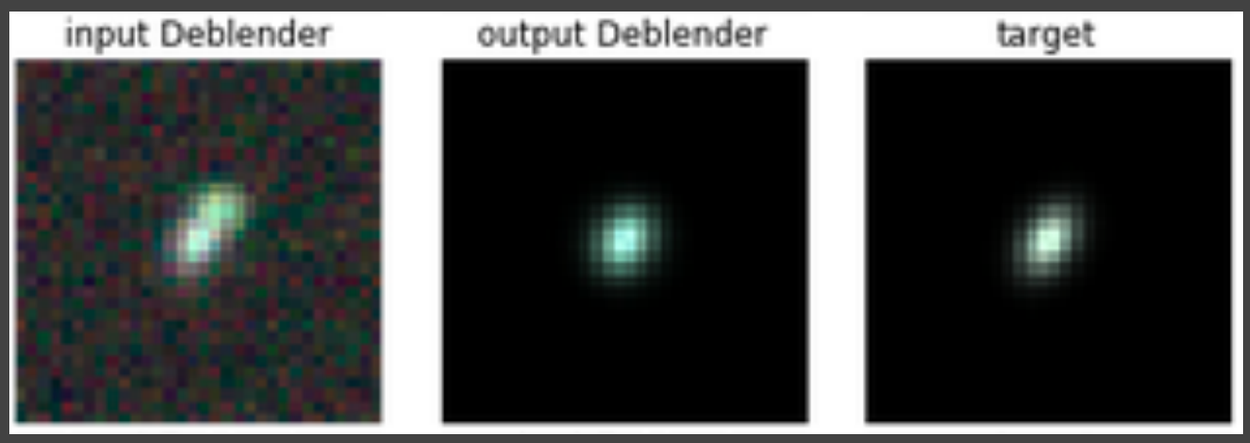
Figure of merit: shape reproduction

- VAE



- Deblender





Where are we ?

- <u>3 steps:</u>

  1) Train VAE on noiseless images of single galaxy

  2) Train on noisy images of single galaxy

  3) Train on noisy images of blended galaxies

<u>Tests :</u>
- Unbiased reproduction of weak lensing parameters
- architectures, latent space, normalization…

- <u>3 cases:</u>

  1) Train on images composed of only ***R band-pass filter***

  2) Train on images composed of the ***6 LSST band-pass filters***

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Conclusion

- VAE :
  - Can reproduce accurately galaxies
  - Provides prior on single galaxies

- **Using several passbands —> improvement of the precision**

- **Using several instruments (LSST+Euclid - different PSF) —> improvement of the precision**

- Deblender :
  - Reproduction of the shape and of the luminosity.

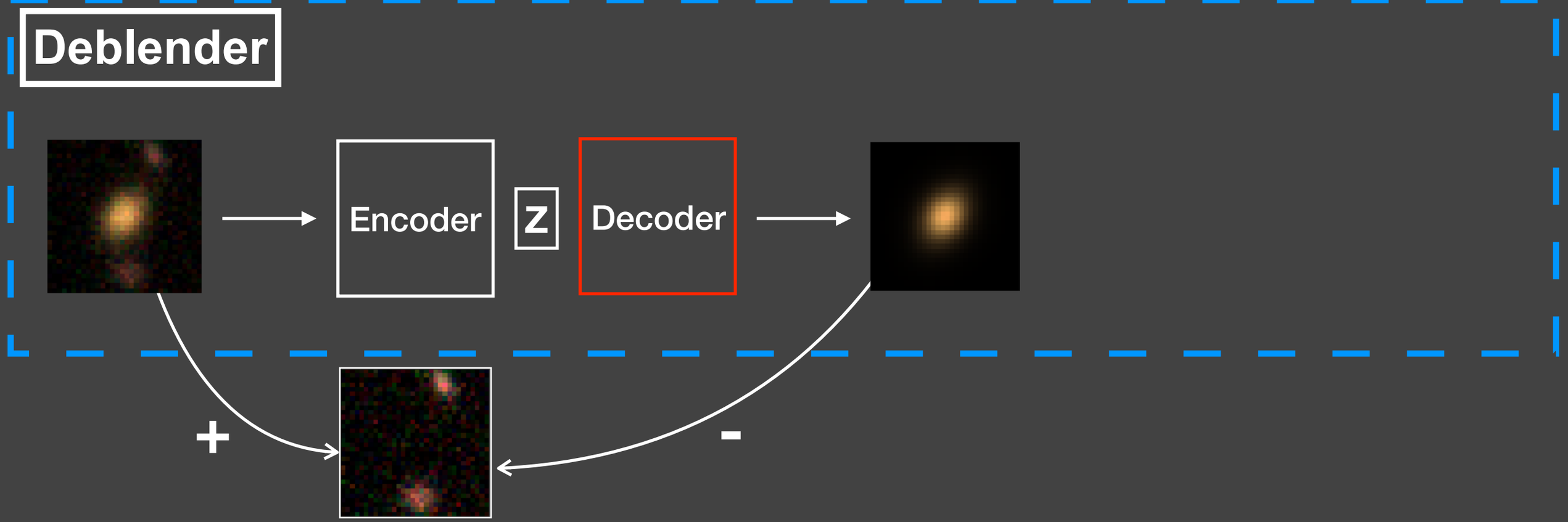
Paper in preparation: Arcelin, Doux et al. (2019). Deblending galaxies with variational Autoencoder: a multi-bands, multi-instruments analysis. (*in prep)*

What's next ?

- **Next:**
  - Train on real data (or DC2 ?)
  - More complex architecture for networks
  - Iterative deblender
  - Work on latent space: have generative model

What’s next ?

- Iterations by substracting the output of the deblender to the blended image



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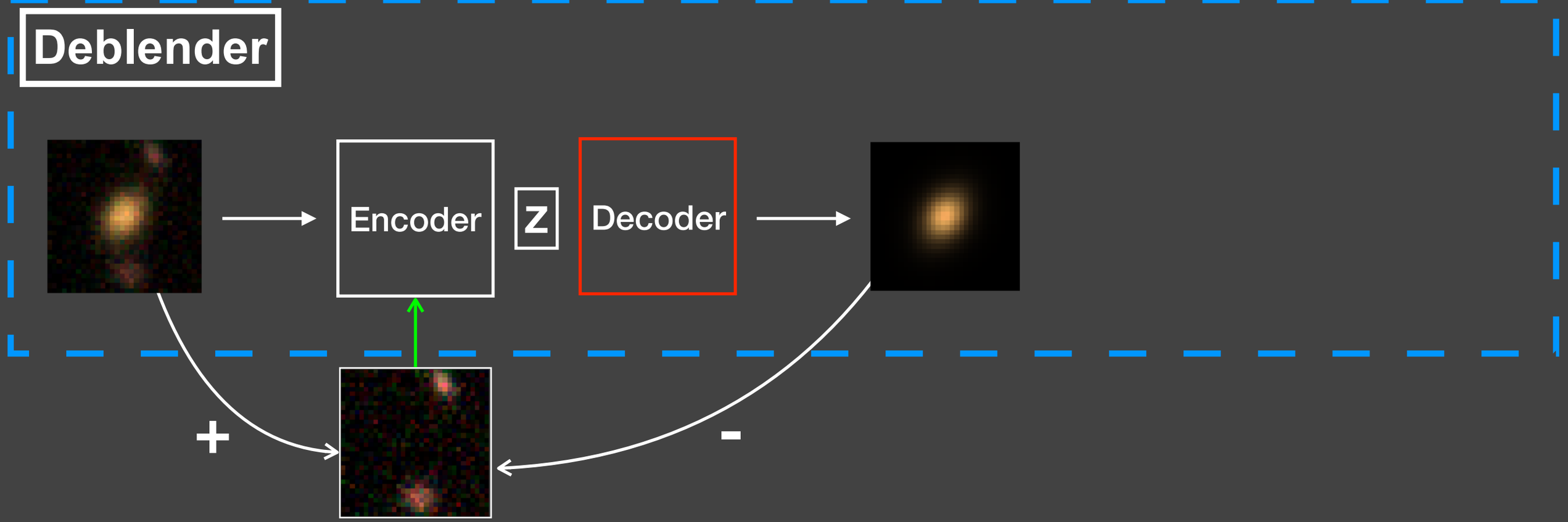

What’s next ?

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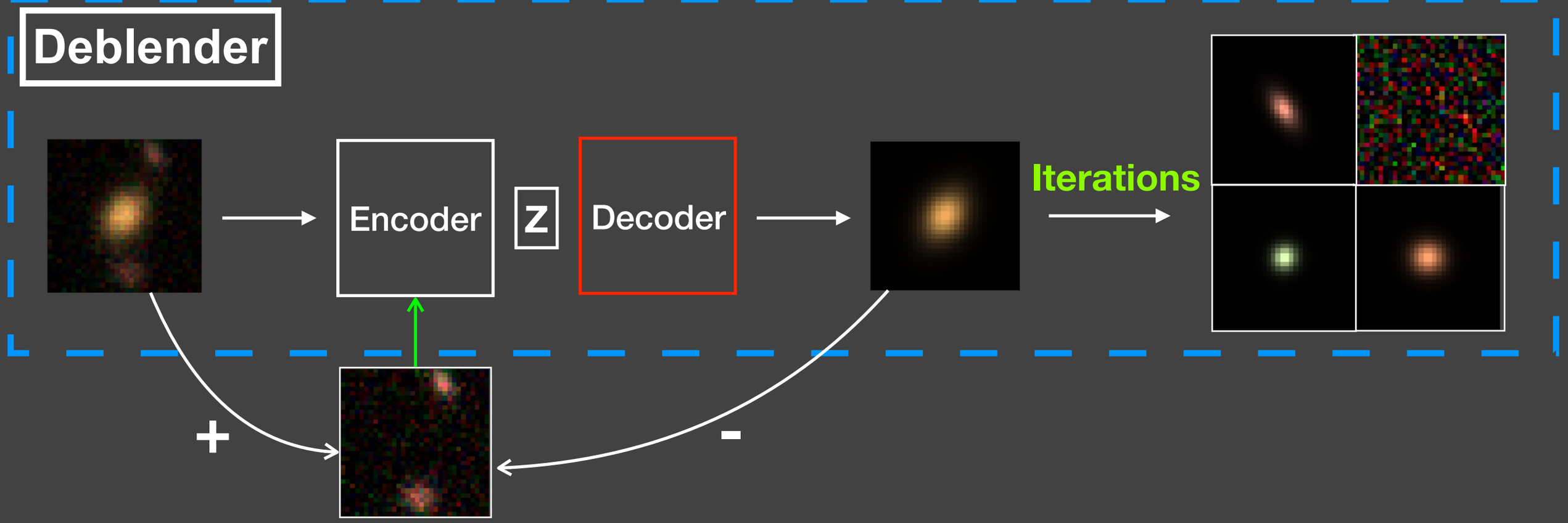
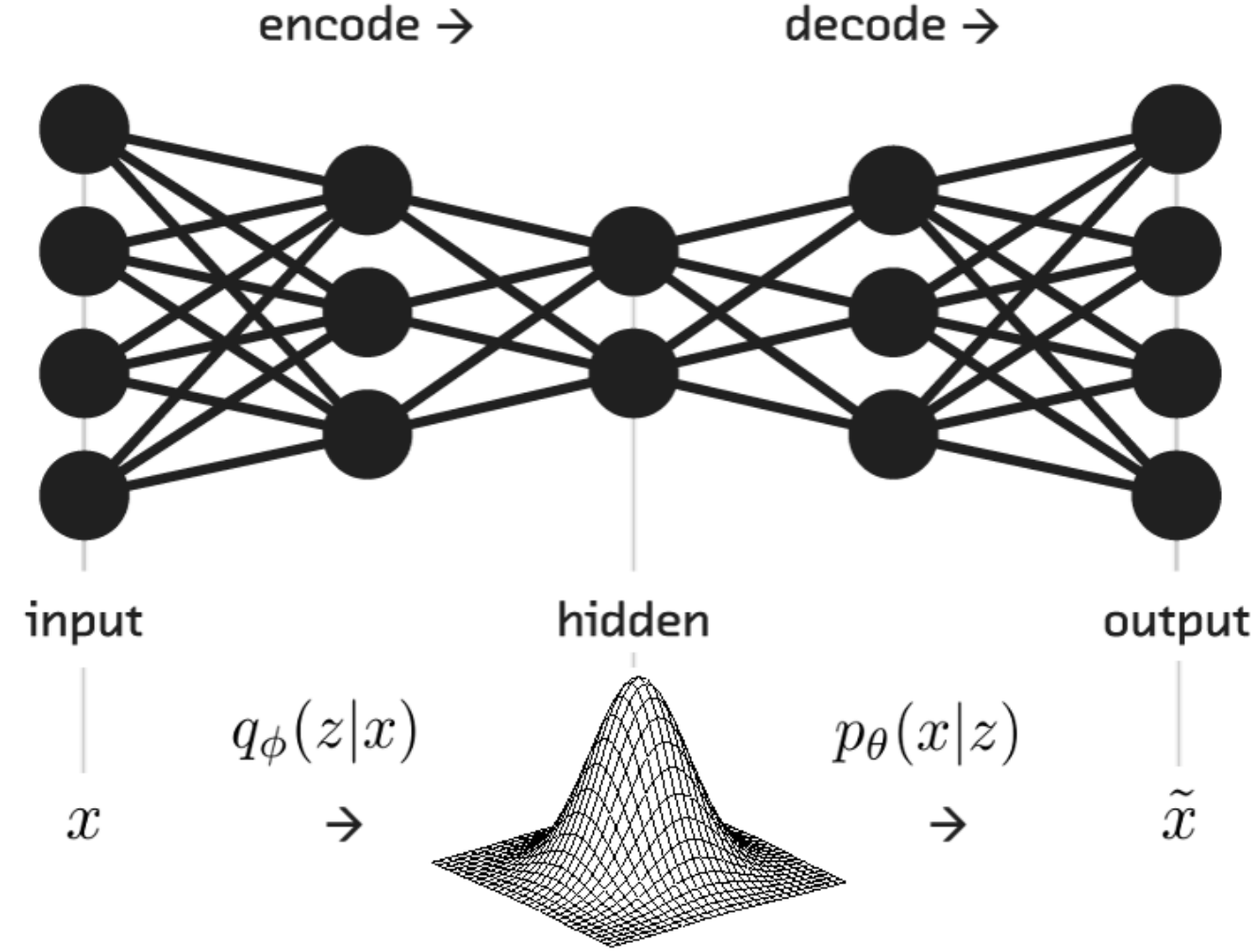


Variational autoencoder (Kingma+2014)



- http://blog.fastforwardlabs.com

Loss function :

$$ELBO = -D_{KL}\left(q_\phi(z|x) \parallel p(z)\right) + \mathbb{E}(\log p_\theta(x|z))$$

Encoder → Regularization term

Decoder → Reconstruction term

What's next ?

- Work on latent space: generate galaxies with VAE