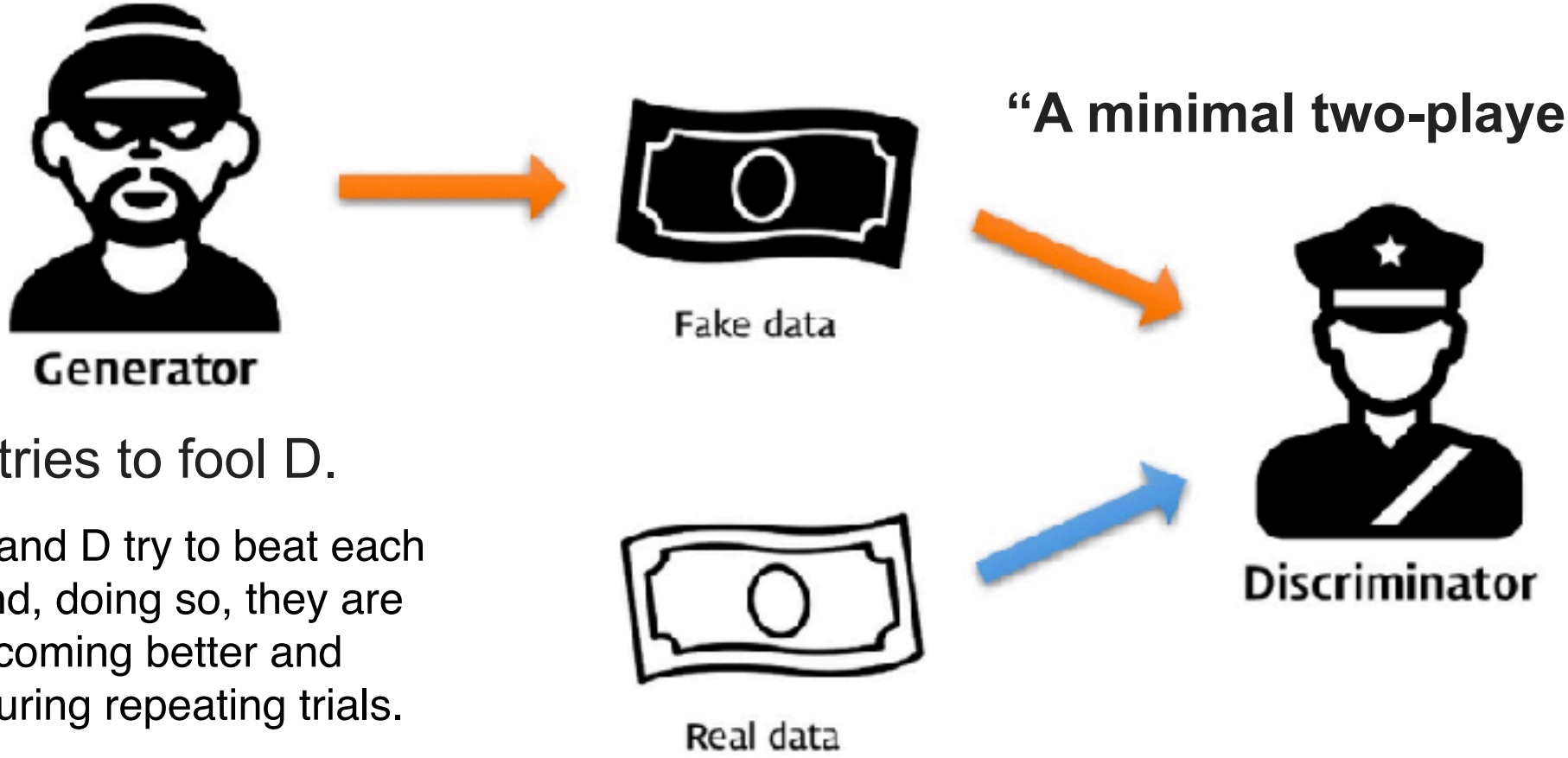
# *Deep Imaging of SDSS by Deep Learning*

Yun-Young Choi (Kyung Hee University)

Youngjun Park, Yong-Jae Moon, Eunsu Park, Beomdu Lim, Taeyoung Kim

# Generative Adversarial Networks

- Goodfellow 2014
- Two neural networks of ‘generator’ and ‘discriminator’ **compete**.



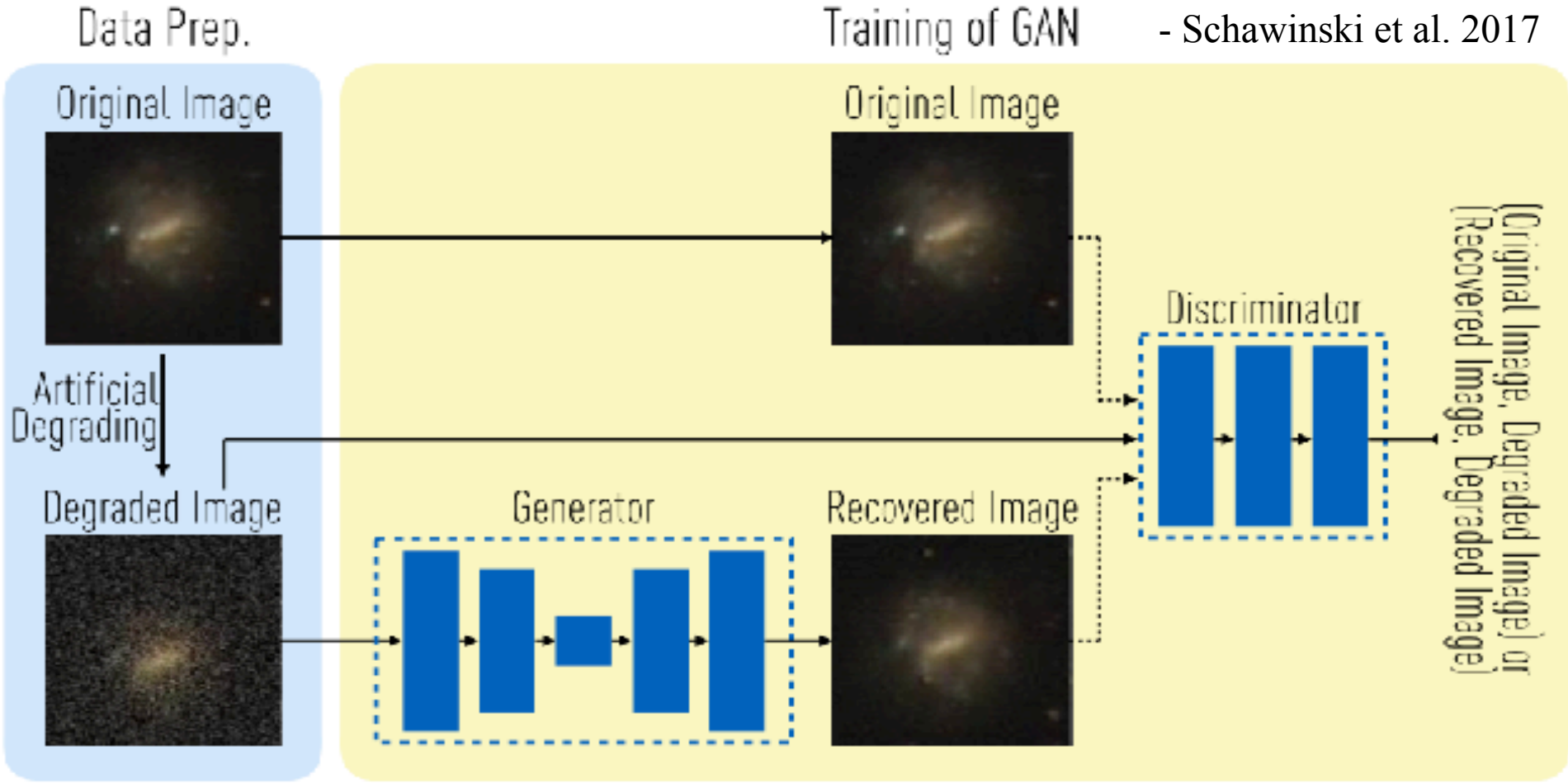

**“A minimal two-players game”**

G tries to fool D.

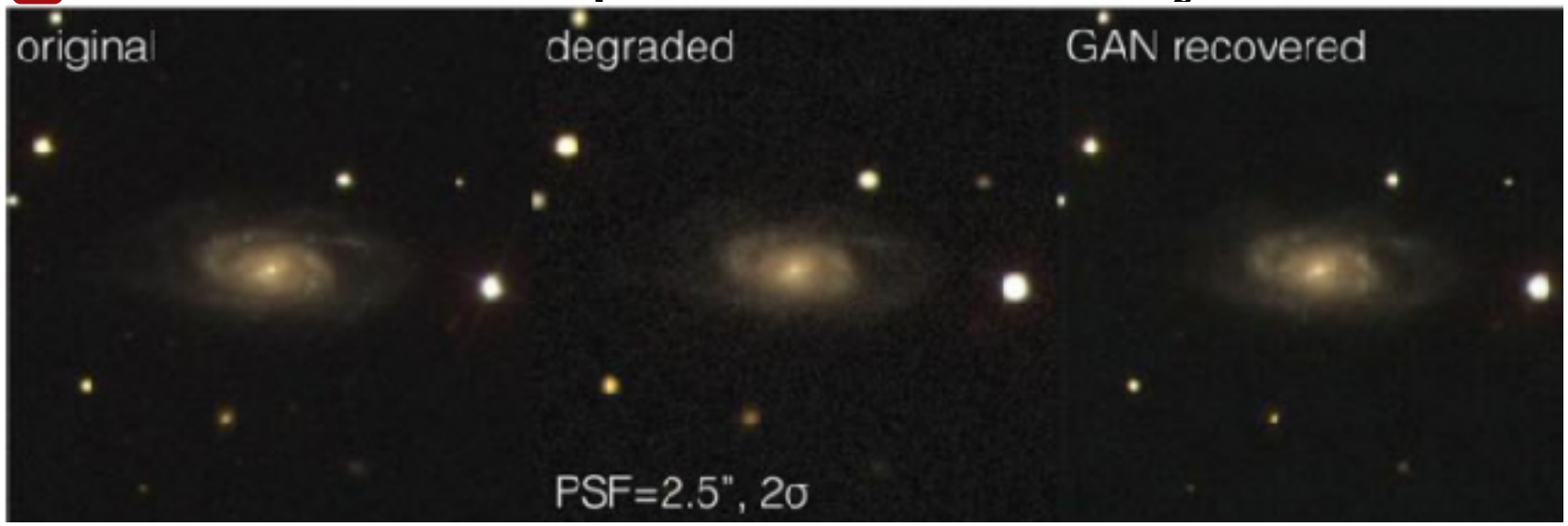
Both G and D try to beat each other and, doing so, they are both becoming better and better during repeating trials.

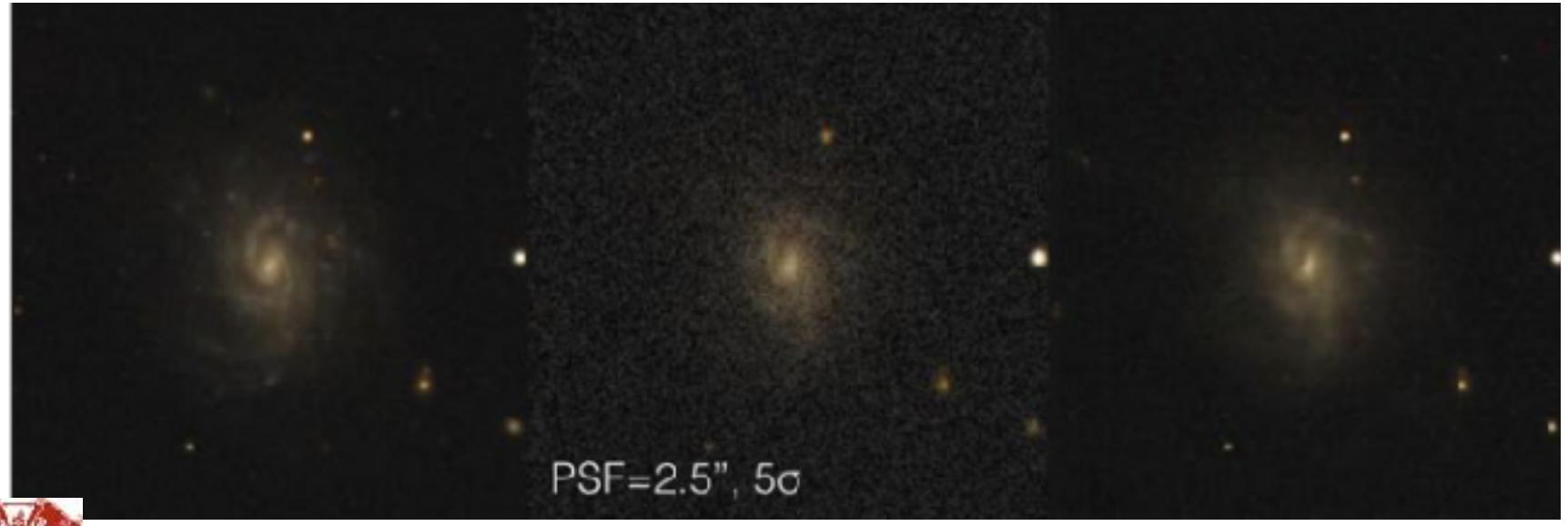
# Several examples in astronomy

A. Restoring galaxy images degraded due to random and systematic noises.



# Several examples in astronomy



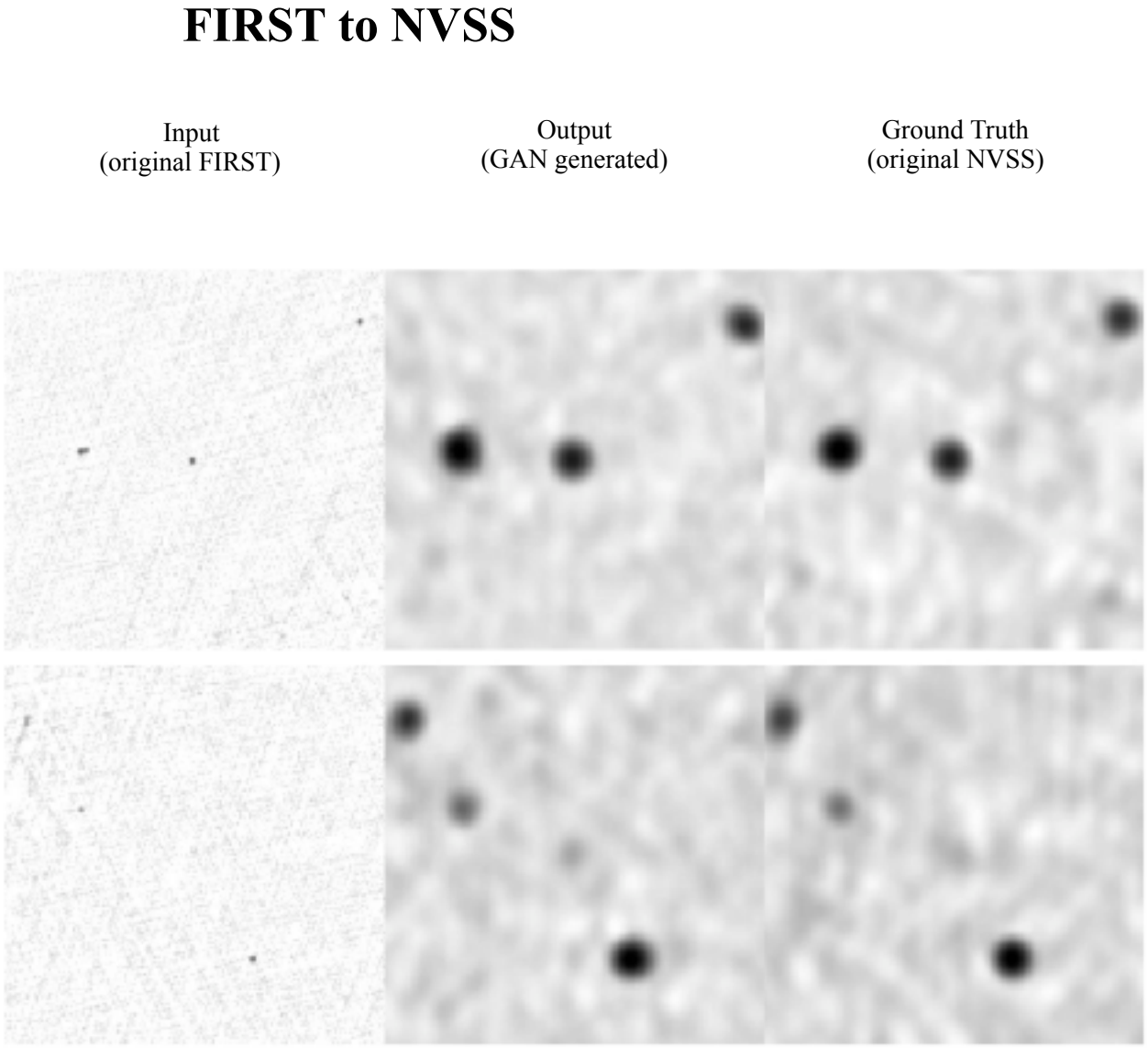

better recover detailed features from low S/N and low angular resolution imaging data

# B. Image-to-image translations between different radio surveys of FIRST and NVSS

- Glaser et al. 2019

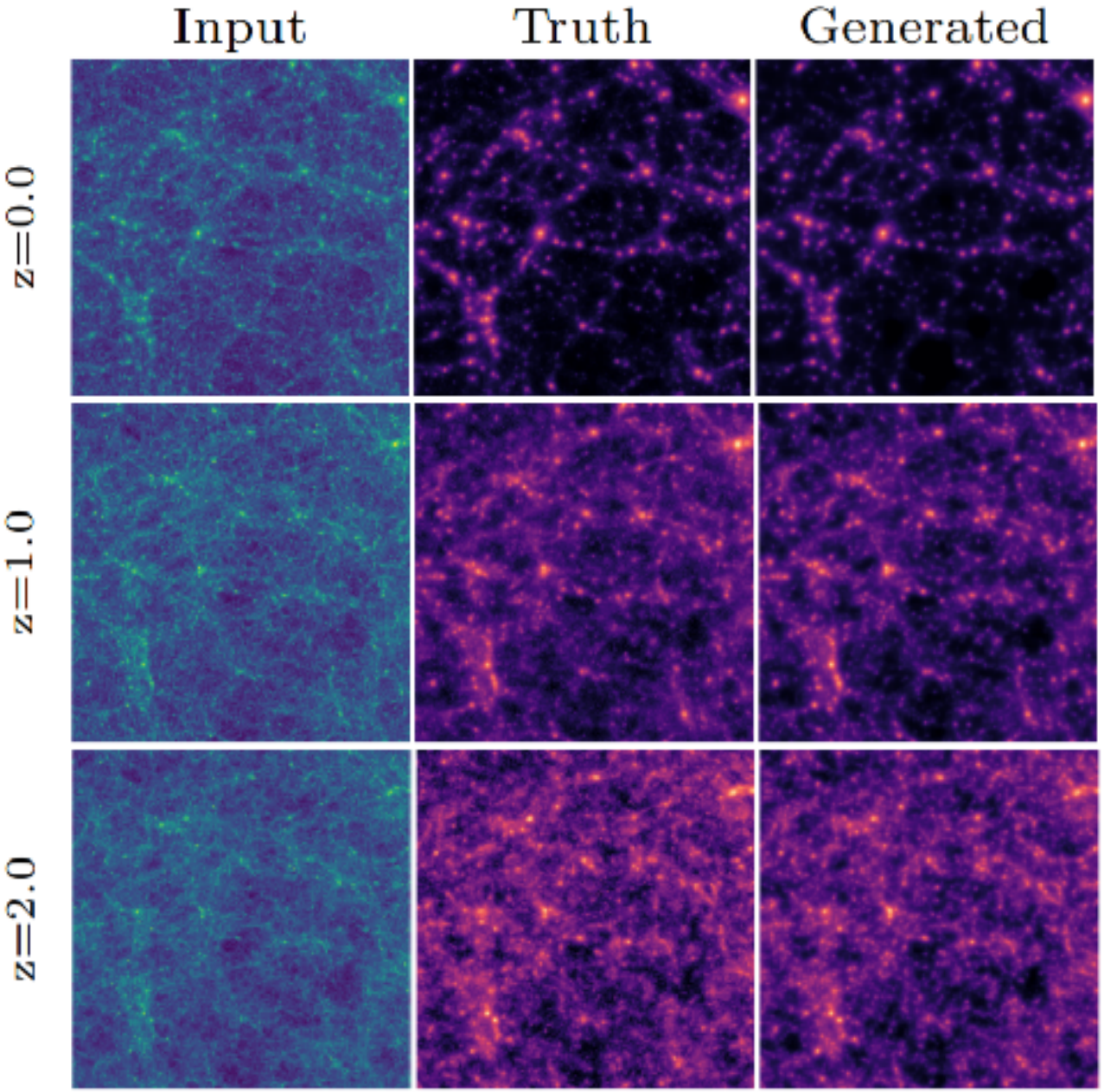
- Faint Images of the Radio Sky at Twenty-Centimeters (FIRST)
  - 20 cm, angular resolution of 5”
- NRAO VLA Sky Survey (NVSS)
  - 21 cm, angular resolution of 45”

- GAN is used to learn complex relations between sources in the two surveys.



# C. Mapping dark matter density to corresponding gas pressure

- Troster et al. 2019

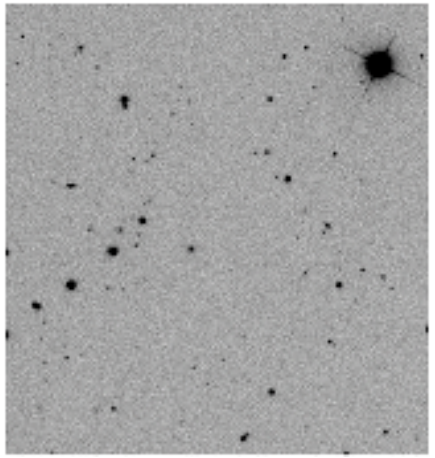


# II. Motivation - De-noise images

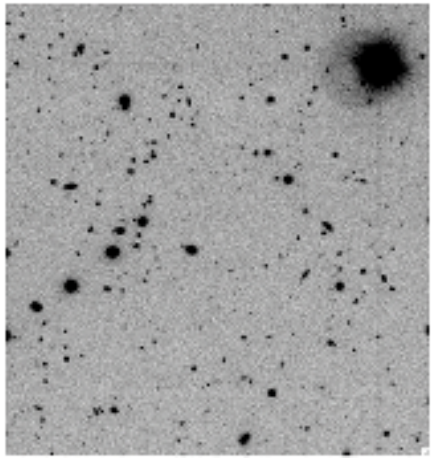
- Noise-induced observation limit hinders the observation of faint celestial objects.

  ✓Stacking multiple images taken repeatedly in a specific area
  - Complicated Point Spread Function
  - Difficult to secure adequate observational time for it

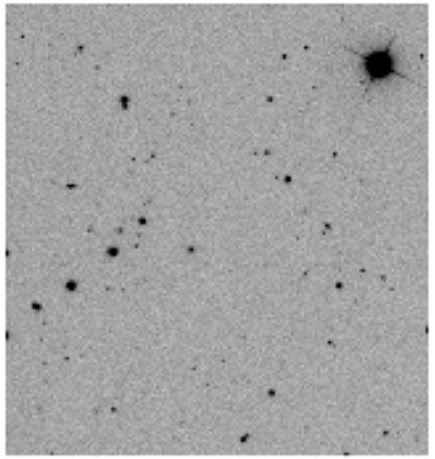
- Deep Survey by ***Deep Learning*** without any additional observation?



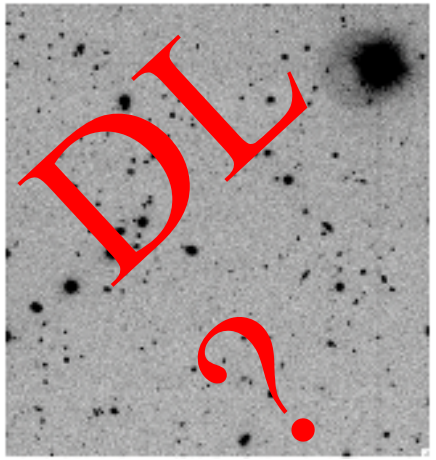
Single-epoch



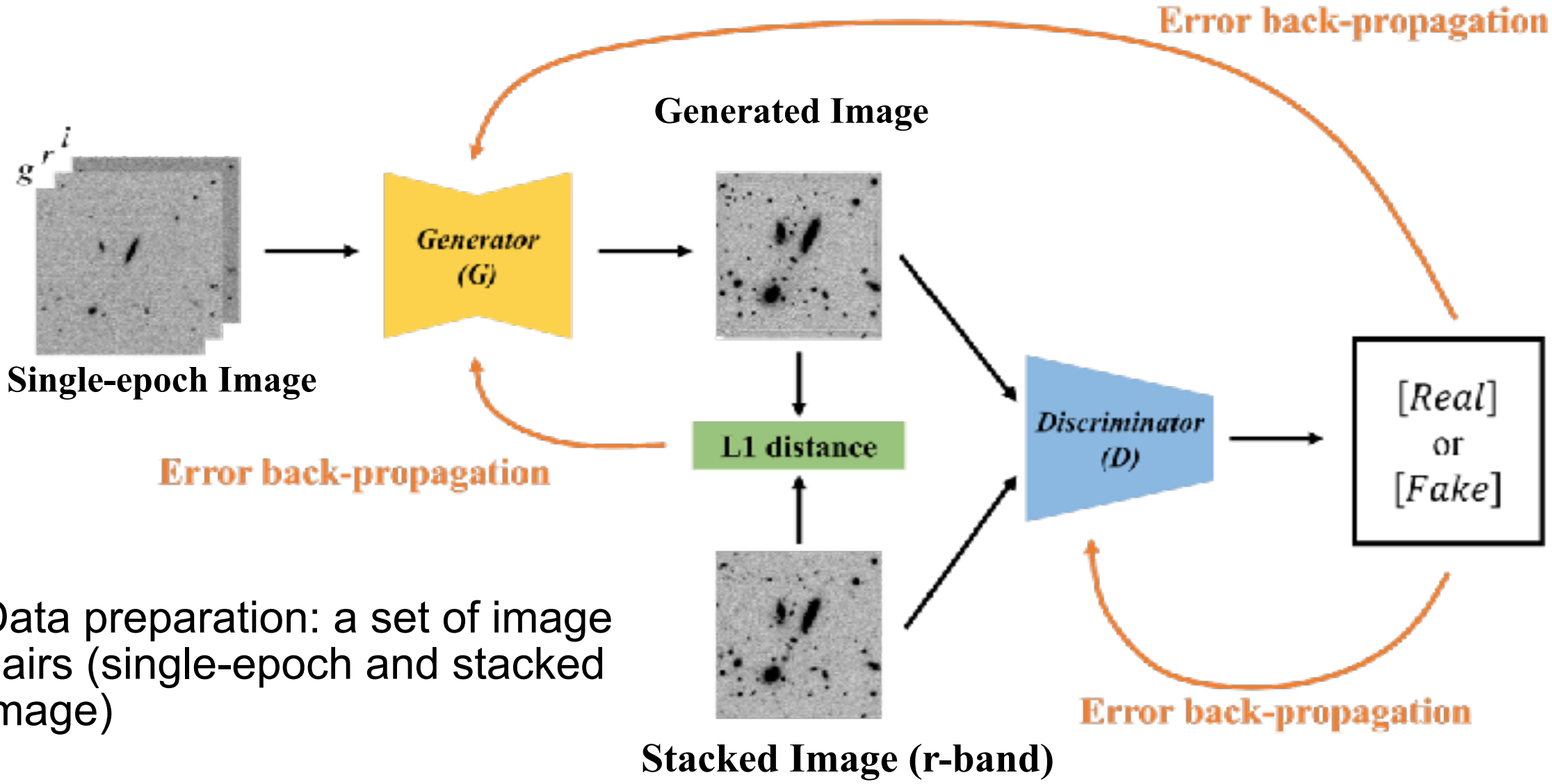
28 repeated scans



Single epoch data

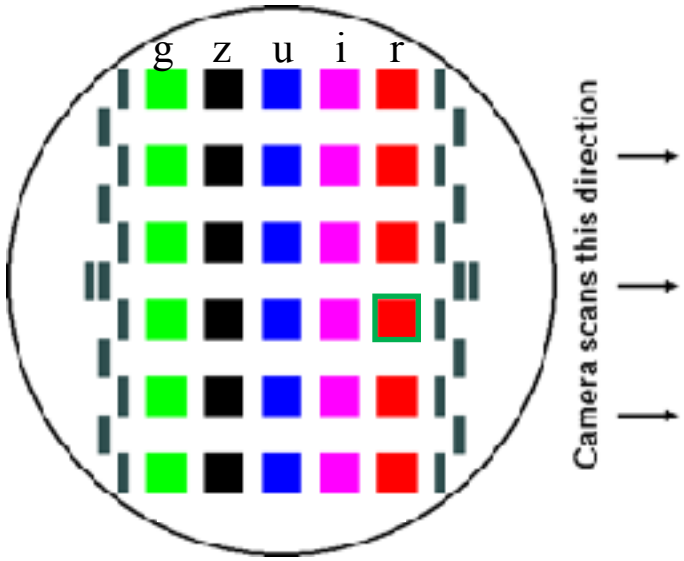


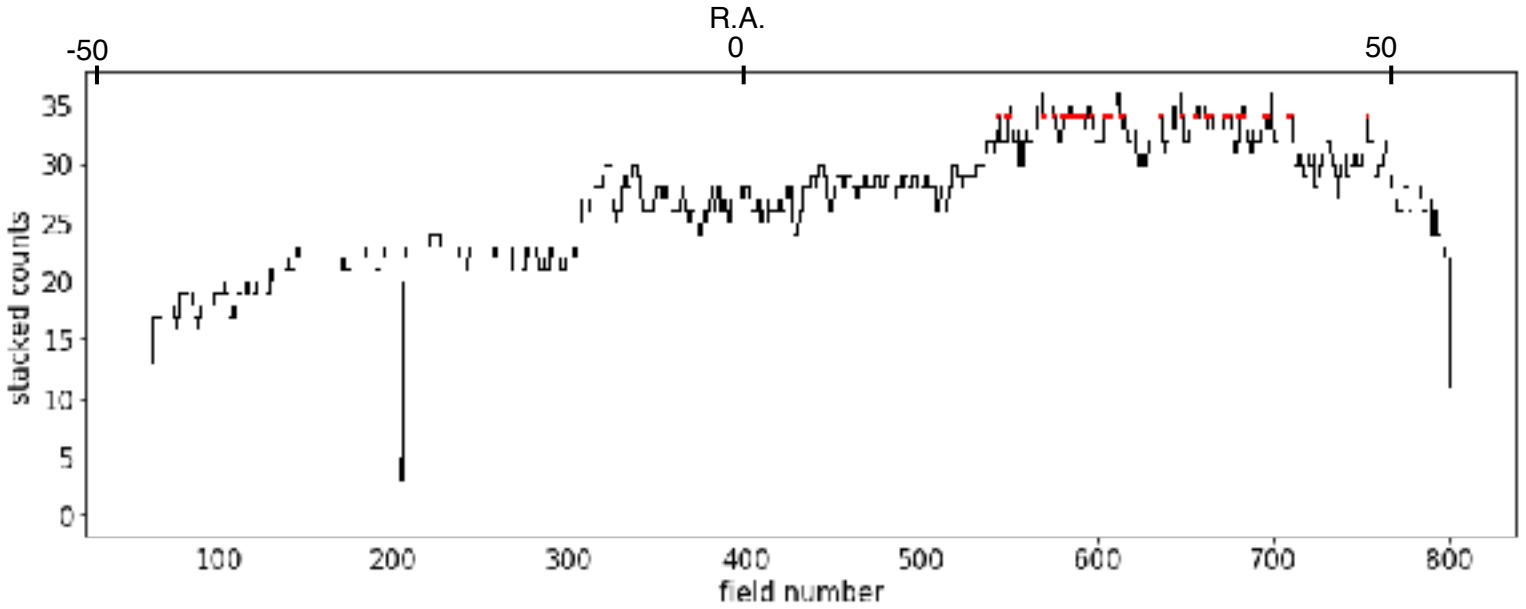
# Generative Adversarial Networks




- Data preparation: a set of image pairs (single-epoch and stacked image)

# III. Data – SDSS stripe 82



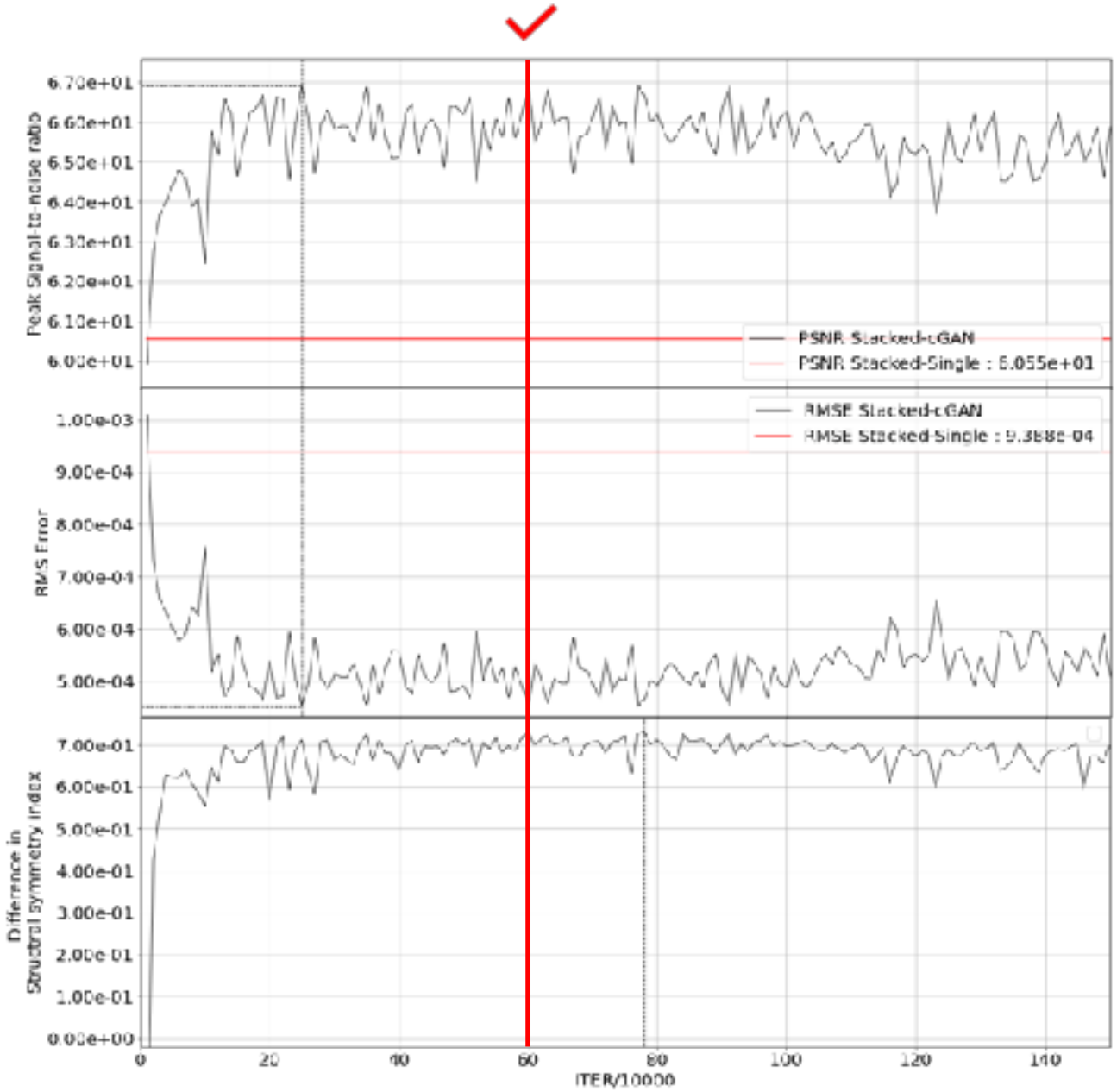

- Selection of 185 Fields with 34 individual scans
- Cut into 256x256 pixel size with 64 pixels overlapping

In total, 14767 of **stacked – single-epoch image pairs**

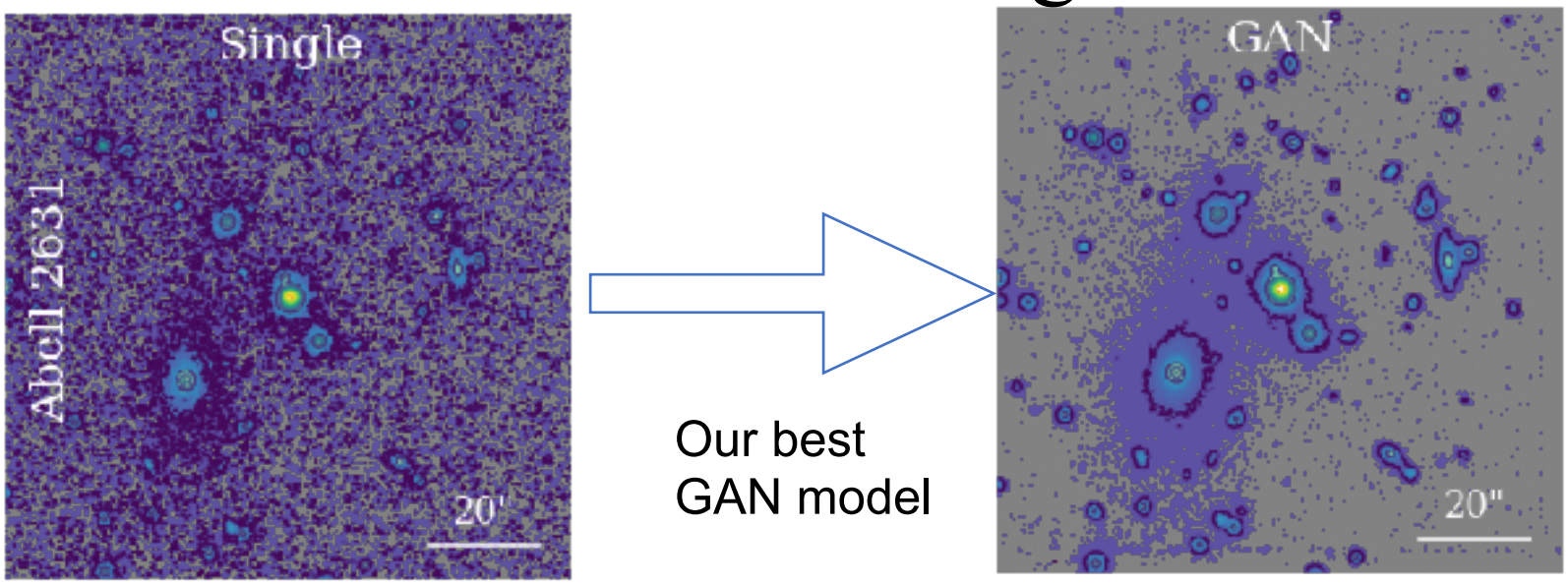
- **11823** for training, **2944** for test

# V. Results
# Training procedure

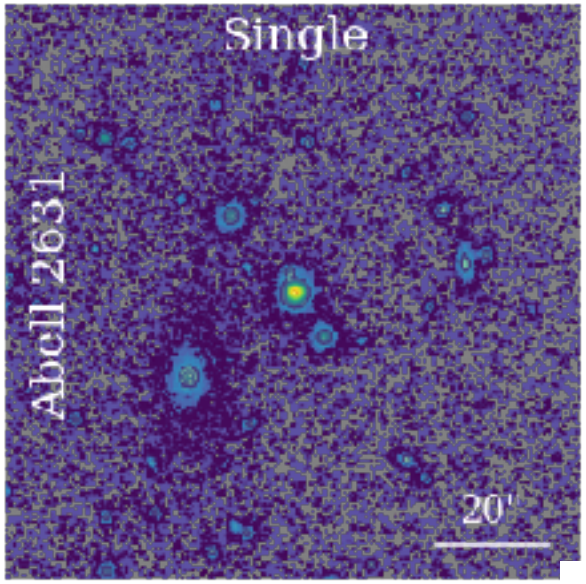
- 1,500,000 iterations.
- The performance were evaluated with RMSE, peak signal-to-noise ratio (PSNR), structural similarity (SSIM)
  - The **600,000th model** is selected as a best model.

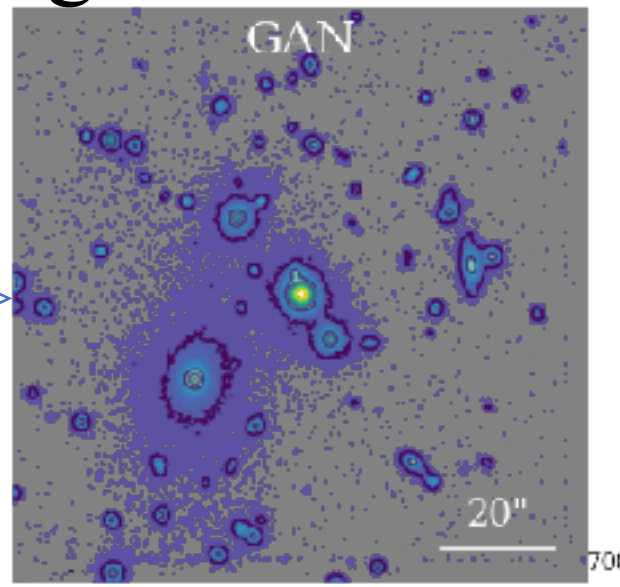


# A. Extended inter-cluster light in Abell 2631

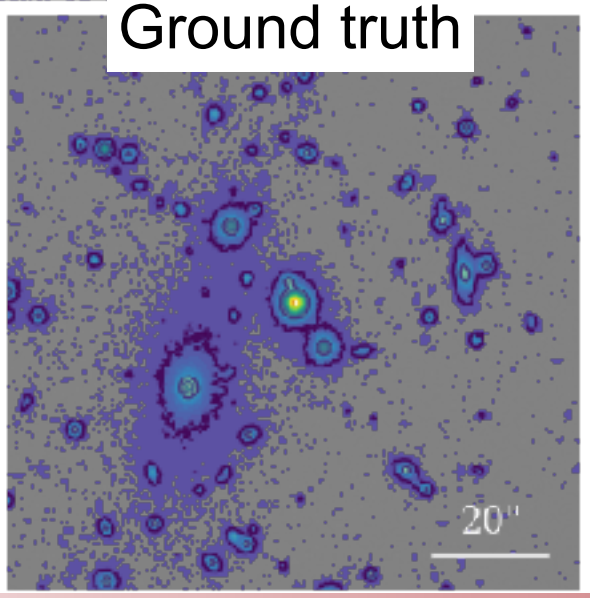


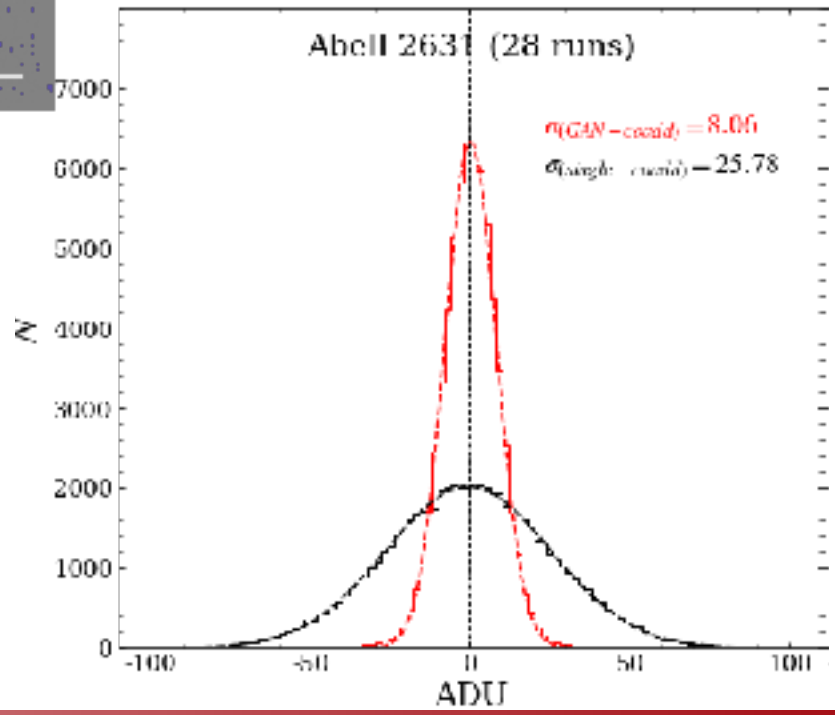
# A. Extended inter-cluster light in Abell 2631



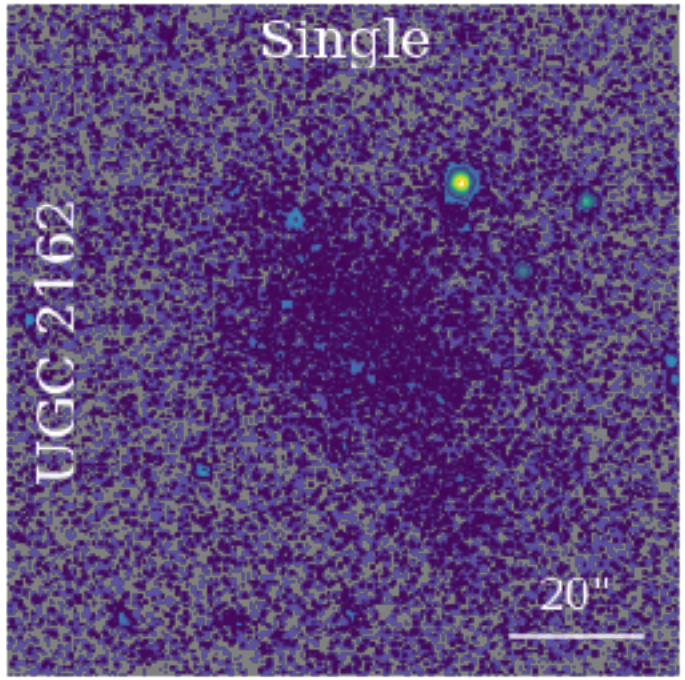



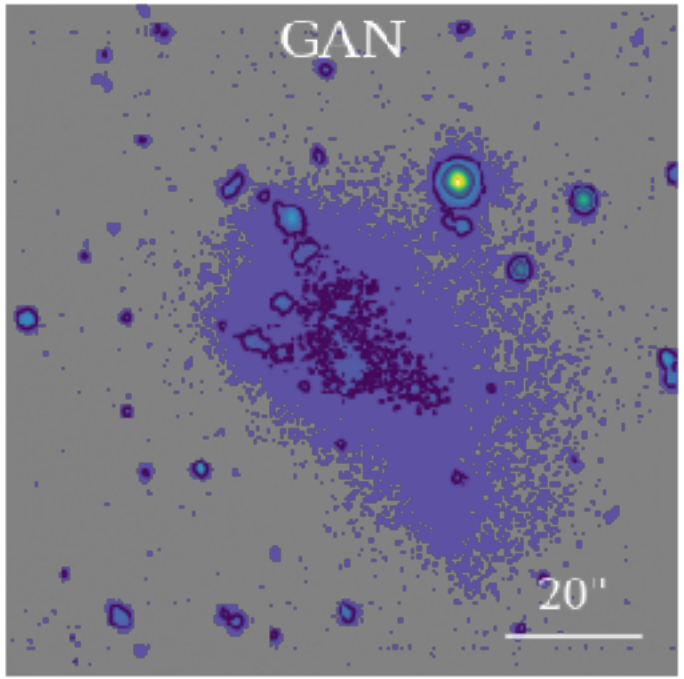

Ground truth



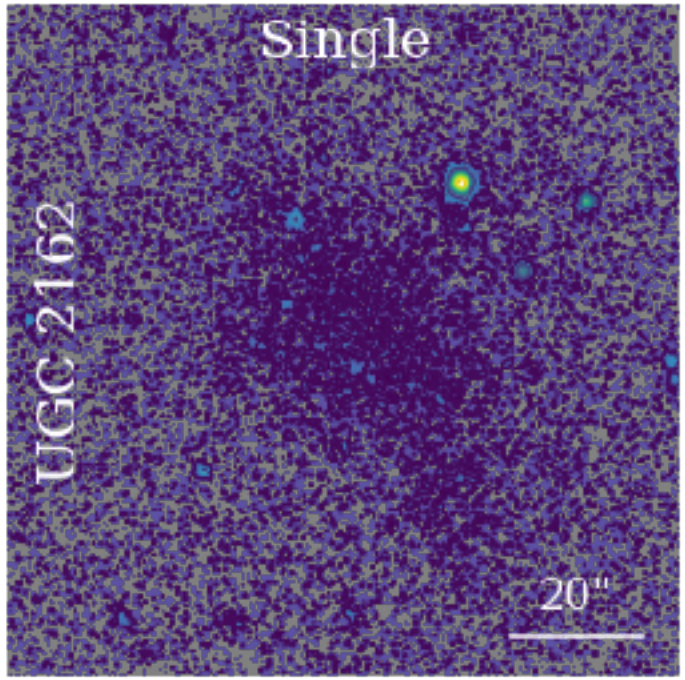



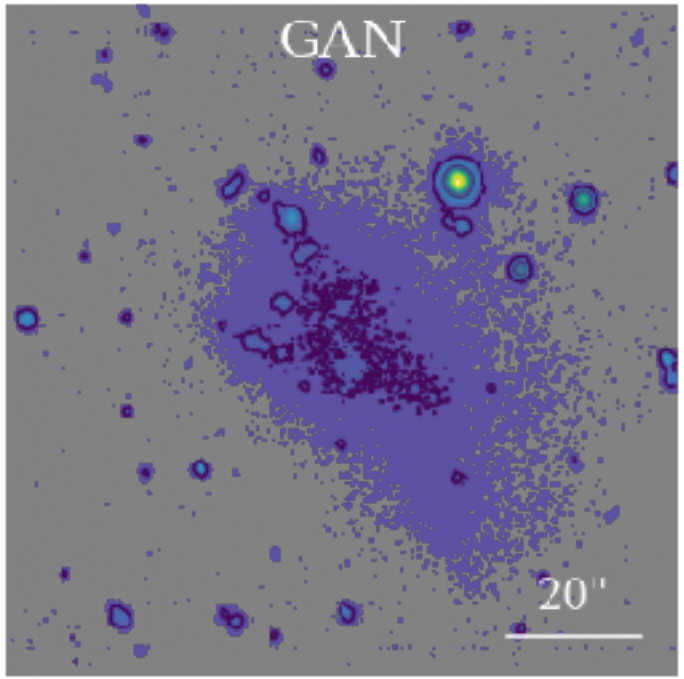
# B. Ultra diffuse galaxy

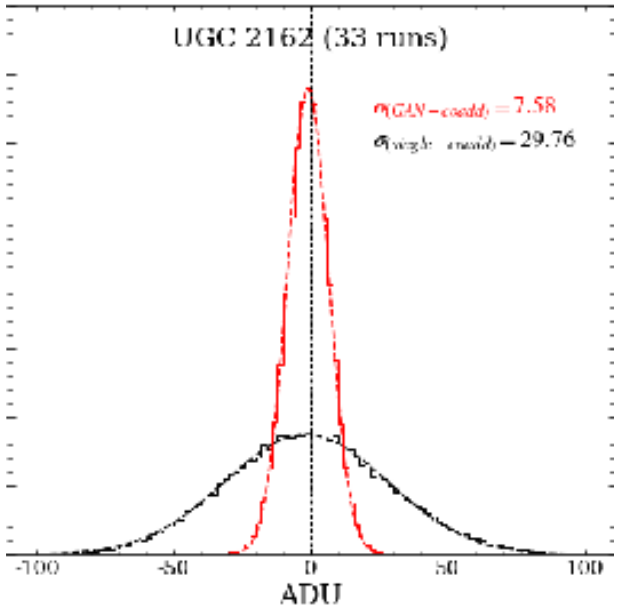


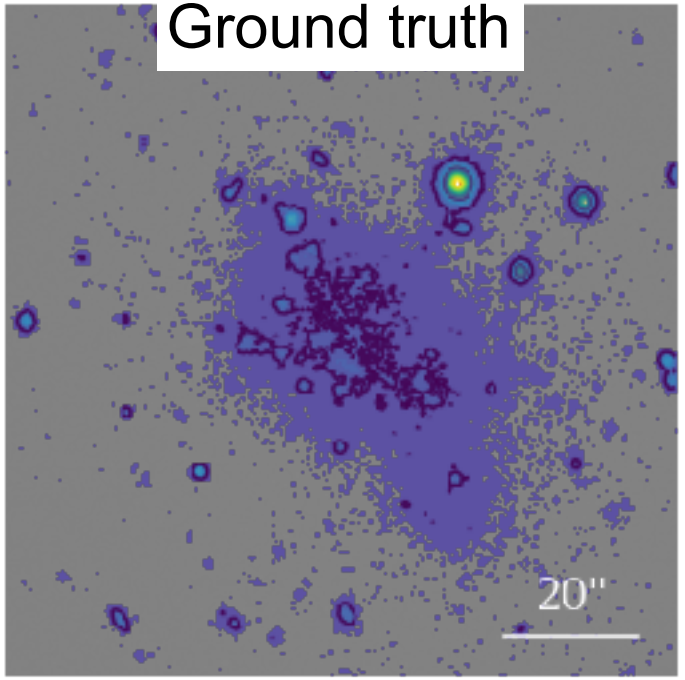



# B. Ultra diffuse galaxy

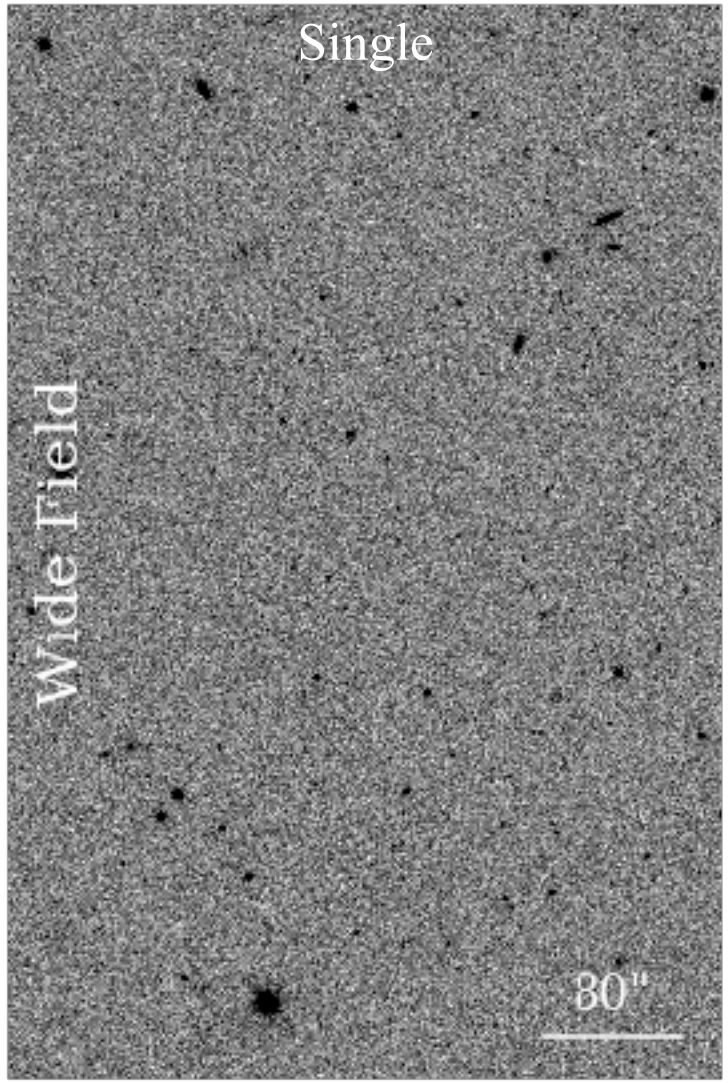


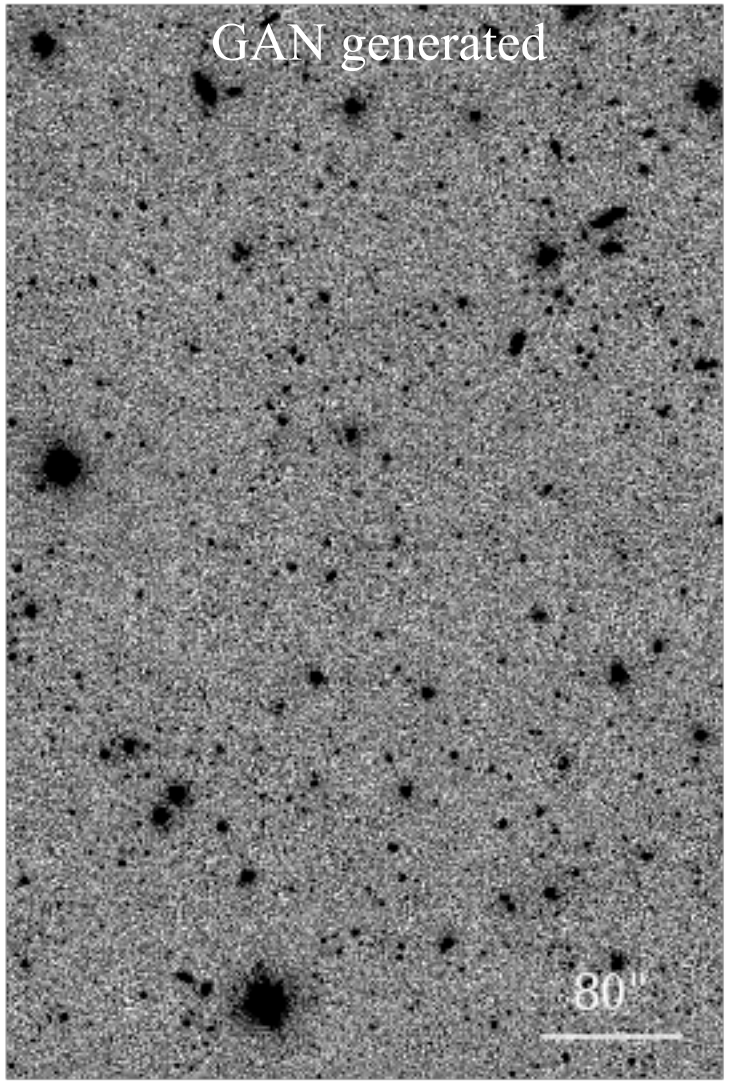



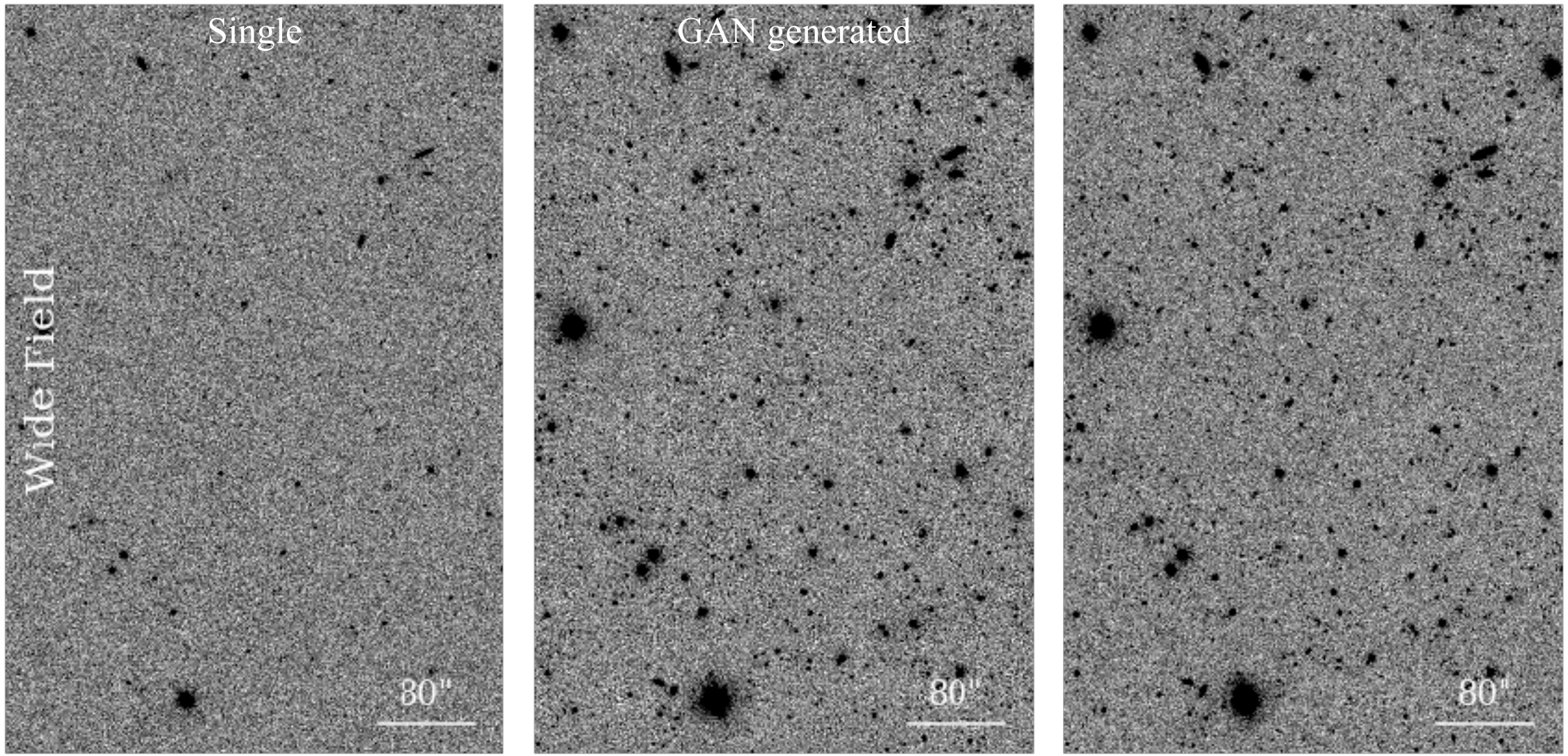



# C. field image

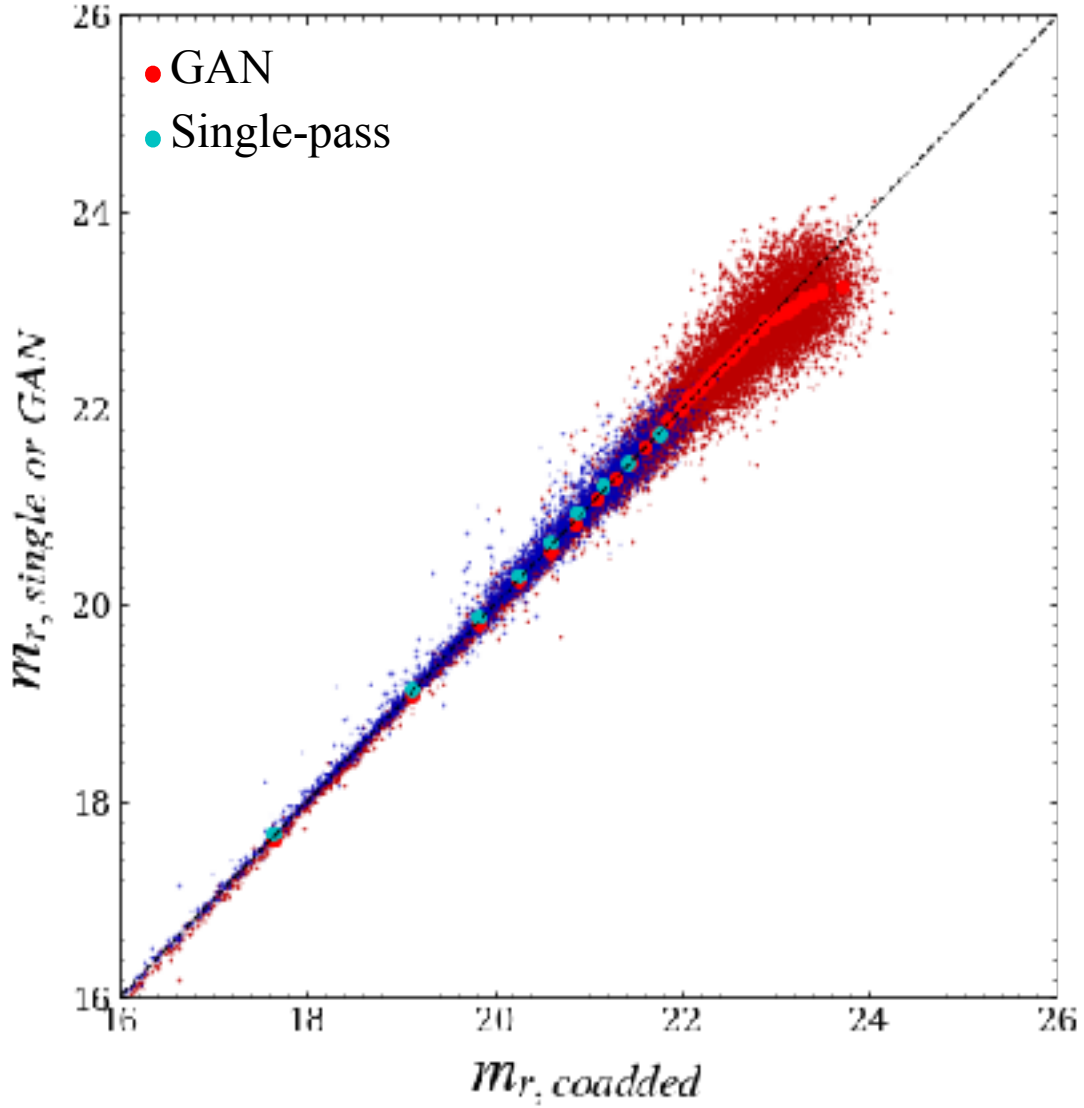


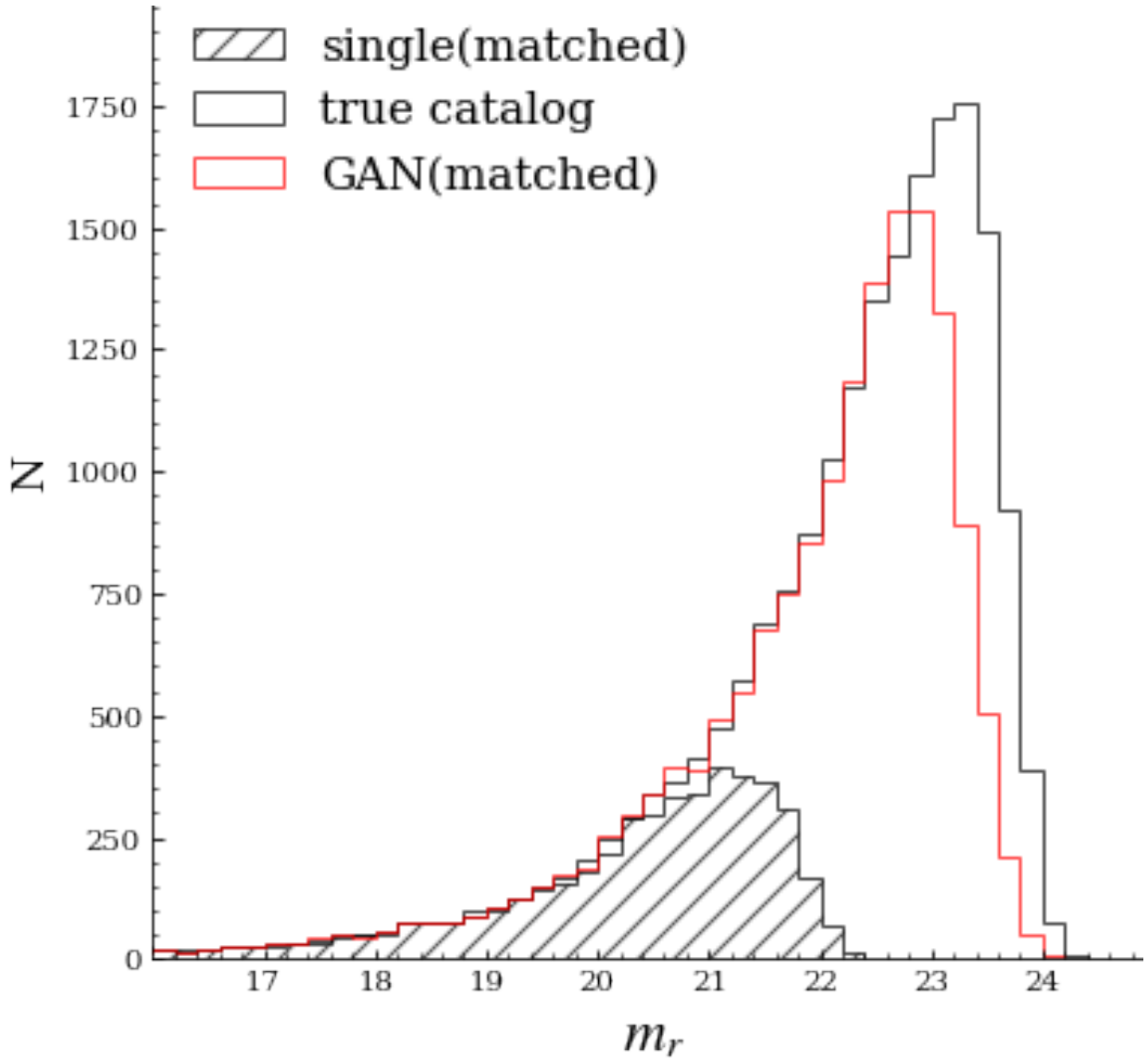



# C. field image



# Photometry (SExtractor) - Magnitude comparison



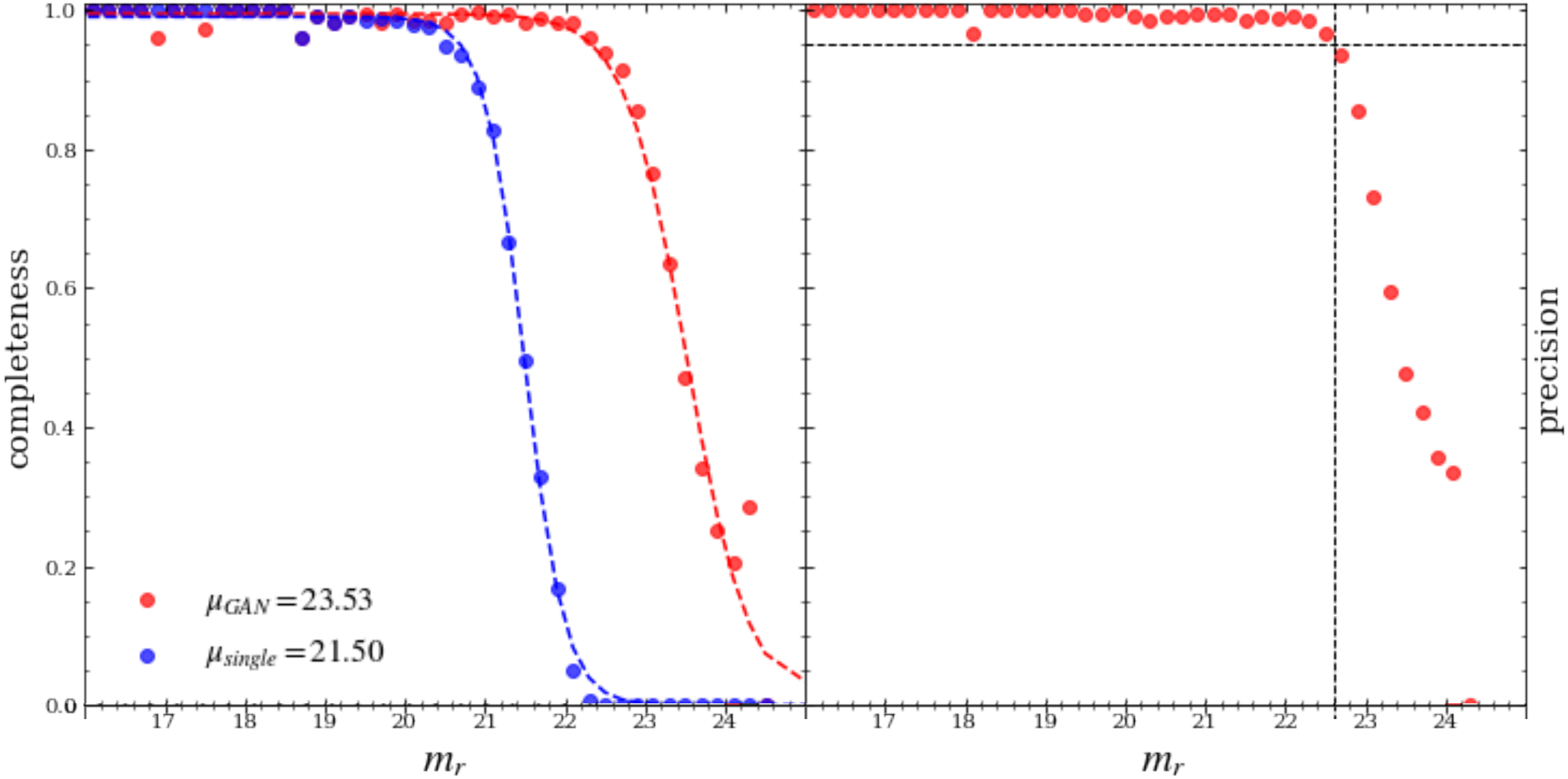



# Reliability Test

$$completeness = \frac{N_i(m)}{N_{true}(m)}$$

$$precision = \frac{N_i(m)}{N_i(m) + N_{false}(m)}$$

- i: # of sources detected in both GAN (or single-pass data) and stacked images
- true: # of true sources detected in stacked image
- false: # of sources detected in GAN, not the true sources.

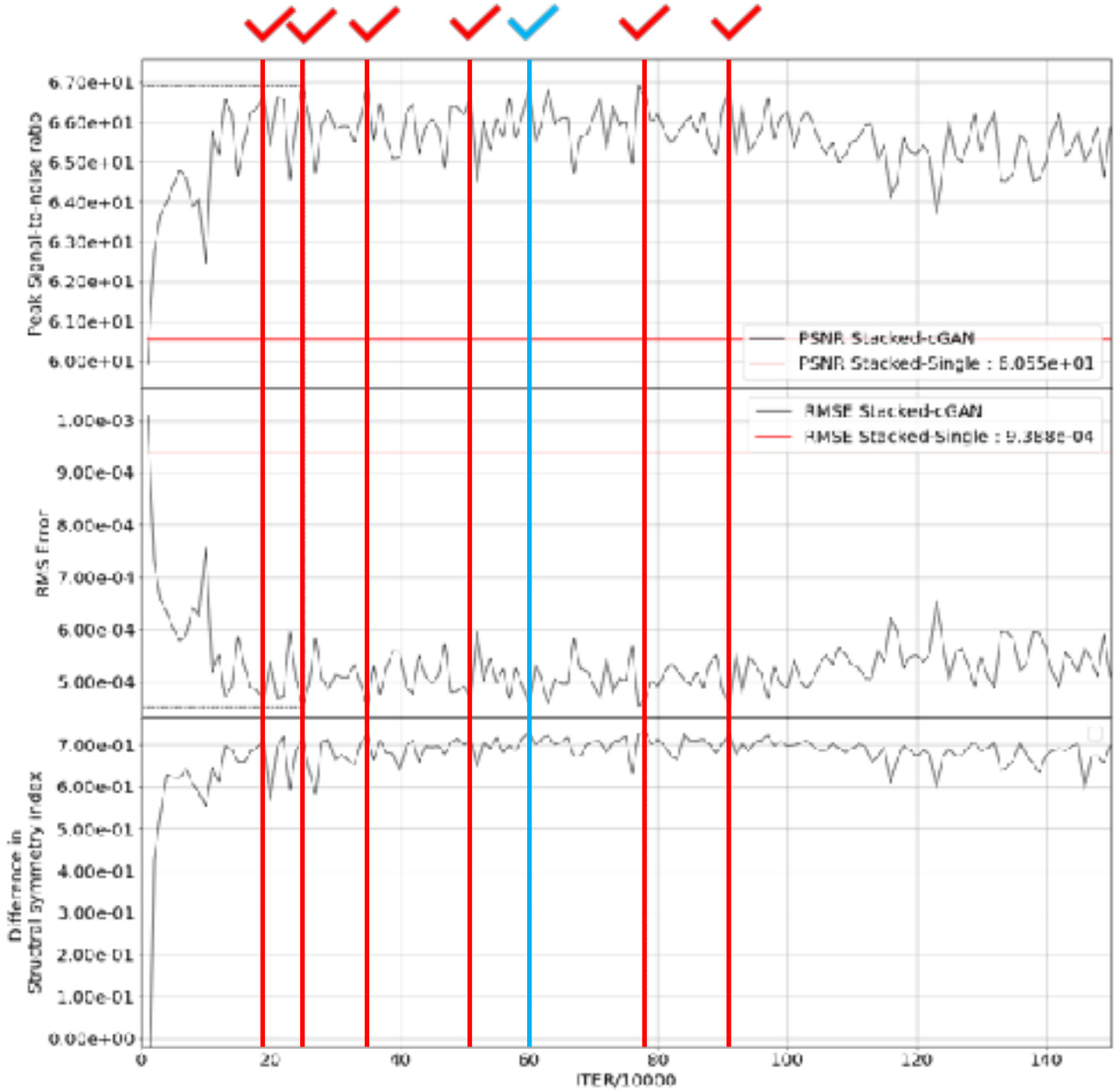

completeness
precision
$m_r$
$m_r$
$\mu_{GAN}=23.53$
$\mu_{single}=21.50$
1.0
0.8
0.6
0.4
0.2
0.0
17
18
19
20
21
22
23
24

# VI. Summary

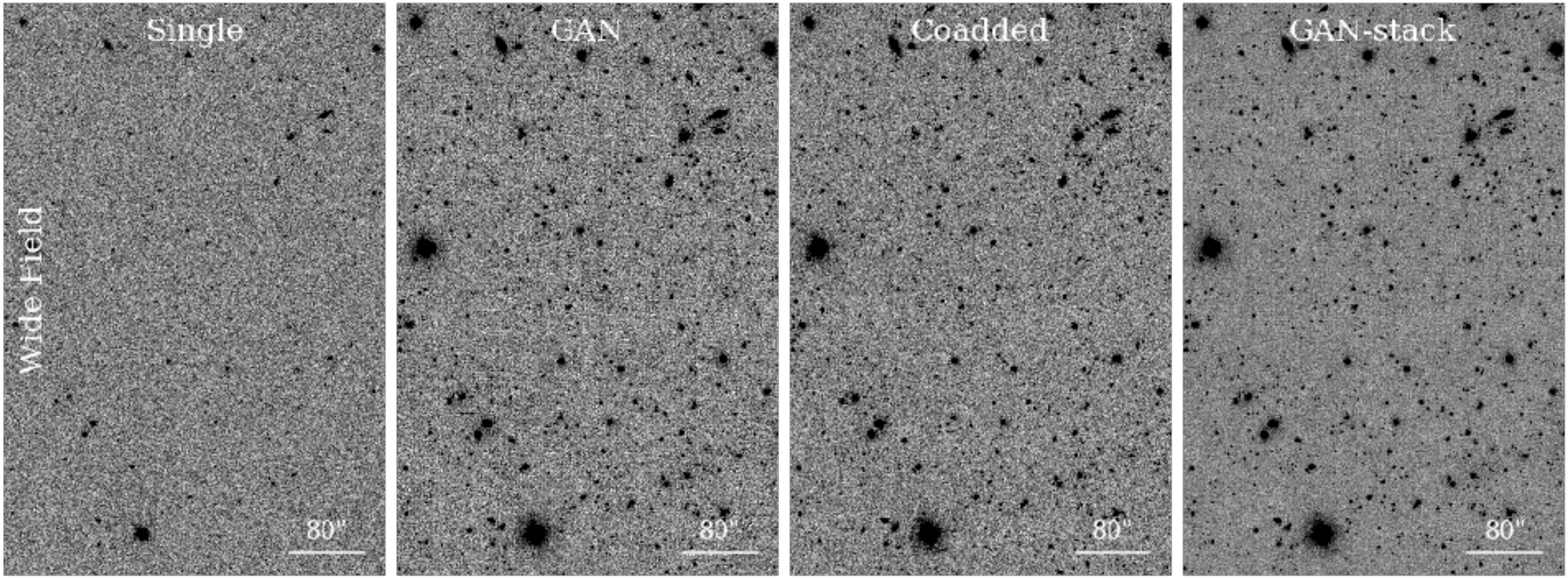
- Successful de-noising of astronomical image with high reliability
  - GAN generates image with higher S/N from real data with less information
- Deep survey of SDSS using deep learning improves the completeness in r-band magnitude by **at least, 1.5 magnitude**

# VII.New Idea?
# GAN-stack

- Formerly, we used only one training outcome that was considered best.
- But even if results from other iteration are not the best, they are not particularly bad.
- Then what if we stack several iterations with good image quality like image stacking?



# VII.New Idea?
# Comparison of field images



# VII.New Idea?
# Residual histogram

