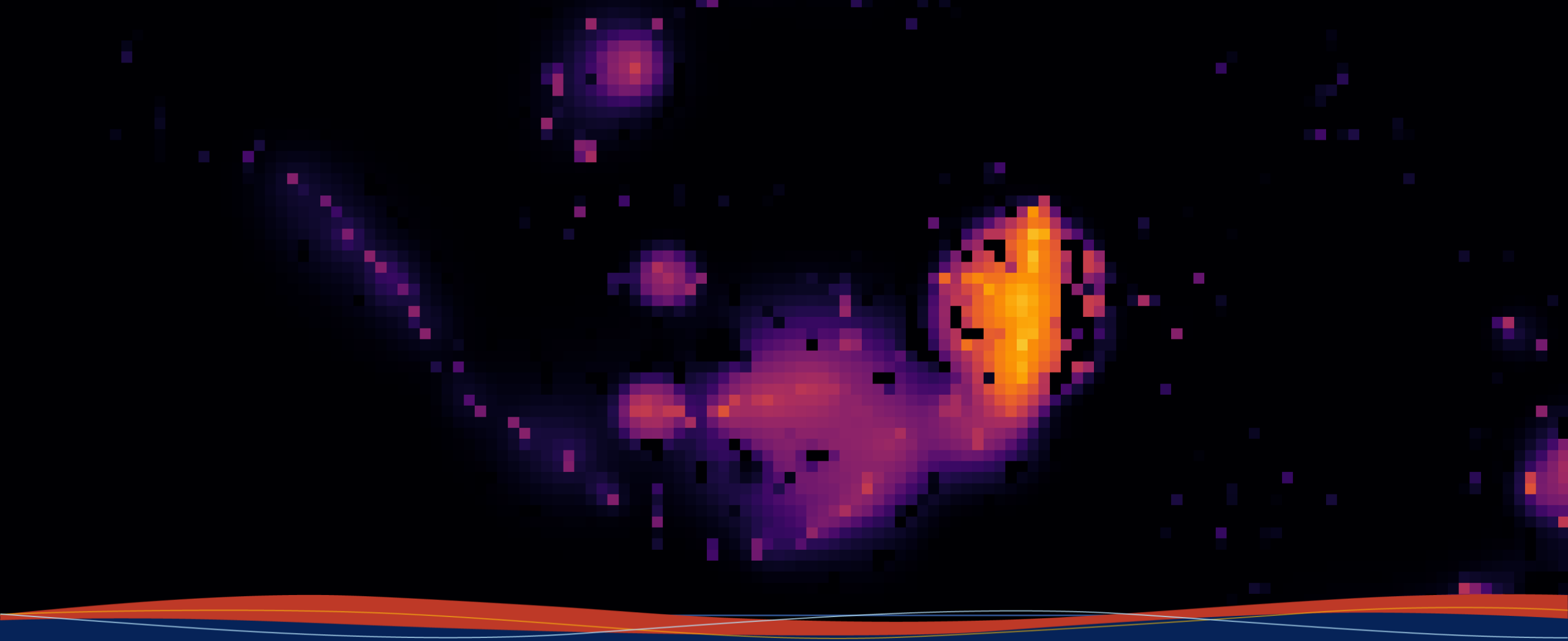


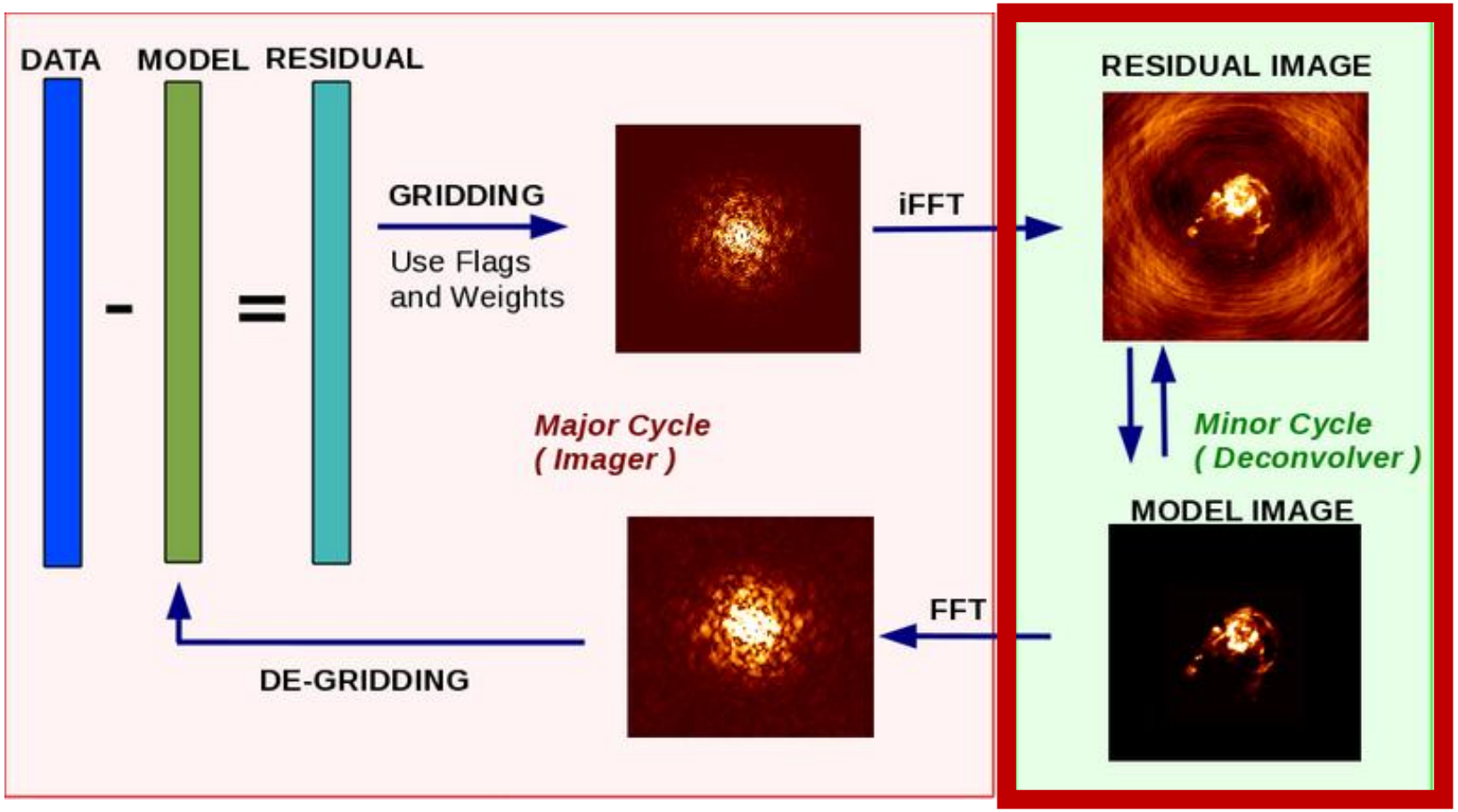
Machine Learns to CLEAN

Keenan Fiedler - 06 August 2025

National Radio Astronomy Observatory

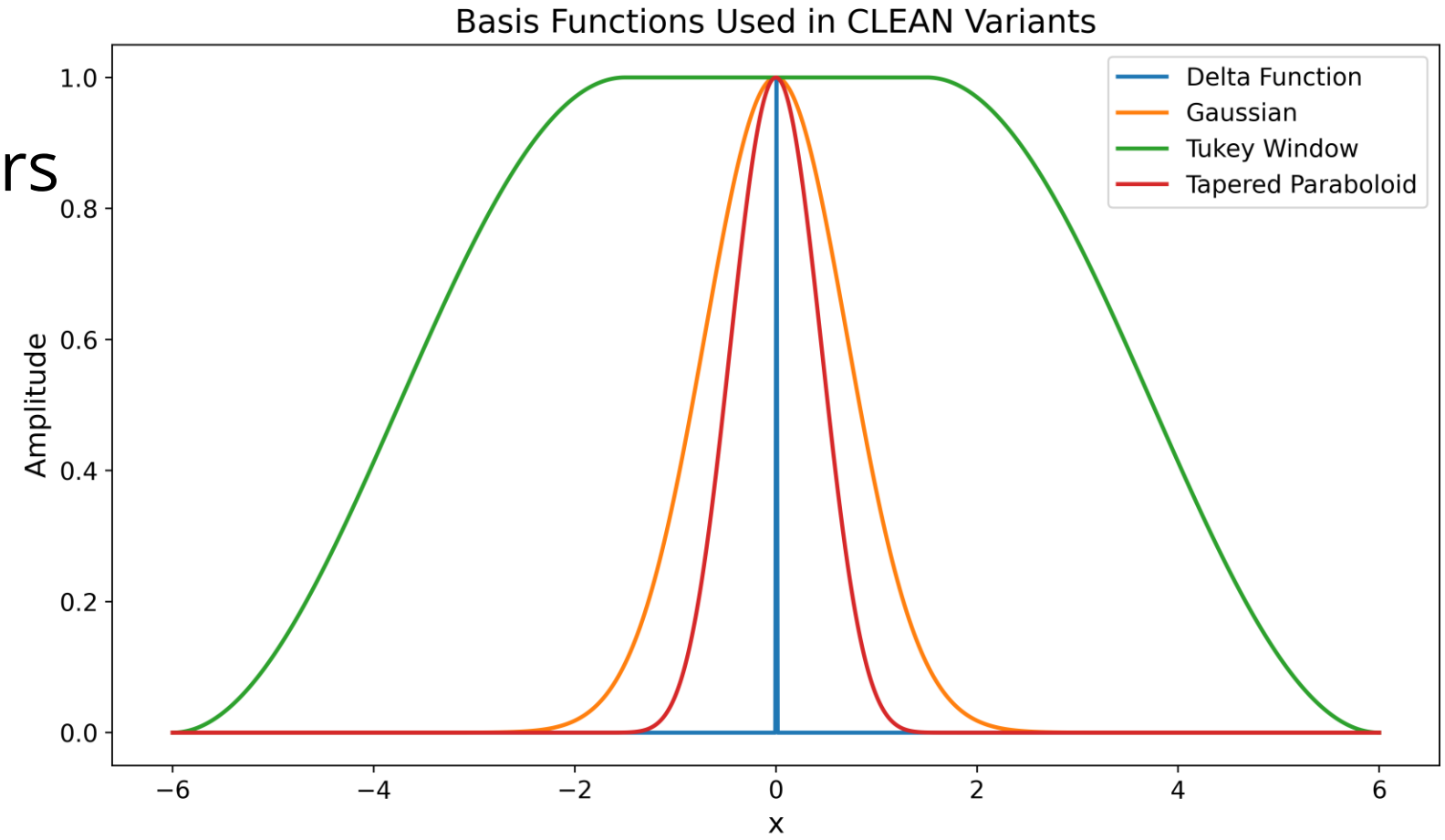
Deconvolution with CLEAN

Image Credit: The CASA Team et al.



Basis Functions of Deconvolvers

- Different bases for different deconvolvers
- More flexible basis compounds computation cost
- Also increased accuracy

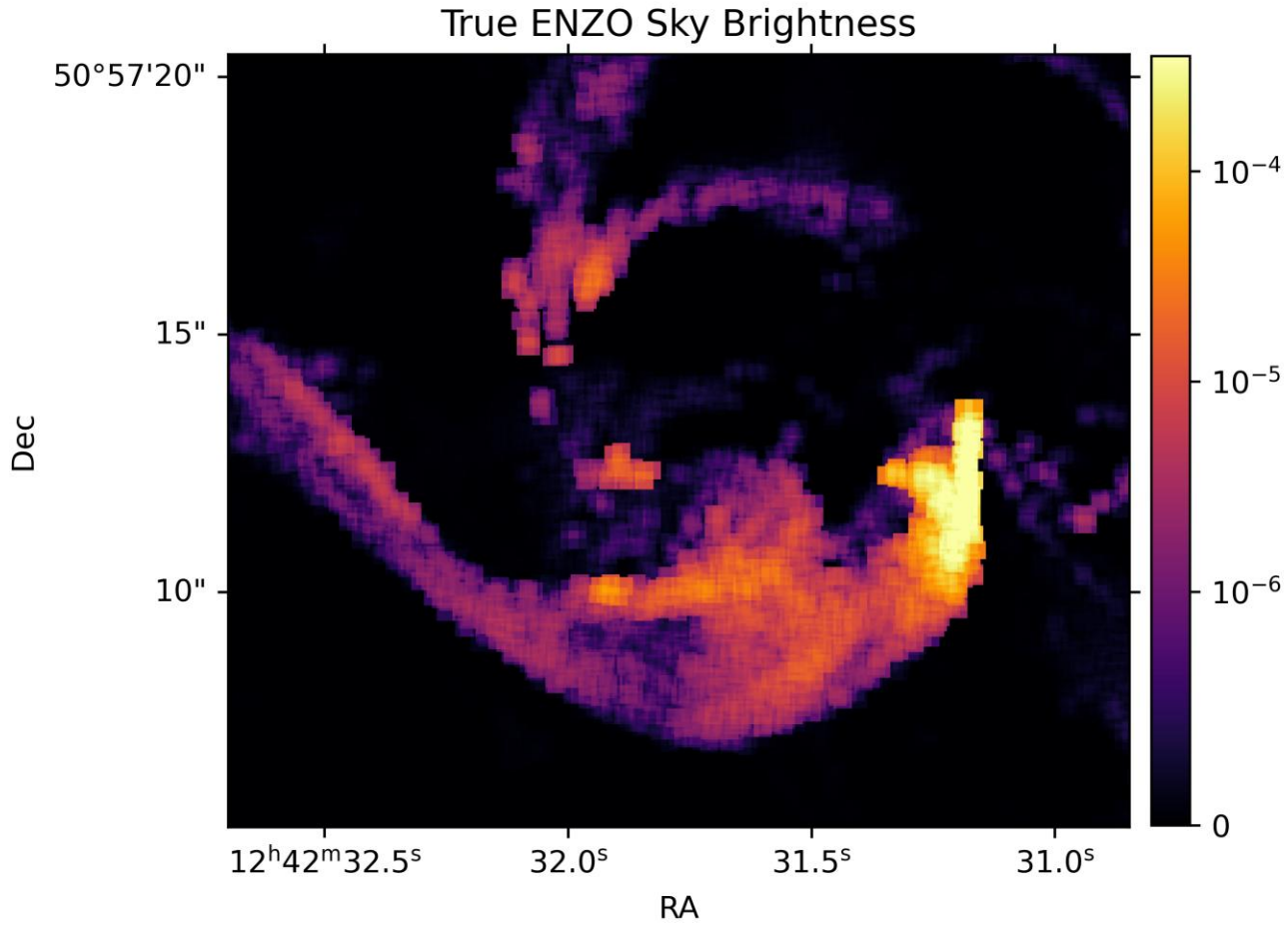


Goals

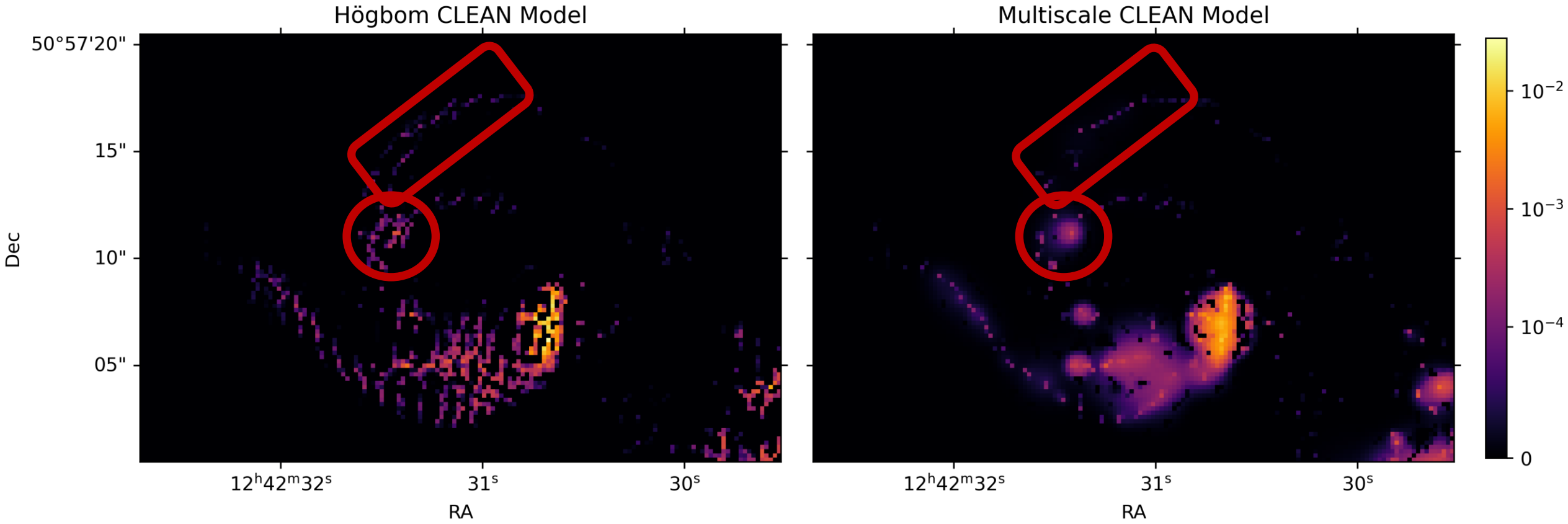
- Create a neural network that can
  - Mimic accuracy effects of MS CLEAN from Högbom CLEAN
  - Reduce computational cost of MS CLEAN accuracy
  - Generalize to more than the data it is trained on
- Insert model into CLEAN algorithm
  - Run Högbom until threshold
  - Run neural network and generate new multiscale-like model image
  - Run Högbom again to deal with effects of neural network

Data from ENZO Simulations

- Gheller and Vazza (2022) generated a series of true sky radio sources using the ENZO simulation suite
- Generated measurement sets using simobserve
- CLEANed the measurement sets with both Högbom and Multiscale CLEAN

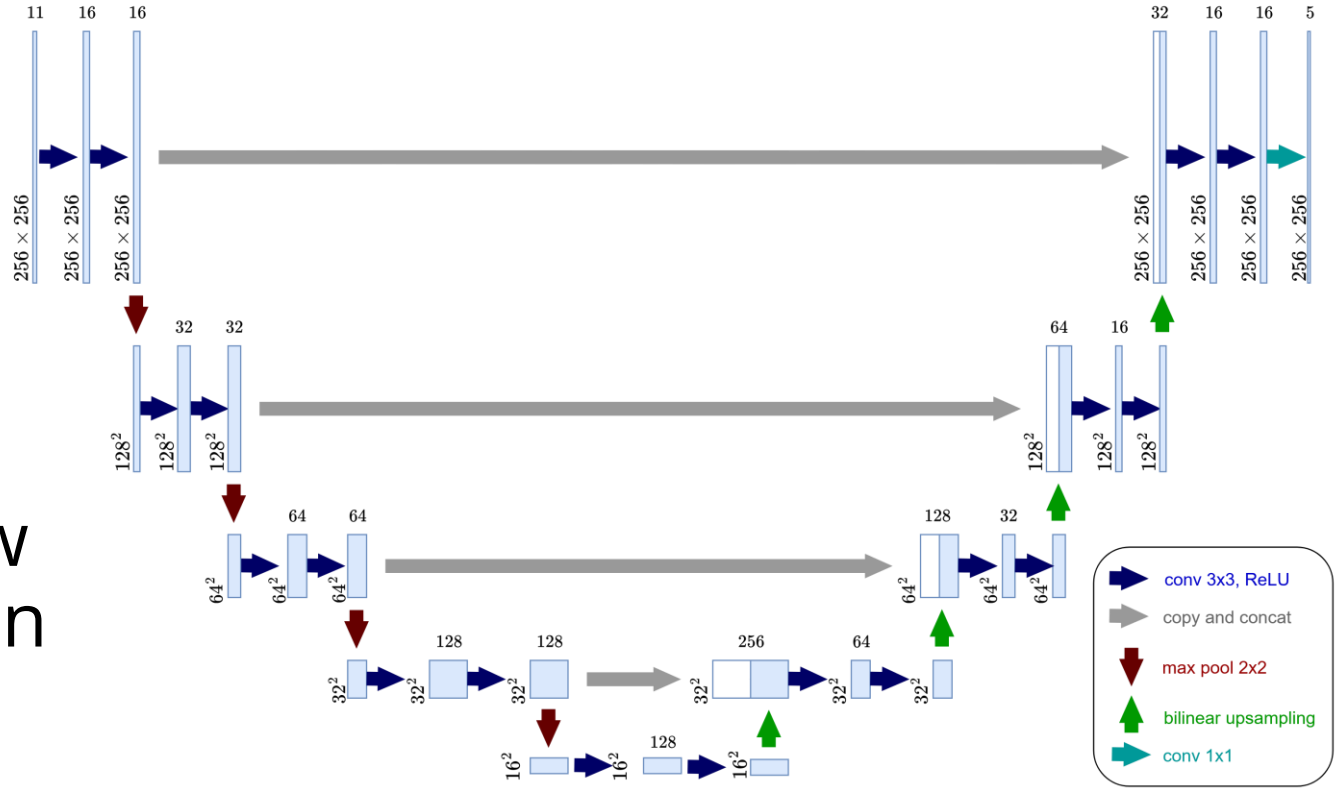


Final Training Data



Network Architecture Basis - UNet

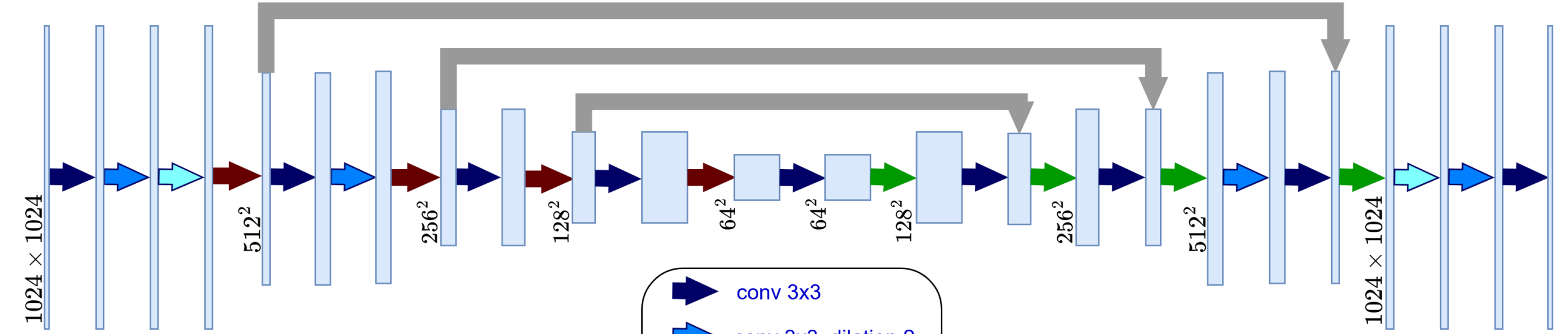
- Typical image processing tasks use convolutional networks
- Allows network to learn spatial context
- Skip connections (gray) allow fine scale structure to remain

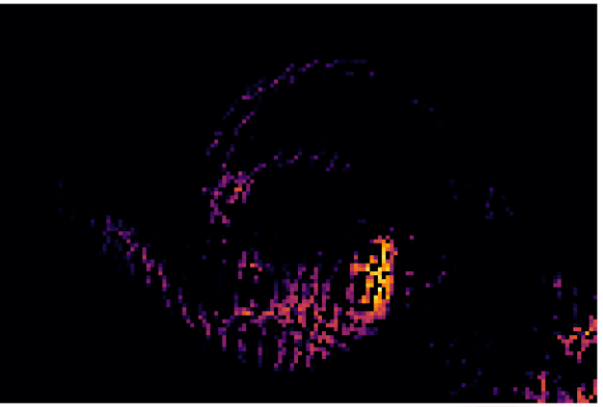


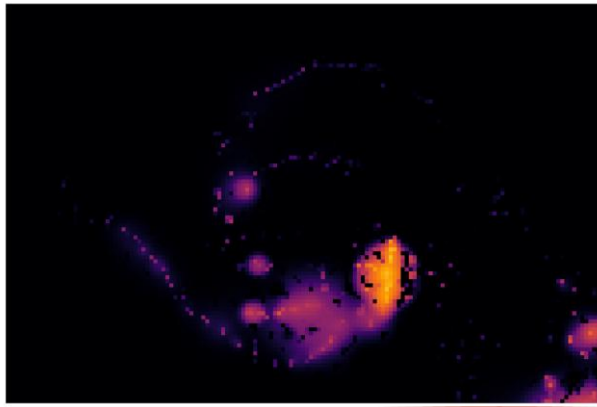
Investigations into Improvements

- Attempts to improve over the basics
  - Additive vs. Concatenative Skip Layers
  - Fully connected bridge
  - Number of Convolutional Layers
  - Differing normalizations of data and network layers
- Hyperparameter Tuning
  - Learning Rate, Optimizer, Bridge Construction

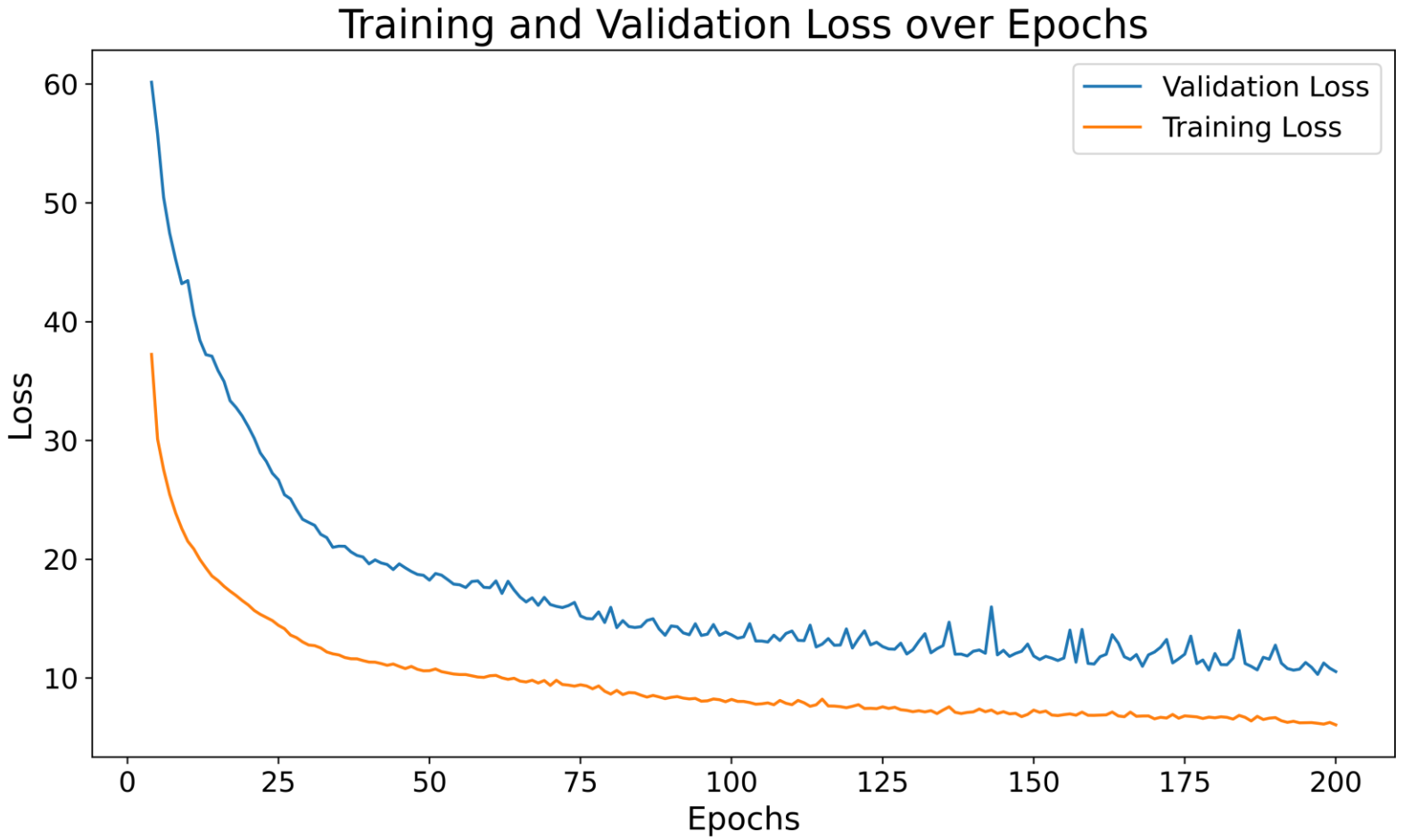
Final Network Layout



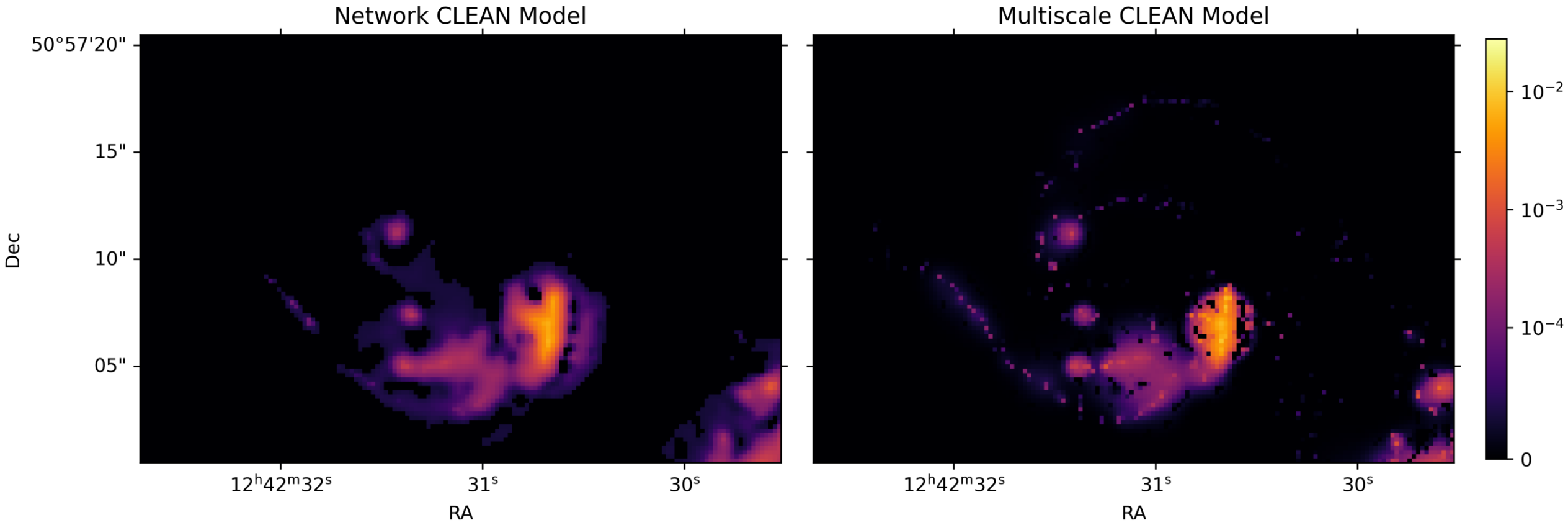




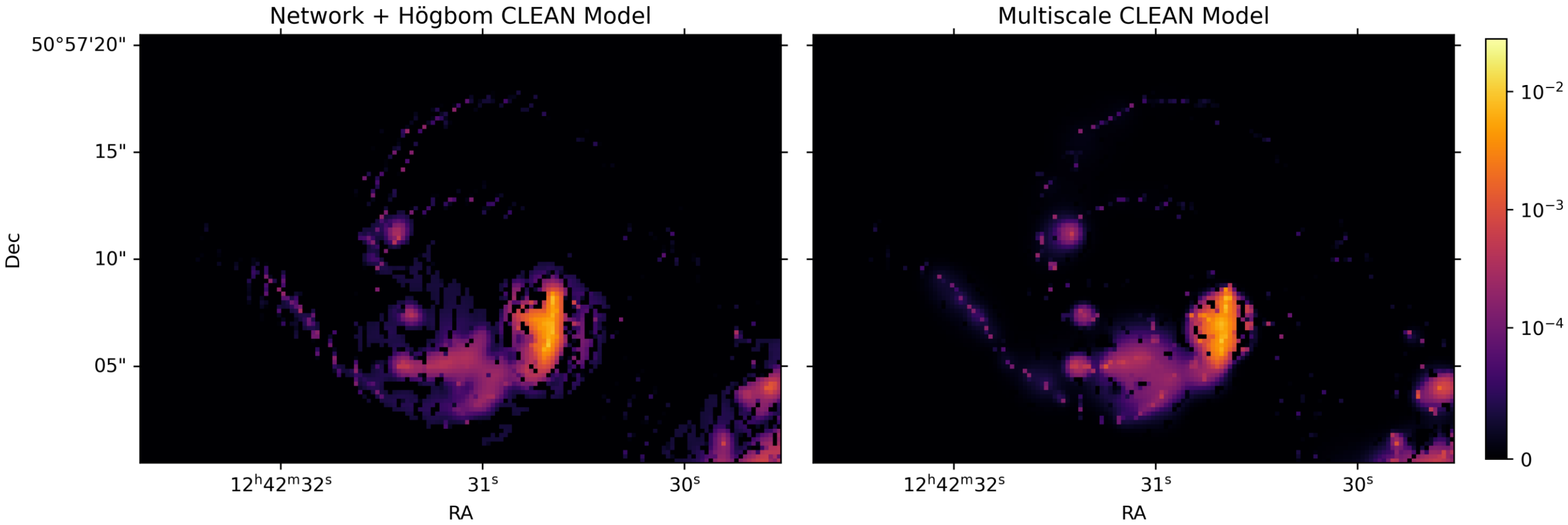
Training and Validation Loss



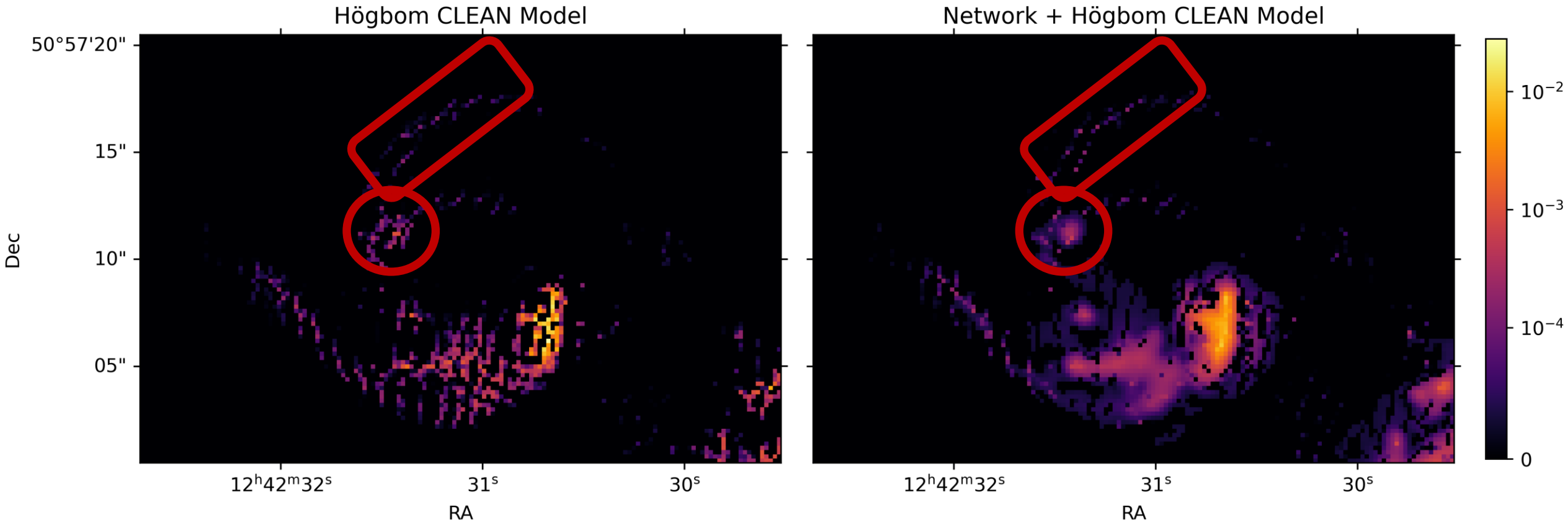
The Original Network Output is lacking

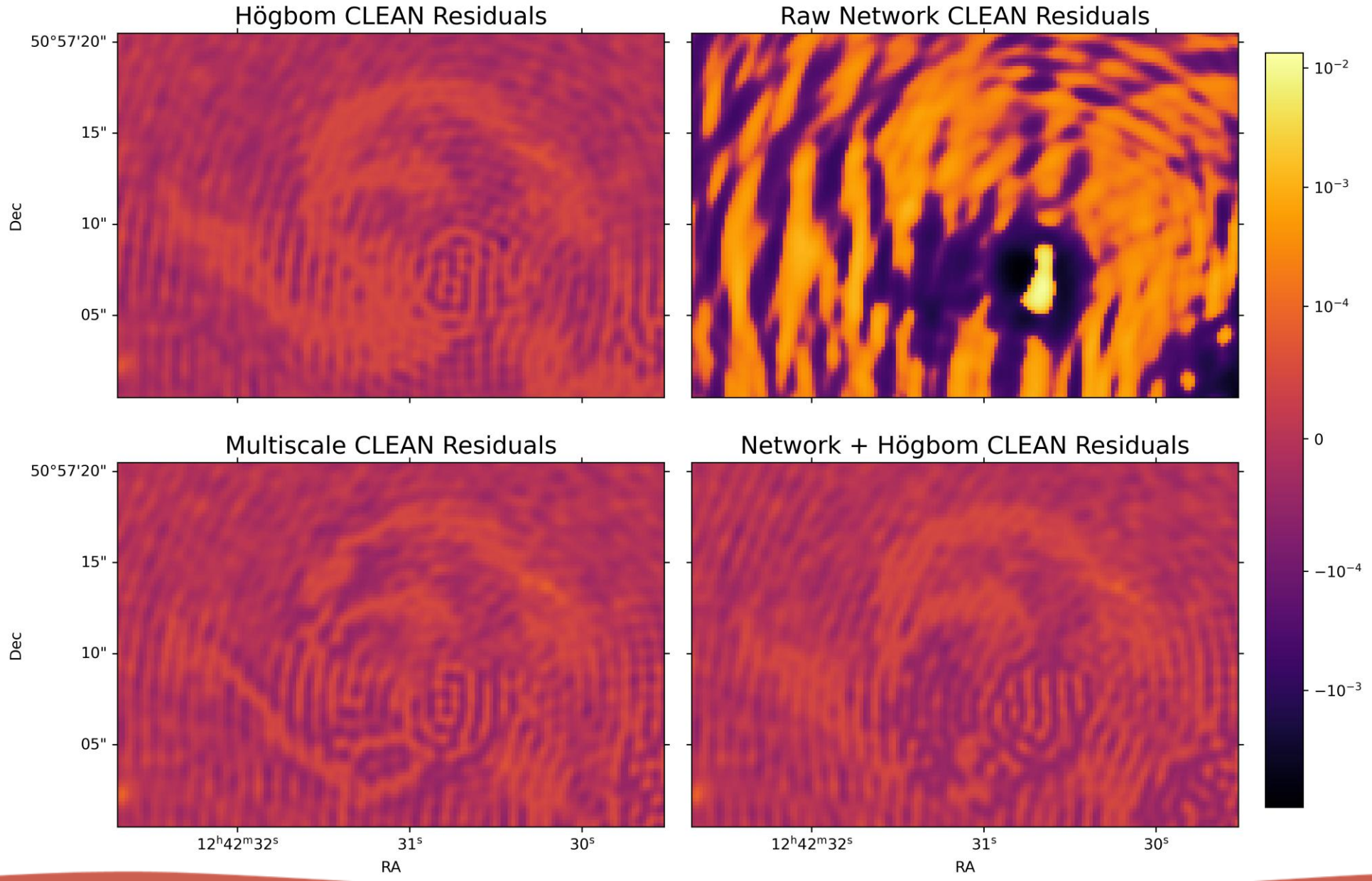


With Högbom Added, Model Improves



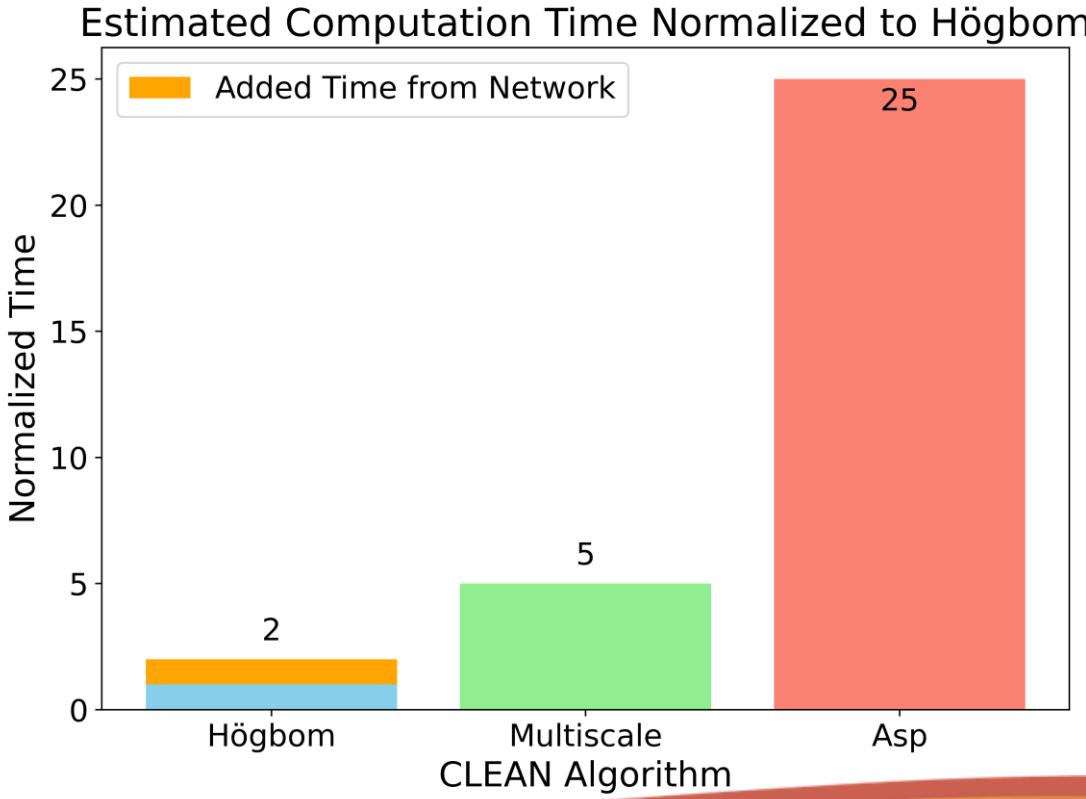
Comparison to Högbom

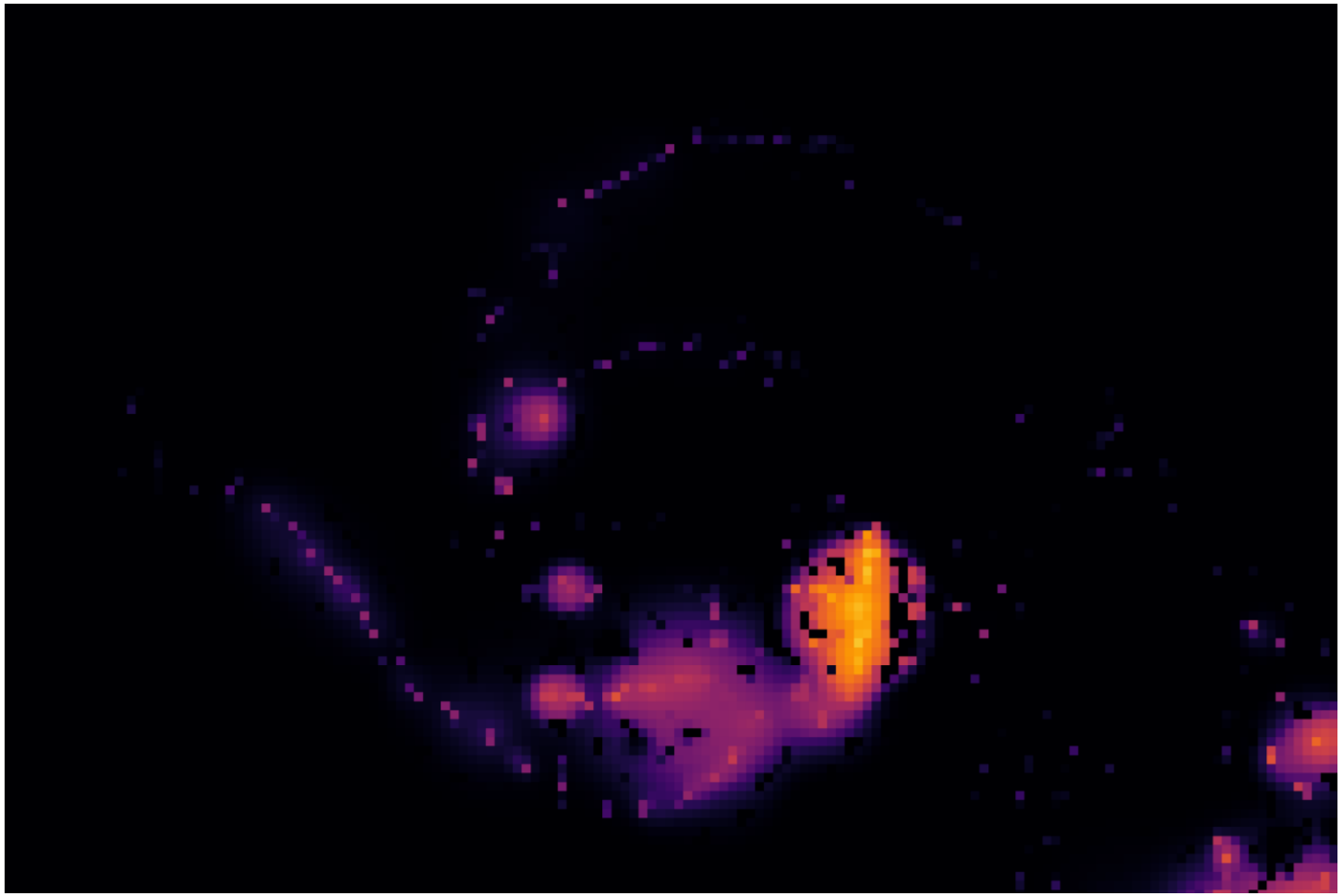




Outlook and Next Steps

- Current best model is not very generalized
  - Multiterm, widefield
- Currently only replicates Multiscale CLEAN
  - Expand to Asp-CLEAN, more expensive methods
  - Ellipticity of Gaussian
  - Angle of Gaussian





Thank You

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References

- [1]Gheller, C. and Vazza, F., “Convolutional deep denoising autoencoders for radio astronomical images”, *Monthly Notices of the Royal Astronomical Society*, vol. 509, no. 1, OUP, pp. 990–1009, 2022. doi:10.1093/mnras/stab3044.
- [2]Bryan, G. L., “ENZO: An Adaptive Mesh Refinement Code for Astrophysics”, *The Astrophysical Journal Supplement Series*, vol. 211, no. 2, Art. no. 19, IOP, 2014. doi:10.1088/0067-0049/211/2/19.
- [3] The CASA Team, et al. 2022, "CASA, the Common Astronomy Software Applications for Radio Astronomy", PASP, 134, 114501. DOI: 10.1088/1538-3873/ac9642