

Deep Learning-based Imaging in Radio Interferometry

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What is Radio Interferometry?

Radio Astronomy

- Ground based telescopes
- Wavelength: millimeter to meter
- **But:** Limited by Rayleigh criterion



Credit: NRAO/AUI/NSF

Radio Astronomy



Credit: Jacobs/Arecibo Observatory

Radio Interferometry

- **Solution:** Correlate multiple telescopes pairwise
- Measure one visibility per antenna pair
- Radio interferometer measurement equation
(**RIME**)

$$V_{pq} = G_p \left(\underbrace{\iint_{lm} \frac{1}{n} E_p B E_q^H e^{-2\pi i(u_{pq}l + v_{pq}m + w_{pq}(n-1))} dl dm}_{\approx \text{Fourier transform}} \right) G_q$$

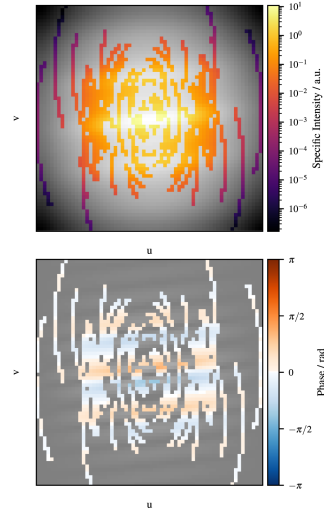


Credit: NRAO/AUI/NSF

Radio Interferometry

- Allocate measured visibilities for observation
- **Gridding:** 2D-Histogram based on baselines

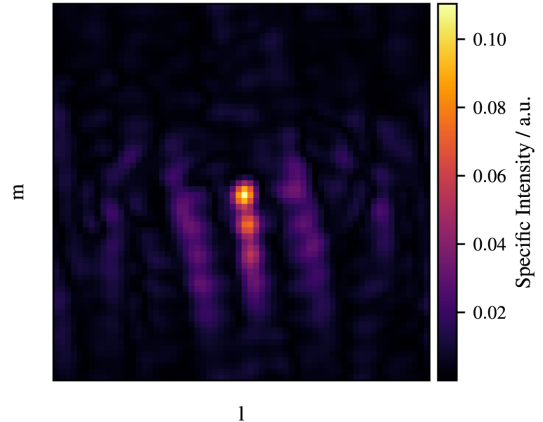
⇒ Radio interferometer samples
Fourier space



'Deep learning-based imaging in radio interferometry', K. Schmidt et al., A&A 664 A134 (2022)

Radio Interferometry

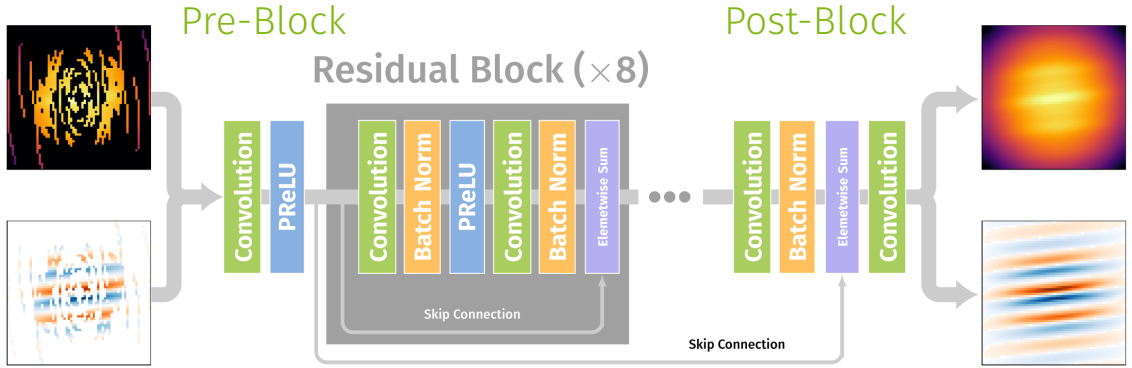
- Inverse Fourier transform → **dirty image**
 - **Problem:** Needs cleaning to do physics
 - Established approaches need human intervention
- ⇒ Solution: Use neural network to fill-in Fourier space



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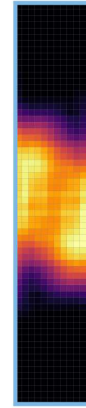
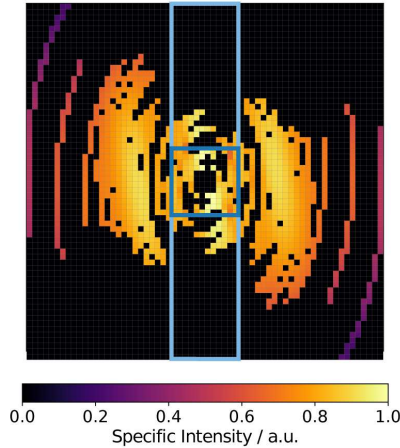
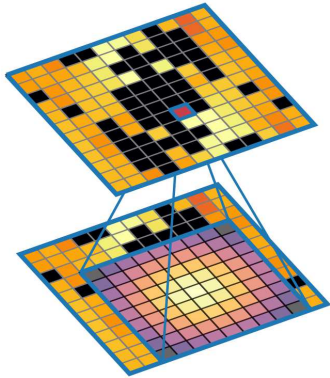
Neural Network Architecture

Neural Network Architecture

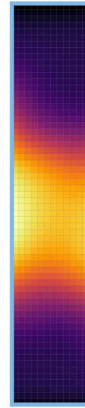


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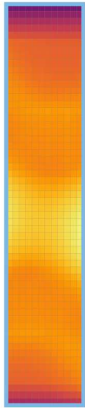
Neural Network Architecture



Pre Block



Residual Block



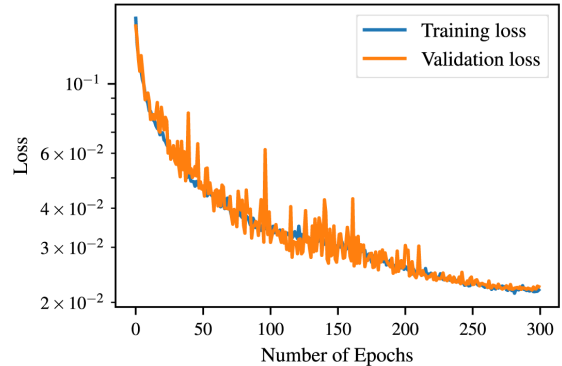
Post Block

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Results

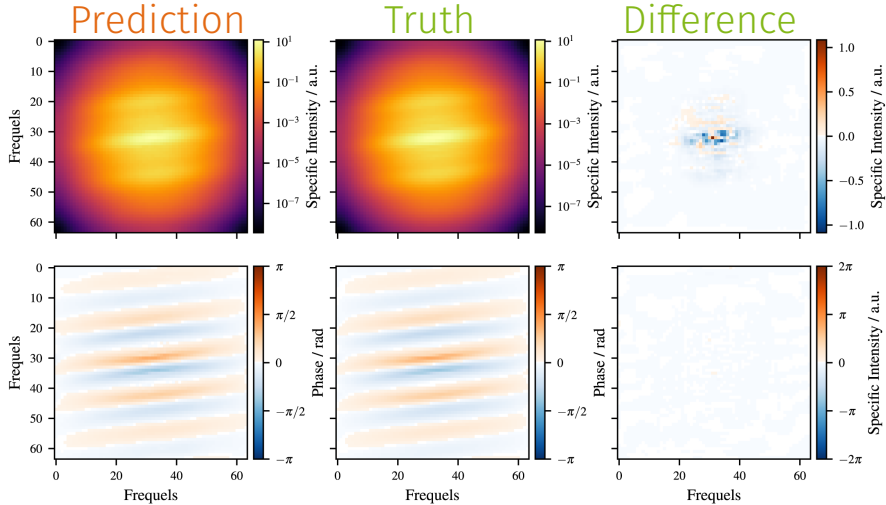
Results - Training

- 300 epochs
- L1 loss
- Batch size of 64 images
- Image resolution of 64×64 pixels
- Simulated toy AGN jets



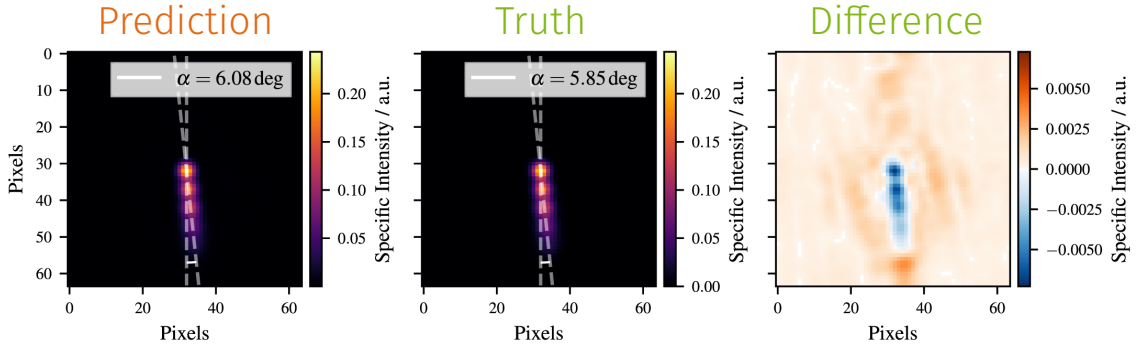
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Results



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Results

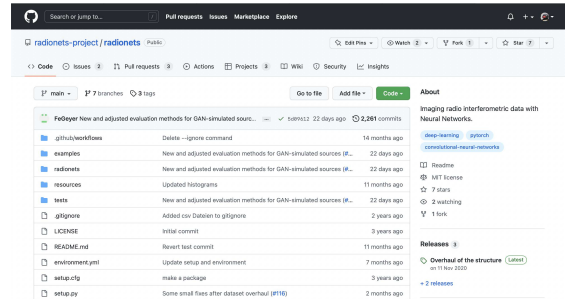


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Outlook

Outlook

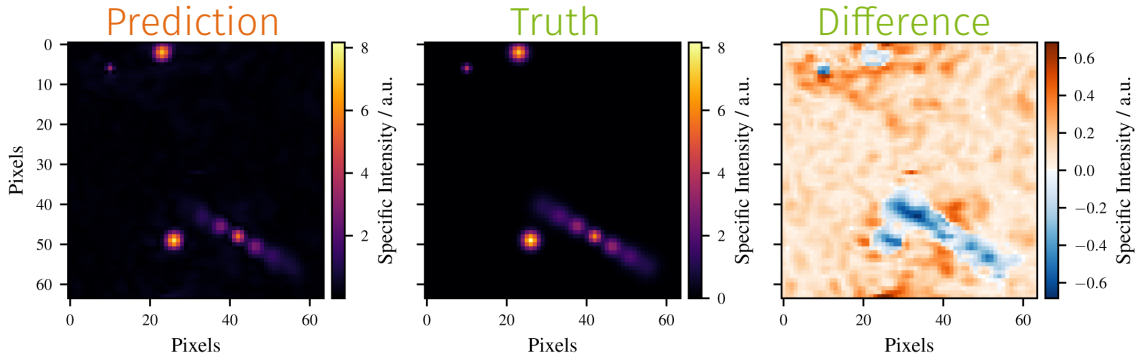
- Extended sources simulated with GAN
- Improved simulation of measurement process → **pyvisgen**
- Uncertainty estimation of the output
- Everything is available on GitHub



Thank you!

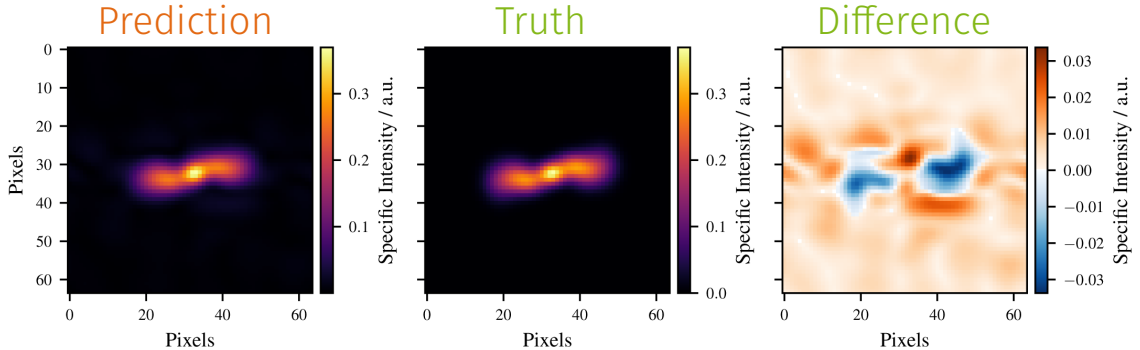
Backup

Backup - Mixed sources



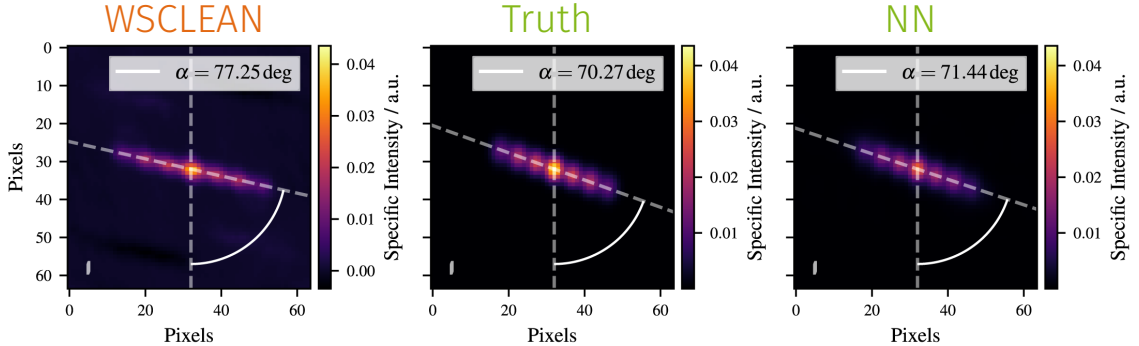
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Backup - Extended sources



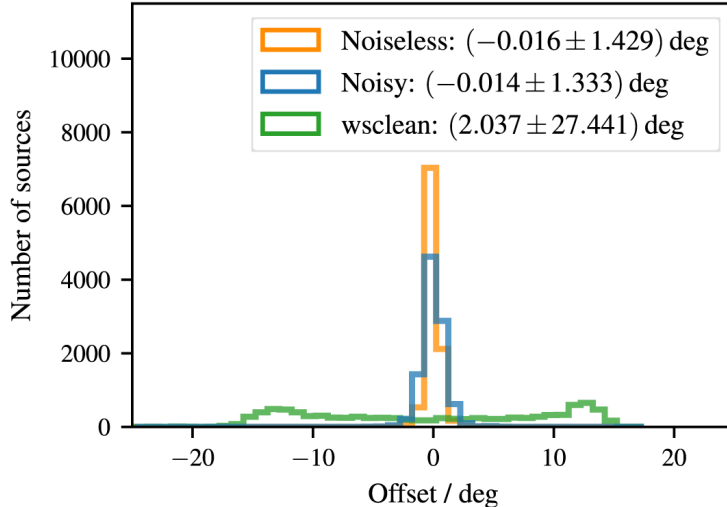
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Backup - WSCLEAN



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Backup - WSCLEAN



¹Deep learning-based imaging in radio interferometry, K. Schmidt et al., A&A 664 A134 (2022)