Deep learning-based imaging of MeerKat observations

Kevin Schmitz

TU Dortmund University
LAMARR institute for ML and AI

Radio 2024
15.11.2024

Exploring deep learning applications in radio astronomy

Simulations

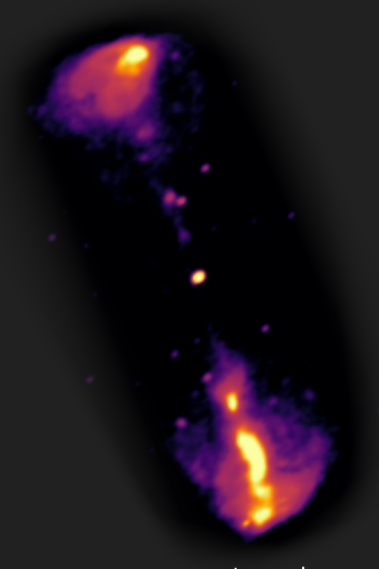
Model Building

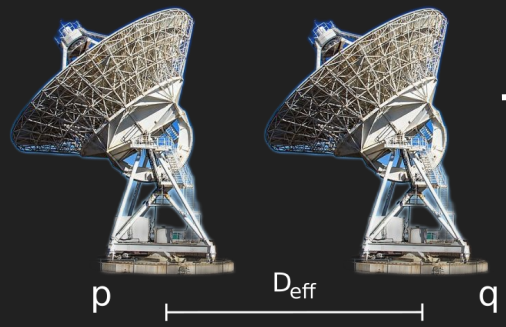
Evaluation

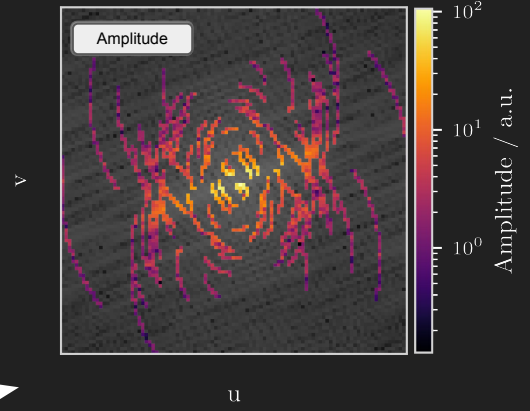
Goal:

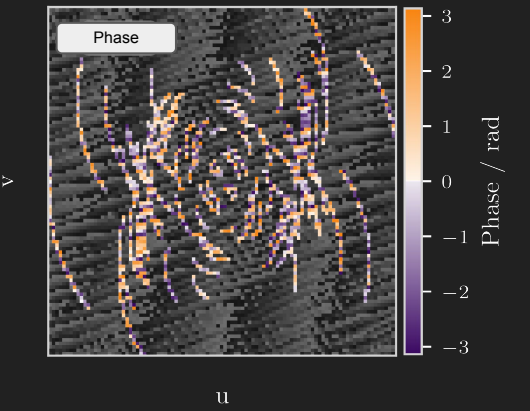
combine computer science and radio interferometry expertise

Radio interferometer measurements

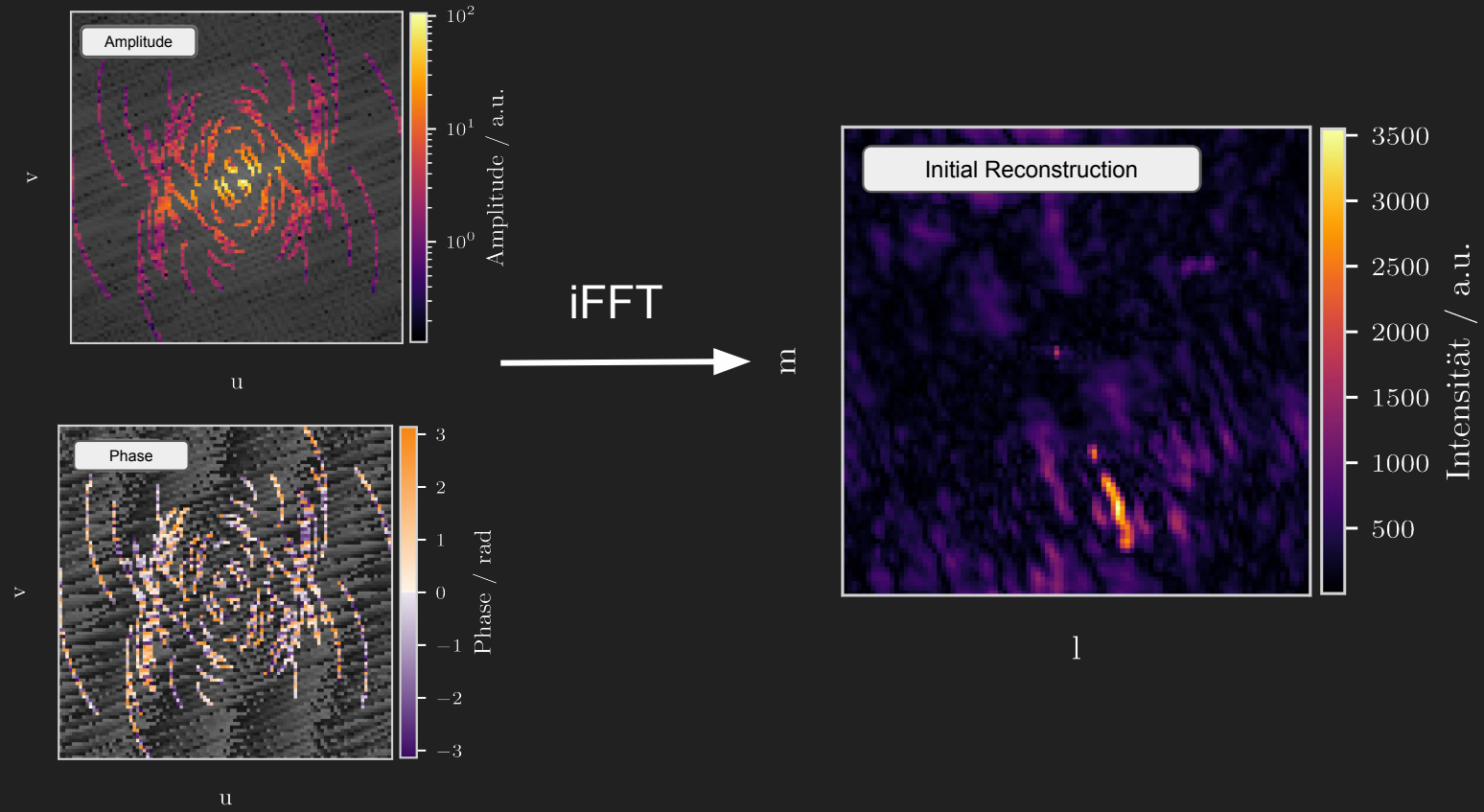








Reconstructing radio interferometric data



Reconstructing radio interferometric data

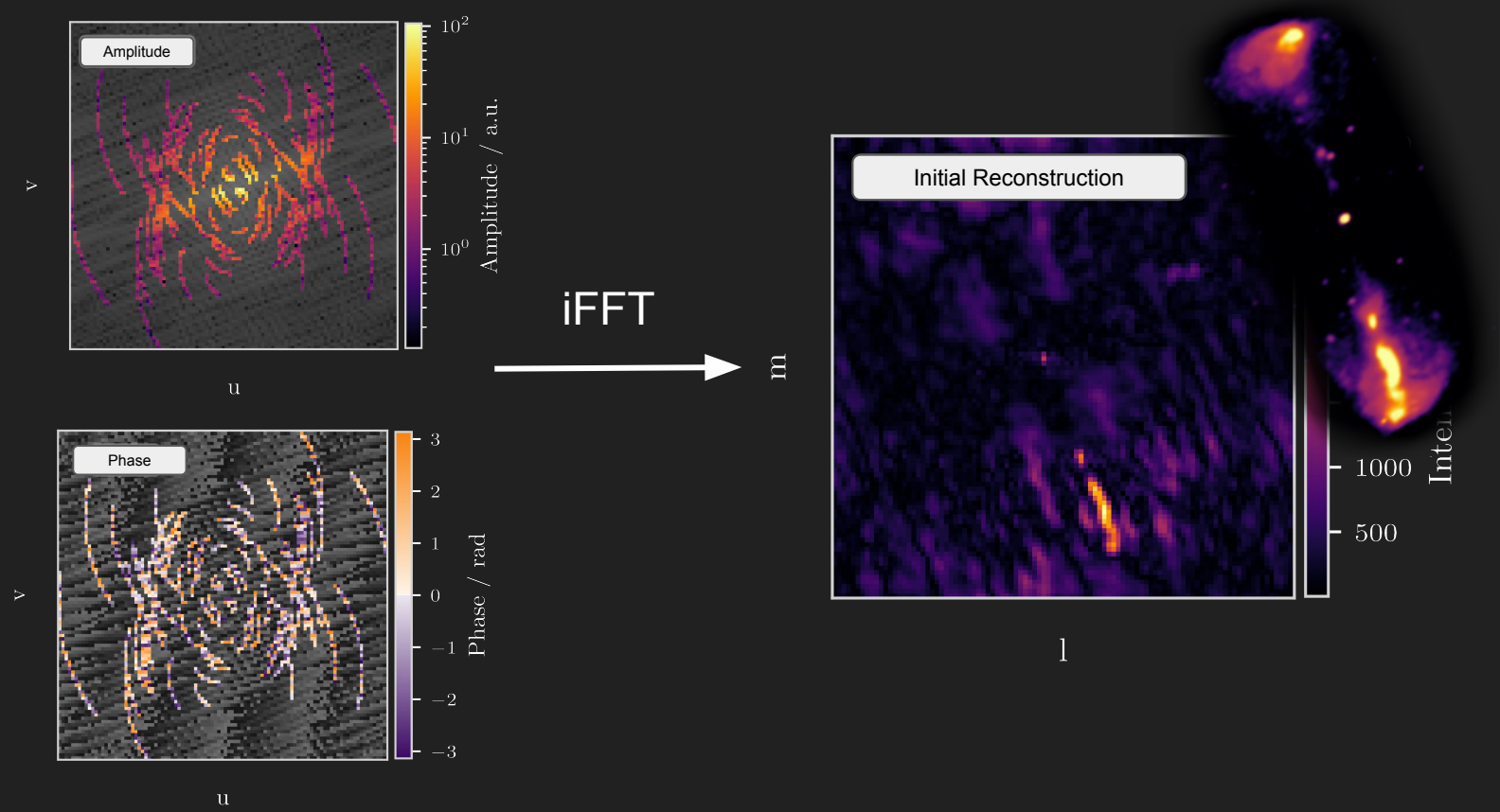
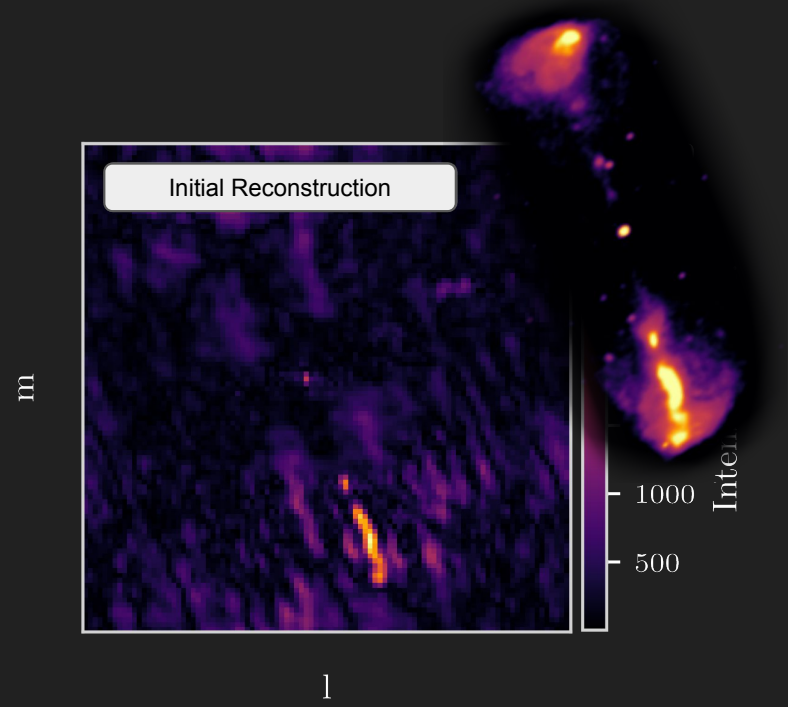


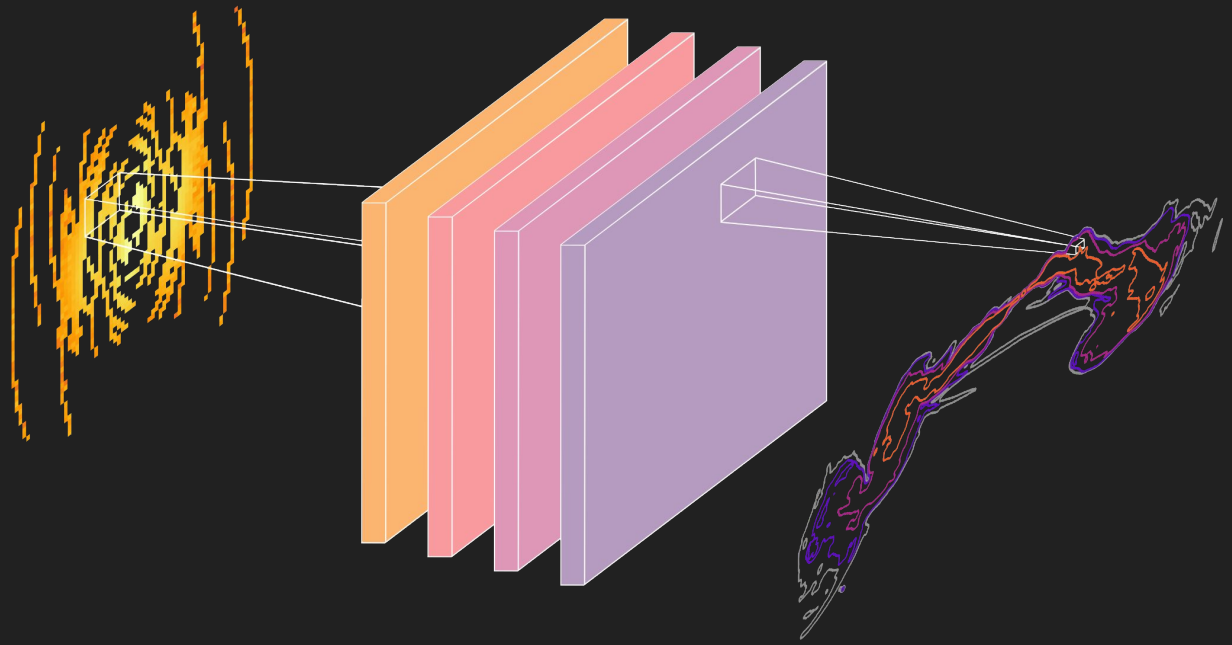
Image cleaning

Traditional CLEAN:
iterative (point-)source model

Deep learning-based cleaning:
reconstruct missing visibilities in uv-space

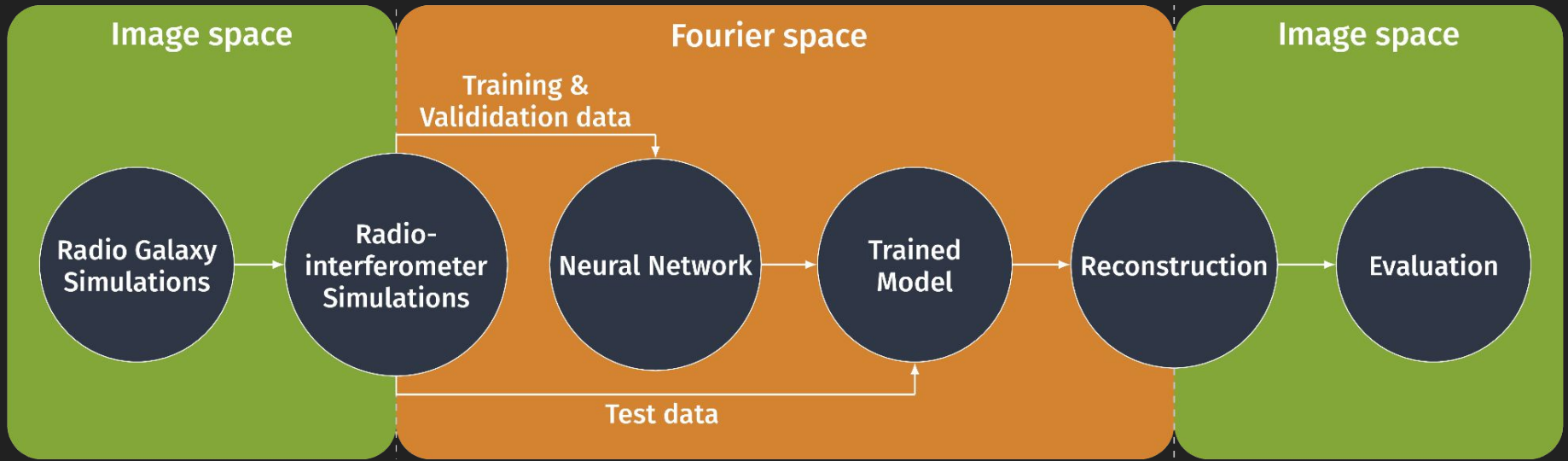


Deep learning for radio interferometric imaging

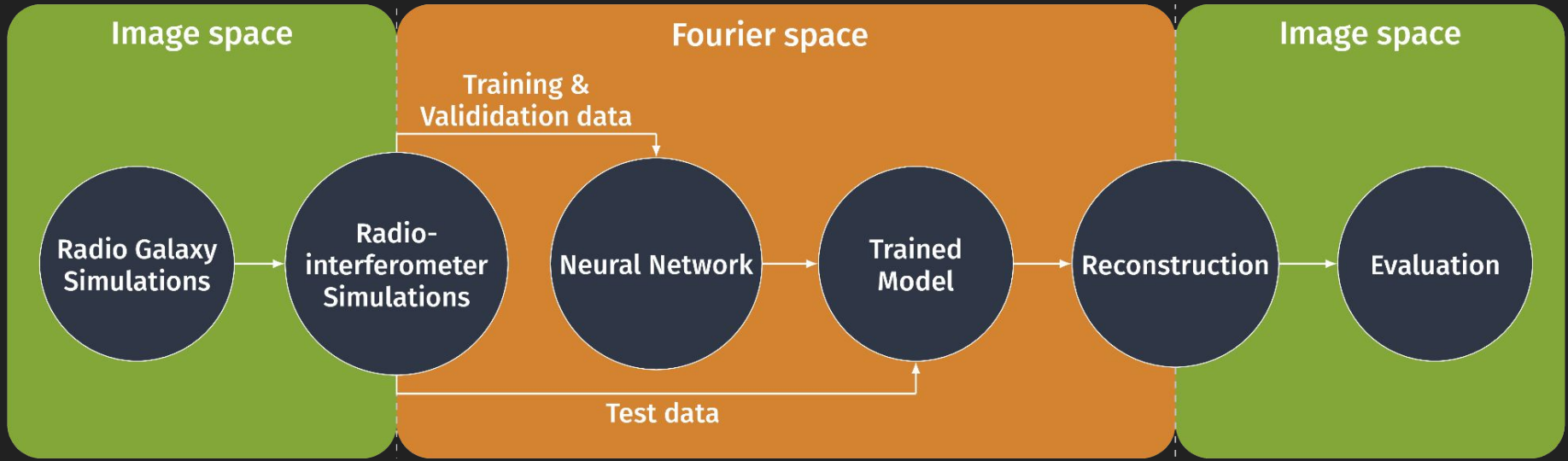


model learns reconstruction based on realistic radio interferometer simulations

radionets-project



radionets-project



Simulations

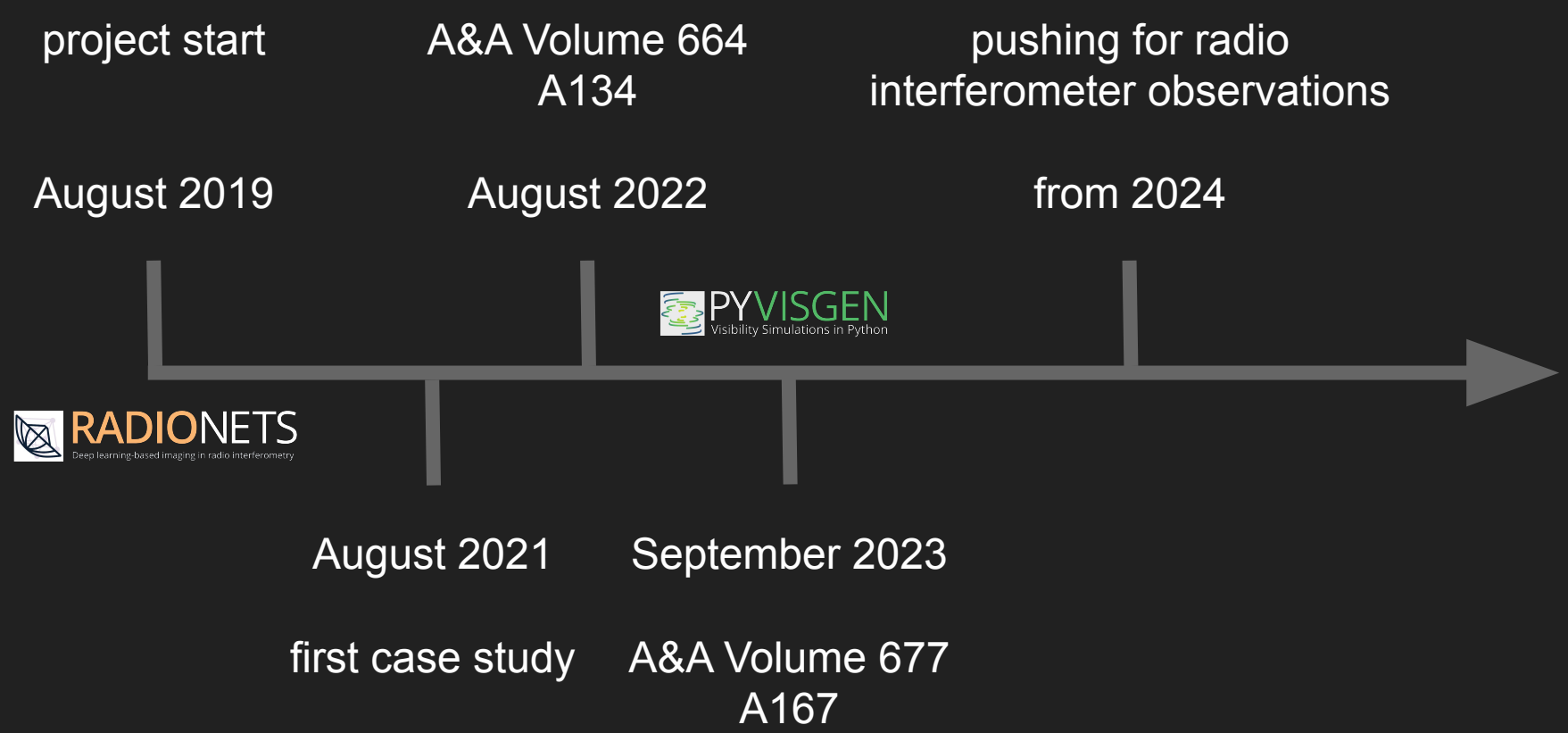
PYVISGEN
Visibility Simulations in Python

Model Building

Evaluation

RADIONETS
Deep learning-based imaging in radio interferometry

radionets-project: timeline

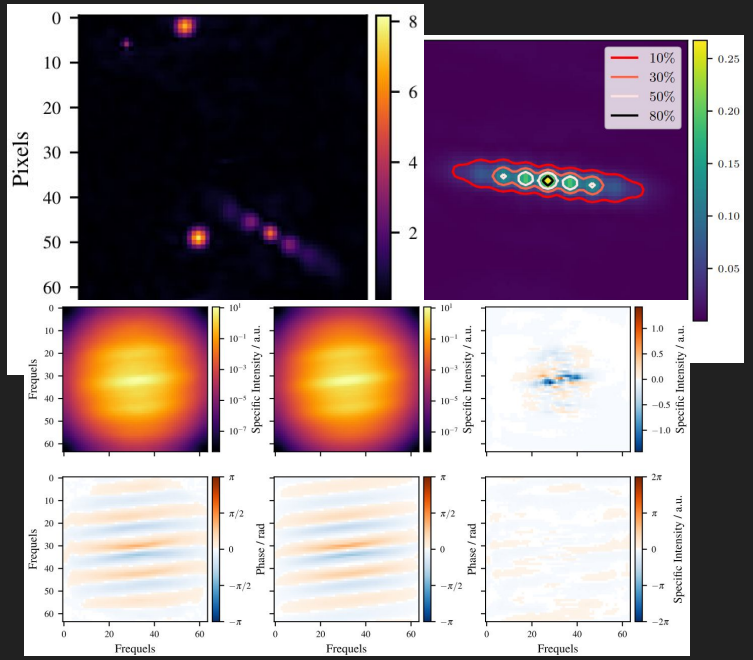


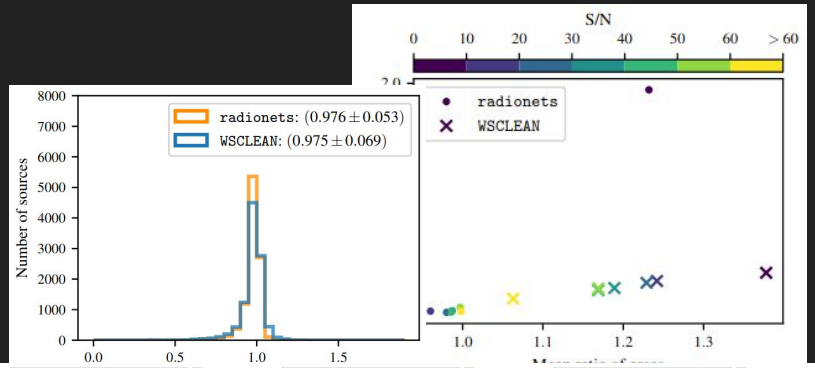
radionets-project

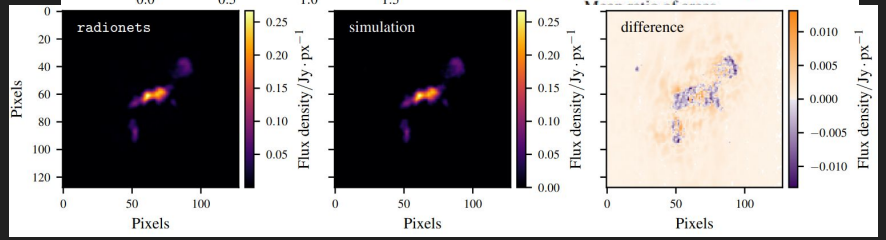
A&A 664, A134 (2022)

Deep learning-based imaging in radio interferometry

K. Schmidt[1], F. Geyer[1], S. Fröse[1], P.-S. Blomenkamp[1], M. Brüggen[2], F. de Gasperin[2,3], D. Elsässer[1] and W. Rhode[1]







A&A, 677, A167 (2023)

Deep-learning-based radiointerferometric imaging with GAN-aided training

F. Geyer[1], K. Schmidt[1], J. Kummer[2,3], M. Brüggen[2], H. W. Edler[2], D. Elsässer[1], F. Griese[3,4,5], A. Poggenpohl[1], L. Rustige[3,6] and W. Rhode[1]

MeerKat data set

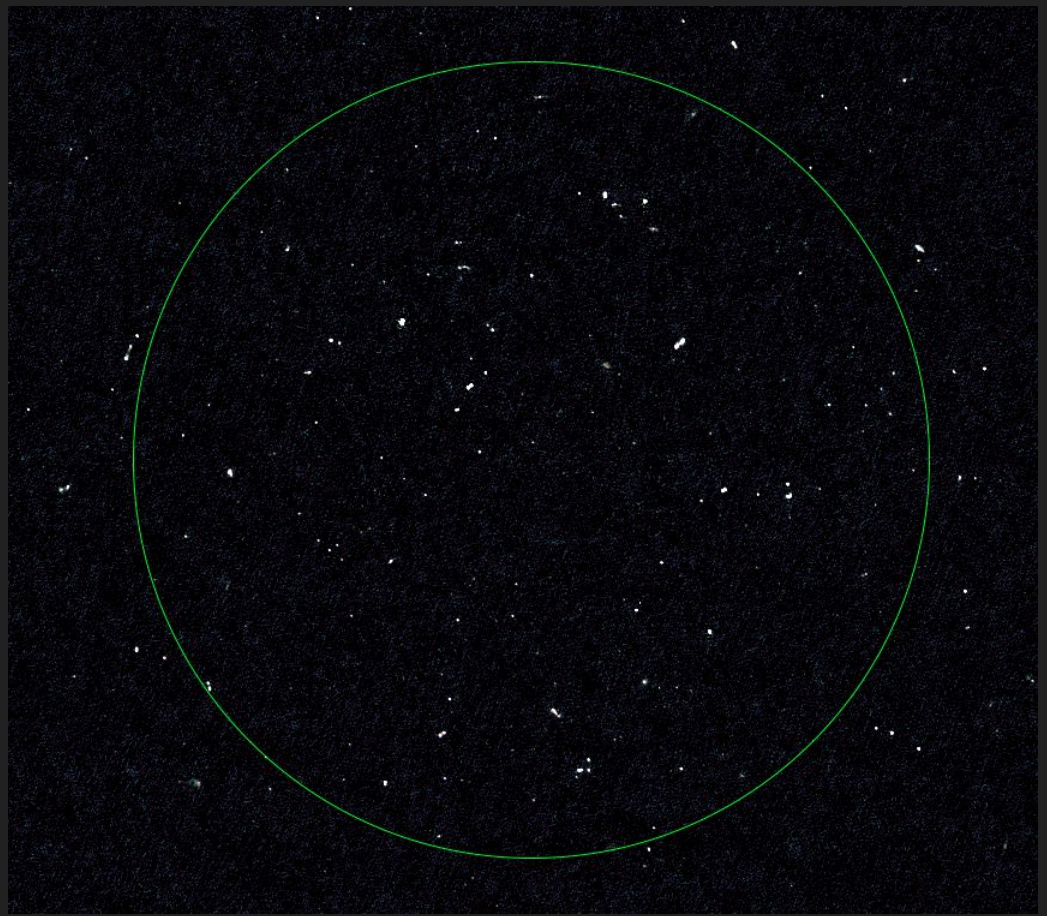
L- Band observations of Virgo cluster

pointing at the outer part

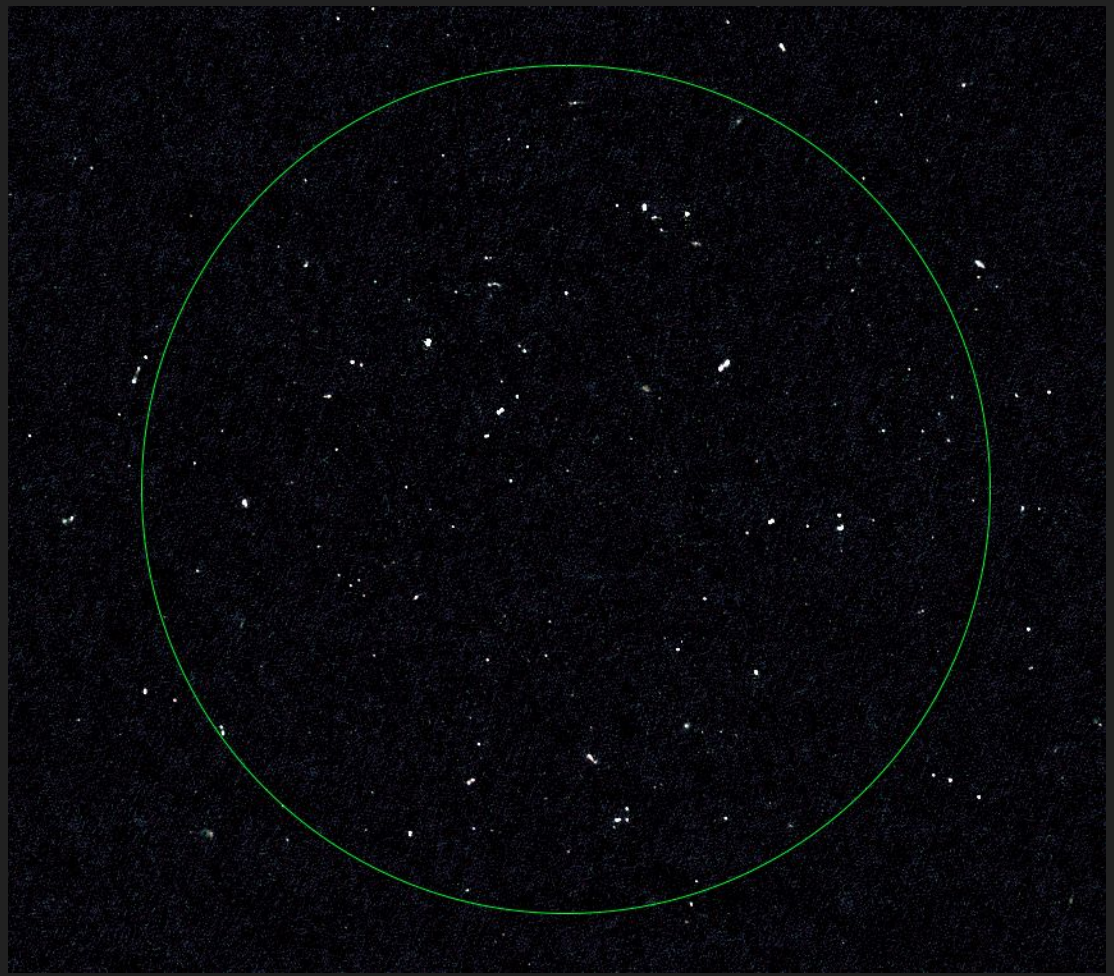
2 arcsec resolution

350.000 visibilities

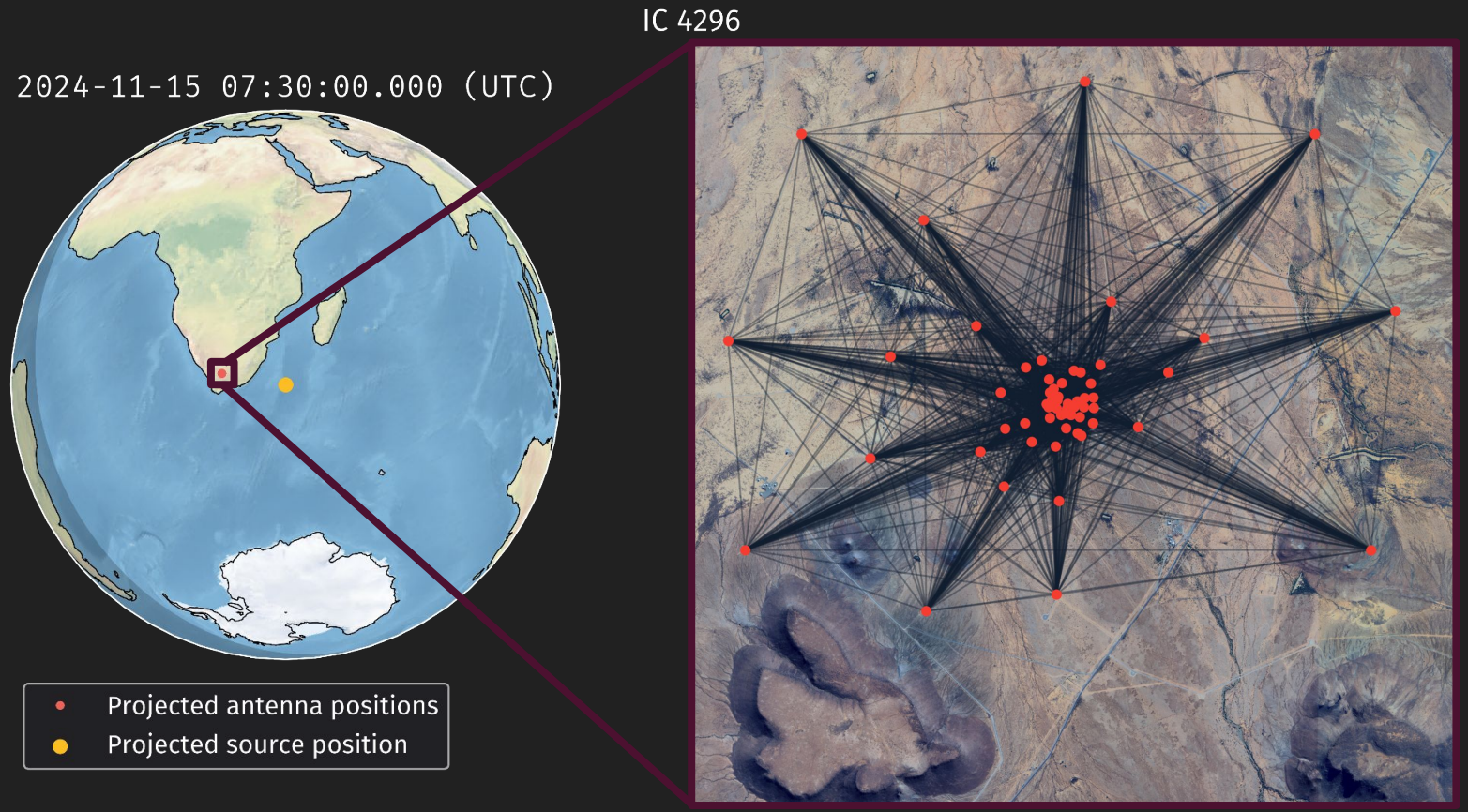
1.3 GHz – 16 channels



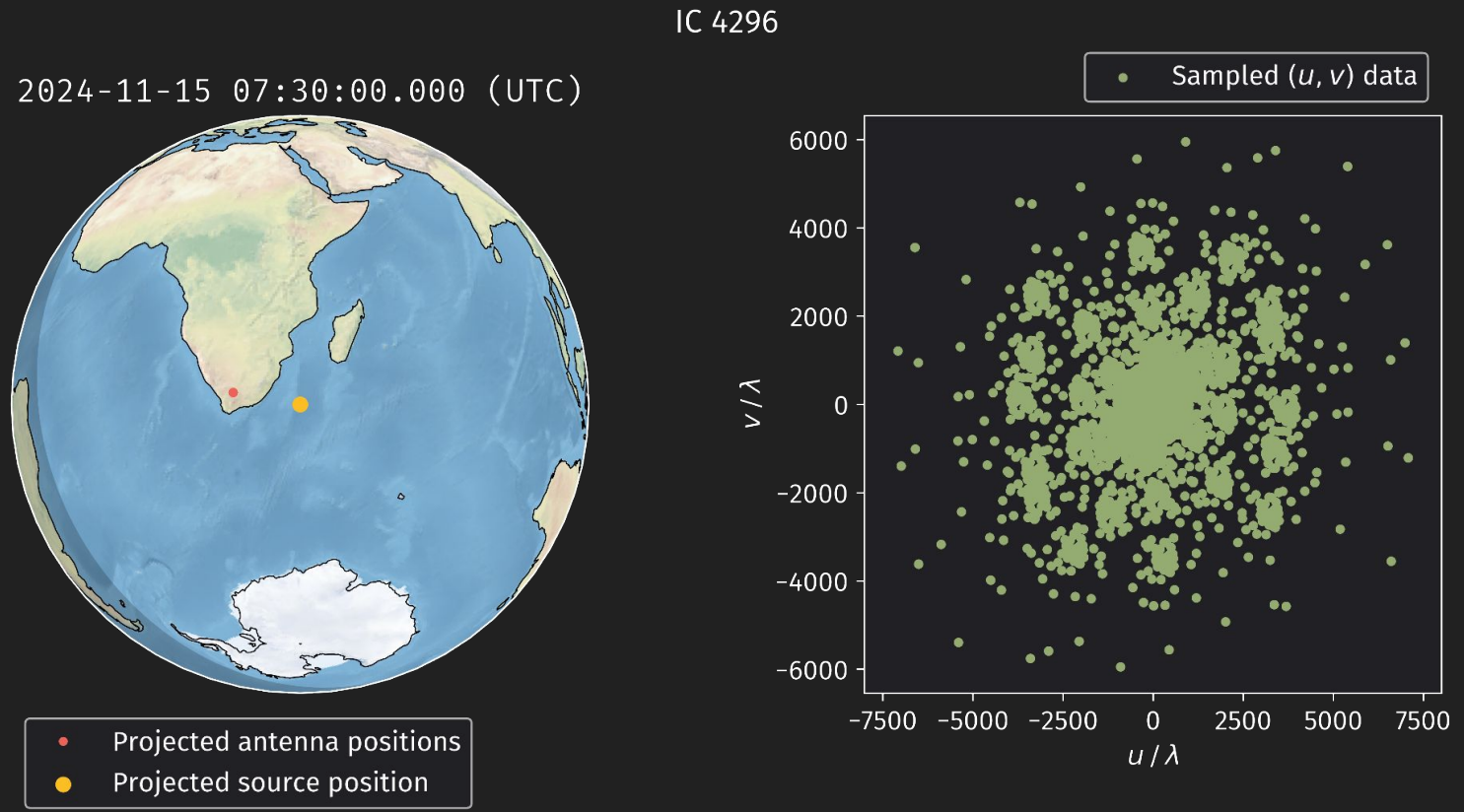
Source simulations



Radio interferometer simulations: RIME



Radio interferometer simulations: RIME



Radio interferometer simulations: RIME

$$\mathbf{V}_{pq}(l, m) = \sum_{l,m} \mathbf{E}_p(l,m)\,\mathbf{K}_p(l,m)\,\mathbf{B}(l,m)\,\mathbf{K}_q^H(l,m)\,\mathbf{E}_q^H(l,m)$$

Source Distribution:

$\mathbf{B}(l, m)$

Phase Delay:

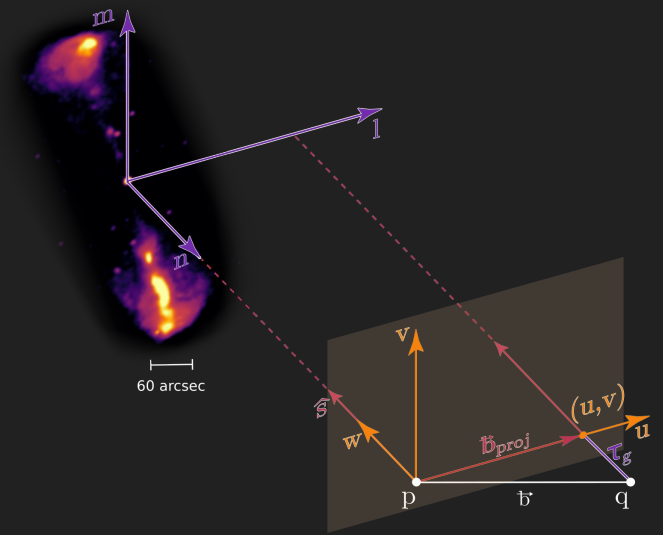
$\mathbf{K}(l,m) = \exp(-2\pi \cdot i \cdot (ul + vm))$

Telescope Beam:

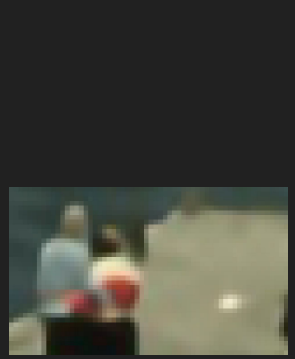
$$\mathbf{E}(l,m) = \text{jinc}\left(\frac{2\pi}{\lambda_{obs}} d \cdot \theta_{lm}\right)$$

$$\text{jinc}(x) = \frac{J_1(x)}{x}$$

(Smirnov 2011)



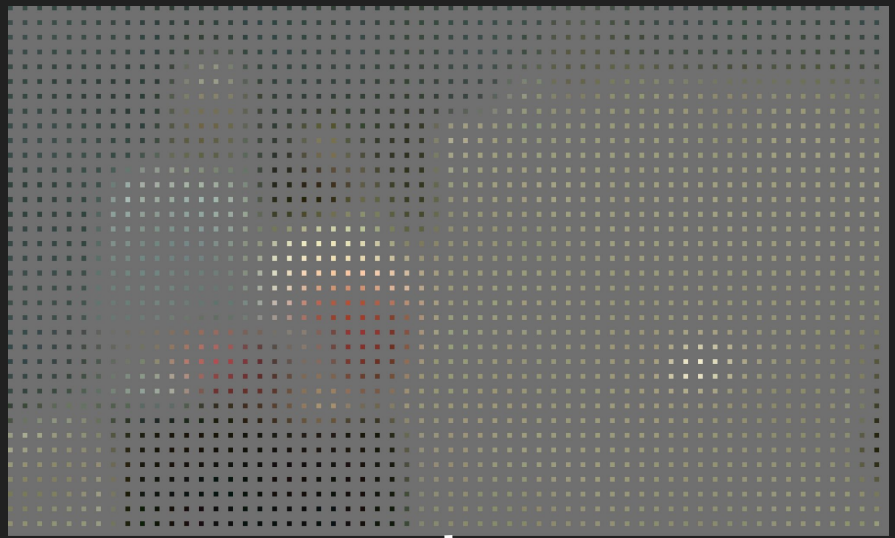
Deep learning model: image inpainting



Zoom

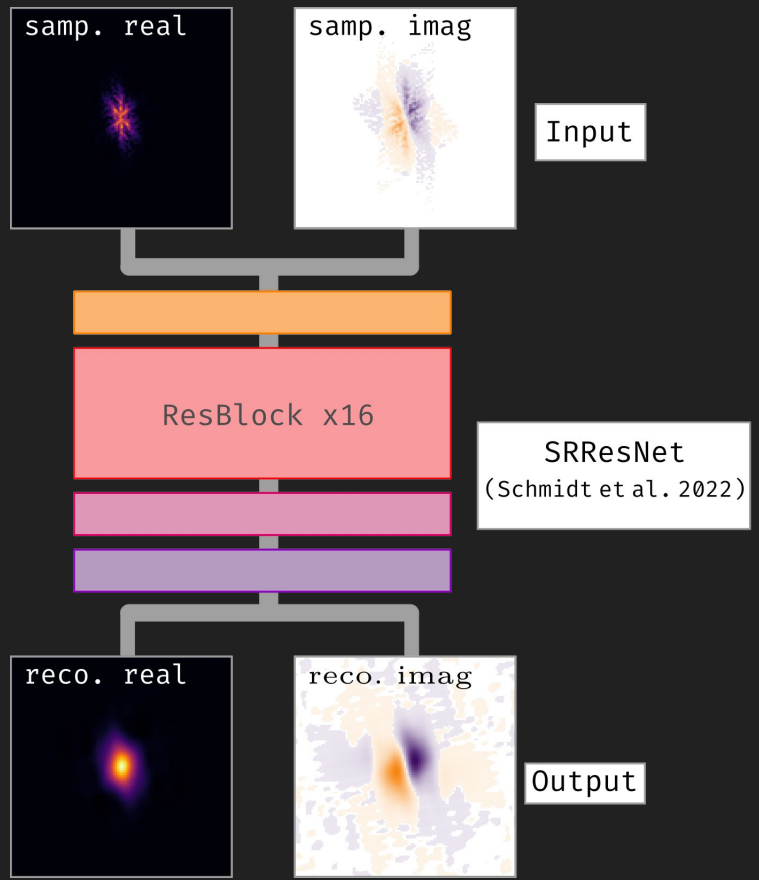
(He et al. 2015; Gross & Wilber 2016)

Deep learning model: SRResNet

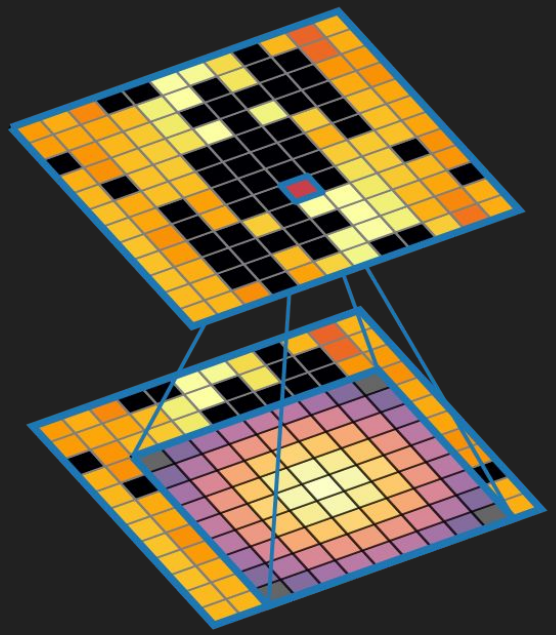


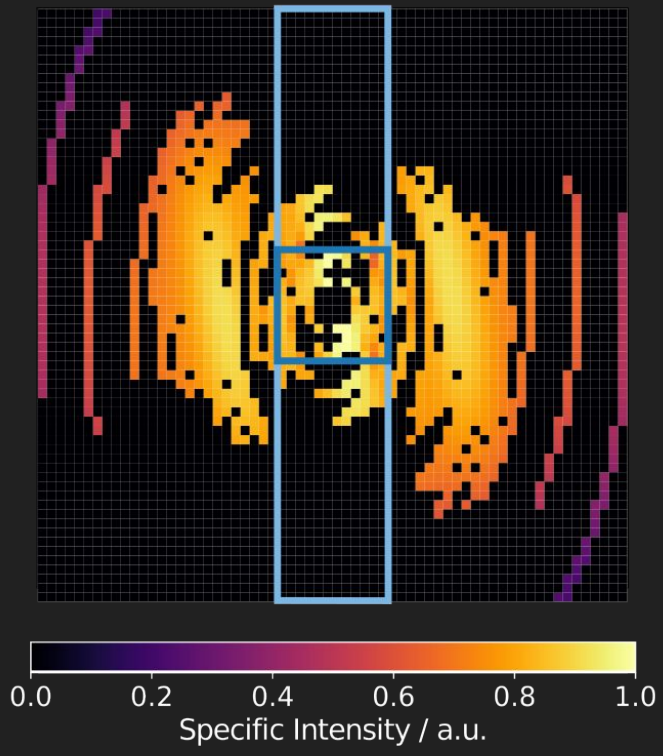
SRResNet (He et al. 2015; Gross & Wilber 2016)

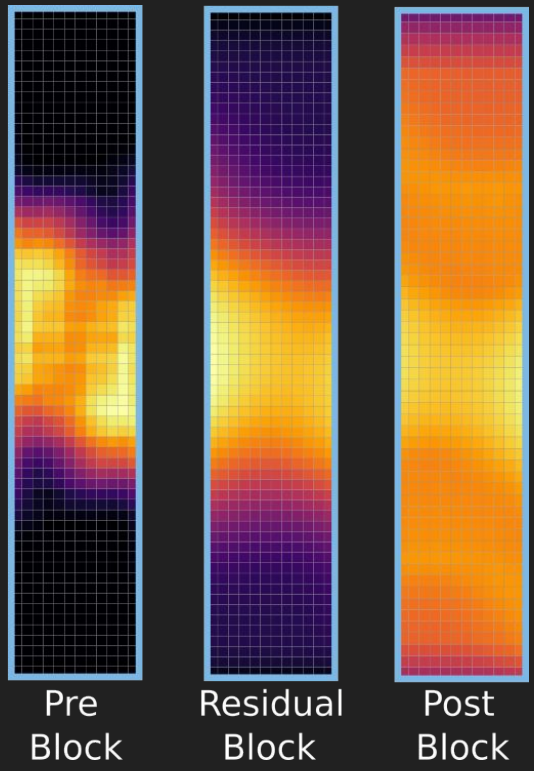
Deep learning model: architecture



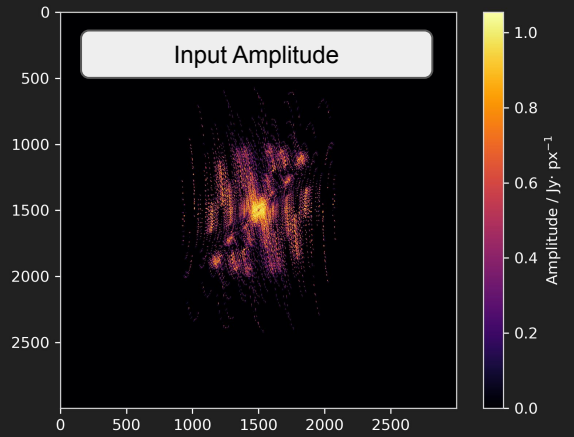
Deep learning model: Convolutional inpainting

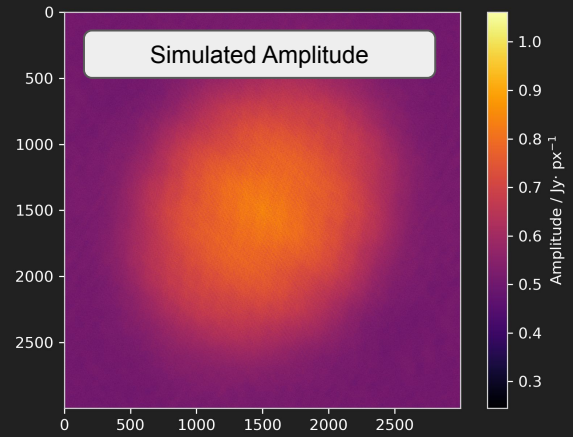


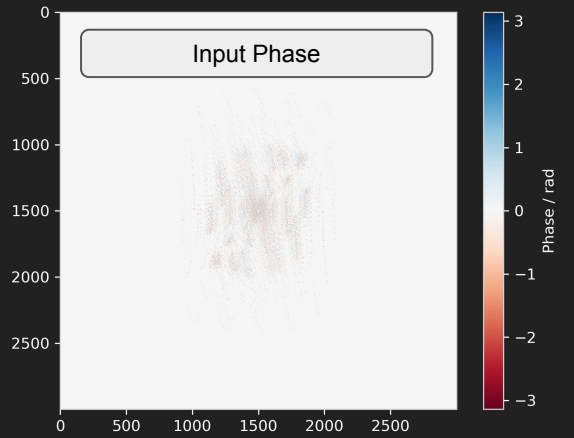


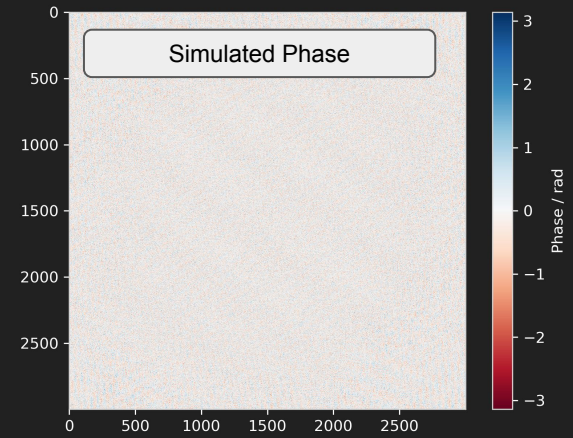


Visibility reconstruction

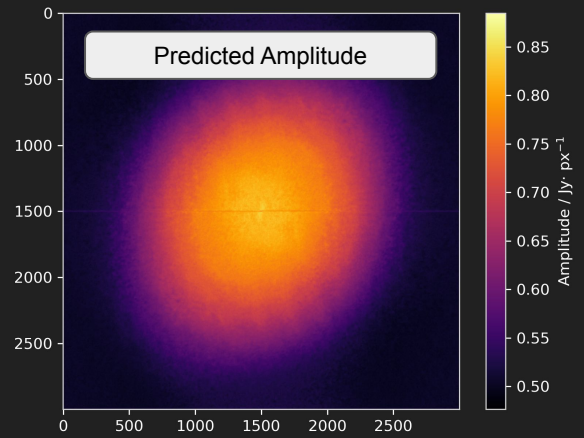


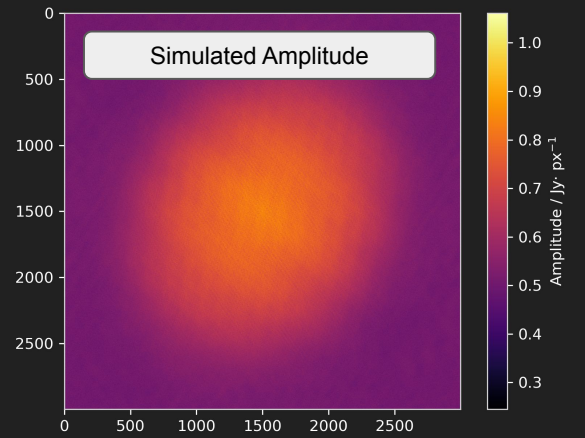


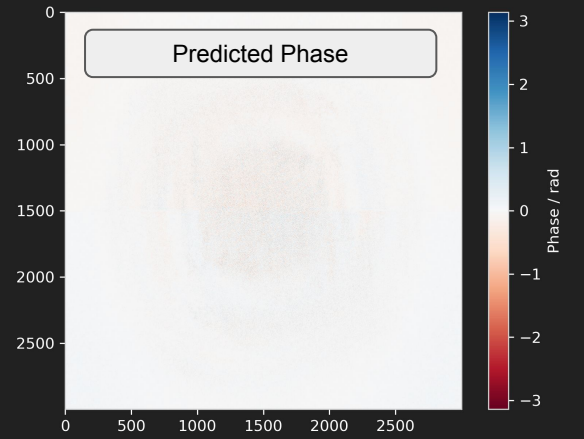


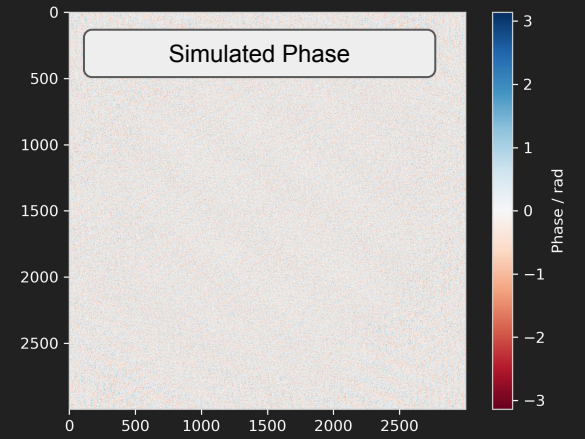


Visibility reconstruction

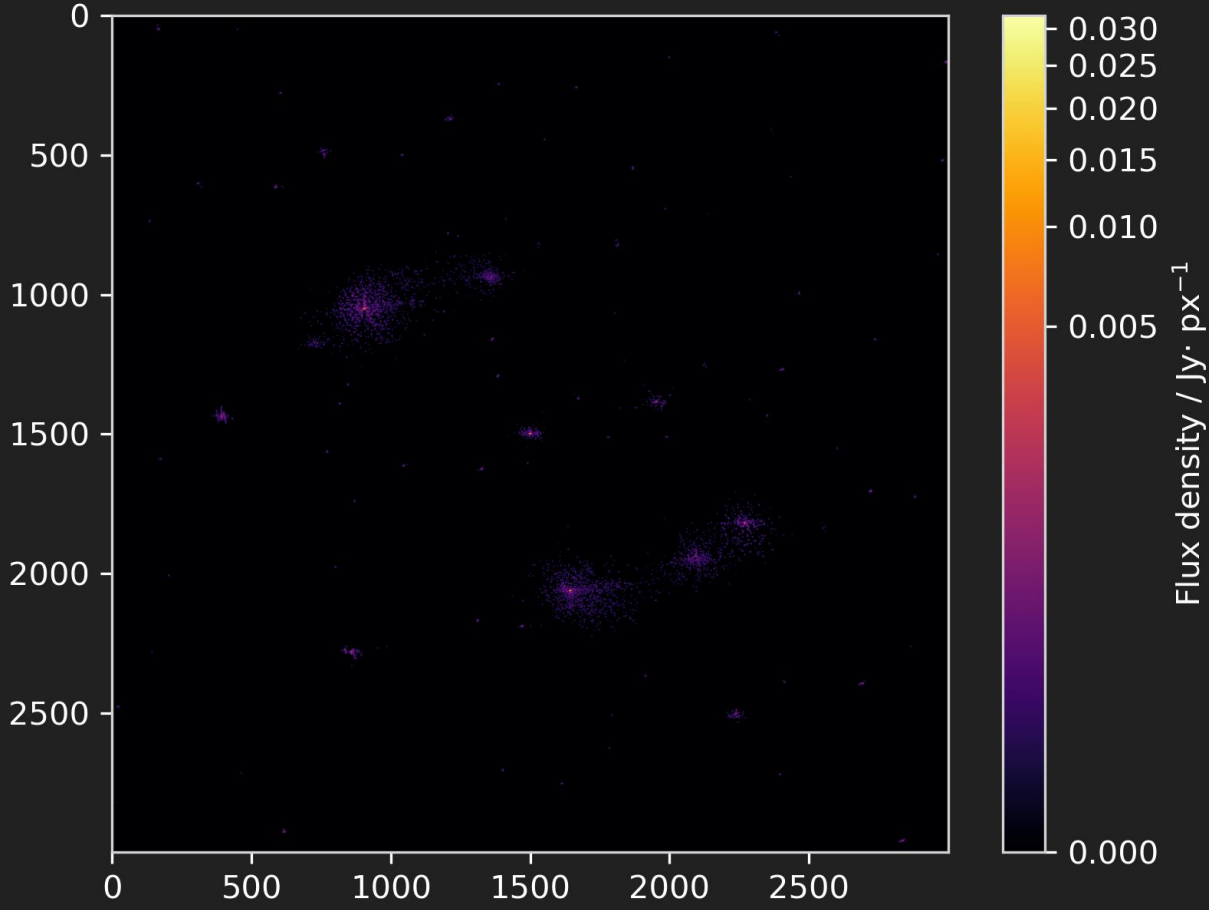




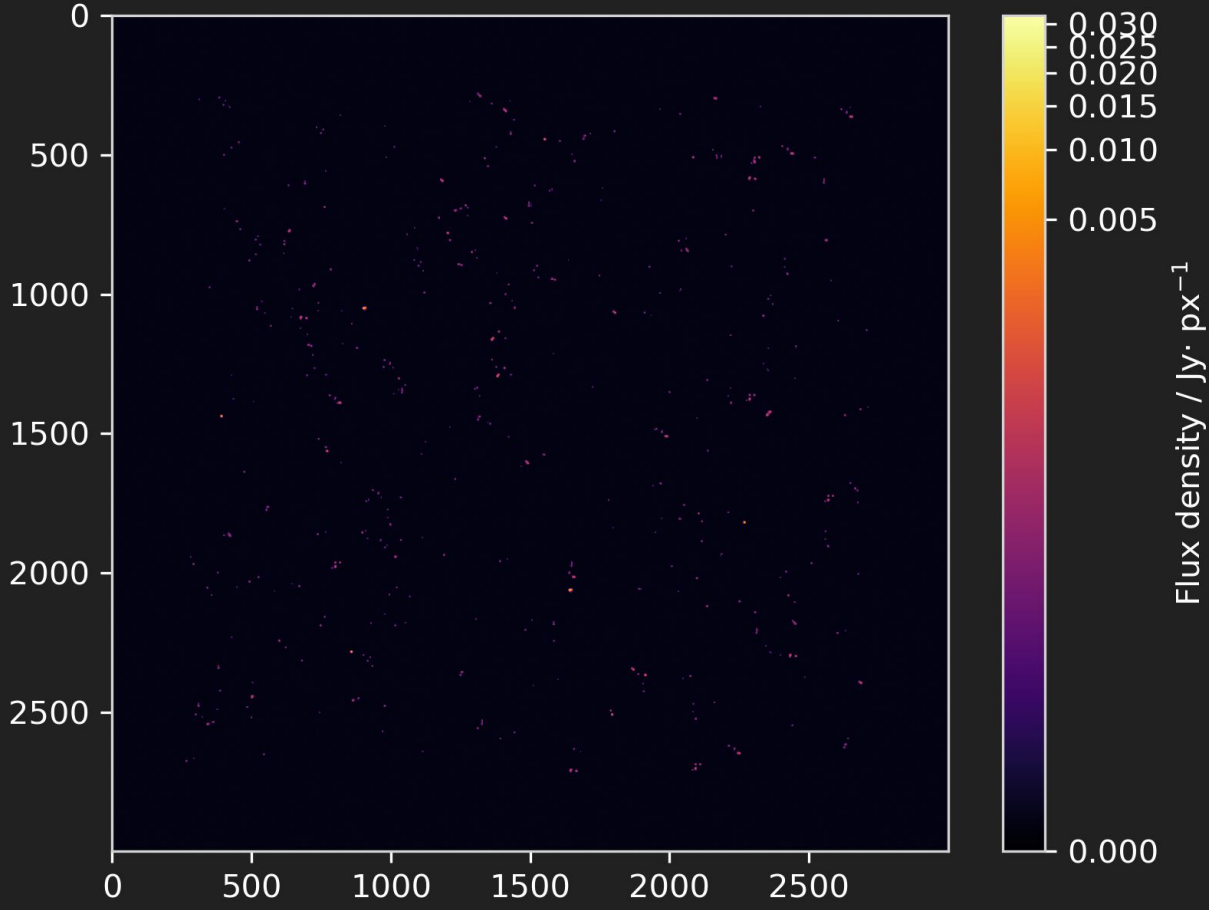




Resulting cleaned images



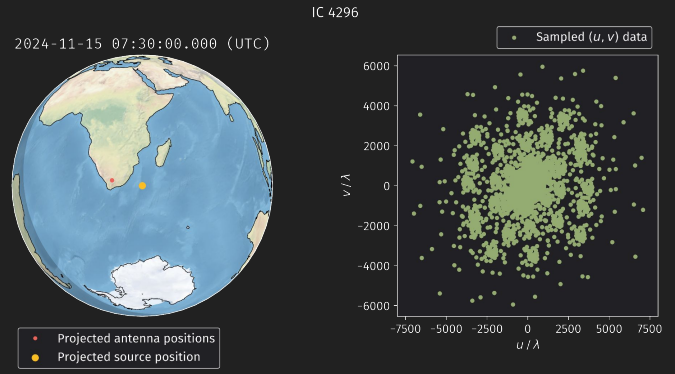
Resulting cleaned images

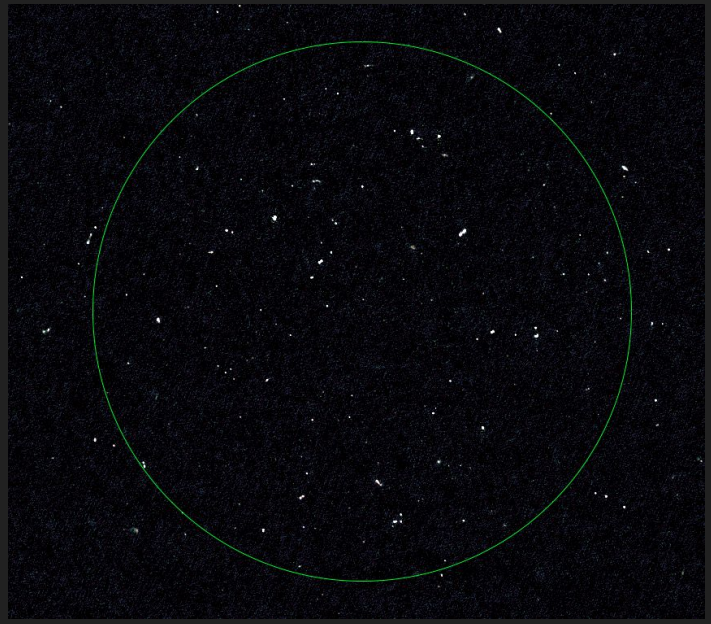


Summary & Outlook

- huge improvements in the last 12 months
- working simulation chain
- identified current problems
- evaluation routines

expect first breakthroughs early 2025





LAMARR INSTITUTE FOR MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

RADIONETS Deep learning-based imaging in radio interferometry

astroparticle physics

PYVISGEN Visibility Simulations in Python