

Machine Learning and Super resolution for radio astronomical data analysis

ML4Astro, La Valletta, Malta
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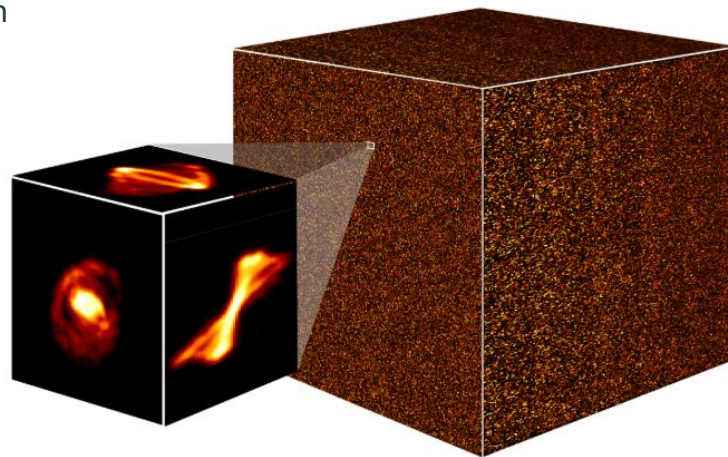


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Grant 2023

Motivation: why Super Resolution in Radio Astronomy?

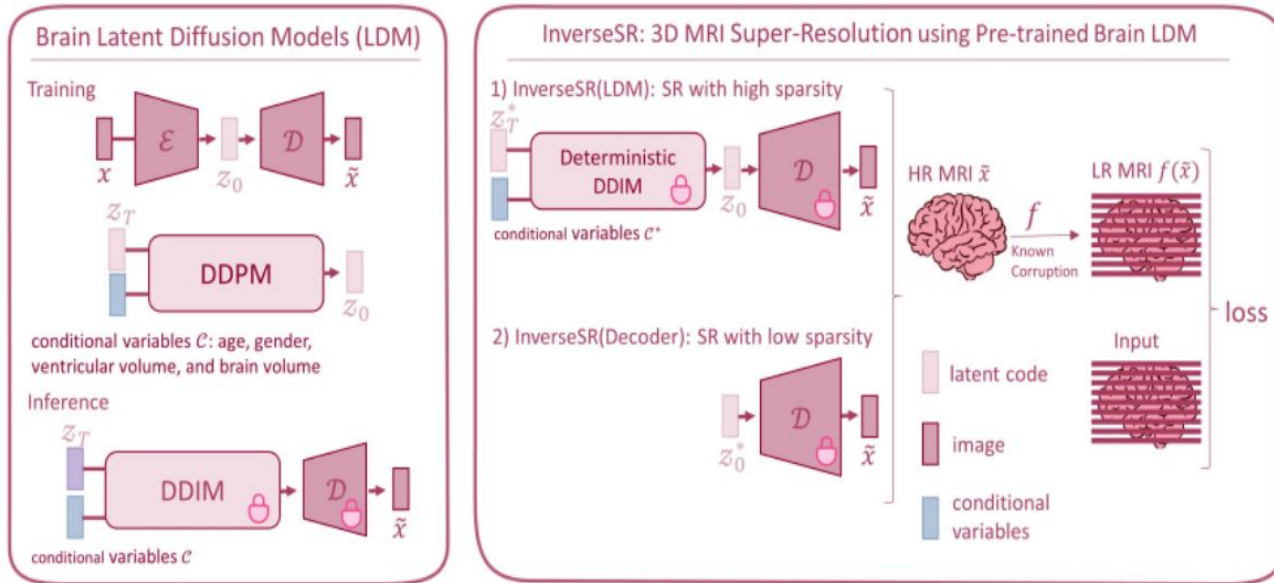
1. **Unprecedented data volumes** SKA datacubes (up to TB-scale) cannot be fully transferred or loaded
SR enables interactive "details on demand" visualization
2. **Bandwidth and storage reduction** compressed cubes are moved between SRCs and users,
SR allows fine detail reconstructed client-side
3. **Enhanced visual inspection** of faint sources and low-contrast structures
SR speeds up human-in-the-loop visual source validation

Novelty: Diffusion models for astronomical data.



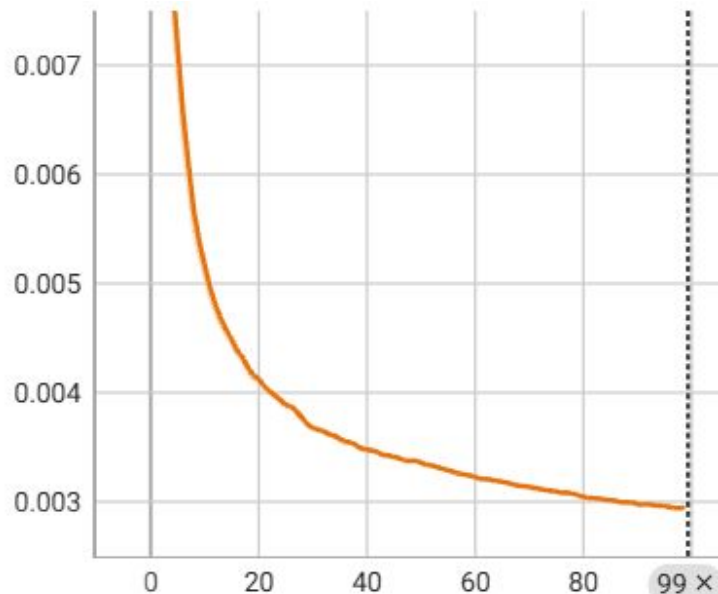
3D Data cube from SKA Data challenge 2.

Machine Learning models for Super resolution tasks: 3D case

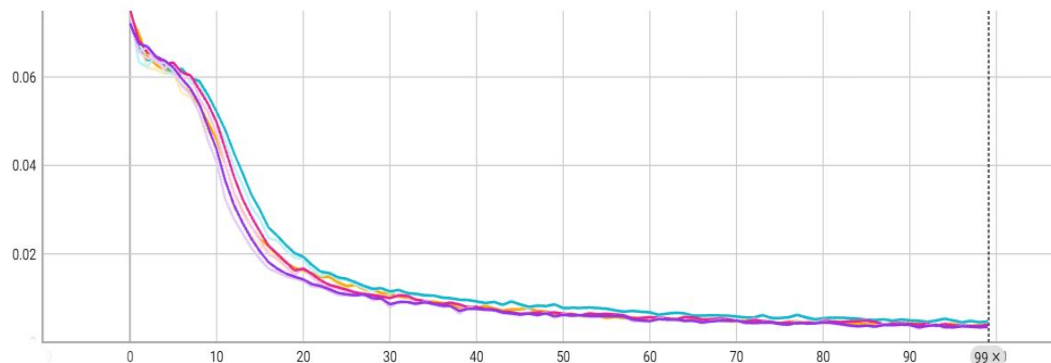


Wang, Jueqi, et al. "Inversesr: 3d brain mri super-resolution using a latent diffusion model." *International conference on medical image computing and computer-assisted intervention*. Cham: Springer Nature Switzerland, 2023.

Plots loss VAE and DDPM



Loss VAE. 100 epochs.



Run ↑

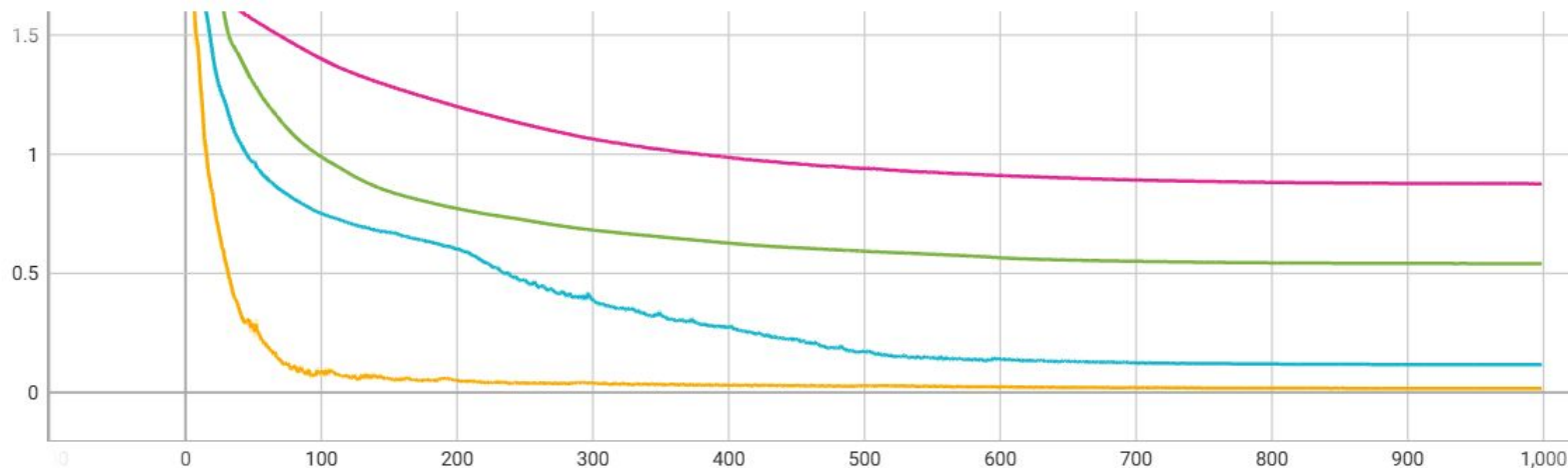
- ddpm_None_100_z3_local_cont_ldev_logvarFalse/run_Aug17_10-22-30_lr_0.0001_z3
- ddpm_concat_100_z3_local_cont_ldev_logvarFalse/run_Aug19_17-52-49_lr_0.0001_z3
- ddpm_crossattn_100_z3_local_cont_ldev_logvarFalse/run_Aug19_17-52-19_lr_0.0001_z3
- ddpm_hybrid_100_z3_local_cont_ldev_logvarFalse/run_Aug19_17-52-55_lr_0.0001_z3

Smoothed	Value	Step	Relative
0,0047	0,0048	99	1.639 day
0,004	0,0041	99	1.657 day
0,004	0,0042	99	1.895 day
0,0034	0,0035	99	1.914 day

Loss DDPM with different conditioning cases. 100 epochs.

BRGM Inversion procedure: DDIM + Decoder

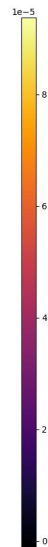
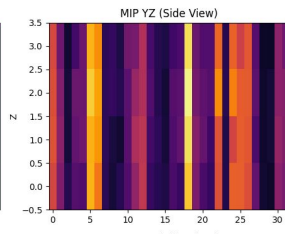
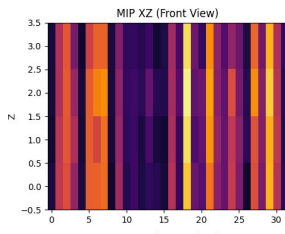
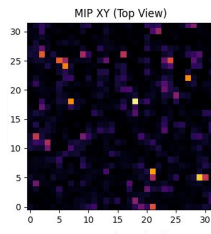
Loss Inversion DDIM plots with different conditioning



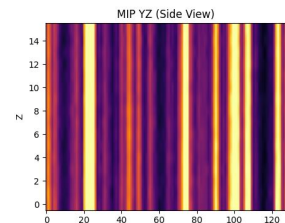
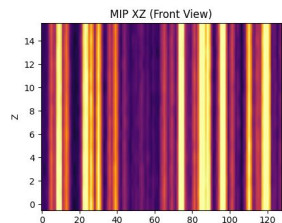
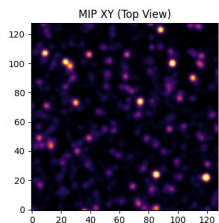
Run ↑	Smoothed	Value	Step	Relative
opt_lr0.01_lam100_steps1000_Hybrid	0,8763	0,8763	999	3.591 hr
opt_lr0.05_lam100_steps1000	0,117	0,117	999	2.73 hr
opt_lr0.05_lam100_steps1000_crossattn	0,5412	0,5413	999	3.573 hr
opt_lr0.1_lam100_steps1000_None	0,0166	0,0166	999	2.742 hr

Visual comparison among HR LR and SR (DDIM+Decoder None cond)

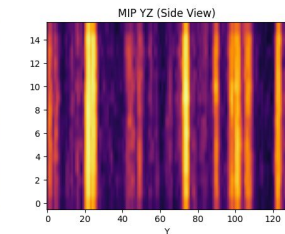
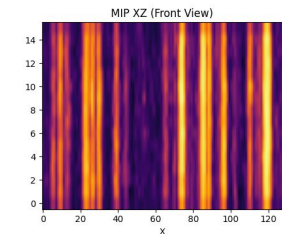
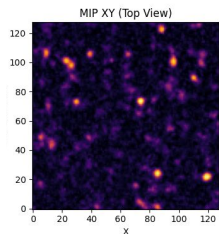
**LOW
RESOLUTION
(4x)**



**HIGH
RESOLUTION**



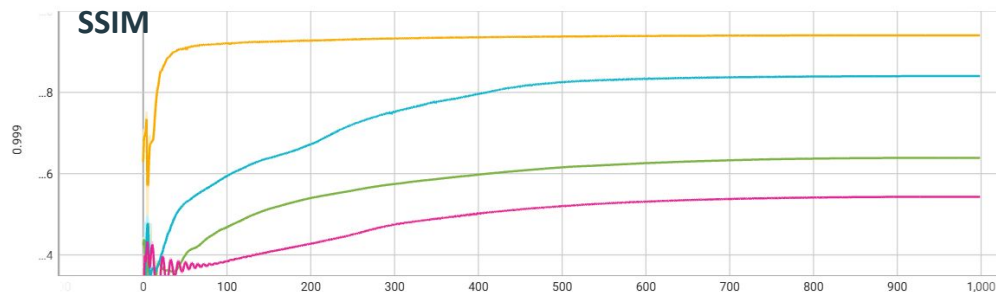
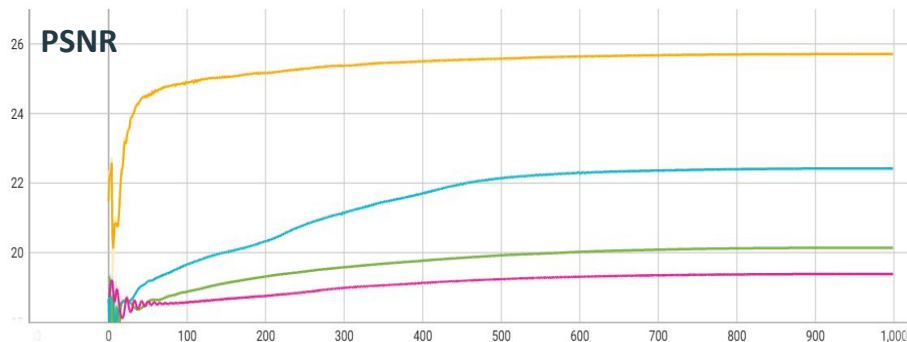
**SUPER
RESOLUTION**



shape:
16x128x128

step of
optimization: 990

Metrics plots: PSNR and SSIM



Conclusion and future goals

1. A 3D LDM for radio astronomical data cube with conditioning has been developed;
2. The model is a novelty in the ML field with radio astronomical data;
3. The memory usage has been optimized thanks to the latent approach.

Future goals include:

- integration of this model in visual analytics (VisIVO) and immersive visualization (iDAVIE) tools in order to help the scientists in the data analysis and source finding, through the HR data reconstruction.
- improvement of the conditional mechanism.

Thank you for your attention!

Questions?