Cosmic Ray Detection

References

Cosmic Ray Rejection with Attention Augmented Deep Learning - https://arxiv.org/pdf/2207.10411

deepCR - https://arxiv.org/pdf/1907.09500

Cosmic CONN - https://arxiv.org/pdf/2106.14922

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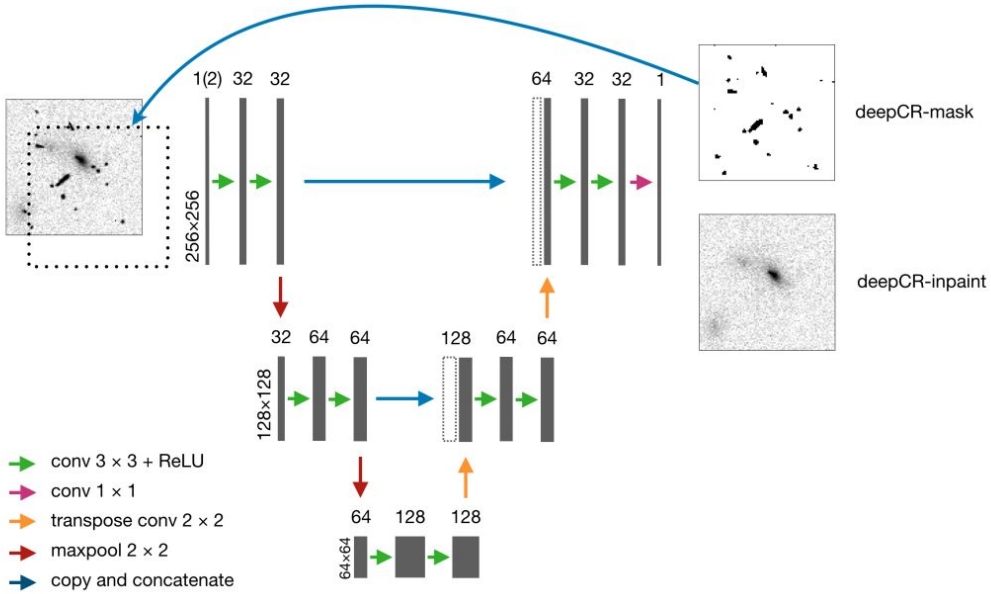
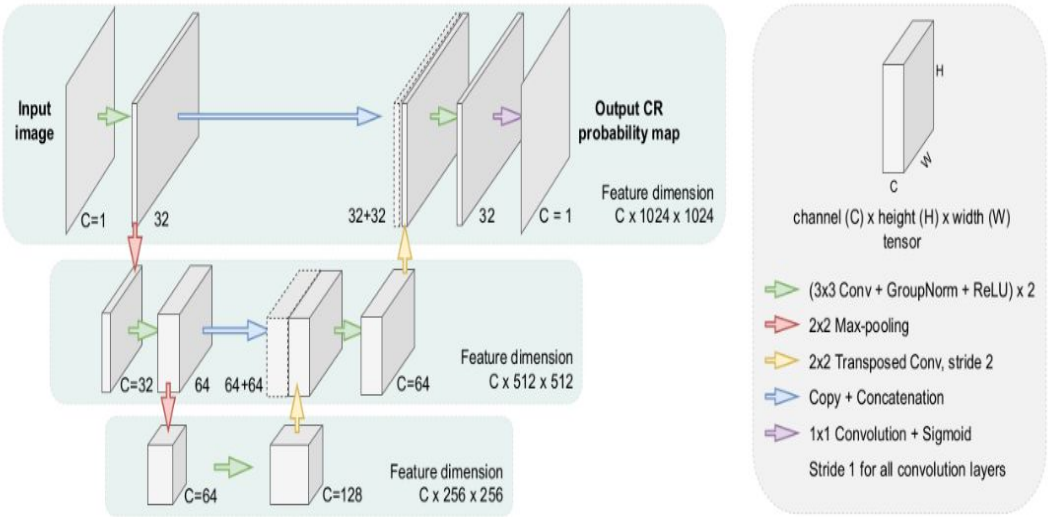


DeepCr - UNet

Trained HST ACS/WFC imaging data of 3 categories

- extragalactic field
- globular cluster
- local group galaxies

Improves on previously SOTA techniques like LA-Cosmic



Cosmic-CoNN UNet

- Trained on data from LCO (Las Cumbres Observatory) global network of 23 telescopes
- Median Weighted Loss Function
- Training on 1024x1024 images
- Group Normalization

Cosmic-CoNN Deep Learning Framework

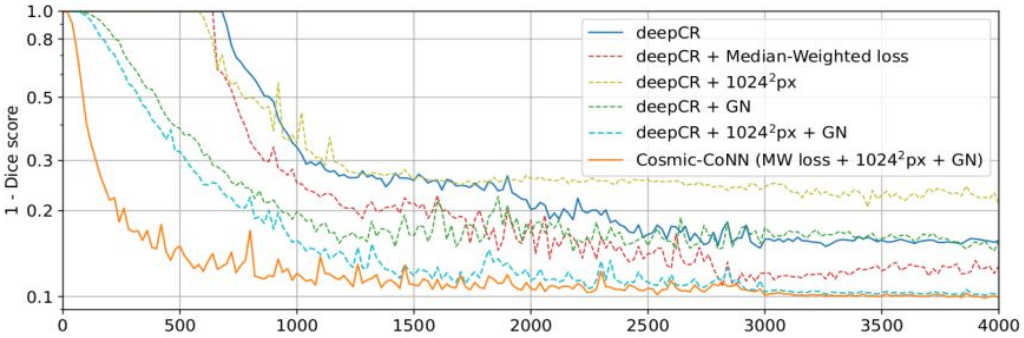
Median Weighted Loss Function :

$$L(P, Y, M) = -\sum_{i,j}(Y_{ij}log(P_{ij}) + M_{ij}(1 - Y_{ij})log(1 - P_{ij}))$$

where P,Y, M are the predictions, labels and median weighted mask Respectively
Median Mask obtained from transformation on the median of consecutive exposures

- sky subtraction
- clipping 1-5 σ's
- Gaussian Smoothing (5x5 Kernel with σ = 2)
- Unit Normalisation and Clamping with lower bound (α)

Cosmic CONN Results



Dice Score vs Epochs for different types of models

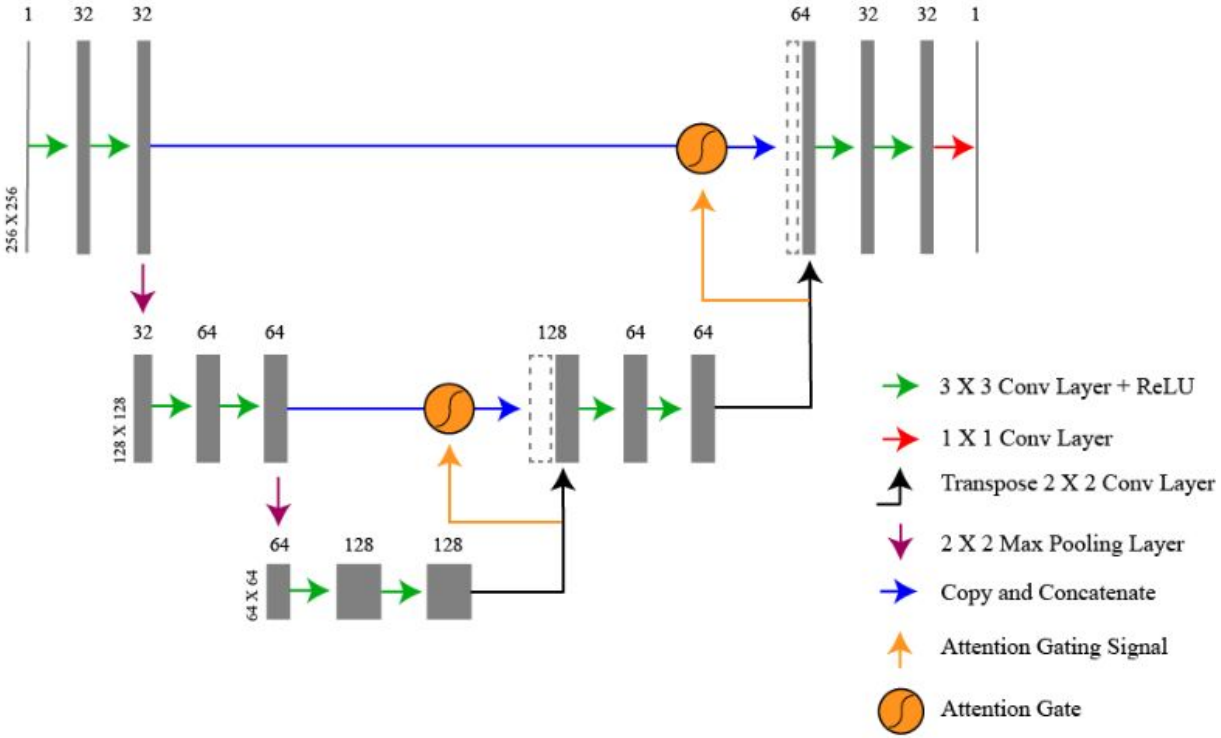
Method	Dice score > 0.85	LCO Precision	Gemini 1×1 Precision	Gemini 2×2 Precision
deepCR (baseline)	2980	89.19%	79.59%	84.88%
deepCR + Median-Weighted loss	2080	92.98%	78.76%	83.08%
deepCR + 1024^2px	n/a	89.35%	82.57%	86.55%
deepCR + GN	1420	90.82%	77.07%	89.30%
deepCR + 1024^2px + GN	1040	93.17%	84.54%	92.09%
Cosmic-CoNN (MW loss + 1024^2px + GN)	**380**	**93.40%**	**86.80%**	**94.37%**

Number of epochs to achieve Dice Score > 0.85 and Precision at 95 % Recall

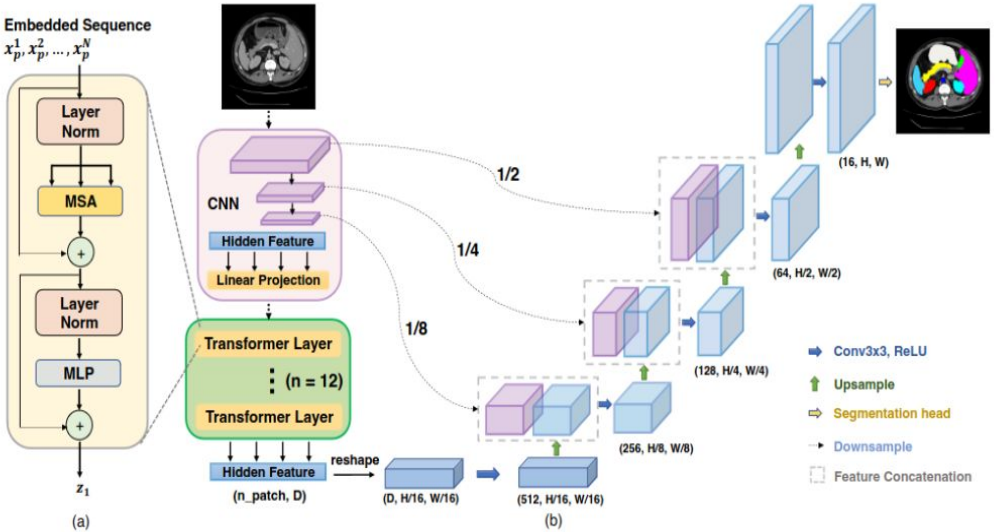
Decam Data

- Train : 50 images from each band (g,r,i,z)
- Test : 14 images from each band (g,r,i,z)
- Each image - 2k x 4k - 128
- 23040 Training and 2560 Validation patches (90% - 10 % Split)
- 7168 Test Patches
- Synthetically generated CR Hits

Attention UNet



TransUNet Architecture



TransUNet: Transformers Make Strong Encoders for Medical Image Segmentation - Chen et al.

Parameters used in Original Paper

ResNet-50 + ViT Encoder

- Base ViT :Input resolution – (224,224)
- P = 16, D = 768
- MLP size = 3072
- No. of layers = 12
- No. of heads = 12
- Cascading Upsampler (CUP) Decoder
- Bilinear Upsampling
- Concatenate features from ResNet encoder

Training

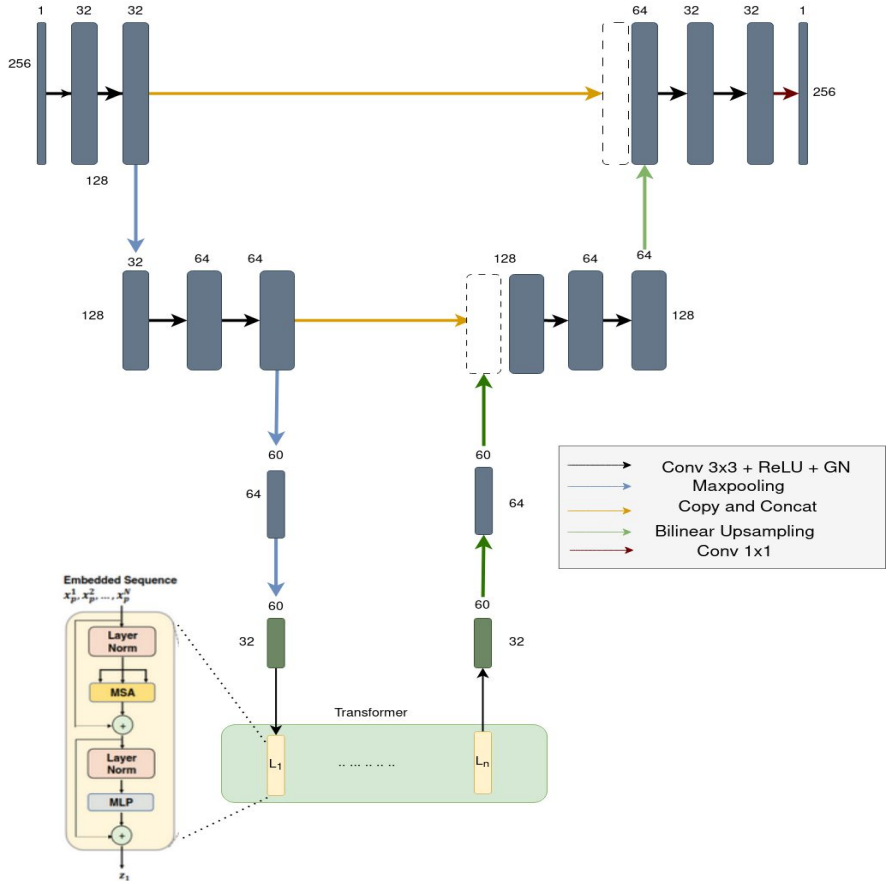
- SGD with learning rate 0.01, momentum 0.9
- Weight decay 1e-4

Model Architecture
Small TransUNet

Hyperparameters:

- Hidden dim : 60
- MLP Dim : 64
- Number of Transformer Layers : 6
- Number of Attention Heads :6

Group Normalization instead of Batch Normalization is leading to better performance



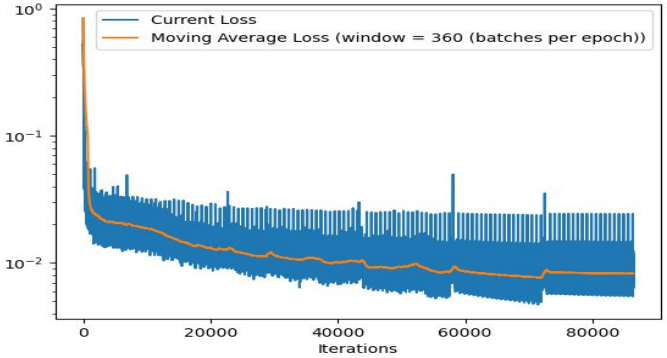
RESULTS ON VALIDATION AND TEST SET

	Transformer Hyperparameters				Validation Set		Test Set	
Model	Attention Heads	Number of Layers	MLP Hidden Dim	Number of Parameters	Dice Score	TPR @ 0.01% FPR	Dice Score	TPR @ 0.01% FPR
deepcr_UNet	-	-	-	467233	0.960542	0.967410042	0.948221	0.9733
UNet	-	-	-	517889	0.966542	0.9751	0.954971	0.9781
Cosmic CoNN				466593	0.963951	0.9701	0.956387	0.976335
Att_UNet				465953	0.96486	0.9726	0.958781	0.9768
TUNet_2	12	12	100	638449	0.970698	0.9798	0.966935	0.9835
TUNet_3	6	6	100	476209	0.972248	0.9798	0.969509	0.9865
TUNet_4	6	6	64	450073	0.97175	0.9811	0.968877	0.9858
TUNet_9	12	6	64	450073	0.971124	0.98	0.966957	0.9853
TUNet_5	6	6	128	496537	0.970352	0.9787	0.963908	0.984
TUNet_6	6	8	64	495441	0.972432	0.9812	0.96857	0.9856

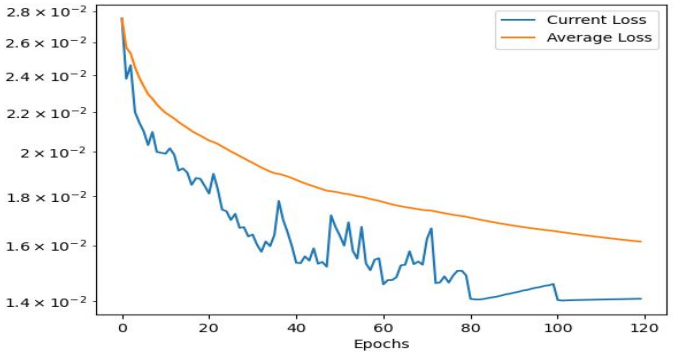
Training:

- Adam Optimizer
- Starting Learning Rate = 0.001
- Manually Reduced LR by 0.001 by monitoring validation loss
- Loss Function = (1-Dice Score +BCE Loss)/2 - leads to faster convergence

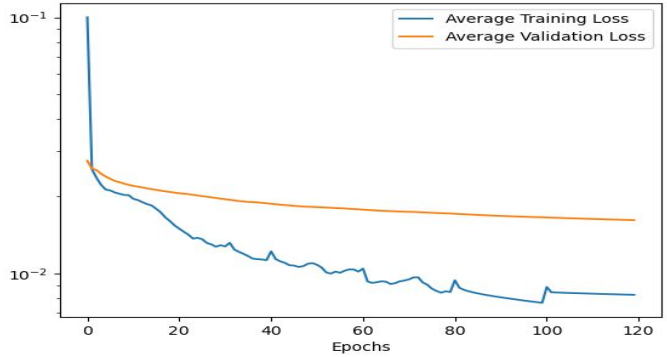
Plots



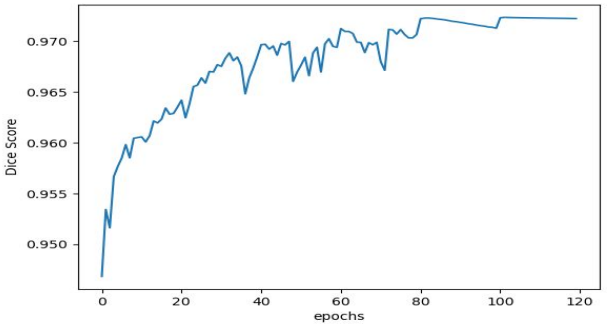
Training Loss



Validation Loss

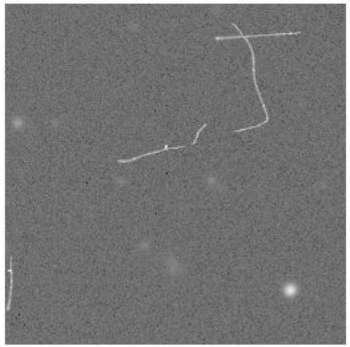


Train vs Validation Loss



Dice Score

Prediction Maps



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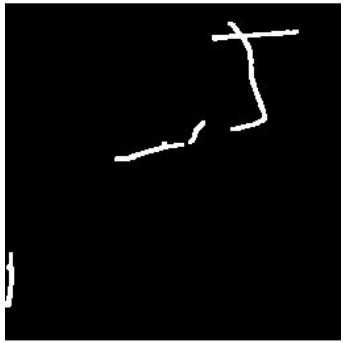
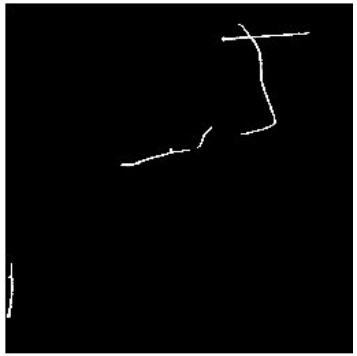
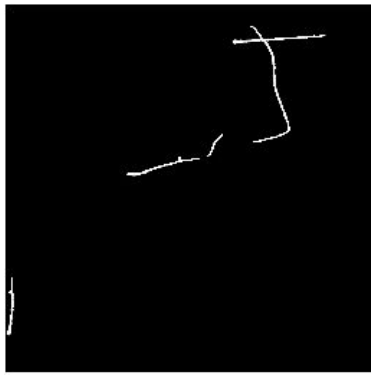


Mask

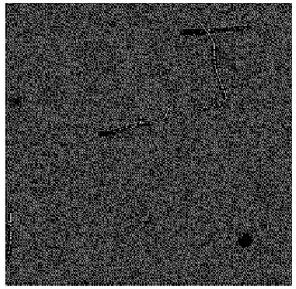
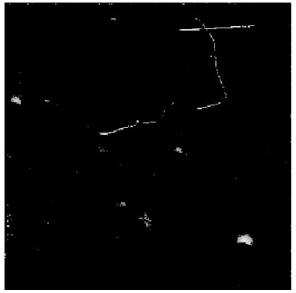
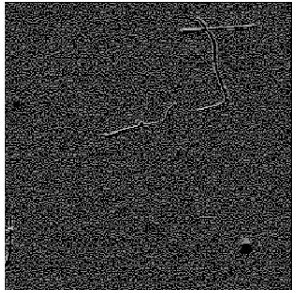
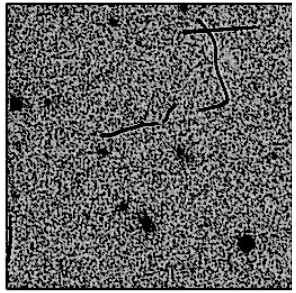
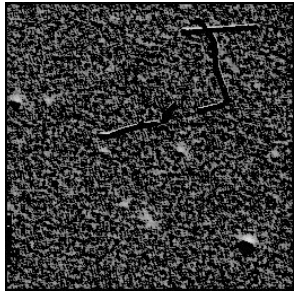
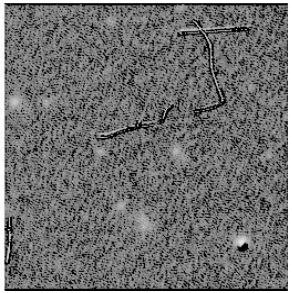
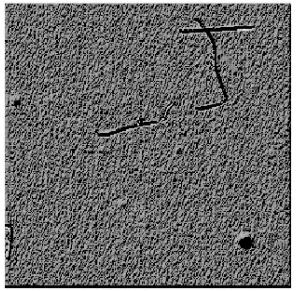


TransUNet

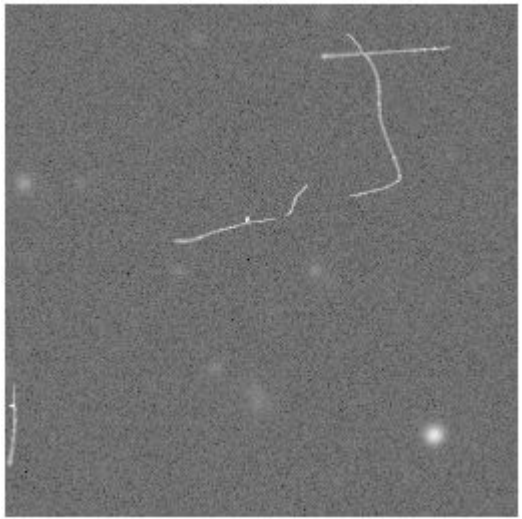


UNet

Activation Maps

	Layer 5	Layer 14	Layer 21	Layer 31
UNet				
TransUNet				

Mean Activation Map



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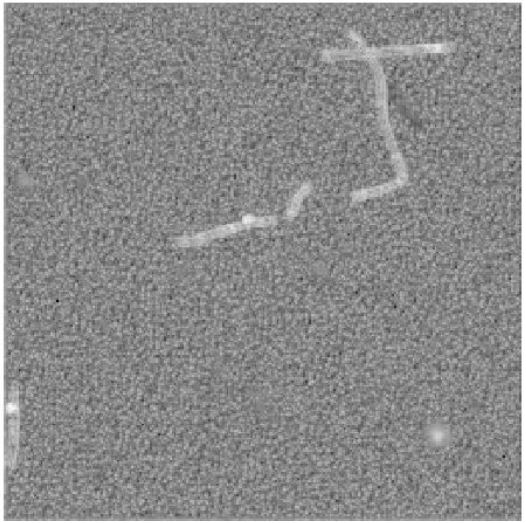


UNet

TransUNet

LCO Dataset

Train

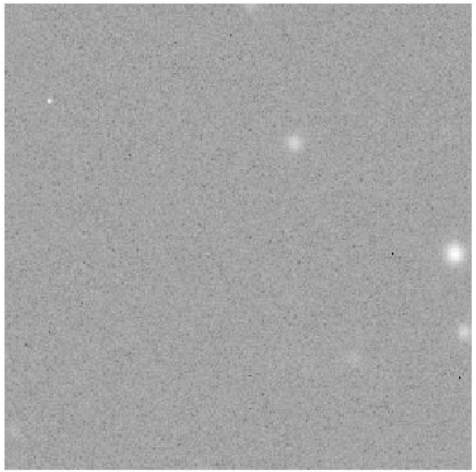
0.4m 576*3

1m 670*3

2m 141*3

Total = 4161

Test - 119*3 = 357



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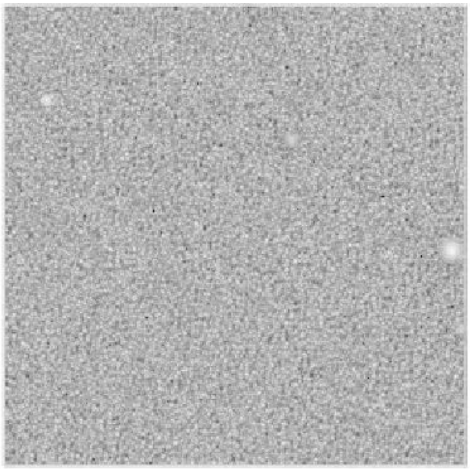

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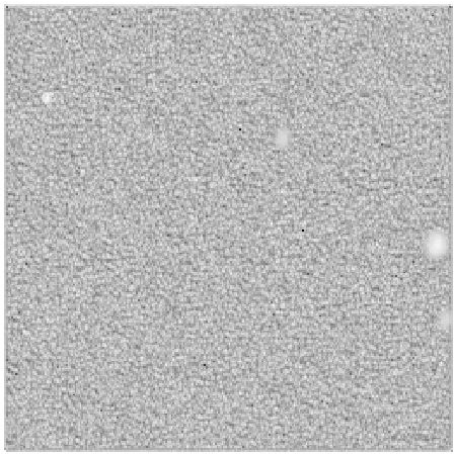

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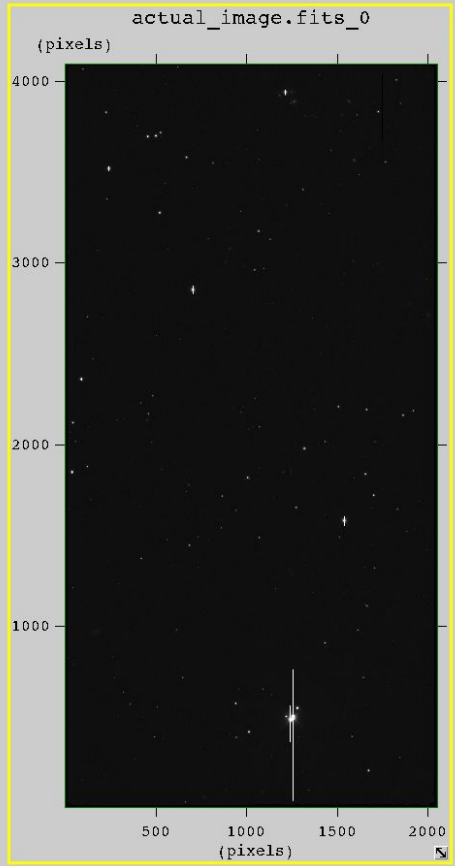
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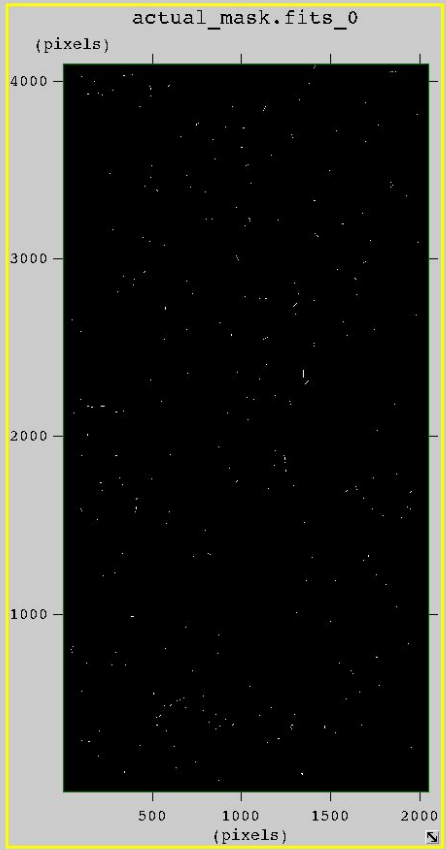
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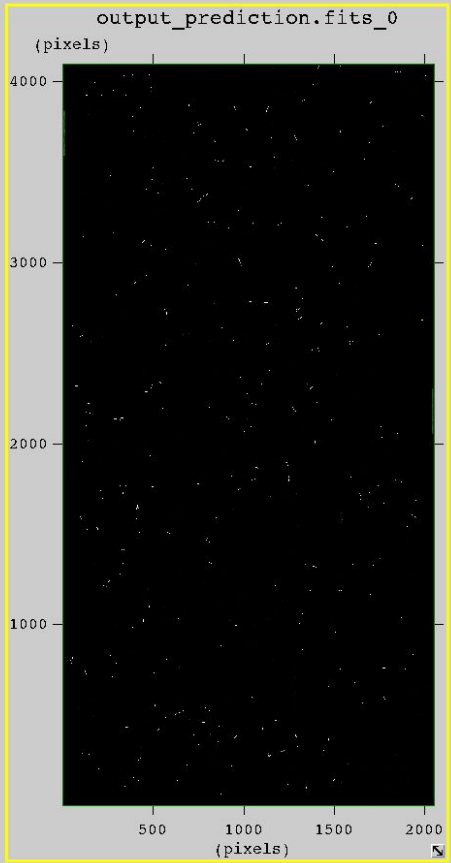
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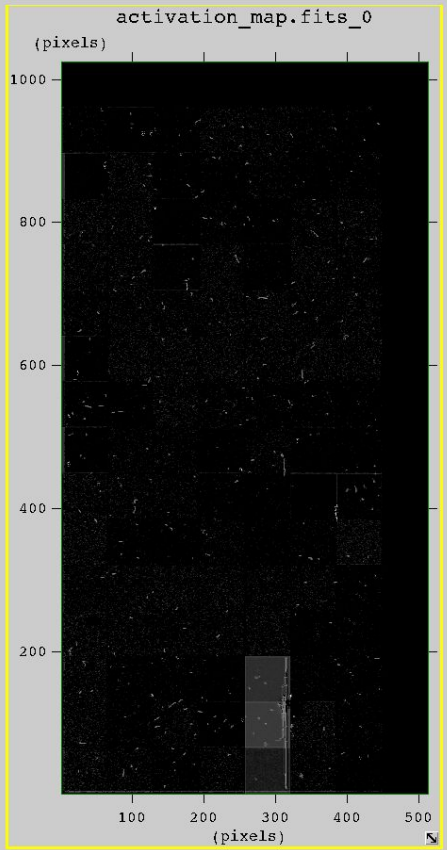
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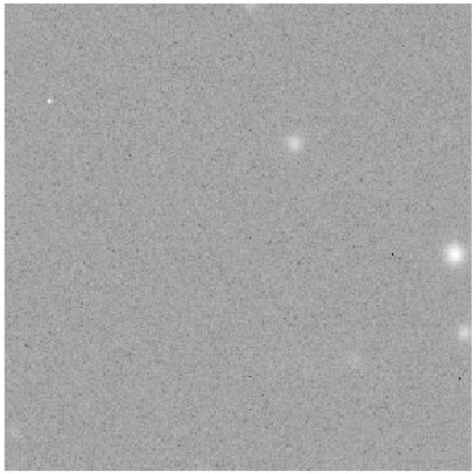

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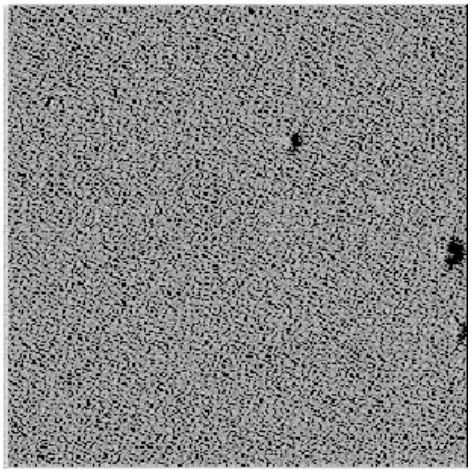

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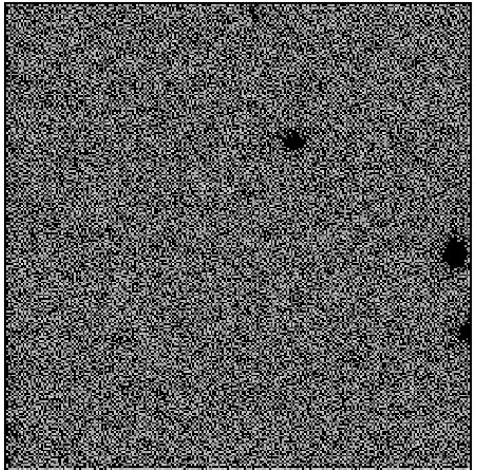

TransUNet