ENHANCING SPACE SURVEILLANCE THROUGH THE UNISTELLAR COLLABORATIVE OBSERVATION PROGRAM

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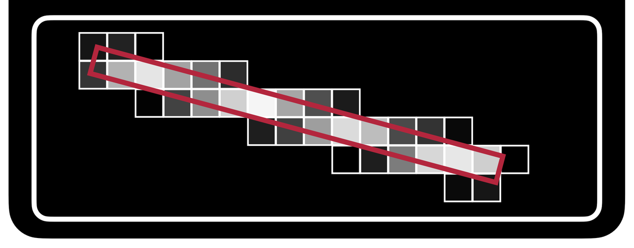
SIMULATIONS

Composite images simulated with our Python library **OrbitAI**

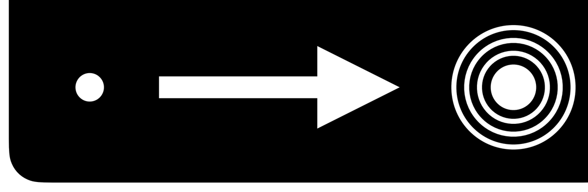
SCENE

A pixelized satellite streak



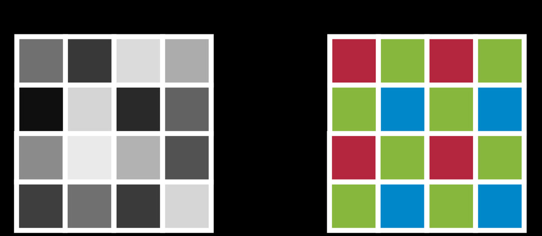
TELESCOPE

Gathers light from the SCENE - Fourier Optics



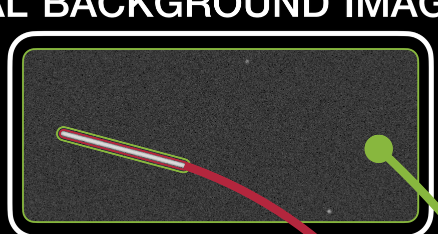
DETECTOR

Add Noise / Bayer Matrix



ADDITION

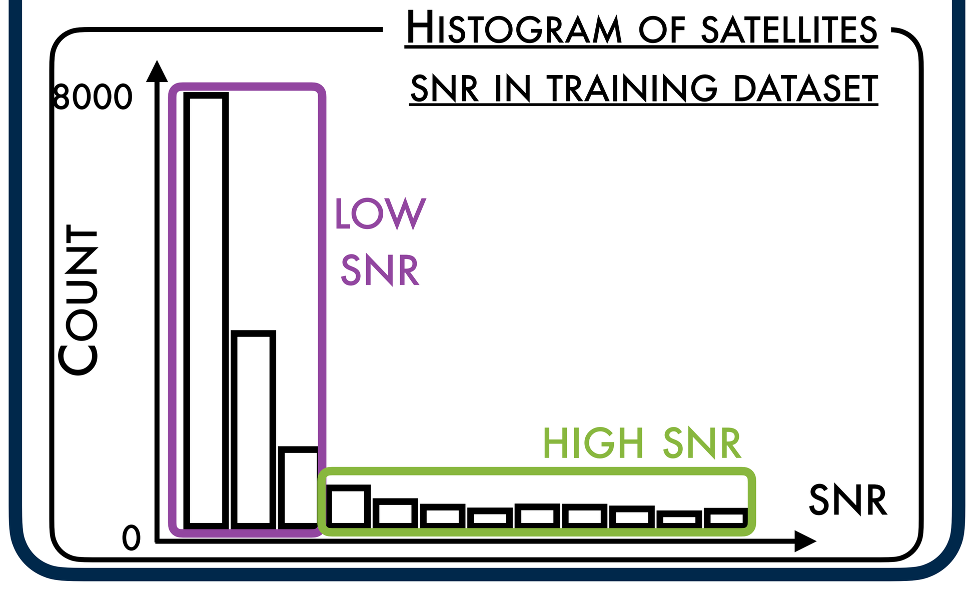
Add the STREAK onto a real background image



DEFINITIONS

The **SIGNAL-TO-NOISE RATIO** is defined as $SNR = \frac{\text{FLUX IN THE STREAK}}{\text{STD OF SKY BACKGROUND}}$

Histogram of satellites SNR in training dataset



THE PROJECT

The goal is to detect **LEO-SATELLITES** from images acquired by the Unistellar collaborative observation program using **NEURAL NETWORKS**. Our method aims at improving efficiency at low **SNR** compared to standard algorithms.

THE DATA

Short exposure frames gathered from the worldwide highly active UNISTELLAR community == database is growing fast ! ❤️

THE METHOD

Use two sequential networks to make the detection

(1) **classification** - is there a streak in the image ?

(2) **segmentation** - which pixels are affected by the satellite streak ?

(1)CLASSIFICATION

*We want to tell **if** a satellite is present in the image.*

Cutouts are used due to the relatively large dimensions of images inputs

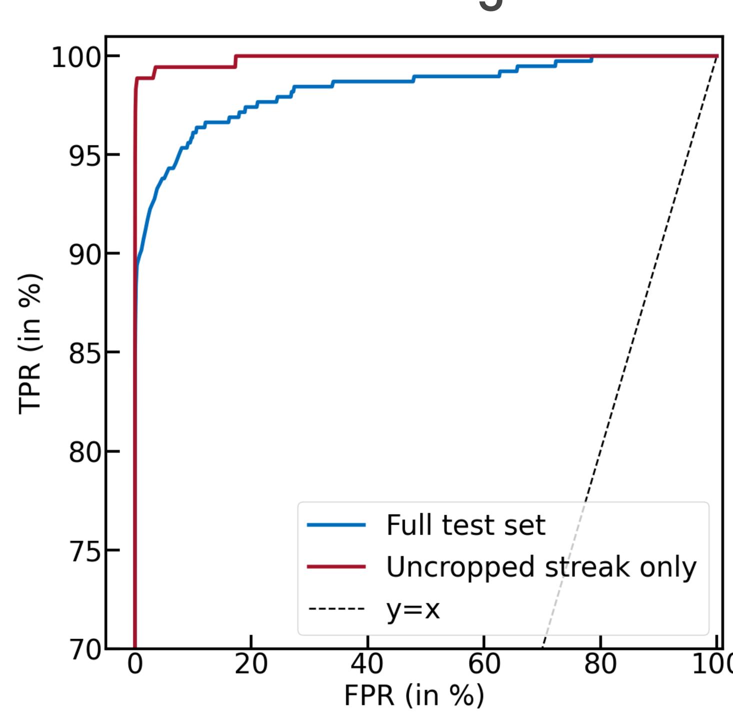
We train the CNN on small cutouts and apply to the larger telescope images using sliding windows

THE NETWORK IS TESTED ON REAL OBSERVATIONS

Images gathered through the Unistellar satellite program are classified with the CNN. We use 387 test images with satellite streak (positives) and 23283 test images without satellite streak (negatives).

THE ROC CURVES ARE SATISFYING

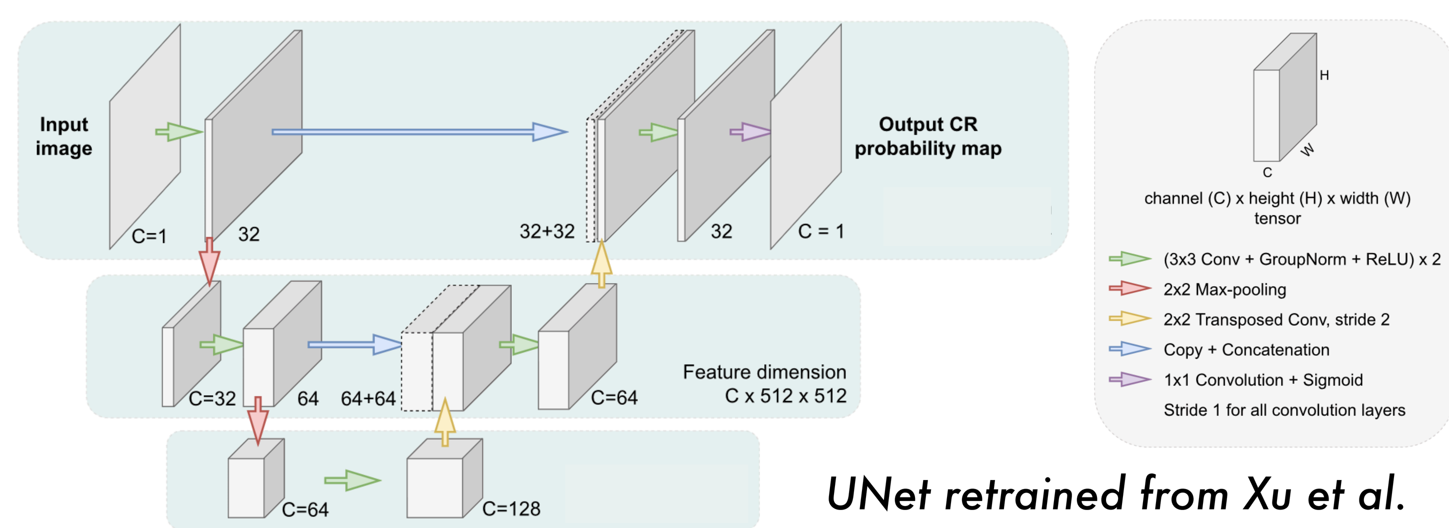
90% TPR @ 1% FPR for all levels of SNR. The performance lowers when including partial streaks cropped by the sensor.



(2)SEGMENTATION

We want to reconstruct the satellite streak to measure its orbital parameters

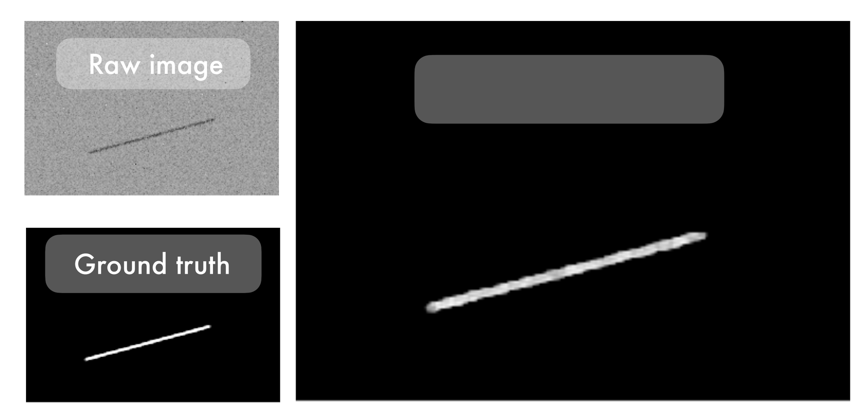
THE NETWORK WE USE



UNet retrained from Xu et al.

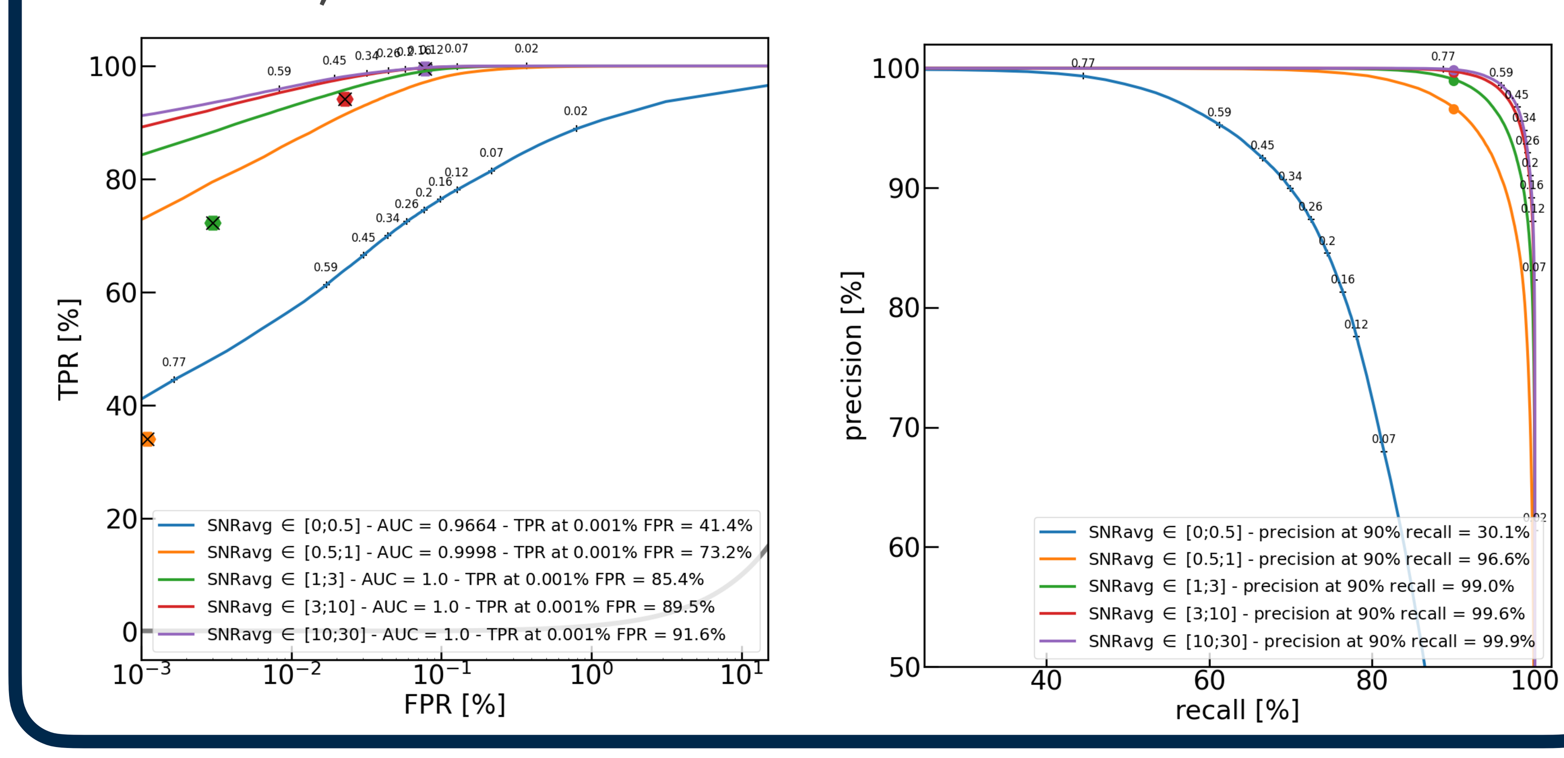
THE NETWORK IS TESTED ON COMPOSITE SIMULATIONS

for which we know the ground-truth masks



PERFORMANCES ARE ONLY LIMITED BY THE SNR OF THE SATELLITE STREAK

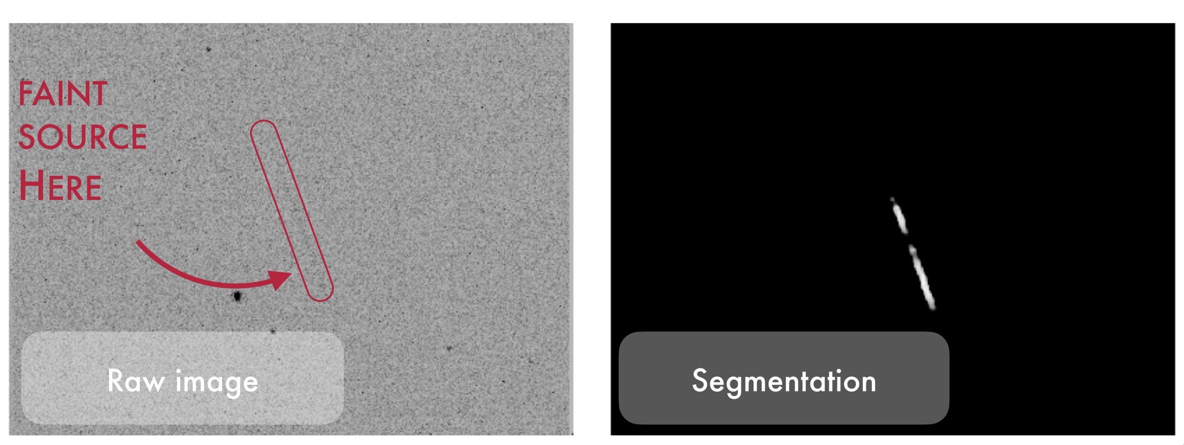
Performances do not dependent on r_0, streak length, number of stars in field, etc.



ON-GOING WORK

IMPROVE PERFORMANCES AT LOWER SNR

Build dedicated network to perform better for fainter targets.



REFERENCES

[1] Zhang, K. and Bloom, J. S., "deepCR: Cosmic Ray Rejection with Deep Learning,"Astrophysical Journal 889, 24 (Jan. 2020).
[2] Xu, C. Et al., "Cosmic-CoNN: A Cosmic-Ray DetectionDeep-learning Framework, Data Set, and Toolkit,"Astrophysical Journal942, 73 (Jan. 2023).
[3] Kruk, S. et al., "Hubble Asteroid Hunter.I. Identifying asteroid trails in Hubble Space Telescope images,"Astronomy and Astrophysics661, A85(May 2022).
[4] Zavagno, A., et al., "Supervised machine learningon Galactic filaments. Revealing the filamentary structure of the Galactic interstellar medium", Astronomy and Astrophysics 669, A120 (Jan. 2023).
[5] Bertin, E. and Arnouts, S., "SExtractor: Software for source extraction.", Astronomy and Astrophysics,Supplement117, 393–404 (June 1996).
[6] Paillassa, M., Bertin, E., and Bouy, H., "MAXIMASK and MAXITRACK: Two new tools for identifying contaminants in astronomical images using convolutional neural networks,"Astronomy and Astro-physics634, A48 (Feb. 2020).
[7] Recio-Blanco, A., et al. "Gaia Data Release 3. Analysis of RVS spectra using the General Stellar Parametriser from spectroscopy", Astronomy and Astrophysics674, A29 (June 2023).
[8] Konnik, M. and Welsh, J., "High-level numerical simulations of noise in ccd and cmos photosensors: review and tutorial," (12 2014).
[9] Krizhevsky, A., Sutskever, I., and Hinton, G. E., "Imagenet classification with deep convolutional neuralnetworks," in [Advances in Neural Information Processing Systems], Pereira, F., Burges, C., Bottou, L.,and Weinberger, K., eds.,25, Curran Associates, Inc. (2012).
[10] Ronneberger, O., Fischer, P., and Brox, T., "U-net: Convolutional networks for biomedical image segmentation," (2015).