Reducing the ATHENA WFI background

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Motivation and Overview

- **WFI:** Detector system on Athena (an satellite observatory)
- **Purpose:** Distinguish between particles (protons) and X-ray photons. Eliminate particle background.
- **Input:** 500 by 500 gray scale image
- **Output:** 500 by 500 gray scale image

Data

- **GEANT4:** Particle simulation database [1]
- **SIXTE:** X-ray photon simulation database [2]

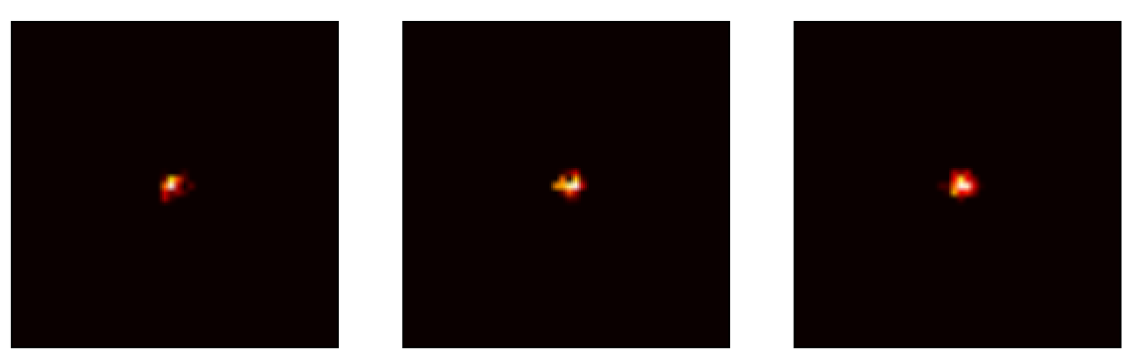


Figure: Typical X-ray Photon patterns

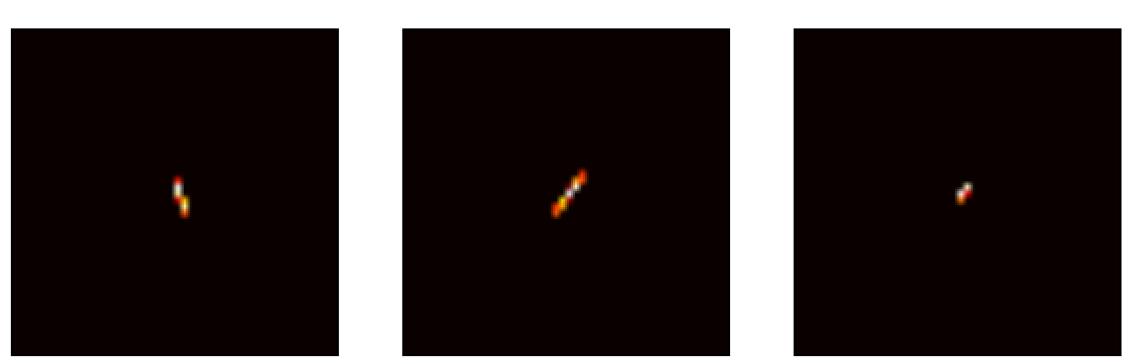


Figure: Typical Particle patterns

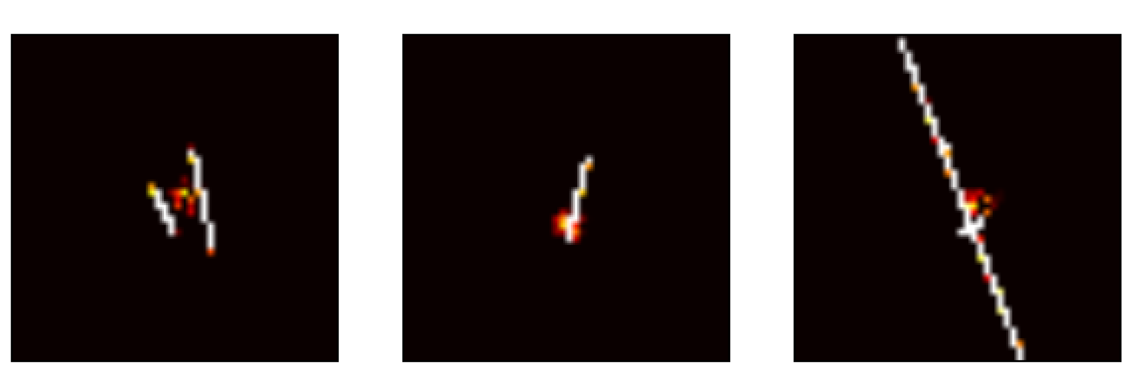


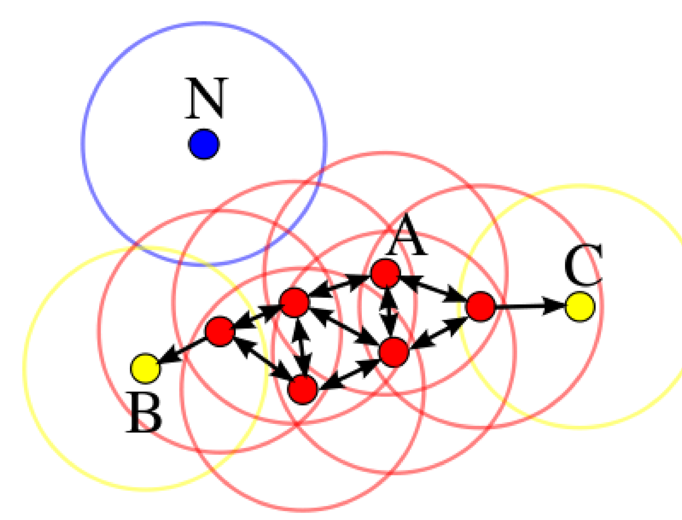
Figure: Train samples for the neural network

Models

First Step: DBSCAN [3]

(Unsupervised Learning)

- **Core point:** A point that has at least $minPts$ neighbor points within its ϵ radius.
- **Border point:** A point within the ϵ radius of a core point but has less than $minPts$ other points within its own ϵ radius.
- **Noise point:** A point that is neither a core point or a border point.



Second Step: Neural Network [4]

- **Preprocessing:** Heaviside step function $\mathcal{H}(x)$
- **First Layer:** Flatten Layer. 2d $\rightarrow$ 1d
- **Second Layer:** Fully Connected Layer. 256 Nodes. Activation: Relu
- **Last Layer:** Fully Connected Layer. 1 Node. Activation: Sigmoid

$$a^{[1]} = max\{0, W^{[1]T} x_{flat}\} \quad (1)$$

$$p(y=1) = \frac{1}{1+exp(-W^{[2]T} a^{[1]})} \quad (2)$$

Experiment

1000 test samples, **averaged error: 0.028**

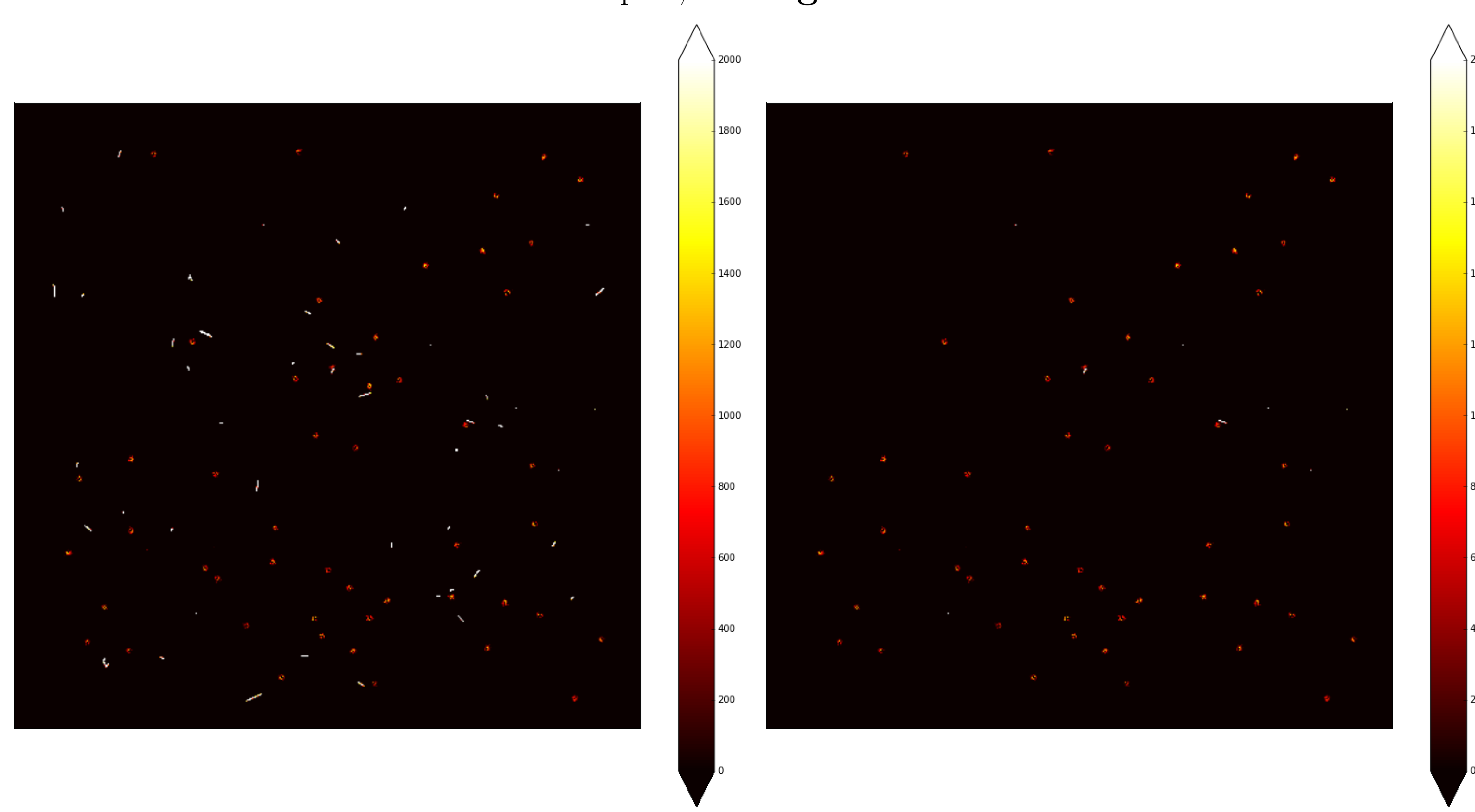


Figure: The left panel shows the image before processing, the right panel shows the image after processing.

Discussions

The energy deposit of a particle is most probably much higher than that of a X-ray photon. The step function preprocessing tremendously improves the accuracy of the neural network, which suggests that **shape** is the key feature for the network to distinguish between particles and photons. In contrast, most existing works use classical algorithms that pay more attention to the **energy value** of pixels to distinguish [5].

Future Work

- Run the algorithm on real dataset
- Analyze overlapping photon and particles.

References

[1] Agostinelli, Sea, et al. "GEANT4-a simulation toolkit." Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment 506.3 (2003): 250-303.

[2] Wilms, Jorn, et al. "ATHENA end-to-end simulations." Space Telescopes and Instrumentation 2014: Ultraviolet to Gamma Ray. Vol. 9144. International Society for Optics and Photonics, 2014.

[3] Ester, Martin, et al. "A density-based algorithm for discovering clusters in large spatial databases with noise." Kdd. Vol. 96. No. 34. 1996.

[4] Hopfield, John J. "Neural networks and physical systems with emergent collective computational abilities." Proceedings of the national academy of sciences 79.8 (1982): 2554-2558.

[5] von Kienlin, Andreas, et al. "Evaluation of the Athena/WFI instrumental background." Space Telescopes and Instrumentation 2018: Ultraviolet to Gamma Ray. Vol. 10699. International Society for Optics and Photonics, 2018.