An Adaptive Low Pass Algorithm for the Removal of Impulse Noise from Photomultiplier Tube Signal

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Introduction

Photomultiplier tubes are widely used to record photon flux. Photon counting has wide-ranging applications from medical imaging and blood tests to astronomy and microscopy. Under certain conditions, photomultiplier tubes observe discontinuous changes in photon counting independent of the signal being measured. Noise of this type may be sufficiently frequent that resampling is not an option. Thus, noise removal becomes the only possibility to ensure accuracy.

Motivation

Sudden large discontinuities cannot easily be removed using smoothing methods. Therefore, other algorithms must be used to remove this type of noise.

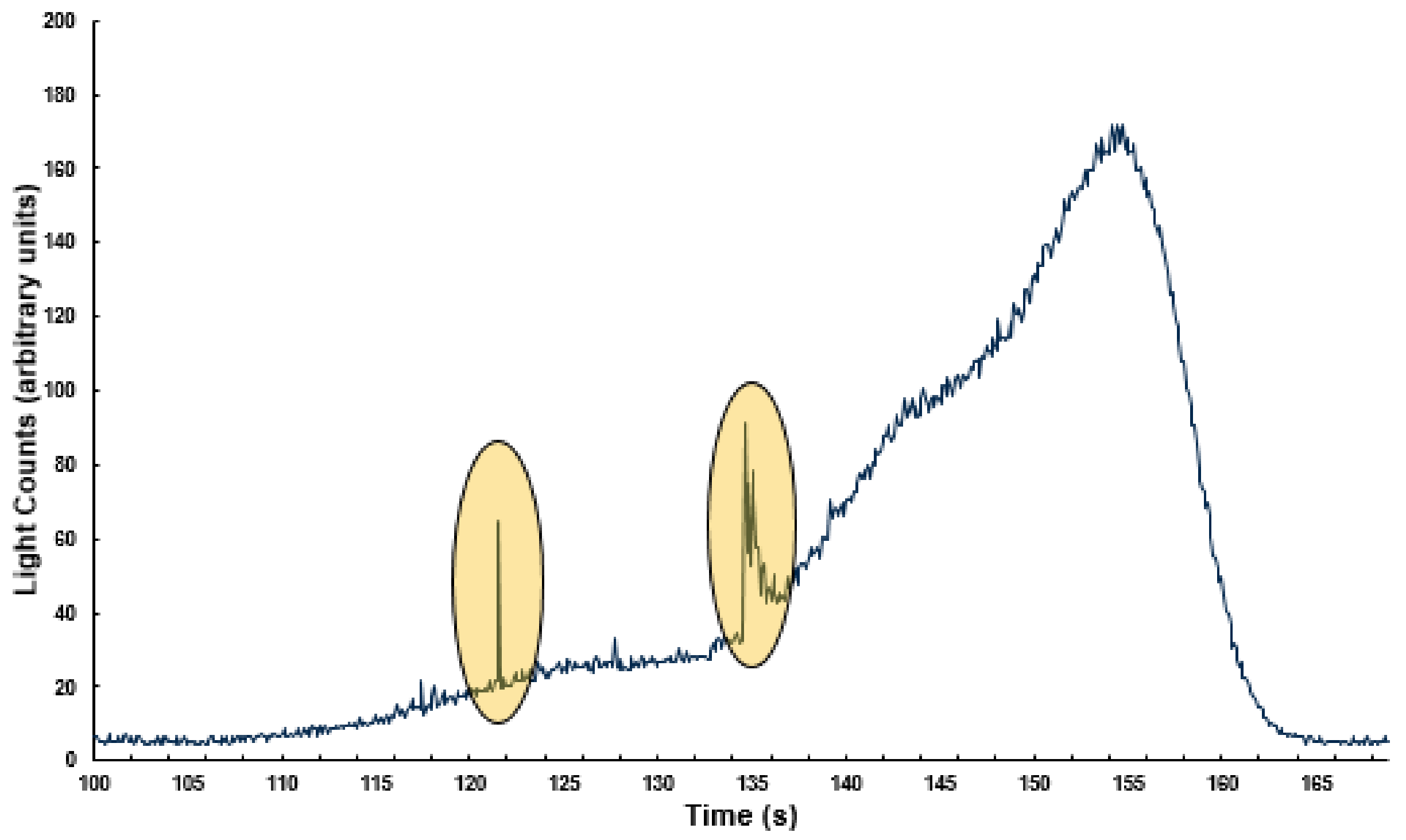

Figure 1: Shown is a measurement from a real photomultiplier tube with impulse noises accented.

Algorithm

1. Traverse input data in linear time, where the time of a linear step is proportional to the number of neighbor points under consideration.
2. Locate discontinuities by creating a low pass filter with an upper limit determined by the arithmetic average, geometric average, or median of neighboring points.
3. Discontinuities are removed using linear interpolation when sufficiently small.

The above algorithm can be repeated iteratively with an increasing number of neighbors and is easily extensible to a band pass setup as well.

Simulation Results

Parametric Analysis:

In order to test the algorithm, $f(x) = 1 - \cos x$ was generated over the region $0 \le x \le 2\pi$ and artificial impulse noise was added.

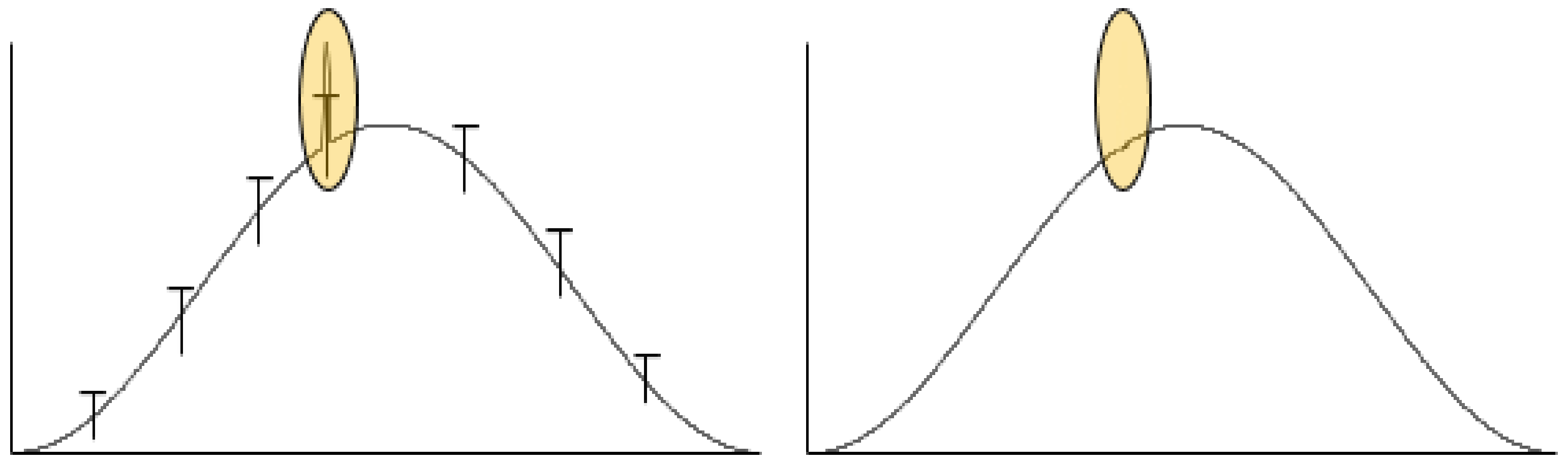

Figure 2: The algorithm runs from left to right checking for discontinuities (left), then linearly corrects the noise (right)

An impulse noise has 3 parameters: height, width, and center point. Parametric analysis of each yields the following plots:

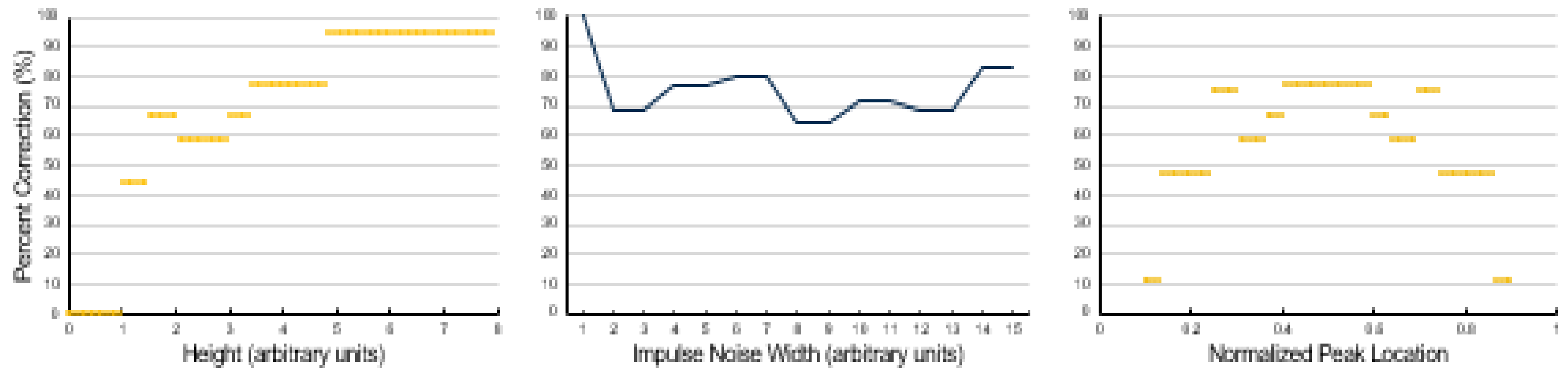

Figure 3: Percent noise removal from the low pass algorithm as a function of spike height (left), spike width (middle), center point location (right)

These results are discontinuous stemming from the inherent discreteness of the linear interpolation. These results show that the algorithm's performance improves with greater height. As expected, the performance is directly dependent on the linearity of the initial signal.

Monte Carlo Method Analysis:

A Monte Carlo method simulation with randomly generated spike parameters was carried out. Each trial included a random number of spikes. As the noise applied increases, the filter correction percentage converges to around 85% independent of the number of spikes. Standard smoothing methods can handle the remaining noise.

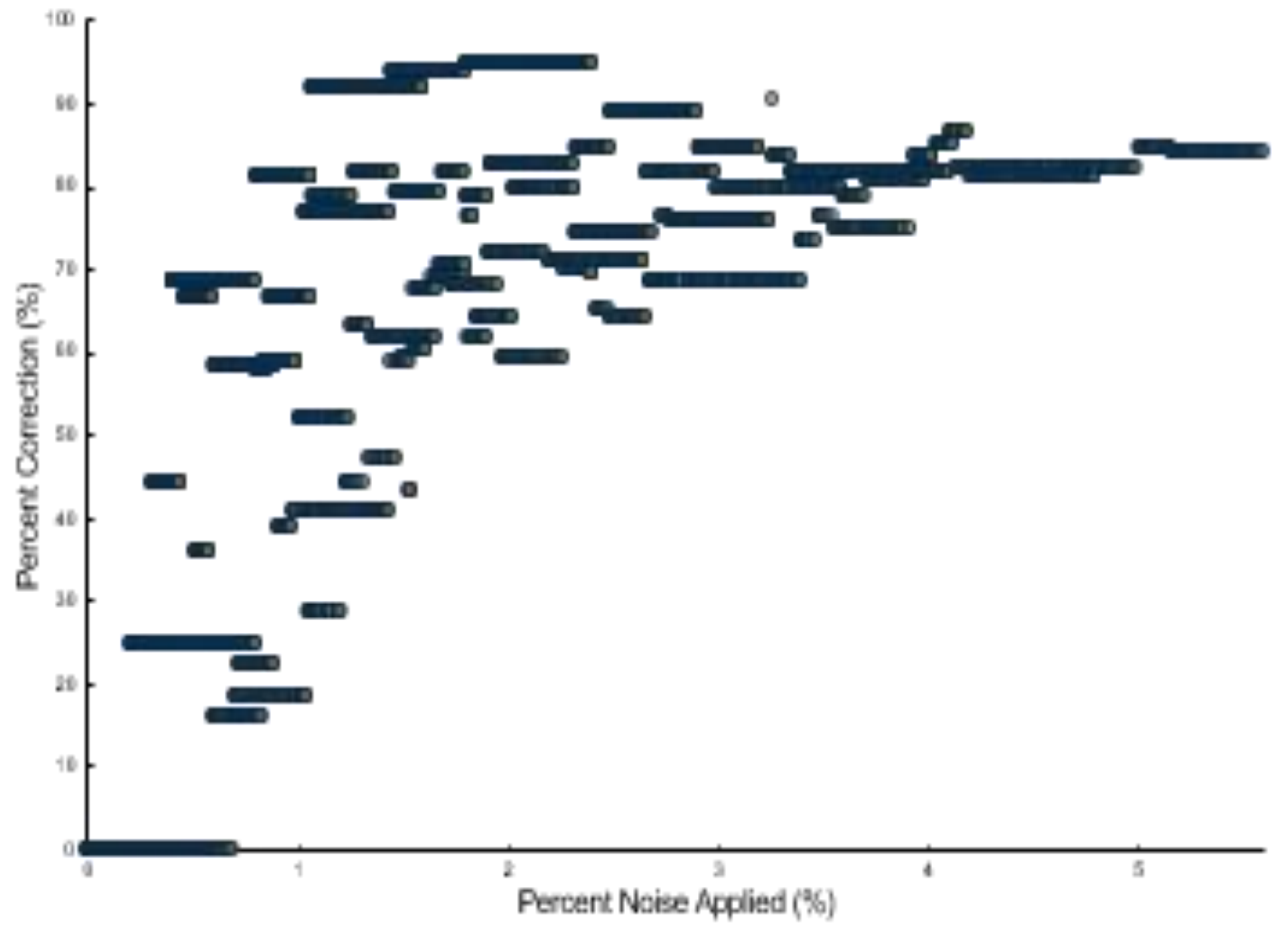

Figure 4: Percent noise removal due to algorithm as a function of noise % randomly applied and sorted

[Poster Code U17]

Experimental Results

Experimental PMT data was tested also. Statistical analysis of this data proved difficult due to inconsistencies in noise parameters. Files were examined by eye and selected results are shown.

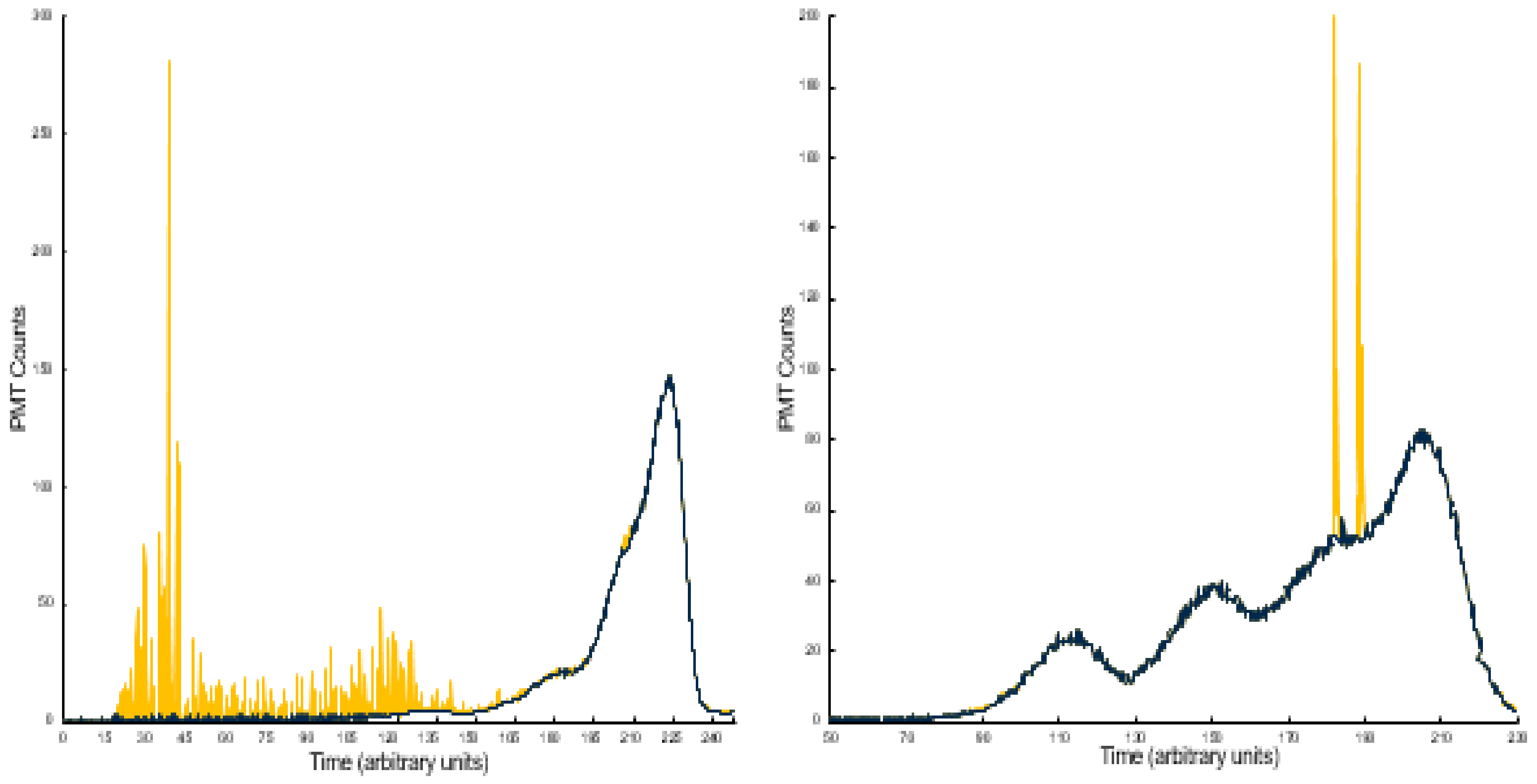

Figure 5: PMT signal after correction (blue) with initial noise shown (maize)

These results are presented to demonstrate the success of this method. The majority of the data is untouched but the large spikes resultant from burning dust are removed. This is intended as a preprocessing step to be done immediately before smoothing.

Acknowledgement

This work was funded in part by the United States Department of Energy National Nuclear Security Administration Consortium for Monitoring, Technology, and Verification award number DE-FOA-0001875.

References

Duraisamy, M., & Narasimman, P. (2017). A Novel Approach for the Removal of Spike Noise from Satellite Milky Way Images. International Journal of Computational Intelligence Research, 13(2), 243-251.

Feuerstein, D., Parker, K., & Boutelle, M. (2009). Practical Methods for Noise Removal: Applications to Spikes, Nonstationary Quasi-Periodic Noise, and Baseline Drift. Analytical Chemistry, 81(12), 4987-4994.

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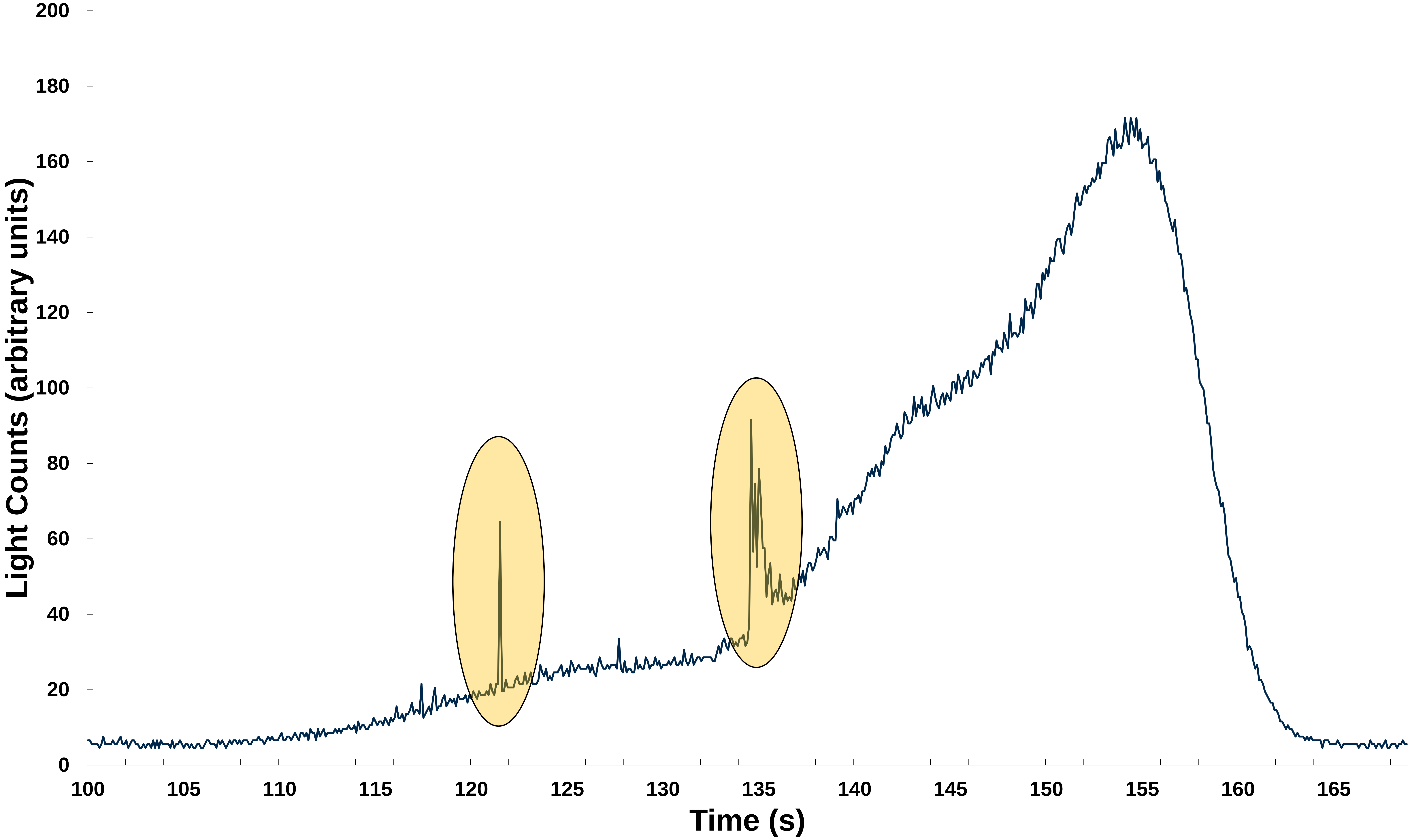

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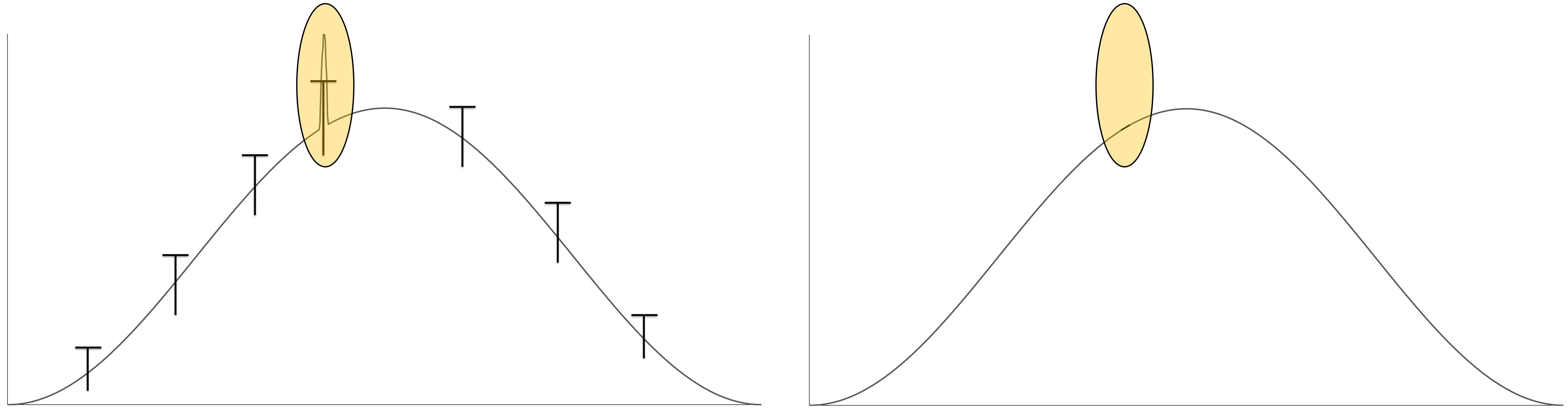

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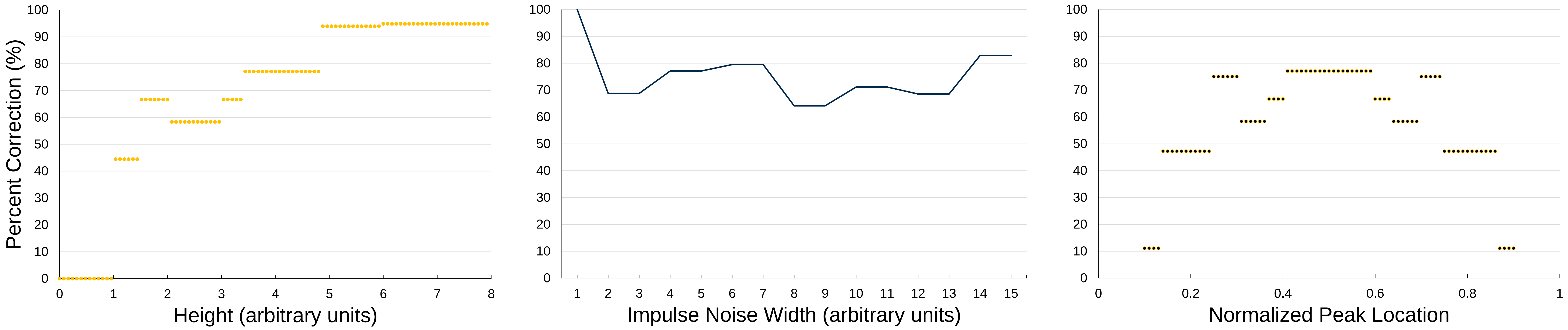

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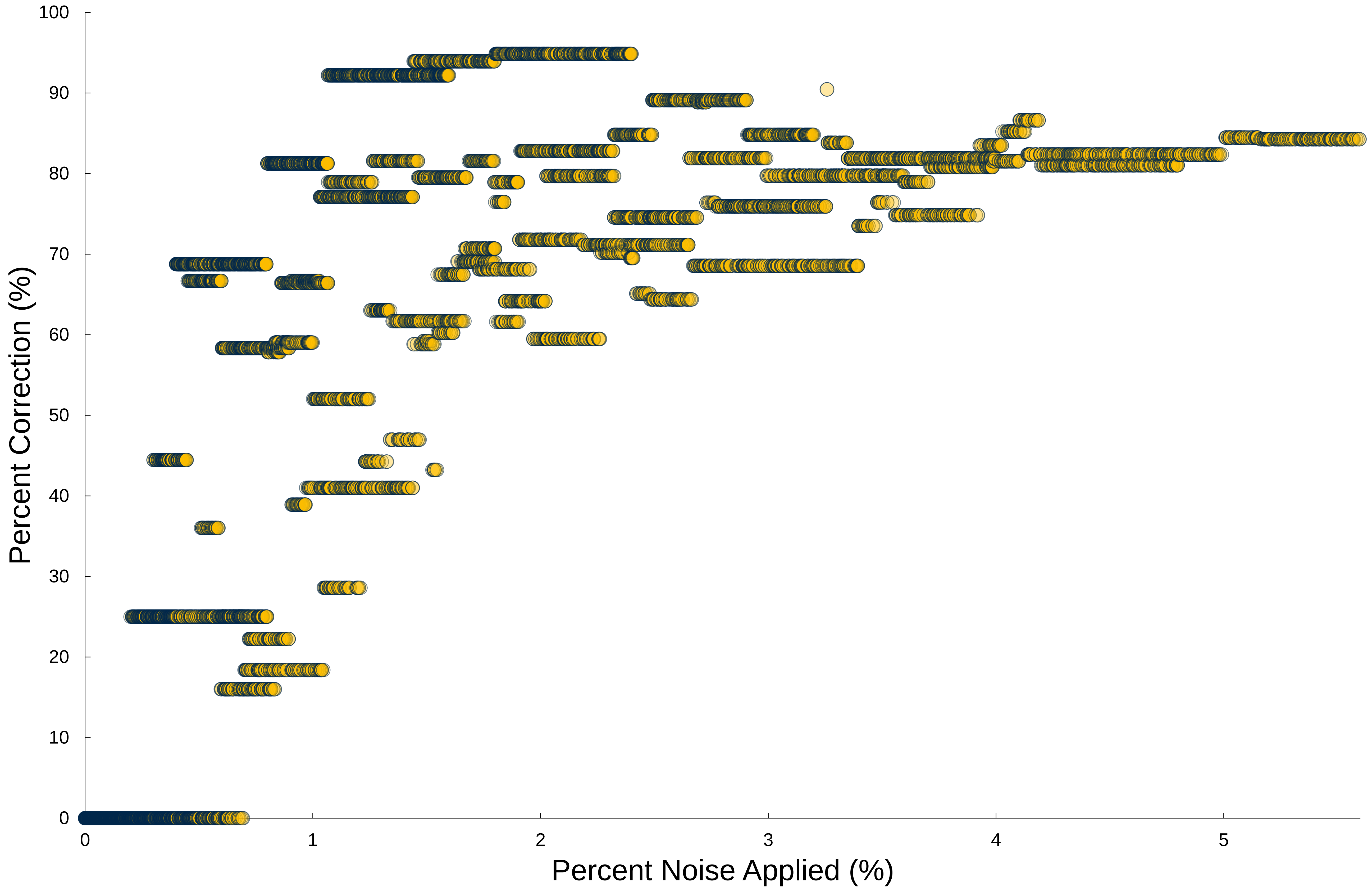

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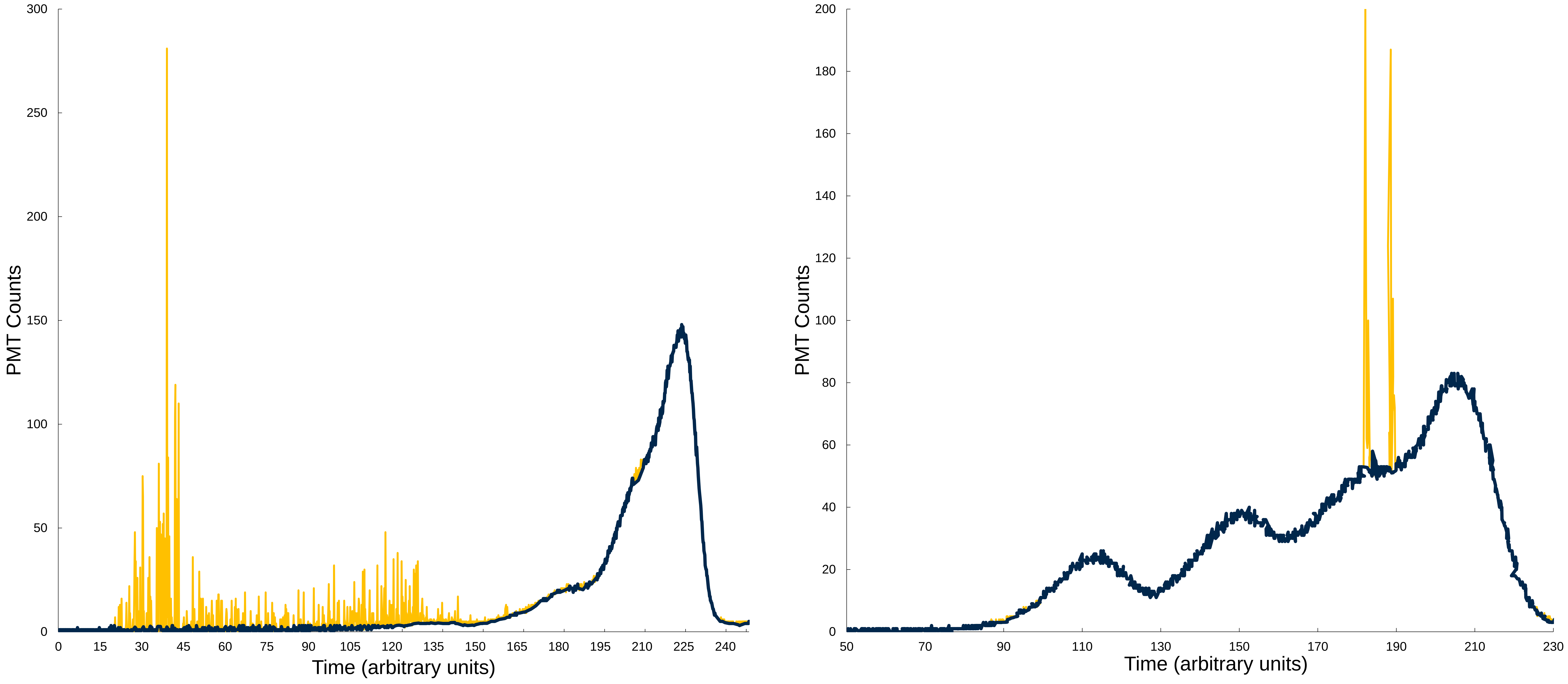

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