ABRA Plans & TIDMAD

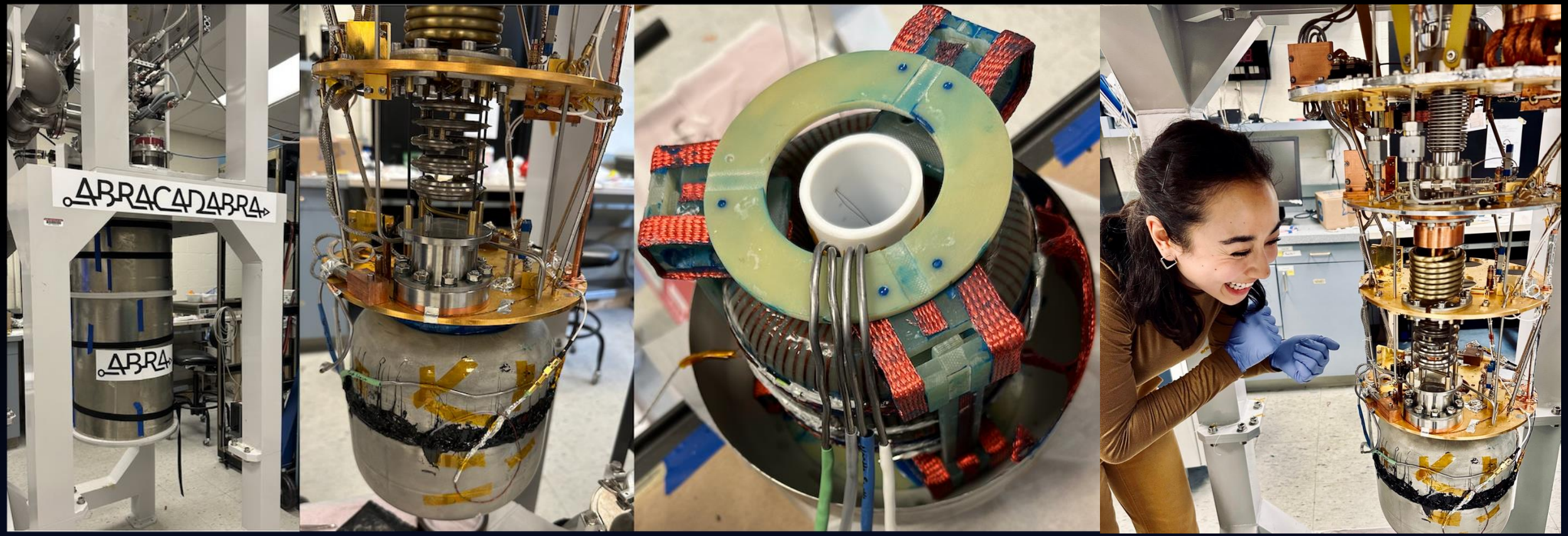
Jessica Fry

DMRadio Collaboration Meeting

October 9, 2025

Outline

1. TIDMAD
2. ABRA plans
3. ML on DMR

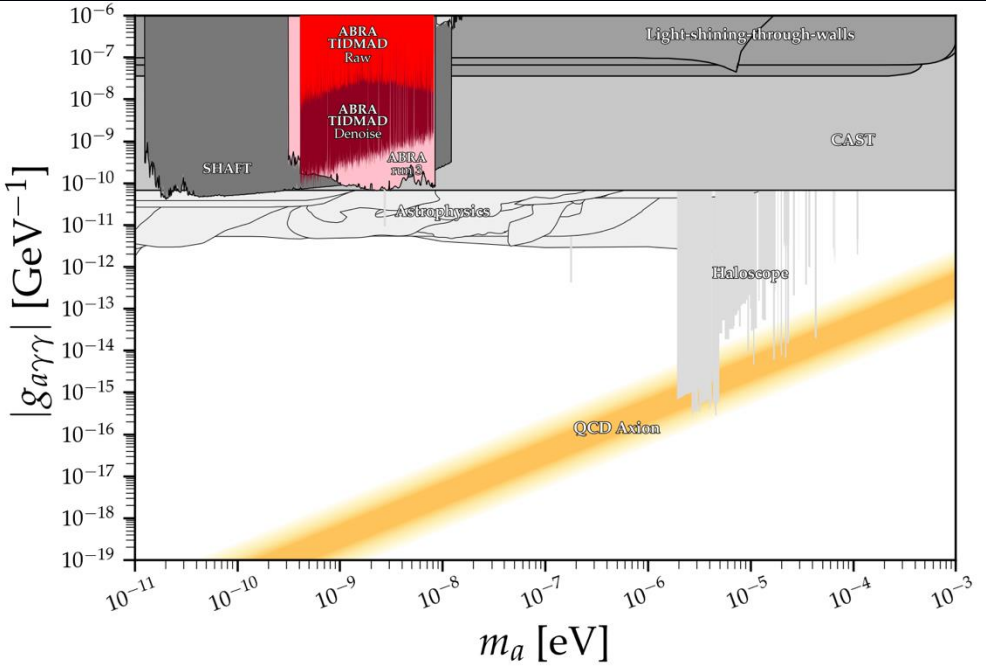


We have a perfectly good detector… what shall we do with it?

Time Series Dataset for Discovering **D**ark **M**atter with **AI** **D**enoising

2406.04378

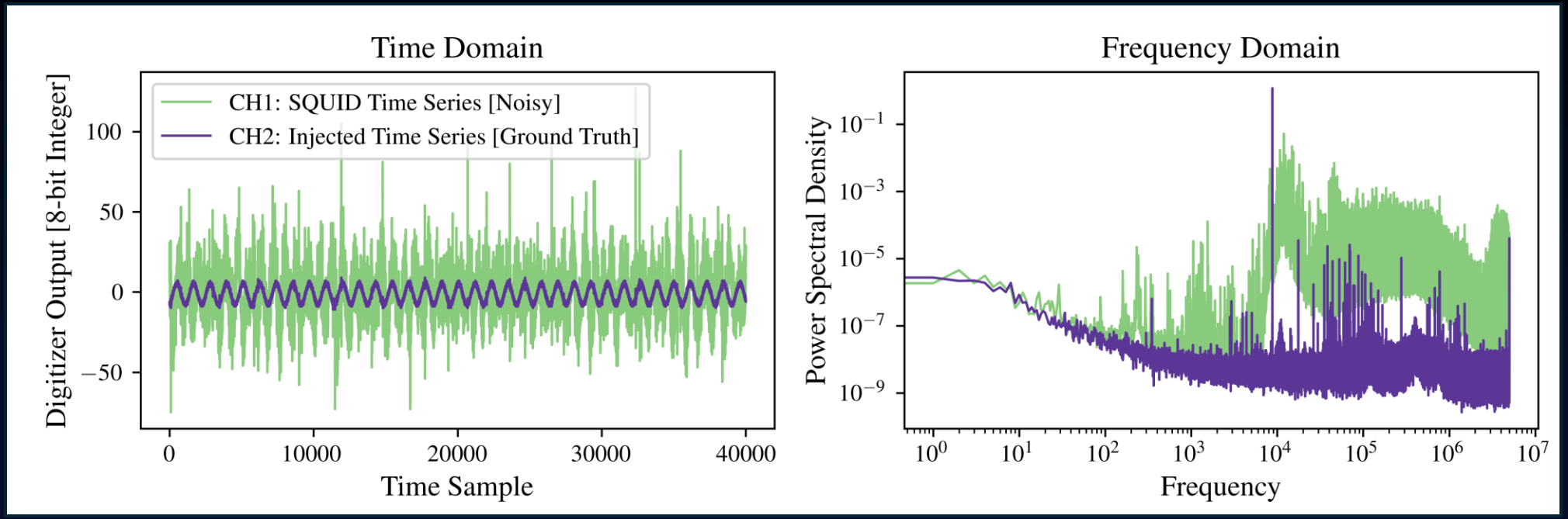
Public data release including (1) calibration training data (2) five trained ML denoising algorithms (3) two novel science-motivated benchmarks.



Algorithm	Segment Size	FS	Parameters	Fine Score	Coarse Score
None	N/A	N/A	N/A	1.00	1.10
Fourier Averaging	1×10^8	N/A	10-fold Average	0.24	0.26
Moving Average	1×10^6	N/A	window = 100	0.86	0.95
SG Filter	1×10^6	N/A	window = 19, order = 11	0.95	1.04
FC Net	4×10^4	Yes	See Appendix A2	6.43	6.55
PU Net	4×10^4	Yes	See Appendix A2	3.69	3.84
Transformer	2×10^4	Yes	See Appendix A2	3.95	4.18
WaveNet	4×10^4	No	See Appendix A2	4.99	5.16
RNN Seq2Seq	4×10^4	Yes	See Appendix A2	3.38	3.79

Time Series Dataset for Discovering Dark Matter with AI Denoising

Public data release including (1) calibration training data (2) five trained ML denoising algorithms (3) two novel science-motivated benchmarks.



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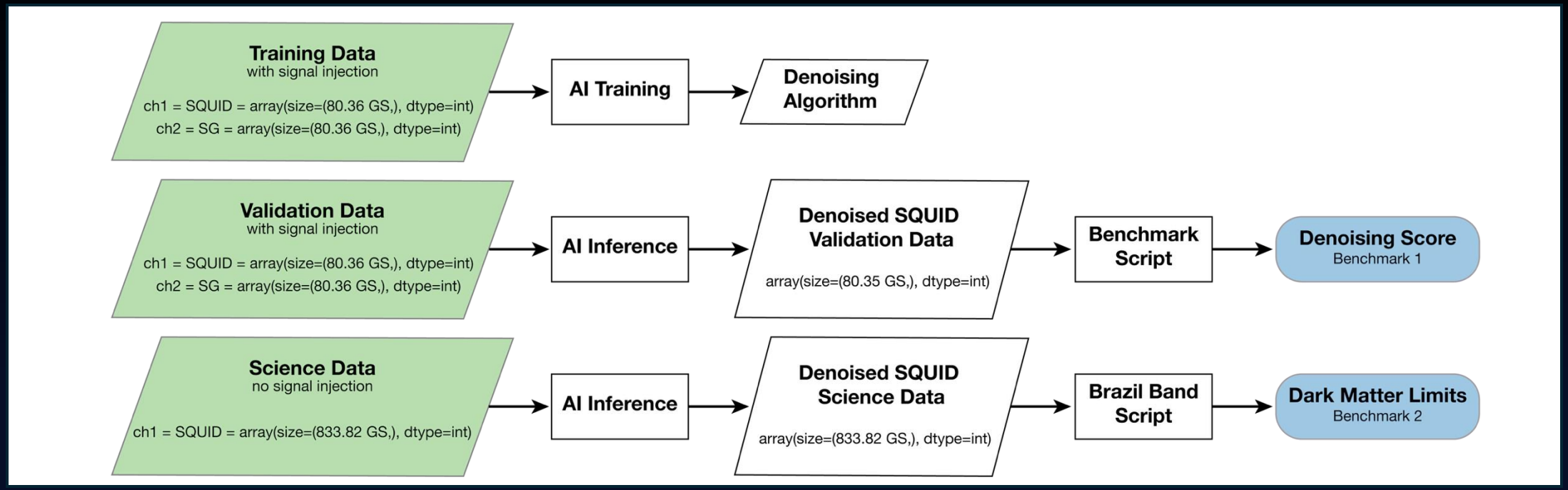

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FC-Net

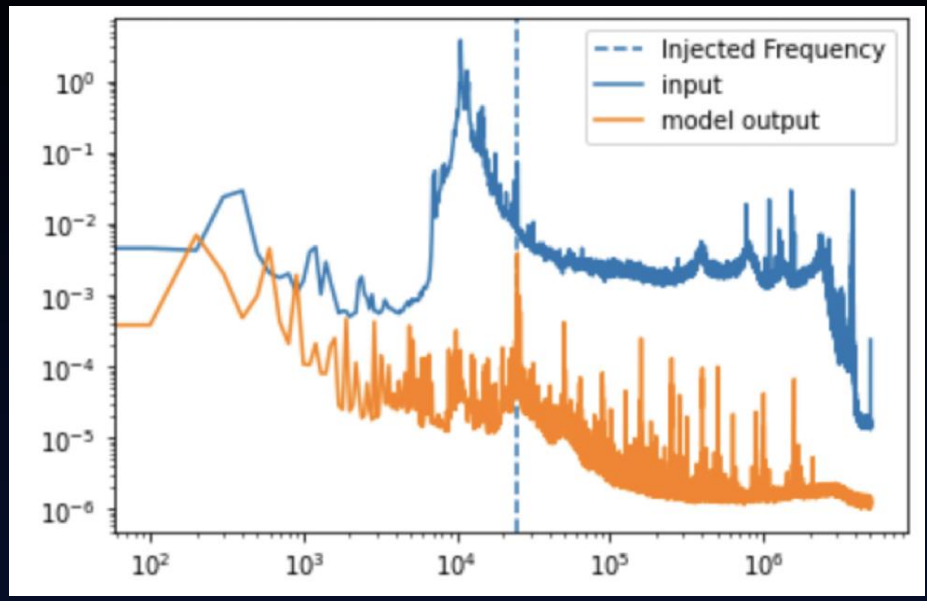
WaveNet

PU-Net

Transformer

RNN Sequence to Sequence Model

Aobo Li & Hope Fu



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… and traditional algorithms

Moving Average

SG Filter

Fourier Averaging

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Denoising score:

$$\nu_0 = \underset{\nu}{\text{argmax}}\Big(PSD_{\text{Injected}}(\nu) - (PSD_{\text{Injected}}(\nu - df) + PSD_{\text{Injected}}(\nu + df))\Big)$$

$$SNR_i = \left(\frac{P_{sig}}{P_{noise}}\right)_i = \sum_{\nu=\nu_0-\nu_{sig}}^{\nu_0+\nu_{sig}} PSD_i(\nu) \Big/ \sum_{\nu=\nu_0-\nu_{bkg}}^{\nu_0+\nu_{bkg}} PSD_i(\nu)$$

$$(SNR'_{\text{Injected}})_i = \frac{(SNR_{\text{Injected}})_i}{\max(SNR_{\text{Injected}})}$$

$$\Lambda = \left(\frac{1}{n}\sum_{i=0}^{n} (SNR_{\text{SQUID}})_i \times (SNR'_{\text{Injected}})_i\right)$$

$$\text{Denoising Score} = log_{5.27}\Lambda$$

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Axion Limits:

Automated end-to-end ABRA analysis over provided science data

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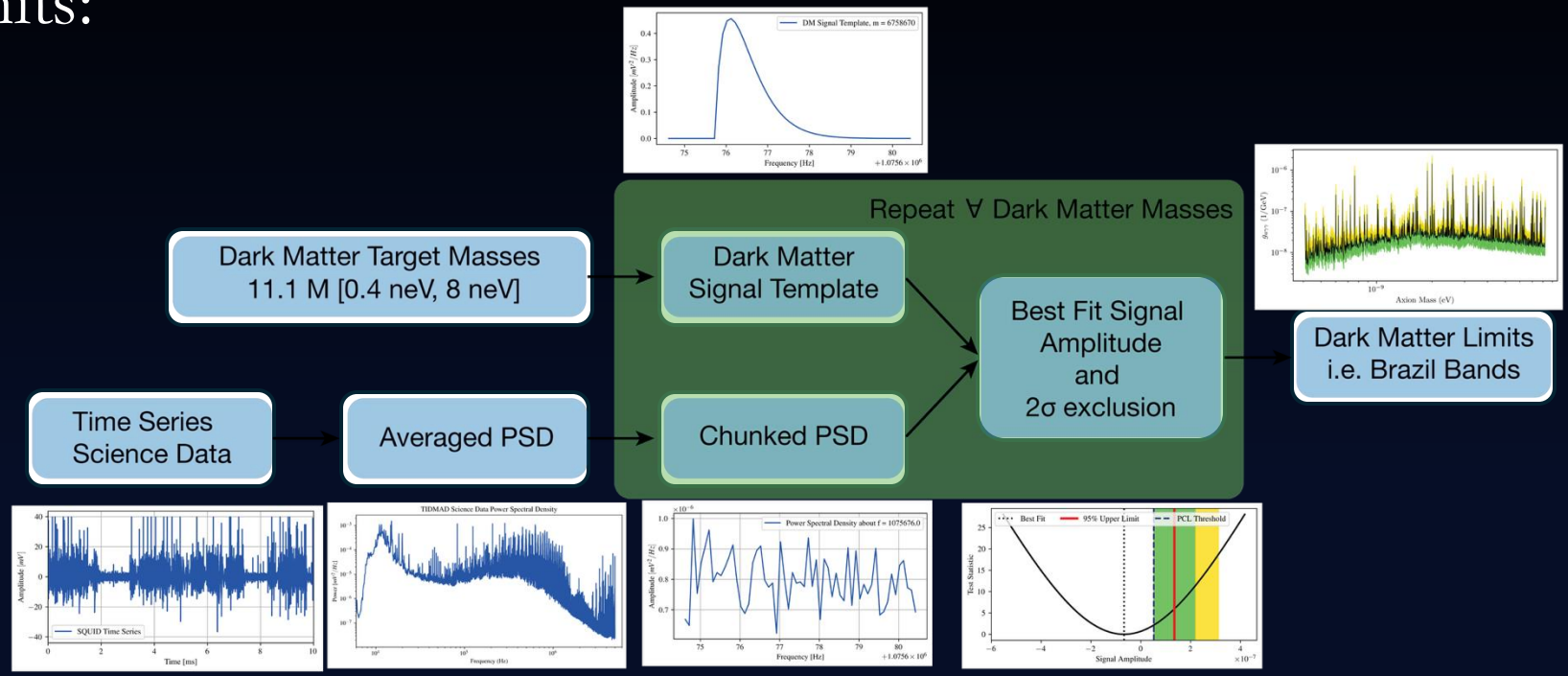

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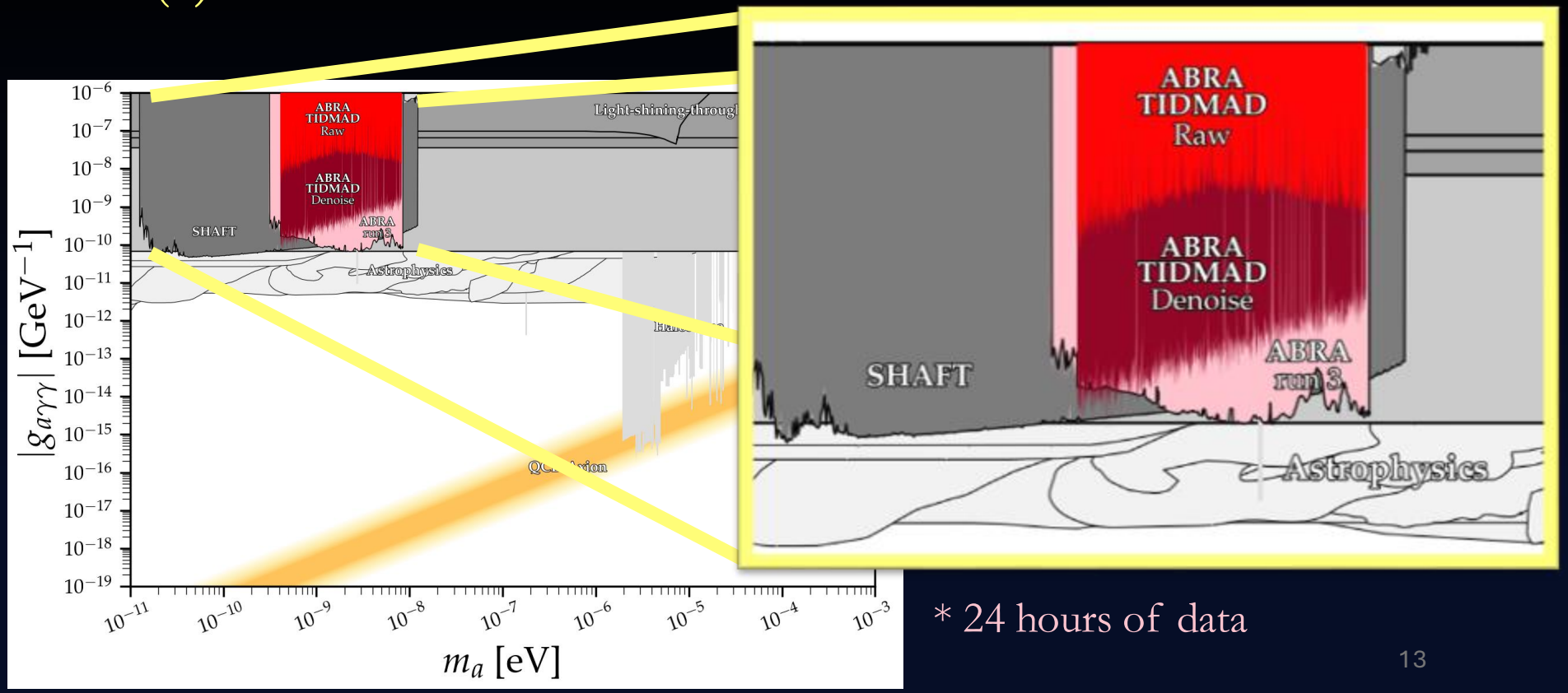

* 24 hours of data

Time Series Dataset for Discovering **D**ark **M**atter with **AI** **D**enoising

- *Why time series data?*
  1. *Can be used in conjunction with GW search.*
  2. *Twice the information as PSD.*
  3. *Online denoising implementation.*
  4. *For ML models, representation matters.*

ABRACADABRA Plans

- Recommission Olaf (ABRA cryostat)
- Implement trained WaveNet on FPGA *Eleonora & Laura*
- Collect online denoised data

ML on DMR and beyond

- Uncertainty propagation on ML denoised data.
- Use SAG data to train frequency domain denoising algorithms in a resonant set up.
- ML enabled GW or anomaly detection with online triggering.
- Reinforcement learning adaptive scan strategy.

I look forward to the day we can ask the following question of DMRadio 50L:

We have a perfectly good detector… what shall we do with it?