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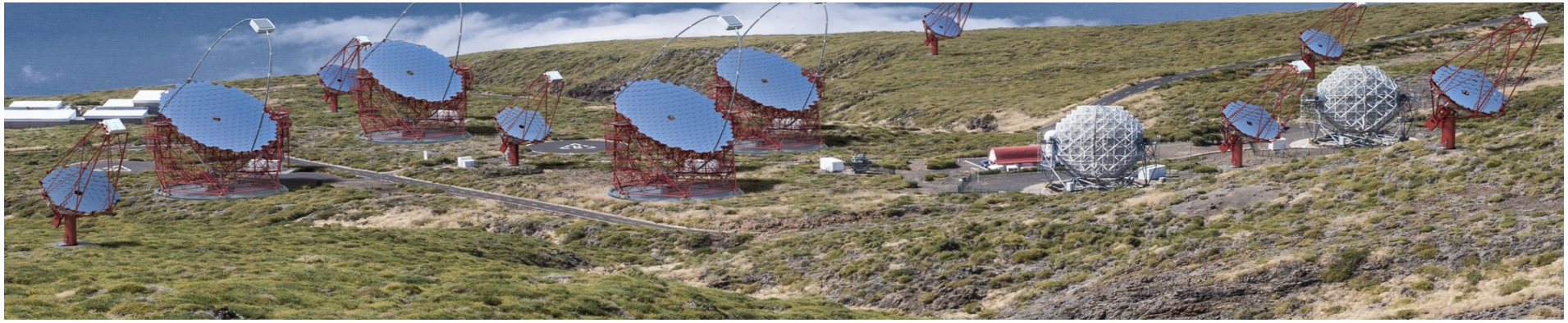

Hunting for Transients with CTA

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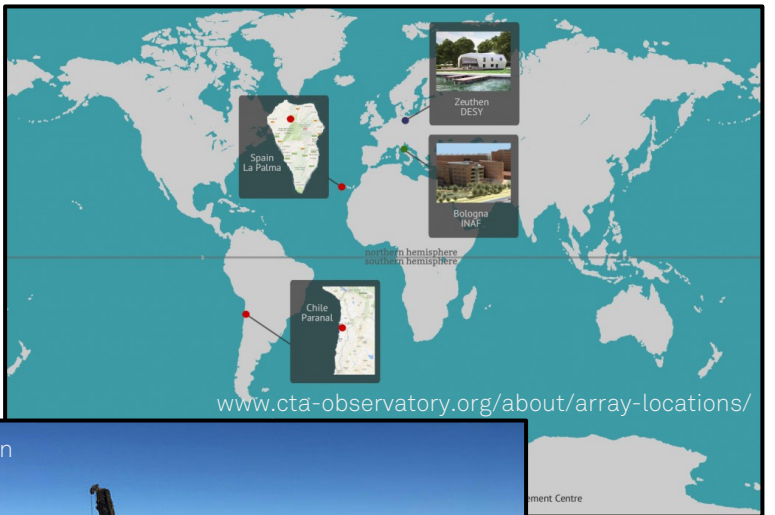
Cherenkov Telescope Array

- Detect VHE gamma rays
- 118 Telescopes
- Northern site: La Palma, Canary Islands (19 telescopes)
- Southern site: Paranal, Chile (99 telescopes)
- Energy range: 20 GeV to 300 TeV

- 3 types of telescopes:
  - Small-Sized Telescope (4 m, 9 °)
  - Medium-Sized Telescope (12 m, 7 °)
  - Large-Sized Telescope (23 m, 4.5 °)



CTA Key Target: Transient Phenomena

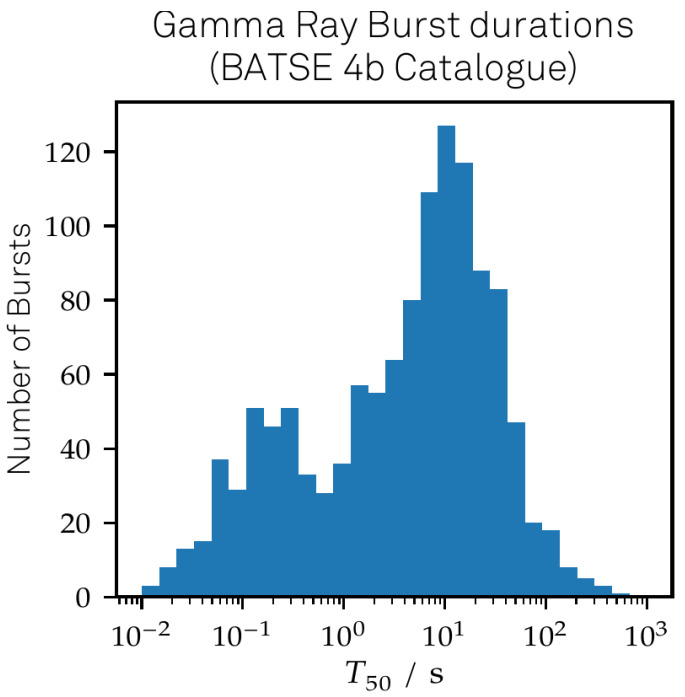
- Galactic Centre
- Large Magellanic Cloud
- Galactic Plane
- Galaxy Clusters
- Cosmic Ray PeVatrons
- Star Forming Systems
- Active Galactic Nuclei
- **Transient Phenomena**

An artistic rendering of GRB 020819B based on ALMA observations.
Credit: NAOJ

Key Target: Transient Phenomena

- High variability in flux and energy range
- Short timescale: milliseconds to hours
- Extragalactic origin: supernovae,

  merger of neutron stars, black holes...
- Multimessenger astronomy
- Unpredictable, poorly understood



https://heasarc.gsfc.nasa.gov/W3Browse/cgro/batse4b.html

How to find them?

CTA data:

- High level data
- Gammalike events (only signal)
- Reconstructed energy and position
- Images: Number of events per ra/dec bin

Challenges:

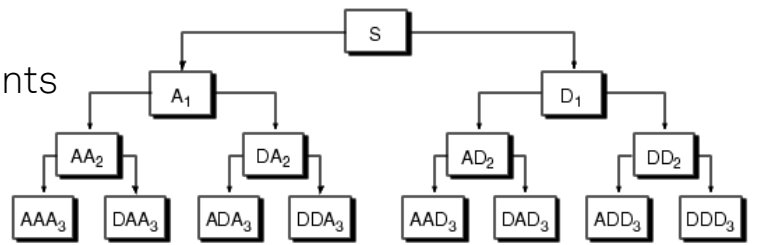
- Unknown source position
- Short timescales
- High background rates → noise

Wavelet Transform: Get Rid of the Noise

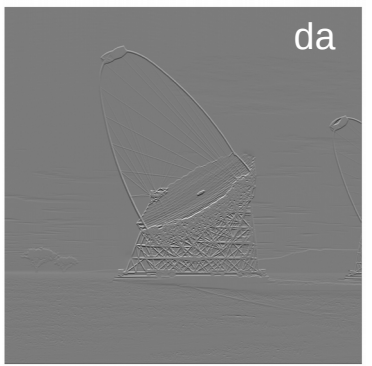
Wavelet in a nutshell:

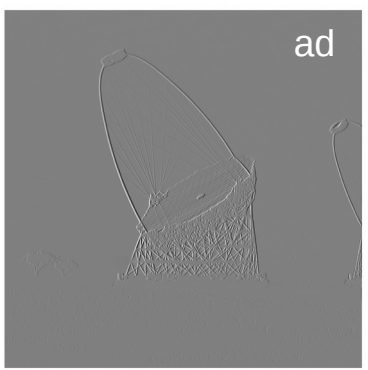
- Mathematcial definition:
  - Convolution with wave packet (wavelet)
  - Similar to Fourier transform

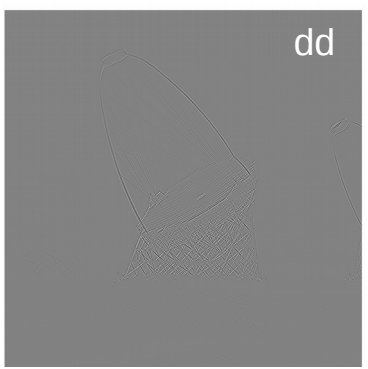
- Image Processing:
  - Discrete wavelet transform → Input: matrix (image)
  - Result: 4 wavelet coefficients
  - Invertible: Reconstruct image from wavelet coefficients



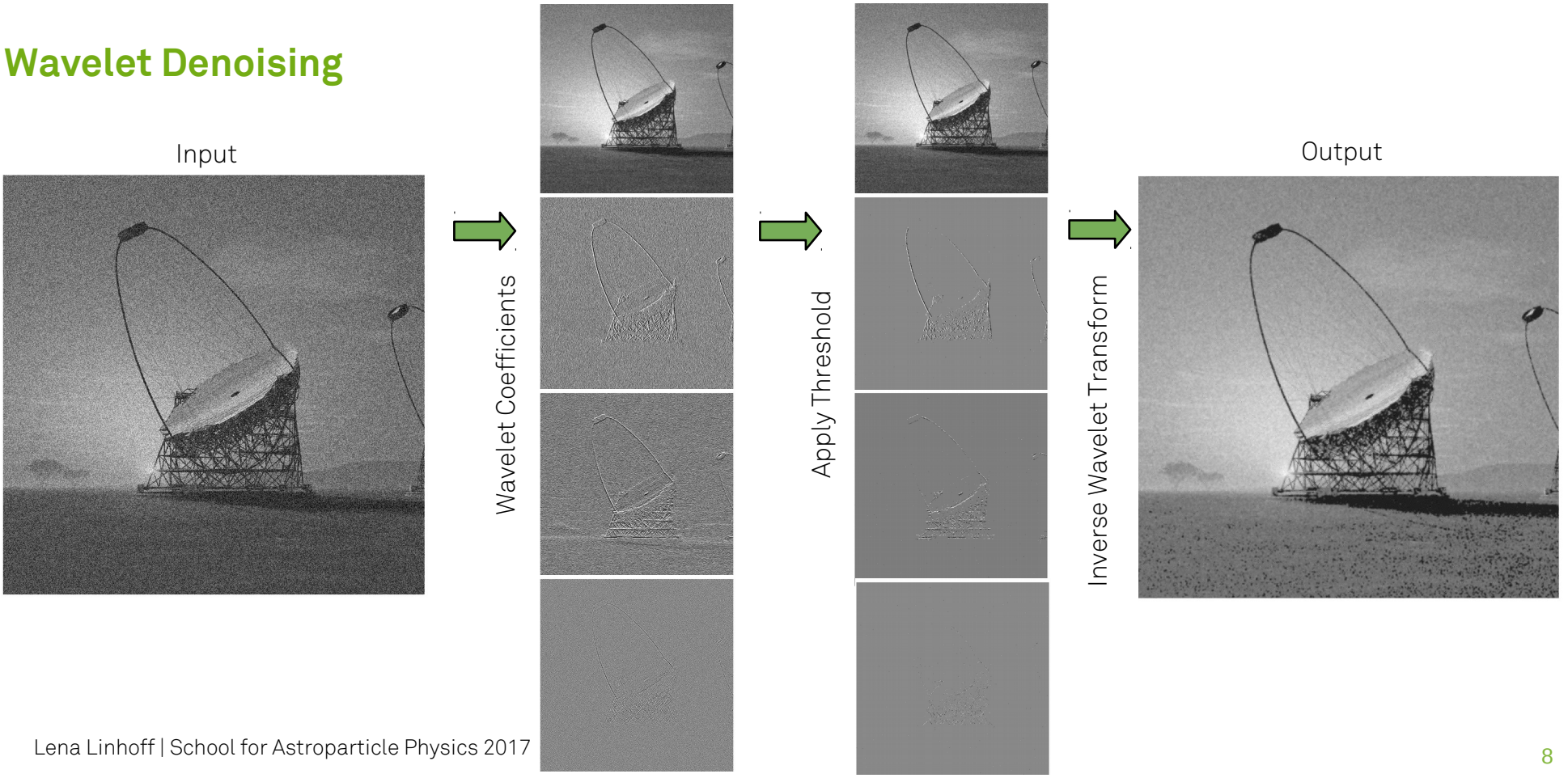
Wavelet Coefficients: Iteration 1







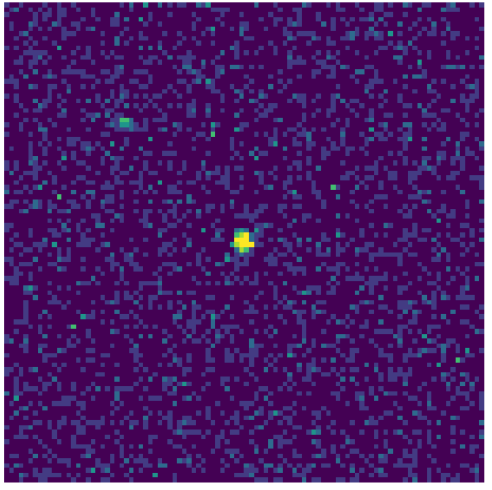
Wavelet Denoising



CTA Images: Simulation

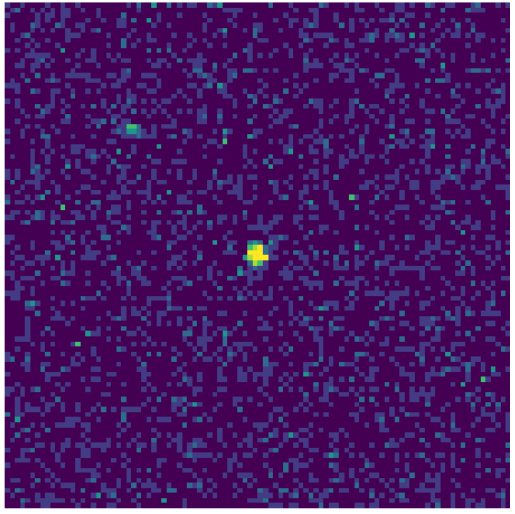
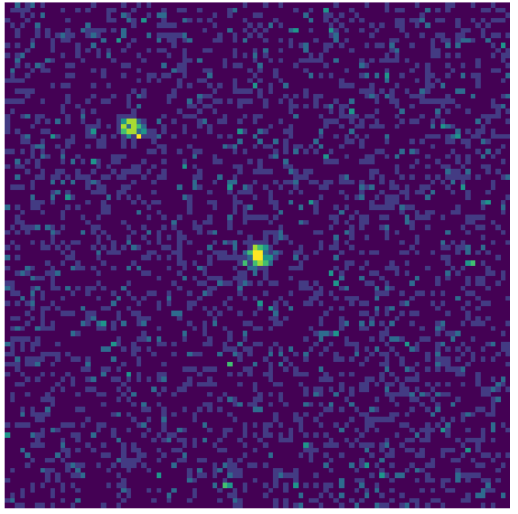
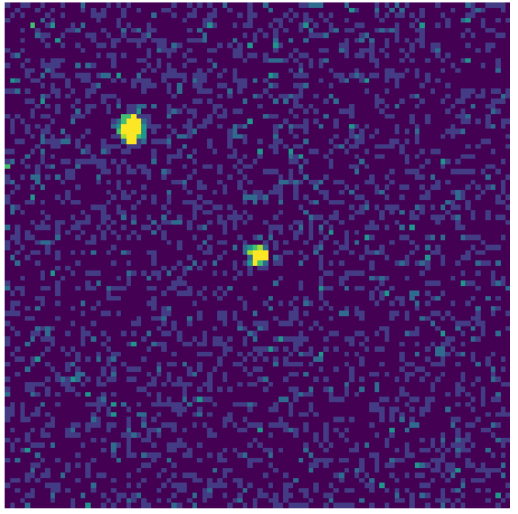
High level images (events per ra/dec bin):

- Steady Source: Crab Nebula, Hegra
- Background: Cosmic ray sprectrum, PDG
- Transient: Templates from PKS 2155 flare (HESS)
  and GRB 130427 (FERMI LAT)



- 30 sec observation time per image
- Field of view: 6° x 6°
- Instrument Response Function (provided by CTA Analysis and Simulation Working Group)

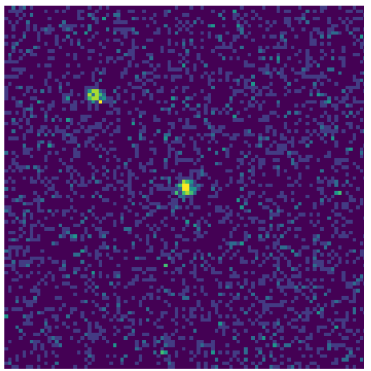
CTA Images: Simulation

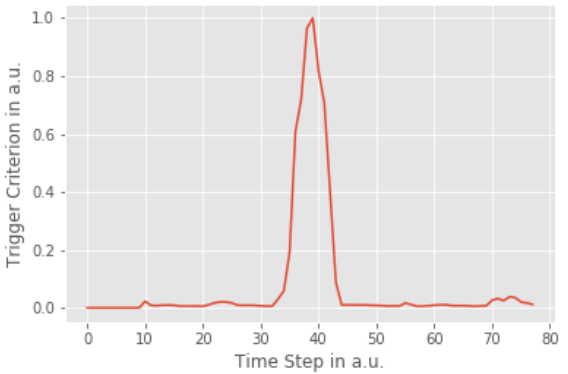




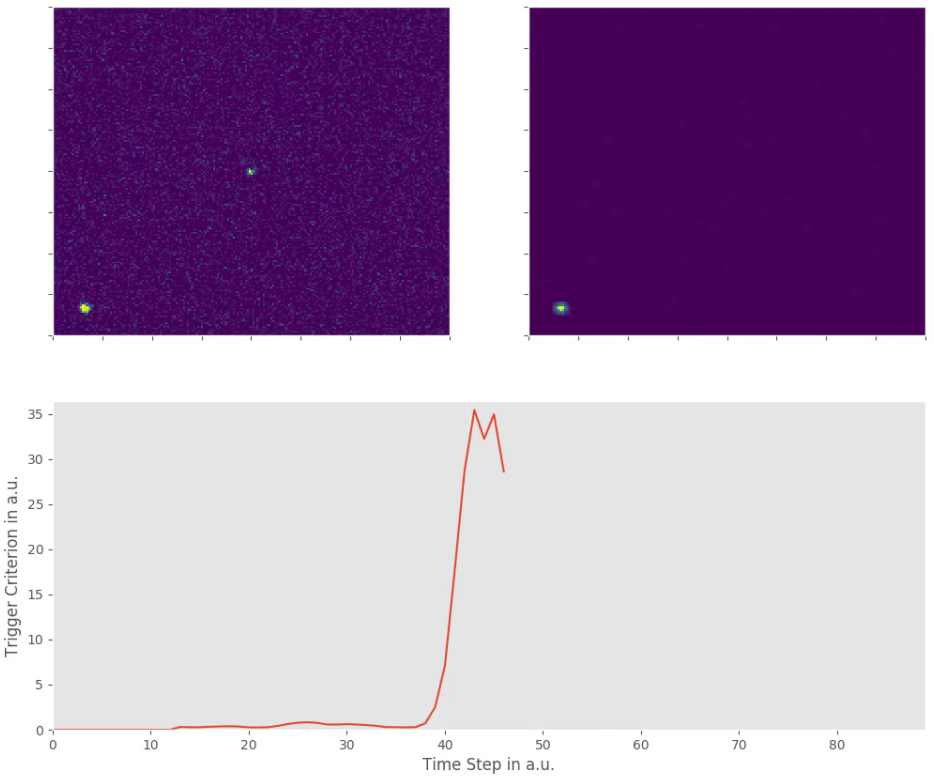
→ Cube of ~100 slices (image), slice = 30 s observation time

Transient Search

1) Remove steady source (subtract mean over given timeframe from slice)
2) Wavelet transform of every slice
3) Thresholding wavelet coefficents
4) Inverse wavelet transform
5) Trigger criterion: e.g. brightest pixel
6) Monitor trigger criterion over time

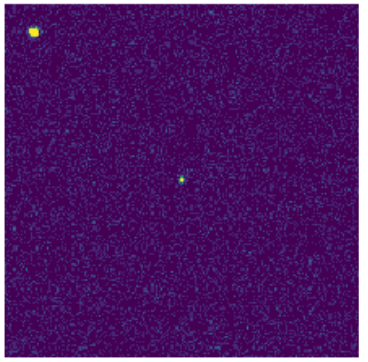


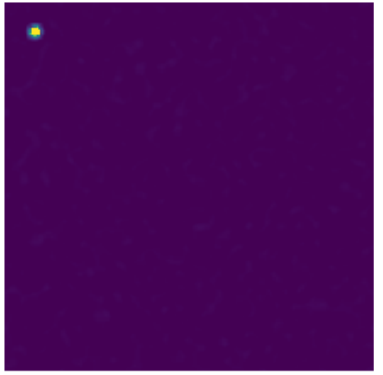


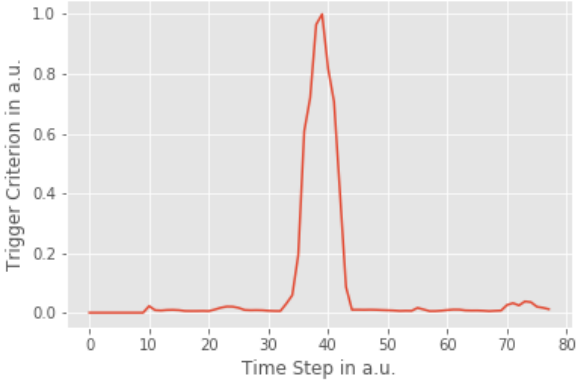

Trigger Criterion in a.u.
Time Step in a.u.
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80

Outlook

- Find suitable trigger criterion
- Systematical tests
- Simulate different transients
- CTA real time analysis







https://github.com/mackaiver/wavelet-denoising