PACS Mapmaking with MADmap

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What is MADmap?

- Map-making technique which will produce maximum likelihood sky maps from time ordered instrument data.
- MADmap uses the data model:

  d = A(p,t) * S(p) + n(t),

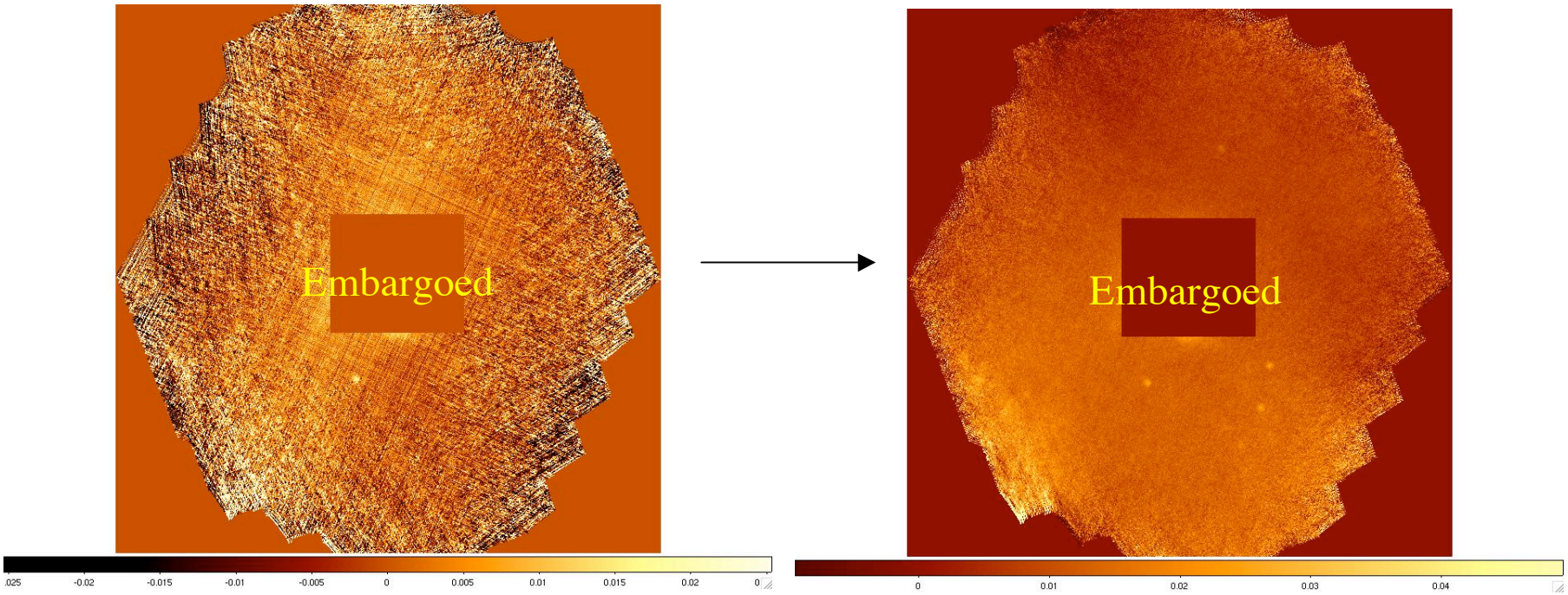
  Where,

  d = detector readout, A=pointing matrix, p=sky pixel, S=signal, n=noise and t is time (or index).
- For all readouts, all detectors, the set of linear equations is too large to invert; thus, conjugate gradient method is used to find the best least-squares fit to the data, given a noise model n(t).

What is MADmap?

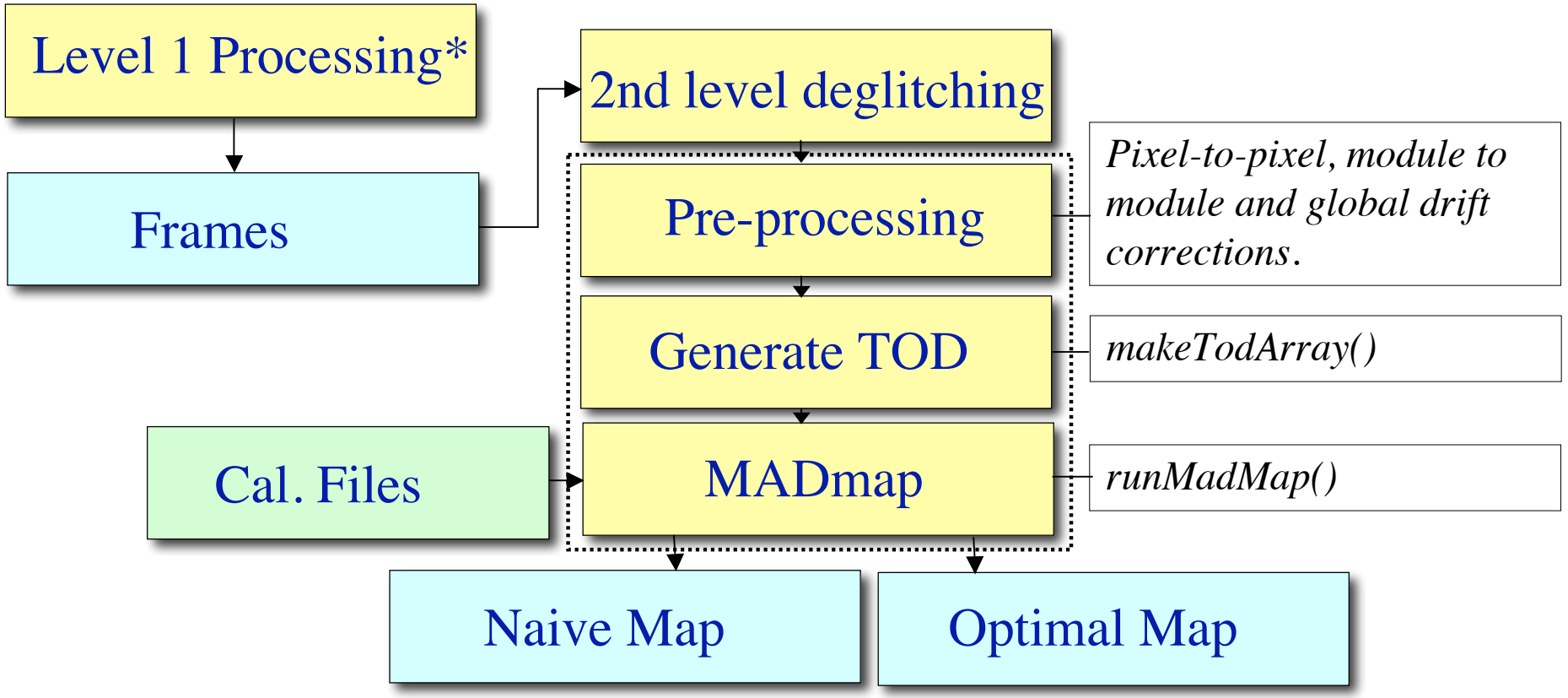
Un-Corrected

Corrected



MADmap is designd to remove 1/f noise effects

Implementation for PACS DP



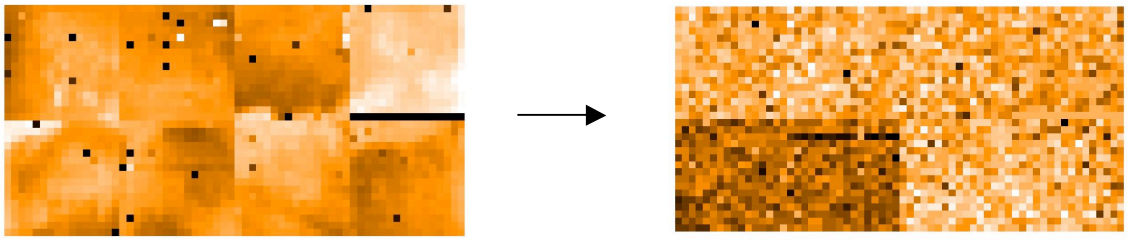
* ***But see caveat about deglitching.***

Use of MADmap in PACS DP

- MADmap should be considered an interactive tool.
- MADmap will produce non-optimal results if:
  - Noise spectrum in data is different from the noise spectrum in cal. files.
  - Correlated signal is not mitigated.
  - Signal drifts (other than 1/f noise) are not mitigated.
    - Preprocessing is critical
- *This talk will mainly focus on pre-processing.*

MADmap pre-processing

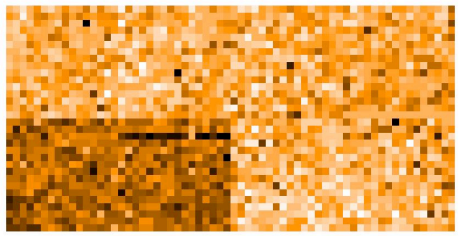
- Correct for pixel-to-pixel signal offsets.
- Two options:
  - Use a calibration offset image
  - Subtract MEDIAN of the entire pixel history
- Both work equally well.



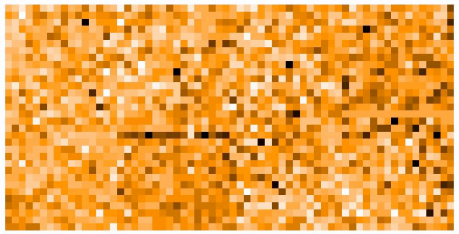
Raw Corrected

MADmap pre-processing (cont.)

- Correct for module-to-module correlated signal drifts.
  - A systematic change in the signal level between individual 16x16 bolo modules.
  - Affects the blue channel more strongly than red.



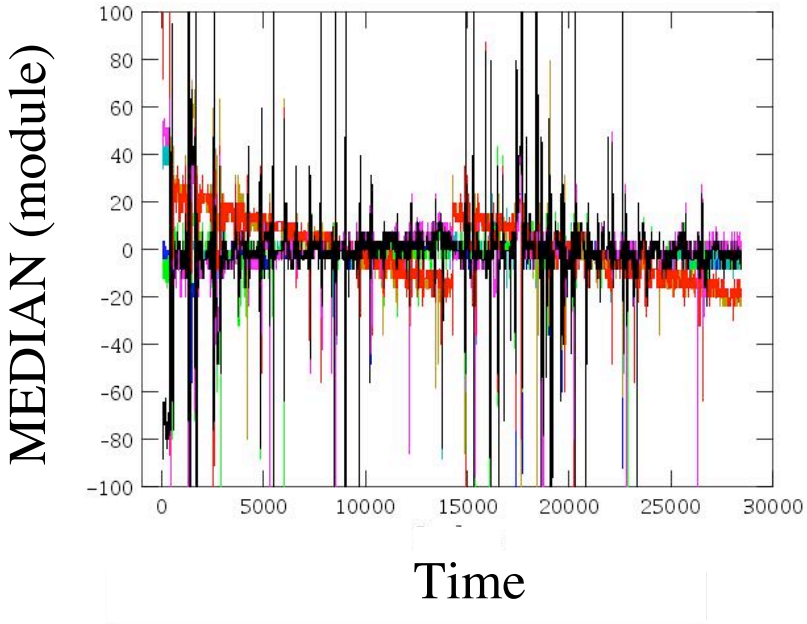
Module signal drift



After mitigation.

MADmap pre-processing: Module drifts

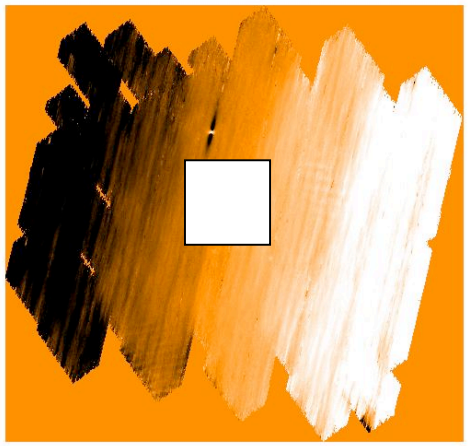
- Mitigation
  - The drift is in the signal and appears linear; thus simple linear fits produce acceptable results.
  - ***HOWEVER***; not all data appear to require it.



Different colors are different modules

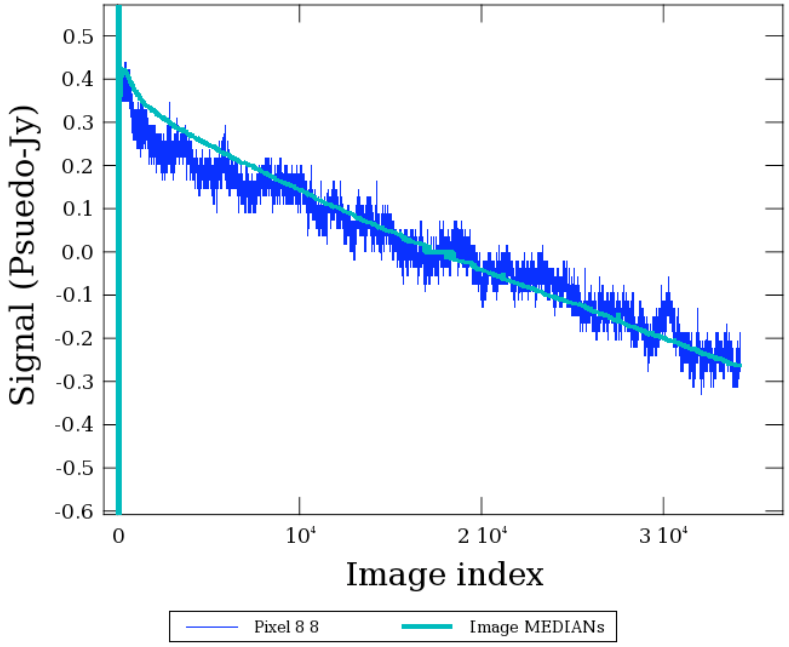
MADmap pre-processing (cont.)

- Global signal drifts.
  - The MEDIAN signal level of the PACS bolometer array decreases systematically in a correlated fashion from start to the end of obervation.



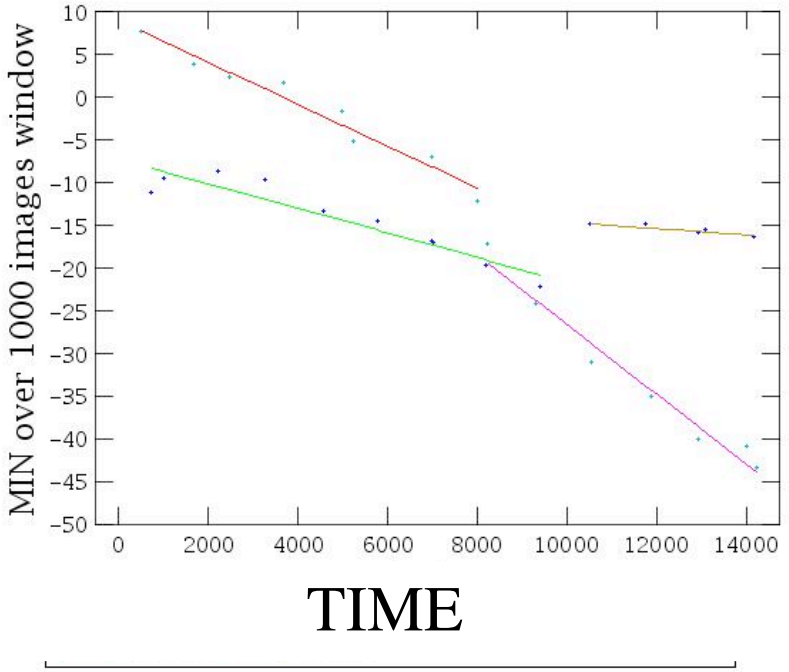
MADmap pre-processing: Global drifts

- The global drift is the dominant trend in the signal time-line.
- The drift is correlated amongst pixels. The time-line for one pixel mimics the trend of the MEDIAN value of the entire array.



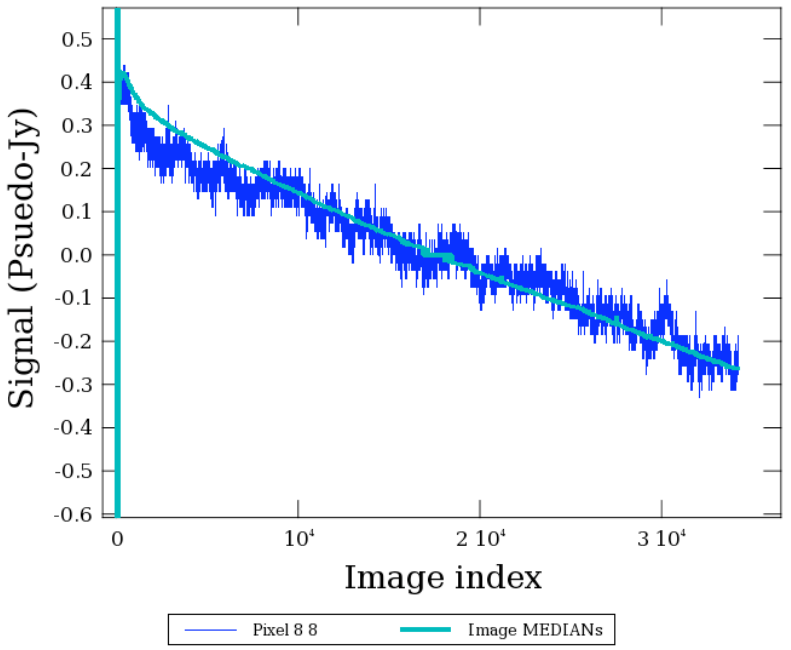
MADmap pre-processing: Mitigating global drifts

- Fit linear or polynomial models to baseline.
  - (1) Baseline determined from minimum value in 1000 readout bins for the entire array.
    - Useful when source signal dominates time-lines
  - (2) Baseline determined from MEDIAN of the entire array for all readouts
    - Useful for very weak sources
    - Each pixel corrected separately.
  - Baseline fit is subtracted from each pixel's readout.



MADmap pre-processing: Mitigating global drifts

- (3) Subtract MEDIAN values:
  - Useful only when source emission << sky emission
  - Fails for Galactic plane and other bright emission region.



Interactivity

- Decisions that have to be made only by examining the data:
  - Whether or not to use module-to-module correction?
  - Which option to use for global signal drifts?
    - Column/row drop outs, signal jumps (electronic glitches), etc., will lead to bad baseline fits.
    - Examine fits for sanity checks.

The other 1/2 of MADmap processing

- Naive maps:
  - Collapse the time line by averaging signal on sky pixels.
  - Equivalent to ‘projection’
  - Used as the “first guess” for ...
- Optimal mapping:
  - Solve for the best sky signal via least-squares fit to the data model.
  - Requires noise model via calibration files.
  - Quality of final maps depends on preprocessing and relevancy of noise models.

Noise calibration files

- We still have much to learn about these.
- Three generations of cal files available:
  - "old": pre-launch noise files based on simulations.
    - Still useful for the red filter.
  - "current": first post launch "dark" field measurements.
    - Produce very little optimization at the moment.
  - "3rd Gen": Second post-launch attempt.
    - To be available in DP shortly
    - Produce much improved results over "current" files.

Summary & Known Caveats

- At the moment preprocessing requires interactivity.
  - Fits must be examined for sanity checks.
- Point source artifacts. 
  - Not entirely understood
    - May be mitigated by larger noise filter lengths, or better projection to TODs
- MMT deglitching changes the noise spectra and may confuse MADmap
- Some residual drifts are still present.
- Still a lot left to be done:
  - Revisit photometric quality of point sources
  - Investigate “background” from MADmap
  - ...