# Preprocesing PACS photometer timelines for map-making with MADmap

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# MADmap in one slide

- Mapping code written by the Berkeley CMB group to remove 1/f noise from bolometers.
  http://newscenter.lbl.gov/feature-stories/2010/02/03/madmap/

- MADmap was ported to Java for use in HIPE.
- MADmap offers the so-called optimal map-making to convert time ordered readouts to a final map.
  - Uses maximum likelihood (given a noise/probability model) to determine the optimal sky value.
- Details in the next talk.

## The need for preprocessing.

- MADmap assumes that bolometer time-lines are relatively calibrated.
  - No pixel-to-pixel variations
- MADmap assumes that 1/f noise is uncorrelated amongst pixels.
- PACS Level 1 timelines contain all of the above.

# Documentation Reference

- PACS data reduction guide, chapter 9
- NHSC Tutorials:
  - **PACS-101**: Introduction to PACS tutorials
  - **PACS-103**: Accessing & Storing PACS data
  - **PACS-104**: Using iPipe scripts
  - **PACS-201**: Level 0 to 1 processing of PACS photometer data
  - **PACS-401**: MADmap map-making.

https://nhscsci.ipac.caltech.edu/sc/index.php/Pacs/DataProcessing

# Preprocessing Steps

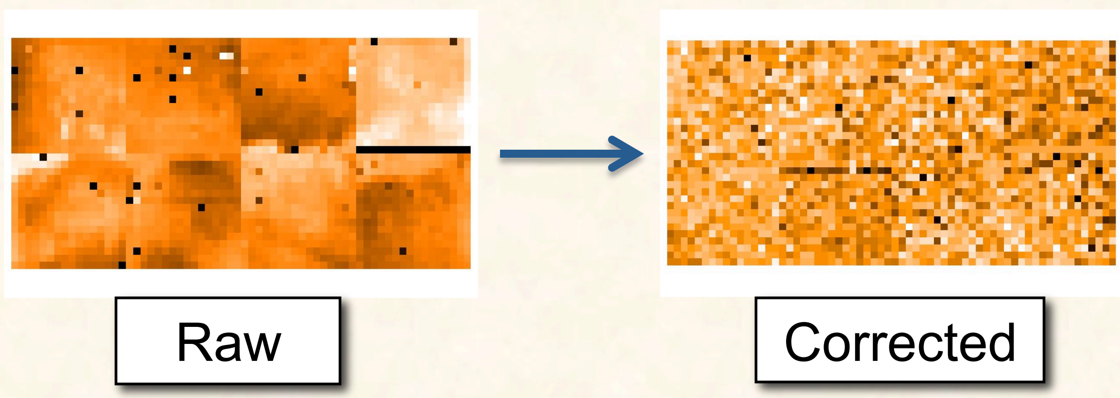
I. Remove pixel-to-pixel electronic offsets (additive).
II. Remove correlated signal drift (additive).
III. Identify and fix module/row/pixel anomalies.

# I: Pixel-to-pixel offsets

## Additive correction

# Electronic Offsets

- “Starting point” of the raw readout value for each pixel is different and additively offset.
- Usually, the offset pattern is the only visible structure in raw PACS readouts
- Correct by using calibration file, or median of the entire timeline for the pixel.

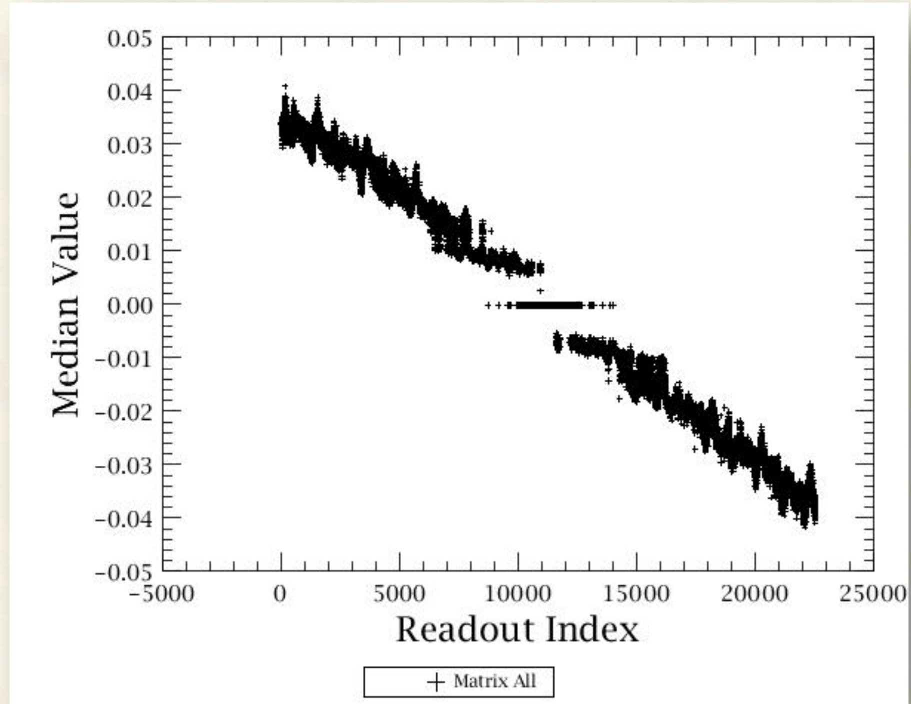


# II: Correlated Signal Drift

## Additive correction

# Properties of Signal Drift

- **The median value of the entire array shows a strong correlation with time.**
- **The trend is usually more dominant than astrophysical signal.**




Median vs. Time

When present, this is the strongest trend in PACS cubes

## Properties (cont.)

- No model has been identified (so far) to explain said behavior.
  - ***Caused by temperature variations?*** But, no thermometers available to confirm or reject.
  - ***Caused by electronics?*** But, not correlated with suspected Housekeeping values tried.
- The trend is strongest at the start of PACS OD and drifts to negligible values by the end of OD

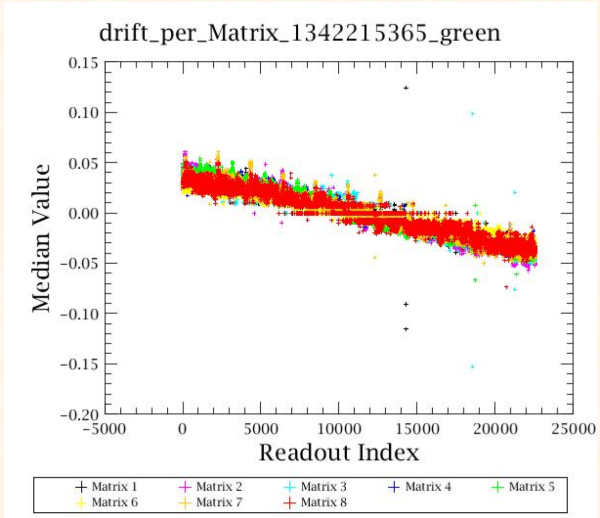
## Properties (cont.)

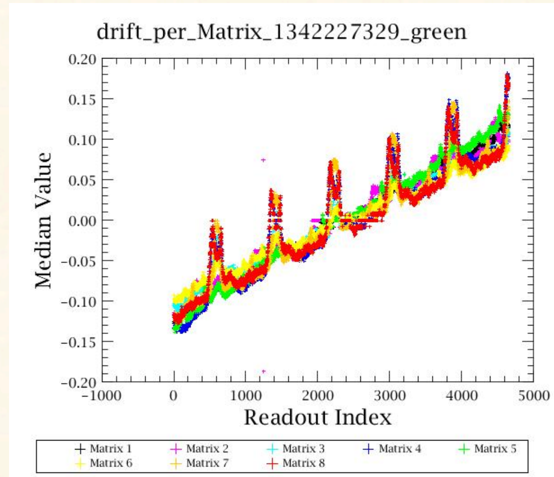
- The trend is also different from module to module.

(next slide)

# Examples of signal drift color coded by individual PACS 16x16 pixel modules

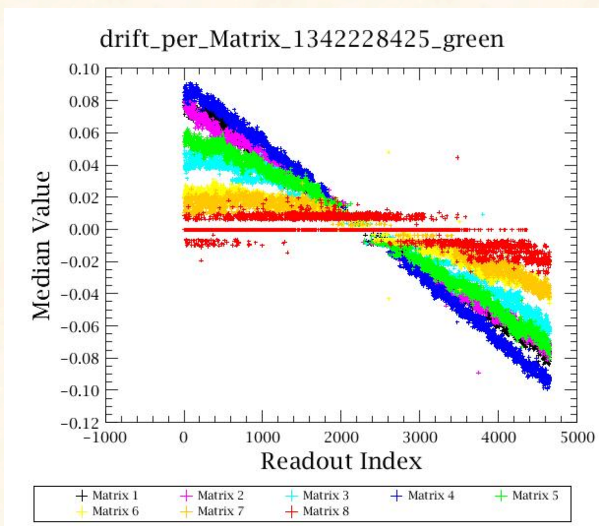
"Usual"

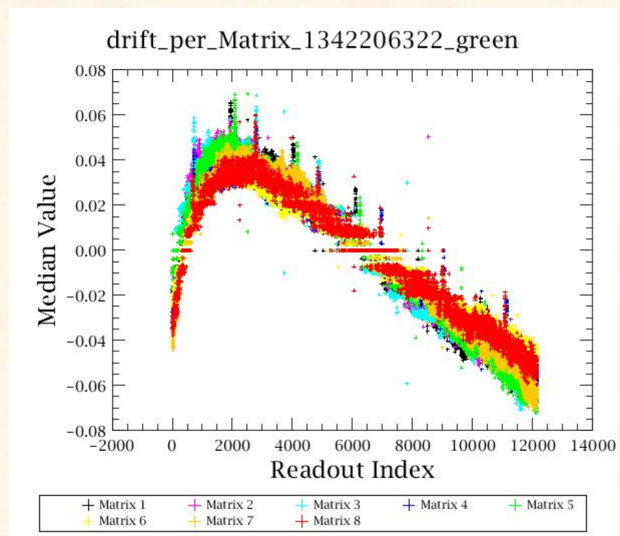



Rare.
Ascending

Strong module-to-module differences




"Hook"

# Properties (cont.)

- There is now evidence that individual pixels or groups of pixels have 2nd-order drifts on time scales larger than used for 1/f correction.
- Will require separate pre-processing
- Or, increased noise filters lengths

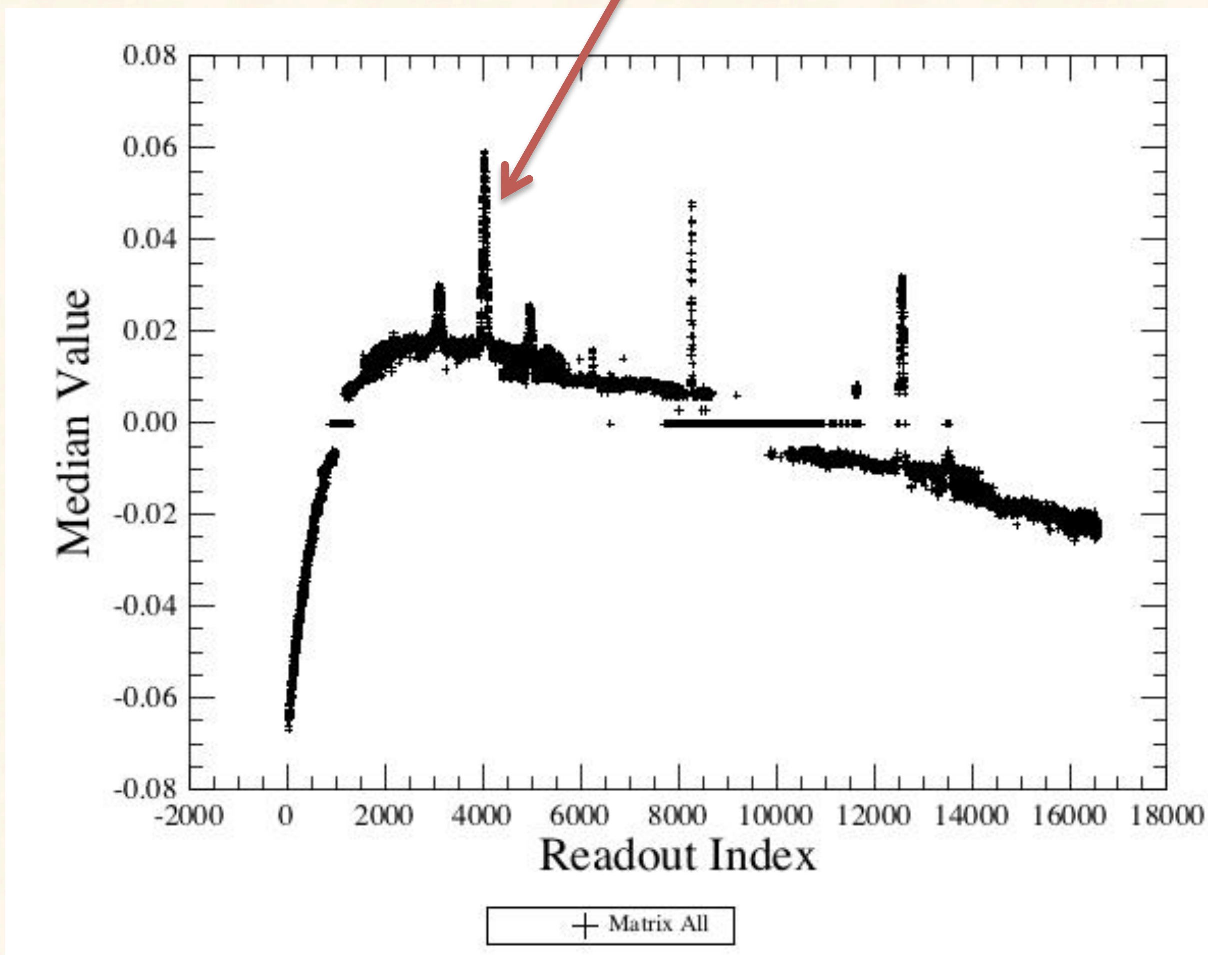
## Correcting Signal Drift

- First step is to define the baseline.

# Estimating Drift Baseline

Use MEDIAN to pick up the correlation.

Astronomical source



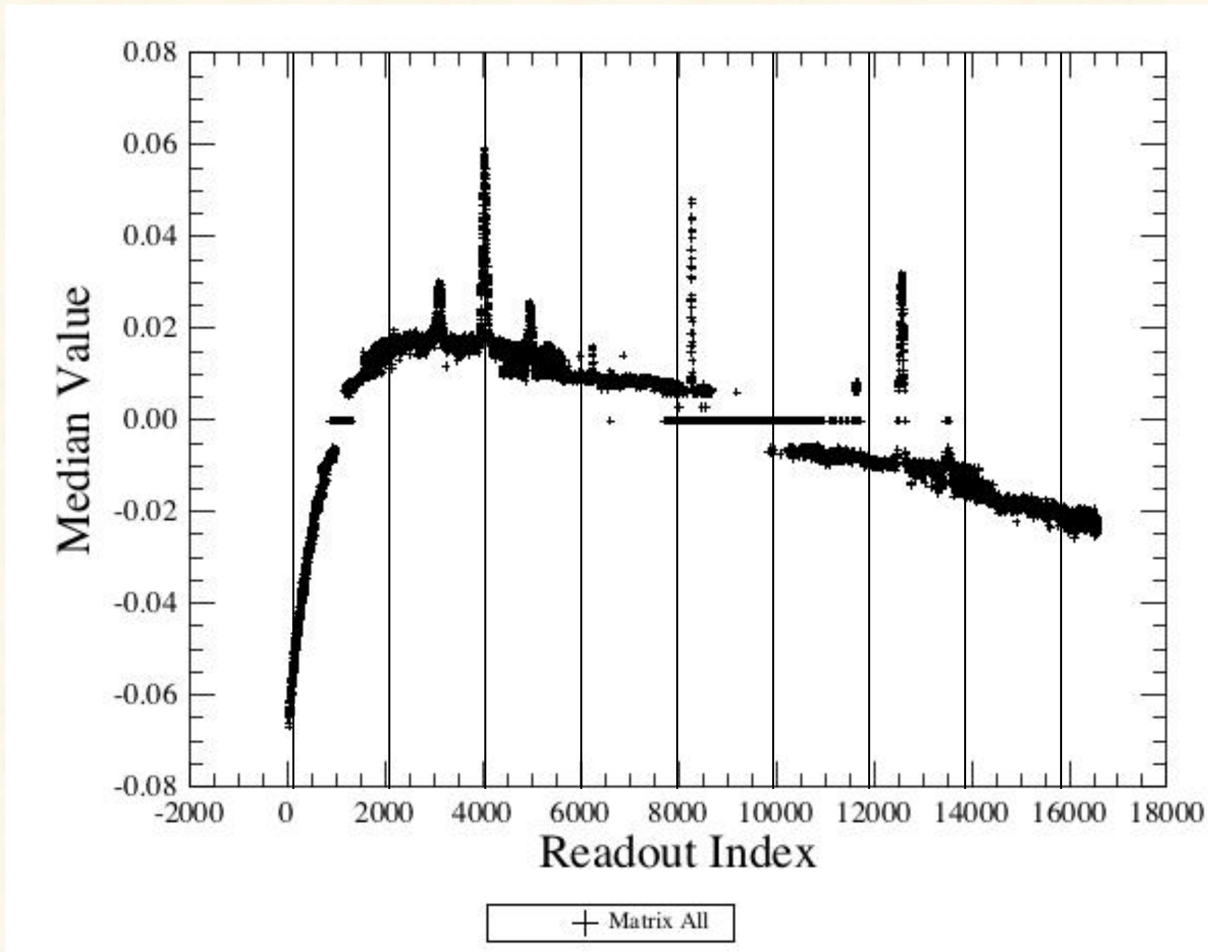



PACS pre-processing MADmap.

# Estimating Drift Baseline

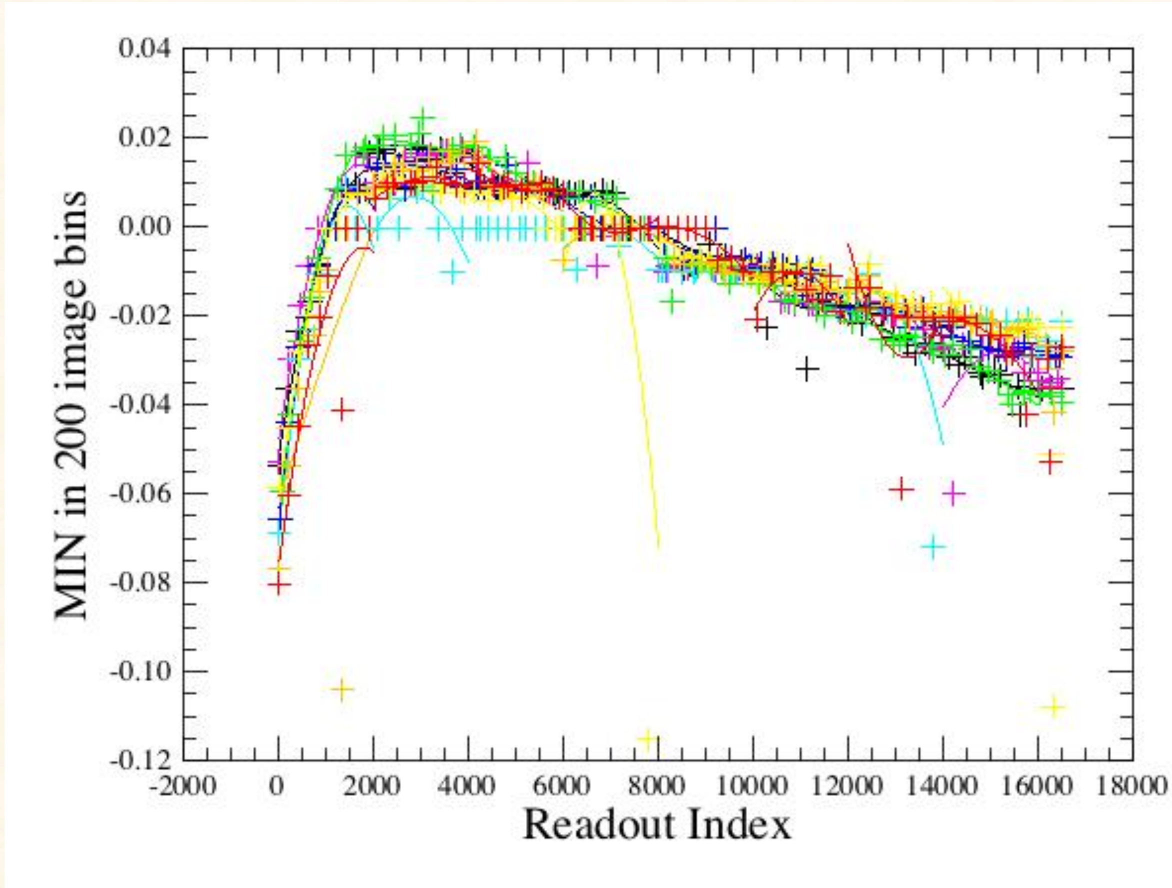
↔ Size of bin.

Divide MEDIAN values in bins.



# Estimating Drift baseline

Take MINIMUM of bins to reject sources. Fit MINIMUM values.



# Drift Correction Modules

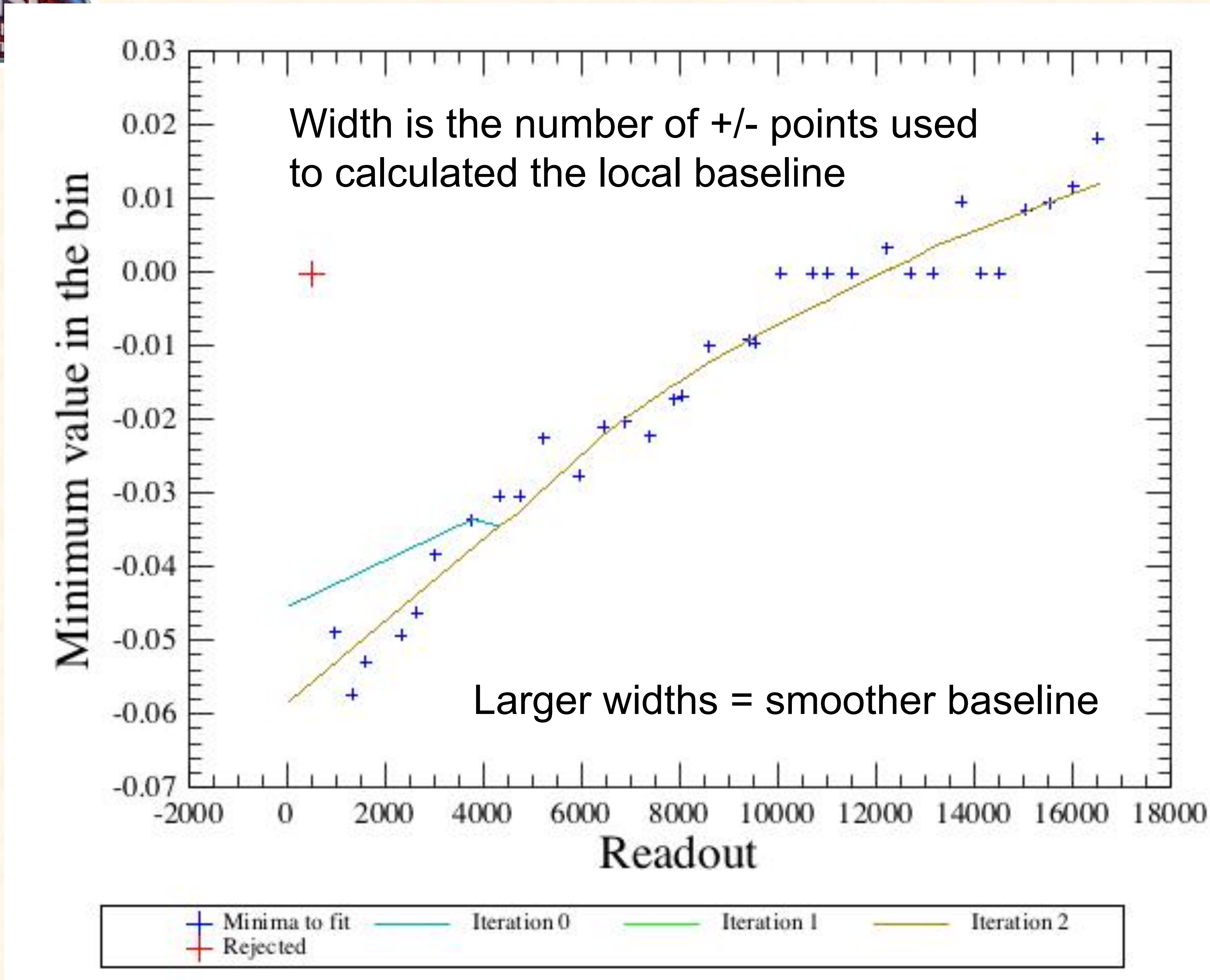
- ***photGlobalDriftCorrection***
  - 1st generation.
  - Same correction for entire FOV
  - Applies a single polynomial fit to baselines.
- ***photBaselineDriftCorr***
  - 2nd generation.
  - Correct module-by-module
  - Segment baseline for spline-like fitting instead of a single polynomial

## Drift Correction Modules

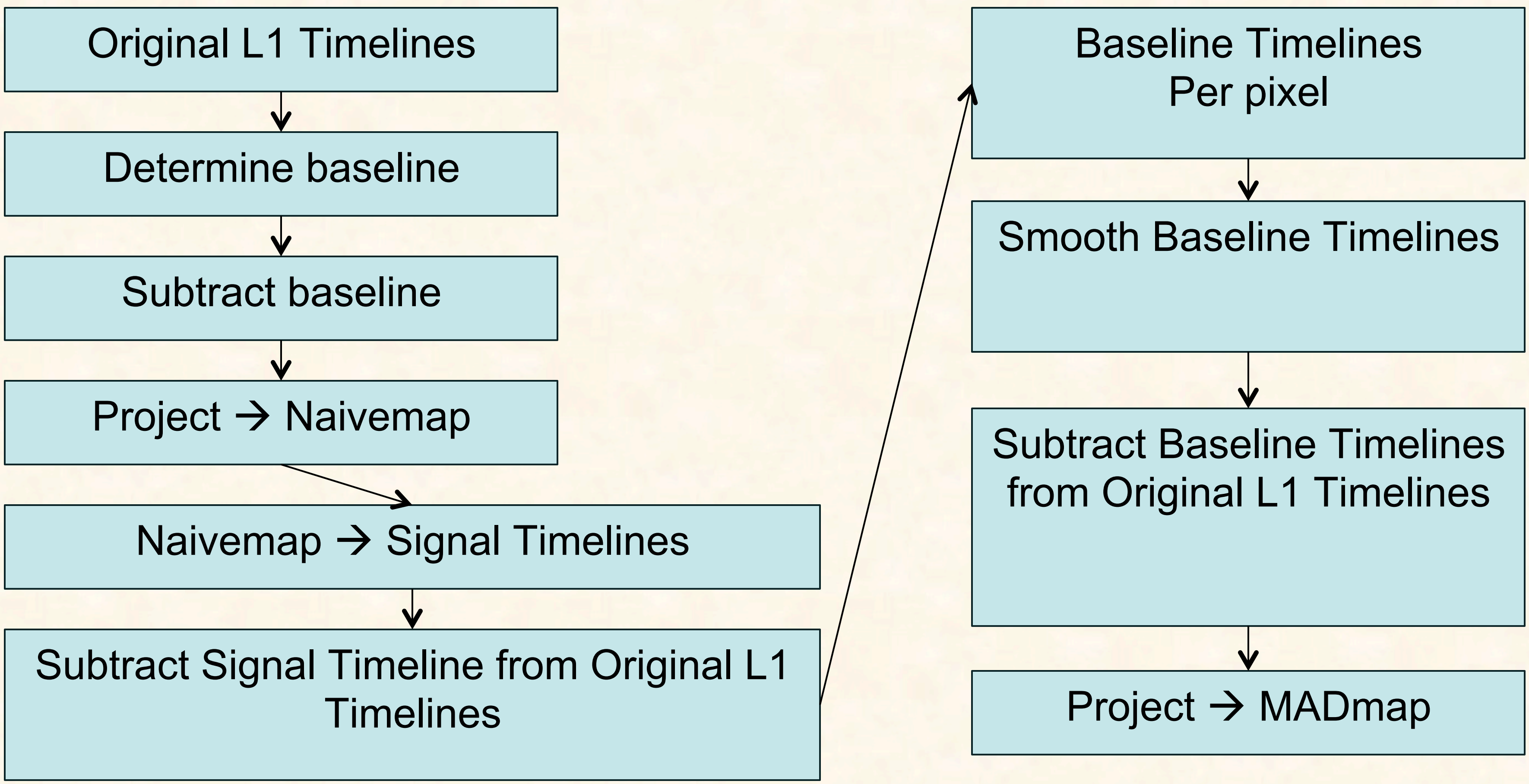
- ***photSignalDriftCorr***
  - $3^{rd}$ generation
  - Development version.
  - Fits the local neighborhood only
    - for better estimate of “hooks” and similar structures.
  - Adds an iterative sigma-clipper to remove deviant points.
  - Adds an “outer iteration”

Width is the number of +/- points used to calculated the local baseline

Larger widths = smoother baseline

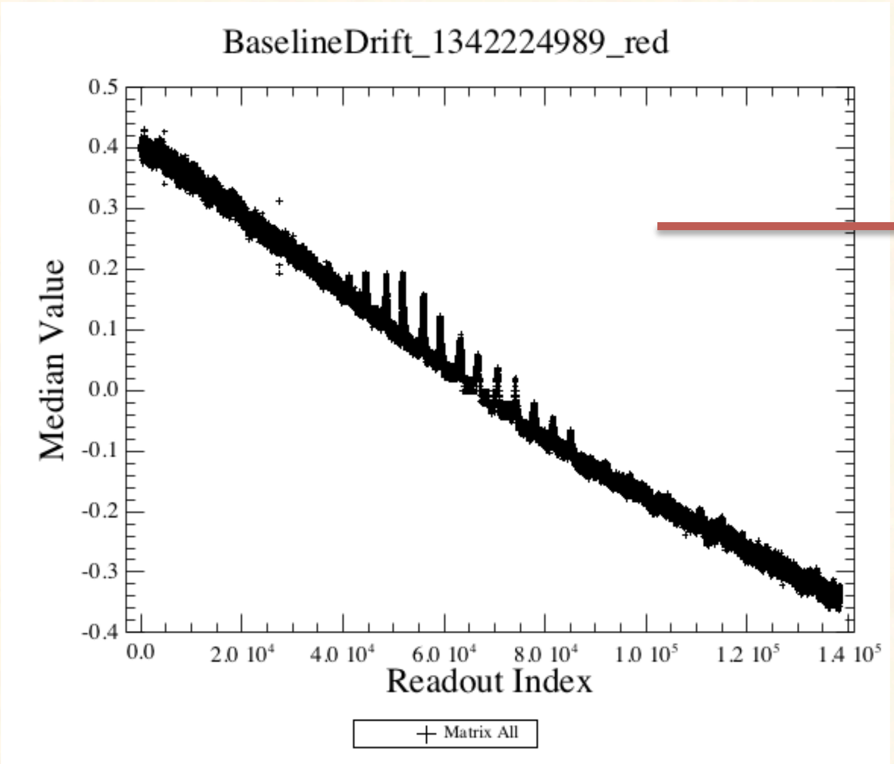


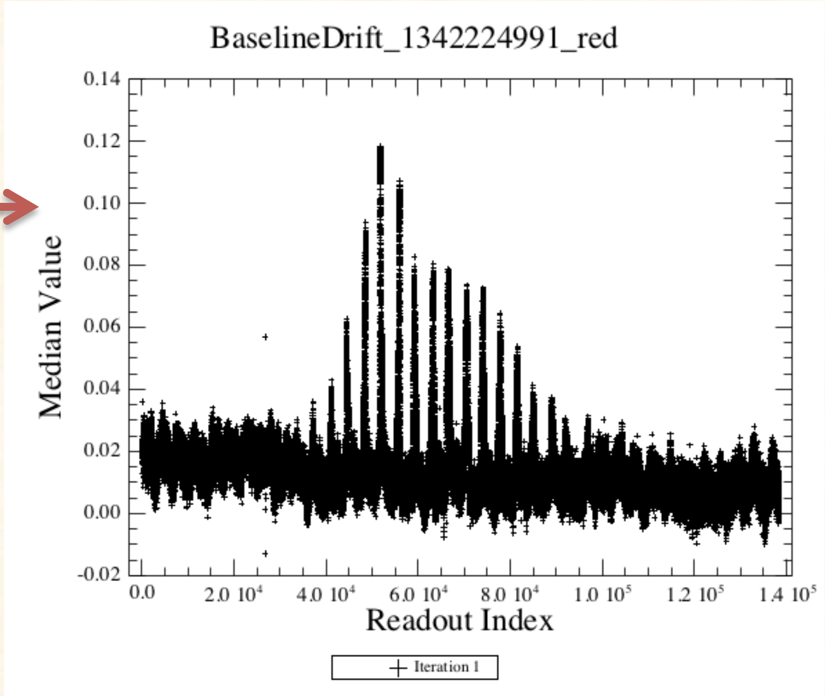
# “Outer Iteration”



# 3rd gen. results

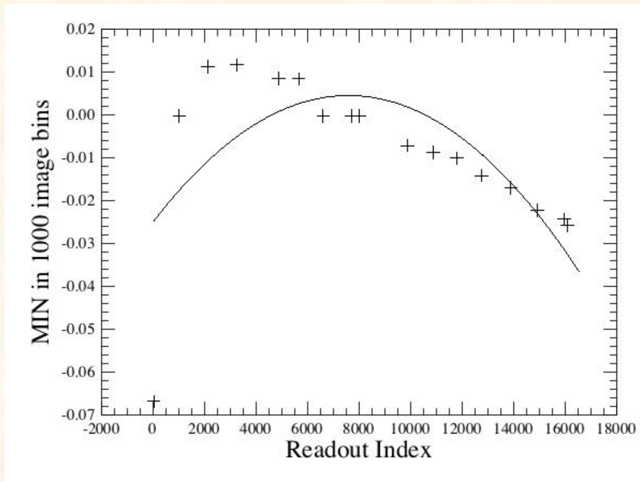
Good, but not fully tested.

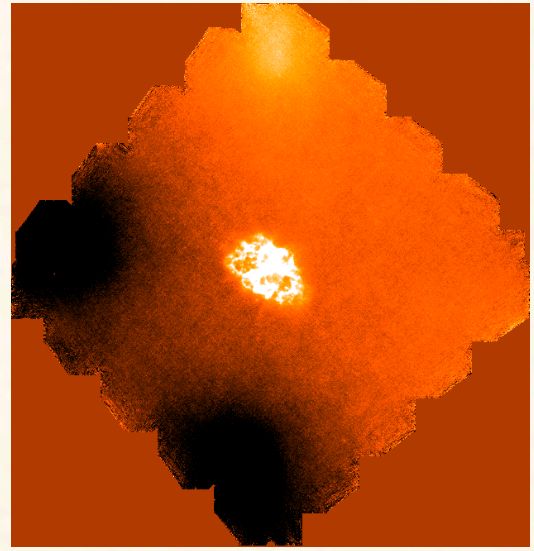


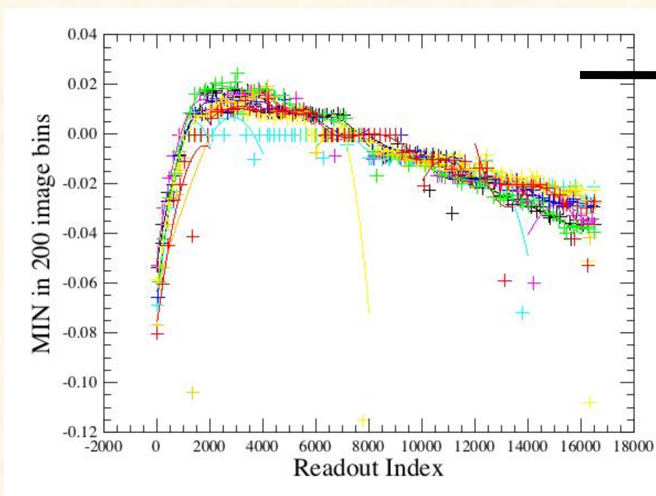
# Proper correction is crucial

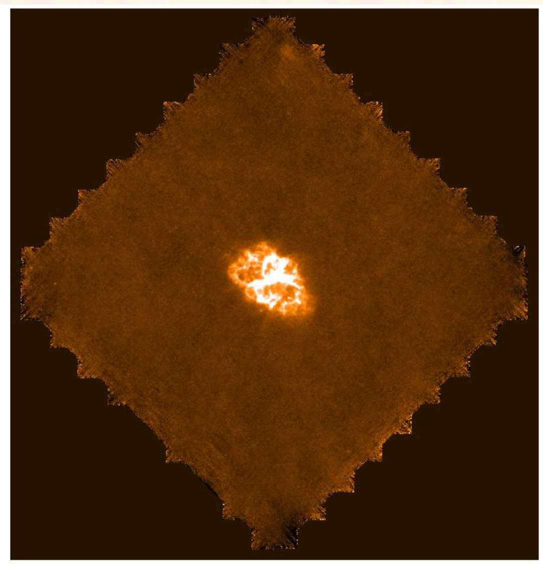
Bad



Good



# Drift Correction

- Preprocessing remains very interactive.
  - Less so with 3rd gen code.
- Crucial to detect and mask remove bad data and avoid pitfalls.

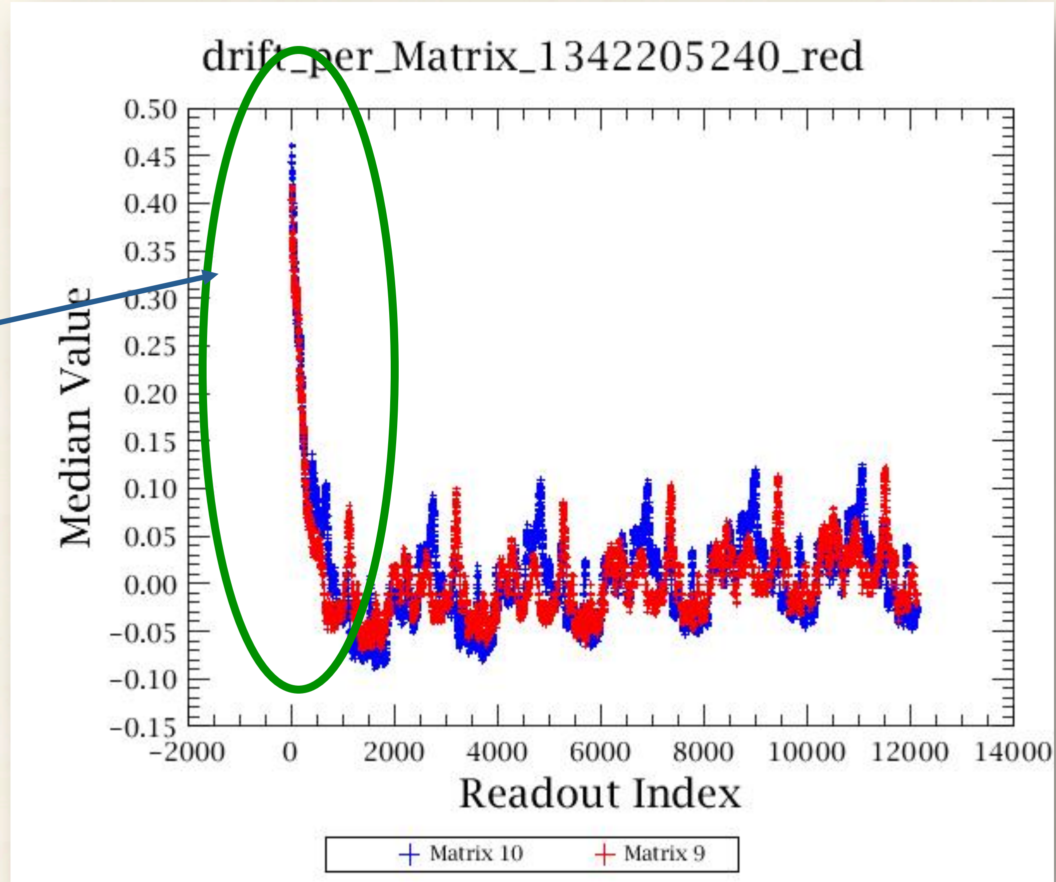
# III. Masking bad pixels

# Calibration block echoes

No correction (yet) in preprocessing.

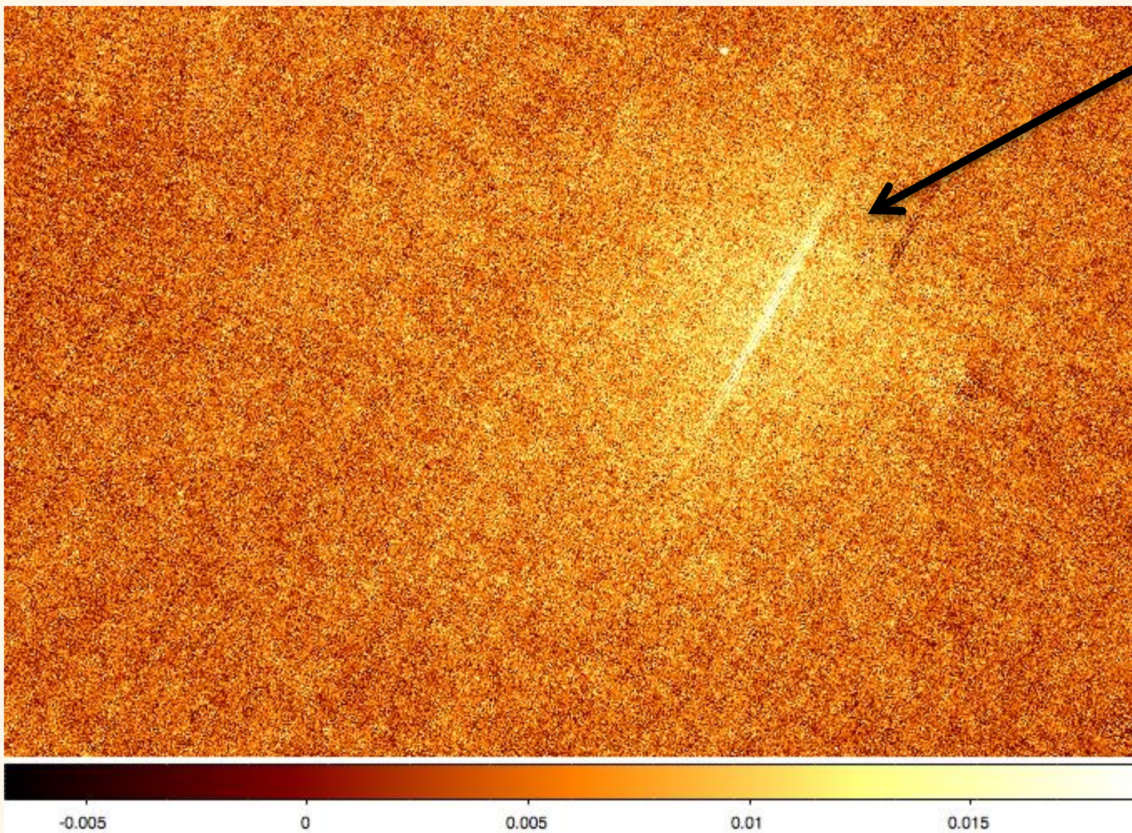
Unstable frames:

Usually at the beginning
Likely due to calibration pre-amble.



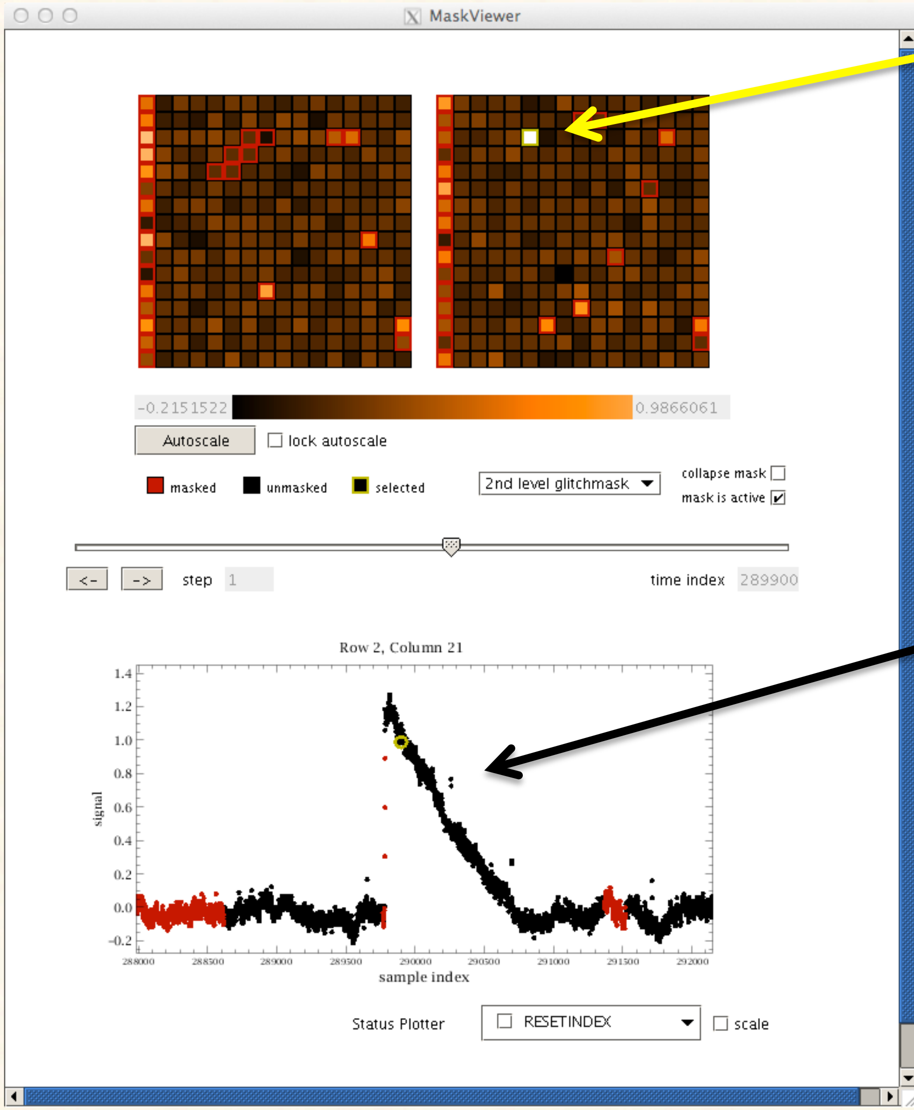

Fix: mask range of readouts as "bad"

# Clean up




Artifacts on projected maps are usually issues in readouts (next slide).

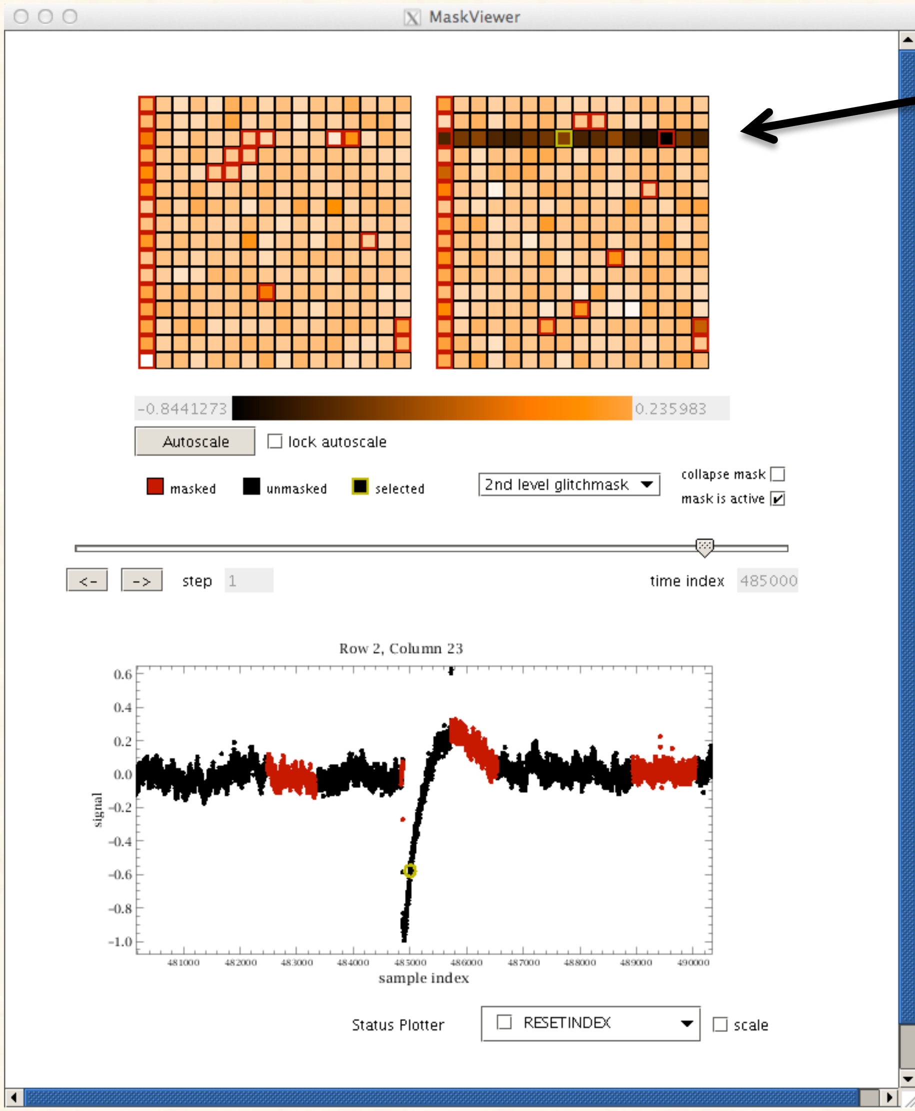
# Clean up (cont.)




Example:
Single pixel that went berserk.

Not a single readout, but 1000s of readouts

# Clean up (cont.)




Example:
An entire row

# Fixes

- There is no PACS pipeline module for automatically detecting these signal anomalies.
- Identify by examining the final map, then reproject to timelines to identify pixels and readout range.
- Masking the affected readouts as “bad glitches” remains the only option.

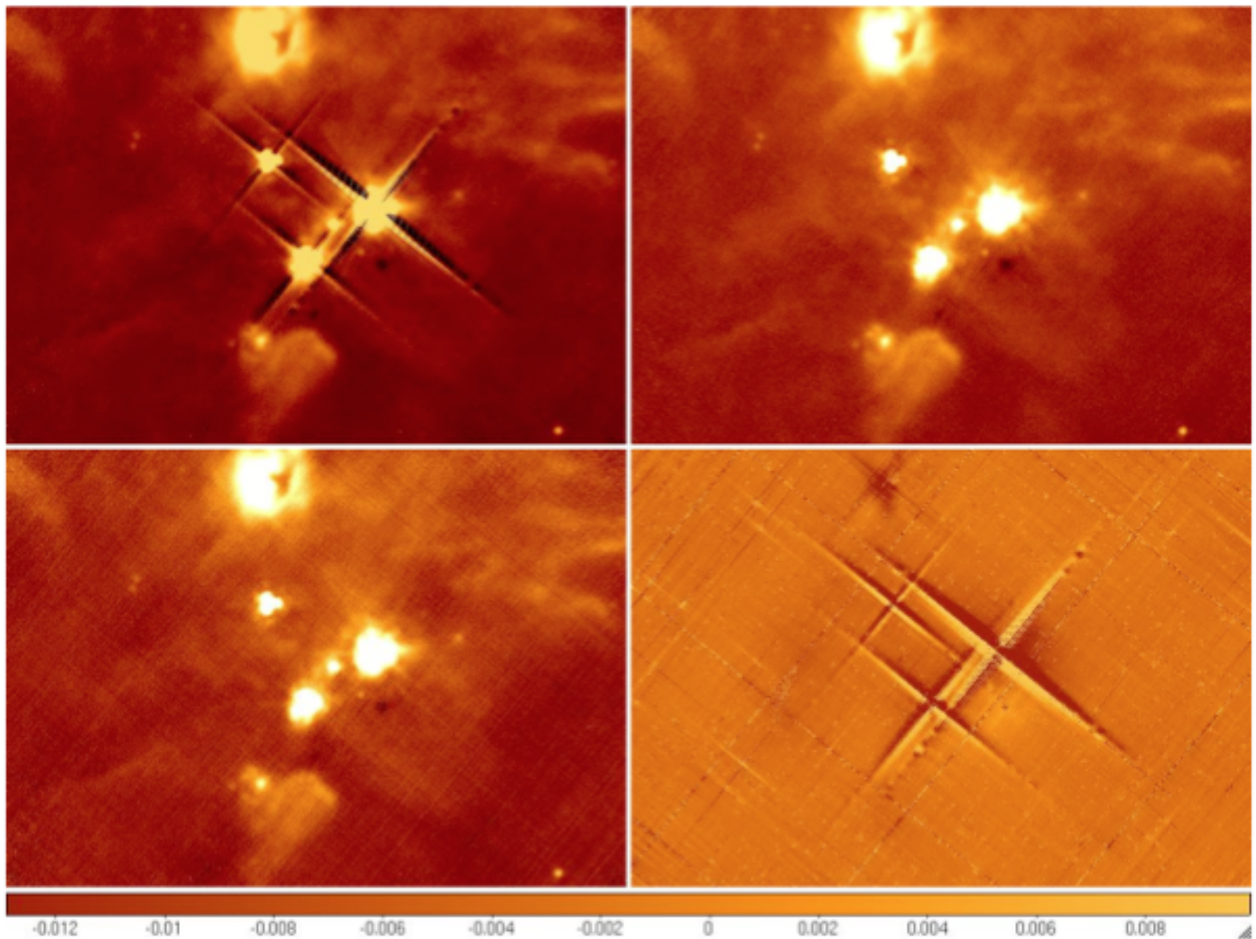
# IV. Post-processing

## Correct the final map for point source artifacts

# Point-source artifacts

Original map

Corrected map




Naïve map

Artifact map

**Figure 1 Results from the point source artifact removal. Top Left. Level 2.5 map generated by MADmap. Top right, the corrected MADmap map. Bottom left the naive (simple projection) map. Bottom right. The artifact map.**

# How does it work?

- Reference:
  - Lorenzo et al. in prep (available on request)
  - Developed for HiGal data processing.
- Uses the optimal map as the starting point for sky emission.
- Subtract sky from original time lines, which leaves only noise +artifacts in the time-line.
- High-pass filter the noise+artifacts time-lines. This removes noise and leaves on artifact.
- In practice, several iterations are necessary.