Hi-C Version 3 Development

* indicates differences from previous versions

Hi-C 4K Processing – End Result

- **Level 0**
  - same, raw
- **Level 0.5**
  - *Time stamp re-corrected (index file times inconsistent with fits file times)
  - *Had to redo the base alignment using a different AIA image due to the time corrections
  - *Determined which rows were missing (center vertical rows from the *untransposed, raw* data), which were causing issues with alignment
  - *Compensated for missing rows
  - *Incorporated fine alignment shifts from C.A.
  - Transposed
  - Corrected the header information
  - *****Not providing to VSO.***
    - Anyone downloading this data would first run hic_prep on it, which just creates Level 1.0. Therefore, to save on computing time overall, providing non-aligned Level 1.0 instead (along with 1.5).

* indicates differences from previous versions

Hi-C 4K Processing – End Result

- **Level 1.0**
  - Prepped
    - Dark-subtracted
    - *Flat-field was not quite normalized (i.e., values > 1). Re-normalized by shifting down to 1 in order to keep same profile.
    - Flat-fielded
    - Dust removed
    - Cropped out unused portion of image
  - *****Providing to VSO.***
    - Provides access to a fully prepped, *non-aligned* data set. (Aligning necessarily alters the pixel values through interpolation.)

- **Level 1.5**
  - Co-aligned
  - *Tracking applied.
  - Normalized by exposure.
  - *Compensated for absorption (explained later).
  - *****Providing to VSO.***
    - Provides access to a fully prepped, aligned, even data set.

* indicates differences from previous versions

Hi-C 1K Processing – End Result

- **Level 0**
  - same, raw

- **Level 0.5**
  - *Time stamp re-corrected (index file times inconsistent with fits file times)
  - *Had to redo the base alignment using a different AIA image due to the time corrections
  - *Determined which rows were missing (center vertical rows from the *untransposed, raw* data), which were causing issues with alignment
  - *Compensated for missing rows
  - Transposed
  - Corrected the header information
  - Incorporated Level 0.5 extractions from the 4K set.
    - *No fine alignment shifts to the 1K set, but the ones applied to the 4K set are transferred to the extractions.*
  - *****Not providing to VSO.***
    - Anyone downloading this data would first run hic_prep on it, which just creates Level 1.0. Therefore, to save on computing time overall, providing non-aligned Level 1.0 instead (along with 1.5 & 2.0).

* indicates differences from previous versions

Hi-C 1K Processing – End Result

- **Level 1.0**
  - Prepped
    - Dark-subtracted
    - Flat-fielded
      - *Used re-normalized flat-field
    - Dust removed
      - *Created and applied additional dust map due to new dust that appears in the images after 18:56:14.460 UT.
      - *Updated dust map is only applied to images with additional dust.
  - Incorporated Level 1.0 extractions from the 4K set.
  - *****Providing to VSO.***
    - Provides access to a fully prepped, *non-aligned* data set. (Aligning necessarily alters the pixel values through interpolation.)

* indicates differences from previous versions

Hi-C 1K Processing – End Result

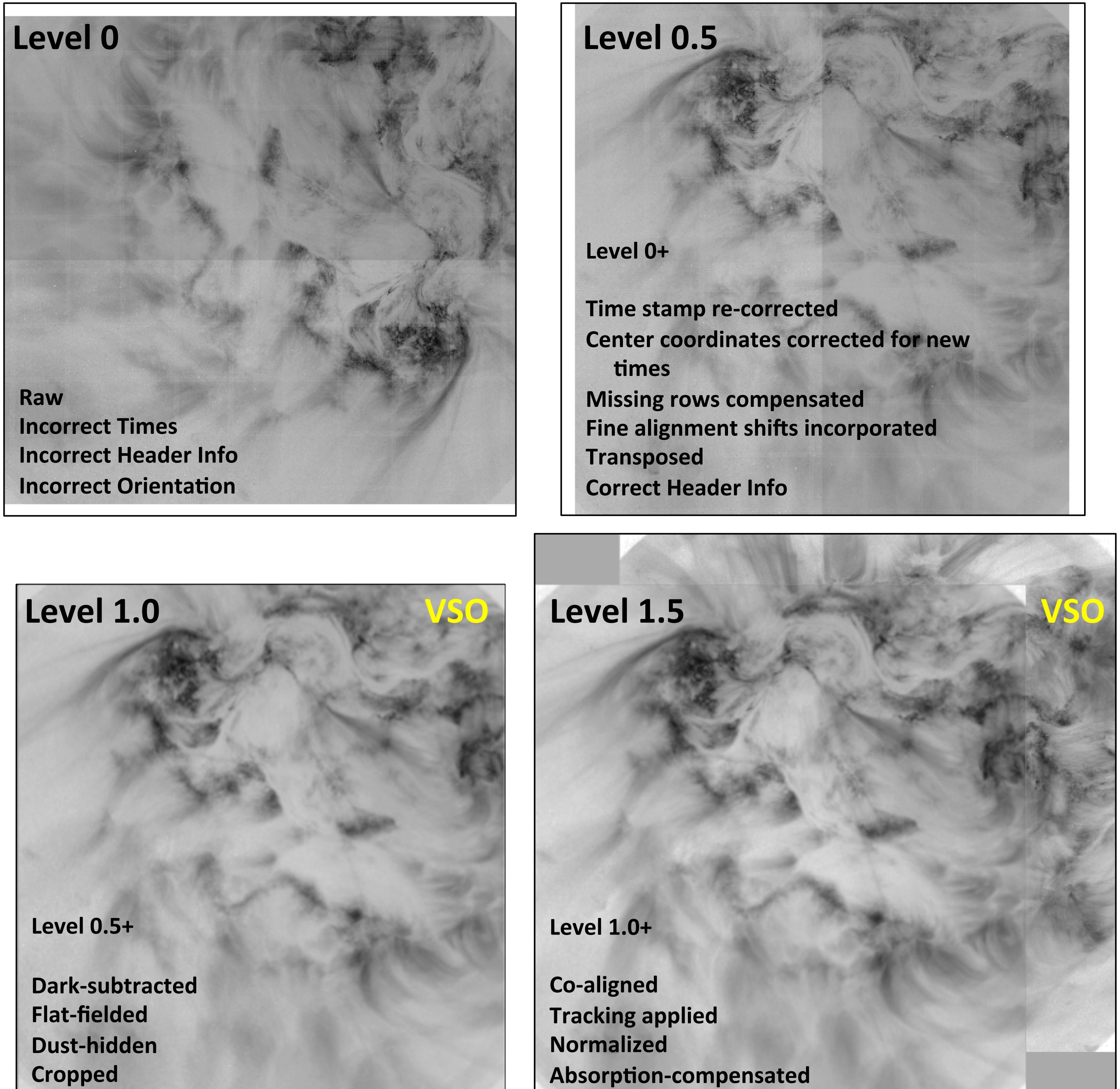
- **Level 1.5**
  - Incorporated Level 1.5 extractions from the 4K set.
  - Normalized by exposure.
  - Co-aligned
  - *Tracking applied
  - Particle hits removed and added to dust map
  - *Compensated for absorption (explained later)
  - *****Providing to VSO.***
    - Provides access to a fully prepped, aligned data set.

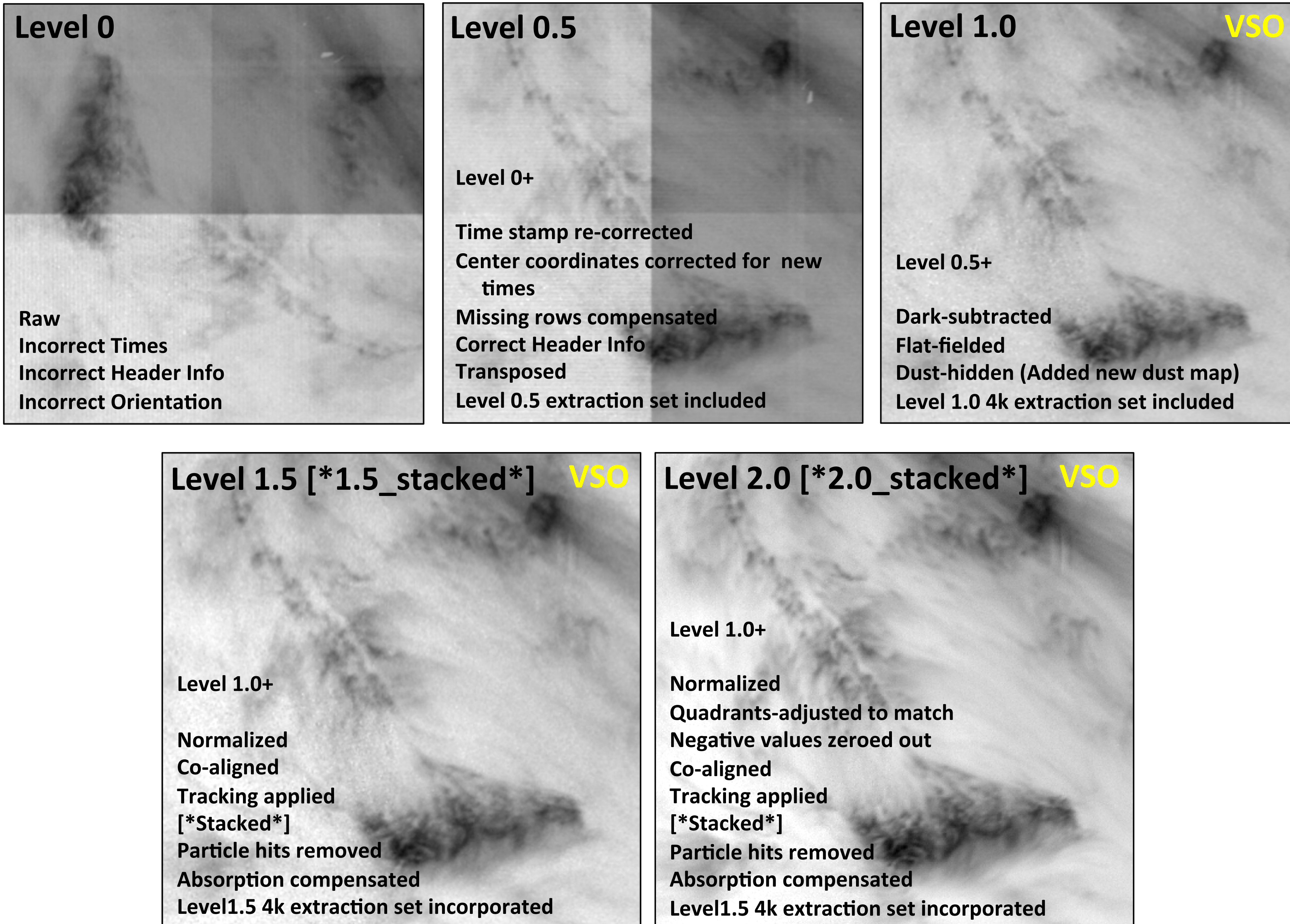
- **Level 1.5_stacked**
  - Same as Level 1.5
  - Additionally, the original 1k 0.5 exposure duration set is co-added and normalized (i.e., averaged)
  - *****Providing to VSO.***
    - Provides access to a fully prepped, aligned, comparable exposure/cadence data set.

* indicates differences from previous versions

Hi-C 1K Processing – End Result

- **Level 2.0 / 2.0_stacked**
  - Same as 1.5 / 1.5_stacked
  - Additionally, the detector quadrants were scaled to match along the boundaries and the negative noise was zeroed out.
  - *****Providing to VSO.***
    - Provides access to a fully prepped, aligned[, stacked], **movie-quality** data set.


Level 0
Raw
Incorrect Times
Incorrect Header Info
Incorrect Orientation
Level 0.5
Level 0+
Time stamp re-corrected
Center coordinates corrected for new times
Missing rows compensated
Fine alignment shifts incorporated
Transposed
Correct Header Info
Level 1.0
VSO
Level 0.5+
Dark-subtracted
Flat-fielded
Dust-hidden
Cropped
Level 1.5
VSO
Level 1.0+
Co-aligned
Tracking applied
Normalized
Absorption-compensated


Level 0
Raw
Incorrect Times
Incorrect Header Info
Incorrect Orientation
Level 0.5
Level 0+
Time stamp re-corrected
Center coordinates corrected for new times
Missing rows compensated
Correct Header Info
Transposed
Level 0.5 extraction set included
Level 1.0
VSO
Level 0.5+
Dark-subtracted
Flat-fielded
Dust-hidden (Added new dust map)
Level 1.0 4k extraction set included
Level 1.5 [*1.5_stacked*]
VSO
Level 1.0+
Normalized
Co-aligned
Tracking applied
[*Stacked*]
Particle hits removed
Absorption compensated
Level1.5 4k extraction set incorporated
Level 2.0 [*2.0_stacked*]
VSO
Level 1.0+
Normalized
Quadrants-adjusted to match
Negative values zeroed out
Co-aligned
Tracking applied
[*Stacked*]
Particle hits removed
Absorption compensated
Level1.5 4k extraction set incorporated

Hi-C 1K Processing – Explained

The following steps are motivated by the need to have a more useful 1K set which is plagued by noise (and extra dust which has been noted as now being removed). But there is noticeable dynamics even at the rapid 1.4 sec cadence of the 0.5 sec duration 1K set (compared to the 5.6 sec cadence of the 2 sec duration 4K extracted set).

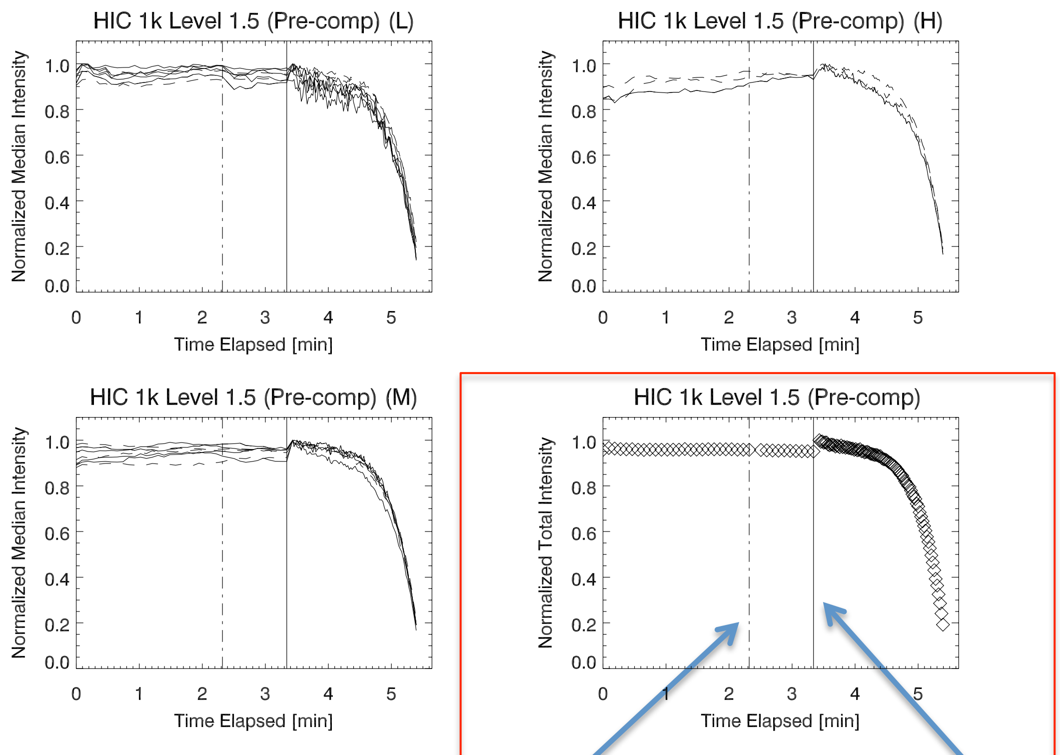
The difference between the noise in the quadrants, the atmospheric absorption, and the "extra" dust contamination mid-flight requires careful processing for scientific and qualitative sets.

Atmospheric Absorption Compensation

Different regions were tracked to see the trends in the data (low, mid, and high signal regions). The normalized total intensities (bottom right) are fit with a smoothed trend (solid black line). Then the images are scaled by the inverse of that trend (i.e., the absorption coefficients). The absorption trend was fit separately to the 4k set and the 1k set and stitched together to get a full absorption coefficient set. The jump in the intensities at the time of the switch to the 1k set is due to the increase in noise-to-signal at low exposures.

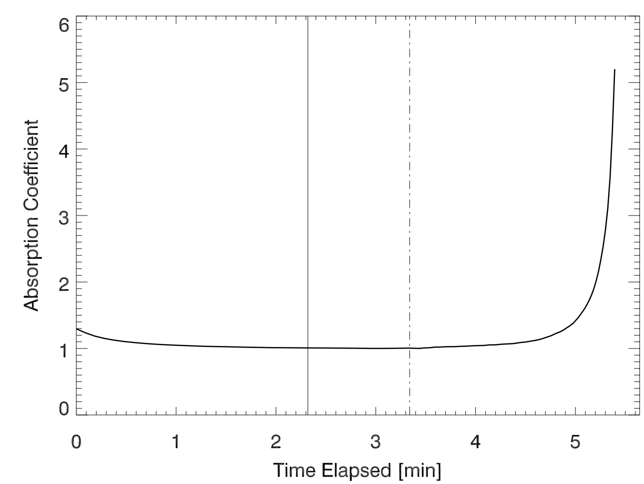
The absorption coefficients have been added to the FITS headers as ABSCOEF.

Prepped, scaled, normalized median ROI and total intensities versus time



Time of 4K pointing shift. Time of switch to 0.5 sec 1K set.

Empirically-derived Absorption Coefficients versus time

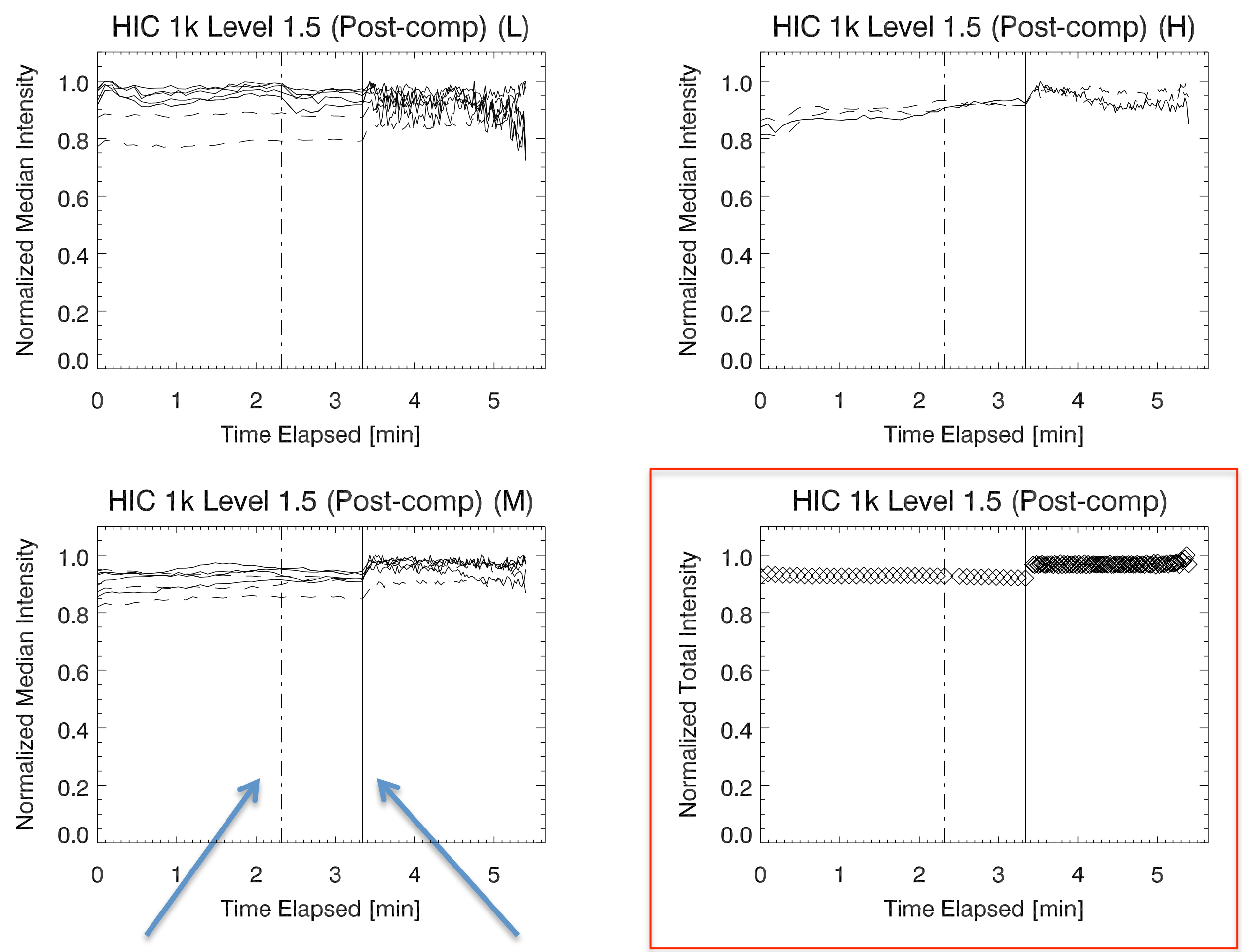


Atmospheric Absorption Compensation

As expected, the noise dominates toward the end of the set which markedly affects the background ROIs as well as the overall levels; ergo, using the background median levels to compensate for absorption does not work very well.

Prepped, scaled, absorption-compensated, normalized median ROI and total intensities versus time

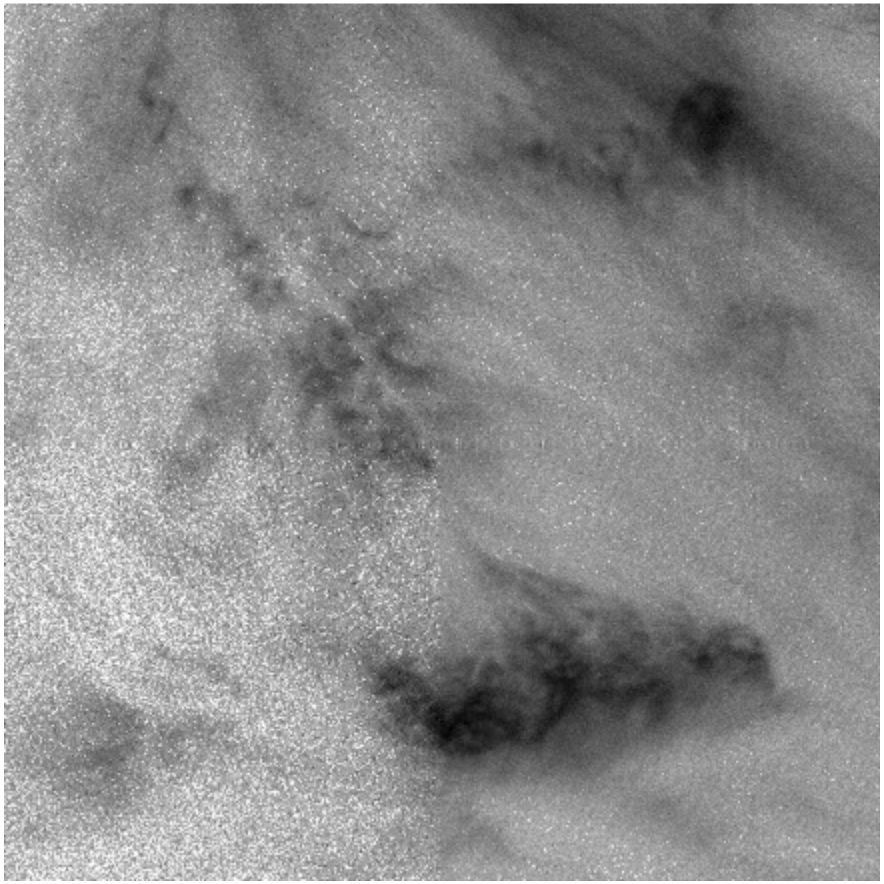
Total intensities were used to derive the proper scaling (previous slide)



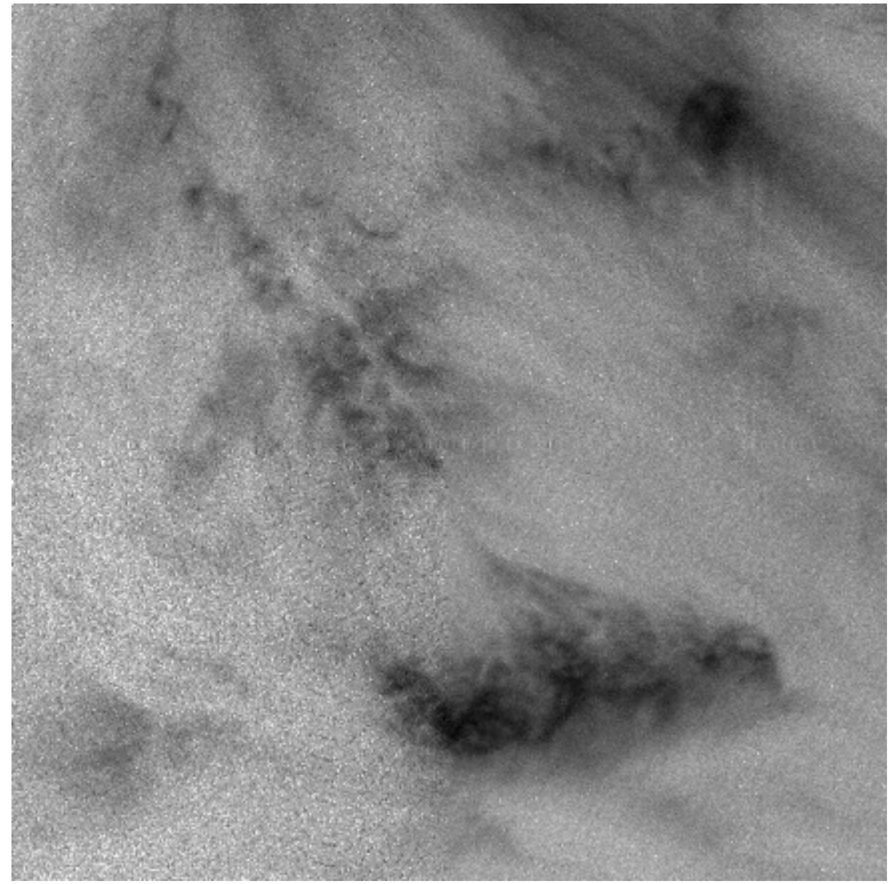
Time of 4K pointing shift. Time of switch to 0.5 sec 1K set.

Example Image Results – **Level 2.0**

Original



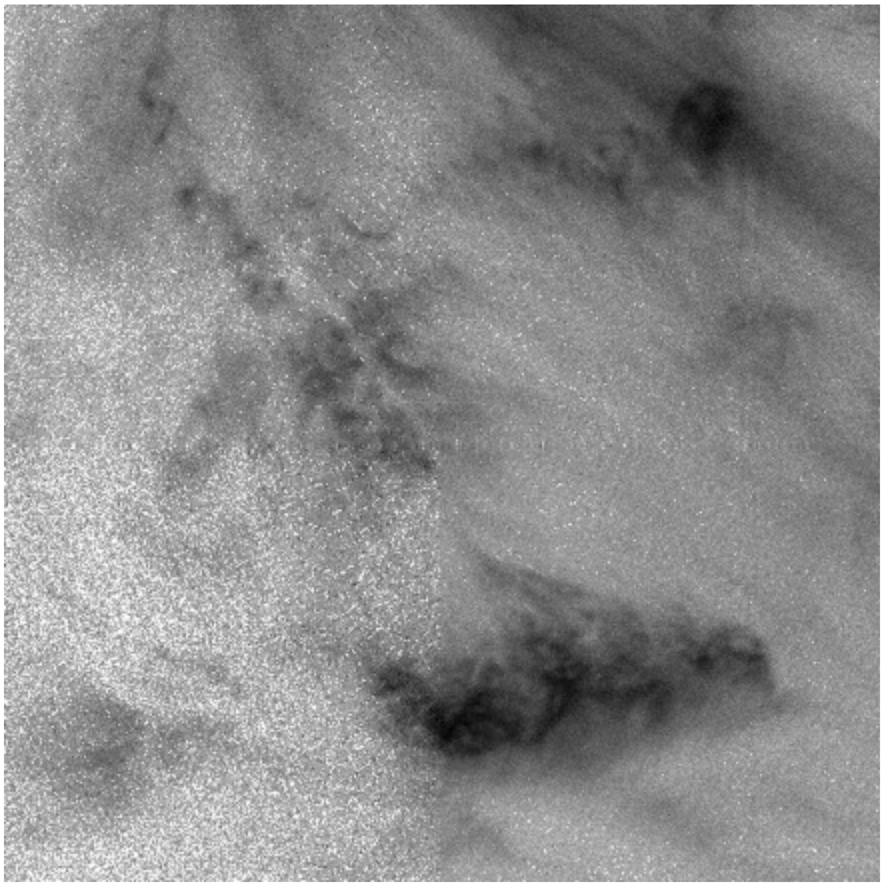
Processed



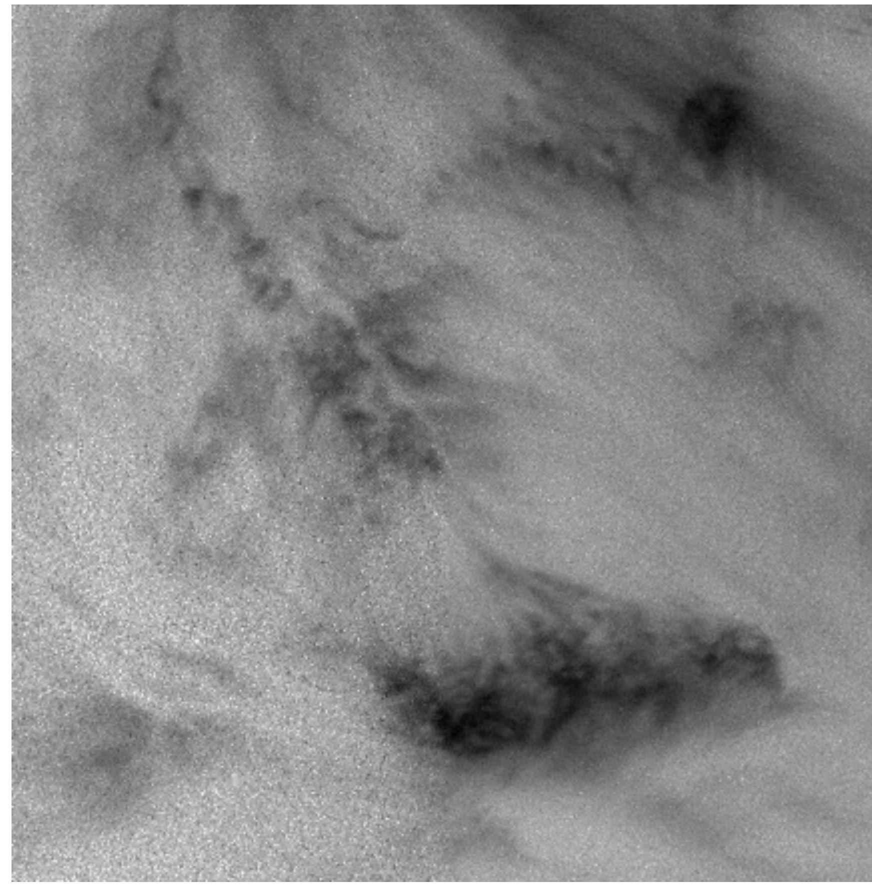
By paying attention to the scaling between and within the images, it is more rewarding to apply further typical scaling techniques to the full set, such as byte or histogram scaling, in order to enhance contrast or movement. ***It also allows us to take advantage of having 86-0.5 sec images that are otherwise under-exposed!*** **Although, uncertainties in the pixel intensities are not being tracked (rocket after all…).**

Example Image Results – **Level 2.0_stacked**

Original



Processed



Not too shabby.

Reference Masks

Worked to provide reference masks for how the pixels were altered during processing:

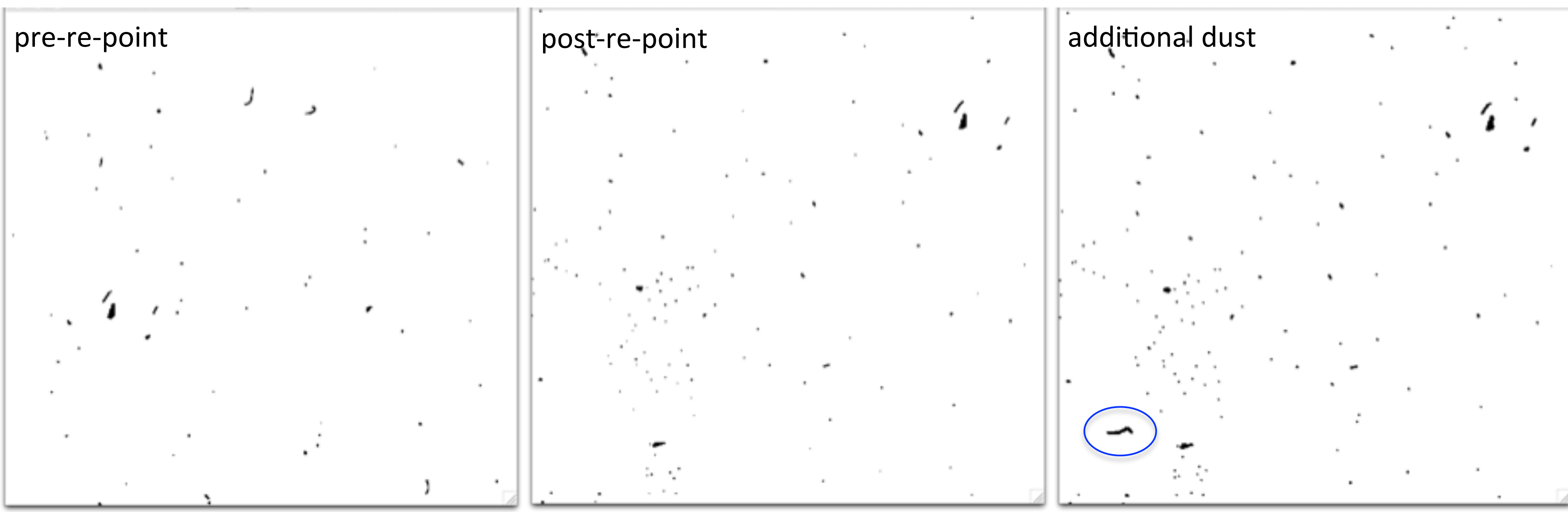
ABSCOEF saved into the FITS headers.

The dust and quadrant masks can be accessed with information contained in a separate .sav file and an IDL program. Using these programs is described on the following slides. I will make the programs available once I can make sure that I have all of the dependencies accounted for.

Reference Dust Masks

- Retrieve reference dust mask from file=dustinfo_*.sav:
  - IDL> restore, file, /v   ;restored variable = dustinfo
  - IDL> restore, hic_map_v3.sav, /v   ;
  - IDL> dustmask = hic_get_dustmask(dustinfo, {hic_map}[index], /sametime)
  - Then use your favorite viewer to display the dustmask image. The hic_map file does not have to correspond to the same level as the dustinfo file and can even be a 4K map, but it will only show the dust in the 1K region if using a 1K dustinfo file.

Different mask per Hi-C image.



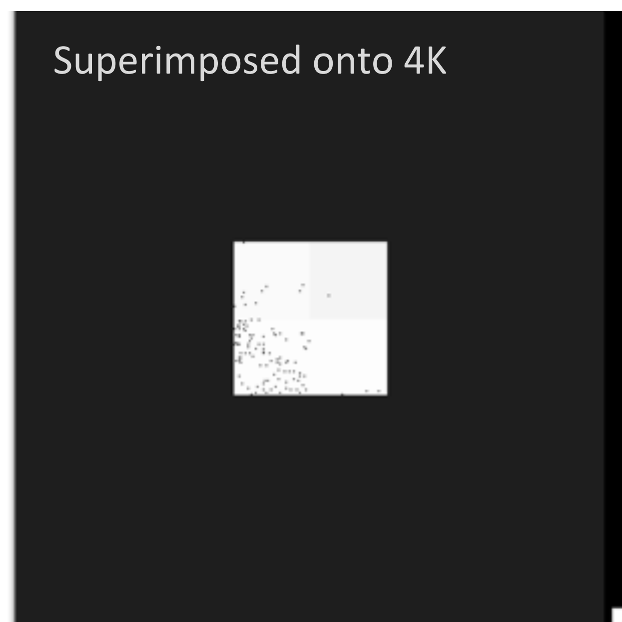
Reference Quad Masks

- Retrieve reference quad mask from file=quadinfo_*.sav:
  - IDL> restore, file, /v ;restored variable = quadinfo
  - IDL> restore, hic_map_v3.sav, /v ;
  - IDL> quadmask = hic_get_quadmask(quadinfo, {hic_map}[index], /sametime)
  - Then use your favorite viewer to display the quadmask image. The hic_map file does not have to correspond to the same level as the quadinfo; however, there are no quadmasks for the 4K set so /sametime cannot be set in that case.

The black dots indicate the negative pixels that were set to 0.

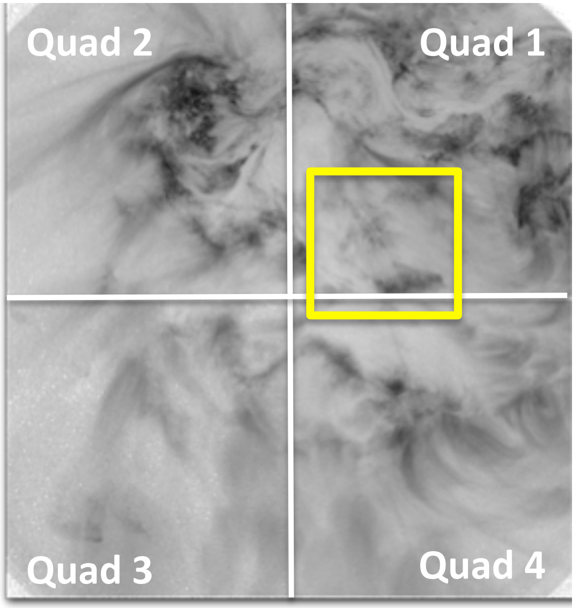
The shading indicates the scaling level of the quadrant.

Different mask per Hi-C image.



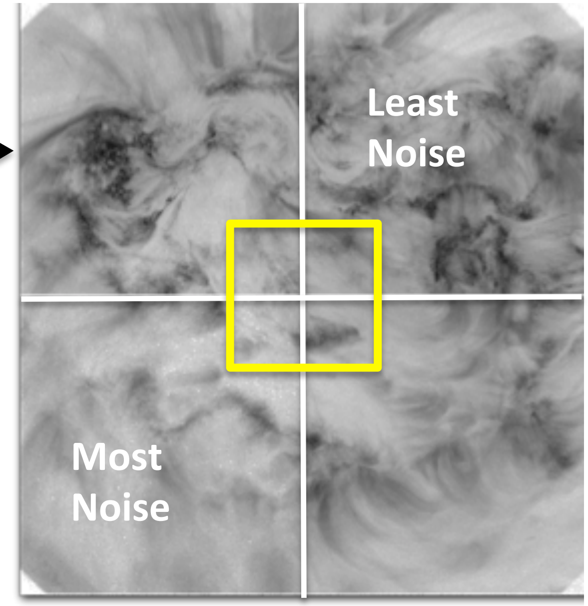
- Discussion about matching the quadrants for the “movie-quality” 1k sets…
  - using the previous results to demonstrate reasoning but the scaling between the 4k and 1k sets has been modified to normalization only

Monitoring Regions of Interest (ROIs) between Quadrants



pointing shift

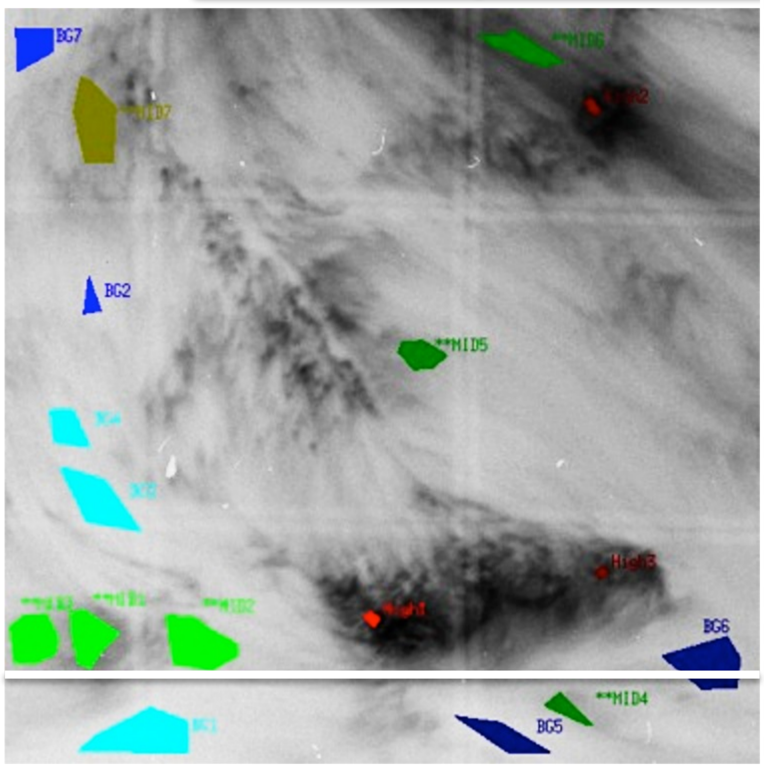
Noise 3 >
Noise 2 >
Noise 4 >
Noise 1



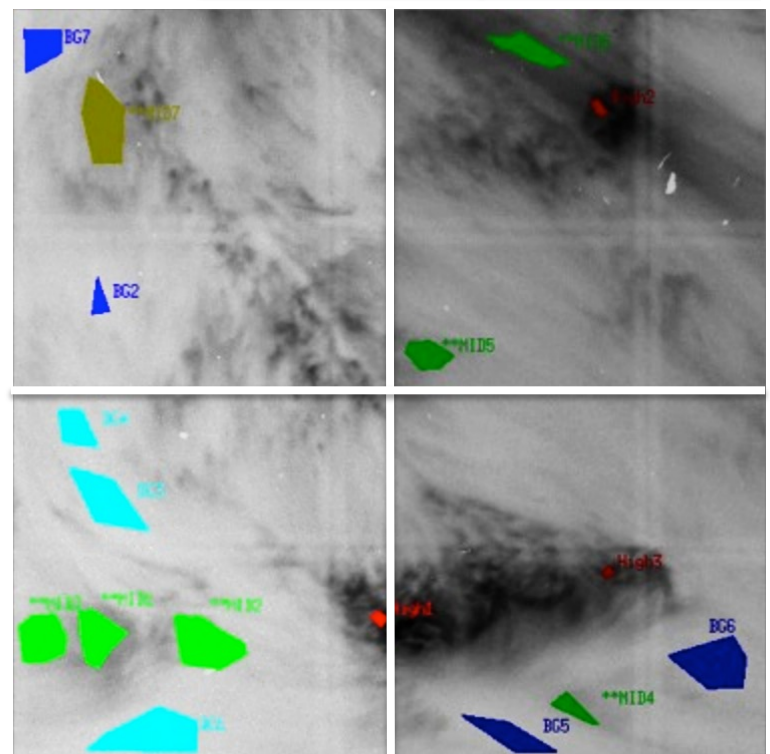
Background
Least affect
Some affect
Most affect

Mid-level
Least affect
Some affect
Most affect

High-level
Least affect
Most affect

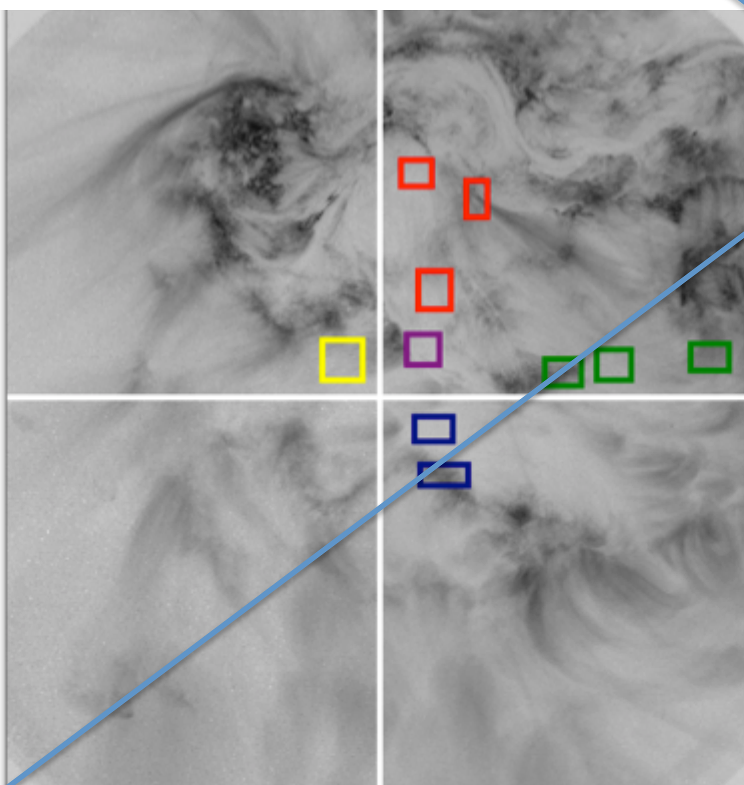


Most affect ROIs

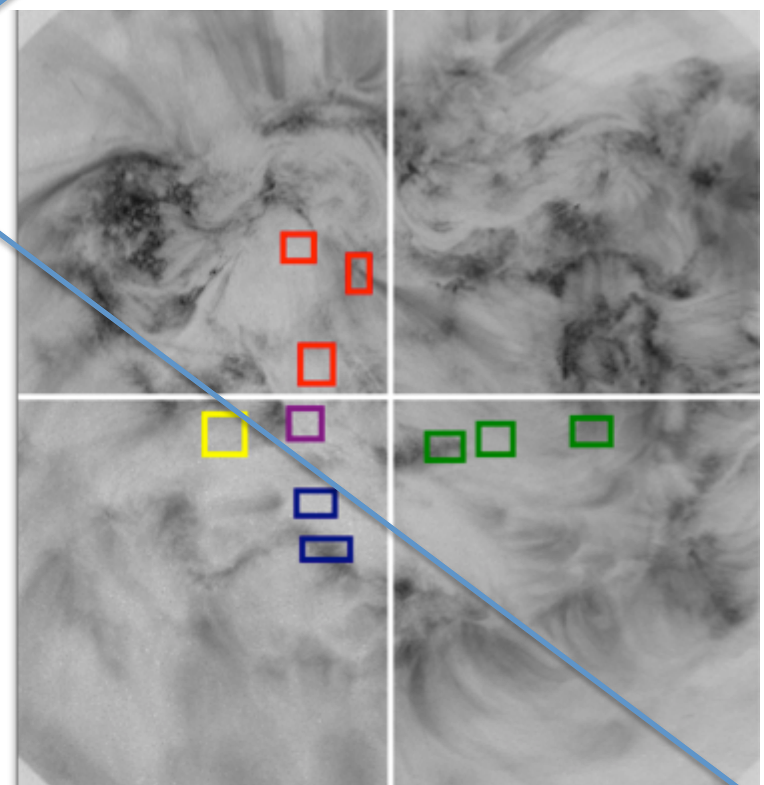


Quadrant Offsets from Dithering

- ***Tried*** to use re-pointing as a straight-forward dither to determine the quadrant adjustments by looking at the change in intensity level of same region from re-pointing between quadrants.
  - This can only be done using the two 4K images taken before and after the re-point.
  - Because these images were long duration, the scaling between images is inconclusive and not applicable to the 1K short-duration set without more calibration sets.



Comparison inconclusive and not applicable to 1K set where noise levels are most pronounced due to short exposure.

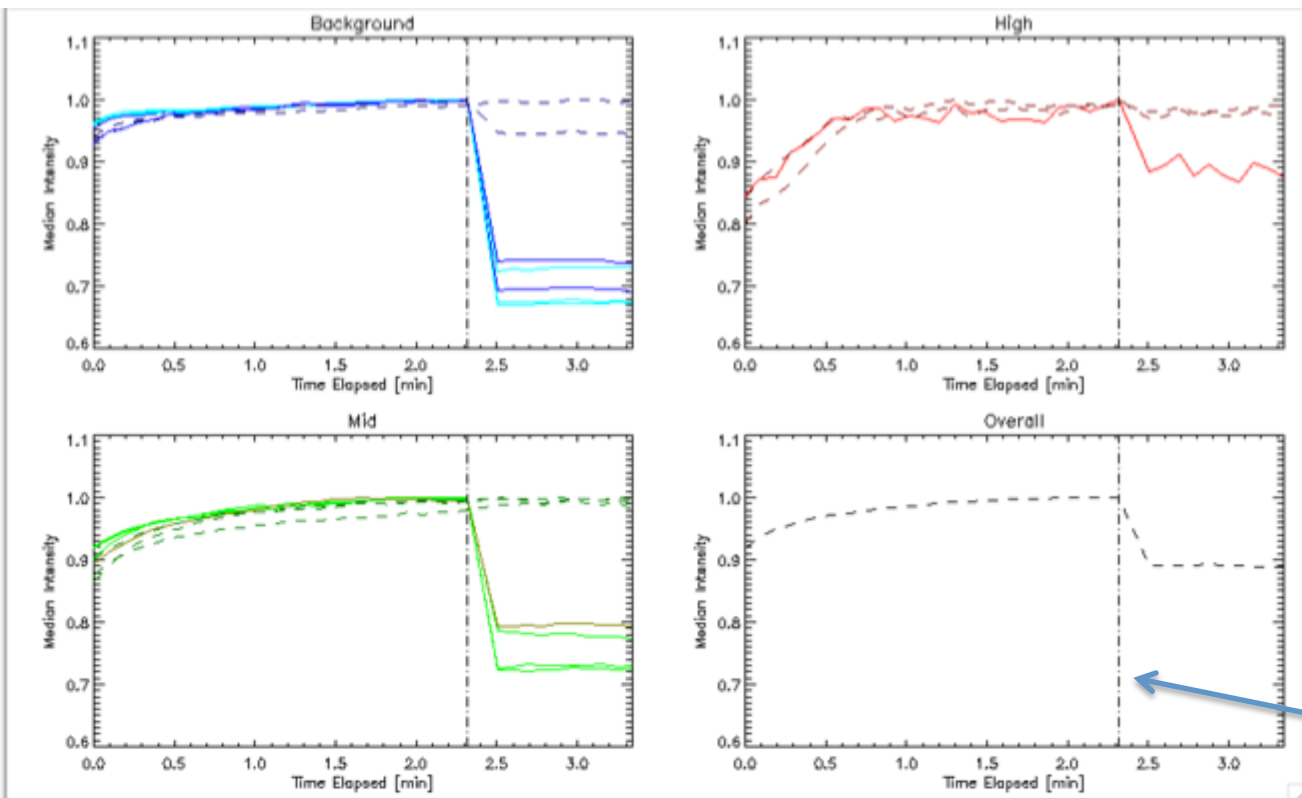


Quadrants

Therefore, monitoring the normalized median values of several aligned ROIs of different intensity levels (background, mid-level, high-level, and overall), shown on slide 8.

Only 4K extractions shown here to empahsize the effect of the pointing shift.

ROIs that changed from low noise to high noise quadrants during re-pointing experience a marked decrease in signal levels. (Colors correspond to previous slide.)

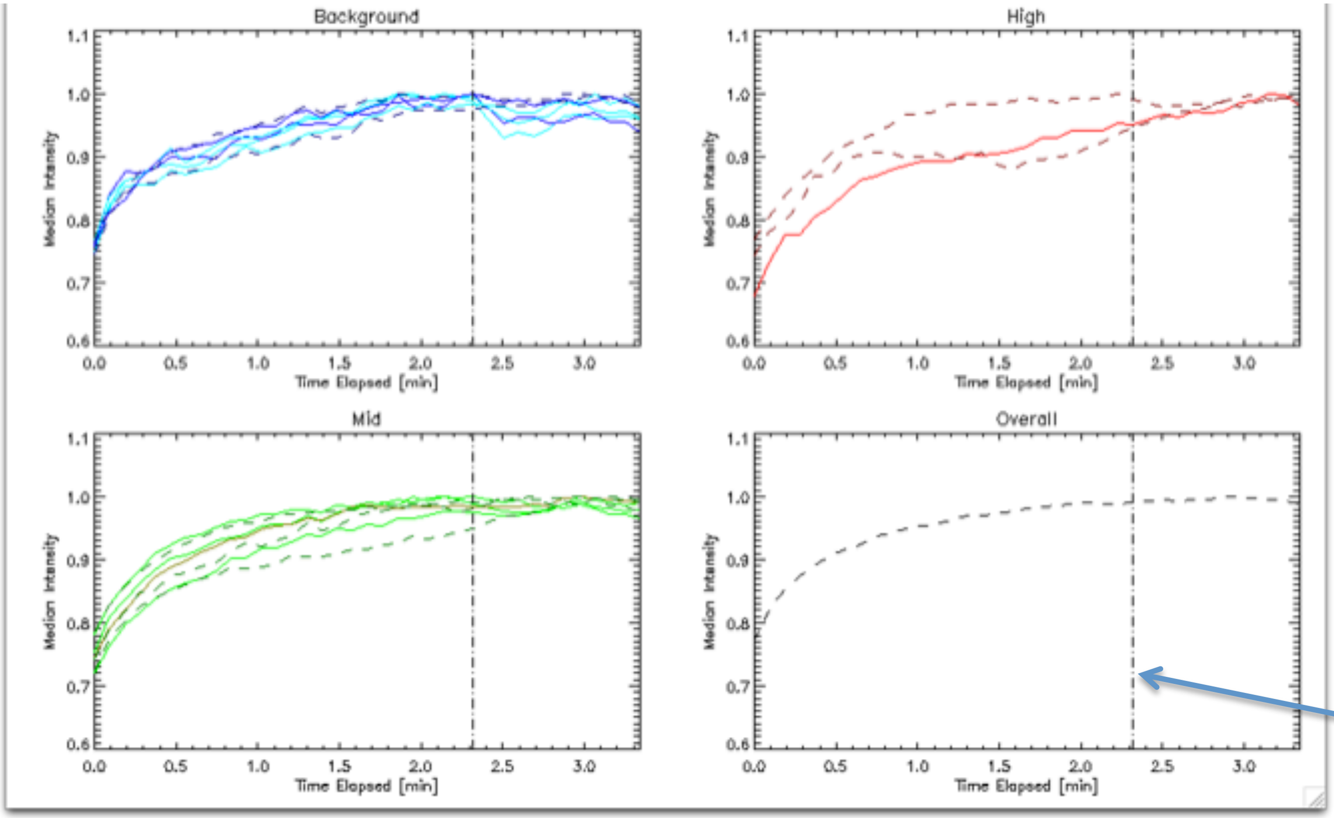


Pre-prepped, normalized median ROI intensities versus time

Time of 4K pointing shift.

Quadrants

Prepping successfully reduces the effect for the long-exposure images due to high signal, but…

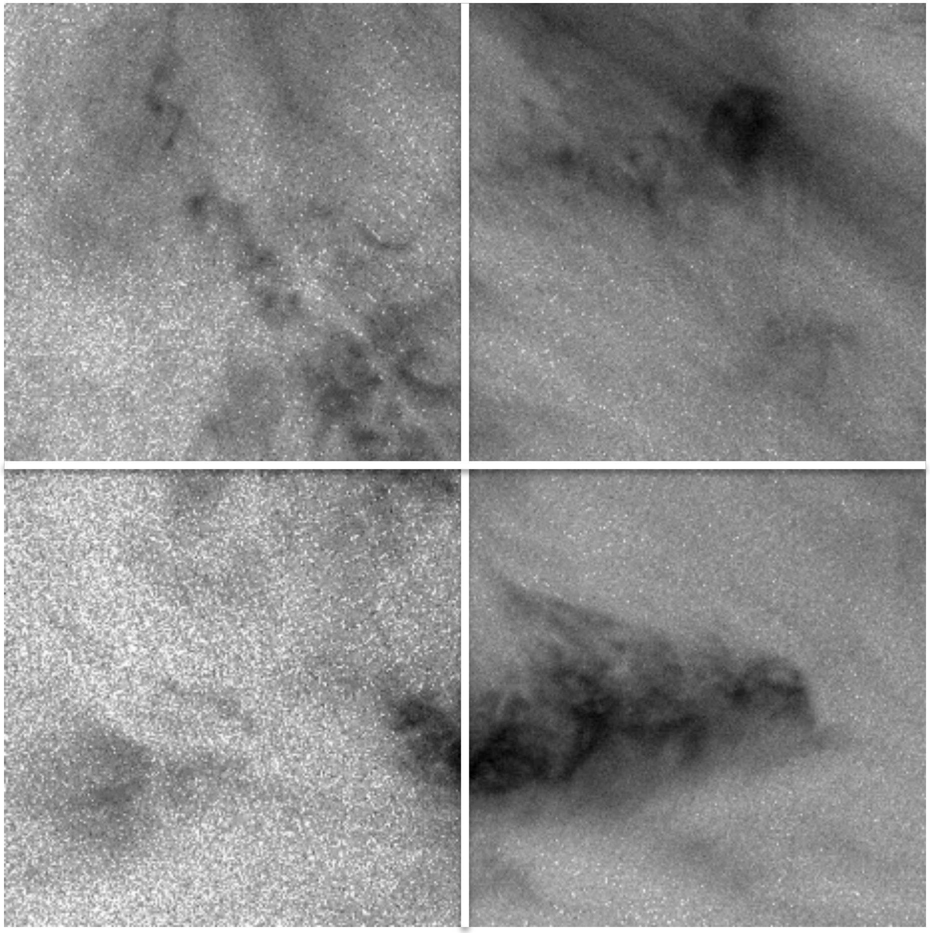


Prepped, normalized median ROI intensities versus time

Time of 4K pointing shift.

Quadrants

…this disparity between quadrants is still noticeable in the noise level of the short exposure set since noise scales differently than signal.



Quadrants

Best solution, based on trying *several* methods:

1. Set negative values to 0. These pixels mapped out noise anyway and were set to negative values due to alignment interpolation.

2. Determine the scaling between the quadrants by "matching" the boundaries between them iteratively (dashed line).

3. Fit a smoothed scaling trend for each quadrant (solid blue line).

4. Re-scale the quadrants by the trend to avoid local maxima from dynamic events.

This has been added to the prepping procedure for creating the Level 1.5 and Level 2.0 1K data sets. Reference masks are created and will be discussed later.

Quadrant Scale Factors