GSAOI bad pixel mask generation
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This document describes the procedure followed to generate the bad pixel mask (BPM) to be used with GSAOI for (a) processing of data frames for science reduction.

1. Detector cosmetic (or lack of it thereof)

Figure 1 presents a 150sec dark (left) and a well-exposed H-band GCAL flat (right) image. The following cosmetic flaws are apparent:

a. Individual bright (hot) pixels – readily detected in the dark frame, characterized by counts several thousand times the local average. As described in the Users Manual, the GSAOI hot pixels "bleed" to the surrounding pixels, forming a cross-shaped feature. The satellite "warm" pixels are usually a factor of 1000 or more fainter than the central hot pixel. (see figure 2)
b. dark circular spots, corresponding to places where the pixels have been "depedded"
c. bright spot in the lower left corner of detector [3]
d. bright vertical streak in the lower right of detector [3]
e. dark scratches in the lower half of detector [1
f. several dark patches in detectors [4] and [2]
g. the "Christmas tree" dark area in the lower half of detector [2]
h. other smaller dark scratches in detector [4] and [2]
i. corner and edge effects. Particularly, four pixels around each detector are blanked out (no signal).
j. The vertical features of hot pixels in detectors [3] and [4] in the dark frame have been explained by Jan (see Report #33).
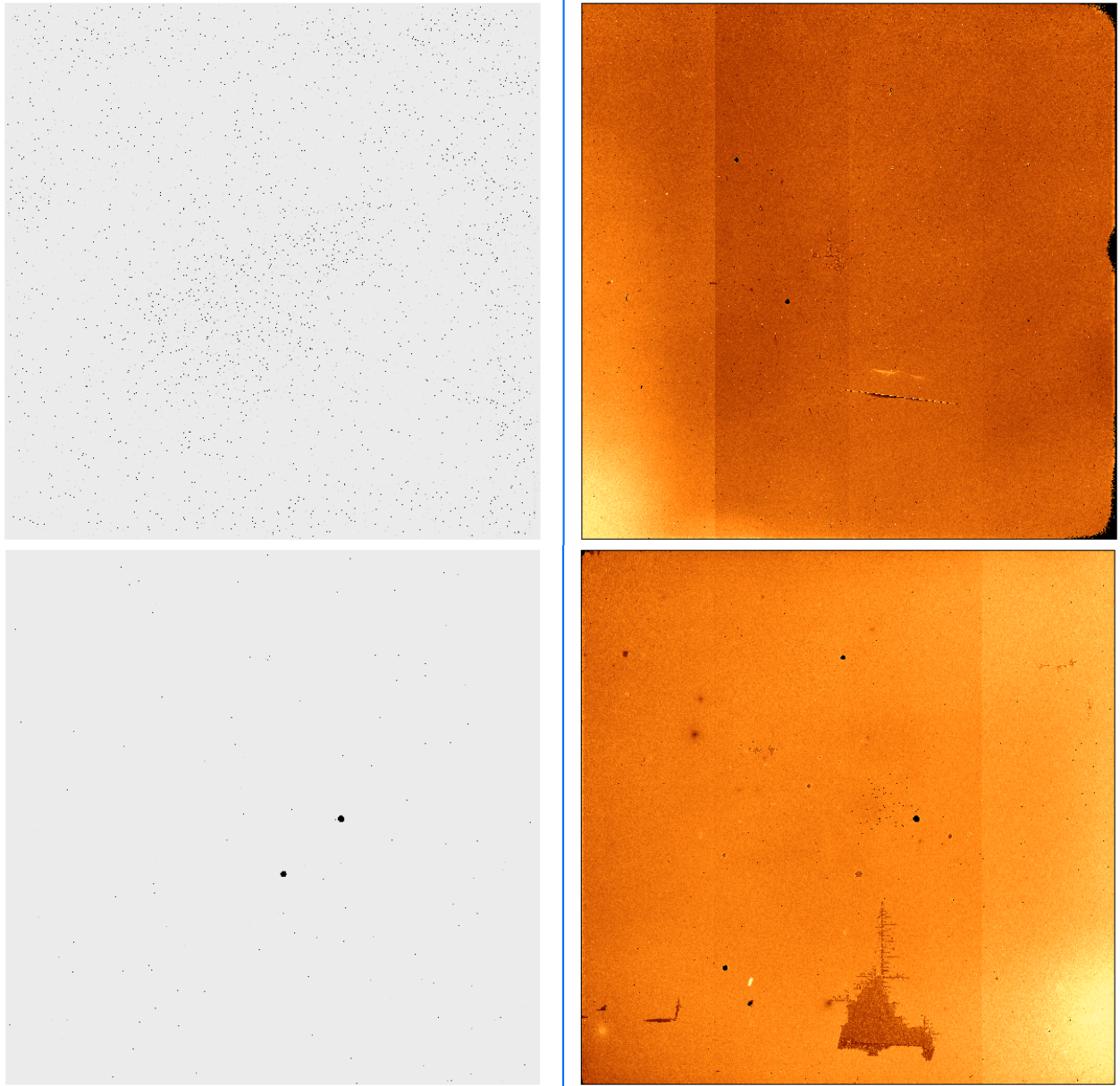
Figure 1a – Top left: Extension [1] of dark frame; top right: extension [1] of flat frame. Bottom left: extension [2] of dark frame; bottom right: extension [2] of flat frame. Note the much larger number of "hot" pixels in detector [1].
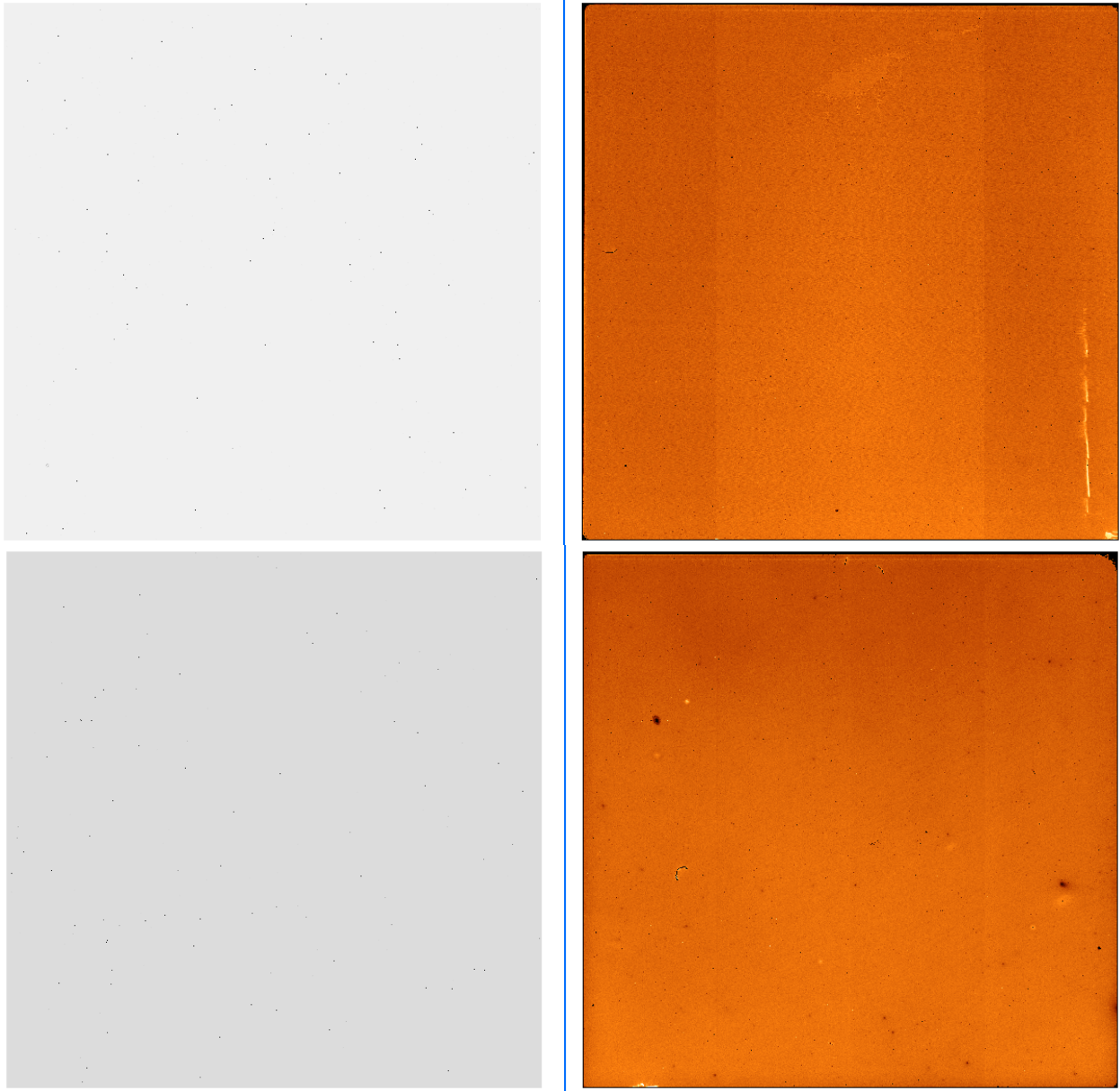
Figure 1b – Top left: Extension [3] of dark frame; top right: extension [3] of flat frame. Bottom left: extension [4] of dark frame; bottom right: extension [4] of flat frame.
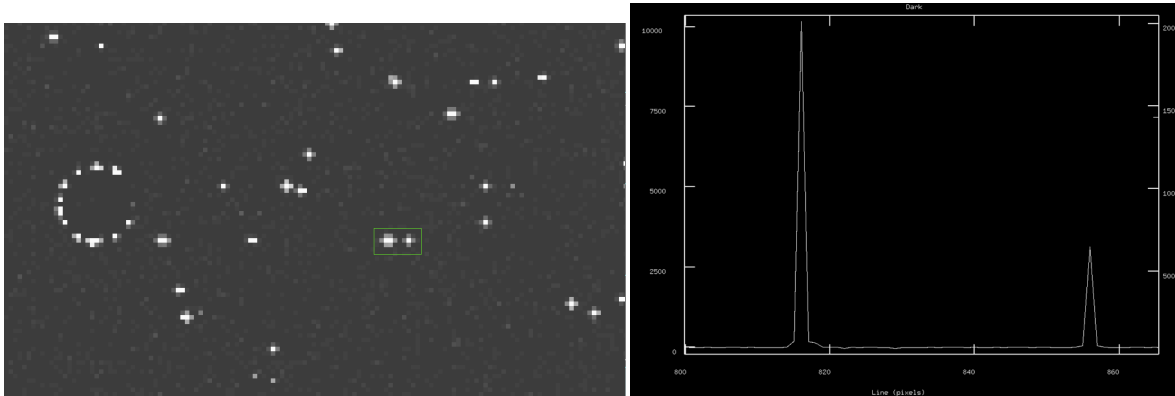
Figure 2 – Left: zoomed in region of detector [1] dark frame, showing one of the depped regions on the left and several hot pixels with the cross-shaped outliers. Right: plot across the central pixel of the two hot clusters outlined by the box in the left, highlighting the relative intensity of the outliers relative to the central hot pixel.

The objective of the BPM is to mask out the relevant defects. Not all the cosmetic flaws above need to be masked out, as some (such as the Christmas tree area) are only reflecting a lower sensitivity of the local pixels and should flat-field out properly when the data are processed. It is, therefore, part of the BPM generation to define the limits when a pixel is considered "bad" and needs to be fully masked out when combining frames.

2. Data and procedure

The data used to generate the 2011 BPM (included in the GSAOI package) were:

  a. set of 5 150sec darks taken 20110120UT (S20110120S0051 to 55)
  b. one H band flat with average counts around or above 20000 in all detectors and no saturated pixels, S20110214S0070.fits

Newer files can be found in the Gemini Science Archive, through a search of the General Catalog. Any set of properly exposed flats will work. Darks for the BPM are taken once per semester, with exposure times in the range 120-160sec. If the user's science frames are longer than 160sec, consider requesting a set of darks to match the observations, in order to experiment with the BPM creation. See the GSAOI Calibrations page for more information on how to search and retrieve flats and darks.

When deriving the original BPM, the dark current behaviour was first checked to verify if the hot pixels were variable in time. This was done within the time span of the set used here, and also comparing two long (600sec) darks taken about a month apart. The hot pixels are found to be constant in terms of presence and position. Intensity for the core pixel correlates with time, but it is not linear.

The five 150sec darks were then combined using gemcombine with combine=median and reject=avsigclip, in order to remove eventual cosmic rays. No trimming was applied (the 4 pix around each detector were left as part of the BPM).

The procedure to generate the BPM is based on two steps:
1. use the flat frame to flag the COLD pixels – since the flat is well exposed, pixels with response below a certain acceptable threshold can be flagged as having too low response. The threshold is defined as below a certain %-ile of the mean counts over the full detector.
2. use the dark frame to flag the HOT pixels – conversely, any pixels with signal too high compared with the dark current can be flagged as having anomalous response. The threshold is defined as above a certain %-ile of the (mean + 3sigma) value over the full detector.

The BPM was generated for different values of the percentile cut (for COLD: 50, 25, 10, 5, 1; for HOT: 50, 75, 90, 95, 99), and checked visually against the original frames to verify whether the mask was properly flagging the cosmetic defects.

The following were the final values:

1. COLD pixels: all pixels with value below 50% of detector median
2. HOT pixels: all pixels with value above 75% of detector +3 sigma (for the science BPM).

The threshold for COLD pixels is chosen as to include all the dark scratches and edges, but not the "Christmas tree" in [2] and bright vertical streak in [3]. Subsequent analysis of the flats indicate those (and most of the similar cosmetic flaws detected in the flat frame) will properly flat-field out when a frame is divided by the normalized flat, correcting the relative pixel-to-pixel variations on each detector.

The user need to exercise some care when defining the limit for the HOT pixels: if the outliers are included in the science BPM, it would be masking around 3% of the pixels in [1] and around 2% in the other detectors. More importantly, the outliers are found to subtract out to within the noise (see section below), so it is not really necessary to mask them out when combining frames (readers are reminded that with NIR data, frames are always subtracted either in pairs or with an averaged sky). Flats are either taken as ON/OFF pairs (H and K bands) or the exposure time is short enough that the intensity of the outlier pixels is a very small fraction of the illumination level.

Below is the sequence of commands with IRAF:

Prepare all images using gaprepare, with all flags set to no (this only aims to set all the keywords correctly).

gaprepare *.fits fl_trim- fl_nlc- fl_vardq- fl_sat-

COLD pixels:

imstat gS20110214S0070[1] (then [2], [3] and [4])

The mean counts for each detector and corresponding 50% level are:

[1] 20900 10450
[2] 23500 11750
[3] 19600 9800
[4] 18900 9450

The COLD pixel mask is generated:

imexpr "((a < b) ? 1 : 0)" gS20110214S0070_1_50 a=gS20110214S0070[sci,1] b=10450.
imexpr "((a < b) ? 1 : 0)" gS20110214S0070_2_50 a=gS20110214S0070[sci,2] b=11750.
imexpr "((a < b) ? 1 : 0)" gS20110214S0070_3_50 a=gS20110214S0070[sci,3] b=9800.
imexpr "((a < b) ? 1 : 0)" gS20110214S0070_4_50 a=gS20110214S0070[sci,4] b=9450.

HOT pixels – science BPM:

imstat gS20110120S0051_comb[sci,1] (then [2], [3], [4])

The mean + 3*stddev values and 75%-ile level cut are:

[1] 1600 1200
[2] 630   473
[3] 501   376
[4] 429   322

The HOT pixel mask is generated:

imexpr "((a > b) ? 1 : 0)" gS20110120S0051c_1_25 a=gS20110120S0051_comb[sci,1] b=1200.
imexpr "((a > b) ? 1 : 0)" gS20110120S0051c_2_25 a=gS20110120S0051_comb[sci,2] b=473.
imexpr "((a > b) ? 1 : 0)" gS20110120S0051c_3_25 a=gS20110120S0051_comb[sci,3] b=376.
imexpr "((a > b) ? 1 : 0)" gS20110120S0051c_4_25 a=gS20110120S0051_comb[sci,4] b=322.

And the two masks above are combined:

imexpr "((a == 1)||(b == 1) ? 1 : 0)" gsaoibpm_50_25_1 a=gS20110120S0051c_1_25 b=gS20110214S0070_1_50
imexpr "((a == 1)||(b == 1) ? 1 : 0)" gsaoibpm_50_25_2 a=gS20110120S0051c_2_25 b=gS20110214S0070_2_50

```
imexpr "((a == 1)||(b == 1) ? 1 : 0)" gsaoibpm_50_25_3 a=gS20110120S0051c_3_25
b=gS20110214S0070_3_50
imexpr "((a == 1)||(b == 1) ? 1 : 0)" gsaoibpm_50_25_4 a=gS20110120S0051c_4_25
b=gS20110214S0070_4_50
```

Finally, pack the MEF file:

```
wmef gsaoibpm_50_25_1,gsaoibpm_50_25_2,gsaoibpm_50_25_3,gsaoibpm_50_25_4
gsaoibpm_high_full  phu=dummy
```

If of interest, the pixel type can then be changed to short or ushort to save disk space:

```
chpixtype gsaoibpm_high_full  gsaoibpm_high_full_short short
```

For comparison, the above mask and an example of a more aggressive cut for the HOT pixels in detector [1] is shown in Figure 3. This alternate mask is set to 50% of detector median + 3 sigma, and flags most of the outlier pixels.

Figure 4 show a few examples of BPM overlap on areas of the different detectors with obvious cosmetic flaws.
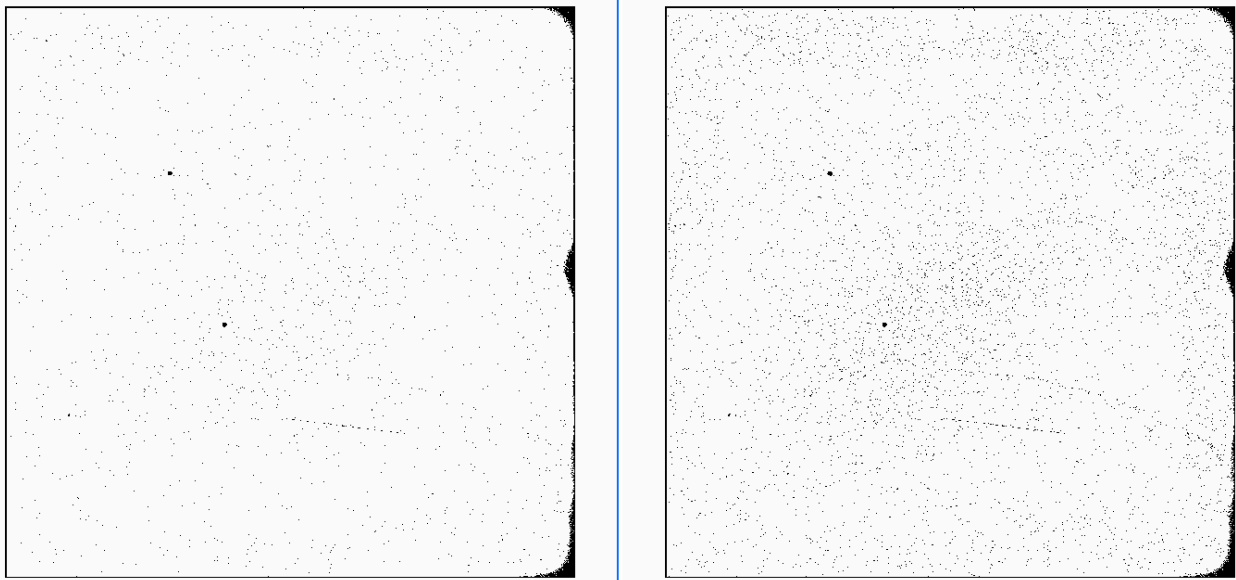

Figure 3 – Resulting BPM for detector [1] left: science; right: 50% cut. The four pixels all around the detector are flagged by the BPM.
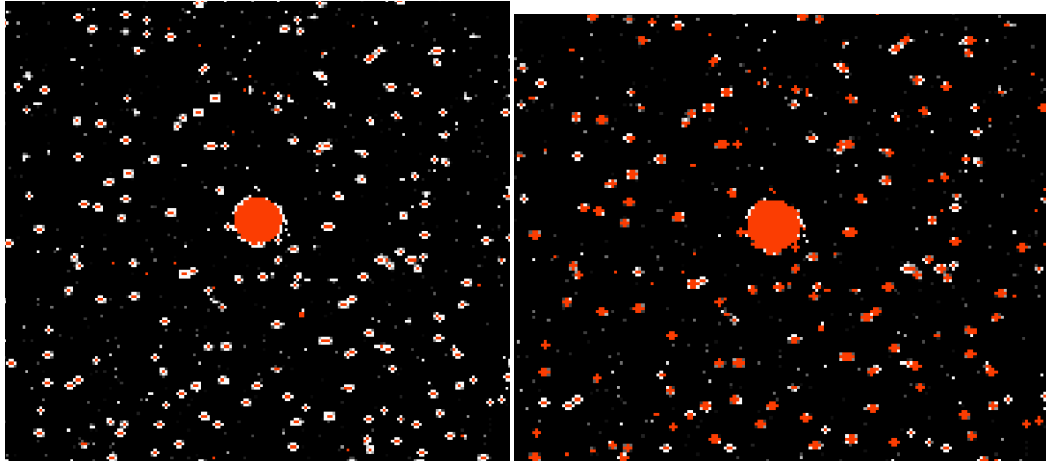
Figure 4(a) – region on detector [1] showing one of the deppeded regions and several hot pixels in a dark frame. Red pixels are masked. Left: science BPM; Right: 50% cut BPM.
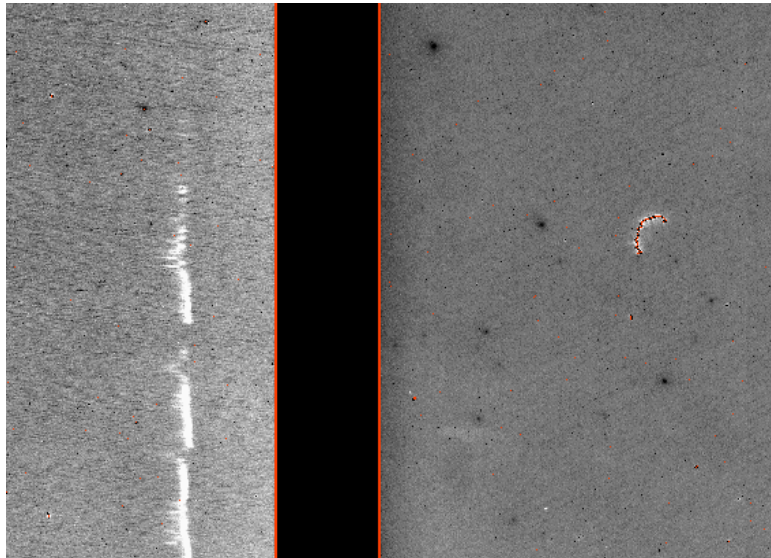

Figure 4(b) – region across the bottom of detectors [3] and [4], showing the masking of the "scratch" in [4] but not the bright streak in [3].
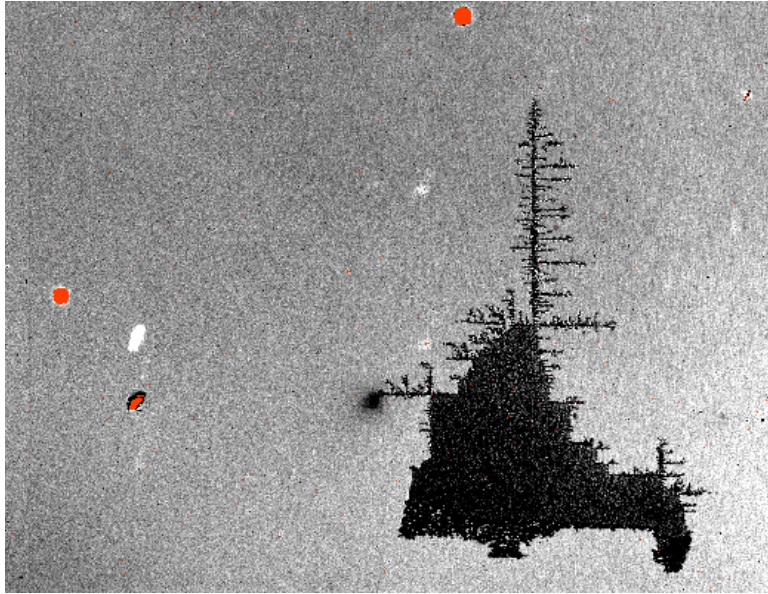
Figure 4(c) – the "Christmas tree" in detector [2] is not flagged as bad, but several deppeded regions and deffects are seen here.
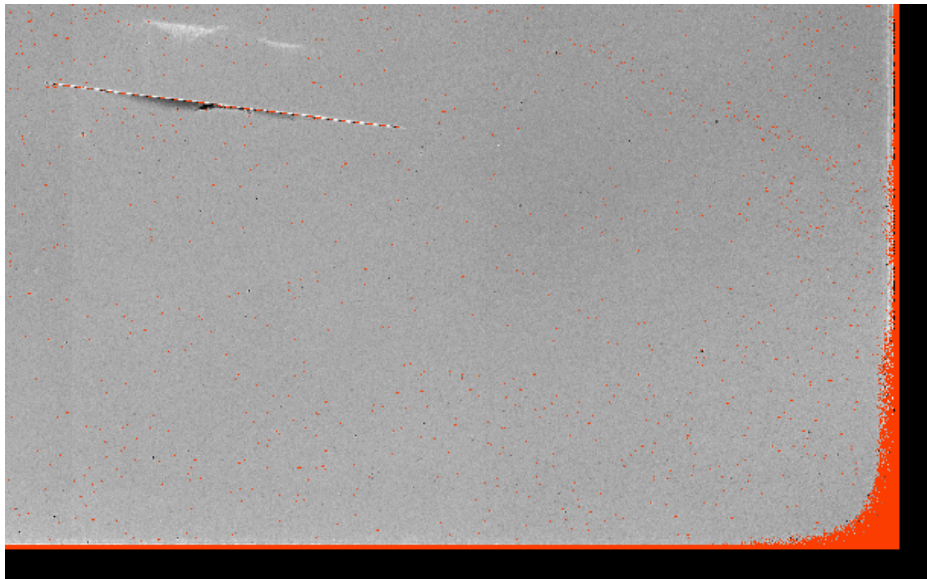

Figure 4(d) – lower right corner of detector [1], showing a lot of hot pixels, the scratch, and the corners/edges of the detector.