MIT Kavli Institute **Chandra X-Ray Center**

MEMORANDUM
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To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	Hot-pixel spec
Revision:	2.3
URL:	http://space.mit.edu/CXC/docs/docs.html#hotpix2
File:	/nfs/cxc/h2/gea/sds/docs/memos/hotpix_spec_2.3.tex

1 Hot pixels

Hot pixels are pixels that have an unusually large number of events during an observation. Pixels that are known to be bad, that have bad bias values, that are in a region associated with the "FEP0" problem, and that are defined as bad by a user are excluded from the search for hot pixels. Pixels associated with bias-parity errors and cosmic-ray afterglows are also excluded, but only during the time interval of the bias-parity error or afterglow. Pixels that are part of a known bad column, that are along the edge of a node, or that were previously identified as being hot are included in the search.

1.1 Input

1. A Level 1 event-data file (acis*evt1.fits)
2. A Level 1 observation-specific bad-pixel file (acis*bpix1.fits)
3. A Level 1 mask file (acis*msk1.fits)

1.2 Output

1. An updated observation-specific bad-pixel file

1.3 Parameters

1. `infile,f,a,"",,,"Name of input event-data file"`
2. `outfile,f,a"",,,"Name of output bad-pixel file"`
3. `badpixfile,f,a,"",,,"Name of input bad-pixel file"`
4. `maskfile,f,a,"",,,"Name of input mask file"`
5. `probthresh,r,h,0.001,1.0e-10,0.1,"Minimum post-trials significance of potential hot pixels (e.g., 1 sigma = 0.159, 90% = 0.1, 2 sigma = 0.0228, 99% = 0.01 and 3 sigma = 0.00135)"`

6. `regwidth,i,h,7,3,255,"Size of reference region (e.g., 7 pixels x 7 pixels)"`
7. `clobber,b,h,"no",,,"Overwrite output file if it exists?"`
8. `verbose,i,h,0,0,5,"Amount of messages produced (0=none, 5=a lot)"`
9. `mode,s,h,"ql",,,`

1.4 Processing

In the standard ACIS pipeline, the hot-pixel identification algorithm is used after the bias file(s) has been searched for pixels with bad bias values, after the bias-parity error file(s) has been searched for bad pixels and the "FEP0" problem, and after the event data has been searched for afterglows. The hot-pixel identification algorithm is summarized below.

1. Verify that the `infile`, `badpixfile`, and `maskfile` exist. If `clobber=no`, then verify that the `outfile` does not exist. Verify that the `infile` has `READMODE=TIMED`. The hot-pixel identification algorithm is not appropriate for continuous-clocking mode event data. Verify that the values of the parameters `probthresh` and `regwidth` are in the valid ranges for these parameters. Note that `regwidth` must be an odd number.
2. Exclude "invalid" pixels[1] from the search.
3. A pixel is identified as hot if

$$P_{\rm post} < \texttt{probthresh} \text{ and} \quad (1)$$
$$P_{\rm ref} \geq \texttt{probthresh}, \quad (2)$$

where the post-trials probability

$$P_{\rm post} = 1 - (1 - P_{\rm pre})^{\rm N_{trial}}, \quad (3)$$

the pre-trials probability

$$P_{\rm pre} = 1 - \left[\left(\sum_{i=0}^{N_{\rm evt}^{\rm hot}-1} \frac{\left(N_{\rm bgd}^{\rm hot}\right)^i}{i!} \right) + \frac{1}{2} \frac{\left(N_{\rm bgd}^{\rm hot}\right)^{N_{\rm evt}^{\rm hot}}}{N_{\rm evt}^{\rm hot}!} \right] e^{-N_{\rm bgd}^{\rm hot}}, \quad (4)$$

$N_{\rm evt}^{\rm hot}$ is the number of events on the potential hot pixel,

$$N_{\rm bgd}^{\rm hot} = \frac{F}{\texttt{SAMP\_CYC}_{\rm hot}}, \quad (5)$$

[1]Here an invalid pixel is one that has one or more of the following `STATUS` bits set in the `badpixfile` or that has `SAMP_CYC=0` in the `maskfile`.

Bit	Description
0	bad pixel
2	bias-parity error
3	bias = 4095
4	bias = 4094
7	user specified
13	FEP0 problem
15	afterglow
16	bad bias value

Note that the `STATUS` bits are numbered from 0 to 31. Some of these conditions, such as a bias-parity error and a cosmic-ray afterglow, may apply to only a subset of the observation. In this case, ignore events on the pixel only during the appropriate start and stop times. It is not necessary to ignore pixels that have bias values of 4096 (i.e., are missing data) because biases with such problems are adjusted on the ground. If they are not adjusted, then all events on pixels with a bias = 4096 are discarded.

$\texttt{SAMP\_CYC}_{\text{hot}}$ is the sample cycle for the potential hot pixel, the number of trials

$$N_{\text{trial}} = \sum_k N^{\text{ccd}}_{\text{pix},k}, \tag{6}$$

$N^{\text{ccd}}_{\text{pix},k}$ is the number of valid pixels[1] for the kth CCD (i.e., $= 1024 \times 1024$ less the number of invalid pixels), the probability that the event fluence in the reference region is consistent with the event fluence on the entire node (i.e., that the potential hot pixel is not part of a dithered source)

$$P_{\text{ref}} = \begin{cases} 1 - \left[\left(\sum_{i=0}^{N^{\text{ref}}_{\text{evt}}-1} \frac{\left(N^{\text{ref}}_{\text{bgd}}\right)^i}{i!} \right) + \frac{1}{2} \frac{\left(N^{\text{ref}}_{\text{bgd}}\right)^{N^{\text{ref}}_{\text{evt}}}}{N^{\text{ref}}_{\text{evt}}!} \right] e^{-N^{\text{ref}}_{\text{bgd}}}, & (N^{\text{ref}}_{\text{evt}} > 0) \\ 1 & (N^{\text{ref}}_{\text{evt}} = 0) \end{cases} \tag{7}$$

$N^{\text{ref}}_{\text{evt}}$ is the number of events in the reference region,[2]

$$N^{\text{ref}}_{\text{bgd}} = F N^{\text{ref}}_{\text{pix}}, \tag{9}$$

$N^{\text{ref}}_{\text{pix}}$ is the number of valid pixels[3] in the `regwidth` pixel $\times$ `regwidth` pixel reference region surrounding the pixel with the potential hot pixel, and the nominal fluence F is computed as follows.

(a) For each 32 pixel $\times$ 32 pixel region l of the node,[4]

$$F_l = \frac{N^l_{\text{evt}}}{N^l_{\text{pix}}}, \tag{11}$$

where N^l_{pix} is the total number of valid pixels[1] in the region, and N^l_{evt} is the total number of events on these pixels.

(b) Select the regions where F_l is greater than zero and less than two times the mean value of the set of F_ls.

(c) Calculate the median value, F_{med}, of the selected values of F_l.

(d) Calculate the root-mean-square, F_{rms}, of the selected values.

(e) Select the regions where F_l is greater than zero, is greater than or equal to $F_{\text{med}} - 2F_{\text{rms}}$, and is less than $F_{\text{med}} + 2F_{\text{rms}}$.

(f) Calculate the median of the selected values.

(g) Calculate the root-mean-square of the selected values.

(h) Repeat steps 3e–3g an additional nine times (i.e., a total of ten times).

(i) Set F equal to the value of F_{med} from the last iteration.

4. Each potential hot pixel that satisfies the criteria in equations 1 and 2 is written to the `outfile`. The contents of the `badpixfile` are also copied to the `outfile`.

Once the hot-pixel identification algorithm has been used, the tool `acis_build_badpix` can be used to mark the pixels adjacent to hot pixels as bad and the tool `acis_process_events` can be used to set the appropriate `STATUS` bit for events associated with hot pixels.

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[2] Equation 9 is valid only if all of the valid pixels in the reference region have the same sample cycle. If, for example, the reference region contains subsets A and B with $N^{\text{ref}}_{\text{pix,A}}$ and $N^{\text{ref}}_{\text{pix,B}}$ valid pixels and sample cycles $\texttt{SAMP\_CYC}_{\text{A}}$ and $\texttt{SAMP\_CYC}_{\text{B}}$, respectively, then equation 9 becomes

$$N^{\text{ref}}_{\text{bgd}} = F \left(\frac{N^{\text{ref}}_{\text{pix,A}}}{\texttt{SAMP\_CYC}_{\text{A}}} + \frac{N^{\text{ref}}_{\text{pix,B}}}{\texttt{SAMP\_CYC}_{\text{B}}} \right). \tag{8}$$

[3] For the purposes of calculating $N^{\text{ref}}_{\text{pix}}$, the central pixel of the region (i.e., the potential hot pixel) is invalid as are pixels that lie on a different node from the central pixel. Other pixels are considered invalid if they satisfy the usual conditions.[1]

[4] Equation 11 is valid only if all of the valid pixels in the region have the same sample cycle. If, for example, the region contains subsets A and B with $N^l_{\text{evt,A}}$ and $N^l_{\text{evt,B}}$ events on $N^l_{\text{pix,A}}$ and $N^l_{\text{pix,B}}$ valid pixels and sample cycles $\texttt{SAMP\_CYC}_{\text{A}}$ and $\texttt{SAMP\_CYC}_{\text{B}}$, respectively, then equation 11 becomes

$$F_l = \frac{\texttt{SAMP\_CYC}_{\text{A}} N^l_{\text{evt,A}} + \texttt{SAMP\_CYC}_{\text{B}} N^l_{\text{evt,B}}}{N^l_{\text{pix,A}} + N^l_{\text{pix,B}}}. \tag{10}$$

1.5 Caveats

1. Although it may not be optimum to do so, the hot-pixel identification algorithm is applied separately to the primary and secondary data for interleaved mode observations.
2. The algorithm is not applied to the data for continuous-clocking mode observations.
3. The choice of the default value for the parameter `regwidth` may not be optimum.