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

MEMORANDUM
May 12, 2010

To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	Bias repair
Revision:	5.3
URL:	http://space.mit.edu/CXC/docs/docs.html#bias_rep
File:	/nfs/cxc/h2/gea/sds/docs/memos/bias_repair_5.3.tex

1 Introduction

Biases can be adversely affected for a number of reasons, including the interaction of charged particles in the detector, the loss of part or all of the bias telemetry, and the transmission of optical light through the optical-blocking filter (e.g. Fig. 1). In order to produce the most accurate ACIS event data possible, biases may have to be repaired or replaced. This spec describes how to use the bias for one observation to replace or repair the bias for another observation.

2 Replacement

If an entire bias file B has problems (e.g. Fig. 1), then the bias file should be replaced (e.g. Fig. 2). The following steps should be performed, in sequence, to (i) identify a suitable replacement bias file B', (ii) copy the bias data from B' to the new bias file B'', (iii) apply an offset to the bias values of each node of B'' to compensate for any differences in the initial overclock values, (iv) produce a suitable header for B'', and (v) verify that the new bias file B'' is consistent with the event data.

1. Create a replacement bias file B''.

   a. Identify a suitable bias file B'.[1] The file B' is suitable if the following conditions are satisfied.

      i. The bias file B' is for the same CCD as the bias file B.

      ii. The parameter-block keywords

$$\texttt{BEP\_MODE}' = \texttt{BEP\_MODE}, \quad (1)$$

$$\texttt{DEALOAD}' = \texttt{DEALOAD}, \quad (2)$$

$$\texttt{DTYCYCLE}' = \texttt{DTYCYCLE}, \quad (3)$$

$$\texttt{EXP\_SKIP}' = \texttt{EXP\_SKIP}, \quad (4)$$

$$\texttt{EXPTIMEA}' = \texttt{EXPTIMEA}, \quad (5)$$

[1] Peter Ford's Perl script `search4bias.pl` (/nfs/acis/h4/tools/bin/sun4/search4bias.pl on the MIT CXC network) can be used to identify a suitable replacement file.

$$\begin{aligned}
\texttt{EXPTIMEB}' &= \texttt{EXPTIMEB}, &(6)\\
\texttt{FEPLOAD}' &= \texttt{FEPLOAD}, &(7)\\
\texttt{FEP_MODE}' &= \texttt{FEP_MODE}, &(8)\\
\texttt{NOBADCOL}' &= \texttt{NOBADCOL}, &(9)\\
\texttt{NOBADPIX}' &= \texttt{NOBADPIX}, &(10)\\
\texttt{OCLKPAIR}' &= \texttt{OCLKPAIR}, &(11)\\
\texttt{ORC_MODE}' &= \texttt{ORC_MODE}, &(12)\\
\texttt{ROWCNT}' &= \texttt{ROWCNT}, &(13)\\
\texttt{STARTROW}' &= \texttt{STARTROW}, \text{ and} &(14)\\
\texttt{SUM_2X2}' &= \texttt{SUM_2X2}. &(15)
\end{aligned}$$

The keywords on the left-hand sides of equations 1–15 are from the parameter-block file (acisf*pbk0.fits) for the same observation as the replacement bias file B'. The keywords on the right-hand sides are from the parameter-block file for the same observation as the bias file B being replaced.

iii. The tabulated parameter-block data

$$\begin{aligned}
\texttt{BIASALG}' &= \texttt{BIASALG}, &(16)\\
\texttt{BIASARG0}' &= \texttt{BIASARG0}, &(17)\\
\texttt{BIASARG1}' &= \texttt{BIASARG1}, &(18)\\
\texttt{BIASARG2}' &= \texttt{BIASARG2}, &(19)\\
\texttt{BIASARG3}' &= \texttt{BIASARG3}, &(20)\\
\texttt{BIASARG4}' &= \texttt{BIASARG4}, \text{ and} &(21)\\
\texttt{VIDRESP}' &= \texttt{VIDRESP} &(22)
\end{aligned}$$

for the CCD associated with B' and B. Again, the left- and right-hand sides of equations 16–22 are from the parameter-block files associated with B' and B, respectively.

iv. The time difference between B' and B,

$$\Delta t \equiv |t' - t|, \qquad (23)$$

should be minimized. (Ideally $\Delta t < 5$ days.)

v. The focal-plane temperature difference between B' and B,

$$\Delta T \equiv |T' - T|, \qquad (24)$$

should be minimized. (Ideally $\Delta T < 1$ °C.) Here, T' and T are the mean temperatures during the intervals over which the data for the bias files B' and B, respectively, were obtained.

b. Copy B' to B'', where B'' will become the replacement bias file. The files B and B' remain unchanged.

c. For the first node of the bias B'' (i.e. columns 1–256 of 1–1024), modify the values of every pixel in the node so that

$$B'' = B' - \texttt{INITOCLA}' + \texttt{INITOCLA}, \qquad (25)$$

where $\texttt{INITOCLA}'$ and `INITOCLA` are keywords in the headers of the bias files B' and B, respectively.

d. If the value of $B' = 4094$, 4095, or 4096 for a pixel on the first node, then $B'' = B'$ for that pixel instead of $B'' = B' - \texttt{INITOCLA}' + \texttt{INITOCLA}$.

e. If the value of $B = 4094$ or 4095 for a pixel on the first node, then $B'' = B$ for that pixel instead of $B'' = B' - \texttt{INITOCLA}' + \texttt{INITOCLA}$.

f. Repeat steps 2.1.c, 2.1.d, and 2.1.e for the other three nodes, using `INITOCLB`, `INITOCLC`, and `INITOCLD`, instead of `INITOCLA`, for columns 257–512, 513–768, and 769–1024, respectively.

g. Copy the header from B to B''.

h. Update the values of the keywords `CHECKSUM`, `DATASUM`, and `DATE` in B''.

i. Add or update the keyword `BIASREP` to represent the version of the spec on which the bias-repair code is based (e.g. `BIASREP` = 5.3).

j. Add appropriate history keywords to the header of the modified bias file B''. For example:

```
HISTORY  YYYY-MM-DD:HH:MM:SS
HISTORY  The name and version number of the code used to produce the file
HISTORY  CXC contact person
HISTORY
HISTORY  This bias file was created by replacing the file
HISTORY  acisf?????????N???_?_bias0.fits with a modified version of the file
HISTORY  acisf?????????N???_?_bias0.fits.  The region that was modified
HISTORY  includes the chip coordinates ...
```

2. Reprocess the ACIS event data using the bias file B''.

3. Examine the pulse-height information of the event data after it has been processed with the replacement bias (e.g. Fig. 3). If `DATAMODE` = `FAINT`, then prepare a histogram of the pulse heights of the 4 corner pixels for every event on the first node. If `DATAMODE` = `VFAINT`, then prepare a histogram using the pulse heights of the outer 16 pixels instead of the 4 corner pixels. The peak of the distribution should be at a pulse height of 0 adu. If it is not, then add the difference between the location of the peak and 0 adu to every pixel on the node for the bias file B''. Repeat this process for the other nodes.

4. Repeat steps 2.2 and 2.3 until the condition specified in step 2.3 is satisfied.

3 Repair

If only a portion of a bias file has problems (e.g. Figs. 4 and 7), then it may be more appropriate to repair the bias instead of replacing it (e.g. Figs. 5 and 8). For example, suppose that one or more pixel in the columns from l–n of bias file B for an observation has excess charge. In this case, the following steps should be performed, in sequence, to (i) identify a suitable donor bias file B', (ii) copy the bias data from B to the new bias file B'', (iii) replace the data in the corrupted region of B'' with data from the same region of B', (iv) apply a node-by-node offset to the bias values in the corrupted region to compensate for any differences in the median values of the biases, (v) produce a suitable header for B'', and (vi) verify that the new bias file B'' is consistent with the event data.

1. Create a replacement bias file B''.

a. Identify a suitable bias file B'.[1] The file B' is suitable if the conditions described in section 2.1.a are satisfied.

b. Copy B to B'', where B'' will become the repaired bias file. The files B and B' remain unchanged.

c. Suppose that the range of columns from l–n straddles a node boundary between columns m and $m+1$ (i.e. $l \leq m < n$). For the columns from l–m of bias B'', replace the bias values of every pixel (i, j) of the region such that

$$B''_{ij} = B'_{ij} - M' + M, \tag{26}$$

where the column number i (i.e. `CHIPX`) is in the range from l–m and the row number j (i.e. `CHIPY`) is in the range from $p(i)$–$q(i)$, where p and q can vary from column to column. M' is the median of the bias values B'_{ij} where i includes all of the columns on the same node as columns l–m and j is in the range from 1–1024. The pixels in the region being repaired, the pixels for which B'_{ij} = 4094, 4095, or 4096, and the pixels for which B_{ij} = 4094, 4095, or 4096 are excluded from the computation of M'. M is computed in the same manner as M', except that the bias

B is used instead of B'. The same set of pixels are used to compute M and M'. If the range from l–n does not straddle a node boundary, then m should be replaced by n in the description of the computation of M' and M. If the file B is for an observation that used one of the standard subarrays or some other user-specified subset of the rows of a CCD, then the appropriate range of j for the computation of M and M' is not 1–1024.

d. The process described in section 3.1.c is repeated for the columns from $m+1$ to n. However, if the range from l–n does not straddle a node boundary, then this step is skipped.

e. If the value of $B'_{ij} = 4094$, 4095, or 4096 for a pixel in the region being repaired, then $B''_{ij} = B'_{ij}$ for that pixel instead of $B''_{ij} = B'_{ij} - M' + M$.

f. If the value of $B_{ij} = 4094$ or 4095 for a pixel in the region being repaired, then $B''_{ij} = B_{ij}$ for that pixel instead of $B''_{ij} = B'_{ij} - M' + M$.

g. Copy the header from B to B''.

h. Update the values of the keywords `CHECKSUM`, `DATASUM`, and `DATE` in B''.

i. Add or update the keyword `BIASREP` to represent the version of the spec on which the bias-repair code is based (e.g. `BIASREP` = 5.3).

j. Add appropriate history keywords to the header of B''. For example:

```
HISTORY  YYYY-MM-DD:HH:MM:SS
HISTORY  The name and version number of the code used to produce the file
HISTORY  CXC contact person
HISTORY
HISTORY  This bias file was created by repairing the file
HISTORY  acisf?????????N???_?_bias0.fits using data from the file
HISTORY  acisf?????????N???_?_bias0.fits.  The region that was modified
HISTORY  includes the chip coordinates ...
```

2. Reprocess the ACIS event data using the bias file B''.

3. Examine the pulse-height information of the event data after it has been processed with the repaired bias (e.g. Figs. 6 and 9). If `DATAMODE` = `FAINT`, then prepare a histogram of the pulse heights of the 4 corner pixels for every event in the region being repaired. If `DATAMODE` = `VFAINT`, then prepare a histogram using the pulse heights of the outer 16 pixels instead of the 4 corner pixels. The peak of the distribution should be much closer to a pulse height of 0 adu after the repair. If it is not, then it may be necessary to use a different bias file B'.

If a region includes all of the pixels in a node, then follow the process described in section 2 for that node. Otherwise, use the process described in section 3.

4 Caveats

1. The algorithms described in this spec were designed for timed-exposure mode observations and may not be appropriate for continuous-clocking mode observations.

2. If a portion of a bias has excess charge, then events in the affected region that have pulse heights near the event threshold may have been lost and cannot be recovered.

5 TBD

1. This spec does not include an algorithm describing how to identify the regions of a bias that should be repaired. Since these regions are readily identifiable by eye (e.g. Figs. 4 and 7), visual inspection may suffice.

2. The algorithms described in this spec do not address systematic offsets at the sub-adu level.

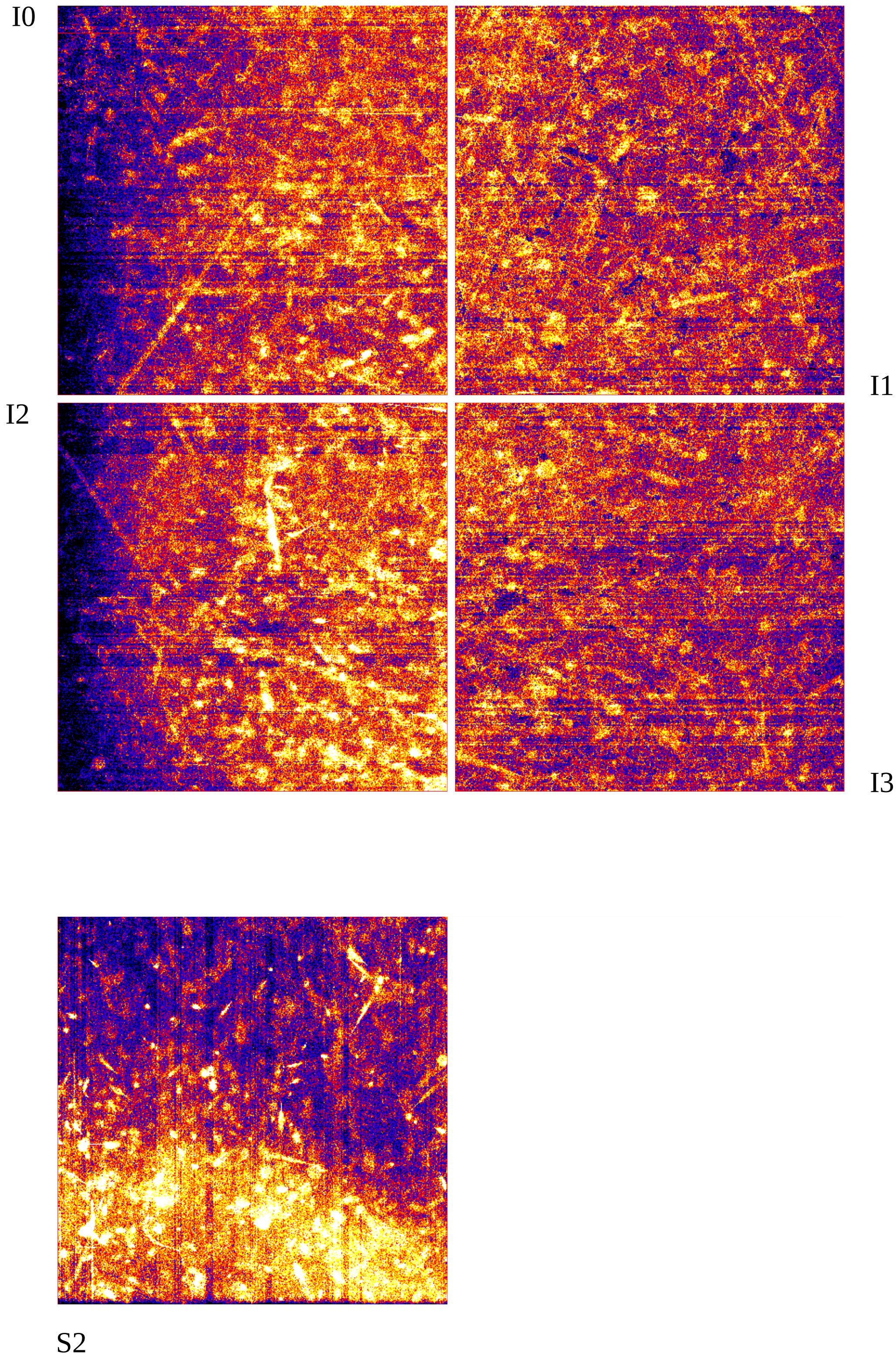

Figure 1: An image of the bias residuals for the five CCDs used for `OBS_ID` 11799. The median of each column has been subtracted from the bias values for the column. Excess charge from an optical light leak is evident, particularly on ACIS-S2, -I2, and -I0. The labels for each CCD are located near the coordinates $(\texttt{CHIPX}, \texttt{CHIPY}) = (1, 1)$.

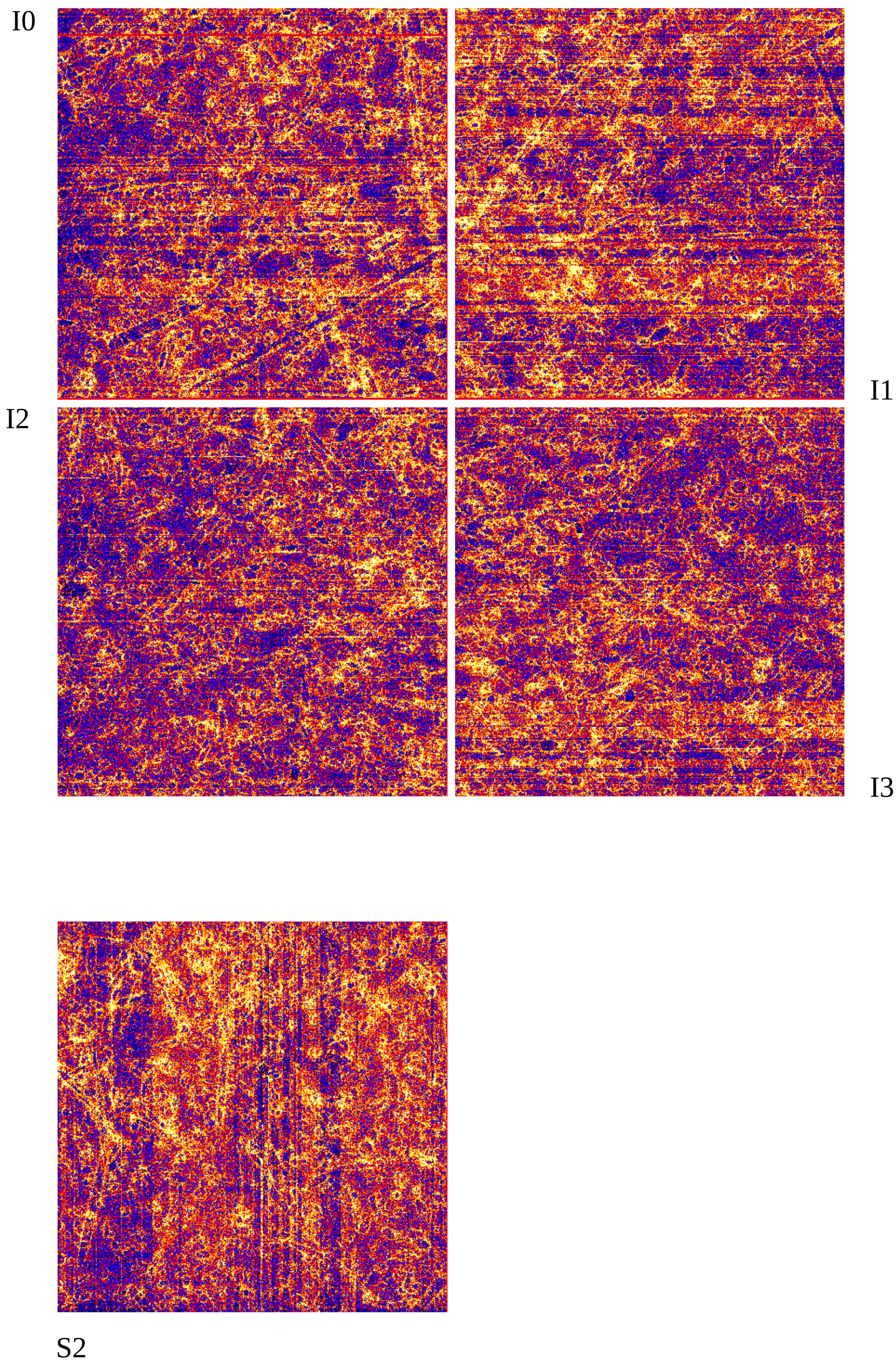

Figure 2: An image of the bias residuals for the five CCDs used for `OBS_ID` 11799 after the bias files were replaced with modified versions of the bias files for `OBS_ID` 9345. The median of each column has been subtracted from the bias values for the column. The labels for each CCD are located near the coordinates (`CHIPX`, `CHIPY`) $= (1, 1)$.

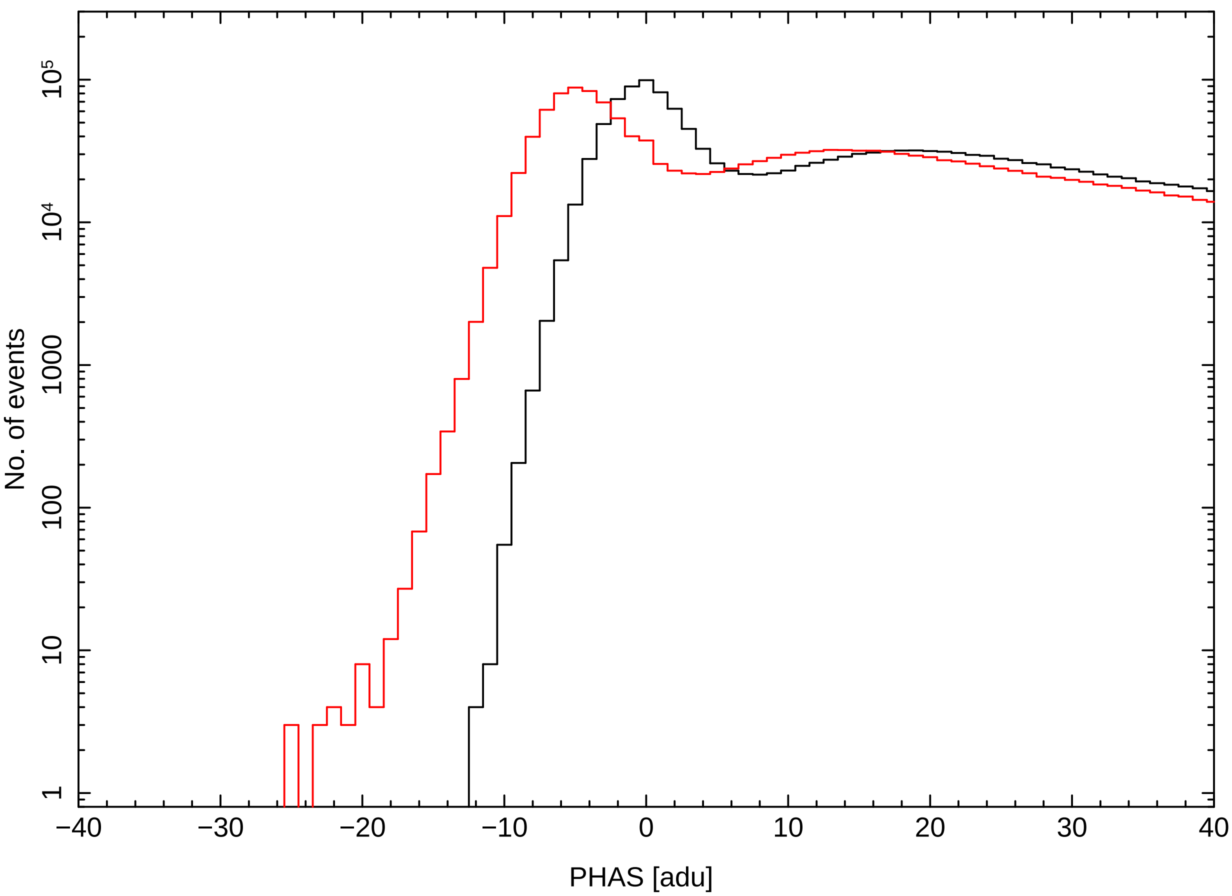

Figure 3: Histograms of the pulse heights of the outer 16 pixels of the 5 pixel × 5 pixel event islands for `OBS_ID` 11799. Only events on the first node of ACIS-I2 are included. The red histogram is the distribution obtained using the data processed with the biases shown in Figure. 1. The peak of the red histogram is at −5 adu, instead of zero. The black histogram is the distribution obtained after the data were reprocessed using the biases shown in Figure 2. The peak of the black histogram is at 0 adu, as desired.

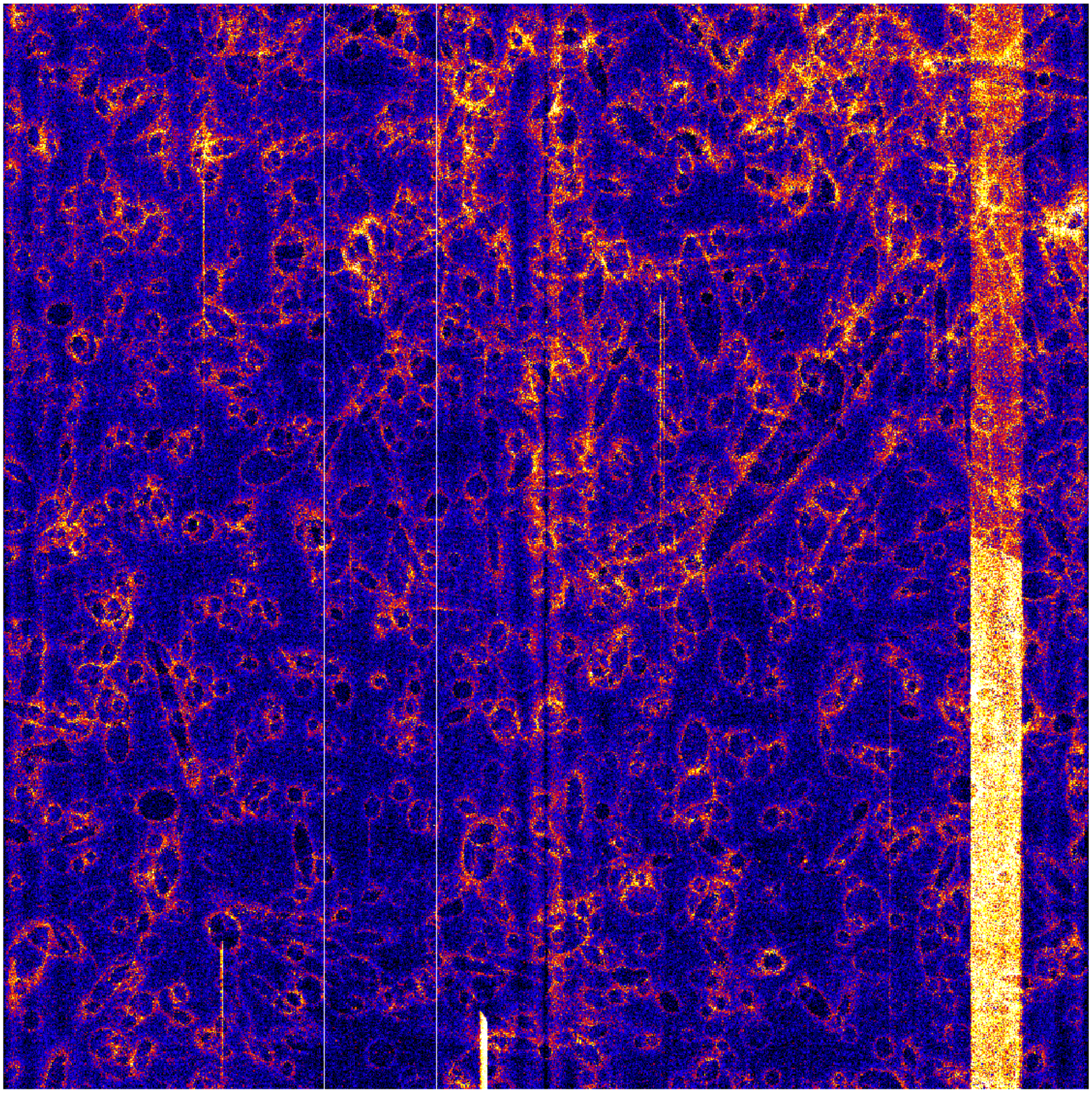

Figure 4: An image of the ACIS-I1 bias residuals for OBS_ID 9336. The median of each node has been subtracted from the bias values for the node. Excess charge is evident in the columns from 913–961.

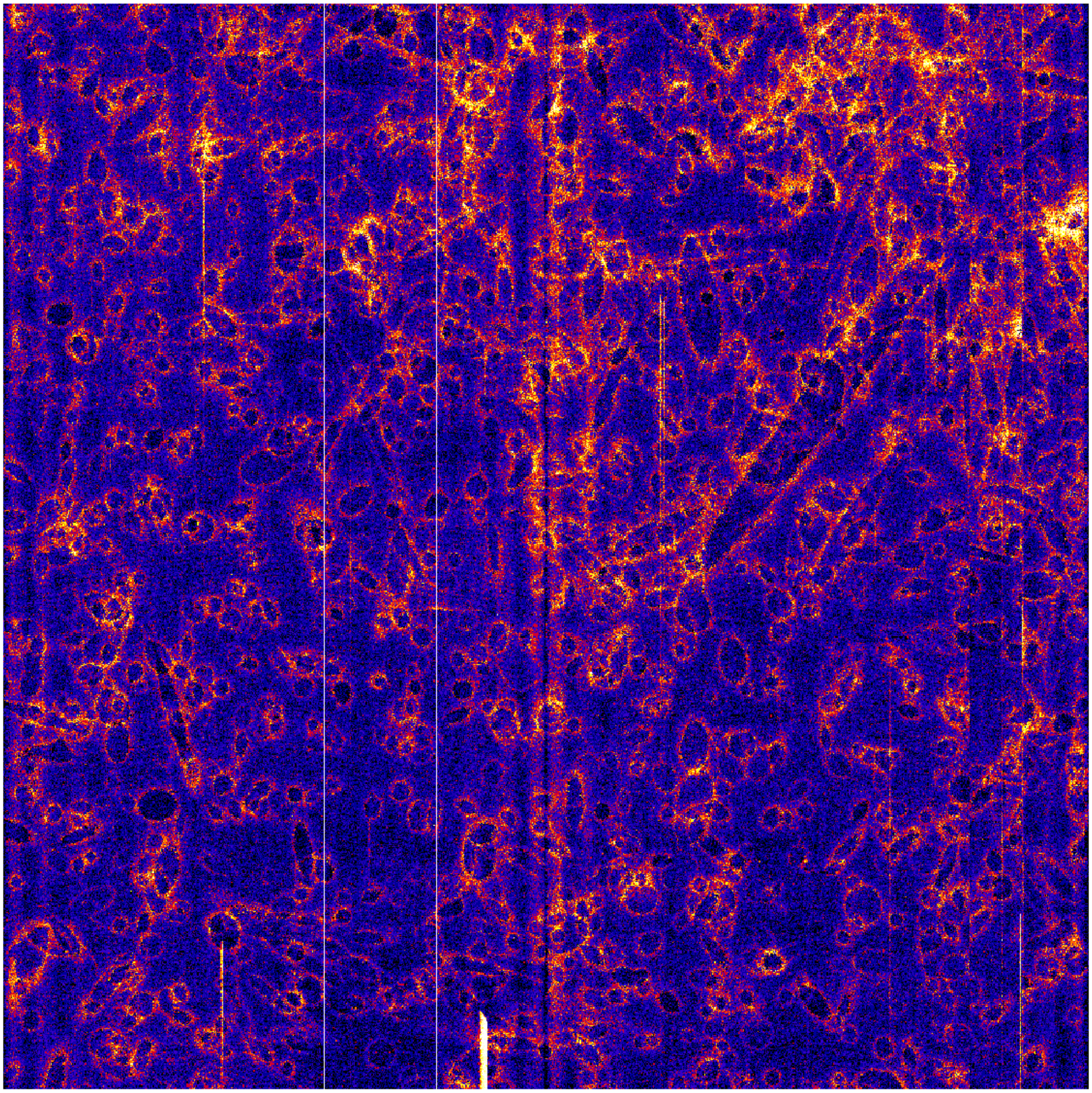

Figure 5: An image of the ACIS-I1 bias residuals for `OBS_ID` 9336 after the data in the columns from 913–961 were repaired using data from a bias file for `OBS_ID` 10811. The median of each node has been subtracted from the bias values for the node.

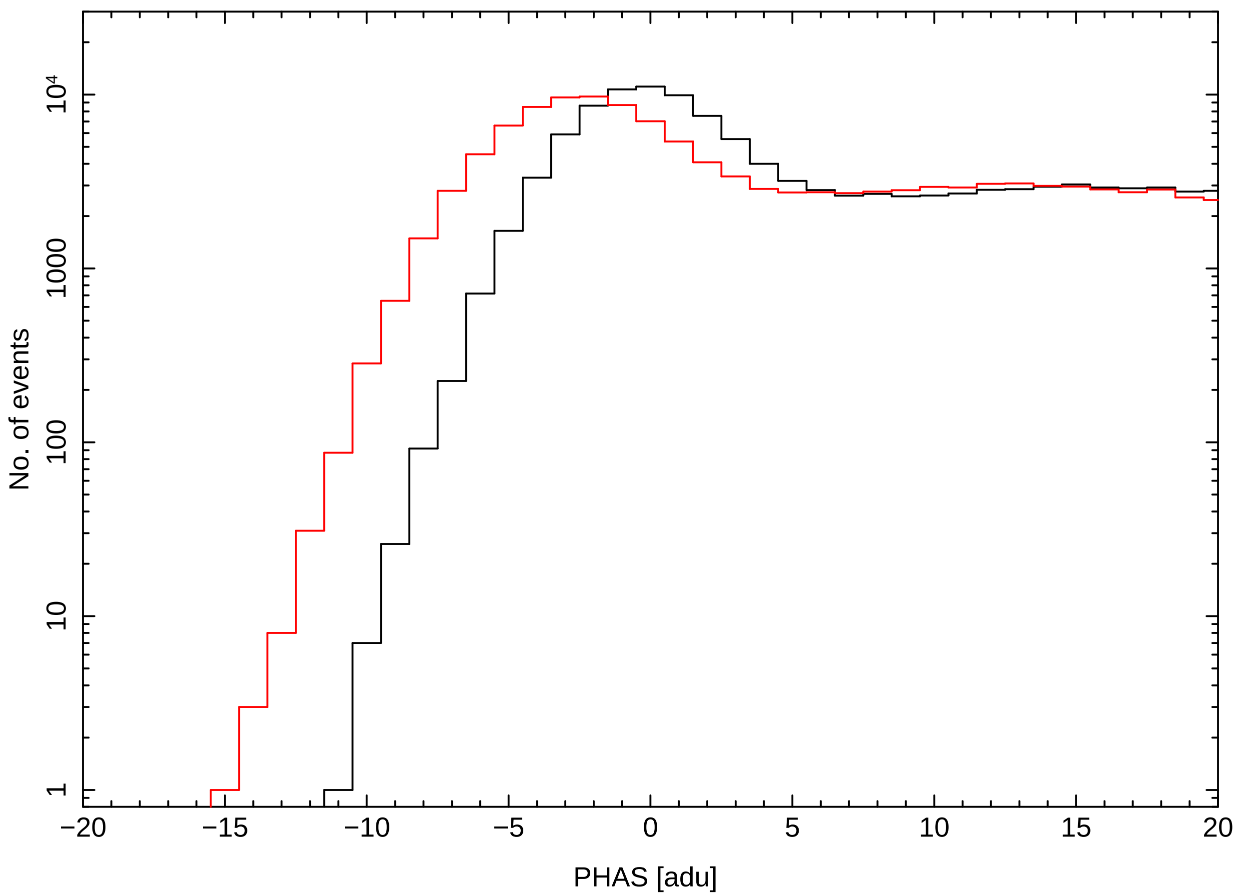

Figure 6: Histograms of the pulse heights of the outer 16 pixels of the 5 pixel × 5 pixel event islands for OBS_ID 9336. Only events in the columns from 913–961 of ACIS-I1 are included. The red histogram is the distribution obtained using the data processed with the bias shown in Figure 4. The peak of the red histogram is at −2 adu, instead of zero. The black histogram is the distribution obtained using the bias shown in Figure 5. The peak of the black histogram is at 0 adu, as desired.

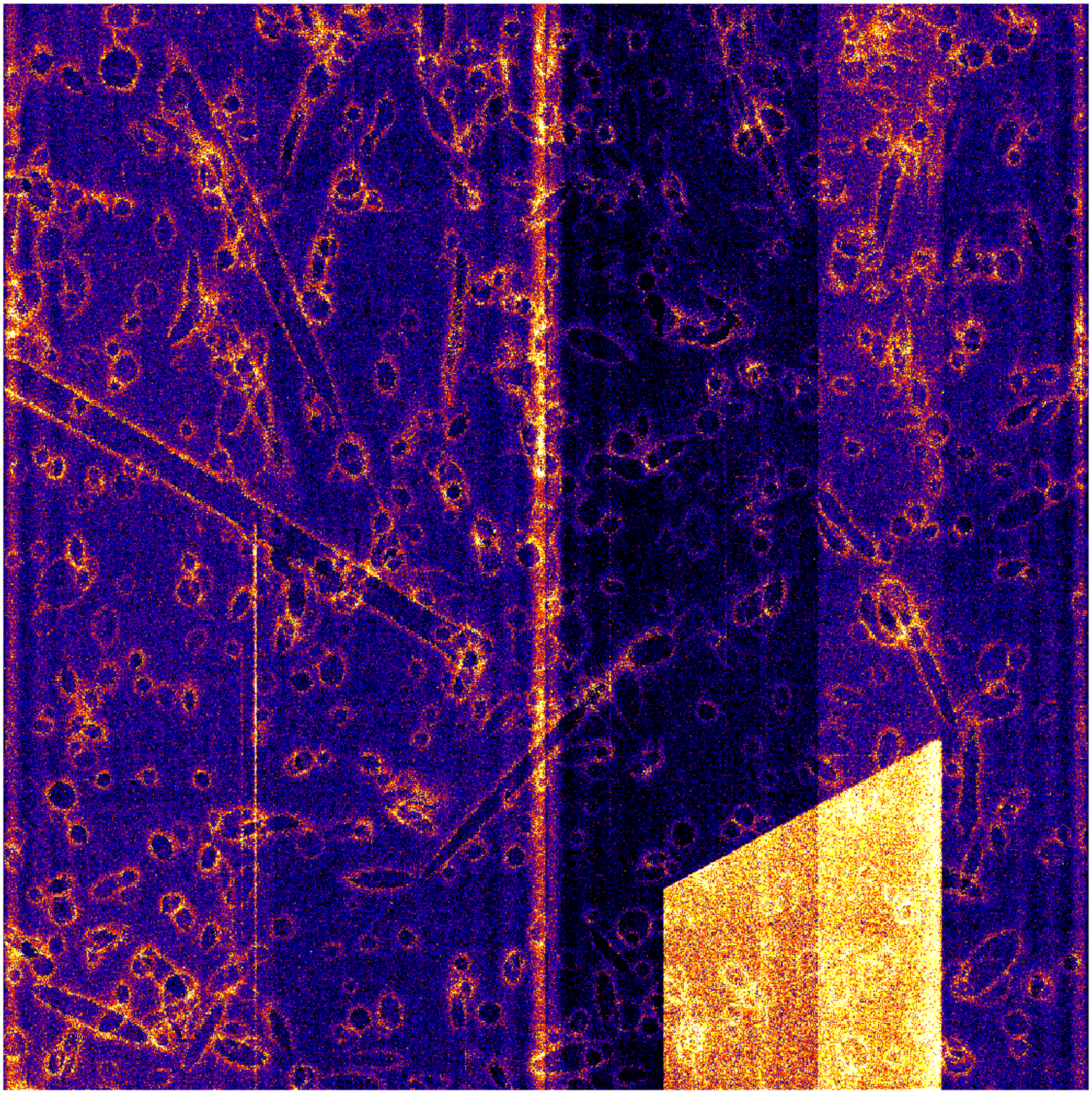

Figure 7: An image of the ACIS-S2 bias residuals for `OBS_ID` 4111. The median of each node has been subtracted from the bias values for the node. Excess charge is evident in a trapezoidal-shaped region that includes portions of the columns from 624–887.

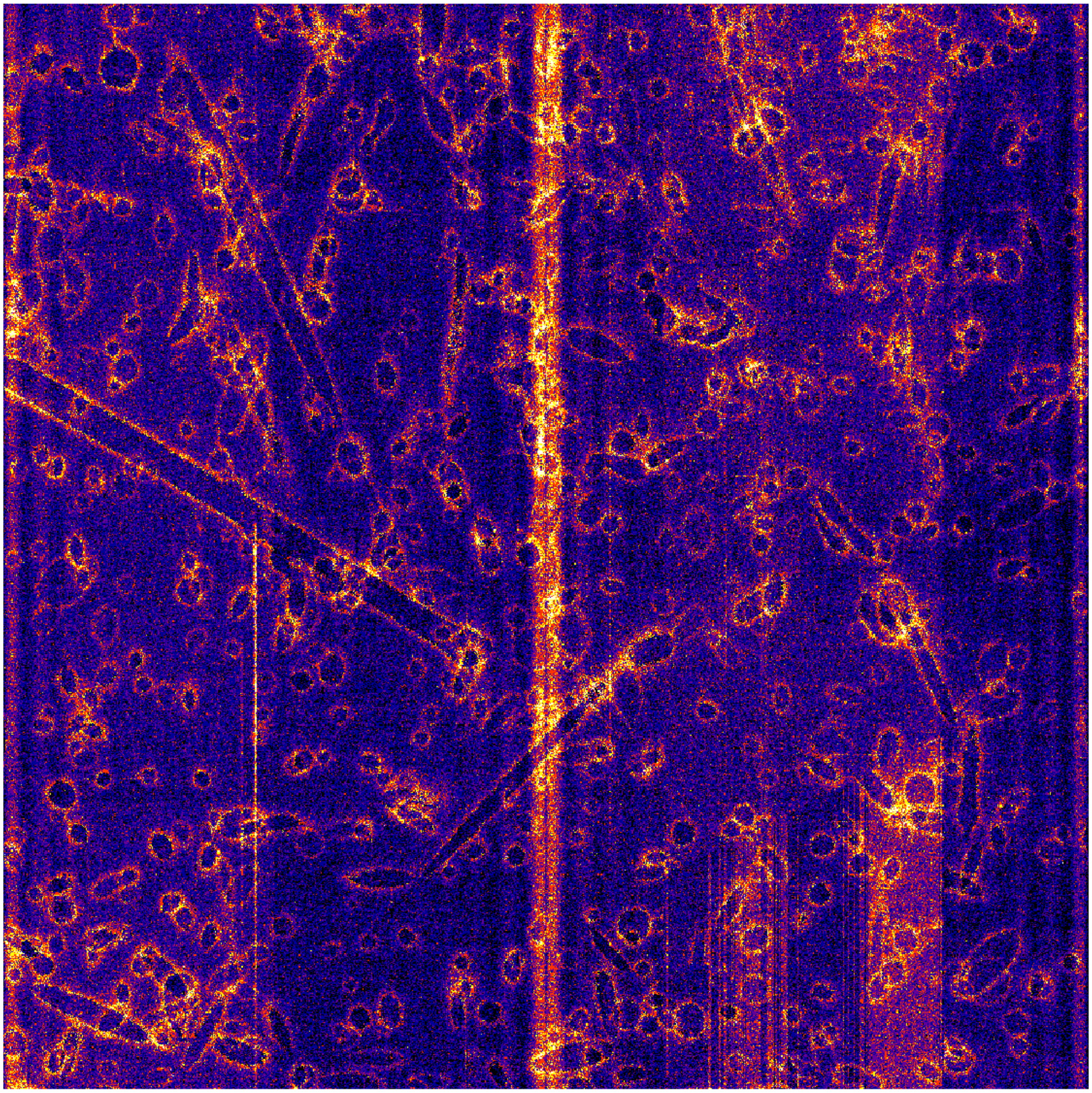

Figure 8: An image of the ACIS-S2 bias residuals for `OBS_ID` 4111 after the data in the trapezoidal-shaped region were repaired using data from a bias file for `OBS_ID` 3920. The median of each node has been subtracted from the bias values for the node.

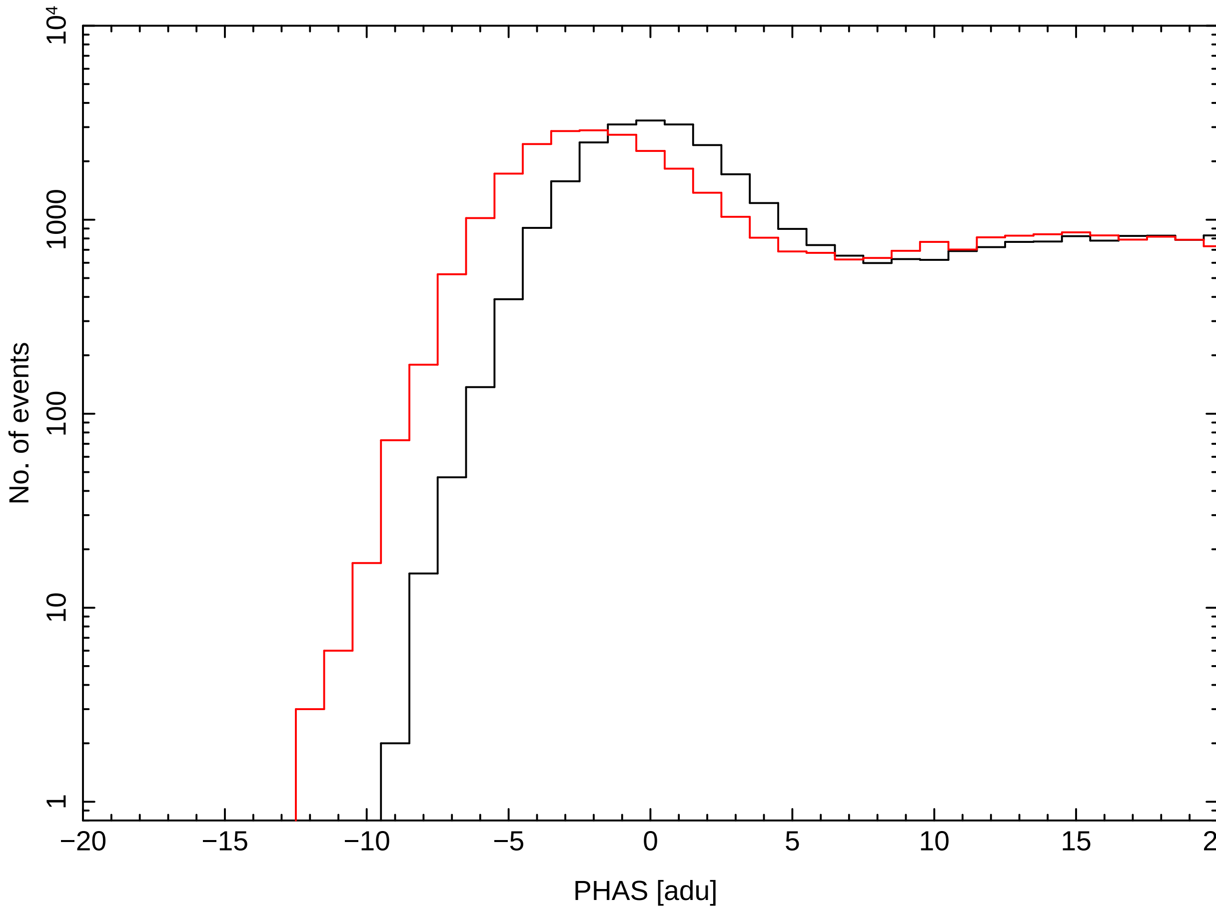

Figure 9: Histograms of the pulse heights of the outer 16 pixels of the 5 pixel × 5 pixel event islands for OBS_ID 4111. Only events in the trapezoidal-shaped region of ACIS-S2 are included. The red histogram is the distribution obtained using the data processed with the bias shown in Figure 7. The peak of the red histogram is at −2 adu, instead of zero. The black histogram is the distribution obtained using the bias shown in Figure 8. The peak of the black histogram is at 0 adu, as desired.