XMM-Newton CCF Release Note

XMM-CCF-REL-419

EPIC PN Bad Pixels

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1 CCF Components

Name of CCF	VALDATE	EVALDATE	Blocks Changed	CAL Version	XSCS Flag
EPN_BADPIX_0146.CCF	2020-04-06T18:03:35		BADPIX		NO
EPN_BADPIX_0147.CCF	2023-06-25T10:52:10		BADPIX		NO

2 Changes

This release addresses the flagging of two EPIC-pn noisy columns resulting from chip damage due to two micrometeoroid impact events. Although damage at several pixel locations was incurred, only two of these resulted in an associated significant increase in column noise:

Event occurrence	RAWX/Y pixel location of damage[1]	Associated column noise
between 2020-03-04T19:48 and 2020-03-06T01:17, revolutions 3706/3707	CCD 01 [33,199]	**Yes**
2023-06-16T00:55, ObsId 0921880401, revolution 4307	CCD 01 [45,158]	No
	CCD 03 [18,199]	No
	CCD 08 [33,197]	No
	CCD 12 [35,148]	**Yes**

[1] All RAWX/RAWY coordinates are given in the [0..63]/[0..199] convention.

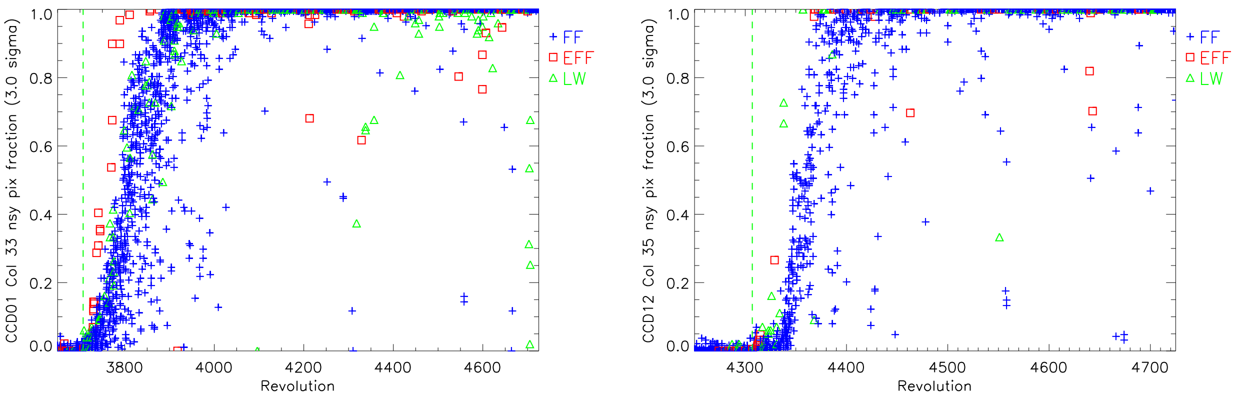

Figure 1: Fraction of noisy pixels versus revolution in CCD 01 RAWX==33 (left panel) and CCD 12 RAWX==35 (right panel). Per-pixel count rates are determined from the raw event lists. Pixels are defined as noisy when the count rate exceeds three standard deviations over the mean count rate of the full CCD excluding the respective noisy column. CCD modes are denoted by the colours and symbols as described in the legend. The revolution of the relevant micrometeoroid impact is denoted by the vertical green dashed line.

As the noise related increase in telemetry load is not sufficient to justify vetoing the respective columns on-board through the uplinked Bad Pixel and Fixed Offset Tables, their flagging is done solely through the data processing (through the task `badpixfind`, which is called by e.g. `epproc` or `epchain`). Analysis shows that in the standard data processing the noisy columns are not consistently flagged and to rectify this they have been explicitly added to the respective EPN_BADPIX CCFs (indicated in the BADPIX "DESCRIPTION" column by "H" for non-uplinked bad pixels).

Both cases show dynamic behaviour of column noise, with the level of noise and the number of noisy pixels in the column gradually increasing over time. In order to limit unnecessary blanking of pixels in unaffected observations, suitable CCF start-of-validity dates were applied. This is detailed in the following section.

3 Scientific Impact of this Update

As mentioned, as a result of micrometeoroid impacts, significant segments of CCD 01 RAWX==33 and CCD 12 RAWX==35 exhibit noisy behaviour due to damaged pixels in the respective columns. For the purposes of this analysis, a pixel is defined as being noisy if, in a given exposure, its total counts exceeds 3 times the standard deviation over the mean of the counts in the CCD excluding the respective noisy column.

The temporal evolution of the noise in *raw event data*, in terms of fraction of pixels in the respective columns which are noisy, is shown in Fig. 1. The behaviour is similar for both columns: after the respective micrometeoroid impacts, over a period of several 10s of revolutions, the fraction of noisy pixels in the column increases gradually until stabilising at $\sim 100\%$.

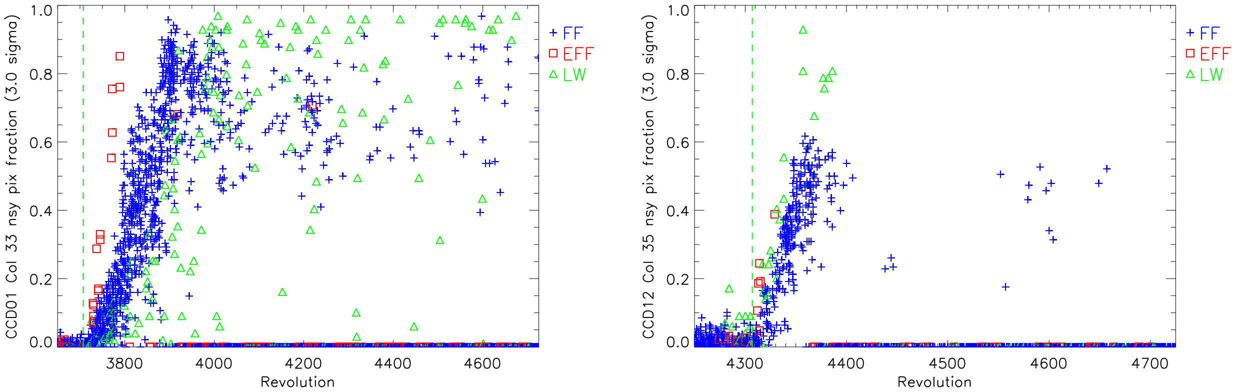

Figure 2: As in Fig. 1, but with count rates determined from the calibrated event lists (obtained with `epproc`) and post filtering with `FLAG==0`. Data with zero noisy pixel fraction indicate exposures where the processing has flagged the respective noisy column in its entirety.

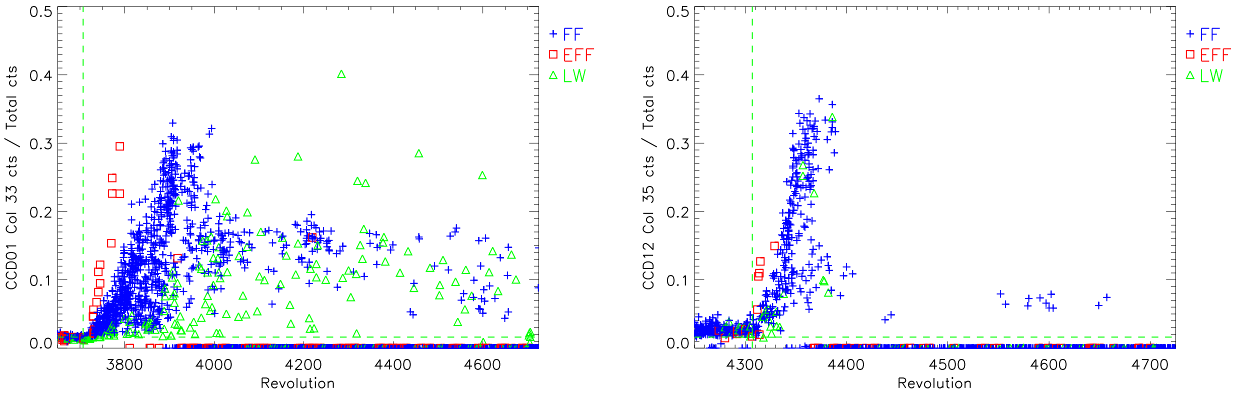

Figure 3: Ratio of total counts from the noisy column with respect to total counts of the respective CCD, where the counts were determined from the calibrated event lists (obtained with `epproc`) and post filtering with `FLAG==0`. The revolution of the relevant micrometeoroid impact is denoted by the vertical green dashed line. The horizontal green dashed line indicates the counts fraction from a single column assuming homogeneous illumination across the CCD.

The equivalent evolution for *calibrated event data* (i.e., after processing with the standard processing chains `epproc` or `epchain`), and after filtering with `FLAG==0`, is shown in Fig. 2. For the same data, Fig. 3 shows the temporal evolution in terms of the ratio of total noisy column counts with respect to the total counts of the respective CCD.

Although the noise is generally successfully filtered out by flagging and removing the columns completely (indicated by the data points with 0 noisy pixel and counts fractions) there are many exceptions where the noise remains present to a significant level. For both columns, this occurs predominantly in the period when the column noise is ramping up.[2] But especially in the case

[2]Note that for CCD 12 RAWY==35 in Full Frame mode and Extended Full Frame mode, approximately one third of the column covers an out-of-FOV region; those pixels will in any case be flagged in the standard processing, and hence for those modes the noisy pixel fraction determined for that column will not exceed $\sim 65\%$.

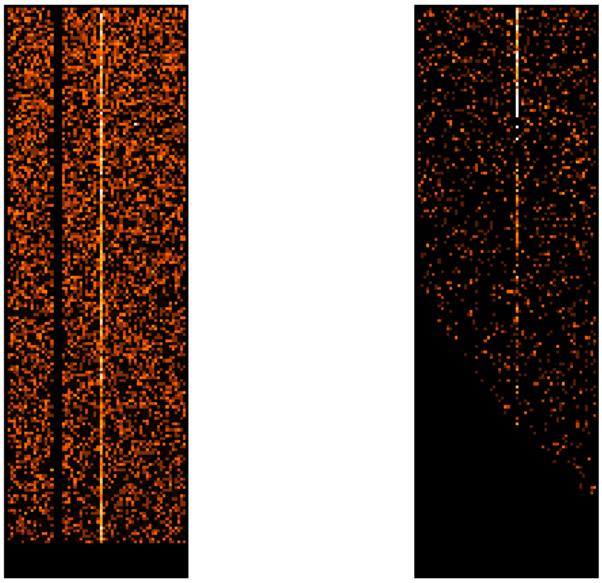

Figure 4: Examples of the column noise that may remain after running `epproc` and selecting `FLAG==0`; ObsID 0923710601; left panel: CCD 01, right panel: CCD 12. Images accumulated for pattern 0–4 events over the 0.1–10 keV band. (Note the blanked columns in CCD 01 are due to an already flagged noisy column at RAWX==18).

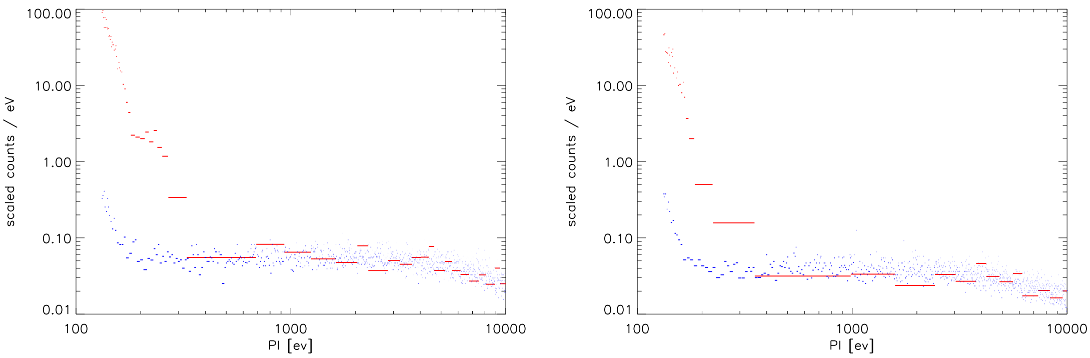

Figure 5: Examples of a comparison of pattern 0–4 events spectra of the respective noisy column (red) versus that of the full CCD excluding the column (blue), where, in order to facilitate comparison, the latter has been scaled down to roughly the equivalent of a single column (1/61 scaling factor); ObsID 0923710601; left panel: CCD 01, right panel: CCD 12.

of CCD 01 RAWX==33, even for a significant number of more recent exposures (especially in Large Window mode) the noise flagging is not fully effective. Typical examples of exposures with incomplete filtering of column noise are shown in Fig. 4. A comparison of the spectra of the respective noisy column versus that of the full CCD excluding the column (see Fig. 5) shows that the additional noise component is very soft and mainly limited to counts below ~ 400 eV.

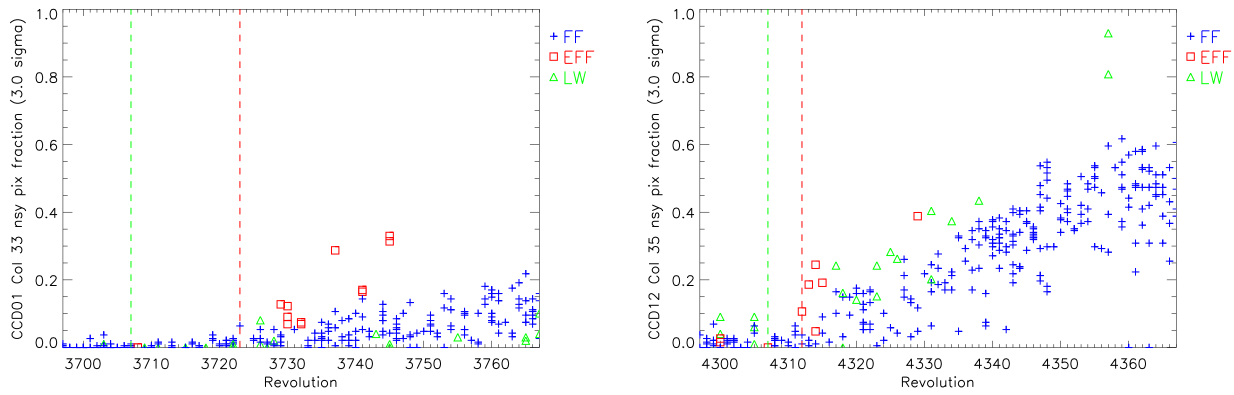

Figure 6: As in Fig. 2, but with a narrower revolution range, limited to close around the time of the respective impact events. The revolutions of the relevant micrometeoroid impact and of the respective CCF validity dates are denoted by the dashed vertical green and red lines, respectively.

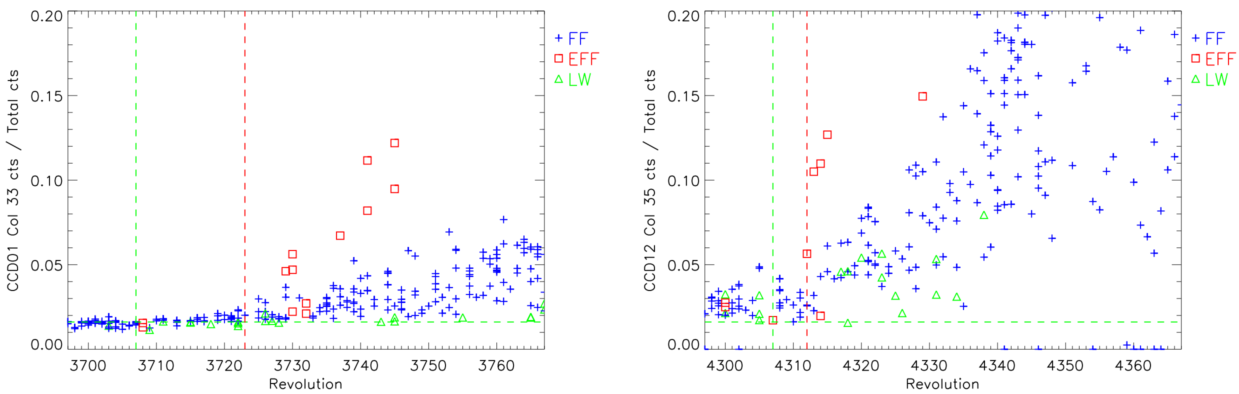

Figure 7: As in Fig. 3, but with a narrower revolution range, limited to close around the time of the respective impact events. The revolutions of the relevant micrometeoroid impact and of the respective CCF validity dates are denoted by the dashed vertical green and red lines, respectively.

In order to ensure the noise is properly flagged, the respective columns have been explicitly included as bad pixels in the respective BADPIX CCFs. As the pixels are not vetoed on-board, they are designated as "H" (for non-uplinked bad pixels) in the "DESCRIPTION" column of the "BADPIX" extension.

Regarding the behaviour at the onset of the column noise, its temporal evolution for calibrated event data zoomed into a narrow revolution range around the respective impact events is shown in Figs. 6 and 7, in terms of fraction of noisy pixels and fraction of counts, respectively. For both columns, the noise does not start exactly concurrently with the impact events, but only after several revolutions' worth of delay. For CCD 01 RAWX==33, significant noise appears to develop after $\sim$ 16 revolutions (revolution 3723, 2020-04-06T18:03:35); for CCD 12 RAWX==35, the delay is shorter: $\sim$ 5 revolutions (revolution 4312, 2023-06-25T10:52:10). In order not needlessly to blank pixels in those unaffected periods, rather than using the times of the micrometeoroid impacts as CCF validity dates, the above mentioned dates are used instead.

4 Estimated Scientific Quality

Noisy column segments related to micrometeoroid impact damage, which may otherwise not have been identified, are now explicitly flagged through the respective CCFs.

The user is recommended to run the bad pixel finding algorithm, and remove flagged events after processing - this is done by default in the SAS pipeline tasks `epproc` and `epchain` and by applying appropriate event selection flags.

5 Test Procedures and Summary of the Test Results

Correct bad pixel contents confirmed with `calview`. Correct functionality and validity dates tested with `epproc` (SAS 22.1.0).