XMM-Newton

The new hot column in MOS1 CCD1 after the MOS1 event in rev. 0961

Proposal for corrective actions

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1 Status summary

1.1 Trigger of new hot column

After an instrument anomaly (possible meteorite impact) in rev. 0961, a new hot column appeared in MOS1 CCD1 RAWX=323[1] close to the bore-sight positions. The exact positions for the different coordinate systems are listed in section 4. The defective column in MOS1 consists of some damaged pixels far from the bore-sight that then bloom to affect the whole column.

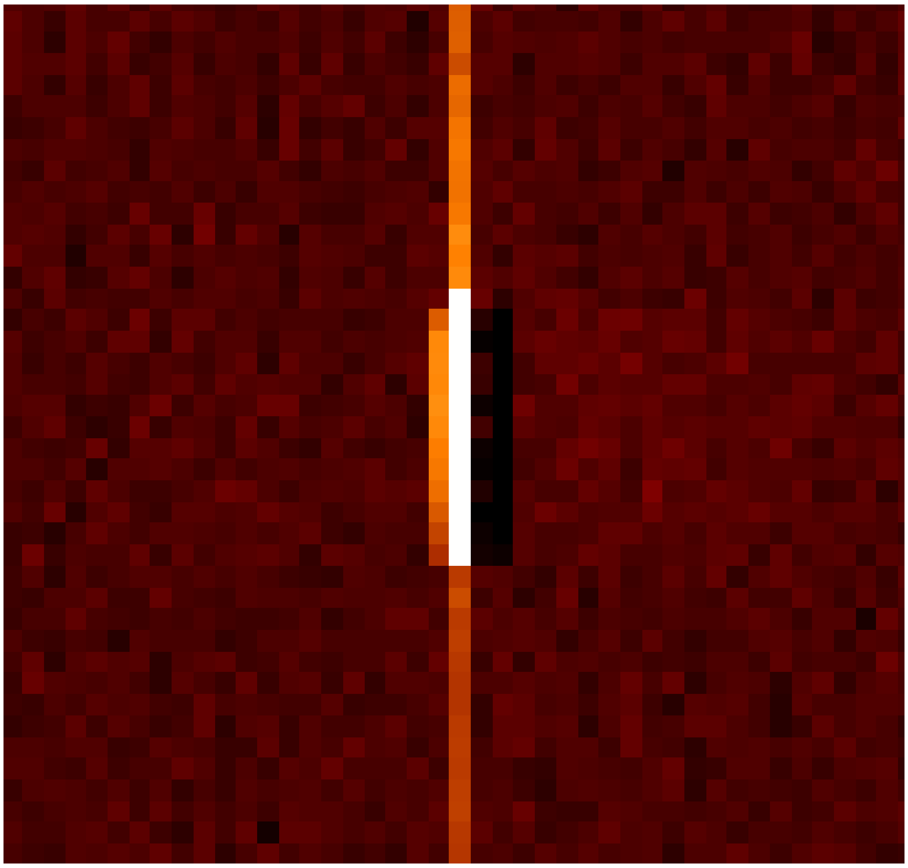

Figure 1: Zoom of median FF diagnostic image. The white area is comprised of saturated pixels with offsets of 4090. The black area is comprised of pixels with offsets of about 90 ADU.

An illustration of the damaged CCD region is provided in figure 1. Figure 1 is a zoom into the median diagnostic image built out of 13 single diagnostic exposures taken in full frame (FF) mode on 2005-05-16. The average offset level of the pixels is about 104 ADU. The white area (RAWY=566-577) is comprised of dead pixels with saturated offsets of 4090. The black area is comprised of pixels with offsets of about 90 ADU. The hot column has offsets of about 123 ADU below (lower RAWY values) the dead area and about 132 ADU above the dead area. The hot pixels left (lower RAWX values) of the dead pixels have offsets between 118-150 ADU.

1.2 Impact on telemetry bandwidth

Due to the hot column — dependent on the observed source — the needed telemetry bandwidth of MOS1 could be the double that of to MOS2. The file sizes for MOS1 could increase by a factor of 6–7.

[1] All positions provided in section 1 refer to the coordinate system of diagnostic images (see section 4).

1.3 Results of investigations using diagnostic images

To investigate the offset of the hot column, diagnostic images have been taken in different modes: full frame mode (FF) diagnostics on 2005-05-16 (13 exposures), small window mode (SW) diagnostics on 2005-05-26 (30 exposures), large window mode (LW) diagnostics on 2005-05-28 (25 exposures). For each mode, median diagnostic images have been created out of the individual exposures to remove cosmics. The resulting energy distributions of single columns of the median diagnostic image were fitted with a Gaussian to evaluate the peak energy and the FWHM of the distribution (see figure 2).

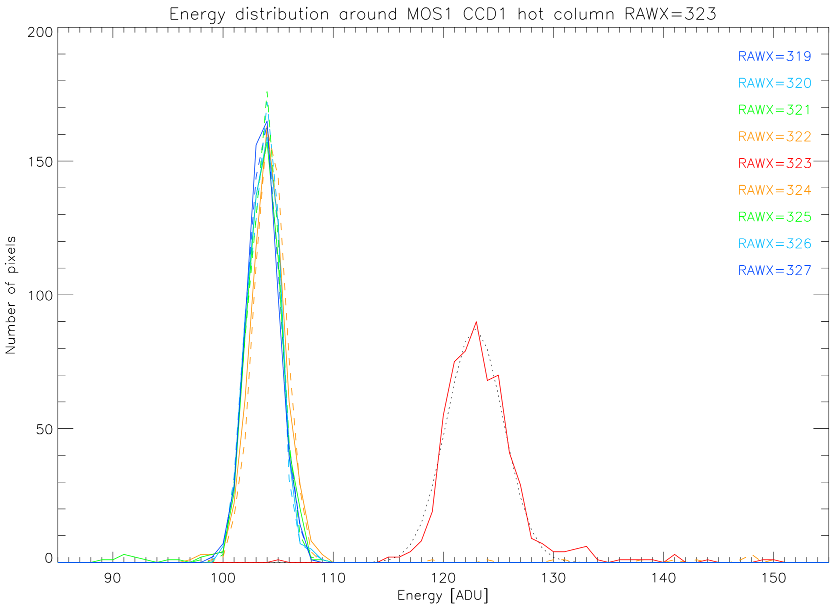

Figure 2: Energy distribution of columns close to the hot column using a median image created out of 14 diagnostic images taken on 2005-05-16. Dashed lines are used for RAWX=323. In the coordinate system of diagnostic images the hot column is RAWX=323 (see section 4).

Common results of diagnostic images of different modes

For FF, LW and SW modes the average offset of the hot column is shifted by 19 ADU to 123 ADU compared to an offset of 104 ADU for normal columns. Timing mode (TI) diagnostics have been performed but the data generation has failed. The problem is under investigation.

Specific results from FF diagnostic images

In FF the FWHM of the hot column was about 6-7 ADU compared to 3-4 ADU for normal columns (see figure 2). Some hot column (RAWX=323) counts are found in channels above the noise threshold of 123+25 ADU = 148 ADU: at 149 ADU (RAWY=579), 150 ADU (RAWY=581) and 3528 ADU (RAWY=578), each with one count. All these pixels are located above (higher RAWY values) the dead pixels and are not inside the LW and SW mode chip windows.

In FF mode also counts from column RAWX=322 are found in channels above the noise threshold of 104+25 ADU = 129 ADU: at 130 ADU (RAWY=568), 131 ADU (RAWY=577), 138 ADU (RAWY=569), 141 ADU (RAWY=570), 143 ADU (RAWY=571), 147 ADU (RAWY=574) and 151 ADU (RAWY=573), each with one count, as well as three counts in channel 148 ADU (RAWY=572,575,576). All these RAWX=322 pixels are located next to the dead pixels in the hot column RAWX=323 RAWY=566-577 (see figure 1) and are not inside the LW and SW mode chip windows.

Specific results from SW and LW diagnostic images

As expected from the FF analysis, no counts in channels above the noise threshold were found for the median diagnostic images of SW and LW modes. In both SW and LW mode the FWHM of the hot column was about 3-4 ADU compared to 2-3 ADU for normal columns.

1.4 Results of investigations using FF calclosed observations

Using FF calclosed observations, a Gaussian was fitted to the Al-Kα line independently for each column. The fit was restricted to an energy range of 430-500 ADU. Due to the very low count rates, for individual observations reasonable results could not be derived for every column. Therefore in figure 3 data points of a specific column could be missing for individual observations.

An offset of about 20 ADU in the hot column is also present at Al-Kα energy. These offsets seem to be constant in time since about rev. 0970. Figure 3 illustrates the fit results for the Gaussian line peak energy as well as the total amount of counts in the analysed energy range of 430-500 ADU.

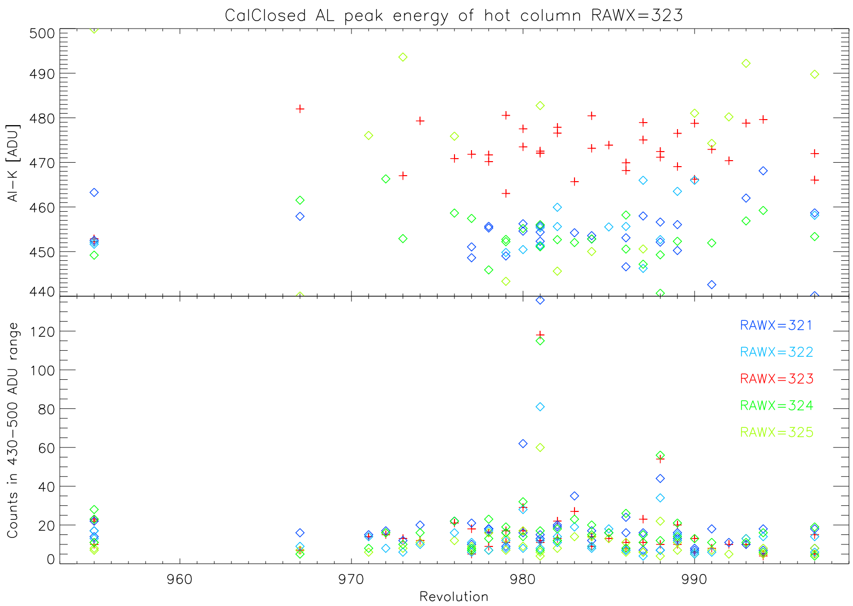

Figure 3: Upper panel: Peak energy of a Gaussian fit in the energy range 430–500 ADU using calclosed observations. Lower panel: Total amount of counts in the energy range 430–500 ADU. For the column numbering in the plot, the coordinate system of diagnostic images is used and the hot column is RAWX=323 (see section 4).

2 Impact on scientific data analyses

Since revolution 0961 a new hot column has appeared on MOS1 CCD1 due to an impact of a micrometeorite dust particle on MOS1 CCD1 at position (RAWX,RAWY)=(318,572)[2] approximately, in the SAS coordinate system. This new defect is leaking into the whole column 318 (henceforward referred to as M-column). As a consequence, the offset of the M-column is raised by about 20 ADUs, therefore generating a lot of noise events at low energy above the low energy threshold, and the whole column is identified as bad by embadpixfind and masked out in the calibrated event list.

[2] All positions provided in section 2 refer to the coordinate system of calibrated SAS eventlists (see section 4).

This new hot column passes 3 pixel away from the nominal target position on CCD1 when EPIC-pn is the prime instrument, and 9 pixels when RGS is prime, therefore, in the pn case, crossing a significant fraction of the on-axis source PSF.

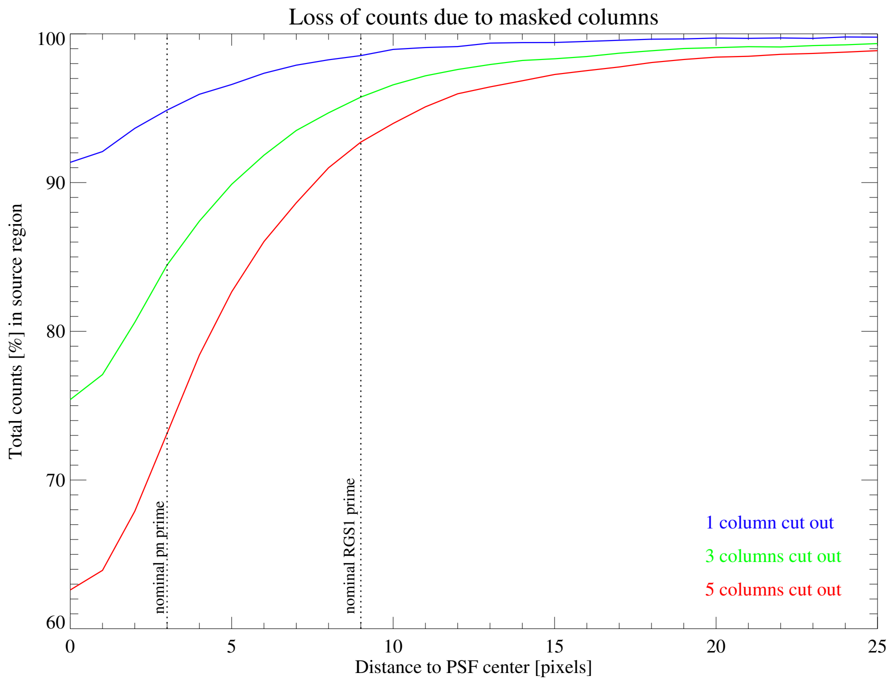

Figure 4: Simulation of count-losses if one, three or five columns are excluded in the PSF, dependent on the distance to the PSF centre.

The influence of the hot column on adjacent columns has been estimated to be minimal. Although for a few revolutions after the impact the count rate on the adjacent columns (columns 317 and 319) was reduced by up to half due to pattern migration, later-on the effects turn out to be negligible on bright sources.

Therefore users are adviced, for data collected between the occurrence of the rev. 0961 event and the taking effect of on-board corrective measures described in sec. 3.2, to continue to apply the selection #XMMEA_EM to the MOS event list to generate spectra for on-axis sources and not FLAG==0.

The more conservative selection flag FLAG==0 masks out also the two adjacent columns, therefore 3 columns are removed, causing the loss of up to 10-15% of the flux of an on-axis source when EPIC-pn is prime (see figure 4). Besides the current SAS (6.1) does not take into account these adjacent missing columns in the computation of the effective area. Therefore the absolute flux/normalisation of a source is too low by 5-10% when RGS is prime when selecting with FLAG==0, but as much as 15-20% when EPIC-pn is prime, depending on the exact position of the source with respect to the M-column and the size and shape of the extraction region. A correct or better handling of the effective area calculation will be implemented in the next SAS version.

However apart from the normalisation the model parameters are found to be the same within errors when using FLAG==0 or #XMMEA_EM.

In addition, for some bright and soft sources, e.g. isolated neutron stars or supernova remnants, some other columns are masked out with the current SAS, because they display too low offsets, that have developed since launch. One of these bad-energy columns is column 320. Applying FLAG==0 in these conditions will then mask out 5 columns: 317–321, which is believed excessive. This feature will also be corrected in the next SAS version.

3 Proposed corrective actions

3.1 Use RGS bore-sight for all observations.

Consequences:

The nominal pn bore-sight position is 3 pixels away from the hot column, whereas the RGS bore-sight position has a distance of 9 pixels. Using the RGS bore-sight position the PSF centre is moved 6 pixels further away from the hot column. Therefore the hot column will have less impact on source spectra.

However, if the bore-sight is changed from nominal pn to nominal RGS position, the MOS2 PSF is moved 4 pixels closer to a bad energy column (flagged via CCF) in RAWX=277 in the SAS coordinate system. The distance is 26 pixels for the nominal pn bore-sight and 22 pixels for the RGS bore-sight. Due to this still large distance, the amount of flux lost in MOS2 is much less than the amount of flux gained in MOS1.

In pn, at nominal pn bore-sight, the PSF centre is 3 pixels closer to the chip gap between CCD4 and CCD7 than for the RGS bore-sight position. Changing to RGS bore-sight position moves the pn PSF centre more in the direction of the SW mode window, thus a larger fraction of the PSF is available in SW mode.

Recapitulating, the advantages for pn and MOS1 at the RGS bore-sight position are larger than the slightly negative impact for MOS2. The different bore-sight positions for MOS1, MOS2 and pn are visualised in figure 5.

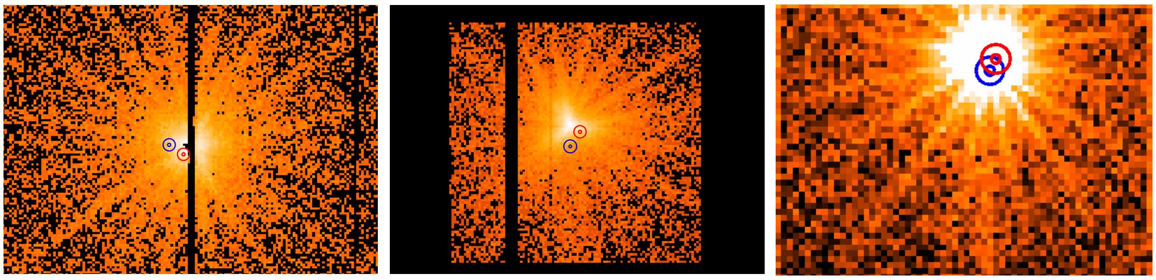

Figure 5: SAS eventlist images of RXJ1856 (left: MOS1 LW; middle: MOS2 SW; right: pn SW) in the RAWX/RAWY coordinate system. The nominal pn and RGS bore-sight positions are indicated in red and blue, respectively.

Time table:

An immediate change to the RGS bore-sight within AO4 is very problematic, because all observations with pn bore-sight would have to be re-planned. Therefore the exclusive use of the RGS bore-sight is planned to start in AO5.

3.2 Increase the offset of the hot column to 123 ADU using the on-board offset table.

Consequences:

The increased noise of the hot column can be suppressed on-board. Real events hitting this column suffer a raised baseline from the leaking hot pixels, and therefore the offset correction restores the correct energy. The column would be usable for science again.

The offset of the hot column could change with time, leading to an energy shift in the column. At a position three MOS pixels away from the nominal pn bore-sight, the column holds about 7% of the total PSF flux. The impact of an energy shift in the column on the total spectrum is to be investigated.

Routine diagnostic images are necessary to monitor the offset and to ensure that the value in the on-board offset table is correct. These diagnostics could be taken instead of calclosed observations at the end of a revolution every TBD revolutions.

4 Positions for different coordinate systems.

Dependent on the kind of data used for analyses (diagnostic images, ODF CCD eventlists, calibrated SAS eventlists), the numbering of the CCD pixels is slightly different. To avoid confusions about different positions of the same pixel/columns within these different files, the column numbers as well as the pixel positions of the nominal pn and RSG bore-sights are provided in the corresponding coordinate systems.

4.1 MOS1 positions

Hot column:

- diagnostics images (*10DII.FIT): RAWX=323
- ODF eventlists (*IME.FIT): RAWX=324
- SAS eventlists (*MIEVLI0000.FIT): RAWX=318

Nominal pn prime bore-sight position:

- diagnostics images (*10DII.FIT): RAWX=320, RAWY=290
- ODF eventlists (*IME.FIT): RAWX=321, RAWY=292
- SAS eventlists (*MIEVLI0000.FIT): RAWX=315, RAWY=291

Nominal RGS prime bore-sight position:

- diagnostics images (*10DII.FIT): RAWX=314, RAWY=294
- ODF eventlists (*IME.FIT): RAWX=315, RAWY=296
- SAS eventlists (*MIEVLI0000.FIT): RAWX=309, RAWY=295

4.2 MOS2 positions

Bad column:

- diagnostics images (*10DII.FIT): RAWX=321
- pmsfits eventlist (*IME.FIT): RAWX=382
- SAS eventlist (*MIEVLI0000.FIT): RAWX=276

Nominal pn prime bore-sight position:

- diagnostics images (*10DII.FIT): RAWX=308, RAWY=304
- pmsfits eventlist (*IME.FIT): RAWX=309, RAWY=306
- SAS eventlist (*MIEVLI0000.FIT): RAWX=303, RAWY=305

Nominal RGS prime bore-sight position:

- diagnostics images (*10DII.FIT): RAWX=304, RAWY=298
- pmsfits eventlist (*IME.FIT): RAWX=305, RAWY=300
- SAS eventlist (*MIEVLI0000.FIT): RAWX=299, RAWY=299

4.3 pn positions

Nominal pn prime bore-sight position:

- SAS eventlist (*MIEVLI0000.FIT): RAWX=38, RAWY=191

Nominal RGS prime bore-sight position:

- SAS eventlist (*MIEVLI0000.FIT): RAWX=37, RAWY=189