CORRECTING FOR THE UNEXPECTED: DEAD ANODES, GLITCHES, HOTSPOTS AND GAIN DRIFT IN JEM-X DATA PROCESSING

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ABSTRACT

Since launch, the JEM-X units have developed a number of interesting effects, which have been observed in the data from the microstrip detectors. These anomalies must be detected and corrected automatically in the ISDC pipeline processing using the Instrument Specific Software (ISSW). The design of the ISSW left room for such corrections, though the exact form of the corrections was unknown before launch. These are implemented through correction tables, instrument characteristics, event flagging and selection, and performance monitoring. We discuss the various correction strategies for dead anodes, gain glitches, hotspots, and gain drift. Many of these problems stem from cosmic ray interactions with the detector gas and microstrip plate. Ion drift through the microstrip substrate also plays a role. While these effects are well beyond our control, the JEM-X experience will certainly benefit future space-based missions using microstrip technology. The original poster of this paper can be seen at:
http://www.dsri.dk/ oxborrow/sdast/int5Poster.pdf

Key words: data processing software; instrumentation; X-ray astronomy; microstrip gas chambers.

1. THE JEM-X ISSW

The instrument-specific software for analysing the science data from the two JEM-X units is described in detail in the JEM-X ISSW Architectural Design Document, Oxborrow et al. (2003). However, general users should refer to the ISDC manual which provide instructions for using the Offline Science Analysis (OSA) package to do science analysis of the raw data, Chernyakova (2003) The ISDC Revolution File Pipeline, Science Window Pipeline and the COR-level of the OSA, all contain ISSW modules that calibrate and correct the raw data automatically, without human intervention.

Before flight the Instrument Team was aware of several conditions requiring continual correction of the raw data:

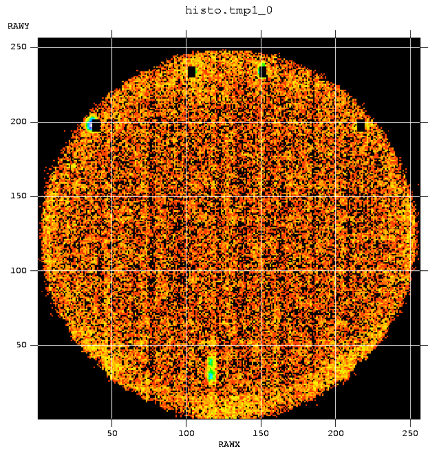

Figure 1. Hotspot seen on JEM-X1 detector at beginning of Revolution 20. Black rectangles along the upper edge are calibration areas.

variations in detector gain with changing temperature, gas presssure and time; gain variations over the surface of the detector and position determination deviations due to irregularities in the microstrips; dead areas on the detector plate. We were also aware that other problems would inevitably arise which would require additional correction and calibration.

It should be noted that some of the problems for which we had made provisions before launch, have not materialised. The behaviour of the 43 amplifiers has not changed significantly, though these are monitored at the beginning of every revolution, nor has the ADC linearity or offset changed. I. Lundgaard Rasmussen (2001), Lund et al. (2002b). It has also not been necessary to correct the event positions from their nominal values.

2. HOT SPOTS

Hotspots on the detector plate, were not unexpected. However, we have found that JEM-X hotspots can be both pulsating and transient. Our strongest hotspot ap-

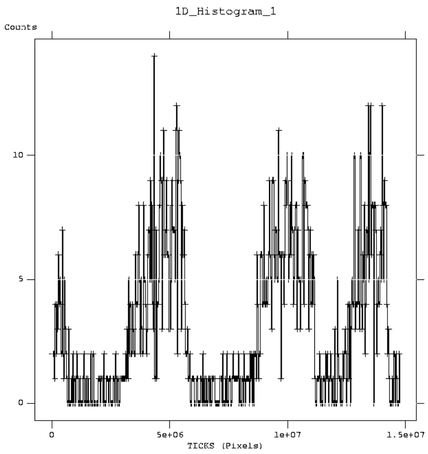

Figure 2. Pulsations observed in Revolution 20 hotspot during the first science window. Counts from hotspot area only.

peared in the JEM-X1 unit after the exit from the radiation belts, at the beginning of Revolution 20 (Fig. 1).

The hotspot pulsated strongly enough to affect the software trigger rate (Fig. 2) and appeared on and off for at least the next 43 science windows. The figure shows the pulsations seen during a 30 minute science window (00200016001) when the hotspot was active, though some science windows either side of this one show no sign of the hotspot.

The spectrum of 'events' from the hotspot area is very soft indeed (Fig. 3), which probably explains why the spot appears so broad in the shadowgram since position determination is worst at low energies. Hotspots probably arise as a result of plate charging near a 'dead' anode (see below), and all those observed have followed anode strips. What causes the initial charging, and why a spot can pulse, disappear and pulse again are not known. It seems likely that some event in the radiation belts is responsible because there is no sign of this hotspot in the later science windows of Revolution 19. This is probably the result of an energetic particle hitting the microstrip plate near a dead anode.

The hotspot problem is dealt with by mapping the affected area in the detector characteristics map JMXi-DETE-MOD. Any events coming from such an area are flagged as undesirable, and software further along the pipeline can remove the flagged events from the processing. OSA 4.0 will contain a more dynamic function whereby events are only flagged if a known hotspot area is deemed to be active.

3. UNSTABLE ANODES

Pre-flight calibration of the JEM-X units had shown that there were some broken anode strips on the detector plate. Within a month of launch it was apparent that additional anode strips were becoming inactive. In November 2002, the high voltage supply to both units was lowered to protect them from this attrition, and no significant loss has occurred since.

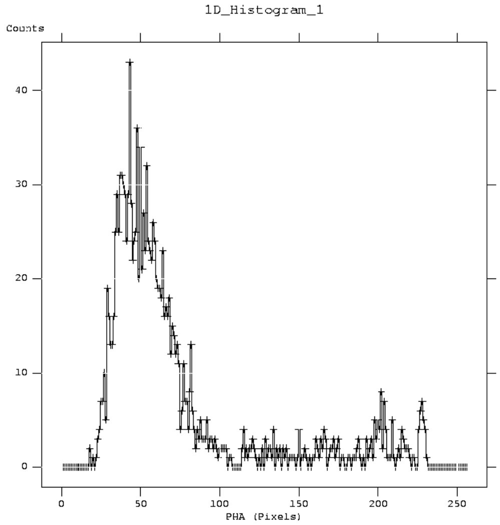

Figure 3. Spectrum of hotspot 'events' from Revolution 20. PHA50≈4.5 KeV, PHA100≈9 KeV

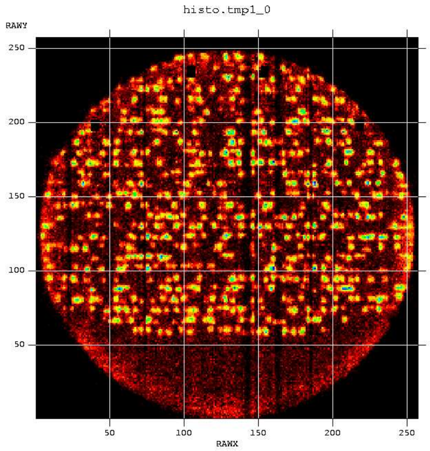

Figure 4. Shadowgram from Crab calibration during Revolution 170, showing effect of dead anodes

Dead anodes appear as vertical strips in the shadowgram with few events (Fig. 4). These are dealt with in two ways. Any events coming from known dead regions are flagged via JMXi-DETE-MOD for removal from the pipeline. The detector gain for every anode position in the data has been determined using the Xe fluoresence line at 30 KeV, so that the energy of each event is corrected according to its x (anode) position using the JMXi-SPAG-MOD spatial gain correction table.

4. GAIN GLITCHES

The detector gain is monitored with 4 min. time resolution using Cd-109 and Fe-55 calibration sources, one for each of the four anode segments. Sudden localised drops in the gain of the detector can occur. Consequently, the

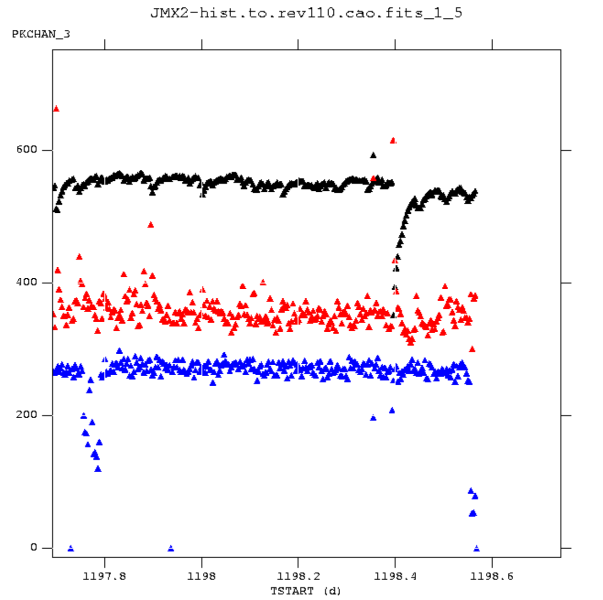

Figure 5. Gain glitch on JEM-X2 anode segment 4 during Revolution 60. Position of 22 KeV line in ADC channels: black; Relative line width: red; Counts in peak: blue

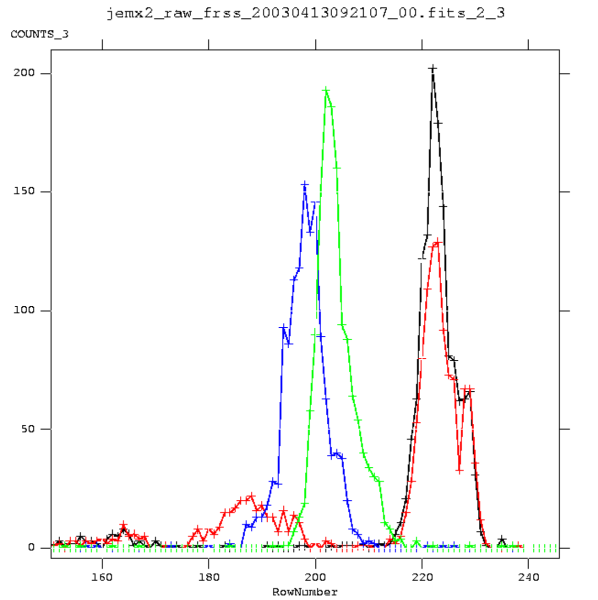

Figure 6. Consecutive calibration spectra during the Revolution 60 glitch event. Order: black, red, blue, green

gain of each segment during one revolution is fitted with a time-dependent model that smooths these glitches out so that all our energy calibrations are not affected by glitches near the calibration areas. The biggest of these glitches was seen in Revolution 60, on anode segment 4 of JEM-X2 (Fig 5).

Glitches of a more usual size are also seen in Figure 5. During the big glitch the position of the Cd-109 22 KeV line drops by about 40%. This is quite an extraordinary event, and like the smaller glitches, is caused by localised charging of the plate caused by nuclear interactions with cosmic ray particles. Presumably an especially massive, energetic cosmic ray nucleus caused the very big glitch, which, like the numerous smaller glitches, is not seen in the neighbouring anode segments.

Looking at the raw calibration spectra (Fig 6), a stable narrow 22 KeV doublet is seen first (black), and for most of the following 4 minutes all is well (upper red peak) but towards the end of the second integration period there is a sudden drop in gain and the peak position drops dramatically (lower red bump). Subsequent spectra show how the gain slowly recovers (blue, green). The later peaks are wider than the original black peak, not because of any intrinsic loss of energy resolution, but because the gain changes significantly during these integration periods. It takes between 1-2 hours for the gain to return to its original value.

Since individual calibration measurements may fluctuate quite a bit locally, the gain of the detector is calculated from the average smoothed values from all four anode segments. However, since instantaneous gain values at all points on the detector cannot be determined, the energy resolution of the detector will be degraded somewhat by the multiplicity of mini-glitches occuring all over the active detector area.

5. ENERGY RESOLUTION

JEM-X2 has been in use continuously since October 2002, and during that time the energy resolution has degraded somewhat. Figure 7 shows the percent relative line width of the calibration spectra from the two central anode segments of JEM-X2 from launch to Revolution 110. Each data point is averaged over one revolution. It should be noted that this increase in line widths is small compared to the variation in line widths seen for individual calibration spectra.

It would appear that this loss of resolution cannot be fully corrected by the software. Despite careful correction for temporal and spatial gain variations, these corrections are limited to four minute resolution for the former and updates on the order of months for the latter. Excess halfwidth caused by glitches simply occur too often and with too great a spatial variation to be monitored and corrected. Also, there is probably an intrinsic component to the resolution degradation related to permanent changes in the microstrip plate that also cause a drift in gain.

6. GAIN DRIFT

One of the most striking characteristics of JEM-X2 has been the steady increase in gain observed from the beginning of the mission (Fig. 8). While it has been easy to correct the energy values of the events for this drift, its has been necessary to control the increase by decreasing the high voltage supply to JEM-X2. This is to ensure that the instrument maintains optimum performance within its most sensitive energy range, and so that the 30 KeV Xe fluorescence line used for gain checking can still be seen. Sudden drops in gain on Figure 8 show where the HV has been stepped down.

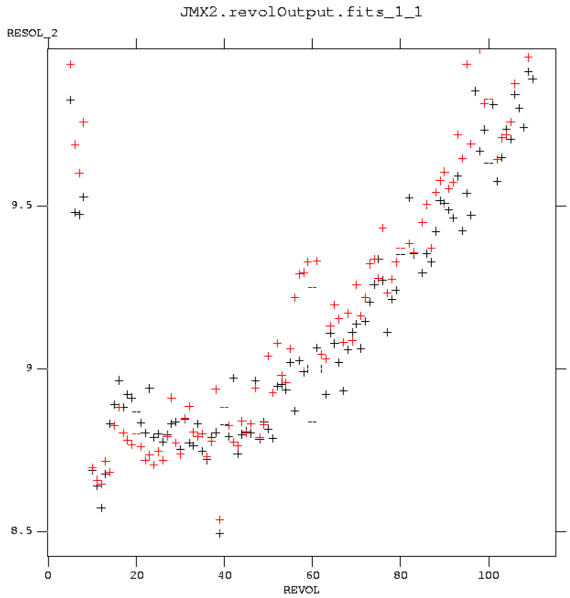

Figure 7. Relative energy resolution in percent for JEM-X2, upto Revolution 110. Each value is averaged over one revolution

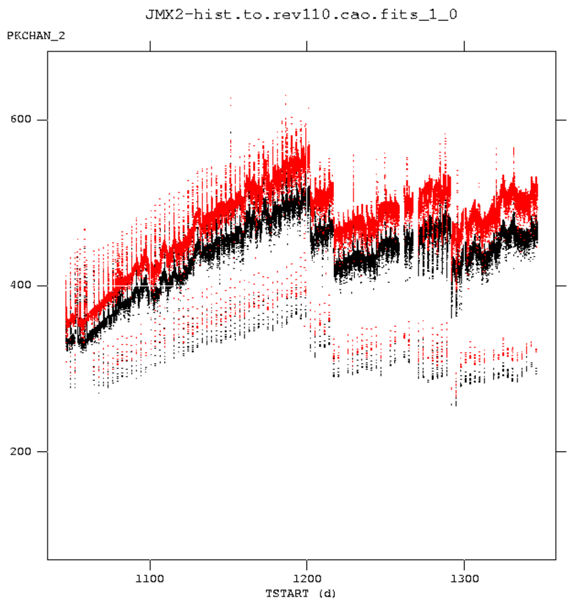

Figure 8. Position of the 22KeV Cd-109 calibration line in ADC channels for anode segments 2(black) and 3(red) of JEM-X2, from launch up to Revolution 110

This effect, though unexpected, has been seen in laboratory tests on microstrip plates. It may be caused by drift of alkaline ions in the substrate glass and/or migration of the strip metal into the glass due to the high field strength applied for a long time, Cicognani et al. (1995). It is probable that the cosmic rays that bombard the plate, the short-term effect of which is clearly seen, degrade both the glass substrate and the metal strips of the detector, giving rise to both changed field patterns and hence gain, and poorer energy resolution.

It is possible that both gain drift and decreased resolution could be due to aging of the gas by cosmic ray interactions, e.g. dissociation of the methane quenching gas.

7. CONCLUSIONS

The majority of unexpected and transient conditions seen in the JEM-X science data can be corrected by using instrument characteristics tables, event flagging and gain smoothing and averaging methods. These include hotspots, dead anode strips and gain glitches. The Instrument Team continues to search out these effects and tune up the software to handle any new detector behaviour.

However, there are some long-term intrinsic changes in the detectors caused by aging of the microstrip plates and/or detector gas that cannot be corrected by the instrument-specific software. Both long-term gain drift and slightly worsening energy resolution belong in this category. However, the JEM-X1 unit has been held in reserve since late 2002 to take over from JEM-X2. JEM-X1 was re-activated just before the Revolution 170 Crab calibration, and appears not to have aged in the way JEM-X2 has during its dormant period. Consequently, users can look forward to data of the same quality as the early phase of the mission. The real question now is whether JEM-X2 can recover its previous gain and energy resolution by being switched off for a period.

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