MONITORING OF THE EPIC CAMERAS AT THE XMM-NEWTON SCIENCE OPERATIONS CENTRE

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ABSTRACT

The XMM-Newton Science Operations Centre (XMM-SOC) at the European Space Astronomy Centre (ESAC) near Madrid/Spain currently operates three scientific instruments on board XMM-Newton. This includes also scientific monitoring of the instruments concerning their stability and health. One of the main instruments onboard XMM-Newton is the European Photon Imaging Camera (EPIC). Main targets of the monitoring are i.e. the behaviour of the Charge Transfer Efficiency (CTE), the gain, the effective area or the bad/hot/noisy pixels. The monitoring is performed by combination of calibration observations with an internal radioactive calibration source and observations of astronomical targets. We describe software tools that search for useful internal calibration data and perform the monitoring. Also we show some examples of the monitoring material available at the XMM-Newton web site.

1. THE XMM-NEWTON EPIC CAMERAS

XMM-Newton[1] was launched in December 1999 on an Ariane 504 rocket from French Guyana. Three Wolter type-1 telescopes with 58 nested mirror shells focus X-ray photons onto the five X-ray instruments comprising the European Photon Imaging[2,3] Camera (EPIC) and the Reflecting Grating Spectrometers[4] (RGS). The Optical Monitor[5] (OM), employing a 30 cm Ritchey Chrétien optical telescope, can perform parallel optical observations of the same field. EPIC is comprised of three cameras employing two distinct detector technologies. The two EPIC-MOS cameras use front illuminated EPIC-MOS (Metal-Oxide Semi-conductor) CCDs as X-ray detectors, while the EPIC-pn camera is equipped with an EPIC-pn (p-n-junction) CCD. Both have been specially developed for XMM-Newton. EPIC provides spatially resolved spectroscopy over a field-of-view of 30' with moderate energy resolution.

2. MONITOR FLOW

The monitoring is performed by a combination of calibration observations with an internal radioactive calibration source and observations of astronomical targets. The offline monitoring is realized through the monitoring of the measured energies and widths of the internal calibration source lines, which are performed with the filter wheel in closed filter position allowing in addition a radioactive Fe-55 source that produces Mn-K and Al-K characterstic lines to shine on the CCD. This is called a CalClosed measurement. Tools were developed to support the trend analysis of parameters, which affect instrument performance and health largely automatic.

3. STANDARD CALCLOSED MESUREMENTS

The collection of CalClosed exposures has been automated by software. The software searches the XMM-Newton Science Archive (XSA) for CalClosed observations, collects them, extracts the needed files and provides them on a central repository for further processing by the instrument team. In the past dedicated CalClosed measurements have been performed in order to sample the performance of the cameras around every 7-10 revolutions. This frequency is necessary to sample sufficiently the behaviour of the MOS-CTE degradation (see Fig. 2).

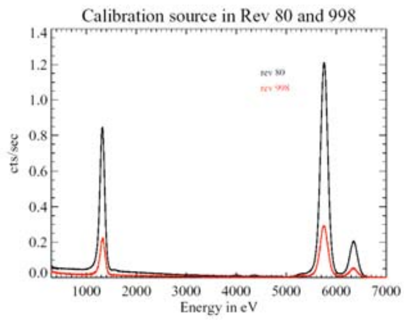

Figure 1: Spectrum of the internal radioactive calibration source in revolution 80 (black) and revolution 998 (red). Note that the calibration source is getting fainter.

4. THE USE OF SLEW CALCLOSED DATA

However, since the calibration source is decaying exponentially the required observation time increased significantly. Analysing data that are taken by XMM-Newton in Medium filter position slewing from one target to the next it turned out that those data are only of scientific use for the EPIC-pn camera.[6] As of revolution 918 it was therefore decided to perform EPIC-MOS slew measurements in CalClosed to gain more calibration data. The dedicated CalClosed measurements have from there on been stopped. For the EPIC-pn camera CalClosed observations will now only be performed during the RGS/OM calibration observations that are not useful as astronomical targets for the EPIC-pn calibration approximately every 2-3 month. This approach saves about 2% exposure time for scientific observations. The EPIC-MOS cameras will of course also use those observations. In order to derive CTE values sufficient statistic needs to be accumulated in a CalClosed measurement. This is not given in one slew data set and therefore software has been developed to merge a number of slew CalClosed datasets to derive from that the CTE parameters. This approach naturally reflects always a trade-off between accuracy in CTE parameters and accuracy in time behaviour since the accumulation of data over time smears out the CTE evolution. The current approach provides a data point every 10 revolutions. We approximated the sample frequency for calibration measurements with time taking a 10 ksec baseline at revolution 1 and an average slew time per revolution of about 4,26 ksec. (see Fig.2)

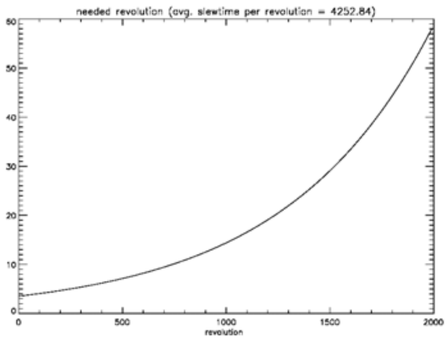

Figure 2: Required sampling period [in rev] of slew CalClosed exposures for CTE measurement as function of revolution

5. MONITORING EXAMPLES

It is known that harsh radiation conditions may induce the formation of electron traps in the detectors, thus degrading the CTE. Fig. 3 shows the evolution of the CTE for the different EPIC cameras. Solar flares created a series of jumps in the CTE of the EPIC-MOS cameras prior to their operation at a lower temperature, while the EPIC-pn CTE degrades independently of solar flares at a nearly constant rate per year.

By the term "bad" or "hot" pixel we mean any pixel within a CCD exhibiting abnormal behaviour which makes it useless for scientific data collection due to its tendency to mimic a signal (hot) or to yield no signal (bad). The number and location of hot pixels has to be monitored in order to flag pixels which have to be masked to reduce loading of the spacecraft telemetry budget, or because they adversely affect science quality. For the EPIC-MOS cameras the number of hot pixels increased through the mission due to micrometeoroid events[7] and due to aging caused by hard radiation particles. Figure 4 shows the evolution of hot pixels for CCD2 in EPIC-MOS2.

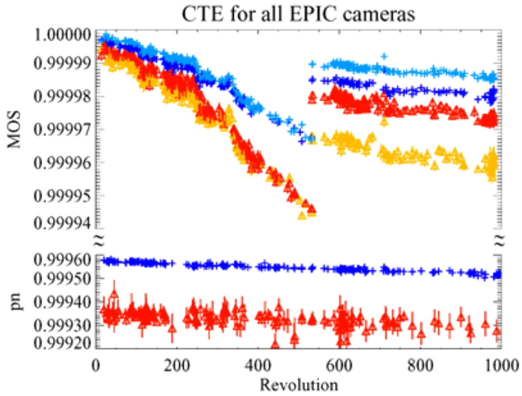

Figure 3: Evolution of the CTE of the EPIC camera CCDs for the energies of the internal calibration source at Mn-K, 5896 eV, (blue crosses) and Al-K, 1486 eV (red triangles). Upper panel: EPIC-MOS, Lower panel EPIC-pn. The different blue and red tones in the upper panel of the figure represent the EPIC-MOS1 (light blue (Mn), orange (Al)) and EPIC-MOS2 (dark blue (Mn), red (Al)). The discontinuity around rev.533 is related to the cooling of the EPIC-MOS cameras

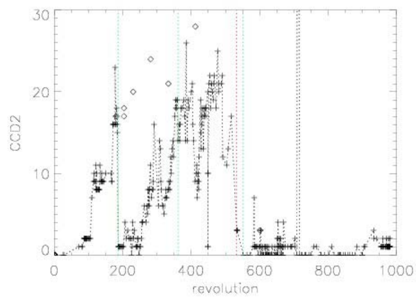

Figure 4 Hot pixel evolution of EPIC-MOS2 CCD2. The diamonds show the absolute number of hot pixels. The crosses show the number of hot pixels that are not yet masked out on board (candidate hot pixels). The green lines indicate an update of the onboard bad pixel table that masks out hot pixels. Note that after the cooling in rev 533 most of the hot pixels have disappeared and the onboard bad pixel table could be relaxed to a few pixels per CCD.

6. CONCLUSION

By the time of this conference in September 2005 we can provide with our current approach of CalClosed data acquisition one data point about every 10 revolution to measure the CTE behaviour of the EPIC-MOS cameras. The monitoring sampling frequency will slow down however up to a point where depending on the future structure of CTE changes we may have to perform in addition to the slew CalClosed again dedicated CalClosed observation in order to maintain a satisfying monitoring sampling frequency.

7. REFERENCES

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