1400 Days of Suzaku XIS Performance Monitoring

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Abstract

We present results from monitoring the performance of the Suzaku XIS CCD sensors during the first three years of operation. Accumulated radiation damage has changed the gain of the XIS sensors as much as three percent and degraded the spectral resolution by as much as thirty percent as measured by the onboard X-ray calibration sources. The spatial non-uniformity of the XIS contamination has changed by a factor two as measured using bright Earth data. These trends are regularly updated at http://space.mit.edu/XIS/monitor.

Key words: XIS, CCD, radiation damage, performance monitoring, contamination

1. Introduction

Suzaku was launched on July 10, 2005 into a circular orbit of approximately 550 kilometers altitude.The X-ray Imaging Spectrometer (XIS) on-board Suzaku contains four x-ray sensitive charge coupled devices (CCDs), three of which are front-illuminated (FI) and one back-illuminated (BI). The BI device has been treated with the chemisorption charging process developed at the University of Arizona.

XIS2, one of the FI devices, failed during the second year of the mission, likely due to a micrometeorite impact, and is not presented here.

We present results from monitoring the performance of the Suzaku XIS CCD sensors during the three years of operation.

2. Performance Monitoring

2.1. Onboard Calibration Sources

Each XIS sensor is equipped with two radioactive ^{55}Fe calibration sources illuminating the upper corners of the CCD. These can be used to track changes in the energy scale and spectral resolution as radiation damage accumulates.

Most XIS operating modes telemeter events from the calibration sources.

Events from each of the regions illuminated by the calibration sources are selected and grouped into one day data sets. A sample of the illumination pattern is shown in figure 1. Each device is slightly different.

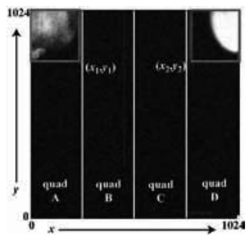

Fig. 1. Onboard Calibration Source Locations

Standard ASCA grade 02346 selection (with split thresholds set to 13 and 7 adu for FI and BI respectively) is applied to distinguish x-ray events from particle background. The energy of each event is calculated assuming a linear CCD energy scale calibrated by the location of the Manganese Kα peak in the data obtained immediately after launch. For each device, the x-ray events from the two calibration source regions are combined into a single spectrum.

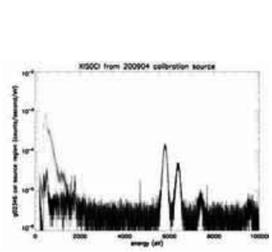

Fig. 2. Spectrum of the Calibration Source

2.2. Energy Scale

The observed locations of the spectral peaks, divided by the nominal locations of the peak, (5.9keV for Manganese Kα), are plotted as functions of time in figure 3.

It is assumed that the majority of the change in gain is due increases in the charge transfer inefficiency (CTI) as a result of radiation damage to the CCDs. The rates of change in the peak locations determined by linear fits to the data range from 0.4 % per year for the FI devices to 0.96 % per year for the BI.

These trends, and those for the Manganese Kβ line at 6.4keV, are regularly updated at http://space.mit.edu/XIS/monitor/ccdperf/.

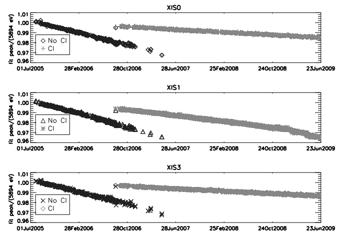

Fig. 3. Energy Scale Trend without Gain Corrections

The standard XIS processing does take out the downward trend nicely as seen in figure 4.

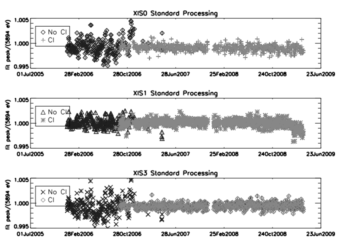

Fig. 4. Energy Scale Trend with CALDB Applied

2.3. Energy Resolution

As the radiation damage increases the spectral resolution degrades. The same Gaussian fit that provides the peak location also provides the width. The full width at half maximum for the Manganese Kα peak since launch is shown in figure 5. See http://space.mit.edu/XIS/monitor/ccdperf/.

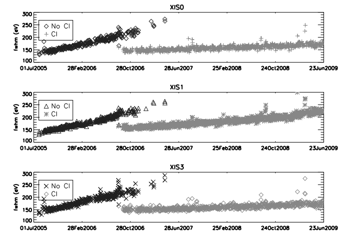

Fig. 5. Energy Resolution without Gain Corrections Applied

3. Contamination Monitoring

The effects of the increase in contamination can be clearly seen in the XIS1 spectra of the bright Earth shown above. The left of figure 6 is from August of 2005, the right is from July 2009. The ratio of the counts in the nitrogen line at about 392eV to those in the oxygen line at 525 eV can be used to track the relative contamination thickness.

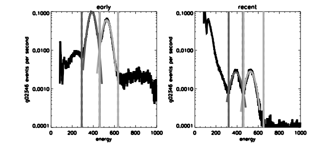

Fig. 6. Bright Earth Spectra

Measuring the ratio in radial bins across the device allows us to track the evolution of the nonuniformity of the contamination. Select profiles are shown in figure 7. It is clear that the shape has evolved over the mission to date.

These trends are regularly updated at http://space.mit.edu/XIS/monitor/brightearth/.

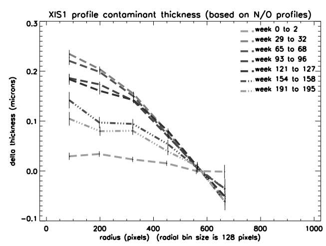

Fig. 7. Selected Thickness Profiles

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