



Tracking Contamination on the *Suzaku* X-Ray Imaging Spectrometer

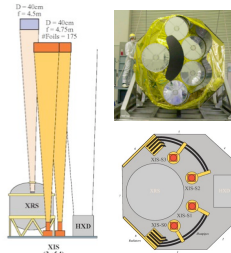
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INTRODUCTION

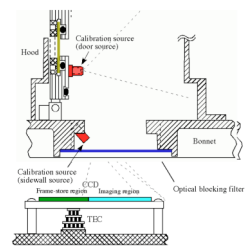
The X-ray Imaging Spectrometer (XIS) aboard *Suzaku* has been operating successfully since August 2005. During that time, the low-energy sensitivity has significantly worsened, likely due to molecular contamination building up on the optical blocking filters (OBFs) of each sensor. The amount of contamination varies with detector, time, and position on each chip. Constraining the composition and surface density of the contaminant is necessary to exploit a unique strength of this instrument, namely its combination of high efficiency and excellent spectral resolution at energies below 1 keV.

At right we show schematic diagrams of the spacecraft and XIS instrument. There are four XIS instruments aboard *Suzaku*, with independent X-Ray Telescopes (XRTs) and CCDs. One XIS contains a backside-illuminated (BI) CCD, greatly improving the effective area at low energies.



A cross-section sketch of the XIS is shown to the right. The molecular contaminant is thought to build up on cold exterior surfaces of the housing, including the OBF.

The most likely source is outgassed plastic material from a shock absorber on the spacecraft's inertial reference unit (not shown). It is thought to be a phthalic ester such as di-2-ethyl hexyl phthalate (DEHP, $C_{24}H_{38}O_4$).



MONITORING THE CONTAMINATION WITH E0102

1E 0102-72.3 (E0102) is a bright, oxygen-rich SNR in the SMC. The X-ray spectrum is dominated by low-energy line emission, making the source a popular X-ray mission calibration target for tracking changes in low-energy gain and effective area. While not a point source for *Chandra*, the $\sim 40''$ size is much smaller than the 2' XIS FWHM, and we have used monthly observations of E0102 to characterize the on-axis OBF contamination.

Spectra of E0102 from four sample epochs are shown to the right, all from the BI chip. The count rate at low energy clearly decreases, indicating increased absorption from the contamination.

SUZAKU OBSERVATIONS OF E0102

date	ksec	notes
2005 Aug 13	3	XIS door open
2005 Aug 31	24	...
2005 Dec 17	105	...
2006 Jan 18	12	SW update
2006 Feb 03	20	...
2006 Apr 16	22	...
2006 May 21	18	...
2006 Jun 27	19	...
2006 Jul 17	22	...
2006 Aug 25	38	...
2006 Sep 19	10	...
2006 Oct 21	18	...
2006 Oct 22	18	SCI on
2006 Dec 13	28	SCI on
2007 Jan 15	22	...
2007 Feb 11	36	SCI on
2007 Mar 19	18	...
2007 Apr 10	18	SCI on

Note: SCI = spaced-row charge injection

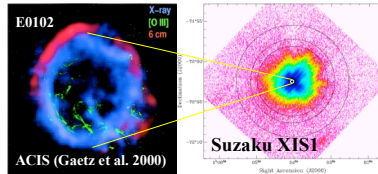
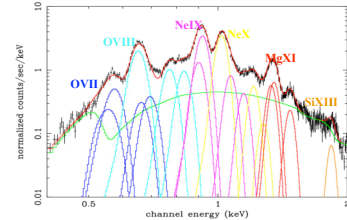
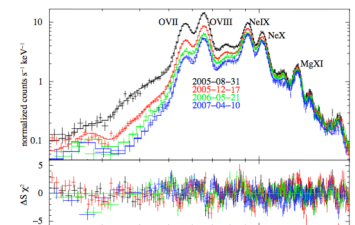


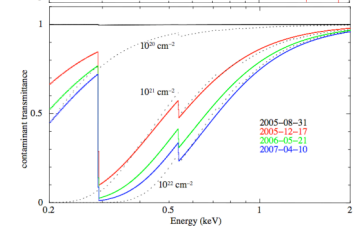
Image of E0102 from *Chandra*/ACIS (left) compared to *Suzaku*/XIS (right). The black circles indicate the source and background extraction regions.



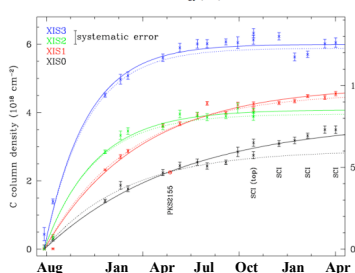
Sample XIS1 (BI) spectrum of E0102. The emission has been empirically modeled from *XMM* and *Chandra* grating data as part of the IACHEC standard candle fitting campaign, and the model consists of 24 Gaussian emission lines (color-coded by species) plus continuum (green).



The transmittance of the contaminant for the same epochs, assuming composition of only C and O in the number ratio C/O = 6 (equivalent to DEHP). Also plotted are the transmittance of solar abundance neutral gas at typical interstellar values. **Improper treatment of contamination can mimic errors in best-fit absorbing column.**



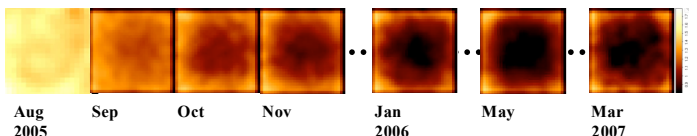
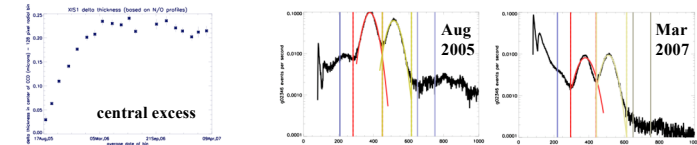
Time history of the on-axis contamination surface density for each detector. The rate of contamination has decreased during the second year, with XIS3 appearing to saturate. The dotted lines show the empirical fits used in the current version of *xissimarfgen*; note that XIS0 diverges from this trend for recent times, while the other sensors are close to the projected values. XIS2 ceased operation in Nov 2006.



NON-UNIFORMITY OF THE CONTAMINATION

The spectra are from observations taken near the bright Earth limb with the BI chip, summed over 4 week intervals. The bright lines are due to atmospheric N K α (392 eV) and O K α (525 eV) emission, which uniformly fill the field of view. Shown are August 2005 (left) and Dec 2006 (right). The line ratio has clearly changed.

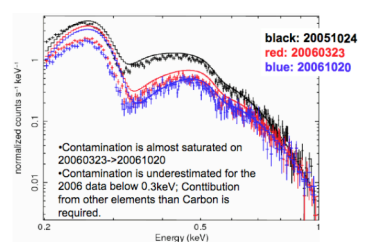
The images are maps of the N/O line flux ratio across the BI chip for these data. In August 2005, this ratio is uniform across the field, as expected. As the contamination increases, the ratio decreases across the FOV, but at a faster rate in the center. **We infer that the contaminant is thicker at the center of the OBF, where the filter is colder.**



CAVEATS FOR SUZAKU OBSERVERS

Improper treatment of the contamination can produce erroneous results when analyzing *Suzaku*/XIS data. The *xissimarfgen* FTOOL accounts for the temporal and spatial variations described here, yet our current understanding suffers some limitations. Here we list several caveats of which all *Suzaku* users should be aware.

- above 0.6 keV**
 - contamination well-modeled for XIS1,2,3, $\sim 10\%$ sys. error
 - contamination on XIS0 is underestimated for mid-2006 onward, fixed in June 2007 CALDB release
- between 0.3-0.6 keV**
 - C/O ratio is not well constrained (C/O > 6?)
 - changes A_{eff} from the C edge (0.28 keV) to just above the O edge (0.53 keV)
 - could introduce spurious features near the O edge
- below 0.3 keV (the "C-band")**
 - decrease in A_{eff} with time is seen in some soft sources, e.g. RXJ1856 (shown)
 - C+O insufficient, additional elements required
 - composition may be time dependent
 - C-band calibration is uncertain at this stage
- extended sources**
 - spatial distribution is modeled from BI chip only
 - FI chips might have different distributions



black: 20051024
red: 20060323
blue: 20061020

• Contamination is almost saturated on 20060323-20061020
• Contamination is underestimated for the 2006 data below 0.3keV; Contribution from other elements than Carbon is required.