JX-ISAS-SUZAKU-MEMO-2010-03
Title: Anomaly of XIS1 in Dec 2009
Category: XIS
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Summary

The XIS1 suddenly showed an anomaly some time between Dec 18, 2009 12:50 UT and 14:10 UT. A bright and persistent spot suddenly appeared at the end of the segment C in all images taken during day-earth observations, while none was found during night-earth observations. We speculate that the anomaly stems from optical light leaked from a hole in the optical blocking filter created by a micro-meteorite hit. We discuss the result of the initial inspection of data and raise possible concerns for the post-anomaly XIS operations and observations.

1 Diagnostics and Results

We inspected a number of event images taken at various conditions before and after the anomaly, in addition to several frame images obtained in post-anomaly diagnostic operations.

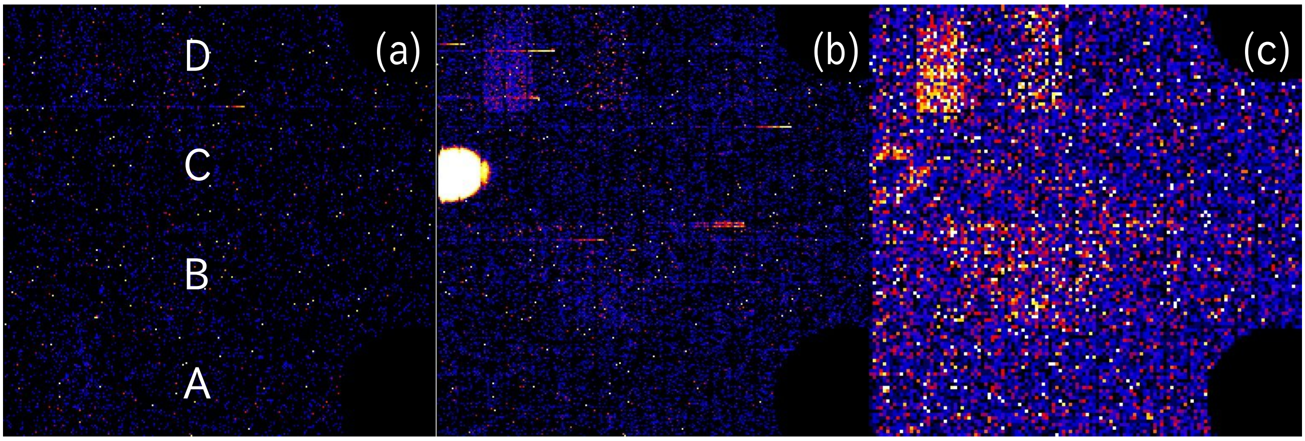

Figure 1: Comparison of three XIS1 event images in the DETX-DETY coordinate during day-earth observations. (a) Event image before the anomaly (Dec 17, 2009) using all grades, (b) Event image after the anomaly (Dec. 18, 2009) using all grades, (c) Event image using X-ray grades only (grades 0, 2, 3, 4, and 6) for the same data with (b). The segment names are shown in (a).

Figures 1 (a) and (b) compare two event images during the day-earth observations before and after the anomaly. Figures 1 (b) and (c) compare two post-anomaly event images constructed by all grades and only the X-ray grades. We see the following symptoms. These symptoms are apparent in all day-earth images taken after the anomaly.

- A bright spot is apparent at the end of the read-out side of the segment C.
- Events in the bright spot are mostly discriminated as non-X-ray events (grade 7).
- The dark level estimated onboard is inappropriate in some parts of the segments B–D.

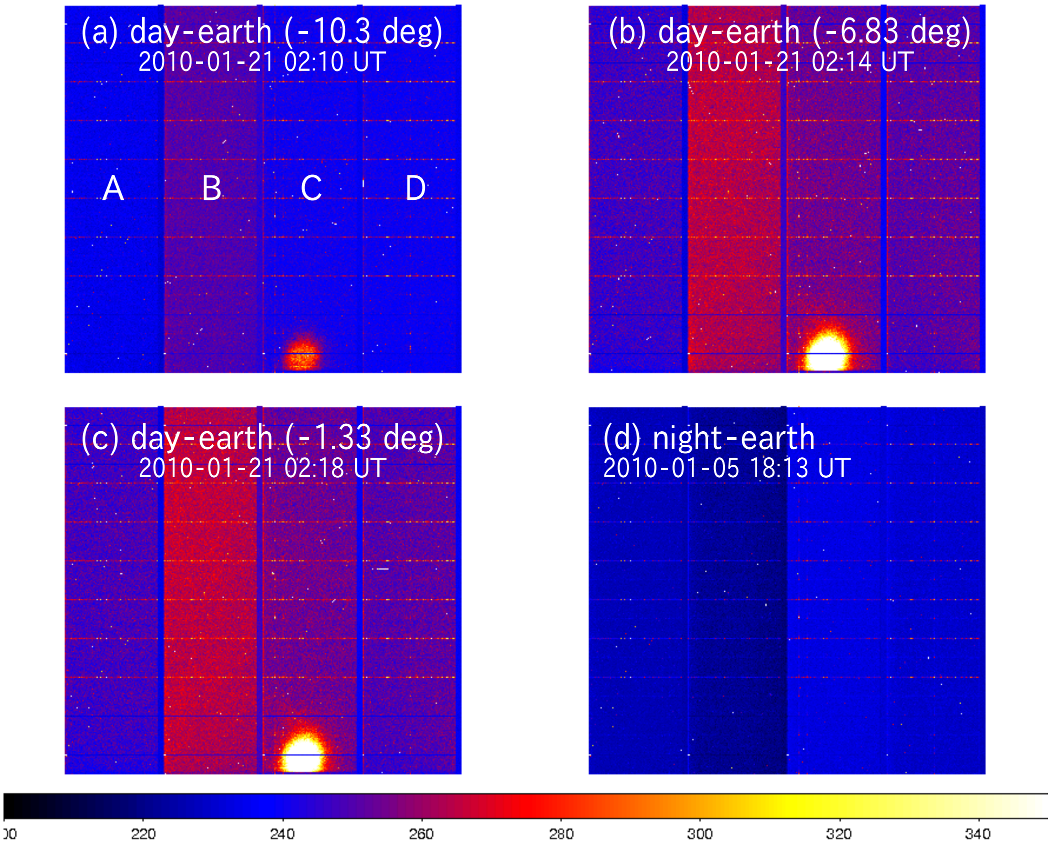

Figure 2: Comparison of frame images in the ACTX-ACTY coordinate taken during day-earth observations at different day-earth elevation angles (shown in parentheses; a–c) and during a night-earth observation (d).

Figure 2 (a)–(c) and (d) show the comparison of four frame images taken during day-earth observations at different elevation angles from the rim of the day-earth (a–c) and during a night-earth observations (d). We see two trends:

- The symptoms described above are apparent in all the day-earth frame images, but not in the night-earth frame image.
- The brightness of the anomalous features changes as the elevation from the day-earth rim changes.

2 Cause

We speculate that the anomaly stems from optical light leaked from a hole in the optical blocking filter (OBF) in the XIS1 created by a micro-meteorite hit.

The OBF is a layer of a 1000 Å polyimide sandwiched by 800 Å and 400 Å Aluminum layers. The distance from the OBF hole to the CCD surface is 20 mm, whereas that to the X-Ray Telescope (XRT) is 4730 mm. Because both layers of the OBF are Aluminum-coated, leaked optical light from the hole reflect between the bottom layer of the OBF and the surface of the CCD, causing increased dark level spreading to the other segments.

From the observed diameter of the light-leak spot ($\sim$90 pixels in FWHM), we estimate the size of the hole to be $\sim$0.5 mm. An optical point source image at the CCD through a pin hole of a negligible size on the OBF has a diameter of $\sim$70 pixels. We attribute the additional $\sim$20 pixels to the hole. The Fresnel diffraction is considered negligible for this size of holes.

3 Concerns

We have several concerns that might impact the XIS1 operation and observations. For science observations, soft diffuse emission of low surface brightness is the only practical case that might suffer some degradation of data. See http://www.astro.isas.jaxa.jp/~tsujimot/pg_xis.pdf for the position of the hole in the R.A.–Decl. coordinate to examine if your observation will have some impact.

3.1 Increased inaccuracy of the calibration

X-rays through the OBF hole are not attenuated by the OBF and the contaminants accumulated on the OBF. This effect is not calibrated at all. For the contamination modelling, we assume that the spatial distribution of the contaminants on the OBF is radially symmetric around the center of the CCD. The assumption is no longer valid, as we expect the contaminants will penetrate through the hole and accumulate on the CCD surface. This leads to increased inaccuracy in flux calibration.

3.2 Increased noise due to optical light

Optical photons through the OBF are reflected between the surface of the CCD and the bottom of the OBF, which increases the dark level induced by these photons across the chip. This is noticeable in figure 1 (c). This happens only for day-earth observations and will not affect science data. However, two cases can be considered when this might be a problem.

- For science data taken at a low day-earth elevation angles can be contaminated by leaked optical photons from the day earth. Note that the current pipe-line processing discards data taken at day-earth elevation angles less than 20 degrees.
- Science data with an optically bright source at the position of the OBF hole in the image may suffer the same problem.

3.3 Increased noise due to extreme UV light

The XIS1 is a back-illuminated CCD, which is also sensitive to extreme UV (EUV) radiation at $\lambda < 140$ nm. Ground tests show that EUV photons increase dark current and substantially degrade the quantum efficiency at an extreme dosage. In the current design of the XIS, the EUV radiation is attenuated by a combination of the thermal shield of the XRT and the OBF of the XIS.

Assuming that the XRT thermal shield is intact, the estimated EUV dose through the OBF hole is $\sim 6\times10^{-6}$ erg pixel^{-1} year^{-1}. Ground tests showed a small change in dark current for dosage above 3×10^{-5} erg pixel^{-1}. Therefore, we consider that the increased dark level is small, if any, for the remainder of the mission. In practice, it is inconceivable that the XRT filter is intact. The XIS team will monitor the possible increase in the dark level.

3.4 Decreased rate of effective data recording

Because a large amount of spurious events are created by optical and EUV photons through the hole, the effective rate of the XIS true event recording decreases. During science observations, we consider this effect is negligible, as most spurious events are discarded onboard as grade 7. During day-earth observations, grade 7 events are also down-linked, but we do not suffer the telemetry saturation so far.

4 Plan for the post-anomaly operation

The XIS team continues to operate the XIS1 in the same way as before the anomaly. For the quantitative assessments for various concerns raised in §3, we plan to perform the following monitoring programs.

- Observations of RX J1856.5−3754 at the position of the hole to calibrate the change of the OBF transparency.
- Periodic acquisitions of the frame data during day-earth observations to monitor possible changes in the dark current and the hole size.
- Occasional observations of Cygnus Loop to monitor the change in the spatial distribution of the amount of contaminants on the OBF and the surface of the CCD.

The results of these diagnostic and calibration observations will be reported separately and will be included in the XIS calibration files.