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Anomaly of XIS2

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1 Summary

XIS2 suddenly showed anomaly on Nov 9, 2006. About 2/3 of the image was flooded with a large amount of charge, which was leaked somewhere in the imaging region. This makes XIS2 effectively useless for the scientific observations. We summarize below details of this XIS2 anomaly.

2 Nature of the anomaly

The anomaly occurred on Nov 9, 2006, 1:03 UT. At that time, the satellite was away from the SAA and was conducting observations in the normal mode (no options applied) using the spaced-row charge injection. We describe below how the HK data of XIS2 changed around the epoch of this anomaly.

Table 1: table

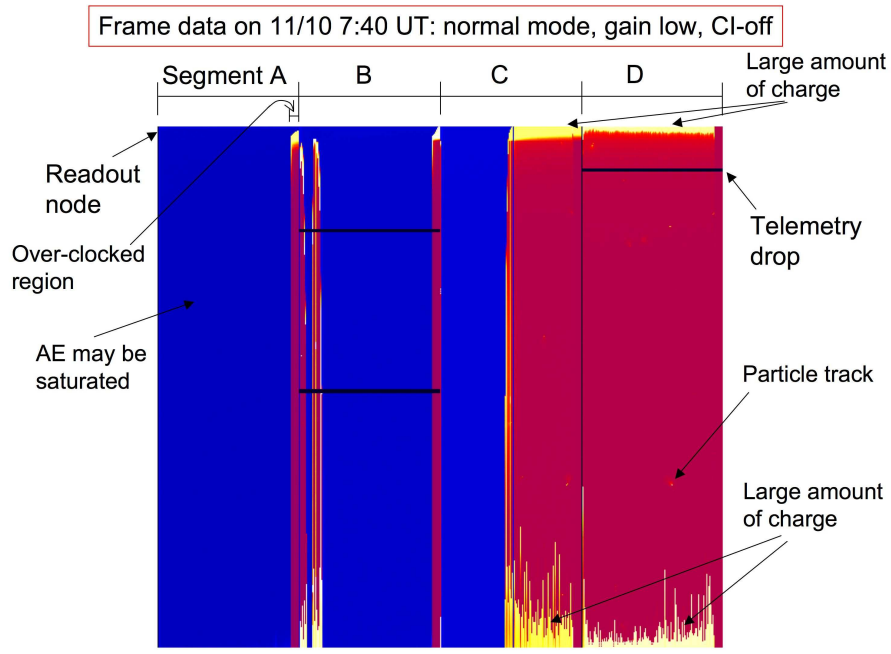
	HOC[1]				event number[2]				pixel number[3]			
	A	B	C	D	A	B	C	D	A	B	C	D
1:02:58	265	255	260	256	6	95	116	13	297	321	2213	1048
1:03:06	265	255	260	256	9	83	94	18	430	254	1401	641
1:03:14	265	255	261	256	12	99	110	10	491	1172	1084	325
1:03:22	265	255	260	256	90	999	1025	191	12539	154582	154098	25848
1:03:38	3354	659	684	254	12	218	407	1547	55	1408	6438	10491
1:03:54	1635	679	688	254	105	5	151	917	618	23	4587	10065

Note: "A", "B", "C", and "D" indicate the segment of CCD.

1. an average pulse height in the horizontal overclocked region.
2. the number of detected events per segment.
3. the number of pixels whose pixel level is larger than the event threshold (i.e. 100 adu).

Because of the sudden increase of "pixel number" at 1:03:22, it is clear that a large amount of charge overflowed in the CCD. This is also clear from the increase of "HOC"; the large amount of charge overflowed even in the overclocked pixels. The "pixel number" decreased soon. We suspect this is because the analogue electronics (AE) was saturated with the large amount of charge.

We show below an image of the frame mode data taken on Nov. 10. The blue region in segments A, B and a half of C indicates that the AE was saturated due to the large amount of charge exceeding the dynamic range of AE. The red region, segments D and a half of C, indicates that the region worked OK; particle tracks were detected.



We confirmed that the readout nodes of the 4 segments and the corresponding analogue chains were all working fine. Charge injection gate was also found to be working, but we could not control the amount of charge very well. We suspect that the leaked charge in the imaging area overflowed into the serial register used for the charge injection.
The XIS CCD is quipped with two serial registers. One is located at the end of the frame-store region and is connected to the readout node, whereas the other is located at the end of the imaging region and is connected to the charge injection gate. Hereafter, we refer the latter as an input register. Because these two registers are run by the same clocks, the input register is always clocked when we operate the CCD. If the extra charge is produced near the charge injection gate and is overflowed into the input register, it causes the leaked charge to spread out over the imaging region. We would like to stress that the charge injection structures are not directly related to the generation of the extra charge.

3 Origin of the extra charge

We tried to reduce the leaked charge by changing the clock pattern and voltages in the imaging region. However, it was not successful, and we could not localize where the leak occurred. Because the leaked charge is suspected to spread over through the input register, the leak may have occurred near the charge injection gate.
When we changed the clock voltages in the imaging region, amount of the leaked charge was observed to change. This indicates likely short between the electrodes and the buried channel. Possible mechanisms to cause the short include micro-meteoroid impact on the CCD, as seen on XMM-Newton (5 times) and Swift (once). Although there is no

direct evidence to indicate the micro-meteoroid impact, the phenomenon observed in XIS2 is not very different from that expected from the micro-meteoroid impact. Low-earth orbit and the low-grazing-angle mirrors of Suzaku may have enhanced the probability of the micro-meteoroid impact.

4 Operation of XIS2

Because it is difficult to recover XIS2, we simple stop operating the sensor. It is unlikely to resume the operation of XIS2 in future.
It is true that 1/3 of the imaging area is almost free from the flooded charge. However, because the region does not covers the nominal pointing positions, it is difficult to utilize the region for scientific observations. Furthermore, reduction of the leaked charge and the nominal operation of the CCD are incompatible. The clock voltages are common to all the segments. We cannot reduce the leaked charge by changing the clock voltages, while reading out the unaffected region in the nominal setting. If we could stop clocking the input register, we might be able to suppress spreading the extra charge over the imaging area. However, this means that the serial registers connected to the readout nodes are also stopped and we cannot read out the data. For these reasons, it is difficult to take scientifically useful data with XIS2.