JX-ISAS-SUZAKU-MEMO-2013-01
Title: New OBF Holes in XIS1 and XIS3
Category: XIS
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Summary

A total of 10 new bright spots were found in the frame dump images of the XIS1 and XIS3 in July 2013. We speculate that they are caused by OBF holes for their similarities with the event in 2009 December for XIS1. The size of the OBF holes are estimated to be very small of ∼0.3 pixel, so they are expected to have no effect in X-ray data unless an optically bright source coincidently falls in one of the holes.

1 Background

The XIS is subject to micro-meteorite hits. It is estimated that each sensor suffers ≈1 hit per year (). Some leave detrimental effects like the ones we had for XIS2 in 2006 November (Dotani et al, 2009) and for XIS0 in 2009 June (Tsujimoto et al, 2010a). Others only leave a small hole in the optical blocking filter (OBF) and have virtually no effect in X-ray observations like the one we had in 2009 December (Tsujimoto et al, 2010b). Events like the latter are hard to spot, as they appear noticeable only by examining images taken during the day Earth (DYE). This practice has not been routinely done by the XIS team to date. During the process of checking the DYE images for other purposes, we noticed similar features seen in the 2009 December event. We conducted a frame dump operation and inspected some DYE and X-ray images to identify the nature of these new features.

2 Data & Results

2.1 Frame Dump Images

We obtained four frame dump images of XIS0, 1, 3 during an Earth eclipse on 2013 July 16. We chose an interval, in which the Earth eclipse changes from night Earth (NTE) to day Earth (DYE), so that we can obtain the frame images with different levels of DYE illumination.

Figure 1 shows the series of frame dump images. The feature by the 2009 December event can be found at the bottom of the XIS1 images. Many similar features ("bright spots") are recognized in the XIS1 and XIS3 images. We observe the following.

- The spots become more apparent as the DYE illumination becomes stronger, indicating that the optical light from the DYE is the cause.
- The size of each spot is approximately the same with ∼100 pixels in FWHM in the most DYE-illuminated images (right column in figure 1).
- The brightness differ from spot to spot.

From the similarity to the 2009 December event, we conclude that all the new bright spots are caused by the optical photons through an OBF hole caused by a micro-meteorite hit. The size of the spots may correspond to the diameter of the X-Ray Telescope (XRT). As the OBF is located about 24 mm above the CCD and the focal length of the XRT is 4750 mm, the XRT (a diameter of 400 mm) produces a spot of $400 \times 24/4750 = 2$ mm on the CCD. This is approximately the observed size of the spots.

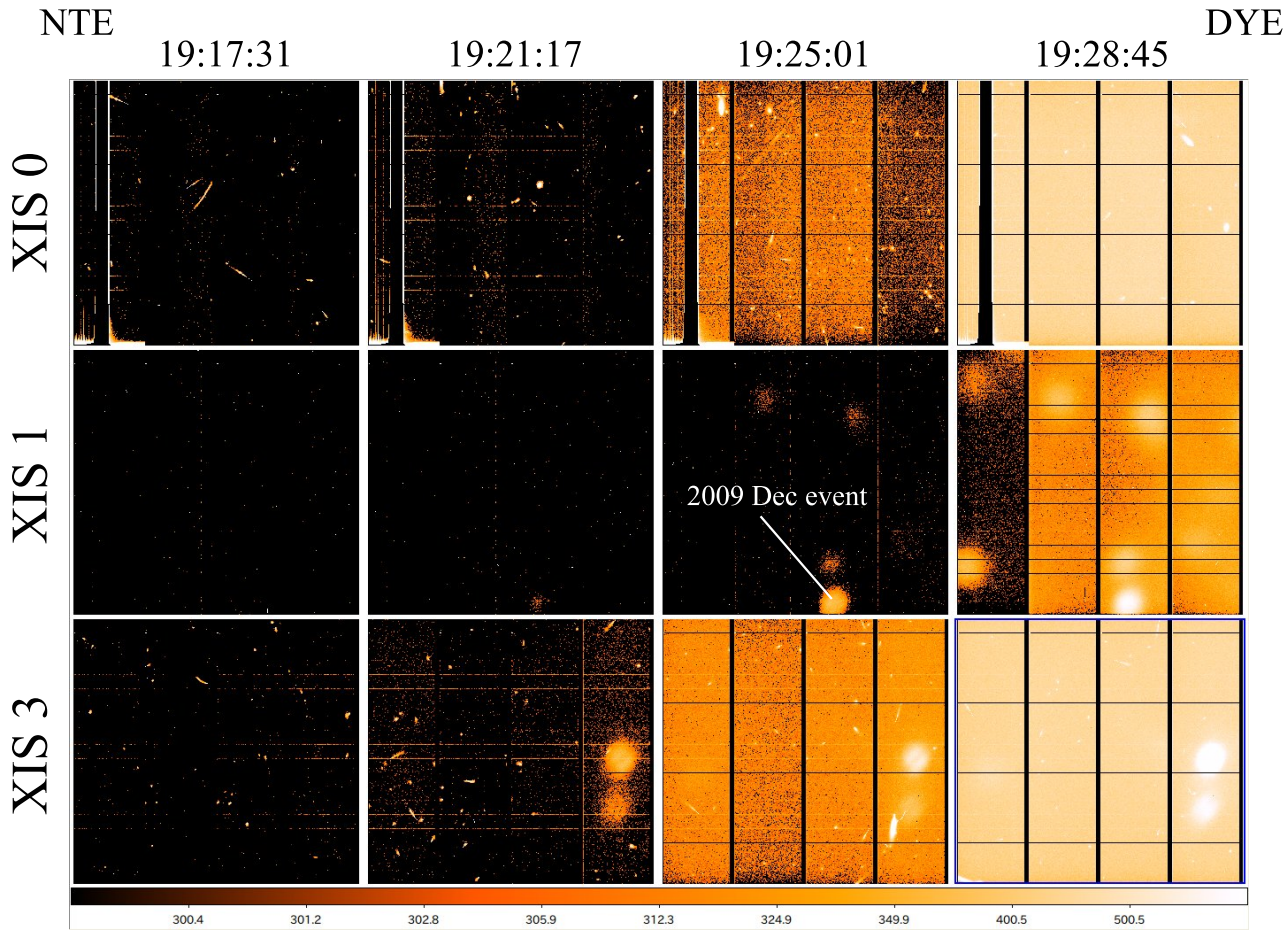

Figure 1: Frame dump images of XIS0 (top), XIS1 (middle), and XIS3 (bottom) taken during an Earth eclipse interval changing gradually from NTE to DYE. The scratches are cosmic-ray events

We can also estimate the size of the hole. Suppose a pin hole of 8×8 μm^2, i.e., 1/10 of a pixel area (24×24 μm^2). Because the optical light transmission of the OBF is $\approx10^{-6}$, it will produce 10^5 times larger number of electrons than other pixels if the optical photons from the pin hole are concentrated in a pixel. In reality, the optical photons are spread over $\sim100\times100$ pixels. Thus, the excess electrons due to the pin hole becomes 10 times the light leak through the OBF. This is close to what was observed for the brightest spot in XIS1. For this spot, we estimated the size of the OBF hole as ~7.5 μm by a different method (Tsujimoto et al, 2010b), which is consistent with the estimate above. We suspect that other fainter spots are caused by smaller OBF holes.

If the estimated size of the OBF holes are correct, they will leave negligible, if any, impact to X-ray data. The point spread function of the XRT has a size of $2'$ in HPD, which coverts to ~2800 μm. The geometric fraction of an OBF hole is only $\sim10^{-6}$.

2.2 Day Earth Images

We constructed postage stamp images of the DYE throughout the mission until the month of this writing. (figures 2–4). The bright spots found in the frame dump images (figure 1) are also found in the DYE images, although they have different appearances. In the XIS1 images, the brightest two spots have holes inside the spot, while the others have no such thing. In the XIS3 images, the the brightest

Table 1: List of OBF holes as of writing.

No.	Sensor	DETX	DETY	First appearance[a]
1	XIS1	57	627	2009/12
2	XIS1	197	619	2010/11
3	XIS1	278	875	2010/11
4	XIS1	764	706	2010/11
5	XIS1	830	375	2011/12
6	XIS1	183	37	2011/12
7	XIS1	478	964	Unknown
8	XIS1	904	69	Unknown
1	XIS3	148	475	2010/05
2	XIS3	135	292	2010/05
3	XIS3	898	427	Unknown

[a] Some features are only apparent in the frame dump images, which are rarely taken, so it is uncertain when these features emerged.

two spots appear as dark spots.

We speculate that these different appearances are caused by different surface brightness of the spots and the different event/split threshold between the FI (XIS0 and XIS3) and the BI (XIS1) sensors. If the charges are too crowded, they are labeled as grade 7 and are discarded together with real X-ray events by the grade filtering, leaving a hole in the image.

With the postage stamp images, we also identified the time ranges, in which each bright spot appeared. The position and the first appearance of the spots are summarized in table 1.

2.3 X-ray Images

We also inspected Perseus cluster images to confirm that the OBF holes have no affect in X-ray images. Figure 5 compares the XIS1 and XIS3 images taken in Aug. 2006 and Feb. 2013, which is before and after most of the events occurred, respectively. No apparent feature is recognized in the X-ray images, suggesting that there is little, if any, impact for X-ray data.

3 Post-event Actions

We do not expect any significant effect on the X-ray data taken after the events, so we do not take any particular action to recover them.

Currently, DYE data are used to model the spatial distribution of the OBF contamination. The lost area by the bright spots is <2–3% of the area used for characterizing the radial profile of the contamination build-up, so they are negligible.

Micro-meteorite hits are expected to occur at a similar rate throughout the mission, and we expect similar features to increase. The team plans to install a DYE image inspection system in the Uchinoura Space Station (USC) and ask the USC duty scientists to check the image routinely. so that new events are identified within a week of their occurrence. The position and the size of the new OBF holes will be kept updated in the web page at `http://www.astro.isas.jaxa.jp/suzaku/analysis/xis/`.

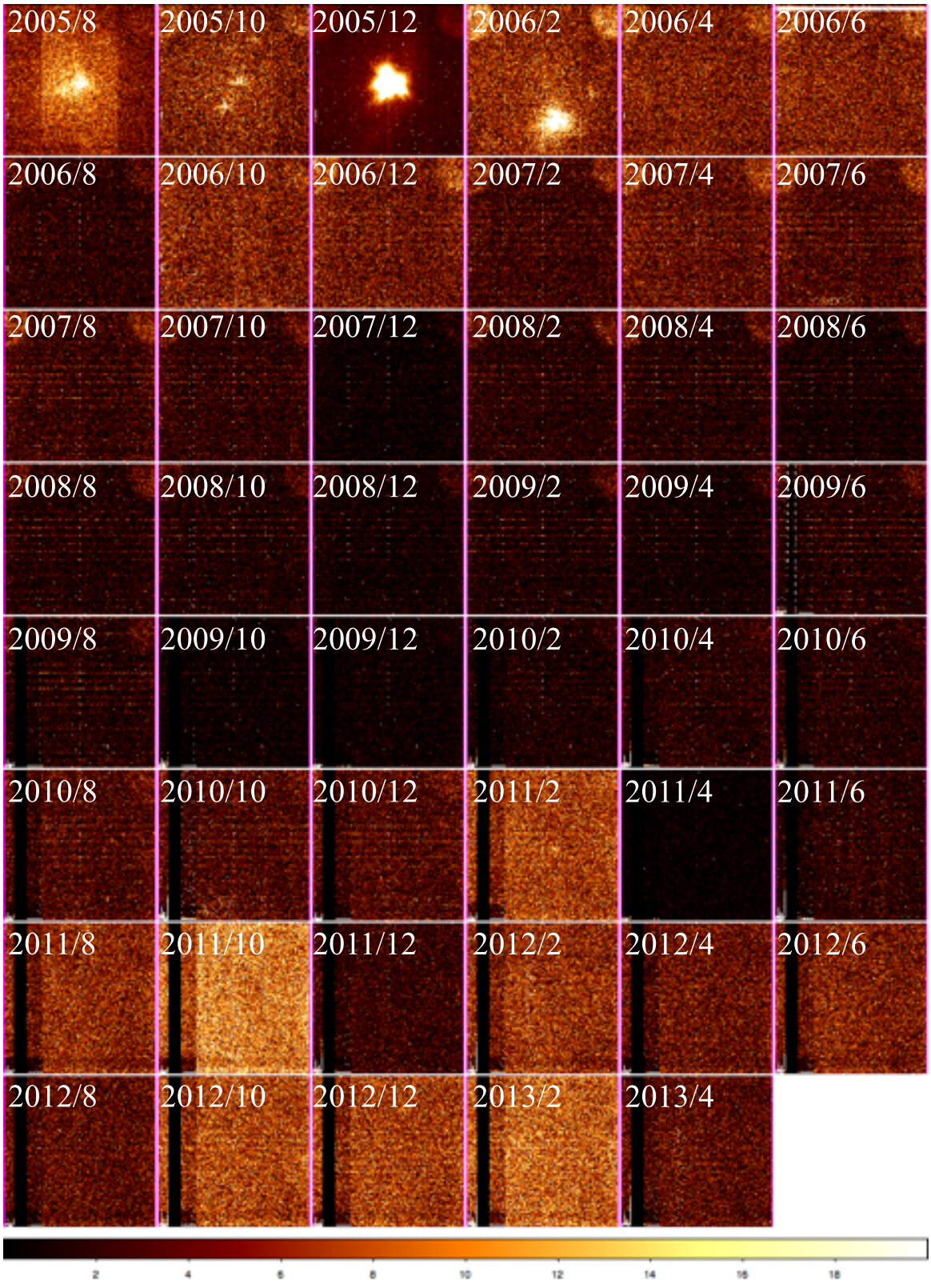

Figure 2: DYE images of XIS0 integrated for two month intervals from 2005 Aug–Sept to 2013 Apr–May. Events with the grade 0, 2, 3, 4, or 6 were used. The first four images should be ignored as they erroneously include some X-ray sources.

XIS1

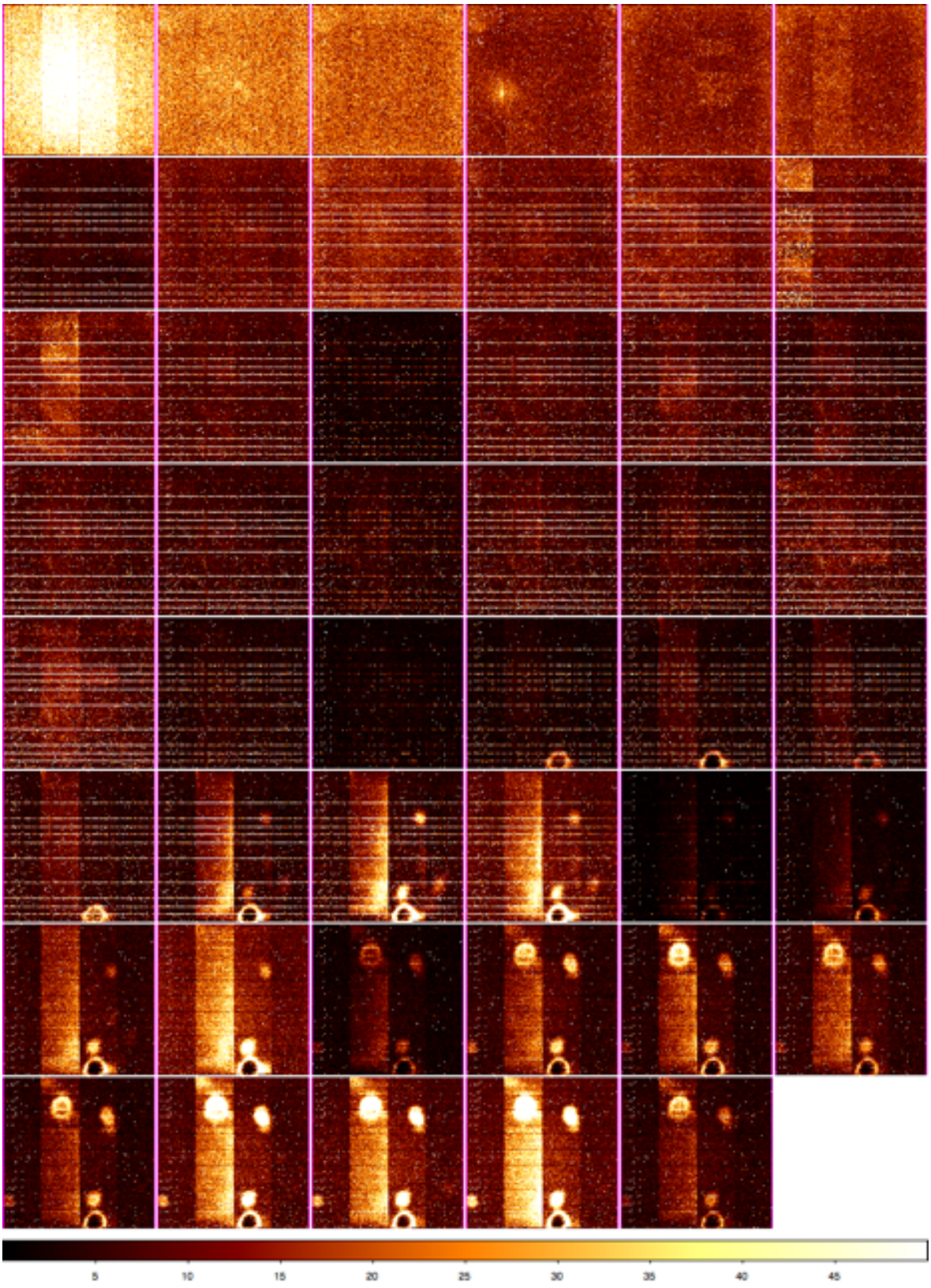

Figure 3: Same with figure 2 for XIS1.

XIS3

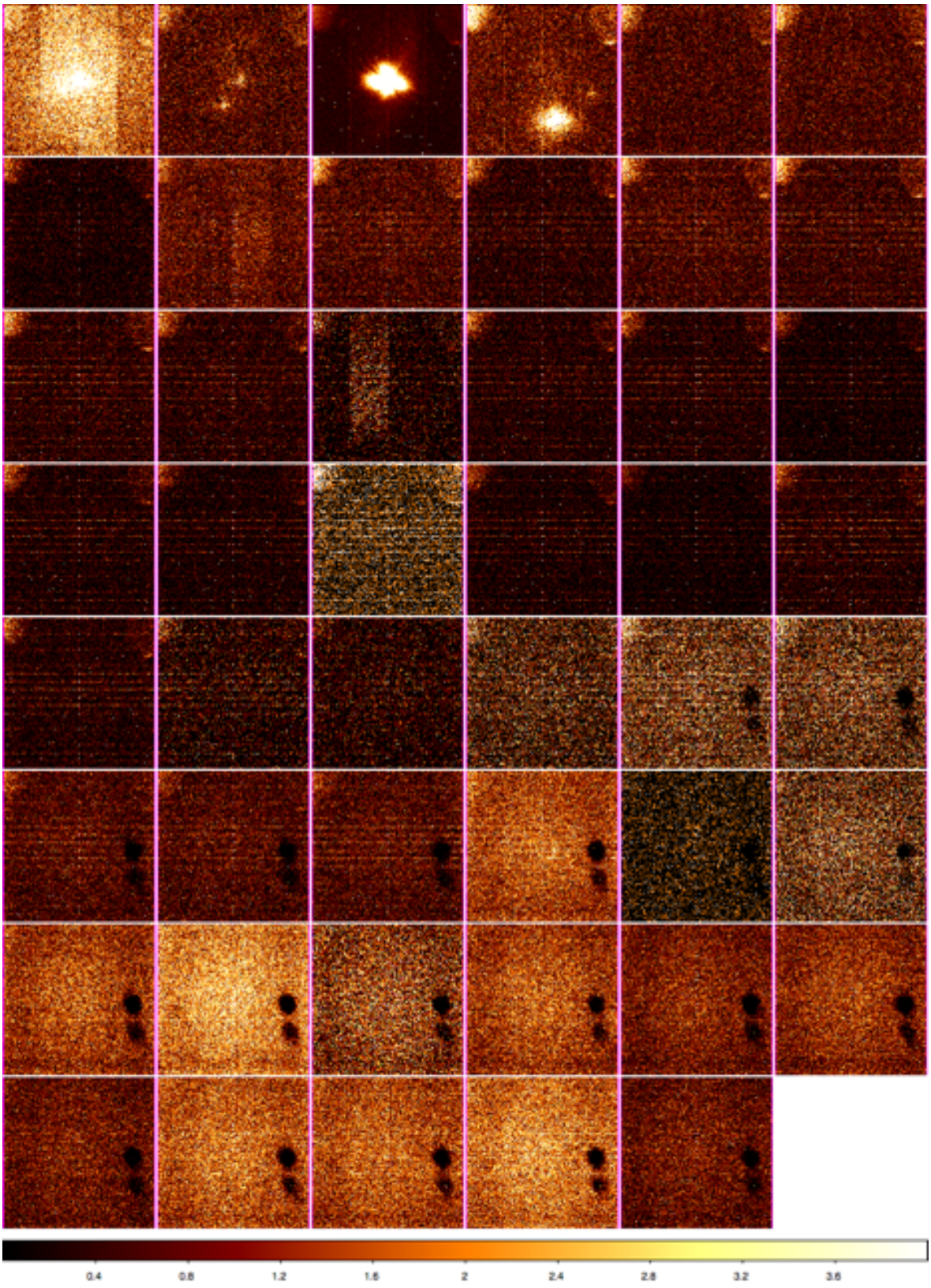

Figure 4: Same with figure 2 for XIS3.

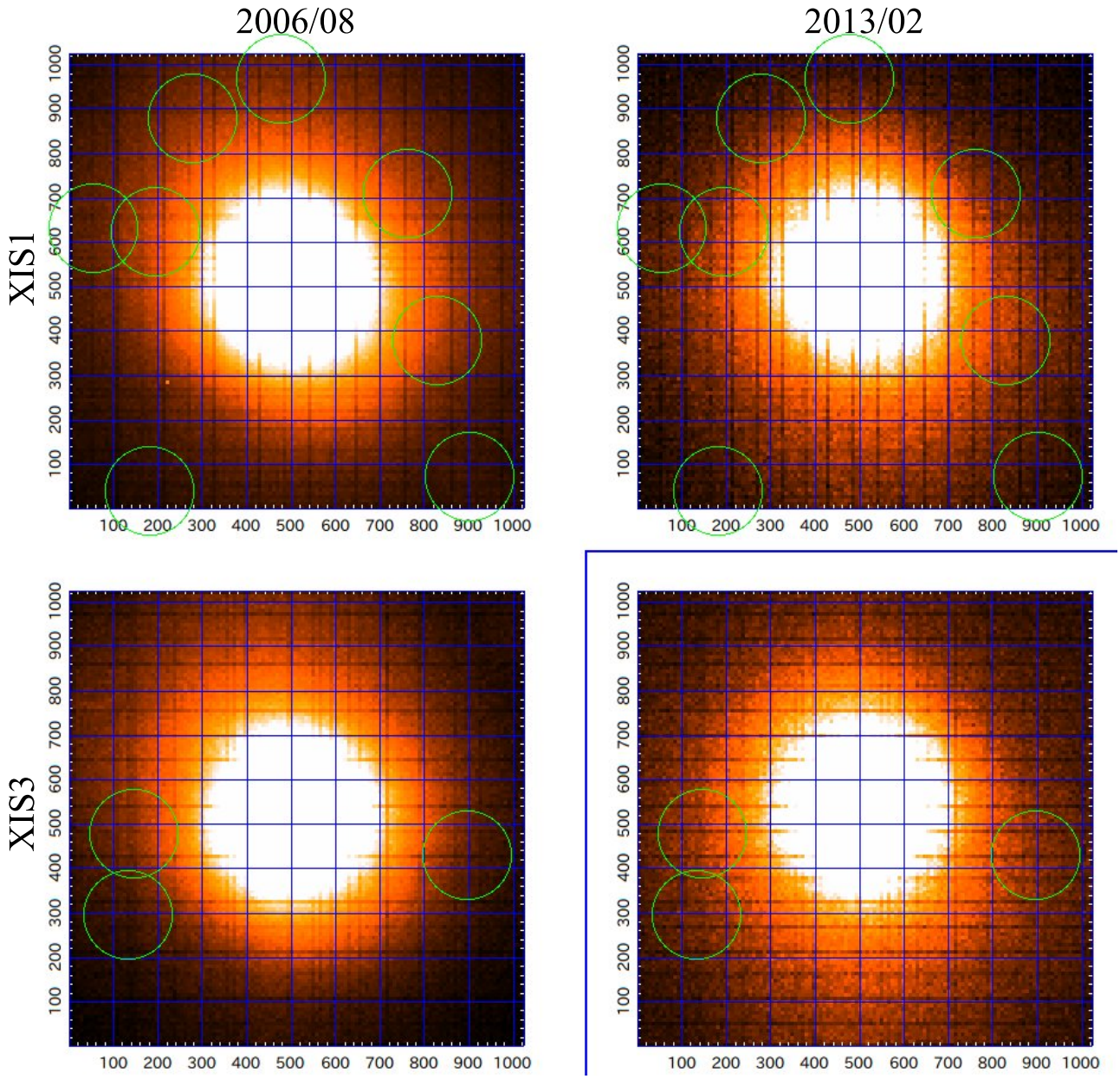

Figure 5: Perseus cluster `DETX–DETY` images in 2006 Aug 29 (left) and 2013 Feb 11 (right). The position of the OBF holes are shown with circles.

References

Dotani, T, et al. 2009, JX-ISAS-SUZAKU-MEMO-2007-08

Tsujimoto, M. et al. 2010, JX-ISAS-SUZAKU-MEMO-2010-01

Tsujimoto, M. et al. 2010, JX-ISAS-SUZAKU-MEMO-2010-03