In Orbit Performance of the MAXI/SSC 2

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Abstract

MAXI was launched in July, 2009 and observation started from August, 2009. MAXI/SSC consists of 32 CCDs each of which is 1 inch square. The CCD is usually working in parallel sum mode(64-binning). When th ISS pases through the South Atlantic Anomaly (SAA), where the background is high, the MAXI/SSC stops observation. Furthermore, the MAXI/SSC doesn't observe when the Sun is near the FOV. This is because the day time image shows the saturation in the electronics on the edge of the CCD and the background is quite different from that of the night time image. In the result, the observation time of the MAXI/SSC is about 30% of one day. The MAXI/SSC has calibration source at the edge of CCDs which radiates Mn-K X-rays. In addition, collimator origin Cu-K emission line can be seen. The gain and energy resolution of the CCD is continuously monitored both by the Mn-K X-rays and by the Cu-K X-rays. In Mn-K X-rays, the energy resolution of the CCD is 147eV (FWHM) at the time of launch. The FWHM at the Cu-K line is gradually decreasing.

In this paper, we report the performance of the MAXI/SSC in orbit and status of calibration.

Key words: instrumentation: detectors — space vehicles: instruments — X-ray CCDs

1. Introduction

The MAXI (Monitor of All-sky X-ray Image, Matsuoka et al. 2009) was launched by Space Shuttle Endeavor on 2009 Jul 16 and installed to the Japanese Experiment Module - Exposed Facility (JEM-EF) on the International Space Station (ISS). The MAXI has two cameras: the Gas Slit Camera (GSC, Mihara et al. 2010) and the Solid-state Slit Camera (SSC, Tomida et al. 2010).

The SSC is a CCD camera covering 0.5-12keV energy range. The SSC has two SSC Units (SSCUs). Since one of two SSCUs is placed so as to monitor the zenithal sky, we call it SSC-Z. The other unit watches +20°C above the horizontal (forward moving) direction of the ISS/MAXI (we call it SSC-H). Each SSCU includes 16 CCD units. The total X-ray detection area of the SSC (32 CCD units) is about 200 cm^2.

In this paper, we report the performance of the MAXI/SSC in orbit and status of calibration.

2. Thermal performance in orbit

It is very important to keep the temperature of the CCD low in order to suppress electrons that excite thermally during the exposure and the charge transfer. The cooling system of the MAXI/SSC consists of peltier device and radiator with a loop heat pipe (LHP) (Tsunemi et al. 2010). The peltier is thermally connected to the body of the SSC. The temperature of the body of the SSC depends on the thermal condition of the radiator. In addition, thermal condition of the radiator depends on the angle of the sun and attitude of the ISS. Figure 1 shows the temperature histories of the CCD after the launch. Each point represents the one-day averaged temperature, the cooling system has been properly working since the operation started.

3. Available Calibration Sources

The gain and energy resolution of the CCD is continuously monitored by the calibration sources. We can use Mn-Kα, Si-Kα, Cu-Kα, Cu-Kβ, Al-Kα (see Figure 1). Mn-Kα derives from ^{55}Fe which are installed at the edge of CCDs. Figure 2 shows the picture of the CCDs in SSC Unit and where the ^{55}Fe are installed. Si-Kα derives from SiO_2 insulator above depletion layer. Cu-Kα and Cu-Kβ are collimator origin emission line. Al-Kα

is from background. Al line can be seen few days per month. (see "In Orbit Performance of the MAXI/SSC 1" in this proceeding)

4. Calibration

In this section, we report the calibration status.

4.1. thermal effects to the gain

We obtain the energy of X-rays by the pixel data after the dark-level subtraction. We call these pixel data "pulse height (PH)" and the value of them "pulse height amplitude (PHA)". PHA is concerned with the temperature of The SSC Electronics (SSCE) and the temperature of the preamplifer. The preamplifer is a part of the SSC Unit and the SSCE controls the SSC Unit (Tomida et al. 2010). So we investigated the relationship between these two temperatures and PHA of Cu-Kα (Figure 3).

4.2. calibration method

We fitted Cu-Kα line with gaussian to know the value of $\mathrm{PHA}_{\mathrm{CuK}\alpha}$. We plot the $\mathrm{PHA}_{\mathrm{CuK}\alpha}$ versus Preamp temperature and SSCE temperature in Figure 3 left and right, respectively. Both show linear dependencies. So we can assume the equation as

$$PHA_{\mathrm{CuK}\alpha} = a \times T_{\mathrm{preamp}} + b \times T_{\mathrm{SSCE}} + c \qquad (1)$$

Moreover, if we assume Energy $\propto$ PHA and $\mathrm{PHA}_{\mathrm{at0eV}} = 0$, we obtain following expression:

$$E(\mathrm{eV}) = 8047\mathrm{eV}\,\frac{PHA}{PHA_{\mathrm{CuK}\alpha}} \qquad (2)$$

by substituing (1),

$$= 8047\mathrm{eV}\,\frac{PHA}{aT_{\mathrm{preamp}} + bT_{\mathrm{SSCE}} + c} \qquad (3)$$

We found values of parameters (a, b, c) of equation(1) of each 32 CCDs by following methods. Most data met the following temperature condition: $-21°\mathrm{C} \leq \mathrm{T}_{\mathrm{preamp}} \leq -6°\mathrm{C}$, $44°\mathrm{C} \leq \mathrm{T}_{\mathrm{SSCE}} \leq 59°\mathrm{C}$. We separated these temperatures to 3 regions respectively and devided data into 9 parts (3×3 temperature regions). We found the value of $\mathrm{PHA}_{\mathrm{CuK}\alpha}$ of each parts. Then, we plotted 9 dots on the 3-dimmensional space. Elements of each dot means (average $\mathrm{T}_{\mathrm{preamp}}$, average $\mathrm{T}_{\mathrm{SSCE}}$, $\mathrm{PHA}_{\mathrm{CuK}\alpha}$). Finally, we fitted these dots to a plane and found parameters (a, b, c). For example, in the case of SSC-H/CCD-11, $a = 0.499$, $b = -0.869$, $c = 1817$.

As a result of calibration, the energy resolution (full width at half maximum: FWHM) at 8keV of SSC-H/CCD-11 improved from 238eV to 228eV.

4.3. future work of calibration

As we wrote, we fitted 9 dots to a plane and found parameters (a, b, c). However, this is a optimistic calculation. So we need more accurate calibration.

Moreover, radiation damages to the CCD caused by charged particles accumulate as time goes by. Because of this effects, the loss of electrons increases when the CCD transfers them. Figure 4 shows that the gain is decreasing. Future CTI (Charge Transfer Inefficiency) calibration is needed.

5. Performance of the CCD in orbit

The energy resolution is gradually decreasing. Figure 5 shows a transition of the FWHM of SSC-H/CCDID=13 at 8keV. Each dot is 7days integration.

Figure 6 shows the gain linearity. The horizontal axis is energy (eV) and the vertical axis is PI (Pulse Invariant). The dots are Al-Kα (1.48670keV), Si-Kα (1.73998keV), Mn-Kα (5.89875keV), Cu-Kα (8.04778keV), Cu-Kβ (8.02783keV). Below table shows residuals. The relation is well reproduced by a linear function.

6. summary

The cooling system of the MAXI/SSC consists of peltier device and radiator with a loop heat pipe (LHP). The cooling system has been properly working.

The gain and energy resolution of the CCD is continuously monitored by the calibration sources. We will carry on more accurate calibration. Also CTI calibration is needed.

The energy resolution is gradually decreasing due to radiation damage to the CCD.

References

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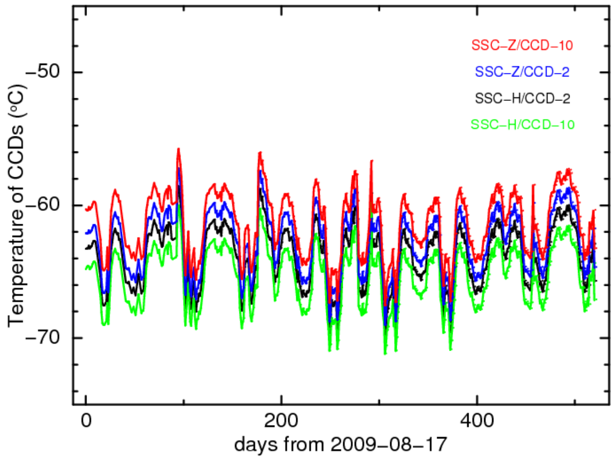


Fig. 1. Temperature histories of the 4 CCDs: SSC-H/CCD-2, SSC-H/CCD-10, SSC-Z/CCD2, SSC-Z/CCD10.

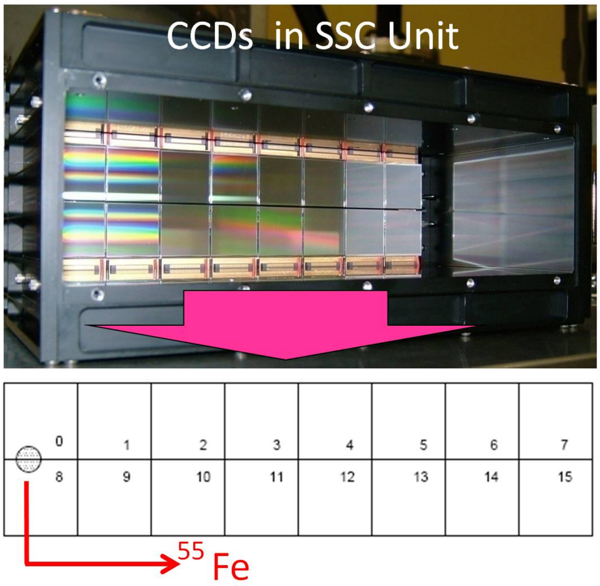


Fig. 2. The upper picture shows the CCDs in the SSC Unit. The numbers (0∼15) are CCDIDs. ^{55}Fe are installed at the edge of the CCDs.

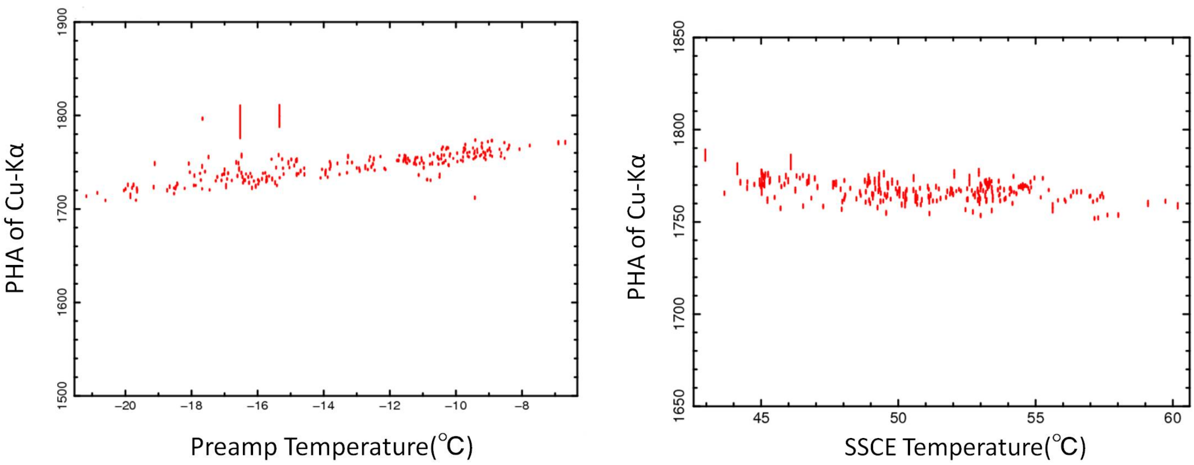


Fig. 3. PHA of Cu-Kα as a function of the temperature of preamp and SSCE.

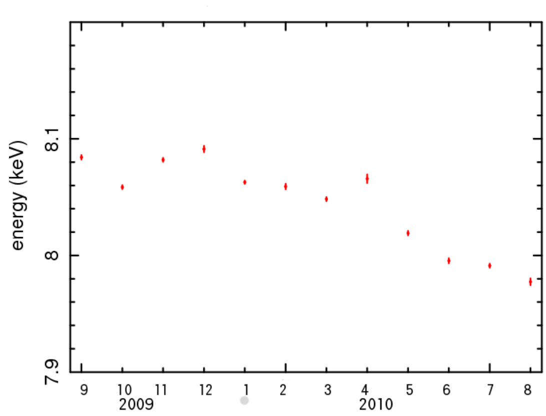


Fig. 4. The history of Cu-Kα line peak energy.

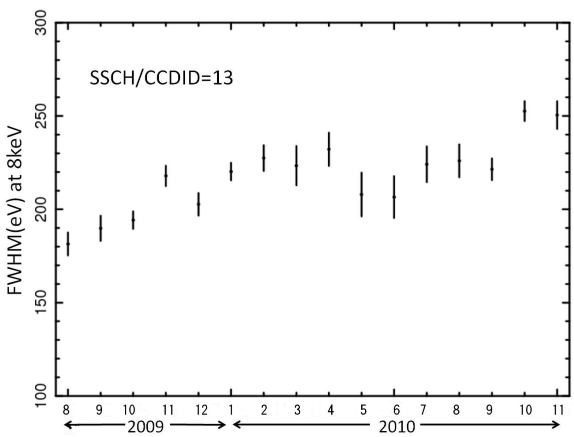
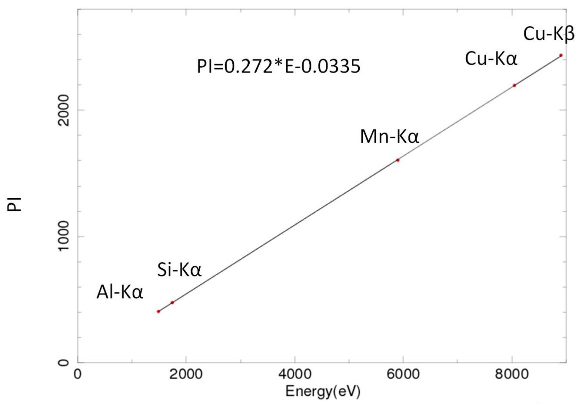


Fig. 5. The history of energy resolution at 8keV.



	Al-Kα	Si-Kα	Mn-Kα	Cu-Kα	Cu-Kβ
residuals	0.4±0.9	1.2±1.9	-5.0±1.5	1.0±0.8	6.0±4.0

Fig. 6. Pulse Invariant (PI) of SSC-H/CCD-0 as a function of X-ray energy. The lower panel shows the residuals between the best fit model (linear funcion) and the data.