The Gas Slit Camera, GSC, onboard MAXI

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Abstract

The Gas Slit Camera (GSC) onboard MAXI consists of 12 slit cameras. Each camera utilizes slat collimator, a slit and a proportional counter (PC). The slat collimator limits the FOV into an arc of 1.5 × 80 degrees. The slit makes one-dimensional image on the PC within the FOV. The one-dimensional position-sensitive PC is filled with Xe gas. Thin carbon fibers (10 μm in diameter) are used as the resistive anodes, which enables position resolution of 1 mm. Six anode cells are surrounded by the veto layers, which achieve a low background rate by anti-coincidence. Six cameras are placed to cover an arc of 1.5×160 degrees of the forward direction, and other six cameras are to the zenith direction. The total area of the twelve PCs is 5350 cm^2. The energy range is 2-30 keV. The sensitivity of one scan is 7 mCrab (5σ), which reaches 1 mCrab in one week.

1. Slit Camera

In the Slit Camera, one point of the sky corresponds to one point on the detector (1:1). We can accumulate multiple scans, which lead to data with high statistics.

In case of the coded mask as RXTE/ASM it is 1 : many. A bright X-ray source in the FOV effects in all the points on the detector. The summation in years and spectral analysis of each source are practically impossible.

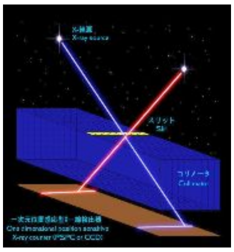

Fig.1. Schematic view of the slit camera .

2. Large Area

To achieve high sensitivity, we made the effective area of the PC as large as possible (5350cm^2 in 12 PCs) in the limiting size of the JEM-EF payload.

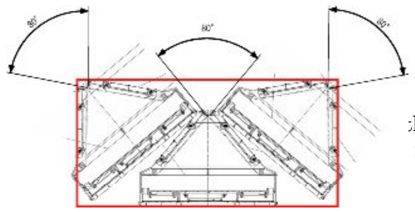

Fig.2. Packing three slit cameras in a rectangular space.

3. Field of view (FOV)

Two FOVs are placed to forward and zenith directions, to compensate the unobservable sky (by SAA etc.) of one FOV with the other. The FOV of one camera is 80 degrees. Two cameras can cover 160 deg. The exposure time of a star near the scan poles is long as 1/cosθ. We placed the third camera in the equator of the scan to even the exposures.

The both edge of 10 deg. are omitted due to the shadow by the ISS structure. The forward FOV is tilted up by 6 deg. not to observe the Earth even when the ISS attitude changes. MAXI scans the all Sky with ISS rotation (90min). The two FOVs have no Earth occultation. The mechanics to move cameras are not needed. By limiting the observable time scale to be longer than 90 min., we can make the instrument simpler,

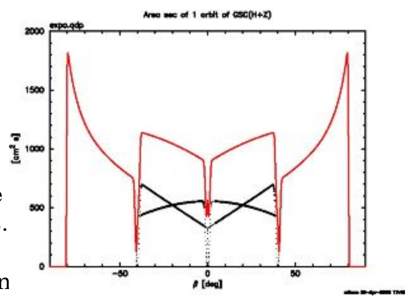

Fig.3. Effective exposure of GSC (Forward + Zenith cameras). Center (0 deg) is scan equator, ±90 deg. are scan poles.

and optimize it to search in the discovery space of the Long-term variability (> 1 hour) of AGNs etc.

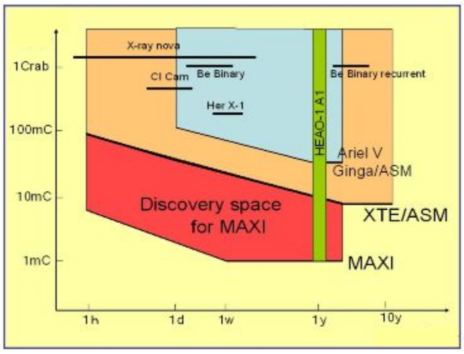

Fig.4. Discovery space of MAXI. Longer time scale than an hour to years in the low flux region.

4. GSC on MAXI

Fig. 5 is the MAXI flight model in the electric test. Radiators and side panels are removed and we can see the X-ray detectors. A slit camera of GSC consists of a slit and slat collimators. In Fig. 6 two cameras are shown.

Fig.5. MAXI in the electric test. Six cameras in forward direction are facing us. The middle two cameras in the center are hidden. See also Fig.2.

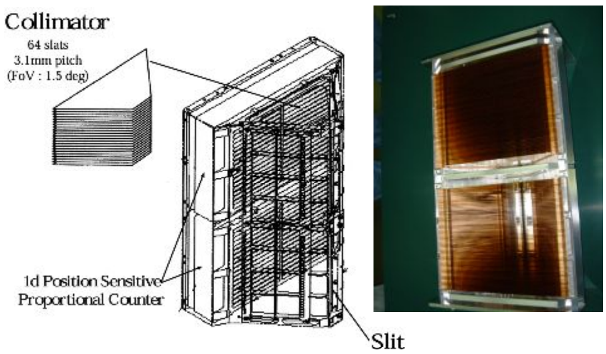

Fig.6. Two GSC cameras in one direction. The slit and slat collimators are shown. Right: collimators in bottom view.

5. Point spread function (PSF)

The PSF of GSC is designed as 1.5×1.5 deg FWHM at the center. The size depends on the incident angle. For example, it is smaller in the edges of the PC by $\cos\theta$, θ=0-40deg. To minimize the source confusion in the galactic center region, the PSF had better to be <1 deg. On the other hand, there is a difficulty in fabricating a finer collimator.

The size of the PSF within the long FOV is determined by the slit width and the position resolution of the PC.

PSF size＝slit width＋pos.res.of PC (1.1mm@8keV)

Narrowing the slit width for better pos. res. results in a low effective area and low sensitivity. By compromising, we chose 1.5 deg for PSF and 3.7mm for slit width. Also, the pos. res. of PC depends on the X-ray energy. The shape of PSF is rectangle convolved by the pos. res. of PC.

The size of the PSF in the scan direction is determined by the spacing between the slat collimators. The 1.5 deg FWHM of FOV gives 3.1mm spacing. The shape of PSF is triangular. The collimator was made of phosphor bronze. The thickness is 0.1mm to be thin compared to the spacing, and still, flat, and parallel. The surface was etched to have diffuse reflection for X-rays.

6. Proportional counter in GSC

The GSC PC was large-scaled the HETE/WXM PC. The GSC has twice longer wires and more cells. Both use the carbon fiber of 10 μm in diameter for the resistive anode, which was developed in RIKEN.

The size of the Be window is 192×272mm, almost A4 paper size. To support the 740kgw pressure on the window, we made tall beams of 14mm height, in every 10mm, not to shadow the X-ray from the slit.

The PC body was made of Ti, which is strong and has a close heat-expansion rate as Be. The window is glued to the body with epoxy. The PC was fabricated by Metorex (Oxford inst.) in Finland.

Fig.7. Proportional counter used in GSC. The body size is 358 × 236 mm. The Be window is 100 μm thick and He-leak tight.

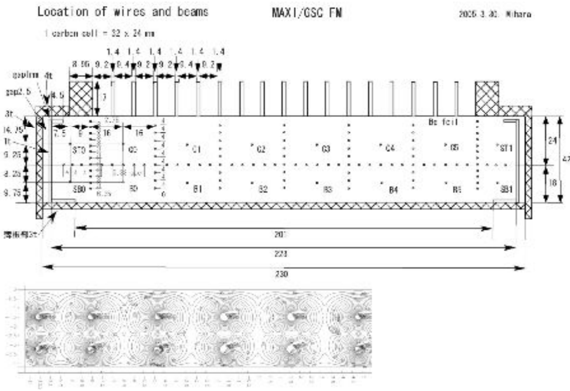

Fig.8. Cross section and sizes of a PC. Numbers are in the unit of mm. Bottom: The electric field calculation.

Compared to WXM PC, the shape of cells of the GSC PC was rectangular to decrease the number of signals from eight to six. The bottom and side vetos were placed. The position and spacing of the GND wires were optimized by the electric field calculation.

We tested several kinds of gas mixture and chose Xe+CO_2(1%) 1.4atm, which has low anomalous gas gain and still has quenching effect.

The position resolution and energy resolution are contradictory requirements. The position resolution is determined by the Johnson noise of the resistive wire. The low resistance of the carbon fiber has higher Johnson noise. Therefore we operate in rather high gas gain to obtain better position resolution. Then the anomalous gas gain appears and makes the energy resolution worse. The phenomena is that the gain depends on the X-ray stopped position in the cell (M curves). The operating gas gain of 5000 (HV=1650V) is determined to have enough position resolution and still have good energy resolution.

7. GSC Electronics (MDP)

The GSC PC has six position-sensitive anodes and 2 series of vetos, which results in14 analog signals in total. MAXI has 12 GSC PCs and the total signal number is 168 ch. Following method was used to process this much of signals .

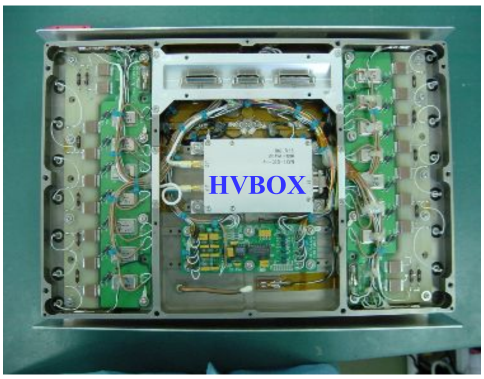

Fig.9. Back side of the PC. Electrical circuits are mounted. Seven readouts are connected to the left and right preamp boards. The low-power high-voltage box is in the middle.

1. Preamps: Low-power hybrid IC Amptek A225 was used.
2. Gain amps: Hybrid IC (HIC) was developed for GSC. One HIC contains gain amp, shaping amp, lower-discriminator (LD) and peak hold in one package. The gain and LD are adjustable from outside to 512 and 4 levels, respectively.
3. HIC: Time constants of the shaping amp were adjusted to maximize the position resolution of GSC PC. Peak-hold capacitor is adjusted to sharpen LD. The radiationally weak MOS FET SD215 was replaced to a stronger type by Calogics company, and 2mm-thick Fe shield was added on the cover of the HIC in the outermost analog boards.
4. Analog board: One analog board was used for one PC. Cross talks between 14 channels were decreased by using coaxial jumper wires, not by the printed circuit.
5. Digital processing: The fuse-type FPGAs by ACTEL company were used for the Data Processing board. The digital errors were exterminated to a very low occurrence, such as once in a million.

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