Monitor of All-Sky X-Ray Image
the all-sky mission from the International Space

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On behalf of MAXI Collaboration

The first astronomical mission on ISS for all-sky X-ray monitor
attached on JEM (Japanese Experimental Module, KIBO) EF (Exposed Facility)
launch: Space Shuttle (Endeavour) on June 13, 2009
Gas Slit Cameras (GSC)
Xe-filled proportional counter
2—30 keV; 5350 cm²

Solid-state Slit Cameras (SSC)
32 CCD chips
0.5—15 keV; 200 cm²

Radiator for X-ray CCD camera

Optical Star Sensor (for attitude determination)

Mass: 530 kg

ISS
JEM/EF

185 cm
80 cm
107 cm
All-Sky Scan with Slit Cameras

MAXI scans almost the entire (90%) sky twice in every ISS orbital period (~ 90 minutes).
Effective area

- Effective area $6.17\,\text{cm}^2/\text{source}/\text{PC}$
- $(2\,\text{Hcamera} + 2\,\text{Zcamera}) \times 2\,\text{FOV} \times \cos22.5 \times 0.5$
  $= 22.8\,\text{cm}^2/\text{source/orbit}$
- Dwell time $45\,\text{s} \times 15\,\text{orbits} \times 1\,\text{yr} \times 0.7$
  $= 3930\,\text{cm}^2\,\text{ks}$
- Corresponds to PCA $(2400\,\text{cm}^2) 1.6\,\text{ks}$

GSC-H and Z added. In one-orbit.
Scientific Objectives

• Detection/monitor of transient X-ray sources in the whole sky
  – Galactic transient
    • X-ray binaries (Novae, QPOs, ..), AXPs, SGRs, flare stars, ...
    – AGNs, GRBs, Supernova breakouts,...

• Rapid nova alerts
  – GRBs, new sources, and outbursts of known sources

• Complete all-sky catalog of X-ray sources
  – 0.5—30 keV, down to 0.2 mCrab in 2 years
  – Census of X-ray sources

• Large scale mapping of diffuse/unresolved X-ray Sky
  – Galactic ridge/loop structures with oxygen (and other) lines
  – Cosmic X-ray background fluctuations and anisotropy
Simulated Sky Images by MAXI

~ 1000 objects and Diffuse hot sources!

GSC 2-30keV
Detection limit (5σ) of GSC by simulation

1 orbit 20 mCrab
1 day 5 mCrab
1 week 2 mCrab
1 month 1 mCrab
2 years 0.2 mCrab
(Source Confusion Limit)

Total number of AGNs by GSC with time.
100 in one week,
1300 in 0.5 year or more (confusion limit).

HEAO A-1 equivalent catalog every month!
MAXI Capability for Black Hole Transients

- 26 novae in 20 yr
- \( \sim 1.3 \) BHC/yr

An energy spectrum can be obtained in a day.

Detectable in a day

10 times better
BHC discovery

Before MAXI: ~1/year
With MAXI: ~1/month

Statistics -> binary evolution
X-ray detectors of MAXI

<table>
<thead>
<tr>
<th></th>
<th>GSC</th>
<th>SSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>detector</td>
<td>Xe Prop. Counter 12 cam</td>
<td>CCD 16chips x 2 cameras</td>
</tr>
<tr>
<td>Energy Band</td>
<td>2 - 30 keV</td>
<td>0.5 - 12 keV</td>
</tr>
<tr>
<td>Energy resol.</td>
<td>15.7% at 8.0 keV</td>
<td>150 eV at 5.9keV</td>
</tr>
<tr>
<td>Time resol.</td>
<td>50 μsec</td>
<td>6 sec</td>
</tr>
<tr>
<td>FOV</td>
<td>1.5 x 160 deg</td>
<td>1.5 x 80 deg</td>
</tr>
<tr>
<td>PSF FWHM</td>
<td>1.5 deg</td>
<td>1.5 deg</td>
</tr>
<tr>
<td>sensitivity</td>
<td>2 mCrab/week</td>
<td>5 mCrab/week</td>
</tr>
</tbody>
</table>

Gas Slit Camera (GSC)

Solid-state Slit Camera (GSC)
Ground cal : collimator transmission

- Effective area: \(~90\%\) of the designed.
- Measured by Cu beam.
- 3 scan paths in FOV.
PSF for incident angles

2 keV

$\phi = 2$ deg.

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$\phi = 20$ deg.

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$\phi = 40$ deg.

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10 keV

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GSC: Energy calibration

Very similar to RXTE/PCA

$^{55}$Fe isotope: $\Delta \text{PH}/\text{PH} \sim 1\%$ in 1 hour $\rightarrow$ gain history

Cas A: 60 days simulation

All anodes and cameras Added.

$E = 6.57 \pm 0.07 \text{ keV}$
Flux, spectral slope : crab

- 1 day simulation
  \( \Gamma = 2.10, \quad \text{norm} = 10 \)
- All cameras added
  \( \Gamma = 2.14 \pm 0.03 \)
  \( \text{Norm} = 10.5 \pm 0.6 \)
Timing of GSC

- Timing method

- Timing will be calibrated by Crab pulsar, ms pulsar, binary X-ray pulsars.
Simulation of MAXI-GSC light curve for 3C273

- 5 mCrab variable source
- PSD slope = 2.0, $T_{\text{brk}} = 100 \text{ day}$
- Flux calibration with Blazars possible
SSC Ground cal: response for monochromatic X-ray

- Fluorescent lines from Al, Si, Cl, Mn, Ti, Fe, Ni, Zn.
- Based on the Suzaku XIS response
- 30 parameters with energy dependence for each CCD.

Energy resolution ~150eV @5.9keV
SSC Ground cal: efficiency

- efficiency of CCD: designed values
- depletion layer: measured values

- Al (light blocking): 0.2 um
- Si (electrode): 0.5 um
- SiO$_2$ (isolation layer): 0.5 um
- Si (depletion layer): ~70 um

- 32 blocks (4 in each CCD)

- Binning is 64 (1024x1024 -> 1024x16 pixels)
- Charge injection is ON
- Time resolution is 5.4 s
Calibrate CTI by

- Isotopes:
  - $^{55}$Fe for 3(4) CCDs
- X-ray sources:
  - Cas A (Si, S)
  - Cygnus loop (O)
- Instrumental:
  - Cu from collimator

Irradiates 2 of the 16 CCDs
Count rate $\sim 10^4$ c/week
SSC in orbit cal: X-ray sources

- **Cygnus Loop**
  - diameter: \(~3^\circ\)
  - Strong O, Ne.
  - OVII: 559 ± 4 eV
  - NeIX: 896 ± 1 eV

- **Cas A**
  - diameter: \(~6\) arcmin
  - Strong Si, S, Fe lines
  - Well known energies with Suzaku, Chandra, XMM
  - Si-Kα: 1851 ± 3 eV
  - Fe-Kα: 6630 ± 20 eV
Schedule

- **2007/10** Final integration Completed
- **2008/9** Final pre-flight tests in Japan
- **2008/10** Transport to KSC
- **2008/11** Final pre-flight test at KSC
- **2009/1** Mounted on Exposed Palette

- **2009/6** Launch with Space Shuttle
  - Initial Phase, In-orbit calibrations
  - L+3 months Start releasing pre-defined data of light curves
  - L+1 year Start releasing on-demand data
Summary

• MAXI is the first astronomical mission carried on ISS to monitor all-sky X-ray image.
• will be launched in June 13, 2009 by Space Shuttle, Endeavour.
• Effective area is small, but all the sources are observed “all the time”, reaching equivalent to 1ks obs. with PCA in 1 year.
• Any bright sources can be used as cross-calibration.

• After 3 months of the start of the observation of MAXI,
  – Nova alerts will start,
  – Regular science products of pre-selected source will be open.