Scientific Results from
Two Years of MAXI Observations

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on behalf of the the MAXI Team
MAXI Team

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Outline

• Mission and Instruments
• Public data and alerts
• X-ray sources seen by MAXI
• Science highlights
  – Black hole candidates
  – Binary pulsars
  – Stellar flares
  – Active galactic nuclei
  – Gamma-ray bursts
  – Others
# MAXI Posters

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MAXI (Monitor of All-sky X-ray Image) on ISS

• The first astronomical mission on ISS
• Transported by Space Shuttle (Endeavour) on July 16, 2009
• Installed on JEM (Japanese Experimental Module, KIBO) EF (Exposed Facility) on July 23.
• First Light on August 15, 2009.

Direction of Motion

inclination = 51.6 deg.
MAXI Instruments

Gas Slit Cameras (GSC)
Xe-filled proportional counter
2—30 keV; 5350 cm²

ISS motion

1.5 deg (FWHM)

FOV of 6 cameras

107 cm

80 cm

185 cm

SSC-HZ

X-ray CCD 16 chips
x 2 cameras

FOV of 6 cameras

160 deg
Detectors

<table>
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<th>Detector</th>
<th>GSC (X-ray Gas Camera)</th>
<th>SSC (X-ray CCD Camera)</th>
</tr>
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<tr>
<td>Detector</td>
<td>Gas(Xe) prop. counter x12</td>
<td>CCD 16 chips x 2 camera</td>
</tr>
<tr>
<td>Energy range (Q.E.&gt;10%)</td>
<td>2−30 keV</td>
<td>0.5−12 keV</td>
</tr>
<tr>
<td>Energy resolution (FWHM)</td>
<td>15.7%(at 8.0keV)</td>
<td>&lt; 2.5%(150eV) (at 5.9keV)</td>
</tr>
<tr>
<td>Time resolution &amp; accuracy</td>
<td>&lt;200µsec</td>
<td>~6 sec</td>
</tr>
<tr>
<td>Instantaneous sky coverage</td>
<td>2.4 % of the whole sky (160 deg x 3 deg x 2 sets)</td>
<td>1.4% of whole sky (90 deg x 3 deg x 2 sets)</td>
</tr>
<tr>
<td>Point Spread Function</td>
<td>1.5 degree</td>
<td>1.5 degree</td>
</tr>
<tr>
<td>sensitivity</td>
<td>2 mCrab (week)</td>
<td>5 mCrab (week)</td>
</tr>
</tbody>
</table>

**Diagram:**
- Collimator
- Proportional counter
- GSC
- SSC
- Slit

**Table:**
- Detectors
- Energy range
- Energy resolution
- Time resolution
- Instantaneous sky coverage
- Point Spread Function
- Sensitivity
GSC All-Sky Scan Movie

- **Red**: 2-4 keV, **Green**: 4-10 keV, **Blue**: 10-20 keV.
- Raw data. Exposure not corrected.
- Not cleaned for background variation, sun-light leak, and solar-paddle reflection.

(C)JAXA/RIKEN/MAXI-Team
MAXI Public Data (http://maxi.riken.jp)

- Daily all-sky image
- For 259 listed Sources
  - Field image
  - Light curve in three energy bands
  - (updated daily)
- For selected sources (currently ~50 sources)
  - Daily energy spectrum with RMF
  - Sources
    - Crab, Sco X-1, Cen X-3, Her X-1, GX 9+9, GX 9+1, GX 13+1, GX 17+2, GRS 1915+105, Cyg X-2, ...

Crab 2010/10/1
MAXI alerts

- Transient alert e-mails
  - Sent after human inspection
    - (except for bright new transients)
  - five categories
    - New Transient (incl. GRBs)
      - Automatic alerts for transients with >150 mCrab
      - Rate: ~1 event/month
      - Automatic alerts followed by manual ones
    - X-ray star
    - Nova-CV
    - AGN
    - Supernova
      - Subscribe at maxi.riken.jp
- GCN notices (to be automated soon)
- ATels
MAXI 7-month catalog

Poster 71: Hiroi et al.

- 143 sources (>7 \( \sigma \), \(|b| > 10^\circ\))
- Limiting sensitivity:
  \(~1.5 \times 10^{-11} \text{ ergs cm}^{-2} \text{ s}^{-1} \) (4-10 keV)
- Consistent with, but deeper than HEAO A-2

MAXI/GSC
4–10 keV

- unidentified: 1
- galaxy clusters: 48
- blazars: 12
- X-ray binaries: 18
- galaxies: 1
- Seyfert galaxies: 39
- CVs/stars: 20
- confused: 4
SSC all-sky map (23 month)

0.7-1.7keV
1.7-4.0keV
4.0-7.0keV

Poster 38: Kimura
Poster 57: Tomida
ROSAT All-Sky Survey

1/4 keV
3/4 keV
1.5 keV
Galactic Center Region

<table>
<thead>
<tr>
<th>Date</th>
<th>Object</th>
<th>Date</th>
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<td>2010-10-17</td>
<td>MAXI J1409–619</td>
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<td>2011-05-08</td>
<td>MAXI J1543–564</td>
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Black hole candidates

New Activity, Spectral State Transition

ATEL#2711
Soft X-ray increase

ATEL#2380
Beginning of new activity

ATEL#2404, #2635
State transition

Cyg X-1

GX 339-4

Cyg X-3

2-4 keV

4-10 keV

10-20 keV

~ 1yr

State transition
Cyg X-1

Suzaku → Yamada’s talk
XTE J1752-223

- Black hole candidate discovered by the RXTE Galactic Center scanning observation
- continuous spectral monitoring by MAXI
Continuous spectral monitoring of XTE J1752-223

Two stable hard states: soe state; hot gas, cool disk

- 0.7 keV: decreasing disk temperature
- 2-4 keV: constant disk radius
- 4-10 keV: Suzaku
- 10-20 keV: Suzaku

Nakahira+ 2010, PASJ

Poster 58: Nakahira
MAXI J1659-152

- Discovered by MAXI and Swift
- Black hole suggested based on QPO (1.6 Hz, 3.3 Hz; RXTE)
- State transition

![Graphs showing data points and state transitions](image)

- "Stable"
- Intermediate (very high?)
- State

Suzaku

Poster 59: Negoro
MAXI J1659-152
Energy Spectra by Suzaku

Disk Blackbody

Non-thermal emission from corona and/or jets

 Rin ≈ 35km ➔

6.3 x (D/10kpc) x (cos θ/cos 60)^{-1/2} M☉
MAXI J1659-152 optical light curve

Vega Magnitude [mag]

Color [mag]

Time since the first detection [day]

T0 (MJD) = 55464.33686 [day]

Kuroda et al. 2011
• 2.4-hour periodicity
  – Double-peaked in optical, single dip in X-ray

Kuroda et al. 2011
MAXI J1409-619 confirmed and accurately localized by Swift

Kennea et al. 2010
MAXI J1409-619
turned to a 500s accreting pulsar

Yamaoka et al. in prep
GX 304–1
Accreting X-ray pulsar with a Be star companion

- Be binary pulsar ($P_{\text{orb}} = 132.5$ d)
- MAXI detection of outburst ➔

Discoveries:
- Discovery of cyclotron line by Suzaku/RXTE follow-up obs.
- 54 keV ➔ 4.7 x $10^{12}$ gauss

Poster 49: Yamamoto
**LS V +44 17**

Accreting X-ray pulsar with a Be star companion

- MAXI detection of first outburst from this source
- Followed up by Swift and RXTE

Usui et al. 2011
Low-Mass X-ray Binaries

- Aql X-1
- Cir X-1
- NGC 6640 X-2 (SAX J1748.9-2021)
- M15 X-2
- 4U 1608-22
- 4U 1323-619
- 4U 1954+319
- RX J1709.5-2639

- Monitoring activities of bursts and jets.

Beginning of new activity (ATEL#2742)

Aql X-1

Type-I bursts

4-10 keV

4.0 - 10.0 keV

~ 1yr
Active Stars

- 23 flares from 12 stars in 2 years

Uzawa et al. 2011
Active Stars (RS CVn, YSO, ...)

Stellar flares as major contribution to Galactic Ridge X-ray Emission?

Scalable from solar flares with constant magnetic field

Poster 46: Tsuboi

Poster 44: Matsuoka et al.
Active Galactic Nuclei

- Mrk 421
- 3C 273,
- Cen A,
- NGC 4151
- IC 4329A
- ...

- Monitoring
  - Large flare events
  - Long term variation

MAXI GSC lightcurve of Mrk 421

Cen A (J1325-430)

Isobe et al. 2010
Two Flares from Mrk421

Jan. 1, 2010  ~120 mCrab.
Feb. 16, 2010  ~164 mCrab.

MAGIC flare
VERITAS ATel #2443

MAXI
2 – 4 keV
(6 hour)

\[
\frac{F_{15-50 \text{ keV}}}{F_{2-4 \text{ keV}}}
\]

\[
\frac{F_{4-10 \text{ keV}}}{F_{2-4 \text{ keV}}}
\]

Isobe et al. 2010, PASJ
MAXI bursts

18 events in 23 months

* 7 are simultaneously detected by other satellites
GRB 090926B

- light curve
  - maxi detected the first 25 seconds of the burst
  - no significant emission above 350 keV
  - low flux below 4 keV

![Light curve of GRB 090926B observed with MAXI/GSC and Fermi/GBM. The light curves of GSC are corrected for the effective area. The change of the effective area is shown in the bottom panel. The vertical dashed lines indicate the borders of the time intervals for spectral analyses.](image)
Rayleigh-Jeans spectrum ($\alpha = 1$)

photospheric emission?

upper limit for a synchrotron spectrum ($\alpha = -2/3$)
Swift J164449.3+573451
Tidal disruption (?) at z=0.35

- High column density ($N_H=2 \times 10^{22} \text{ cm}^{-2}$)
- Featureless wide-band spectrum
- Highly variable
- 5mHz QPO

MAXI pre-outburst upper limit $< 1.1 \times 10^{-11} \text{ erg s}^{-1} \text{ cm}^{-2}$

Suzaku “unfolded” spectrum

Poster 92: Usui
Crab at GeV flare

- No significant variation in the pulse fraction during the gamma-flare in September 2011

Morii et al. 2011
Summary

• MAXI is detecting variable X-ray sources of all classes.
• MAXI provides continuous monitoring of light curves and spectra for outburst episodes.
• Follow-up and multiwavelength observations are tremendously valuable
• Unanticipated detections, new class of sources emerging
• Please support MAXI, so that it can continue beyond the “official” 2 year mission
• Raw data. Exposure not corrected.
• Not cleaned for background variation, sun-light leak, and solar-paddle reflection.