The First Light from MAXI onboard JEM (Kibo)-EF on ISS

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Abstract. MAXI, the first astronomical payload attached to ISS JEM-EF, began operation on August 3, 2009 for monitoring all-sky X-ray images every ISS orbit (92 min). This paper reports the first results obtained during the 1-month test observations. All instruments as well as two main X-ray slit cameras, the GSC and SSC, worked as we expected. The detection limits of MAXI-GSC are about 25 mCrab and 8 mCrab for one ISS orbit (92 min) and 1-day observations, respectively. GSC covers about 76% and 96% of the entire sky for respective single-orbit and 1-day observations. MAXI has detected a transient X-ray pulsar A0535+26, an X-ray burst, and a gamma-ray burst in the first month of the test observation period.

Keywords: MAXI, ASM, X-ray nova, GRB, Transient, ISS, JAM-EF, Kibo, Alert
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INTRODUCTION

Recently MAXI (Monitor of All-sky X-ray Image) has started to operate its cameras, which are capable of monitoring all-sky X-ray images. We are pleased that we can present the first light from MAXI onboard JEM (Kibo) - Exposed Facility (EF) on the ISS in a timely manner. The MAXI mission is the first astronomical payload attached to the Japanese Experiment Module - Exposed Facility (JEM-EF or Kibo-EF) on the International Space Station (ISS). MAXI was launched with Endeavour on July 16, 2009. The commission of MAXI started on August 3, 2009 when MAXI instruments were first switched on. We will tune various settings and observational modes of MAXI to target for steady observation from December, 2009. Meanwhile, two kinds of X-ray cameras, GSC and SSC (Matsuoka et al. 2009), have been used for test observations. At the first step of test observations all instruments of MAXI worked well and gave us normal data.

The GSC and SSC of MAXI have X-ray detectors consisting of gas proportional counters covering the energy range of 2 to 30 keV and X-ray CCDs covering the energy range of 0.5 to 12 keV, respectively. Both cameras scan all-sky X-ray images twice due to two different directional cameras every 92 minutes synchronized with the ISS orbit. The data are sent from the ISS to a ground station via data-relay satellites. The transient alert system on the ground rapidly reports X-ray novae or bursting events with 0.1 to 0.2 degree position accuracy to astronomers worldwide for further follow-up observations (Negoro et al. 2009). Furthermore, scans of each source are combined on the ground to detect weak sources including AGNs.

FUNDAMENTAL RESULTS OF MAXI INSTRUMENTS

After all the instruments were powered on to normal settings, we checked calibration data for twelve proportional counters. All data giving the pulse height distributions and positions of ^{55}Fe calibration sources were normal, little different from the pre-launch data. It was confirmed that a point spread function for a point source was also normal using an image of Crab Nebula. A check of the energy spectrum and sensitivity was made using the observational data of the Crab Nebula. The spectrum of the Crab Nebula is consistent with a well-known spectrum giving a power law index of 2.1 and a little absorption column density although further calibration of low-energy efficiency is required. The sensitivity with MAXI-GSC was estimated from the observational data of the Crab Nebula. The estimation suggests that MAXI-GSC is capable of detecting 25 mCrab for one orbit and 8 mCrab for 1-day in the 5-sigma level. These sensitivities are a little worse than the simulated ones, because the background particle flux is unexpectedly stronger in the ISS environment.

MAXI has the radiation belt monitors, i.e. two sets of pin-diode type solid-state detectors sensitive to particles such as precipitation electrons and protons from radiation belts. The particle radiation around SAA was as usual, as we learned from the low orbit X-ray satellites, Ginga, ASCA and Suzaku. However, precipitation electrons increased according to pitch angle distribution at high latitude regions beyond ± 40 degrees. On the other hand the proportional counters of MAXI-GSC detected a strong background 30 – 50 times to 200 times as high as the background anticipated from the previous data of low earth orbit small ($<$1 ton) satellites. We understand that a background of 200 times (sometimes 1000 times) in a high latitude region comes from precipitation electrons around an auroral region, while the background is stronger by 30 – 50 times for normal satellites even in the equatorial region. We suppose that the latter background comes from the secondary cosmic-rays produced at the massive ($\sim$400 tons) structure of the ISS by primary cosmic-rays. Even if the particle background is high, the present proportional counter system can reduce non-X-ray background to 1.5 – 5 times that of the Ginga LAC (Turner et al. 1989) with our excellent veto-system.

The SSC of MAXI uses 16 CCDs for horizontal and azimuthal directions respectively (Matsuoka et al. 2009). All CCDs were tentatively cooled down to –60 °C, and test

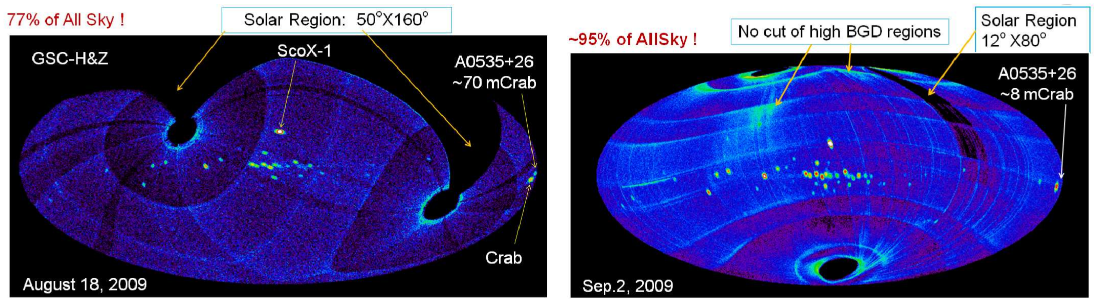

FIGURE 1. The all-sky X-ray images (raw data) on the galactic coordinate, obtained for one orbit on August 18, 2009 (left) , and for 1-day on September 2, 2009 (right). The two circular dark regions correspond to unobservable regions around both directions of the ISS pitch axis. Unobservable solar region is also indicated. Since non-X-ray background is not removed, some bright sky regions are false due to the background originated from strong precipitated particles.

observations were made from the middle of August, 2009. Each energy resolution for CCDs was checked using ^{55}Fe calibration sources and the Cu K-lines, which is produced as fluorescent lines from a slat collimator made of phosphide bronze plate. Distribution for all CCDs showed an energy resolution of about 147 eV for Mn Kα line without correction of pixel data. The SSC is very sensitive to visible light even though the CCDs are covered with an Al optical blocking filter. In the first test observation during daytime on the ISS, all CCDs were noisy by stray solar light. Therefore, we first performed all-sky test observations during the night time. We have confirmed that the SSC detected many X-ray sources in the Galactic center region, and the Crab Nebula. Currently we are adjusting levels and modes to be capable of making day-time observation.

HOW DOES MAXI OBSERVE THE ENTIRE SKY?

As we mentioned in the introduction MAXI has two sets of slit cameras: horizontal and azimuthal. In accordance with one ISS orbit, each set scans the sky with a field of view (FOV) of 160 degrees, but both cameras cannot scan around the solar region, and some directions to be scanned while high voltage is made to shutdown due to the high radian zone. However, the latter regions are compensated considerably by an alternate directional camera. If the region of high voltage reduction is limited to the SAA only, MAXI-GSC can scan 96% of the sky, where it cannot observe two polar regions of 10 degrees and a solar region of ± 5 degrees (adjustable). At the time of test observations we examined how we could reduce the solar region without damage. We have discovered that there is no problem until it reaches the sun avoid angle of ± 4 degrees. We can scan 96% of the sky on every orbit except for the final ± 4 degrees of the avoided angles. This means that no ASM has ever scanned such a wide swath of sky so deeply in such a short time, while it is noted that MAXI usually observes a source for only 45 seconds or 90 seconds on every orbit. Figure 1 shows two samples of all-sky images obtained in one ISS orbit (92 min) and 1-day observations, respectively.

MAXI has a nova alert system to utilize the characteristics of the GSC. MAXI is monitoring each single orbit map, 4-orbit integrated map, 1-day map, and so on in

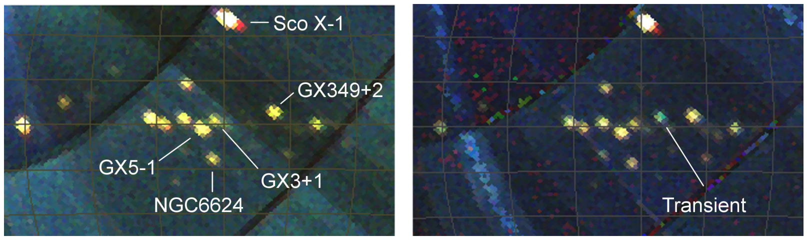

FIGURE 2. Type-I X-ray burst from 4U1724-307 (right panel) was discovered with MAXI-GSC at 18:37(UT) on August 20, 2009 as indicated as the transient. X-rays from 4U1724-307 before and after this orbit were very weak or less than 10 mCrab. The image accumulated for 4 orbits before the burst is shown on the left panel.

real time as long as communication is available (Negoro et al. 2009). New objects or suddenly brightened objects are monitored by comparing the present image with previous images. Once a new object or suddenly brightened object is discovered, the nova alert system will work to issue the alert with time, location, and intensity to astronomers worldwide.

Although data communication on the ISS is relayed by DRTS, about half of the data are downloaded in real time, and the remaining half are downloaded after a nominal one-hour delay through the memory on the ISS. Furthermore, although we tried to switch on even during strong precipitated electrons in the first test phase, at present all high voltages are reduced in a high latitude because the background is too high.

SOME TOPICS OF MAXI PRELIMINARY OBSERVATIONS

Type I X-ray burst from 4U1724-307 in Terzan 2

The duty scientist who was staying up all night, watching the alert system in the test phase, discovered a bursting object near the Galactic center. Since MAXI was still in commission phase, the MAXI team members checked carefully whether this event was a burst or nova. First, they analyzed the location of this new source. Then, they found that the location is consistent with 4U1724-307 within an uncertainty of 1 degree. This event appeared in just single scan orbit as shown in Figure 2. 4U1724-307 is well-known as an X-ray burster. Thus, we decided this event was a typical Type-I X-ray burst.

Detection of GRB090831A

Another bursting object was discovered clearly in the Ursa Major region. This burst was detected fortunately in the FOV of the GSC. Since the intensity of this burst was as strong as 30 Crab unit, we could find this burst-up immediately. We checked the map before this was detected. There was no source above 0.1 Crab. At that time, MAXI was operating just after the space shuttle, Discovery, was attached to the ISS and the ISS had turned by 180 degrees half a day earlier. We carefully examined what may or

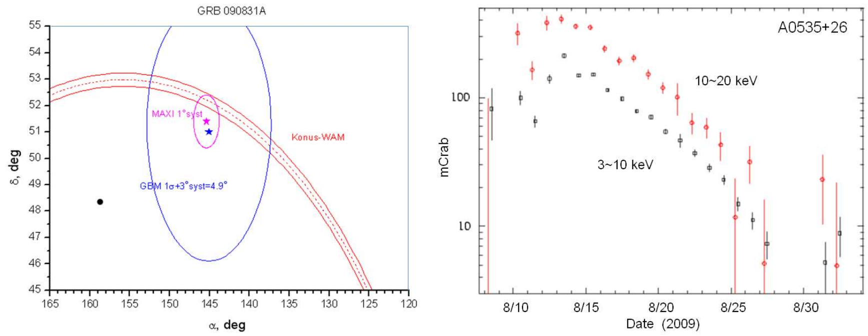

FIGURE 3. (left) GRB090831A location obtained from MAXI, Fermi, Suzaku-WAN, Konus, and INTEGRAL (GCN Circular No.9864). (right) X-ray light curves of A0535+26, an X-ray transient pulsar.

may not have happened in these special maneuvers. We are convinced that this event was not connected with any ISS or instrumental events. Thus, we analyzed the location and intensity according to the time sequence. A double check and triple check were performed even though the soft-ware and data communication were still in the test phase. More than 10 hours passed after discovery. Meanwhile, Fermi team reported the location of new GRB090831A which was consistent with that of MAXI. Thus we have confirmed GRB090831A(GCN 9852). The location of this burst is shown in Figure 3 with other Satellites (GCN 9864). GRB090831A has very hard spectrum and very short time peak. Surprisingly this GRB was detected accidentally just in the narrow field of view of MAXI-GSC, 3×160 degrees. A detection probability with MAXI-GSC is estimated to be a few times per year.

Observation of a recurrent X-ray pulsar, A0535+26

When GSC started to switch on high voltages one by one, a recurrent X-ray pulsar, A0535+26, was already in increasing phase as shown in Figure 3. After this source achieved a peak intensity of 400 mCrab in the energy band of 2-30 keV on August 14, the source decreased gradually up to an upper limit around 7-8 mCrab for 1-day to the end of August, 2009.

Observations of AGN, Cen A and Cen cluster of galaxies

Preliminary analysis gave significant intensities from the Cen A and Centaurus cluster of galaxies. Both sources are seen significantly in wide and narrow FOV of the 1-day observation as shown in Figure 4. The intensity in the energy band of 2-20 keV was about 20 mCrab for Cen A. This is stronger than that of the 5-sigma detectability of the 1-day observation. Thus we have confirmed being able to monitor some of AGN in a 1-day observation.

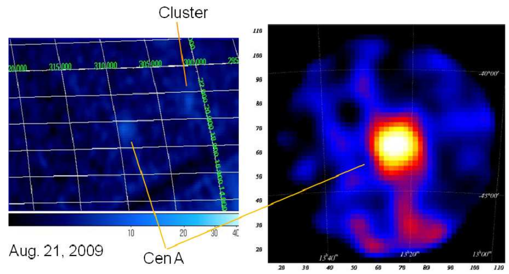

FIGURE 4. Cen A image observed by MAXI-GSC on August 21, 2009, with intensity of $\sim$ 20 mCrab.

SUMMARY AND FUTURE PROSPECT

MAXI on ISS JEM-EF worked excellently in the first test phase during August, 2009. We have learned of the high background situation on the ISS. Since we had believed that MAXI proportional counters could stand strong irradiation and worked well with veto-detection, we performed various tests even in high latitude, the precipitation electron regions. Unfortunately two proportional counters met trouble due to a malfunction of anode wires. Therefore, currently all high voltages are reduced in the high background region over ± 40 degrees of latitude. Nevertheless , the main function of the all-sky monitor is maintained for sending rapid nova and burst results from MAXI to astronomers worldwide. The MAXI nova-alert system (Negoro et al. 2009) is going to work and light curves and some spectra of considerable X-ray sources are also going to be public. Combined data for individual sources will be edited for variable catalogues in future. This is the first report of MAXI results obtained in 1-month test observations. Please access the MAXI web-site, `http://maxi.riken.jp/` for further information.

ACKNOWLEDGMENTS

M. Matsuoka would like to express his deepest gratitude to SOC and LOC for inviting him in commemoration of 70th birthday of Prof. Giorgio Palumbo. MM wishes personally to express congratulations to Prof. Giorgio Palumbo on his 70th birthday. We are reminded of the Japanese legend, which originated with the Chinese poet, Toho, that gives a person of 70 years a special celebration. Toho's poem suggests that a person who is able to live up to 70 years old was very rare historically in 8th century. Therefore, a 70-year-old person should be celebrated. This is a traditional Japanese custom. However, since a person to living to 70 is not rare nowadays, Giorgio can, of course, enjoy a new advanced life past 70. Thus Giorgio will give us useful advice with his activity. Please take care of your health, so you may enjoy your life to come.

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