MAXI Catalog and Extragalactic Survey

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Abstract

We summarize the prospects for extragalactic survey with the MAXI mission and expected properties of the MAXI source catalog, on the basis of realistic estimate of the sensitivity by extensive simulation studies. Using the MAXI simulator, we develop a program of source detection of faint sources from MAXI/GSC data, in which maximum likelihood fit is performed to a projected image by taking into account the image response and background. We find that the 5σ sensitivities are approximately 20–25 mCrab, 4–5 mCrab, and 1.7 mCrab for the 1-orbit, 1-day, and 1-week operation, respectively, assuming a nominal background rate. The MAXI source catalog will eventually contain more than 1,300 Active Galactic Nuclei (AGNs) at the confusion limit from extragalactic sky at Galactic latitudes higher than 15 degree.

Key words: catalogs — galaxies:active — X-rays:galaxies — X-rays:general

1. INTRODUCTION

One of the main goals of the MAXI mission is to provide a new X-ray catalog from the entire sky, including both transient and persistent sources. The Gas Slit Cameras (GSCs; Mihara et al. 2009) and the Solid-state Slit Cameras (SSCs; Tomida et al. 2009) cover the energy band of 2–30 keV and 0.5–12 keV, respectively, with unprecedented sensitivities as an all-sky mission. In particular, the large effective area of the GSCs at energy above 2 keV enables us to detect absorbed Active Galactic Nuclei (AGNs) that were missed in the *ROSAT* All Sky Survey, and thus provides a unique database of extragalactic populations.

In this paper, we quantitatively evaluate the sensitivity and position accuracy of the MAXI GSCs, which are the most fundamental properties of the source catalog. Here we extensively utilize the MAXI simulator developed by Eguchi et al. (2009).

2. ANALYSIS METHOD

To extract the best sensitivities from the data, we have developed an analysis method by employing image fitting with the maximum likelihood algorithm. Firstly, we project the positions in RA and DEC of photon events in the vicinity of a target in the "sky coordinates", as in the case of an image analysis of pointing satellite's data. To derive the flux, position and their errors, we perform 2-dimensional fitting to this simulated image by a model consisting of the point spread function (PSF) and background (the non X-ray background (NXB) and the cosmic X-ray background).

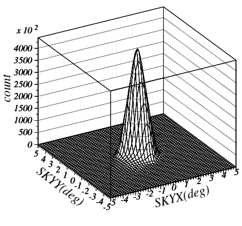

Fig 1: An example of the PSF integrated for the 1-week observation.

- Software
  - maxisim ver.7.1.1 (simulation)
  - dis45 ver.2.04 (image analysis)
- Source Spectrum
  - Crab-like (a power law of $\Gamma = 2.1$)
- Non-X-ray Background Rate
  - 10 counts sec^{-1} $\mathrm{counter}^{-1}$
- Energy Band Used in the Analysis
  - 2–30 keV
- Exposure (Operation Time)
  - 1 week, 1 day, or 1 orbit (= 90 min)

One complexity in the analysis of MAXI data is that the PSF and background are position dependent, being determined by the orbit and attitude condition. To take this into account, we also utilize the MAXI simulator to construct the PSF and background models with a sufficiently larger number of photons to suppress the statistical fluctuation. An example of the PSF model integrated for the 1-week observation is displayed in Figure 1.

In the fitting, the normalization of the PSF (i.e., flux) and background level are set to free parameters, as well as its position. Here we assume that the shape of the PSF does not significantly differ in the region of interest, and ignore its position dependence for simplicity.

We define the detection significance (σ_D) as

$$\sigma_D = \text{(best-fit flux) / (its } 1\sigma \text{ statistical error)}$$

and set $\sigma_D \geq 5$ as the criteria for secure detection (i.e., relative $\leq 20\%$ error in the obtained flux). To evaluate the position accuracy, we make the error contour at 90% confidence level, or more simply, calculate the root sum square of the position errors in the two (x and y) directions.

3. RESULTS

3.1. Sensitivity

The results are plotted in Figure 2, which are obtained by assuming a nominal NXB rate (10 counts/sec/counter at the cut-off rigidity of 8 GeV/c). The 5σ sensitivities from the 1-week, 1-day, and 1-orbit observation are found to be $\sim$2 mCrab, 4–5 mCrab, and 20–25 mCrab, respectively, where the unit "mCrab" is defined as the flux of the Crab nebula in the 2–10 keV band, $\sim 2 \times 10^{-11}$ ergs cm^{-2} sec^{-1}. These sensitivities are approximately five times better than that of the all sky monitor on *RXTE*, although this result is based on ideal conditions. We confirm that the observing condition of this target in terms of effective exposure (i.e., exposure multiplied by the slit area) is close to the average over the entire sky. Hence, these results can be regarded as typical performance of MAXI.

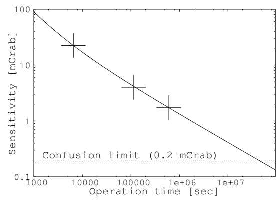

Fig 2: Sensitivity curve as a function of integration time. The three points correspond to the sensitivities of 1-orbit, 1-day, 1-week observations, from left to right, obtained from our simulations.

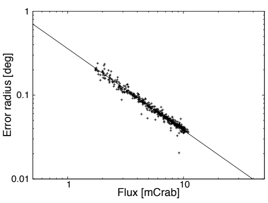

Fig 3: A correlation between the flux and error radius (combined from the two directions). The solid curve represents the best-fit power law.

3.2. Position Accuracy

Figure 3 displays the relation between the flux F and the error radius (combined from the two directions). We find that a typical error radius for targets with fluxes close to the 5σ sensitivity limit is approximately 0.2 degree, regardless of exposure time. We also find that the positional error is roughly proportional to $F^{-0.7\sim-1.0}$, steeper than a naive prediction of $F^{-0.5}$. We infer that this is due to coupling between the position and flux determination in the fitting process.

3.3. Sensitivity Dependence on Non X-ray Background

Based on the above simulations and theoretical formula, we examine the dependence of sensitivities on the NXB rate. Figure 4 displays the expected sensitivities as a function of a NXB rate for the case of 1-orbit, 1-day, and 1-week observation (from top to bottom). It is seen that the sensitivity for a 1-week observation is inversely proportional to the square root of the NXB rate because background events are dominant over those from the source. The slope of the sensitivity curve for a 1-orbit observation is flatter than the 1-week case, because the detection significance is mainly determined by the photon counts from the source in this short exposure.

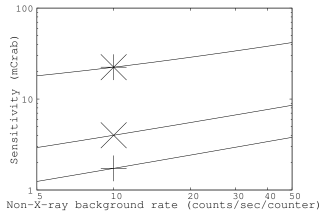

Fig 4: Expected sensitivities as a function of a NXB rate for the cases of 1-orbit, 1-day, and 1-week observation (from top to bottom). The three points correspond to the results obtained from our simulations.

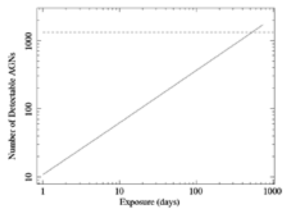

Fig 5: The total number of extragalactic AGNs detected with MAXI given as a function of the operation time. Dashed line corresponds to the source confusion limit.

4. SUMMARY

Figure 5 displays the total number of extragalactic AGNs detected with MAXI as a function of the operation time. We estimate that the sensitivity reaches the confusion limit ($\sim$0.2 mCrab) from approximately 1.5 years operation of MAXI. According to the population synthesis model of Ueda et al. (2003), at this flux level, approximately 1,300 AGNs are expected to be detected at Galactic latitudes larger than 15 degree. The number of detected AGNs in the MAXI survey is larger than that in any other all-sky survey covering the energy band above 2 keV. The MAXI catalog will contain many new transient and/or absorbed AGNs, and hence become a unique database of extragalactic populations complementary to other catalogs of all-sky missions performed by *ROSAT*, *Swift*/BAT, or *INTEGRAL*.

References

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