

Extragalactic Survey with MAXI and the First MAXI/GSC Catalog

Y. Ueda¹, K. Hiroi¹, N. Isobe¹, M. Hayashida¹, and the MAXI team

¹ Department of Astronomy, Kyoto University,
Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan
E-mail(YU): ueda@kusastro.kyoto-u.ac.jp

ABSTRACT

We report the properties of X-ray sources in the first *MAXI* extragalactic catalog by Hiroi et al. (2011, this conference). The Gas Slit Camera (GSC) data in the 4–10 keV band integrated for the first 7 months since 2008 September are utilized to unbiasedly detect sources at Galactic latitudes higher than 10 degrees. The results of cross identification with existing catalogs are presented for the total 140 *MAXI* sources detected with significances above 7σ . The $\log N - \log S$ relation is in good agreement with the *HEAO1* A-2 result (Piccinotti et al. 1982), although the list of the brightest AGNs in all sky has been dramatically changed since 30 years ago.

KEY WORDS: catalogs — X-rays: galaxies — galaxies: active

1. Introduction

Investigation of X-ray populations in the local universe is a fundamental issue in X-ray astronomy, which is critical to elucidate the cosmological evolution of Active Galactic Nuclei (AGNs) and clusters of galaxies. The *MAXI* mission achieves the best sensitivity in the 2–10 keV band as an all sky survey after *HEAO1* and *RXTE* slew survey, and thus is able to contribute to bridge the “flux gap” between previous all-sky missions and more sensitive observations like those by *ASCA*, *XMM-Newton*, and *Chandra*. The *MAXI* survey is particularly useful to detect moderately absorbed AGNs with intrinsically soft spectra, and is complementary to the *ROSAT* all sky survey (below 2 keV) and hard X-ray (>10 keV) surveys by *Swift* and *INTEGRAL*. *MAXI* also provides us with a unique opportunity to detect highly variable objects including “transient” AGNs.

Here we report the first results of the *MAXI*/GSC catalog at high Galactic latitudes ($|b| > 10^\circ$). We utilize the first 7 months data of 8 cameras taken between 2009 September and 2010 March, when they were all operated with a high voltage of 1650 V. The energy band used in the analysis is limited to 4–10 keV, which is best calibrated at present. The details of the source detection technique and basic properties of the catalog are presented in Hiroi et al. (2011).

2. Revised Estimate of MAXI Sensitivity

Figure 1 plots the most updated estimate of the survey sensitivity of *MAXI*/GSC in the 2–10 keV band as a function of operation time, based on the analysis of

the onboard data including the actual count rate of the non X-ray background. Comparing with the ideal observing conditions from which our pre-launch estimate was calculated by Hiroi et al. (2009), the averaged observation efficiency is decreased to 40% due to the high-voltage turn-off at high latitudes during each orbit and the reduction of the number of available cameras from twelve to eight. We find that expected 5σ sensitivities in the 2–10 keV band are ≈ 1.3 mCrab, ≈ 0.5 mCrab, and ≈ 0.2 mCrab from 1 month, 7 months, and 3 years operation, respectively. The confusion limit at 1 source per 10 beams corresponds to ~ 0.2 mCrab.

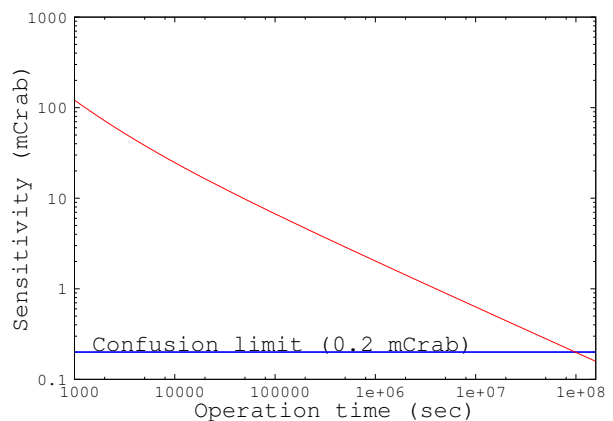


Fig. 1. The revised figure of *MAXI*/GSC sensitivity in the 2–10 keV band versus actual operation time (observing efficiency of 40% is assumed).

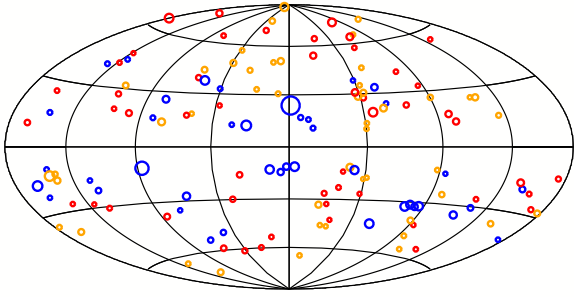


Fig. 2. Location of identified *MAXI* sources with $\sigma_D \geq 7$ in the Galactic coordinates. The radius is proportional to logarithm of the flux. Blue, yellow, and red circles correspond to Galactic, clusters of galaxies, and AGNs, respectively.

3. Cross Correlation with Other Catalogs

As a step of source identification, we cross-correlate the *MAXI* sources with the *Swift*/BAT 58-months catalog (Baumgartner et al. 2011), *Fermi*/LAT AGN catalog (Abdo et al. 2010), and *ROSAT* All Sky Survey Bright Source Catalog (Voges et al. 1999; only 2200 brightest sources in the 0.5–2 keV band are considered). We calculate the position error as

$$\sigma_{\text{posi}} = \sqrt{\sigma_{\text{stat}}^2 + \sigma_{\text{sys}}^2},$$

where $\sigma_{\text{sys}} = 0.05$ degree is the systematic error and σ_{stat} is the statistical error, which is roughly proportional to the inverse of detection significance (σ_D). Typically, $\sigma_{\text{posi}} \sim 0.2$ degree at $\sigma_D = 7$. We then search for possible counterpart(s) in each catalog within a distance of $3\sigma_{\text{posi}}$ from the *MAXI* position. The results for *MAXI* sources with $\sigma_D \geq 7$ are summarized in Table 1. Based on this result and further inspection by referring to other catalogs in the literature, we finally identify 41 Galactic (plus Magellanic) objects, 47 clusters of galaxies, and 51 AGNs including 11 blazars, out of the total 140 sources.

Table 1. The results of cross correlation with other X-ray/gamma-ray catalogs.

<i>MAXI</i> /GSC ($\sigma_D \geq 7$)	140
<i>Swift</i> /BAT 58-months	93
<i>Fermi</i> /LAT AGN (1LAT)	12
RASS BSC (1RXS)	109

4. $\log N - \log S$ Relation

Source number counts ($\log N - \log S$ relation) are the most basic result derived from an unbiased survey. We calculate the survey area of the total 7-months GSC data used for our catalog as a function of limiting flux. For

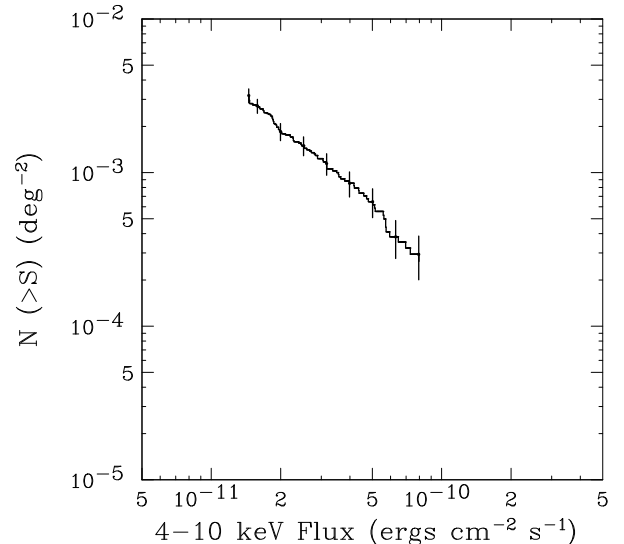


Fig. 3. The $\log N - \log S$ relation obtained from the 7-months *MAXI* extragalactic survey. Galactic objects are excluded.

this procedure, we estimate sensitivities at each sky position from the background photon counts and the product of effective detector area \times exposure. The background is modelled as a function of time for each camera based on extensive calibration of the onboard data, which is found to well reproduce the observed sky image. We confirm that the achieved 5σ (7σ) sensitivity is ≈ 0.8 mCrab (≈ 1.1 mCrab) in the 4–10 keV band, which is consistent with the expectation (see Figure 1 for that in the 2–10 keV band).

Dividing the flux distribution of the detected sources by the survey area gives $\log N - \log S$ relation in the differential form. Figure 2 shows that in the integral form for the $\sigma_D \geq 7$ sources, where the source number density $N(> S)$ above flux S is plotted. Here we exclude Galactic objects. Our results are in an excellent agreement with the *HEAO1* A-2 result by Piccinotti et al. (1982). However, about half AGNs in the Piccinotti et al. catalog are not detected above 7σ in our *MAXI* survey, indicating that the list of brightest AGNs in the sky has dramatically changed since ~ 30 years ago.

References

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