New Magnetar Frontiers with MAXI Survey

Nakagawa Yujin E.,[1] Yoshida Atsumasa,[2] Yamaoka Kazutaka[2]

[1] Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[2] Graduate School of Science and Engineering, Aoyama Gakuin University, 5-10-1 Fuchinobe, Sagamihara, Kanagawa 229-8558, Japan
E-mail(YEN): yujin@crab.riken.jp

Abstract

Feasibility studies of searching new magnetar candidates by the GSC on-board MAXI are presented. The GSC/MAXI can marginally detect a faint $\sim 1\,$mCrab source with only 7 days time integrated observations. Furthermore, the faint $\sim 1\,$mCrab source is clearly detected by observations with a 30 days exposure time. A survey of the galactic plane ($|b| \leq 5$) by the GSC/MAXI may find numerous new magnetar candidates and may reveal new frontiers of magnetar studies.

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1. Introduction

There has been great discussion about magnetars which may be neutron stars with a super strong magnetic fields $\sim 10^{15}\,$G (Duncan & Thompson 1992; Paczyński 1992; Thompson & Duncan 1995; Thompson & Duncan 1996). Several studies have found 12 X-ray magnetar candidates in the galactic plane as well as 2 candidates in the Large Magellanic Cloud or the Small Magnllanic Cloud (e.g., Woods & Thompson 2006; Barthelmy et al. 2008). There are two apparent types in the magnetar candidates that is soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs).

Over the past three decades, the candidates were observed by many satellites. However, some important issues such as a birth rate, a nature of a super strong magnetic field and an emission mechanism still remain unclear. What seems lacking is statistical spectral and temporal studies. Muno et al. (2008) reported that a birth rate of the X-ray candidates could range between 0.003 and 0.06 yr^{-1} based on the XMM-Newton and *Chandra* archive data for the galactic plane ($|b| \leq 5$). Let us look at an important fact, namely that their suvey region covers just $\sim$4% of the galactic plane. Thus a survey of entire region of the galactic plane should be the first prioritized issue.

The main objective of our study is to survey the new X-ray mangetar candidates and to give their accurate birst rate using the Gas Slit Camera (GSC) onboard Monitor of All-sky X-ray Image (MAXI) which has the best sensitivity in near future. Considering an unabsorbed flux of known candidates lies around $F \sim 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ (e.g., Nakagawa et al. 2009), the GSC/MAXI may survey the most sky with just 7 days observation. In this paper, we present simulation results of the GSC/MAXI for the X-ray magnetar candidates.

2. Feasibility Study with GSC/MAXI Simulation

2.1. Simulation Setup

The simulations of the GSC/MAXI were made using *maxisim* (6.3.103). In the simulations, cosmic X-ray background (CXB) and non X-ray background (NXB) should be considered. The spectrum of CXB was assumed to be $F(E) = 4.93 \times 10^{-3} E^{-1.29} e^{-E/40.0}$ (Boldt 1987), where E is a photon energy. The count rate of NXB was assumed to be 10 $\mathrm{counts\,s^{-1}}$.

The simulations were performed with all 12 cameras of the GSC/MAXI for the time period from 54103 to 54433 (MJD). The field of view was assumed to be $(\phi, \theta) = (42.0^\circ, 1.6^\circ)$, where ϕ and θ are incident angles in a detector coordinate frame. To protect the GSC/MAXI from the solar heat, its incident angle was restricted to be $(\phi, \theta) > (70^\circ, 30^\circ)$.

To investigate feasibility of searching the new X-ray magnetar candidates with the GSC/MAXI, the simulations were performed for sources with two brightness $\sim$1 mCrab and $\sim$3 mCrab. A two blackbody function was used as the spectral model. The spectral parameteres of SGR 1806$-$20 ($\sim$1 mCrab) and AXP 4U 0142+614 ($\sim$3 mCrab) were used in the simulations. The spectral parameters are summarized in table 1 (Nakagawa et al. 2009). Here, the non-thermal hard component ($> 20\,$keV) discovered by INTEGRAL (Molkov et al. 2005; Götz et al. 2006; Kuiper et al. 2006) was not considered in these simulations. The reductions of the simulated GSC/MAXI event data were made using HEAsoft 6.5 software. The foreground and background

Table 1. The spectral parameters for SGR 1806−20 and AXP 4U 0142+614 which were used in the simulations (Nakagawa et al. 2009).

Source	$N_{\rm H}^{\rm a}$ ($10^{22}\,{\rm cm}^{-2}$)	$kT_{\rm LT}^{\rm b}$ (keV)	$R_{\rm LT}^{\rm c}$ (km)	$kT_{\rm HT}^{\rm b}$ (keV)	$R_{\rm HT}^{\rm c}$ (km)	$F^{\rm d}$
SGR 1806−20	5.18	0.84	1.64	2.62	0.28	2.5
AXP 4U 0142+614	0.53	0.36	9.38	0.82	0.89	5.7

a. $N_{\rm H}$ denotes the column density.
b. $kT_{\rm LT}$ and $kT_{\rm HT}$ denote the blackbody temperatures.
c. $R_{\rm LT}$ and $R_{\rm HT}$ denote the emission radii.
d. F denotes a flux in the energy range 2-10 keV in units of $10^{-11}\,{\rm erg\,cm^{-2}\,s^{-1}}$.

regions were determined by eye. The foreground data was extracted around the sources with a circular shape of a 2° radius. The background data was extracted around the sources with an annulus shape where the inner and outer radii were 2° and 8°, respectively. The center of the foregound and backgroud regions was aligned to the center of the sources.

2.2. Simulation Results

To investigate source detectability of the GSC/MAXI, the images with 7, 30 and 330 days time integrations were created from the simulation data for SGR 1806−20 (the *top* panels in figure 1) and AXP 4U 0142+614 (the *bottom* panels figure 1). The sources were marginally detected with only 7 days time integration. In addition, the sources were clearly detected with the 30 and 330 days time integrations.

Figure 2 shows the simulated light curves with a 1 day time resolution during a period from 54103 to 54433 (MJD) for SGR 1806−20 (*top*) and AXP 4U 0142+614 (*bottom*). Although one can see the apparent temporal variations of a count rate, they are due to variations with time of effective area. Furthermore, the apparent high count rate of SGR 1806−20 relative to AXP 4U 0142+614 was due to a difference of incident angles to the GSC/MAXI.

The simulated spectra in 2-30 keV for SGR 1806−20 and AXP 4U 0142+614 are presented in figures 3 and 4, respectively.

3. Conclusions

The GSC/MAXI has a great sensitivity to detect new magnetar candidates in the unsurveyed galactic plane ($|b| \leq 5$). The $\sim$ 1 mCrab source was marginally detected with just 7 days time integration in the simulations. Considering that the survey region of the XMM-Newton and *Chandra* covers just $\sim$ 4% of the galactic plane ($|b| \leq 5$; Muno et al. 2008), a survey by the GSC/MAXI may find numerous new magnetar candidates and may reveal new frontiers of magnetar studies.

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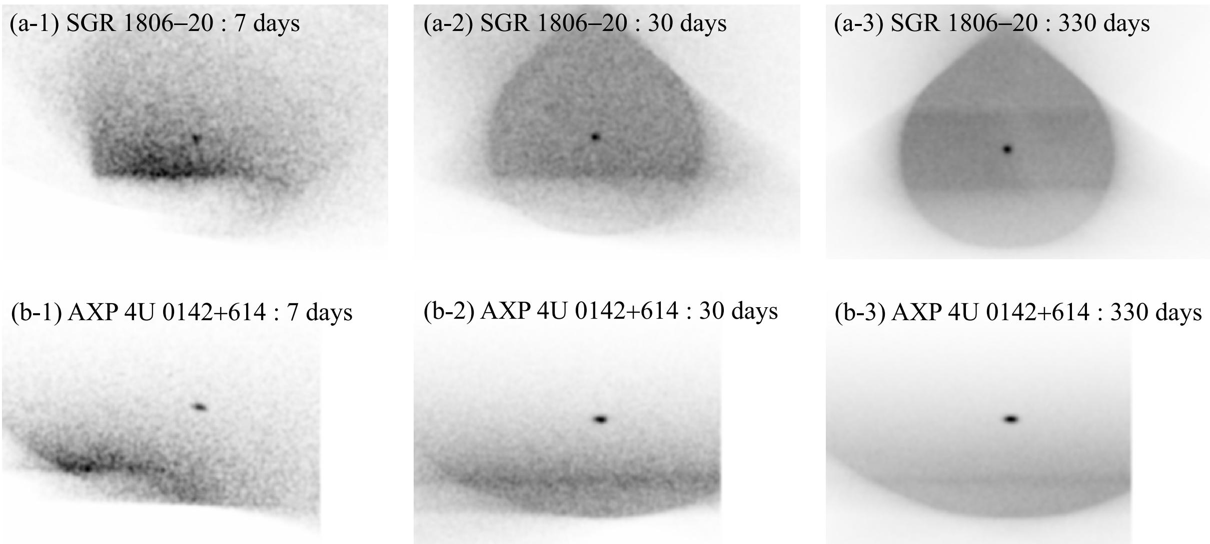

Fig. 1. The simulated images for three exposure times 7, 30 and 330 days for SGR 1806−20 (*top*) and AXP 4U 0142+614 (*bottom*).

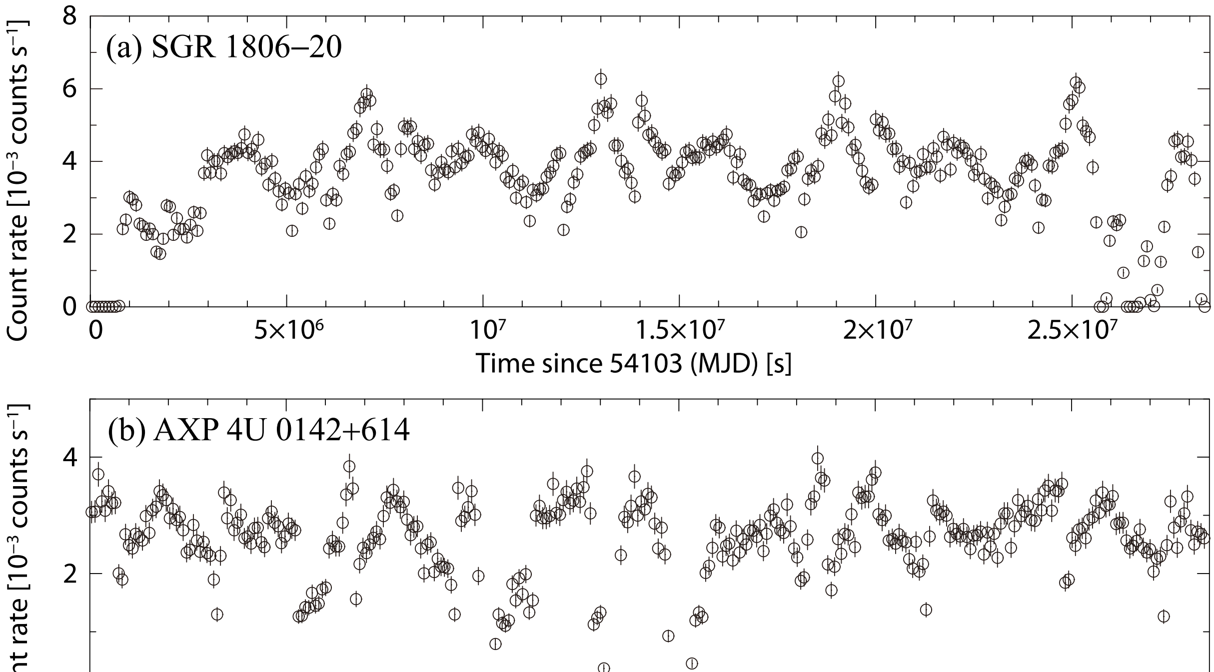

Fig. 2. The simulated 1 day light curves during a period from 54103 to 54433 (MJD) for SGR 1806−20 (a) and AXP 4U 0142+614 (b). The apparent temporal variations of a count rate are due to variations with time of effective area. In addition, the apparent high count rate of the SGR 1806−20 light curve relative to the AXP 4U 0142+614 light curve was due to a difference of incident angles to the GSC/MAXI. Note that the background was not subtracted from the count rate.

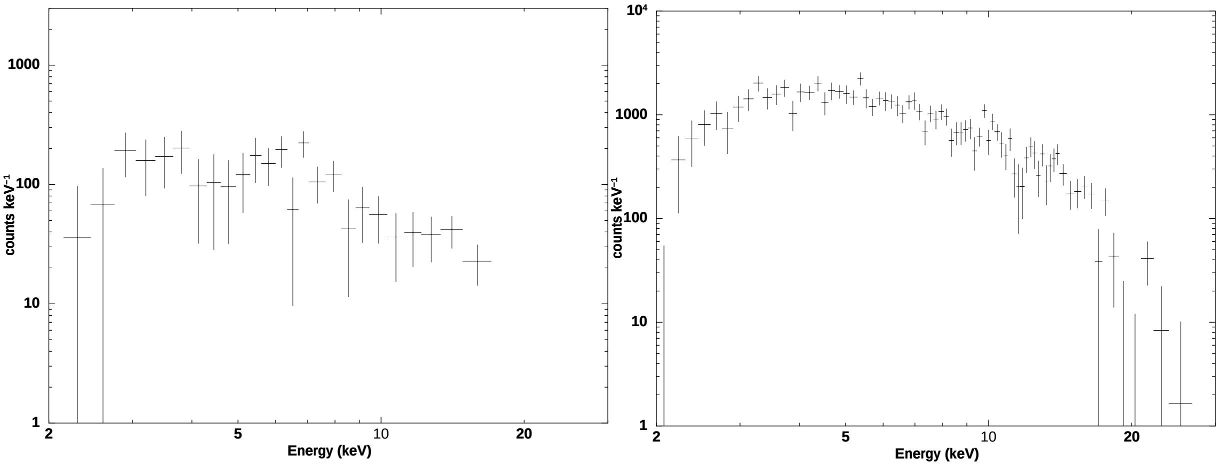

Fig. 3. The simulated spectra in 2-30 keV accumulated data over 30 (*left*) and 330 (*right*) days for SGR 1806−20.

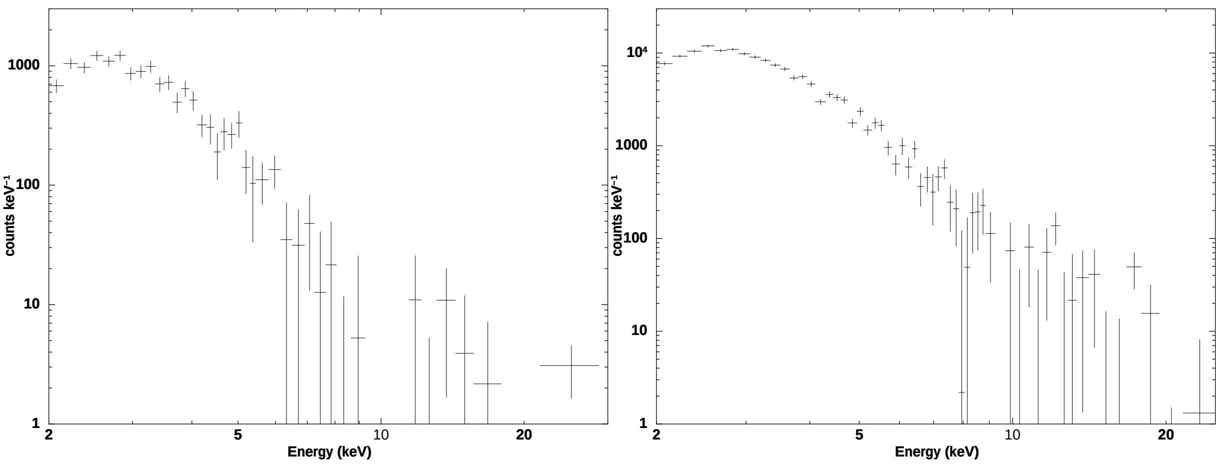

Fig. 4. The simulated spectra in 2-30 keV accumulated data over 30 (*left*) and 330 (*right*) days for AXP 4U 0142+614.