High-mass X-ray Binaries: Illuminating the Passage from Massive Binaries to Merging Compact Objects
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MAXI observations of long-term X-ray activities in SFXTs

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Abstract. Supergiant Fast X-ray Transients (SFXTs) are of great interest not only because of their peculiar properties but also as possible progenitors of gravitational-wave objects. The all-sky X-ray monitor MAXI/GSC has detected short flares on timescales of hours and long flares on timescales of days from SFXTs. Using nine-years of MAXI/GSC data, I attempted to search periodicity of eight SFXTs of which the one-day average fluxes were below the detection limit (~ 10 mCrab), and confirmed the orbital periods of IGR J18483−0311 and IGR J17544−2619. This demonstrates that MAXI data are useful to find periodicities of sources even if the sources are undetectable in one day.

Keywords. X-rays: binaries, stars: early-type, neutron

1. Introduction

Monitor of All-sky X-ray Image (MAXI, Matsuoka *et al.* 2009) on the International Space Station has been observing all the X-ray sky since August 2009. Recently, MAXI plays a more important role to find an electromagnetic counterpart of a binary neutron star merger, i.e., gravitational wave (GW) objects (Kawai *et al.* 2017 for GW 150914, Serino *et al.* 2016 for GW 151226, and Sugita *et al.* 2018 for GW 170817). MAXI will be operated at least until March, 2021.

Studies of the current number of high mass X-ray binaries (HMXBs) and the binary parameters, e.g., binary separation and eccentricity, must also be important to understand the binary evolution of the HMXBs to GW objects (e.g., Tauris & van den Heuvel 2006). Thus, such studies for a relatively recently discovered subgroup of HMXBs, Supergiant Fast X-ray Transients (SFXTs, e.g., Sguera *et al.* 2005, Negueruela *et al.* 2006, Walter *et al.* 2015, and also see Martínez-Núñez *et al.* 2017), are important to cover various binary parameter spaces of HMXBs. Here, the MAXI/GSC results of the detection of the sources and their orbital periods are presented.

2. Short Flares

Due to the limited spatial resolution (~ 1 deg) of MAXI/GSC (Mihara *et al.* 2011; Sugizaki *et al.* 2011), about half of SFXTs can not be resolved (Sakamaki & Negoro 2017, hereafter SN17). It is also difficult to observe short and hard X-ray flares from SFXTs because of monitoring observations. Nevertheless, short X-ray enhancements probably due to activities of IGR J08408−4503, AX J1739.1−3020/XTE J1739−302, AX J1841.0−0536/IGR J18410−0535, and IGR J18483−0311 sometimes triggered the MAXI nova-alert system (Negoro *et al.* 2016; SN17). Two examples are shown in Fig. 1.

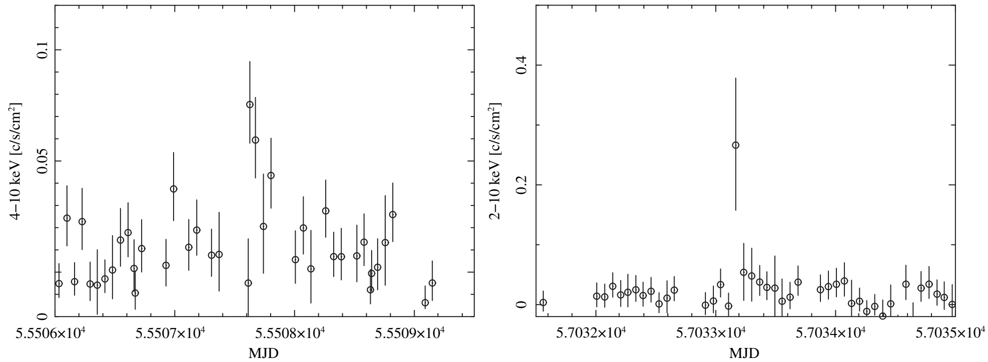

Figure 1. X-ray flares probably from AX J1841.0−0536/IGR J18410−0535 (*left*, Negoro *et al.* 2011) and AX J1739.1−3020/XTE J1739−302 (*right*, Negoro *et al.* 2015).

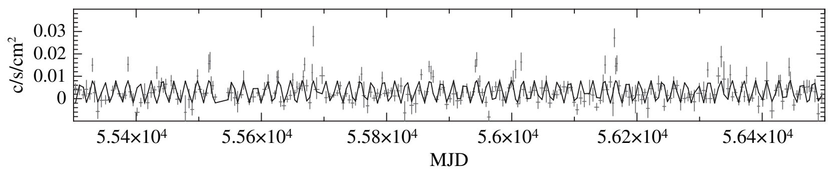

Figure 2. Longterm 4-10 keV X-ray light curve of IGR J18483−0311 observed with MAXI/GSC, and the fitted sine curve.

3. Periodicity

From IGR J18483−0311, MAXI often detected long flares lasting a few days, not short flares lasting a few hours or less. As shown in Fig. 2, bright (more than 10 mCrab, ~ 0.01 c/s/cm^2 at 4-10 keV) and periodic (18.54 days) flares can be seen. The periodicity is thought to be related with the orbital period just like a type-I outburst. To investigate such a property in a soft X-ray band, using nine-years of MAXI/GSC data I searched the periodicity of the following eight SFXTs, IGR J08408−4503, AX J1739.1−3020, AX J1841.0−0536, IGR J18483−0311, AX J1845.0−0433/IGR J18450−0435, IGR J17544−2619, XTE J1901+014, and 2XMM J185114.3−000004.

Since most SFXTs are on the galactic plan and close to other bright sources (SN17), the image fitting analysis (Morii *et al.* 2016) was performed to obtain reliable light curves taking into account the point spread functions of the cameras and the X-ray count leaks from nearby sources. Then, Lomb-Scargle periodograms (Scargle 1982) for unevenly spaced data were calculated.

IGR J18483−0311 : The periodogram in Fig. 3 (*left*) clearly shows a strong peak at 6.24×10^{-7} Hz (18.54 d). This period is consistent with previous measurements (e.g., 18.55 ± 0.03 d obtained with RXTE/ASM by Levine *et al.* (2006), also SN17). Note that other peaks are due to the ISS orbital precession (1.6×10^{-7} Hz ~ 72 d) and its harmonics.

IGR J17544−2619 : The second example of known-period detection is that of IGR J17544−2619, for which we measured a period of 4.93 days (2.35×10^{-6} Hz, Fig. 3 (*right*)). This is compatible with the period of 4.926 days reported by Clark *et al.* (2009). In addition to strong peaks (harmonics) below 2×10^{-6} Hz due to severe count leaks from nearby bright persistent sources and the ISS orbital precession, some peaks are also detected at 1.11×10^{-5} (1.04 d), 1.16×10^{-5}, and 1.18×10^{-5} Hz. However, in AX J1739.1−3020, peaks at similar frequencies can also be seen at 1.13×10^{-5} and 1.18×10^{-5} Hz. Currently, there is no consolidated explanation to interpret these peaks.

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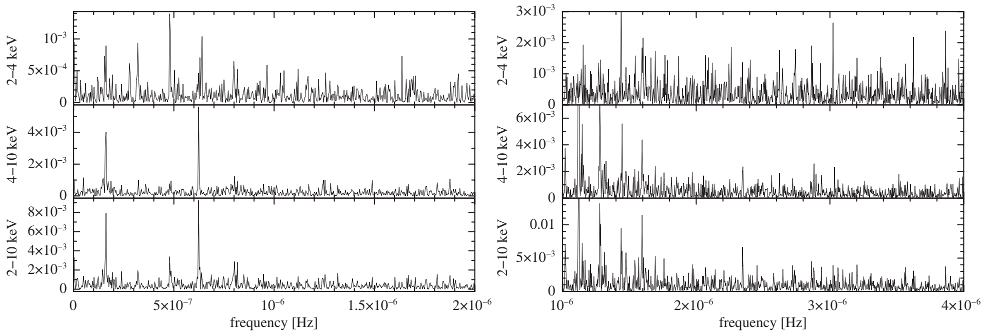

Figure 3. Preliminary periodograms obtained for IGR J18483−0311 (*left*) and IGR J17544−2619 (*right*).

We note that no similar peaks in the frequency range (1.1–1.2)$\times 10^{-5}$ Hz were deteceted in the periodograms of the remaining SFXTs analyzed here.

4. Discussion and other HMXBs

We successfully obtained the periods of the two SFXTs, IGR J18483−0311 and IGR J17544−2619, average fluxes of which were below the 1-d MAXI/GSC detection limit by more than one order of magnitude (e.g., Romano 2015). On the other hand, the periodicities of AX J1739.1−3020, AX J1841.0−0536 and AX J1845.0−0433 with similar average fluxes were not confirmed. This is not easy to be explained assuming the relations between outburst duration, frequency and rate shown by Sidoli (2013).

For bright HMXBs, long-term MAXI monitoring data are informative on periodic and aperiodic variability (e.g., see Asai *et al.* 2014 for Cir X–1, and Sugimoto *et al.* 2016 for Cyg X–1). This work demonstrates that MAXI data are also useful to find periodicities in the X-ray emission of sources that cannot be detected with 1 day-long integrations.

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