MAXI Detections of Superbursts

– Updates on Long X-ray Bursts –

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Abstract

In seven years, MAXI observed twelve long X-ray bursts, which were observed during at least two consecutive scans. We divided them into two classes according to their e-folding decay time: the bursts with longer e-folding decay time (> 1 hour) are superbursts, and the others are intermediate duration bursts. MAXI detected superbursts from two bright persistent source (Ser X-1 and 4U 1705−44), a dim persistent source (4U 0614+091), and four transient sources (Aql X-1, SAX J1747.0−2853, EXO 1745−248, and SAX J1828.5−1037). Two of the superbursts from transient sources occurred at the time of very low accretion rate, which may be before the outbursts. Four out of five intermediate duration bursts had low (< 2% of the Eddington limit) persistent flux. Four intermediate duration bursts are from ultracompact X-ray binary. These characteristics are common to the intermediate duration bursts which were observed before the MAXI era. We found possible anti-correlation between the decay time and the peak flux. Superbursts have low peak fluxes (10–50% of the Eddington limit) and intermediate duration bursts have the peak fluxes of about the Eddington limit.

Key words: stars: neutron — X-rays: bursts — MAXI

1. Introduction

MAXI scans about 85% of the whole sky in 92 minutes. It is efficient for searching for transient events with long (>92 min) duration such as long X-ray bursts. As of the end of 2016, we found twelve long X-ray bursts in the MAXI data. Table 1 shows the list of long X-ray bursts. Eight of them overlap with the list in in ’t Zand et al. (2017). Most of them are described in the previous papers (Serino et al. 2016; Serino et al. 2017). Three new events were found after Serino et al. (2016), which were IGR J17062−6143 (Negoro et al. 2015; Iwakiri et al. 2015; Keek et al. 2017), Ser X-1 (Iwakiri et al. 2016), and 4U 1705−44 (Iwakiri et al. 2016). Details of Ser X-1 and 4U 1705−44 are also introduced by Iwakiri et al. (2017) in this proceedings. In this paper, we focus on the persistent flux of the long X-ray bursts and possible anti-correlation between the decay time and the peak flux.

Table 1. A list of long X-ray bursts observed by MAXI (sorted by date)

Name	date	decay time > 1h?
4U 1820−30	2010-03-17	n
SAX J1747.0−2853	2011-02-13	Y
EXO 1745−248	2011-10-24	Y
SAX J1828.5−1037	2011-11-12	Y
Ser X-1	2011-12-06	Y
SLX 1735−269	2012-12-06	n
Aql X-1	2013-07-20	Y
4U 1850−086 (1)	2014-03-10	n
4U 0614+091	2014-11-03	Y
4U 1850−086 (2)	2015-05-09	n
IGR J17062−6143	2015-11-03	n
4U 1705−44	2016-10-22	Y

2. The persistent emissions of the long X-ray burst sources

MAXI monitors the persistent fluxes of X-ray burst sources. Figure 1 shows an image of galactic sources in 4–10 keV. The previously known superburst sources (dashed circles) and the sources in Table 1 (solid circles)

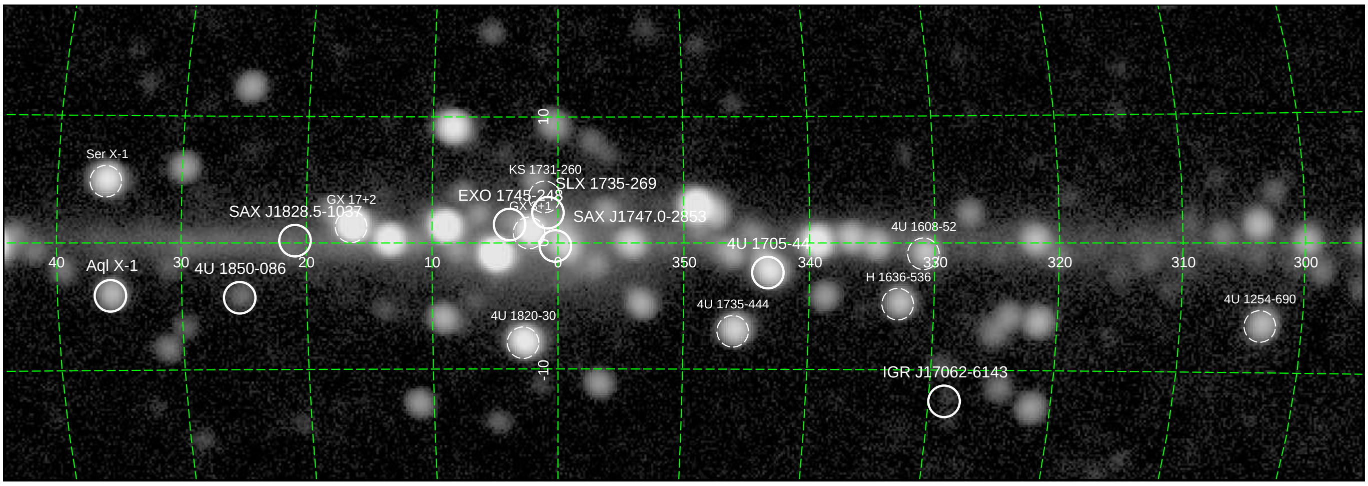

Fig. 1. A MAXI image of galactic sources in 4–10 keV, based on data collection in 4.7 years. The previously known superburst sources (dashed) and the sources in Table 1 (solid) are marked with circles.

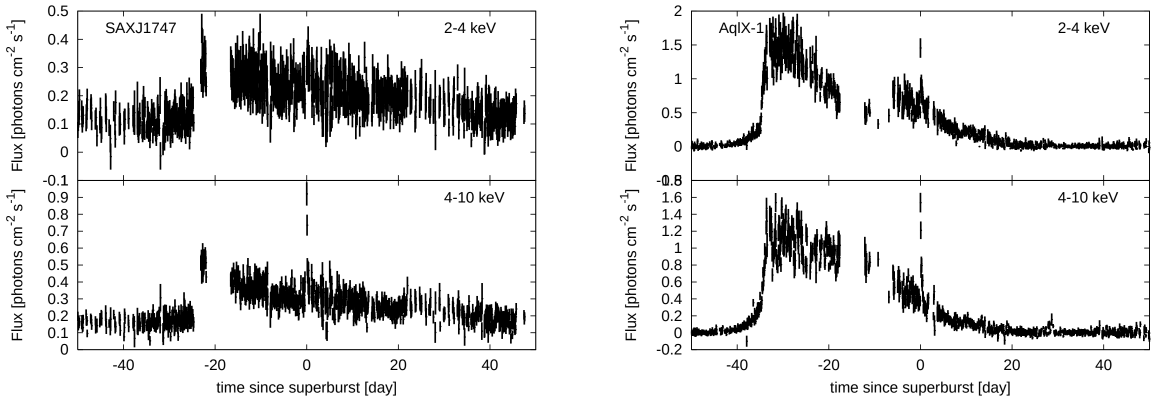

Fig. 2. Light curves of the outbursts of SAX J1747.0−2853 (left) and Aql X-1 (right). A point correspond to a scan. The short flares at time= 0 are superbursts.

are marked. The former tend to be brighter than the latter.

Two superbursts from SAX J1747.0−2853 and Aql X-1 occurred during transient outbursts. The outbursts of these sources started ~ 25 and ~ 40 days before the superbursts. They are similar to 4U 1608−522, which also occurred during the outburst and it started 57.6 days before the superburst (Keek et al. 2008).

No superburst was found from bright and persistent sources in the MAXI data before 2016. Serino et al. (2016) mentioned that it should be a selection bias, because it is easier to find superbursts from sources with weaker persistent emissions. Then we searched for superbursts from bright sources carefully, and found a superburst from Ser X-1. Another superburst, which was observed just before "7 years of MAXI" conference, was also from a bright persistent source 4U 1705−44 (Iwakiri et al. 2016; Iwakiri et al. 2017).

The MAXI light curve[1] of SAX J1828.5−1037 stays constant at ~ 10 mCrab. We note that this emission is dominated by the galactic ridge emission (see figure 1). The light curves of the sources near the galactic center region (SLX 1735−269, SAX J1747.0−2853, and EXO 1745−248) are also contaminated by nearby sources. Therefore it is difficult to estimate the persistent flux from these sources.

We classified five bursts into the intermediate duration bursts, because they have exponential decay time below 1 hour. Four out of these five had low ($< 2\%$ of the Eddington limit) persistent flux. Three sources (4U 1820−30, 4U 1850−086, and SLX 1735−269) with the intermediate duration bursts are (candidate) ultracompact X-ray binaries, while the compactness of the other source (IGR J17062−6143) is not known. Ultracompact nature and low persistent luminosity are common to the sources of intermediate duration bursts (Falanga et al. 2008). The persistent emission of 4U 1820−30 is exceptionally bright unlike other sources of intermediate duration bursts.

3. Peak flux – decay time correlation

Figure 3 shows a scatter plot of the peak flux and the e-folding decay time τ of long bursts. Since the peak fluxes are normalized with the observed maximum fluxes of the normal bursts, which are an approximation of the Eddington ratio[2]. There are systematic uncertainties of the burst peak flux, because of the limited scan time window. Then we estimate the "possible maxima" by extrapolating the exponential function to the epoch of the previous scan transit. The upper ends of the horizontal bars in figure 3 are these "possible maximum".

There may be an anti-correlation between the decay time and the peak flux. Superbursts have low peak fluxes (10–50% of the Eddington limit) and intermediate duration bursts have the peak fluxes of about the Eddington limit.

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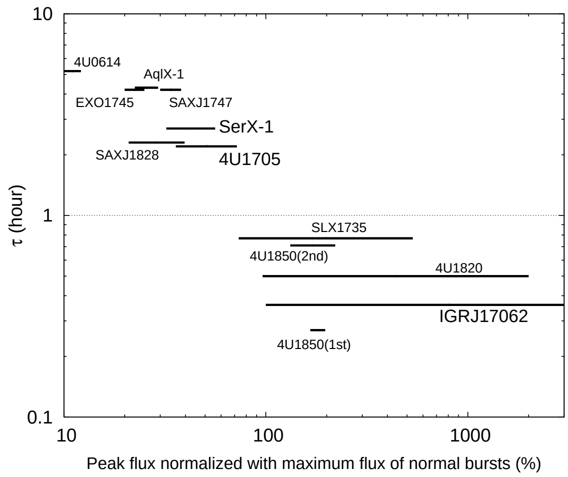

Fig. 3. A scatter plot of peak flux and e-folding time of long bursts. Each peak flux in the plot are normalized with the maximum flux of the normal bursts of the same source. Three new events discovered after Serino et al. (2016) are labeled with larger font. Note that the horizontal bars are not statistic errors. The lower ends of the fluxes are the observed ones, and the upper ends are possible maximum fluxes (see text).

*1 http://maxi.riken.jp/top/

*2 We do not have information of a normal X-ray burst from IGR J17062−6143. We assume the observed peak flux of the long burst in our sample was the Eddington limit, because the inferred radius suggested a photospheric expansion (Keek et al. 2017).

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