Swift/BAT and MAXI/GSC broadband transient monitor

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Abstract

We present a newly developed broadband transient monitor using the Swift Burst Alert Telescope (BAT) and the MAXI Gas Slit Camera (GSC) data. Our broadband transient monitor keeps vigil for high-energy transient sources from 2 keV to 200 keV in seven energy bands by combining the BAT (15–200 keV) and the GSC (2–20 keV) data. Currently, daily and 90-minute (one orbit) averaged light curves are available for 106 high-energy transient sources. This transient monitor is available to the public through our web server, http://yoshidalab.mydns.jp/bat_gsc_trans_mon/, for wider use by the community. We discuss a daily sensitivity of our monitor and possible future improvements on our pipeline.

Key words: binaries: general — methods: data analysis — stars: activity — stars: black holes — stars: jets

1 Introduction

High-energy astrophysical sources show a temporal variability in a broad spectral range. The soft X-ray (1–10 keV) and hard X-ray (10–100 keV) ranges are especially important observing windows to understand the temporal characteristics of high-energy sources which involve spectral changes. For instance, a black hole candidate shows state changes in its flux and spectrum; in the quiescent state the X-ray emission is dominated by the hard emission, whereas in outburst the soft emission from the accretion disk becomes dominant. Some low-mass X-ray binaries produce bright bursts in X-rays, “X-ray bursts”, which are caused by thermonuclear flashes of accreting material on the surface of the neutron star. An accreting X-ray binary pulsar sometimes shows intense outbursts...
in X-rays when the neutron star passes the disk or dense stellar wind of its companion. Cyclotron resonance lines, one of the direct observational approaches to measure the magnetic field of a neutron star, are most easily observable in the hard X-ray range from binary pulsars during outburst. An isolated neutron star with a high magnetic field, a “magnetar”, occasionally shows an outburst with multiple short-duration bursts in hard X-rays believed to originate from a large release of its internal magnetic energy. Time-domain astronomy, which has been revolutionized by Swift (Gehrels et al. 2004), has become a frontier field of astronomy.

The Burst Alert Telescope (BAT: Barthelmy et al. 2005) on board Swift has been monitoring the hard X-ray sky (14–200 keV) with its wide field of view since 2004. On the other hand, the Gas Slit Camera (GSC: Mihara et al. 2011) on the MAXI mission (Matsuoka et al. 2009) has been observing the sky in the softer energy band (2–30 keV) since 2009. Both instrument teams provide the light curve data in real time to the public (Krimm et al. 2013; Sugizaki et al. 2011). However, the Swift/BAT transient monitor (Krimm et al. 2013) is limited to the single energy band of 15–50 keV because the pipeline uses the data extracted in a single 15–50 keV band on board (the data product called the BAT scaled-map data). Furthermore, there is no real-time transient monitor producing light curves in the full dynamic range of the BAT and the GSC data with the same time axis. By combining the data of the BAT and the GSC, we are able to construct broadband light curves of high-energy transient sources which are of high scientific merit. For example, spectral state changes of several black hole candidates are investigated intensively using BAT and

1 ⟨http://swift.gsfc.nasa.gov/results/transients/⟩.
Fig. 2. Systematic trends in the BAT observed count rate of the Crab nebula as a function of the incident angle ($\theta$) in the 14–20 keV band (left) and in the 100–150 keV band (right). The dashed line is the best-fitting quadratic function (table 1) for the data.

### Table 1. Best-fitting equations between the BAT Crab count rate and the incident angle $\theta$.

| Energy band | Best-fitting quadratic equation |
|-------------|---------------------------------|
| 14–20 keV   | $\text{Rate} = 0.0123169 - 1.15218 \times 10^{-5} \theta - 1.4965 \times 10^{-6} \theta^2$ |
| 20–24 keV   | $\text{Rate} = 0.006923 + 6.10315 \times 10^{-6} \theta - 6.78433 \times 10^{-7} \theta^2$ |
| 24–35 keV   | $\text{Rate} = 0.0105085 + 5.19742 \times 10^{-6} \theta - 6.91427 \times 10^{-7} \theta^2$ |
| 35–50 keV   | $\text{Rate} = 0.0069828 + 7.88677 \times 10^{-6} \theta - 5.25433 \times 10^{-7} \theta^2$ |
| 50–75 keV   | $\text{Rate} = 0.0057086 + 4.41883 \times 10^{-6} \theta - 2.67754 \times 10^{-7} \theta^2$ |
| 75–100 keV  | $\text{Rate} = 0.0020645 + 8.86035 \times 10^{-7} \theta + 5.79986 \times 10^{-8} \theta^2$ |
| 100–150 keV | $\text{Rate} = 0.0013577 - 6.27195 \times 10^{-6} \theta + 2.51476 \times 10^{-7} \theta^2$ |
| 150–195 keV | $\text{Rate} = 0.0001824 - 3.96457 \times 10^{-6} \theta + 1.74441 \times 10^{-7} \theta^2$ |

GSC data (XTE J1752–223, e.g., Nakahira et al. 2010; Swift J1753.5–0127, e.g., Yoshikawa et al. 2015; Swift J1910.2–0546, e.g., Nakahira et al. 2014; GX 339–4, e.g., Shidatsu et al. 2011b). The state transitions of bright low-mass X-ray binaries have also been studied in detail using both BAT and GSC data (e.g., Asai et al. 2015). When using both the MAXI and the INTEGRAL data, there is a webpage for monitoring X-ray and hard X-ray activities of high-mass X-ray binaries. Therefore, there is a great demand to gather broadband light curves of high-energy transient sources from multiple missions and to present them in a consistent format along a single time axis.

In this paper, we introduce a broadband transient monitor utilizing the BAT and GSC data. This transient monitor covers the dynamic range from 2 keV to 200 keV, which is ideal for monitoring high-energy transients in a broad spectral coverage.

The paper is organized as follows. We present the analysis method in section 2. In section 3, our broadband transient monitor is introduced. We further discuss our broadband transient monitor in section 4.

2 Analysis

The flowchart of our pipeline is shown in figure 1. As the initial step to construct the broadband transient monitor, independent pipelines were developed just to mirror the Swift BAT data to our server. This step is rather crucial for the entire process because it takes a significant amount of time to download the BAT data from the Swift data archive center in the US (Swift Data Center, SDC; HEASARC) to Japan. Since the Swift data are initially stored at the SDC and then archived to the HEASARC seven days after the observation, two separate pipelines were developed to mirror both SDC and HEASARC data; these are available to the public from our web server (the SDC data mirror and the HEASARC data mirror) located in Japan. Note that only the Swift/BAT-related data are mirrored from HEASARC to our server. The script to mirror the SDC data runs once an hour, whereas the script to mirror the HEASARC archive runs once a day.

2 ⟨http://integral.esac.esa.int/bexrbmonitor/webpage_oneplot.php⟩.

3 ⟨http://swift.gsfc.nasa.gov/cgi-bin/sdc/ql?⟩.

4 ⟨http://heasarc.gsfc.nasa.gov/FTP/swiftdata/obs/⟩.

5 ⟨http://yoshidalab.mydns.jp/swift_sdc_ql/⟩.

6 ⟨http://yoshidalab.mydns.jp/swift_bat_heasarc/⟩.
Table 2. Products of the broadband transient monitor.

Plots of daily seven-channel light curves and the hardness ratio between the BAT 50–100 keV and the GSC 2–5 keV band
Plots of zoomed-in daily light curves over the last ten days and the hardness ratio between the BAT 50–100 keV and the GSC 2–5 keV band
Interactive plots of daily seven-channel light curves and the hardness ratio between the BAT 50–100 keV and the GSC 2–5 keV band
Plots of 90-minute seven-channel light curves
Plots of zoomed-in 90-minute seven-channel light curves over the last ten days
FITS light curve files of BAT four-channel daily light curves
FITS light curve files of BAT four-channel 90-minute light curves

Fig. 3. Daily averaged broadband light curve of Cyg X-1. A clear hard-to-soft state transition is visible in MJD 55300, and also the short soft-to-hard and hard-to-soft state transitions are visible in MJD 55700, 55900, and 56800.

The basic BAT data analysis is performed using the HEASOFT software package. The batsurvey script is used to process the BAT survey (Detector Plane Histogram, DPH) data. The eight default energy bands (14–20 keV, 20–24 keV, 24–35 keV, 35–50 keV, 50–75 keV, 75–100 keV, 100–150 keV, and 150–195 keV) and the original time resolution of the DPH data (timesep = “DPH”) were specified in the script. The typical exposure time of the original DPH data is five minutes. Products are made for 146 sources which were flagged as bright hard X-ray...
Fig. 4. Daily averaged broadband light curve of GRS 1915+105. Several hard-to-soft state transitions are clearly visible in MJD 55700, 56300, and 57200.

sources in the BAT 70-month all-sky hard X-ray survey (Baumgartner et al. 2013). The data on and after 2009 August, when MAXI and Swift operations overlap, were processed. The batsurvey script produces “level 2” catalogs for each source which contain the extracted count rate and the incident angle of the source. Once the batsurvey process is completed, all the level 2 catalogs (the final outputs of the batsurvey script) are merged using the batsurvey-catnum script and time sorted by ftsort for all 146 sources.

The BAT count rates extracted by the batsurvey script must be corrected for the energy-dependent vignetting of incoming photons (Tueller et al. 2010). To model this off-axis effect in the count rate at each energy band, we processed the survey data between 2004 and 2005, when the Crab nebula was in the field of view at various incident angles. Figure 2 illustrates the significant energy-dependent systematic effects between the Crab count rate and the incident angle in the 15–20 keV band and between them in the 100–150 keV as an example. A quadratic function was fitted to the trend between the count rate and the incident angle for all eight energy bands (table 1). In each band, the count rate is corrected by the ratio of the on-axis Crab rate to the estimated Crab rate at the given incident angle. Next, the original eight energy bands are binned to four energy bands.
Fig. 5. Daily averaged broadband light curve of GX 339–4. During the outburst around MJD 55200, the hard-to-soft spectral evolution at the tail part of its outburst is evident between the GSC 2–4 keV and BAT 50–100 keV bands.

(14–24 keV, 24–50 keV, 50–100 keV, and 100–195 keV), and then one day averaged and 90 minutes (1 orbit) averaged light curves are generated using rebingausslc.

The MAXI GSC one-day and 90-minute light curves are downloaded from the MAXI public web page\(^7\) for the common sources of the BAT 146 bright sources in the input catalog of the BAT data process and the 369 (as of 2015 July) sources listed in the MAXI public web page. The number of common sources in the current monitor is 106. This limitation mainly comes from the number of sources in the BAT input catalog. However, since all the created BAT sky images are stored in our computer, only the source extraction tool, batcelldetect, is needed to run through all the archival images to add a new source from the BAT data. We plan to add the sources which were detected in outburst in the BAT transient monitor (Krimm et al. 2013) in the past six years to our transient monitor pipeline.

The light curves of the BAT and the GSC are combined and plots are generated using the Python matplotlib module.\(^8\) The BAT light curve data are available in FITS

\(^7\) [http://www.maxi.riken.jp](http://www.maxi.riken.jp).

\(^8\) [http://matplotlib.org](http://matplotlib.org).
Fig. 6. Daily averaged broadband light curve of Mrk 421. The hard X-ray emission is detected by the BAT data during outburst episodes such as those in MJD 55250 and 55800.

format. The interactive light curve based on the Python mpld3 module\(^9\) is also available, so that a user can move and zoom in the light curve interactively.

3 BAT and GSC broadband transient monitor

Our broadband transient monitor is available to the public from the web server at Aoyama Gakuin University.\(^10\) Currently, the broadband light curves of 106 known sources are accessible from the web page. The web page is updated \(~3\) times a day depending on the amount of data that needs to be processed. The products of our BAT/GSC broadband transient monitor are summarized in table 2.

Here, we highlight the products of several sources in our broadband transient monitor. Figures 3 and 4 show our broadband light curves of the black hole binaries Cygnus X-1 and GRS 1915+105. These light curves clearly show multiple spectral state transitions between “low-hard” and “high-soft” states, which are believed to indicate a change in the geometry of the accretion disk (e.g., Esin et al. 1997). For example, the last clear state change was happening around MJD 57125 for Cygnus X-1 and around MDJ 56252 for GRS 1915+105. As can be seen

\(^{9}\) (http://mpld3.github.io).

\(^{10}\) (http://yoshidalab.mydns.jp/bat_gsc_trans_mon/).
in the light curves, the borderline energy where the emission becomes brighter or dimmer when the source is in the high-soft state is around 10 keV for Cygnus X-1 and 15 keV for GRB 1915+105.

Figure 5 shows the long-term temporal behavior of GX 339–4, a Galactic transit black hole with a low-mass companion. During the giant outburst in the year 2010 (e.g., MJD 55200–55600), the burst emission showed a strong hard-to-soft evolution. The initial hard emission was visible up to the highest energy band of 100–195 keV. This hard X-ray emission episode is dominated by Comptonized photons from its accretion disk (e.g., Shidatsu et al. 2011a).

The γ-ray blazar Mrk 421 showed several flares visible up to 100 keV (figure 6). Since the BAT energy range is located at the dip between the two broad peaks in the spectral energy distribution of Mrk 421 (e.g., Abdo et al. 2011), the BAT hard X-ray emission is not so evident compared to the soft X-ray band of the GSC. However, during the outburst, the hard X-ray emission is clearly visible in the BAT data, and the broad spectral properties of the source can be investigated using our monitor.

Figure 7 shows the light curve of the Seyfert 1.5 galaxy NGC 4151 which has a hard continuum in its spectrum (Keck et al. 2015). Unlike previous examples, its emission
and its temporal variability are clearly visible in the BAT data rather than in the GSC data.

In figure 8, several giant outburst episodes are visible in the broadband light curve of the high-mass X-ray pulsar 1A 0535+262. Since the emissions during giant outbursts were so intense, the temporal profile up to 100 keV is clearly visible even in the one-orbit light curve (right-hand panel of figure 8). A recent study showed that the energy of the cyclotron resonance line of 1A 0535+262, which was found typically around 45 keV, increased when the flux was high (Sartore et al. 2015). Thus, it is important to monitor those cyclotron sources in a broad energy band to understand the transient spectral features at various flux levels. As can be seen in these examples, our transient monitor includes various types of sources and can monitor interesting temporal and spectral stages of high-energy sources.

4 Future prospects

We constructed the broadband transient monitor using the Swift BAT and MAXI GSC data and made it available to the public. This work is the first attempt to analyze the BAT survey data in real time for constructing multiband light curves. Although the updating frequency of the light curve is still not ideal, we can now run the pipeline several times a day in real time.

Although it varies based on the Swift pointing, a typical exposure time of an individual object for BAT is roughly four hours per day (about eight hours at the highest). Applying the BAT survey sensitivity equation described in Baumgartner et al. (2013), this typical exposure corresponds to a $5\sigma$ sensitivity of $\sim 10$ mCrab (14–195 keV). On the other hand, the daily averaged $5\sigma$ sensitivity of the GSC is $\sim 15$ mCrab in the 4–10 keV band (Sugizaki et al. 2011). Therefore, the daily sensitivities of the BAT and the GSC are comparable, and thus it is a good match to combine the BAT and the GSC data for the high-energy transient source monitor on a daily basis.

All the MAXI GSC light curve data in the current broadband transient monitor are downloaded from the MAXI public web page. Since all of the light curves are created using an aperture photometry method (Sugizaki et al. 2011), the count rates in the light curves could be contaminated with bright X-ray sources located near the...
Due to the relatively poor position resolution of the GSC, if another bright X-ray source is located within 2° of the object, there might be an issue in the light curve. For those sources which could be affected by nearby contamination, we have a future plan to generate the GSC light curve of the source using the point spread function fitting method, which should provide a contamination-free light curve (Hiroi et al. 2011; M. Morii et al. in preparation) using the GSC data. At the current stage, sources which are located within 2° of catalog sources in the ROSAT bright source catalog (Voges et al. 1999) contaminated at a count rate greater than 1 counts s⁻¹ are flagged as possible contaminated sources on the top page of the monitor (see table 3).

The processing time of the current pipeline is limited by the analysis of the BAT survey data. Our pipeline is processing the BAT survey data at the finest time resolution for the eight energy bands. Although we can process the data at a coarser time resolution and in smaller energy bands to speed up the process, the best spectral and temporal information can be extracted in the current setup for the BAT data. For example, the outputs of our pipeline can provide eight-channel spectral data of the sources every five minutes when high-energy sources are in the very bright state. We have a plan to process the data with multiple object.

### Table 3. Source list of the broadband transient monitor.

| Name       | RA    | Dec    | Possible contaminated source |
|------------|-------|--------|------------------------------|
| V709 Cas   | 7.2036| 59.2894| T                            |
| Mrk 348    | 12.1964| 31.9750| T                            |
| Gamma Cas  | 14.1772| 60.7167| T                            |
| SMC X-1    | 19.2714| -73.4433| T                            |
| 2S 0114+650| 19.5112| 62.9516| T                            |
| 4U 0115+634| 19.6330| 63.7400| T                            |
| GC Eri     | 38.5940| -43.9260| T                            |
| GK Per     | 52.7993| 43.9047| T                            |
| BQ Cam     | 53.7495| 53.1732| T                            |
| X Per      | 58.8462| 31.0458| T                            |
| LSV+44 17  | 70.2470| 54.3500| T                            |
| LMC X-4    | 83.2075| -66.3705| T                            |
| Crab Nebula Pulsar | 83.6332| 22.0145| T                            |
| IA 0535+262| 84.7274| 26.3158| T                            |
| LMC X-3    | 84.7342| -64.0823| T                            |
| NGC 2110   | 88.0474| -7.4362| T                            |
| 4U 0614+091| 94.2804| 9.1369| T                            |
| MXB 0656+072| 104.5703| -7.2105| T                            |
| EXO 0748+676| 117.1388| -67.7500| T                            |
| Vela Pulsar| 128.8361| -45.1764| T                            |
| GS 0334+430| 128.9790| -43.1850| T                            |
| Vela X-1   | 135.2826| -51.5470| T                            |
| MCG −05−23−016 | 146.9173| -30.9489| T                            |
| GRO J1008+57 | 152.4417| -58.2917| T                            |
| NGC 3227   | 155.8774| 9.8651| T                            |
| Mrk 421    | 166.1138| 38.2088| T                            |
| NGC 3516   | 166.6979| 25.6868| T                            |
| XTE J1181+480 | 169.5450| 48.0370| T                            |
| Cen X-3    | 170.3158| -60.6230| T                            |
| NGC 3783   | 174.7572| -37.7386| T                            |
| IE 1145.1−6141 | 176.8682| -61.9539| T                            |
| NGC 4151   | 182.6357| 39.4057| T                            |
| GX 301−2   | 186.6567| -62.7706| T                            |
| 3C 273     | 187.2779| 2.0428| T                            |
| GX 304−1   | 195.3217| -61.6019| T                            |
| Cen A      | 201.3651| -43.0191| T                            |
| 4U 1323+619| 201.6504| -62.1361| T                            |
| IC 4329A   | 207.3303| -30.3094| T                            |
| NGC 5506   | 213.3119| -3.2075| T                            |
| PSR B1509−58 | 228.4813| -59.1358| T                            |
| Cyg X-1    | 230.1703| -57.1667| T                            |
| H 1538−522 | 235.9791| -52.3861| T                            |
| IE 1547.0−5408 | 237.7255| -54.3066| T                            |
| H 1533−542 | 239.4512| -54.4150| T                            |
| 4U 1608−522 | 243.1792| -52.4231| T                            |
| Sco X-1    | 244.5979| -15.6402| T                            |
| SWIFT J1626.6−5156 | 246.6510| -49.1985| T                            |
| 4U 1624−490 | 247.0118| -49.1985| T                            |
| 4U 1626−67 | 248.0700| -67.4619| T                            |
| 4U 1636−536 | 250.2313| -53.7514| T                            |
| GX 340+0   | 251.4488| -45.6111| T                            |
| GRO J1655−40 | 252.5006| -39.3858| T                            |
| Her X-1    | 254.4576| 35.3242| T                            |
| OAO 1657−415 | 255.1996| -41.6731| T                            |
| XTE J1701−407 | 255.4349| -40.8583| T                            |
| GX 339−4   | 257.7063| -48.7887| T                            |
| GX 349−2   | 258.4354| -36.4231| T                            |
| 4U 1705−440 | 257.2270| -44.1020| T                            |
| 4U 1722−30 | 261.8883| -30.8019| T                            |
| GX 9+9     | 262.9342| -16.9617| T                            |
| 4U 1728−34 | 262.9982| -33.8347| T                            |
| GX 1+4     | 263.0090| -24.7456| T                            |
| MXB 1730−335 | 263.3504| -33.8777| T                            |
| SLX 1735−269 | 264.5667| -27.0044| T                            |
| 4U 1735−44 | 264.7424| -44.4500| T                            |
| SGR A Gal center complex | 266.4168| -29.0078| T                            |
| 2E 1742.9−2925 | 266.5229| -29.5155| T                            |
| XTE J1746-3213 | 266.5650| -32.3335| T                            |
| GX 3+1     | 266.9833| -26.5363| T                            |
| SWIFT J1753.5−0127 | 268.3679| -1.4325| T                            |
| GX 5−1     | 270.2842| -25.0792| T                            |
| GX 9+1     | 270.3846| -20.2899| T                            |
| SAX J1808.4−3658 | 272.1150| -36.9790| T                            |
| XTE J1810−189 | 272.6079| -19.0700| T                            |
available computers or Graphical Processing Units to speed up the process.

The current broadband transient monitor contains 106 sources. However, it is not a difficult task to add sources to the monitor. We are planning to add sources not only based on the information from various observatories (e.g., the Astronomer’s Telegram, the Gamma-ray Coordinates Network) but also in response to requests from the community.

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References
Abdo, A. A., et al. 2011, ApJ, 736, 131
Asai, K., et al. 2015, PASJ, 67, 92
Barthelmy, S. D., et al. 2005, Space Sci. Rev., 120, 143
Baumgartner, W. H., Tueller, J., Markwardt, C. B., Skinner, G. K., Barthelmy, S., Mushotzky, R. F., Evans, P. A., & Gehrels, N. 2013, ApJS, 207, 19
Esin, A. A., McClintock, J. E., & Narayan, R. 1997, ApJ, 489, 865
Gehrels, N., et al. 2004, ApJ, 611, 1005
Hiroi, K., et al. 2011, PASJ, 63, S677
Krimm, H. A., et al. 2013, ApJS, 209, 14
Keck, M. L., et al. 2015, ApJ, 806, 149
Matsuoka, M., et al. 2009, PASJ, 61, 999
Mihara, T., et al. 2011, PASJ, 63, S623
Nakahira, S., et al. 2010, PASJ, 62, L27
Nakahira, S., Negoro, H., Shidatsu, M., Ueda, Y., Mihara, T., Sugizaki, M., Matsuoka, M., & Onodera, T. 2014, PASJ, 66, 84
Sartore, N., Jourdain, E., & Roques, J. P. 2015, ApJ, 806, 193
Shidatsu, M., et al. 2011a, PASJ, 63, S785
Shidatsu, M., et al. 2011b, PASJ, 63, S803
Sugizaki, M., et al. 2011, PASJ, 63, S635
Tueller, J., et al. 2010, ApJS, 186, 378
Voges, W., et al. 1999, A&A, 349, 389
Yoshikawa, A., Yamada, S., Nakahira, S., Matsuoka, M., Negoro, H., Mihara, T., & Tamagawa, T. 2015, PASJ, 67, 11

11 ⟨http://www.astronomerstelegram.org⟩.
12 ⟨http://gcn.gsfc.nasa.gov/gcn_main.html⟩.