Observational results of the Galactic X-ray sources with MAXI

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Abstract

X-ray binaries in Galaxy are known to wander several different spectral states, which may be related to the geometry of the accretion flow. Hardness-Intensity diagrams (HIDs) and Color-Color Diagrams (CCDs) are conveniently and widely used to monitor the time evolution of the spectral states. Using the public archive of the MAXI GSC data, we calculated the HIDs and CCDs of the selected Low-Mass X-ray Binaries (LMXBs) and Black Hole Candidates (BHCs). The public MAXI GSC data are available in three energy bands, and are convenient to calculate the HIDs and CCDs. We could observe evolution of the spectral states in HID and CCD throughout the outburst for several X-ray transients.

Key words: stars: binaries: spectroscopic — X-rays: bursts —X-rays: stars

1. Introduction

Among the Galactic X-ray binaries, those containing a weakly magnetized neutron star or a black hole are mostly found as LMXBs. They are known to wander several different spectral states, which may be related to the geometry of the accretion flow. Because different spectra state shows different correlation between the X-ray intensity and the spectral shape, it is convenient to use the correlation diagrams to show the spectral state. The correlation diagrams often used are the hardness-intensity diagrams (HIDs) and the color-color diagrams (CCDs). Because MAXI scans large portion of sky frequently, its data are very suited to calculate the diagrams. In this paper, we calculate the HID and CCD for some selected X-ray binaries (mostly LMXBs) in Galaxy using the MAXI public archive. They are useful not only to study the nature of the sources but also to demonstrate the ability of the MAXI data.

2. MAXI and the public archive

We used GSC (Gas Slit Camera) on MAXI (Monitor of All-sky X-ray Image) for the current study. GSC uses proportional counters and covers the energy band of 2-30keV. The field of view (FoV) is 1.5×160 degree through which each target may be observed for 40-150 s with the orbital motion of ISS. The observation data of MAXI are down linked from International Space Station to Tsukuba Space Center via NASA. The data are further transferred to the server at Riken for automatic processing. The processing produces light curves, images, and CSV data file. The MAXI data, including those of GSC, are made public through " MAXI home page " (http://maxi.riken.jp) since the beginning of observations in Aug, 2008. Users can download the light curves in three energy bands, X-ray image and the numerical data. The numerical data include the count rates in three energy bands, and are available in two different time bins, an orbital period of ISS and a day. Energy spectra are also calculated for some sources, but the event files do not become open to public. Because the public archive data are generated automatically, users should be careful on the noisy or bad data, which are difficult to reject in the automated processing. We show several examples of the HIDs and CCDs for some selected low-mass X-ray binaries (LMXBs) and black hole candidates (BHCs) calculated with these public data.

3. Analysis and Results

3.1. XTE J1752-223

We first pick up the Black Hole Candidate (BHC) XTE J1752-223 discovered by RXTE on Aug, 23, 2009 near the Galactic Centre. MAXI observations of the source were reported in Nakahira et al. (2010). We show the light curve of XTE J1752-223 retrieved from the MAXI archive with a binning of the orbital period. As seen from the light curve, MAXI covered whole the evolution of the outburst. In light curve, XTE J1752-223 showed two long plateaus after LHS (Low Hard State).
This characteristic may be uncommon compared to the canonical evolution of the BHC outburst. Because transition among the spectral states is already clear in the light curve, we divided the data into several states. We show the HID in Fig 2. We can find that the HID show

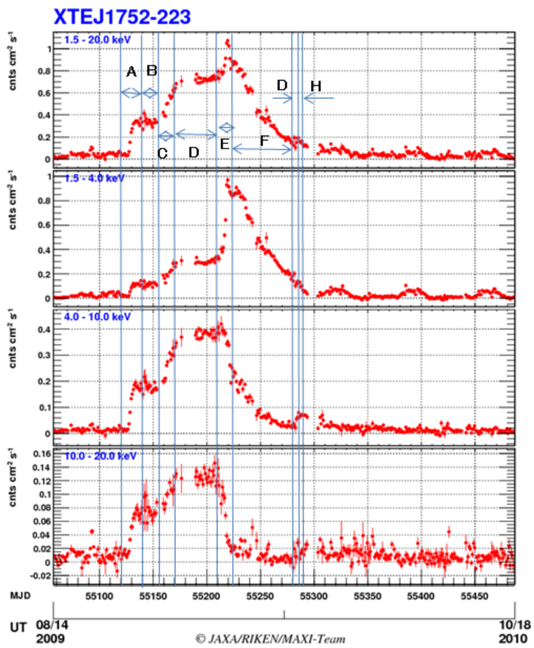

Fig. 1. Light curves of J1752-223 by MAXI in three (and the total) energy bands. Each state are described by A to H as divided by the vertical lines. The source showed two plateaus in the brightening phase of the outburst, which may be uncommon to the canonical X-ray novae.

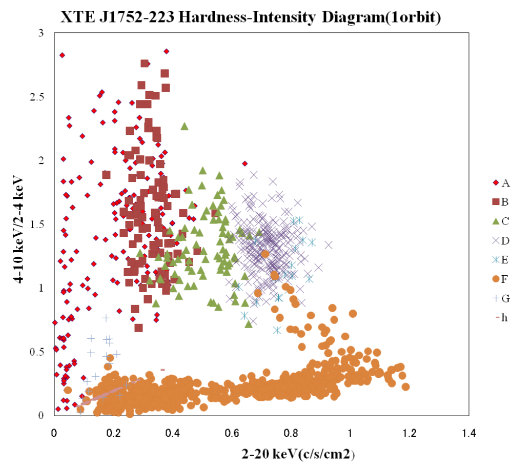

Fig. 2. HID for J1752-223 by MAXI. Each dot is corresponding to A to H states in light curve. From A to D state, we notice that 4-10keV/2-4keV value decreasing with 2-20keV counts increasing. Therefore change into Soft state and jet state is appeared on E state.

clear " The Unified Model for Radio Jets " proposed by Fender et al. (2004). For example, the jet state was detected in state E on 2010 January 21 (Nakahira et al. 2010).

3.2. Sco X-1

It is the brightest X-ray source in the sky. It is a close binary system consisting of a late-type star and a neutron star. The source is known to show time variations in time scale of hours. Fig3 shows color-color diagram of Sco X-1 with the MAXI archive data. Sco X-1 is known as one of the Z-sources, which show a Z shape in the CCD. As seen in Fig. 3, we can see a part of the Z-shape in the CCD characteristic to Sco X-1 similar to that observed by INTEGRAL (T.Di Salvo et al., 2006).

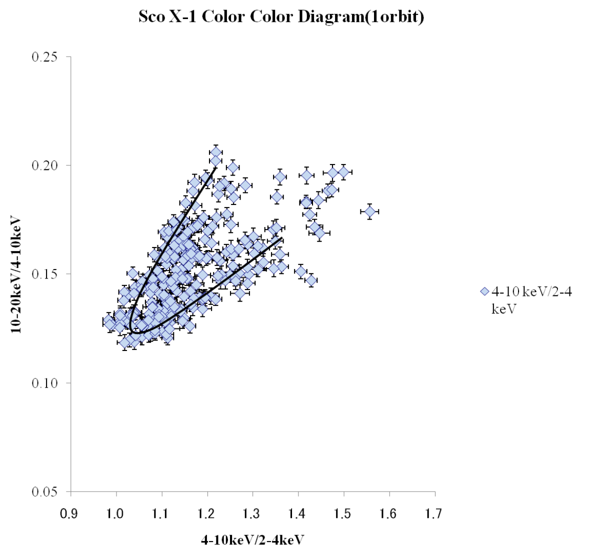

Fig. 3. Color-color diagram of Sco X-1 by MAXI. The line shows average trajectory of the data points.

3.3. Cyg X-1

Fig 4 and Fig 5 are light curve and color-color Diagram respectively, obtained from the most famous BHC Cyg X-1. In fig 4,the state transition from low/hard state to high/soft state is clearly seen as an increase of the soft-band count rate..

3.4. GX339-4

GX339-4 is also an well-known BHC in LMXB. Fig 6 shows the light curve of GX339-4, which covers more than a year. After the high/soft state of the outburst, the count rate remained about a half of the high/soft state value for a long period, which corresponds to the very high state. Fig 7 shows the HID of GX339-4; we can see three spectral states. One has low count rate in 2-20 keV and corresponds to the low/hard state. Another with

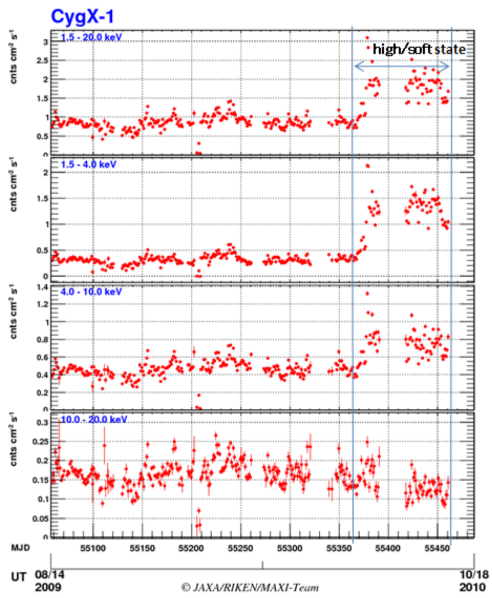

Fig. 4. Light curve of Cyg X-1. The source showed state transition at the epoch indicated by the vertical line from the low/hard to high/soft state..

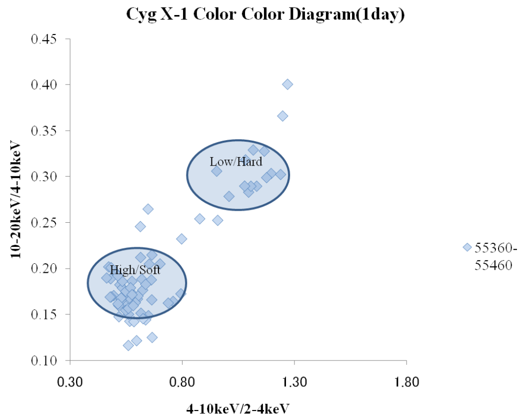

Fig. 5. color-color Diagram of Cyg X-1 from low/hard to high/soft states. The spectrum states are shown in each circle.

medium count rate in 2-20 keV with low 4-10 keV/2-4 keV ratio corresponds to the very high state. The other has low values in 4-10 keV/2-4 keV ratio and high count rate in 2-20 keV, which indicates the high/soft state.

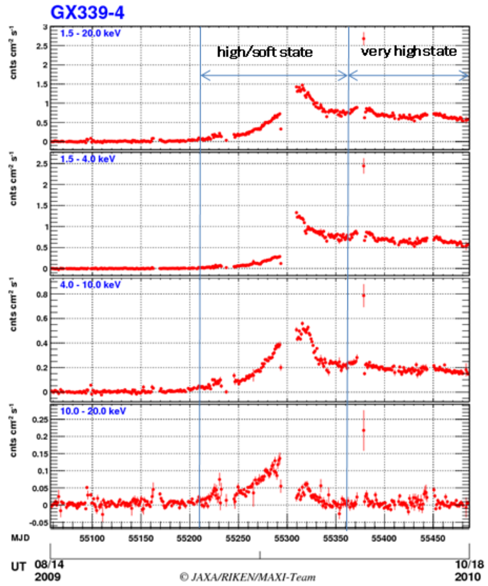

Fig. 6. Light Curve of GX339-4. There is very high state after first high/soft state.

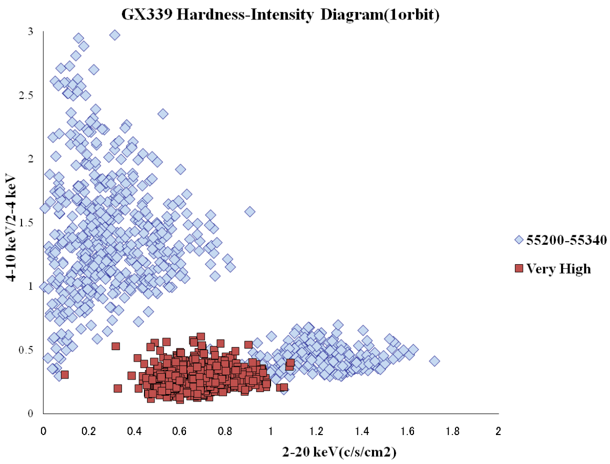

Fig. 7. HID for GX339-4 from the beginning of outburst to the very high state. Both the high/soft and the very high states show similar soft spectrum in this energy bands.

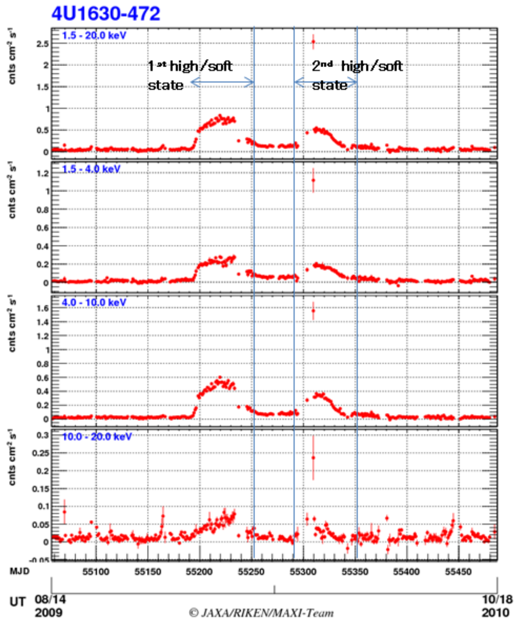

Fig. 8. Light Curve of 4U1630-472. Two outbursts were detected separated by 200 days.

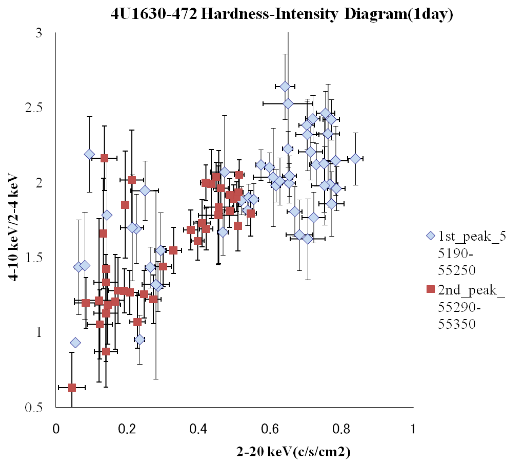

Fig. 9. The HID of 4U1630-472. Data points from the two outbursts constitute a single branch.

3.5. 4U1630-472

This is a BHC in LMXB, which shows outburst with an approximate interval of 600 days. Fig 8 show a light curve of 4U1630-472 outburst begun in December, 2009. In this outburst 4U1630-472 showed two high/soft state within 200 days. The HID in Fig 9 cleanly show that the two high/soft states constitute a single branch with only a smaller count rate in the 2nd one.

3.6. Aql X-1

Aql X-1 is known as one of the soft X-ray transients containing a neutron star and shows outburst rather frequently. Type 1 X-ray bursts are often detected in the decay of the outbursts, which shows the presence of a neutron star. Fig 10 and Fig 11 are light curve and color-color diagram of Aql X-1. Two outbursts were detected in November, 2009 and September, 2010.

4. Conclusion

We calculated the HIDs and CCDs for selected LMXBs and BHCs using the public MAXI archive data. We demonstrated that the MAXI archive data are very use-

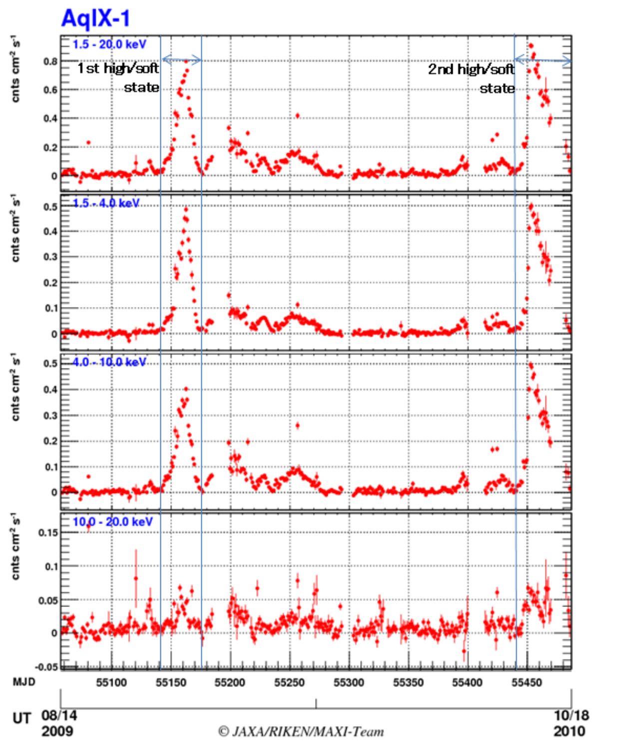

Fig. 10. Light curve of Aql X-1. Two outbursts were clearly seen in the light curves.

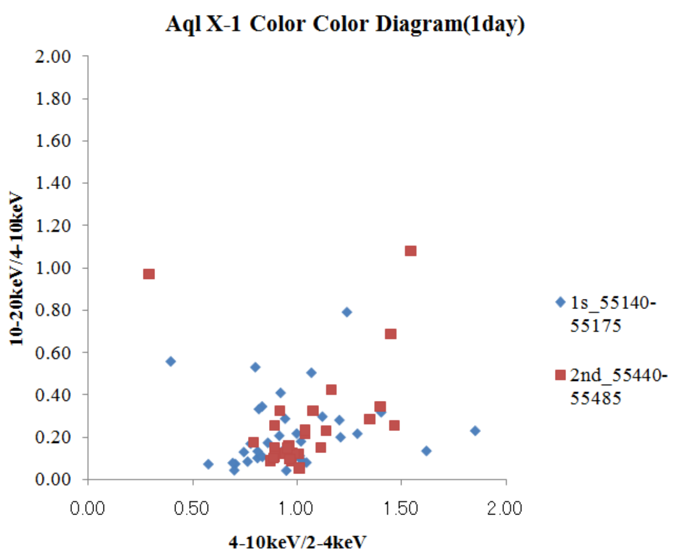

Fig. 11. Color-color diagram of Aql X-1. The diagram shows that the evolution of the outburst is different from that of J1752-223.

ful to calculate the HIDs and CCDs, which may be used to identify the spectral states and to study their time evolution. In fact, we could observe the transient sources throughout the outbursts with MAXI. Therefore, the MAXI archive data enable us to study how the spectral states change through the evolution of the outbursts. Because the sensitivity of MAXI is much higher than the previous all-sky monitors, e.g. RXTE ASM, more complete patterns may be observed in the HIDs and CCDs.

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