Outburst of LS V +44 17 detected by MAXI, RXTE, Swift

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Abstract

We report the discovery of a dip structure in the pulse profile of Be/X-ray binary LS V +44 17 observed by RXTE during an outburst detected by MAXI on 2010 March 31. The outburst was first transient activity of LS V +44 17 since 1997 when the source was identified as a Be/X-ray binary. After the discovery with MAXI, the RXTE observations provided a pulse profile with the narrow dip structure in the soft X-ray band (3–10 keV). Our phase-resolved spectroscopy showed that the accretion column density at the dip phase is much higher than those at the other intervals. Thus we can conclude that the partial eclipse of the emission region by the accretion column of the neutron star causes the dip structure in the pulse profile of LS V +44 17 during the first outburst.

Key words: stars: neutron — stars: pulsars: individual: LS V +44 17 — stars: binaries: general — X-rays: bursts — X-rays: individual: LS V +44 17

1. Introduction

The accreting pulsar LS V +44 17 is one of Be/X-ray binaries consisting of a neutron star (a pulsar) and a Be companion star. Be/X-ray binaries typically show periodic and/or non-periodic outbursts which are thought due to a matter accretion from the circumstellar disk of the Be star to the neutron star. LS V +44 17 was discovered during the ROSAT all-sky survey (Motch et al. 1997). Reig & Roche (1999b) performed the RXTE observation and obtained the sinusoidal pulse profile with 202.5 ± 0.5 sec period. They concluded that LS V +44 17 was classified into one of persistent Be/X-ray binaries which show no outburst and low luminosity ($\leq 10^{34-35}$ergs s^{-1}).

1.1. MAXI discovered an outburst

MAXI (Matsuoka et al. 2009) has been monitoring the flux of LS V +44 17 since 2009 August. Fig. 1 shows the light curve of the source obtained by MAXI/GSC (Gas Slit Camera, 2–20 keV) from 2009 August 15 to 2010 December 30. On 2010 March 31, MAXI detected an outburst of LS V +44 17 and reported it as the first transient activity for the source (Morii et al. 2010). The X-ray flux increased for a week and finally reached ∼150 mCrab in the 2–20 keV band.

1.2. RXTE observation

Following the detection, Rossi X-ray Timing Explorer (RXTE) confirmed the outburst on 2010 April 6 (Finger & Camero-Arranz 2010) and carried out other observations on April 12 and 15 (the epochs of these observations, Obs.A, B and C, are shown in Figure 1). RXTE provided the data in the 2–60 keV band with Proportional Counter Array (PCA) and 15–250 keV with High-Energy X-ray Timing Experiment (HEXTE).

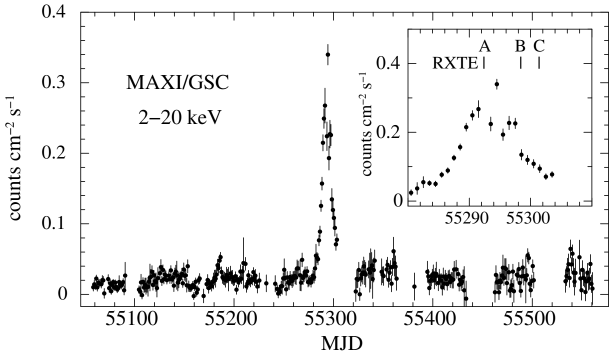

Fig. 1. MAXI/GSC light curve of LS V +44 17. The count rate corresponding to the flux of Crab is 2.5 count cm^{-2} s^{-1}.

2. Analysis and Results

2.1. Timing Analysis

We estimated pulse periods from the RXTE/PCA light curves after appliying barycentric correction. Performing epoch folding search, we obtained $\sim$ 205 sec pulse periods of LS V +44 17 during the outburst.

Folding with this period, we obtained energy-resolved pulse profile of the PCA observation as shown in Figure 2 which corresponds to Obs.A. Phase 0.0 was arbitrarily chosen to coincide with the minimum in the average

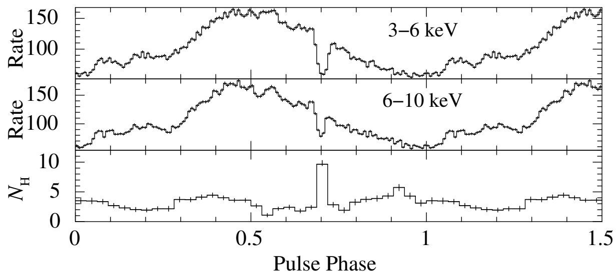

Fig. 2. Pulse profiles of LS V +44 17 in the 3–6 (top) and 6–10 (middle) keV bands in Obs.A and result of phase-resolved spectroscopy. The unit of accretion column density $N_{\rm H}$ is $\rm cm^{-2}$.

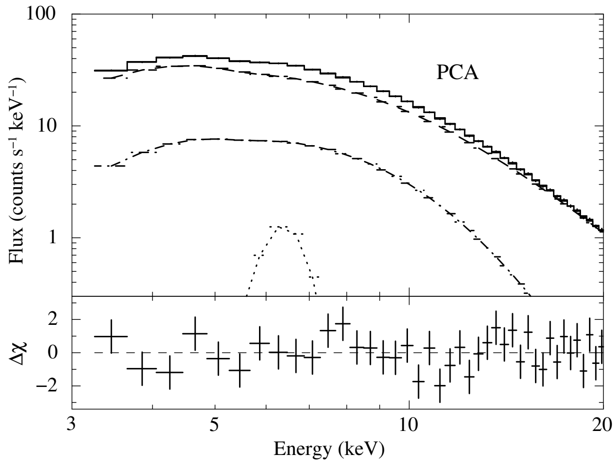

Fig. 3. PCA (3–20 keV) spectrum of LS V +44 17 observed in Obs.A. The solid line presents the best-model fit; a power-law (dash line) plus blackbody (dash-dot line) and a gaussian (dot line). The residuals are shown in the lower panel.

PCA pulse profile. Notable point is that a narrow dip structure can be seen at phase 0.7 in Figure 2. The dip appeared only in the soft energy bands (3–6 and 6–10 keV), but not in the hard band (10–20 keV). Such dip structure was reported for some Be/X-ray binaries and can originate from a local absorption with higher density matter, such as an accretion stream (Čemeljić & Bulik 1998).

2.2. Phase-Average Spectroscopy

At first, we carried out phase-averaged spectroscopy for the three RXTE observations. We used a power-law model with an exponential cut-off plus a blackbody and a Gaussian function corresponding to an Fe emission line. Figure 3 represents the PCA spectrum and the fitting result; the power-law index $\alpha = 1.15 \pm 0.04$ and accretion column density $N_{\rm H} = 3.3 \pm 0.3 \times 10^{22}$ $\rm cm^{-2}$), where error corresponds 1σ, with reduced $\chi^2/{\rm d.o.f.} = 1.10/116$.

2.3. Phase-Resolved Spectroscopy

In order to confirm the picture of the dip origin as mentioned above, we performed pulse phase-resolved spectral analysis for the observation. We used the same spectral model of the phase-average spectroscopy, where the photon index, the blackbody temperature and the peak energy of Fe line were fixed to the values obtained with the phase-averaged analysis. Figure 2 shows the phase dependence of accretion column density. You can see the highest absorption column density at dip phase, which supports the physical picture of the dip origin.

3. Discussion

According to Figure 2, the pulse profile obtained on 2010 April 6 had the dip structure. Similar sharp dips have been seen in the pulse profiles of the some Be/X-ray binaries (e.g. A 0535+262 and RX J0812.4−3114). The origin of the dip has been considered as an accretion flow eclipses (Čemeljić & Bulik 1998, Galloway et al. 2001). In this picture the X-ray emission originating on the surface of the neutron star is reprocessed by the accretion flow when it passes through the line of sight as the star rotate. Čemeljić & Bulik (1998) modeled the emission from a neutron star considering the accretion flow eclipse and reconstructed the pulse profiles of A0535+262. Galloway et al. (2001) showed phase-resolved spectroscopy which had the maximum of optical depth and absorption column density at dip phase of GX 1+4 and RX J0812.4–3114. They argued that the results confirmed the dip origin which was the partial eclipse by the accretion column. Our result shows that the column density is the highest at the dip phase (Figure 2). This result is consistent with the model proposed for the three binary systems, indicating that the accretion column eclipse affects the pulse profile of LS V +44 17 and generates the dip structure.

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