Analysis a new activity of the Be X-ray pulsar A 0535+26

Motoki Nakajima[1] on behalf of the MAXI team

[1] School of Dentistry at Matsudo, Nihon University, 2-870-1, Sakae-cho Nishi, Matsudo-City, Chiba, Japan
E-mail: nakajima.motoki@nihon-u.ac.jp

Abstract

We report on the analysis results of the current 2008–2010 X-ray activities of Be/X-ray transient pulsar A 0535+26 observed with MAXI/GSC. From 2008, the source again re-entered an active phase showing the periodic X-ray outbursts. In the current activities, the precursor events have been observed before the normal/giant outbursts. The present precursor and outburst period is 115-days instead of the 110-day oribital period. This difference would be related to the structure of the circumstellar disk of the companion Be star.

Key words: pulsars: individual(A0535+26) — X-rays: binaries

1. Introduction

A 0535+26 is one of the well studied Be/X-ray transient system which contains a highly-magnetized neutron star ($B \sim 5.2 \times 10^{12}$G ; Cabballero et al. 2008) and a O9.7 IIIe optical companion (Giangrande et al. 1980). The neutron star in this system was discovered by the Ariel V satellite (Rosenberg et al. 1975) when the source exhibited a large X-ray ouburst. A ∼104 sec pulsations were found subsequently to its discovery. Following the pulse detection, monitoring observations were carried out by several observatories to investigate the pulse period evolutions. In addtion, the orbital parameters, such as the orbital period of 110.3±0.3 days and the eccentricity of $e = 0.47 \pm 0.02$, were determined (Moritani et al. 2010 and references therein).

Since the discovery of A 0535+26, a number of normal outbursts (or type-I outburst) and 7 giant outbursts (or type-II outburst) have been observed so far. It is well known that the type-I outbursts generally take place at periastron passages, whereas the correlation between the giant outbursts and the orbital phase is not well understood (Priedhorsky & Terrell. 1983). This unexpected large X-ray outburst might be related to the condition of the circumstellar disk of companion Be star. In this paper, we report on the X-ray activity of A 0535+26 started from 2008, and discuss a new periodicity of the giant outbursts.

2. X-ray Activity of A0535+26 in 2008–2010

After 3 years of quiescent state from the previous outbursts in 2005, the source re-entered an active phase since August 2008. Figure 1 shows the entire X-ray lightcurve of current activity observed by MAXI/GSC (Mihara et al. 2011) and Swift/BAT (Barthelmy et al. 2005). Swift/BAT have been monitoring the current activity since the source entered in a new active phase.

The 3 outbursts observed before MJD 55000 occurred at each periastron passage. Thus those observed events can be considered as type-I outburst. The outburst profiles were symmetric, while the 4th outburst on MJD 55050 exhibited double-peaked profile whose peak luminosities were almost in the same, ∼ 500 mCrab in 15-50 keV band. The interval of the two peaks is ∼ 10 days, and the periastron passage (MJD 55051) located in the trough of the double outburst. Althogh a similar double-peak event was observed in 2005 (Cabballero et al. 2008, Postnov et al. 2008), this double-peak outburst can be considered as a different phenomenon from the previous ones in the point of the event; the pre-outburst flare observed in 2005 lasted for only ≤ 1 day.

Following the double-peaked outburst, the small flux enhancement, "precursor", was found by MAXI/GSC and Swift/BAT on MJD 55131 and MJD 55147. The arrows in figure 1 represent the precursor positions. After these precursor events, the source exhibited the giant outburst peaking at MJD 55177. Comparing with the peak position of the previous normal (type-I) outbursts in the current activity, the peak of the giant outburst slightly shifted to the later in the orbital phase. Next to this giant outburst, the source again exhibited the large outburst on MJD 55291, and its peak position further moved to later in the orbital phase. The precursor event on MJD 55259 also appearred at ∼ 30 days before the peak of the second large outburst. Although Swift/BAT were not able to observe the source between MJD 55350–55380 due to the sun constraints, MAXI/GSC could cover the third precursor peaked on MJD 55378 and the peak position of the third precur-

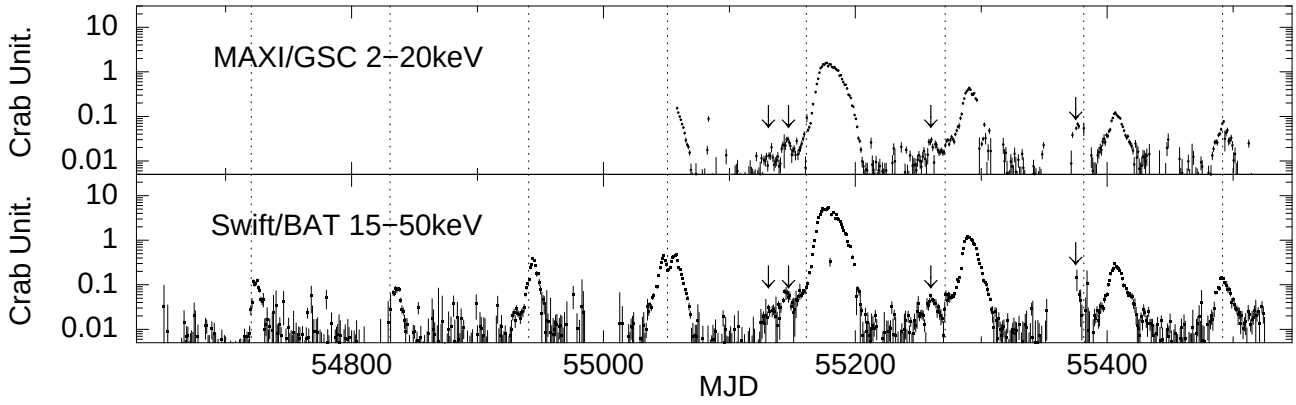

Fig. 1. The lightcurves of A 0535+26 acquired by MAXI/GSC(upper panel) and Swift/BAT (bottom panel). The vertical dotted lines denote the day of the periastrion passage. The arrow marks represent the precursor events.

sor on MJD 55378 and the ourburst on MJD 55407 also moved toward the later in the orbital phase as shown in figure 1.

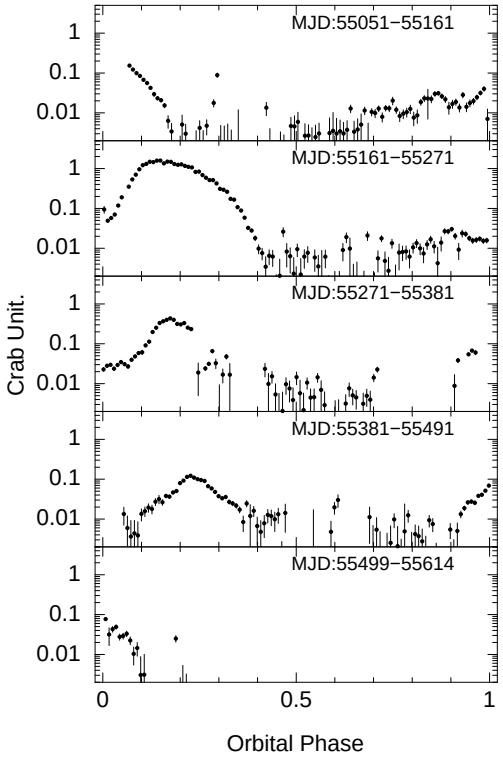

Fig. 2. Folded light curve of A 0535+26 observed with MAXI/GSC. 110.2 days orbital period is considered in this figure.

In order to examine the orbital-phase dependence of the precursors and the outbursts after MJD 55051, we folded the light curve with the orbital period 110.2 days (Moritani et al. 2010) as shown in figure 2. From this figure, we confirmed that the outburst peaks shifted to later orbital phase along the orbital revolutions. In addition, the precursors also moved to later orbital phase, and we found that the intervals between the precursors and the outbursts were ~ 30 days throughout this period. Next to the precursor and the outburst event on MJD 55407, the source exhibited only the normal outburst on MJD 55492.

3. Precursors and New Periodicity

As mentioned in the previous section, the ourburst periodicity was consistent with the orbital period 110.2 day till MJD 55000. After the double-peak outburst (MJD 55051), the source exhibited the precursor event. Moreover, the outburst peak shifted to the later orbital phase. Figure 3 shows the peak positions of the outbursts and the precursors on the orbital plane. As shown in this figure, all of the precursor and the outburst always locate in the opposite side, i.e. in the 180 degrees apart around the companion star. In addition, the peak position of the outburst/precursor shifted to later orbital phase of $0.01 \sim 0.04$ every orbit.

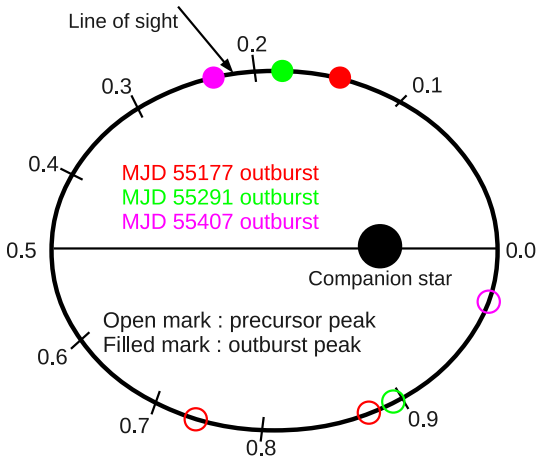

Fig. 3. Orbital geometry of A 0535+26. The open circles and filled circles represent the position of the precursor peak and those of main outburst respectively.

Since the systematic shift of the outburst/precursor peak positions were observed after the detection of double-peak outburst (MJD 55051), it can be considered that another period in X-ray activitiy would emerge in the current activity. Based on the change of the peak position of the outbursts/precursors, we introduce another X-ray acitivity period of 115-day. Same as figure 2, we folded the A 0535+26 light curve with new activity period of 115-day as shown in figure 4. From this figure, we found that all of peak position of the outburst come to the ~ 0.1 phase of 115-day period. In addition, the phase of each precursor peak is consistent at around ~ 0.83.

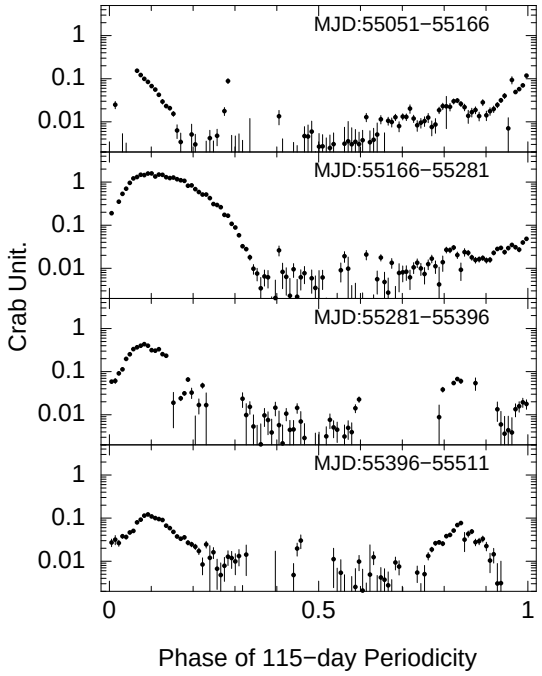

Fig. 4. Same as figure 2, but the lightcurves are folded with 115-days period.

The present X-ray activity observed by MAXI/GSC and Swift/BAT has exhibited a new periodicity of 115-day instead of its orbital period (110.3-day). Before the current X-ray activity, optical observations revealed that the period of the V/R variability associated with the one-armed oscillation in the equatorial disk of Be star changed when the source exhibited the large X-ray outburst (Negueruela et al. 1998). Since the X-ray activity is related to the orbital phase and the condition of the circumstellar disk of Be star, the present new periodicity might be related with the the density profile in the Be disk. Or, considering the fixed intervals between the precursor and the outburst, the tilted/warped circumstellar disk that probably emerged after the detection of the double-peak outburst (MJD 55051) would play an important role to produce such periodic precursor/outburst event. The detailed analyses and discussions will be appearred in the forthcoming paper.

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