MAXI observation of Crab pulsar during the gamma-ray flare in September 2010

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Abstract

We report on the MAXI monitoring of Crab nebula during the GeV gamma-ray flare on September 18-20 detected by AGILE and Fermi-LAT. There were no significant changes on the nebula flux and the pulsed flux during the flare. There was also no significant changes in the pulse profile at that time. The variation of the pulse-phase-averaged flux and the pulsed flux on the flare duration were less than 2% and 10% (1 sigma level) in 4−10 keV band, respectively. The lack of variations in the pulsed component in multi-wavelength supports the nebula origin for the gamma-ray flare.

Key words: stars: neutron — stars: pulsars : individual (Crab) — X-ray: individual (Crab)

1. Introduction

The Crab nebula has been the standard candle of high energy X-ray and gamma-ray astronomy. The X-ray and gamma-ray fluxes and spectra have been believed to be stable for a long time scale of years. Surprisingly, AGILE and Fermi-LAT reported a flare on September 18−20, 2010 in GeV gamma-ray energy range (Tavani *et al.* 2011, Abdo *et al.* 2011). RXTE-ASM, Swift-BAT, INTEGRAL did not detect variation for the pulse-phase-averaged flux (Markwardt *et al.* 2010). Radio observation showed no evidence for a glitch, and no changes of pulsed flux and pulse profile shape (Espinoza *et al.* 2010).

Swift-XRT and RXTE-PCA follow-up observations did not detect any changes of flux, spectrum and pulse profile (Evangelista *et al.* 2010, Shaposhnikov *et al.* 2010). Chandra and HST follow-up observations found some activated region around the nebula (Tavani *et al.* 2011). Recently, two more GeV flare episodes, happened on October 2007 and February 2009, were reported by AGILE and Fermi, respectively (Tavani *et al.* 2011, Abdo *et al.* 2011).

2. Observation

MAXI (Monitor of All-sky X-ray Image) is the best sensitive all-sky X-ray monitor on ISS (Matsuoka *et al.* 2009). MAXI has two types of X-ray cameras: the Gas Slit Camera (GSC; Mihara *et al.* 2011, Sugizaki *et al.* 2011) for 2−30 keV band and Solid-state Slit Camera (SSC; Tsunemi *et al.* 2011) for 0.5−12 keV band, using gas proportional counters and X-ray CCDs, respectively. MAXI/GSC scans almost all sky every 92 mins by a transit duration about 1 min. The time resolution of GSC is less than 0.2 ms (Sugizaki *et al.* 2011). MAXI has been monitoring the Crab nebula since the start of the operation on August 15, 2009 (UT), including the whole duration of the gamma-ray flare on September 2010. Here, we report on the MAXI monitoring of the Crab nebula during the GeV gamma-ray flare. The details will be shown in Morii *et al.* (2011) in the near future.

3. Light curve and pulse profile

To measure the pulse-phase-averaged flux, we extracted the circular source region in the sky coordinate and subtracted the background counts from the near-by region as done in the usual photometry method. To measure the pulsed flux, we proceeded the following steps. At first, the times of events were barycentric-corrected. The time sequence was folded in the pulse period of Crab pulsar provided at the web site of the Jodrell Bank radio observatory (Lyne *et al.* 1993). In this folding, the time variation of effective area and exposure times were corrected (Morii *et al.* 2006, 2010). We fitted the pulse profiles with a model of $a \times T + b$, where T was a template pulse profile made from the data from December 13, 2009 to January 11, 2010, and the baseline offset of un-pulsed component was subtracted from the all phase bins. From this fit, we obtained the pulsed flux

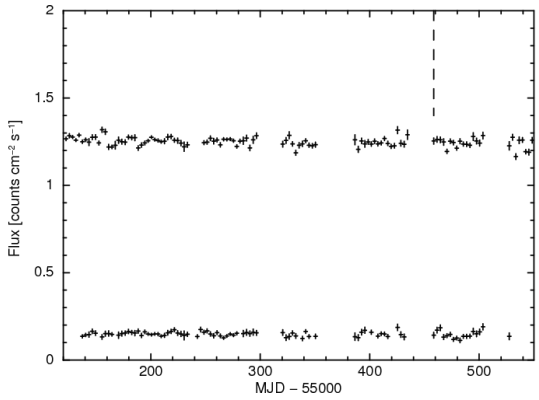

Fig. 1. The light curve of the Crab in 4 - 10 keV: The upper and lower data points represent the pulse-phase-averaged and pulsed fluxes, respectively. The vertical dashed line denotes the time of the gamma-ray flare.

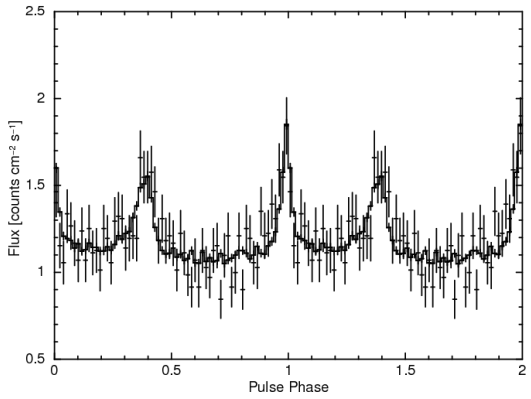

Fig. 2. Pulse profile of the Crab pulsar during the gamma-ray flare in 4 - 10 keV, which is compared with the template pulse profile (solid histogram).

by $F_{\rm pulse} = a \sum_i T_i/N$.

Figure 1 shows the light curves of the pulse-phase-averaged and pulsed fluxes in 4−10 keV band. There is no significant flux change on the gamma-ray flare duration within the uncertainty of the light curve. Therefore, the variation of the pulse-phase-averaged and pulsed fluxes on the flare duration were constrained to be less than 2% and 10% (1 σ level) in 4−10 keV band. The pulse profile during the flare was shown in Figure 2.

4. Summary

We reported on the MAXI/GSC observation of the Crab pulsar during the gamma-ray flare. It is the only report showing the pulse profile and pulsed flux of the Crab pulsar on the whole duration of the gamma-ray flare in the X-ray band. The lack of the changes on the pulsed component in multi-wavelength supports the nebula origin for the gamma-ray flare.

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