Quick Follow-up Observation of the Largest X-ray Flare from the TeV blazar Mrk 421

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Abstract

We carried out the VLBI follow-up observations of the largest X-ray flare from Mrk 421, which was detected in Feb 16, 2010 with MAXI (ATel #2444), using the Japanese VLBI Network array. It is usually expected that the delayed increasing of the flux density in the radio band be seen after the high-energy flare. In order to examine it, a quick VLBI follow-up observation is essential. Here we report that the VLBI follow-up observation for the largest flare at the first epoch was carried out Mar 7, 2010, which is 19 days after the detection of X-ray flare with MAXI. The observations at the total of five epochs were done using JVN array at approximately 20-day intervals. Through the follow-up observation of Mrk 421, a significant radio flux variation was not seen. We discuss an adiabatic expansion loss by setting an upper limit on the decay time from radio observations.

Key words: BL Lacertae objects: individual (Mrk 421) — galaxies: active — galaxies: jets

1. Introduction

MAXI detected X-ray flare from Mrk 421 on Feb 16, 2010 (Isobe et al. 2010a, Isobe et al. 2010b). Its X-ray flux increased to 164 ± 17 mCrab (1.5 - 10 keV). Also, the VHE gamma-rays with the maximum VHE flux exceeding the 10 Crab level, detected on 2010 February 17 (MJD = 55244) by the VERITAS Observatory (Ong et al. 2010).

Mrk 421, which is known as the first extragalactic TeV gamma-ray source, is located at z = 0.031 (1 mas $\sim$ 0.61 pc). By carrying out the follow-up observations of the flare with VLBI, we purpose to obtain the VLBI image with mas scale, and to determine 1). the time scale of adiabatic cooling from rise/decay of the radio counterpart to the flare, 2). the physical parameters of Mrk 421 from multi-frequency data (in prep.). Referring to the previous studies in which they carried out follow-up observations of high-energy flare of blazars with VLBI (Piner et al. 2005, Marscher et al. 2008), it is necessary to do follow-up with VLBI as soon as possible and several observations at the interval of a few weeks.

We report on the result of VLBI observation and discuss the case of 1). an adiabatic cooling.

2. Observation / Analysis

We carried out the follow-up observation of X-ray flare from Mrk 421 using the Japanese VLBI network (JVN) array, at 22 GHz with 256 MHz bandwidth. The JVN is a VLBI array with baselines ranging from 50 to 2560 km spread across the Japanese islands. Three observing bands of 6.7, 8.4, and 22 GHz are now available (Doi et al., 2007).

In analyzing procedure, we carried out calibration, fringe-fitting using the NRAO Astronomical Image Processing System (AIPS), and obtained naturally weighted images using standard CLEAN and phase self-calibration procedures from the DIFMAP software package. We flagged out the data of several antennas at each epoch, because the fringe finder 4C 39.25, which has strong correlated flux at 22 GHz (several Jy), for the some baseline including them did not detect [1].

*1 The flux density of 4C 39.25 is strong sufficiently for all baselines of our array configuration

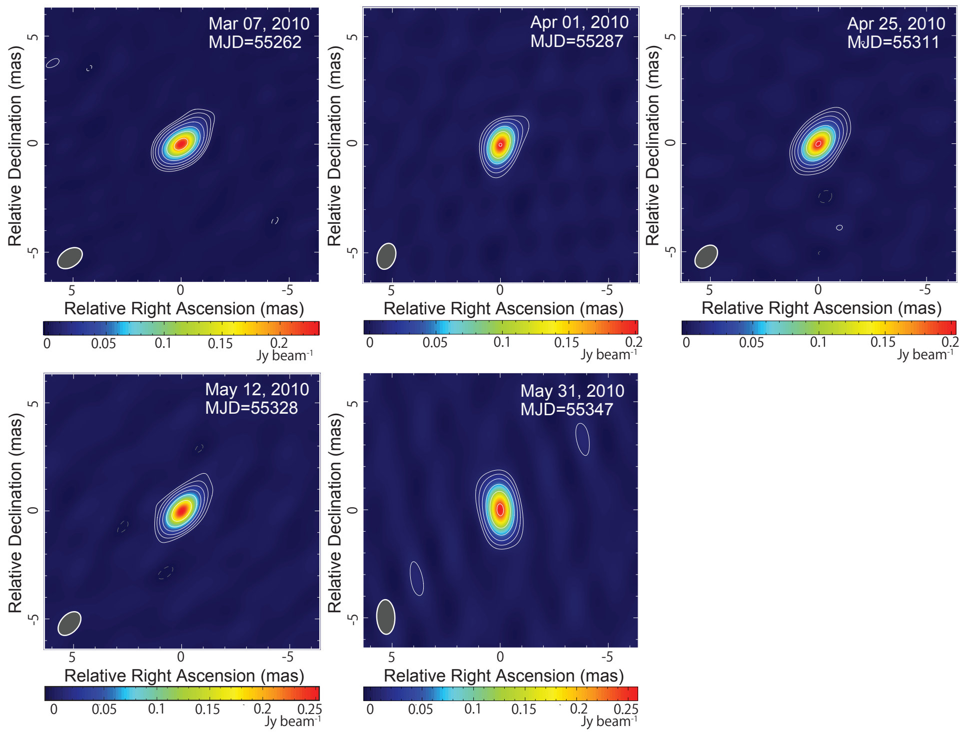

Fig. 1. VLBI images of Mrk 421 at 22 GHz. the lowest contours are set to 3 times the rms noise in the images. Each contour is a factor of 2 higher.

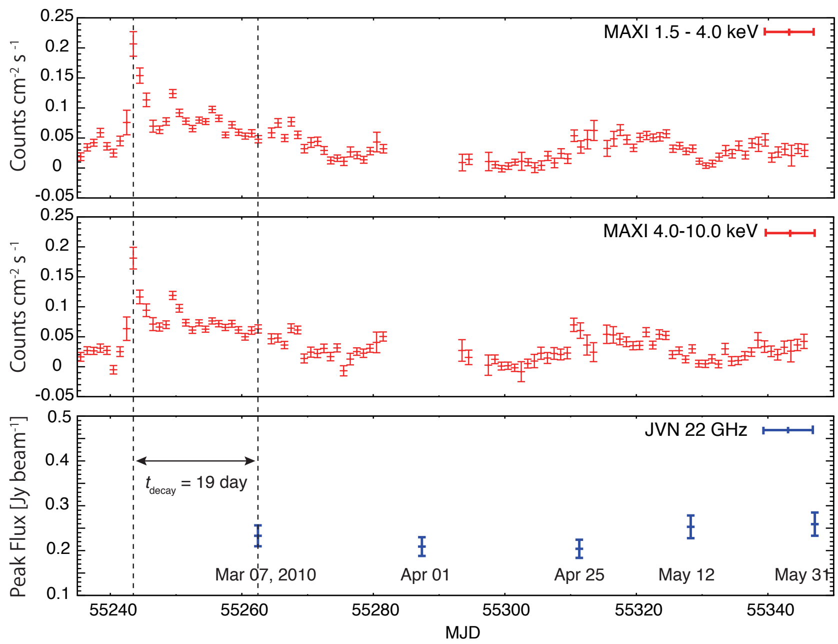

Fig. 2. The light curves of Mrk 421 at X-ray (MAXI 1.5-4.0 keV, 4.0-10.0 keV band, MAXI web site) and radio (JVN 22 GHz:our follow-up) are arranged from Top to Bottom. Feb 16, 2010 (MJD=55243; the day when X-ray flare detected with MAXI) and the 1st epoch of our follow-up observation with VLBI (MJD=55262) are marked by vertical dotted line.

Table 1. The result of follow-up observation.

Epoch [UT] (MJD)	Antennas*1	Synthesized beam Major [mas]	Minor [mas]	PA [deg]	Peak Flux (err) mJy beam^{-1}	Image rms noise [mJy beam^{-1}]
Mar 07, (55262)	M, I, O, S	1.26	0.82	-56.2	233 (23)	1.00
Apr 01, (55287)	M, I, O, S	1.08	0.75	-41.1	209 (21)	2.08
Apr 25, (55311)	M, I, O, S	1.24	0.84	-43.5	204 (20)	1.03
May 12, (55328)	M, I, O, S	1.28	0.82	-42.2	253 (25)	1.60
May 31, (55347)	I, O, S	1.60	0.84	2.3	259 (26)	2.49

*1: JVN Antennas related with several baselines for which the fringe of calibrator was detected are indicated here. "M" is Mizusawa, "I" is Iriki, "O" is Ogasawara, and "S" is Ishigaki-jima

*2: 1 sigma errors are defined as 10 % of the Peak Flux measured at each epoch

3. Result

We show VLBI images of Mrk 421 in Figure 1, and the results of analysis are summarized in Table1. Also, the light curves at radio wavelength (JVN at 22 GHz) and at X-ray observed by MAXI are indicated in Figure 2.

In Figure 1, the structure of jet are shown in the north-west direction. However, through the follow-up observations, a radio counterpart that was expected to be associated with X-ray flare, or the significant peak flux variation were not seen at all epochs.

4. Discussion / Summary

A significant radio flux variation related with X-ray flare was not seen. So, we estimated that the decay time in radio band (22 GHz) $t_{decay} \sim 19$ day (1.6×10^6 sec) from light curve (Bottom panel of Figure 2). The time scale of synchrotron cooling t_{sync} in radio band is much longer than in X-ray. Especially, in 10 GHz, if we consider that the synchrotron radiation cooling is dominant, t_{sync}, 10 GHz need to be the order of 103 day. However, an upper limit on the decay time from our follow–up observation of the flare is 19 day. So it would appear that an adiabatic loss was dominant in radio band. For the February flare, the emission region R_0 was estimated as $R_0 \leq 4.0$ x 10^{16} cm from the result of MAXI. Assuming that the emission region expanded adiabatically to $R = 2R_0$ after 19 days at the constant velocity, the expanding velocity is calculated as ≤ 2.4 x 10^{10} cm s^{-1}. It seems that this value is too large for an expanding velocity, because it exceeds the velocity of sound. So, there are possibilities that the R_0 is narrower than estimated above, or t_{decay} is longer than our estimation.

We are grateful to collaborators of all the JVN stations for their assistance and operations in observations.

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