The 22/43GHz polarization monitoring of a flaring gamma-ray blazar 3C 454.3 after its 2010 November outburst

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After 19 November 2010, a flaring gamma-ray blazar, 3C 454.3 shows the decrease of fractional polarization at 22 GHz by a factor of 5 in 30 days and the gradual increase of total flux density at 22 and 43 GHz by 10 %.

ABSTRACT

We report the results of the monitoring of a flaring gamma-ray blazar, 3C 454.3 in total flux density at 22 and 43 GHz and in polarization at 22 GHz with KVN Ulsan 21-m radio telescope every 3-4 days from 19 November 2010 to 31 January 2011. After an extraordinary 5-day gamma-ray outburst in November 2010, the radio total flux density at 22/43 GHz has been increased and the linear polarization at 22 GHz decreased with a variation of a short time scale. The flux density has decreased and the spectral index has changed after ~80 days since the flaring peak.

A flaring gamma-ray blazar 3C 454.3

A flat-spectrum radio quasar (z=0.859), 3C 454.3 has experienced a gamma-ray flaring in November, 2010 (Abdo et al. 2011). The flaring indeed was an extraordinary 5-days gamma-ray outburst during 17-21 Nov. 2010 (MJD=55517-55522) as shown in Figure 1. The daily flux measured with Fermi LAT is a factor of 3 higher than the flare in Nov. 2009, and even more than 5 times brighter than the Vela pulsar (Abdo et al. 2011).

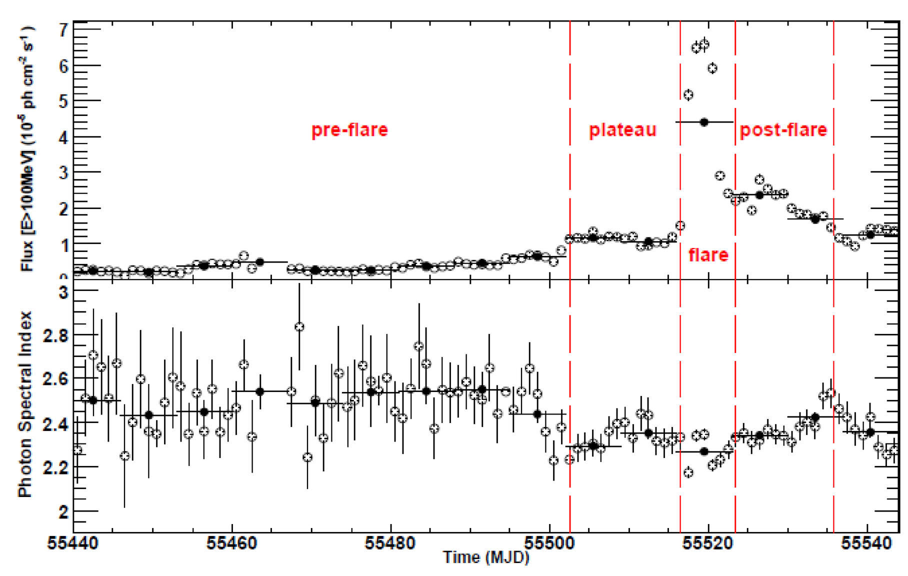

Figure 1. Light curve of the flux F100 (top) and Γ (bottom) for a 103-day period including both the slowly increasing flux phase, the plateau, the flare and the post-flare. The open and filled symbols correspond to daily and weekly averaged quantities respectively. Error bars are statistical only.

Korean VLBI Network 21-m radio telescope

The Korean VLBI Network (KVN) project aimed to build the first millimeter-dedicated VLBI network in Korea. KVN has a unique observing system, simultaneous multi-frequency observing system at up to four frequency bands, 22, 43, 86, 129 GHz. A new millimeter-wave receiver optics system with three frequency selective surfaces (dichroic filters) is an essential fact of the unique system (Han et al. 2008). The KVN antennas are shaped Cassegrain antennas with an alt-az mount. The characteristics of the antenna systems are summarized in Table 1 (Lee et al. in prep.).

KVN receivers at 22 and 43 GHz bands have been constructed at Korea Astronomy and Space Science Institute (Figure 2). They cover the frequency bands of 21.25-23.25 GHz and 42.11-44.11 GHz, respectively. They are dual polarization with circularly polarized feed horn and are cooled HEMT receivers.

Figure 2. Korean VLBI Network 21-m radio telescope in Ulsan, Korea.

Table 1. Specification of KVN antenna

General performance	
Workable frequency(GHz)	20-150 GHz
Aperture efficiency	50-70%
Pointing accuracy	4" @wind10m/s
Mounting	AZ/EL type
Optics (shpaed cassegrain)	
Main Reflector (axisymmetric paraboloid)	
diameter	21 m
focus length	7 m
focal ratio	0.35
Subreflector (hyperboloid)	
diameter	2.25 m
focal length	37 cm
surface accuracy	50 μm
effective focal ratio	4
Blockage	
HPBW	133" @22 GHz
	67" @43 GHz

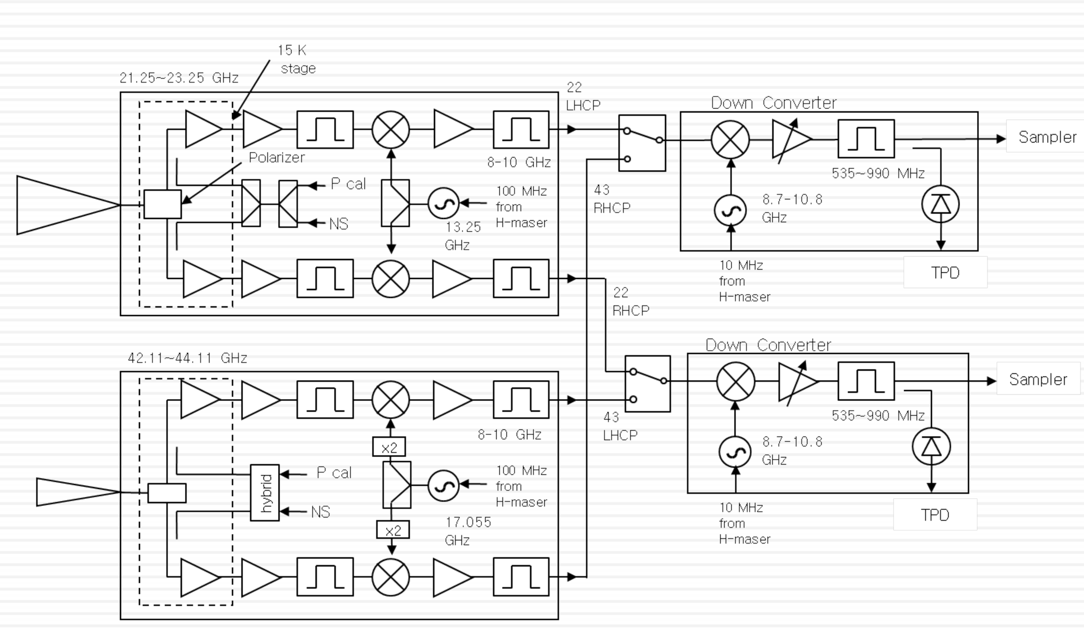

Figure 2. Schematics of KVN receivers at 22 and 43 GHz bands.

Monitoring of polarization at 22/43 GHz

We have monitored the source every 3-4 days since 19 Nov. 2010 for 70 days with using the Walsh position switching mode for removing sky fluctuation. In polarization observations, Stokes I, Q, U, V measurements were done with KVN DAS (Data Acquisition System) (Oh et al. in prep.). The total bandwidth for the observations is 512MHz.

Instrumental polarization was calibrated by observing 3C 84 and Jupiter once per day. Polarization angle was referenced with measuring the polarization angle of CRAB nebula once a day. A standard polarization calibrator, 3C 286 was observed once per month for checking the calibration consistency.

Results of the monitoring

Degree of polarization at 22GHz

The light curve of the degree of polarization at 22GHz is displayed in the upper panel of Figure 4. After the peak of the gamma-ray flaring (MJD=55520), the degree of polarization at 22GHz decreased by a factor of 5 from ~2.2% in about 30 days. A weak variation of the fractional polarization is preceded after the least polarization. It is also interesting to see a 5-day long plateau after the peak.

Polarization angle at 22GHz

The polarization angle at 22GHz is shown in the middle panel of Figure 5. For the period of 70 days, the polarization angle changes by ~60 degrees. Short-time variations are also shown. The angle is not absolute, since the data are not completely referenced to CRAB nebula yet.

Stokes I at 22GHz and total power at 22 and 43 GHz

Stokes I at 22GHz gradually increased by ~ 10% as shown in the bottom panel of Figure 4. This is also seen in the light curves of total power at 22 (blue) and 43GHz (green) in the upper panel of Figure 5, which has been measured up to 110 days after the flaring peak. The flux density of the source seemed to peak at around 55600 days and started to decrease.

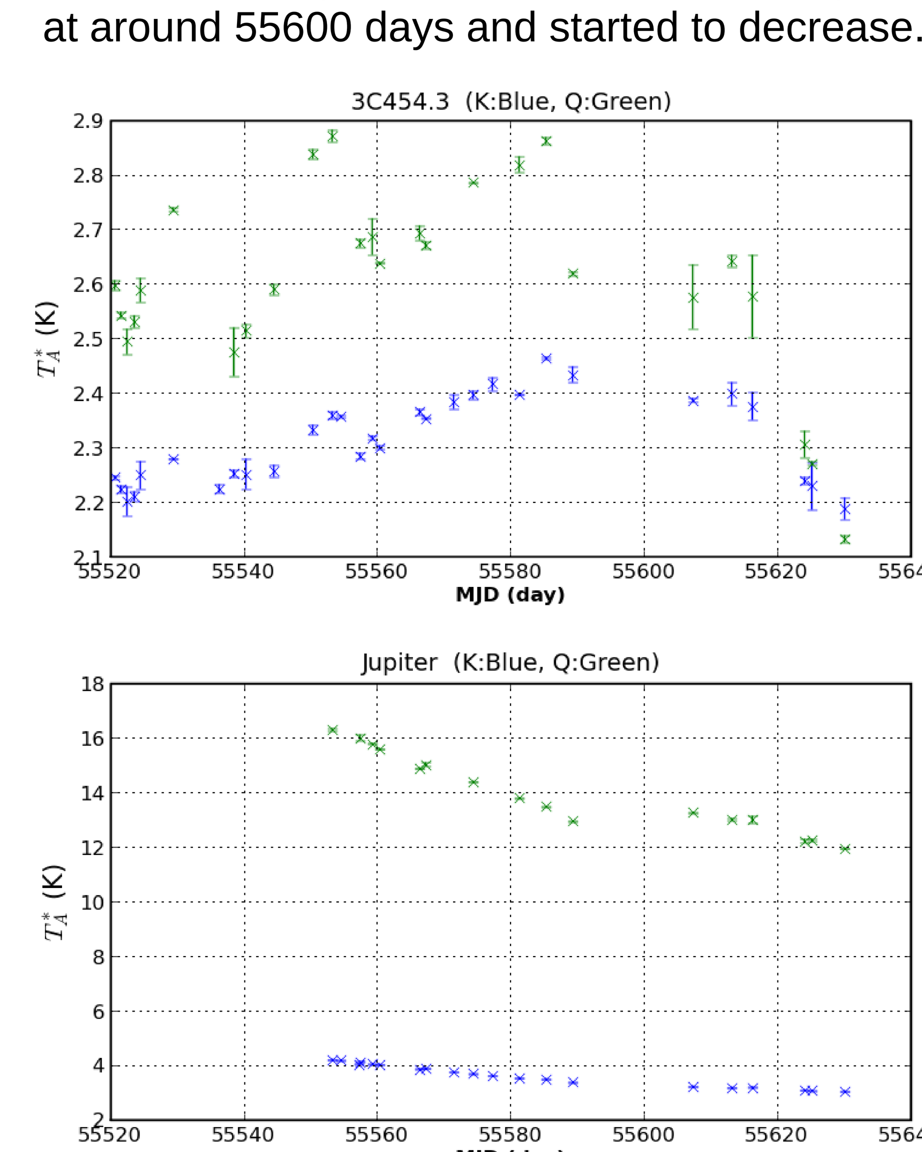

Figure 5. Light curves of the total power at 22 (blue) and 43 GHz (green) for 3C 454.3 (Top) and Jupiter. Error bars are statistical only.

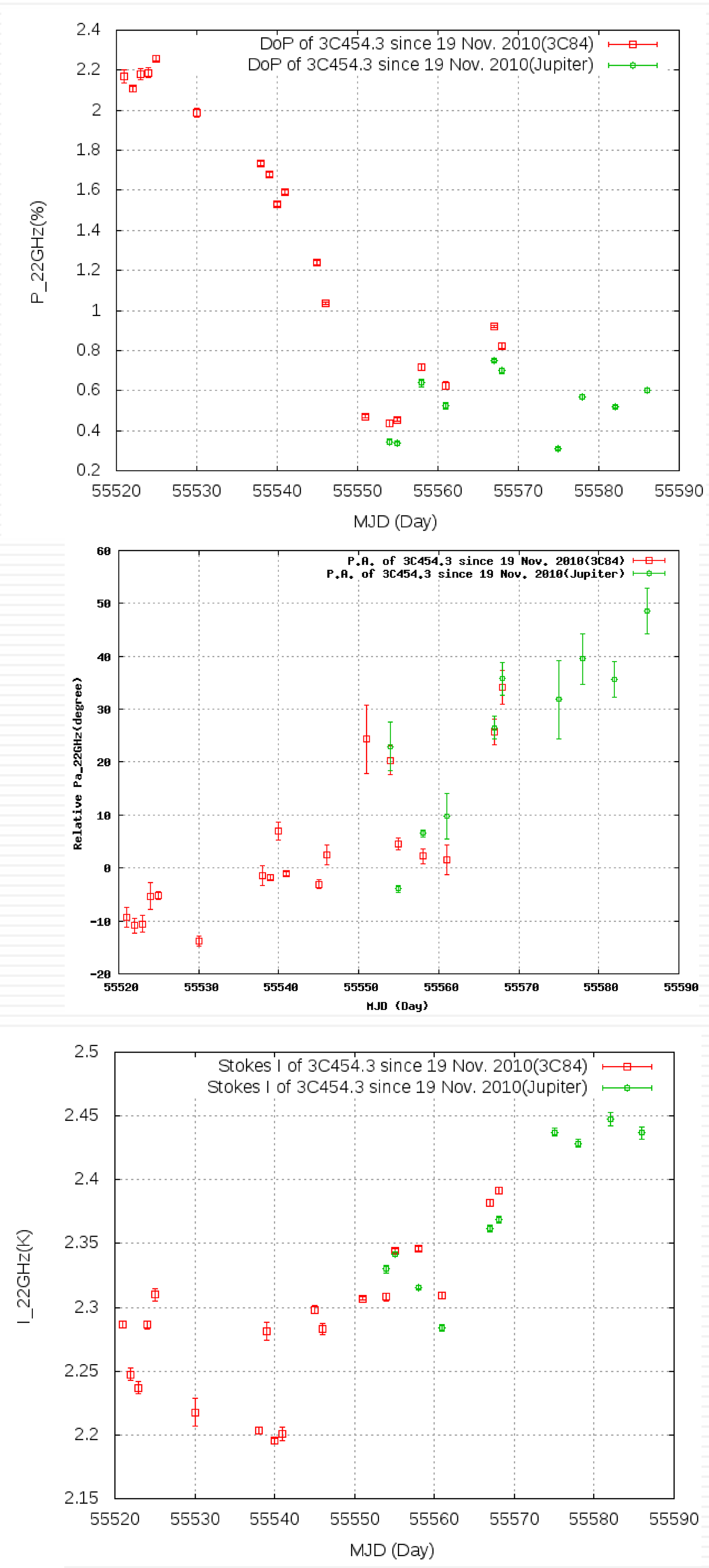

Figure 4. Light curve of the degree of polarization (Top), relative angle of polarization (Middle) and Stokes I (Bottom), at 22.4 GHz for a 70-day period. The red square and green circle symbols correspond to data calibrated with 3C 84 and Jupiter respectively. Error bars are statistical only.

Spectral index evolution

In this preliminary result, we also see the evolution of possible spectral index between 22 and 43 GHz. It is obvious that the spectral index of the source has changed after the peak of the flux density.

References

Abdo et al. 2011, arXiv:1102.0277
Han, S.-T. et al. 2008, IJIMW, 29, 69
Lee, S.-S. et al. in prep.
Oh, S.-J. et al., in prep.

Summary

We monitored the flaring gamma-ray blazar, 3C 454.3 in total flux density at 22 and 43 GHz and in polarization at 22 GHz with KVN Ulsan 21-m radio telescope every 3-4 days from 19 November 2010 to 31 January 2011. After an extraordinary 5-day gamma-ray outburst in November 2010, the source shows the decrease of fractional polarization at 22 GHz by a factor of 5 in 30 days and the gradual increase of total flux density at 22 and 43 GHz by 10 %. The flux density has decreased and the spectral index has changed after ~80 days since the flaring peak.