Mutiwavelength analysis of 3C 279 : Two scenarios to explain light-curves

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ABSTRACT

Blazars are active galactic nuclei with relativistic jets aligned to Earth and bright in the entire electromagnetic wavebands. The broadband emission is believed to be produced in the jets until now there is no complete picture of blazar behavior. Thus, multi-wavelength data may give us hints towards the mechanisms of the emission, such as flaring, occurring within the jet, and so contemporaneous broadband observations are key to understanding blazar physics. 3C 279 is a very bright blazar and exhibits frequent gamma-ray flares. This source has shown long-term variability in radio band since 2010 and more recently explosive activities at gamma rays. We have made contemporaneous radio observations of the source using KVN, and here we present our analysis results of the KVN radio data archival data in other bands, and discuss two scenarios that could describe the behavior of the light-curves in 3C 279.

1. Introduction

variability is one of properties often observed from blazars. While many of research has been focused on short periods of change in the high-energy bands(e.g., γ-ray), some blazars exhibit long-term periods of variation in the radio bands(Dermer and Giebels. 2016, Hovatta et al, 2008). The recent behavior of 3C 279 was a rare case among them in radio band(Hovatta et al, 2008), and we would like to talk about the analysis results considered with two scenarios to account for this change in 3C 279. (1) A large flare drives the change of the light curve. (2) The overlap of the small flares results in changes in the light curve.

2. Data

Owens Valley Radio Observatory (OVRO) is a 40m single-dish radio telescope with an observing frequency of 15 GHz. Observation data monitoring over 1800 blazars are available on the web at (www.astro.caltech.edu/ovroblazars/).

Korean VLBI Network (KVN) is a radio interferometer operated by Korea and consists of 21m 3 telescopes. Four frequency simultaneous observation is possible, and the observing frequency is 22/43/86/129Ghz. The KVN single-dish observation, Monitoring of Gamma-ray Bright AGNs (MOGABA) data (Kang et al , was used to compare interferometric MOGABA (iMOGABA) data, and OVRO and iMOGABA data were used for spectral analysis.

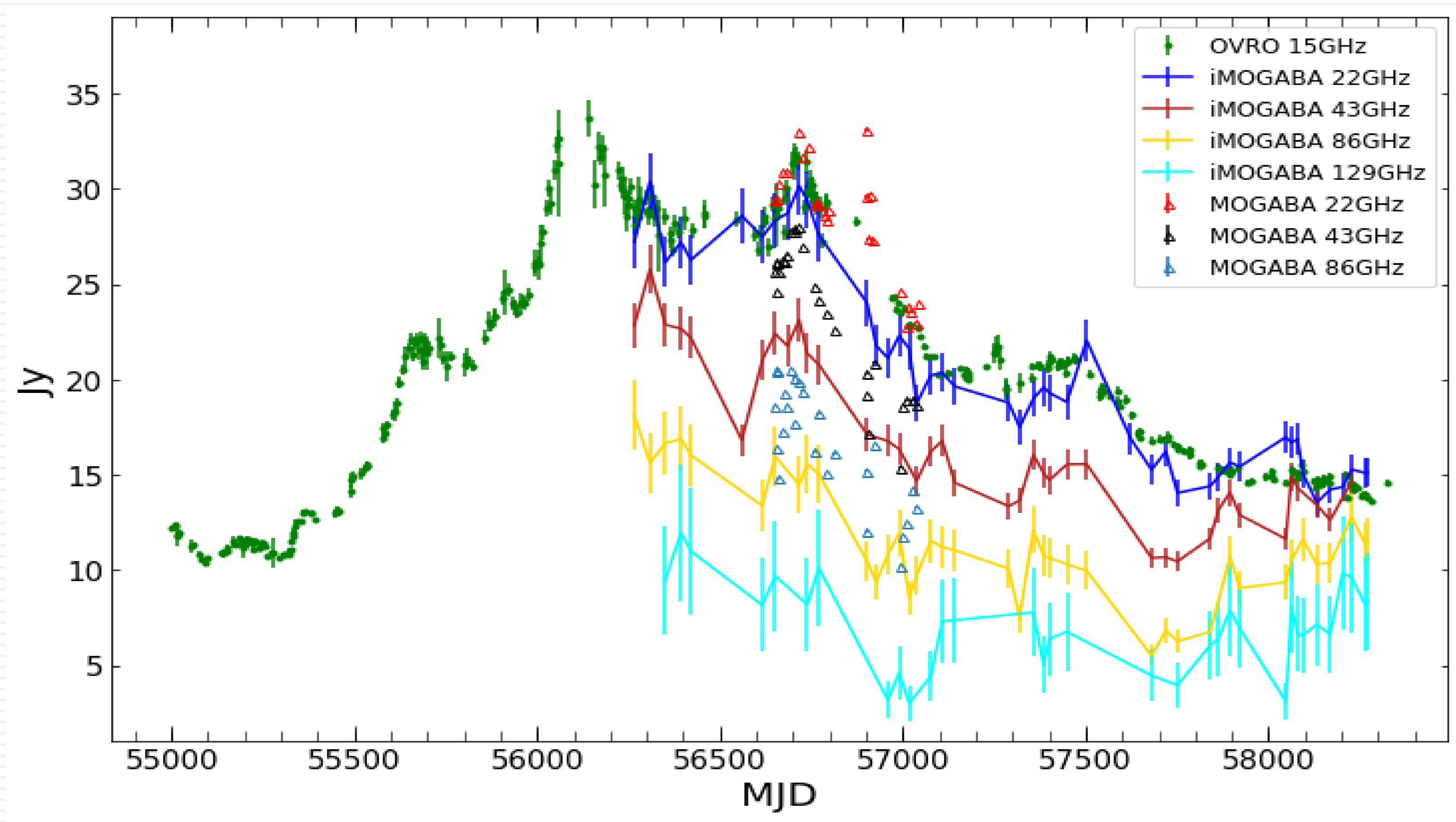

Figure 1. Light curve of 3C 279. MOGABA data was reported by Kang et al. 2015

3. Results and Analysis

3-1 First scenario : A large flare drives the change of the lightcurve

- Large trends up to MJD 57750 correspond to decay in the evolution of shock
- Considering observing frequency, It is difficult to specify the peak frequency within the observing frequency range.
- Comparison with other studies of the same method (Figure 3, bottom) :
  - Valtaoja et al. 1992 : -0.26$\pm$0.08
  - Hovatta et al. 2008 : -0.24
  - model prediction: -0.2
- There are flux difference between single-dish(MOGABA) and VLBI (iMOGABA) observation.

3-2 Second scenario : The overlap of the small flares results in changes in the light curve.

- Twenty flares were decomposed using the OVRO data.
- Variation of the viewing angle due to precession can change Doppler boosting effect on the flux.
  - Flux increment by Flare1 : 1.39 Jy
  - Flux increment by Flare6 : 13.42 Jy
- we estimate Bulk Lorentz factor(Γ) to be ~ 28 from the change in peak flux of flare 1 and flare 6 (9.65 times flux increase)

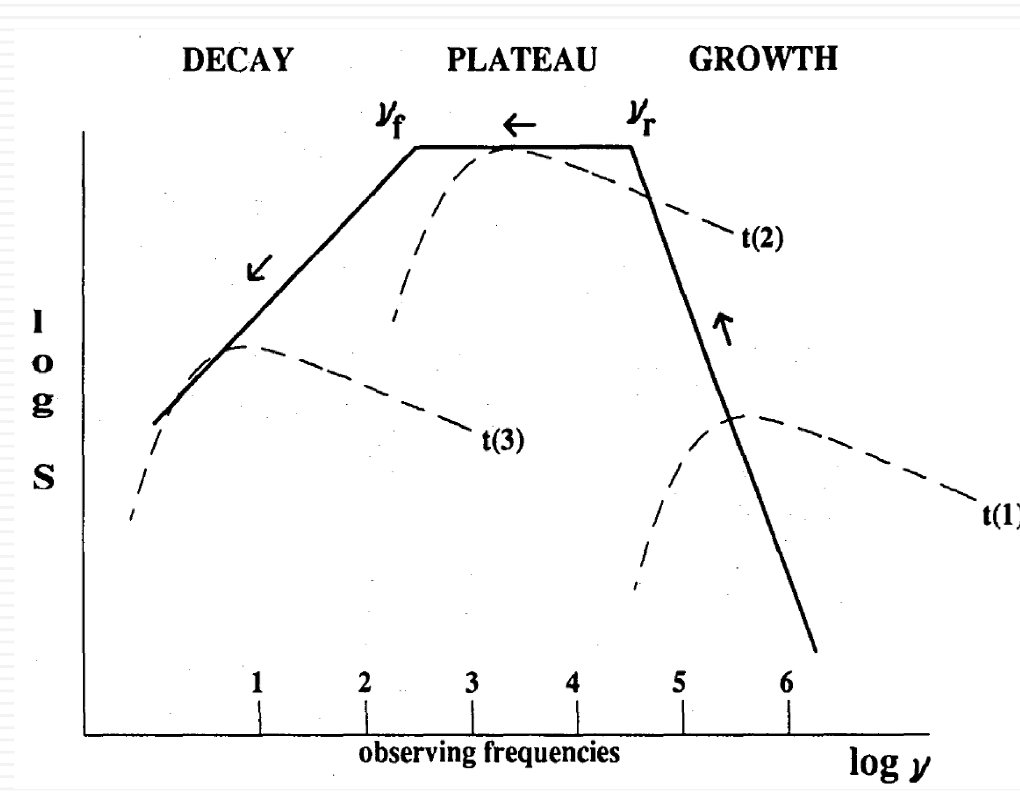

Figure 2. Spectral evolution in the shock model described by Valtaoja et al. 1992. The shape of the shock spectrum, shown at three epochs, remains unchanged, but its turnover peak frequency moves along the evolutionary track (solid line) through the growth, plateau, and decay stages. If a new shock occurs, the turnover frequency can be expected to increase rapidly and then decrease.

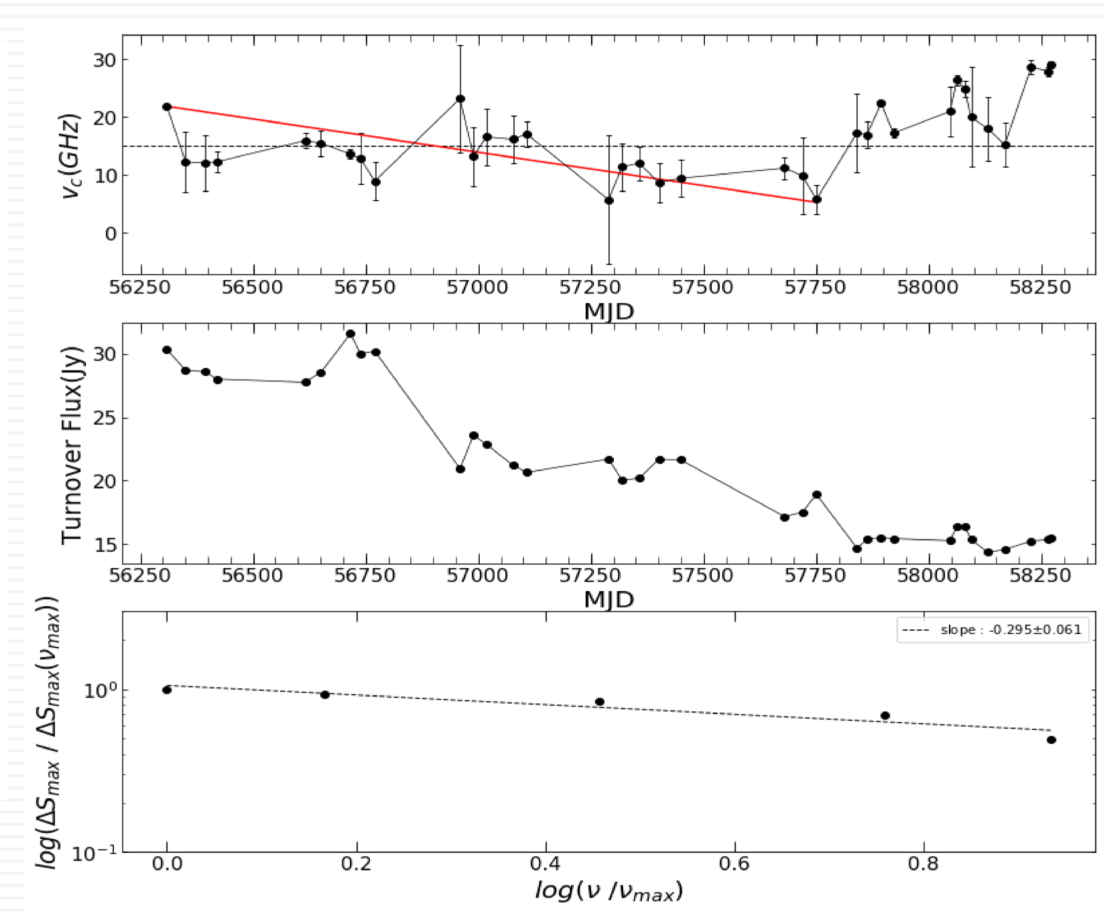

Figure 3. **(Top)** The change in turnover frequency over time. The red solid-line is the result of chi2 fitting from MJD 56250 to 57750 and the slope is -0.0115 $\pm$ 0.0014. Dashed-line is 15 GHz(OVRO), which corresponds to the limit of the turnover frequency. **(middle)** Turnover peak flux changes over time. **(bottom)** Normalized relative flux density against the normalized frequency. This is to compare the predictions with the shock model (Valtaoja et al, 1992). As a result of linear fitting, the slope is -0.295 $\pm$ 0.061.

4.Discussion

3C 279 is a highly variable object, and various efforts have been made to explain the phenomenon : a) phenomena caused by precession (Qian 2011, Abraham & Carrara 1998), b) interactions between interstellar medium and jet (Homan et al. 2003), c) jet components conflicts between them (Jorstad et al. 2017) and etc.

This study examine the possibilities of two scenarios to account for variations in 3C279. If variation is dominated by one large flare, it will show spectral changes through GROWTH-PLATEAU-DECAY by shock evolution (Valtaoja et al. 1992). The change in turnover frequency until MJD 57750 may imply the DECAY phase in the shock model and the increase in turnover frequency after MJD 57750 may be interpreted as a spectral change caused by a new shock (see Figure 2 (Top)). On the other hand, since the observing frequency range is 15 ~ 129 GHz, hence it is difficult to trust the turnover frequency below 15 GHz. In addition, the flux difference between MOGABA (sigle-dish) and iMOGABA (VLBI) implies the possibility of missing flux in VLBI observations. Flux difference may be caused by (1) filtering effect caused by few number of telescope, (2) effects of pointing accuracy during four frequency simultaneous observation, and (3) effect of diffused flux in the area far from radio core. If we try with MOGABA data instead of iMOGABA, the turnover frequency range appears to be determined between 15 and 22 GHz during decay (see Figure 1).

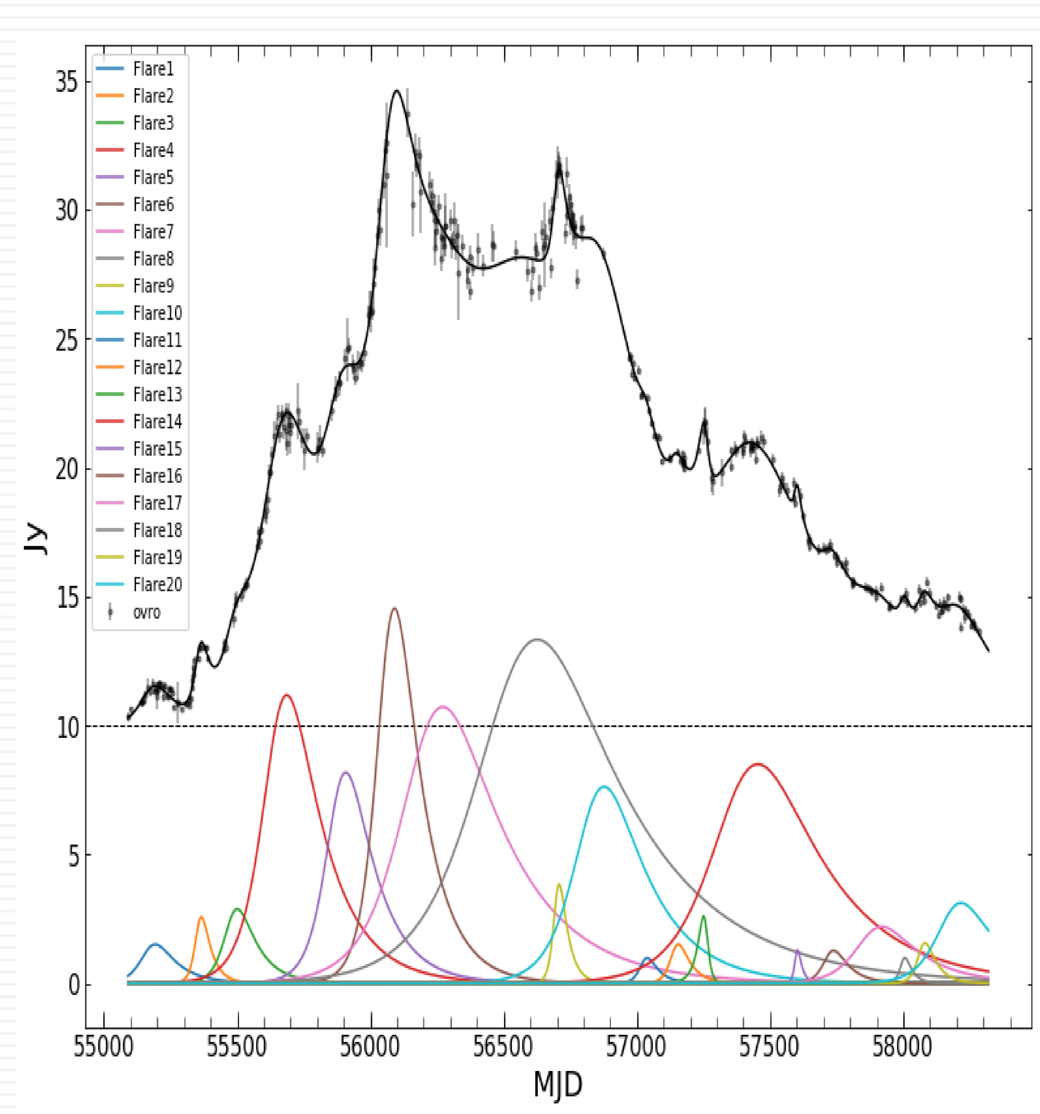

Figure 3. Decomposed flaring in the OVRO light curve using 20 flares. The horizontal dashed line represents the quiescent level (= 10 Jy). As a result of χ^2 fitting, χ^2 / DOF = 813.36 / 246 = 3.31

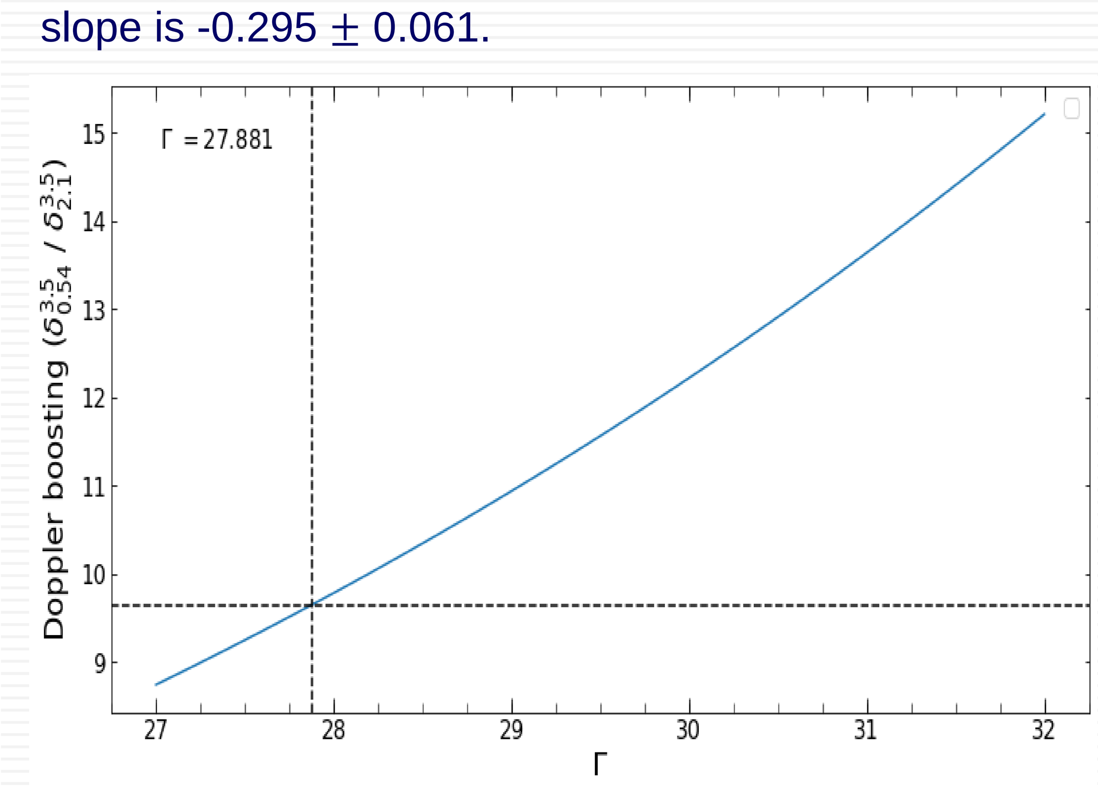

Figure 4. When assuming the viewing angle change due to precession from 2.1 to 0.54 degrees (Qian 2011), we can estimate Bulk Lorentz factor(Γ) through the flux enhancement between flare 1 and flare 6 (see Figure 3). In the Doppler factor ($\delta^{3+\alpha}$) calculation, spectral index (α) is taken to be 0.5 (Homan et al. 2003).

To illustrate the second scenario, the OVRO data is decomposed by multiple flares to show the overlapped results of multiple flares. Although it is difficult to identify each component that causes flare in OVRO observations, it is assumed that the events occur in the radio core of the relativistic and dominate the change of the overall flux. The Bulk Lorentz factor (Γ ~ 28), estimated by the change in viewing angle, explains why 3C 279 is a very bright and highly variable object in the space.