Summary of Graduation Thesis

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Title: New insight in the spectral evolution of Mrk 421 observed with NuSTAR

1. Introduction

Active Galactic Nucleus (AGN) is a luminous galaxy with massive black hole at the center, emitting over wide range, from radio to gamma rays, of electromagnetic spectrum. Blazar is a sub-category of AGN, for which non-thermal jet emission is enhanced along the observer's line of sight, affecting spectrum by relativistic beaming. Blazar has been showing flare activity, which has caused variation of spectrum in short time-scale. Numerous studies have been done through activity of blazar however, fundamental causes of the origin of such flares still remain uncertain. This thesis focuses on the spectral and temporal studies of TeV blazar Mrk421 for further understanding on origin and locations of the its flaring activity and blazar itself. For analysis, we used the archival data observed with hard X-ray telescope NuSTAR in 2013.

2. Analysis of Time-resolved Flare Spectrum

Mrk421 is known to be highly variable on time scales of hours to a day in the X-ray band. Fig.1 shows an example of such flare activity in 2013 April with a time scale of 60ksec. Increase of the count rate entering the observatory can be seen.

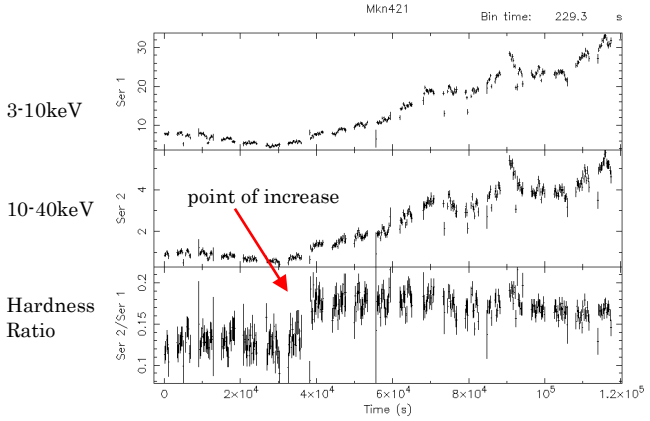

Fig. 1 Light curve and hardness ratio of flare

Particularly, this observation successfully caught a "trigger" of flaring activity. Looking at hardness ratio of flux in low energy band and high energy band, it showed a sudden change of hardness ratio around t ~ 4×10^4 sec. The point of increase in hardness ratio by flare can be set as a starting point for flare activity emitting variable components. For further analysis of this variable components, the quiescent state spectrum data before the point of increase was subtracted from active spectrum of each time interval during the flare.

3. Analysis and Discussion

The spectra of variable components taken out by subtraction (Fig.2), were fitted with broken power-law function and the quiescent state spectrum was described also by broken power-law function. Parameters of broken power-law function, low and high energy photon index and break energy of the variable components from different time intervals stay almost constant, only differing themselves by normalization. The low-energy photon index and high-energy photon index is ~2.3 and ~2.8 respectively, and break energy is ~10.7keV.

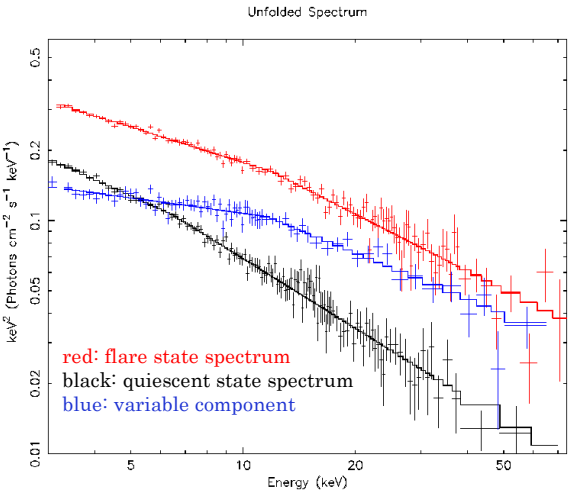

Fig. 2 Spectrum of each state, and variable component

Considering the obtained parameters of variable components and physical condition of synchrotron emission, the observed result implies that the energy density of magnetic field must be greater than density of synchrotron photons. The value of synchrotron density can be calculated to be 1.6×10^{-3} erg/cm^3. According to previous studies of quiescent state, using one-zone Synchrotron self-Compton model, the magnetic field density was 4×10^{-4} erg/cm^3, which is smaller than that of flare state. This difference implies that the origin of variable components comes from very different region in the relativistic jet, probably closer region to the central black hole than that producing the quiescent emissions.

4. Summary

Mrk421 shows sudden increase of high energy emission from flare. For analysis of it, the variable components were extracted. The result implies that the region responsible for flare emission must have stronger magnetic field than the region of quiescent state emission. This suggests that emitted fresh electrons during flare are injected and newly accelerated from region near the central black hole, where the magnetic field is stronger.