Time Resolved Spectral Energy Distribution (SED) of Blazars

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Abstract: Blazars are a subclass of AGN, whose relativistic jet makes small angle to line of sight, therefore the jet emission is significantly Doppler boosted and dominates the entire spectral energy distribution. They are also bright in γ-rays and show high variability throughout the electromagnetic spectrum, particularly in γ-rays, hence these are best sources in order to study the physics of AGN jet. Construction of SED during high activity or low activity from the observed data and comparing them with the theoretical jet emission models will tell us the jet parameters that play key role in high and low activity states. In this work, we select the blazar PKS 0208-512 for a detailed study about its long time behaviour. The six years data in γ-ray was taken from *Fermi LAT*, x-ray data from *SWIFT* XRT and the optical data from Yale/SMARTS optical near IR monitoring program. The source shows high and low activity states at different time intervals. SED has been constructed during these high and low activity states. Preliminary result of our study is presented here.

Introduction

• Blazars, a subclass of active galactic nuclei (AGNs).
• Jet-dominated sources having a small jet to line-of-sight angle [1].
• Bolo-metric luminosity is dominated by γ -rays, sometimes extend to TeV energies.
• Observationally, blazars are sub-divided into :
→ FSRQs (equivalent line width (EW) >5 Å)
→ BL Lacs (equivalent line width (EW) <5 Å)

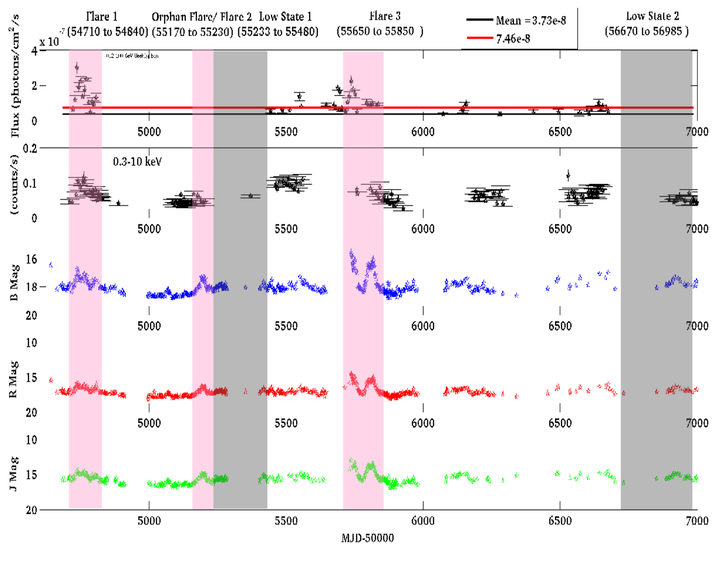

Fig 1: Variation of 0.2-100 GeV γ-ray flux from *Fermi-LAT* in weekly bins, X-ray flux from Swift -XRT monitoring program of *Fermi-LAT* sources of interest [7] and optical data from SMARTS optical/near-infrared light curves [8].The shaded regions indicate three intervals during which the source under went long-term and powerful outbursts at opticalnear IR wavelengths.

Spectral Energy Distribution

• A typical broad-band SED of blazars has two hump structure.
• First hump peaks near optical/UV (due to Synchrotron process). Second peaks near hard X-ray/γ-ray (due to inverse Compton process) [4] [5].
• Based on broad-band SED [2], further classified into :
→ low synchrotron peak - $\nu_{synch}^{peak} < 10^{14}$ Hz.
→ intermediate synchrotron peak - $\nu_{synch}^{peak} \sim 10^{14-15}$ Hz.
→ high synchrotron peak - $\nu_{synch}^{peak} > 10^{15}$ Hz.
• γ-ray emissions from jets of FSRQs are dominated by the up scatter of low energy photons from accretion disk, broad line region, dusty torus etc., (external Compton (EC) process) [4,5].
• Time resolved SED construction during high activity and low activity state tells us about the jet parameters that play key role in these states.

Objective

• A list of blazars is selected based on their quasi simultaneous observations in multi-band, in order to study the role of emission parameters during low and flaring states utilizing SED.

Source: PKS 0208-512

• Showed optical-near infrared outburst with no accompanying γ-rays [6].
• This source is suitable to investigate the role of different jet parameters during low activity, correlated and orphan flare.

Methodology

Data used

• **γ-ray data:** *Fermi-LAT*; Time period: 12/08/2008 to 09/12/2014.
• *LAT* Analysis software: *Science Tools v9r33p0*; Energy range : 200 MeV to 100 GeV; Response function: *P7REP_SOURCE_V15*; ROI=10°; likelihood: Unbinned; Spectral model: Powerlaw (for weekly bin); Detection significance : TS $>$ 25 ($\sim 5\sigma$).
• **X-ray data:** *Swift* -XRT monitoring program of *Fermi-LAT* sources of interest for above mentioned time period.[7]
• **Optical/IR data:** SMARTS Optical/IR Observations of Fermi Blazars [8].
• Multi-wavelength light curve is shown in Fig 1.

SED creation

Broad band SED constructed for

• Two correlated flare and one orphan optical flare.
• Two low flux states (55233 MJD to 55480 MJD, 56670 MJD to 56985).
• In γ-ray, 5 band analysis was carried out by freezing all spectral parameters.
• The OIR SEDs are created by averaging the flux over the corresponding time interval in *B, V, R, J, and K* bands.
• The X-ray spectra in the 0.3-10 keV energy range was created using *Swift*-XRT data products generator [9].

Low State and Flaring State :

γ-ray

• Flare: source flux $\geq 7.46 \times 10^{-8}$ photons cm^{-2} sec^{-1} (twice the mean value).

Optical waveband

• Flare: 1) if there is steady rise and fall in lightcurve. 2) the difference between the peak point of the flare and point where the rise in the flux has started is 1.3 magnitude or more [6].

Model used

One-zone leptonic model [10] which includes
• synchrotron emission and comptonization of synchrotron and external radiation fields.
The parameter values are shown in table.

Parameters of the SED model

state of the source	r [pc]	Γ_j	B' [G]	p_1	p_2	N_0 [cm^{-3}]
flare 1	0.03	26	0.36	1.92	3.76	5299
orphan flare	0.03	21	0.43	1.82	4.34	2981
flare 3	0.03	34	0.39	2.02	3.79	4661
low state 1	0.03	26	0.30	1.78	4.00	2703
low state 2	0.03	28	0.29	1.80	3.76	2933

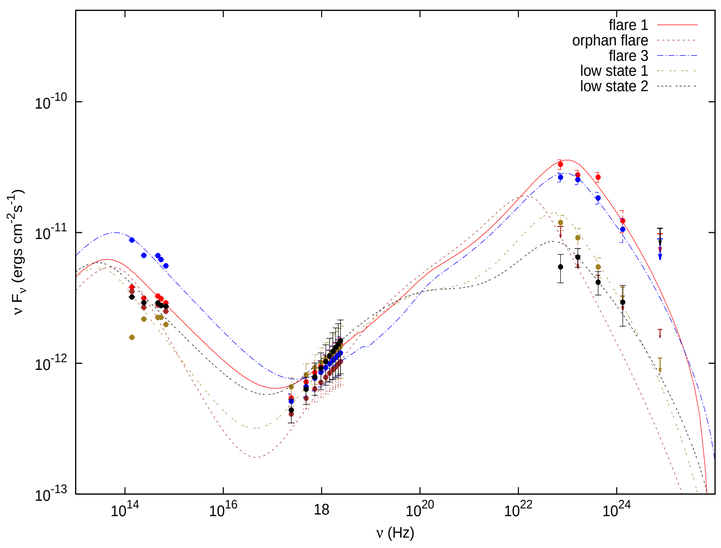

Fig 2: SED of PKS 0208-512 for flaring and low states. Lines show leptonic models matched with data.

Discussion and Future work

• Both correlated and uncorrelated flares observed.
• During quiescent γ-ray state optical emission shows both low state and flaring behavior.
• There is significant difference in the average optical emission during two optical low states.
• SED modeling of flaring (correlated and orphan) and low states indicate that there is an increase in particle number density during correlated flare.
• It is observed that though there is significant variation in optical over the six years of observations, source remains mostly low state in γ-rays.
• There is an increase in the magnetic field during orphan optical flare which is in agreement with earlier findings [11].
• To carryout similar study for other blazars and study their high and low state properties.

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