Flaring activity from Magnetic reconnection in Bl Lac jets

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Abstract

The evolution of **the spectral energy distribution** during flares constrains models of particle acceleration in blazar jets. In 2020 and 2021, the archetypal **blazar BL Lac** gave a rare opportunity to explore spectrum variation during an extended period of intense flaring. During its highest gamma-ray state, the measured flux (0.1-300GeV) was as high as 2.15 × 10^(-5) ph cm-2 s-1, with **sub-hour scale variability**. The **synchrotron** hump **extended into the X-ray regime up to 7.5 KeV** and was **accompanied by a minute-scale flare and a peak shift of the inverse-Compton hump in gamma rays**. In shock acceleration models, a Doppler factor value of more than 100 is necessary to explain the observed rapid variability, change of state, and gamma-ray peak shift. Assuming particle acceleration in mini-jets produced **by magnetic reconnection during flares alleviates the constraint on the bulk Doppler factor**. In such jet-in-jet theories, the unexpected alignment of a magnetic plasmoid with the direction of the line of sight causes the observed spectrum shift to higher energy (towards the TeV domain) and simultaneous fast variability.

Introduction

- Bl lac, a classified Low peak Bl lac displays behavioural shift to an Intermediate Bl lac type.
- Detected H_α and H_β lines hints at **presence of Broad line region** despite of Bl lac behaviour.
- Known **TeV emitter** → observed fast variability (13 min) [Arlen et al. 2013]
- Onset of increased activity during 2020 – 2021 in GeV band (100MeV – 300GeV)

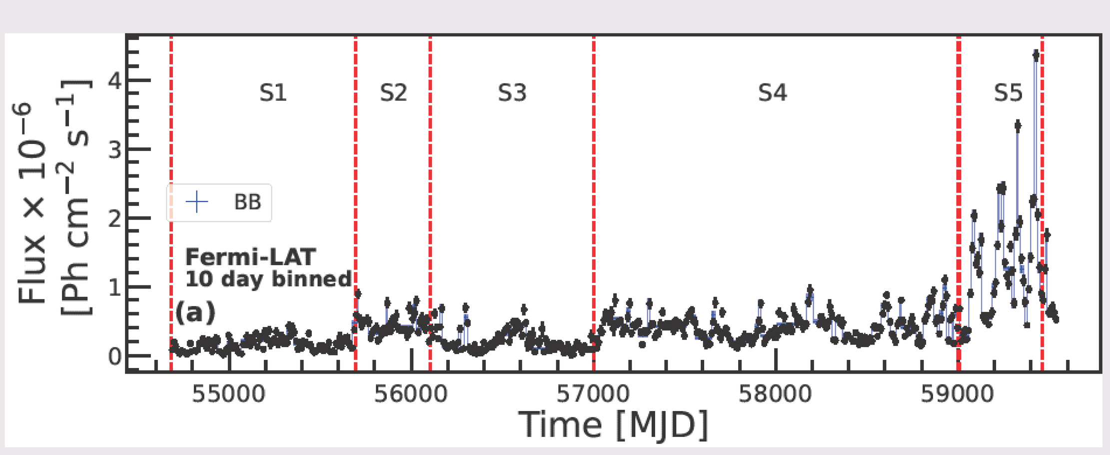

Fig 1: 10 day binned Fermi-LAT LCs of Bl lac for MJD 54683-59473. Red line characterizes 13 yr data into 5 flux states

What is fuelling the jet activity and simultaneous shifts in SED for the flux states ?

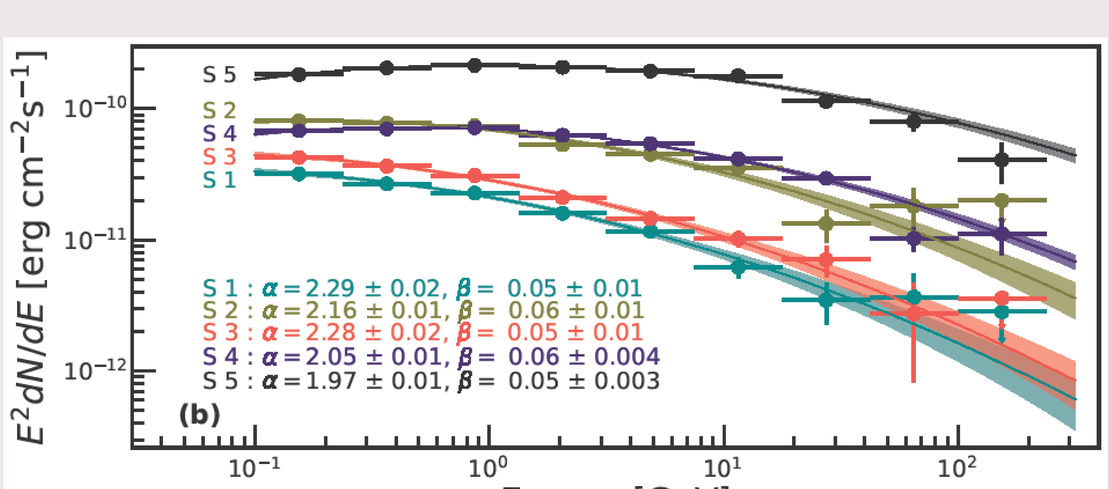

Fig 2: High energy spectrum (0.1 -300GeV) of 5 states. The shift in spectrum identified with changing values of alpha.

Data Acquisition

We have taken data in 3 wavebands for spectral study:

- Fermi LAT [Fig 1 & 3]
- Swift XRT and Swift UVOT

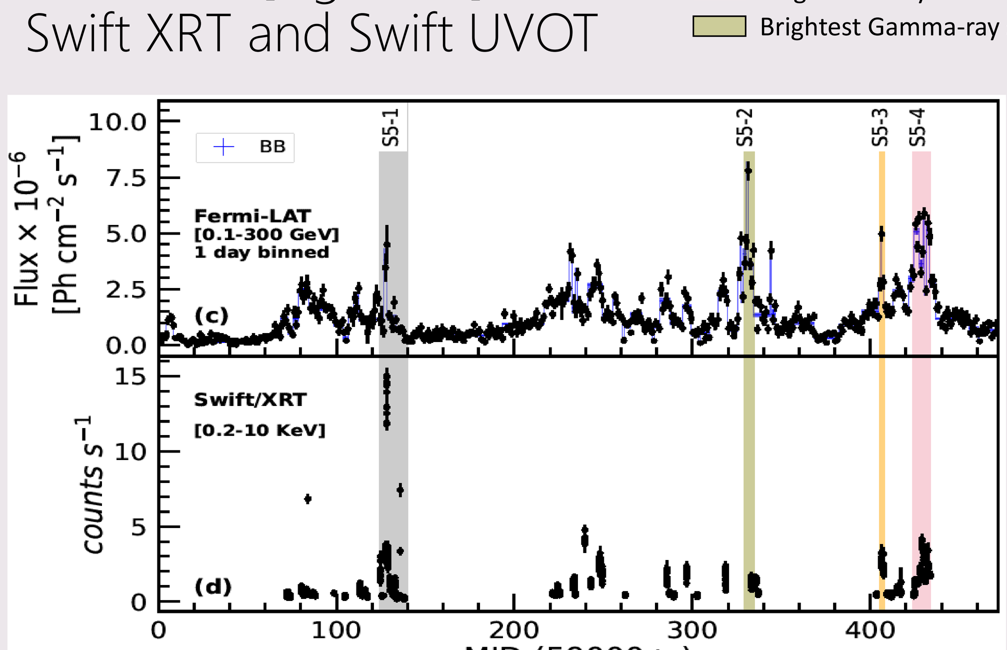

Fig 3: (Top) 1 day binned Fermi/LAT lightcurve for State-5. Five flaring episodes selected for studying flux evolution

Results

1. Bl lac found to be **variable** and evolves with time.
2. **Power spectrum** reveal similar variability over 13 years of Fermi era consistent **with pink noise**.
3. Observed Fast X-ray **variability** upto **7.7 min** (4.8σ).
4. **Flux distribution** preferred to be **log normal** (State 5 and 3) indicating **mini jet-in-jet model**.
5. Observed **Synchrotrn emission upto 7.5 KeV** for high flux state.
6. **Shift in spectrum to high energies** (Right) **during high flux state** followed by a shift to lower energies (Left) as flux decays further.
7. **Electron energies** responsible for observed emission of 7.5 KeV found to be $\mathbf{6.5 \times 10^4 - 5.5 \times 10^5}$ limiting **magnetic field** within 0.3 – 2.2 G.

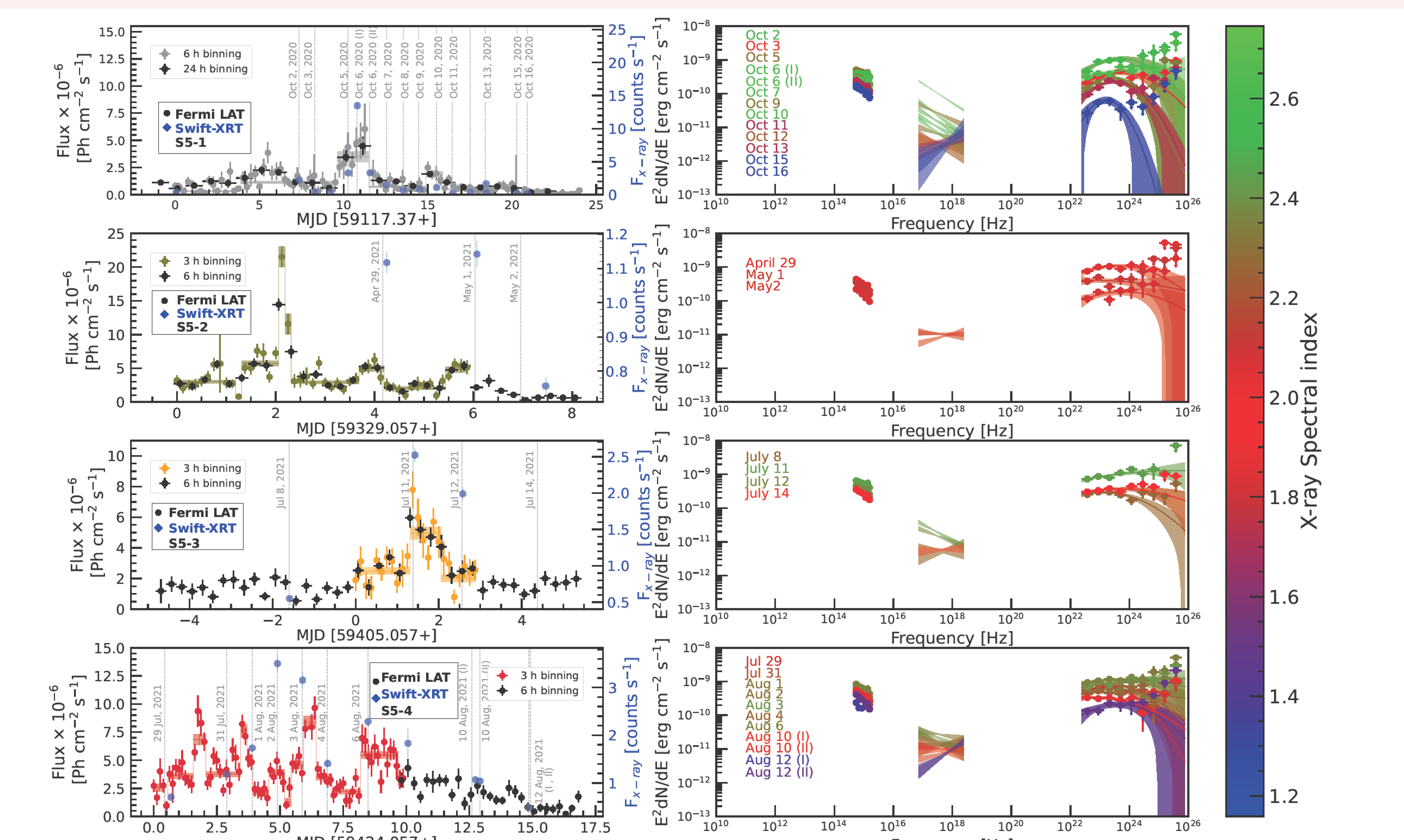

Fig 4: (Left) Fermi LC of periods highlighted in Fig 3. Swift Lc plotted in twin axis (in blue). (Right) Simultaneous multiwavelength of SED for chosen time stamps

Summary

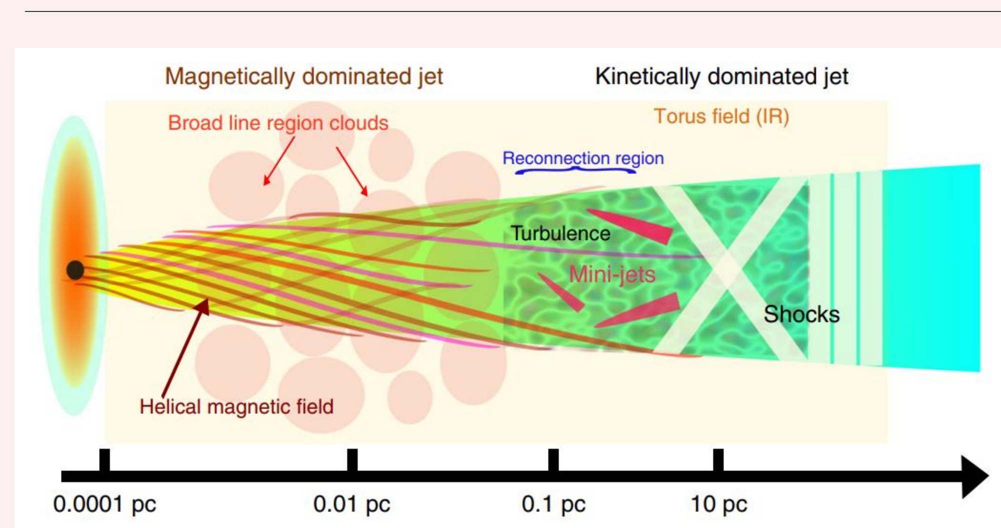

Fig 5: A representation of site of magnetic reconnection. [Shukla et al. 2020]

- Fast variability coinciding with apparent shift of X-ray spectrum to second hump along with observed synchrotron emission upto 7.5 KeV could be associated with preferred alignment of emission along the line of sight. Through jet-in-jet interation [Meyer et. al 2021, Giannios et al 2013].
- Simultaneous shift of second hump to higher energy further support magnetic reconnection.
- Expected TeV emission on occasions of such flaring episodes.

References

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