Flare States Modeling and Spectral Study of S5 1044+71

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Abstract

Blazars are a special kind of active galactic nuclei (AGNs) with jets oriented at small angles to our line of sight. Due to the relativistic motion of plasma along the jet, it constitutes one of the most rapidly varying classes of objects over a broad energy band (radio to γ-ray). S5 1044+71 (z = 1.15) is a known distant blazar observed in the GeV energy band. In the latest Fermi-LAT source catalog, 4FGL 1048.4+7143 is associated with S5 1044+71. Based on 12.5 years good quality Fermi-LAT data, we have detected three long-term flaring activities of S5 1044+71. In this work, we report a detailed temporal and spectral study of all three long-term flares of S5 1044+71 which provides some insight into acceleration and emission mechanisms inside the jet. For the temporal study, we have decomposed Fermi data into two energy bands (0.1-0.4 and 0.4-300 GeV) and produced corresponding weekly binned Fermi light curves for all flares. The modelling of weekly binned light curves includes the rise and decay time analysis and study of flux-index correlation for each flare. We have also performed the correlation study and hardness ratio test between two energy bands. The temporal analysis provides a detailed evolutionary picture of flares over different energy bands. The multi-wavelength data were taken from different publicly available telescopes like SPOL-CCD of Steward Observatory, Swift-XRT and Swift-UVOT. As a part of the spectral study, broadband SEDs of three flares are modelled using a leptonic scenario with two emission zones where the second zone is only responsible for high energy emission. The modeling of broadband SED provides some insight into the intrinsic jet parameters which help us to understand the nature of different emission mechanisms inside the jet.

Introduction to Blazars

- Radio-Loud Active Galactic Nuclei with jets aligned towards line of sight.
- High flux variability of minute to day timescales.
- Flat Spectrum Radio Quasars are blazars having broad emission lines in optical-UV spectra.
- Blazars can exhibit both short and long time flaring activities
- Study of flare state provide valuable information about jet kinematics

Source Description

- **S5 1044+71: Distant GeV emitter**
  - FSRQ with cosmological redshift z = 1.15
  - R.A = $10^h\ 48^m\ 27.6^s$, Dec = $71^0\ 43'\ 36.1''$
  - Detected in GeV by Fermi-LAT (4FGL 1048.4+7143)
  - Observed flaring activity in Optical, NIR and Soft X-ray band

Epochs of long term flaring activity

- **Epochs for Temporal Study (Purple colored band):**
  - > **Flare-A: MJD 56000 - 56900 (Mar 2012 - Aug 2014)**
  - > **Flare-B: MJD 57420 - 58100 (Feb 2016 - Dec 2017)**
  - > **Flare-C: MJD 58600 - 59250 (Apr 2019 - Feb 2021)**
- **Epochs for Spectral Study (Cyan colored band):**
  - > **Flare-A1: MJD 56670 - 56710 (Mar 2012 - Aug 2014)**
  - > **Flare-B1: MJD 57545 - 57575 (Mar 2012 - Aug 2014)**
  - > **Flare-B2: MJD 57810 - 57835 (Mar 2012 - Aug 2014)**
  - > **Flare-C1: MJD 58830 - 58855 (Mar 2012 - Aug 2014)**

Spectral analysis methods

- Study of correlation between flux and photon index
- Modeling of energy resolved light curves
  Energy Bands: E1 band: 0.1 - 0.4 GeV
  E2 band: 0.4 - 300 GeV
  Fitting func:
  $C + 2F_0\ [\exp[(t-T_0)/T_D] + \exp[(T_0-t)/T_R]]^{-1}$
- Hardness ratio test: $F_{0.4\text{-}300\ GeV} / F_{0.1\text{-}0.4\ GeV}$

Broadband Spectral Energy Distribution Model

- Leptonic model with two simultaneous emission regions (using ***jetset*** code [1], [2], [3])
- 1st zone emits low energy radiation i.e. optical to few GeV
- 2nd zone produces high energy photons (> 10 GeV)
- Location of 2nd zone is assumed well outside BLR ([4])
- Disk thermal emission modelled as multi-temperature black body emission

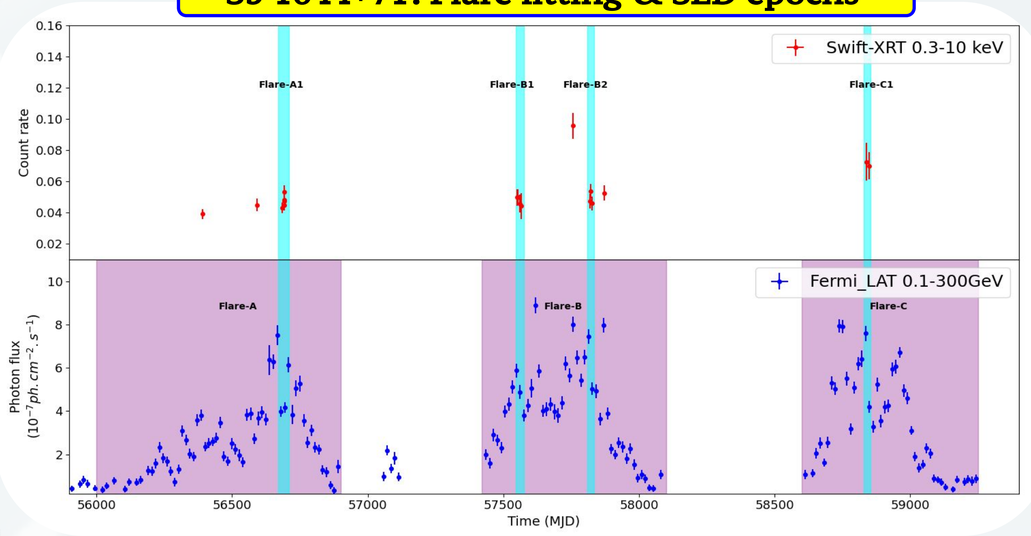
Results and Discussion

Flare-A
- Flux-index Correlation is stronger in low flux region
- Total 13 subflares: P7, P9 & P11 dominated by low energy photon
  P10 dominated by high energy photon
- Flare-A1(P10) is possibly triggered by high energy injection ([5], [6])

Flare-B
- Total 10 subflares: P6 & P10 dominated by low energy photon
  P4 & P7 dominated by high energy photon
- Flare-B1(P4) & Flare-B2(P8): both possibly triggered by high energy injection ([5], [6])
- In Flare-B2, Low spectral index & high particle density results emission above 100 GeV

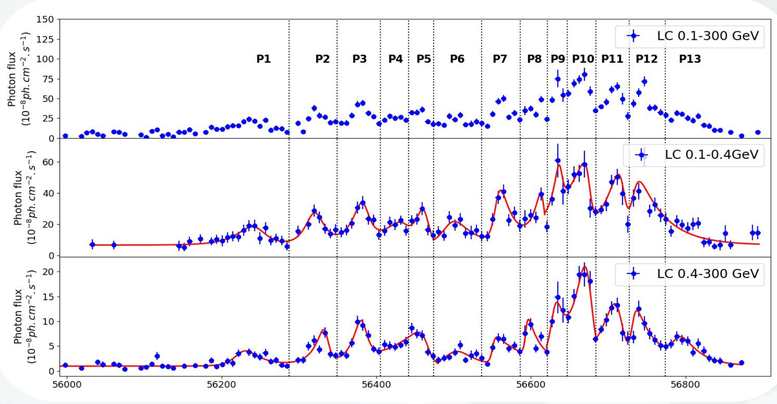
Flare-C
- Combination of 9 subflare
- X-ray emission is the result of both SSC and EC-BLR component
- EC-DT component of 2nd zone emits photon above 10 GeV

S5 1044+71: Flare fitting & SED epochs

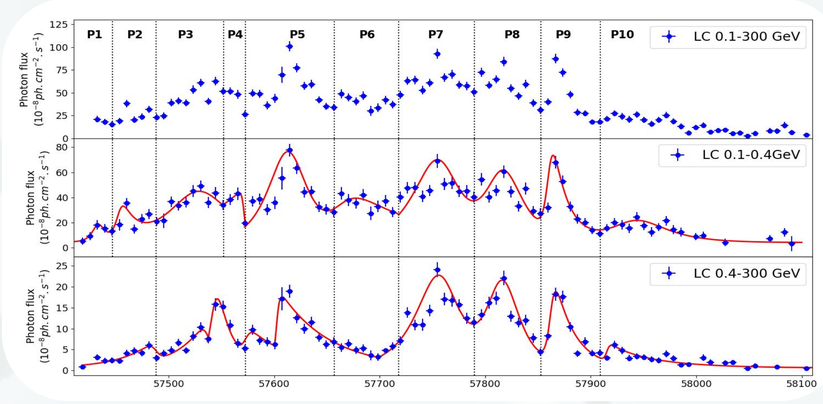


S5 1044+71: Flare fitting

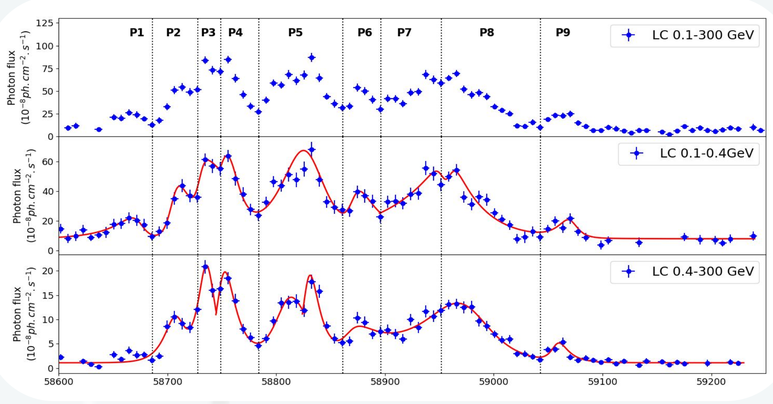
Flare-A



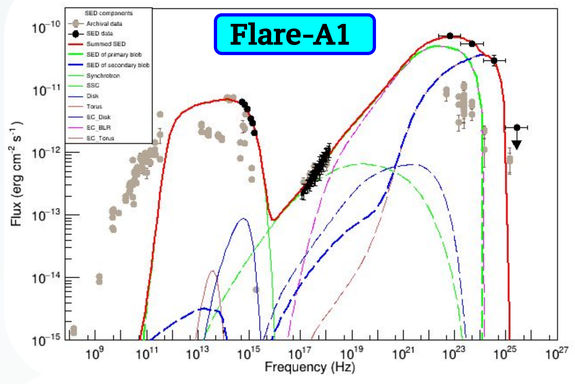
Flare-B

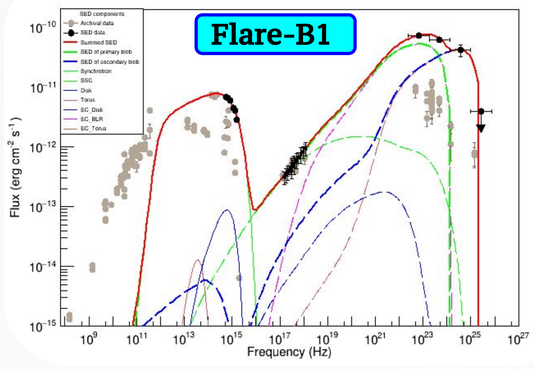


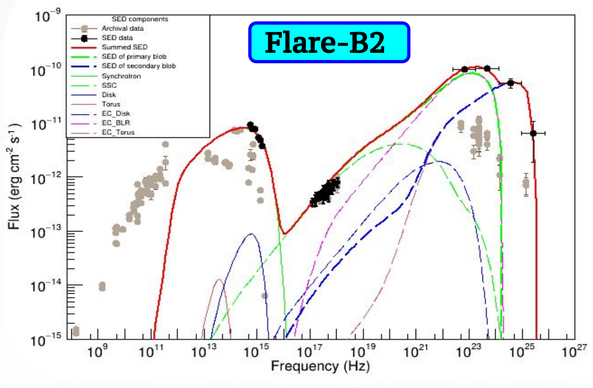
Flare-C

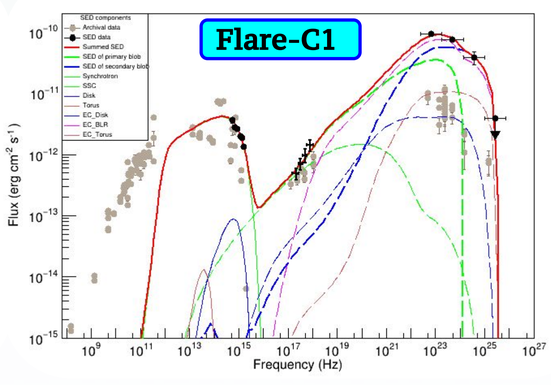


S5 1044+71: SED modeling



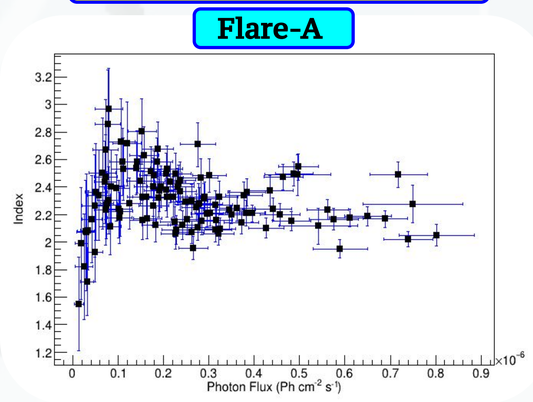




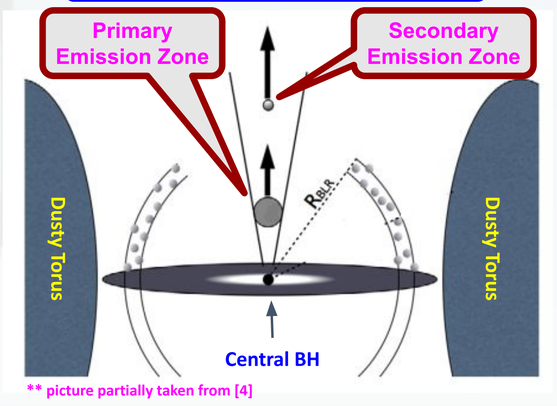


Flux-index correlation

Flare-A



Two zone SED model



** picture partially taken from [4]

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