Fermi-LAT Discovery of a Gamma-ray Outburst from the Peculiar Compact Steep-Spectrum Radiogalaxy 3C 216

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in Fermi-LAT PubBoard referee stage

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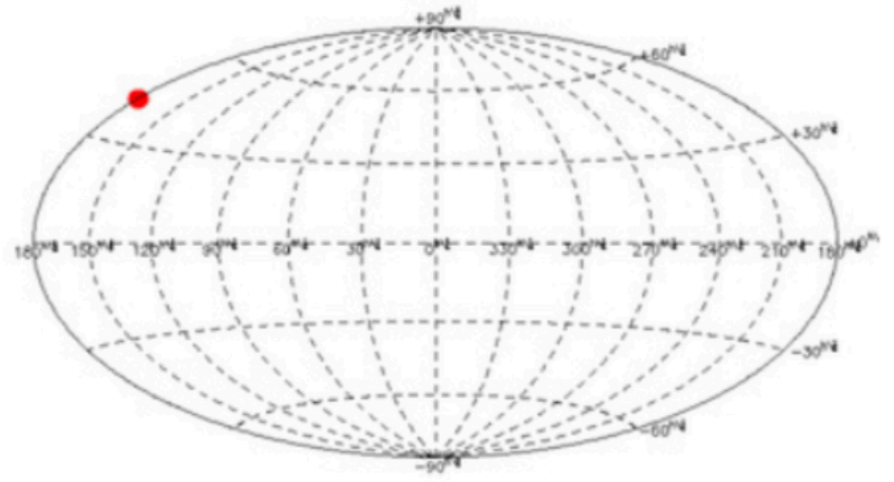
Outline of the talk

1. Gamma-ray flaring activity detection by *Fermi*-LAT
2. Introduction of the source
3. *Fermi*-LAT observations analysis
4. *Swift*-XRT *and Swift*-UVOT observations analysis
5. Multi-wavelength (**MWL**) SED during the flare and physical modelling
6. Summary and Conclusions

Fermi-LAT observations



1. Flare Activity: ATel#16024 *"Fermi LAT detection of increasing gamma-ray activity from Compact Steep-Spectrum Radio Source 3C 216"*

On **May 1, 2023** a flare activity was detected during my flare advocate shift from r.a. =(137.51 ± 0.11)°, dec. = (42.99 ± 0.11)° position of 4FGL J0910.0+4257 in 4FGL-DR3 Abdollahi et al. '22 associated to 3C 216.

From preliminary dedicated analysis:

- $\langle \Phi \rangle_\gamma = (7.5 \pm 1.4) \times 10^{-9}\,\mathrm{ph/cm^2/s}$ in the $(1 - 100)$ GeV energy range ⇒ Ratio ~177 compared to 4FGL-DR3 flux
- $\Gamma = 2.11 \pm 0.09$ ⇒ Difference ~ 0.5 smaller than 4FGL-DR3 photon index

Introduction of source 3C 216

2. Identity card and what we know

- $z = 0.67$ Smith & Spinrad 1980
- R.A. = 137.38957°, DEC. = 42.89624° Petrov et al. '05
- AGN classified as extragalactic Compact Steep Spectrum (CSS) radio source with a peak in lower frequency range $\nu < 0.5$ GHz: extended radio structure with a blazar core seen under a small viewing angle Impey et al. 1991, Principe et al. '21
- young ($t \sim 10^2 - 10^5$ yr) since compact ⇒ progenitor of extended radio source Fanti et al. 1995
- **AIM:** making light on extremely bright γ-ray flaring episode from distant steep radio sources ⇒ we investigate the variability of the source during the flaring state ⇒ MWL analysis: *Swift*-UVOT and *Swift*-XRT ToO with 5 visits ⇒ interpretative radiative model

Fermi-LAT observations

3. Gamma-ray analysis

Three period analysed:

- 'Flare period*': from 2022-11-14 to 2023-06-06
- 'Total period': from 2008-08-04 to 2023-06-06
- 'Peak Flare period': from 2023-04-28 to 2023-05-11

Excluding photon with zenith angle $> 90^\circ$ for Energy < 1GeV

$> 105^\circ$ for Energy > 1GeV

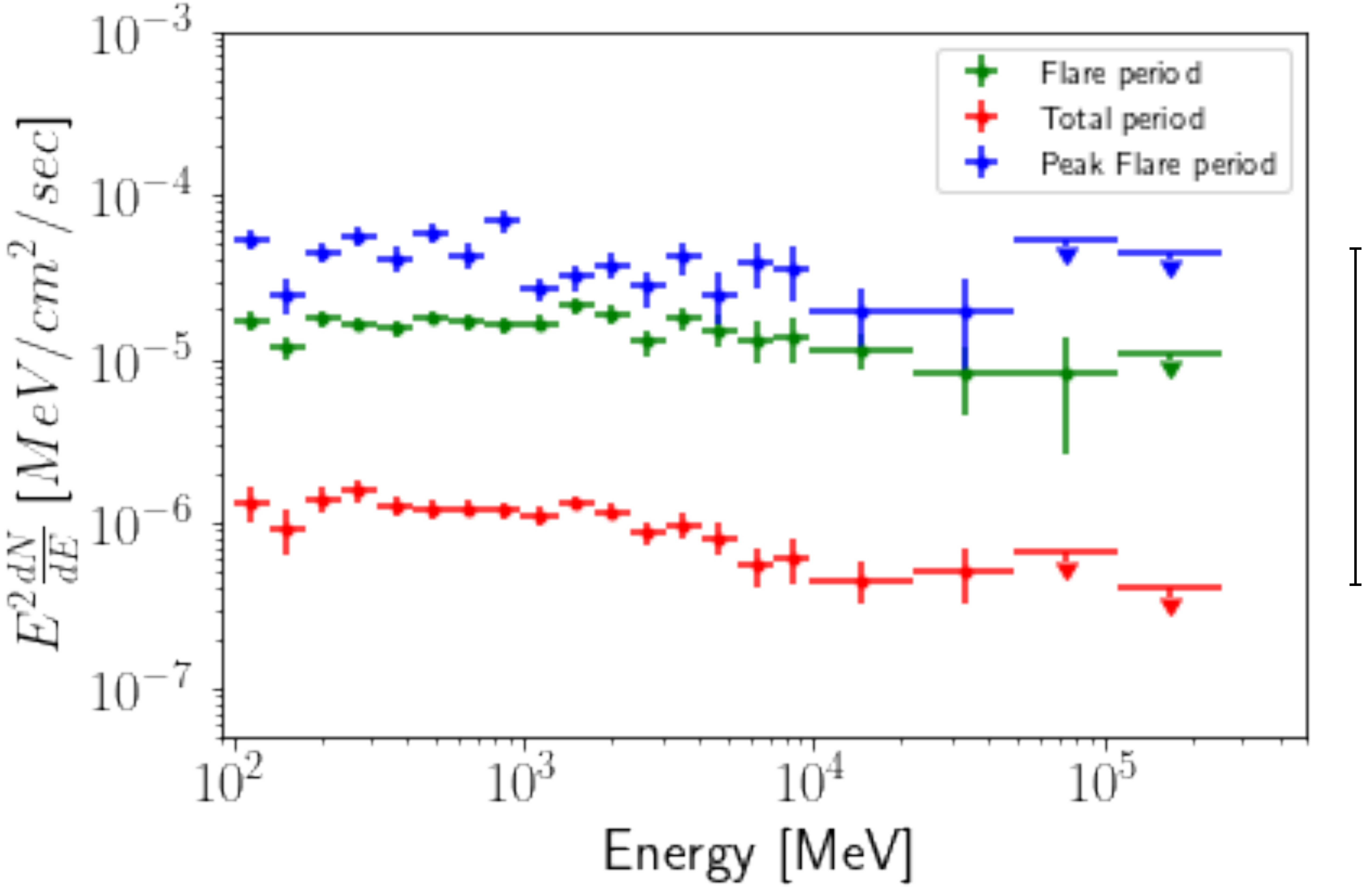
Energy range	100 MeV to 300 GeV
IRF	P8R3_SOURCE_V3
Event Type	FRONT + BACK
Point Source Catalog	4FGL-DR3
ROI size	$15^\circ \times 15^\circ$
Pixel size	0.1°
Bins per energy decade	8
Galactic diffuse model	gll_iem_v07.fits
Isotropic diffuse model	P8R3_SOURCE_V3_v1.txt

Table 1. Table of fermipy analysis parameters

* enhanced gamma-ray activity started in December 2022: ATel#15801

Fermi-LAT observations

3. Spectral analysis



~ 1 - 2 order of magnitudes

Fermi-LAT observations

3. Spectral analysis

Power-law model

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_b}\right)^{-\Gamma}$$

Log-Parabola model

$$\frac{dN}{dE} = \Phi_0 \left(\frac{E}{E_0}\right)^{-\alpha-\beta Log(E/E_0)}$$

Period	Γ	Φ_0 [1/MeV/cm^2/sec]	α	β	N_0 [1/MeV/cm^2/sec]
PF	1.97 ± 0.05	$(5.87 \pm 0.46) \times 10^{-11}$	1.79 ± 0.23	0.12 ± 0.09	$(3.83 \pm 0.72) \times 10^{-11}$
Flare	2.03 ± 0.01	$(2.45 \pm 0.09) \times 10^{-11}$	1.99 ± 0.16	0.06 ± 0.03	$(1.73 \pm 0.25) \times 10^{-11}$
Total	2.17 ± 0.04	$(1.69 \pm 0.07) \times 10^{-12}$	1.95 ± 0.20	0.12 ± 0.07	$(1.02 \pm 0.47) \times 10^{-12}$
DR4	2.43 ± 0.07	$(8.05 \pm 0.71) \times 10^{-13}$	2.24 ± 0.15	0.17 ± 0.10	$(9.02 \pm 0.91) \times 10^{-13}$

$TS_{LP} = 2[log\mathscr{L}_{LP} - log\mathscr{L}_{PL}] > 4\ (2\sigma)$ definition of good description with curved spectral model Abdollahi et al. '22

$= 1.68\sigma$ 4FGL-DR3

$= 2.39\sigma$ 4FGL-DR4

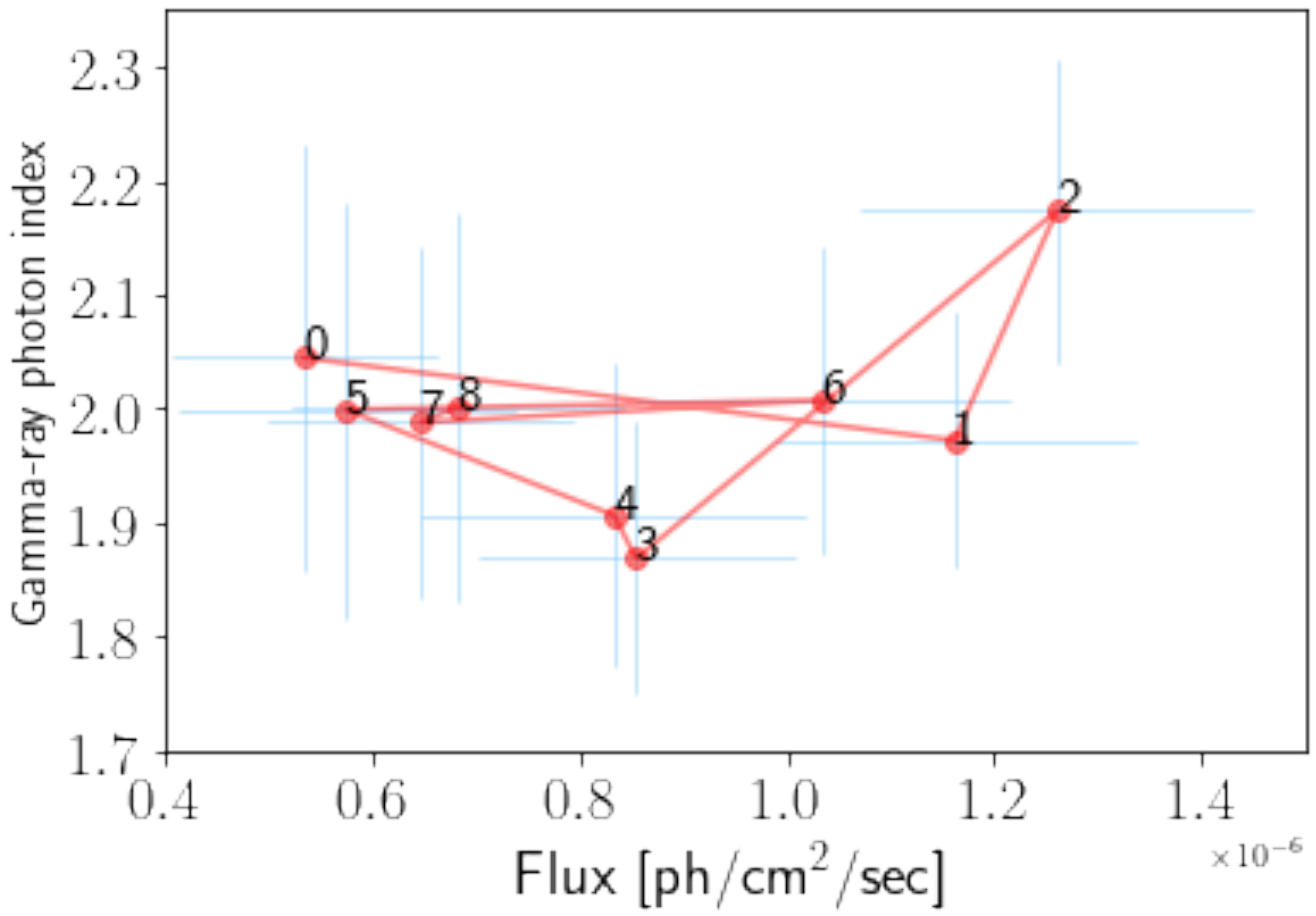
Fermi-LAT observations

3. Light Curve analysis

Fermi-LAT analysis

3. Spectral Index analysis

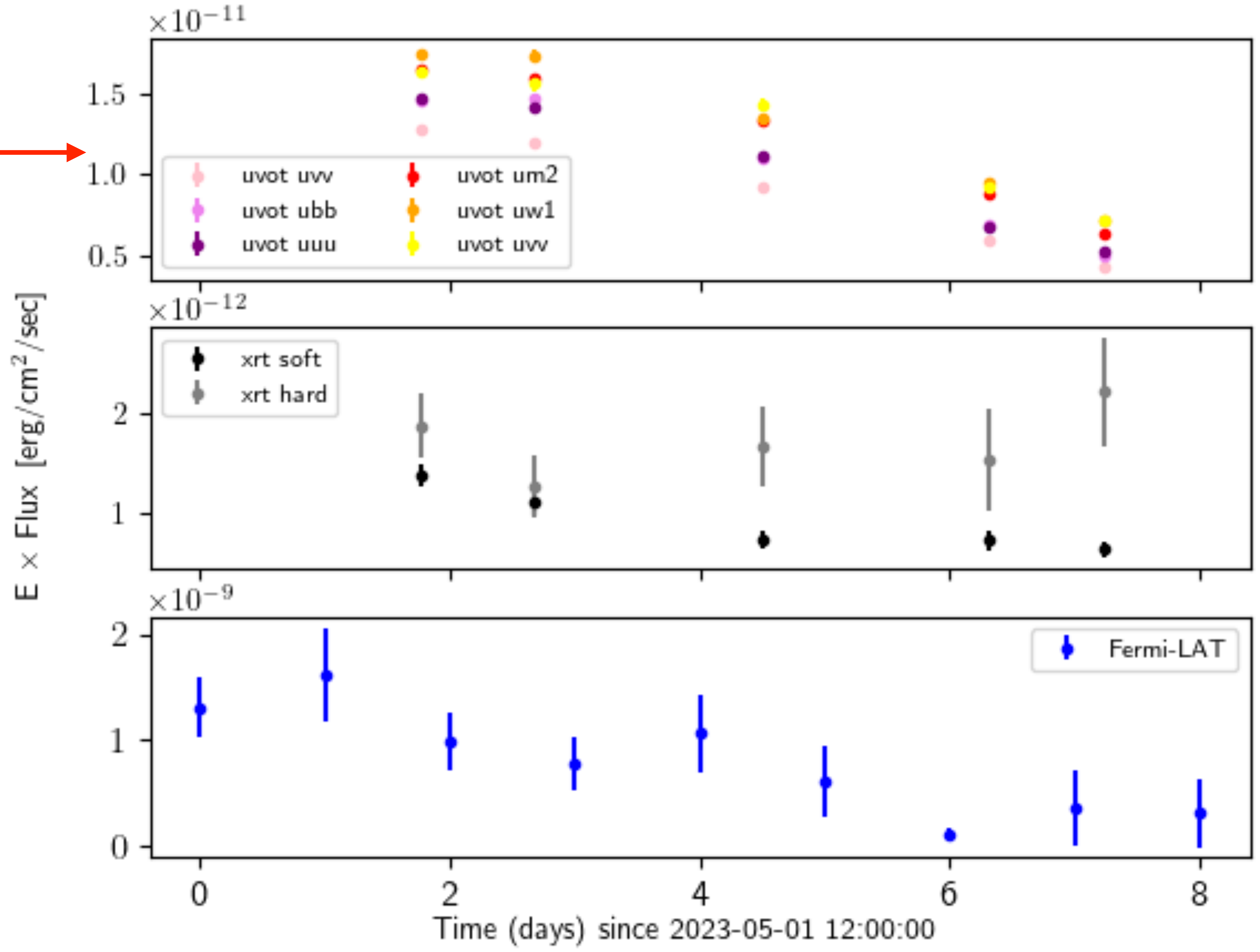
From Kirk et al. 1998, we know that a spectral variability with the flux analysis can characterise the radiative emission model: the loop-like pattern in γ-ray is related to synchrotron emission model and consequent cooling (stay tuned - the section 5)



SWIFT observations

4. XRT and UVOT analysis

- UVOT ANALYSIS: using UVOT software analysis, heasoft-6.32.1. High state, statistical significance $> 20\sigma$ in all visits and the six photometric filters. We have considered the effects of foreground extinction due to the MW's interstellar medium, and reddening effect. Yi et al. (2023)

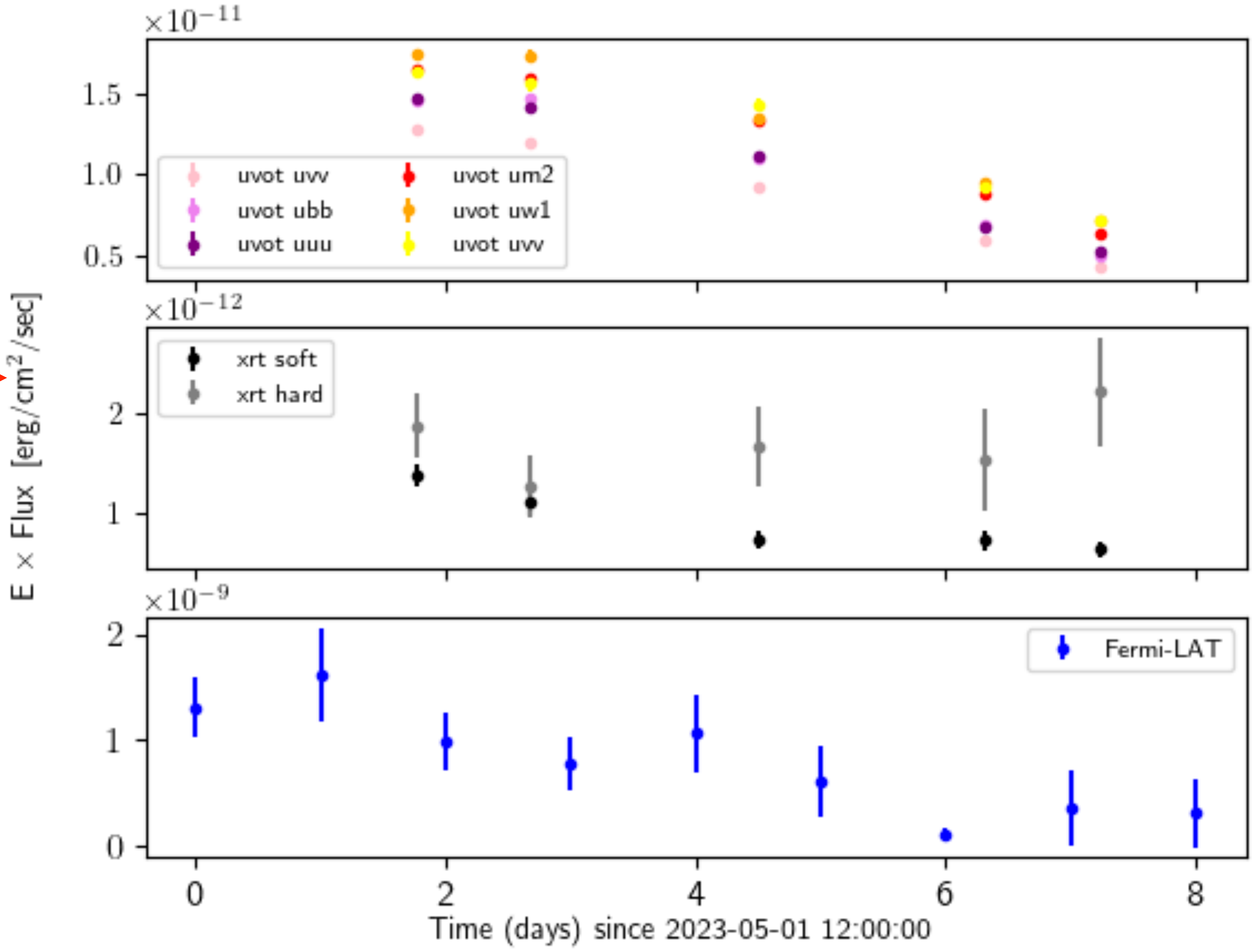


- XRT ANALYSIS
- RESULTS

SWIFT observations

4. XRT and UVOT analysis

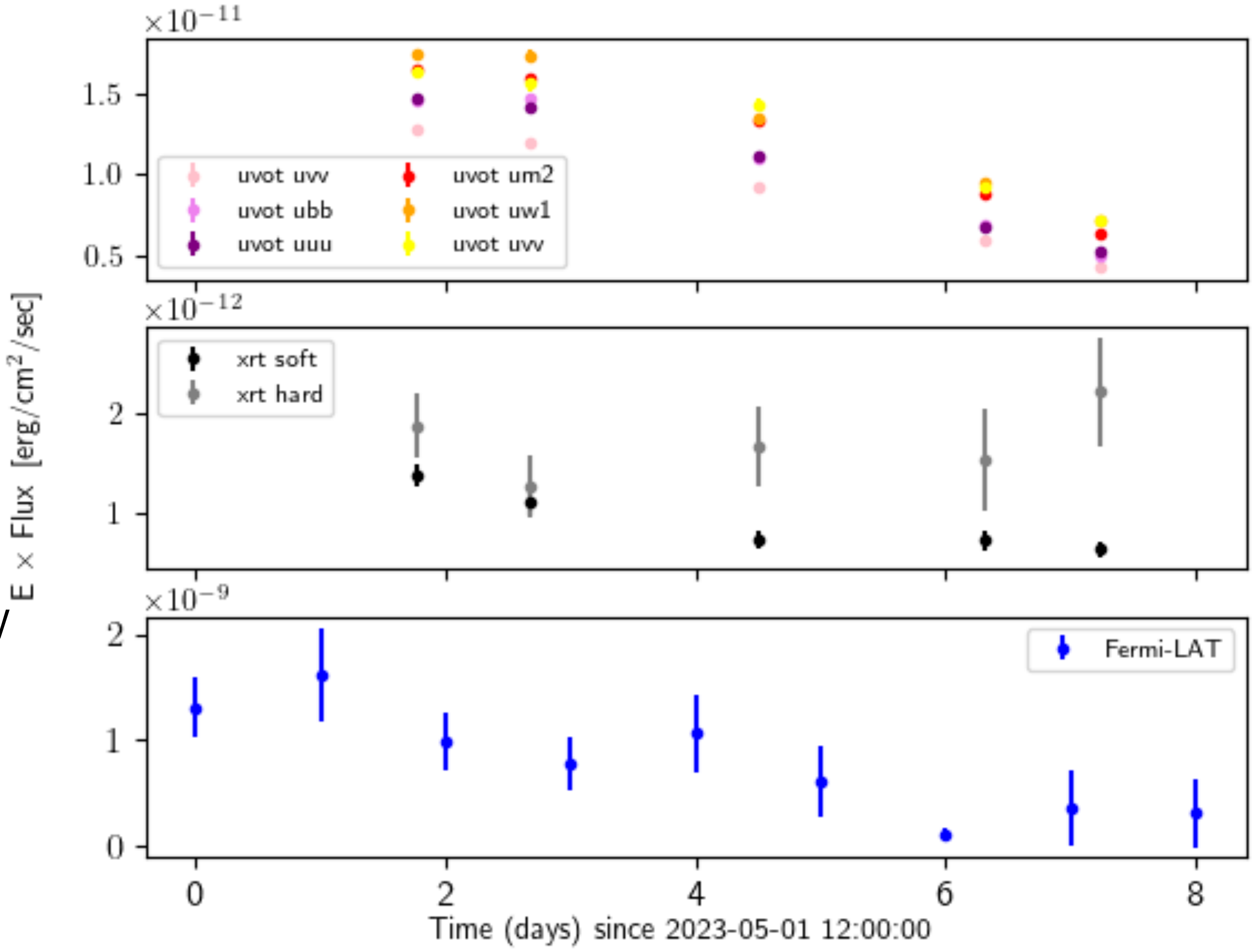
- UVOT ANALYSIS
- XRT ANALYSIS: using XRT softwares data, xrtpipeline v3.7.0. for processing and XSPEC v12.13.1e for spectral analysis: soft band $[0.5-2]$keV and hard band $[2-10]$keV, spectral model adopted is $TB_{abs} \times z_{pow}$
- RESULTS



SWIFT observations

4. XRT and UVOT analysis

- UVOT ANALYSIS
- XRT ANALYSIS
- RESULTS: except for hard X-ray regime, we see after the outburst a slow decreasing flux with the time ➠ initial simultaneous injection of energy both in the low frequency synchrotron component and in the gamma-ray IC component followed by a radiative cooling stage



MWL SED for HE emission models

See Tramacere's talk of yesterday

5. JetSet tool Tramacere 2020

We have studied time variability of the MWL SED for understanding the physical process of the flare activity in 3C216.

MWL SED for HE emission models

5. JetSet tool Tramacere 2020

We have studied time variability of the MWL SED for understanding the physical process of the flare activity in 3C216: Synchrotron Self-Compton

Jet-frame description

Value	Parameter
$R = 8.3 \times 10^{15}$ cm	Size of the spherical emitting region
$n = 10^3\,\mathrm{cm}^{-3}$	Particle density
$B = 1\,\mathrm{G}$	Intensity of the magnetic field in R
$\Gamma = 8.5$	Bulk Lorentz factor in R
$\theta \simeq 1/\Gamma = 4°$	Jet viewing angle

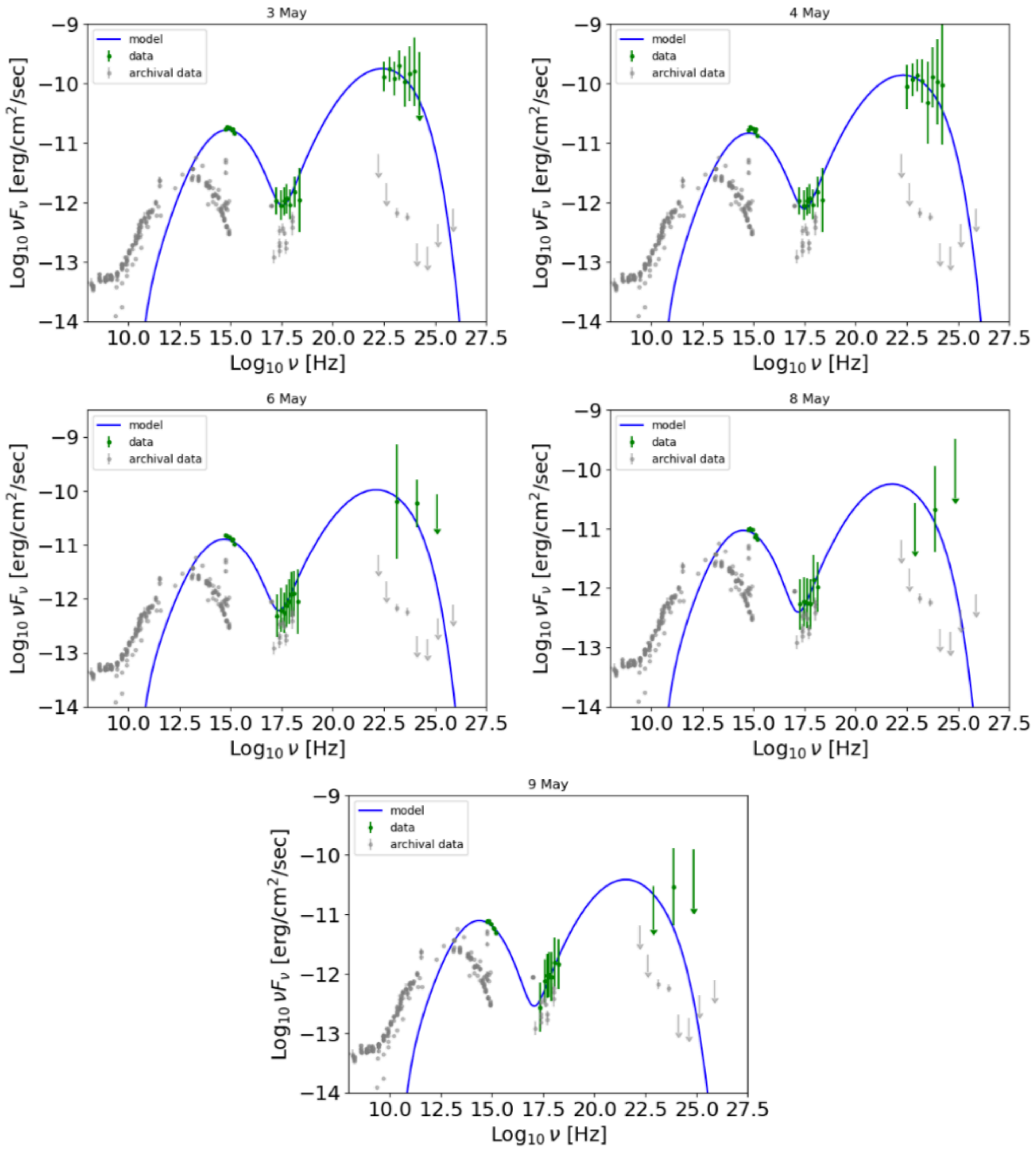
number of emitting particles N per unit volume

$$N \propto \int_{\gamma_{min}}^{\gamma_{max}} f(\gamma)d\gamma \text{ with } f(\gamma) = (\gamma/\gamma_0)^{-(s+rLog[\gamma/\gamma_0])}$$

spectral law

time	$\gamma_{\max}$	r	s	γ_0
3 May	5×10^5	1.05	1	580
4 May	4×10^5	1.05	1.05	575
6 May	4×10^5	1.07	1.07	540
8 May	3×10^5	1.15	1.15	540
9 May	3×10^5	1.15	1.2	530

Table 4. List of parameter model values from JetSeT tool which change in the time. We report time, maximal energy of energy interval for the emitting electron distribution ($\gamma_{\max}$), curvature of log-parabola (r), spectral index of log-parabola (s), reference energy of log-parabola (γ_0).



Summary and Conclusions

- Combining the *Swift* ToO analysis with *Fermi*-LAT one, we can identify the gamma-ray flare activity to the CSS 3C216.
- Hard spectrum during the flare emission.
- **Synchrotron Self-Compton** (SSC) model in all frequencies with a cooling process in the days after the flare peak.
- In order to study the morphology of the source, there are archival VLBA data not during flaring state

THANKS