Long-term study of the light-curve of PKS 1510-089 in GeV energies

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Overview

- Light - curve
- $\gamma - ray$ SEDs
- Results and Conclusions

Light-curve

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- Data collected from 2008 to 2016, Fermi-LAT
- Fermi Science Tools (https://fermi.gsfc.nasa.gov/ssc/data/analysis/)

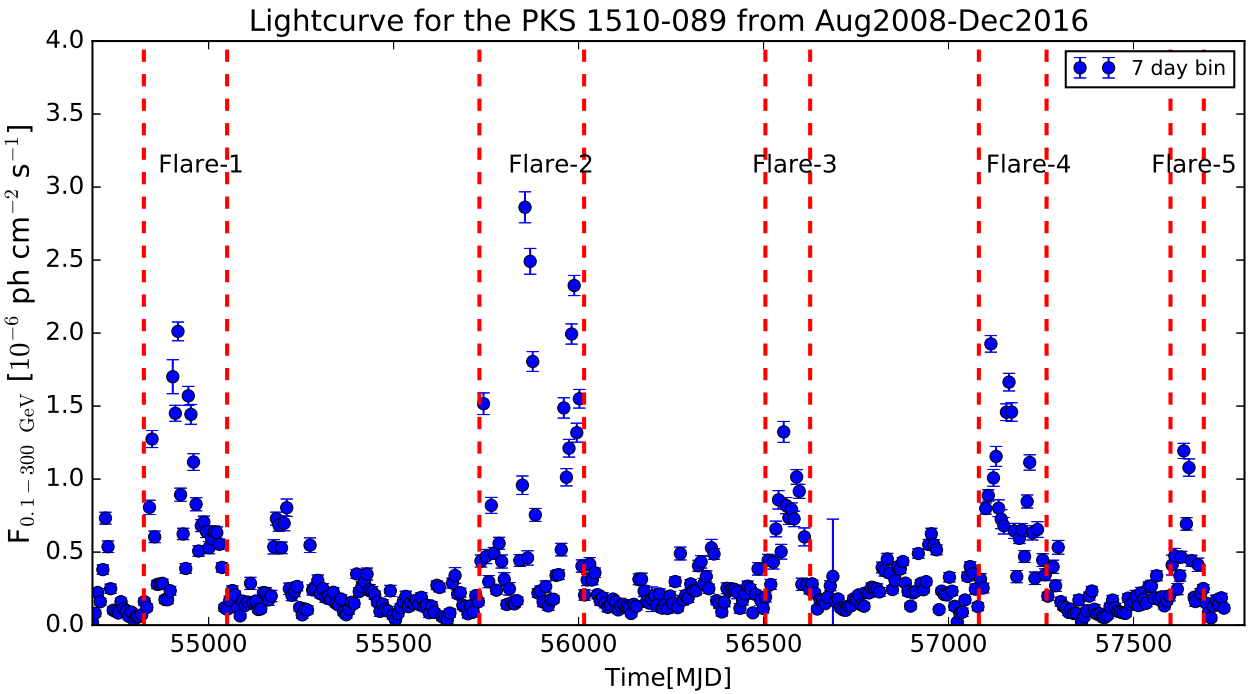

Figure : Light-curve history of PKS 1510-089

Light-curve

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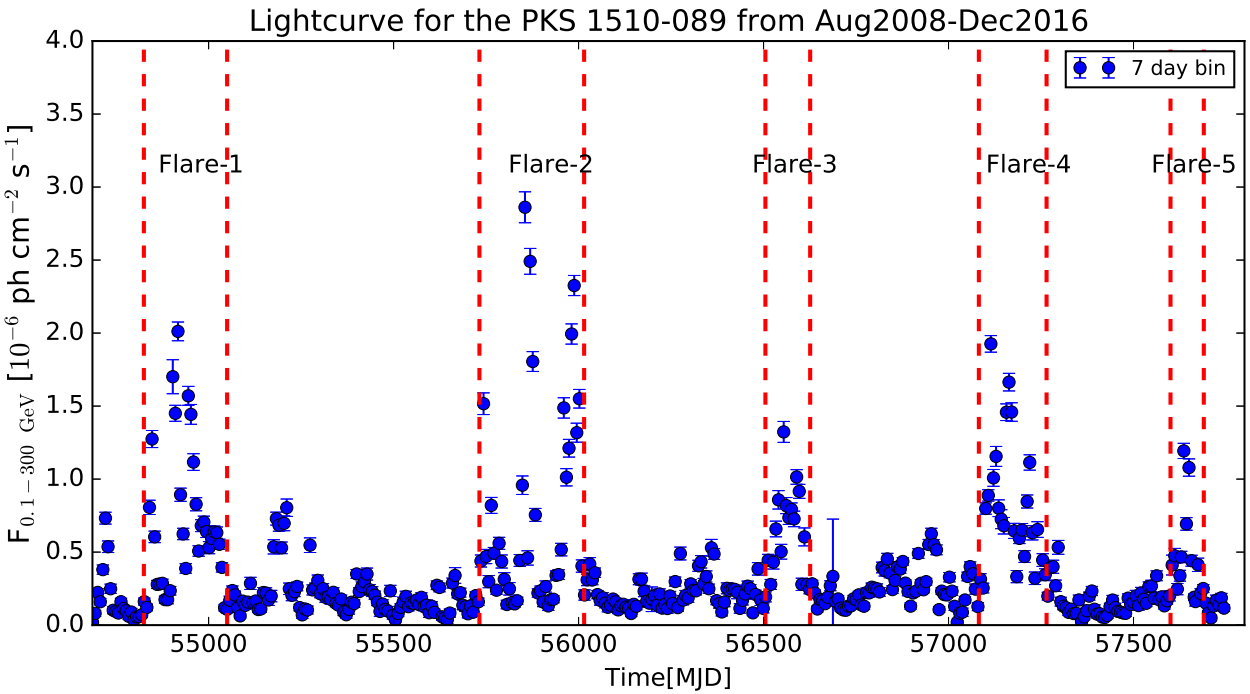
- Flare-1,2 and 4 shown 2,5 and 3 sub-structures, 1 day binning



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- Fermi Science Tools (https://fermi.gsfc.nasa.gov/ssc/data/analysis/)
- Flare-1,2 and 4 shown 2,5 and 3 sub-structures, 1 day binning
- Flare-3 and Flare-5 do not have any sub-structures

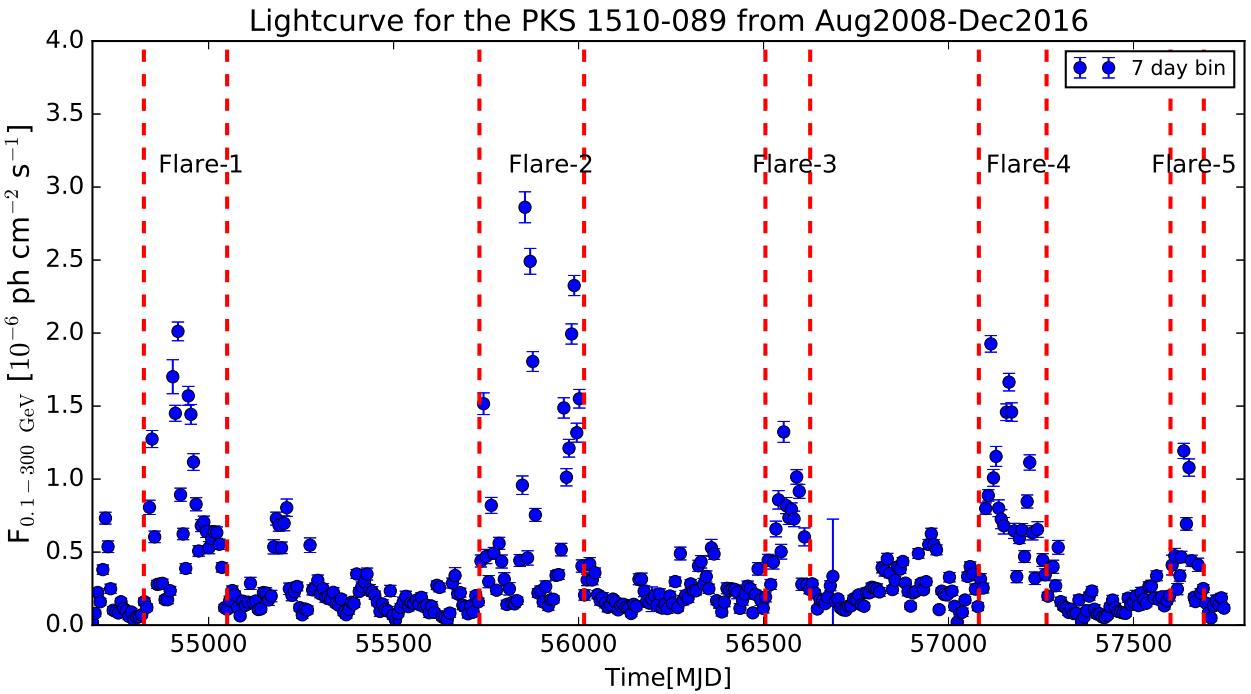


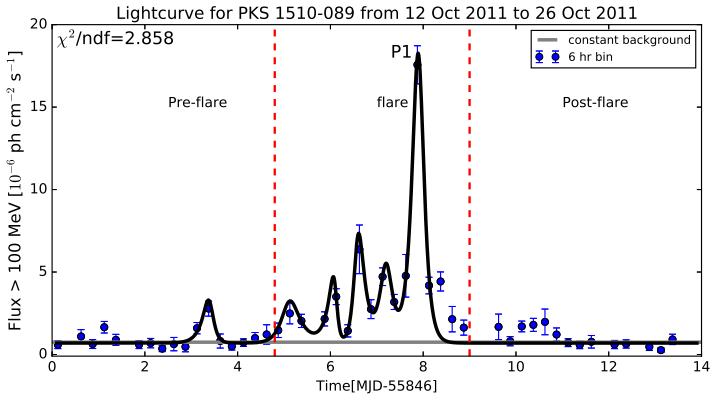
Figure : Light-curve history of PKS 1510-089

Light-curve contin....

- Each sub-structure have different phases: pre-flare, flare, post-flare
- Sum of exponentials

$$F(t) = 2F_0[exp(\frac{t_0 - t}{T_r}) + exp(\frac{t - t_0}{T_d})]^{-1} \quad (1)$$

- T_r and T_d are the rise and decay time of the flare
- 2.92±0.89 hr and 2.50±0.27 hr



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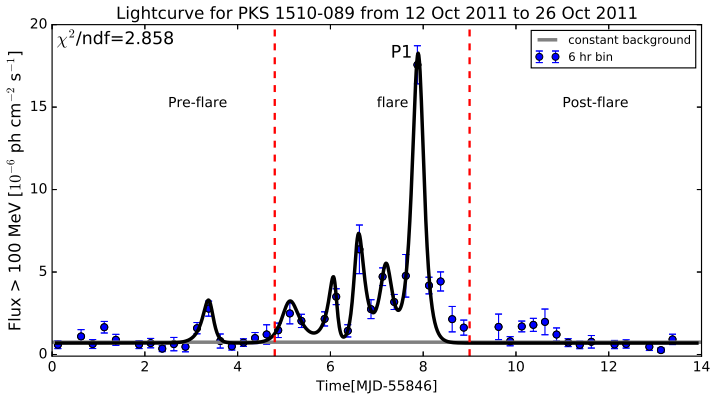

Figure : Temporal fitting of flare-2C

- Rising and decay time have been calculated for all the major peaks

Light-curve contin....

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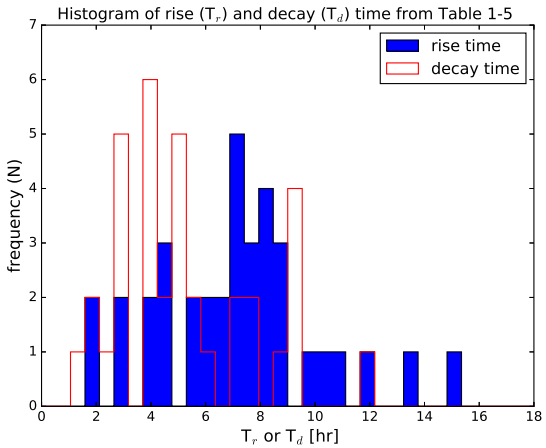

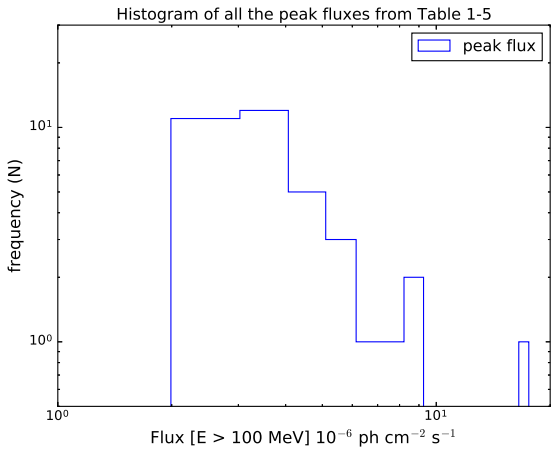

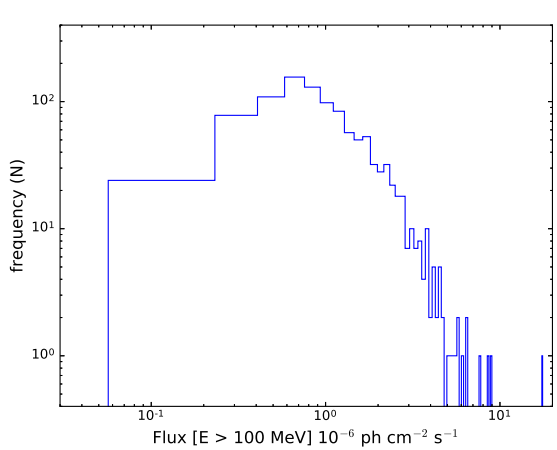

- Variability time

$$F(t_2) = F(t_1).2^{(t_2-t_1)/t_d} \tag{2}$$

- $F(t_1)$ and $F(t_2)$ are respectively the fluxes measured at t_1 and t_2 and t_d represents the doubling/halving timescale
- 1.30$\pm$0.18 hr, hour scale variability
- Size of the emission region, R $\sim 10^{15}$ cm

$$R \leq ct_{var}\delta(1+z)^{-1} \tag{3}$$

BLR or/and MT ?

- Important difference between the two possible locations for the γ-ray emission region is the role that photon-photon pair production plays in to attenuating the γ-ray flux
- BLR of FSRQ is opaque to γ-ray above 20 GeV while MT is not (Brown,2013)
- As a result, emission region located within the BLR expect a cut-off at higher energy in γ-ray spectrum
- γ-ray emission originating from MT would not have such features

γ – *ray* SEDs

- SEDs are calculated for all the different phases of flare
- PL, LP, PLEC models are used to fit all SEDs

$$dN(E)/dE = N_p(E/E_p)^{-\Gamma}, \tag{4}$$

$$dN(E)/dE = N_0(E/E_0)^{-\alpha-\beta\ \ln(E/E_0)}, \tag{5}$$

$$dN(E)/dE = N_p(E/E_p)^{-\Gamma}\ \exp(-E/E_c), \tag{6}$$

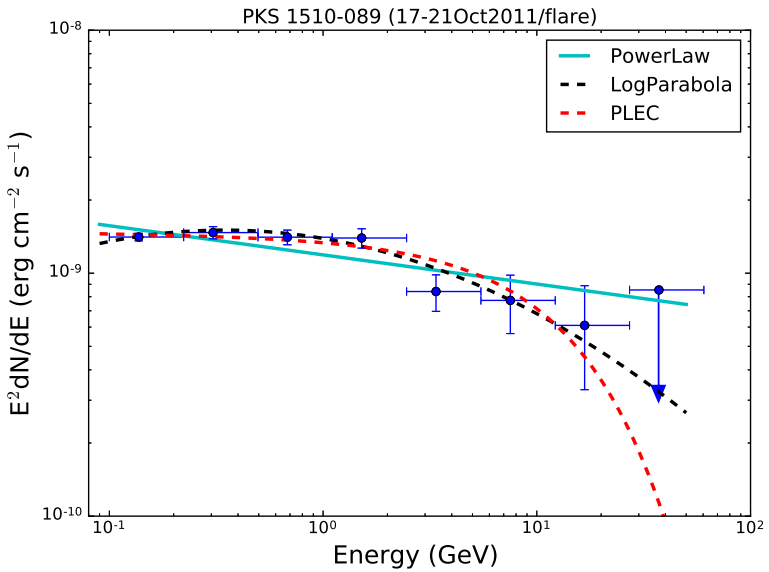

Figure : γ-ray SED of flare-2C

γ – *ray* SEDs

- Significant spectral hardening with increasing flux, as expected

Activity	$F_{0.1-300\ \mathrm{GeV}}$ (10^{-6} ph cm^{-2} s^{-1})	PowerLaw (PL) Γ		-log(Likelihood)	
pre-flare	2.55 ±0.17	2.44±0.06	-	13635.9	-
flare	9.16 ±0.30	2.13±0.03	-	17028.5	-
post-flare	2.25 ±0.17	2.30±0.07	-	11397.9	-
Activity	$F_{0.1-300\ \mathrm{GeV}}$ (10^{-6} ph cm^{-2} s^{-1})	LogParabola (LP) α	β	-log(Likelihood)	Δlog(Likelihood)
pre-flare	2.70 ±0.17	2.45±0.08	0.051±0.050	13642.8	6.9
flare	8.92 ±0.30	2.03±0.04	0.06±0.02	17023.4	-5.1
post-flare	2.25 ±0.17	2.30±0.07	0.00±0.00	11397.9	0.0
Activity	$F_{0.1-300\ \mathrm{GeV}}$ (10^{-6} ph cm^{-2} s^{-1})	PLExpCutoff (PLEC) Γ_{PLEC}	E_{cutoff} [GeV]	-log(Likelihood)	Δlog(Likelihood)
pre-flare	2.50 ±0.17	2.34±0.10	9.067±8.024	13634.8	-1.1
flare	9.00 ±0.31	2.05±0.04	18.030±7.530	17023.2	-5.3
post-flare	2.22 ±0.17	2.26±0.07	30.000±0.080	11398.6	0.7

Activity	Reduced-χ^2			E_{cutoff} for PLEC (GeV)
flare-1(A)	PL	LP	PLEC	
flare(I)	2.28	2.31	1.98	30.00±0.25
flare(II)	2.90	0.12	1.09	15.98±6.36
flare-1(B)				
flare	5.06	0.58	1.03	5.74±1.83
flare-2(A)				
flare(I)	3.66	1.91	2.40	11.27±8.13
flare(II)	2.84	0.92	0.48	2.70±0.73
flare-2(B)				
flare	2.15	0.23	0.43	5.82±2.36
flare-2(C)				
flare	1.73	0.41	0.83	18.03±7.53
flare-2(D)				
flare	8.14	0.43	2.83	12.31±3.51
flare-2(E)				
flare(I)	10.23	1.63	2.41	7.61±1.53
flare(II)	0.43	0.15	0.06	9.71±5.12
Flare-3				
flare(I)	2.73	0.91	1.19	5.02±0.18
flare(II)	0.41	0.42	0.34	9.04±0.22
flare-4(A)				
flare	11.93	3.25	5.82	12.78±8.11
flare-4(B)				
flare(I)	2.41	2.95	1.78	9.07±0.31
flare(II)	8.60	0.50	3.30	9.74±3.16
flare-4(C)				
flare	4.41	1.00	1.84	29.71±8.16
Flare-5				
flare	1.55	0.43	0.50	5.01±2.00

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- In few cases where Reduced-χ^2 for PLEC is comparable to LP, cut-off energy is well constrained. It has strong physics implications regarding the location of the emission region.

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Results and conclusions

- Light-curve comprises of five major flares and each flares comprises of several sub-flares
- Most of the peaks have hr scale rise and decay time
- Flare-2(C) was found as the brightest flare in the history of PKS 1510-089
- Few new flares were also found that have not been studied before
- Hour-scale fastest variability time
- Sub-parsec scale of emission region

Results and conclusions

- LP found as the better fit of γ-ray SEDs, over PL and PLEC, for flaring periods
- Variations in the spectral index and cut-off energy of flares indicate that different flares might have originated from different emission region along the axis of the jet
- **Comment:** Detailed broad-band spectral modelling of all the flares is work to be done in future. That will help to explore the complex nature of flares of this highly variable source


Thanks for
your
attention!