



Fermi

Gamma-ray Space Telescope

Observation of Large Flare from 3C 454.3

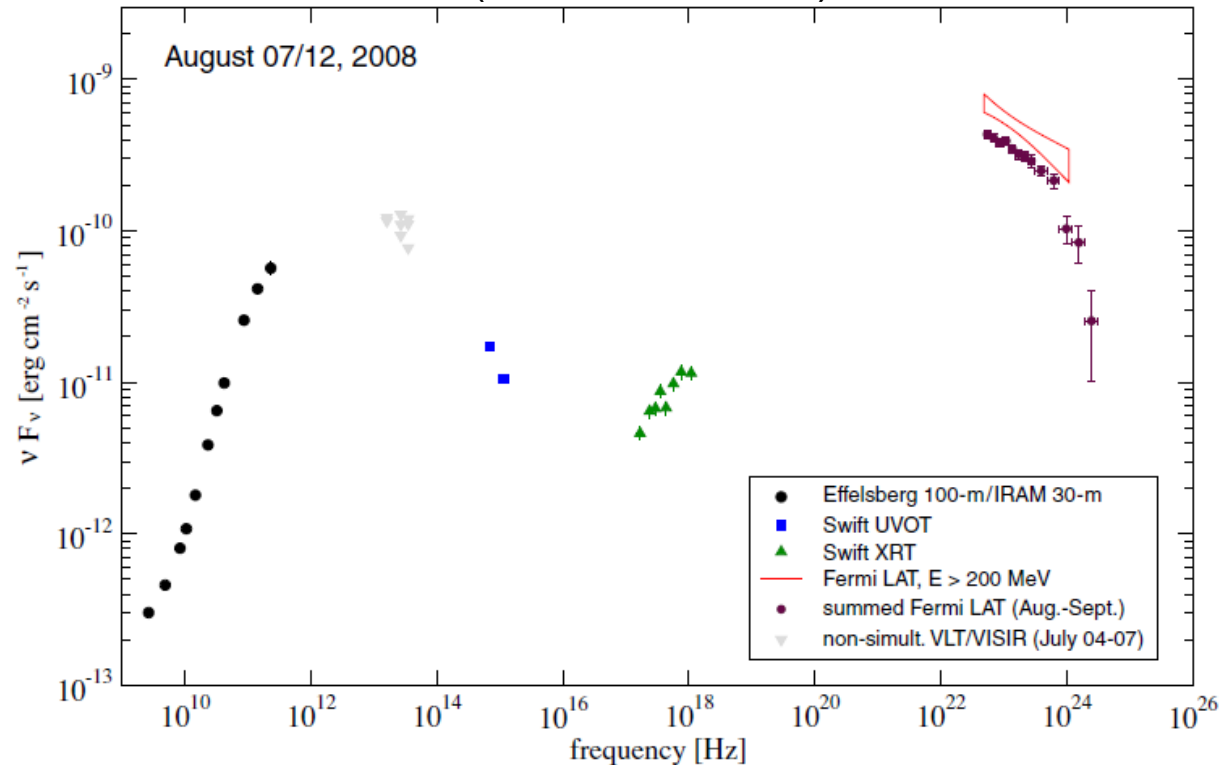
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And on behalf of Fermi LAT Collaborations

2010ApJ...721.1383A

Blazar 3C 454.3

- Blazars are highly variable AGN observed in all wave length from radio to gamma-ray band.
- They have strong relativistic jet aligned with the observer's line of sight

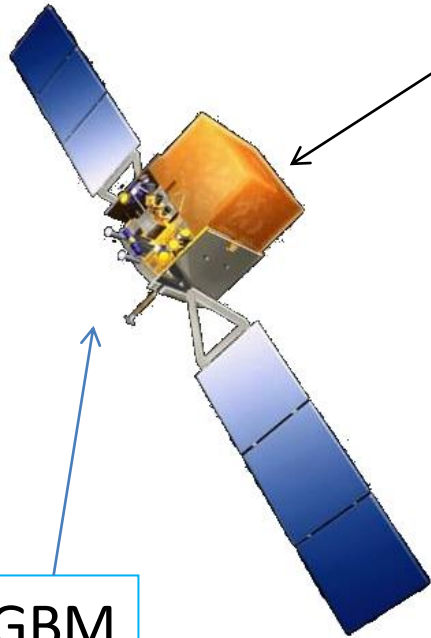
Spectral Energy distribution of 3C 454.3
(Abdo et al 2009)



3C 454.3 is one of famous blazars classified as FSRQ (flat spectrum radio quasars) with red shift $z = 0.859$

About Fermi/LAT

Large Area Telescope



GBM

- Pair-conversion telescope
- Launched in Jun.12 2008

- Broad energy band : 20MeV -- 300GeV
- Large effective area : 8000 cm²@1GeV
- Wide Field of View : 2.4 str
- High angular resolution : <1 deg@1GeV

Survey mode covers the entire sky in **3** hr

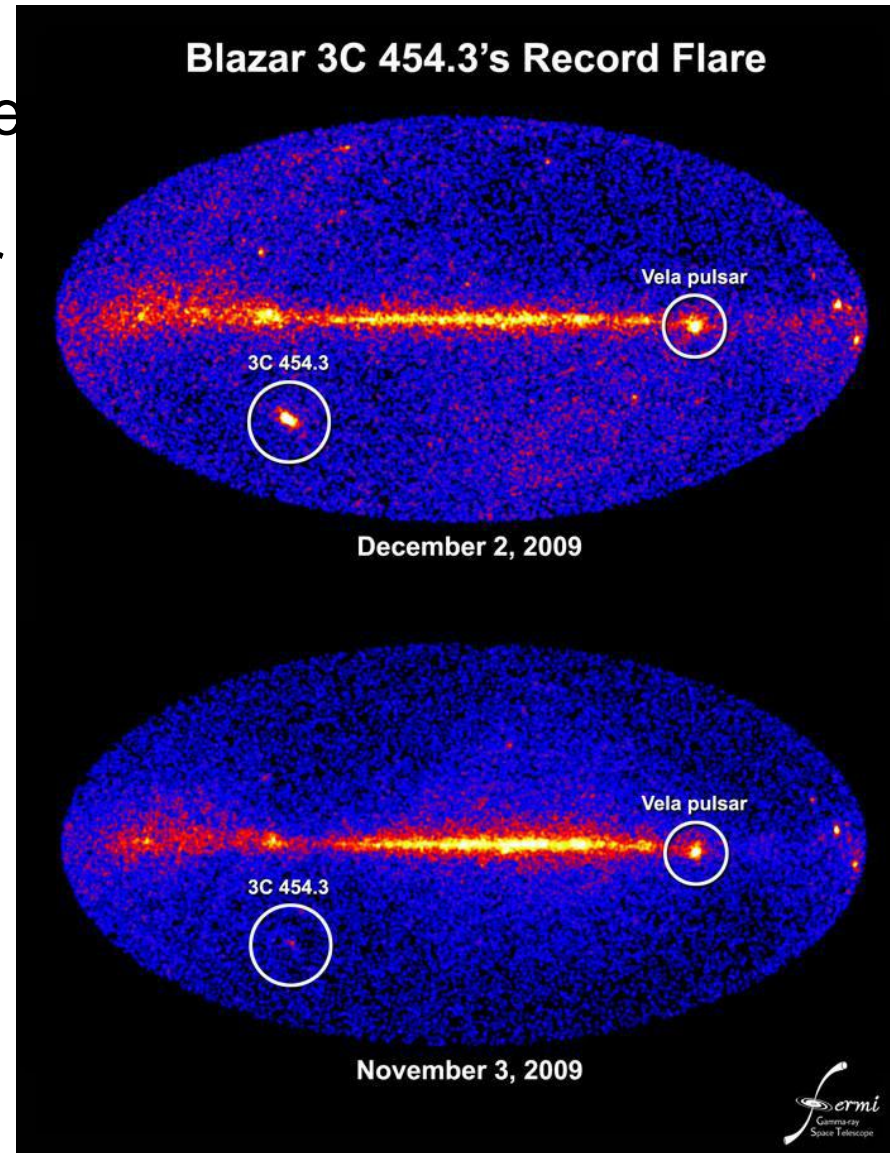
Best Instrument for monitoring the variation
of all sky AGN in gamma-ray band.

Large gamma-ray outburst on Dec. 2009 and ToO observation on Apr. 2010

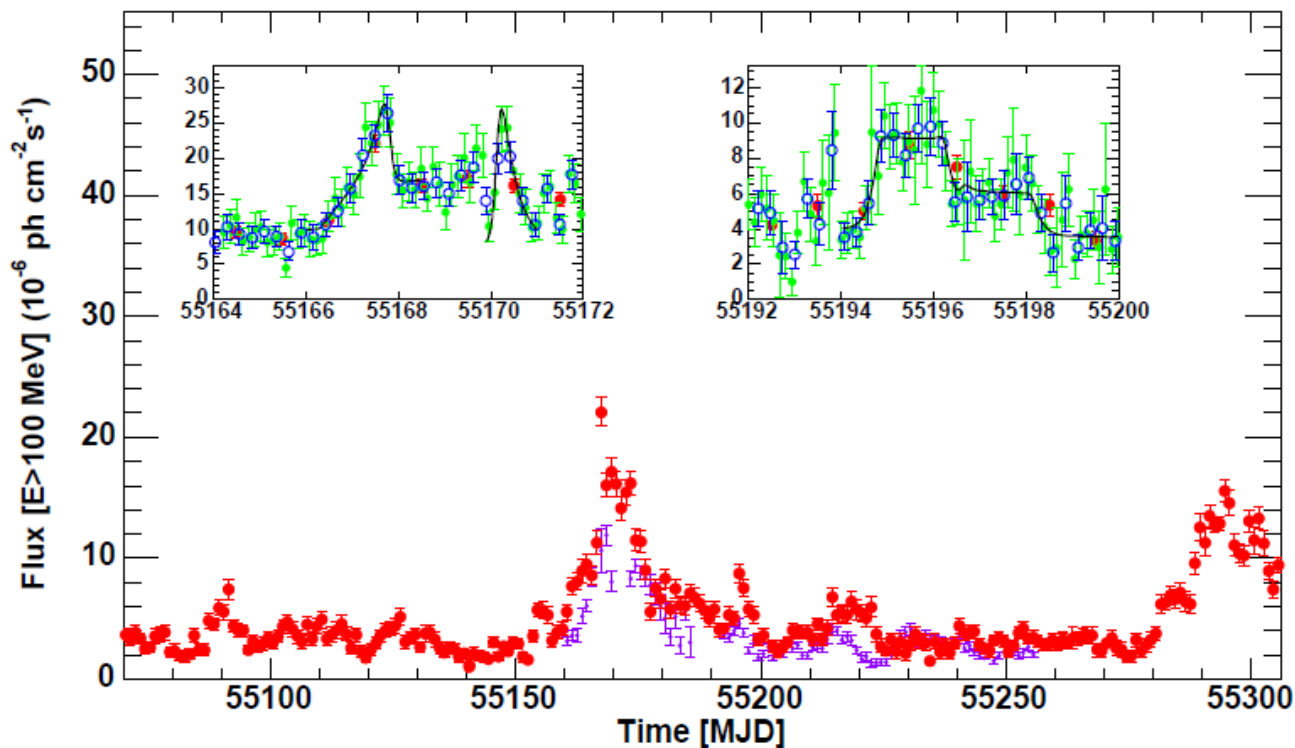
- 3C 454.3 shows external outburst and it becomes the brightest source in the gamma-ray sky for over a week, even higher than Vela pulsar on Dec. 2009
- The source remained active afterwards with a slowly decaying flux until Apr. 2010
- On 3rd Apr. 2010, 3C 454.3 brightened up again and ToO pointed observation began on Apr. 5 lasting for 200 ksec.

→連続的な観測が可能

Also see ATel #2328,2534



LAT Light curve (E>100MeV)

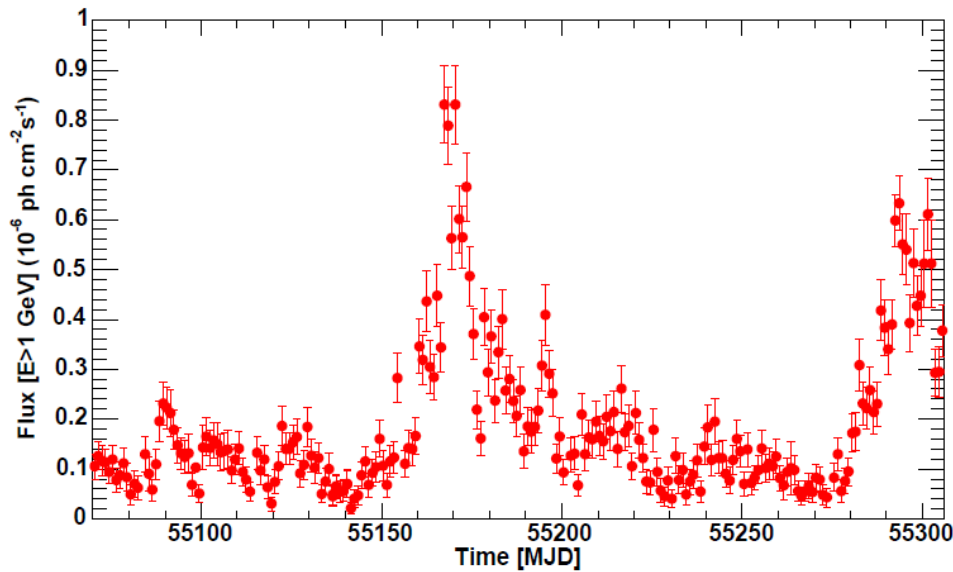


- Gamma-ray flux (E>100MeV) reached $(22 \pm 1) \times 10^{-6}$ [ph/cm²/s]

$$F = 2F_0 \left(e^{(t_0 - t)/T_r} + e^{(t - t_0)/T_f} \right)^{-1} + F_{bgd}(t),$$

- T_{rise} = 0.37 [day] and T_{fall} = 0.06 [day] for Dec. 2 flare
- T_{rise} = 0.07 [day] and T_{fall} = 0.26 [day] for Dec. 5 flare

Variation of spectral index



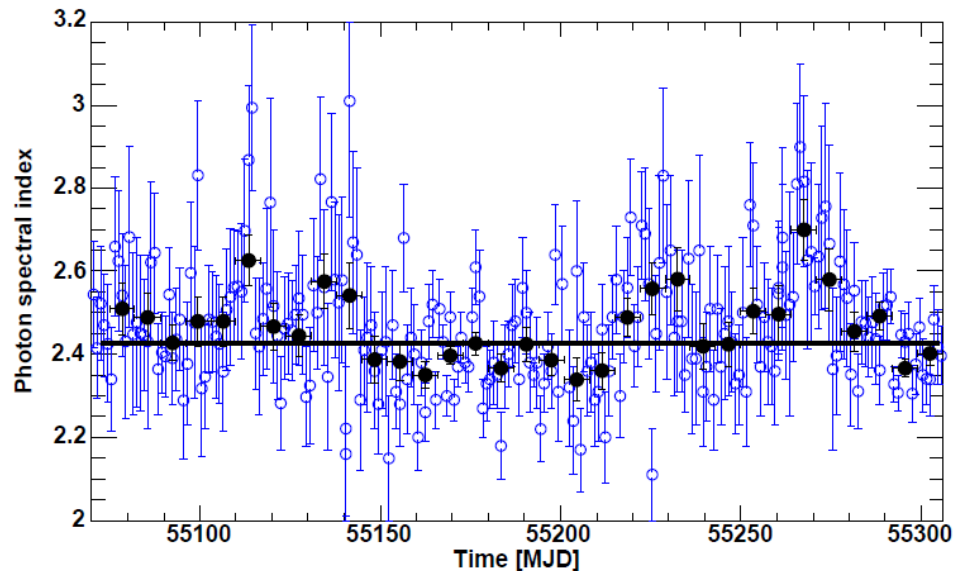
Light curve of the flux
for 1 GeV to 200 GeV

Variation of photon index

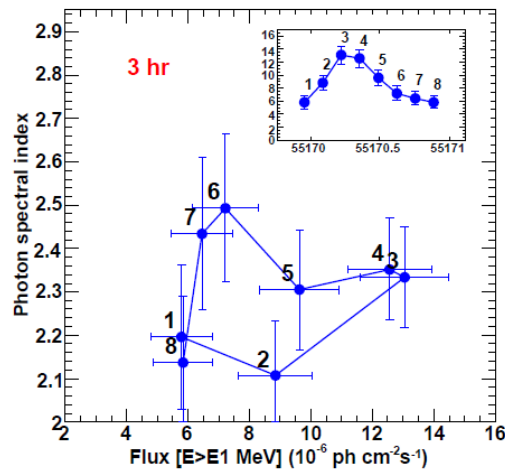
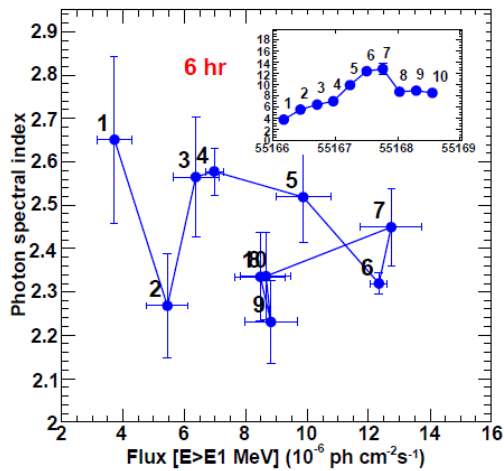
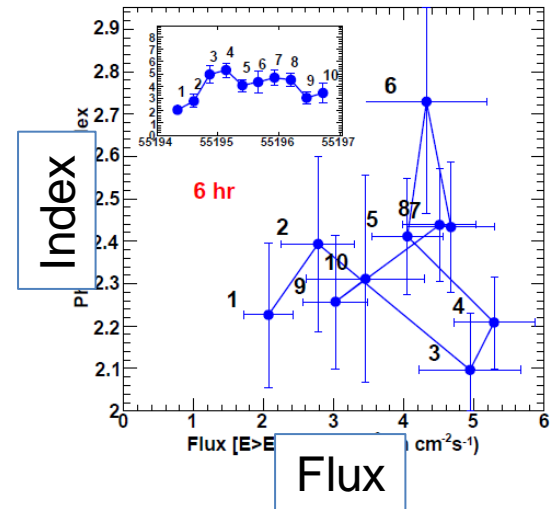
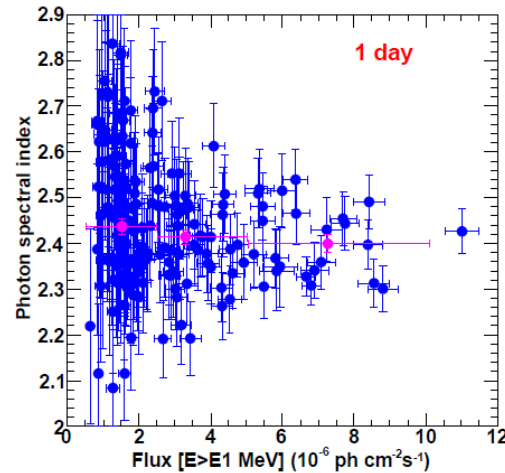
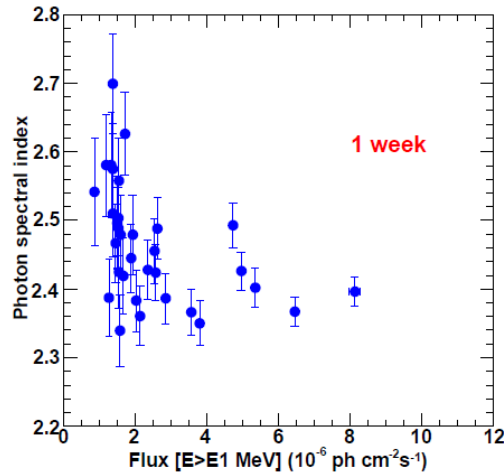
- color indicates **daily**(blue) data point and **weekly** (black) data point.

- Reduced chi-square = 86.4/32

Weekly photon index is variable, and the variation $\Delta\Gamma = 0.35$ at most

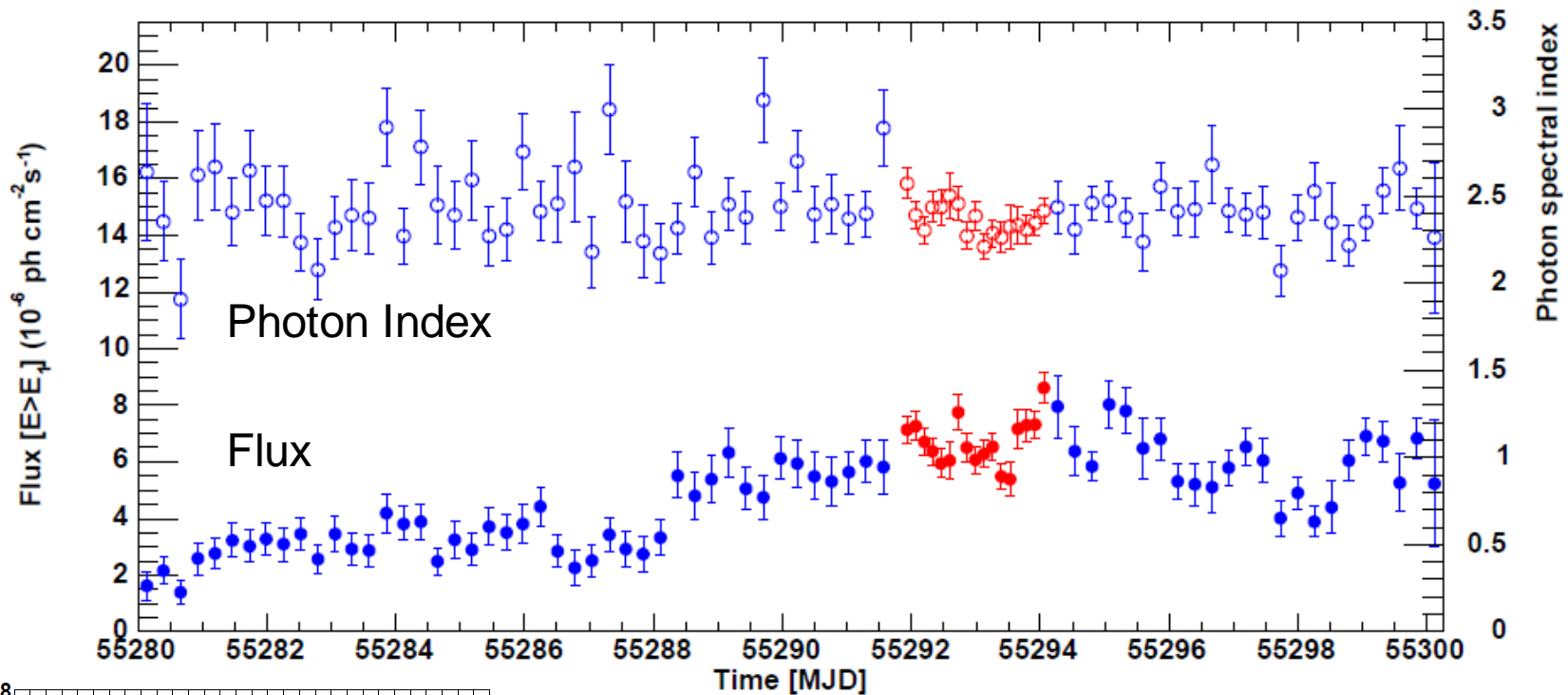


Flux vs Index plot



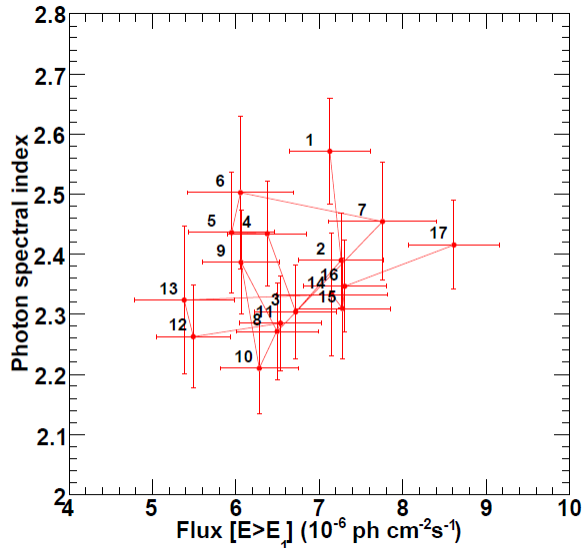
- Weak “harder when brighter “ effect is seen in weekly bins
- Due to the lack of statistical significance, it is difficult to draw any firm conclusion from these patterns

Results for ToO observation on Apr. 2010



Blue : 6 hour bin

Red : 3 hour bin (**ToO** for 200 ksec)



3C 454.3 brightened again on 3rd Apr. 2010
3-hour binned photon index is statistically constant.

Discussion

- Minimum Doppler factor δ is calculated using νF_ν flux (f_ϵ) at ($\epsilon=2d^2/(1+z)^2\epsilon_1$), variability time (t_{var}), and highest energy photon measurement ($E_1=mec^2\epsilon_1$) under the $\gamma\gamma$ opacity constraints and using the results from contemporaneous Swift/XRT observation (νF_ν flux @ 3keV) to estimate the νF_ν Flux @ ϵ_1 .

$$\delta_{min} \cong \left[\frac{\sigma_T d_L^2 (1+z)^2 f_{\hat{\epsilon}} \epsilon_1}{4 t_{var} m_e c^4} \right]^{1/6} \sim 13$$

Dondi & Ghisellini 1995 ; Ackermann et al. 2010

- This results consistent with obtained by observations of superluminal motion in the radio band, $\delta = 24.6 \pm 4.5$ (Jorstad et al. 2005)

- The distance r between emission region and BH on Dec. 2009 are estimated with variability time (minimum value of $t_{var} = 2.3$ h),

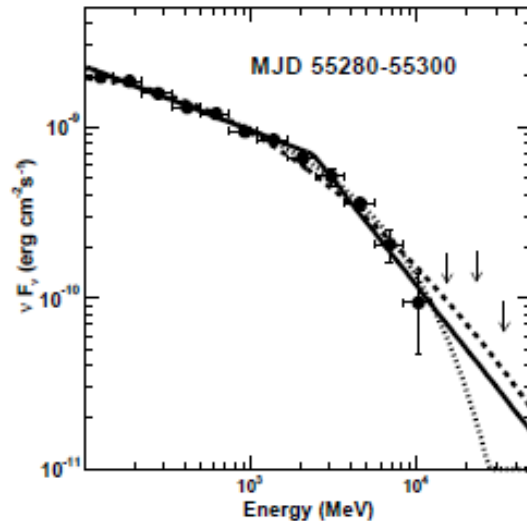
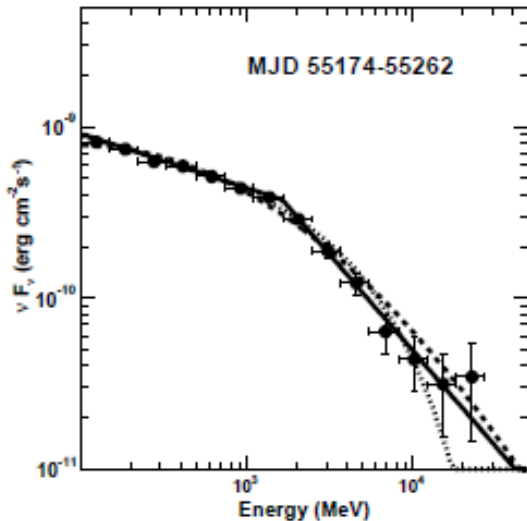
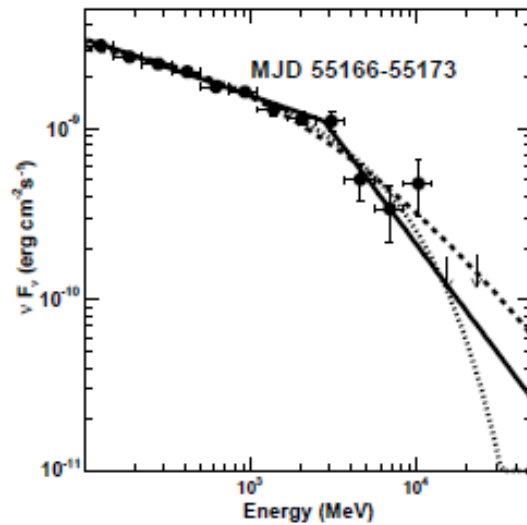
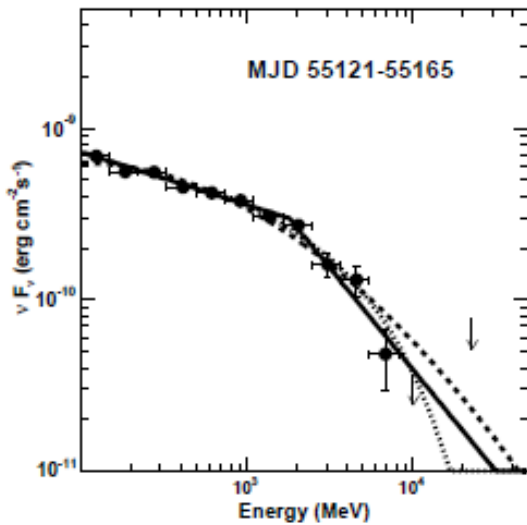
$$r \lesssim 2c\Gamma^2 t_{var} / (1+z) \approx 0.2\Gamma_{15}^2 t_{var,d} \text{ pc}$$

- Most rapidly varying flare suggest location at the sub-pc scale. (within BLR)
- But in other band (Optical , radio , ...) , the radiation is suggested to take place in several pc scale.

Summary

- Fermi/LAT observed two very bright outbursts from 3C 454.3 on Dec. 2009 and Apr. 2010. The ToO observation was performed for the latter.
 - Weekly spectral index is variable ($\Delta\Gamma = 0.35$)
 - No clear patterns were found in the photon-index/flux plane.
 - The gamma-ray spectral shapes do not show significant variations despite the large flux change by factor ~ 5
- $\delta_{\min} \sim 15$ is consistent with results from radio observations.
- The short time flare suggests an origin of the gamma-ray emission region within BLR (\sim sub pc)

Gamma-ray spectra for different time period



- Fitted with
Broken power-law (solid)
log parabola (dashed)
PL + exp. cutoff (dotted)
- Spectra are best
represented by Broken PL,
and cutoff PL is also
acceptable statistically
- Apparent spectral
evolution was not seen.