

# Fermi Large Area Telescope Detection of Two Very-High-Energy ( $E > 100$ GeV) Gamma-ray Photons from the $z=1.1$ blazar PKS 0426-380

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C.D.Dermer (NRL), on behalf of Fermi-LAT collaboration

Y.T.Tanaka et al. ApJL, 2013 (arXiv: 1308.0595)

# Outline

- Recent progress on Extragalactic Background Light (EBL) study
- Redshift determination of PKS 0426-380
- Fermi-LAT detection of 2 VHE ( $E > 100$  GeV) events from directional vicinity of the  $z=1.1$  blazar PKS 0426-380
- Possible presence of additional flat spectrum component above several tens of GeV
- Summary

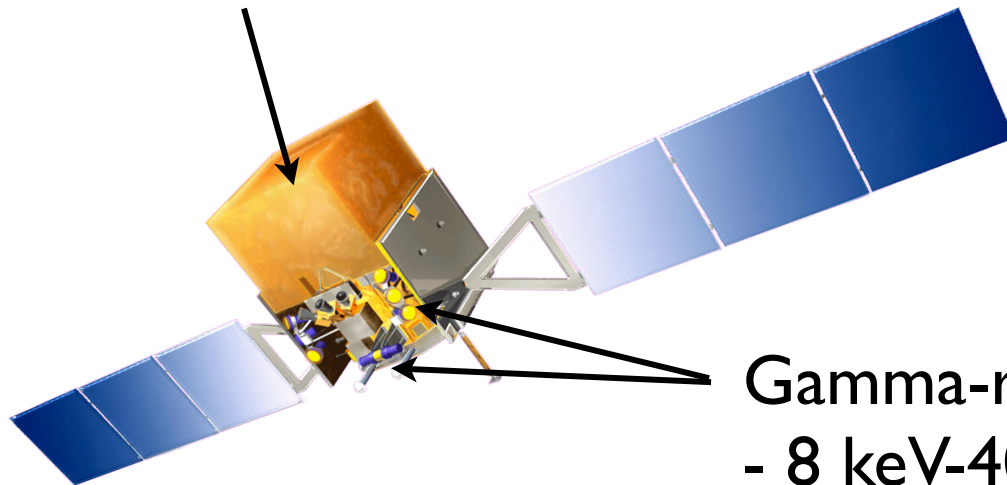
# Fermi Gamma-ray Space Telescope

- Launched on June 11, 2008
- Science operation has continued without any problem

## Large Area Telescope (LAT)

- 20 MeV-300 GeV

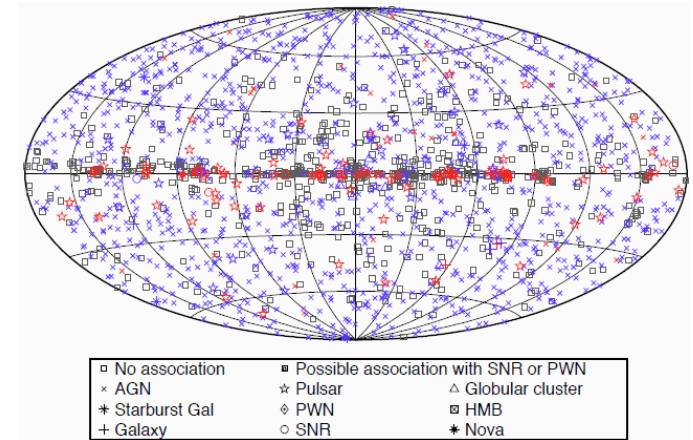
- Scan all-sky every 2 orbits (~3 hours)



## Gamma-ray Burst Monitor (GBM)

- 8 keV-40 MeV

- Detect transient events



2-year catalog (2FGL)  
includes 1873 srcs:  
Extragalactic sources  
( $b > 10$  deg) are mostly  
blazars (BL Lacs, FSRQs)

# Large Area Telescope

## *Pair-conversion telescope*

### **Si-strip Tracker with tungsten foil converter:**

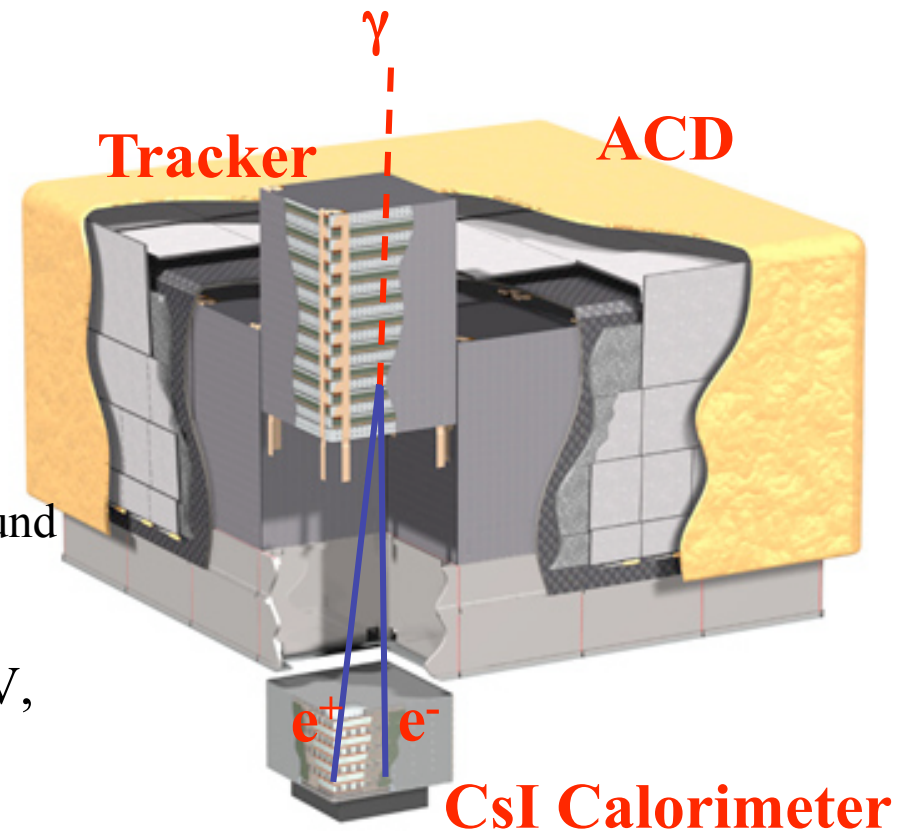
Measure the photon direction

**CsI Calorimeter:** Measure the photon energy,  
Image the shower

### **ACD (Plastic scintillator):**

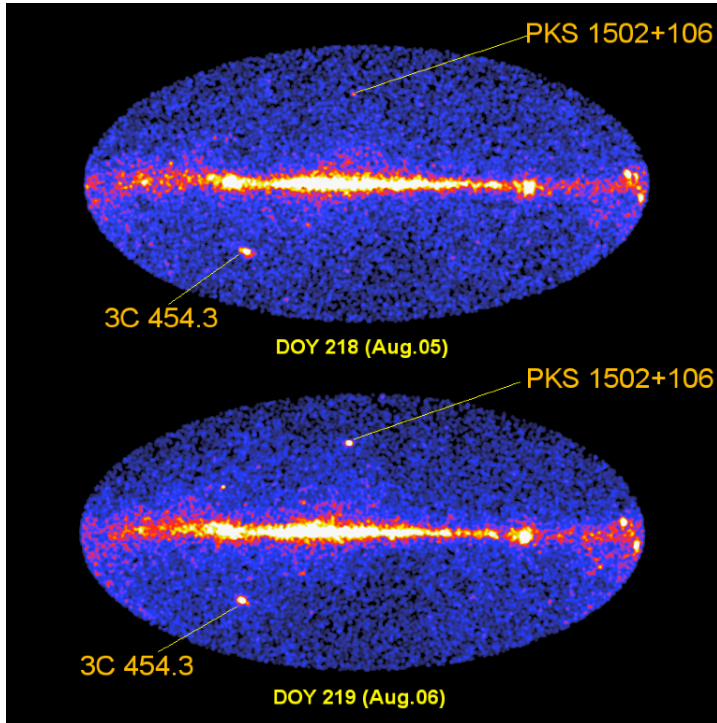
Reject charged-particle background

- Large effective area (9000 cm<sup>2</sup> @ 1 GeV, normal incidence)
- Large field-of-view (2.4 str)
- The entire sky is observed every ~3 hours
- Energy range: 20 MeV – 300 GeV
- Angular resolution (68% contaminant radius): 0.6 deg @ 1 GeV



4 x 4 modular array  
3000 kg, 650 W

# How to detect flaring flazars



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## GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106

ATel #1650; [S. Ciprini \(Univ./INFN Perugia\) on behalf of the GLAST Large Area Telescope Collaboration on 8 Aug 2008; 00:02 UT](#)  
Credential Certification: [Stefano Ciprini \(stefano.ciprini@pg.infn.it\)](mailto:stefano.ciprini@pg.infn.it)

Subjects: Gamma Ray, >GeV, AGN, Quasar

Referred to by ATel #: [1661](#), [1905](#)

The Large Area Telescope (LAT), one of two instruments on the Gamma-ray Large Area Space Telescope (GLAST) (launched June 11, 2008), which is still in its post-launch commissioning and checkout phase, has been monitoring high flux from a source positionally consistent with the blazar PKS 1502+106 (R.A.:15h04m24.9797s; Dec.:+10d29m39.198s, also known as OR 103 and S3 1502+10) since August 6, 2008.

Preliminary analysis indicates that the source is in a high state with a gamma-ray flux ( $E > 100 \text{ MeV}$ ) well above pre-defined LAT flaring source reporting threshold of  $2 \times 10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$ .

This is a well-known radio source classified as a Flat Spectrum Radio Quasar (FSRQ), observed by several X-ray instruments. This is the first time that it has been reported to have gamma-ray emission.

Please note that PKS 1502+106 has two possible redshifts listed in the literature:  $z=0.56$  and  $1.83$ ; the former seems preferred (A.E. Wright et al. 1979 ApJ 229,73; B.J. Wilkes 1986, MNRAS, 218, 331).

Because GLAST has just started its scientific standard operations, regular gamma-ray monitoring of this source will be pursued. In consideration of the ongoing activity of this source we strongly encourage multiwavelength observations of PKS 1502+106.

The GLAST LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.

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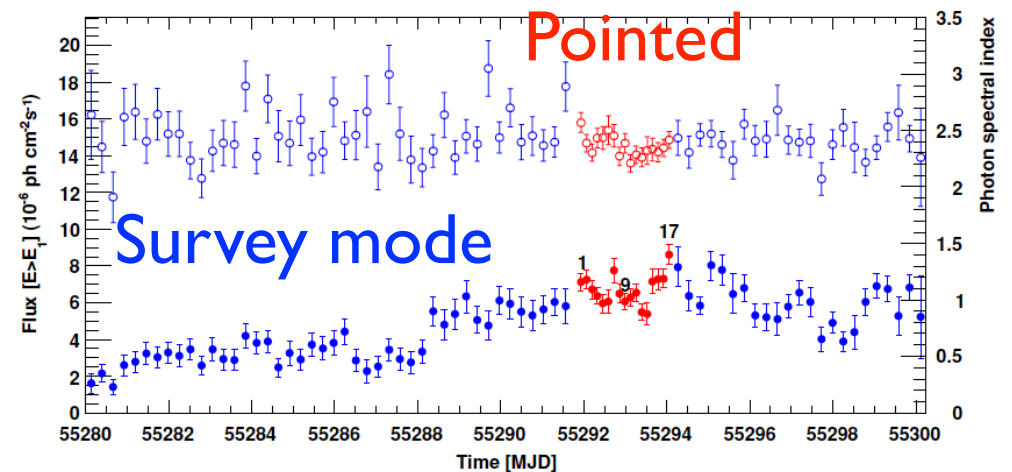
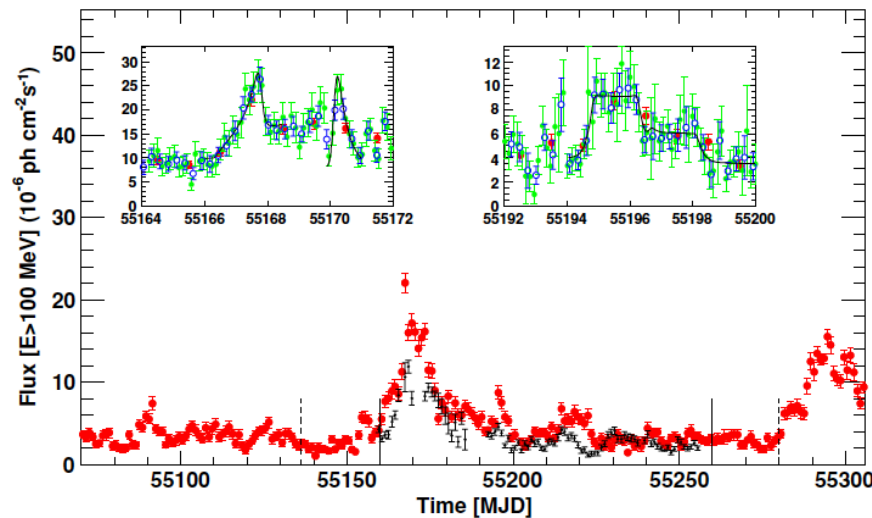
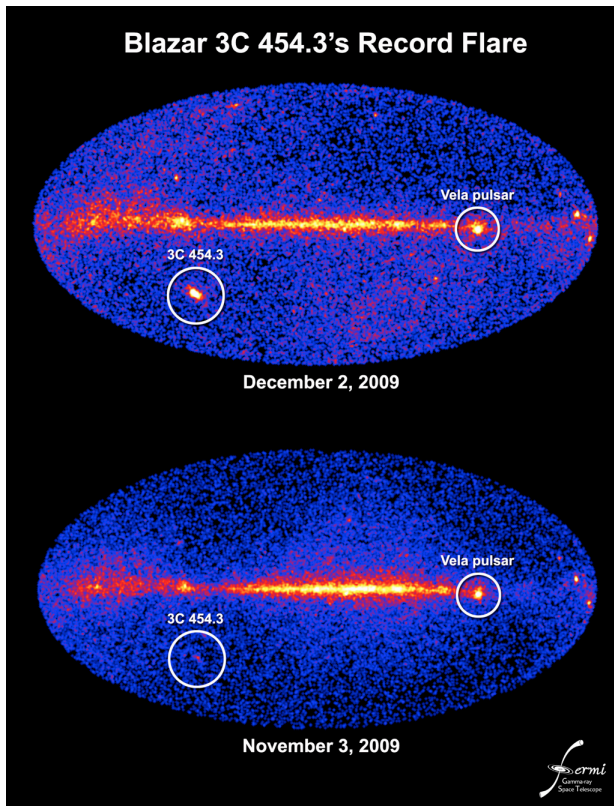


[ [Telegram Index](#) ]

Related	
1905	<a href="#">Fermi-LAT detection of renewed activity from the blazar PKS 1502+106</a>
1661	<a href="#">Archival light curve for the flaring GLAST blazar PKS 1502+106</a>
1650	<a href="#">GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106</a>

- Automatic pipeline analysis for 6-hour/1-day binned LAT data.
- Flare Advocate(s) also analyze the data manually and check the result, once flaring objects ( $\text{Flux} > 1.0 \times 10^{-6} \text{ photons/cm}^2/\text{s}$  for  $E > 100 \text{ MeV}$ ) are detected
- After the confirmation, Astronomers Telegram are issued

# TOO Pointing-mode

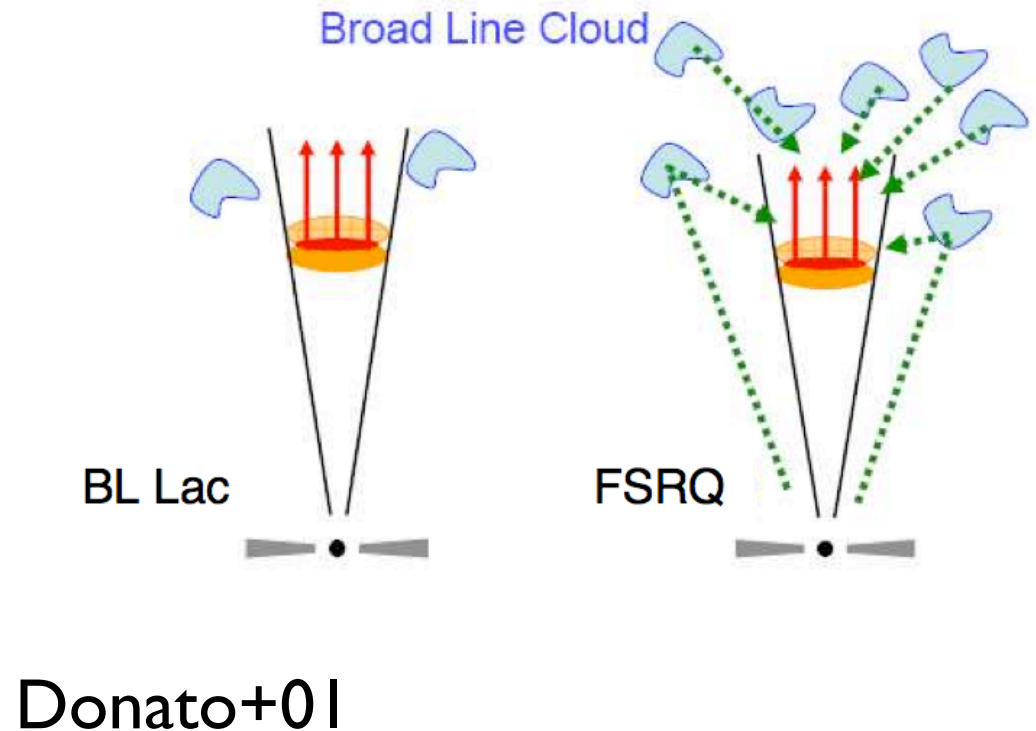
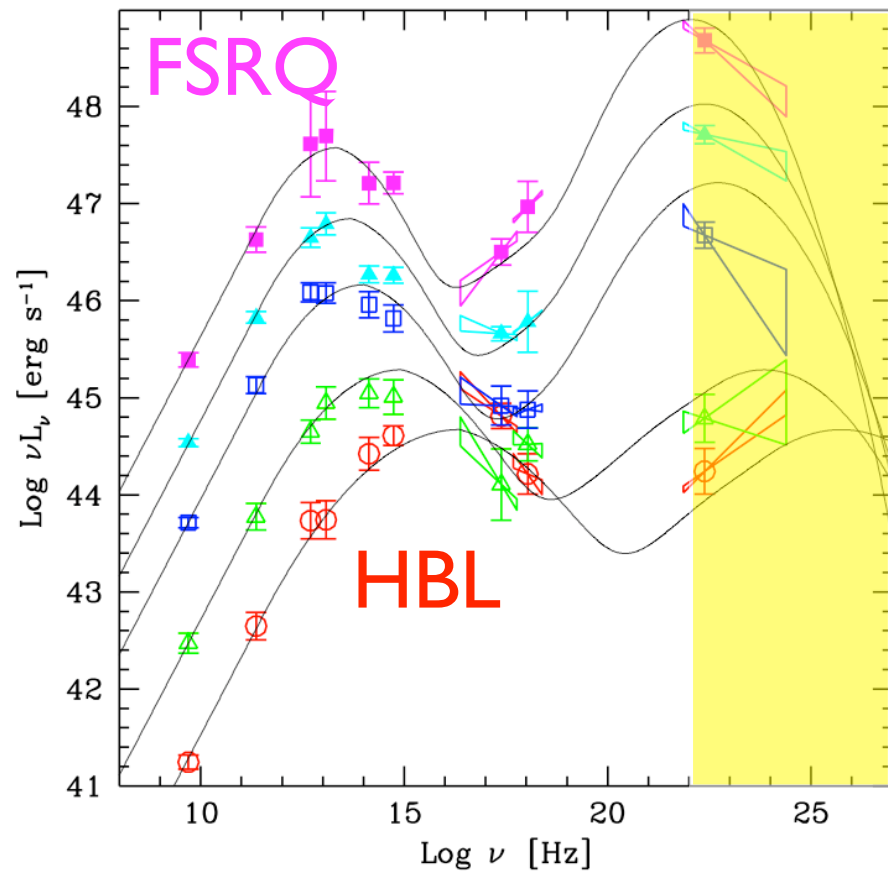


Ackermann+10  
(CA:YTT, C. Dermer, L. Escande, B. Lott)

- About 95% of observing time is all-sky survey mode
- But if interesting phenomena (Strong blazar flare, GRB, Novae etc) are detected, TOO pointing-mode is triggered

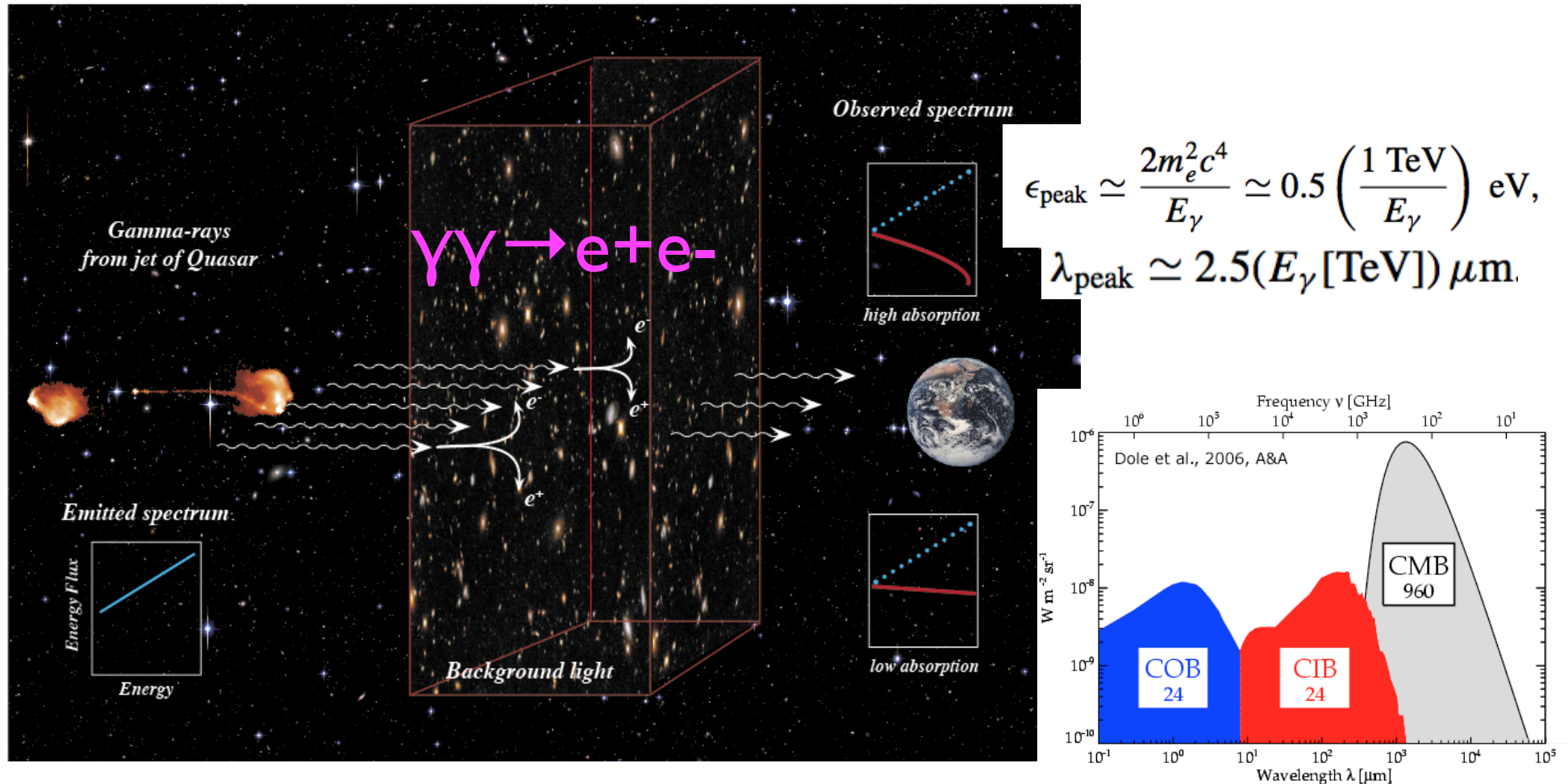


# Blazar emission in gamma-ray band ( $E > \sim 10^{22}$ Hz)



- Flat spectrum radio quasars (FSRQs): Bright disk  $\rightarrow$  External compton dominant
- BL Lac: Disk and BLR are faint (no optical emission line)  $\rightarrow$  SSC

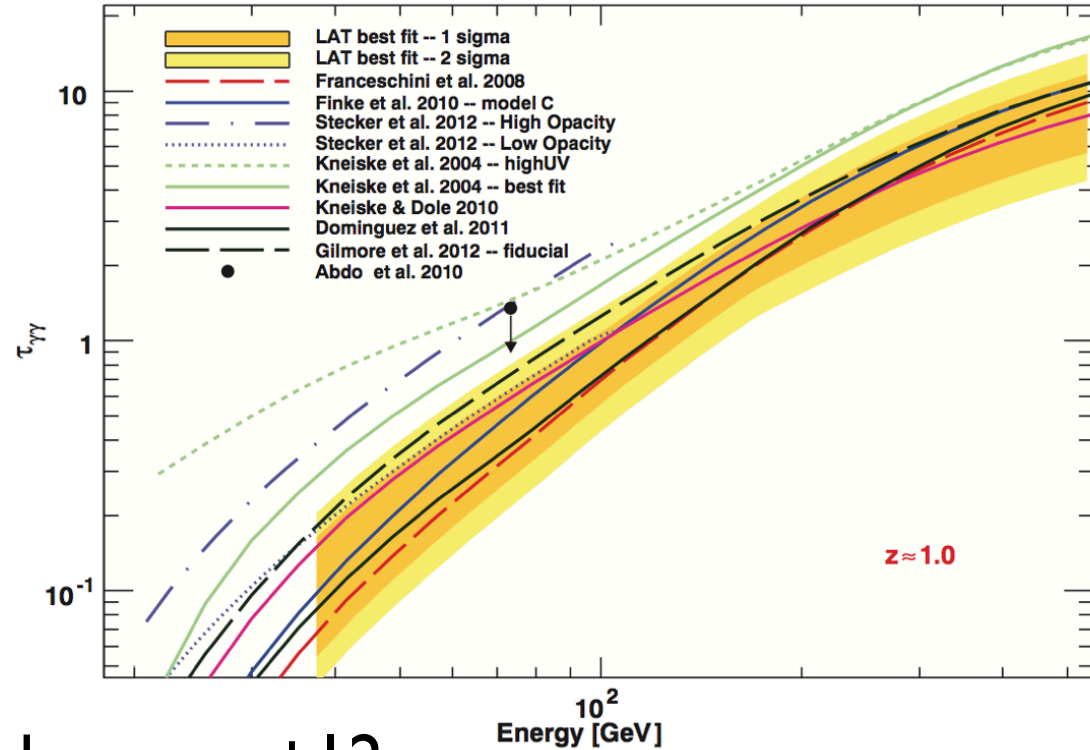
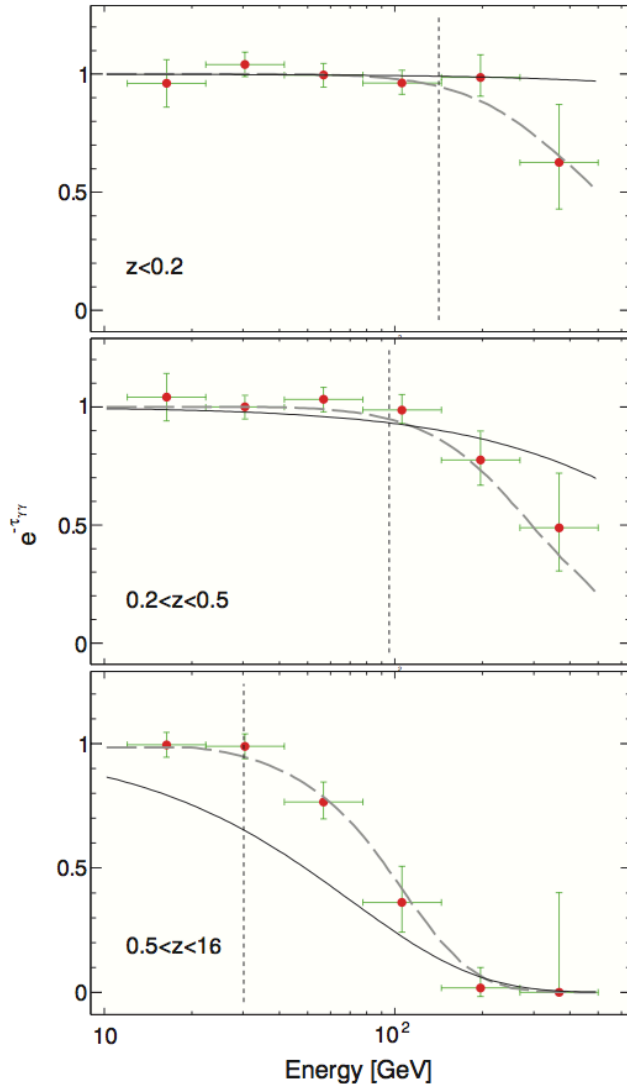
# Extragalactic Background Light



- Level of EBL intensity, which is difficult to measure directly, can be estimated by absorption feature in sub-TeV~TeV gamma rays



# Fermi-LAT constraint on the EBL

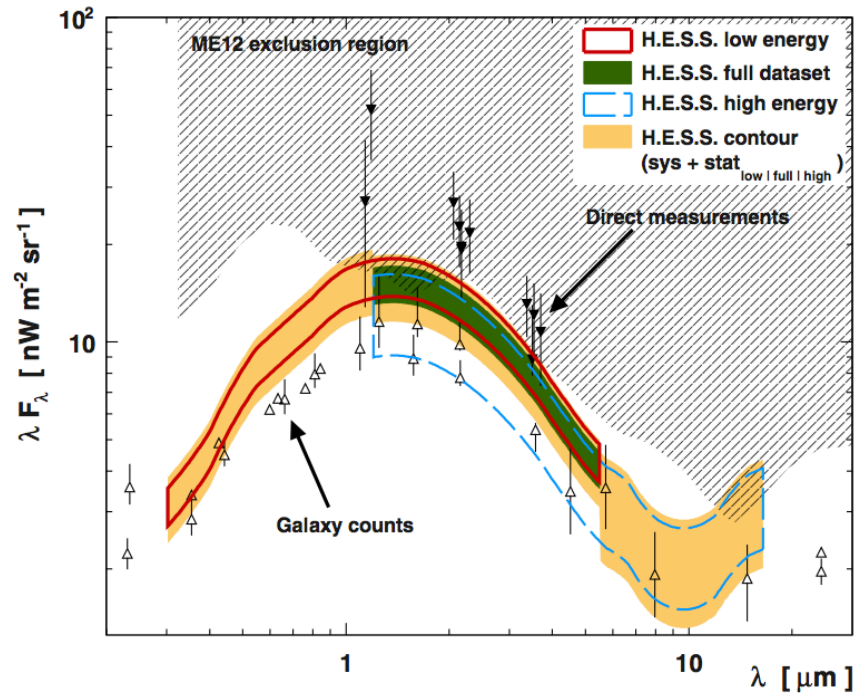


Ackermann+12

Statistical study of the Fermi-LAT BL Lac data revealed the minimal level of EBL intensity, which was expected by e.g., Franceschini+08, Dominguez+11, Inoue+13

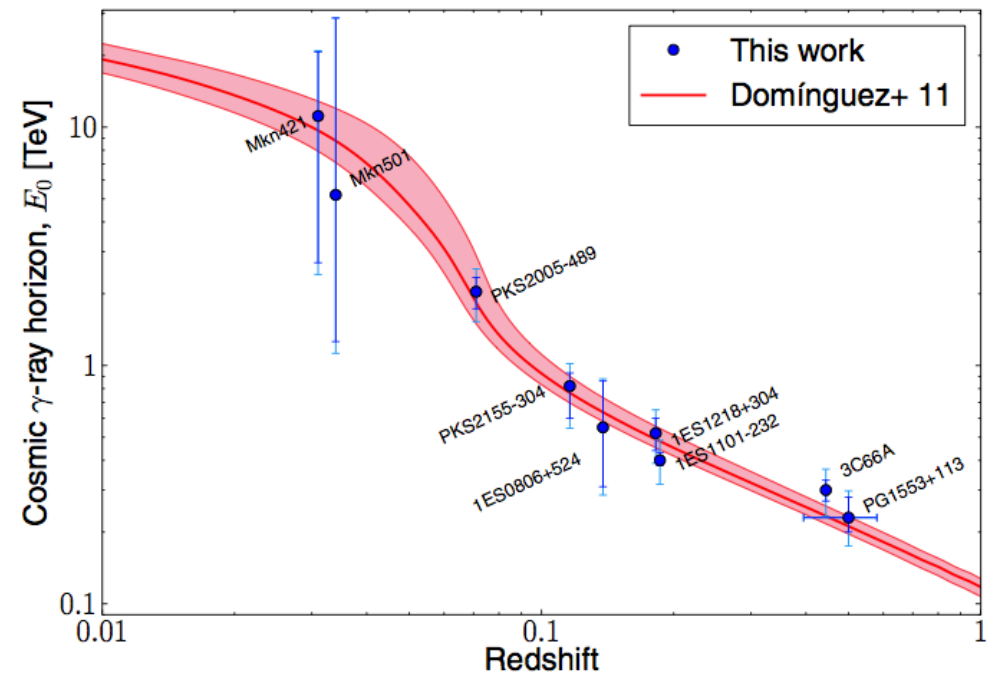
# Further observational constraints

From HESS data



Abramowski+13

Estimation of gamma-ray horizon based on SED modeling

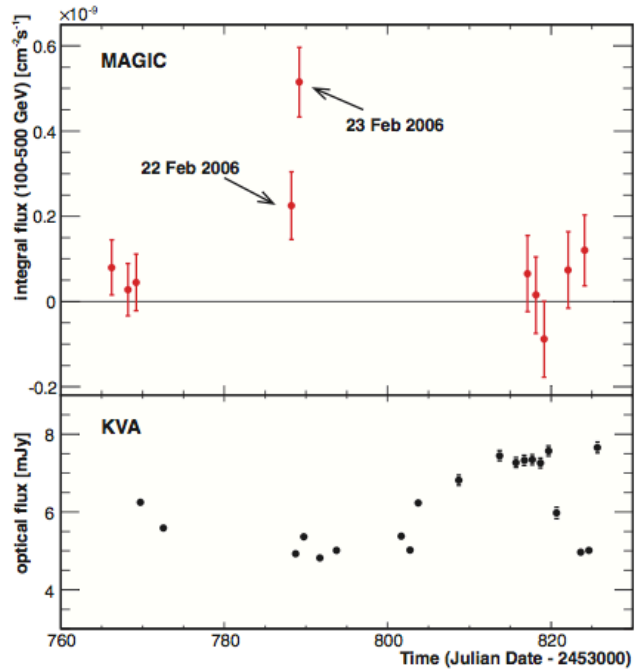


Domínguez+13

- Again, consistent with the lowest level EBL intensity

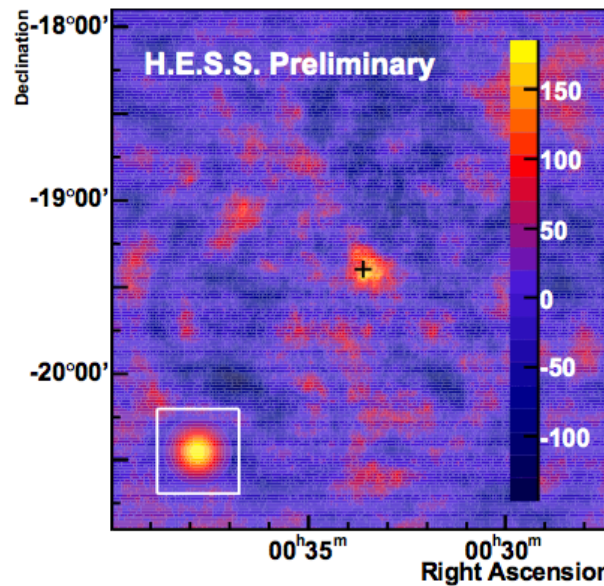
# Distant VHE ( $E > 100$ GeV) sources

3C 279 at  $z=0.536$



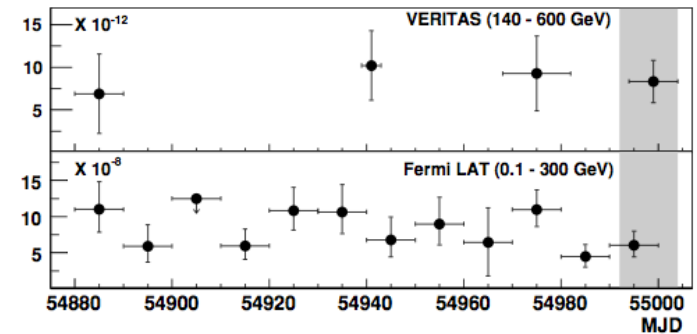
Aleksic+08

KUV 00311-1938  
at  $z=0.61(?)$



Becherini+12

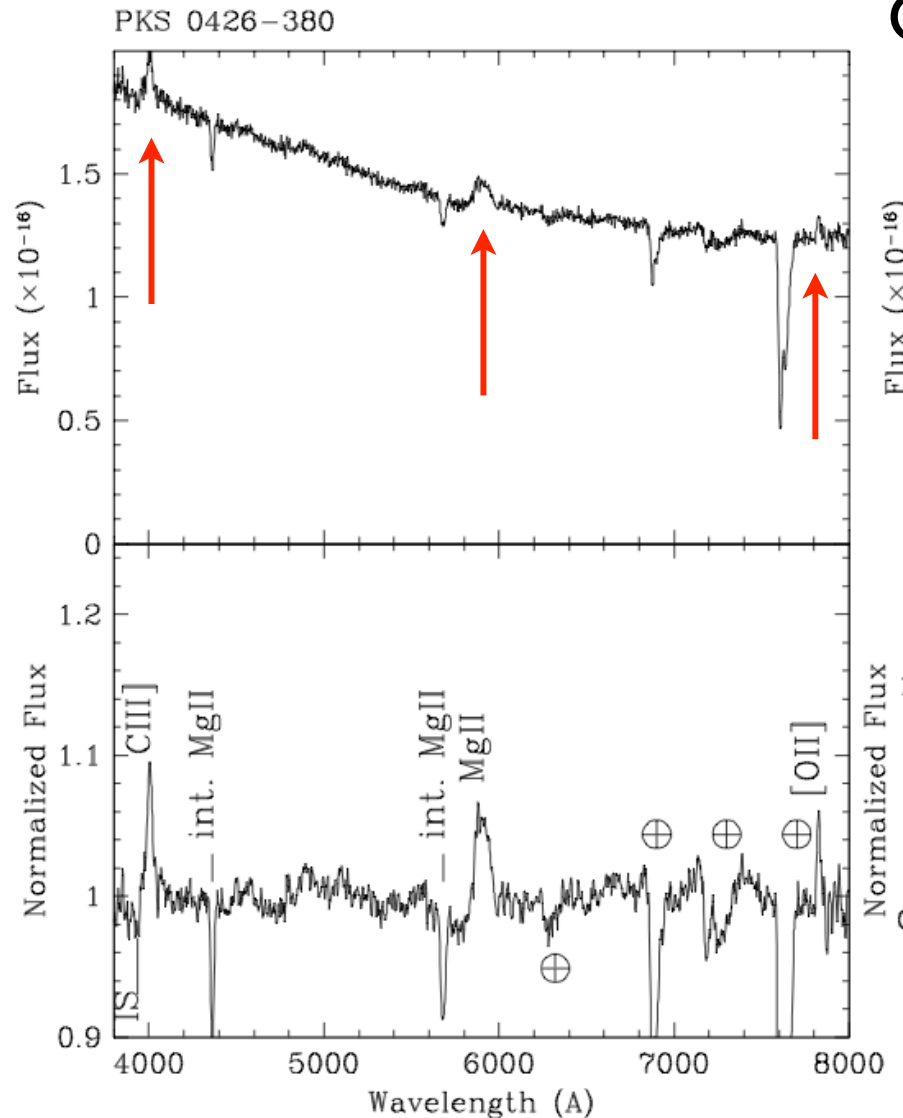
PKS 1424+240  
at  $z > 0.6035$



Acciari+10, Furniss+13

Current VHE detection is still limited to  $z < 1.0$ , while the low-intensity EBL models imply a  $z \sim 1$  horizon for  $\sim 100$  GeV gamma-rays (e.g., Franceschini+08, Dominguez+11, Inoue+13)

# Robust redshift of PKS 0426-380

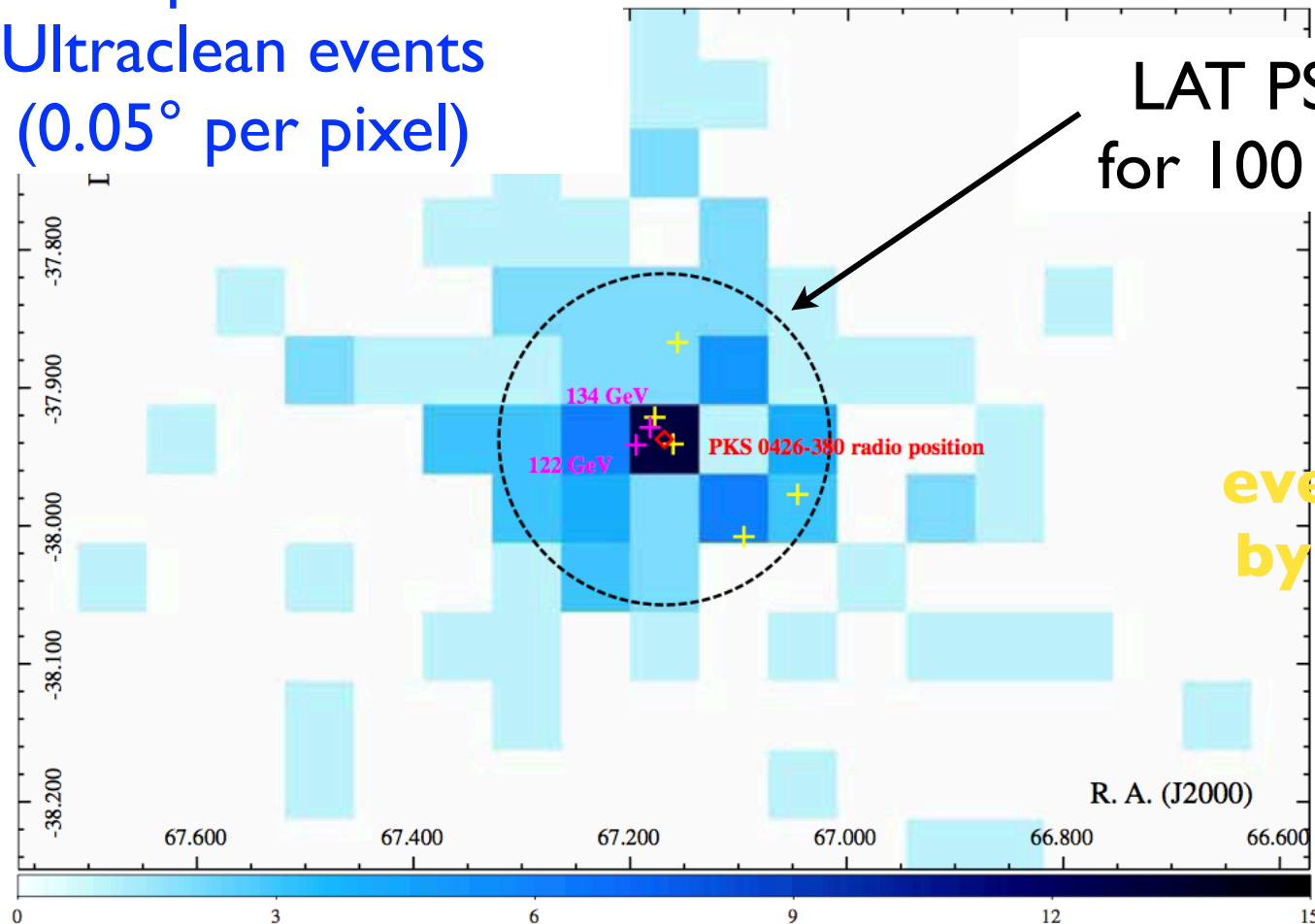


Optical spectrum taken by  
8m VLT (Sbarufatti+05)

- ◆ **3 Emission Lines**
  - ✓ Mg II  $\lambda$ 2798 at  $z=1.112$
  - ✓ C III] at  $z=1.098$
  - ✓ [O II]  $\lambda$ 3727 at  $z=1.099$
- ◆ **2 Intervening systems at  $z=1.030$  and  $0.559$**
- ◆ **No Host galaxy in HST image, consistent with high redshift (Urry+00)**

# Location of 2 VHE events

Count map of 5-300 GeV  
Ultraclean events  
( $0.05^\circ$  per pixel)



LAT PSF (0.12 deg)  
for 100 GeV photons

**50-100 GeV  
events are shown  
by yellow crosses**

- **134 GeV and 122 GeV ULTRACLEAN events** were detected from close vicinity of PKS 0426-380



# Detailed description of the 2 VHE events

**Table 1**  
Detailed Description of the Two VHE Events Detected by *Fermi*-LAT

Energy <sup>a</sup> (GeV)	MET (UT)	R.A. (J2000) (deg)	Decl. (J2000) (deg)	Angular Separation <sup>b</sup> (deg)	gtsrcprob <sup>c</sup> Probability
134 (2010 Jan 13 02:51:39.724)	285043901.724	67.182	−37.930	0.013	0.9999763
122 (2013 Jan 22 09:32:21.325)	380539944.325	67.194	−37.943	0.021	0.9999720

**Notes.** Both of the events are ULTRACLEAN class and FRONT converting.

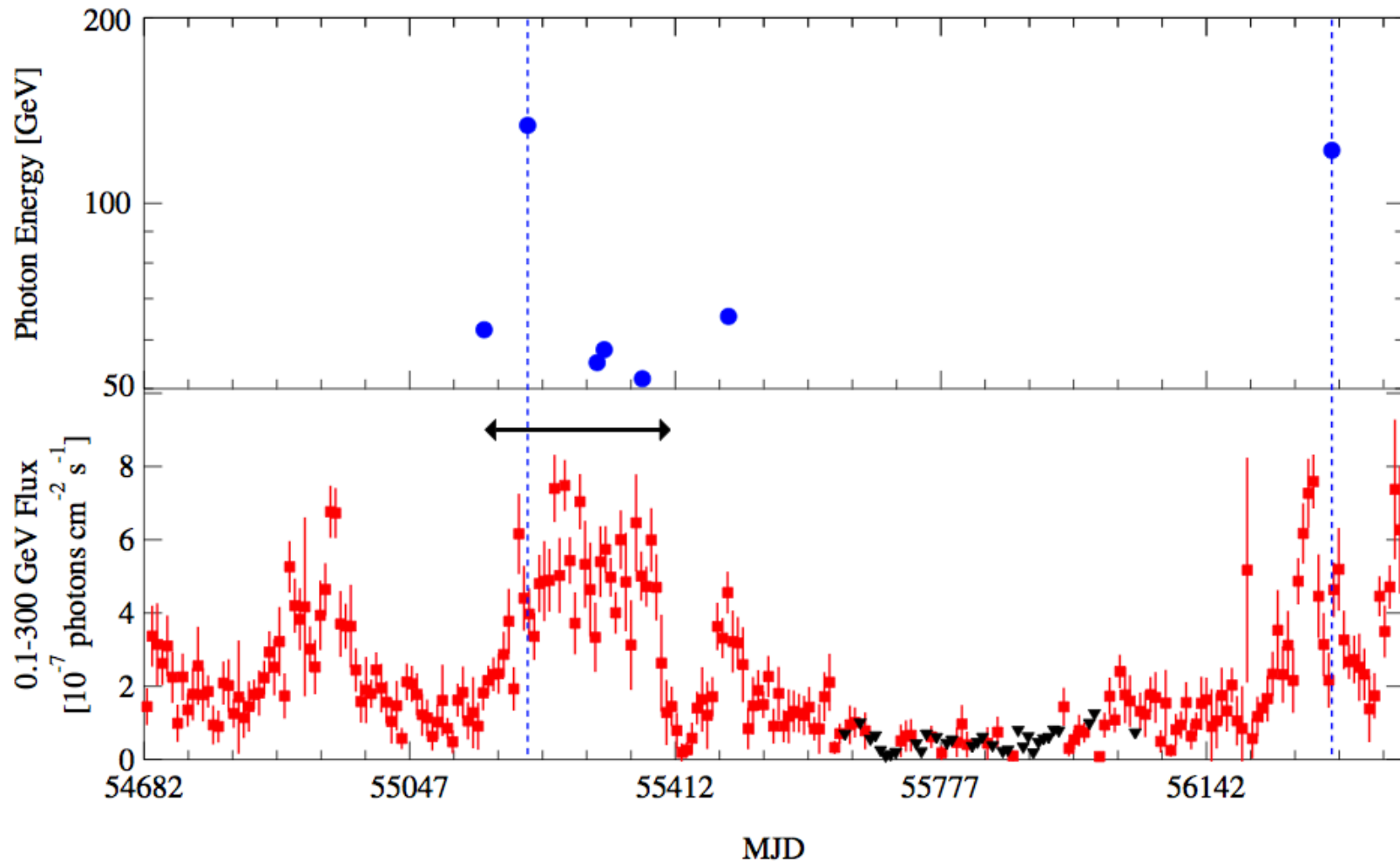
<sup>a</sup> The energy resolution is of the order of 10% (Ackermann et al. 2012a).

<sup>b</sup> Angular separation is calculated from the radio position of PKS 0426−380, R.A. = 67.1684342° and decl. = −37.9387719° (J2000; Johnston et al. 1995).

<sup>c</sup> The probability that the event belongs to PKS 0426−380, which is calculated by using gtsrcprob.

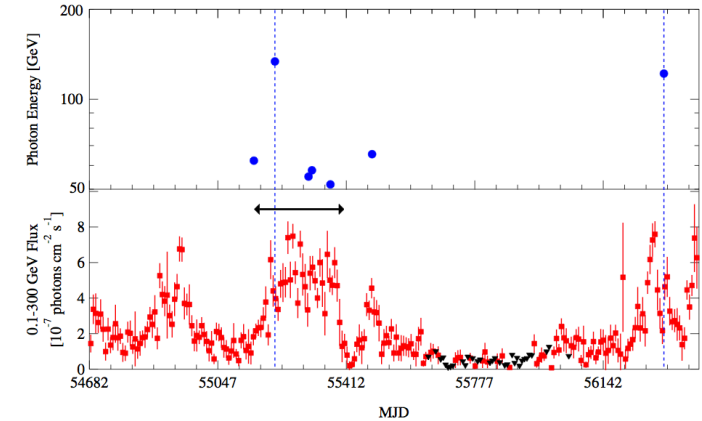
- ULTRACLEAN class (highest probability of being gamma-rays)
- Angular separations are within 0.021 deg at most

# Arrival times of $E > 50$ GeV ULTRACLEAN events

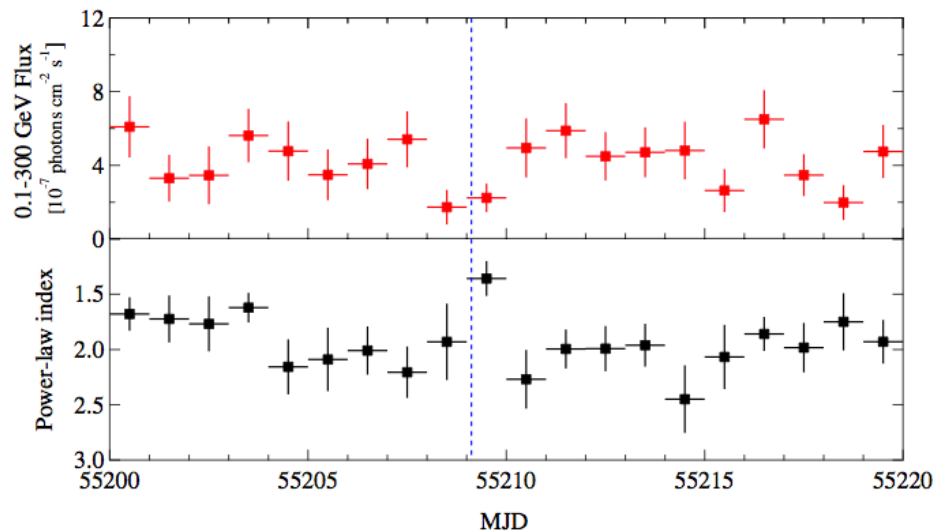


- All of the seven  $E > 50$  GeV events were detected during high state of the source

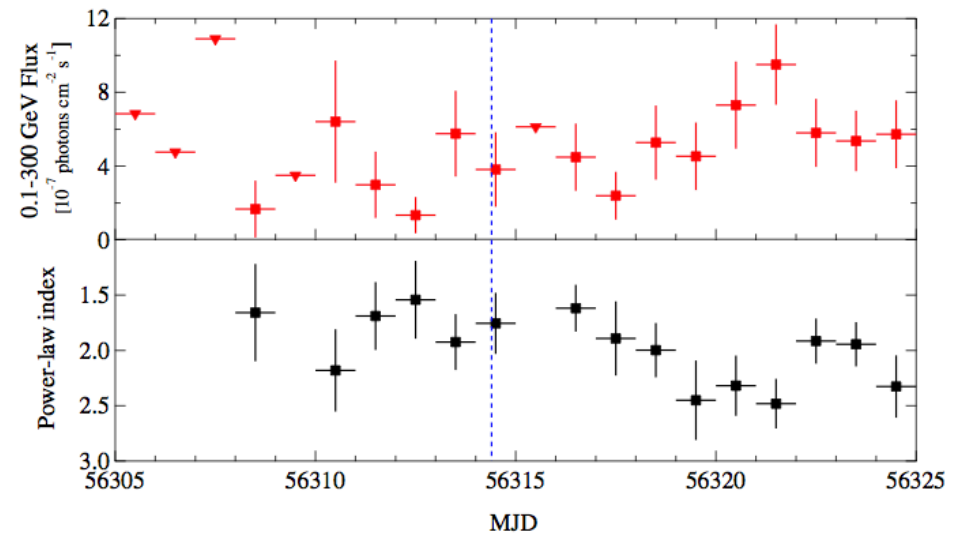
# Daily LAT flux ( $E > 100$ MeV, red) and Power-law index (black) around 2 VHE events



## 1st VHE event



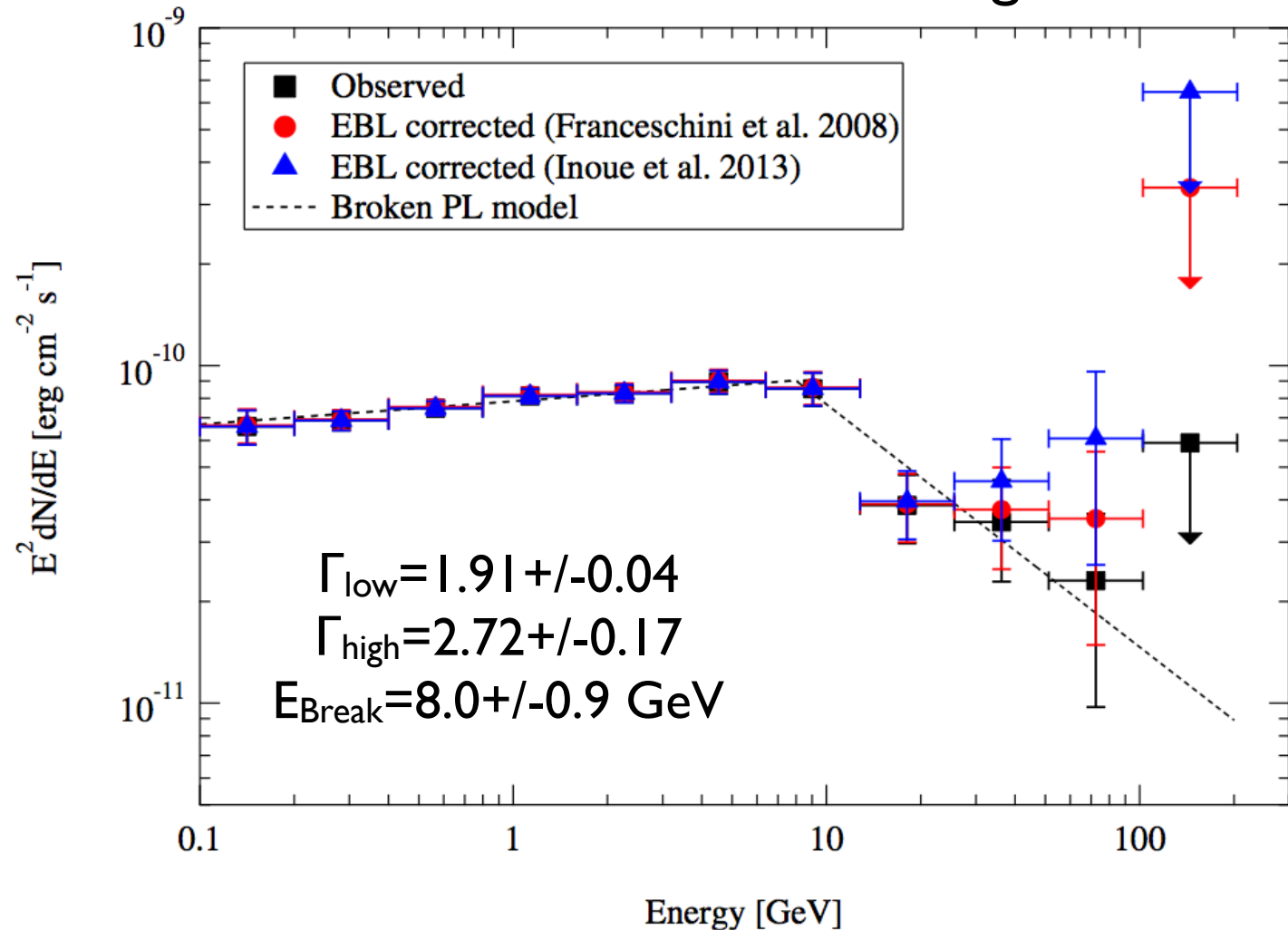
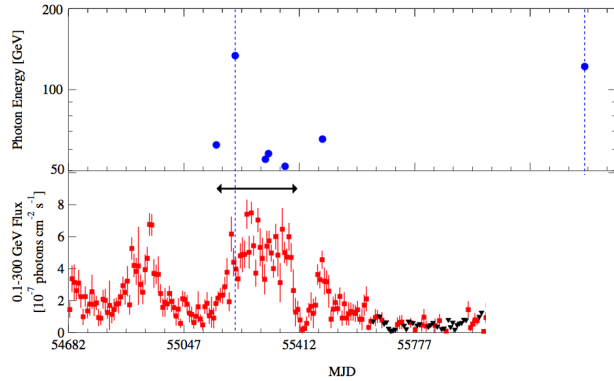
## 2nd VHE event



- Apparent spectral hardening at the day of the 1st VHE event ( $\Gamma \sim 1.4$ )
- No significant spectral and flux change during the 2nd VHE event

# Sharp break and Hint of additional flat spectral component

LAT spectrum accumulated over the ~8 months high state



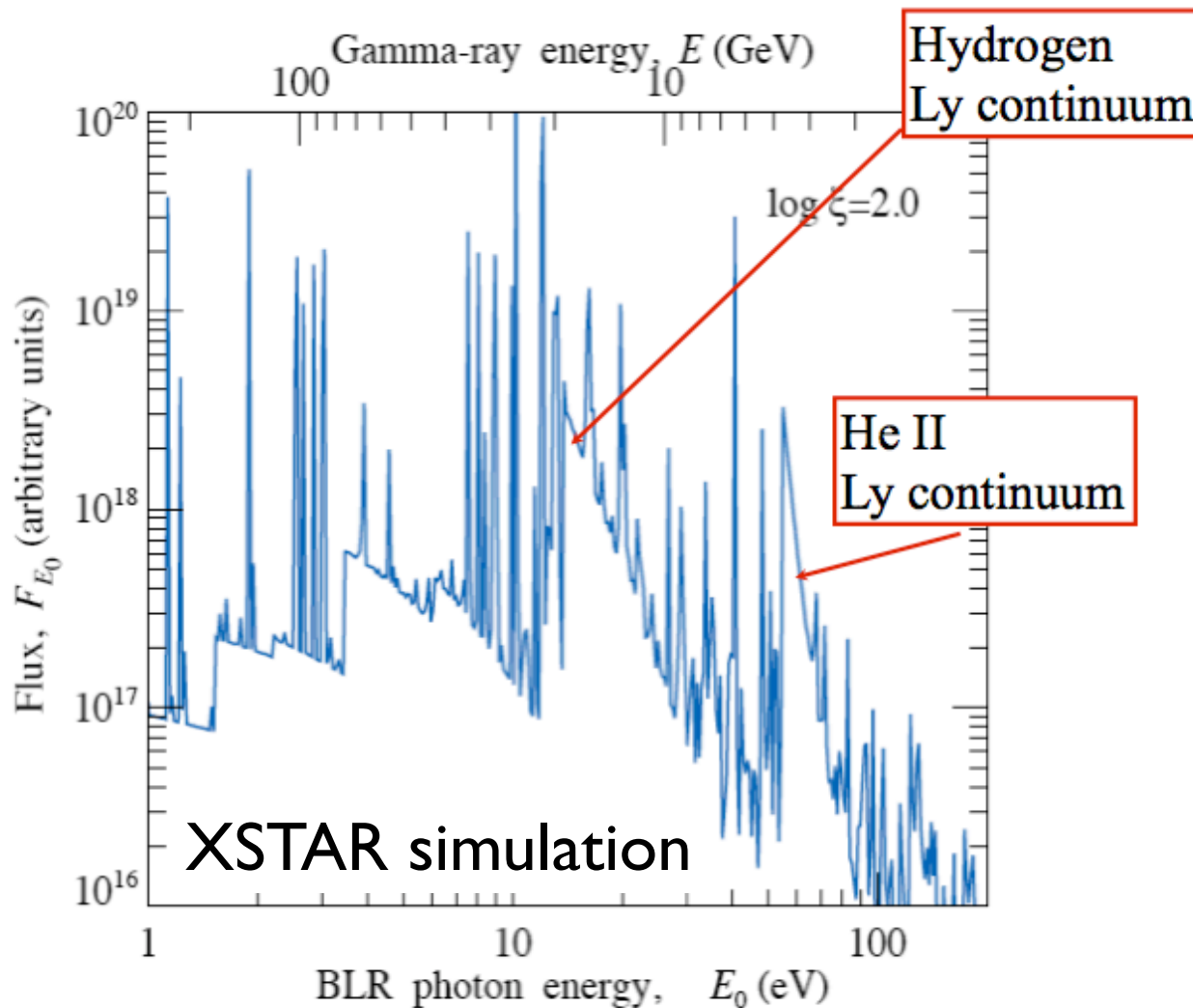
See also  
Senturk+13

# Emission from BLR cloud photo-ionized by accretion disk

## BLR line energy

BLR Strongest Lines and Recombination Continua Causing Jumps in the  $\gamma$ -ray Opacity

Feature	$\lambda_{\text{BLR}}^{\text{a}}$ (Å)	$E_{\text{BLR}}^{\text{b}}$ (eV)	$E_{\gamma}^{\text{c}}$ (GeV)
Low-ionization lines			
O VII (blend)	22	560	0.47
C V (blend)	40.5	305	0.86
Low-ionization H I 10 eV complex			
Ly continuum	911	13.6	19.2
Ly $\alpha$	1215	10.2	25.6
C IV	1549	8.0	32.6
Low-ionization He I 20 eV complex			
He I rec. continuum	504.2	24.6	10.6
He I	584.3	21.2	12.3
High-ionization lines			
O VIII	16.01	774	0.34
O VIII	18.97	653	0.40
C VI	33.74	367	0.71
He II 50 eV complex			
He II Ly continuum	227.8	54.4	4.8
Fe XV	284.2	43.6	
Si XI	303.3	40.9	
He II Ly $\alpha$	303.8	40.8	6.4



- Poutanen & Stern (2010) considered absorption of gamma-rays by these BLR optical/UV photons



# Intrinsic PL gamma-ray spectrum is modified by absorption of BLR photons

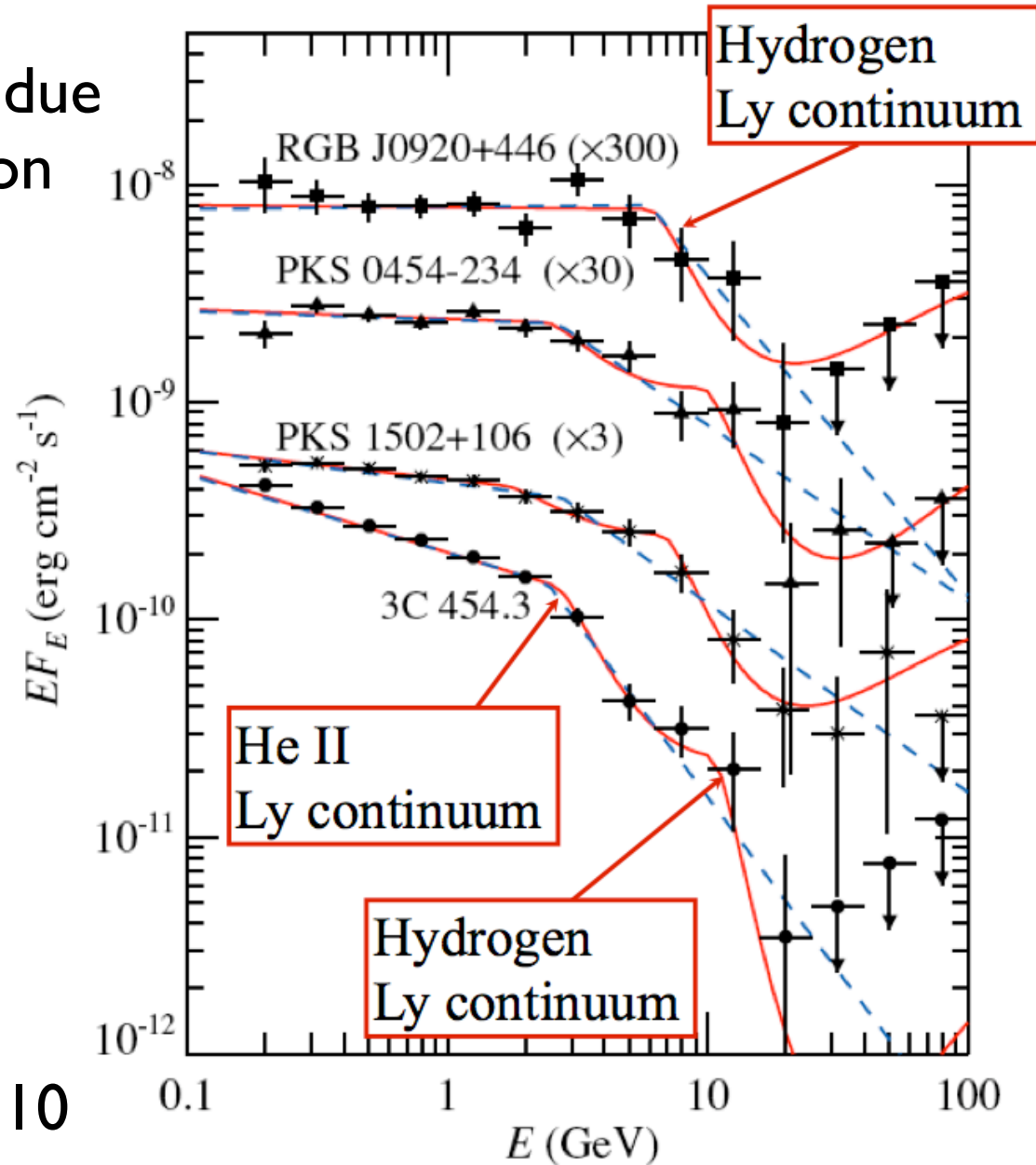
Threshold of pair creation due to photon-photon collision

$$E_\gamma E_{\text{BLR}} = (m_e c^2)^2$$

$$E_{\text{break}} = 4.8 \text{ GeV} \left( \frac{54.4 \text{ eV}}{E_{\text{BLR}}} \right)$$

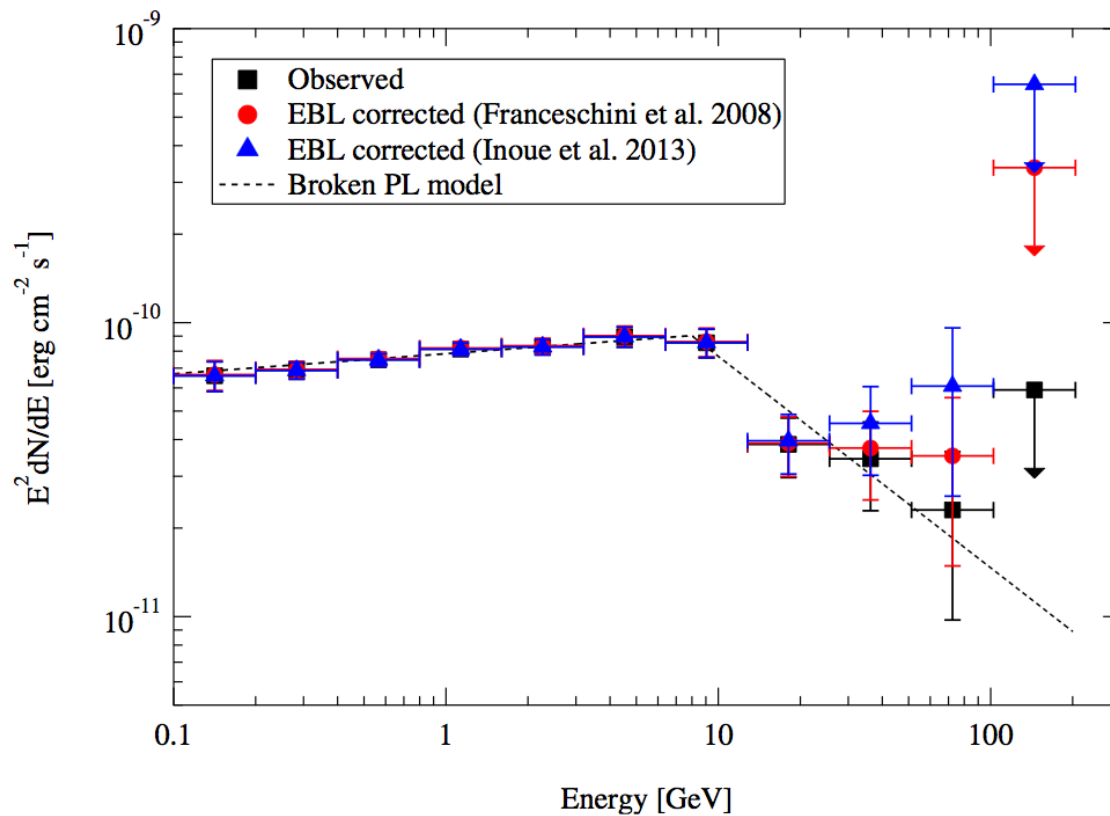
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Poutanen+10

# Possible additional flat component above several tens of GeV



- First of all, the detection is still tentative, so future follow-up by IACTs is necessary
- Electron pile-up by efficient and continuous acceleration (Stawarz+08, Lefa+11)
- Cosmic-ray and gamma-ray induced cascade emission (Essay+10, Murase+12, Takami+13)

# MAGIC detection of VHE gamma-rays from the $z=0.95$ blazar S3 0218+035

## Discovery of Very High Energy Gamma-Ray Emission From Gravitationally Lensed Blazar S3 0218+357 With the MAGIC Telescopes

ATel #6349; *Razmik Mirzoyan (Max-Planck-Institute for Physics) On Behalf of the MAGIC Collaboration*  
on 28 Jul 2014; 14:20 UT

Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, UHE, AGN, Blazar, Cosmic Rays, Microlensing Event



The MAGIC collaboration reports the discovery of very high energy (VHE;  $E > 100$  GeV) gamma-ray emission from S3 0218+357 (RA=02h21m05.5s, DEC=+35d56m14s, J2000.0). The object was observed with the MAGIC telescopes for a total of 3.5 hours from 2014/07/23 to 2014/07/26. The preliminary analysis of these data resulted in the detection of S3 0218+357 with a statistical significance of more than 5 standard deviations. From the preliminary analysis, we estimate the VHE flux of this detection to be about 15% of the flux from the Crab Nebula in the energy range 100-200 GeV. S3 0218+357 is a gravitationally lensed blazar located at the redshift of  $0.944 \pm 0.002$  (Cohen et al., 2003, ApJ, 583, 67). Fermi-LAT observations during the flaring state of S3 0218+357 in 2012 revealed a series of flares with their counterparts after  $11.46 \pm 0.16$  days delay, interpreted as due to the gravitational lensing effect (Cheung et al. 2014, ApJ, 782, L14). On 2014 July 13 and 14 Fermi-LAT detected another flaring episode (ATel #6316). Due to the full-moon time, the MAGIC telescopes were not operational and could not observe

Energy Gamma-Ray Emission From Gravitationally Lensed Blazar S3 0218+357 With the MAGIC Telescopes

6316 Fermi LAT Detection of a Hard Spectrum Gamma-ray Flare from Gravitationally Lensed Blazar S3 0218+357

4411 Fermi LAT Detection of New Gamma-ray Flaring from Gravitationally Lensed Blazar S3 0218+35 and Scheduled Fermi Pointed Observations from 2012 September 24 - October 1

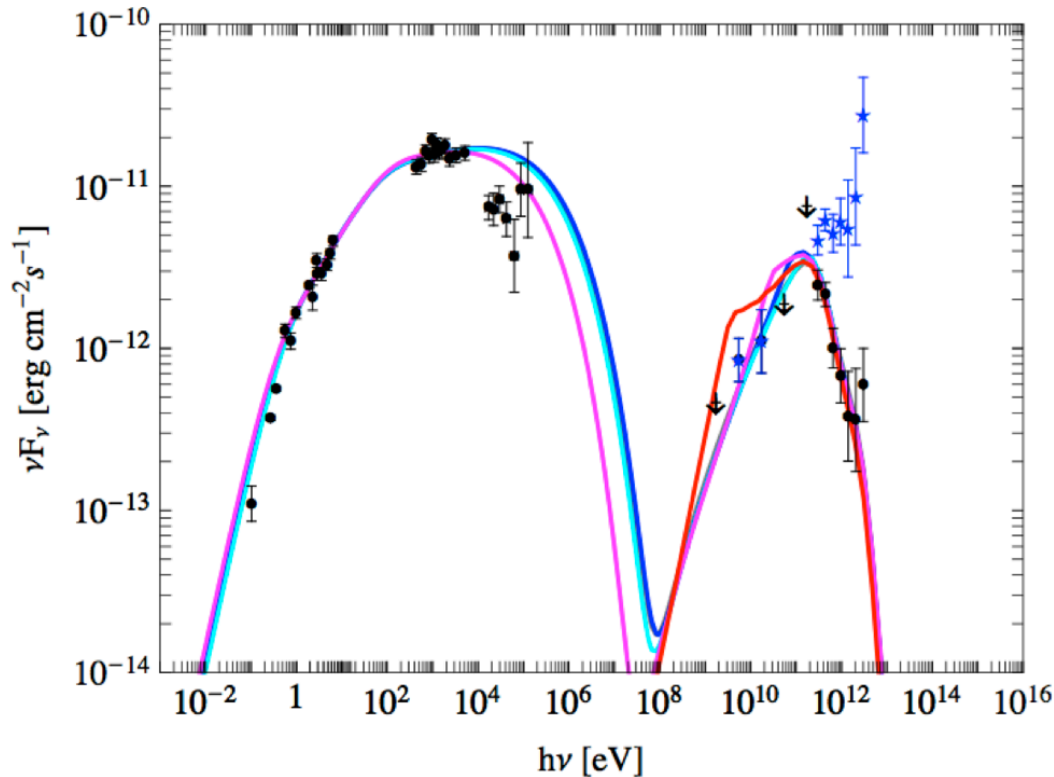
4371 Fermi LAT detection of a potential echo gamma-ray flare from gravitational lens S3 0218+35

4361 M. Giroletti (INAF-IRA Bologna), M. Orienti (Univ. Bologna, INAF-IRA Bologna), C. C. Cheung (NRL/NRL) on behalf of the Fermi Large Area Telescope Collaboration

4351 Swift XRT/UVOT follow-up of the gravitationally lensed

- Can we see a similar spectral hardening at VHE range?

# High minimum electron energy



IES 0347-121  
(Tanaka+14)

$$\gamma_{\min} = 2 \times 10^4$$

$$\delta = 50-60$$

$$B = 1-3 \text{ mG}$$

(see also e.g. Tavecchio+10)

- Proton cyclotron or other hadronic scenarios, rather than one-zone Sync+SSC?

# Summary

- Fermi-LAT detected 2 VHE events from directional vicinity of PKS 0426-380 at  $z=1.1$ , making it the most distant VHE emitter known to date
- Detection of VHE events from the  $z=1.1$  blazar is consistent with the minimal level of EBL intensity revealed by recent theoretical and observational works such as Ackermann+12, Franceschini+08, Dominguez+11, and Inoue+13
- The EBL-corrected LAT spectrum above several tens of GeV suggests possible presence of an additional flat component
- Follow-up by HESS II and future CTA during high state for PKS 0426-380 is strongly encouraged