

A bright gamma-ray flare from the blazar B2 1215+30 detected by VERITAS and *Fermi*-LAT

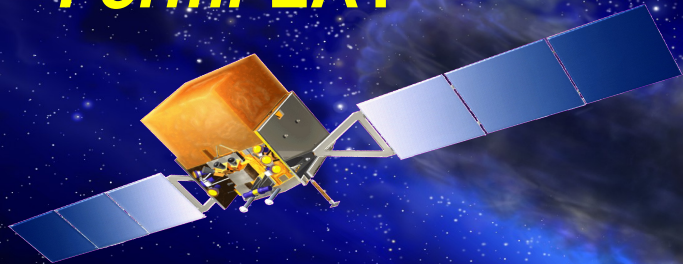
Floriana Zefi¹

R.Mukherjee² for the **VERITAS** collaboration

1. LLR-Ecole Polytechnique, France
2. Barnard College, New York

- **VERITAS and *Fermi*-LAT detectors**
- **TeV Blazars**
- **B2 1215+30 analysis and results**
- **Size of the emission region estimation**
- **Summary and conclusions**

Fermi-LAT



~ 20 MeV - 300 GeV

VERITAS



~ 85 GeV - <30 TeV

Data Analysis

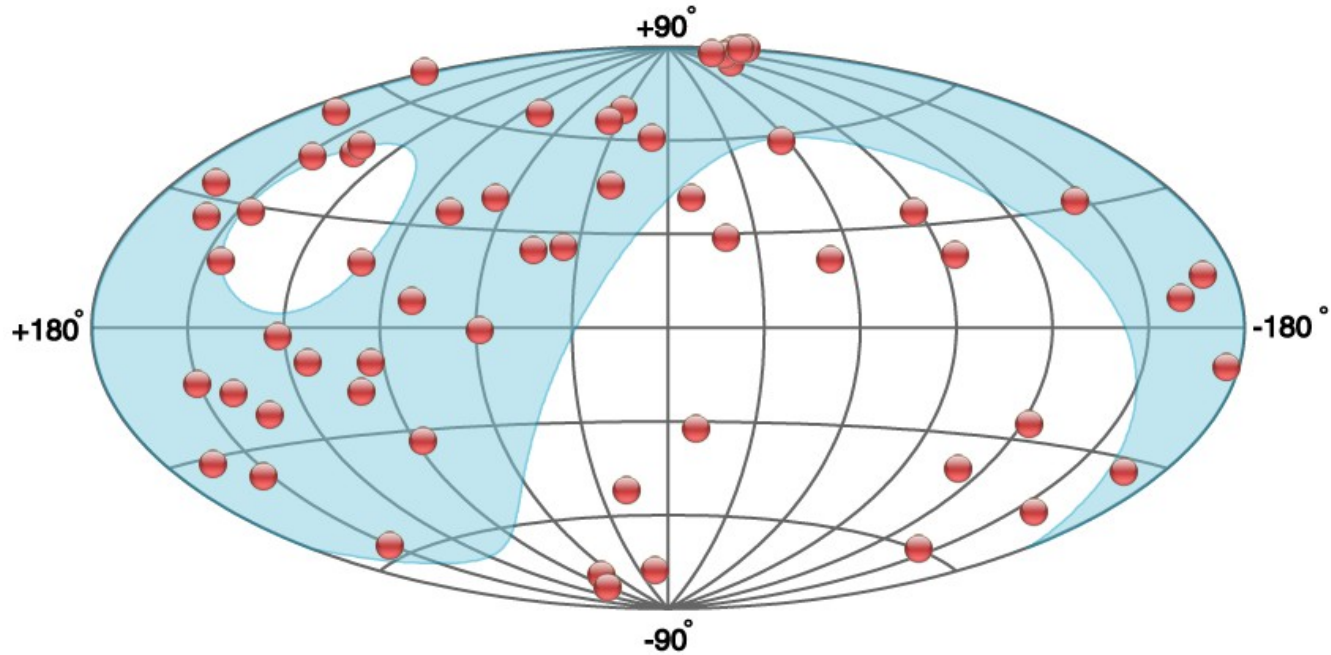
- Fermi Science Tools (PASS 7)
- 1 Jan 2014 – May 2014
- 0.1-100 GeV

Data Analysis

- 29 Jan-25 May 2014; Exposure 748 min
- 8 Feb 2014; Exposure 45 min.
- “wobble” observation mode on 1ES 1218+304
- Energy threshold 200 GeV

<http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools.html>

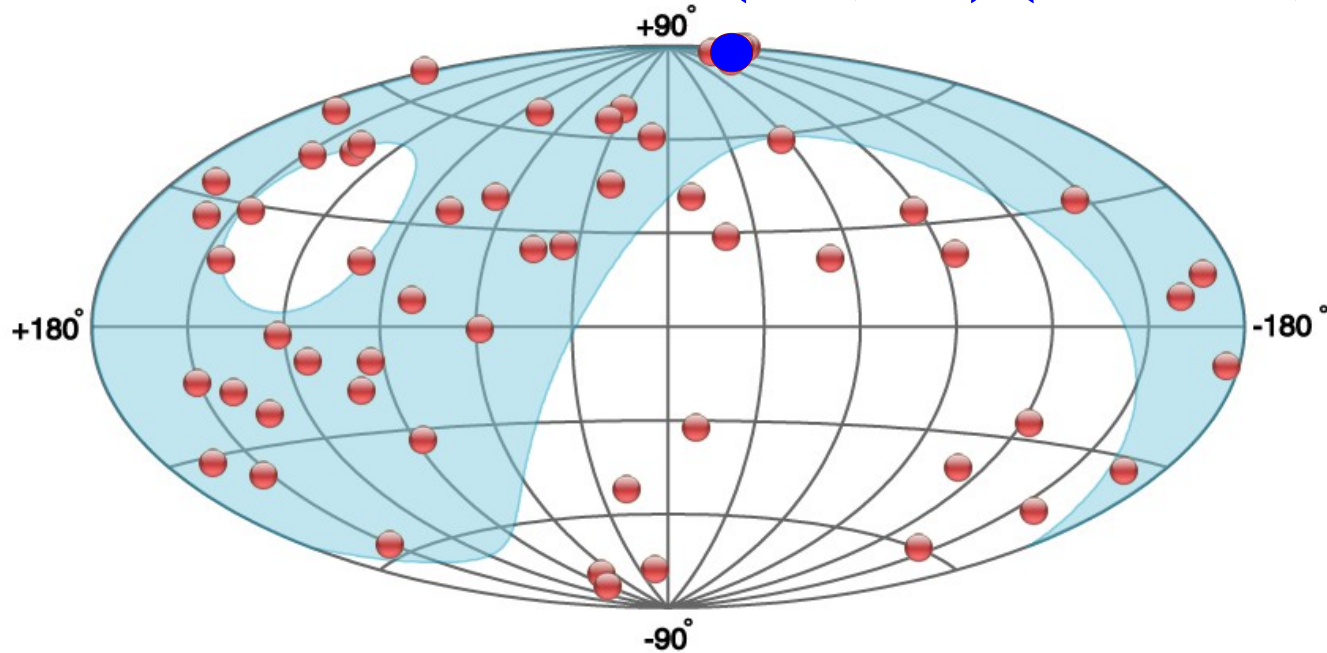
TeV Blazars



<http://tevcat.uchicago.edu/>

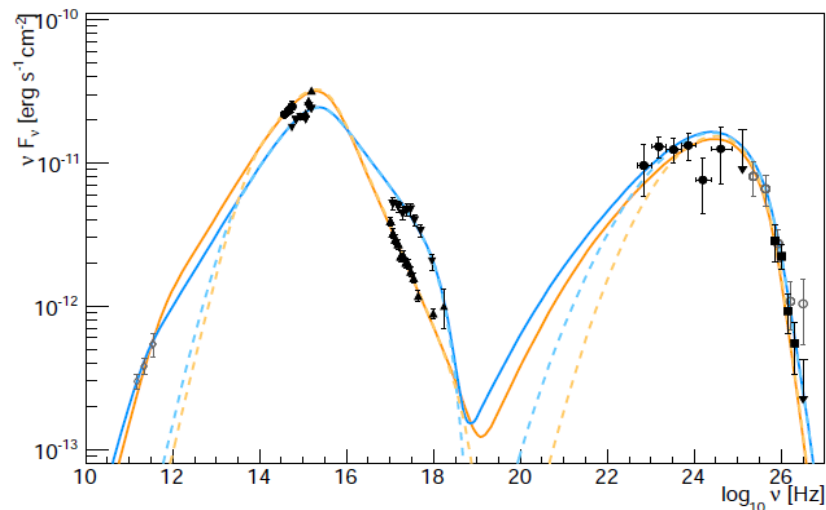
TeV Blazars

B2 1215+30 (R.A.;Dec.)=(12h17m52s;30°07'00")



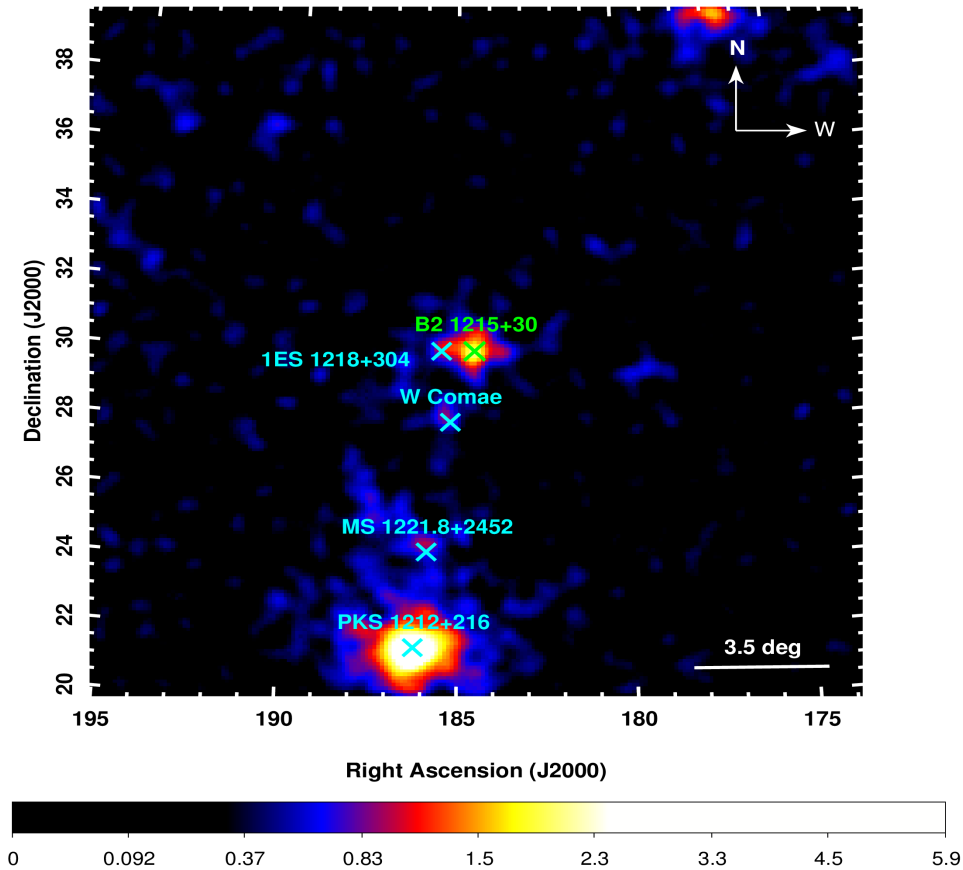
<http://tevcat.uchicago.edu/>

- BL Lac object; also known as **ON 325/1ES 1215+303**.
- 1970: 408 MHz survey conducted with the Bologna Northern cross telescope.
- Uncertain distance: $z=0.130$ (1.8 Gly); $z=0.237$ (2.6 Gly)
- First detection in TeV energies: MAGIC in 2011.
- Intermediate BL Lac object.

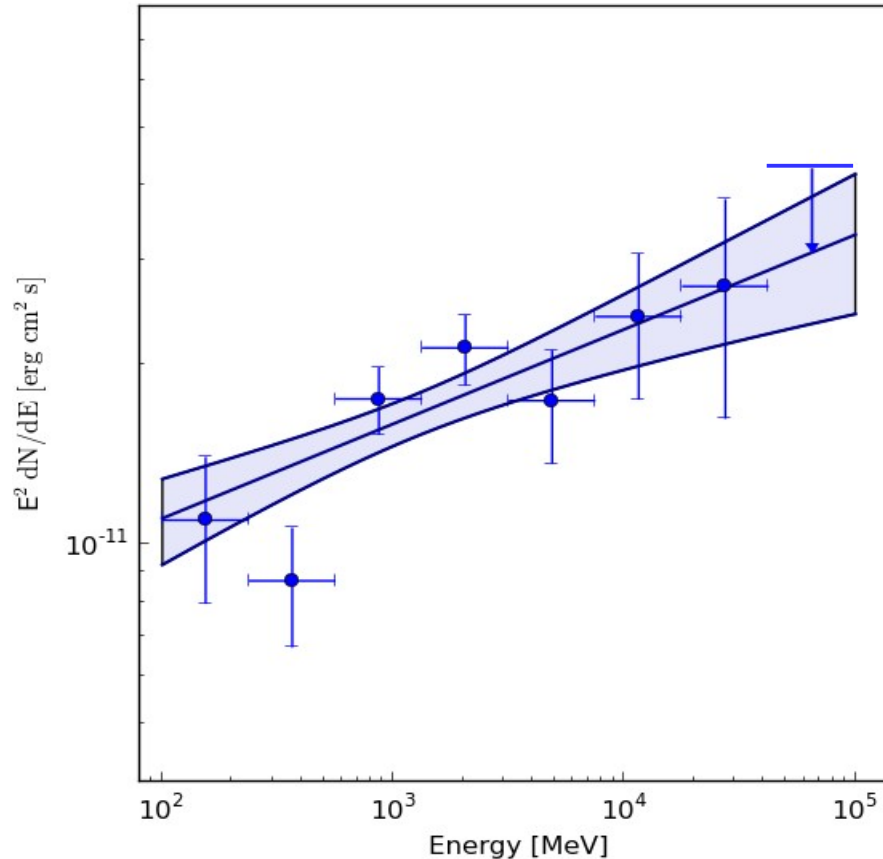


VERITAS archival SED of B2 1215+30 (Aliu et al.2013)

Fermi-LAT counts map



Fermi-LAT Spectrum

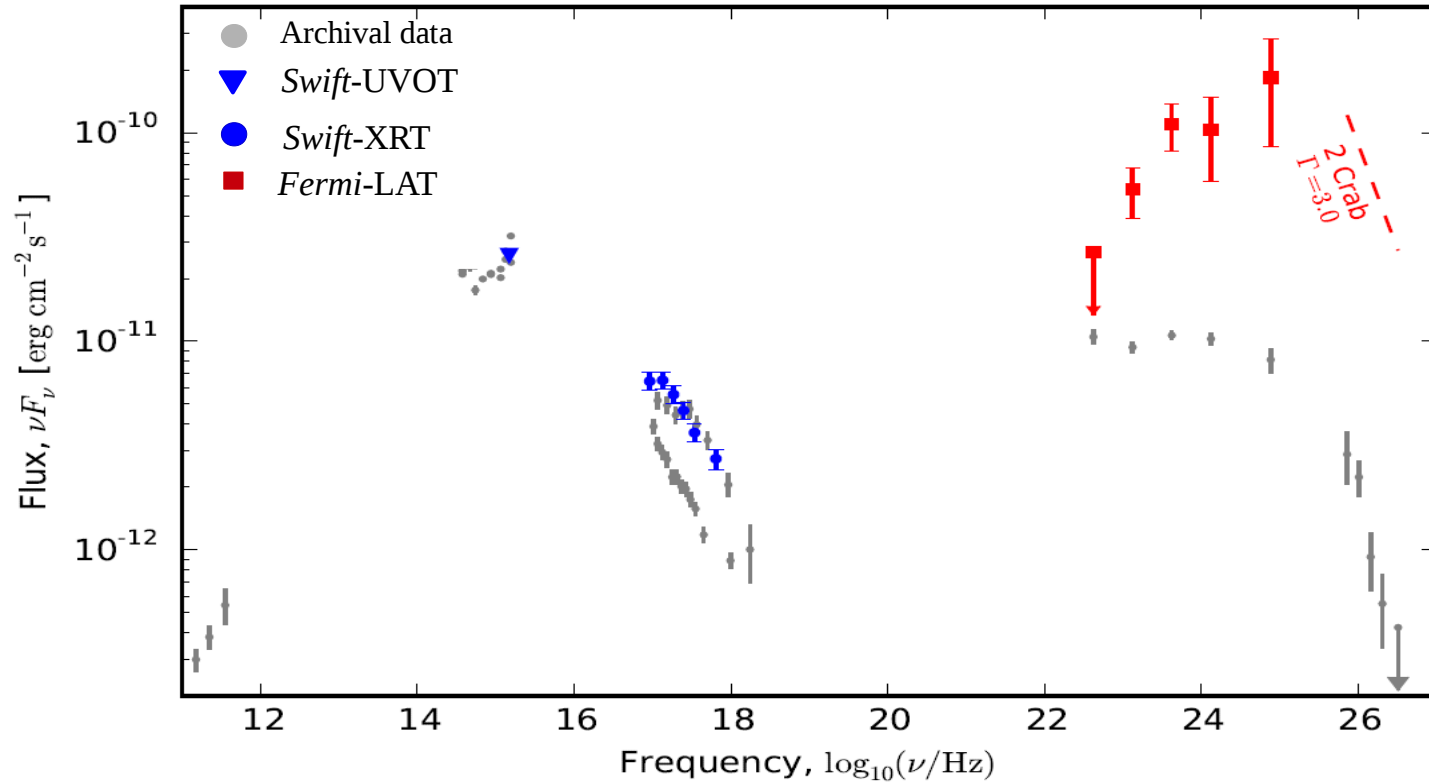


- Time range: 1 Jan -25 May 2014
- Spectrum compatible with a PL:

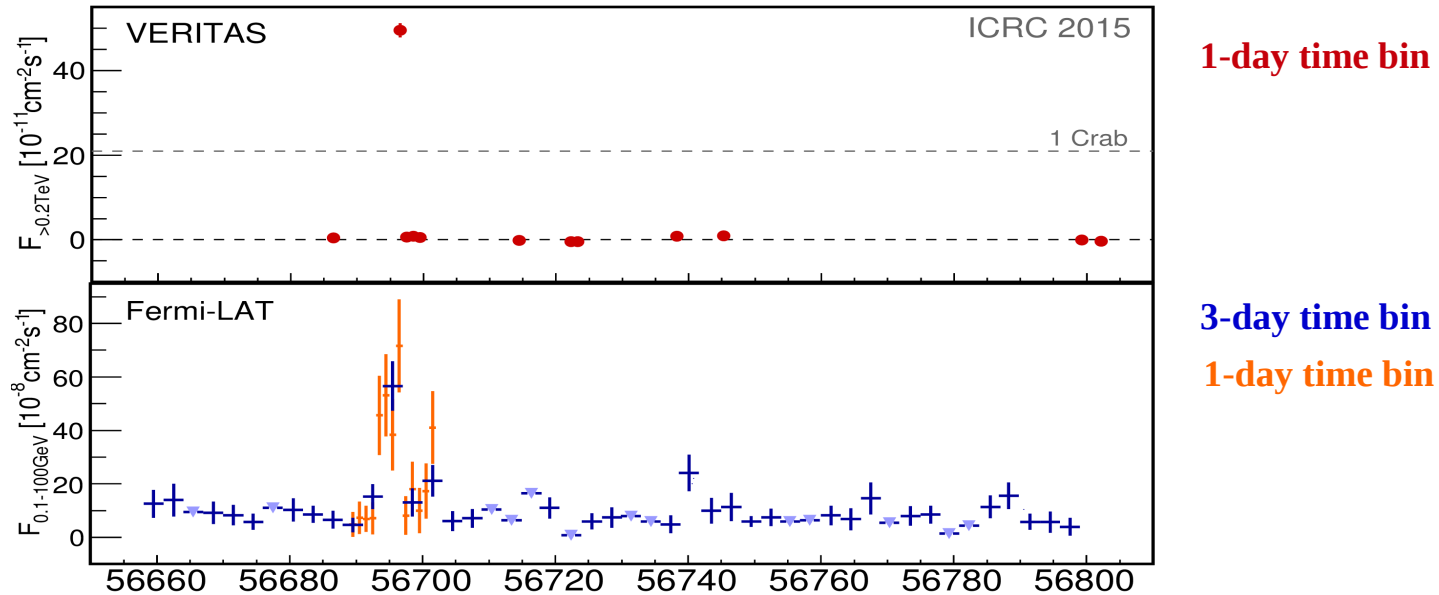
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0} \right)^{-\Gamma}$$

- Spectral index: $\Gamma=1.84$

SED of B2 1215+30



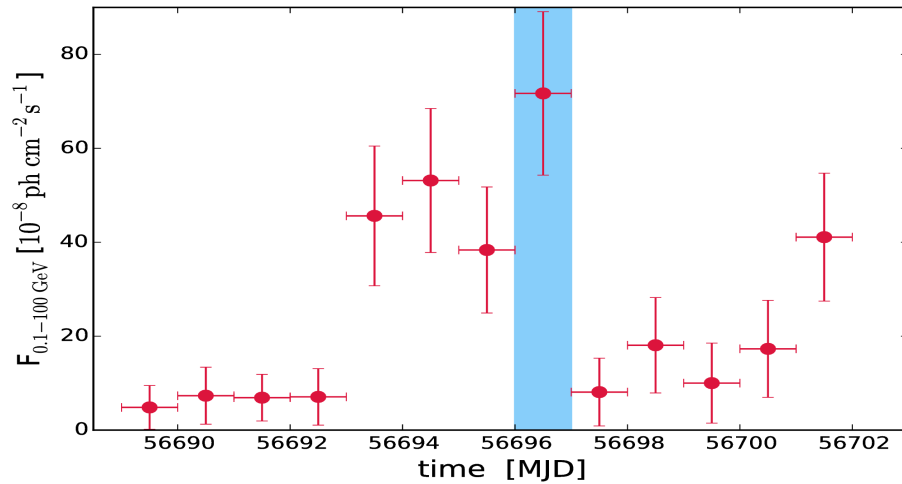
Fermi-VERITAS light curve



Instrument	Energy range	Observation time	Signal	Multiple Flux
<i>Fermi-LAT</i>	0.1-100 GeV	2014 Jan 01-May 25	23.6 σ	x16
VERITAS	>0.2 TeV	2014 Jan 29-May 25	26.6 σ	x60

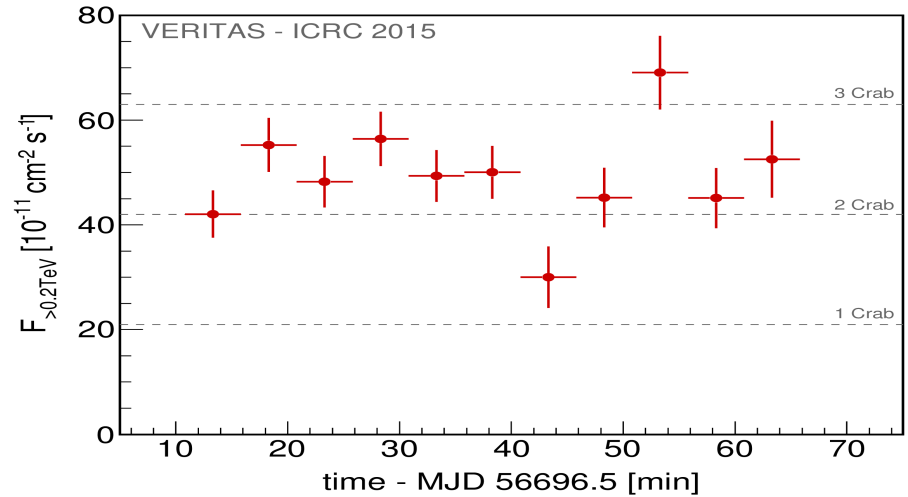
Fermi-VERITAS light curve

100 MeV < E < 100 GeV



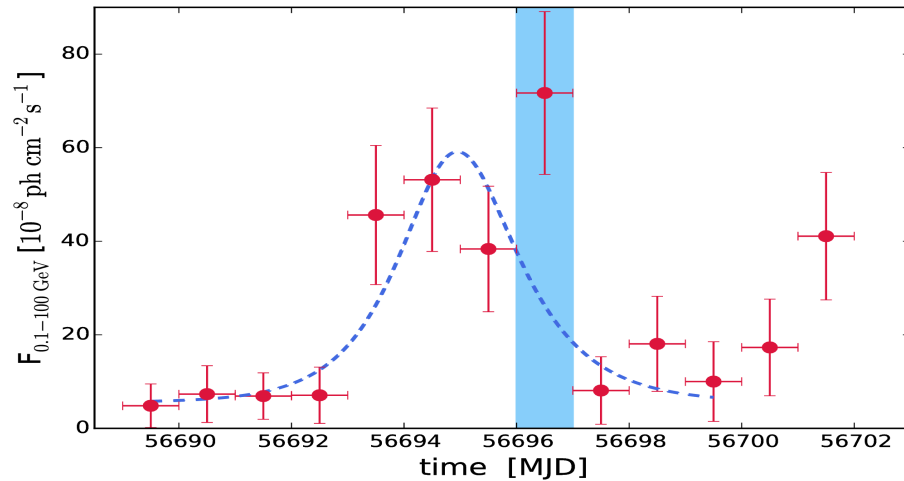
1-day time bin

E > 200 GeV

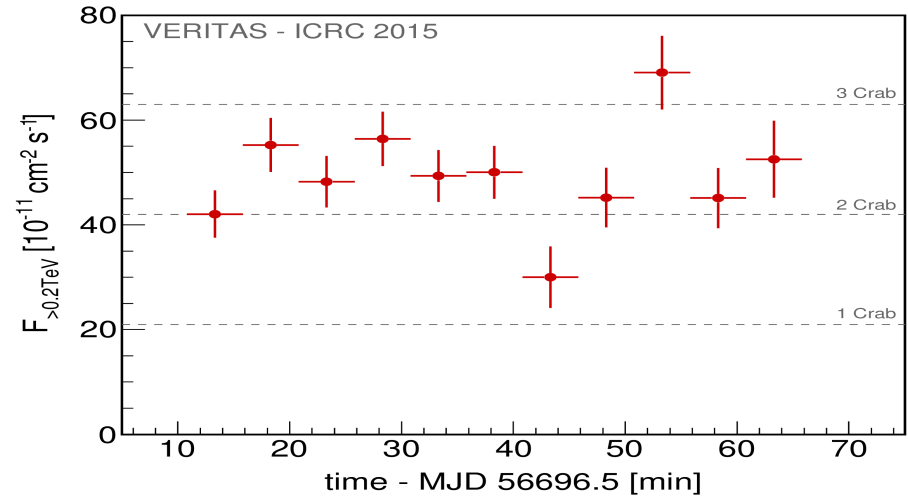


5-minute time bin

100 MeV < E < 100 GeV



E > 200 GeV



$$F(t) = F_c + F_0 \cdot \left(e^{\frac{(t_0-t)}{T_r}} + e^{\frac{(t-t_0)}{T_d}} \right)^{-1}$$

(equation 6, Abdo et al.2010)

$$t_{var} = (0.18 \pm 0.09) d$$

Emission region size

$$\left\{ \begin{array}{l} F_{>200 \text{ GeV}} = (2.4 \pm 0.2) \times 10^{-11} \text{ ph/cm}^2/\text{s} \\ z = 0.130 \end{array} \right. \longrightarrow L = 1.5 \times 10^{46} \text{ erg s}^{-1}$$

$$\left\{ \begin{array}{l} t_{\text{var}} = 4.5 \text{ h} \\ R \leq \frac{c \cdot t_{\text{var}}}{1+z} \delta \end{array} \right. \longrightarrow R \leq 4.3 \times 10^{14} \text{ cm}/\delta$$

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Size of the Solar System: $\sim 5.9 \times 10^{14} \text{ cm}$

Luminosity of the Milky Way: $\sim 10^{44} \text{ erg} \cdot \text{s}^{-1}$

$$R \leq \frac{c \cdot t_{\text{var}} \cdot \delta}{1+z}$$

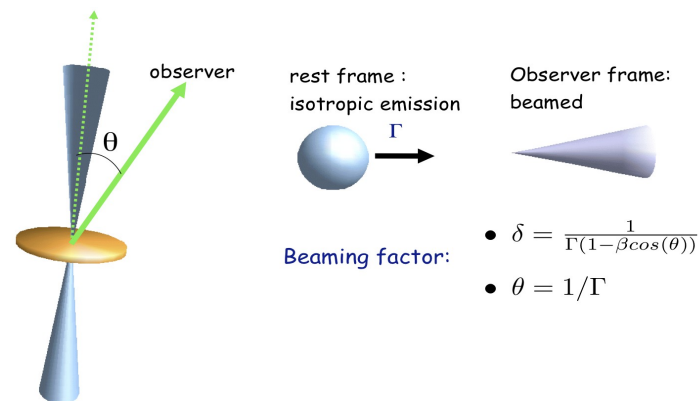
Jet Doppler factor

Pair-production optical depth (Dondi et al. 1995)

- High energy gamma rays collide with softer photons $\gamma + \gamma \rightarrow e^+ + e^-$
- Optical depth: $\tau_e \sim \frac{\sigma_T}{5} \cdot N \cdot X_{target} \cdot R$
- The criterion for gammas to escape the source: $\tau \ll 1$

$$\delta \geq \left[\frac{\sigma_T \cdot d_L^2}{5hc^2} (1+z)^{2\alpha} \frac{F_{1keV}}{t_{var}} \left(\frac{E_\gamma}{GeV} \right)^\alpha \right]^{\frac{1}{(4+2\alpha)}}$$

$$\left\{ \begin{array}{l} F_{0.3-10 keV} = 1.28 \text{ erg cm}^{-2} \text{ s}^{-1} \\ \alpha = 2.54 \\ d_L = 592 \text{ Mpc} \\ z = 0.13 \\ E = 73.6 \text{ GeV} \end{array} \right.$$



$$\delta \geq 5.7$$

- Fermi-LAT & VERITAS detected a simultaneous flare from B2 1215+30 on 08 Feb 2014.
- The measured TeV flux x60 brighter than the yearly average flux.
- x35 Crab flux if was at the distance of the Mrk 421.
- The variability time scale derived from Fermi-LAT light curve $t_{var} = 4.5 h$
- Using pair production optical depth arguments, the minimum Doppler factor of the relativistic jet is estimated to be $\delta > 5.7$.

Publication with final numbers in preparation.

Thank You!

Backup slides

Photon flux ($E > 200$ GeV) of Crab Nebula = 2.1×10^{-10} cm²/s

Long term observations of B2 1215+30 with VERITAS

Power-law fit: spectral index 3.6

Flux (>200 GeV) = $(8.0 \pm 0.9) \times 10^{-12}$ ph/cm²/s

Based in its synchrotron peak location: $10^{15.6}$ is classified as a bright intermediate frequency peaked BL Lac object.

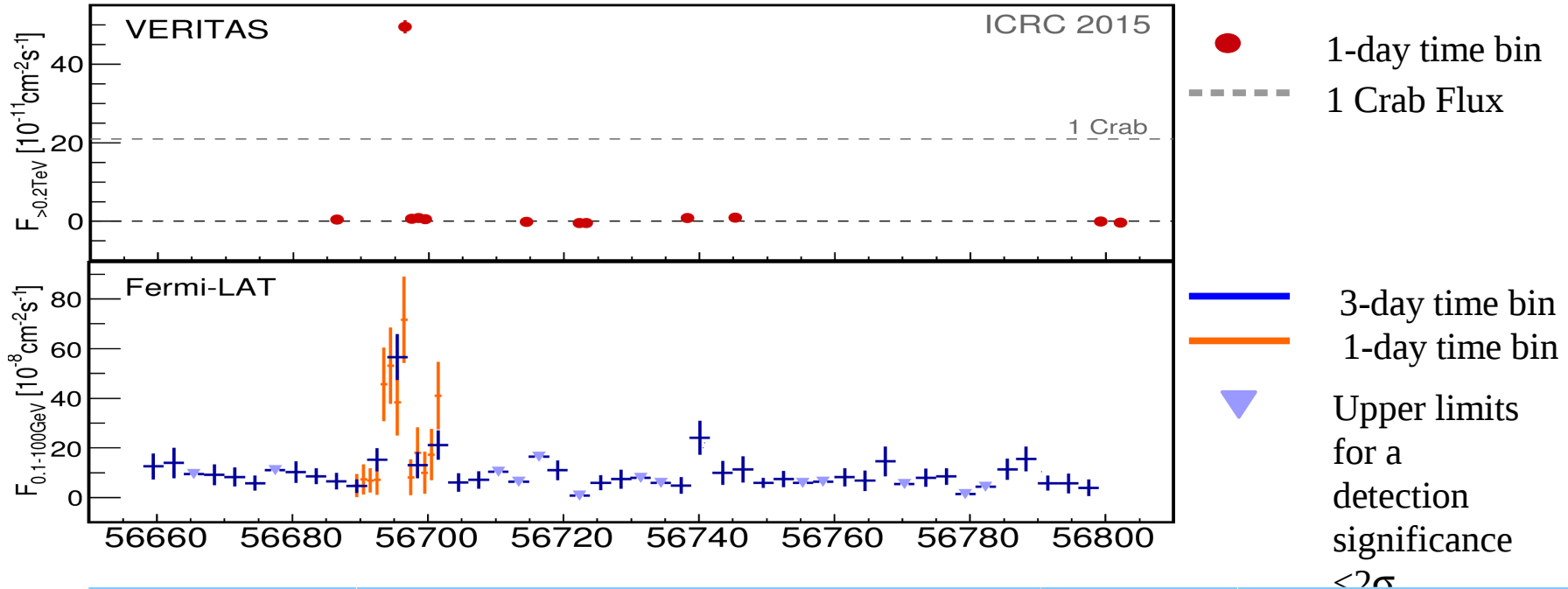
MAGIC detection

After an optical high state in early January 2011

Flux (>200 GeV) = 7.7×10^{-12} ph/cm²/s

Spectral index: 2.96

Fermi-VERITAS light curve



Instrument	Energy range	Observation time	Signal	Flux [ph/cm ² /s]
<i>Fermi-LAT</i>	0.1-100 GeV	2014 Jan 01-May 25	23.6σ	$(8.2 \pm 1.0) \times 10^{-8}$
VERITAS	>0.2 TeV	2014 Jan 29-May 25	26.6σ	$(2.4 \pm 0.2) \times 10^{-11}$