Study of the γ-ray variablility of B2 1215+30

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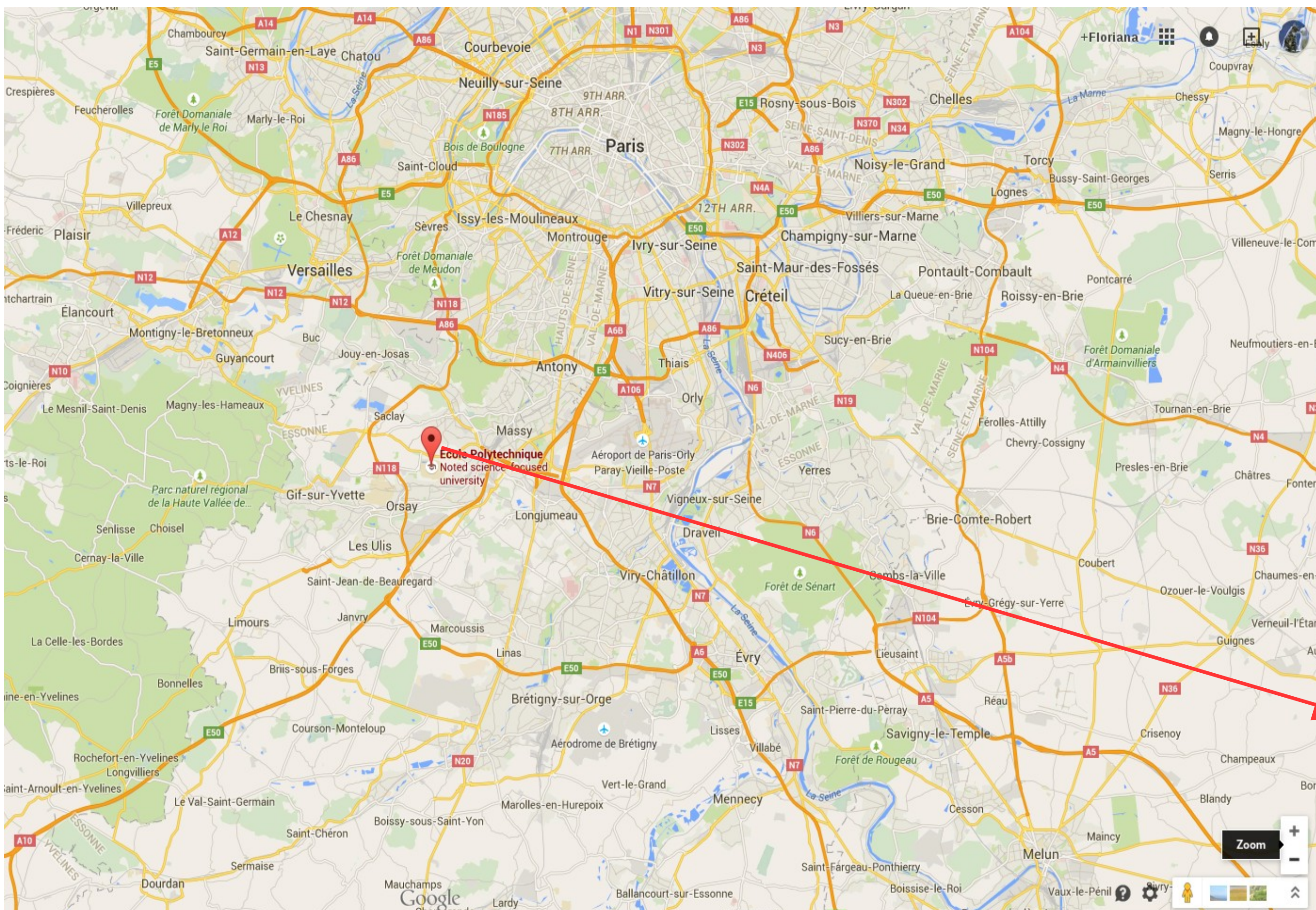

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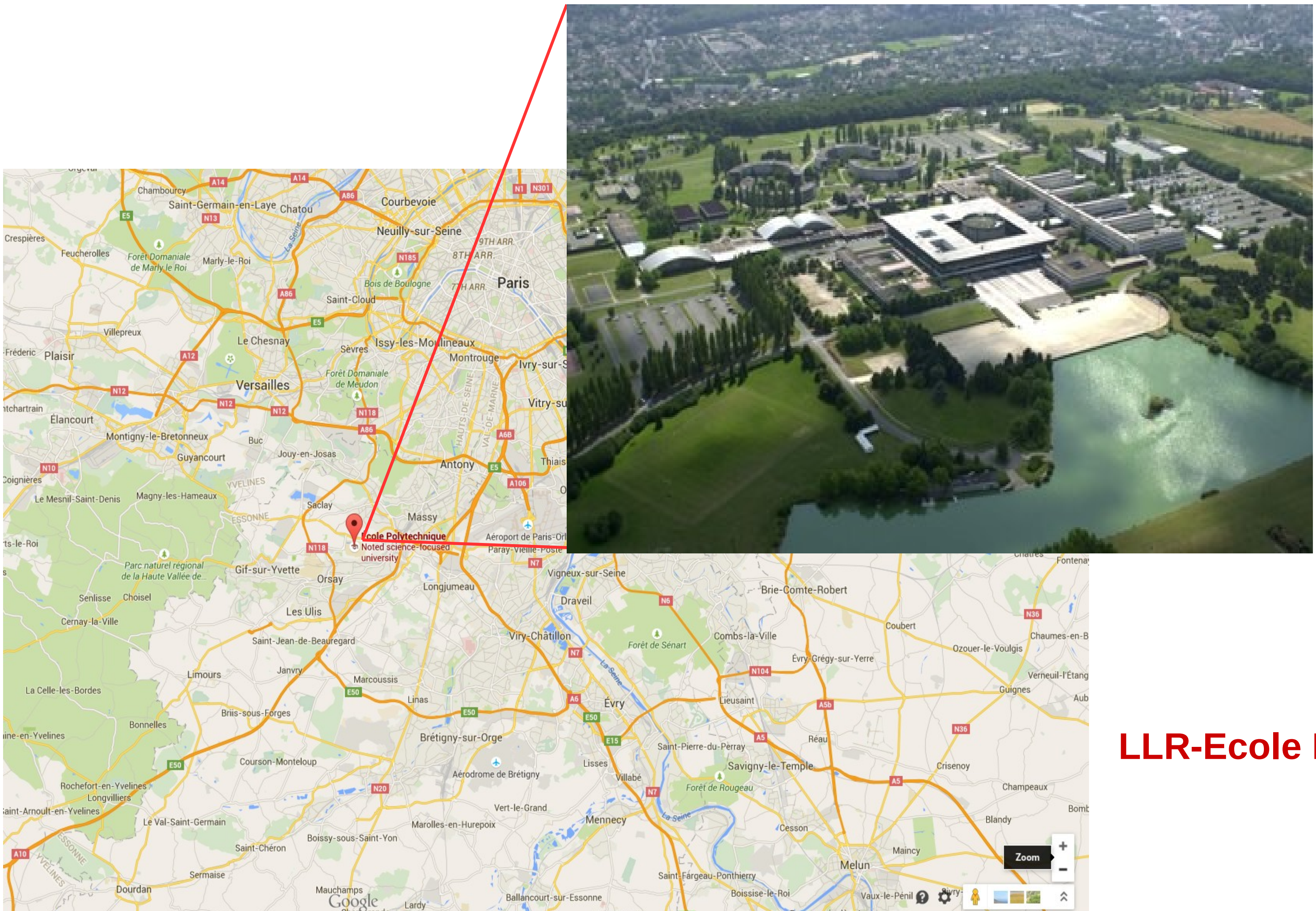

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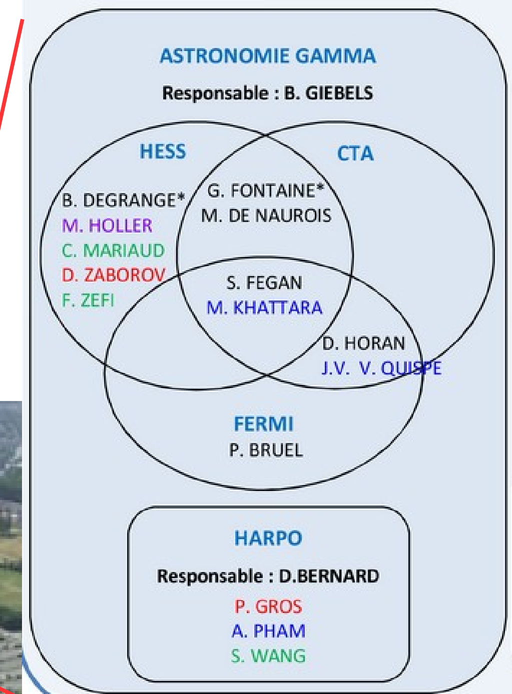

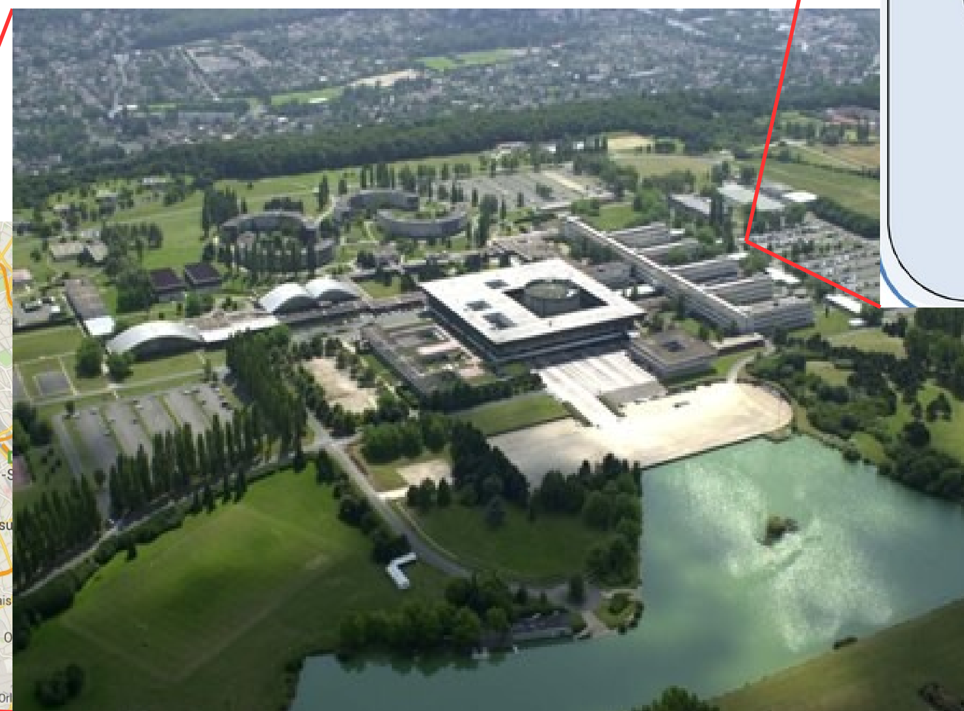

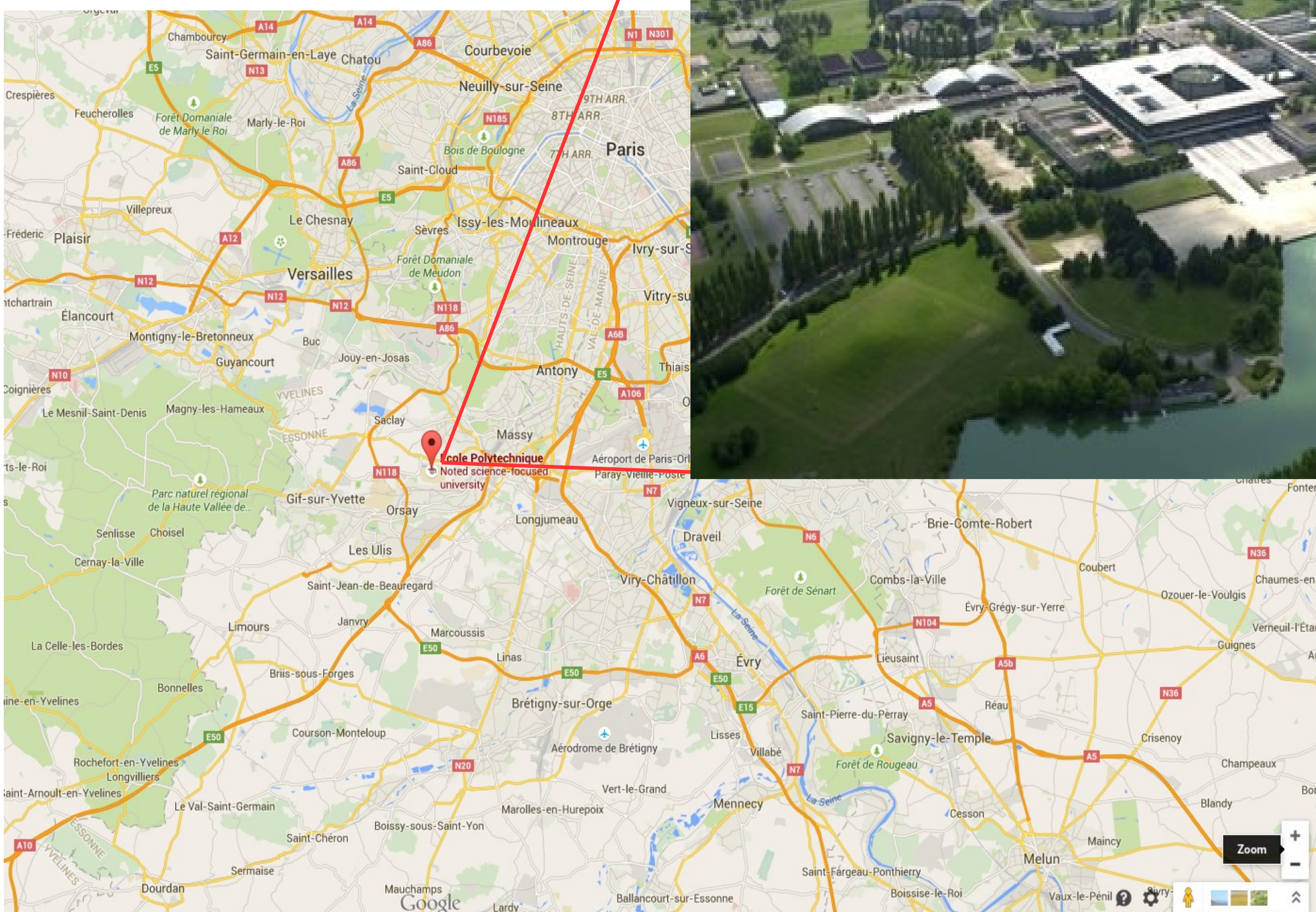

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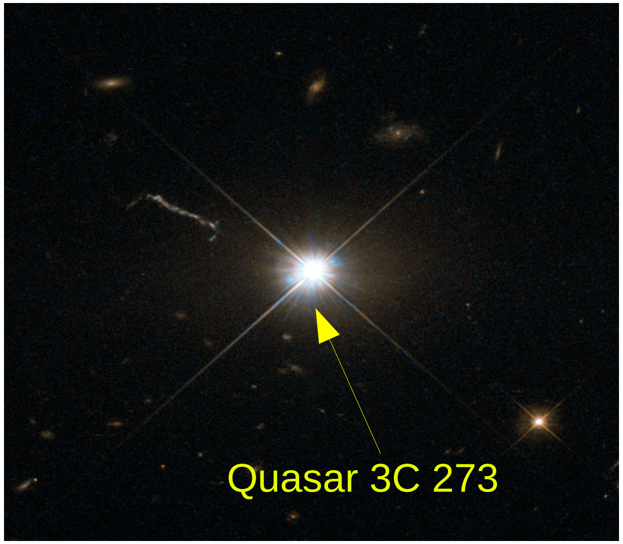
Active Galactic Nuclei

What is an AGN?

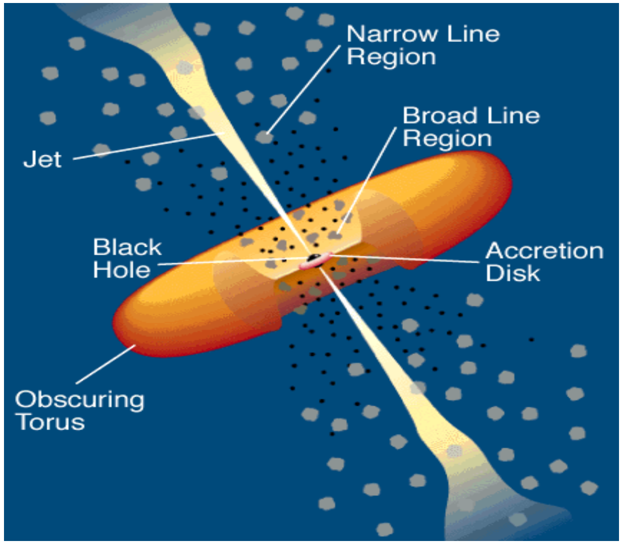
- AGN → Active Galactic Nuclei
- Active Galactic Nuclei (AGN) is a nucleus (of a galaxy) that has higher luminosity than the rest of the galaxy.
- High power: most powerful “non-explosive” sources in the Universe.
- AGN are among the most luminous objects in the sky.
- Very distant sources, that yet can be among the brightest sources in the sky at γ-ray energies.

Main characteristics

- High luminosity: $L_{AGN} \leq 10^{48} erg/s$
- Small emitting regions ~ few light day radius $R \leq \frac{c \cdot t_{var} \cdot \delta}{1+z}$
- Variable emission
- Broad-band emission: from radio to gamma ray band



NASA, A.Martel: Quasar 3C 273

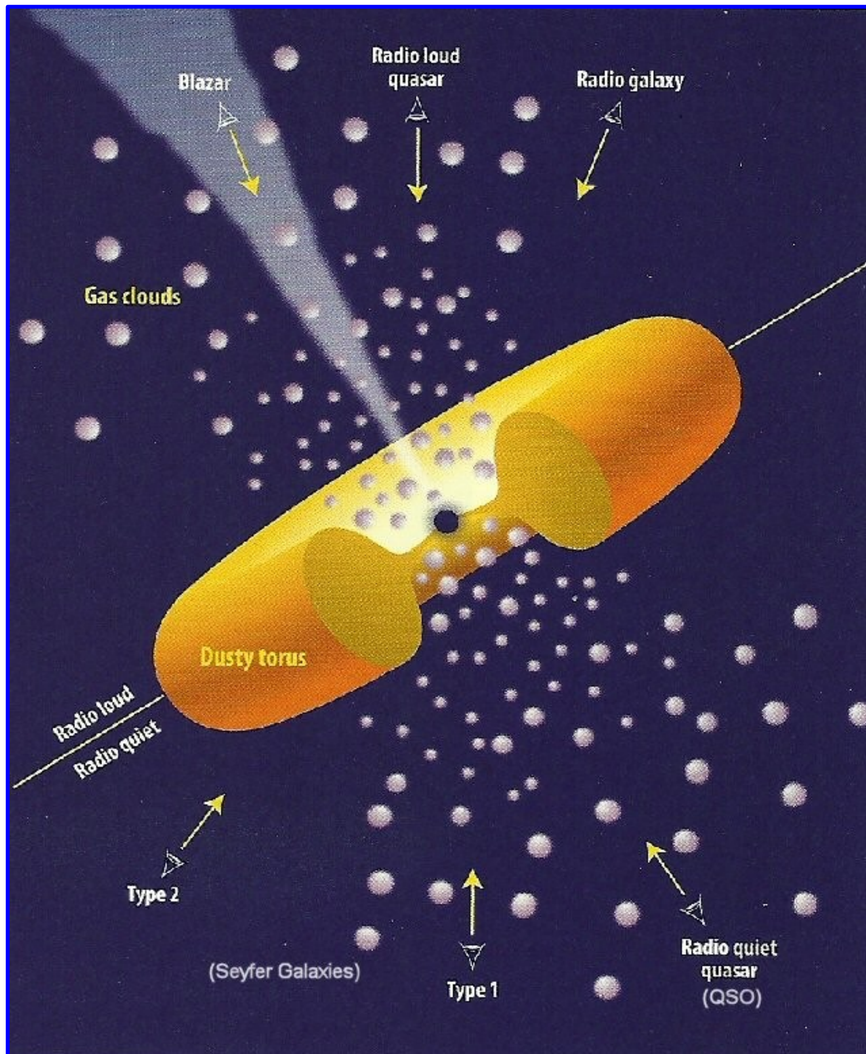


Urry & Padovani 1995: Schematic picture of an active galaxy, including its ingredients.

AGN classification

Active Galactic Nuclei

- Radio-Quiet
  - Seyfet Galaxies
    - Type1
    - Type2
  - Quasars
    - Radio-Quiet
- Radio-Loud
  - Quasars
    - Radio-Loud
  - Blazars
    - BL Lacertaes (BL Lacs)
    - Optically violent Variable Quasars (OVVs)
  - Radio Galaxies
    - Narrow Line
    - Broad Line



Urry & Padovani 1995: Unification scheme of AGN

AGN classification

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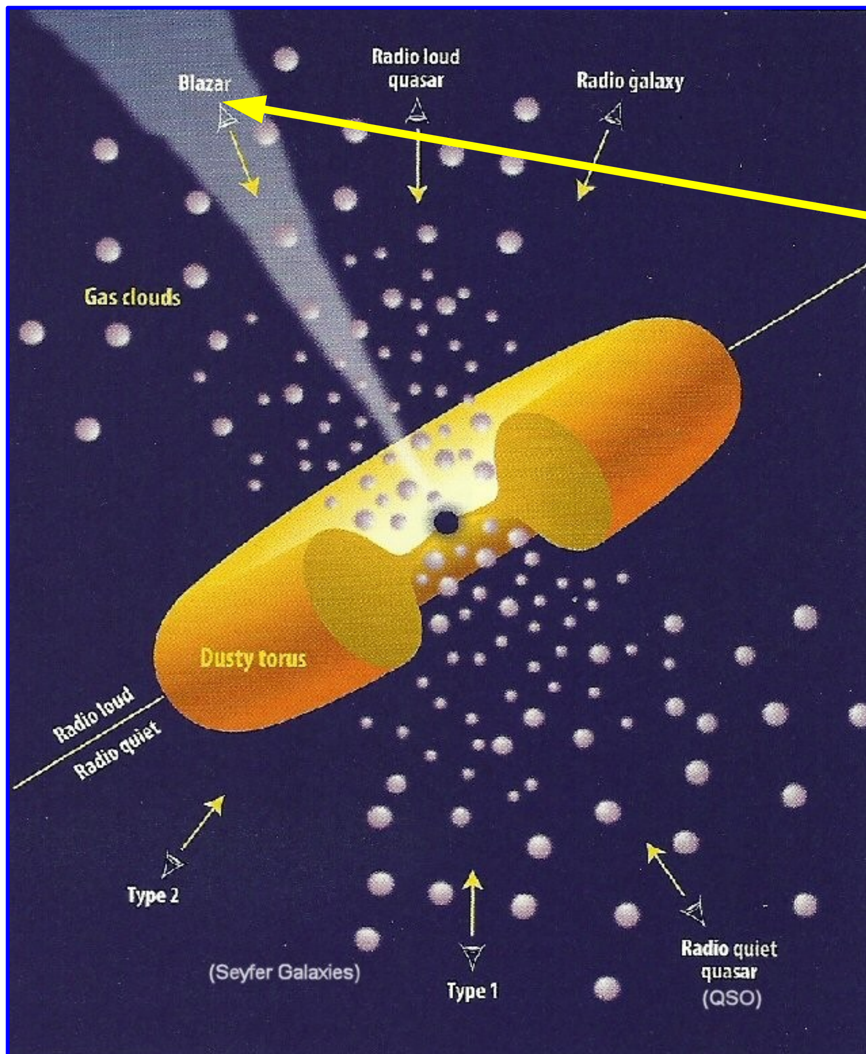
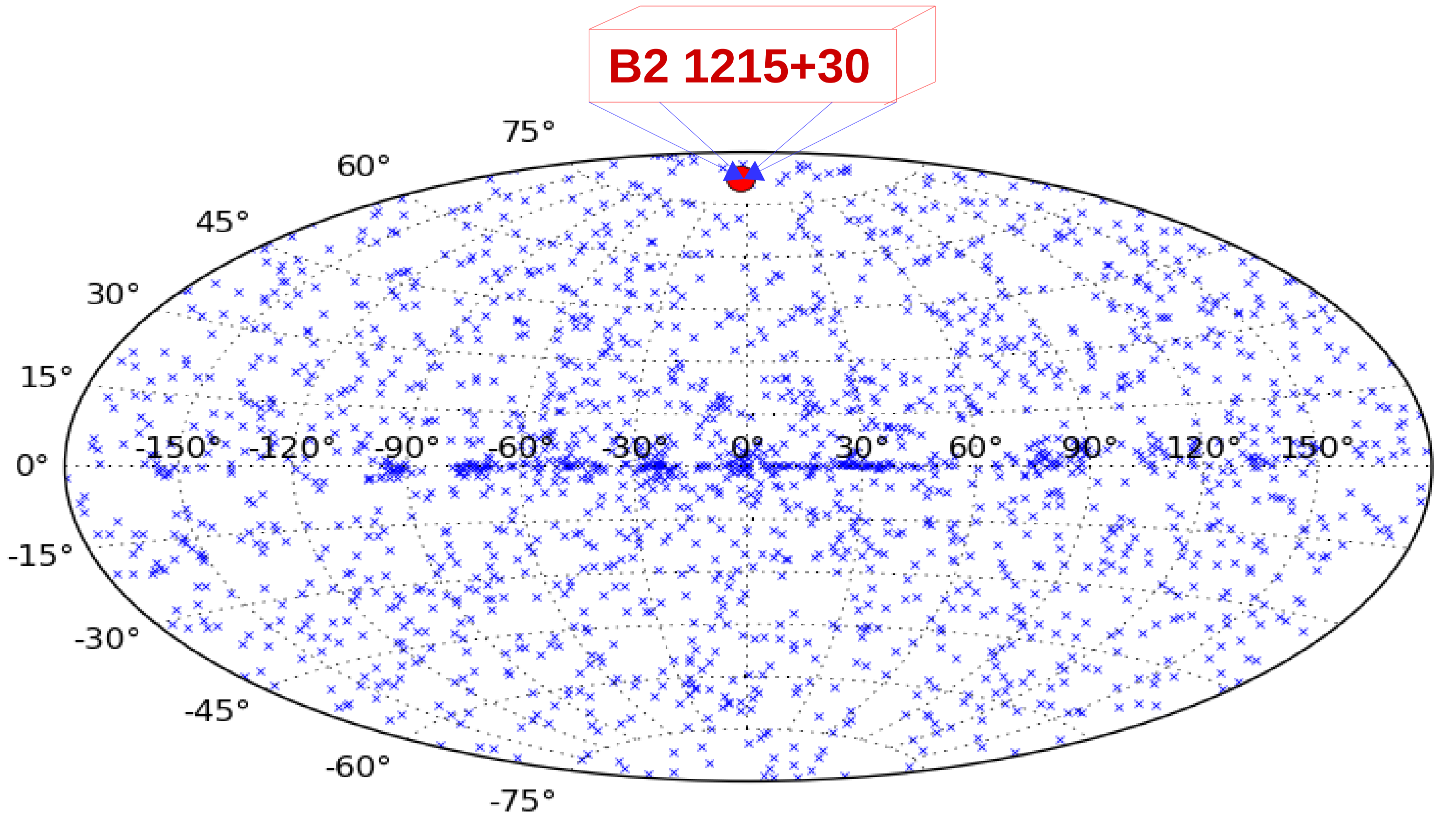


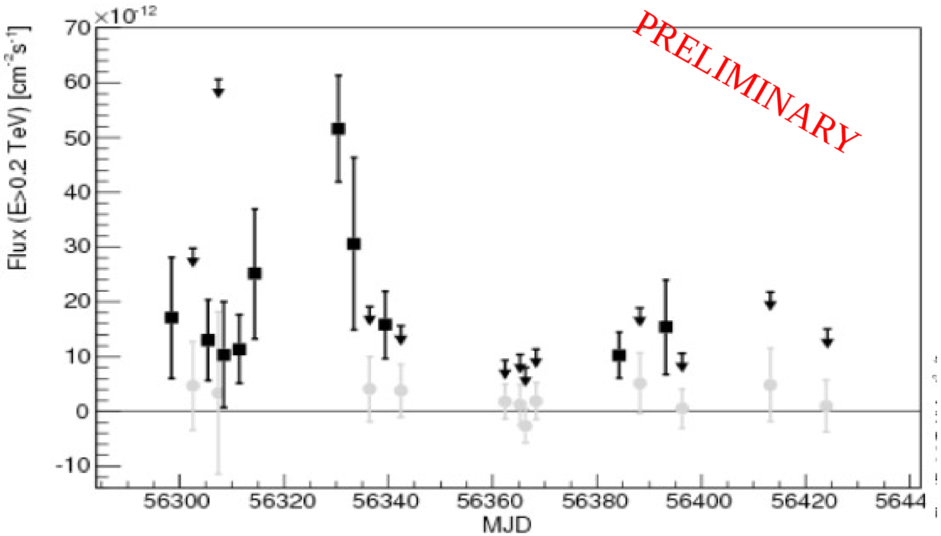
Urry & Padovani 1995: Unification scheme of AGN

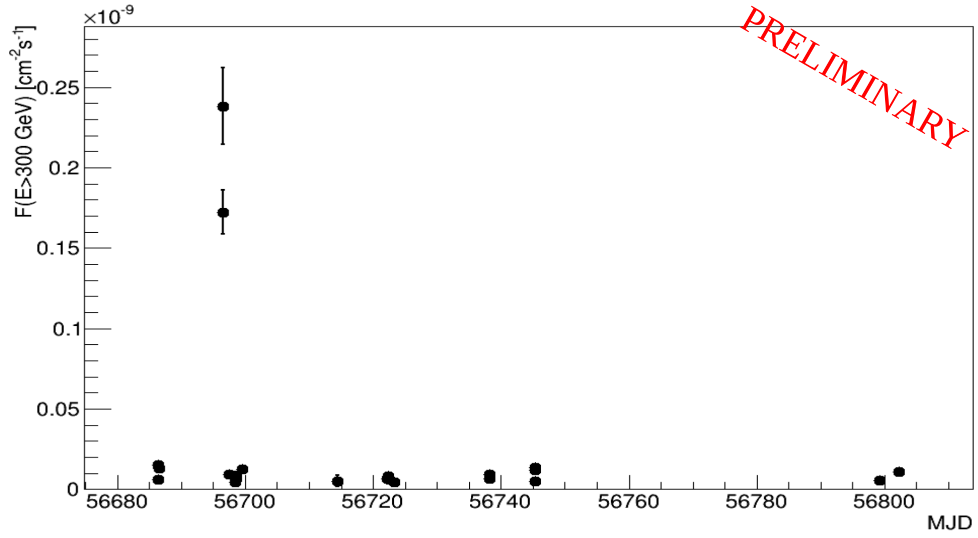
Introduction: B2 1215+30

- B2 1215+30 is a BL Lac object, also known as ON 325 or 1ES 1215+303.
- It was first detected in the 408 MHz survey conducted with the Bologna Northern cross telescope, called B2 1215 (Colla et al. 1970).
- First detected at VHE energies by MAGIC telescope in 2011 (J. Aleksić et al. 2011).
- Uncertain distance due to weak emission lines: **z=0.130 (1.8 Gly) ; z=0.237 (2.6 Gly)**
- Location (R.A.:Dec) : (12h17m48.5s:30d06m06s)



Aim of the work





Does *Fermi* detect the flare?

Is the source variable at *Fermi* energies?

Aim of the work:

Observations of B2 1215+30 across the electromagnetic spectrum with the aim to measure:

- correlation time variability

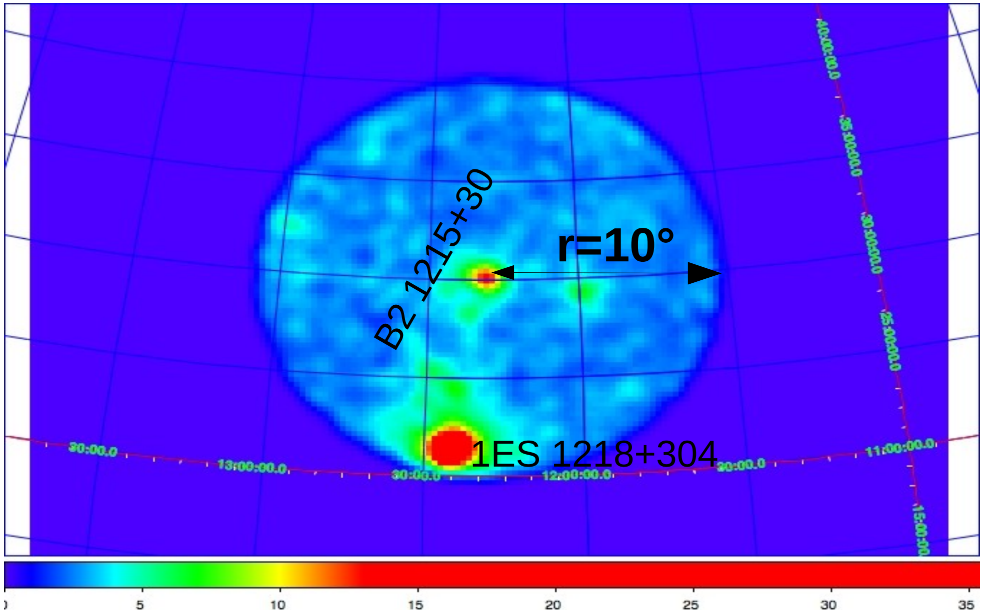
- spectral characteristics

- intensity-spectrum correlations

Fermi-LAT Analysis

Data selection:

- Coordinates: (12.297,30.1017)
- Time range:
  1. 1 Jan 2013 – May 2013
  2. 1 Jan 2014 – May 2014
- Energy range: *100 MeV – 100 GeV*
- Region of Interest (ROI) radius: *10 °*
- Only photons arriving with a rocking angle >52° and a zenith angle >100° to avoid contamination from the albedo photons from Earth's limb.
- Event class for point source analysis: P7REP_SOURCE_V15



Count map of ROI produced with the 2014 data of Fermi-LAT.

The background model:

- The background model was constructed the 2FGL including all known gamma-ray sources and diffuse emission inside ROI.
- In the background model were included also sources outside ROI within 5° of the ROI edges.
- Spectral models: Power law, Broken power law, Power law2, Broken Power law2, Log Parabola.

Fermi-LAT Analysis

Likelihood analysis:

- Perform a standard likelihood over the full period of time
- Identify the sources inside ROI: 33 point sources
- Measure the spectra over the full time range
- Get the best fit

2013 observation

TS (B2 1215+30) = 742.2 σ = 25

2014 observation

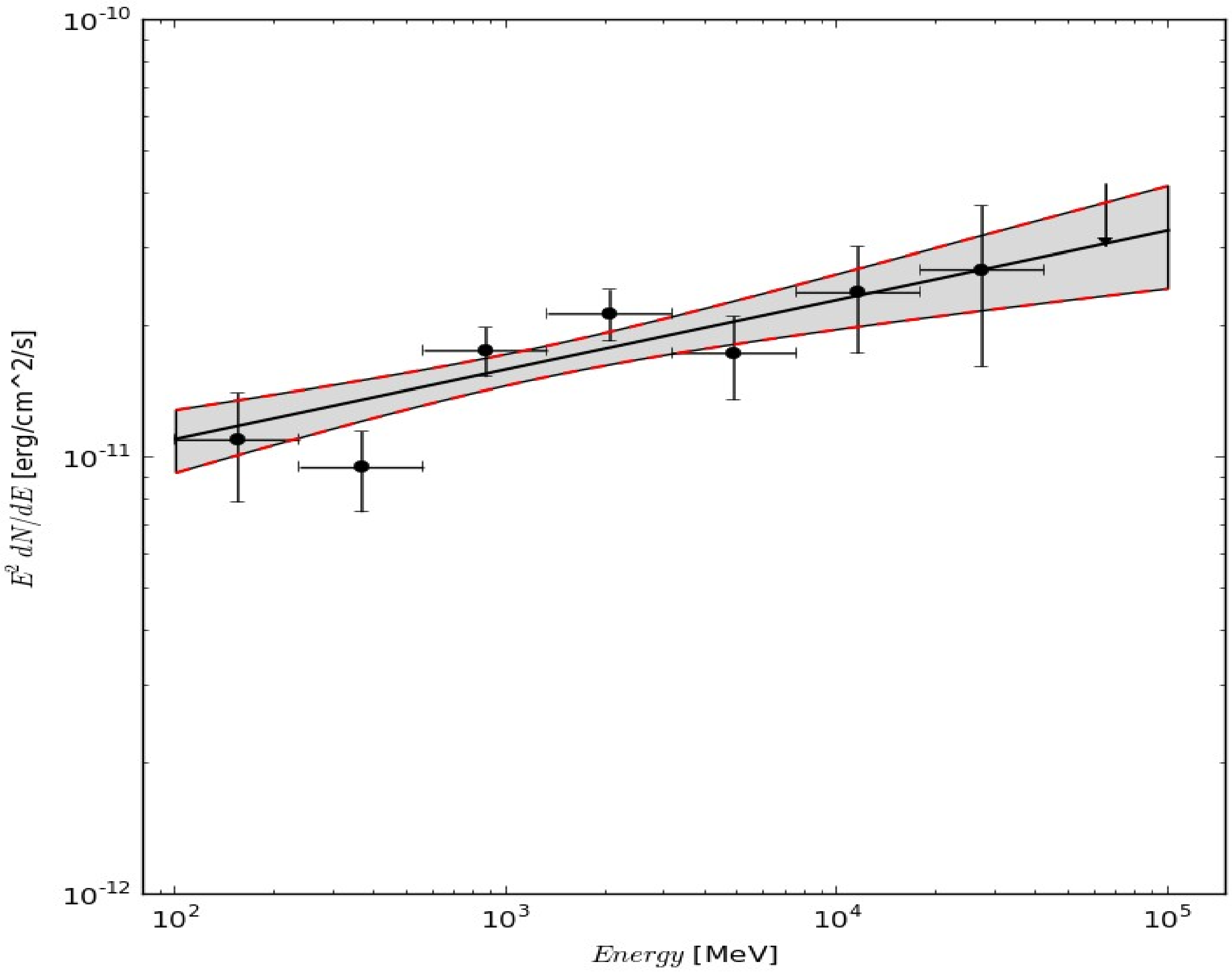
TS (B2 1215+30) = 705.3 σ = 27

$$TS = -2log\left(\frac{\mathcal{L}_{max,0}}{\mathcal{L}_{max,1}}\right)$$

ROI model for the time/energy bins:

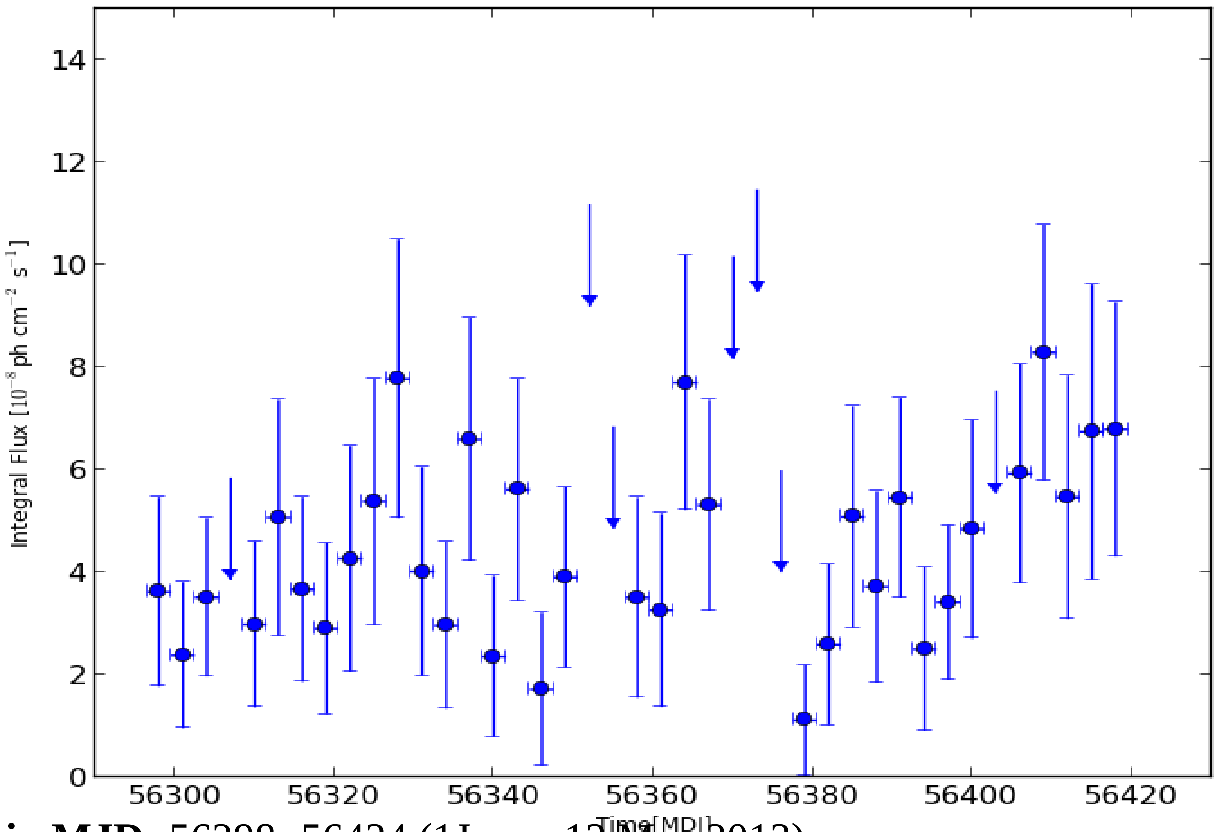
- Fix spectral shapes of all background sources
- Fix all parameters for the sources detected with a TS < 9
- Run likelihood at each bin

Fermi-LAT Analysis: Spectrum



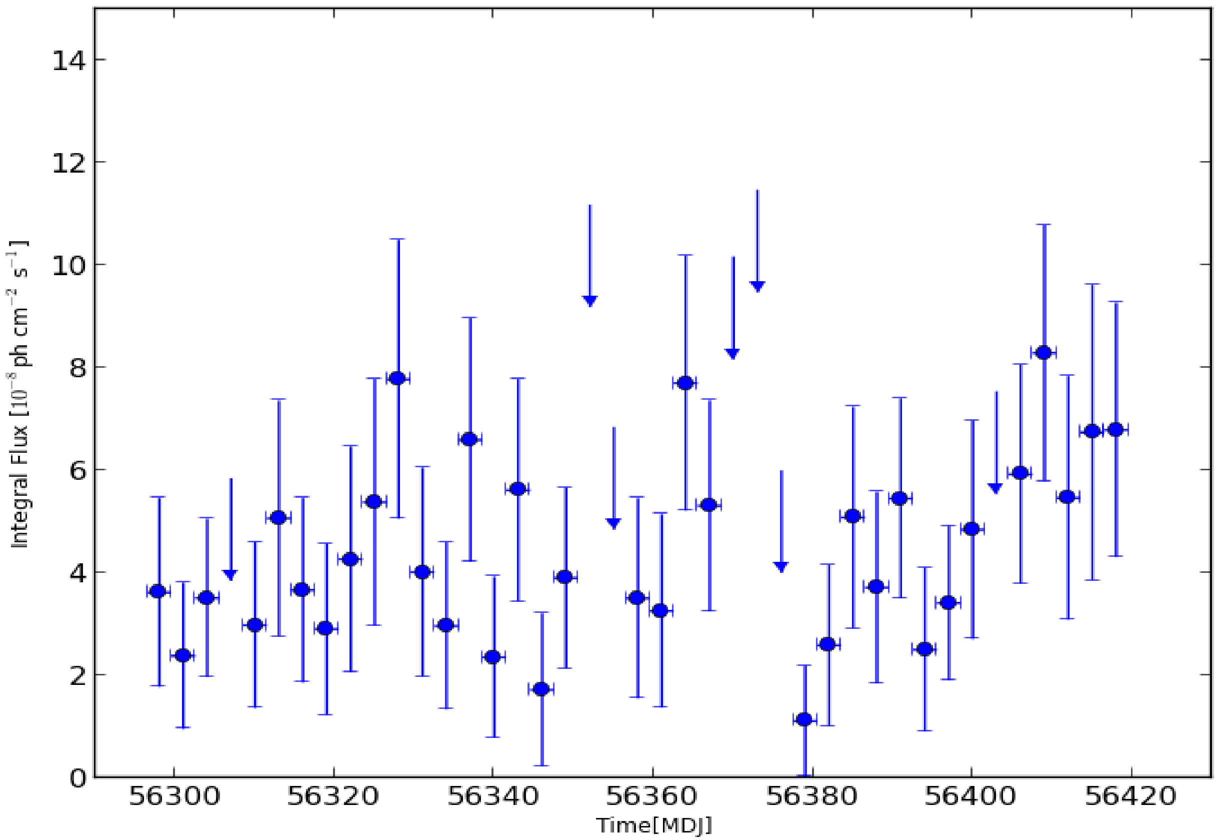
Time period: 56658 - 56802 (1Jan – 25 May 2014)
Energy range: 100 MeV – 100 GeV
Upper limits : TS<4/bin
Spectral index: 1.85

Lightcurve: 2013 data



Time of observation in MJD: 56298- 56424 (1Jan – 12 May 2013)
Time bin: 3 day

Lightcurve: 2013 data



Time of observation in MJD: 56298- 56424 (1Jan – 12 May 2013)
Time bin: 3 day

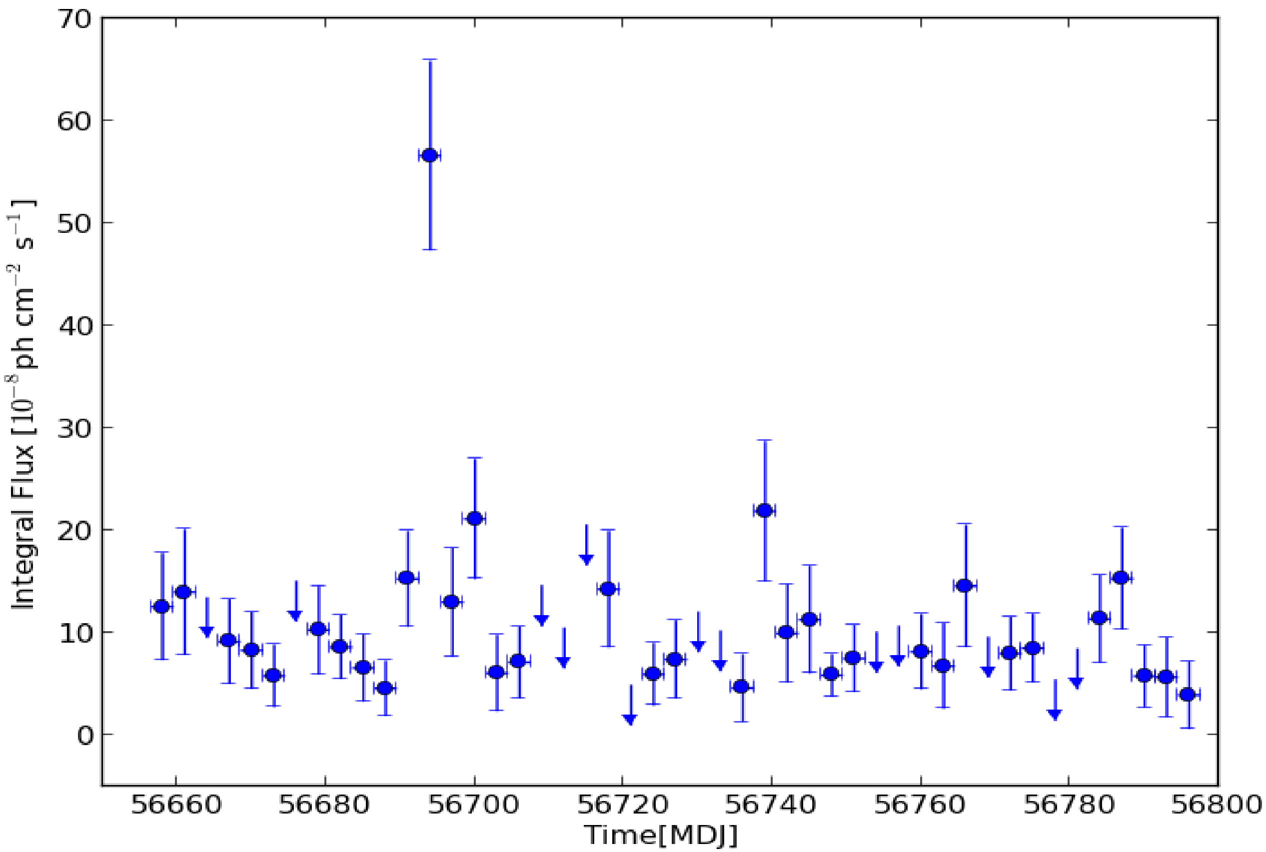
$$F_{avar} = 3.1879 \cdot 10^{-08}\ ph/cm^2/s$$

χ(const) = 55.8748

Chance Probability P = 0.2267

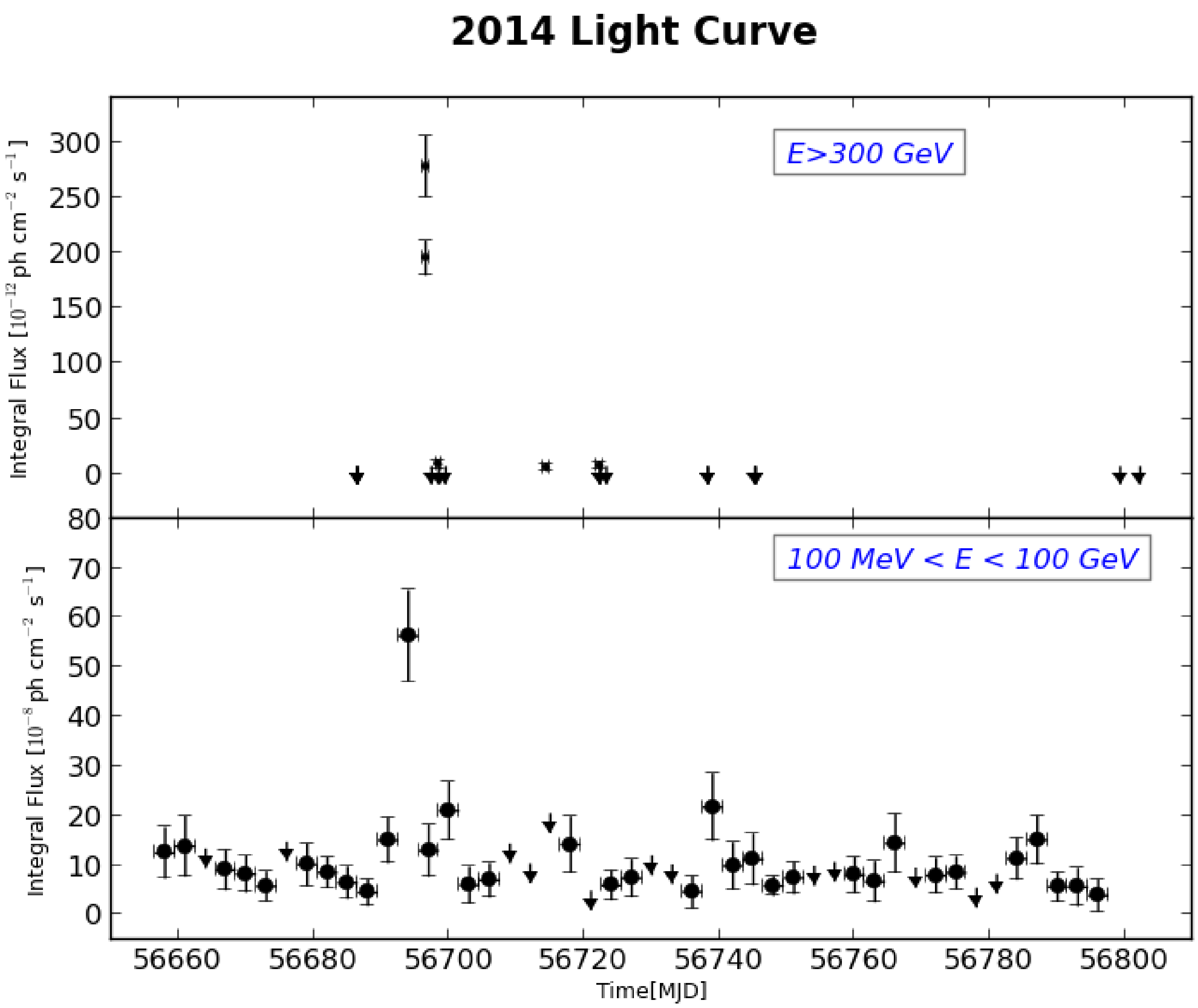
No variability detected by *Fermi*!

Lightcurve: 2014 data

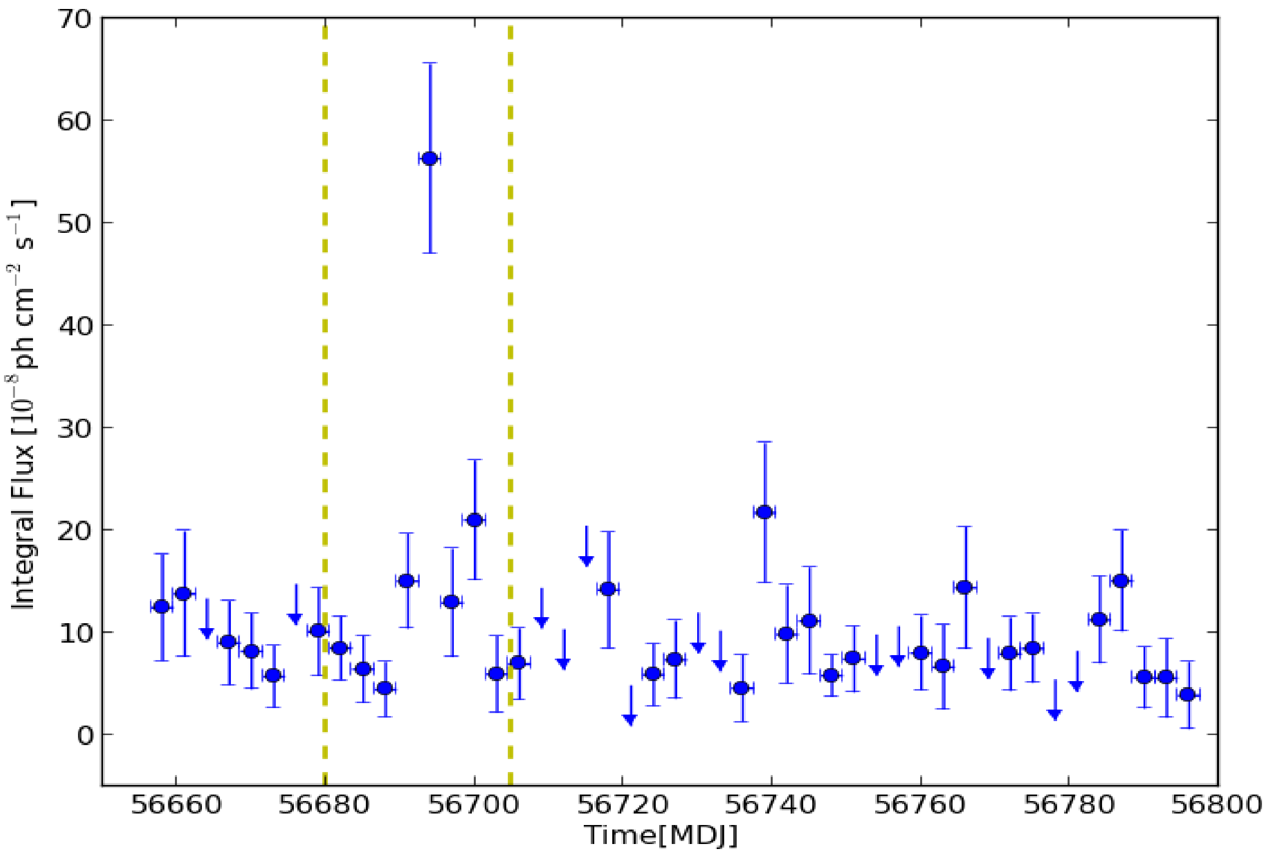


Time of observation in MJD: 56658 - 56802 (1Jan – 25 May 2014)
Time bin: 3 day + 1day time bin around the flare

Lightcurve: 2014 data



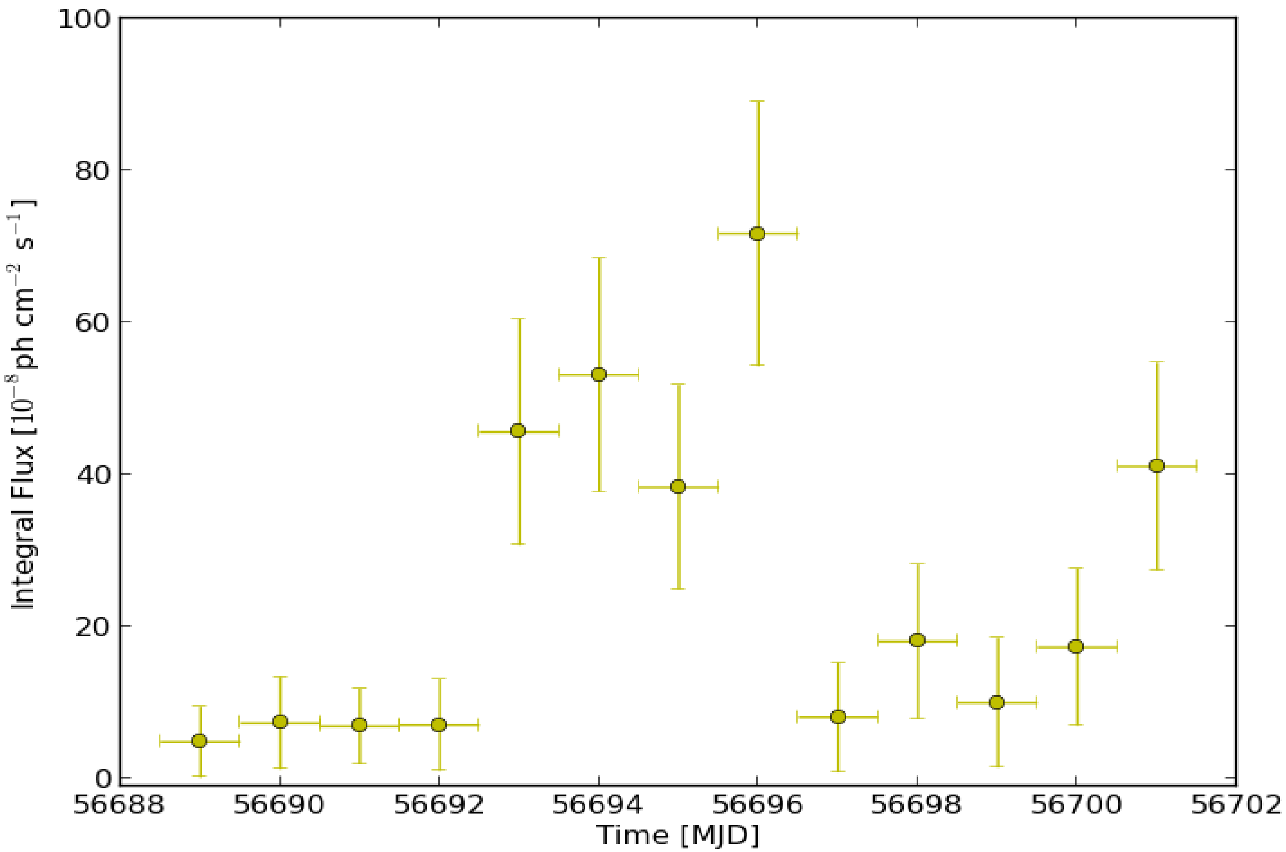
Lightcurve: 2014 data



Time of observation in MJD: 56658 - 56802 (1Jan – 25 May 2014)
Time bin: 3 day + 1day time bin around the flare

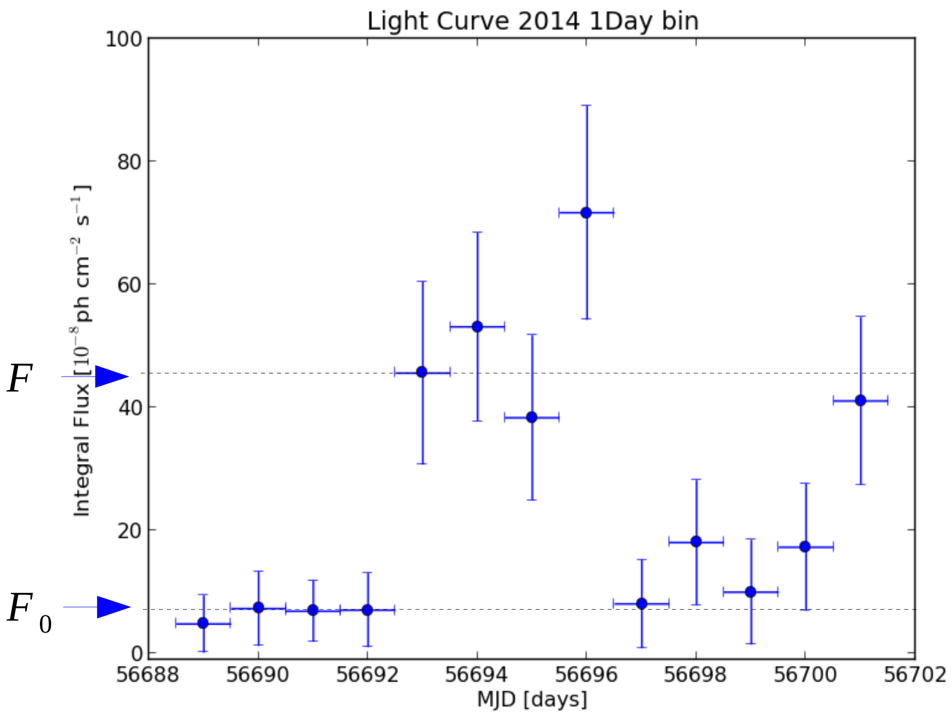
χ/NDF = 219/46

Lightcurve: 2014 data



Time of observation in MJD: 56658 - 56802 (1Jan – 25 May 2014)
Time bin: 1day time bin around the flare MJD 56695-56703 (7Feb – 15Feb 2014)

Variability time scale



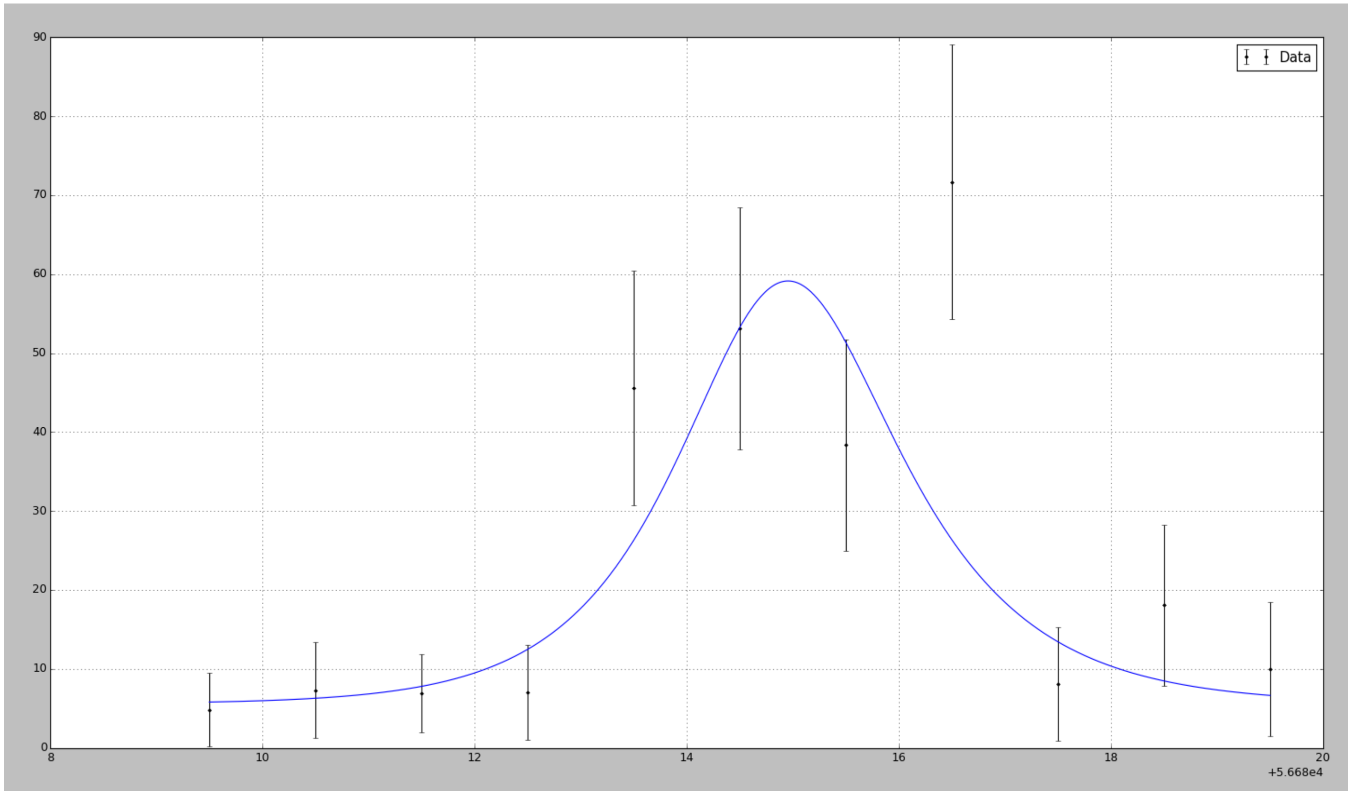
Variability time scale:

Estimate the variability when the flux increases by a factor of two:

$$F(t) = F_C + F_0 e^{\ln(2)(t-t_0)/t_{var}}$$

$$t_{var} = (0.188 \pm 0.09)\, d$$

Variability time scale



Variability time scale:

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

(equation 6, Abdo et al.2010)

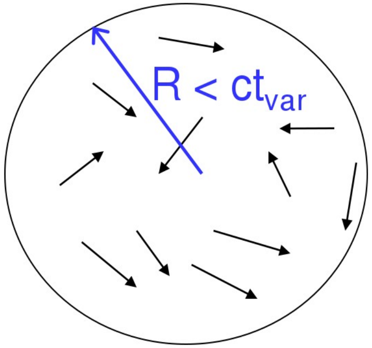
$$t_{rise} = (0.184 \pm 0.09)\, d$$

Doppler factor calculation

Use opacity to set a limit for the Doppler factor δ:

$t_{var} = 4.5\,h$

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



$$\gamma + \gamma \rightarrow e^{+} + e^{-}$$

$$R\delta^{-1} \leq ct_{\rm var}/(1+z) \leq 4.3 \times 10^{14}\,{\rm cm}.$$

Gamma-rays "escape" the source → the optical depth: $\tau_{\gamma\gamma} \ll 1$
Relativistic boost on the emission region.

The optical depth:

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

(Dondi et al. 1997)

σ = Thomson cross section
d = luminosity distance
z = redshift
R= size of the emission region
F(E) = flux density

Doppler factor calculation

Use γ-ray variability to set a limit for the Doppler factor δ:

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

X-ray flux (0.3-10 keV)=1.28 erg/cm^2/s
Spectral index = 2.54
Highest energy photon (Fermi) = 73.6 GeV
Luminosity distance = 592 Mpc
Redshift = 0.13

⇨ **δ > 5.7**

Future plans

Paper

Draft version May 17, 2015
Preprint typeset using LaTeX style emulateapj v. 08/13/06

STUDYING THE GAMMA-RAY EMISSION FROM THE BRIGHT, VARIABLE BLAZAR B2 1215+30

VERITAS Collaboration[1], S. Fegan[3], B. Giebels[3], D. Horan[3], J. Kuan[4], H. Prokoph[5], and F. Zefi[3]

Draft version May 17, 2015

ABSTRACT

The VERITAS imaging atmospheric Cherenkov telescope array originally reported the detection of TeV gamma-ray emission from the BL Lac object B2 1215+30 in 2013 based on observations carried out between 2008 and 2012. In 2014 February, a massive flare was detected from the same source during routine monitoring observations of the blazar 1ES 1218+304, located in the same field of view. The flare lasted less than a day, and VERITAS detected TeV gamma-ray emission from the source approximately at the level of 200% of the Crab Nebula flux, a standard measure in gamma-ray astronomy. Such bright gamma-ray emission is detected from only a handful of nearby TeV blazars, such as the three well established, TeV-bright blazars in the northern hemisphere, Mrk 421, Mrk 501, and 1ES 1959+650. The TeV flare was found to be correlated with a flare detected in the Fermi-LAT data at energies between 100 MeV to 100 GeV. We report here on the remarkable flare from B2 1215+30 at gamma-ray energies. Given that the source is located at a distance of at least 4.5 times that of Mrk 421, its luminosity makes it one of the brightest TeV blazars detected to date. We use the VERITAS and Fermi-LAT data to constrain the size of the emission region, and place a preliminary limit on the Doppler factor of the blazar jet.

Subject headings: galaxies: active – galaxies: nuclei – gamma rays: general

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ICRC conference

Thank you for the attention!