# Gamma-ray variability analysis from Fermi to LHAASO

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# Gamma-ray variability analysis

Based on Fermi-LAT

New Fermi gamma-ray sources

Gamma-ray

QPOs

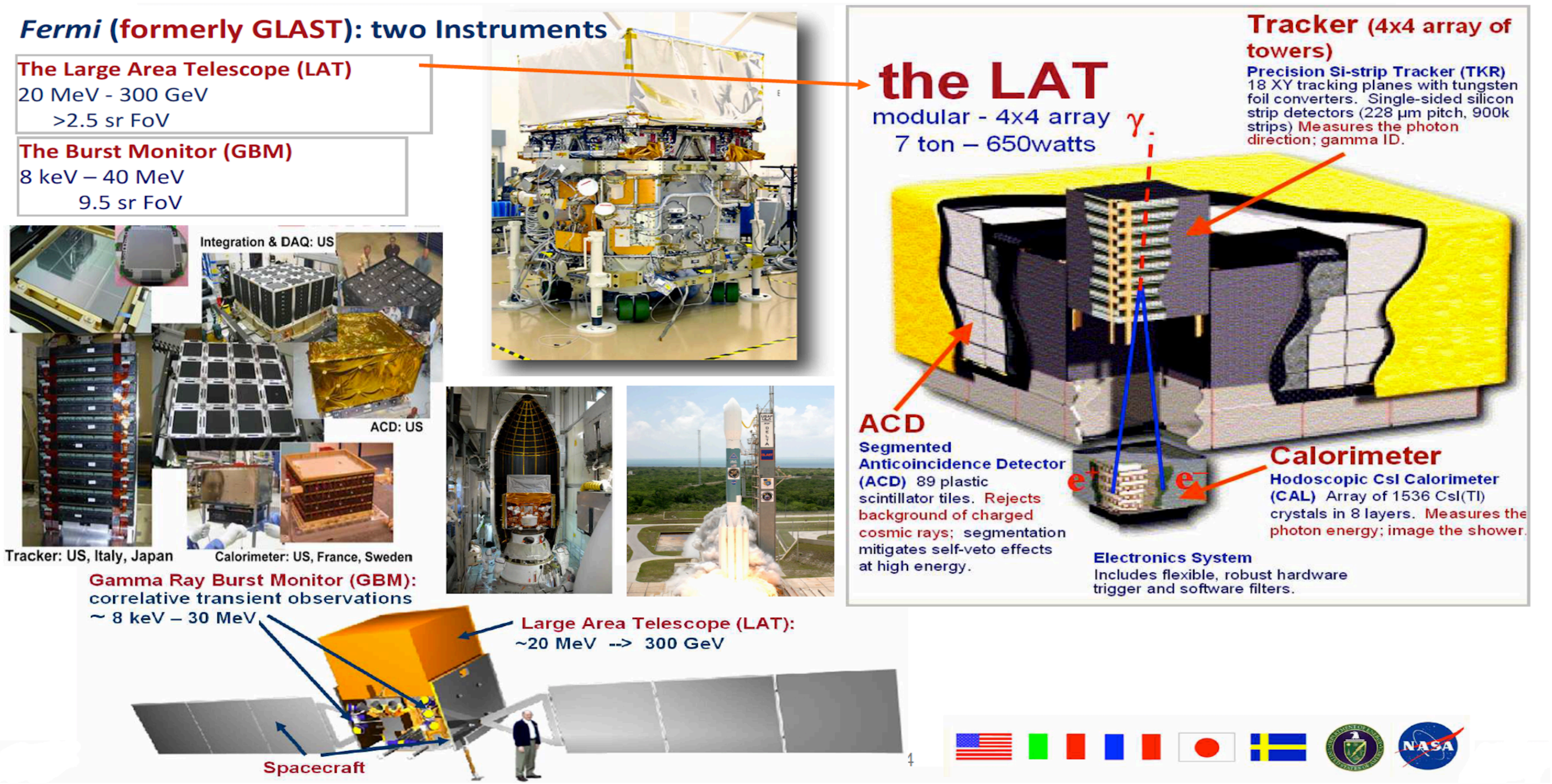
Local temporal analysis

QPO origination

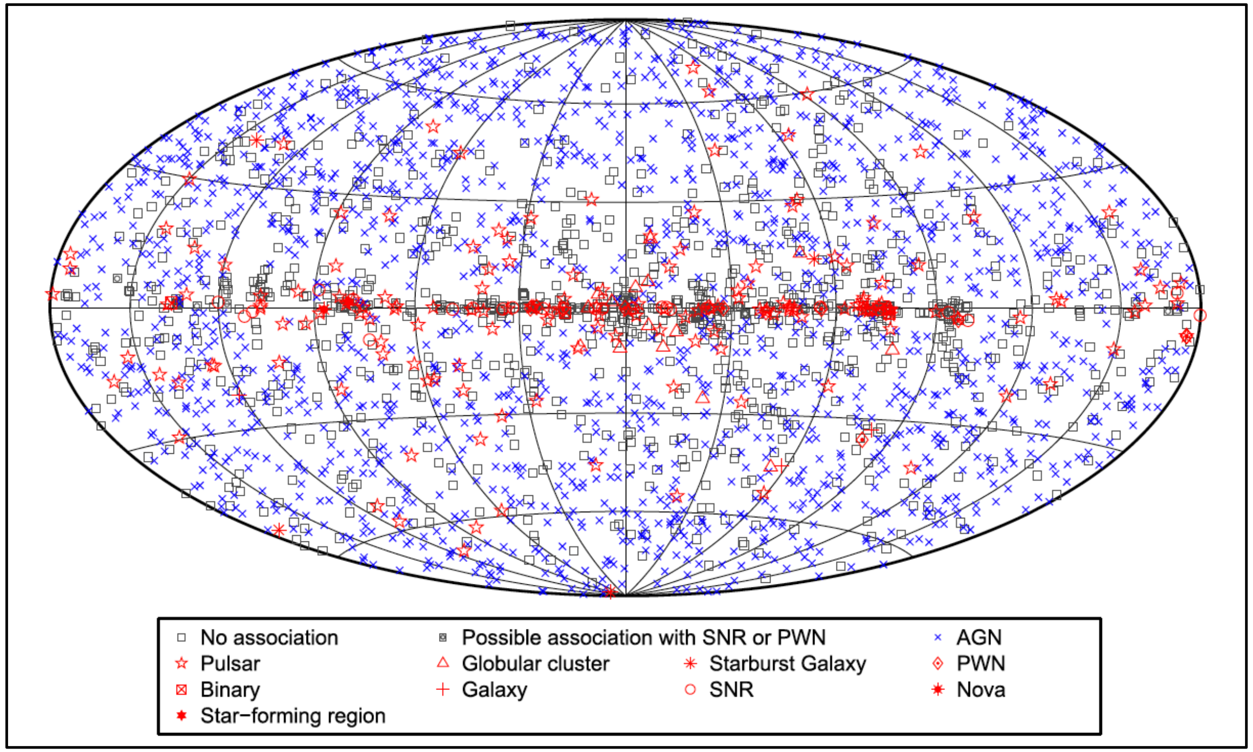
To LHAASO

Expectation

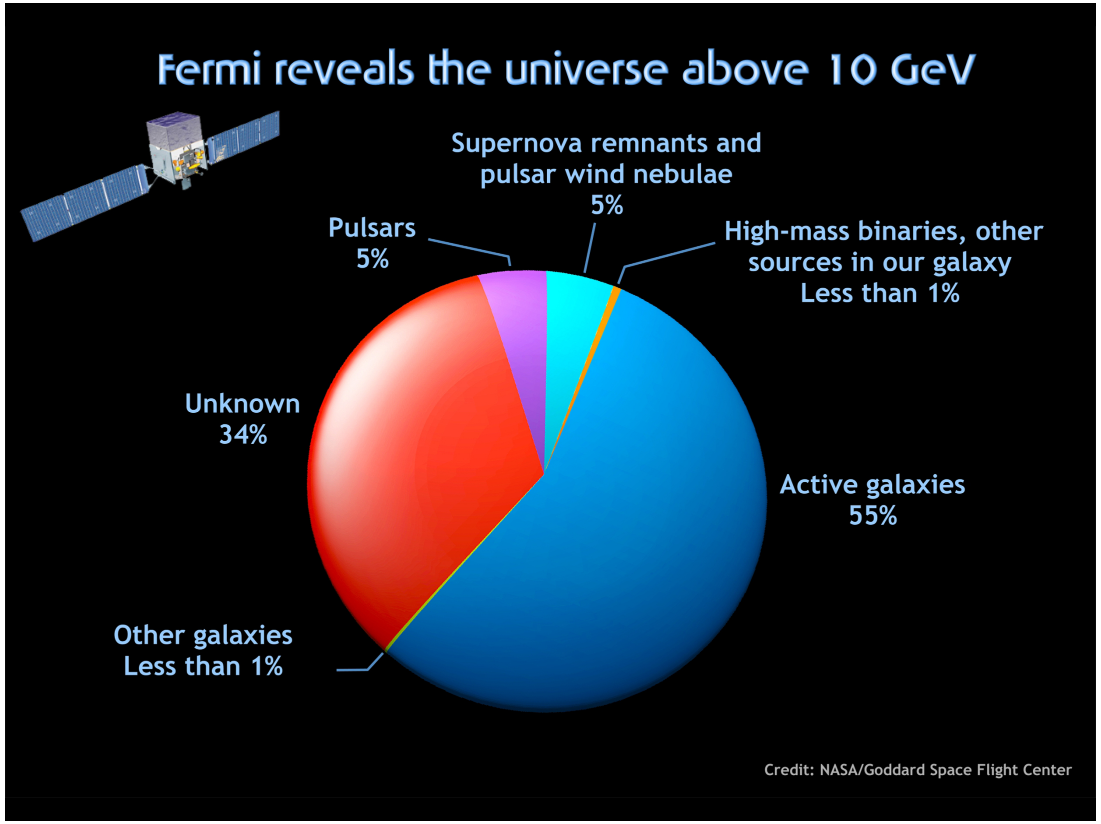
# Fermi large area telescope



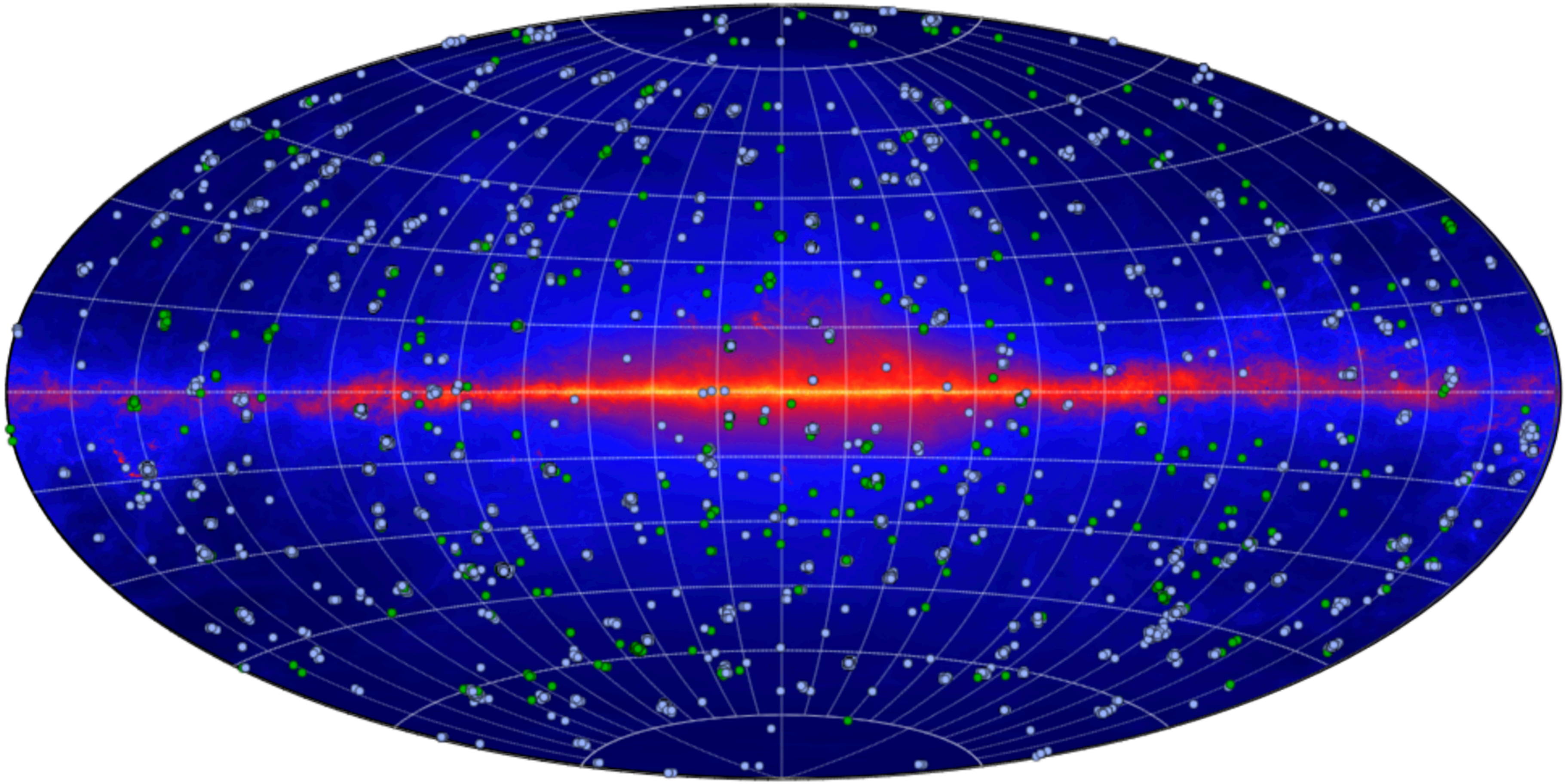
# Fermi Large Area Telescope third catalog sources map




| | Identified | Associated |
|---|---|---|
| FSRQ | 38 | 446 |
| BL Lac | 18 | 642 |
| Unknown type | 5 | 568 |

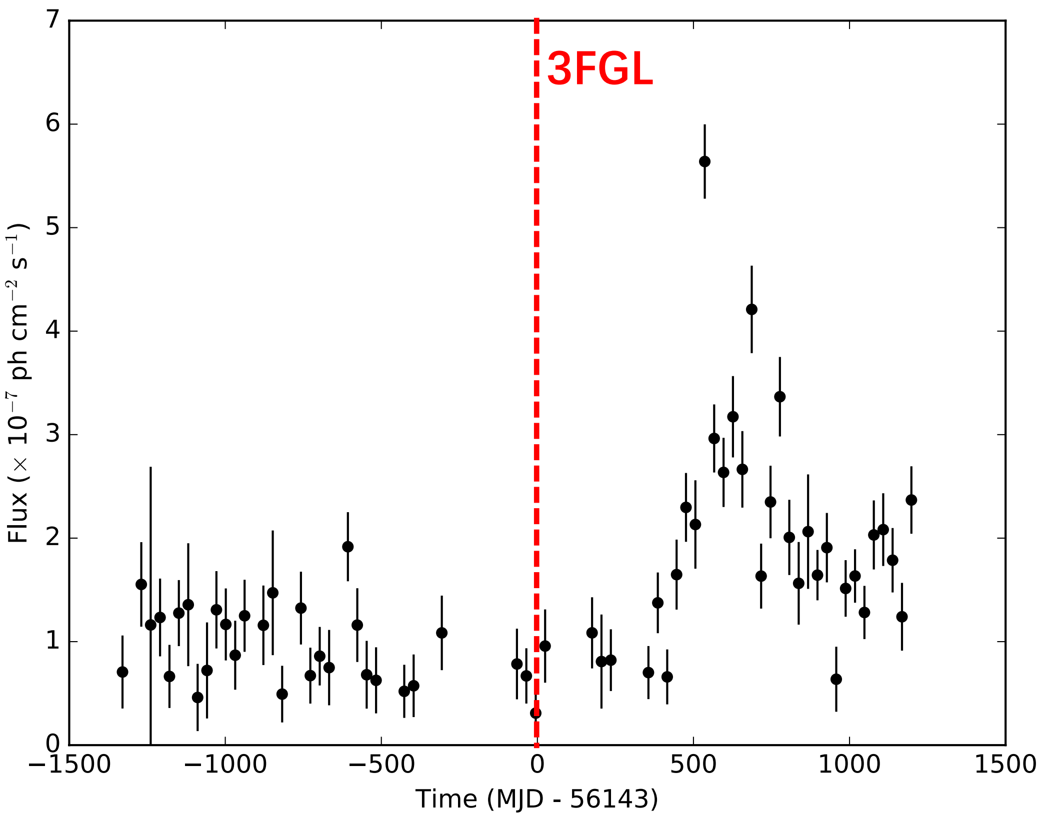


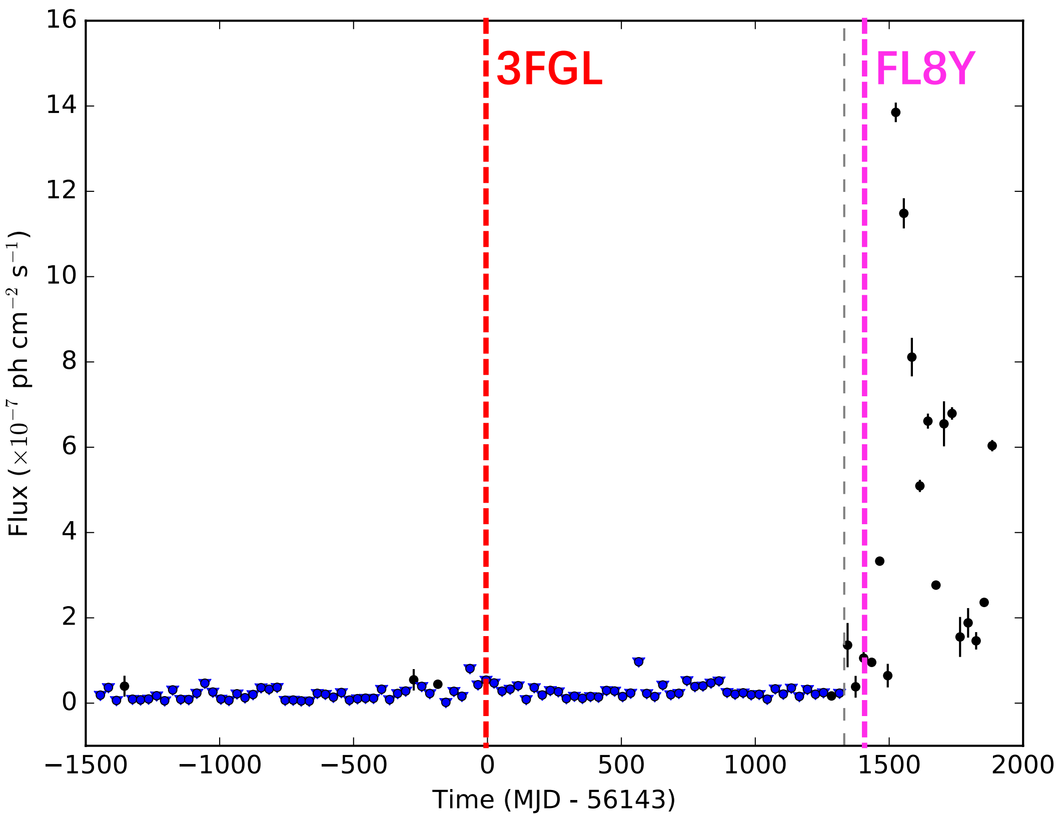
# Fermi All-sky Variability Analysis



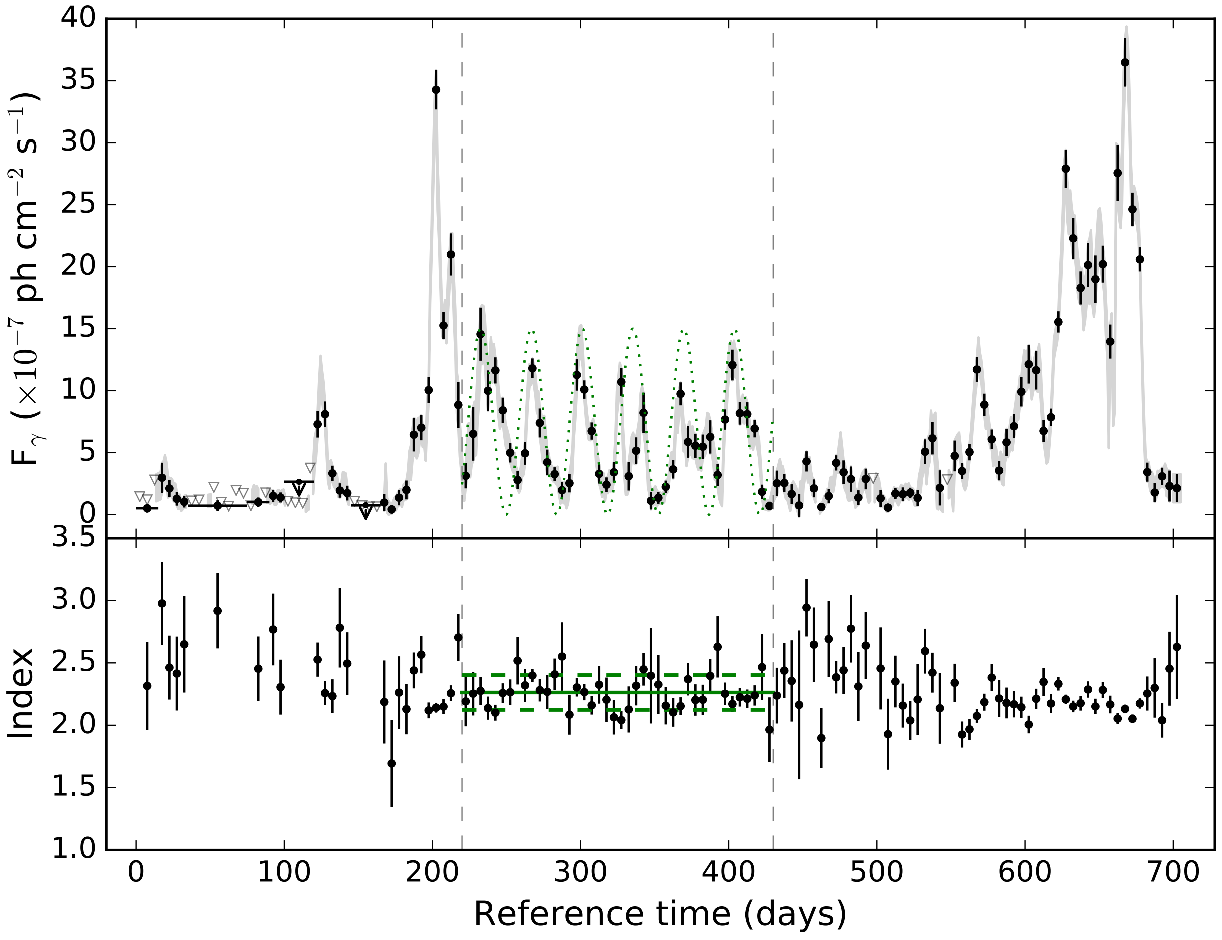
Up to now, with 479 weeks data, 4647 flares were detected.
518 sources are identified.
393 of which are blazars…

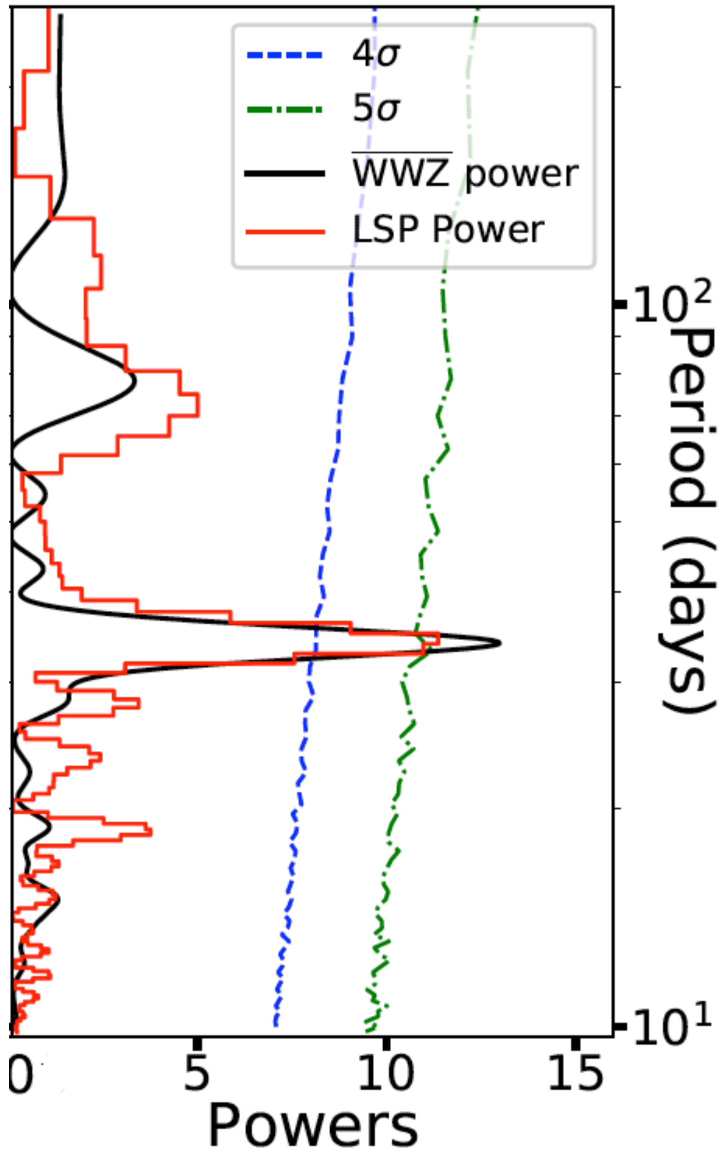
# “new” gamma-ray sources



# Timing analysis



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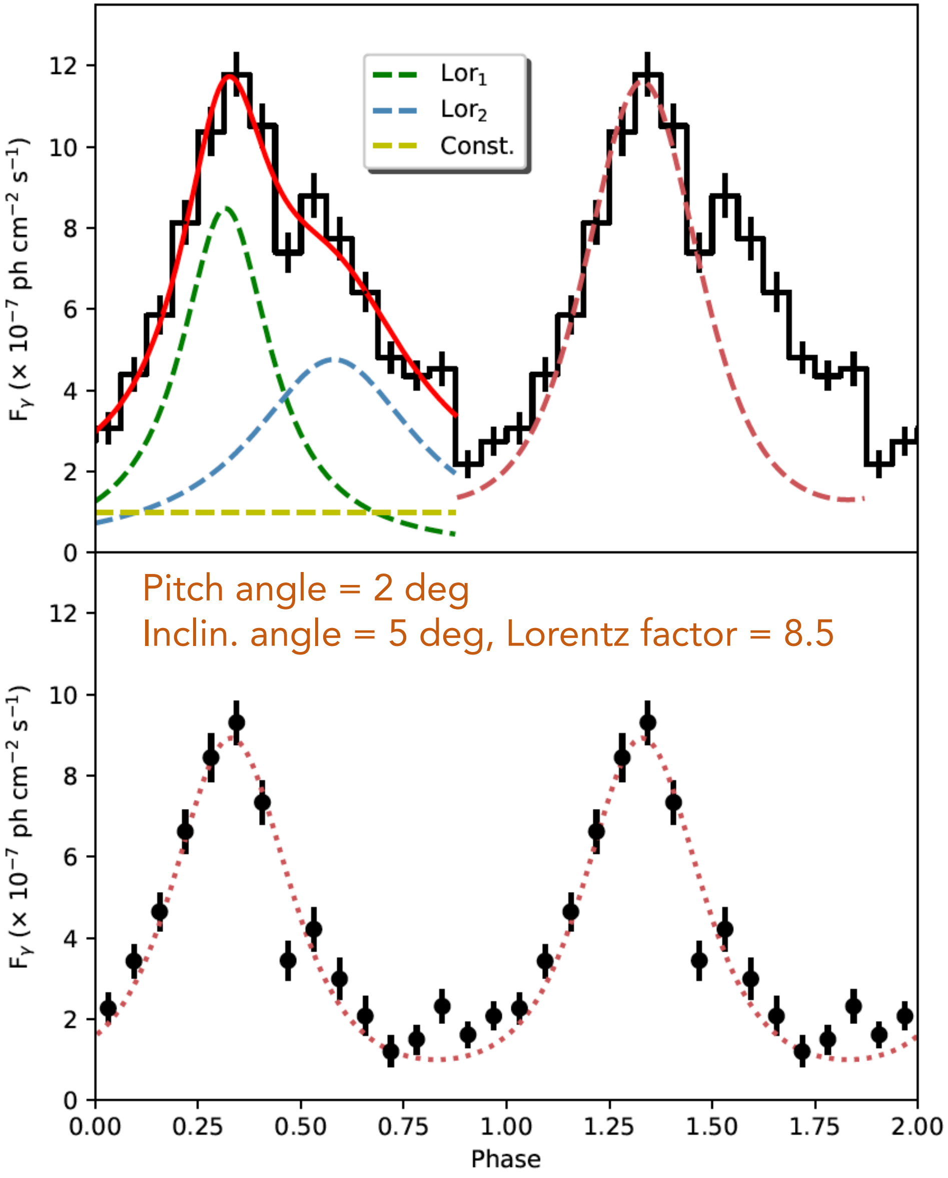
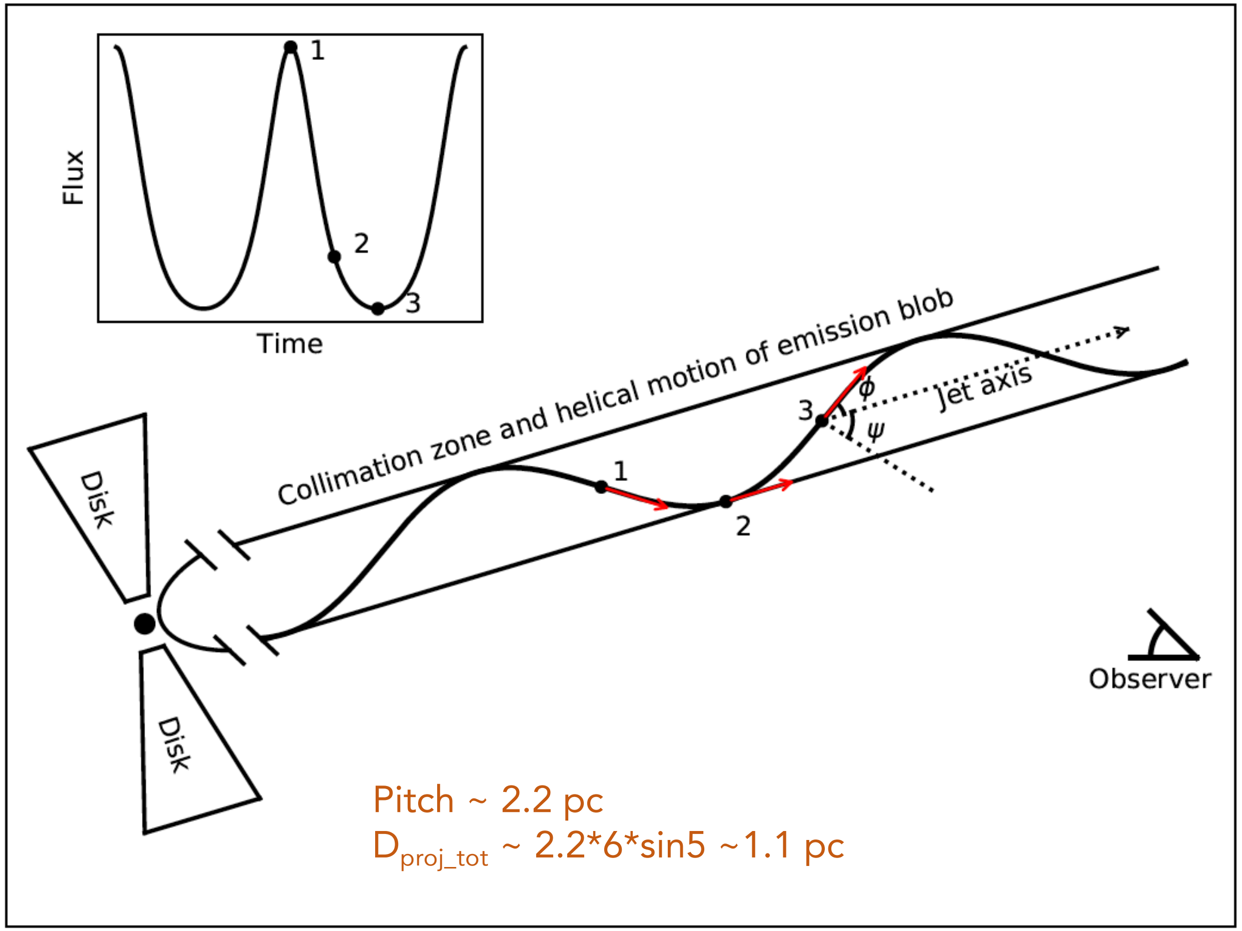
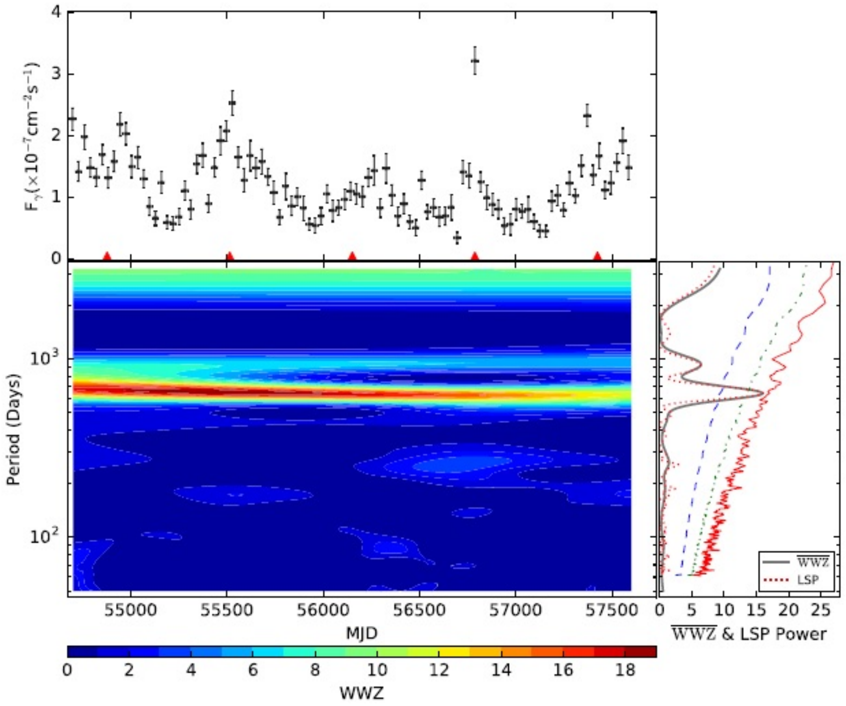


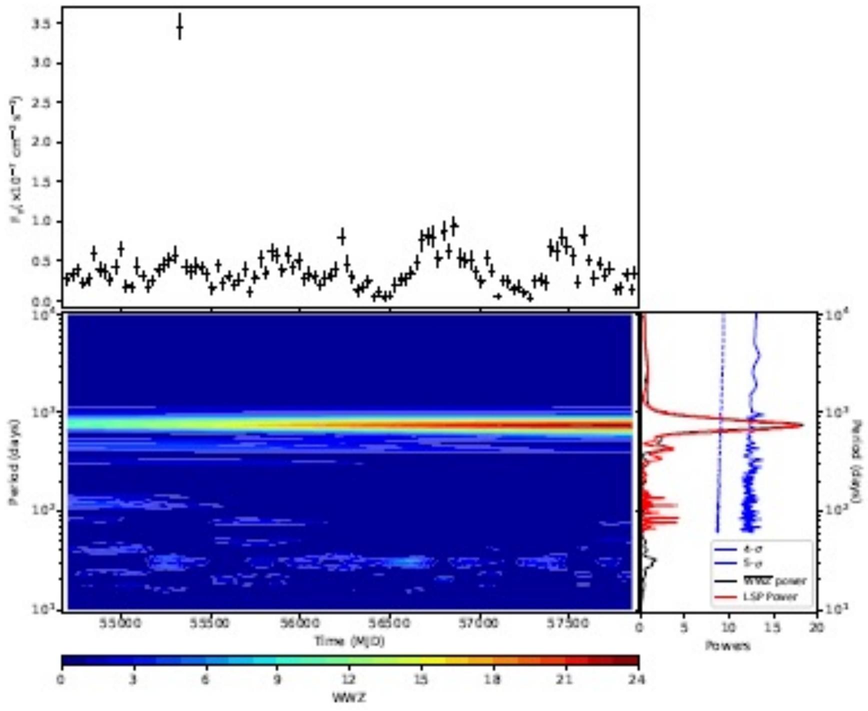




This is the only case in more than 1700 Fermi detected blazars !!

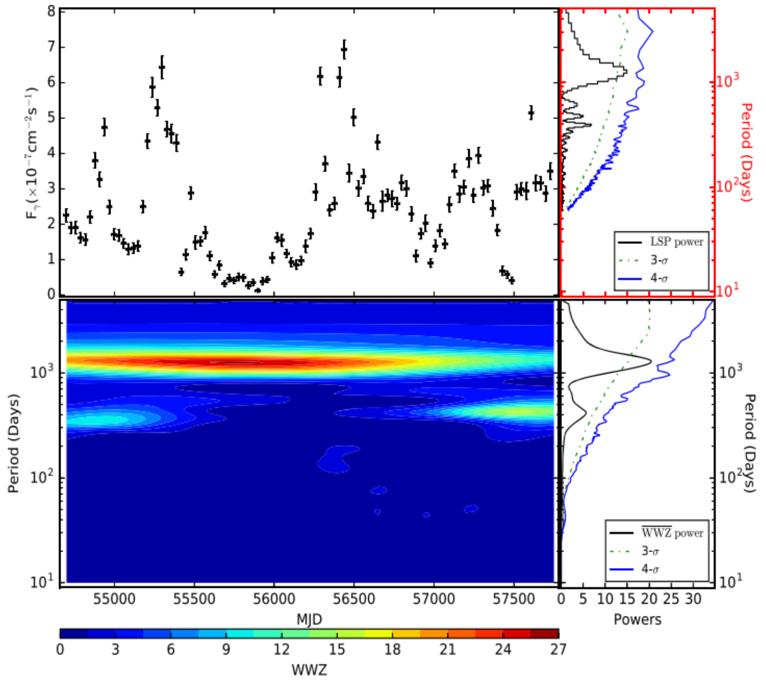
# QPOs on year-long timescale



PKS 2155-304:
P = 1.74 yrs
4.9sigma significance
(Zhang et al. 2017)

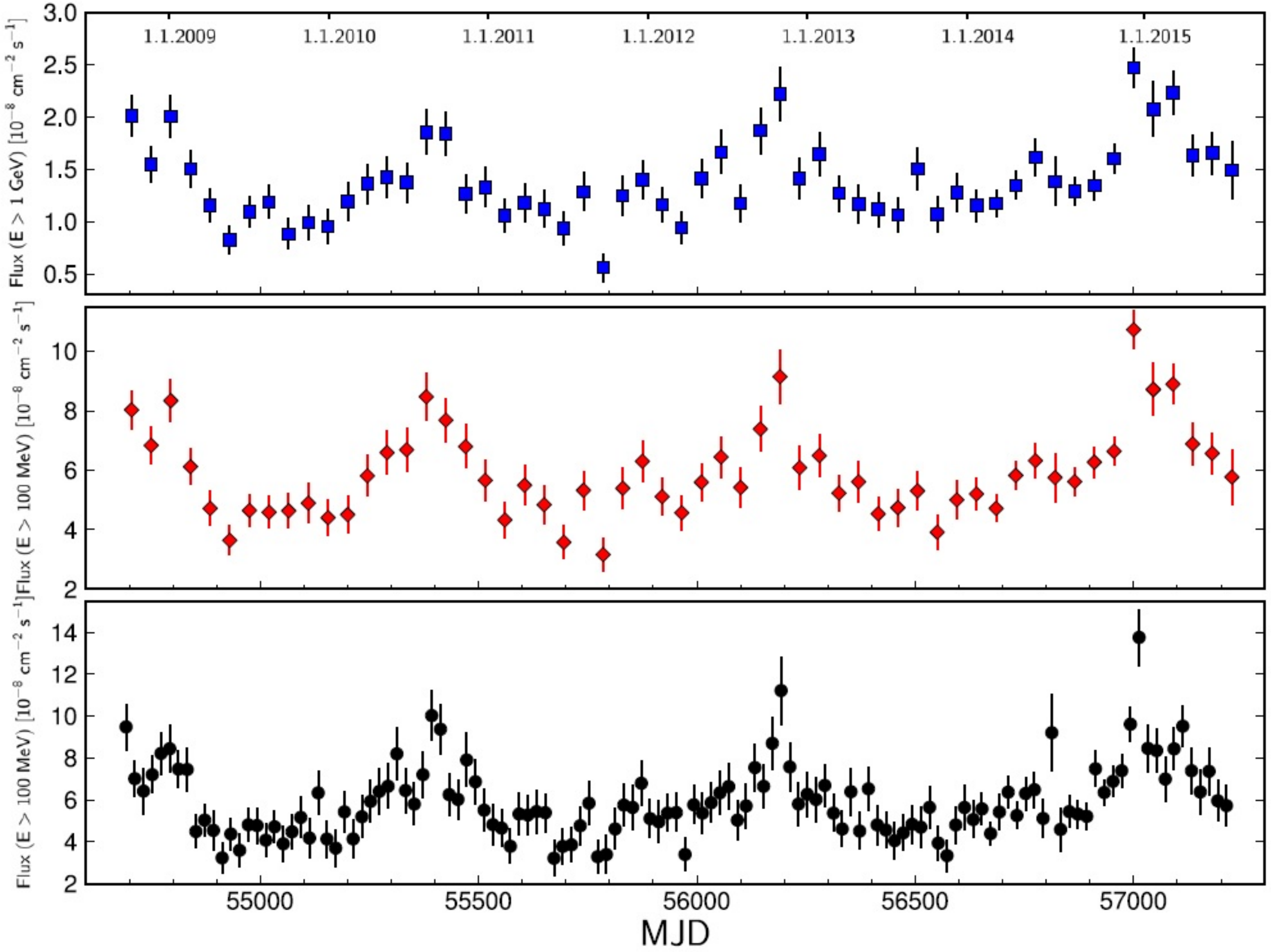


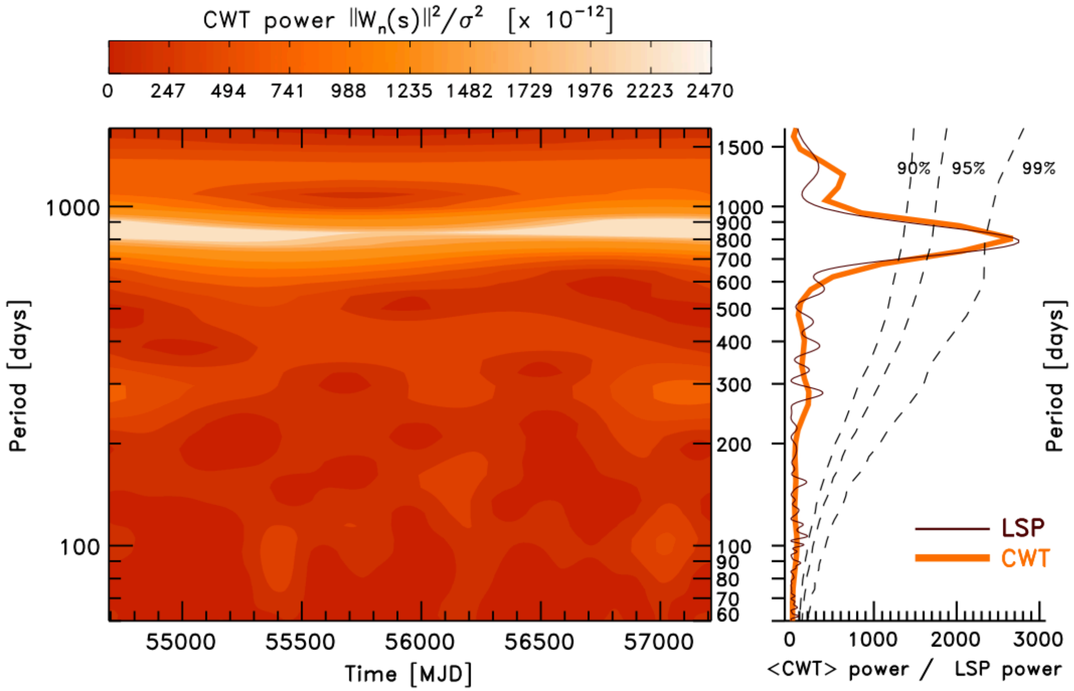
PKS 0301-243:
P = 2.1 yrs
~5sigma significance
(Zhang et al. 2018)



PKS 0426-380:
P = 3.35 yrs
~3.6sigma significance
(Zhang et al. 2017)

# PG 1553+113 – a 2.18 years QPO




- Intrinsic origin:
  Pulsational accretion

- Apparent origin:
  periodically Doppler factor changing

# Cause of gamma-ray QPO in blazar - PG 1553+113

Assuming emission originating from a relativistically moving blob, if the emission in the frame of the blob is isotropic, and follows a power-law distribution of the form $F'_{\nu'} \propto \nu'^{-\alpha}$.

To observer, $F_\nu(\nu) = \delta_D^{3+\alpha} F'_{\nu'}(\nu)$ [Urry & Padovani 1995]
$\delta_D$ is Doppler factor.

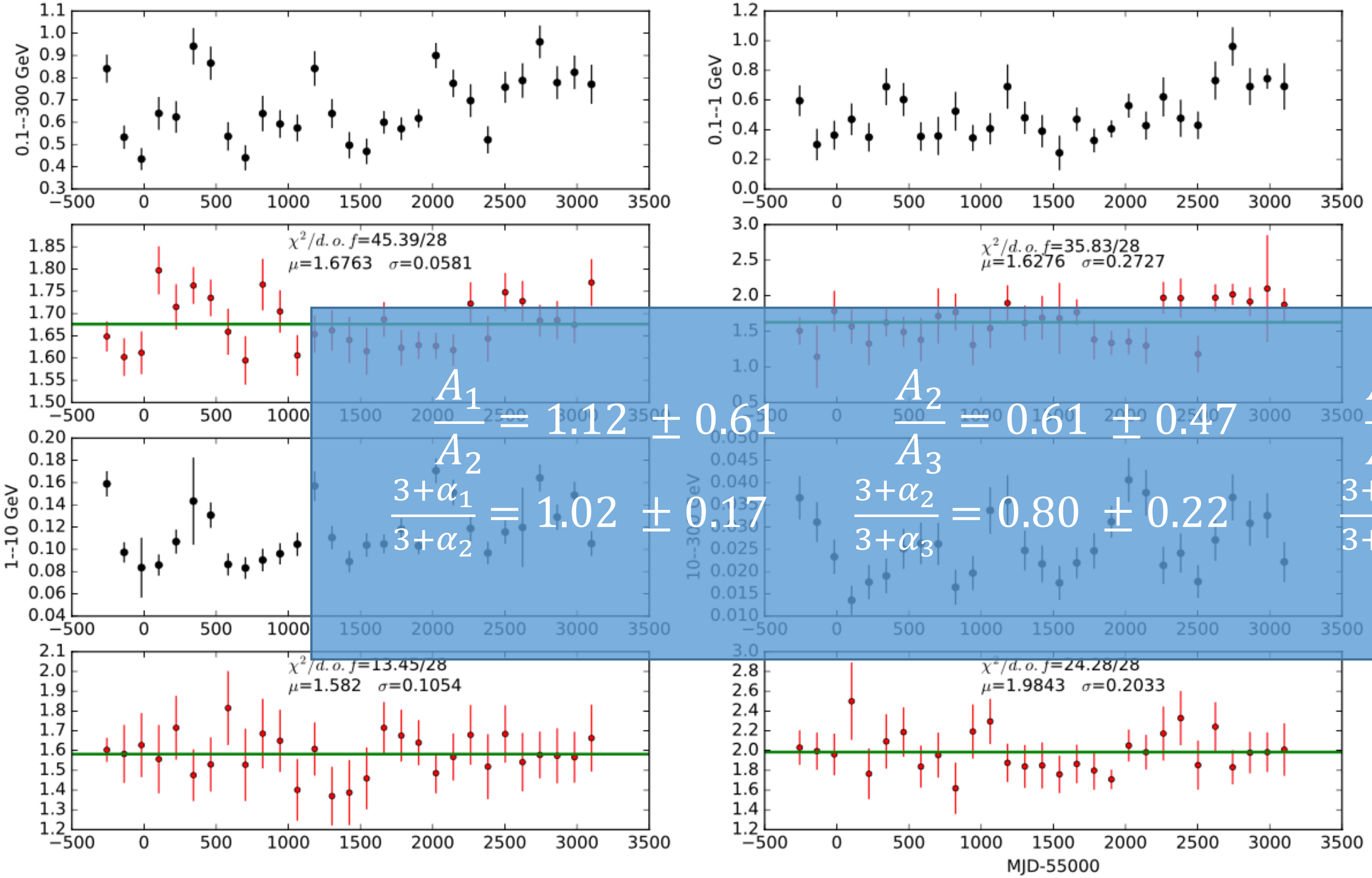
The relative variability amplitude is derived as: [D'Orazio et al. 2015; Charisi et al. 2018]

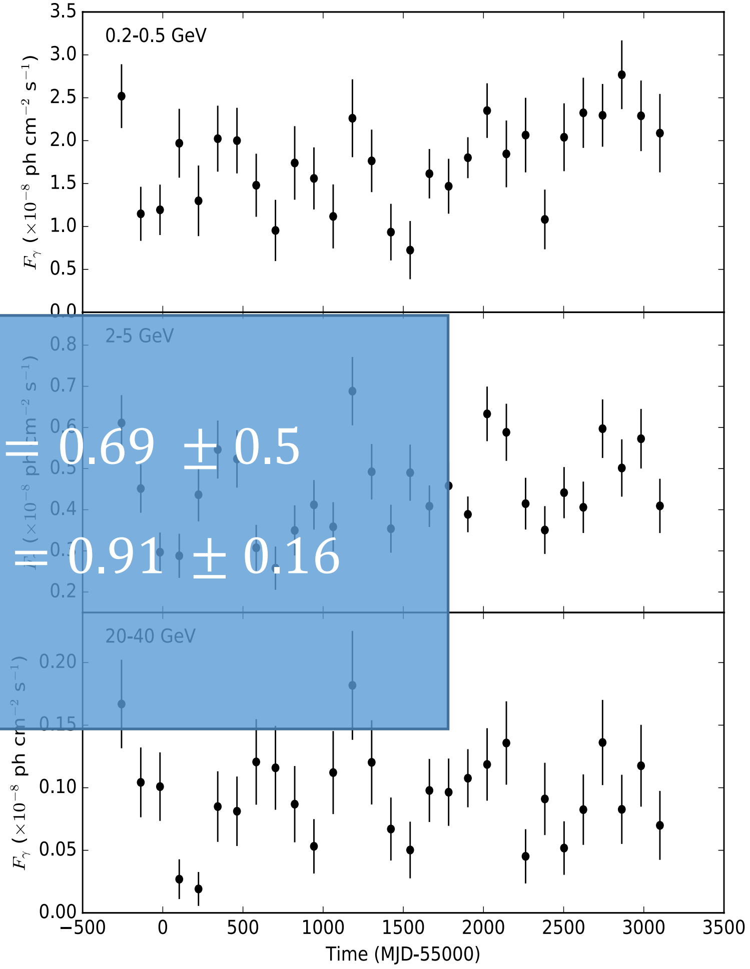
$$A = \frac{\Delta F_\nu}{F_\nu} \propto \frac{3+\alpha}{\delta_D}$$

The ratio between low and high gamma-ray energies is

$$\frac{A_H}{A_L} = \frac{3+\alpha_H}{3+\alpha_L}$$

# Cause of gamma-ray QPO in blazar - PG 1553+113




$$\frac{A_1}{A_2} = 1.12 \pm 0.61 \qquad \frac{A_2}{A_3} = 0.61 \pm 0.47 \qquad \frac{A_1}{A_3} = 0.69 \pm 0.5$$

$$\frac{3+\alpha_1}{3+\alpha_2} = 1.02 \pm 0.17 \qquad \frac{3+\alpha_2}{3+\alpha_3} = 0.80 \pm 0.22 \qquad \frac{3+\alpha_1}{3+\alpha_3} = 0.91 \pm 0.16$$

*Yan et al., 2018, ApJ accepted*

# Expectation on detecting blazar flares by LHAASO

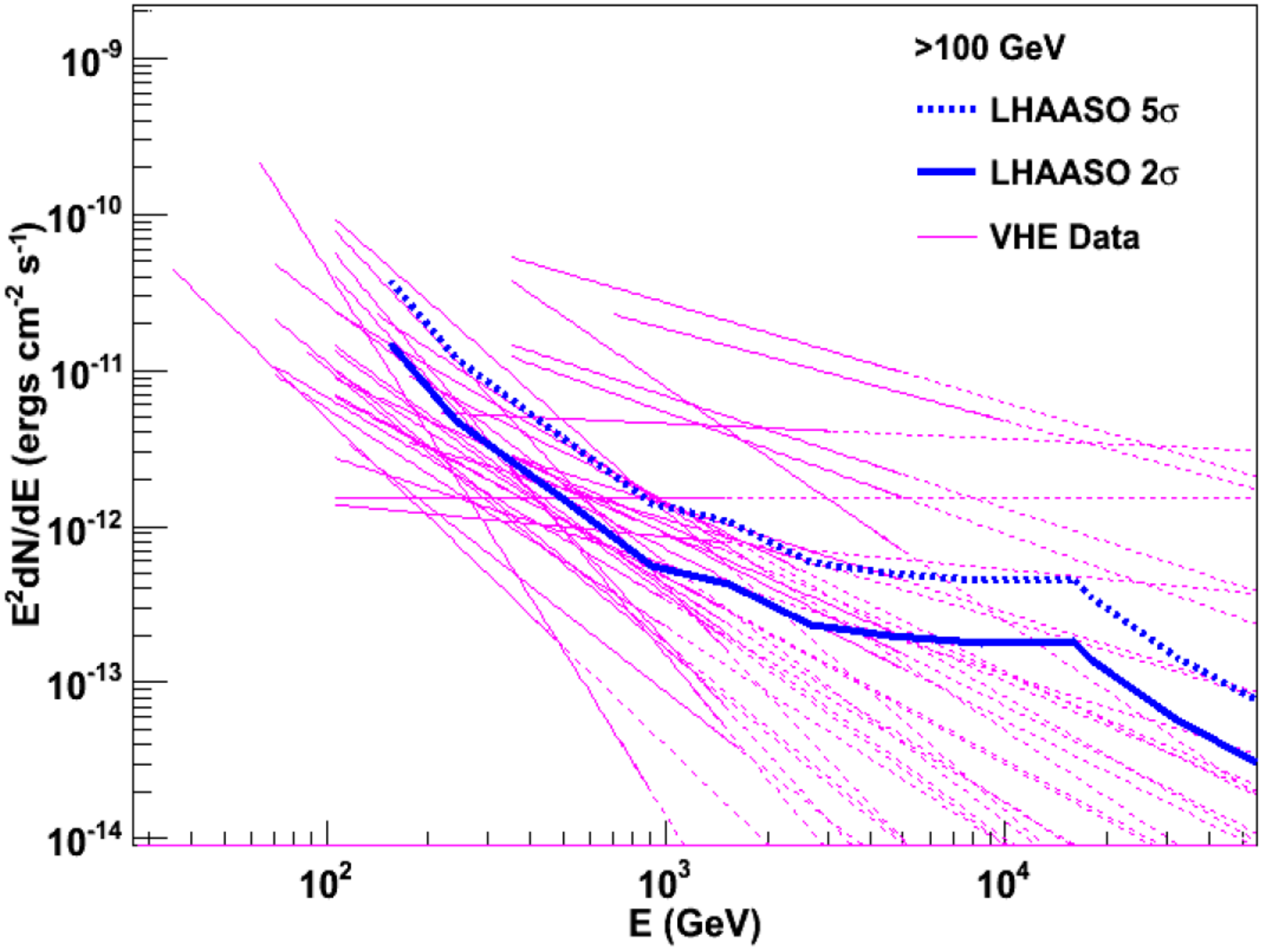
3FHL Source Classes ( 10 GeV – 2 TeV )

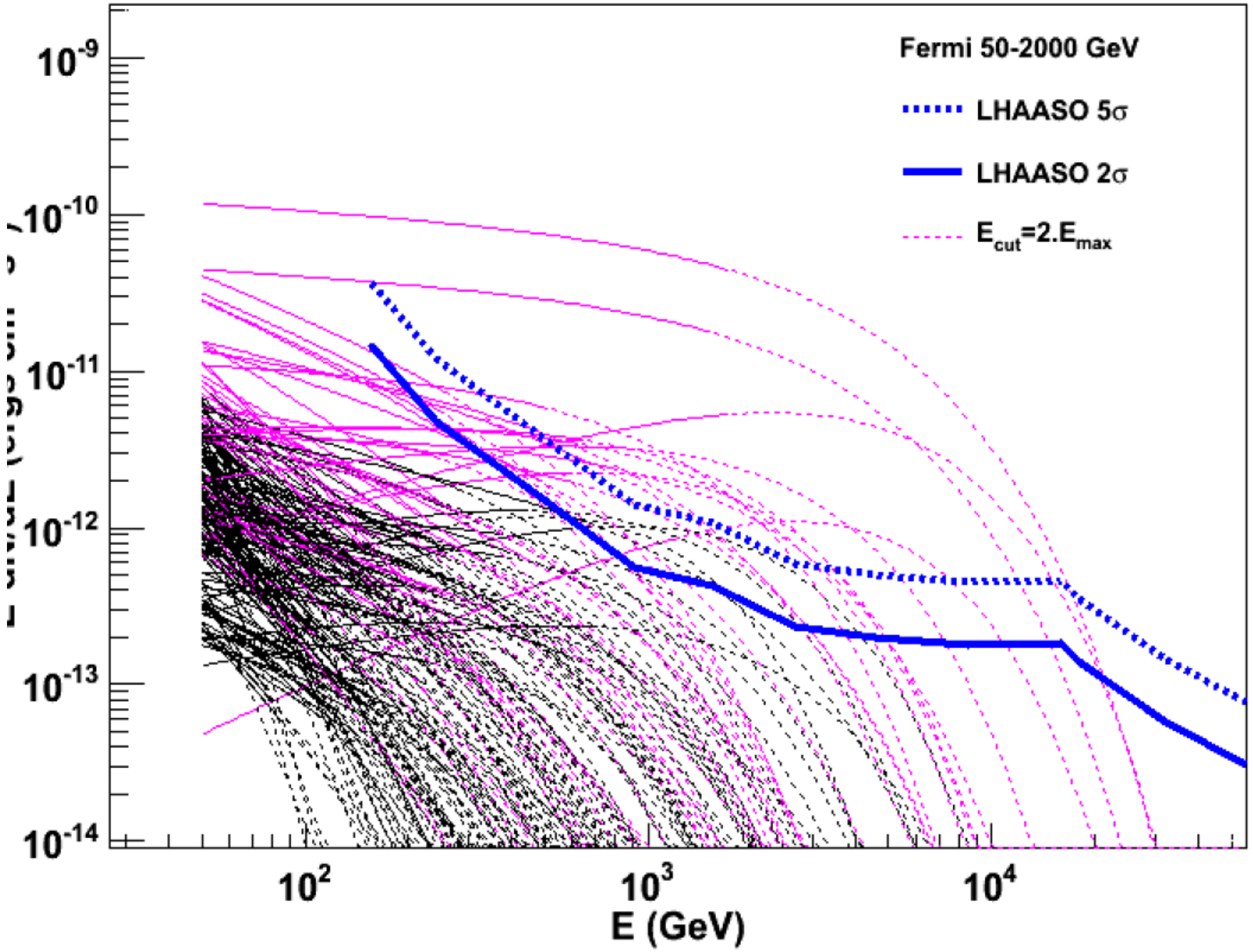
| Description | Identified Designator | Identified Number | Associated Designator | Associated Number |
|---|---|---|---|---|
| Pulsar | PSR | 53 | psr | 6 |
| Pulsar Wind Nebula | PWN | 9 | pwn | 8 |
| Supernova remnant | SNR | 13 | snr | 17 |
| Supernova remnant / Pulsar wind nebula | ... | ... | spp | 9 |
| High-mass binary | HMB | 4 | hmb | 1 |
| Binary | BIN | 1 | ... | ... |
| Globular cluster | ... | ... | glc | 2 |
| Star-forming region | SFR | 1 | sfr | 1 |
| Starburst galaxy | ... | ... | sbg | 4 |
| BL Lac type of blazar | BLL | 19 | bll | 731 |
| Flat spectrum radio quasar type of blazar | FSRQ | 30 | fsrq | 142 |
| Non-blazar active galaxy | ... | ... | agn | 1 |
| Narrow-line seyfert 1 | NYLS1 | 1 | ... | ... |
| Radio galaxy | RDG | 4 | rdg | 9 |
| Blazar candidate of uncertain type | ... | ... | bcu | 290 |
| Total | identified | 136 | associated | 1220 |
| Unclassified | ... | ... | unknown | 23 |
| Unassociated | ... | ... | ... | 177 |
| Total in the 3FHL | ... | ... | ... | 1556 |

360 sources for 2FHL

*Ajello et al. 2018, ApJS*

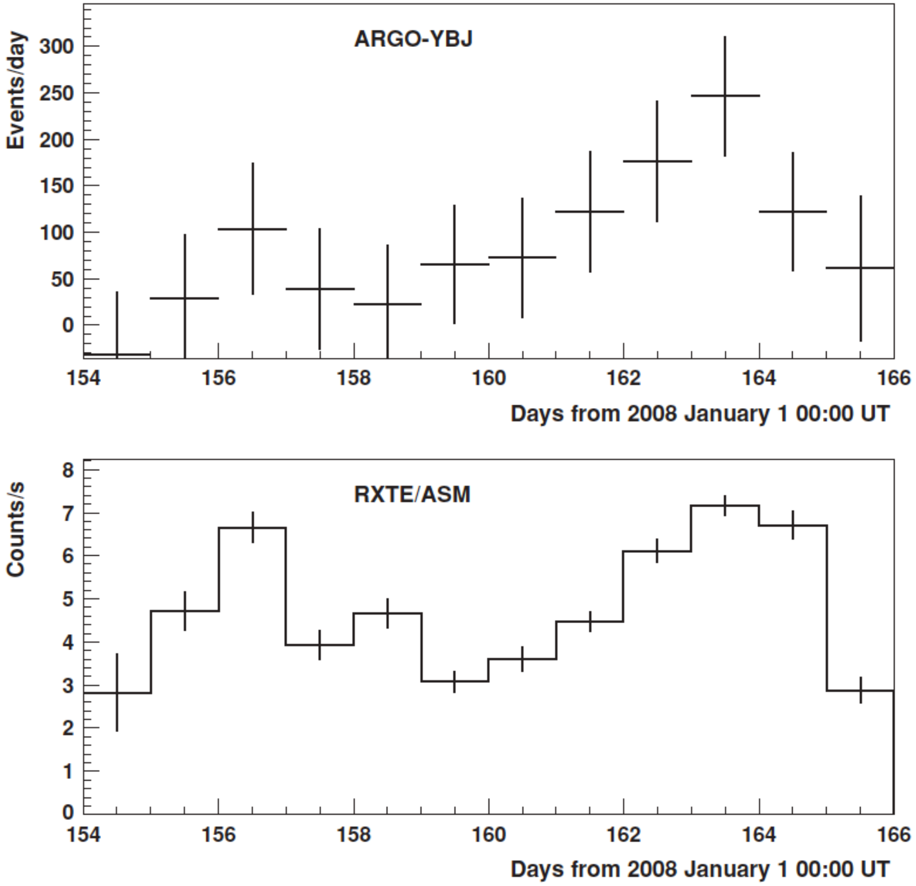
# Expectation on detecting blazar flares by LHAASO



# Expectation on detecting blazar flares by LHAASO

Rate of excess events with $N_{pad}$>=100 observed from Mrk421 by ARGO-YBJ




- ✓ Flares
- ✓ High energy photons

All benefit from long-term monitoring by LHAASO

*Aielli et al. 2010, ApJL*

THANKS