Coordinated observations and Targets of Opportunity

Matteo Cerruti
CNRS, LPNHE, Paris

Coordinated observations and ToOs

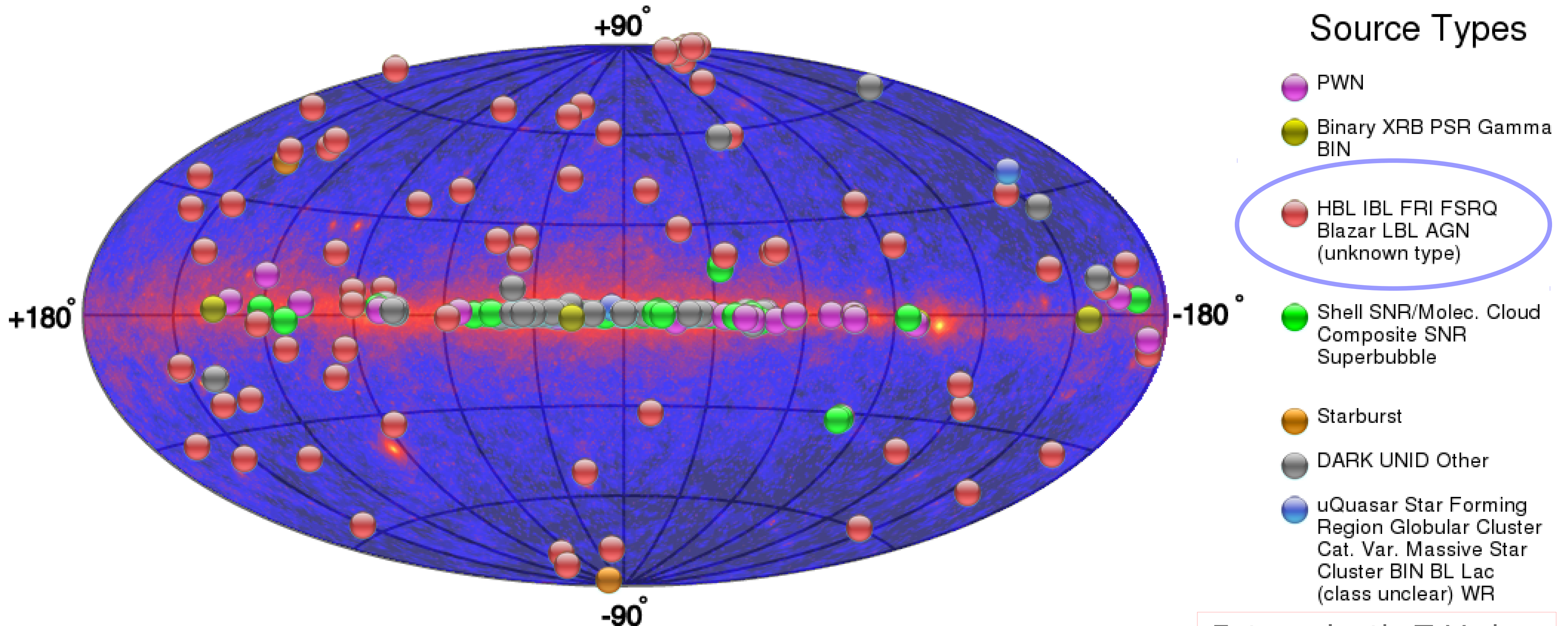
CAVEAT!

- H.E.S.S. point of view

- Extragalactic sources

(subtitle: „What have we learnt from H.E.S.S., MAGIC and VERITAS?“)

THE TeV SKY

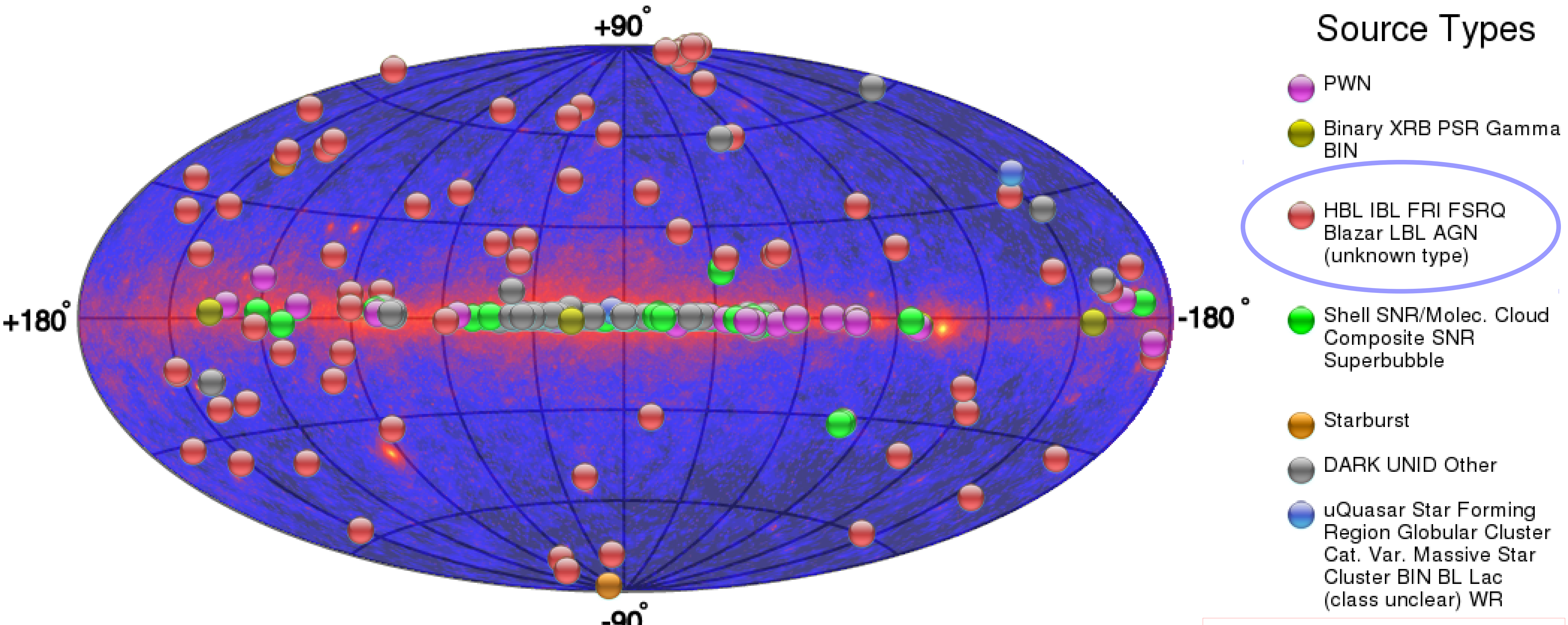


From TeVCAT

Extragalactic TeV sky:

2 starburst galaxies
4 radio-galaxies
67 blazars

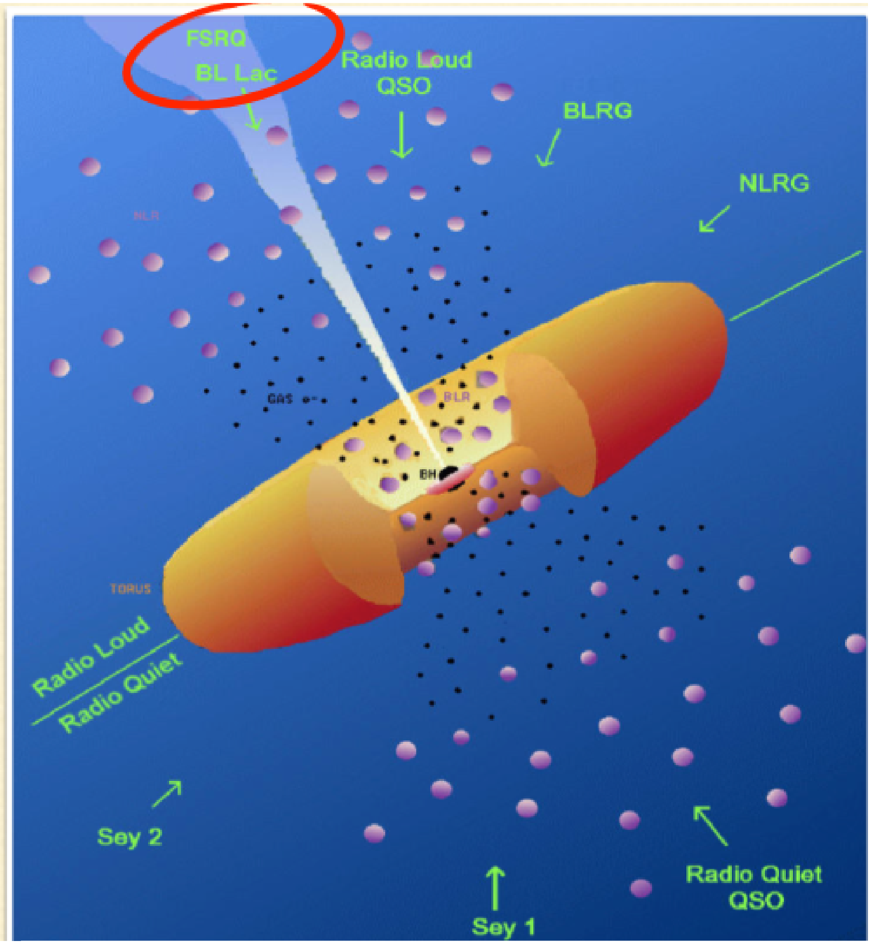
THE TeV SKY



From TeVCAT

Extragalactic TeV sky:
of these 67 blazars
- 49 are HBLs
- 12 are I/LBLs
- 6 are FSRQs

BLAZARS



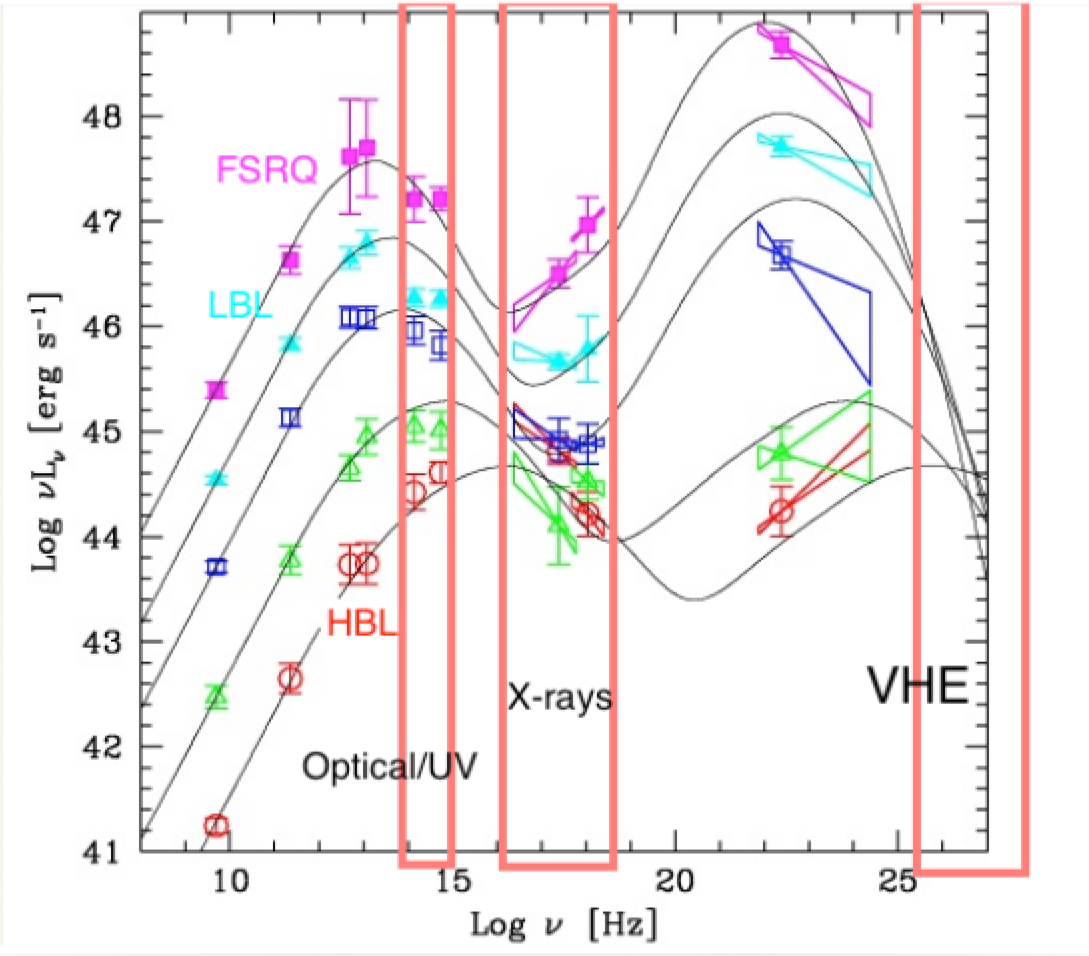
Blazar : radio-loud AGN whose relativistic jet points in the direction of the observer

→ emission from the jet dominates over any other AGN component (the disk, the BLR, the X-ray corona,...)

→ non-thermal emission from radio to gamma-rays, and extreme variability

- Flat-Spectrum-Radio-Quasars: optical spectrum with broad emission lines
- BL Lacertae objets : optical spectrum featureless

BLAZARS



Fossati et al. 1998

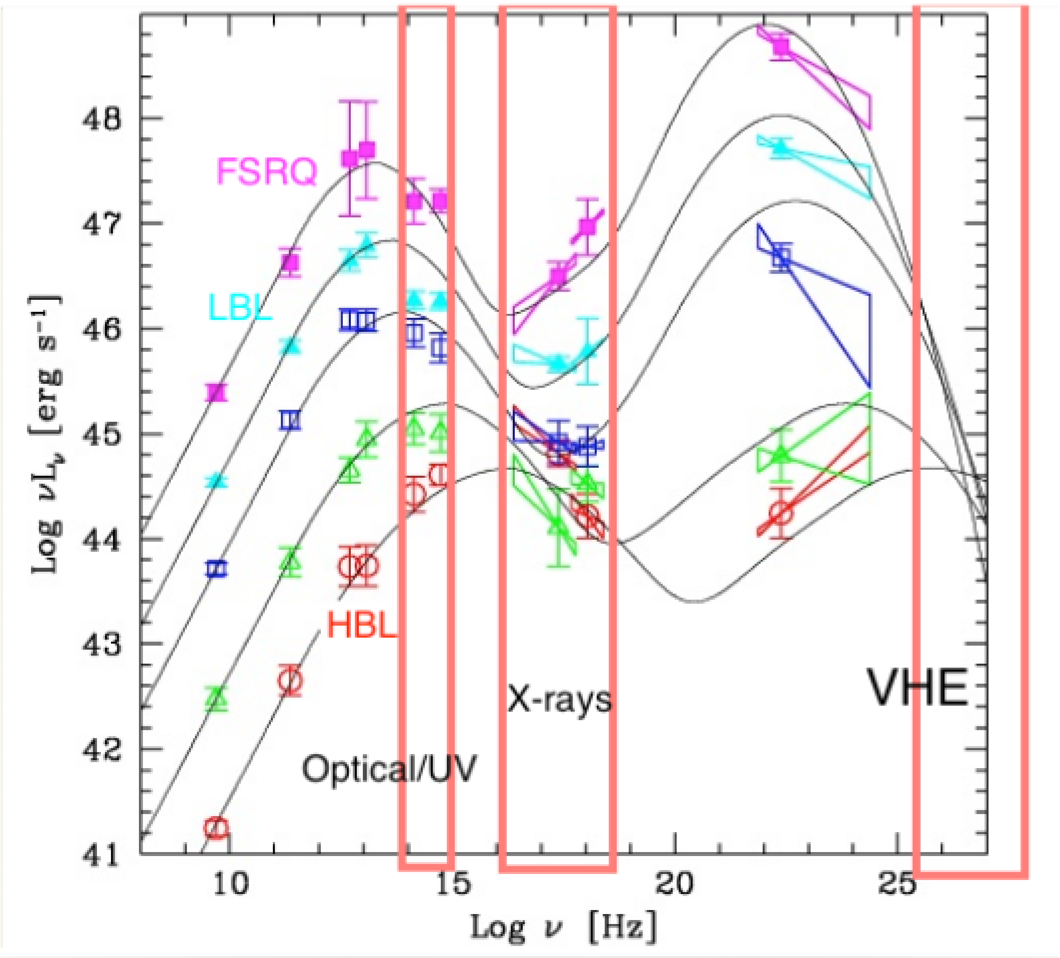
Spectral energy distribution (SED) two distinct components

FSRQs show a peak in IR

BL Lac objects are classified in:

- peak in optical : Low-frequency peaked (LBLs)
- peak en UV/X : High-frequency peaked (HBLs)
- peak >10 KeV : Ultra-high-frequency peaked (UHBLs)

BLAZARS



Fossati et al. 1998

In whichever band you observe, you ‘select’ a blazar with a given peak frequency

→ Radio blazar catalogs and X-ray blazar catalogs don’t 100% overlap!

At TeV energies we are dominated by ***high-frequency-peaked blazars***

VHE photons are absorbed by pair-production on the extragalactic-background-light (EBL)

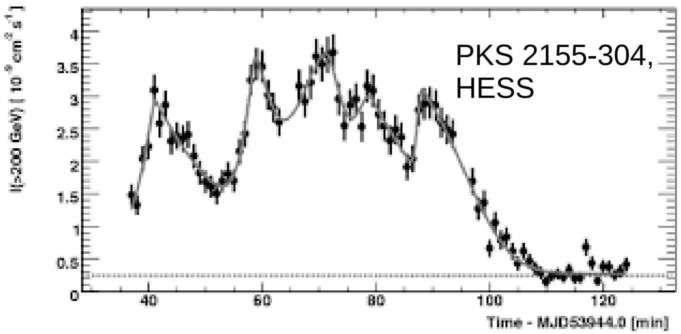
BLAZARS

of IACT blazar papers (2006-2017): 168

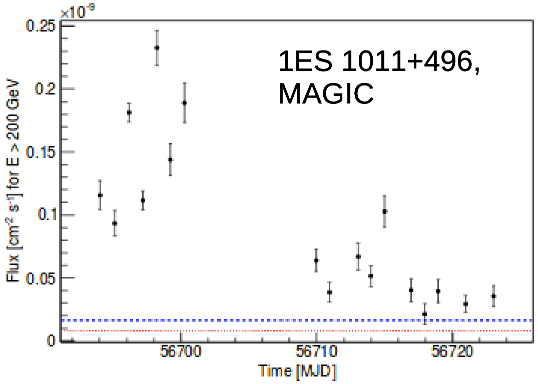
# of IACT blazar papers including MWL SED: 124, or 74%

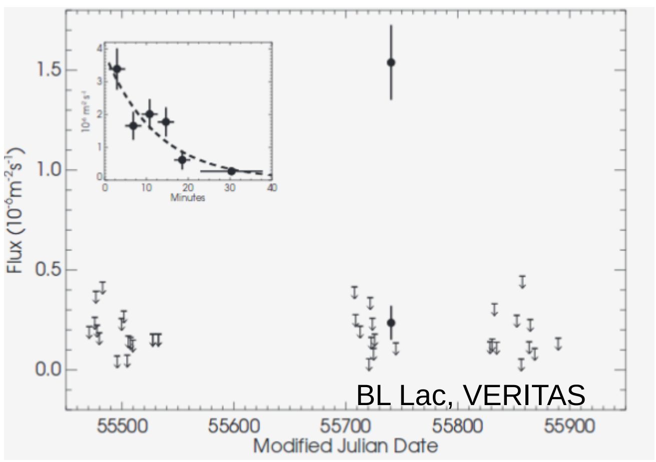
Blazar physics is accesible only / mainly via MWL campaigns → coordinated MWL campaigns are a major part of our work

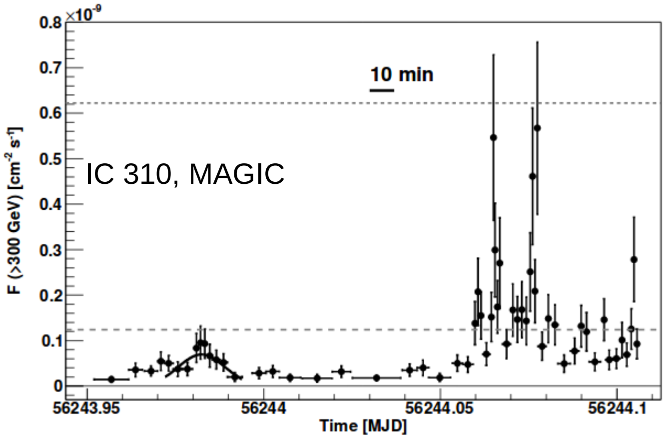
BLAZARS



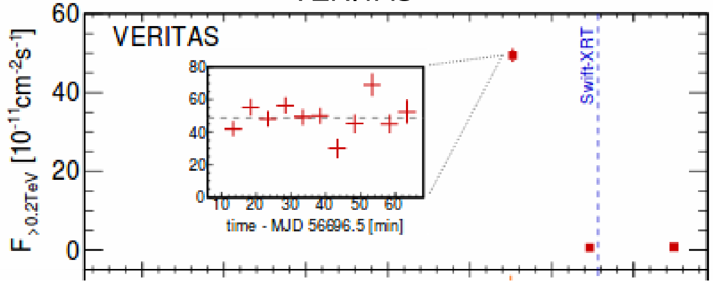
Blazars are variable, at all wavelengths and on different timescales!

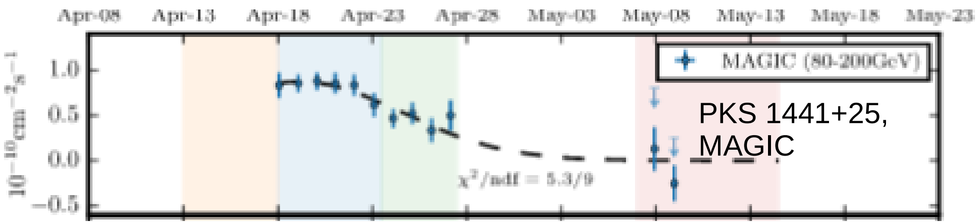






1ES 1215+303
VERITAS





BLAZARS

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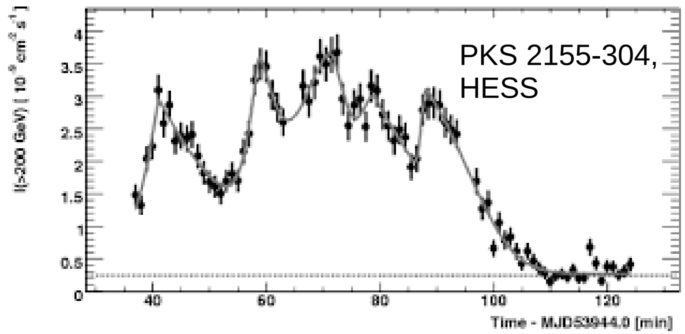
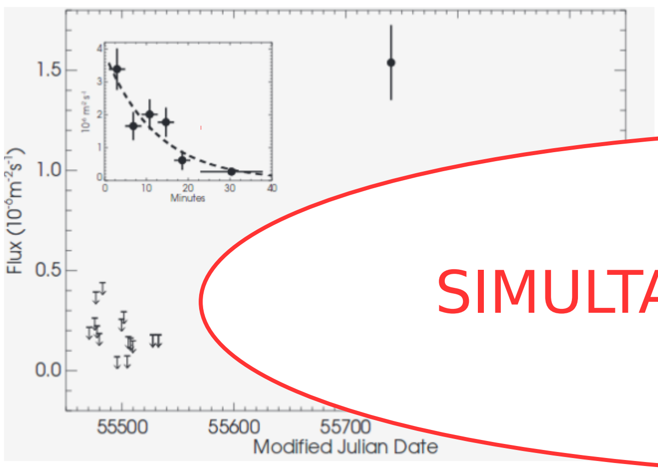
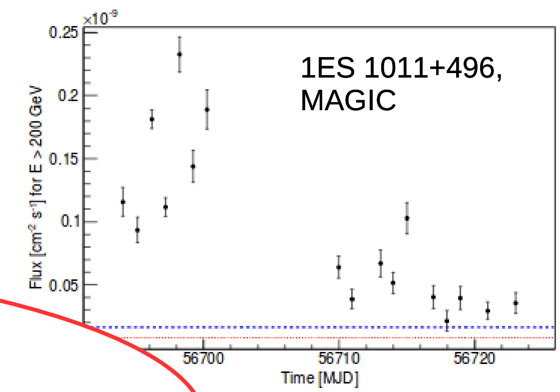
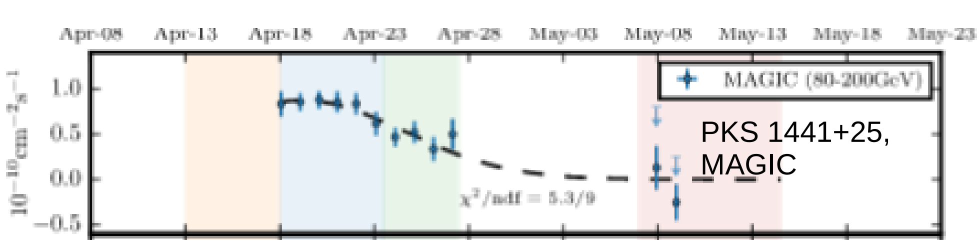
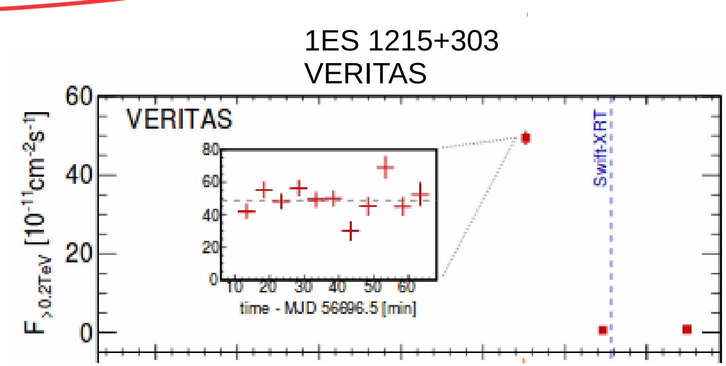






SIMULTANEOUS MWL campaigns!



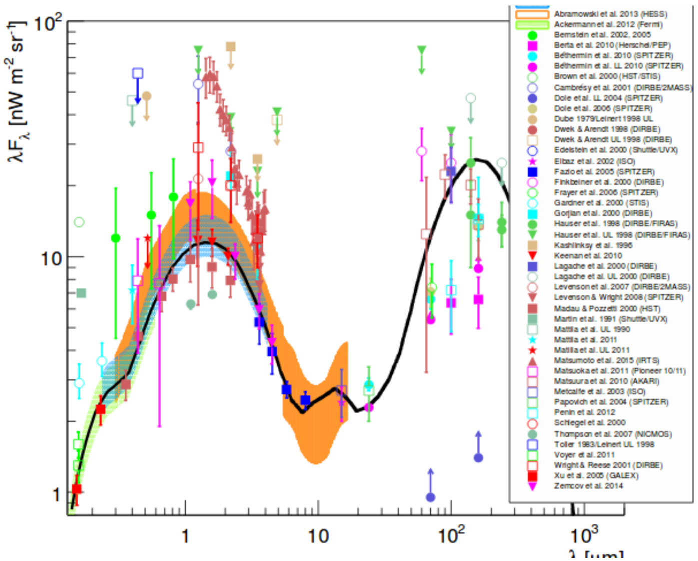


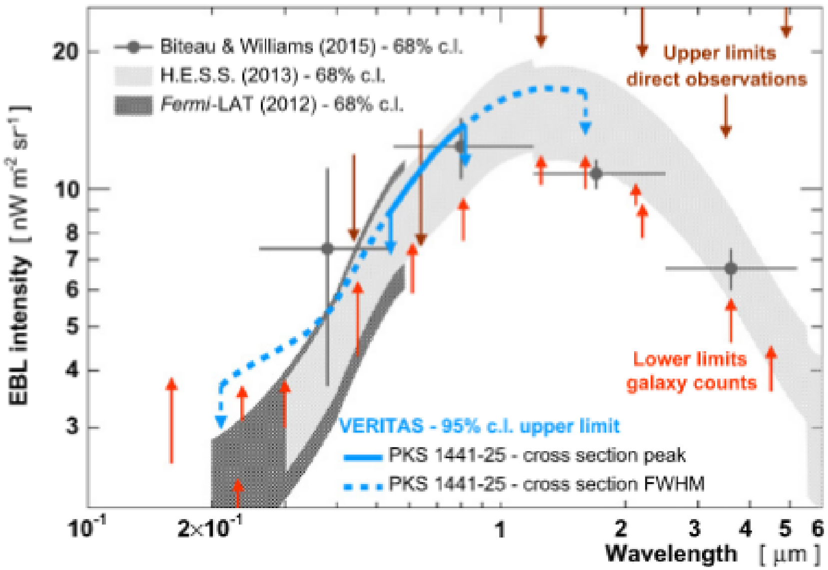
BLAZARS

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

1) Higher statistics!
A single night of TeV observations on a flaring blazar may be worth years of data taking of non flaring blazars

Example: EBL contraints from single source (single night!)





BLAZARS

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

2) FSRQs have been detected at VHE only during flaring states
(are they VHE emitter at all during quiescence? CTA will answer)

2b) High-redshift sources have been detected at VHE only during flaring states
S3 0218+35 z=0,944
PKS 1441+25 z=0,939

BLAZARS

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

3) Variability properties of VHE blazars are not known and one of the questions we would like to answer:

How common are flares like the one from PKS 2155-304 in 2006?
Why some blazars don‘t flare at all in gamma-rays?
(or is their duty cycle just >> than the history of Cherenkov astronomy?)

3b) Are flares and quiescent emission produced in the same region / same radiative processes ?

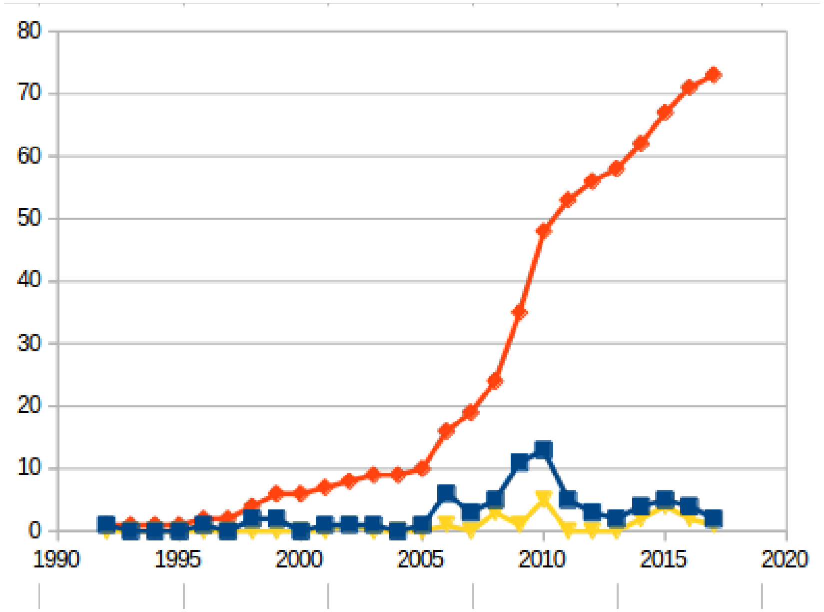
BLAZARS

COORDINATED MWL OBSERVATIONS OF FLARING BLAZARS

High risk observations, but also high reward

→ constraints on physics of outflows from black holes
→ gamma-ray cosmology
→ AGN population

ToO discoveries in recent years:
2014: 50%
2015: 50%
2016: 80%
2017: 50%



H.E.S.S. ToOs

The H.E.S.S. Blazar ToO system

How much we trigger?
Around 70 hours per year (after quality cuts): 15% of all extragalactic obs

On what we trigger?

- information from other gamma-ray observatories under MoUs (MAGIC and VERITAS, FACT, HAWC, Fermi)

- public Fermi data (own automatic pipeline for rapid alerts, see Lenain 17)

- private ATOM data (optical telescope on the HESS site)

- public MWL data which are openly available (optical and X-rays)

H.E.S.S. ToOs

The H.E.S.S. Blazar ToO system

How do we organize observations?

- all pipelines are processed by the morning. If one blazar is above our predefined thresholds, and is visible from the H.E.S.S. site, we are able to request observations on the same night

- we ask for Swift follow-ups (~100% success) to secure UV and X-ray observations SIMULTANEOUSLY WITH H.E.S.S.

- we secure optical observations with ATOM

H.E.S.S. ToOs

Where is the risk?

We don‘t know how many days the flare will last

Some results from the latest H.E.S.S. blazar ToO seasons:

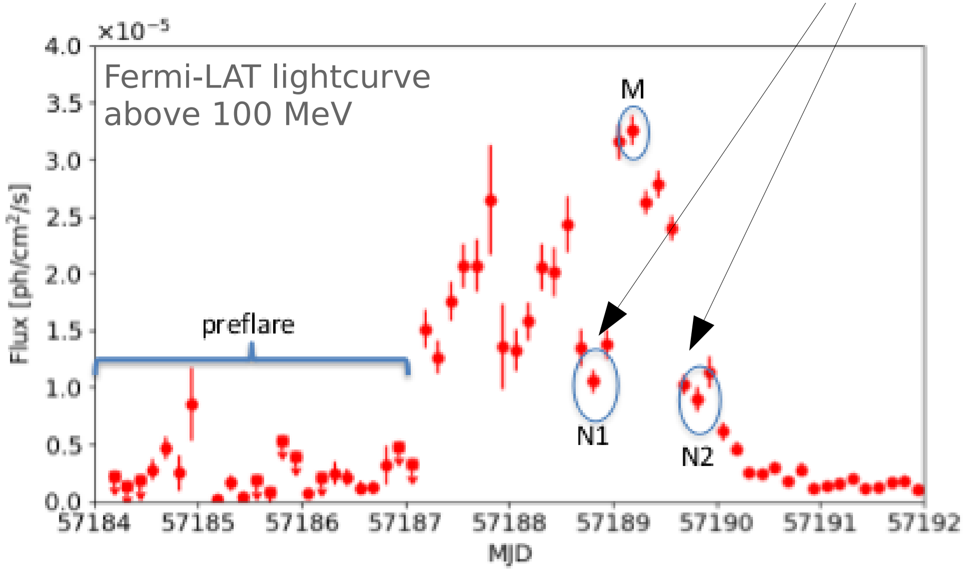
- 3C 279 (June 2015 flare)
- PKS 0736+017 (February 2015 flare)
- PKS 1749+096 (June 2016 flare)

(Results from the ToOs of 2017 are not public yet)

3C 279

Bright γ-ray flare seen with Fermi-LAT in June 2015:

- 3-days flare with peak flux of $3.6 \cdot 10^{-5}$ cm^{-2} s^{-1}
- 80 times brighter than 3FGL average
- Minute-scale variability detected with Fermi-LAT
- Target of Opportunity observations with H.E.S.S.



Romoli et al. ICRC 2017 arXiv 1708.00882

3C 279

H.E.S.S. observations : Detection only during the second night:

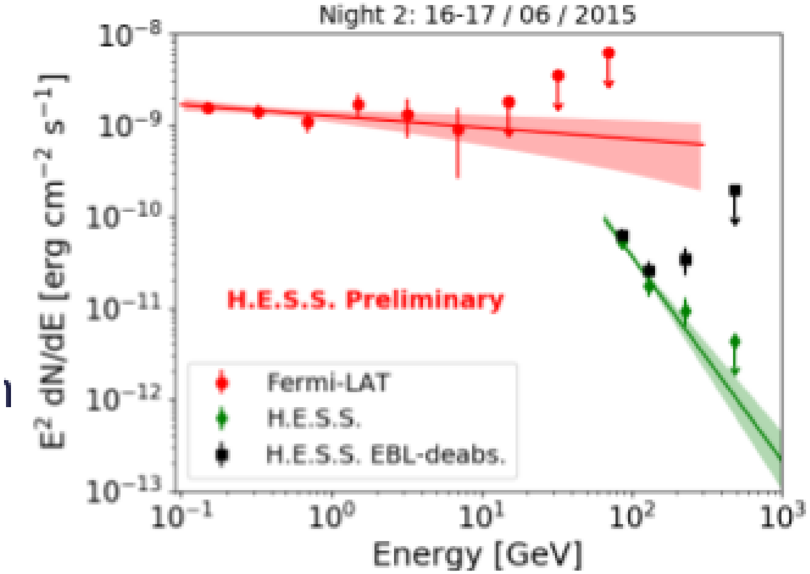
$E_{threshold}$ = 66 GeV (Monoscopic reconstruction)

$F_{100\ GeV} = (2.5 \pm 0.2) \cdot 10^{-12}\ cm^{-2}\ s^{-1}\ GeV^{-1}$

$\Gamma = 4.2 \pm 0.3$

Detection at 8.7 σ in 3 hours of observations

Strictly simultaneous Fermi-LAT – H.E.S.S. II spectrum



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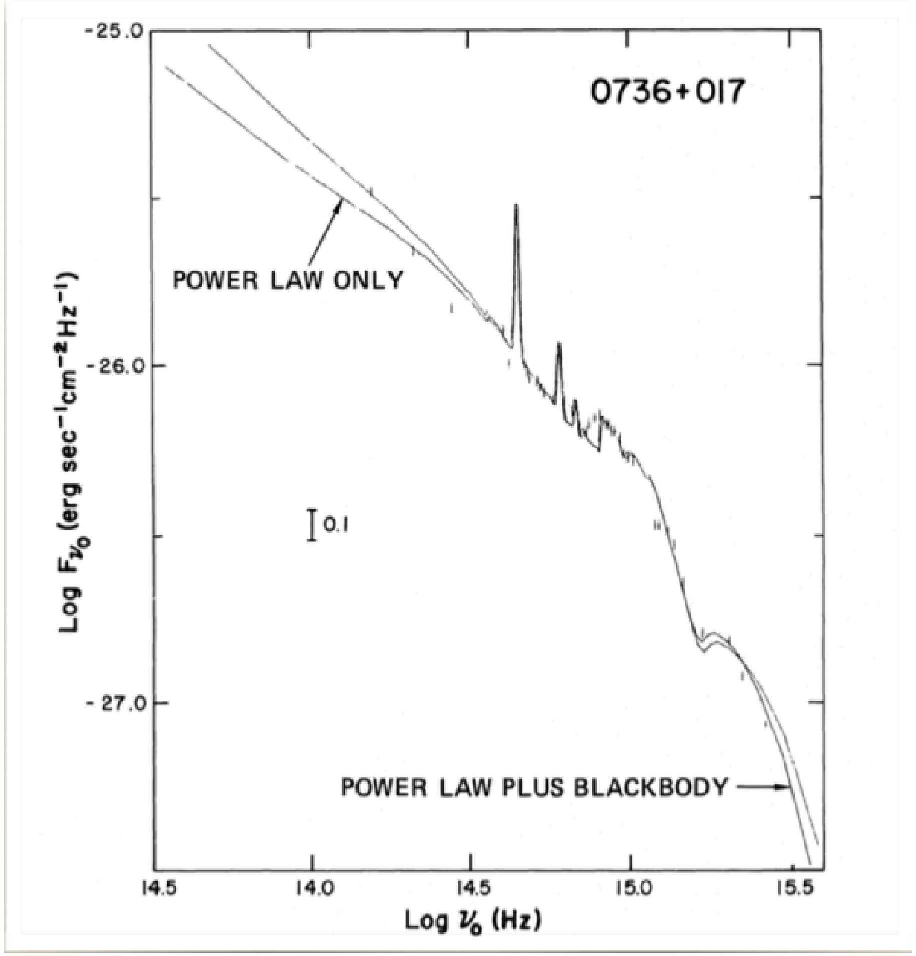
PKS 0736+017



Milkan & Moore, 1986

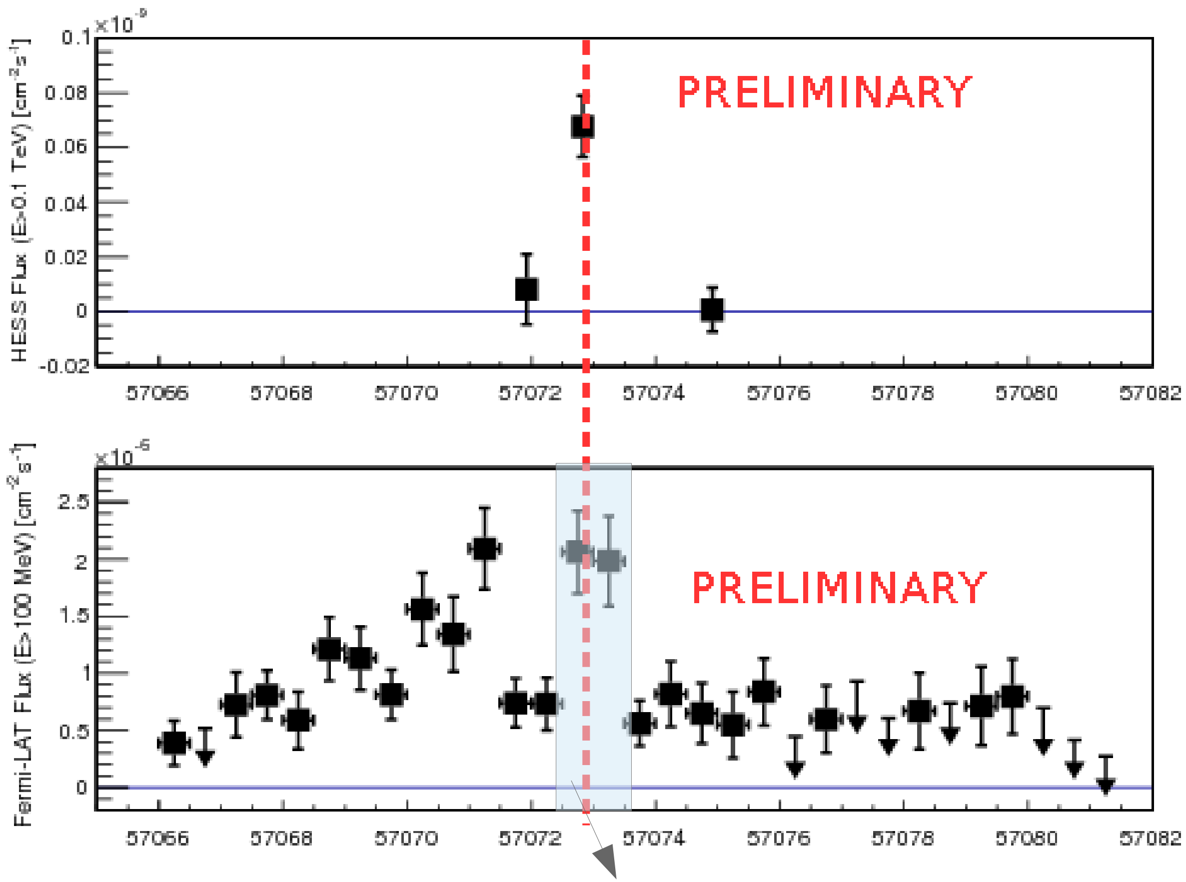
Well known radio quasar

- z = 0.1894 (Ho & Kim 2009)
- typical FSRQ optical spectrum
- presence of big-blue bump
- SMBH mass = $10^{8.47}$ $M_{\odot}$ (McLure & Dunlop 2001)
- Host galaxy is a standard giant elliptical (Wright 1998, Kotilainen 1998, ++)

Cerruti et al. ICRC 2017 arXiv 1708.00658

PKS 0736+017

H.E.S.S. ToO observations following a Fermi-LAT flare
Detection during the second night only



Time selection for contemporaneous LAT analysis

PKS 0736+017 : MWL picture

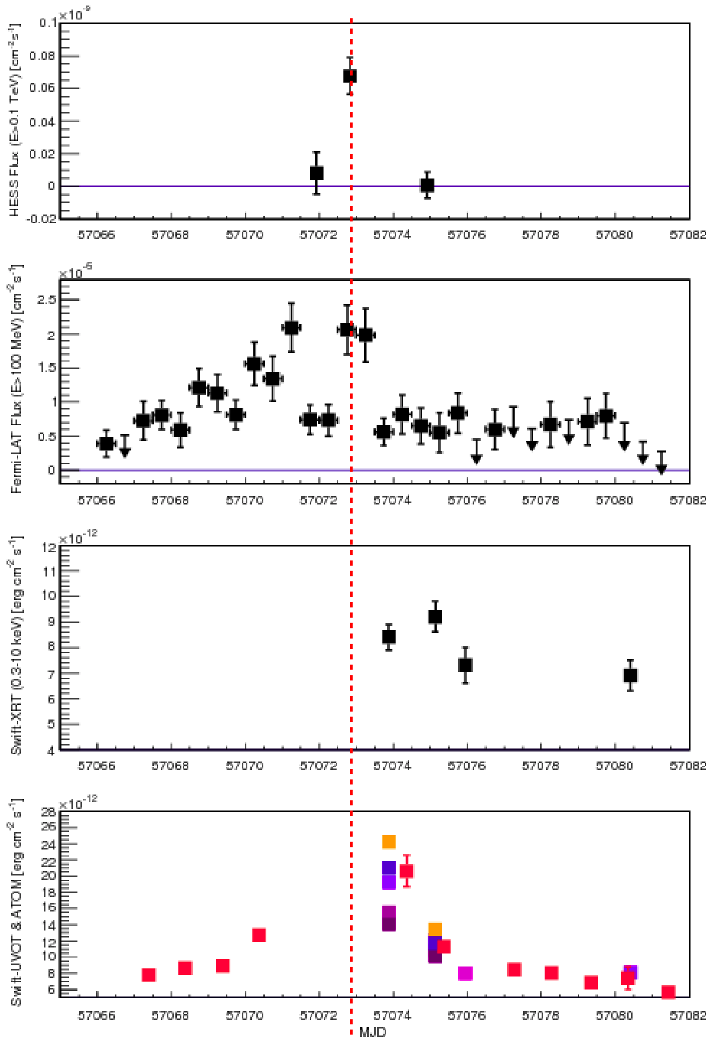
Day-by-day variability in H.E.S.S. data, but
only Fermi-LAT simultaneous with H.E.S.S.

H.E.S.S.

Fermi-LAT

XRT

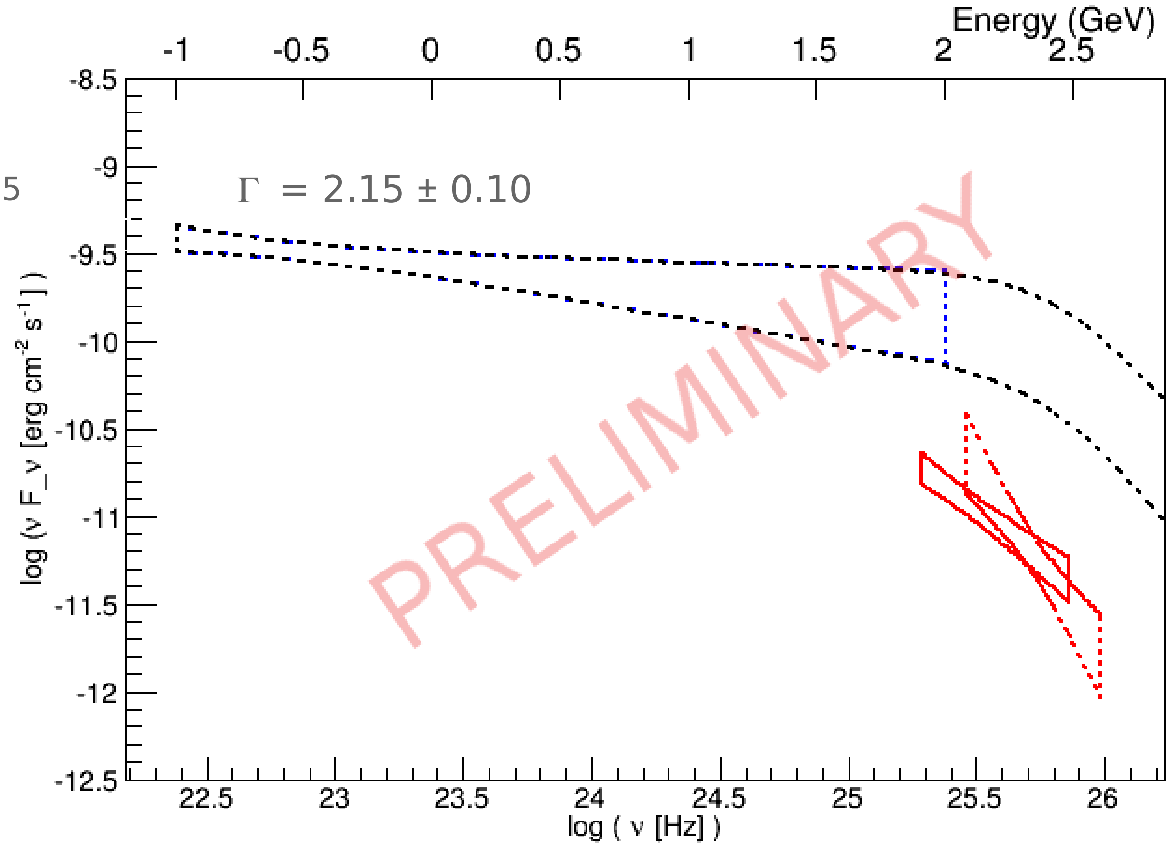
UVOT/ATOM



PKS 0736+017

Fermi-LAT and H.E.S.S. spectra (mono & stereo)

Fermi-LAT spectrum integrated from MJD 57072.5 – 57073.5



H.E.S.S. spectrum on the night of MJD 57073

$\Gamma_{mono} = 3.1 \pm 0.3$

$\Gamma_{stereo} = 4.2 \pm 0.8$

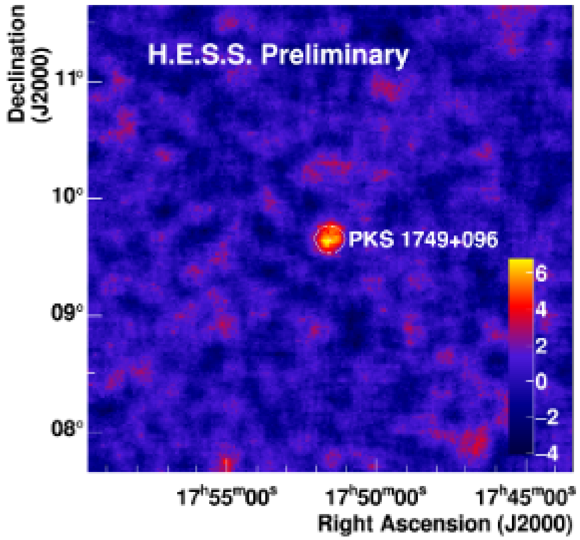
Fermi-LAT spectrum extrapolated towards higher energies, including EBL absorption → spectral break between LAT and H.E.S.S.

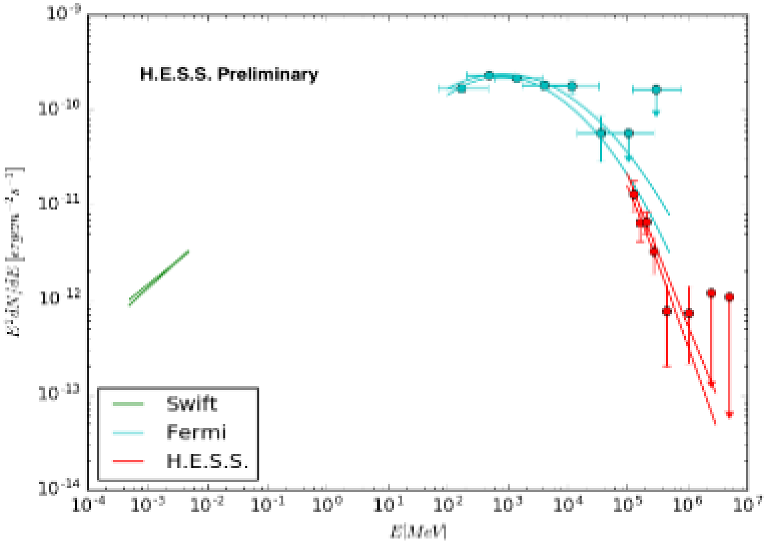
Cerruti et al. ICRC 2017 arXiv 1708.00658

PKS 1749+096

New Low-Frequency-Peaked BL Lac

Detected by MAGIC and HESS following a Fermi-LAT trigger





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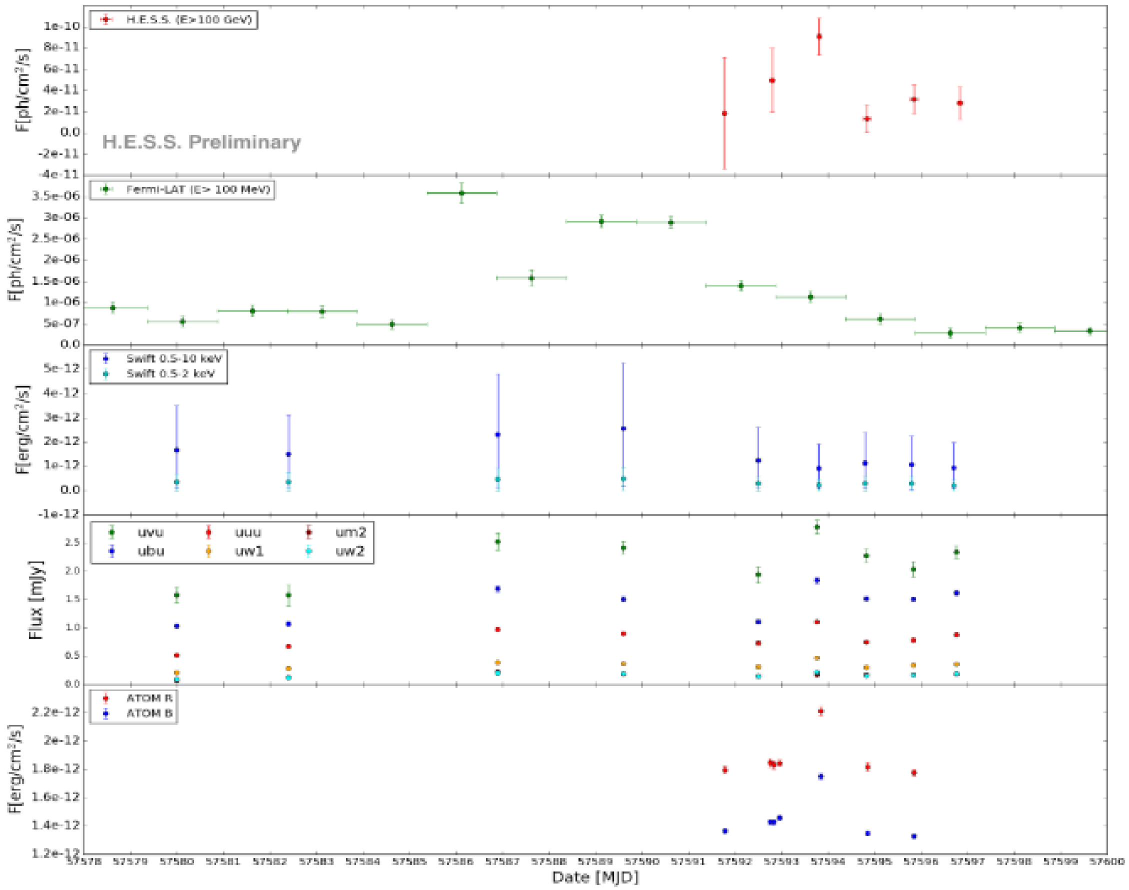

CONCLUSIONS

Blazar observational properties (broad-band emission and variability) require coordinated MWL campaigns during flares

Target of Opportunity observations are a fundamental part of the H.E.S.S. extragalactic observing program. From 2015 and 2016:

2015 flare from 3C279
a new FSRQ, PKS 0736+017
a new LBL, PKS 1749+096