Monitoring blazars with *Fermi*-LAT and prompt triggering on flares at very high energies with H.E.S.S.

J.-P. Lenain (LPNHE, CNRS/IN2P3)

Monitoring2018, Cochem, Sept. 2018

H.E.S.S.

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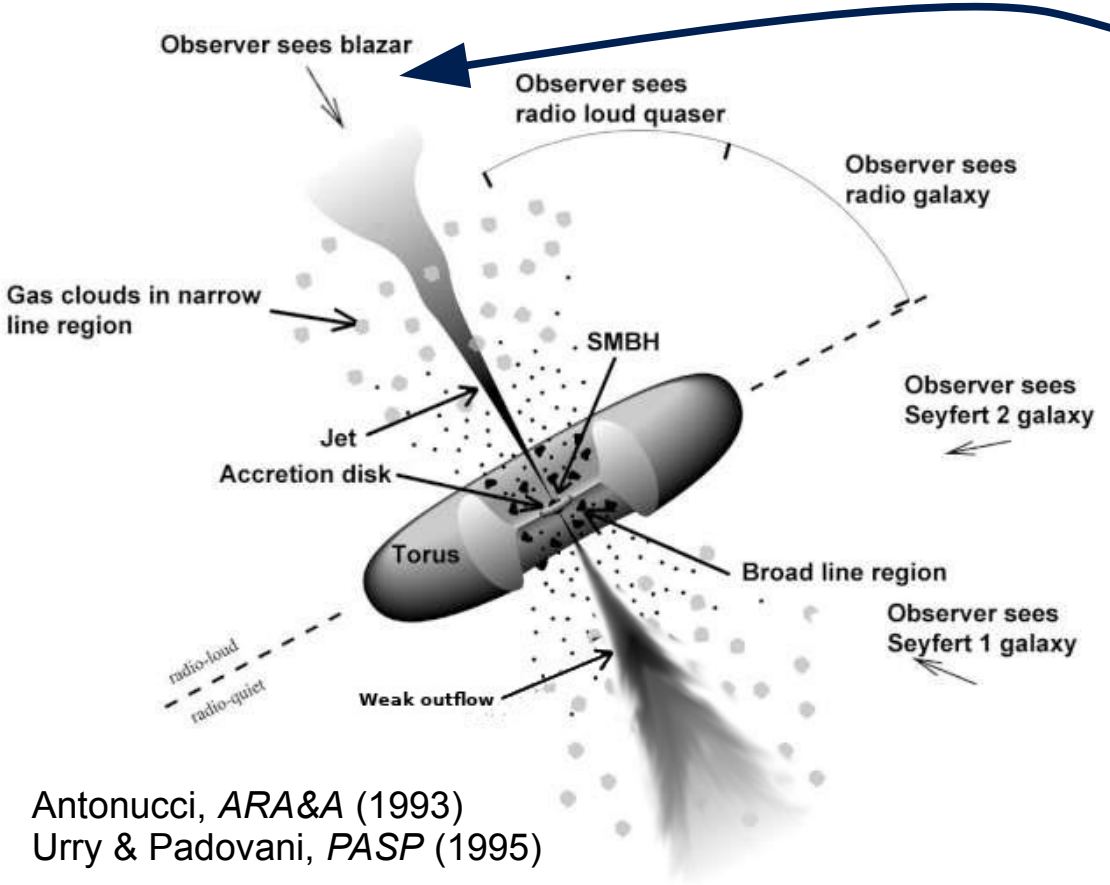
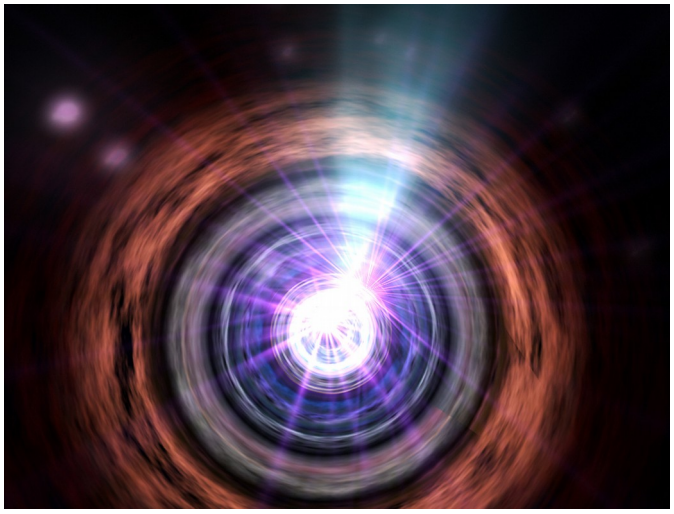
cnrs IN2P3 Les deux infinis

LPNHE PARIS

Blazars

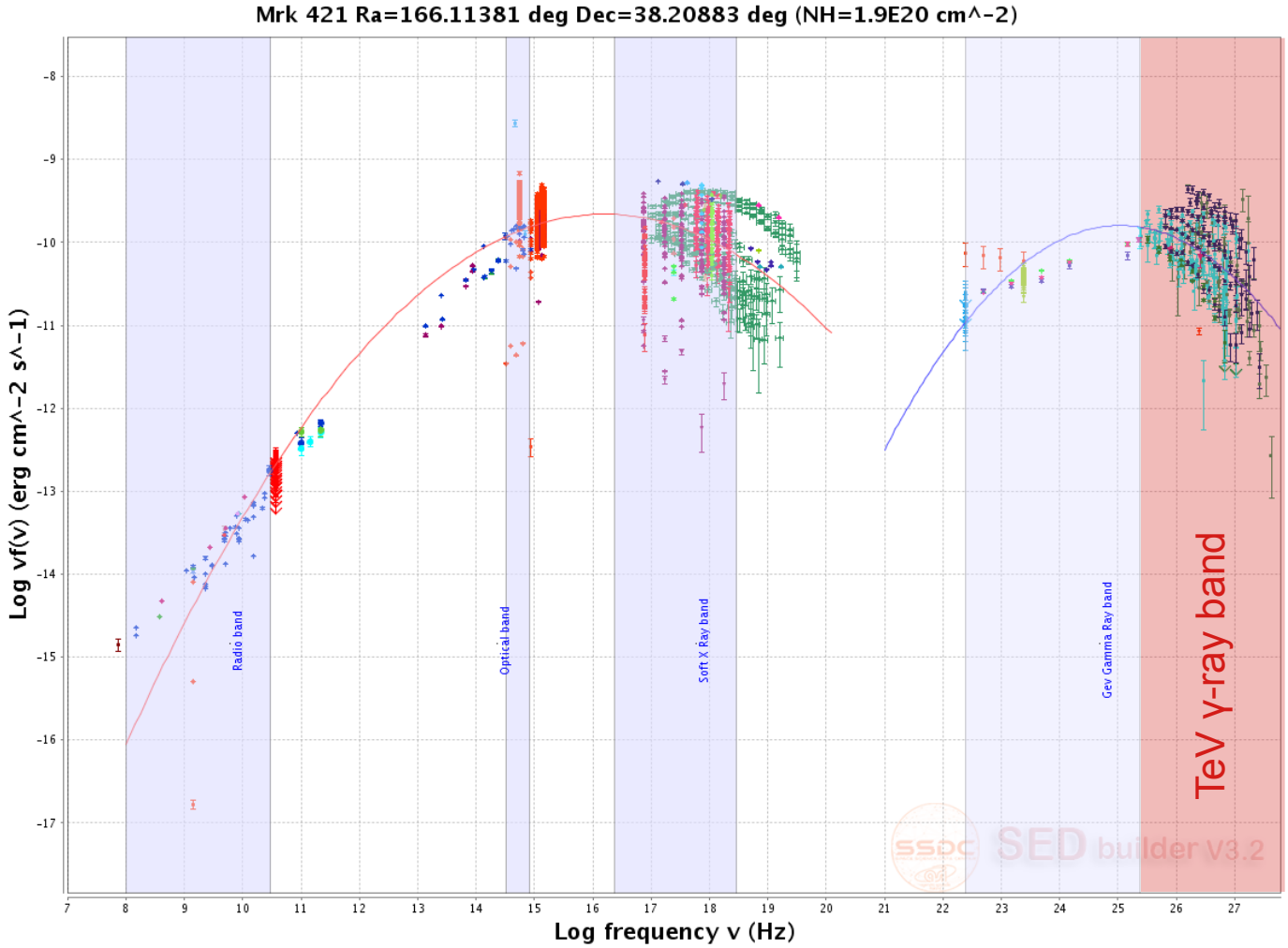
- Central enging outshines other components
- Highly relativistic jets





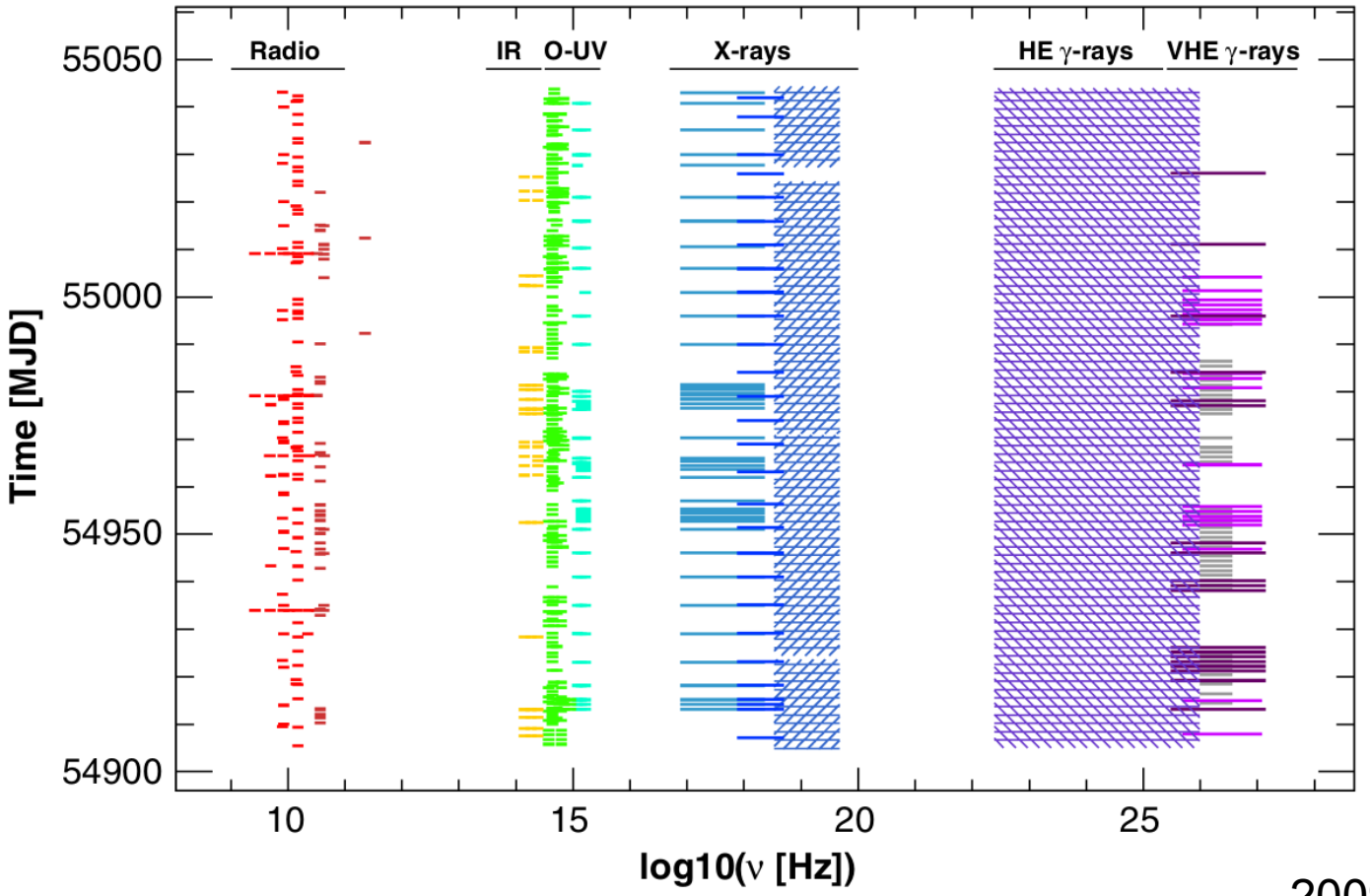
Antonucci, *ARA&A* (1993)
Urry & Padovani, *PASP* (1995)

Blazars



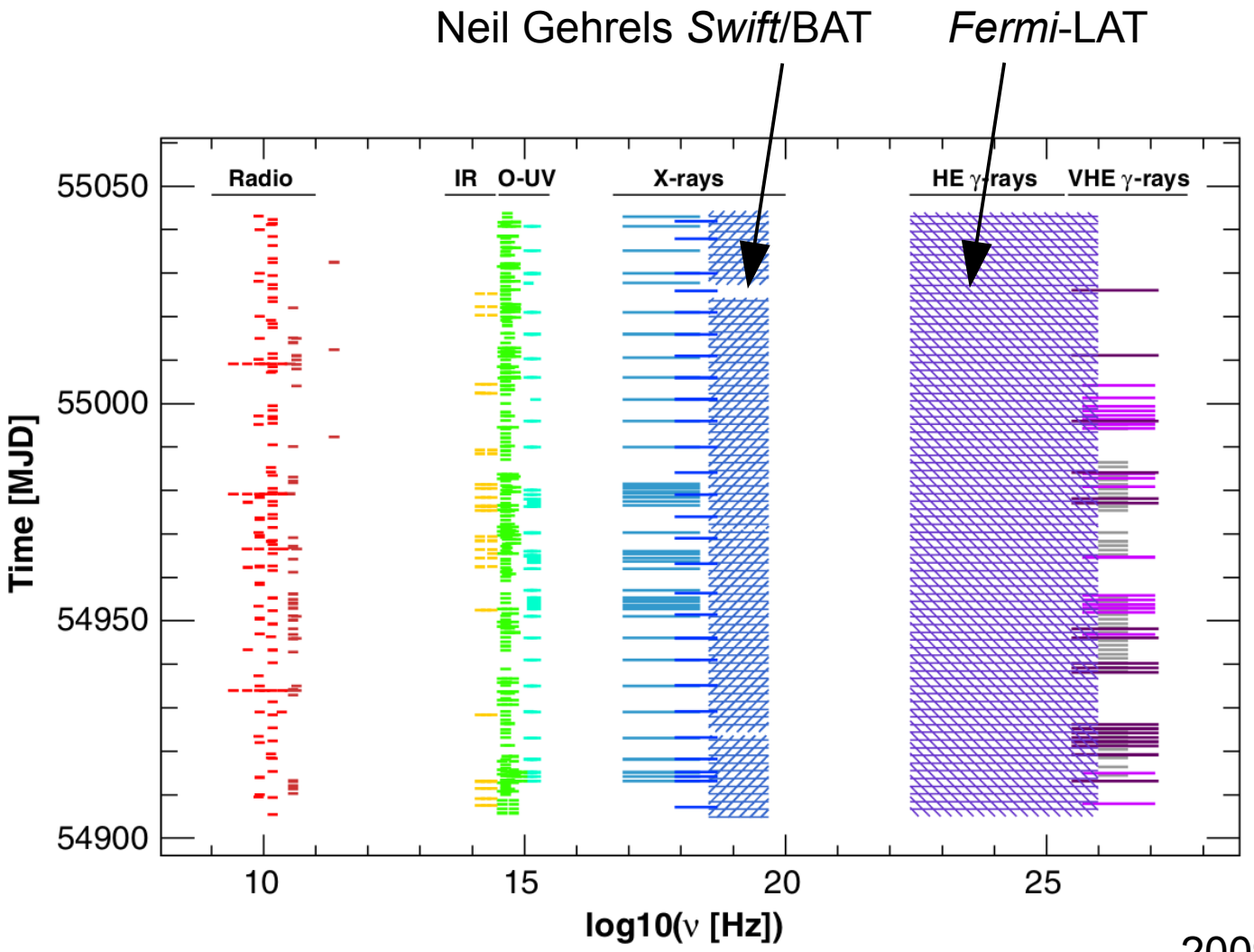
- SED: 2 main components
- Highly variable

Multi-wavelength campaigns



Mrk 501
2009 campaign
Fermi-LAT, MAGIC, VERITAS et al. (2011)

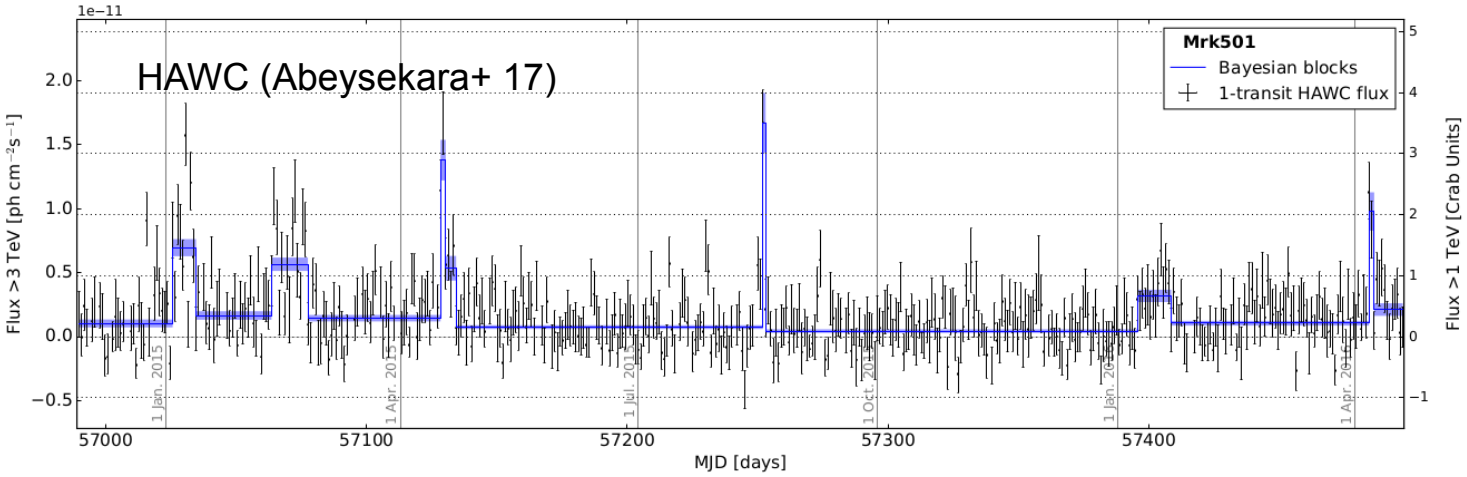
Multi-wavelength campaigns



Mrk 501
2009 campaign
Fermi-LAT, MAGIC, VERITAS et al. (2011)

Multi-wavelength campaigns

- Facilities with “small” FoV and/or $\ll$100% duty cycle
  $\rightarrow$ naturally biased to high-flux states (flares, via ToO).
- Except for all-sky instruments



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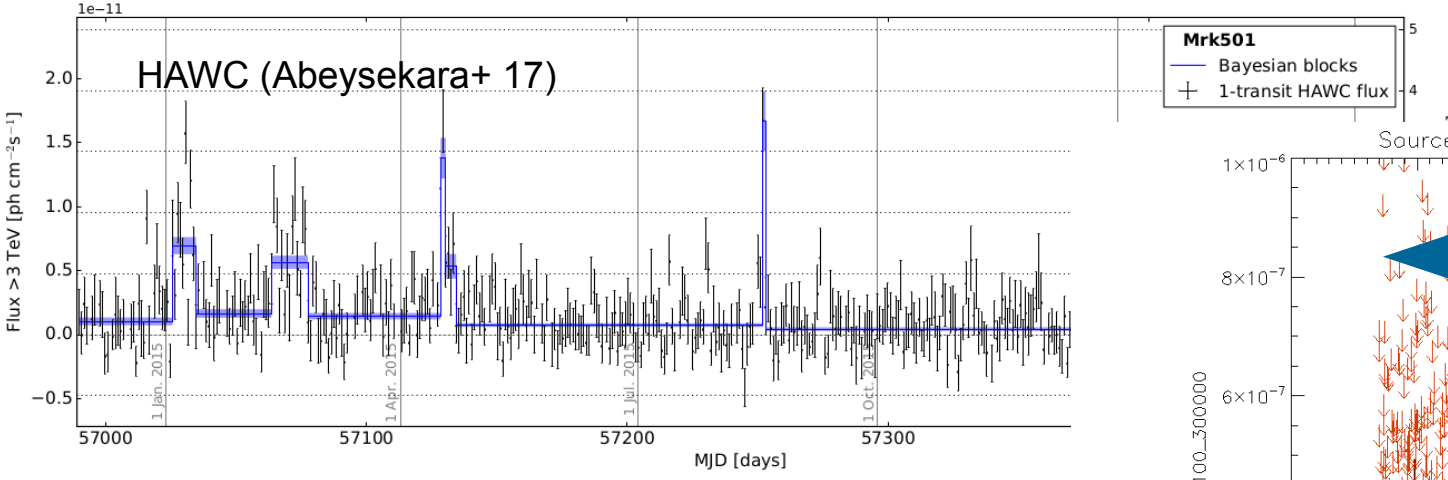
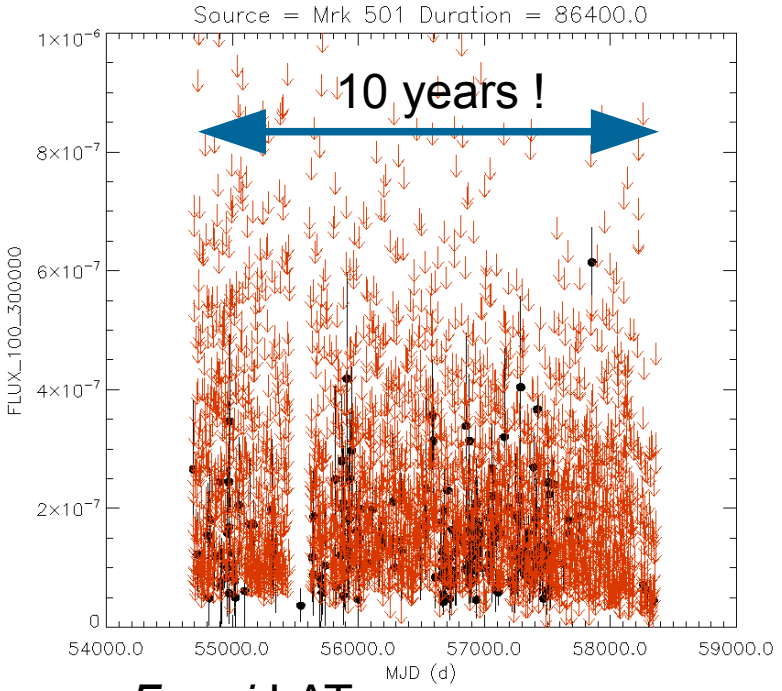




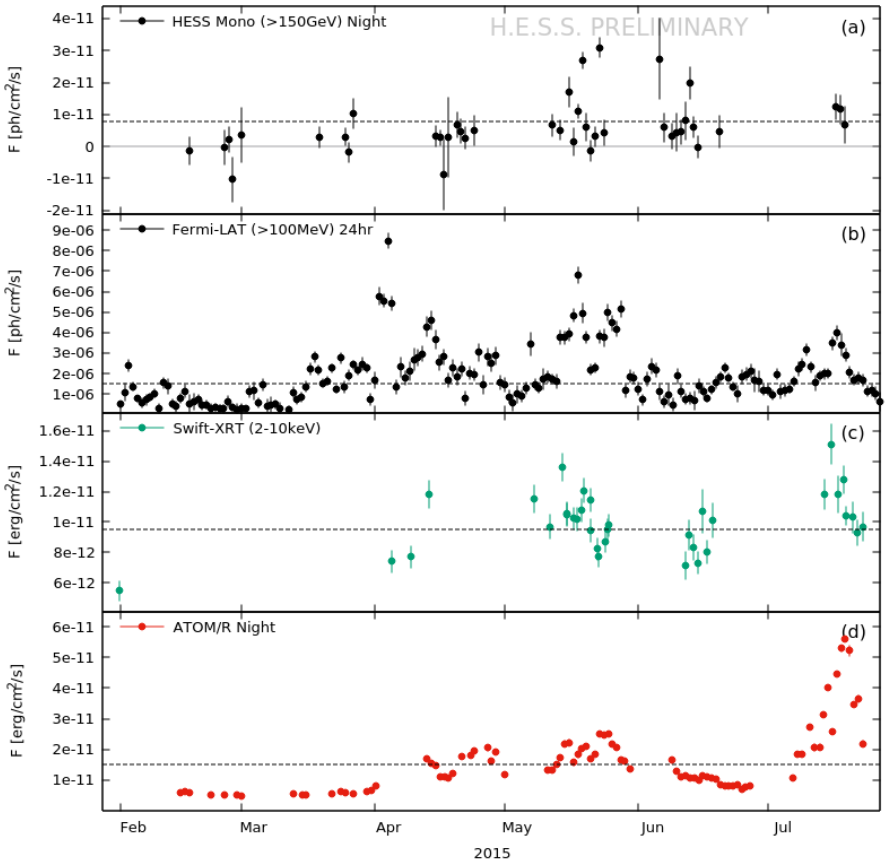
Fermi-LAT

See also C. Romoli’s talk just after this

Monitoring blazars at VHE

- Or persevering long-term monitoring programs

PKS 1510-089
2015 data

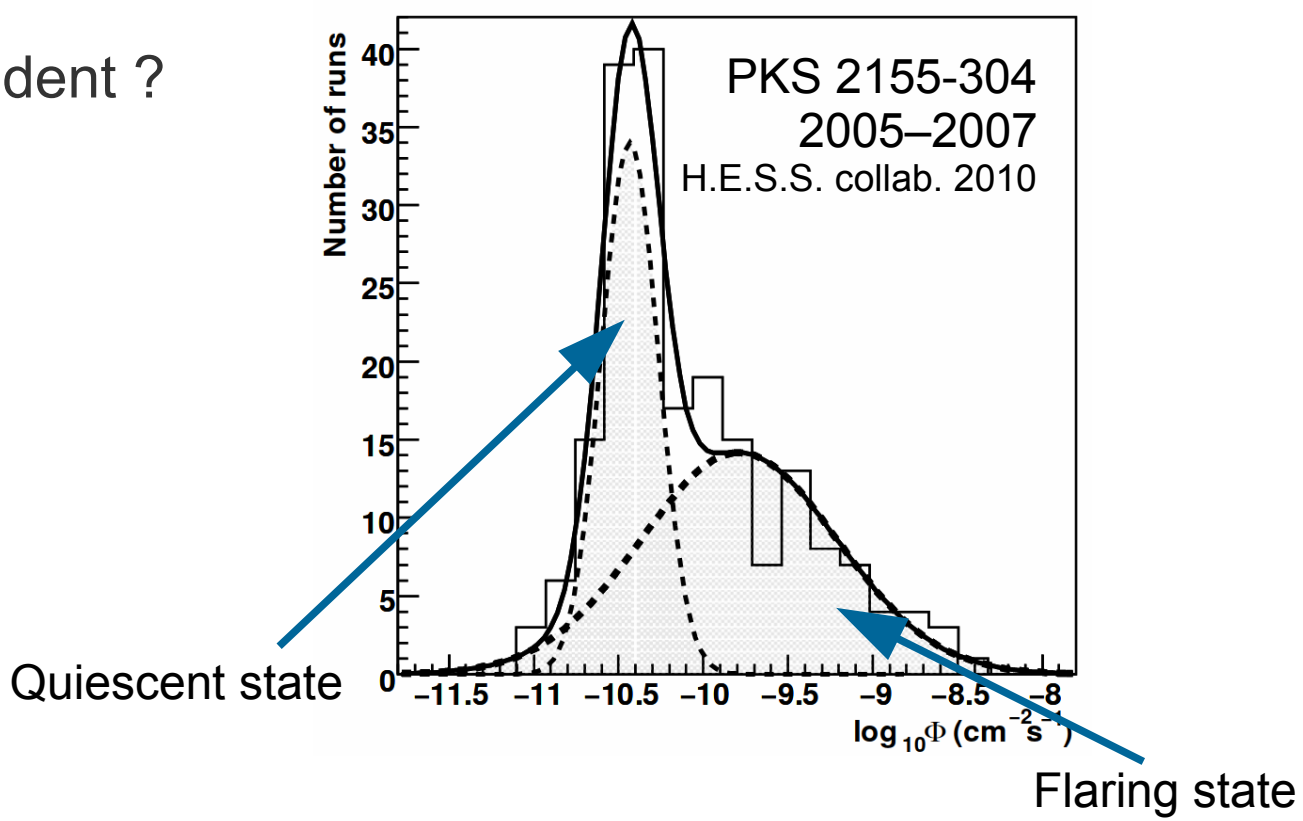


See also M. Zacharias' talk tomorrow

Zacharias et al. (for the H.E.S.S. collaboration), ICRC (2017)

Monitoring blazars at VHE

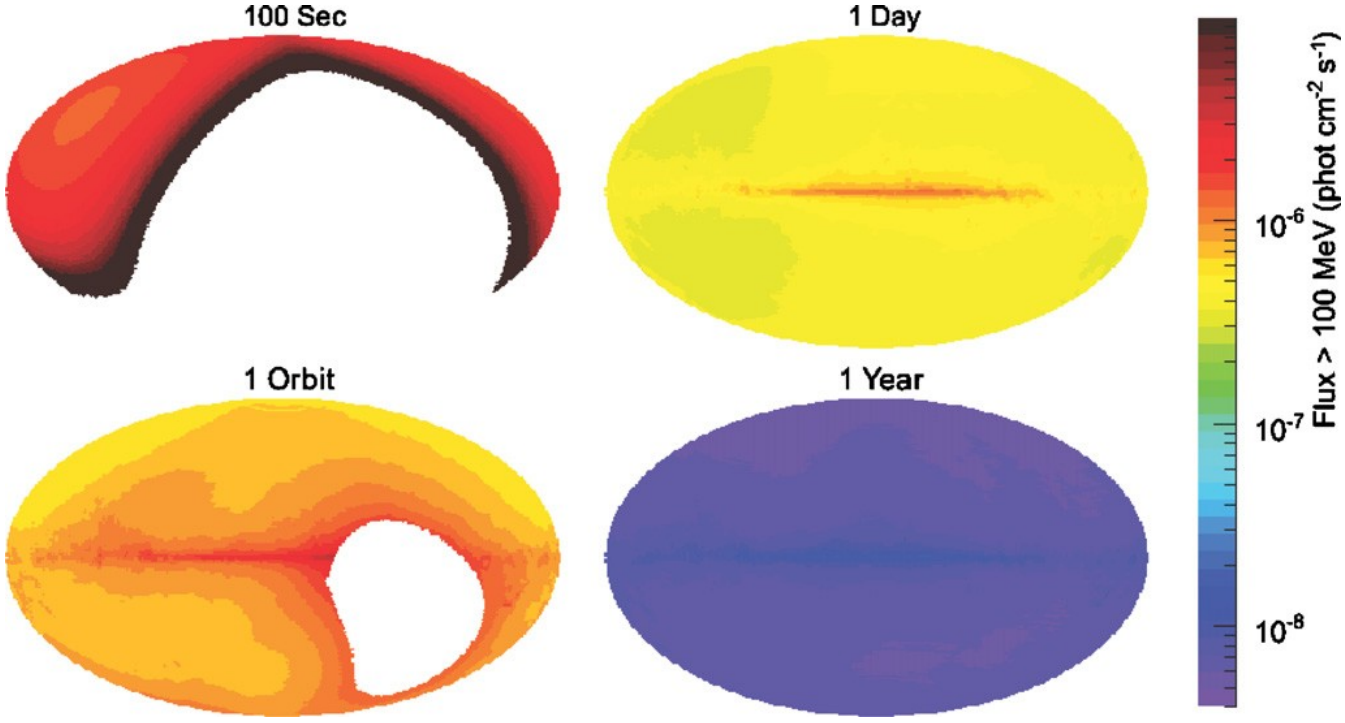
- No “ground” state firmly identified, except in the case of PKS 2155-304
- Blazar duty cycle ?
  - Is it energy-dependent ?



Fermi-LAT as alert launcher

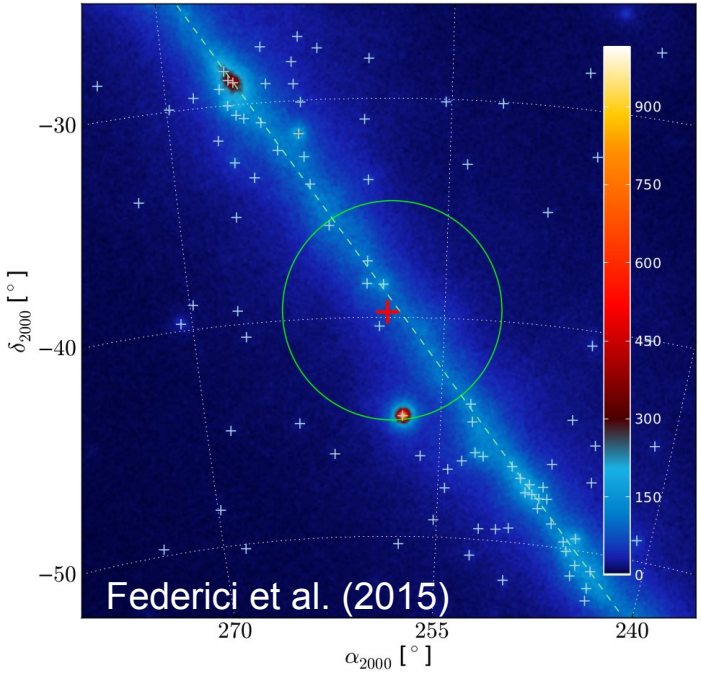
- Wide field of view
- Regularly samples any region of the sky

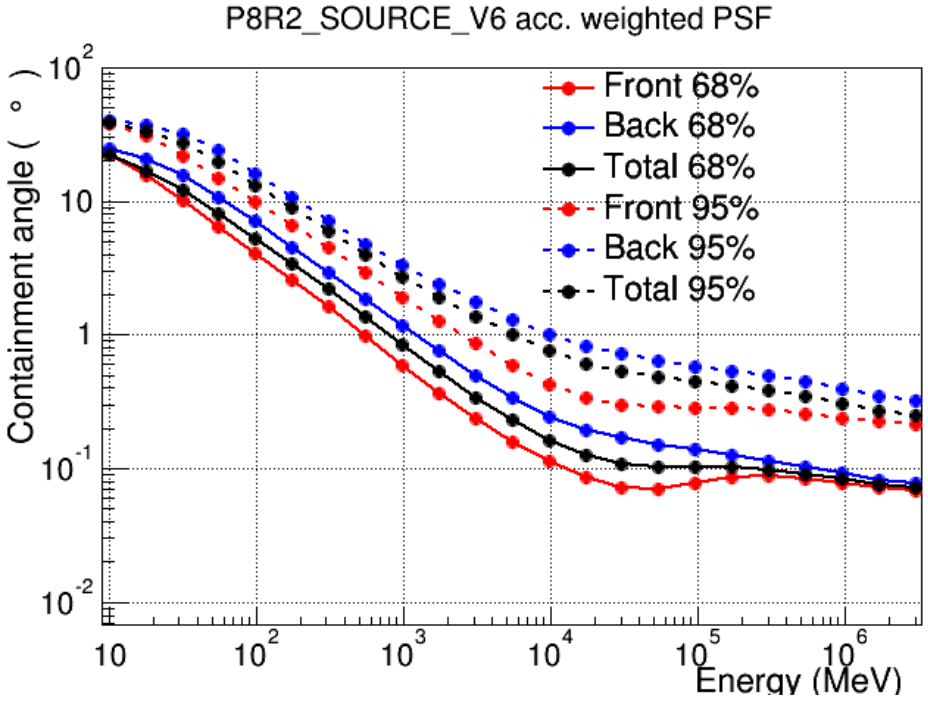
  → allsky coverage every 3h.



Atwood et al. (*Fermi*-LAT), 2009

Fermi-LAT analysis techniques



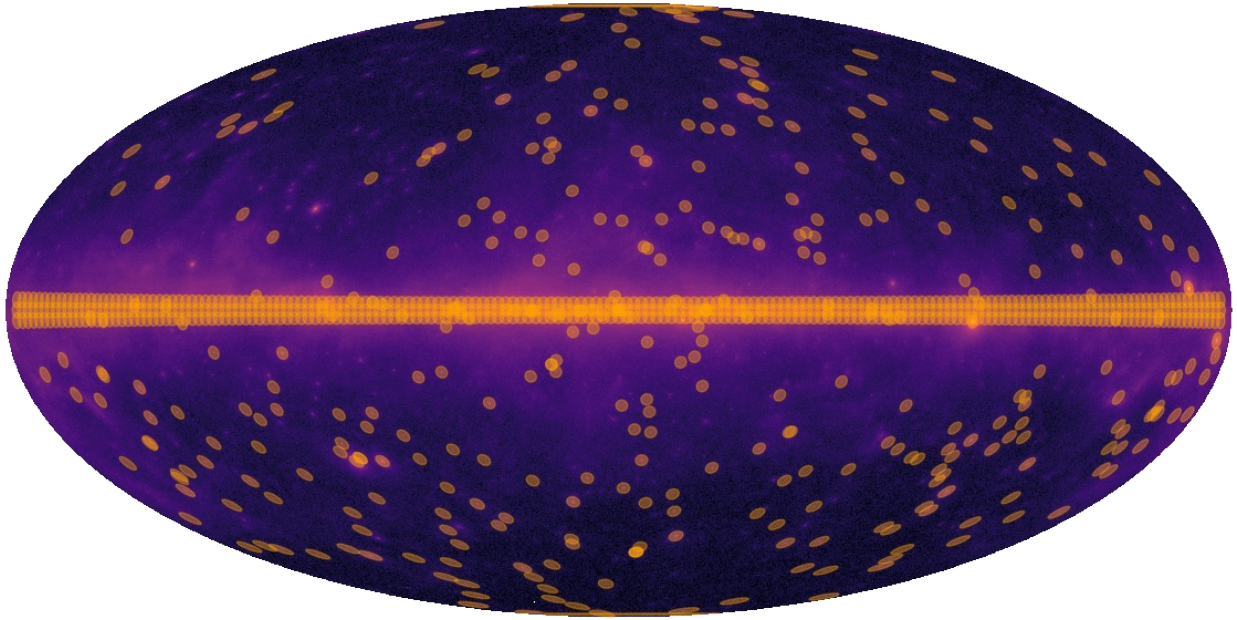


- Likelihood approach
  - Global fit, accounting for all components in RoI
  - Drawback: long computation
- Aperture photometry
  - Small RoI, photon counts/exposure
  - Misses low-energy photons, RoI "polluted" by nearby sources and diffuse emissions
  - Drawback: Assumes background-free RoI → wrong absolute flux
    Provides **quick** but dirty results

Motivation: why a home-made pipeline ?

- *Fermi*-LAT & FSSC collaboration provides (cf. data products):
  - Aperture photometry LC on all 3FGL source (updated weekly)
    https://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/ap_lcs.php
  - FAVA (week latency)
    https://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/
  - Monitored source list (updated daily)
    https://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/
  - ATels, GCN notices, ...
  - ...
- But one may:
  - be interested in other sources not covered by the above
  - want to keep control on threshold on which we are alerted
  - want fast feedback to promptly trigger follow-up observations

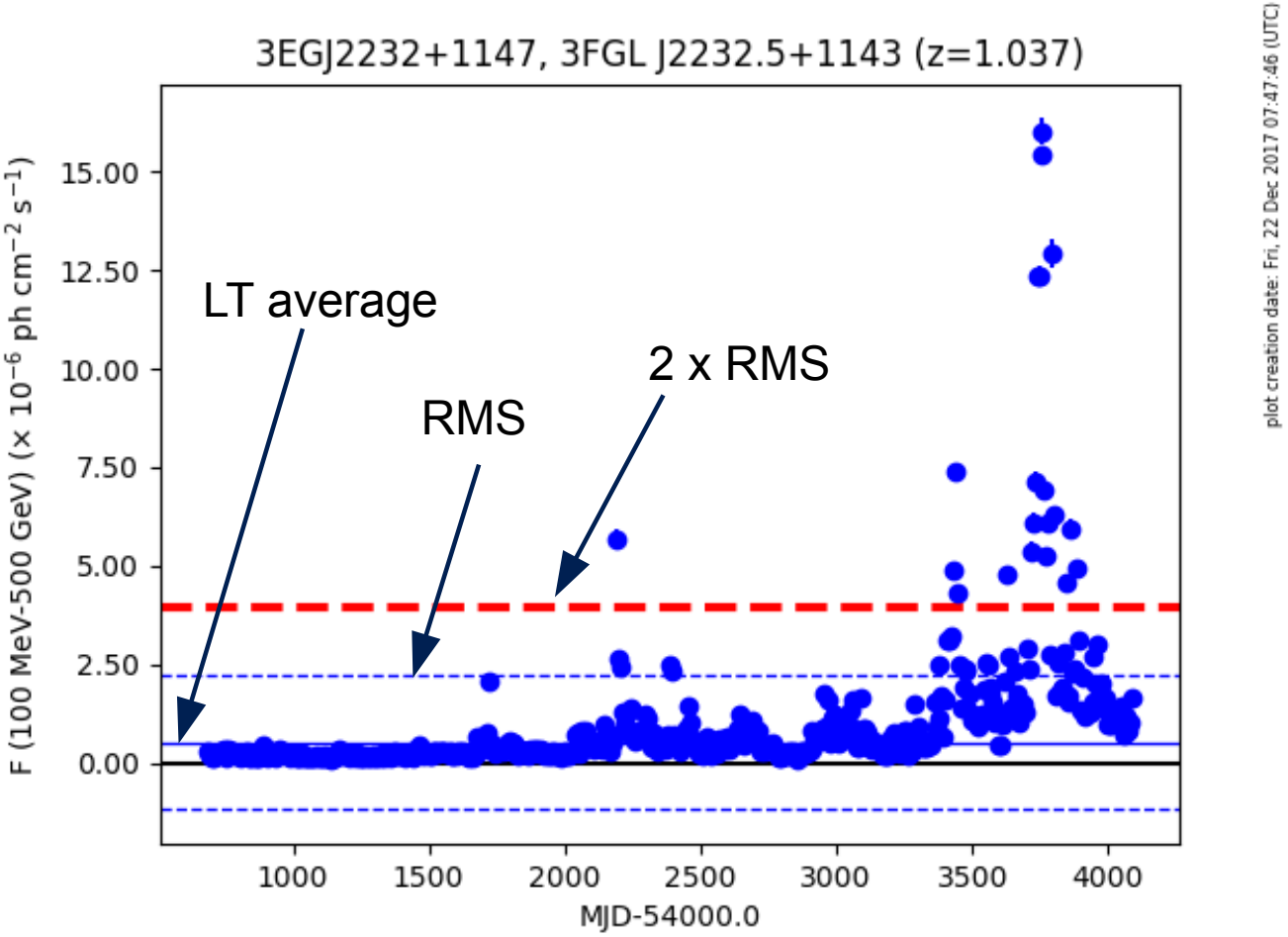
FLaapLUC:
Fermi-LAT automatic aperture photometry Light C↔Urve



- Search for active sources at high energies
  - ~900 fields of view monitored every morning
    - ~320 AGN
    - ~60 γ-ray binaries/binary candidates
    - Galactic plane survey

Lenain, *Astronomy & Computing* (2018)
https://github.com/jlenain/flaapluc

FLaapLUC: generation of alerts



Use long-term flux average as baseline

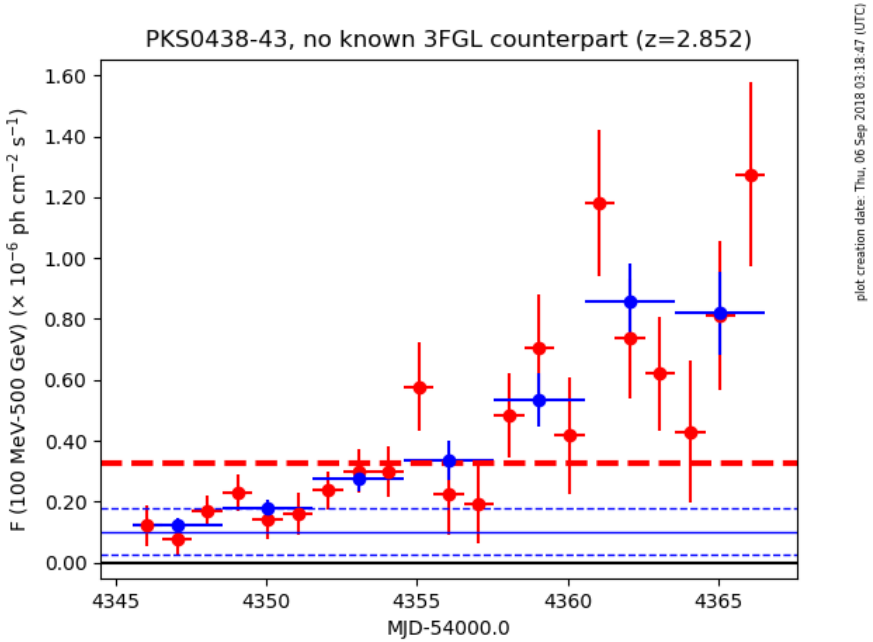
Lenain, *Astronomy & Computing* (2018)
https://github.com/jlenain/flaapluc

FLaapLUC: generation of alerts

- 2-step process: N_1- & N_2-binned light curves

1) $$F_{N_1} - \delta F_{N_1} > \overline{F_{LT}} + \alpha_{N_1}\ \mathrm{RMS}(F_{LT})$$

2) $$F_{N_2} - \delta F_{N_2} > \overline{F_{LT}} + \alpha_{N_2}\ \mathrm{RMS}(F_{LT})$$

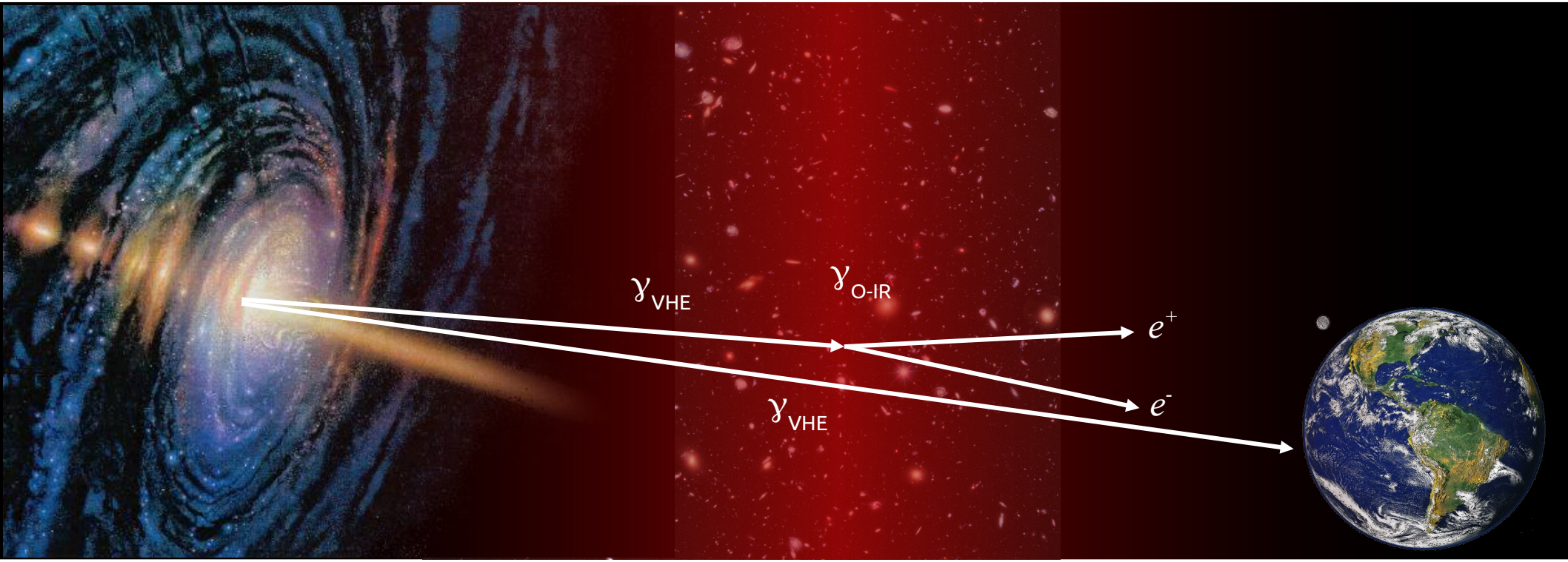


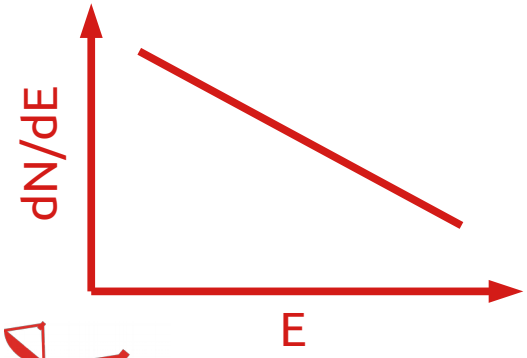
- If 1), then computes N_2-binned LC and assess 2)
- E.g. for AGN, N_1=3 days, N_2=1 day,

$$\alpha_{N_1} = 2\,,\ \alpha_{N_2} = 3$$

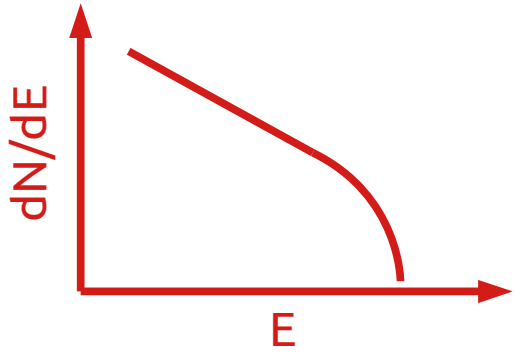
Lenain, *Astronomy & Computing* (2018)
https://github.com/jlenain/flaapluc

Alert vetoing: EBL effect

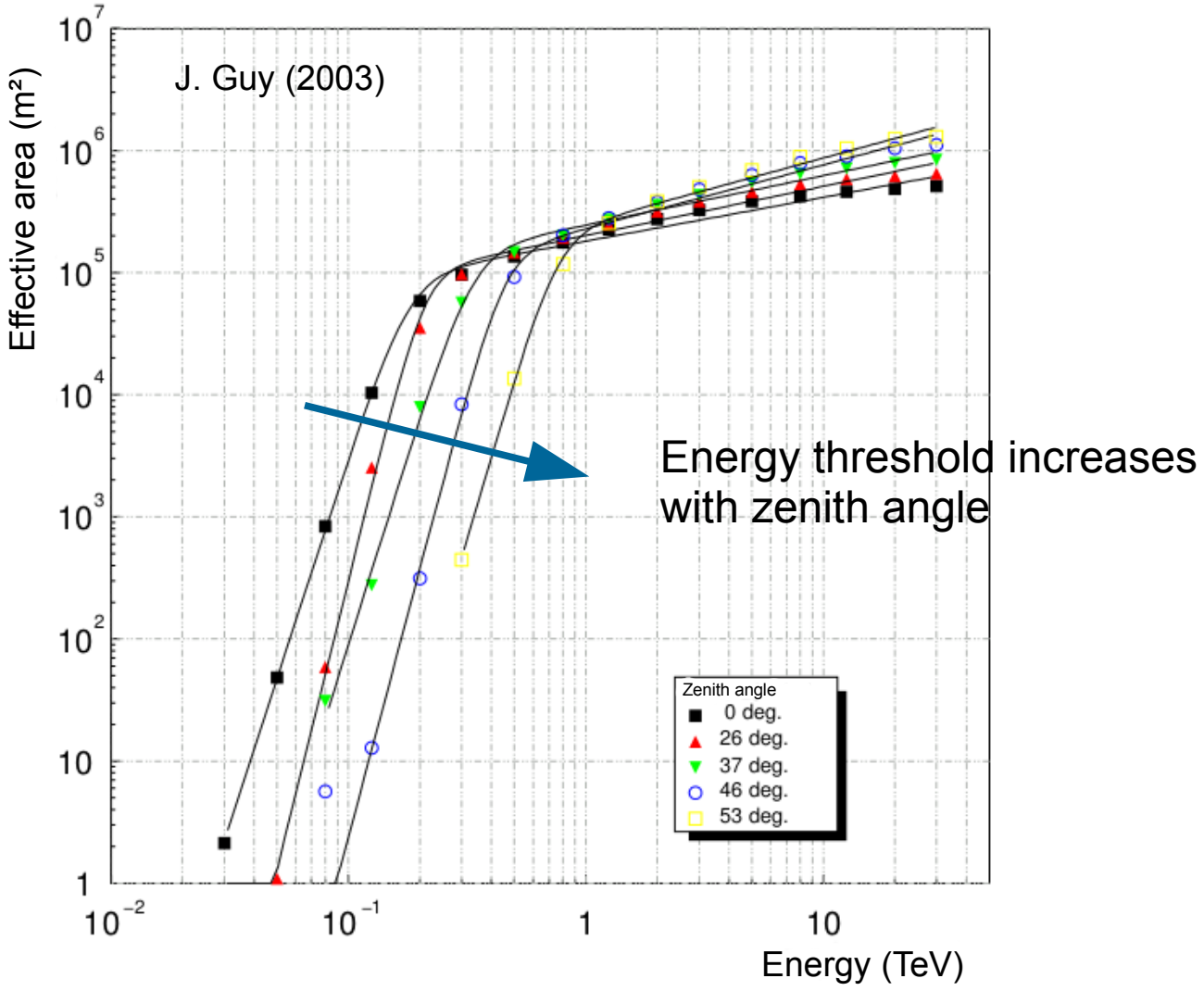




$$\gamma_{VHE} + \gamma_{O\text{-}IR} \rightarrow e^+ + e^-$$

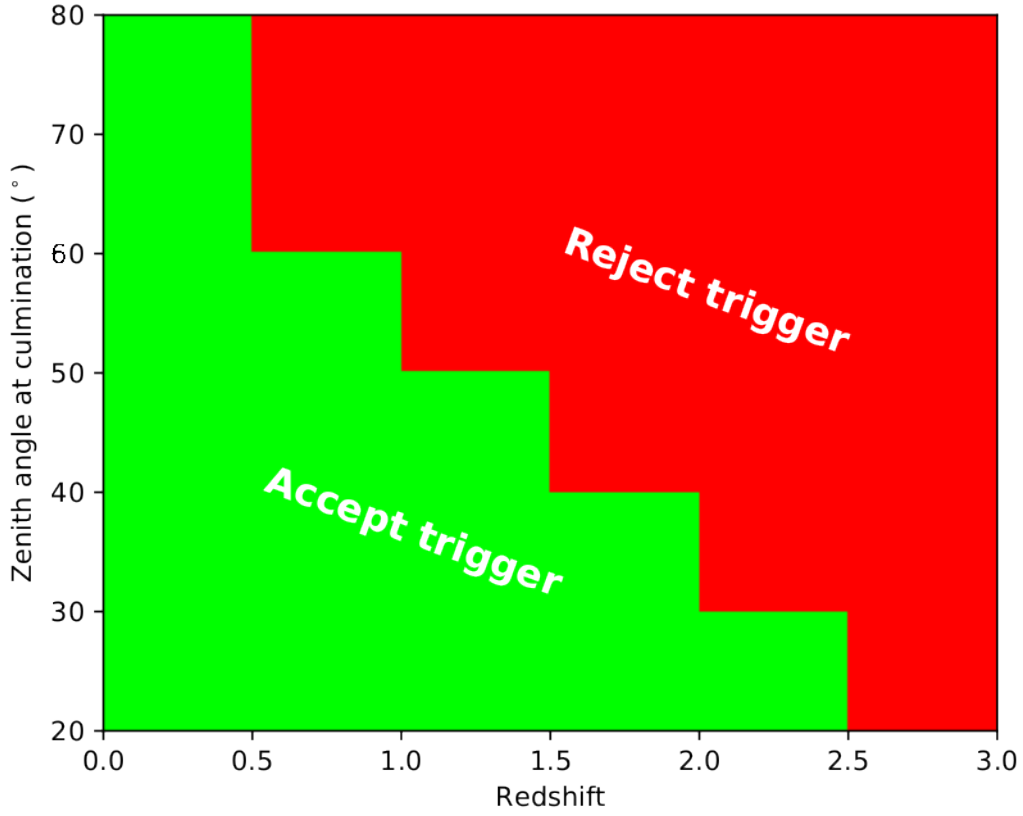


Alert vetoing: Energy threshold vs zenith angle



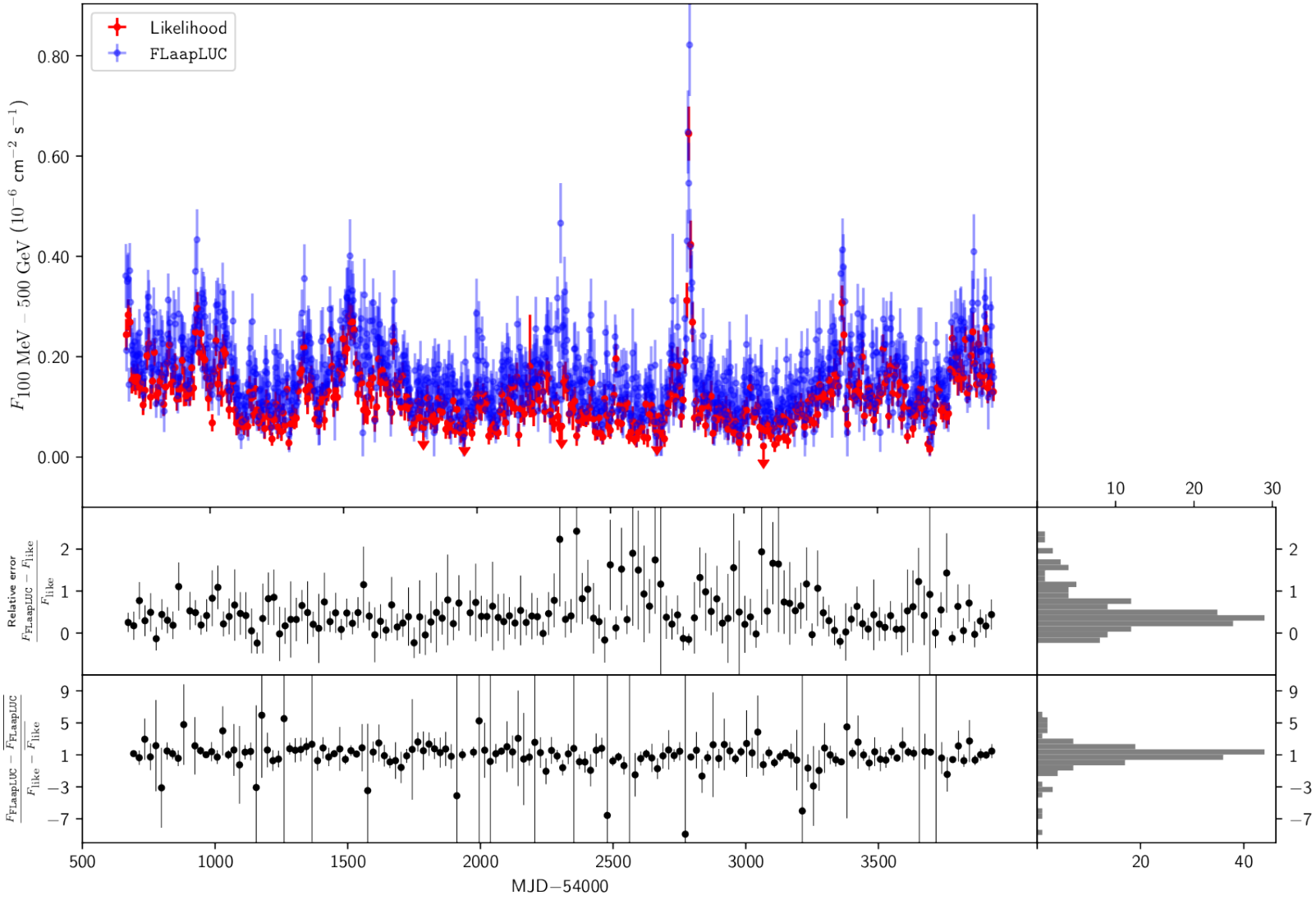
Alert vetoing

- Veto on:
  - Zenith angle vs redshift (EBL absorption, energy threshold)
  - Visibility at H.E.S.S. site



Lenain, *Astronomy & Computing* (2018)
https://github.com/jlenain/flaapluc

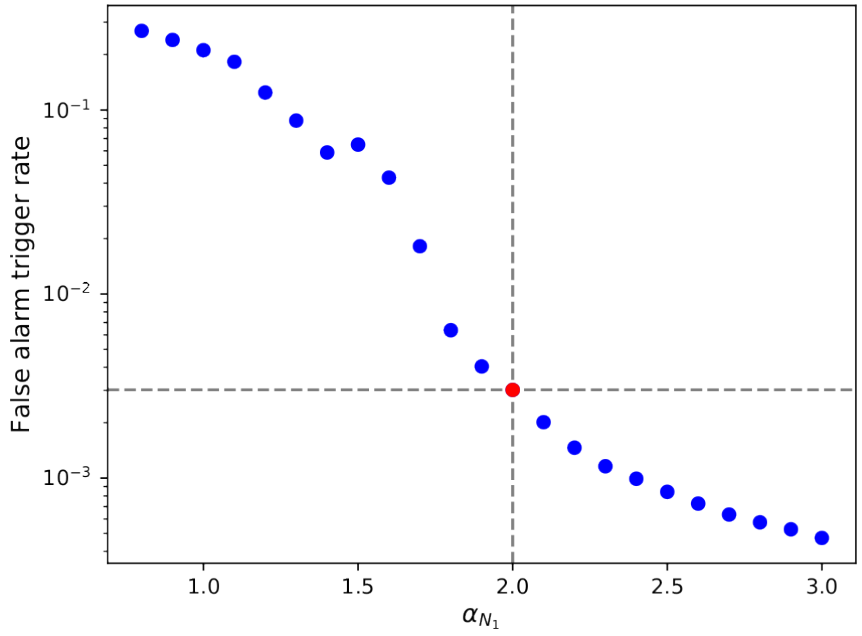
Aperture photometry vs. likelihood analysis



Lenain, *Astronomy & Computing* (2018)

False alarm probability

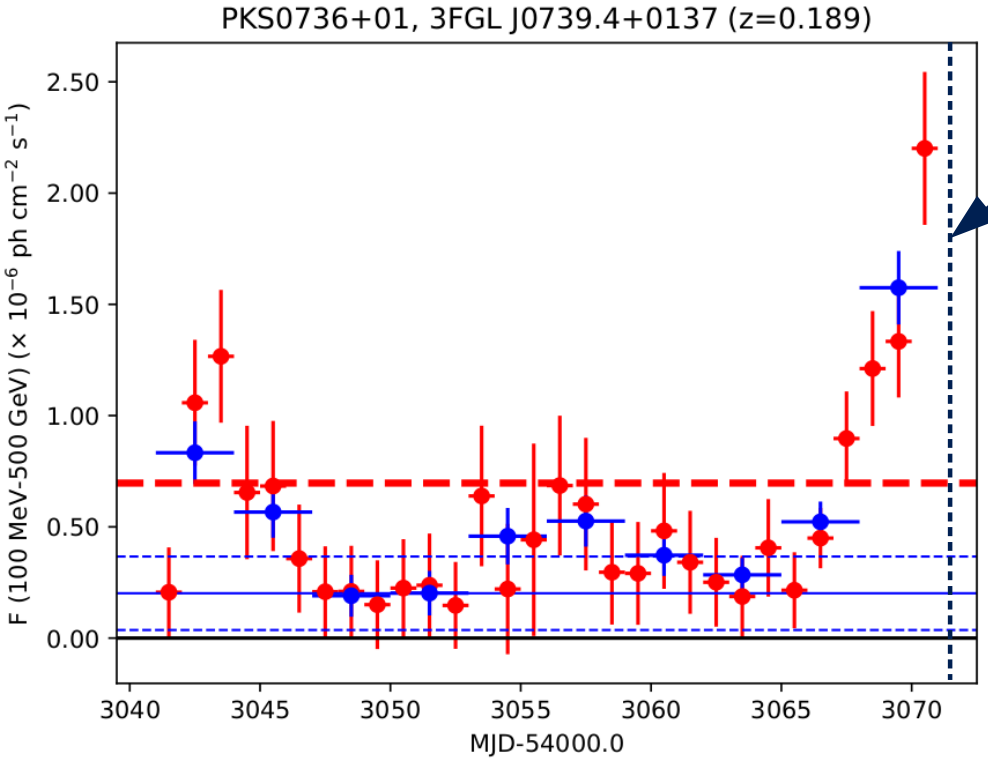
- From sources never active
  - Toy MC → 1000 simulated LC for each of such source
  - Use method from Emmanoulopoulos et al. 2013 so as to preserve PDF and PSD.



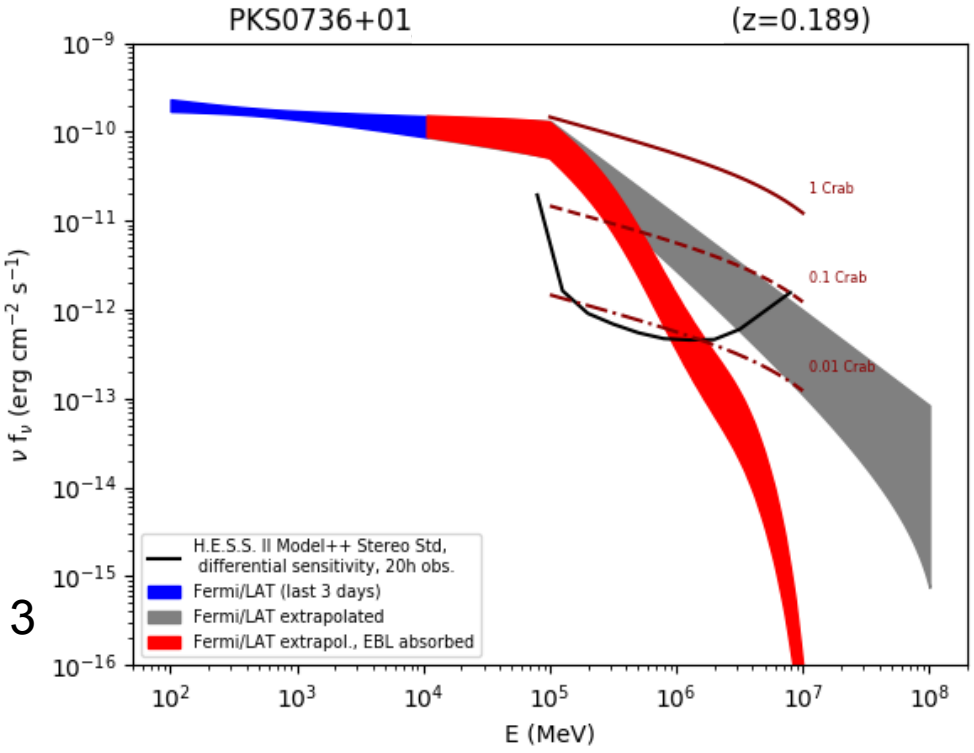
  - After 2-step procedure, FAR<0.1% within H.E.S.S.

Lenain, *Astronomy & Computing* (2018)

Triggering H.E.S.S. observations
PKS 0736+01

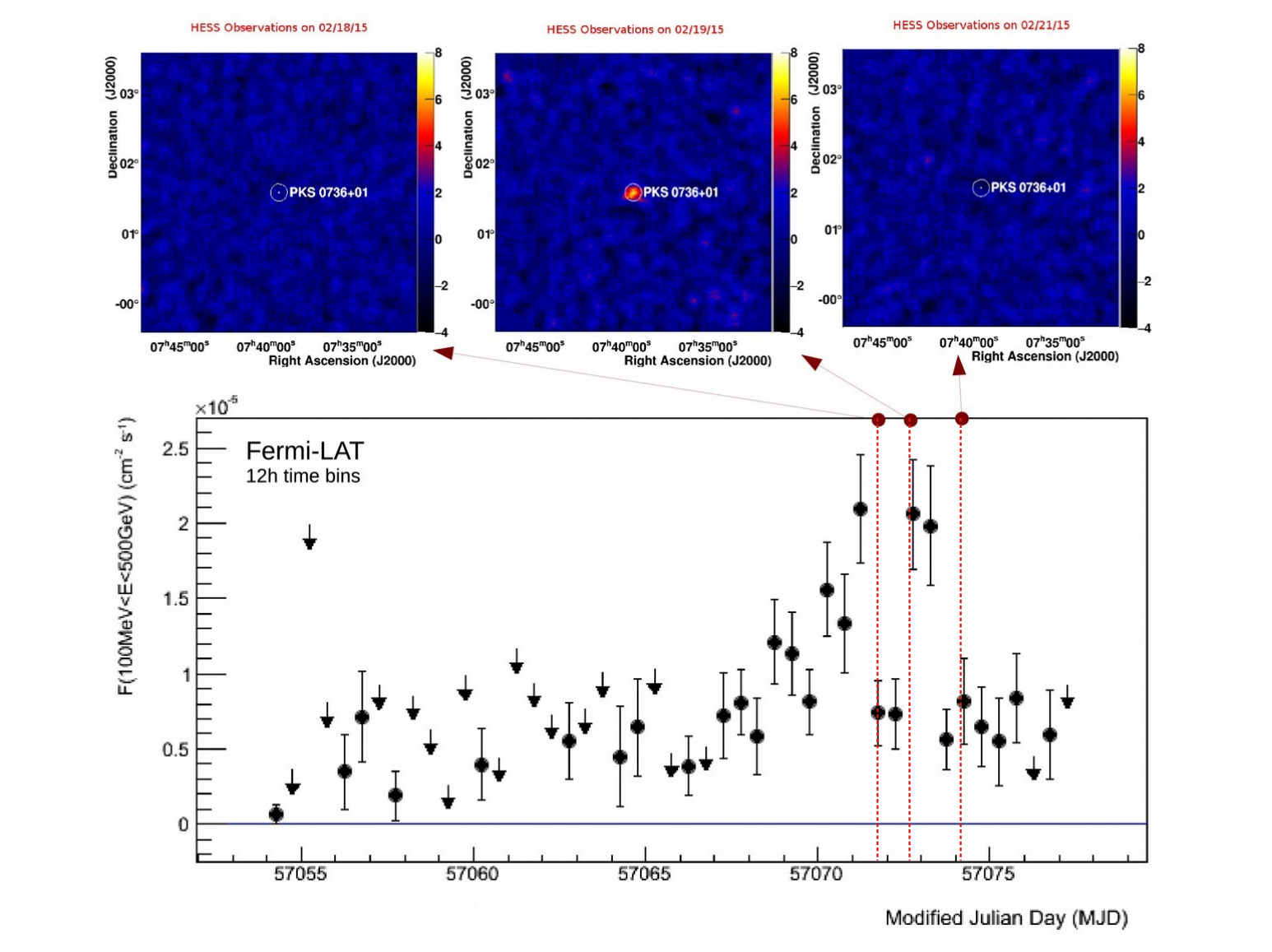


H.E.S.S. triggered & begun observing



If alert, follow-up likelihood analysis on last 3 days of data automatically performed

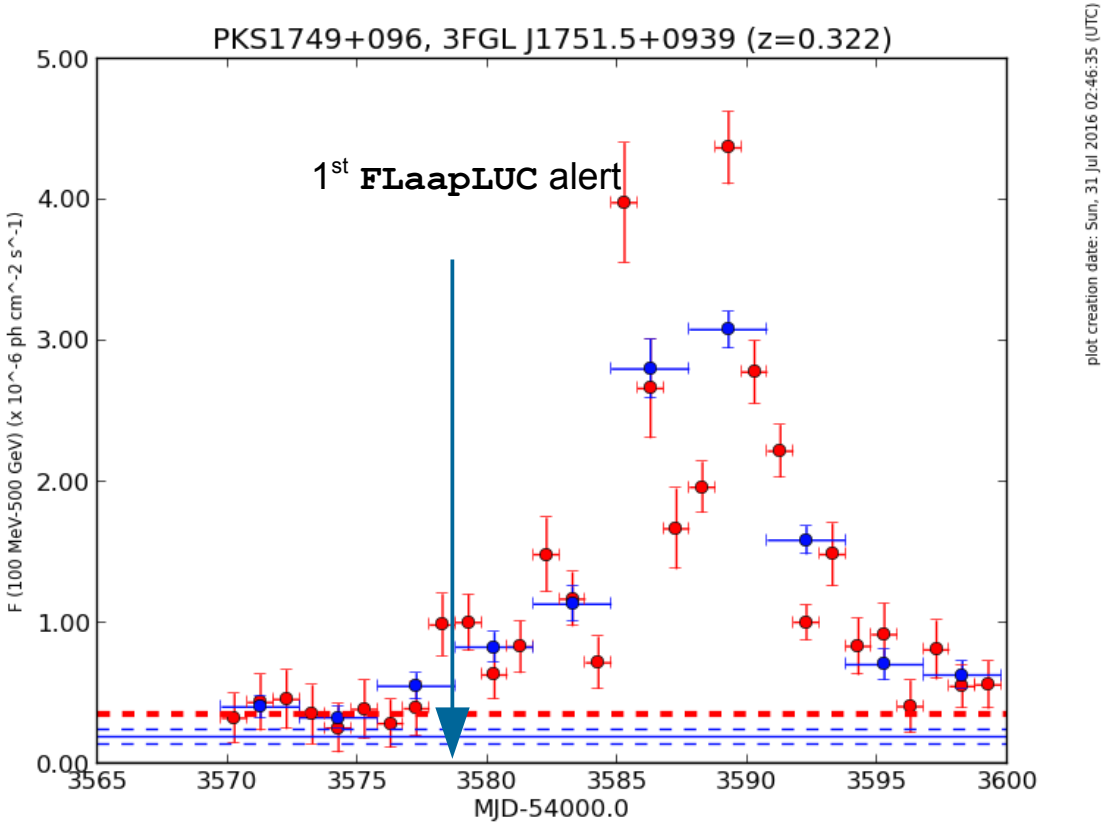
Triggering H.E.S.S. observations
PKS 0736+01



Cerruti et al. (for the H.E.S.S. collaboration), ICRC (2017)

Triggering H.E.S.S. observations
PKS 1749+096 / OT 081

- Only 2nd LBL discovered at VHE so far, with AP Lib



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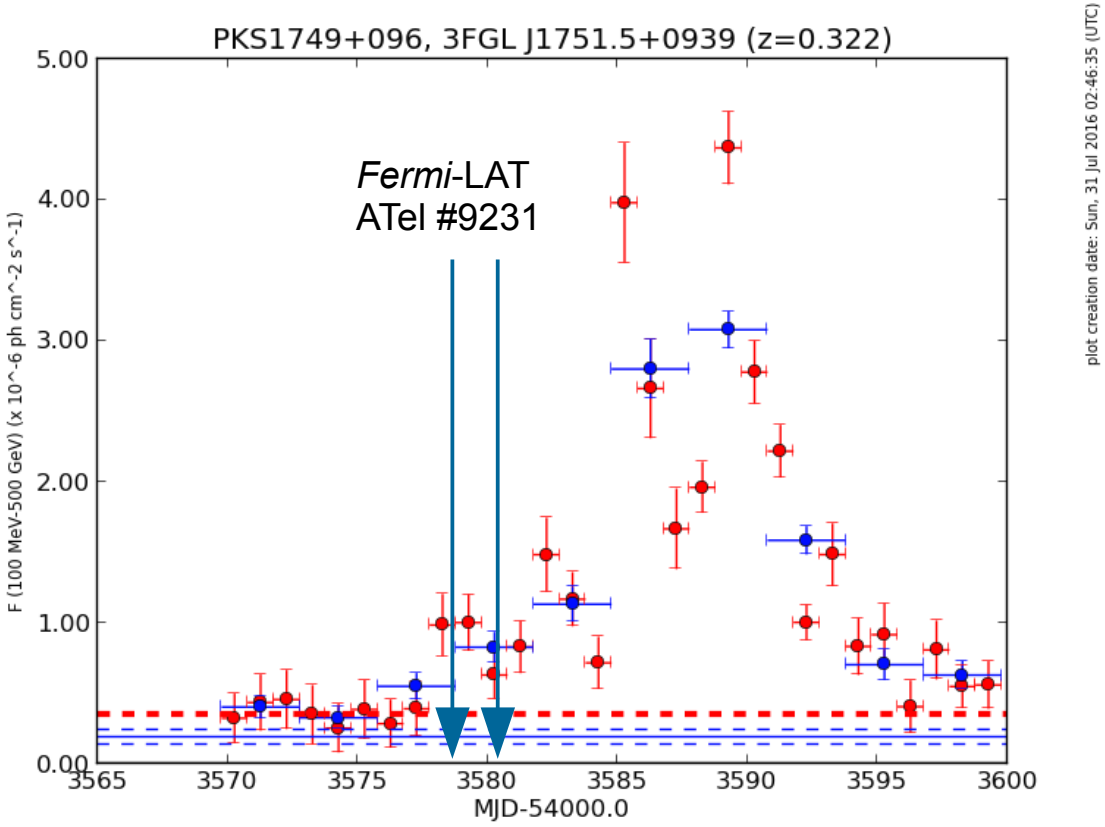

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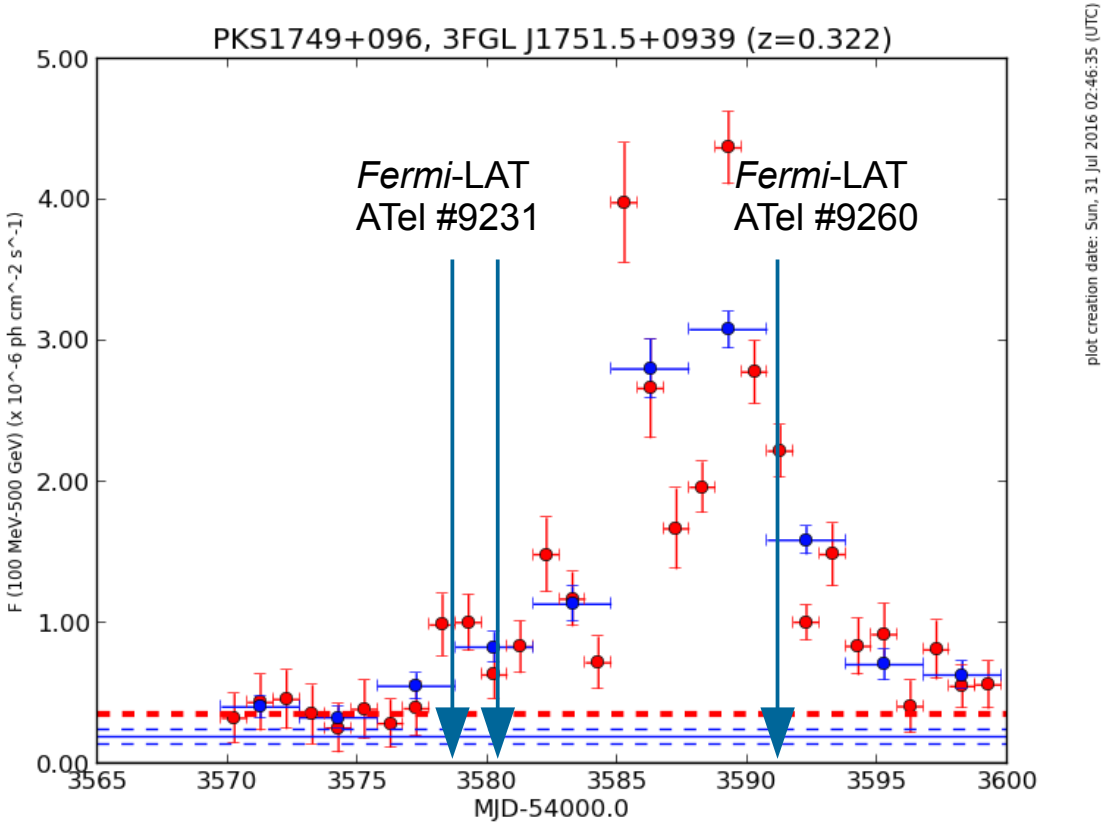

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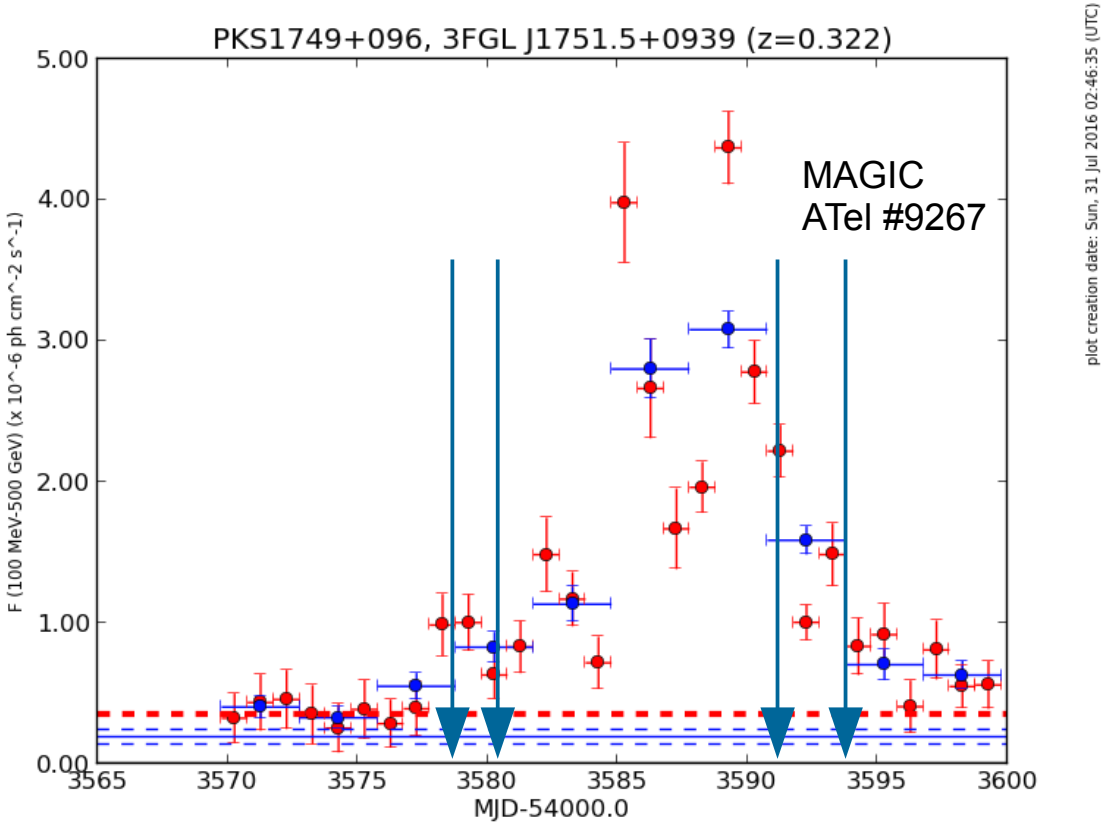

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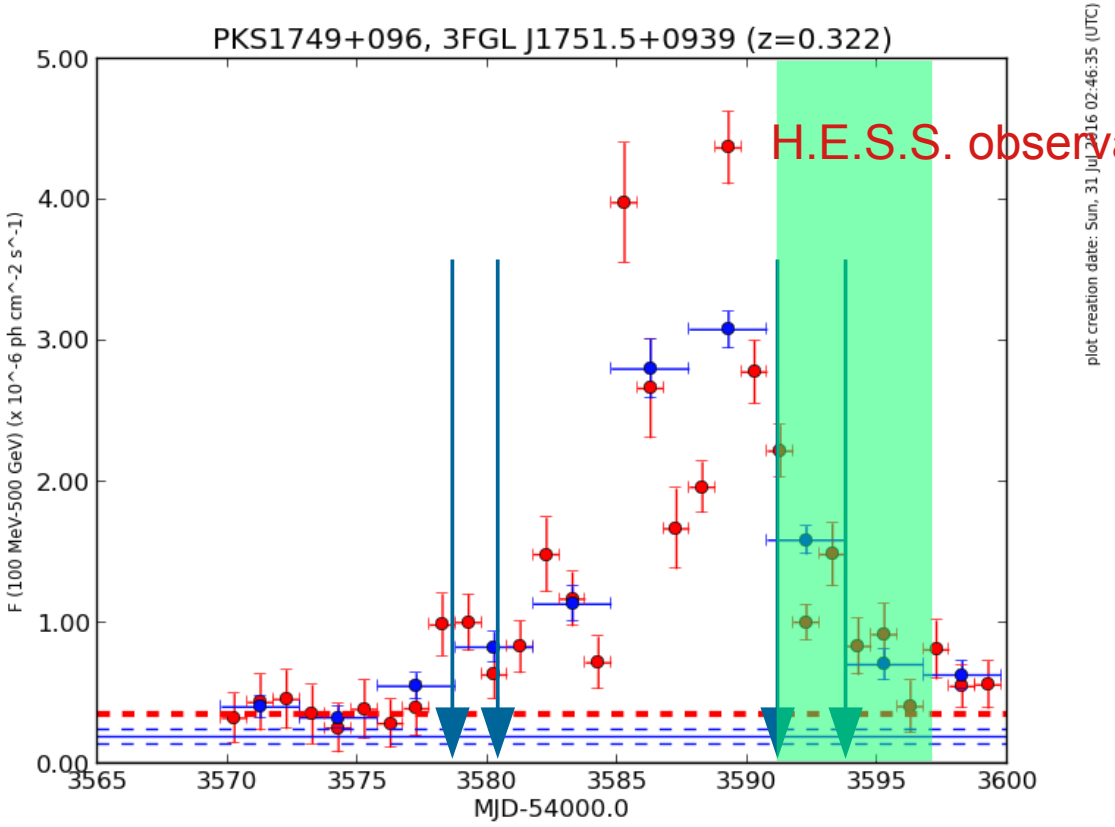

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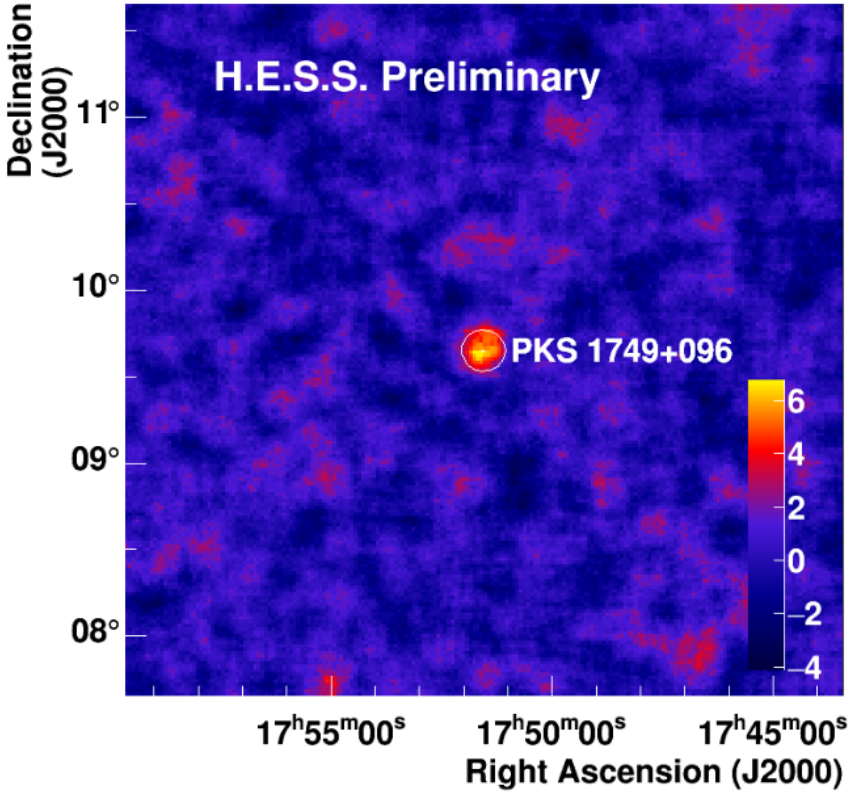
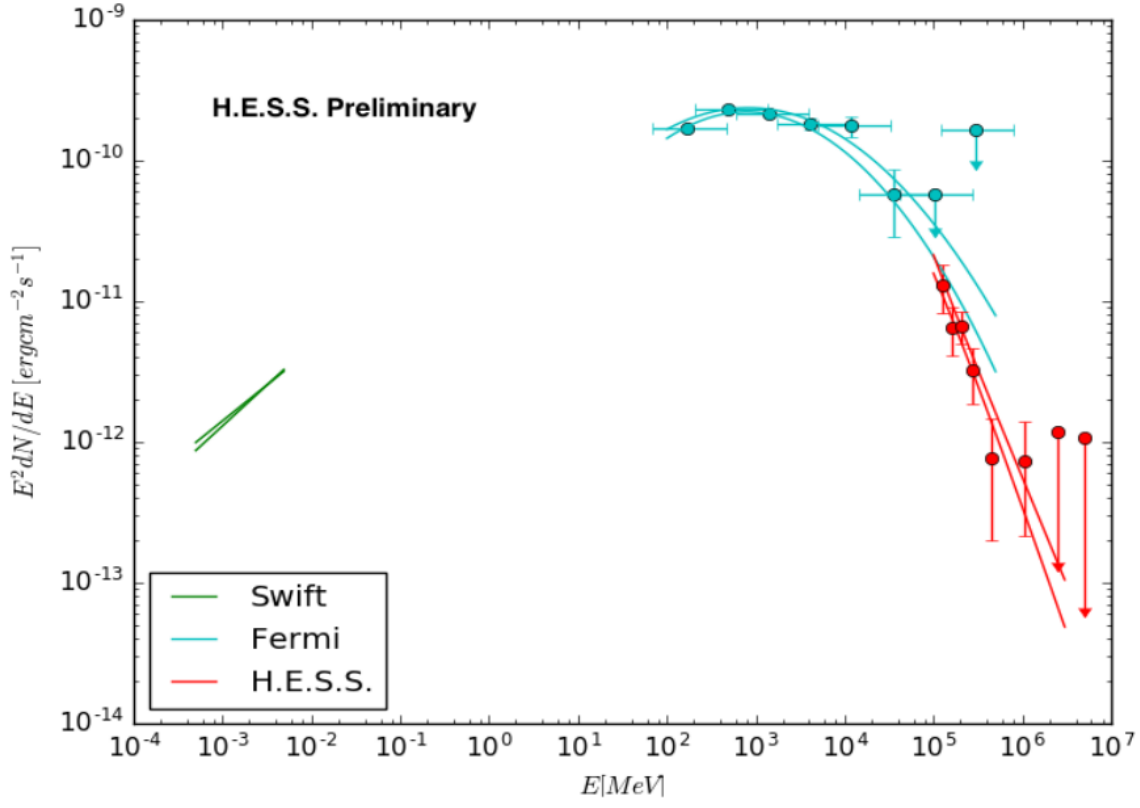
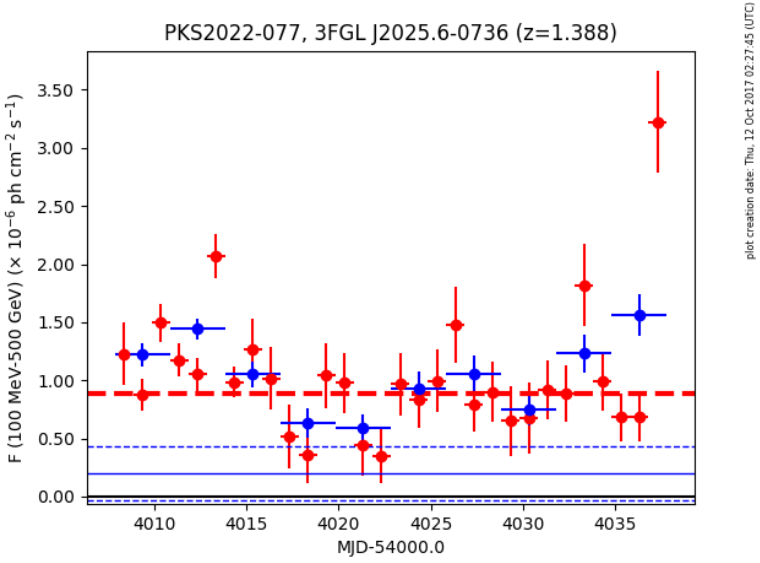


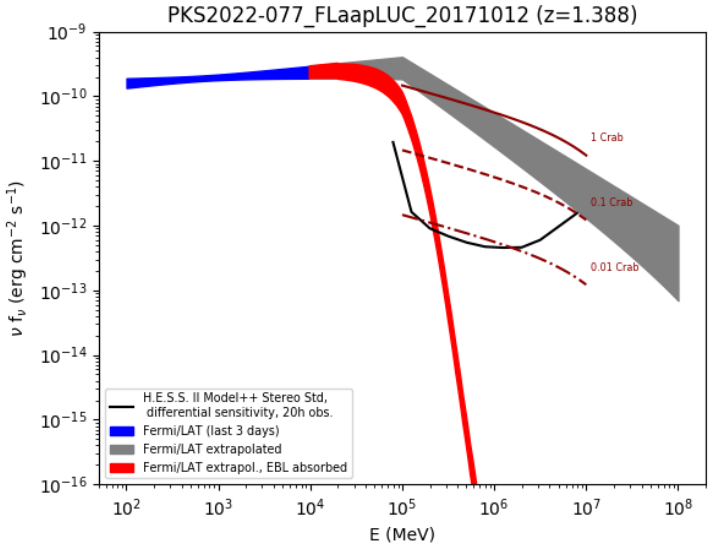


Schüssler et al. (for the H.E.S.S. collaboration), ICRC (2017)

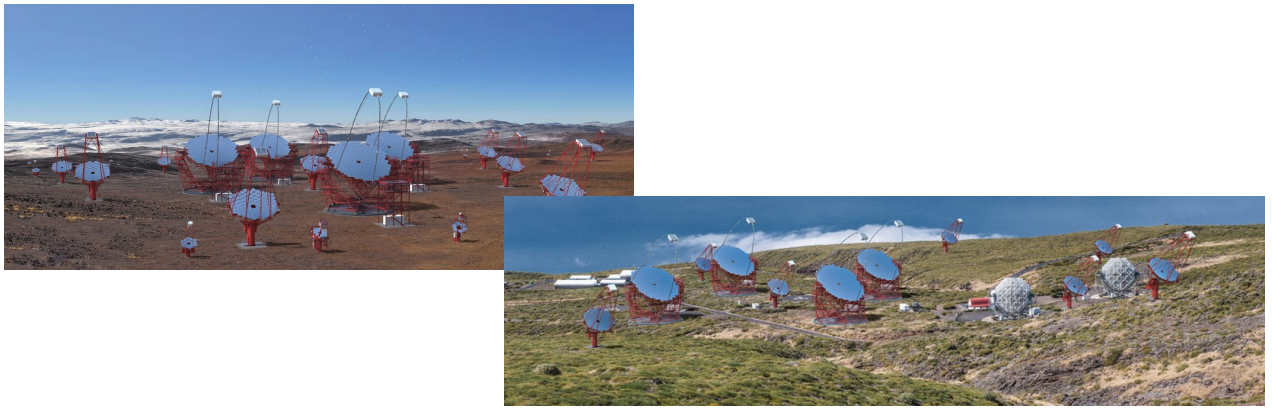
Triggering H.E.S.S. observations

- Other examples of H.E.S.S. ToO initiated with **`FLaapLUC`**:
  - 3C 279 in 01/2018 (ATel #11239), 02/2018, 06/2018
  - TXS 0506+056 in 03/2018, along with *Fermi* ATel #11419
  - PKS 2022-077 in 04/2016, 09/2017, 10/2017

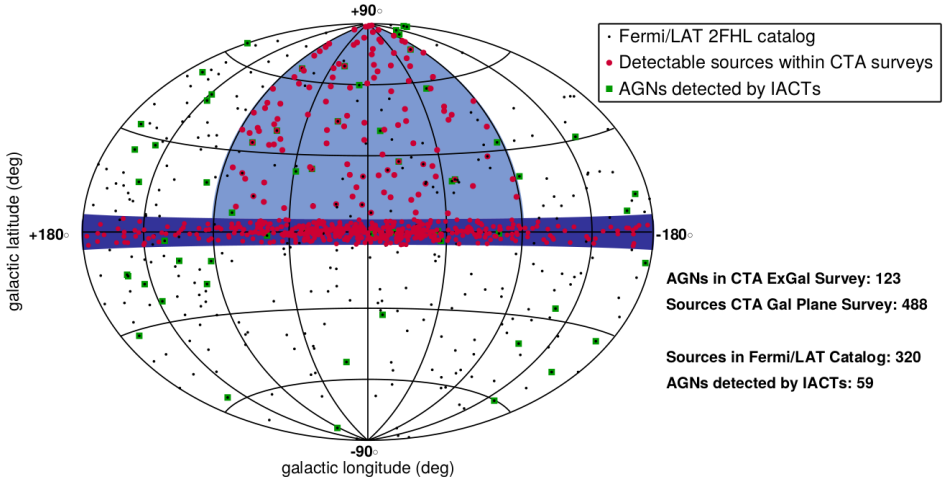




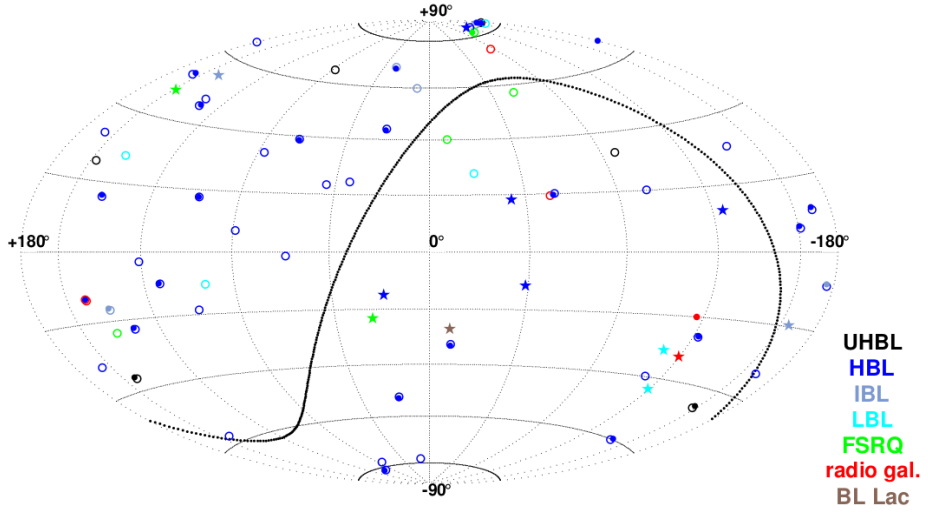
Future with CTA



- Surveys



- AGN long-term monitoring

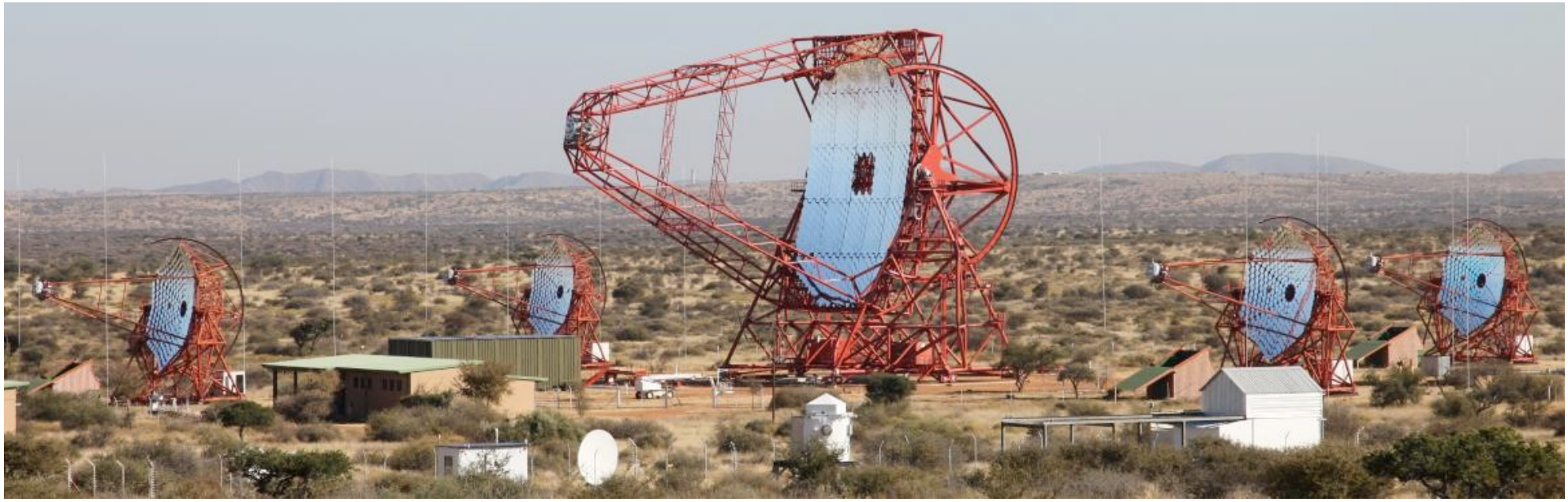


CTA consortium (2017), arXiv:1709.07997

Thanks !

BACKUP

H.E.S.S. I and H.E.S.S. II

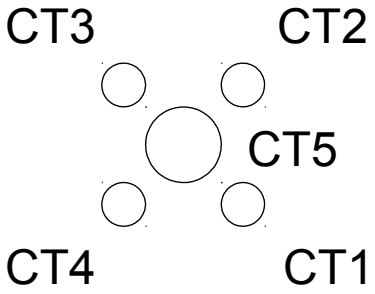


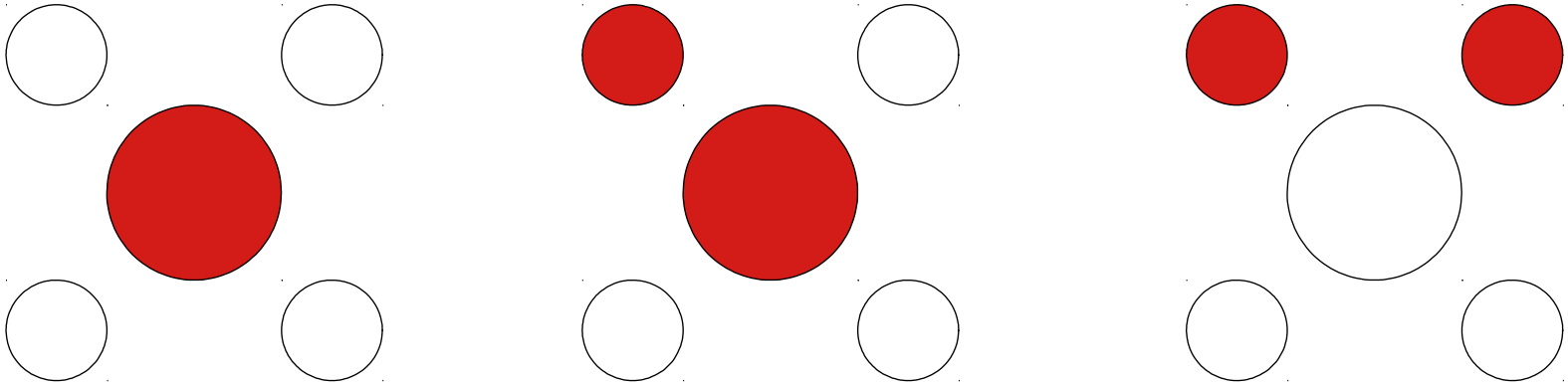
- H.E.S.S. phase 1:
  - 4 telescopes CT1-4
  - Ø 12 m,107 m^2
  - Stereoscopic reconstruction
  - 960 PMTs/camera, field of view: 5°
  - Source position : ~ 10''
- H.E.S.S. phase 2:
  - addition of a 5th telescope CT5
  - Ø 28 m, 600 m^2
  - 2048 PMTs, field of view : 3.5°
  - mono and hybrid

→ Energy threshold (zenith) ~ 30 GeV

Observations : ~1000 h/year

Hybrid array - trigger





CT5 mono
65%

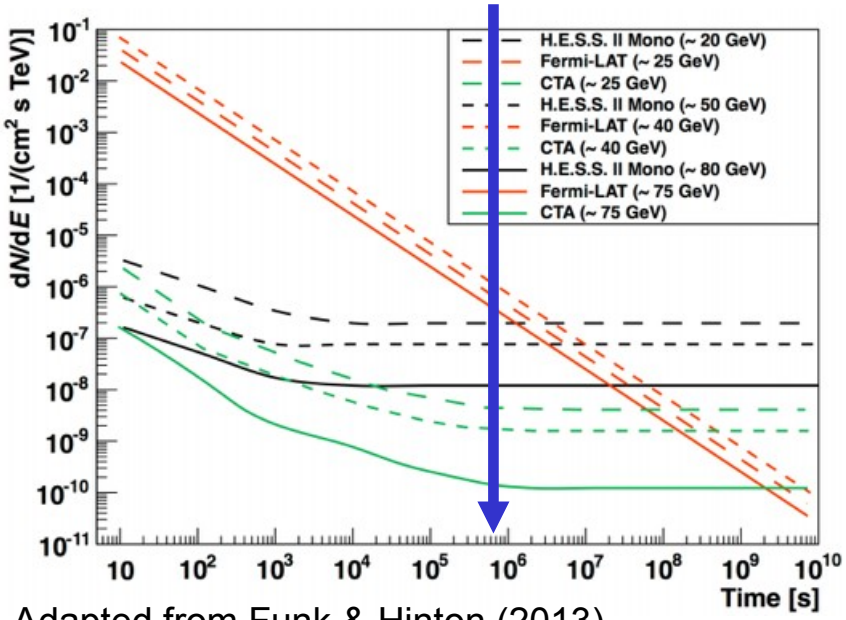
CT5 + ≥ 1 CT1-4
30%

≥ 2 CT1-4
5%

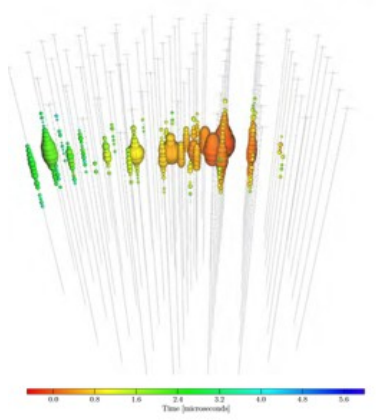
Systematics limited

Statistics limited

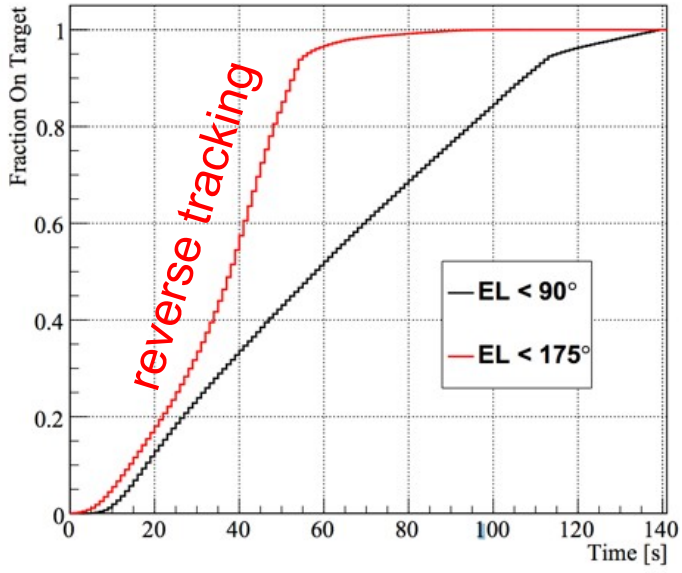
H.E.S.S. II as a transient machine



Adapted from Funk & Hinton (2013)



H.E.S.S. 28 m telescope slewing time



- Fast response time of 28m telescope
- >90% of targets within 60 sec
- Large MWL program: GRBs, FRBs, neutrino counterparts, GW, …
- Stay tuned !

H.E.S.S. ToO policy

- Different channels (facility, wavelength, …)
- External alerts received via:
  - Public information (Atel, GCN, …)
  - MoU (e.g. among IACTs, *Fermi*-IACT, …)
  - Internal tools (H.E.S.S. self-trigger, **`FLaapLUC`**, …)
- H.E.S.S. ToO:
  - Class A:
    - Predefined criteria (flux, latency, hardness, …)
    - Direct contact with shifters
  - Class B:
    - Looser criteria but strong scientific justification
    - First discussed with H.E.S.S. Observation Committee