Very high energy gamma-ray observations of distant AGNs with MAGIC and Fermi/LAT

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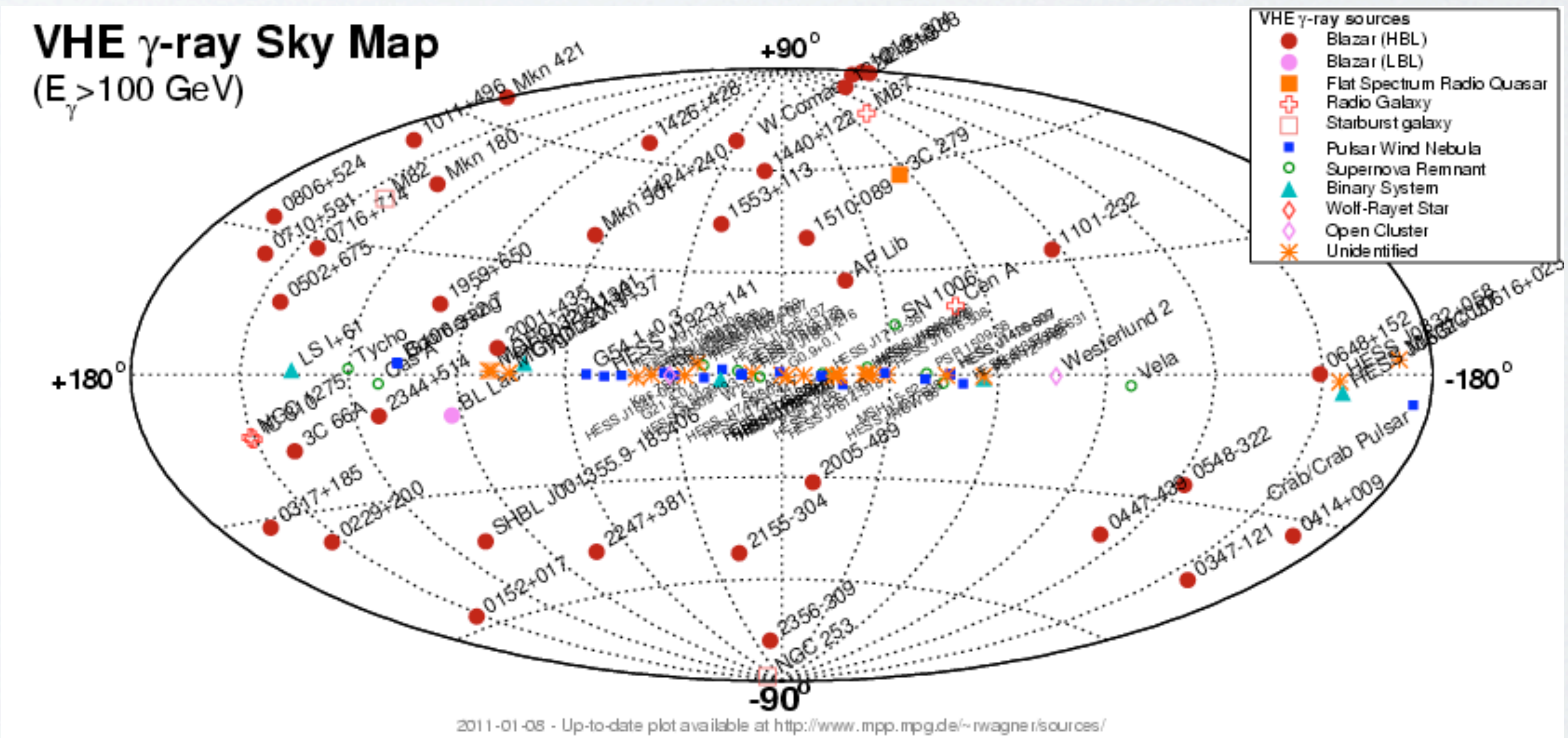
13.05.11
PPSM Colloquium

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

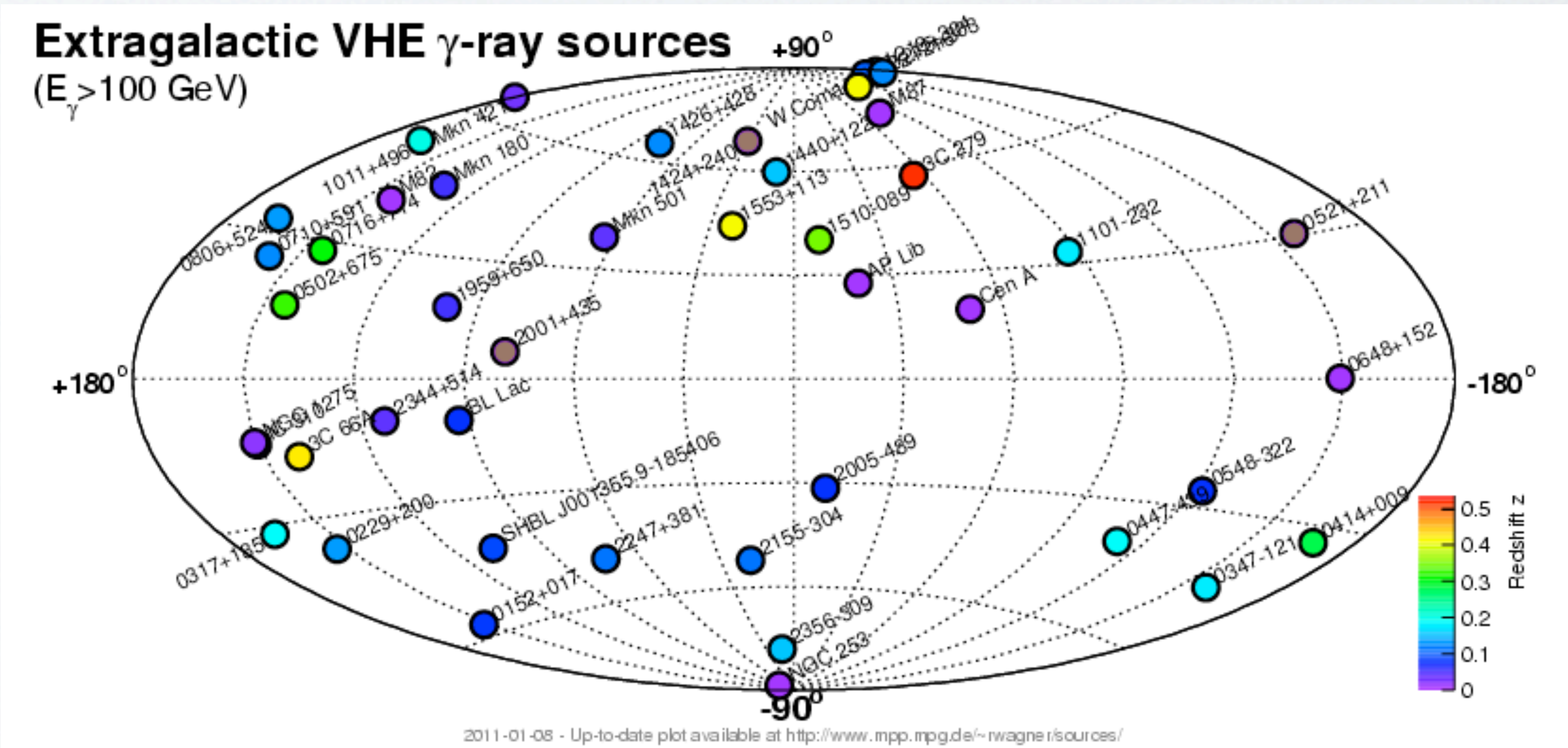
LMU TUM

Very High Energy Gamma-rays



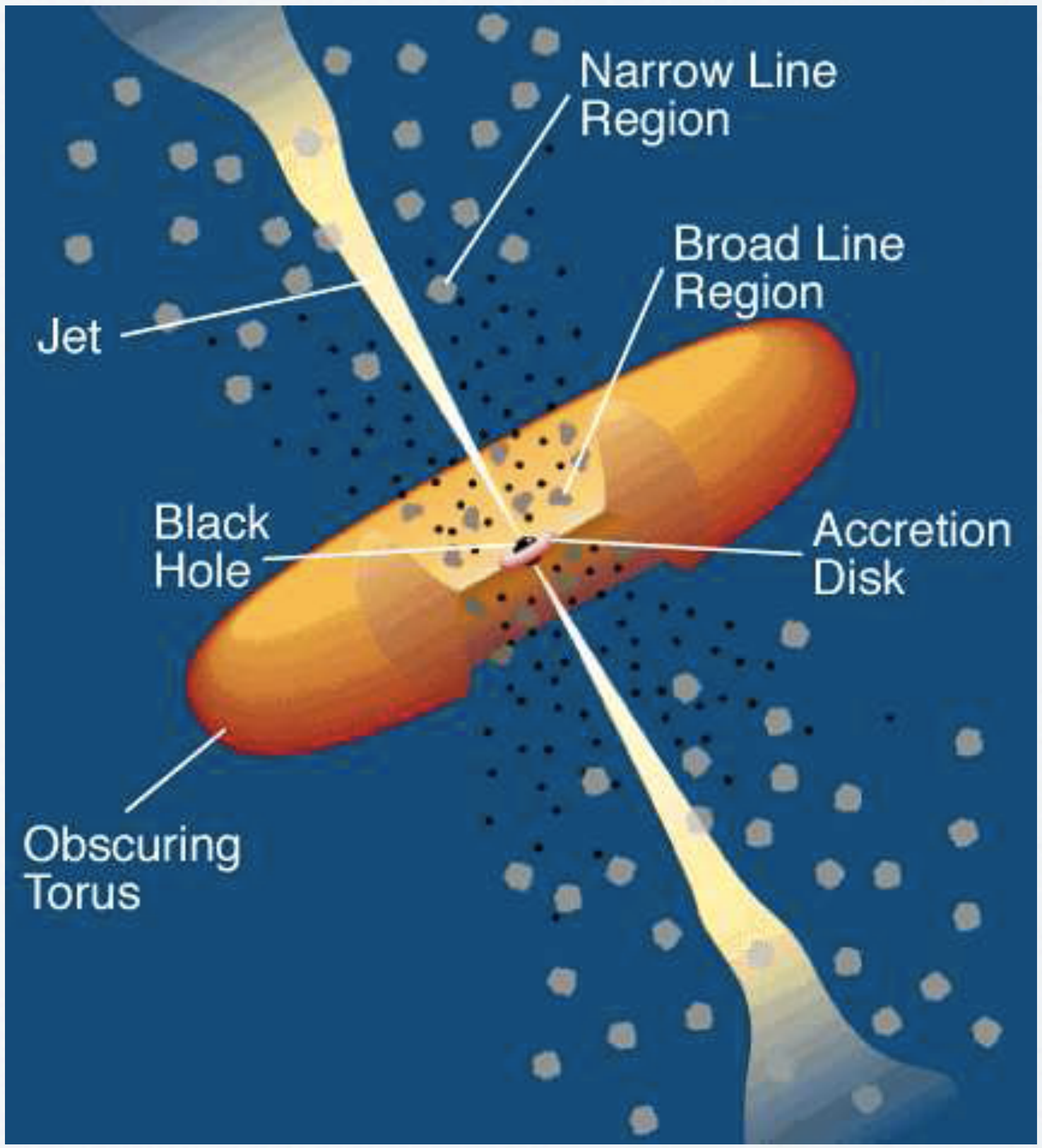
106 sources

Very High Energy Gamma-rays



46 sources

Active Galactic Nuclei



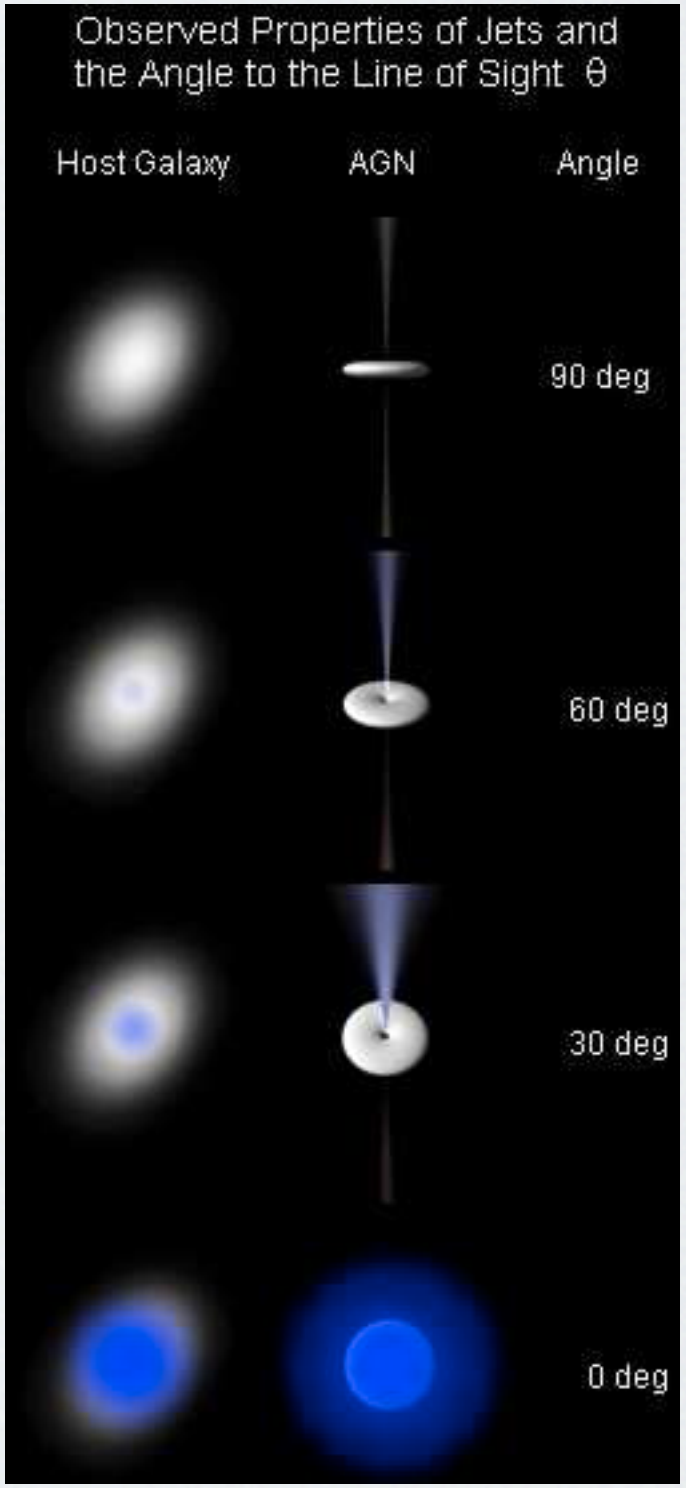
* Super massive black hole: 10^6-10^9 $M_{\odot}$

* fed upon accreting matter
* Torus surrounding accretion disk
* Broad emission line region
* Narrow emission line region
* Two narrow jets emerge from BH and extend for several kpc

Active Galactic Nuclei

Unified model
different features are due to a different orientation w.r.t. the observer

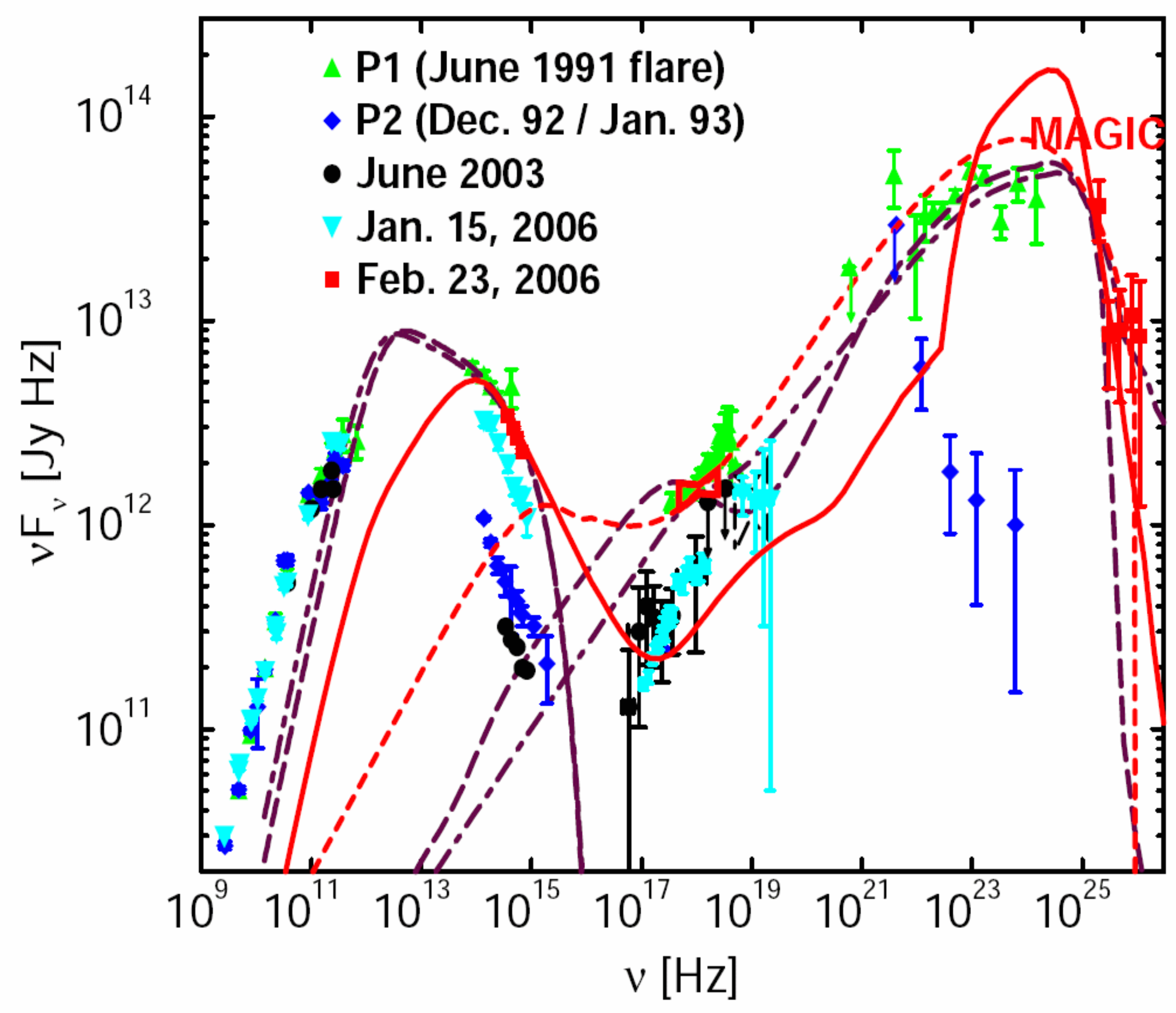
Radio galaxy:
Jets lie at large (>30 deg.) angle w.r.t. the line of sight
Blazar:
Jets point towards the observer
- BL Lac : no feature of BLR or NLR
- Flat Spectrum Radio Quasar (FSRQ) : shows evidence of BLR and NLR + thermal emission from accretion disk



Active Galactic Nuclei

<u>Spectral Energy Distribution (SED)</u>

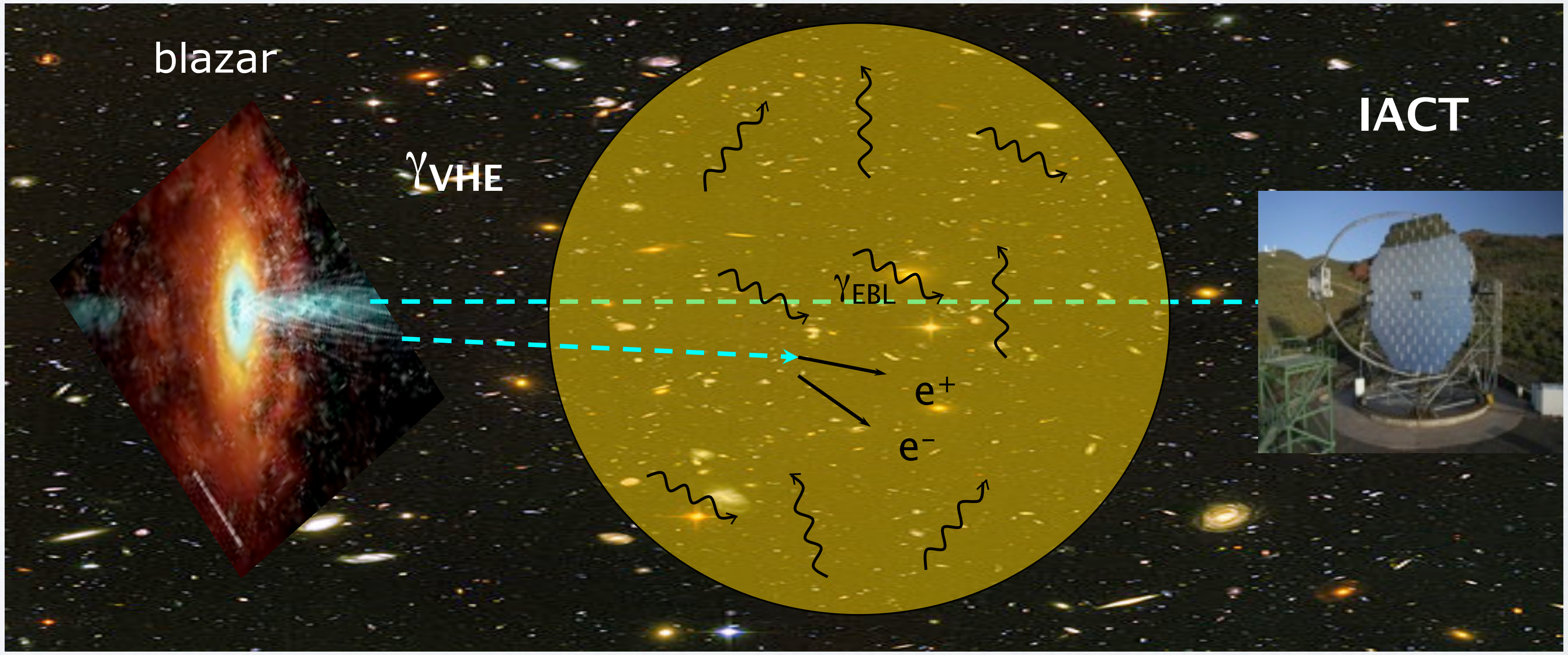
* Dominated by non-thermal continuum produced within the jet
* Consists of two bumps
 - First bump (UV to optical or X-ray): synchrotron radiation
 - Second bump (X-ray to gamma-ray): inverse Compton or hadronic



Böttcher et al. 2009

Red: Leptonic
Maroon: Hadronic

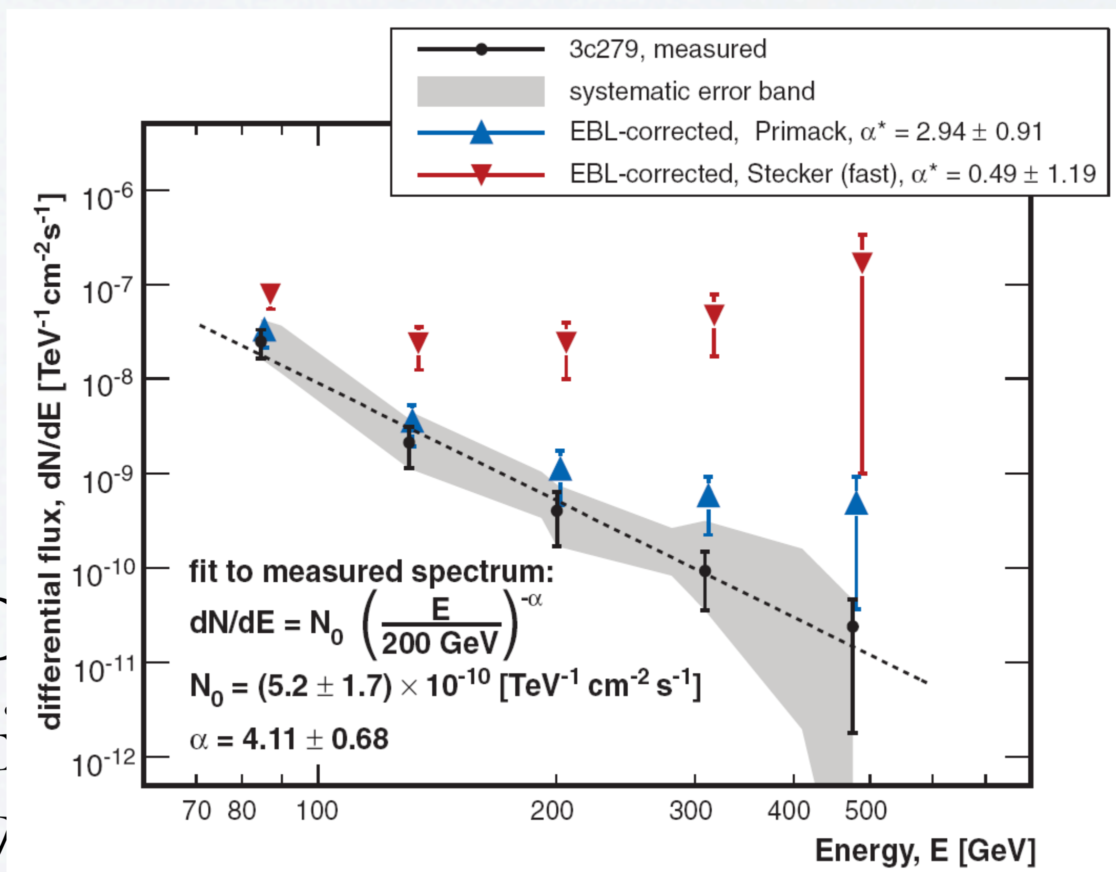
Extragalactic Background Light (EBL)

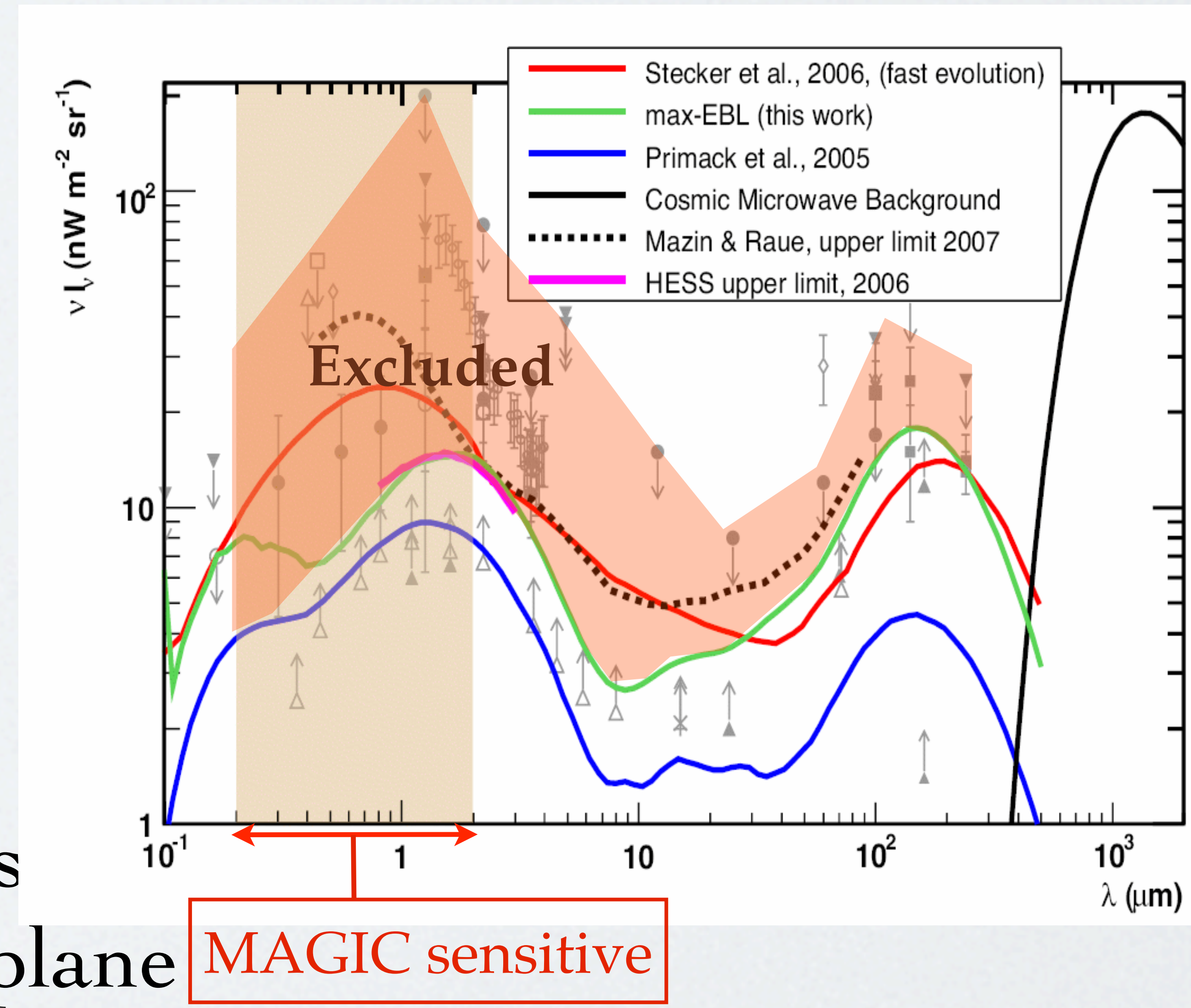


* Direct measurement of EBL is difficult due to the foreground emission from sun and galactic plane
* VHE gamma-rays from distant sources are strongly attenuated by the extragalactic background light (EBL) → Strong constraint on EBL models could be derived indirectly

Extragalactic Background Light (EBL)

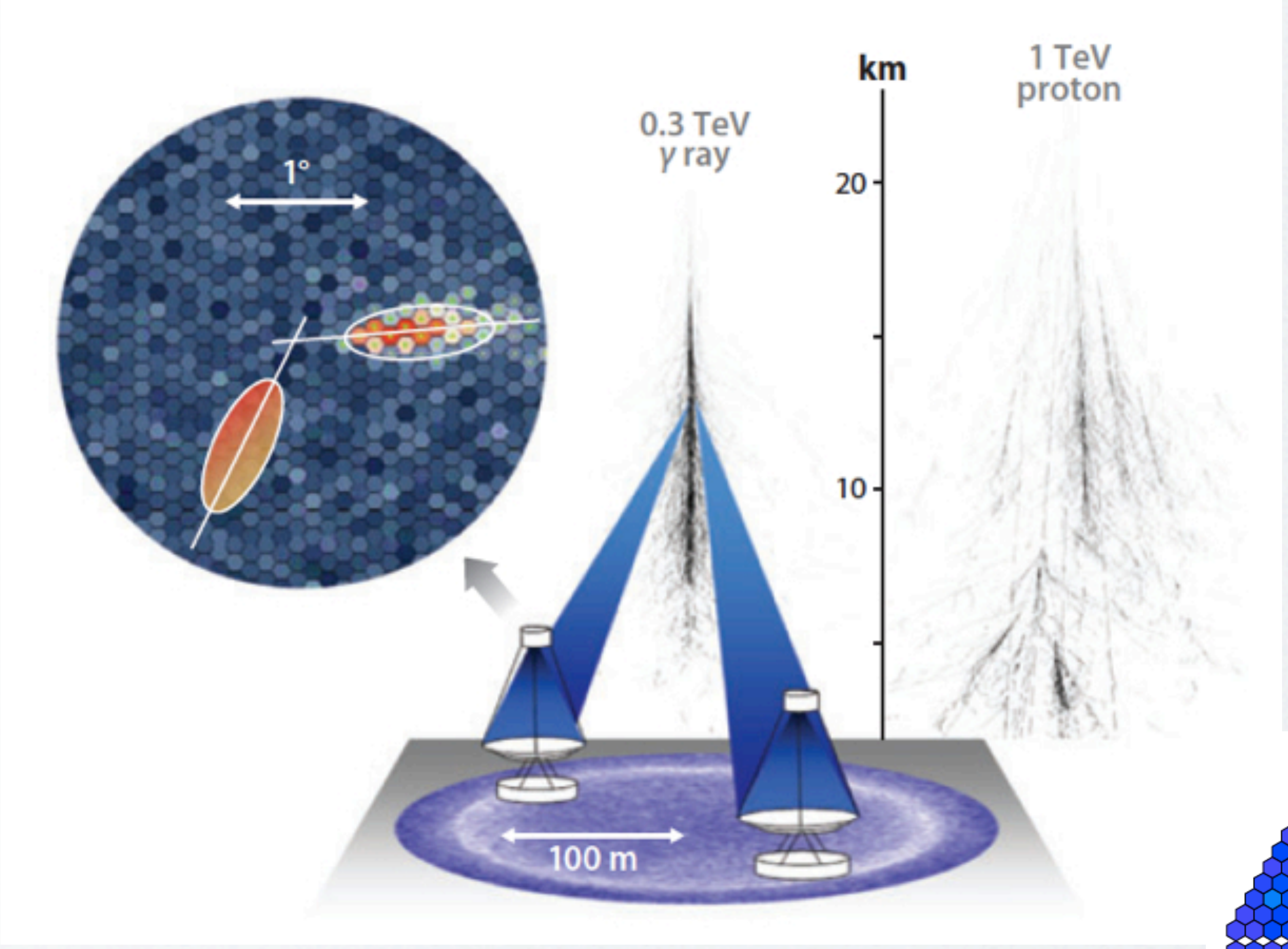
3C 279 (z=0.54), MAGIC observation in 2006





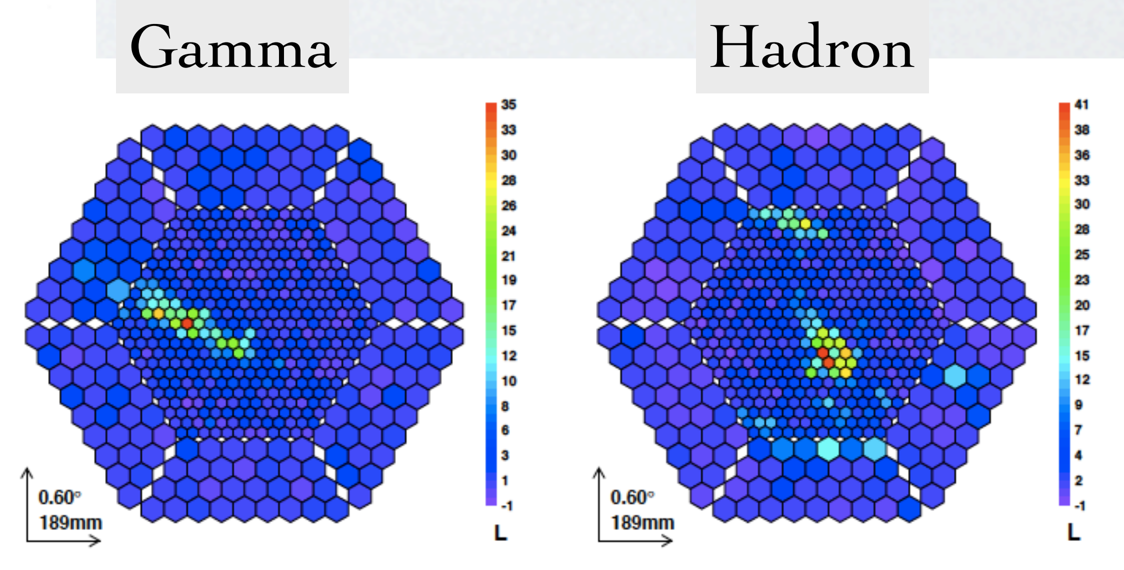
* D … is
emi … plane
* V … nt sources are strongly attenuated by the extragalactic background light (EBL) → Strong constraint on EBL models could be derived indirectly

Imaging Air Cherenkov Technique (IACT)



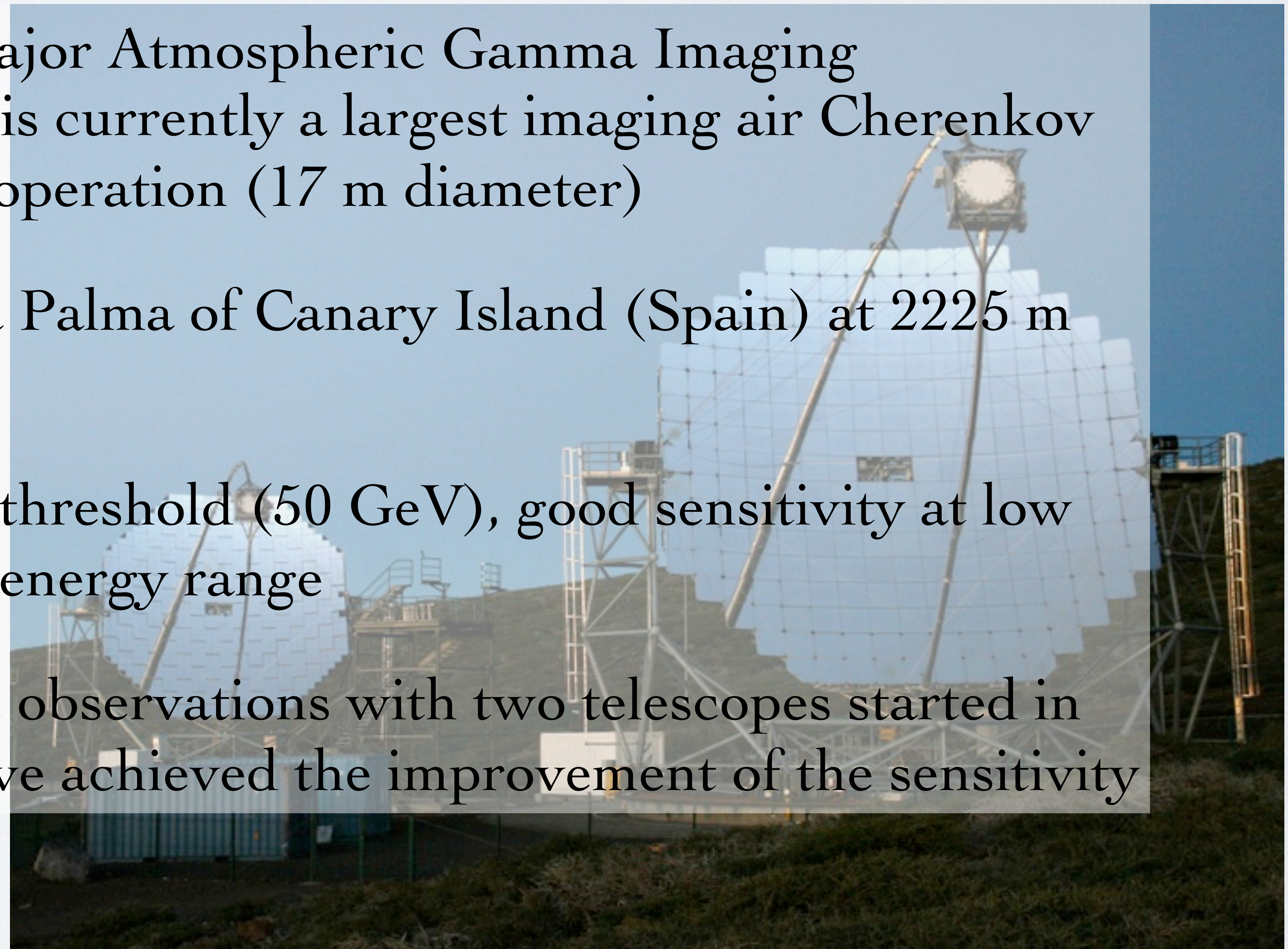
- High energy gamma-rays/ hadrons induce extensive air showers

- From the shower image we reconstruct the direction and energy of primal gamma-ray



MAGIC Telescopes

* MAGIC (Major Atmospheric Gamma Imaging Cherenkov) is currently a largest imaging air Cherenkov telescope in operation (17 m diameter)
* Location: La Palma of Canary Island (Spain) at 2225 m a.s.l.
* Low energy threshold (50 GeV), good sensitivity at low (~100 GeV) energy range
* Stereoscopic observations with two telescopes started in 2009 and have achieved the improvement of the sensitivity



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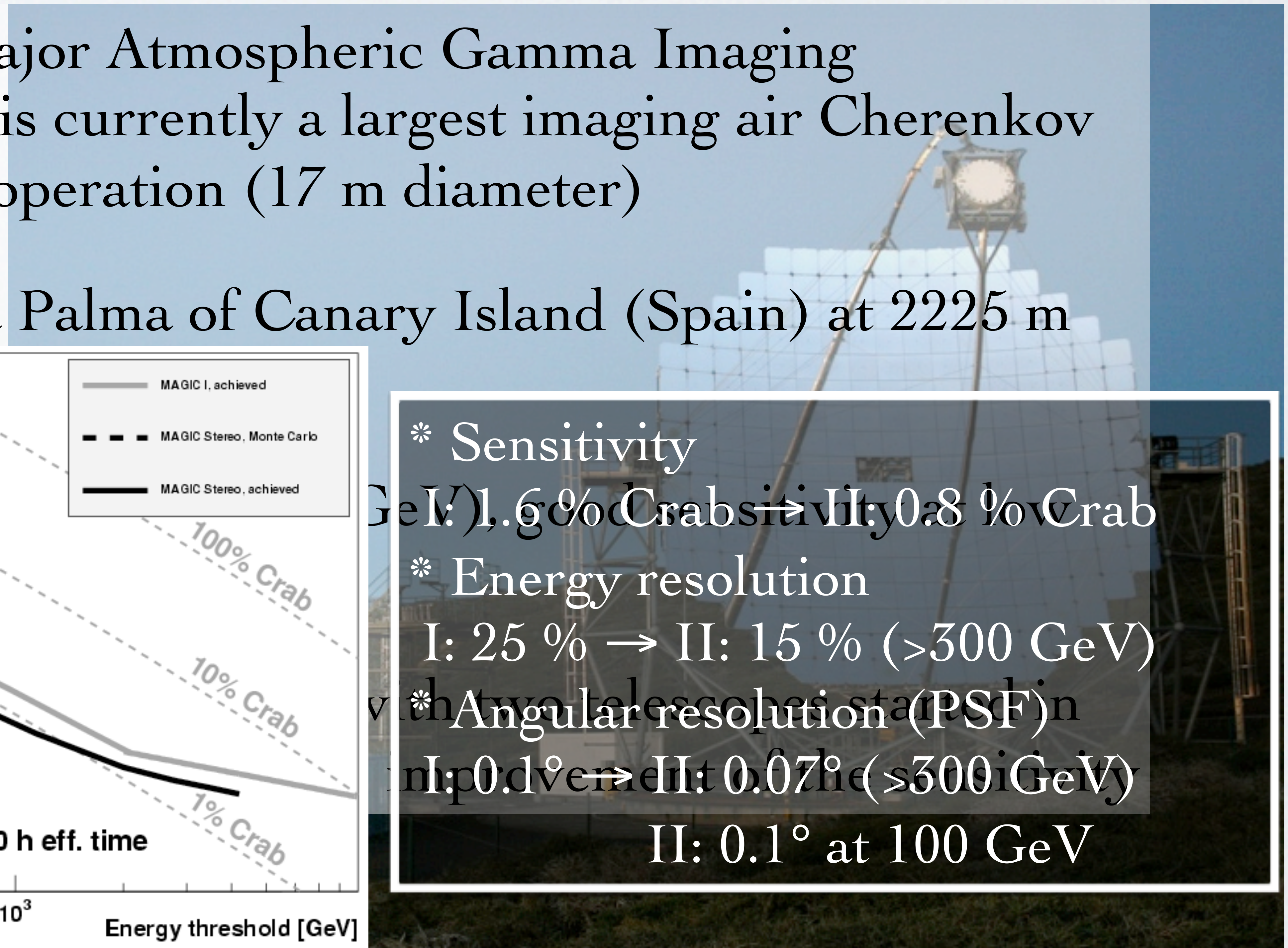
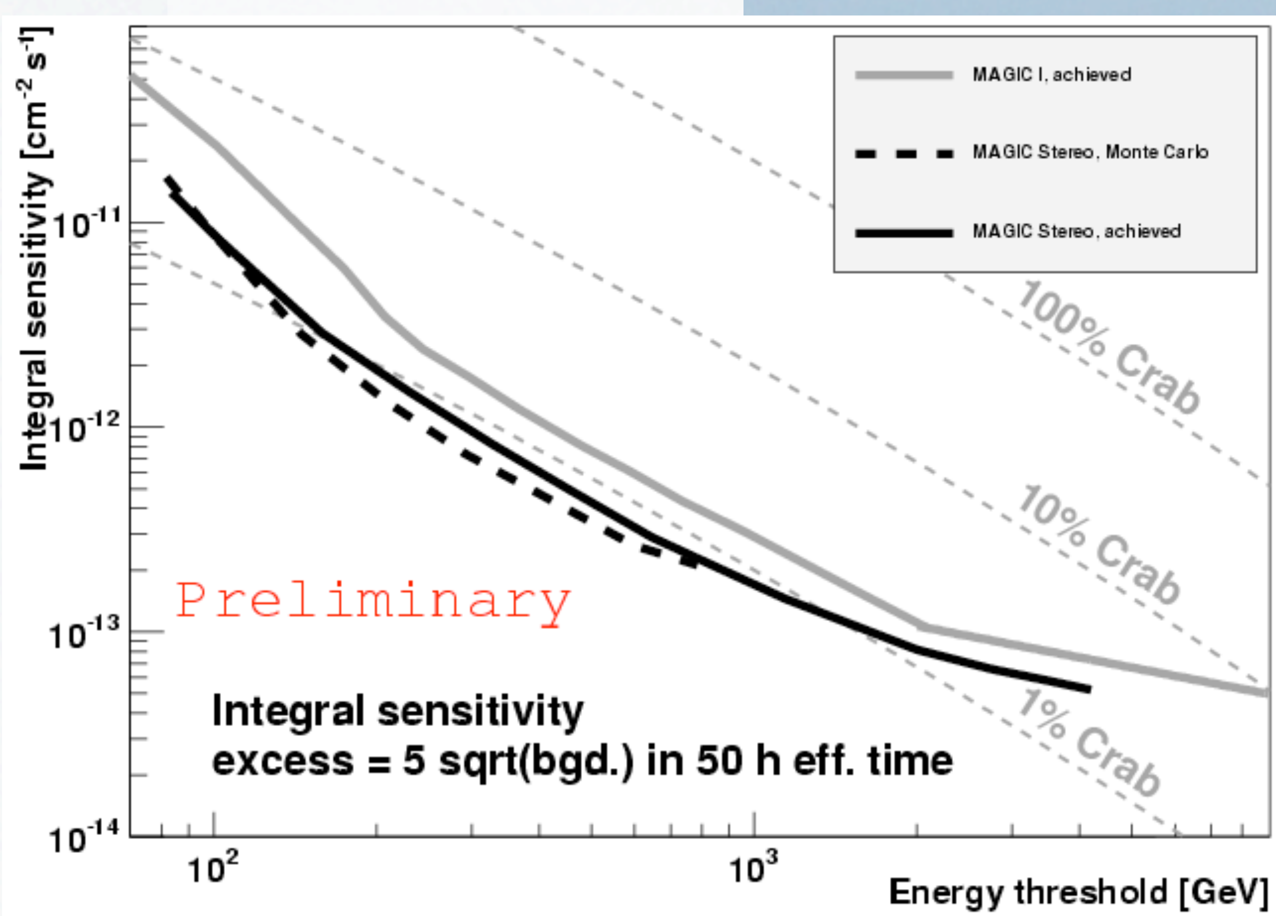
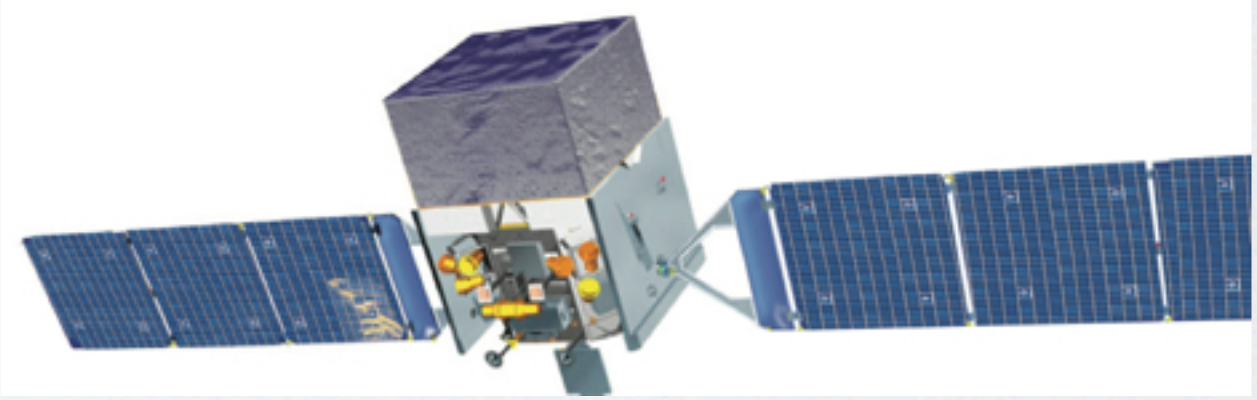




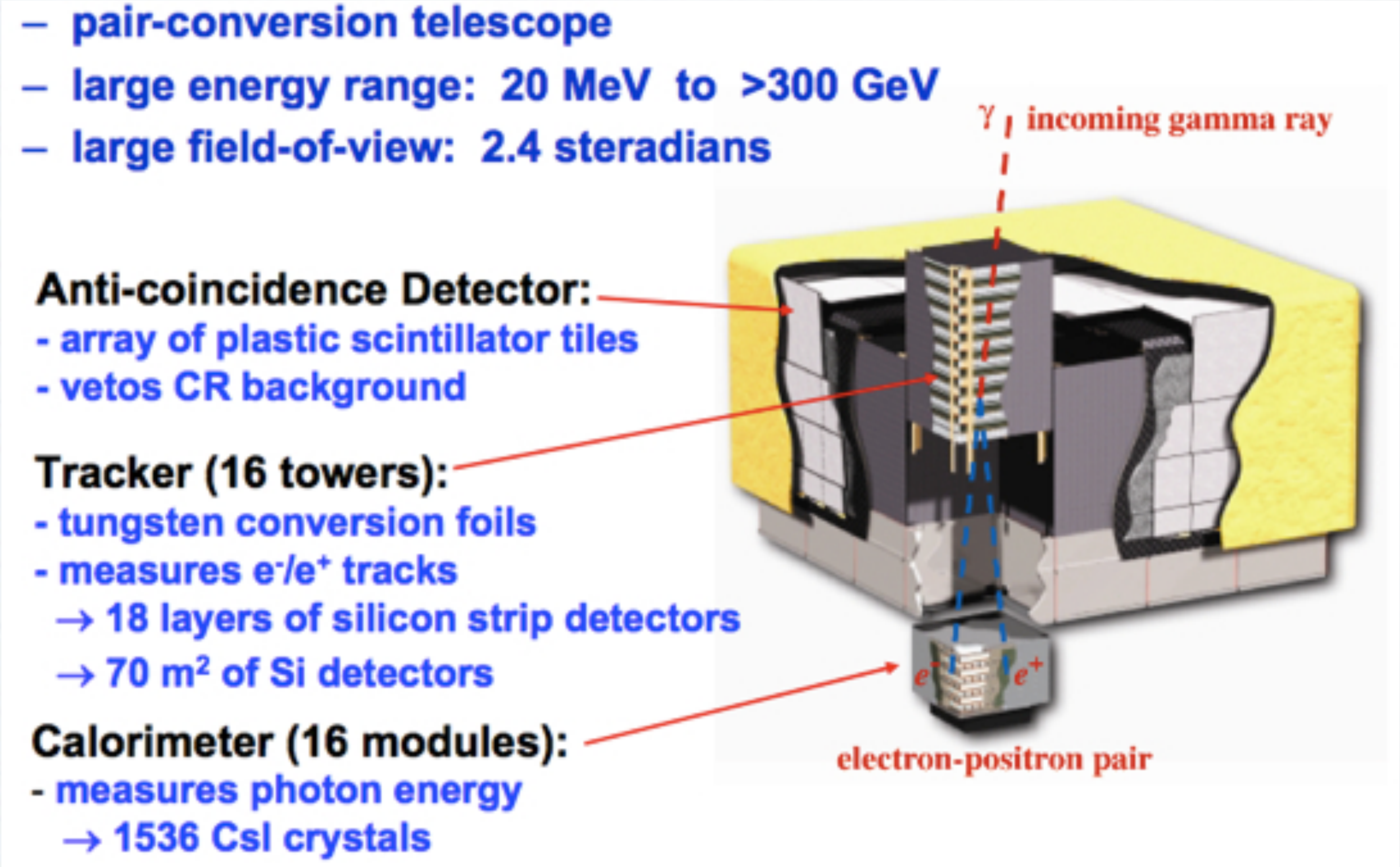
* Sensitivity
  I: 1.6 % Crab → II: 0.8 % Crab
* Energy resolution
  I: 25 % → II: 15 % (>300 GeV)
* Angular resolution (PSF)
  I: 0.1° → II: 0.07° (>300 GeV)
  II: 0.1° at 100 GeV

Fermi Gamma-ray Space Telescope

Fermi satellite launched on June 2008, carries Large Area Telescope (LAT) and GBM



- Fermi operates in an all sky scanning mode
- LAT covers the energy range >100 MeV



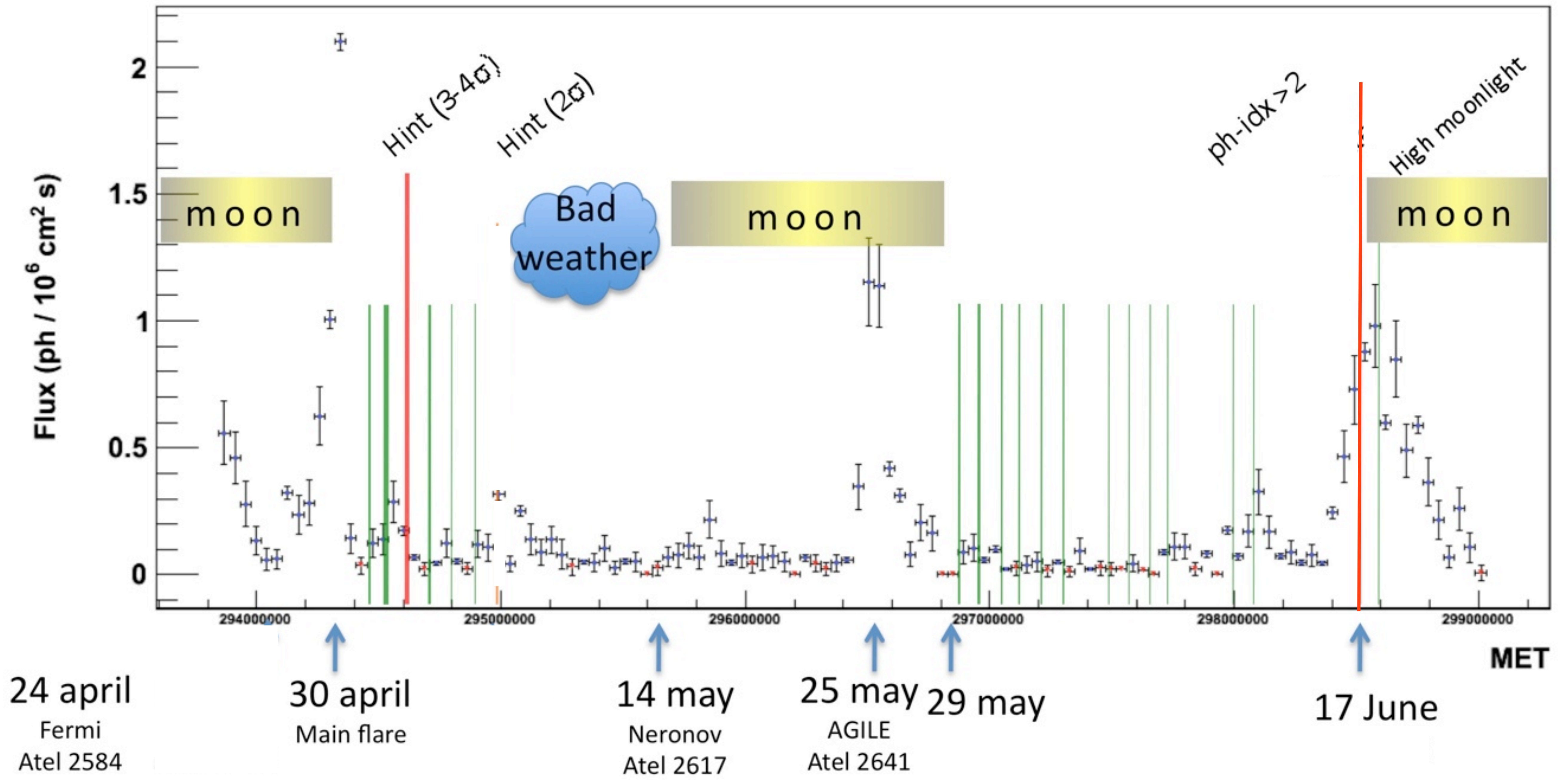
Most sensitive Fermi energy range (100 MeV ~ few GeV): Not affected by the EBL absorption

PKS 1222+216

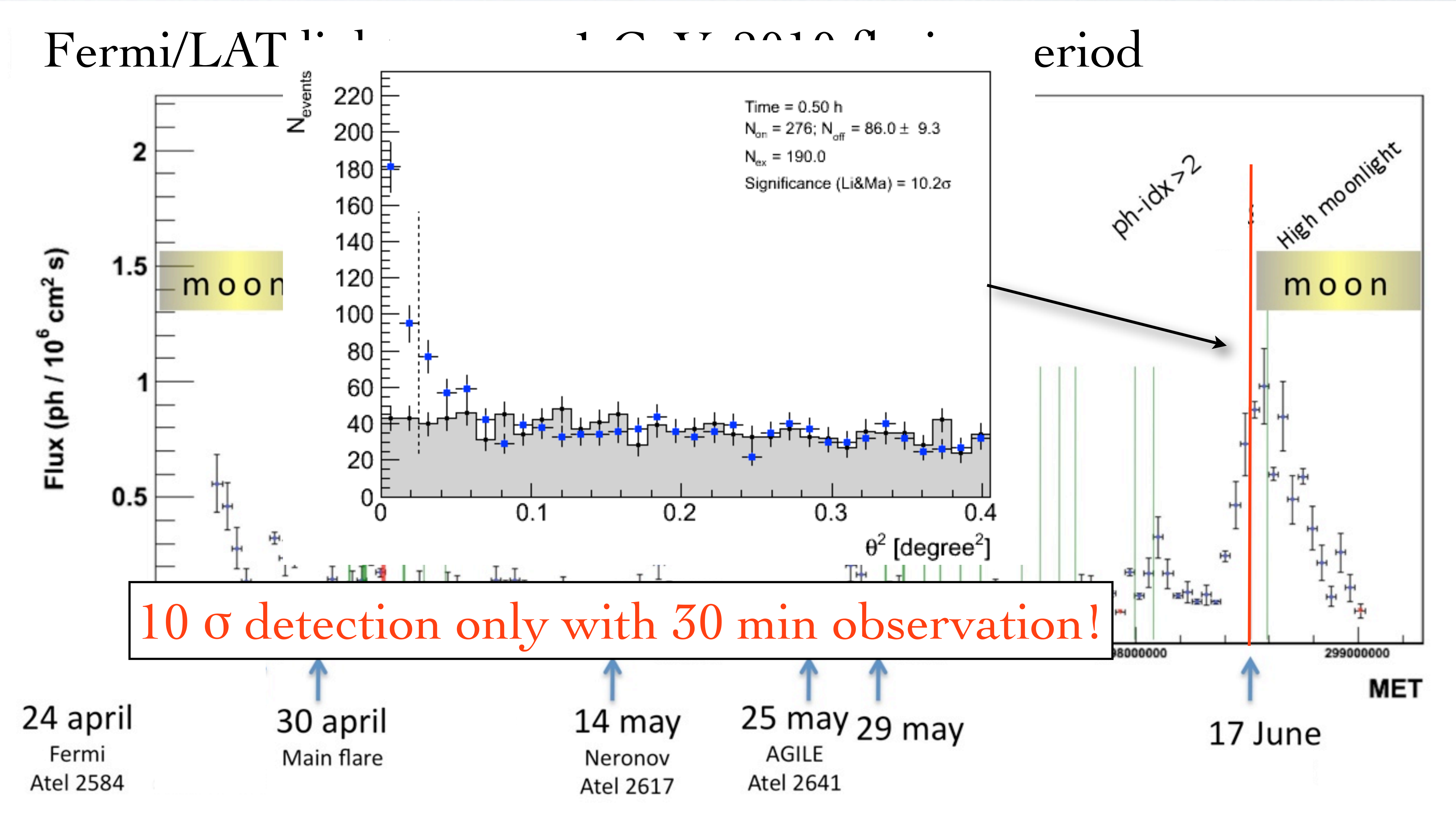
- A. k. a. 4C +21.35
- Flat-Spectrum Radio Quasar, z=0.432
- RA:12h24m54.4s, Dec: +21d22m46s (J2000)
- GeV detection by EGRET
- Whipple observation in 1994: Flux upper limit (10 % Crab Unit, >300 GeV)
- From 2009, several gamma-ray flares were reported by Fermi and AGILE

PKS 1222+216

Fermi/LAT light curve >1 GeV: 2010 flaring period



PKS 1222+216

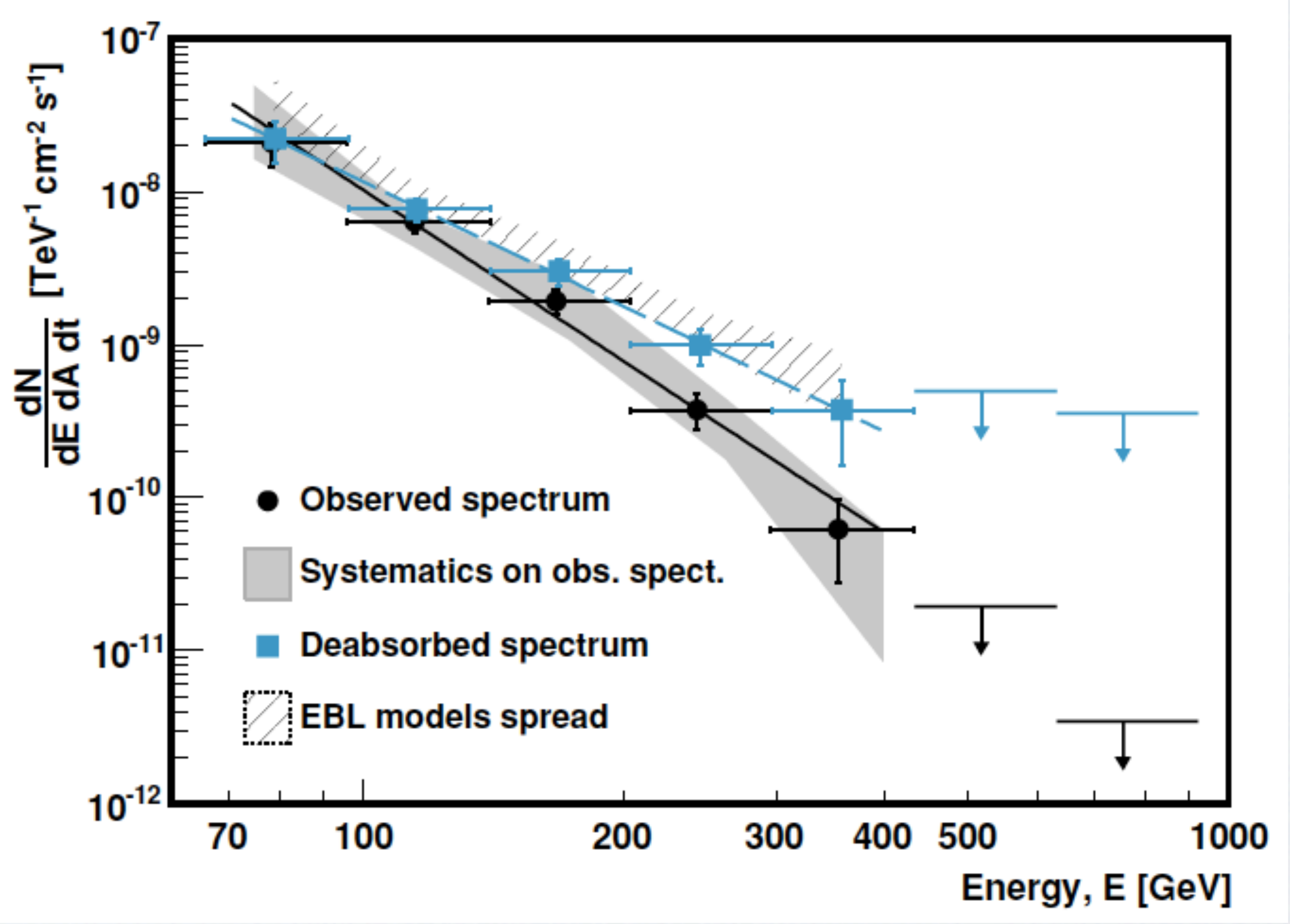


Fermi/LAT ... eriod
Time = 0.50 h
N_{on} = 276; N_{off} = 86.0 ± 9.3
N_{ex} = 190.0
Significance (Li&Ma) = 10.2σ
N_{events}
θ^2 [degree^2]
Flux (ph / 10^6 cm^2 s)
moon
moon
ph-idx>2
High moonlight
MET
299000000
10 σ detection only with 30 min observation!
24 april
Fermi
Atel 2584
30 april
Main flare
14 may
Neronov
Atel 2617
25 may
AGILE
Atel 2641
29 may
17 June

PKS 1222+216

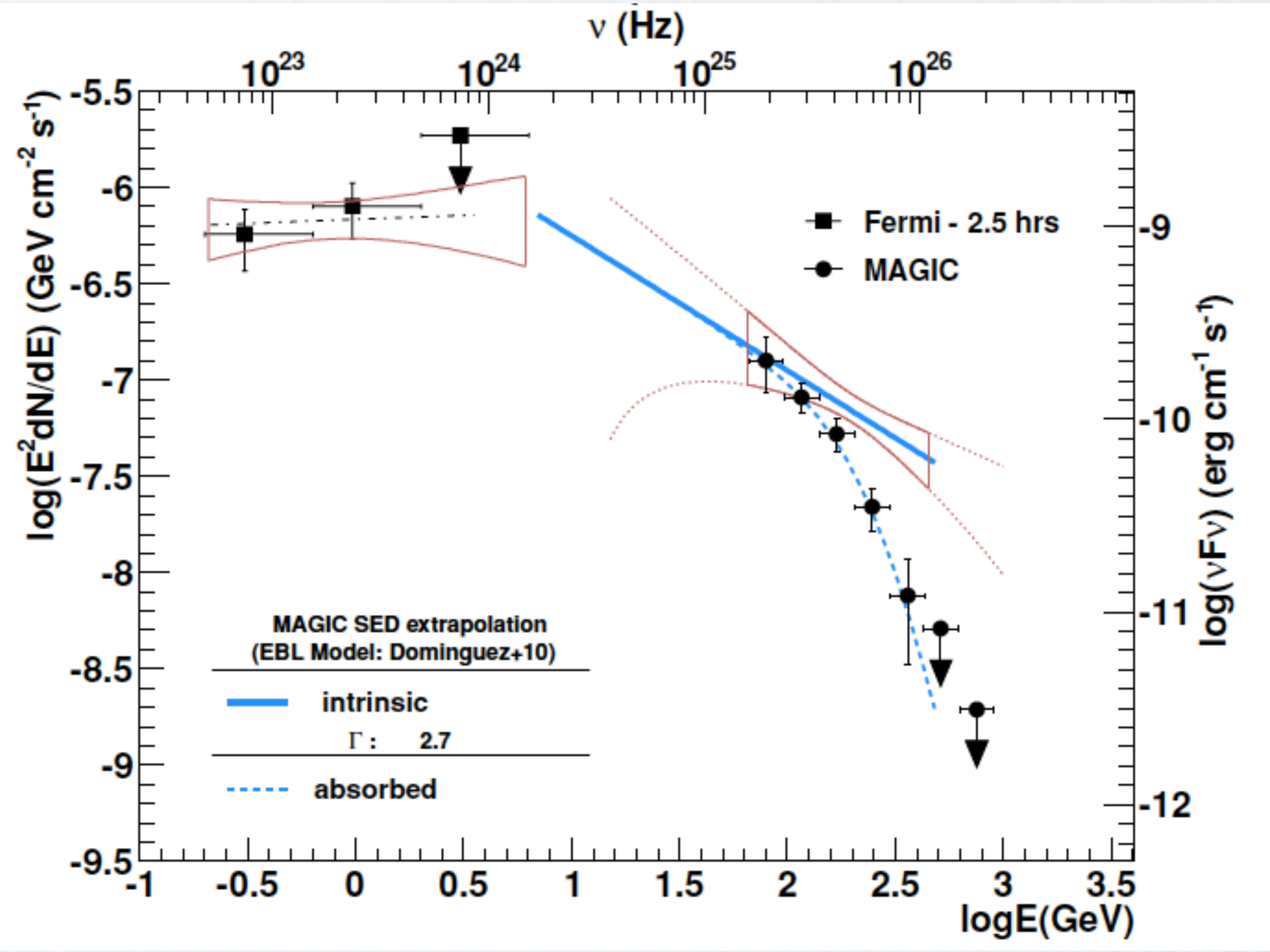
Observed and de-absorbed spectra are compatible with simple power-law

- Measured spectrum: α=3.75 ± 0.29
- De-absorbed Spectrum *(Dominguez+10)*: α=2.72 ± 0.34



PKS 1222+216

- Simultaneous *Fermi*/LAT 2.5 hrs encompassing MAGIC obs.



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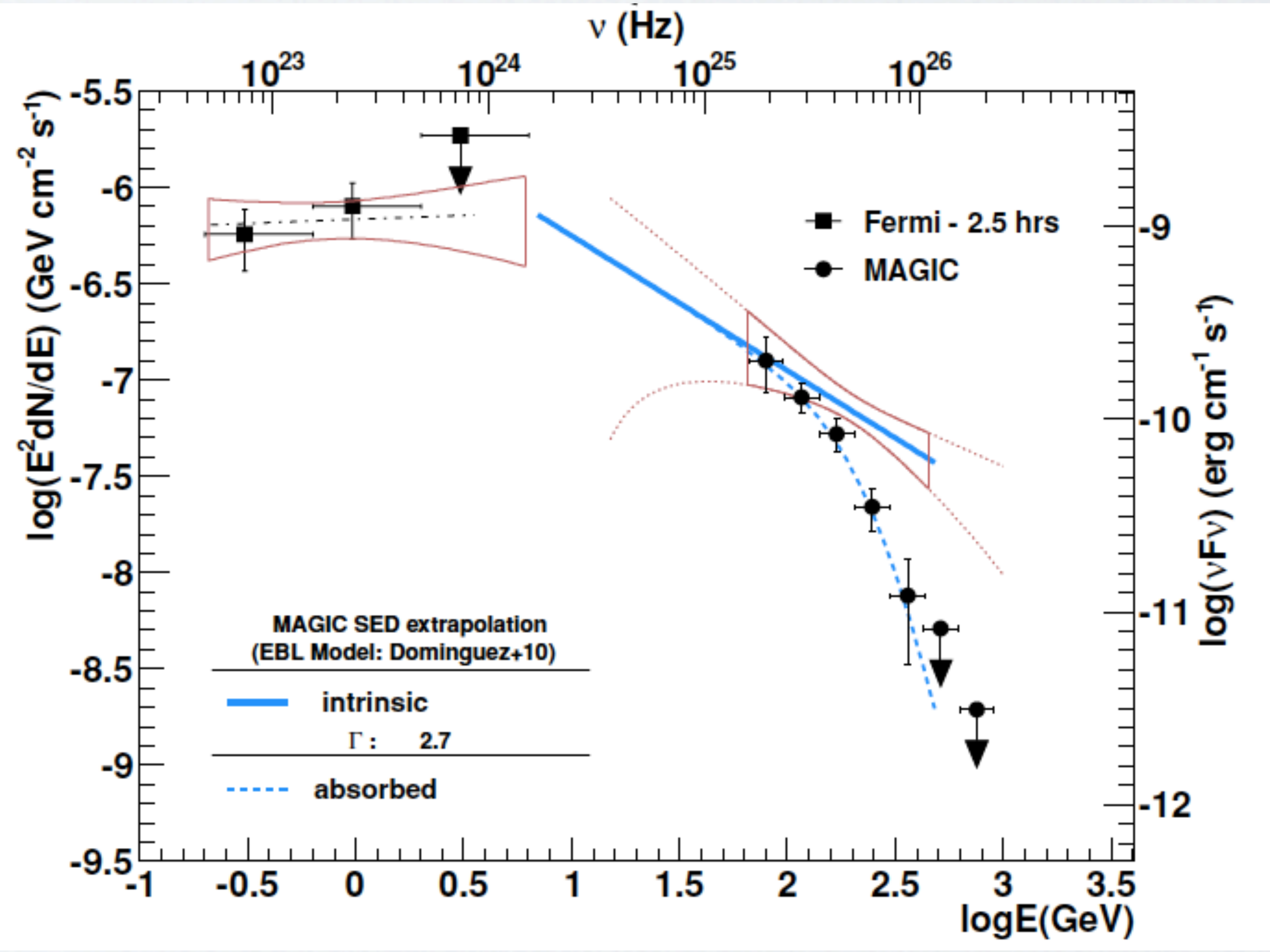
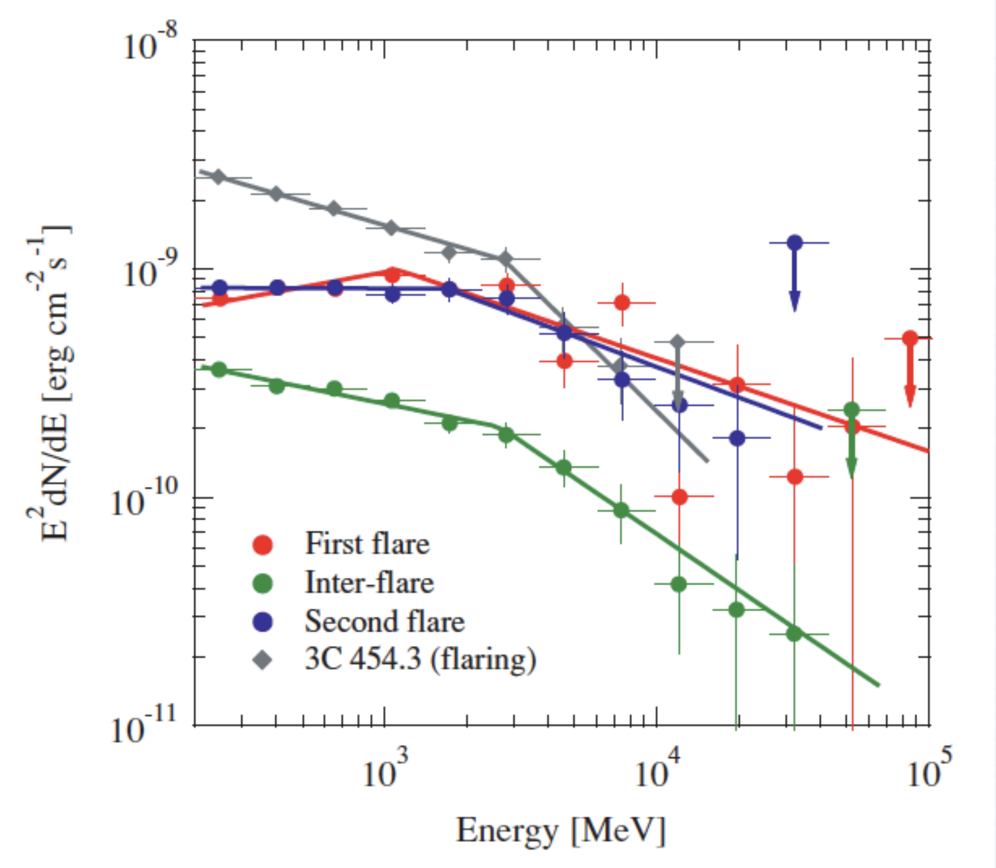


Fermi spectra
(longer time period)



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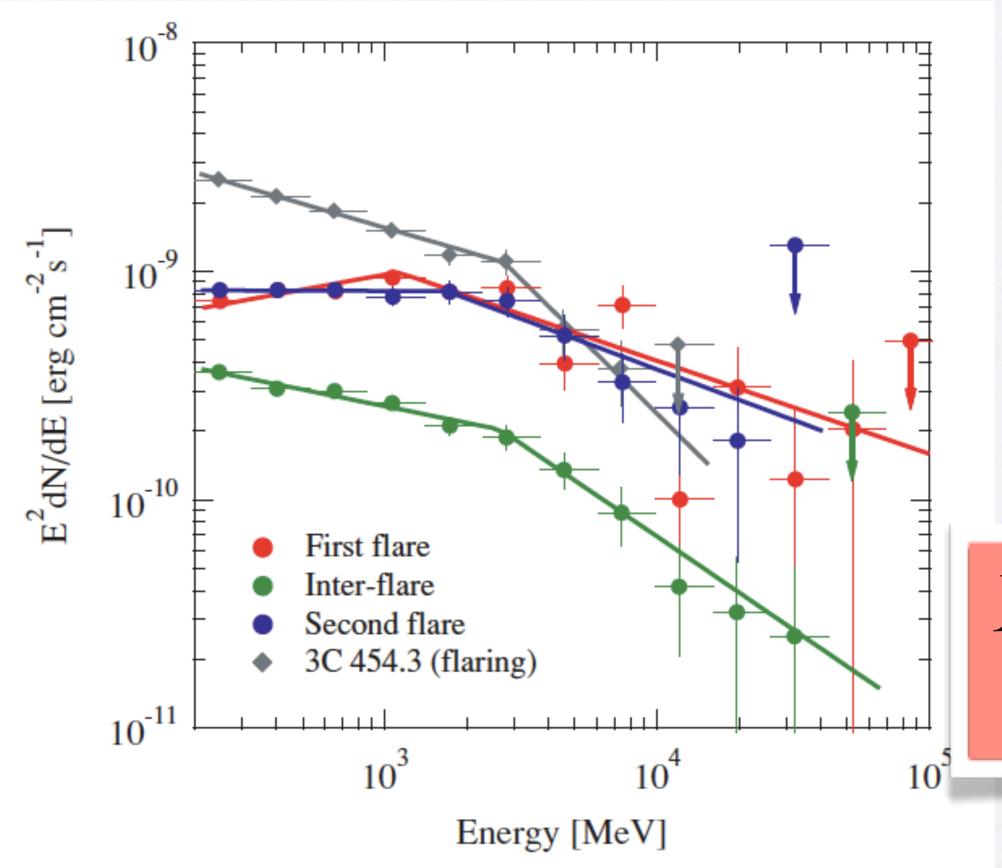
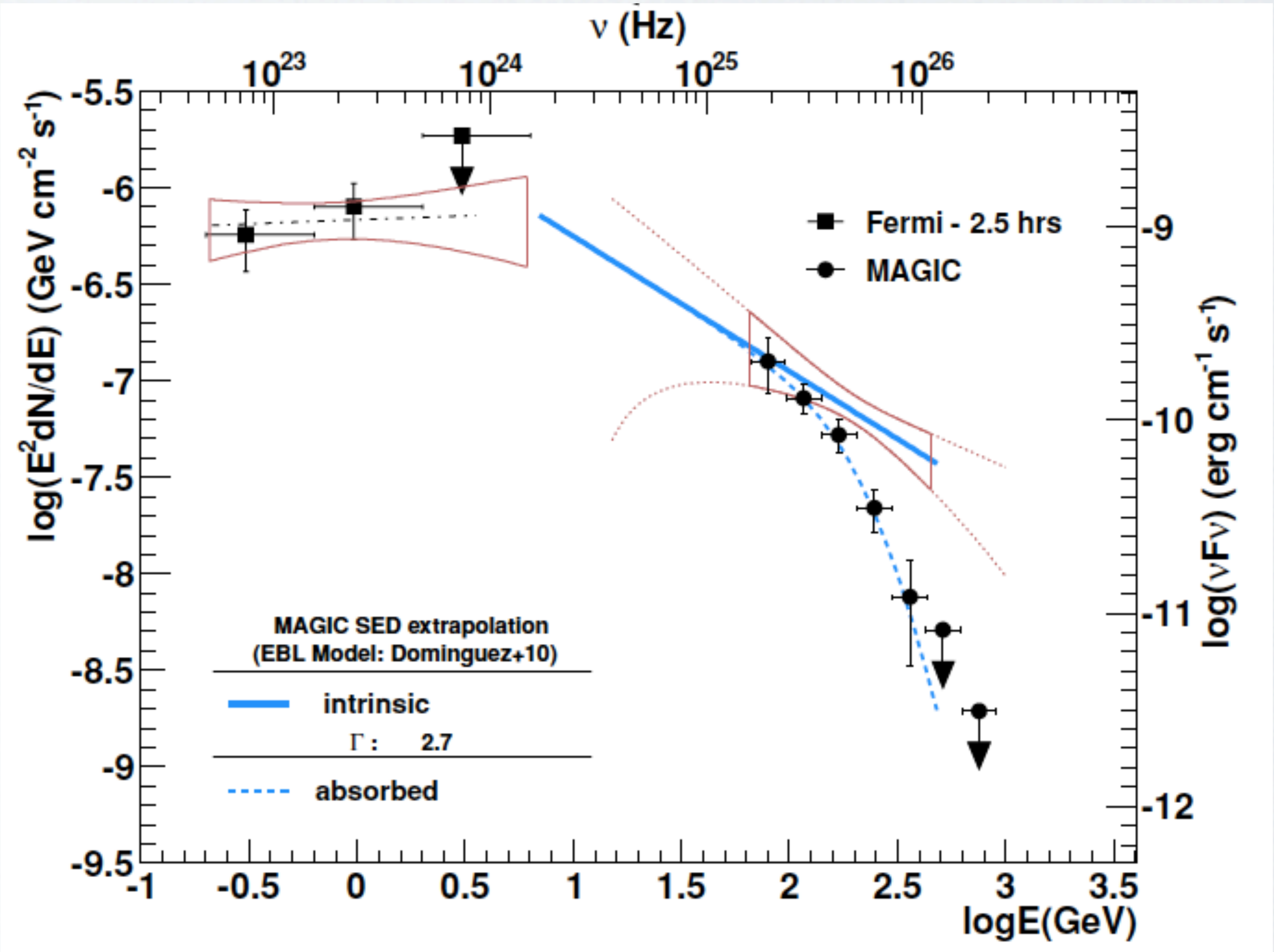




MAGIC intrinsic spectrum index is consistent with Fermi spectrum index after the break

PKS 1222+216

- Very fast variability

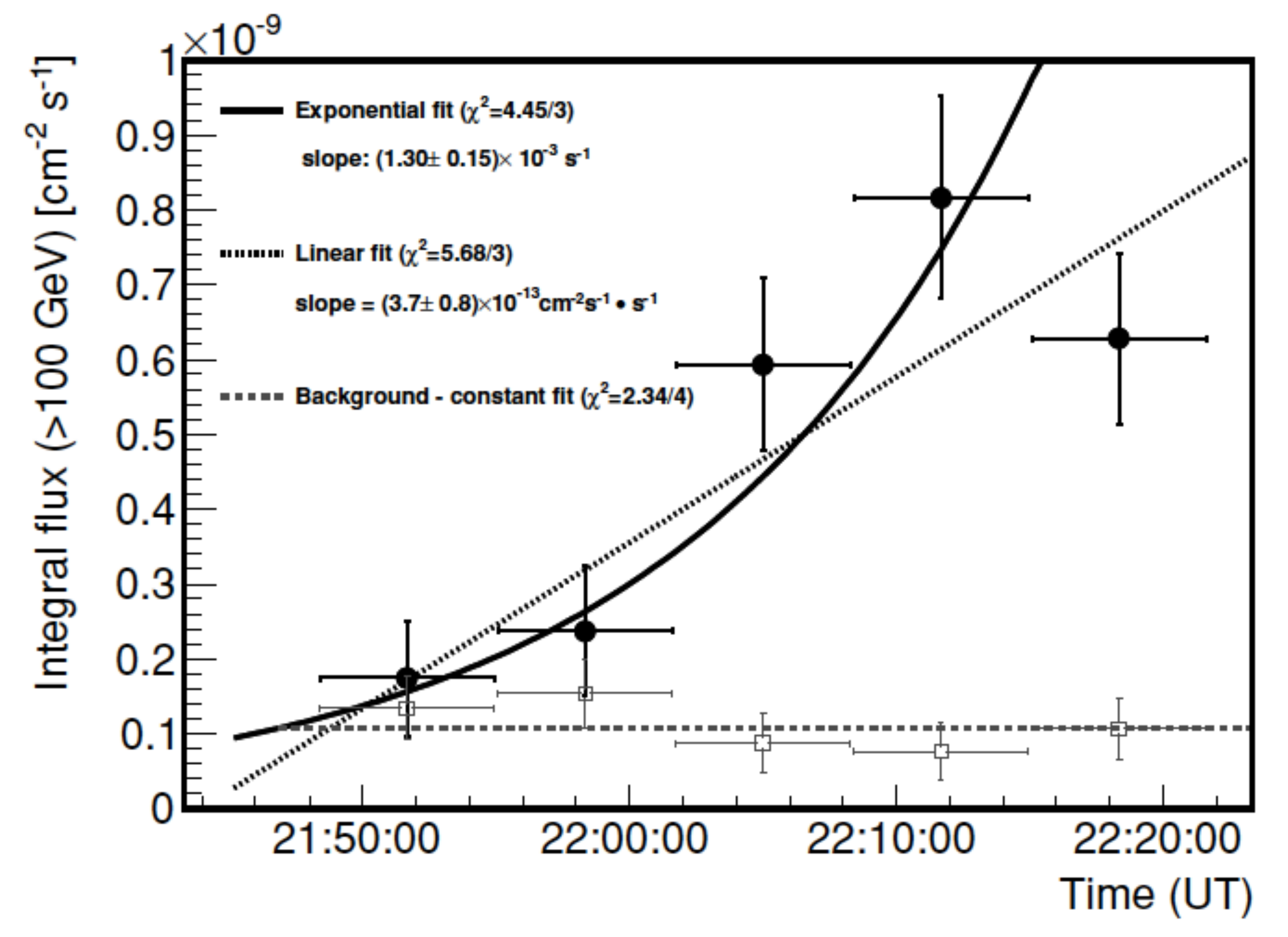
Doubling flux scale:
~ 10 minutes

Size emission region:

$R \sim 10^{14}$ cm

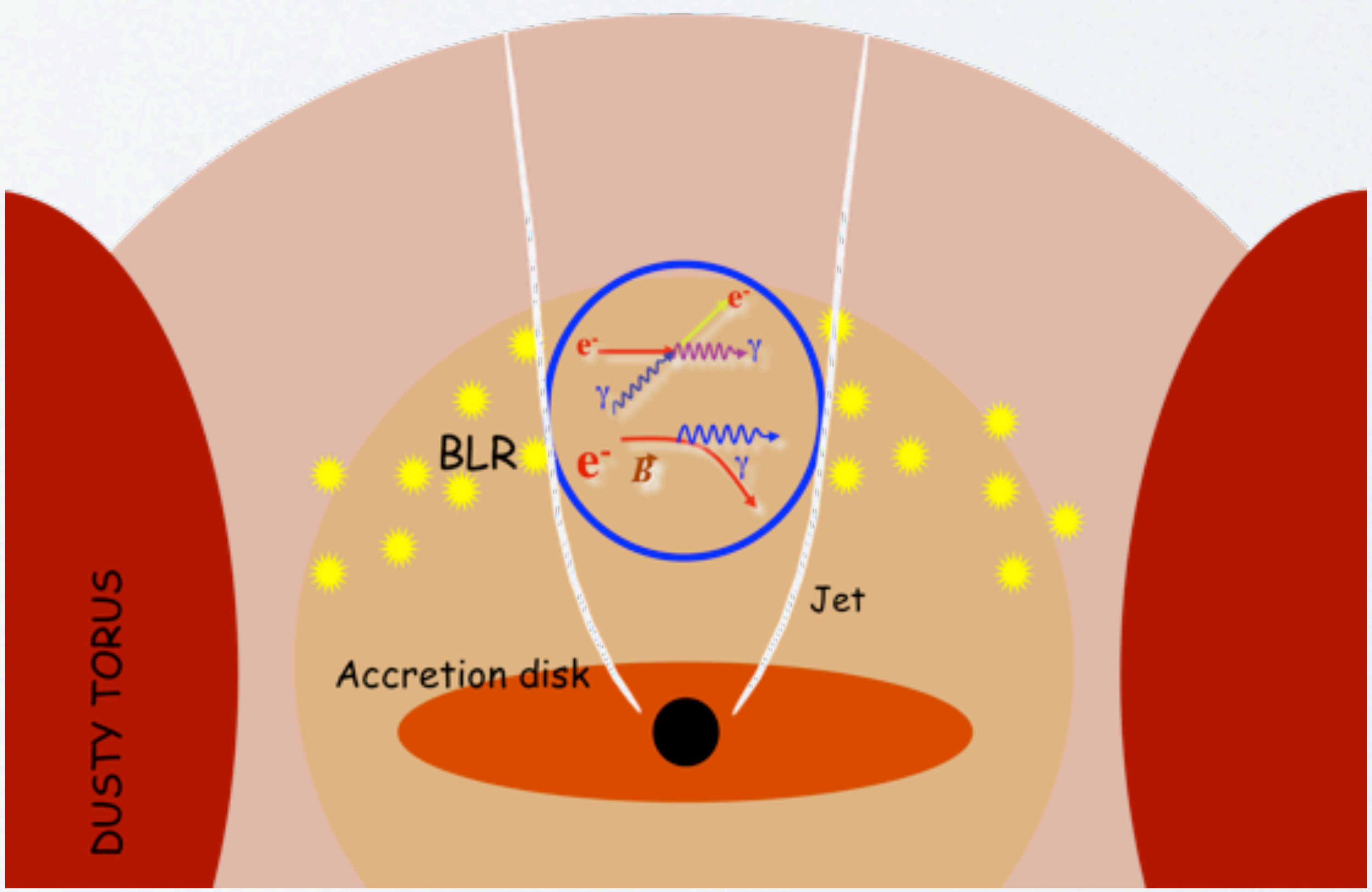
$$R < ct_{\mathrm{var}} \frac{\delta}{(1+z)} \approx$$

$$1.3 \times 10^{14} \left(\frac{\delta}{10}\right)\left(\frac{t_{\mathrm{var}}}{10\mathrm{min}}\right) \mathrm{cm}$$



Emission Zone

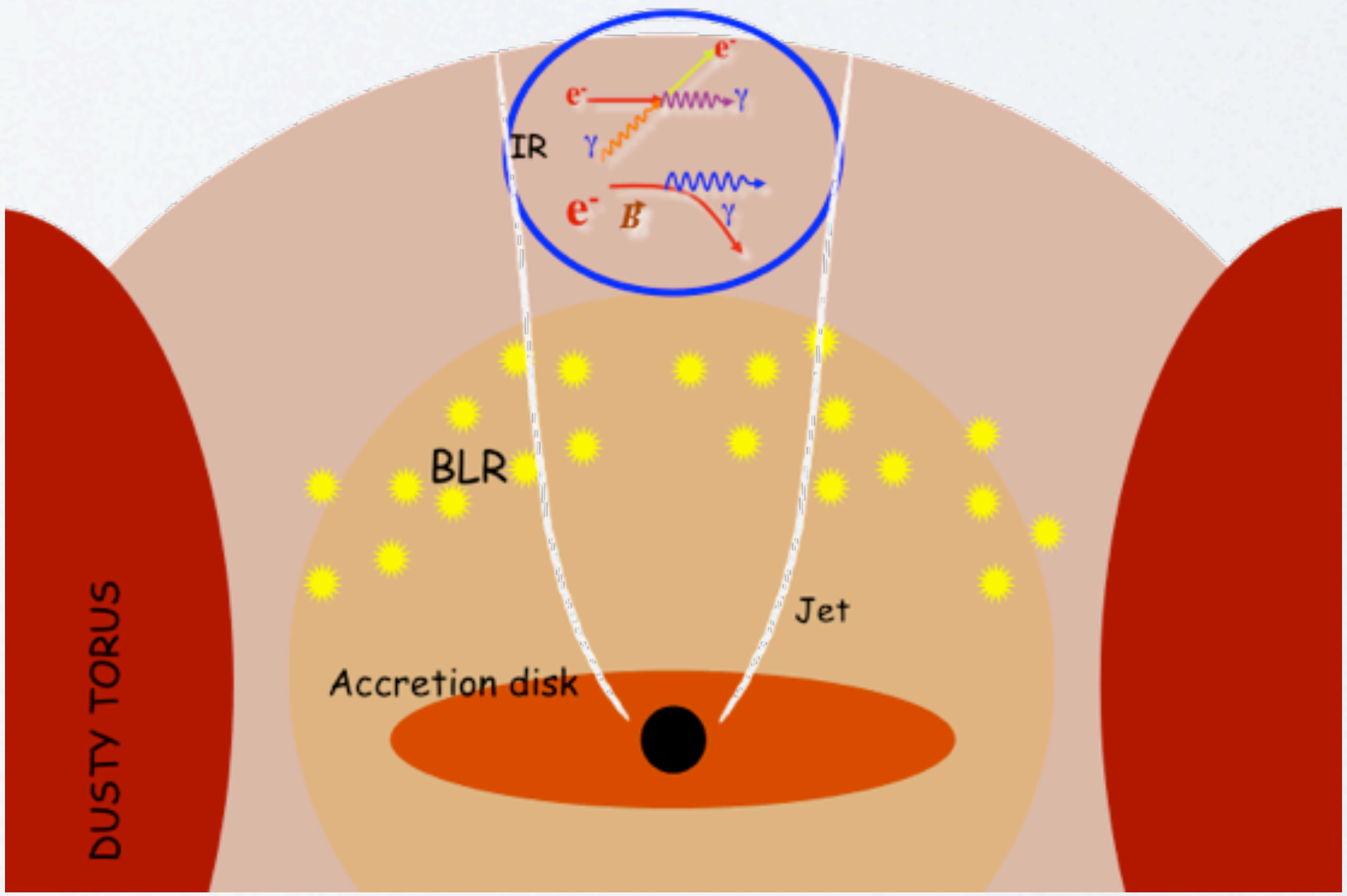
The "canonical" scenario



- ¤ Emission zone <0.1pc in conical jet within BLR
- ✓ Short time variability
- ☹ Internal absorption *e.g.* *Liu et al. 2008, Reimer 2007, Tavecchio & Mazin 2009*
- ☹ Reduced scattering efficiency Klein-Nishina (KN) e.g. *Albert et al. 2008, Tavecchio & Ghisellini 2008*

Emission Zone

The far-dissipation scenario

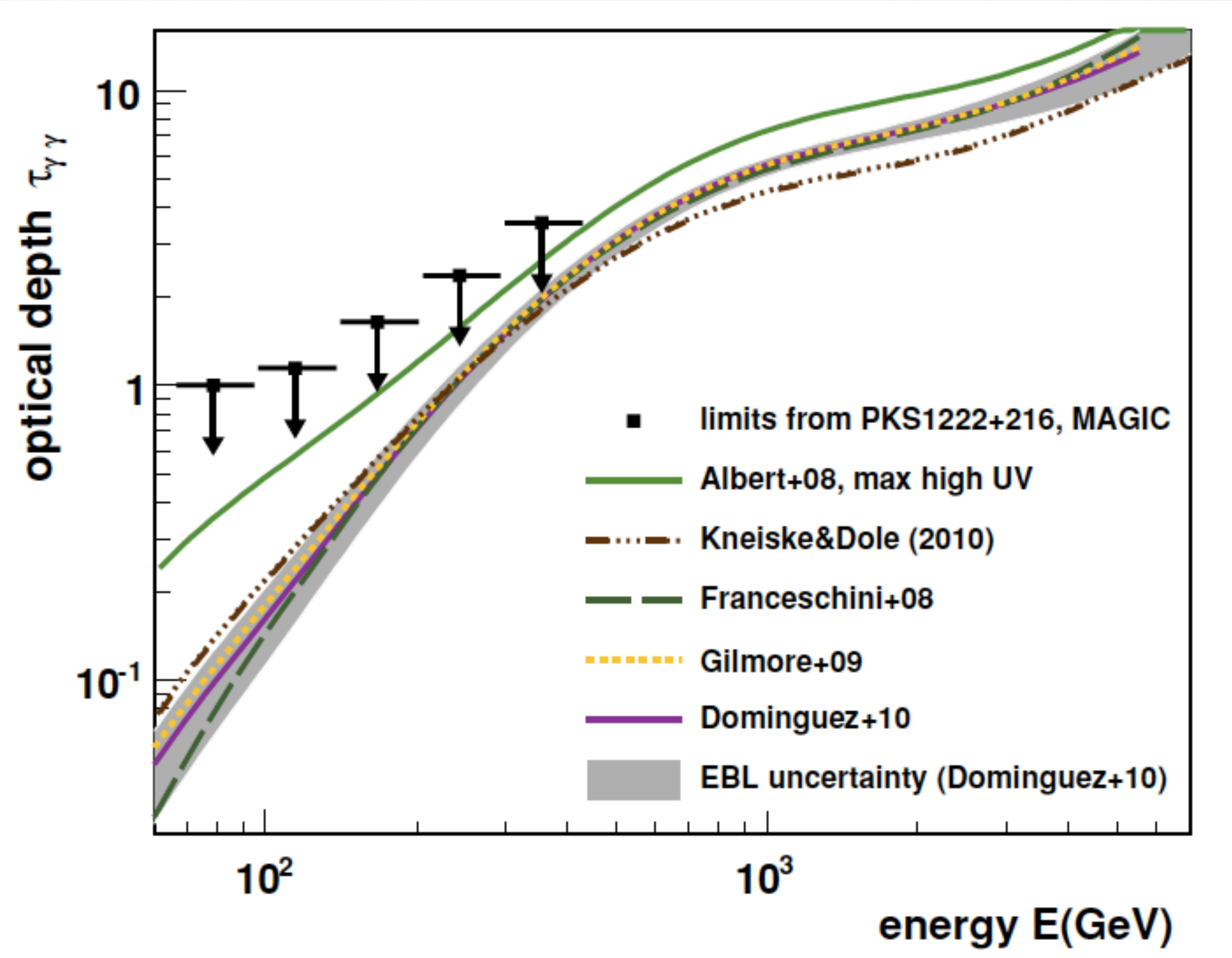


- ✧ Emission zone ~1-10 pc dusty/IR torus
- ✓ γ-ray ~ radio flares → optical thin → >1pc
- ☹ Fast variability ~<1 day e.g. 3C 454.3, PKS 1510-089 *Tavecchio 2010*
- ➤ E.g. 3C 279: t_{var}~20d bended jet R~10^{19}cm (10^5 R_{Sch}) *Abdo et al. 2010*

Summary

- MAGIC detected VHE gamma-rays from a distant AGN (FSRQ) PKS 1222+216 during the GeV flare observed by Fermi
- Energy spectrum can be reproduced by a single power-law
- Fast variability ~10 min
- Challenge to "canonical" and far-dissipation scenarios

More detail: Aleksič et al. ApJL 730 (2011)



optical depth $\tau_{\gamma\gamma}$
10
1
10^{-1}
10^2
10^3
energy E(GeV)
limits from PKS1222+216, MAGIC
Albert+08, max high UV
Kneiske&Dole (2010)
Franceschini+08
Gilmore+09
Dominguez+10
EBL uncertainty (Dominguez+10)