Recent MAGIC Observations of Active Galactic Nuclei: Studies in the E>50 GeV Region

Robert Wagner on behalf of the **MAGIC Collaboration**
Max-Planck-Institut für Physik & Excellence Cluster "Universe"
Munich, Germany

The MAGIC Telescopes

MAGIC Coll, Astropart. Phys. subm. arXiv:1108.1477
Carmona+ (MAGIC Coll), Proc ICRC 2011, arXiv:1110.0947

- Two-dish stereoscopic Cherenkov telescope, 17 m diameter each
- Located at the European Northern Observatory, Instituto Astrofísica de Canarias on the Canary Island of La Palma, Spain
- Currently upgrade of readout, of MAGIC-1 camera in 2012

- 150 physicists
- 23 institutes

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

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- Substantially lower energy threshold than other installations:
  - 50-60 GeV nominal
  - 25 GeV pulsar ("sum") trigger
- Sensitivity: 0.75% Crab in 50 h
- Angular resolution: <0.07°
- Energy resolution: 15-20%
- Enhanced duty cycle (by 20%) thanks to moonlight & twilight observations Britzger, RMW+09

- 150 physicists
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MAGIC
Major Atmospheric
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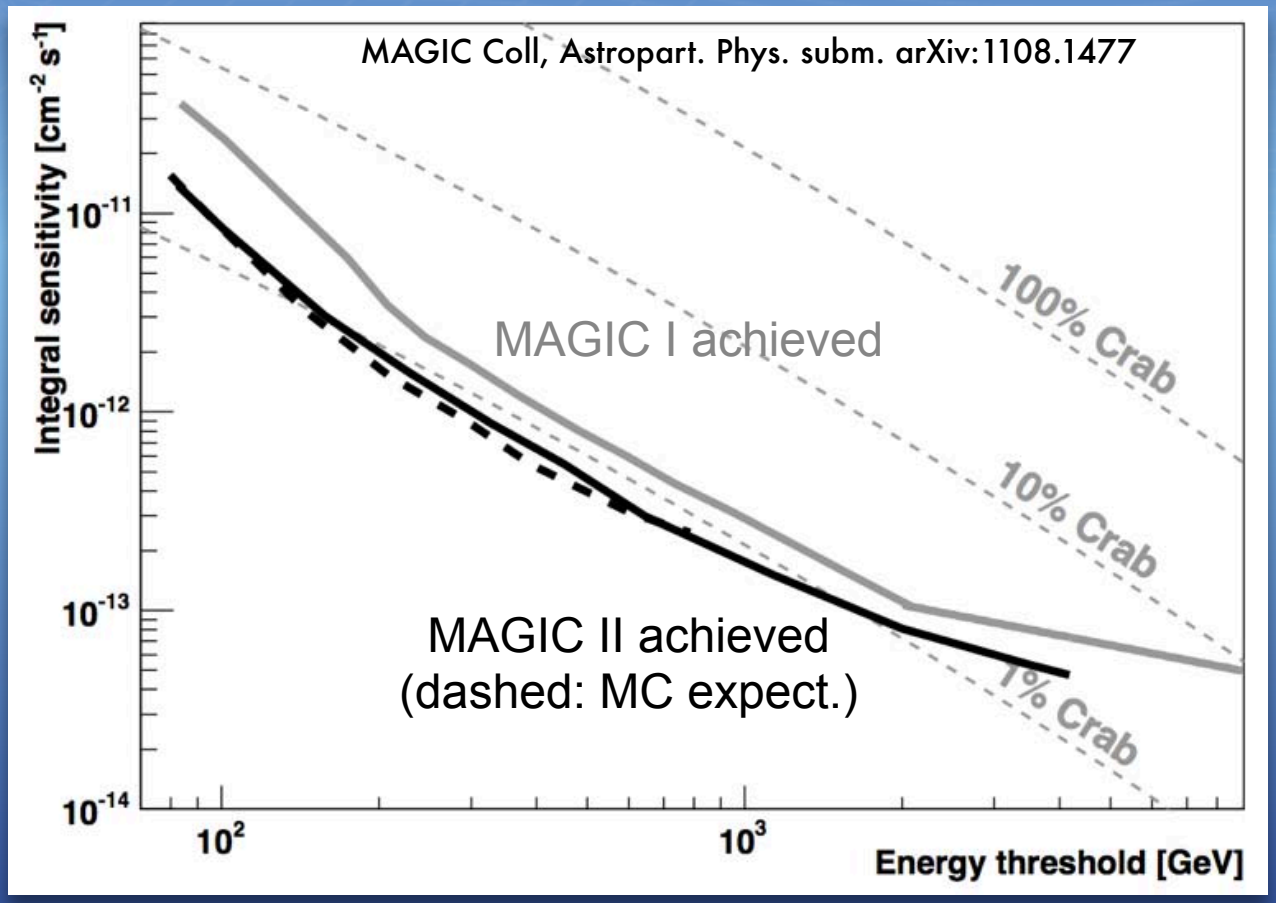
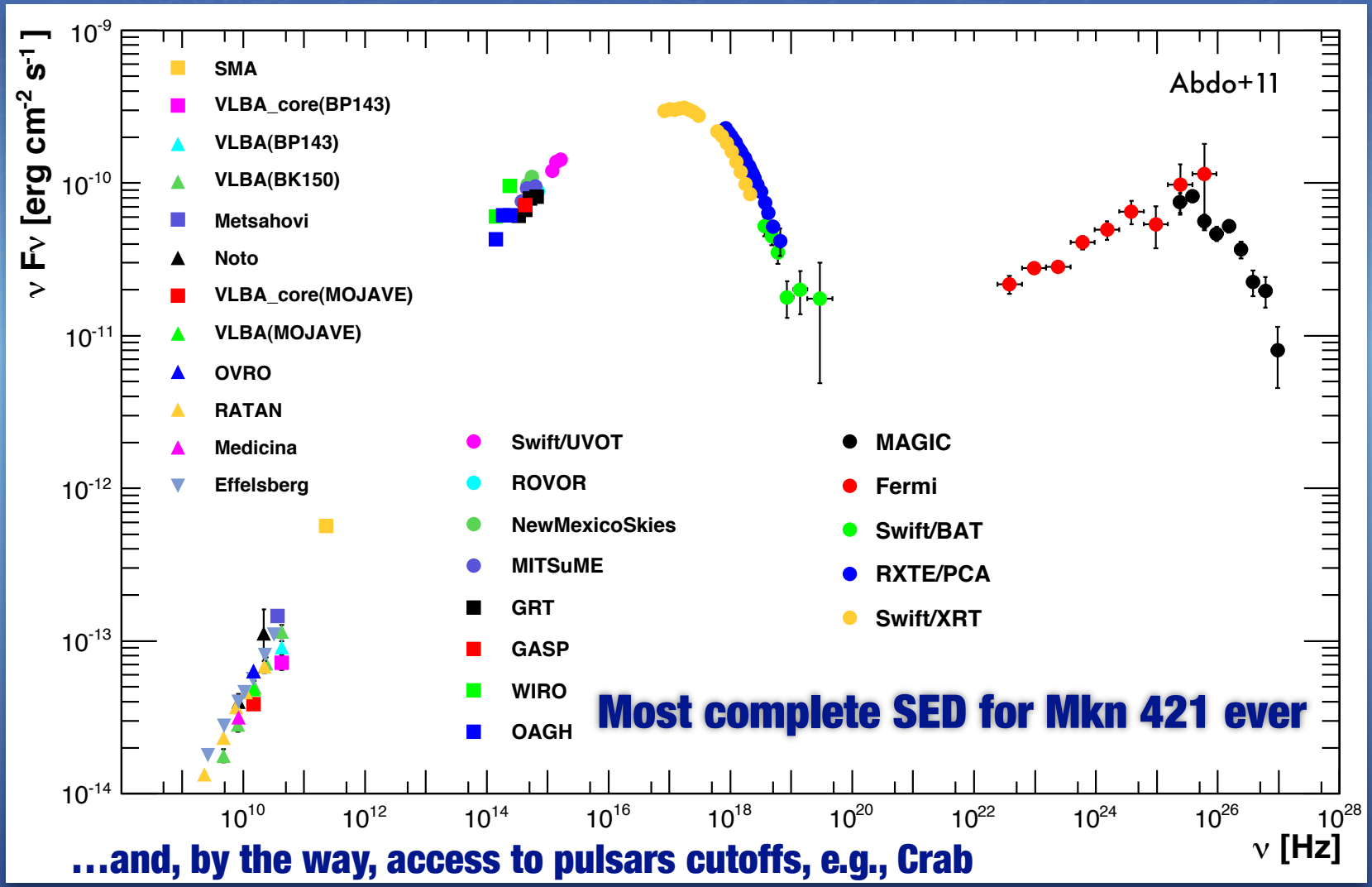
Some Key Features

- Fast repositioning (below 1 minute) → sensitivity to transients: GRB
- Low energy threshold (50-60 GeV, 25 GeV in sum-trigger mode)
  - Overlap with Fermi-LAT
  - Deep universe

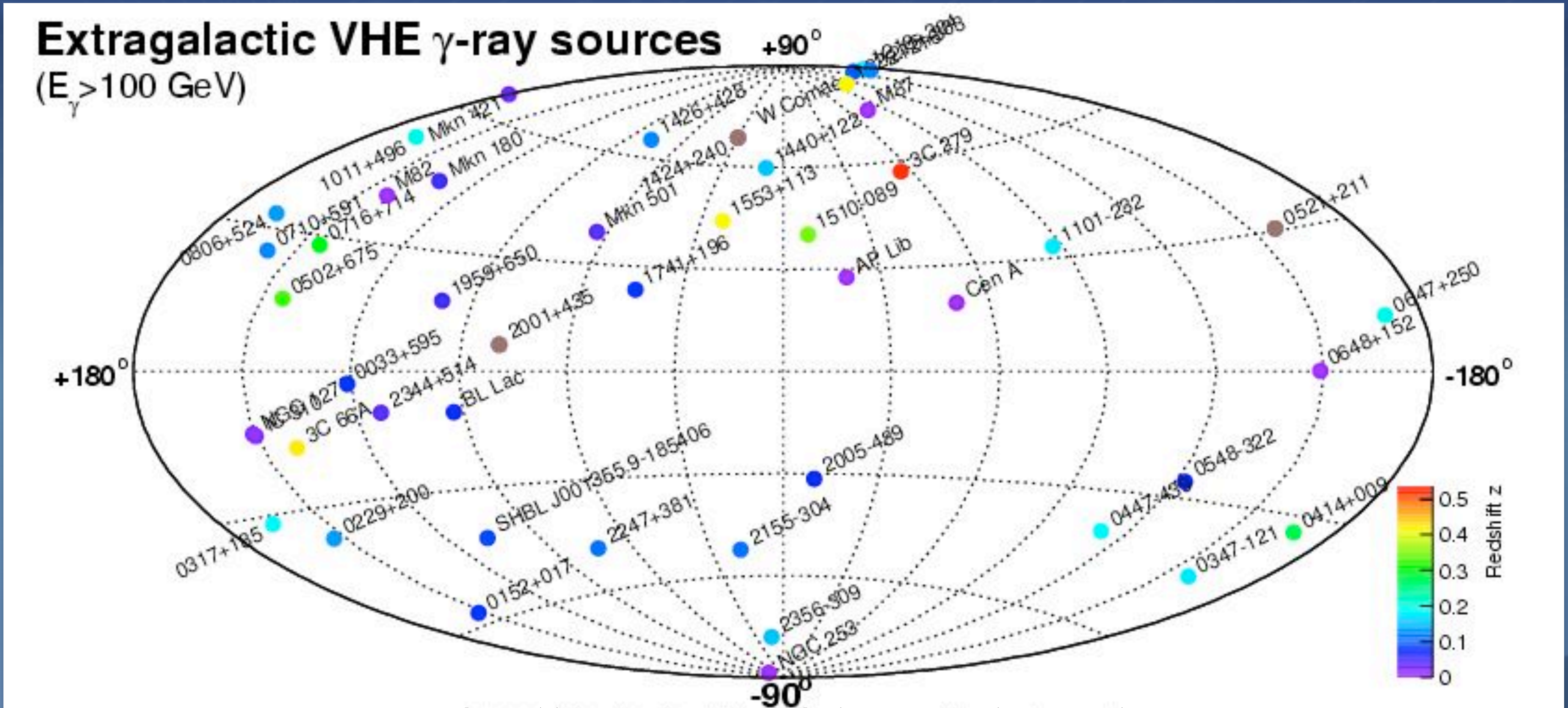


Low Threshold: Overlap with Fermi-LAT

(IC peak, cross-calibration)



The Extragalactic TeV Sky

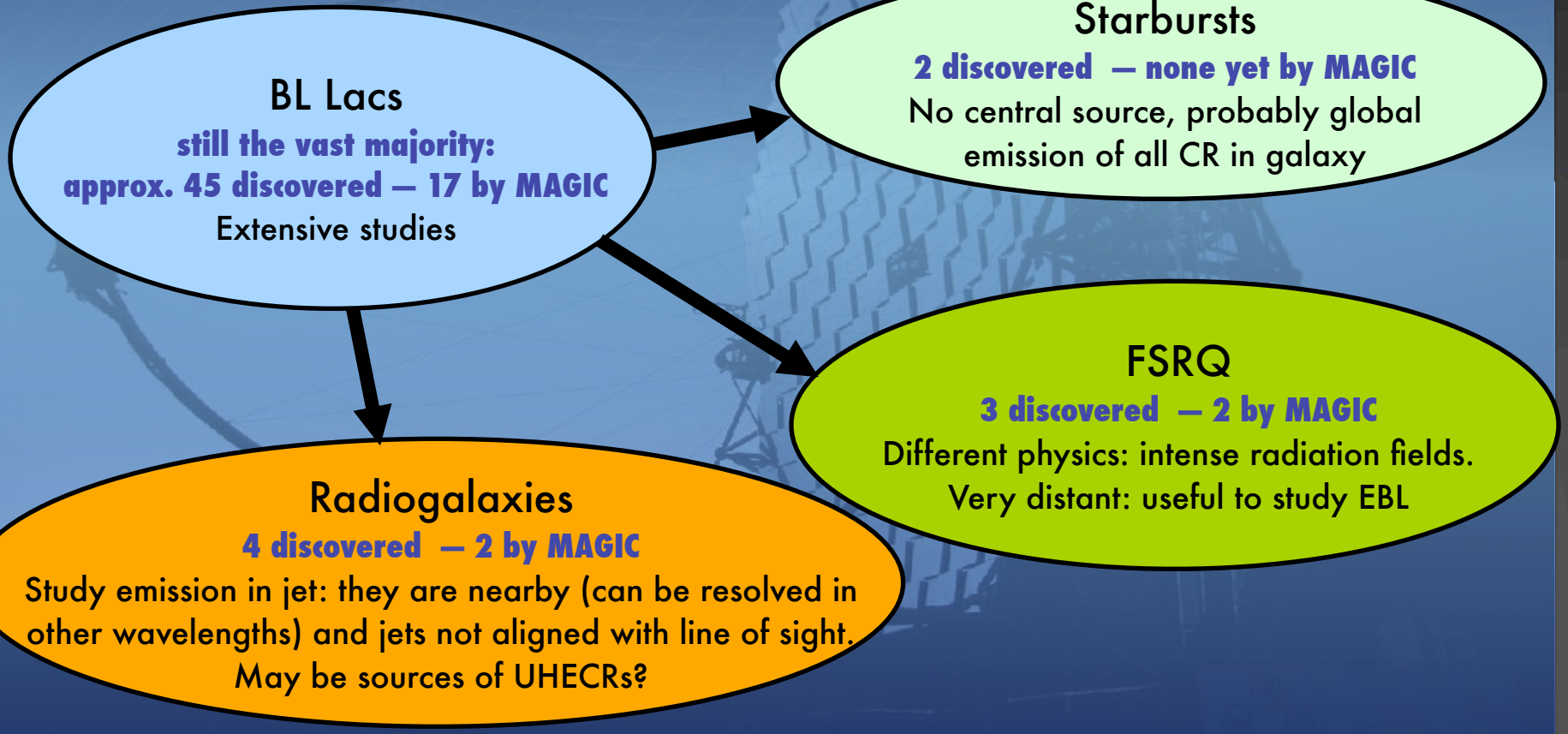


http://www.mpp.mpg.de/~rwagner/sources/

- approx. 50 VHE γ-ray sources, mostly blazars
- Relativistically beamed gamma-ray emission

Beyond blazars…

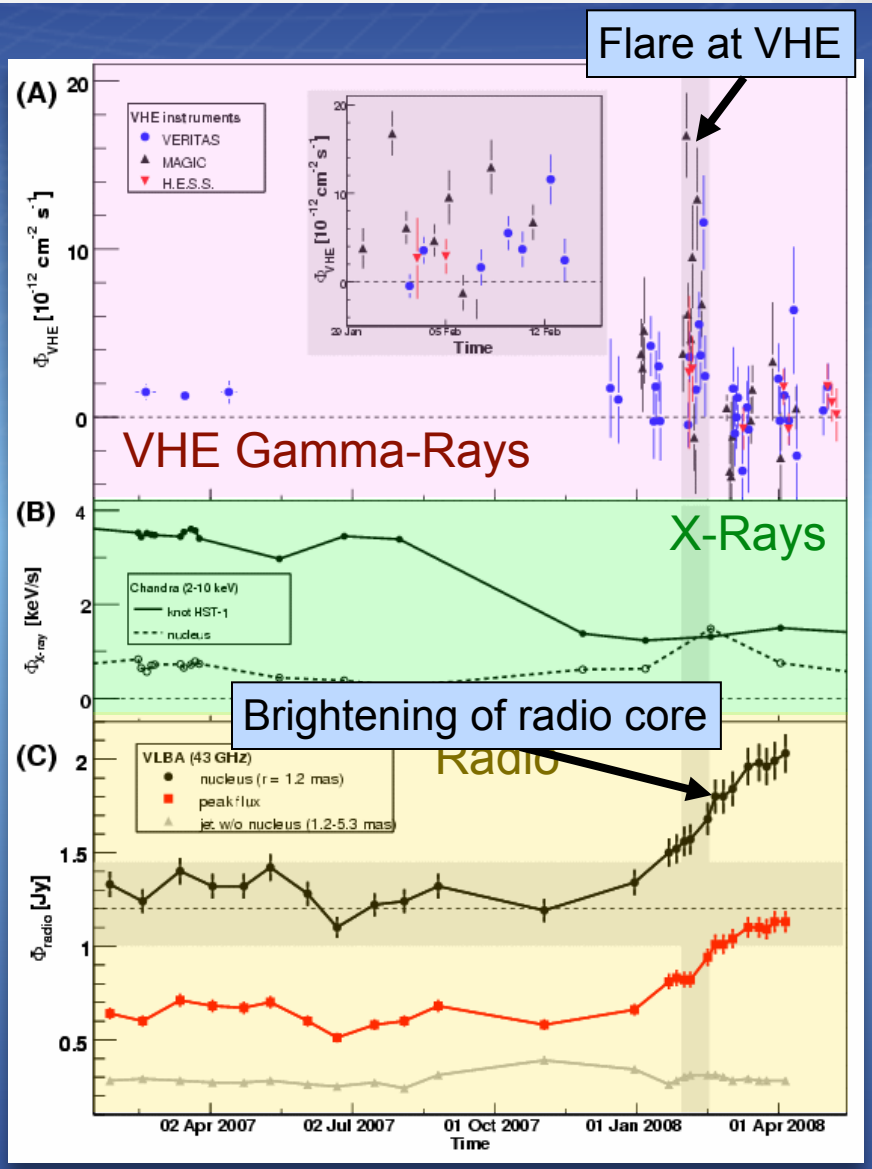
- New generation IACTs have established new classes of VHE active galaxies different than BL Lacs…
- Radio galaxies M87, Cen A, starburst galaxies M82, NGC 253, Perseus cluster galaxies IC310, NGC 1275



Radiogalaxies: M87

Science 325 (2009) 444

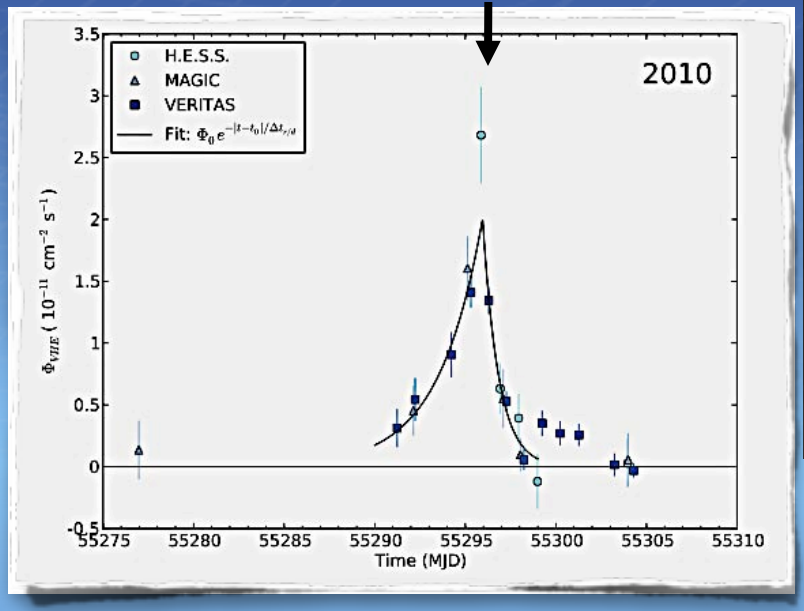
- Very close (17 Mpc)
- Very well characterized in other frequencies.
- M87 was the first radiogalaxy discovered a VHE (HEGRA/HESS) and has been extensively studied by HESS, VERITAS & MAGIC.
- In 2008, using all 3 experiments and simultaneous radio VLBI: VHE emission came from very close to the central BH (a few Schwarzschild radii, R_s~100 A.U.). Science 325 (2009) 444



Radiogalaxies: M87

VERITAS/MAGIC/HESS/
Walker+/Harris+ ApJ subm.
Harris+ ApJ subm.

Very dense sampling: 21 observations in 15 days. Rise in 1.7 days, decay in 0.6 days



Further cooperation of the 3 experiments and multiwavelength add essential information...
but may be complicating the picture!
Results submitted to ApJ:

- In total, 3 flares at VHE: 2005, 2008 and 2010.
- Flare in 2010 showed exponential rise and decay. Not so clear for the others.
- 2nd flare was followed by a radio brightening of the core Science 325 (2009) 444. The others not.
- In 2008 and 2010, VHE simultaneous to increase in X-rays. Unclear in 2005.
- Do all flares come from the same emission site? How are they produced?

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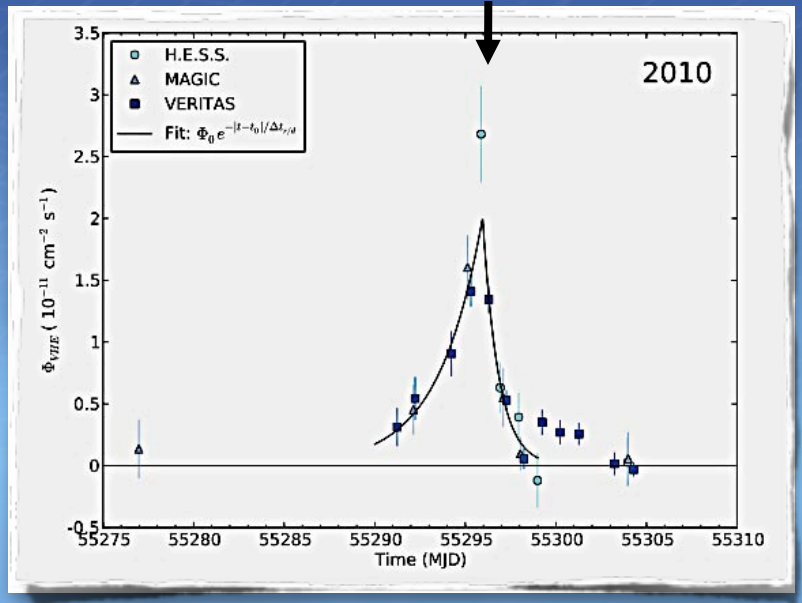
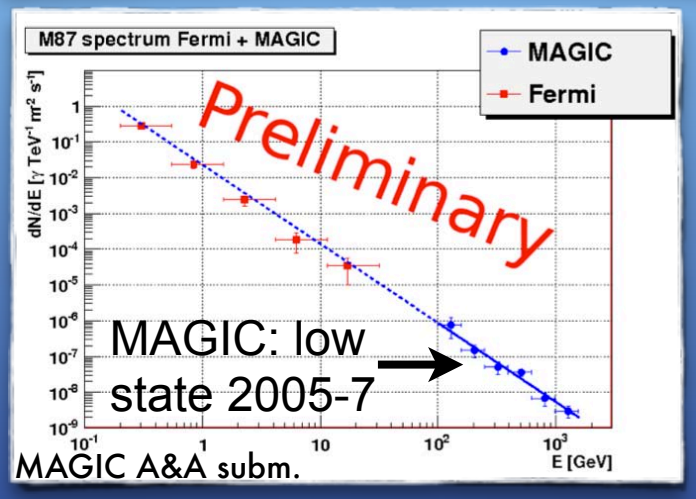


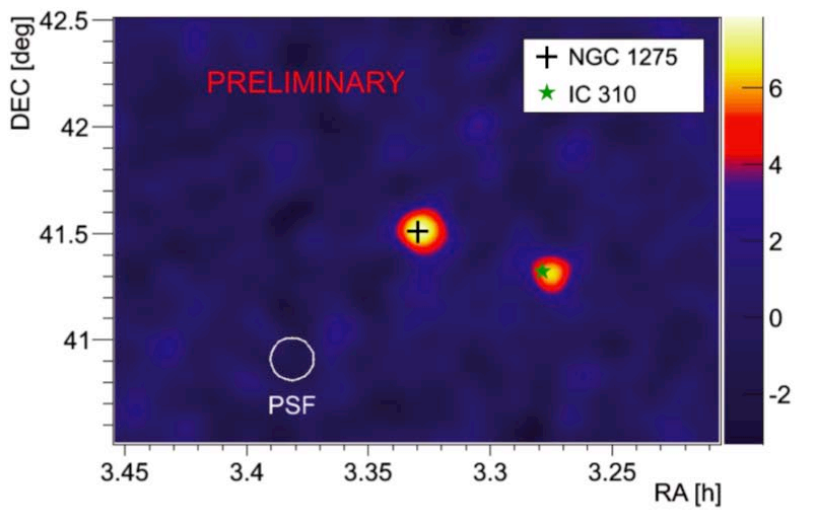
Recently, MAGIC studied only low state: spectral index consistent with high state emission, pointing to the same emission mechanism.



Radiogalaxies: IC 310, NGC 1275

MAGIC Coll., ApJL 723 (2010) L207
Hildebrand+ ICRC 2011
MAGIC Coll.

MAGIC has discovered 2 radiogalaxies: IC 310 and NGC 1275, both in the Perseus cluster



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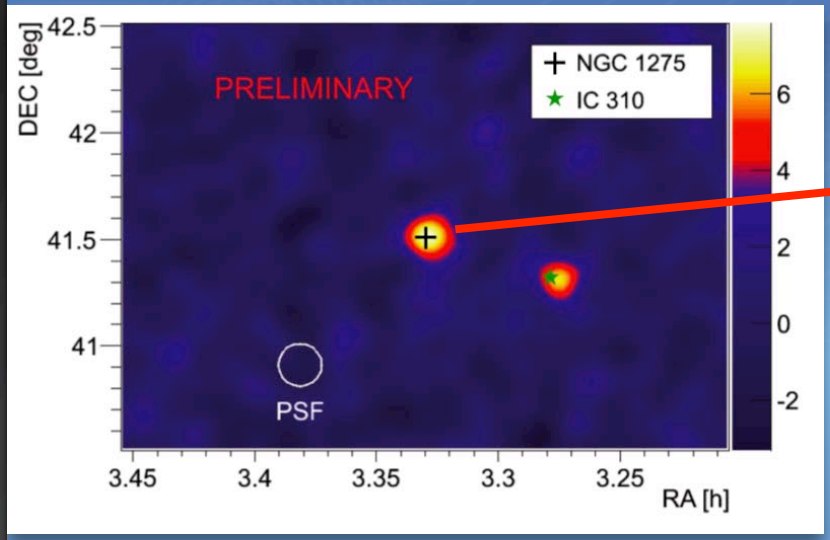
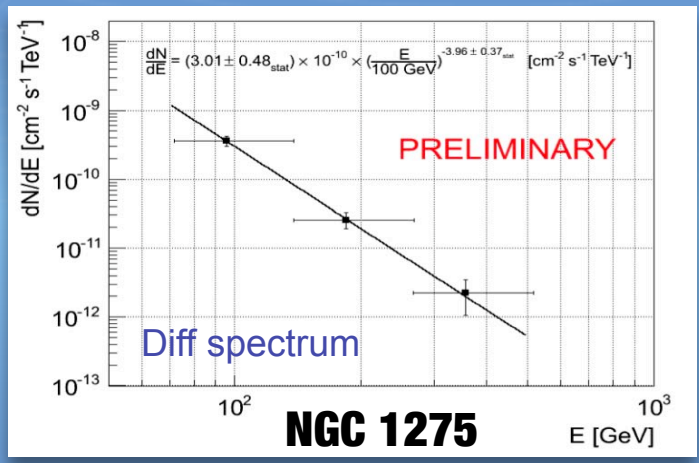


Detected during enhanced activity seen in Fermi-LAT. Very steep spectrum Γ=-4.0±0.4. Detection only possible thanks to stereo threshold and sensitivity



Hildebrand+ (MAGIC) ICRC 2011
from August 2010 to Feb 2011
46 h of observations
3% Crab nebula (E>100 GeV)
5.2 standard deviations

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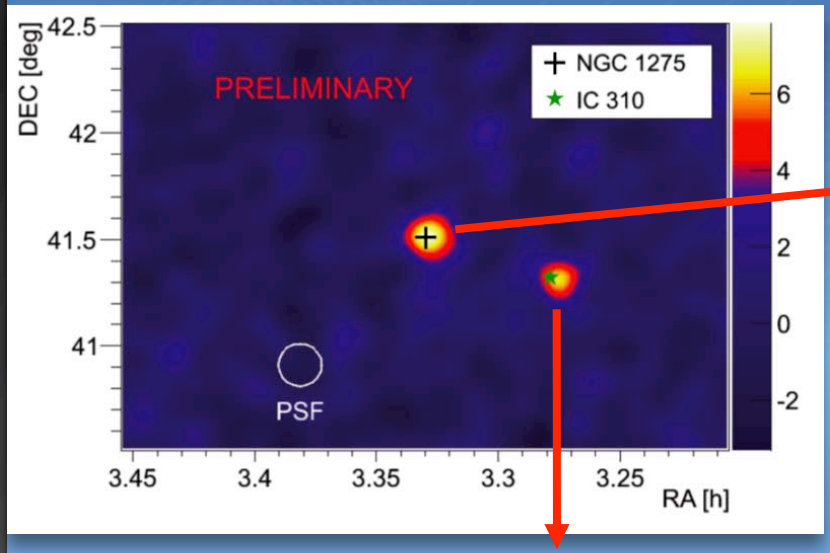

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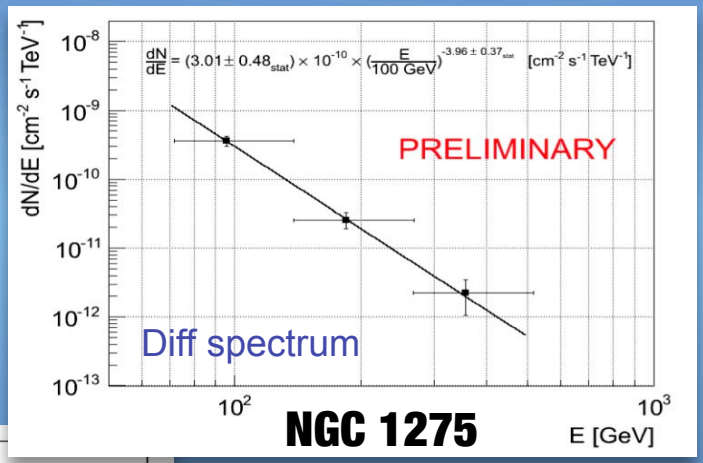

Hildebrand+ (MAGIC) ICRC 2011
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3% Crab nebula (E>100 GeV)
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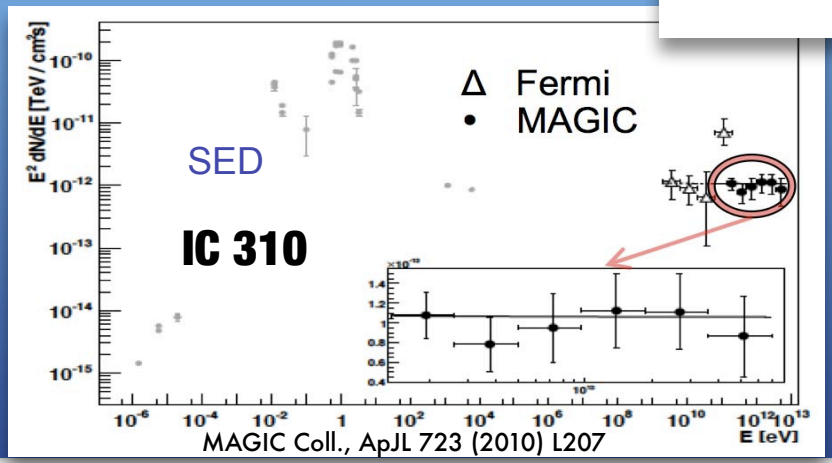
"Head-tail" radiogalaxy. Very hard spectrum: Γ=2.00±0.14

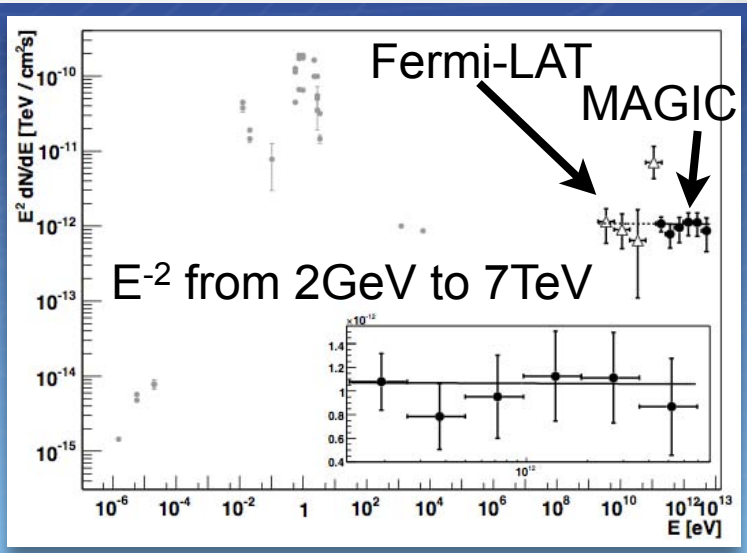


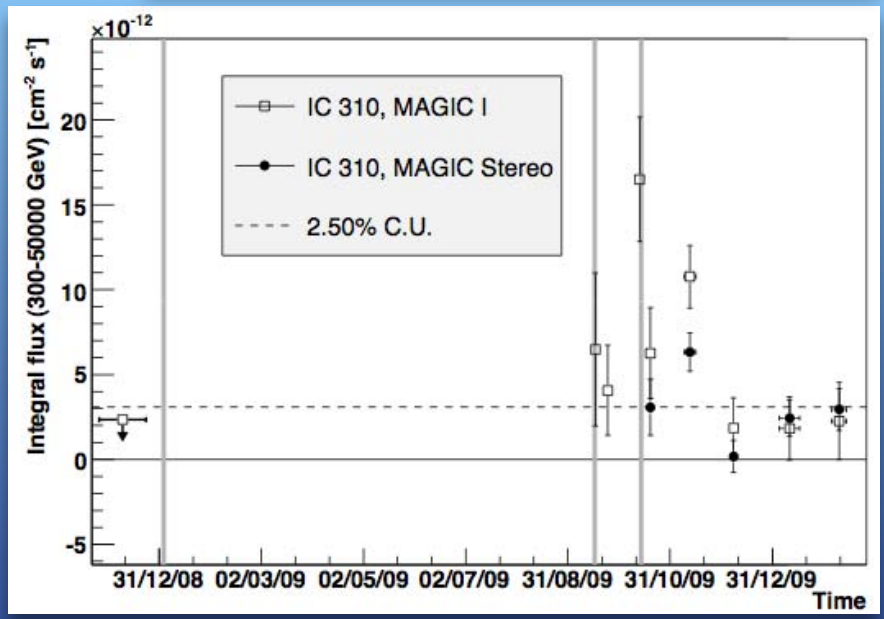
MAGIC Coll., ApJL 723 (2010) L207

Radio Galaxy IC 310

MAGIC Coll., ApJL 723 (2010) L207

- Belongs to Perseus cluster
- 7.6 sigma significance from 20.6 hrs stereo
- 2.5% Crab nebula flux
- **Radio galaxy** at z=0.019
- 22×/5× further away than Cen A, M87
- must be intrinsically much more luminous
- (could also be weakly beamed blazar)
- **Mechanism?**
  - Close to black hole
  - at shocks with cluster medium?
  - **Variability excludes CR/medium interaction**
  - very hard spectrum: probably IC scattering off IR photons, difficult in SSC

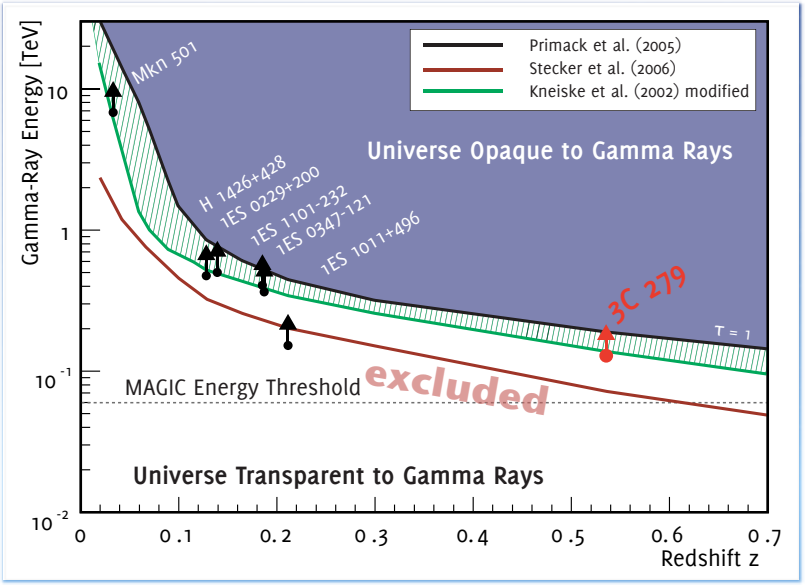




Quasars: 3C 279 & PKS 1222+21

MAGIC Collab.
A&A 530 (2011) A4
ApJL 730 (2011) L8

- 3C 279 (z=0.536) is the farthest VHE source, discovered by MAGIC in 2006.
- **Spectrum for such a far source allowed to place strong constraints on Extragalactic Background Light.**



Science 320 (2008) 1752

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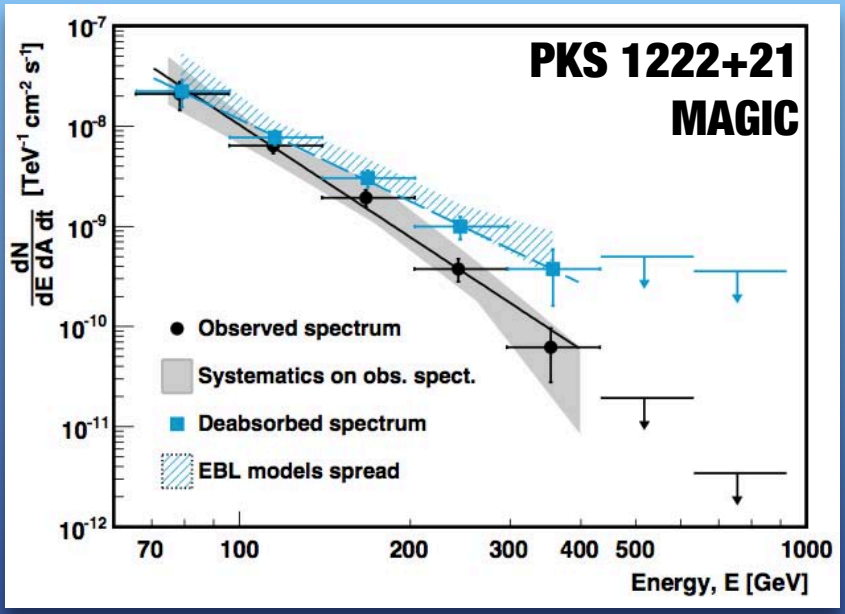
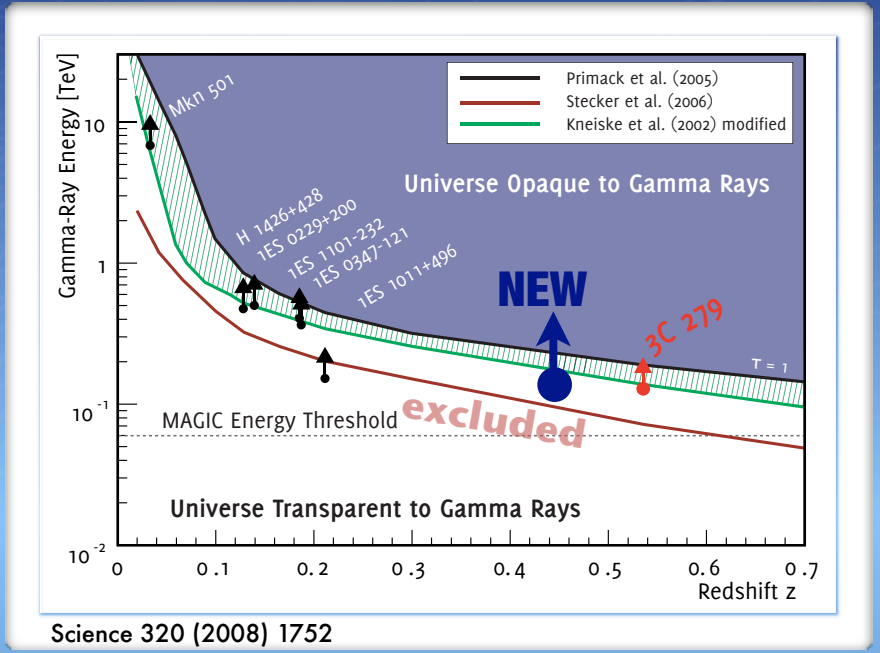
- 3C 279 (z=0.536) is the farthest VHE source, discovered by MAGIC in 2006.
- **Spectrum for such a far source allowed to place strong constraints on Extragalactic Background Light.**
- PKS 1222+21 (z=0.432) discovered by MAGIC in 2010. Spectrum confirms past claims on EBL!





Science 320 (2008) 1752

- 2010 June 17, flare state
- PKS 1222+21 (4C +21.35) is a high redshift FSRQ

  (only 3C279, PKS1510-089 so far)
- Observations triggered by a high state reported by Fermi-LAT

Quasars: 3C 279 & PKS 1222+21

MAGIC Collab.
A&A 530 (2011) A4
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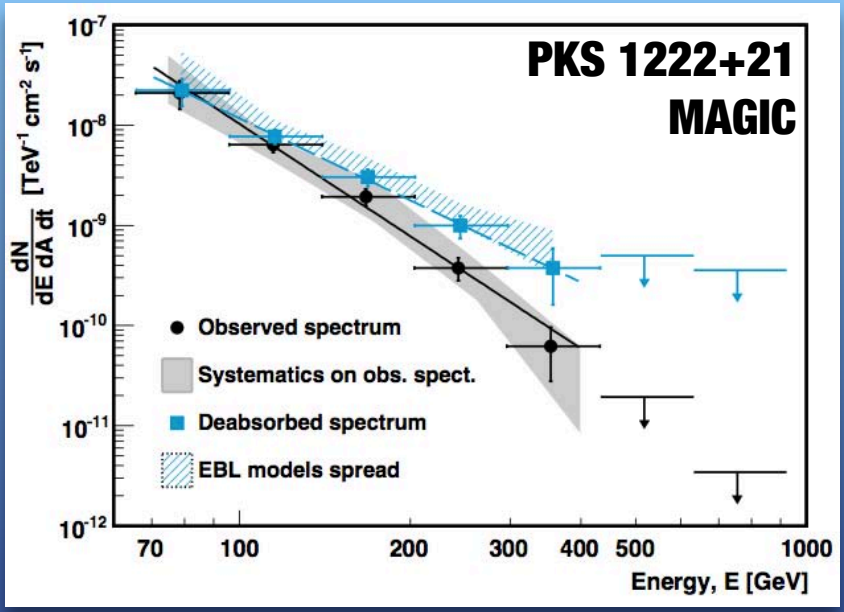
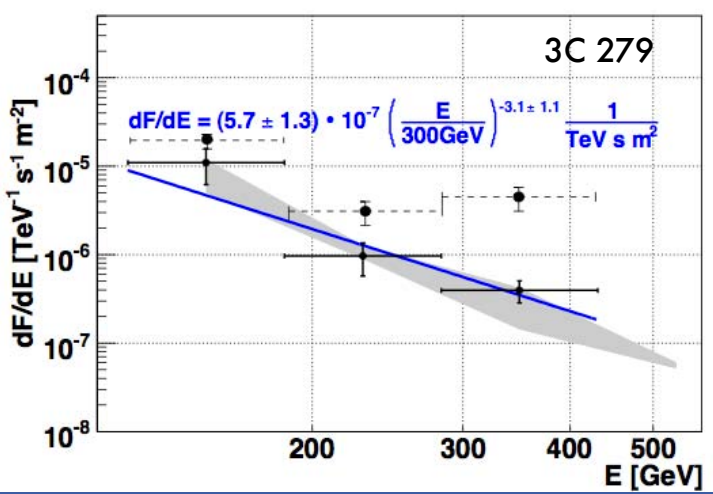
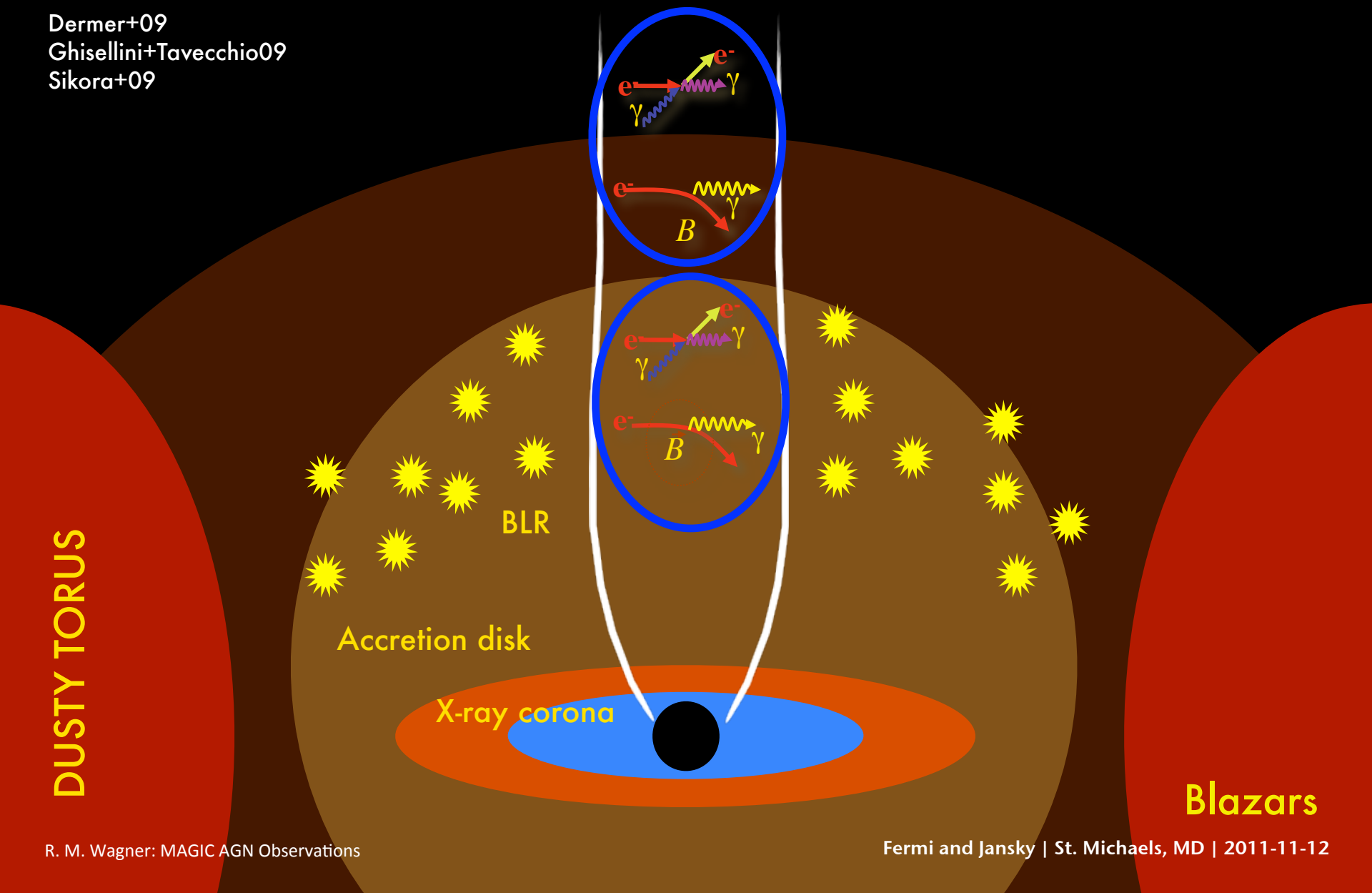
- PKS 1222+21 and recent observations of 3C279 show the same problem A&A 530 (2011) A4
  - Emission up to hundreds of GeV
  - Fast variability (9 min doubling time in PKS 1222+21)
- Why is this a problem?





FSRQs: the "canonical" scenario

Dermer+09
Ghisellini+Tavecchio09
Sikora+09



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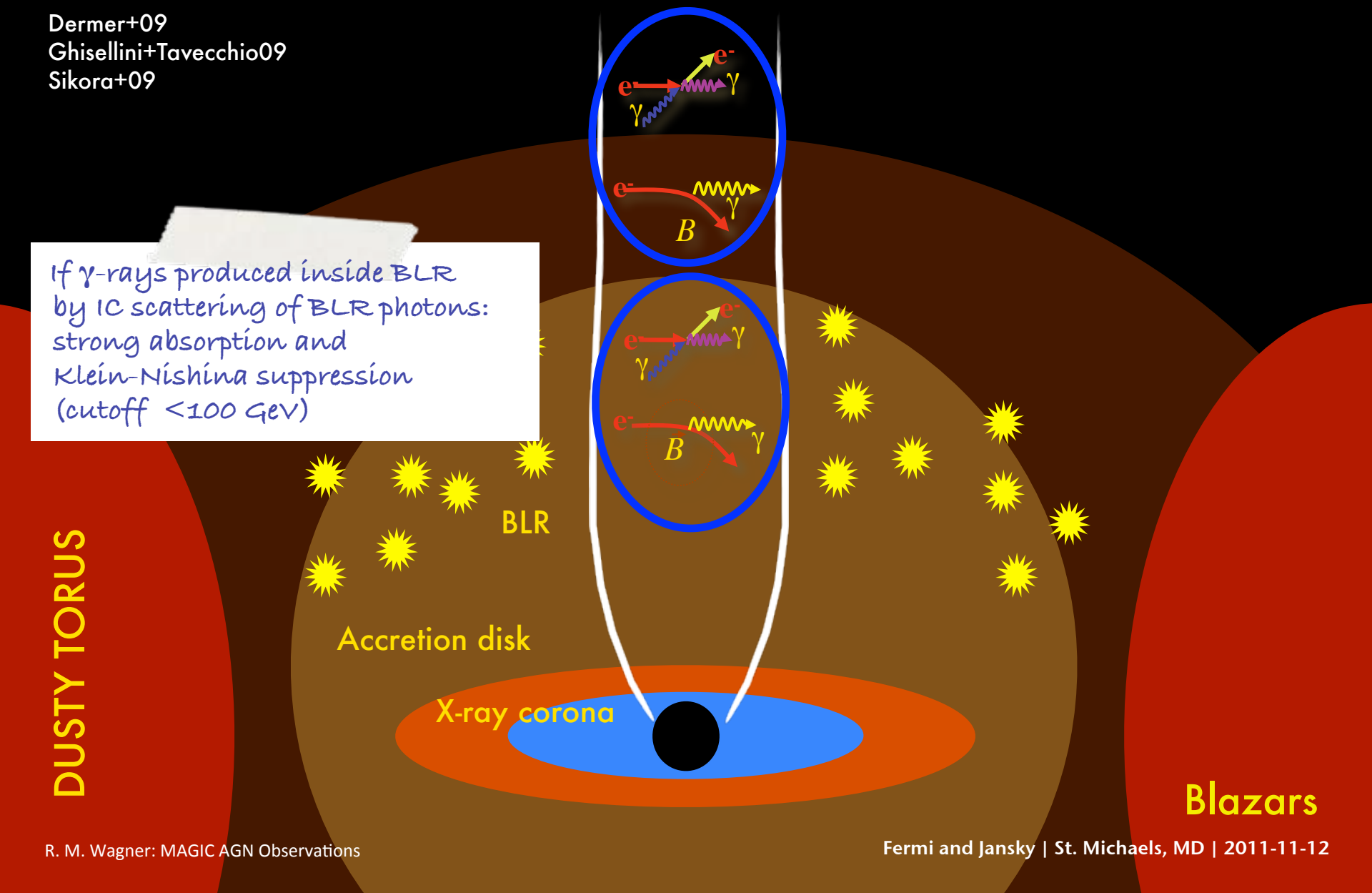

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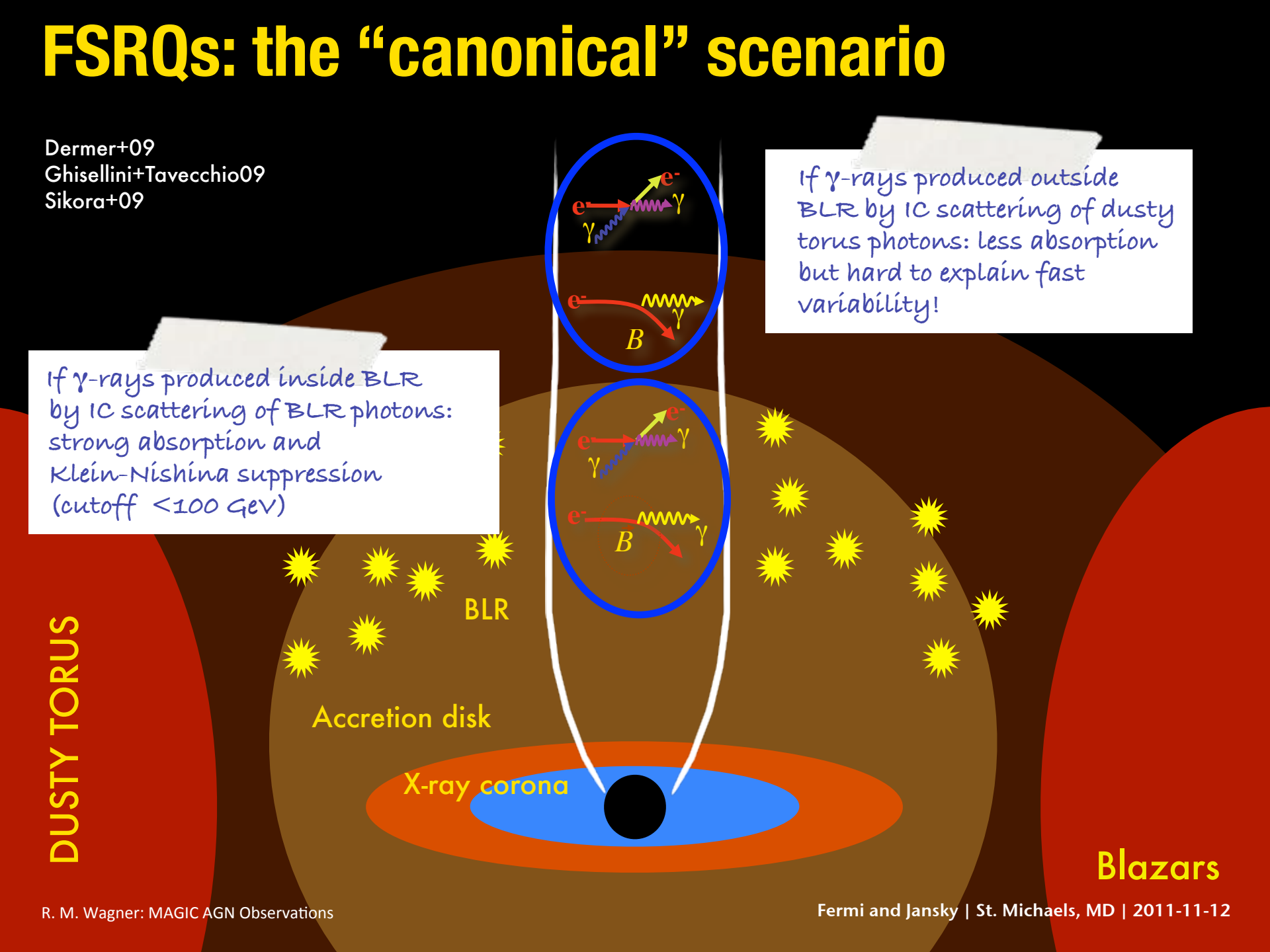
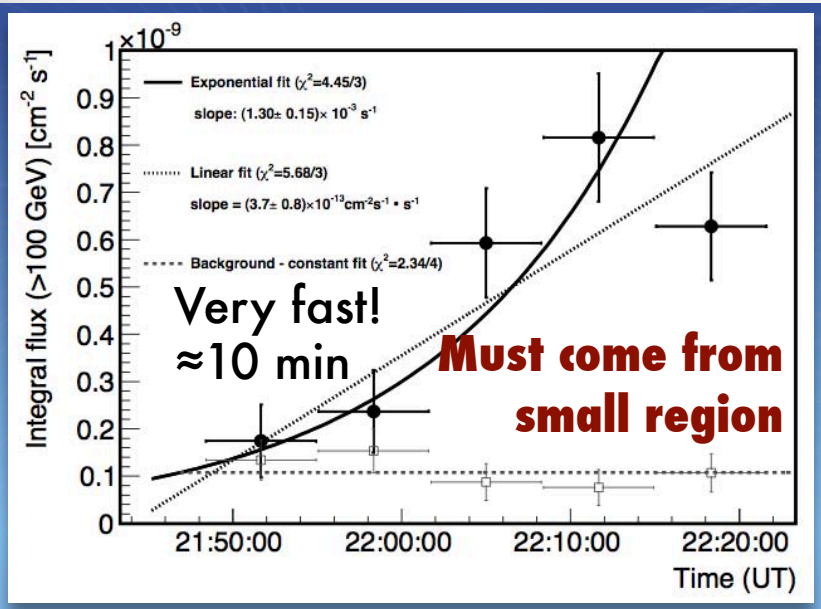


If γ-rays produced outside BLR by IC scattering of dusty torus photons: less absorption but hard to explain fast variability!

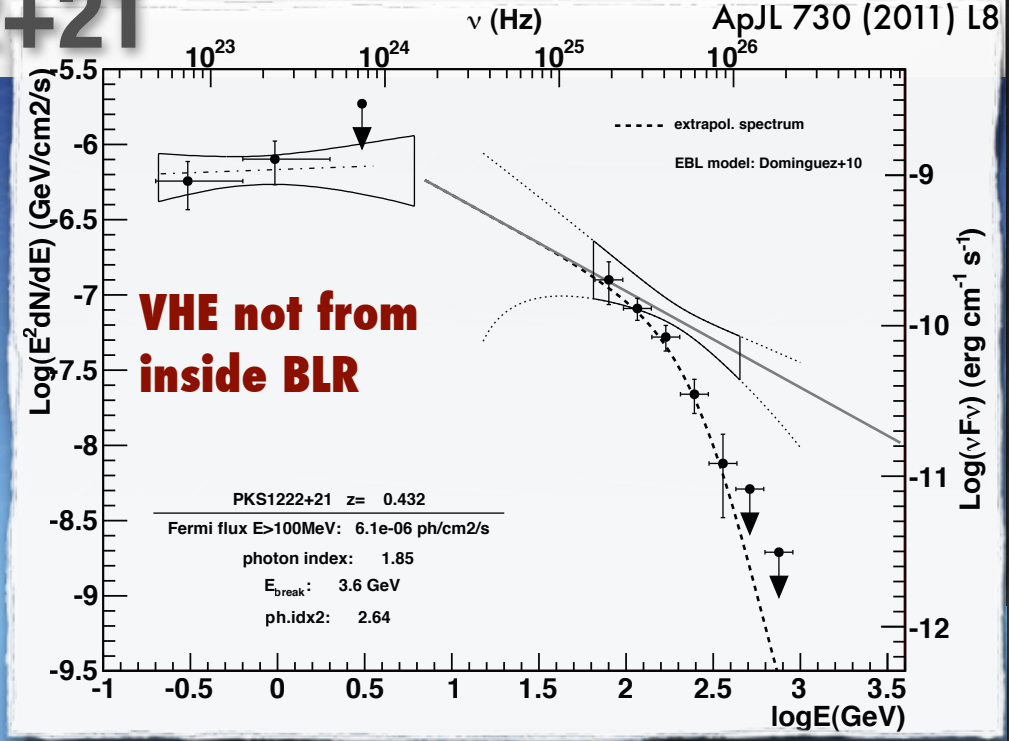
If γ-rays produced inside BLR by IC scattering of BLR photons: strong absorption and Klein-Nishina suppression (cutoff <100 GeV)

Blazars

4C +21.35 aka PKS 1222+21



MAGIC Coll., ApJL 730 (2011) L8



- **A strong signal of 8.7 σ significance in just 0.5h of observations!**
  - → allows short-term variability studies
- Flux ≥30% of the Crab Nebula flux
- Also detected by *Fermi*-LAT in 100-300 GeV energy range

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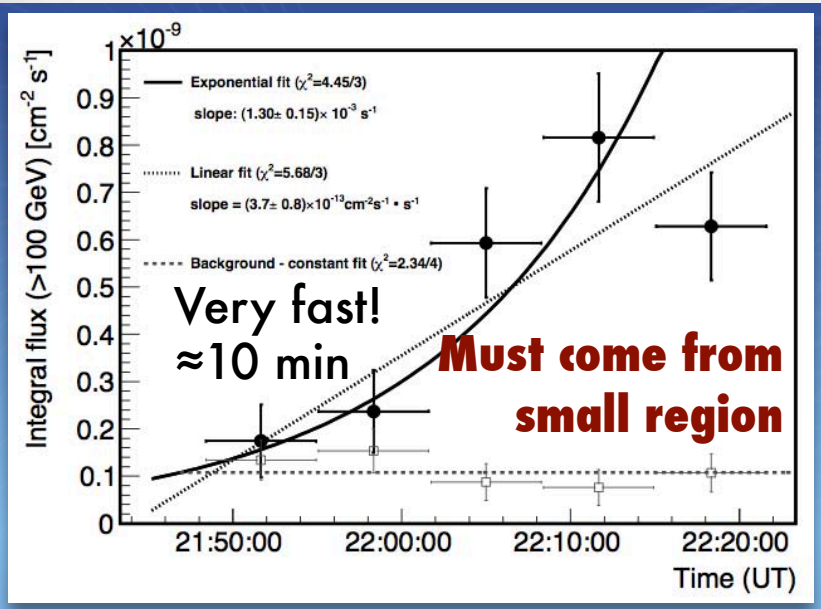

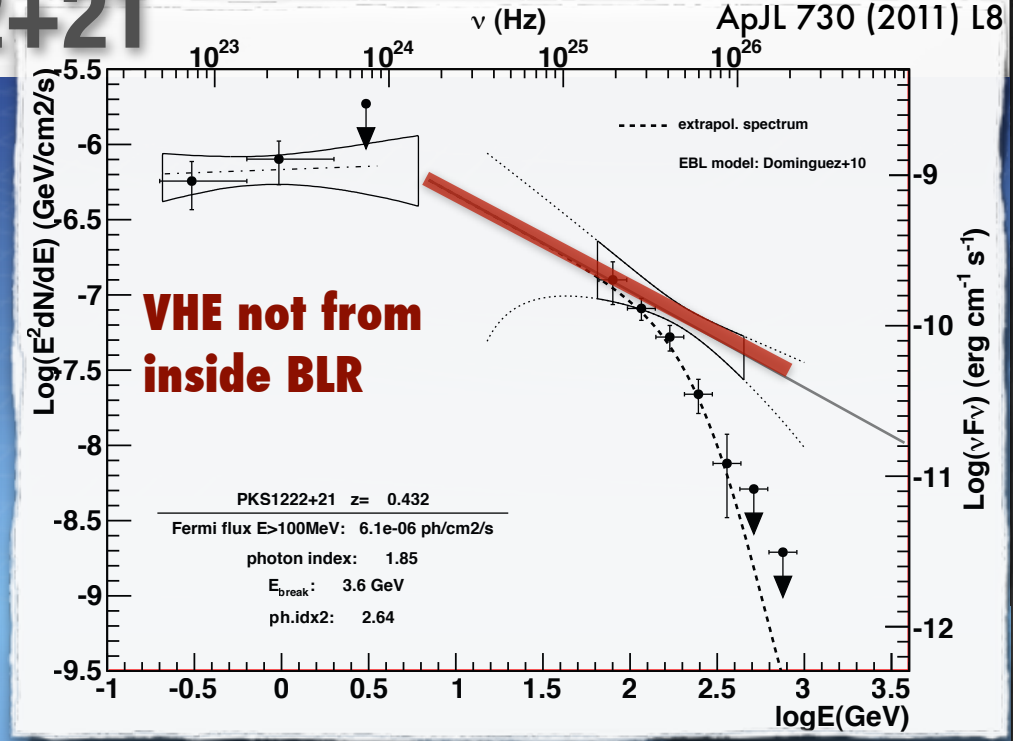

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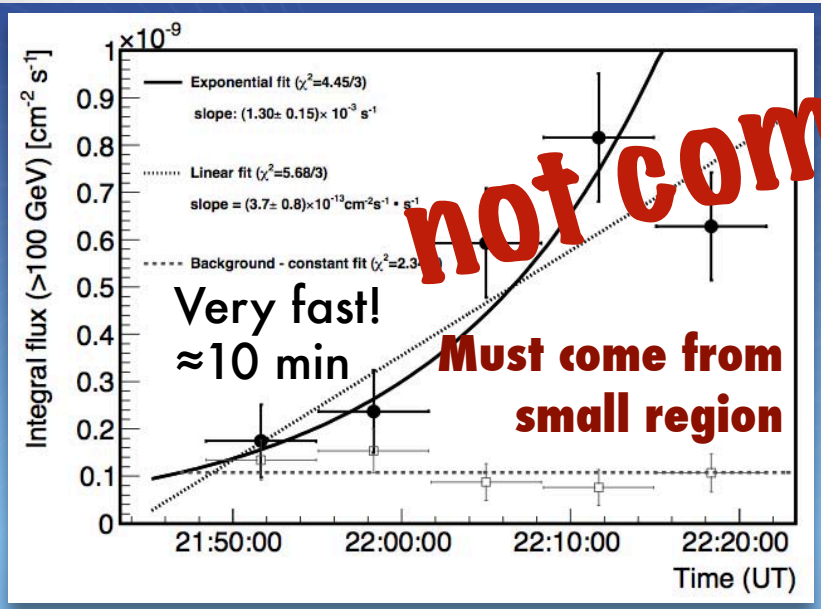
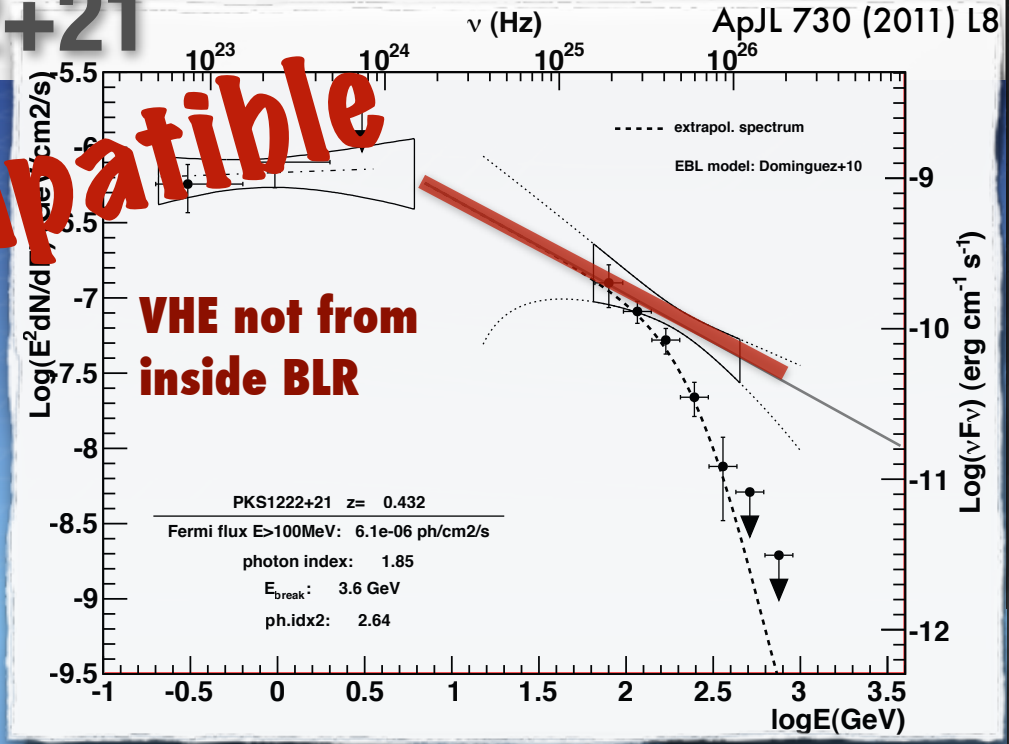


not compatible

MAGIC Coll., ApJL 730 (2011) L8



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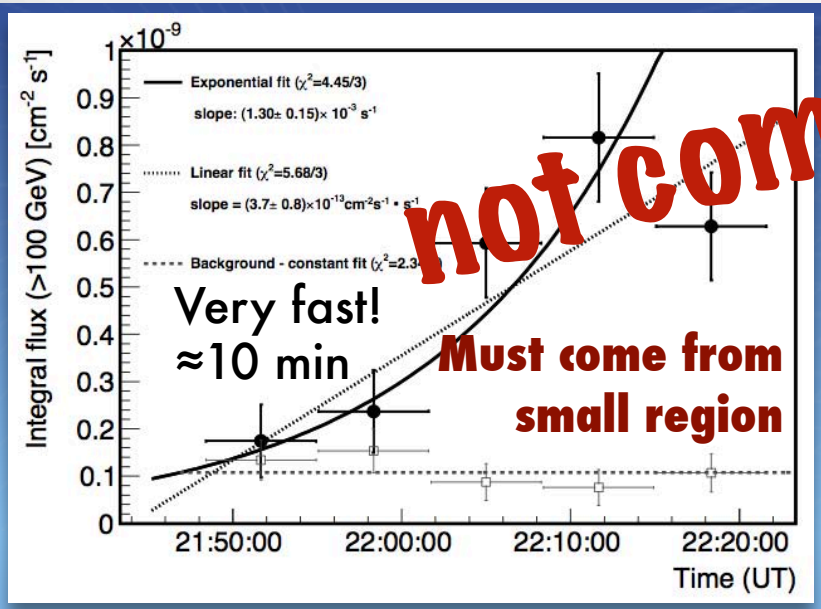
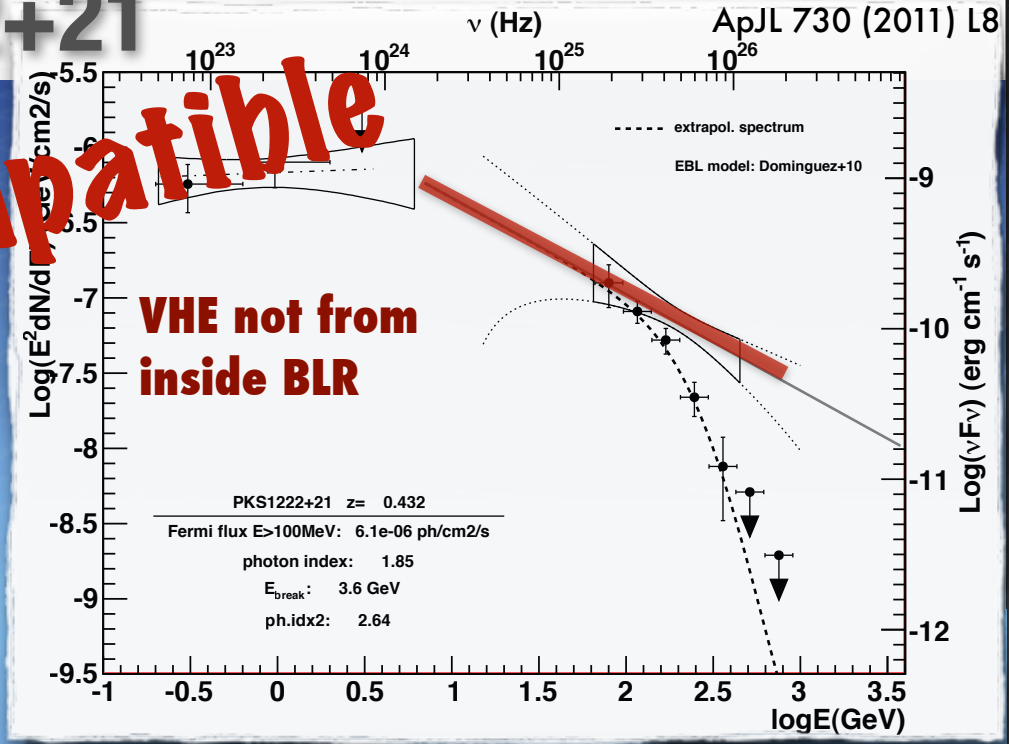


not compatible

Very fast!
≈10 min

Must come from small region

MAGIC Coll., ApJL 730 (2011) L8



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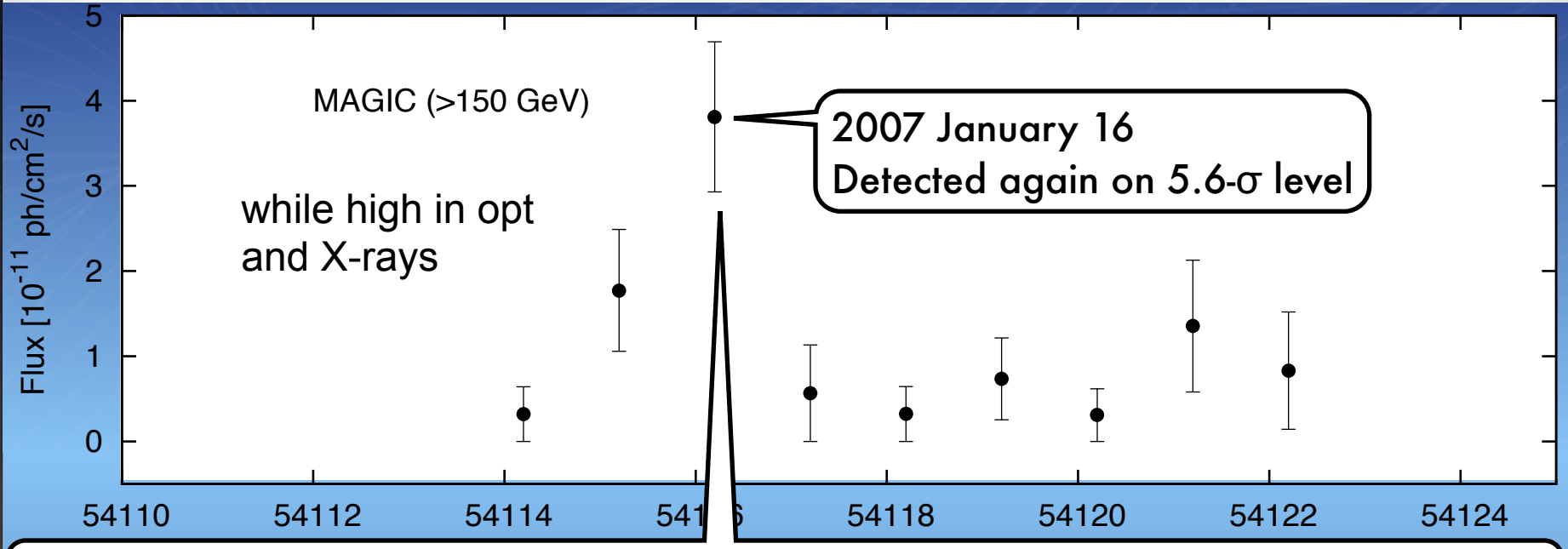
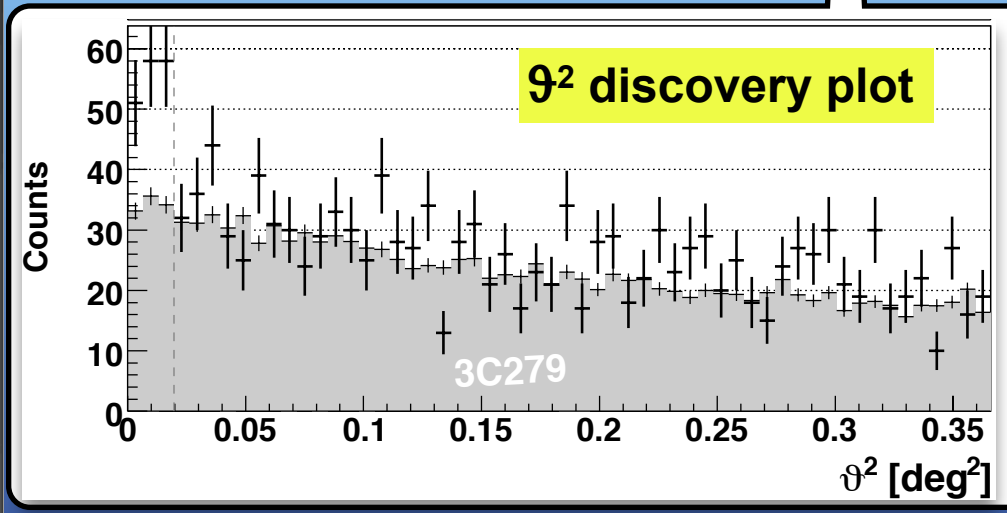
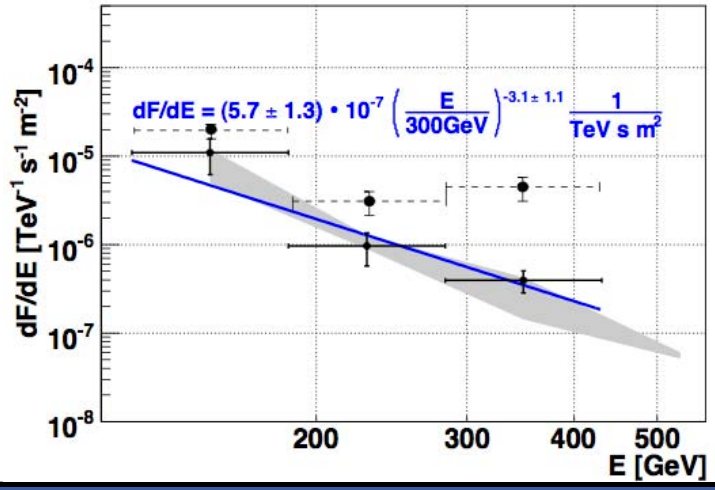
Possible solutions:
- Strong recollimation of the jet
  e.g. Nalewajko&Sikora 2009
  Bromberg & Levinson 2009
- "Blobs" or "minijets" inside of the jet. Already proposed for PKS 2155-304 e.g. Ghisellini et al. 2008, 2009, Giannios et al 2009, Nalewajko et al. 2010, Marscher &Jorstad 2010

3C 279: Re-detected in 2007

MAGIC Collab.
A&A 530 (2011) A4







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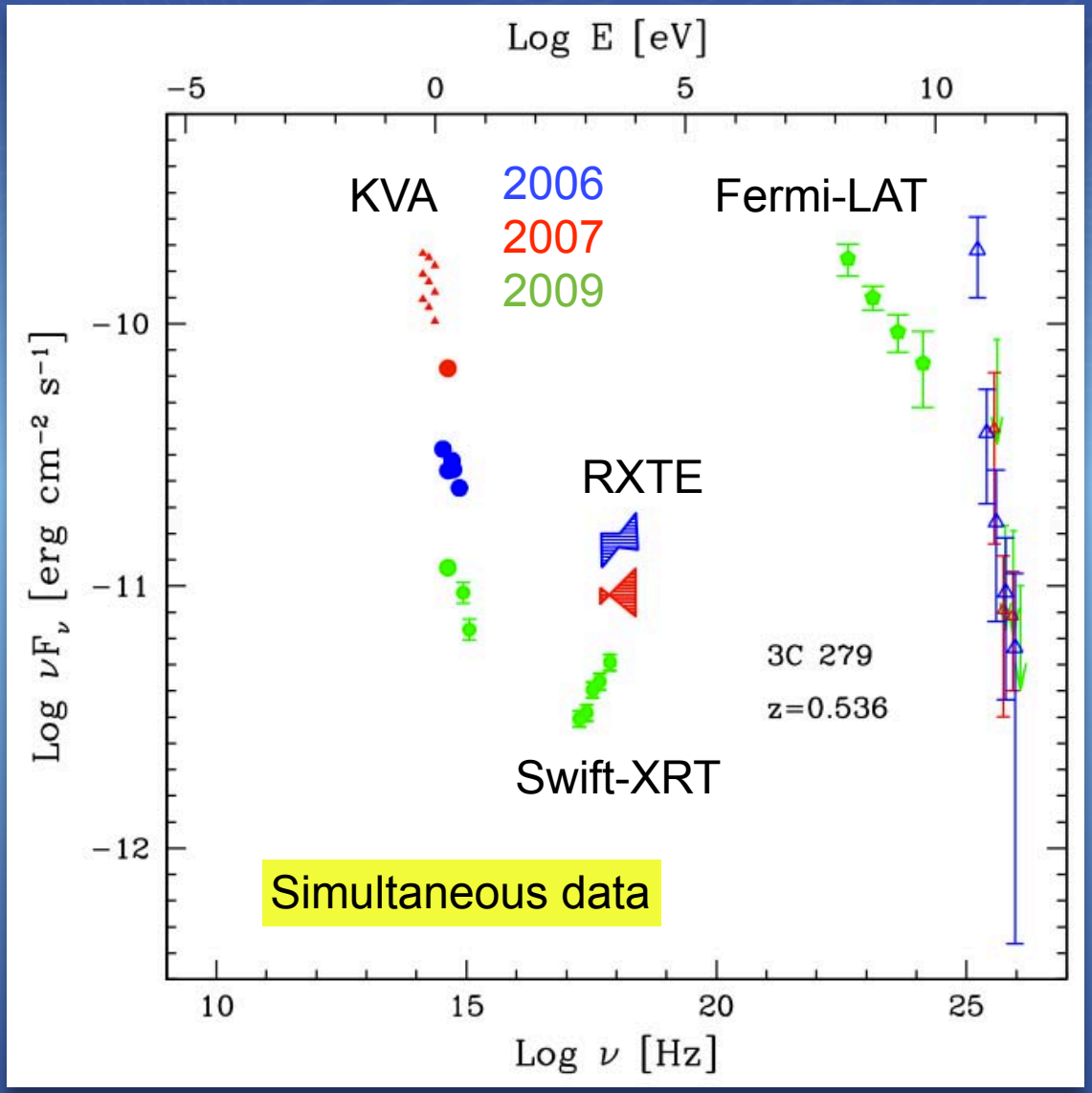


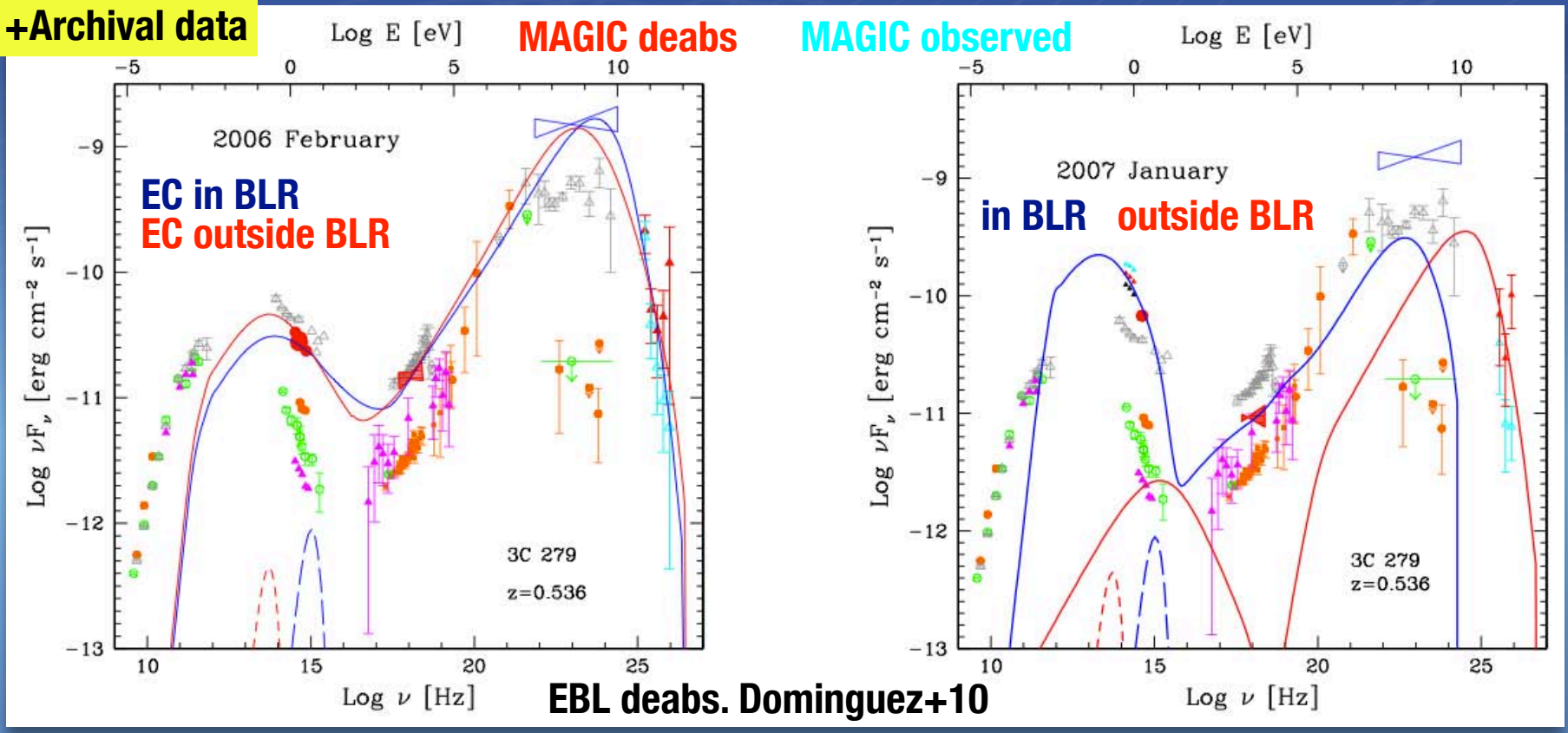
SEDs of simultaneous optical, X-ray and γ–ray data at the epochs of MAGIC observations.

Blue: February 23, 2006, red: January 16, 2007, green January 21-February 1 2009.

3C 279: SEDs 2006 / 2007

MAGIC Collab.
A&A 530 (2011) A4

+Archival data



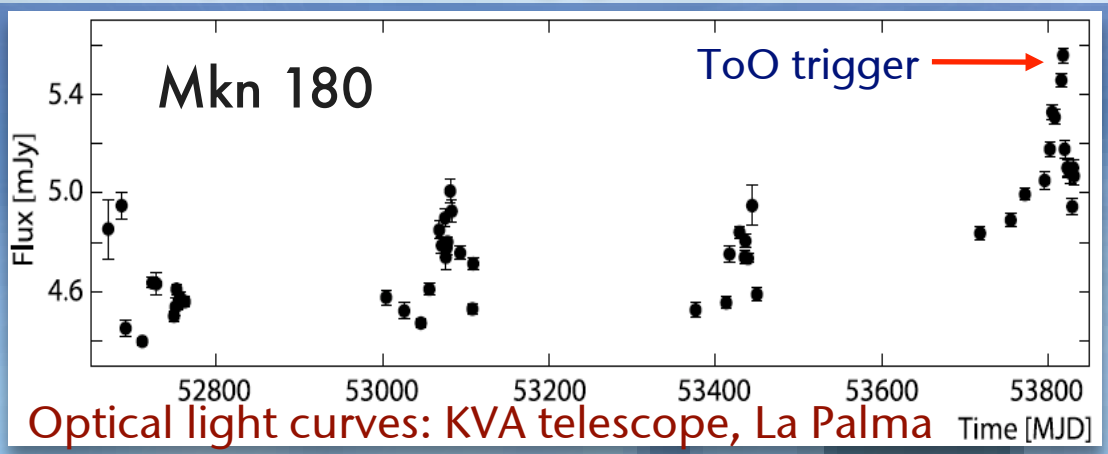
One-zone models EC/BLR and EC/IR require, however, rather large MeV-GeV flux

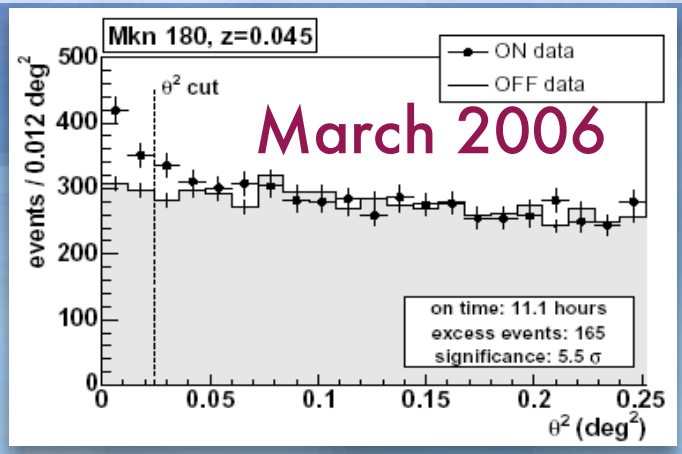
Two-zone: VHE outside BLR, minimizes gamma absorption

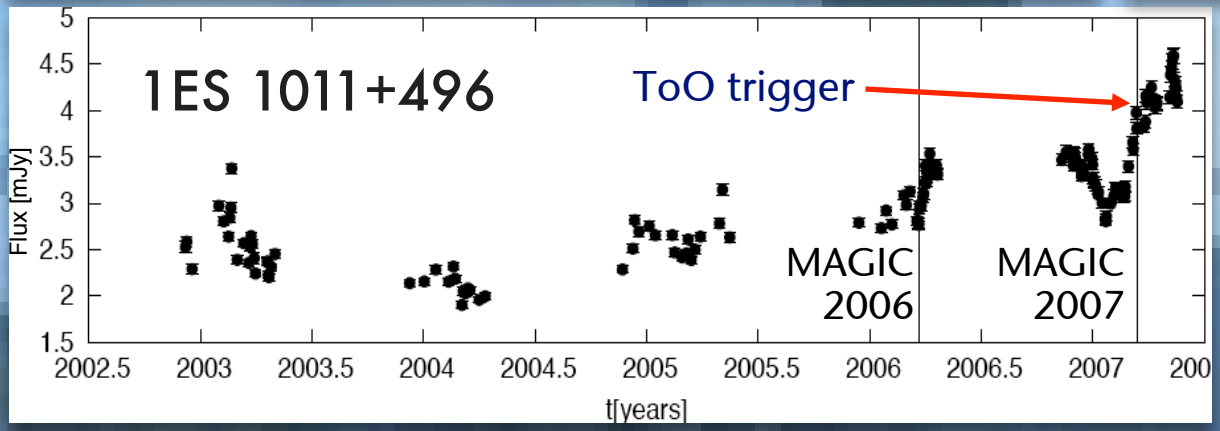
2-zone model would also work

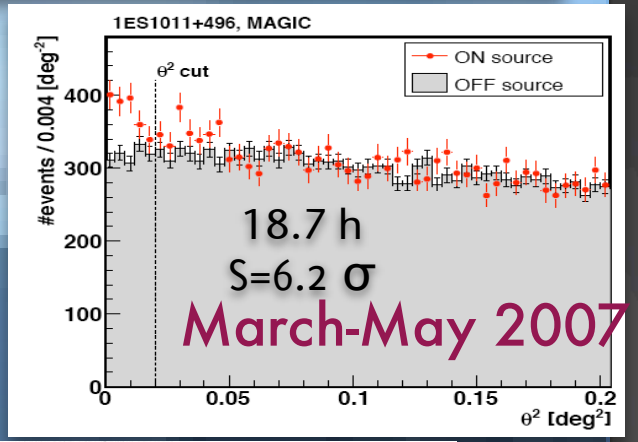
Do Optical Triggers Work?

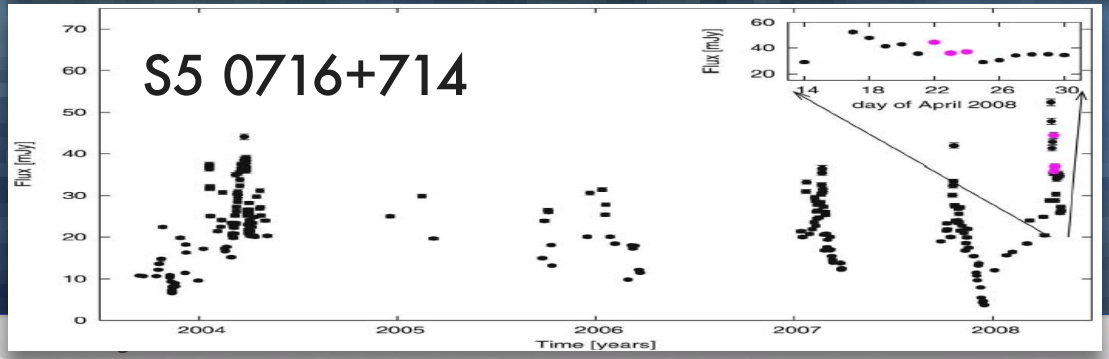
MAGIC Collab., ApJ 648 (2006) L105
ApJ 667 (2007) L21
ApJ 704 (2009) L129

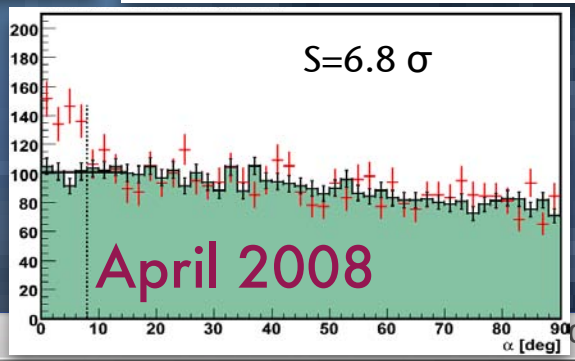








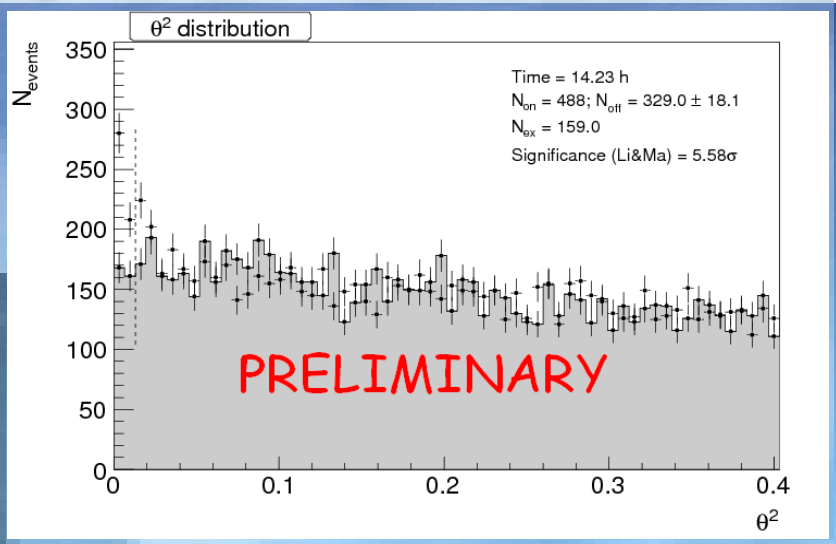


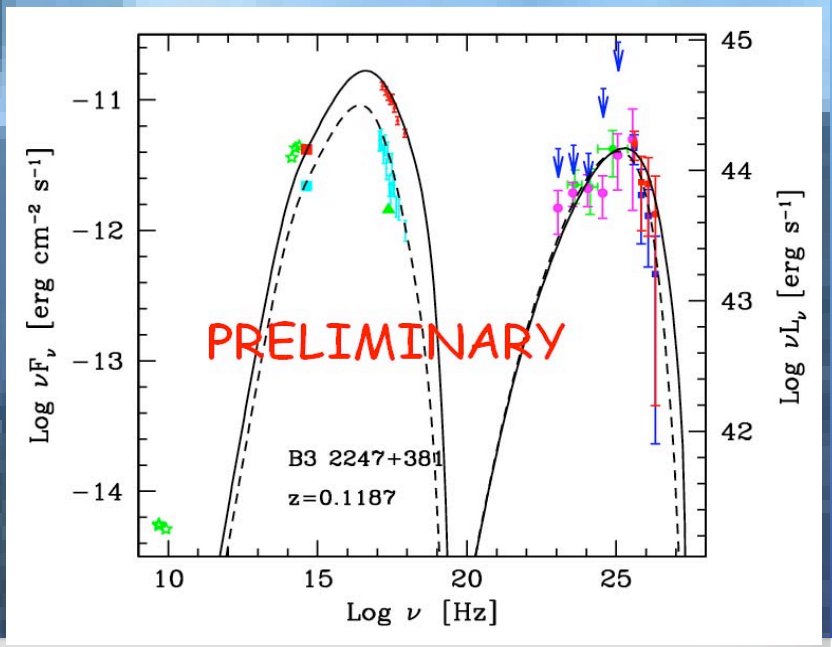


A Continuing Success Story...

MAGIC Collab., ATel 2910
RFO released October 7, 2010

- Included in stacked HBL sample, no detection with MAGIC –I (Aleksić+ 2010)
- Another successful optical trigger, detection consistent with previous MAGIC upper limit -> variability unclear
- Integral flux (E > 200 GeV):
  ≈ 2.3% C.U.
- Soft power law spectrum:
  $-3.2 \pm 0.5_{stat} \pm 0.5_{sys}$
- SED: narrow peaks, similar to PG 1553+113
- SSC model fit with parameters typical for HBLs

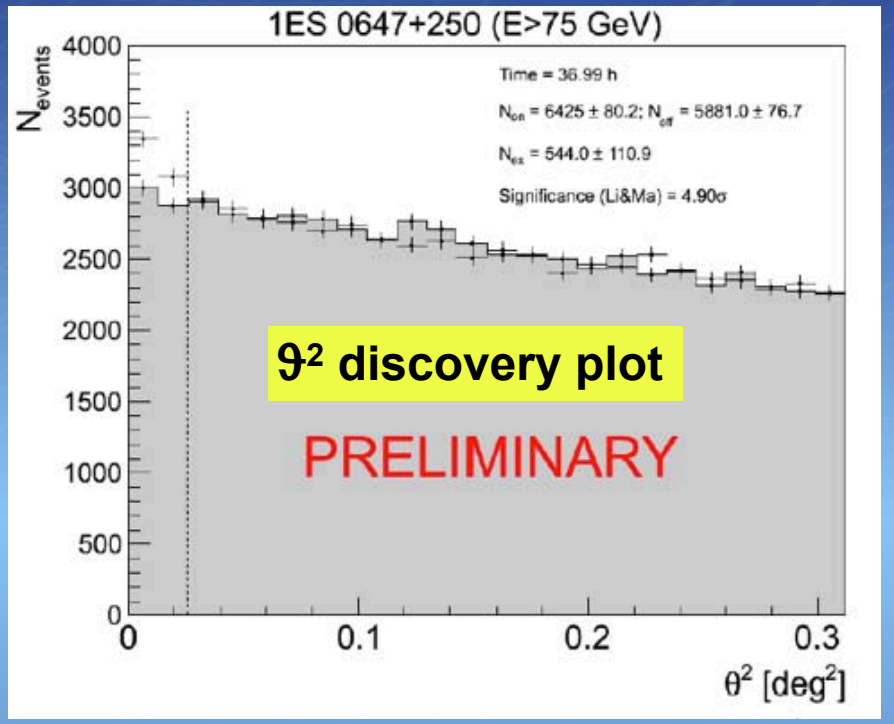




New Discoveries: 1ES 0647+250

De Lotto et al. (Proc. TAUP 2011)
MAGIC Collab.
released 9 Sept 2011

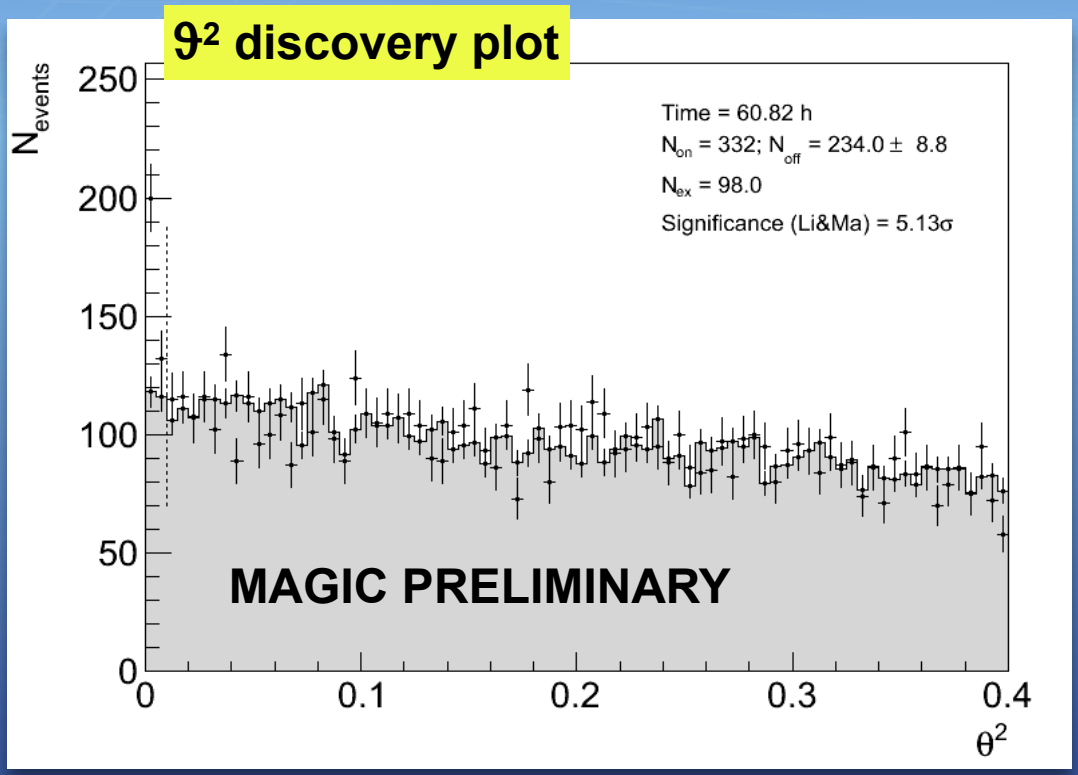
- HBL
- z=0.45 (Meisner+Romani10)
  z=0.41 (Kotilainen+11)
- Tentative detection at 4.9 sigma
- One of the best extragalactic TeV candidates after 2 years of Fermi-LAT data
- 30 hrs observations during 6 months w/ Swift, RXTE,Fermi-LAT
- prelim. flux estimation: (3.0±0.7)%CU above 100 GeV
- Analysis in progress



New Discoveries: 1ES 1741+196

Berger et al. (Proc. ICRC 2011)
MAGIC Collab.
released 13 July 2011

- HBL, z=0.083
- Host galaxy one of the most luminous and largest of all BL Lacs
- Triplet of interacting galaxies with tidel streams? Heidt+99
- Promising candidate from Costamante & Ghisellini list
- 60h of data, clear 5σ signal
- Hard spectrum
- Weakest AGN detected by MAGIC so far, start to explore mCrab regime
- Analysis ongoing

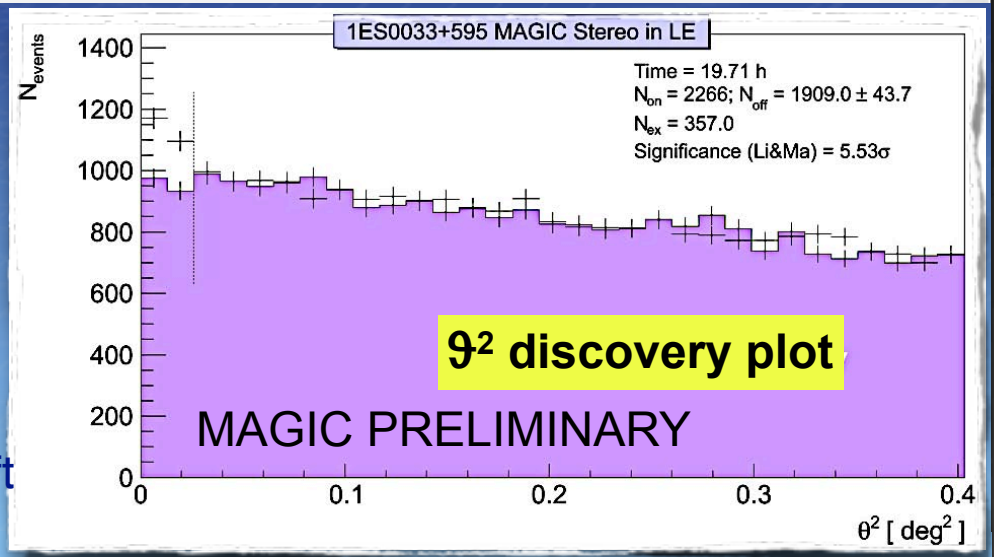


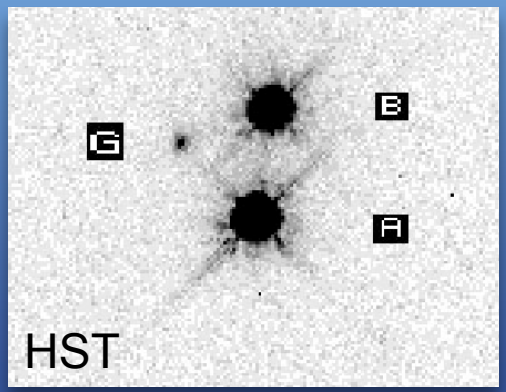
And one more: 1ES 0033+595

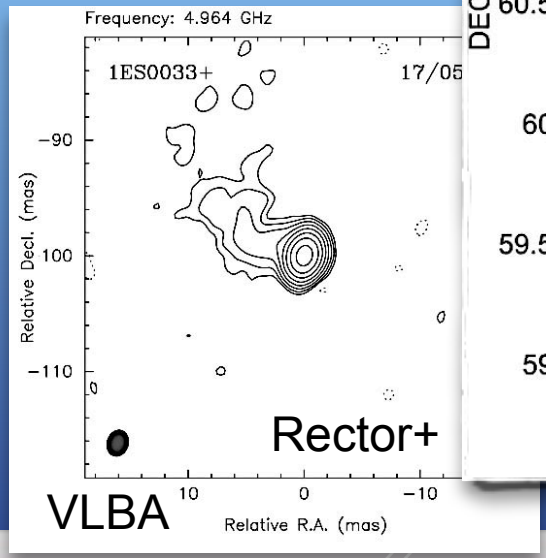
MAGIC Collab.
released Oct 27, 2011

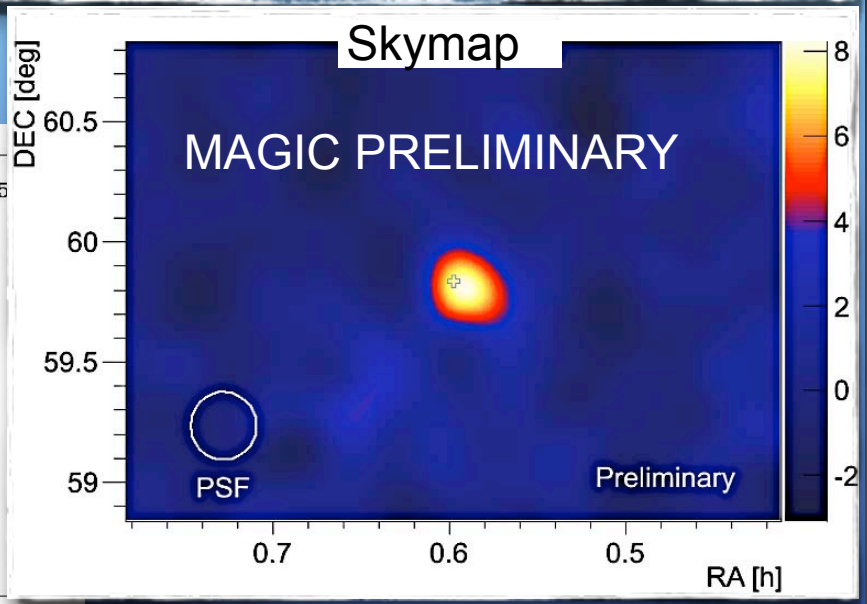
Previous upper flux limit: 8.55% CU (Ethr=165 GeV)
Season 2009: 19.7h, 357 excess events
August-October 2009
1.5% CU (Ethr=150 GeV)

- Host unresolved: no photometric redshift
- Morphology unclear:
HST observes two point sources (comparable brightness)
- BUT VLBA (1997) only one radio counterpart









Mariotti et al., ATel. 3719

Summary

- MAGIC-II fully commissioned and highly successful. Currently being upgraded with new readout electronics and camera (MAGIC-I)
- truly largest Cherenkov telescope, lowest energy threshold
- Stereoscopic system fully competitive with other installations +
  only instrument to access the energy region between 50 GeV and 100 GeV
  overlap with Fermi-LAT
- Recent results on extragalactic sources: AGNs, galaxy clusters
- Revealing the location of the TeV engine in Blazars: M87
- 3C279, distant quasar, 2006 flare + 2nd detection 2007
- PKS 1222+21 discovered, distant source, EBL, fast variability
- Perseus cluster of galaxies: IC 310 (shedding light on nature?/LAT-triggered), NGC 1275 discovered
- Some recent new MAGIC additions to the TeV blazar catalog:
  1ES 1741+196 B3 2247+381, 1ES 1215+303
  1ES 0033+595 (all *"Costamante-Ghisellini"* sources) 1ES 0806+524...
- Fermi-LAT inspired discovery of 1ES 0647+250