Recent Results from the MAGIC Telescopes

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Paris, July 19-23, 2010

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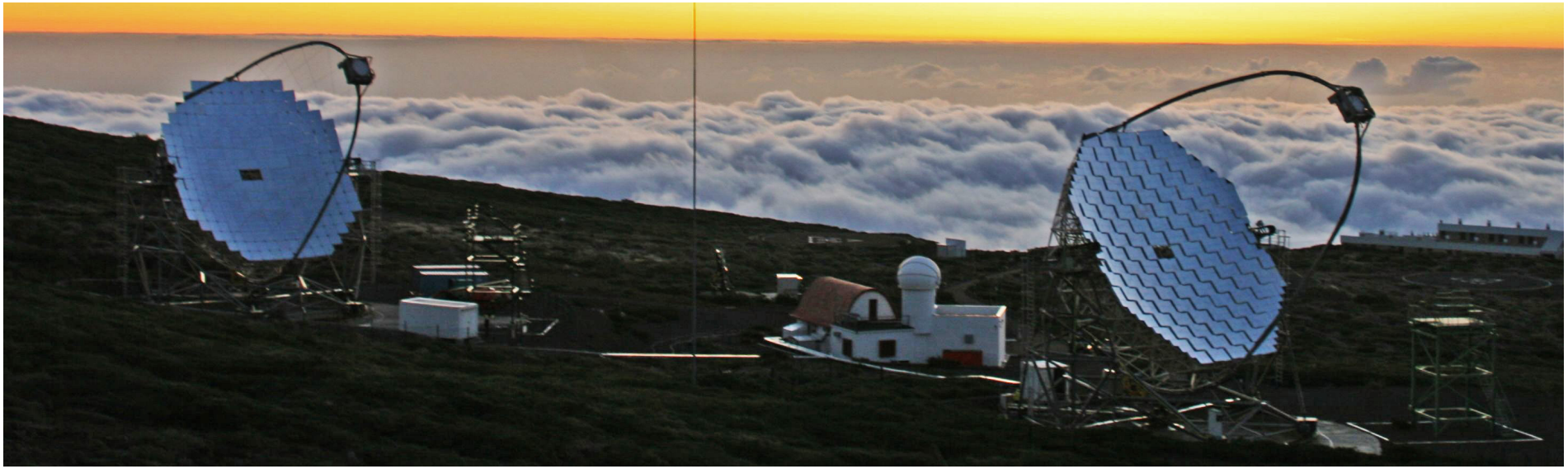
MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

Very-High Energy (VHE) γ-Ray Astronomy with MAGIC



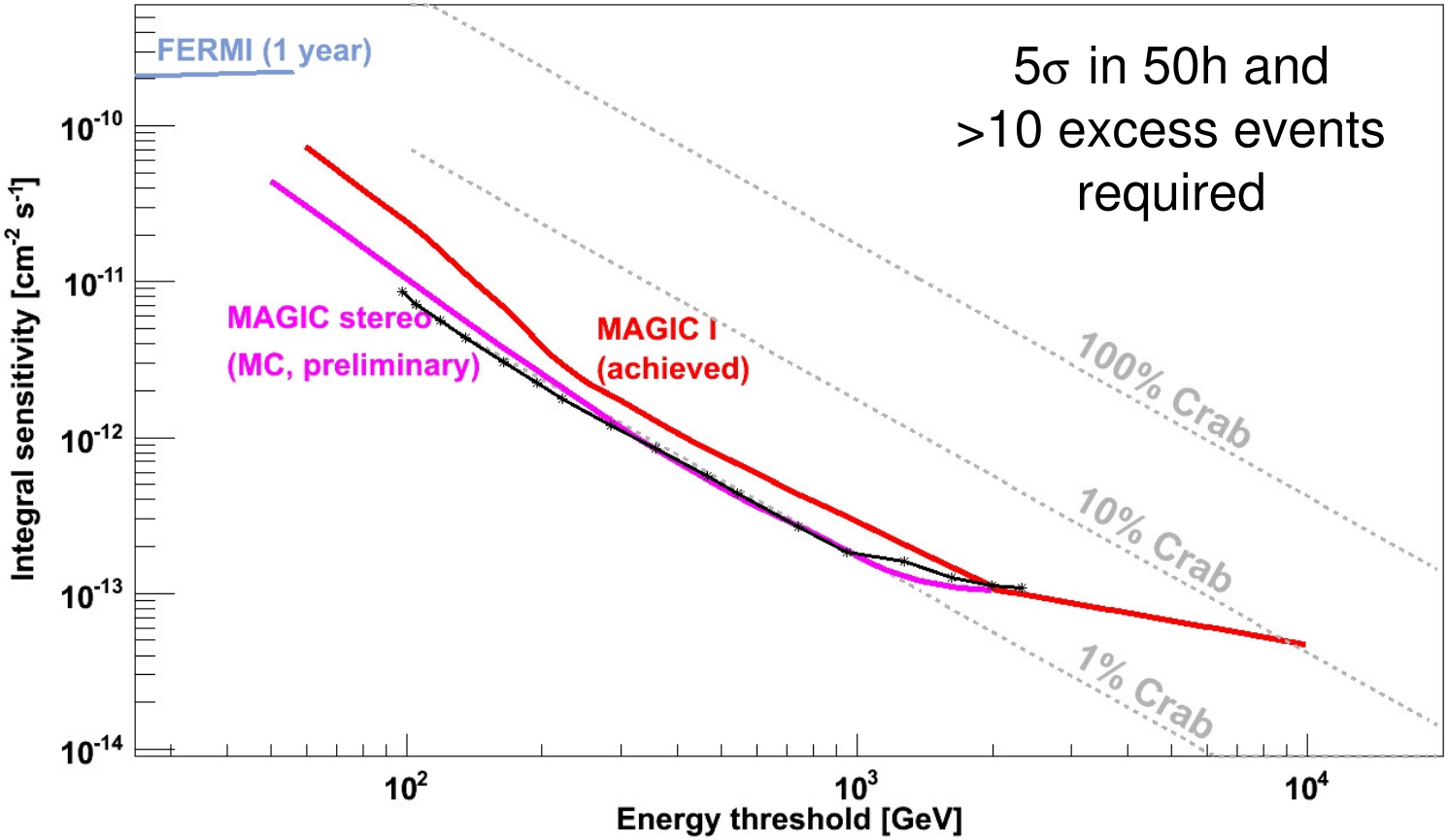
- System of two Imaging Atmospheric Cherenkov Telescopes
- Roque de los Muchachos, 2200 m, Canary Island of La Palma, Spain
- MAGIC-I in operation since 2004, MAGIC-II since 2009
- 17 m $\oslash$ mirror dish each to focus Cher. light $\rightarrow$ active mirror control
- Cameras: 577/1039 pixel, 3.5° FOV
- Analog signals transfered via optical fibers to counting house
- 2 Gsamples/s (MUX-FADC/DRS2)
- Stereo trigger (100 ns gate) on top of single telescope triggers (3NN)
- Analysis of air shower images

MAGIC-I and MAGIC Stereo Performance

Integral Sensitivity:

MAGIC-I: 1.6% Crab

MAGIC Stereo: 1.0% Crab



- Trigger threshold:
  - ~ 50 GeV with standard trigger
  - ~ 25 GeV with sumtrigger
- Analysis threshold:
  - ≥ 60 GeV (MAGIC-I)
  - ~ 50 GeV (MAGIC stereo)
- Energy resolution: 20% resp. 15%
- Angular resolution: $\sim 0.1^{\circ}$
- Fast repositioning: < 20 s !

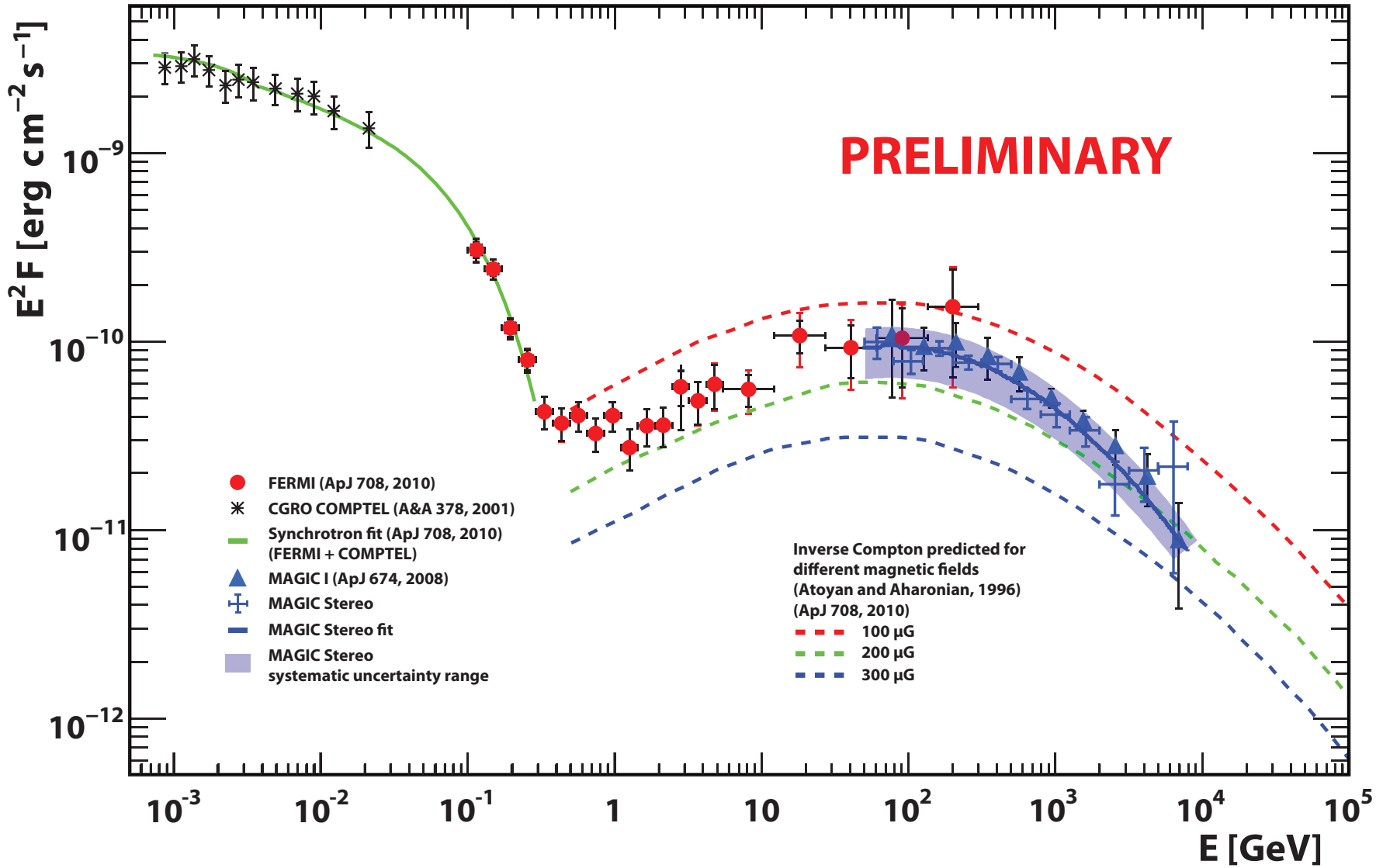
Selected Scientific Results

(MAGIC-I and MAGIC stereo data)

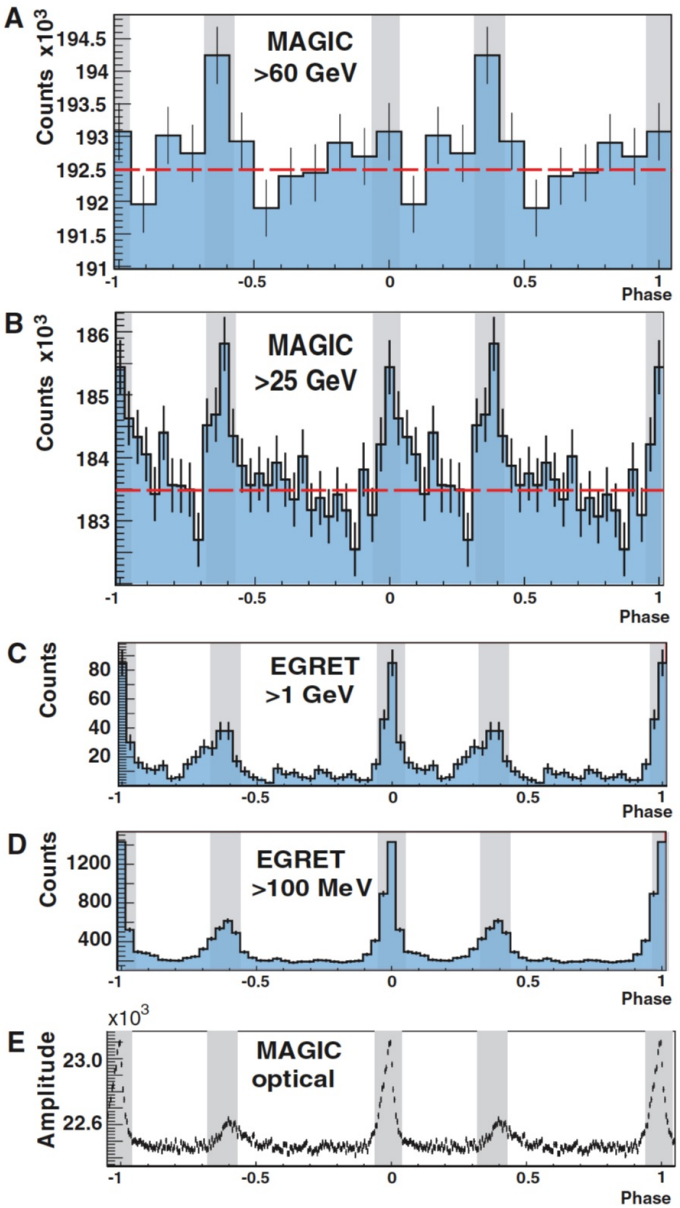
Galactic Sources

Crab Nebula Spectrum

MAGIC Stereo in combination with neighbouring wavelengths

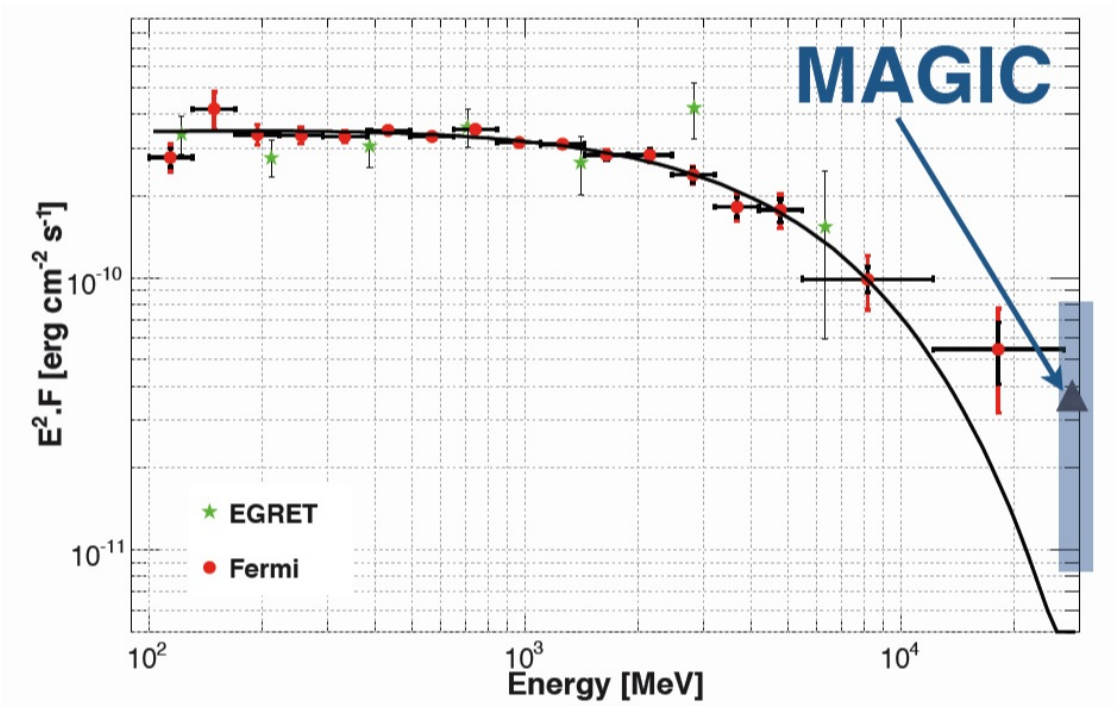


Crab: Not only the "Standard Candle"



[Science, Vol. 322, 1221–1224, Nov 2008]

- First detection of a pulsar above 25 GeV
- Special trigger used for MAGIC-I
  → energy threshold of 25 GeV
- Flux compatible with FERMI results
  → exponential cutoff?



[ApJ, Vol. 708, 1254–1267, Jan 2010]

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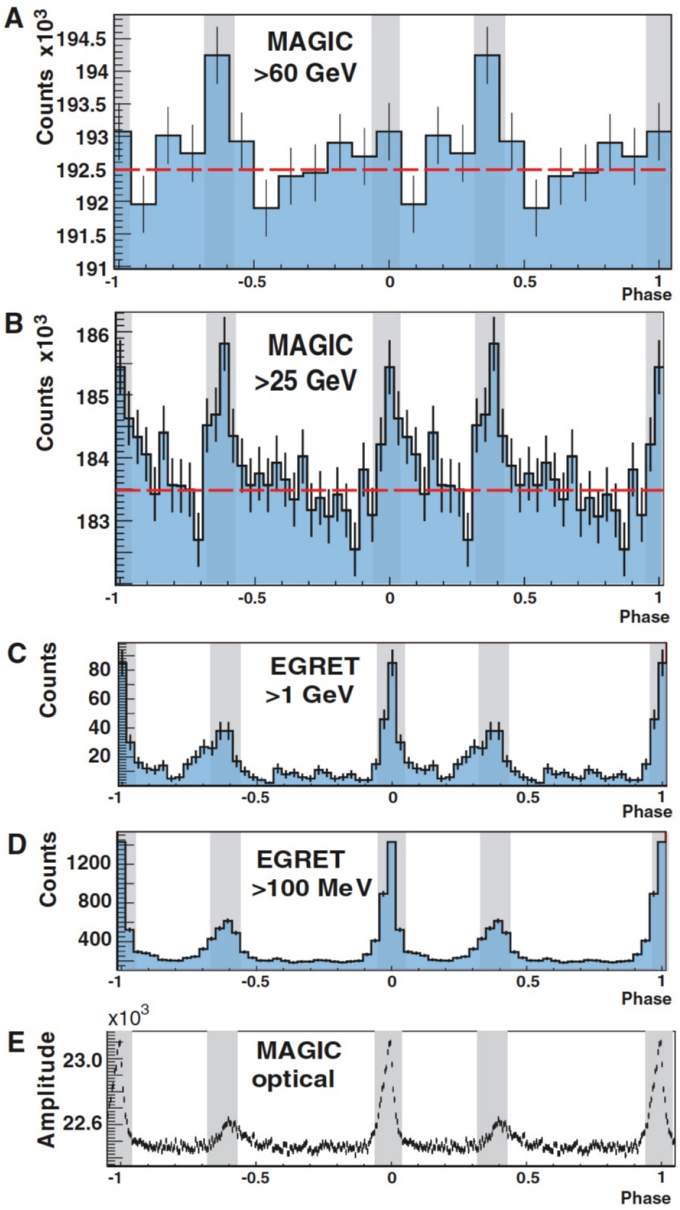

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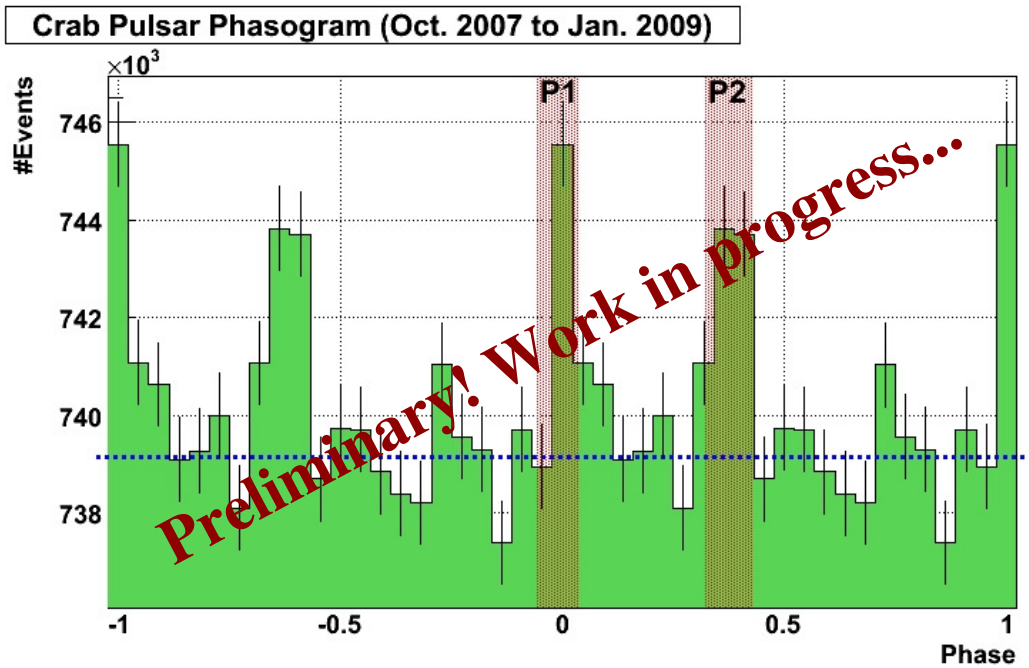
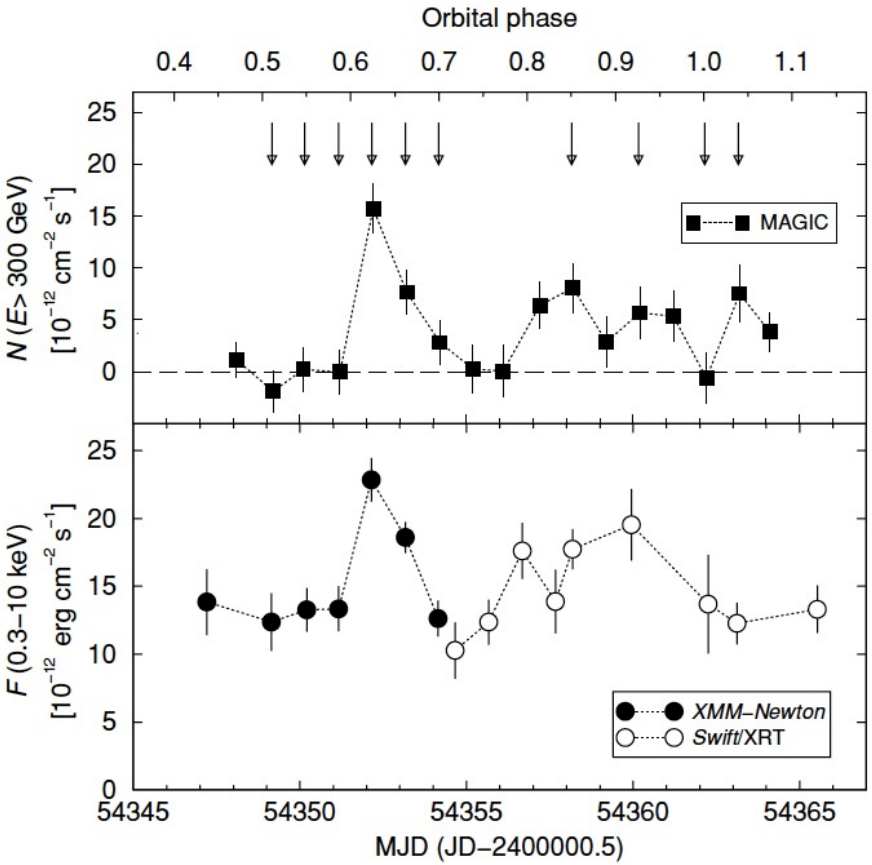
- First detection of a pulsar above 25 GeV
- Special trigger used for MAGIC-I
  $\longrightarrow$ energy threshold of 25 GeV
- Flux compatible with FERMI results
  $\longrightarrow$ exponential cutoff?
- Follow-up observations confirmed signal



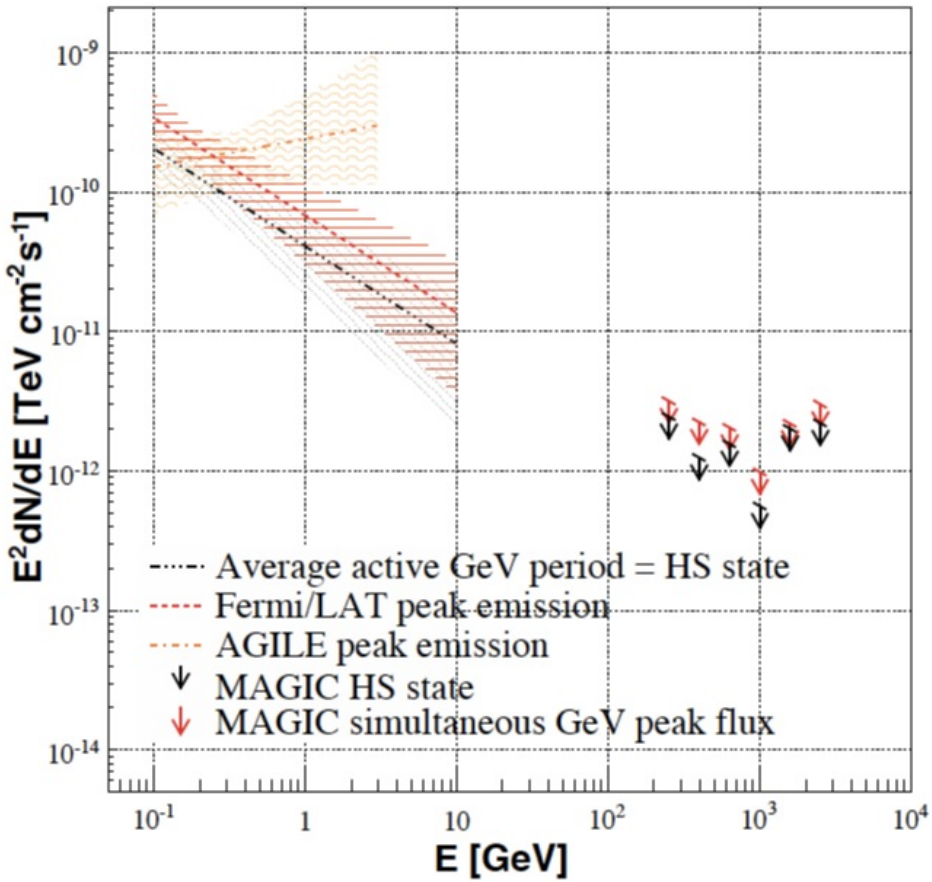
Binary Systems: LS I +61 303 and Cyg X-3

- LS I +61 303 detected by MAGIC
  [Science, Vol. 312, 1771–1773, Nov 2006]
- Periodicity 26.8 ± 0.2 days
  [ApJ, Vol. 693, 303–319, Mar 2009]
- Possible correlation with X-rays



[ApJ, Vol. 706, L27–L32, Nov 2009]

- Cyg X-3 observed 2006–2009 (70h)
  $\longrightarrow$ no detection, best upper limits
- Different X-ray states covered



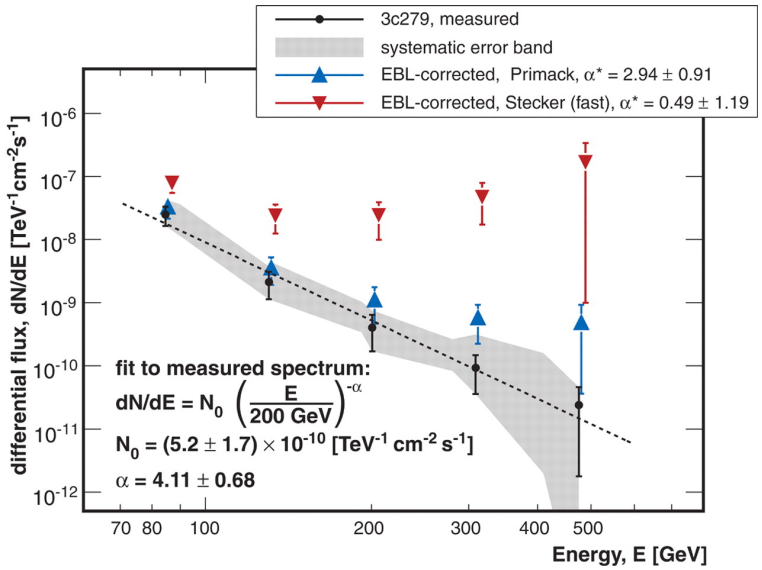
[arXiv:1005.0740, submitted to ApJ (2010)]

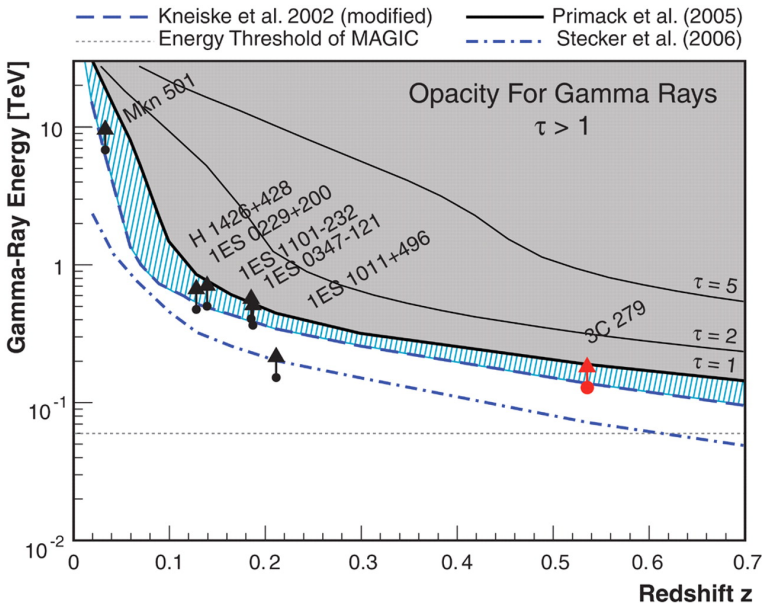
Selected Scientific Results

(MAGIC-I and MAGIC stereo data)

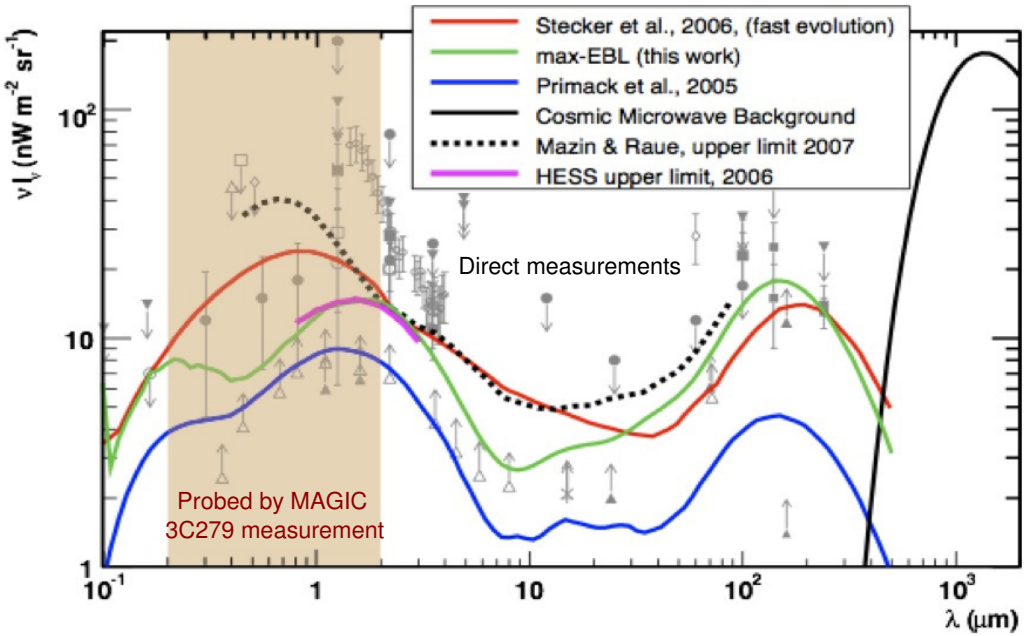
Extra-Galactic Sources

3C279: Probing the Transparency of the Universe



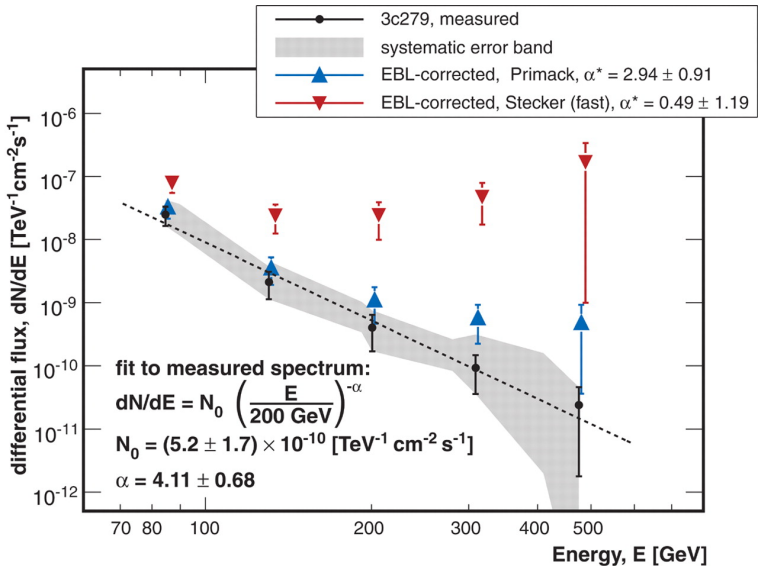


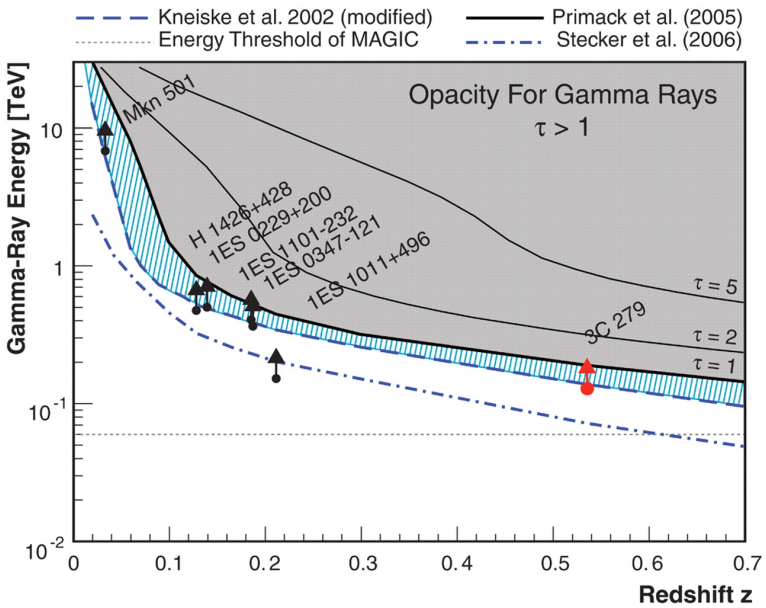
[Science, Vol. 320, 1752–1754, June 2008]



- Flat spectrum radio quasar at $z = 0.536$ $\longrightarrow$ farthest source ever seen in VHE!
- High-z VHE sources challenge Extragalactic Background Light (EBL) models at $\sim 1\,\mu$m
- Important to have precise energy spectrum
- More sources at high-z needed

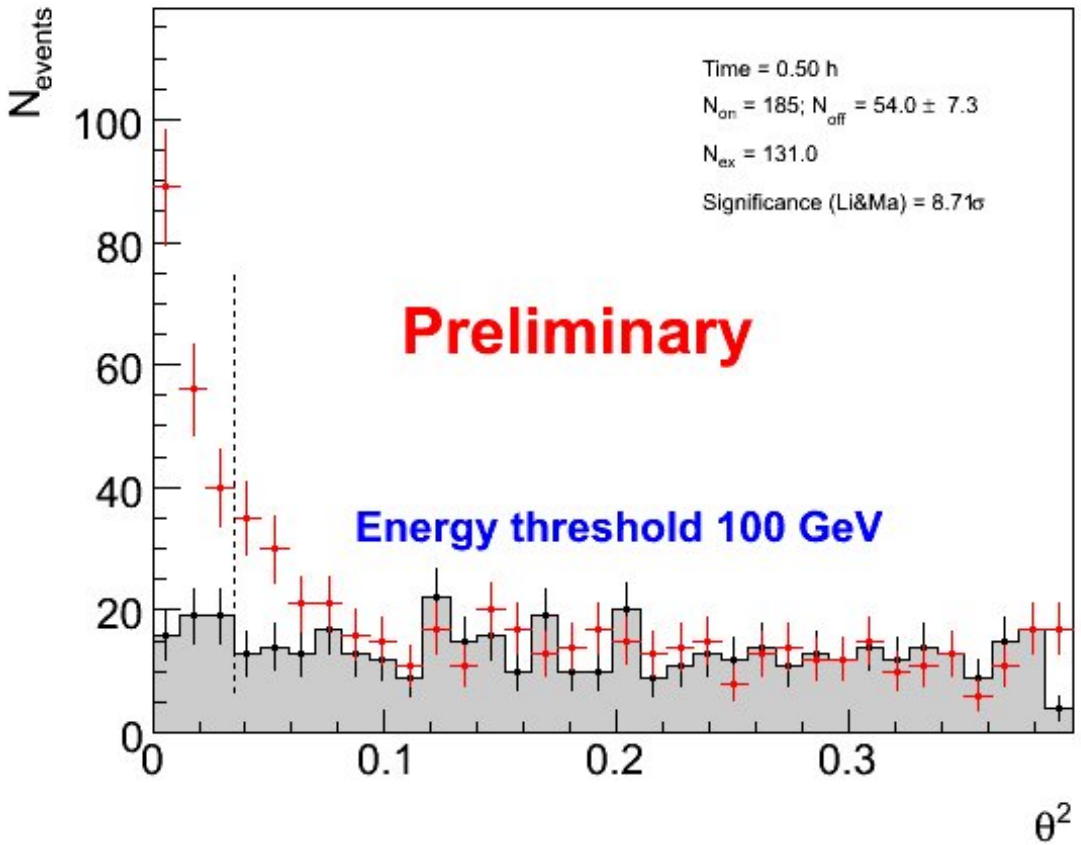
3C279: Probing the Transparency of the Universe



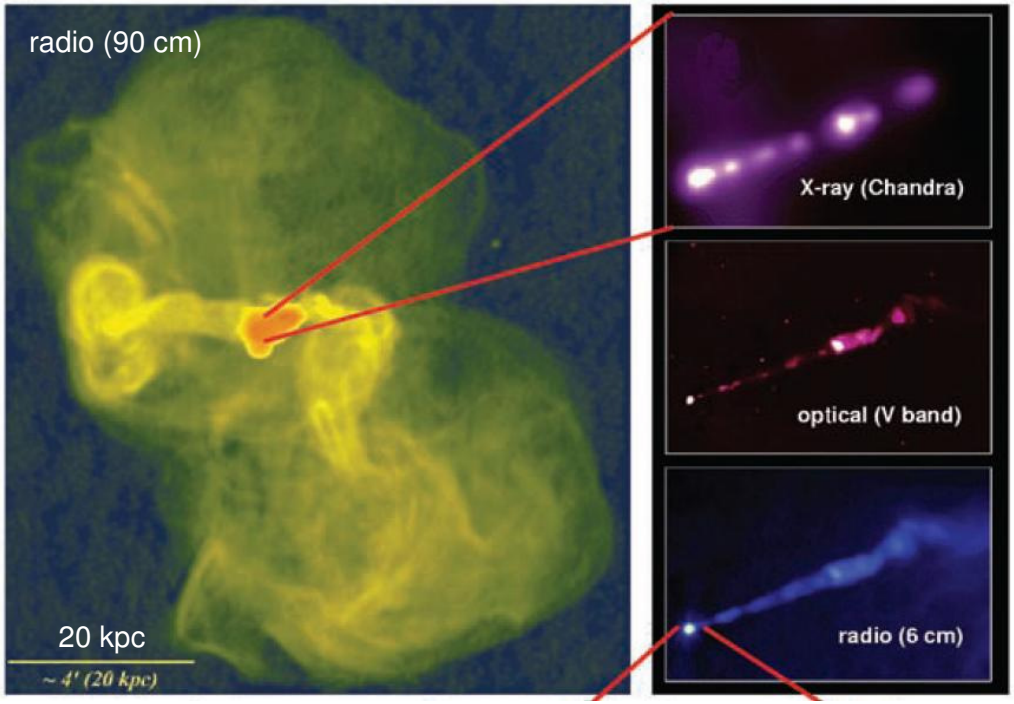


[Science, Vol. 320, 1752–1754, June 2008]

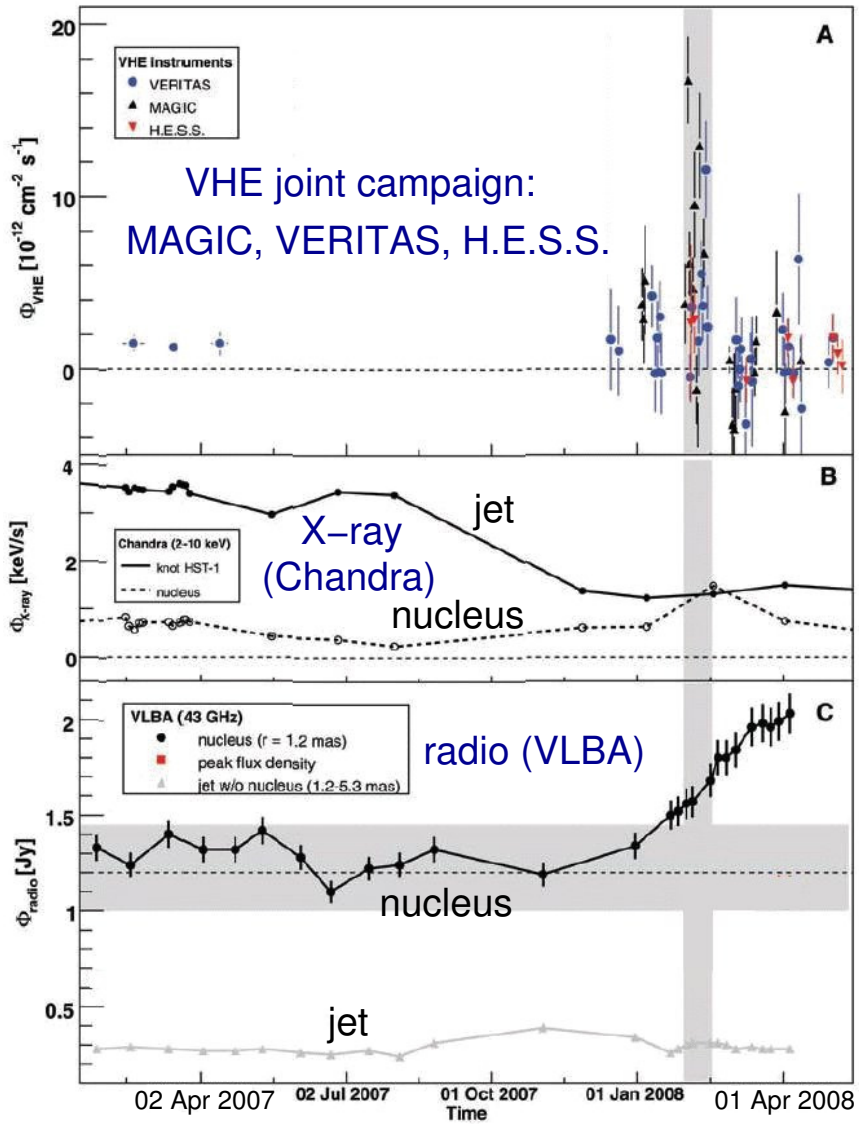
4C+21.35 detected by MAGIC in June 2010!
$\rightarrow z = 0.432$, $> 8\sigma$ from 0.5h [ATel 2684]



M87: Investigate the Origin of VHE γ-Rays



- Radio galaxy at 16 Mpc with super-massive black hole of $6 \cdot 10^9$ solar masses at center
- Coordinated multi-wavelength effort
- Flare in Feb 2008: 8σ in single night
  $\rightarrow$ MAGIC alerted other telescopes
- TeV corr. with radio and X-rays from core!
  $\rightarrow$ Hint that γ-rays came from close to BH
- More flares in 2010! [ATels 2431, 2437, 2542]

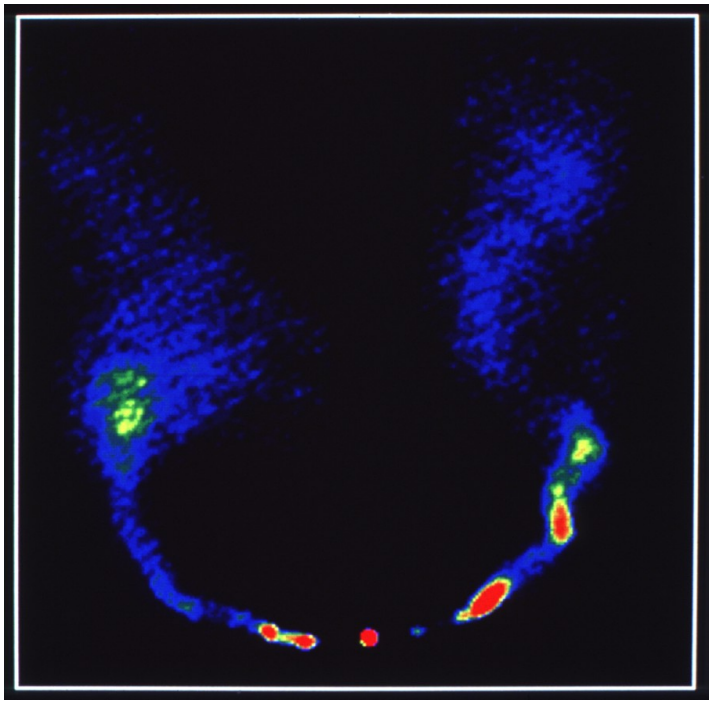


Details, references and credits:
[Science, Vol. 325, 444–448, July 2009]

IC310: First Head-Tail Radio Galaxy seen in VHE Regime

- Located in Perseus cluster (80 Mpc) $\rightarrow$ 5x more distant than M87
- Detected by MAGIC: [ATel 2510, March 2010]
  - 6σ from 20h stereo data (2010) and 38h MAGIC-I data (2008 to 2010)
  - Preliminary emission level: $\sim$2.5% of Crab Nebula flux ($E > 300\,\mathrm{GeV}$)
- Also detected by FERMI/LAT above 100 GeV [arXiv:1003.4615]

- "Relative" in Perseus cluster: NGC1265
  (radio image on the right)
  $\rightarrow$ Not detected in VHE regime!
- How are γ-rays produced in IC310?
  - Close to central BH like in M87?
  - Or by interaction of relativistic outflow with intracluster medium?
- Important to check variability!
- Detailed publication in preparation



[Courtesy of NRAO/AUI, C. O'Dea/F. Owen]

Summary and Outlook

- MAGIC-I (2004-2009) has been a great success
  - Largest IACT (17m mirror) $\rightarrow$ lowest energy threshold (25–50 GeV)
  - Many detections, e.g. first pulsar > 25 GeV and farthest VHE source ($z > 0.5$)
- Big potential of MAGIC stereo system (since 2009)
  - Better performance, especially sensitivity increased by $\sim 50\%$
  - Excellent overlap with FERMI data on Crab Nebula spectrum
  - First detections of VHE sources: IC310 ($z = 0.0189$), 4C+21.35 ($z = 0.432$)
- Many more results and physics objectives: bright blazar monitoring, gamma-ray bursts, supernova remnants, galaxy clusters, dark matter, ...
- Upgrade in summer 2011
  - New MAGIC-I camera $\rightarrow$ clone of MAGIC-II (1039 PMTs, higher QE)
  - New readout system for both telescopes based on DRS4 chip
  - Increase M-I trigger area, implement improved sumtrigger in both telescopes
  - Currently HPDs are evaluated as alternative photo sensors