



***Highlight results
from the **MAGIC**
telescopes***

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Padova University & INFN

From neutrino to multimessenger astronomy :
status and perspectives

Marseilles 4th April 2011

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OUTLINE

- **MAGIC: A LOW ENERGY THRESHOLD IACT**
- **RECENT RESULTS**
 - **GALACTIC**
 - **EXTRAGALACTIC**
- **FINAL REMARKS**

MAIN IACT OBSERVATORIES IN THE WORLD



MAGIC



VERITAS



H.E.S.S.

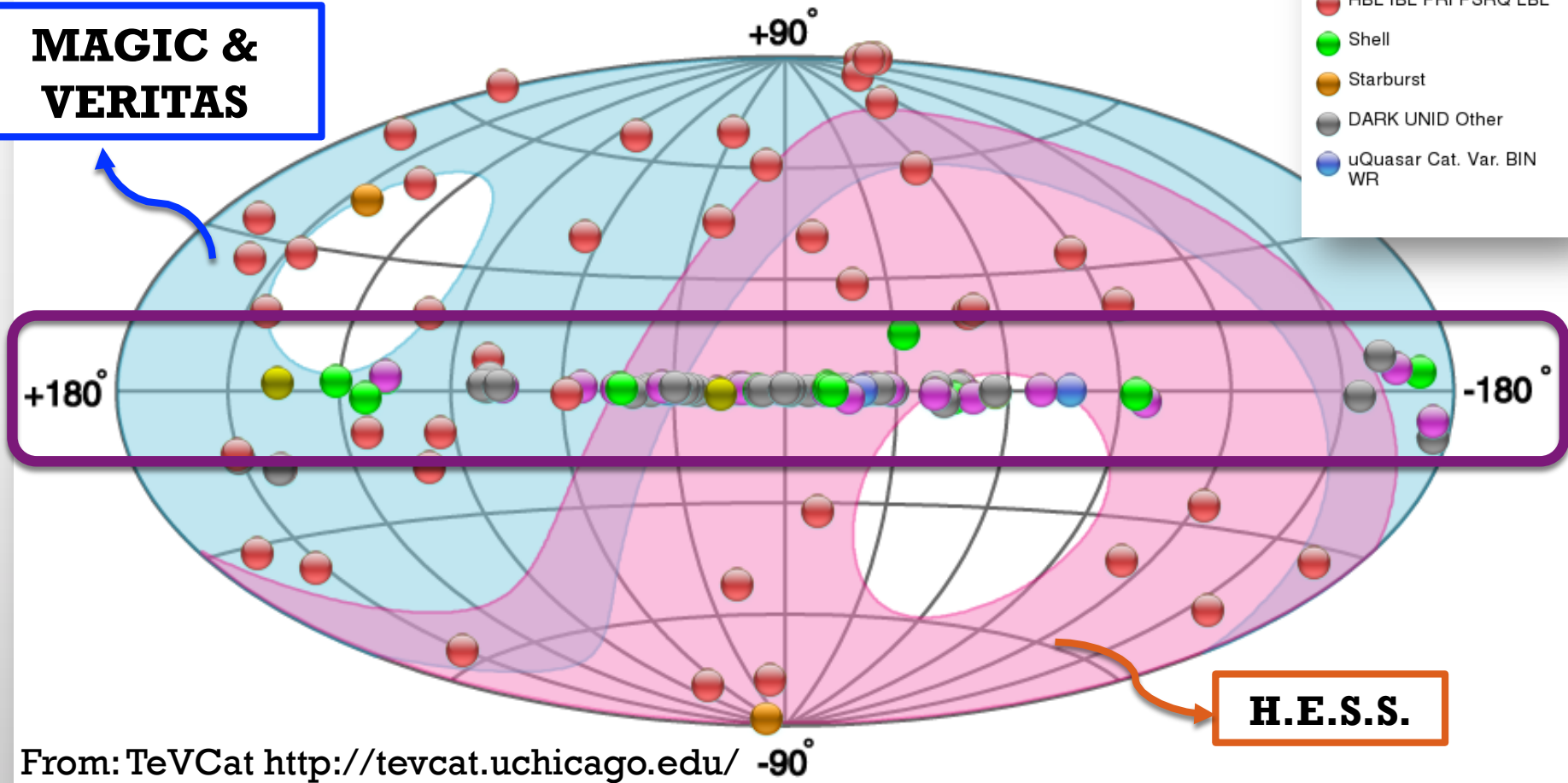


THE TEV SKY

Source Types

- PWN
- XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL
- Shell
- Starburst
- DARK UNID Other
- uQuasar Cat. Var. BIN WR

**MAGIC &
VERITAS**



From: TeVCat <http://tevcat.uchicago.edu/>

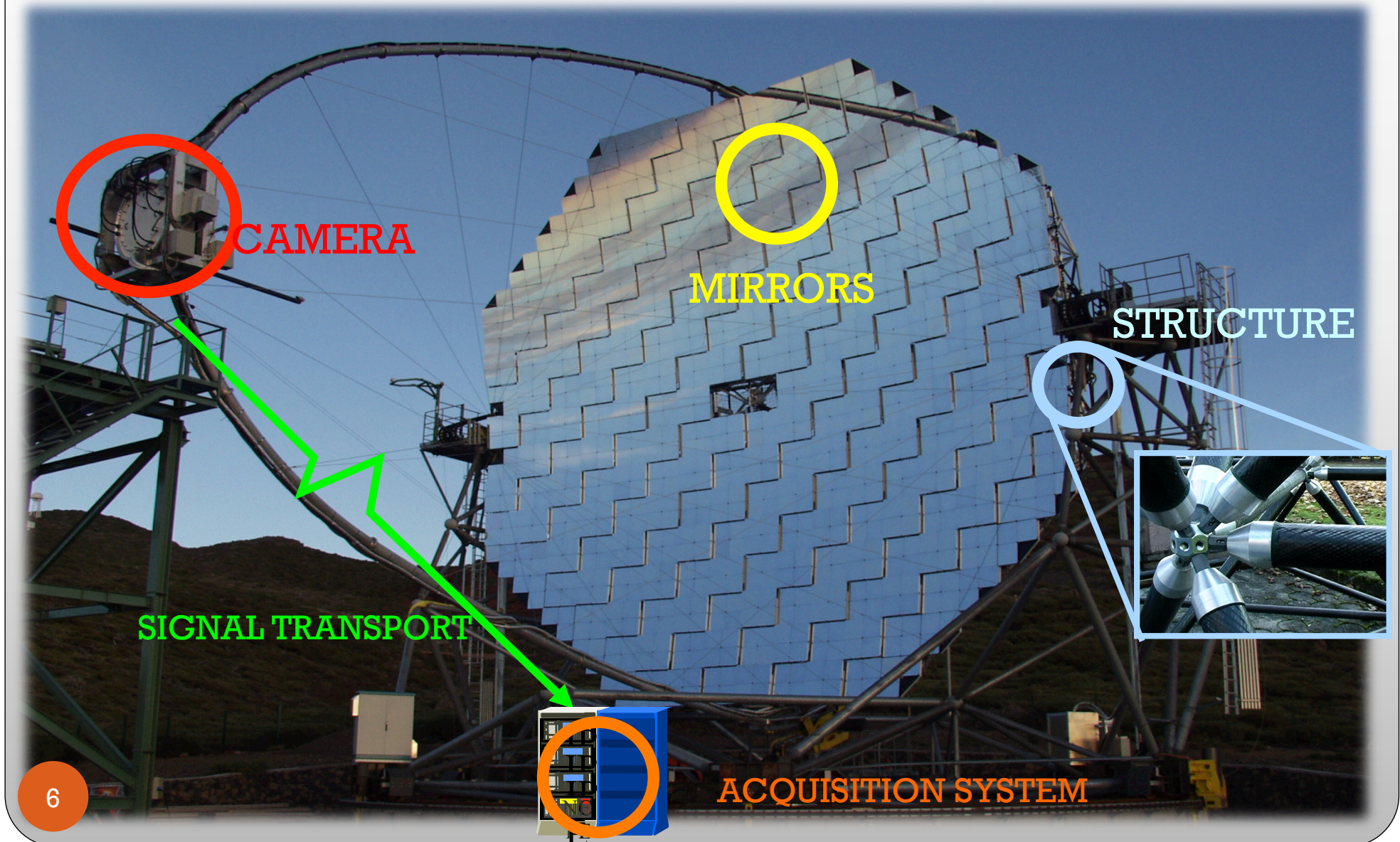
- 46 extragalactic objects
- 61 galactic objects

THE MAGIC TELESCOPES

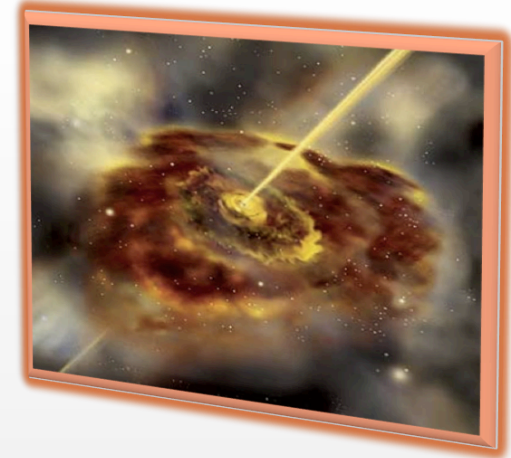
- Energy threshold ~ 50 GeV (~ 25 GeV with a special trigger)
- FOV 3.5°
- Energy Resolution $\sim 16\%$ ($E > 300$ GeV)
- Angular Resolution $\sim 0.07^\circ$ ($E > 300$ GeV)
- Sensitivity (5σ in 50 hours) $\sim 0.8\%$ Crab Nebula flux (> 250 GeV)



MAGIC: THE INSTRUMENT



MAGIC ASTROPHYSICS



Source detection and monitoring

Populate the TeV sky

Origin of the emission (and CRs)

γ -ray propagation

Dark Matter and new physics

Cosmology and fundamental physics

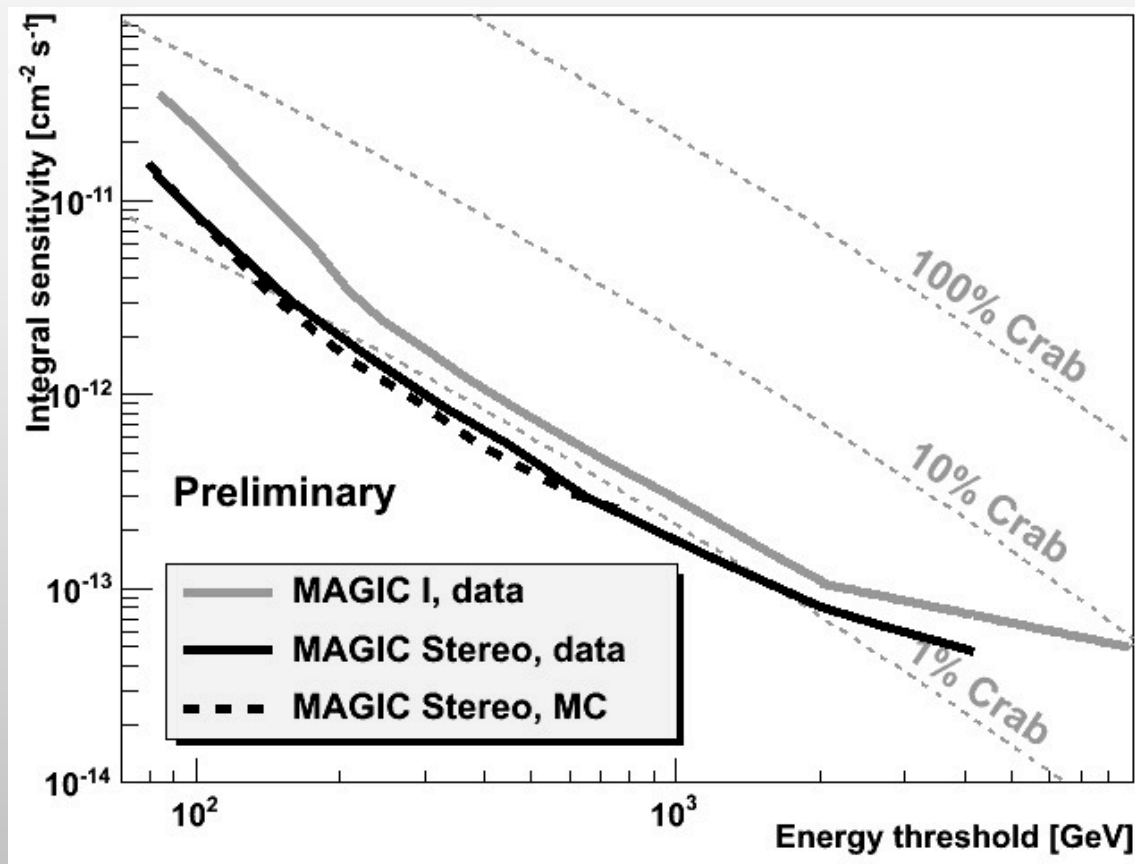
THE STEREO IMPROVEMENT (2009)

- **THE SENSITIVITY:**

a factor of two more sensitive above 250 GeV, up to factor 3 at 100 GeV



required observation time for DETECTION greatly reduced!



ACHIEVEMENTS...

New discoveries

6 new sources in 1 year!

ToO program

Optical triggers
HE γ -rays triggers

MWL campaigns

Characterization of the SED
Combined information

... AND OPEN SEARCH FIELDS

Dark matter emitters

GRBs

...



MAGIC SOURCES

pulsar

Supernova
Remnants

X-ray
binaries

MAGIC SOURCES

pulsar

FSRQs

Supernova
Remnants

blazars

X-ray
binaries

radiogalaxies

MAGIC SOURCES

pulsar

FSRQs

GRBs

Supernova
Remnants

Dwarf
Galaxies

blazars

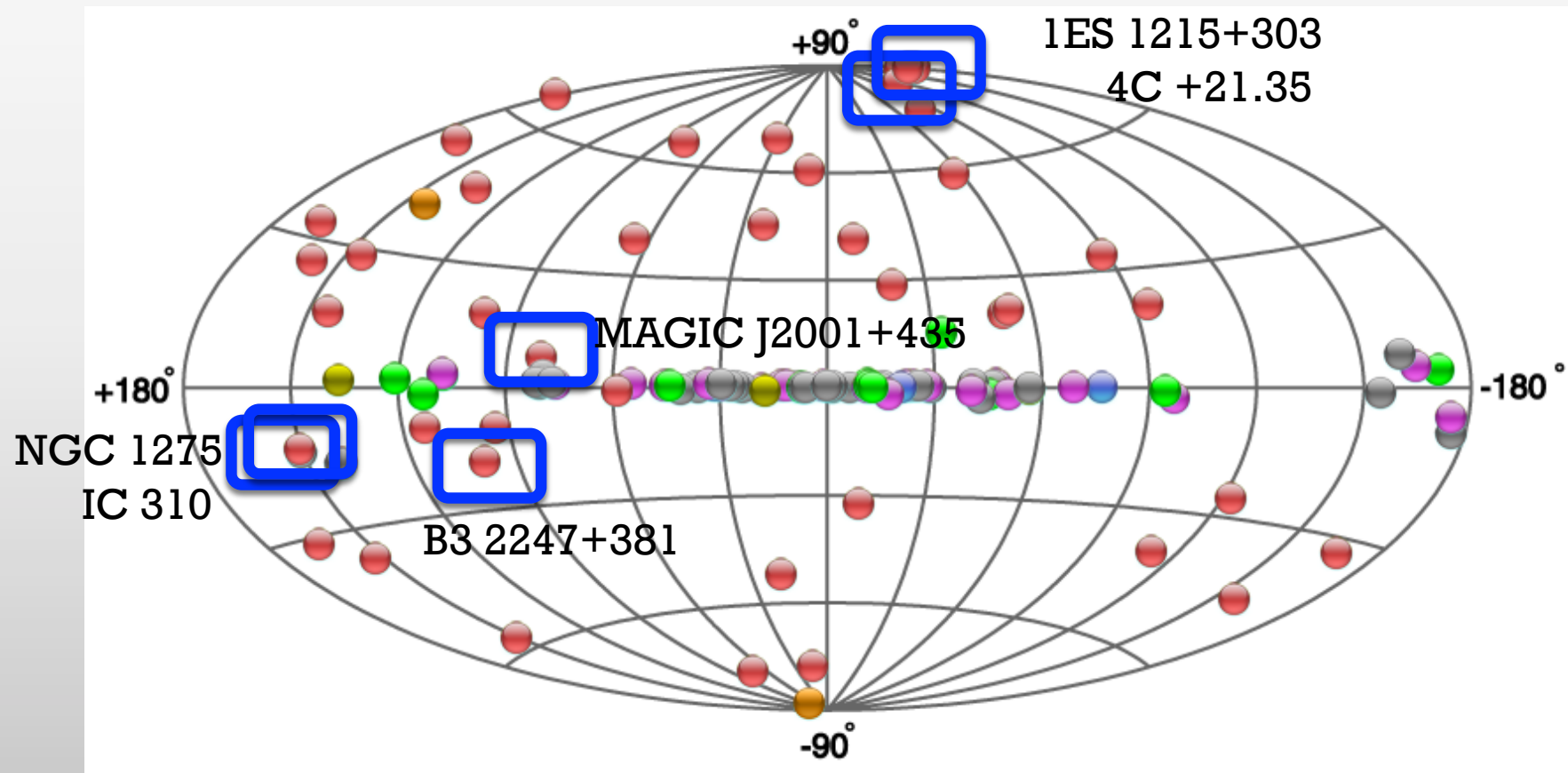
X-ray
binaries

Galaxy
Clusters

Unidentified
objects

radiogalaxies

LATEST STEREO DISCOVERIES



6 new extragalactic objects in 12 months!

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HE γ -ray triggers
Neutrino triggers

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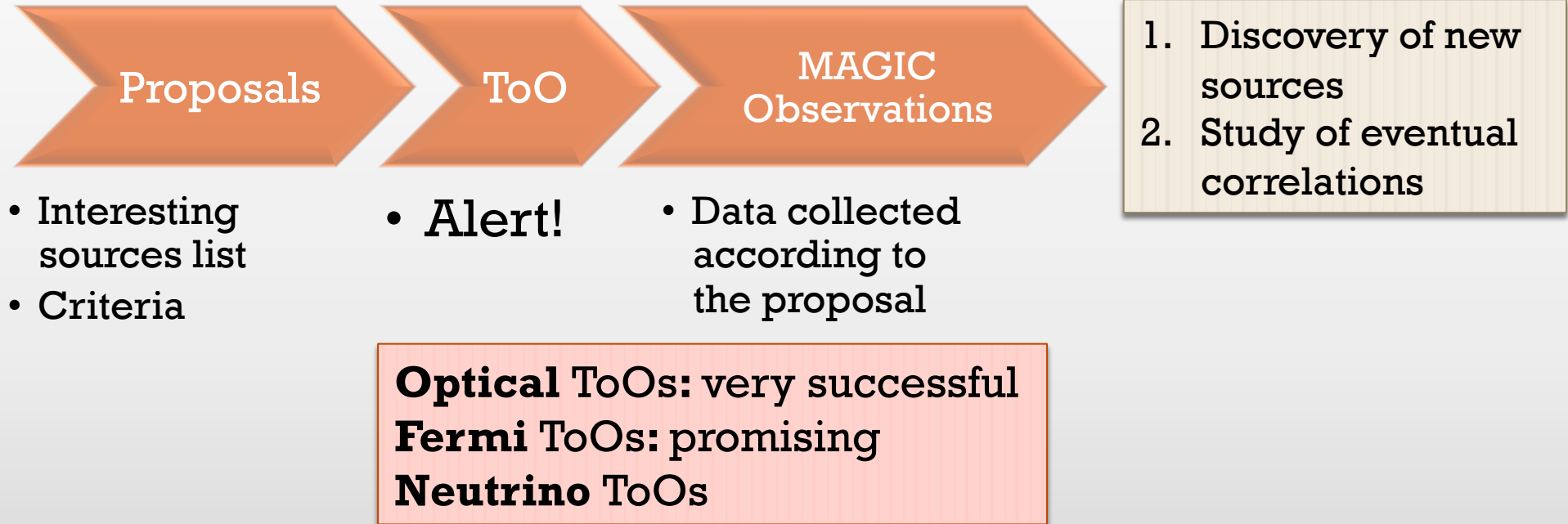
... AND OPEN SEARCH FIELDS

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GRBs

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TARGET OF OPPORTUNITY OBSERVATIONS



TARGET OF OPPORTUNITY OBSERVATIONS



- Interesting sources list
- Criteria

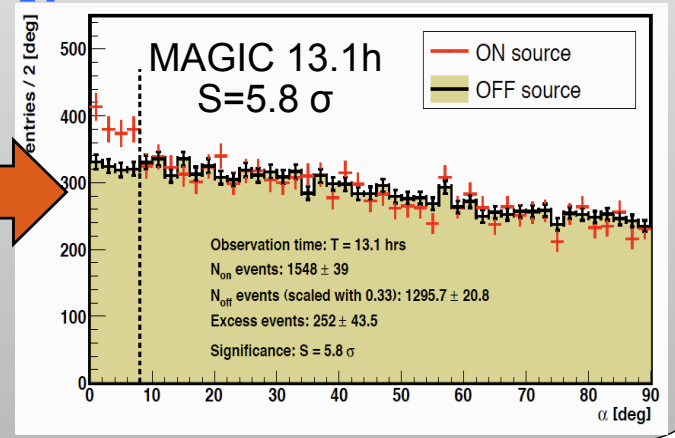
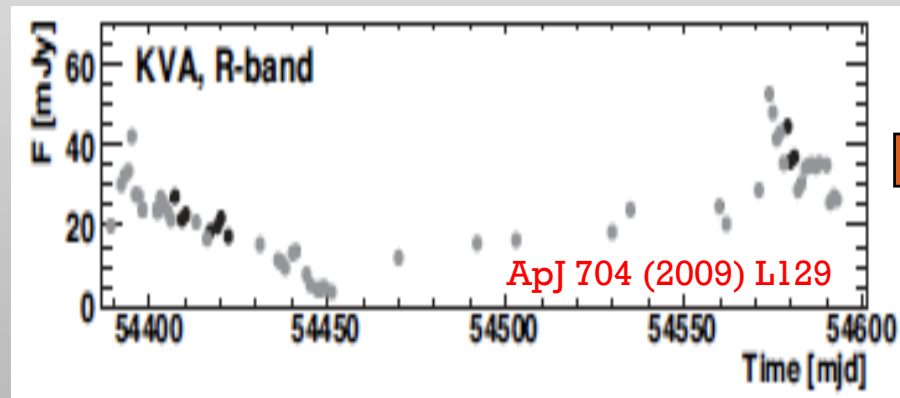
• **Alert!**

- Data collected according to the proposal

1. Discovery of new sources
2. Study of eventual correlations

Optical ToOs: very successful
Fermi ToOs: promising
Neutrino ToOs

Example - the discovery of S5 0716+714:



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Characterization of the SED

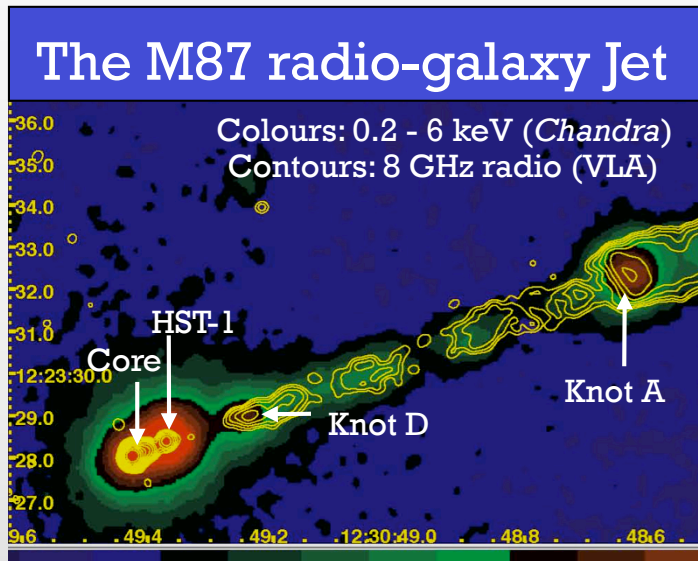
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Dark matter emitters

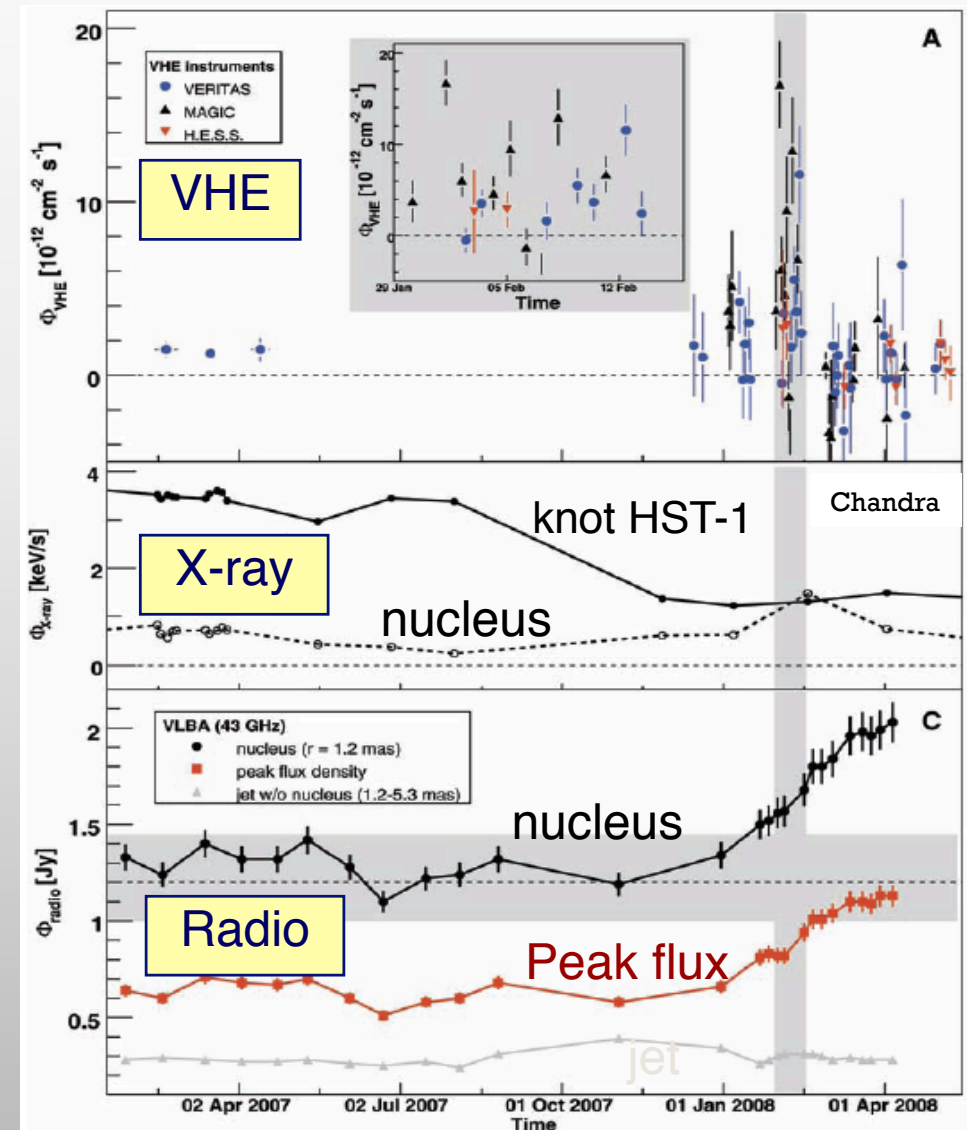
GRBs

...

JOINT HESS-MAGIC-VERITAS CAMPAIGN OF M87 (SCIENCE 2009)



- Shared monitoring HESS, MAGIC, VERITAS
- Confirmation of day-scale variability at VHE
- Evidence of central origin of the VHE emission (60 R_s to the BH)



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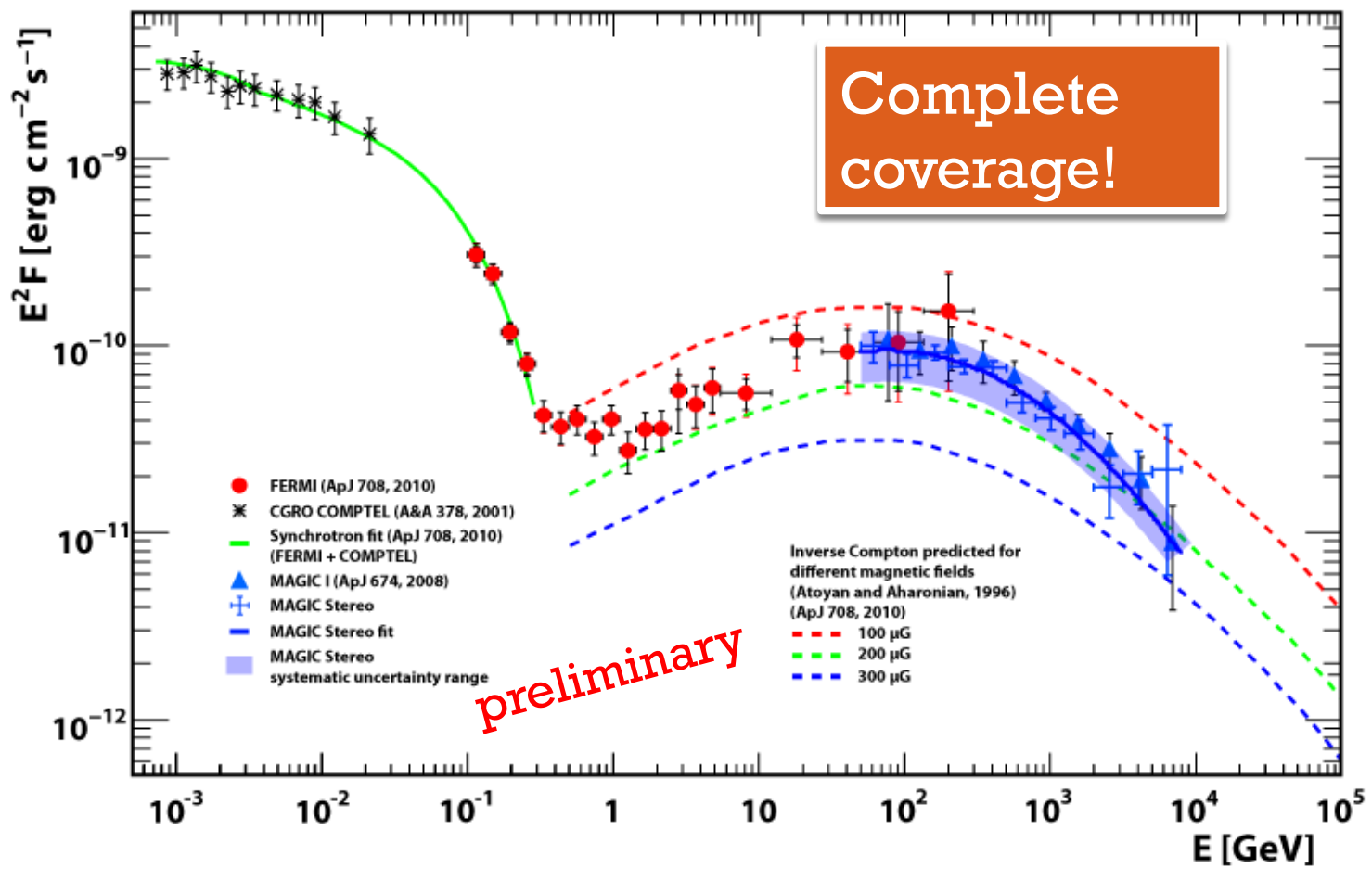
Criterion: Recent/
incoming publications!

OUR STANDARD CANDLE: THE CRAB NEBULA

- 3.2 hours of Crab Nebula data
- stereoscopic system
- November 2009

Crab Nebula Spectrum

MAGIC Stereo in combination with neighbouring wavelengths

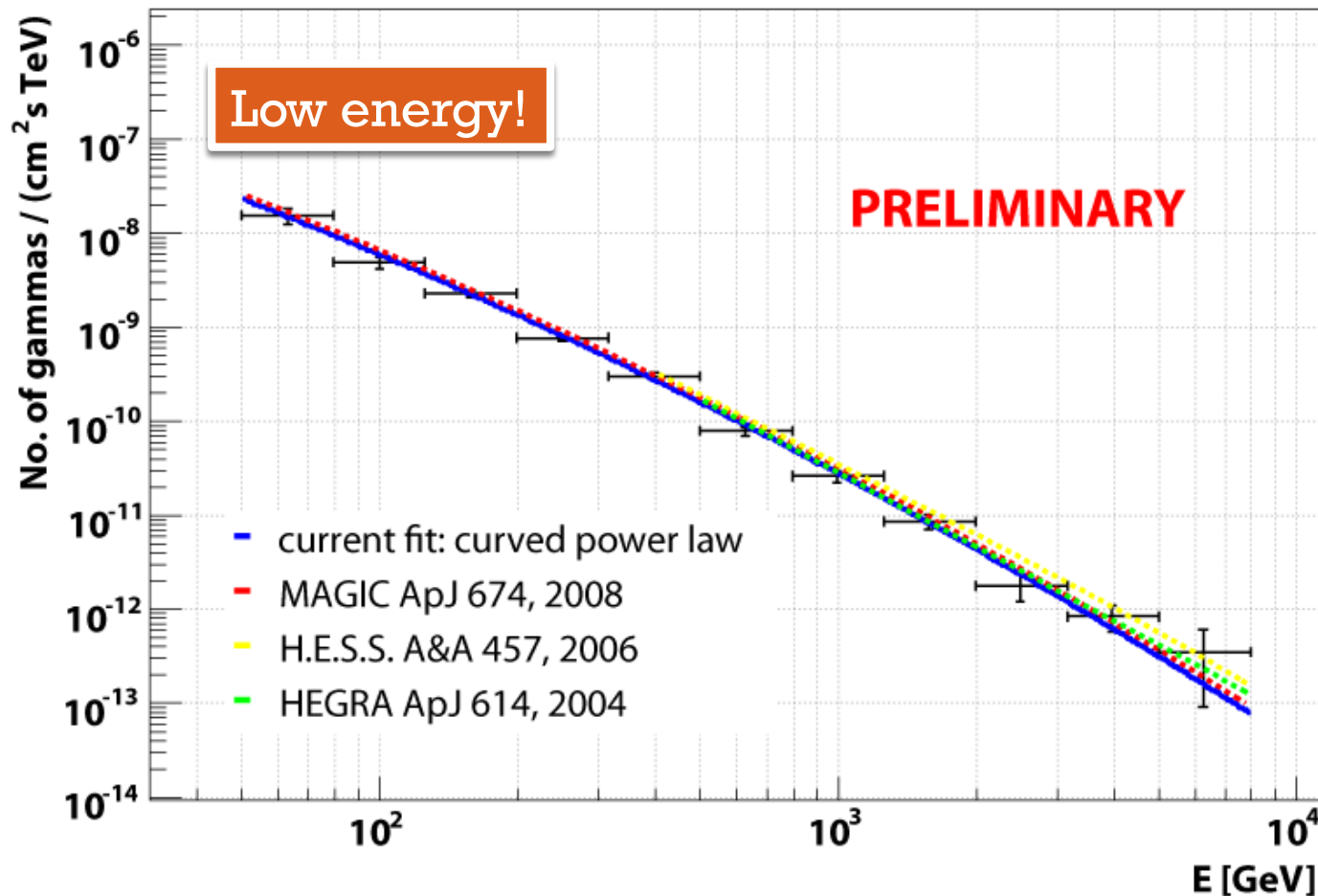


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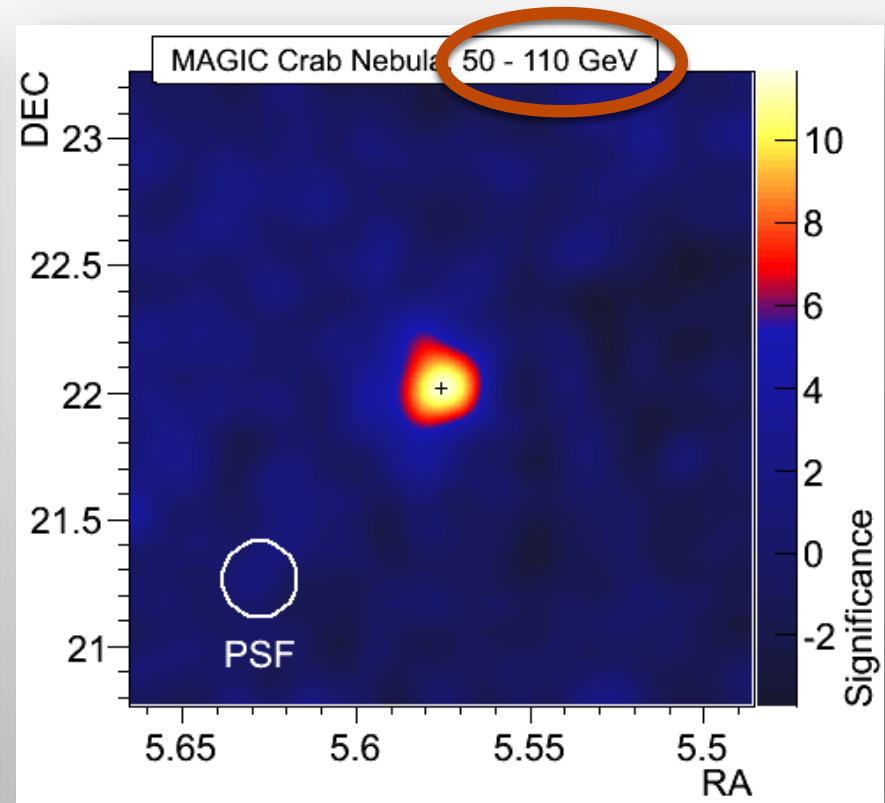
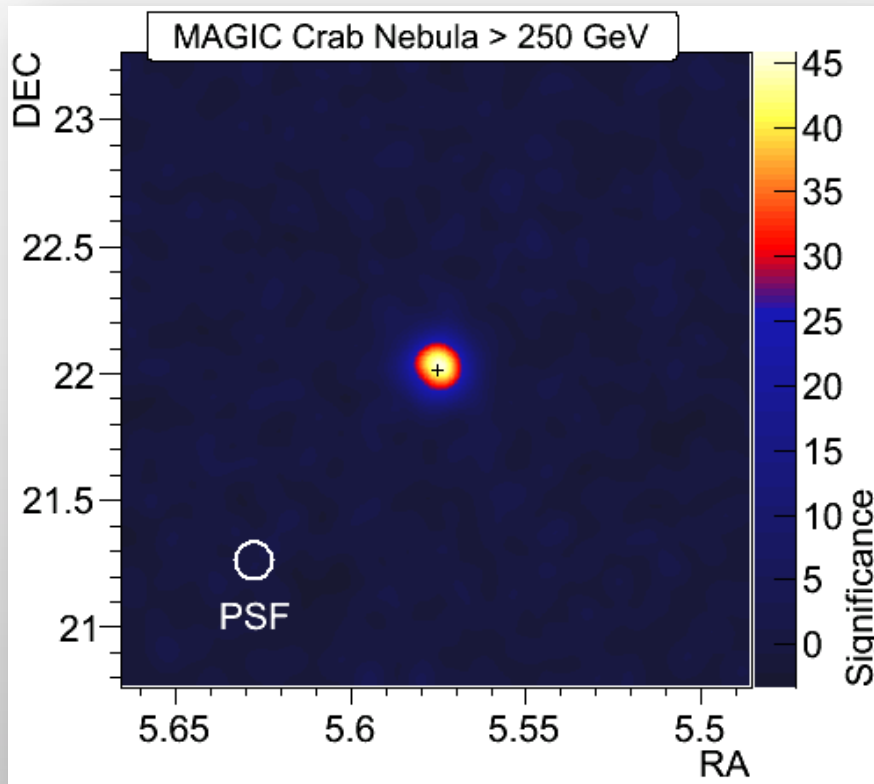
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- November 2009

Crab Nebula Spectrum MAGIC Stereo

November 13-15th 2009, 190min effective observation time



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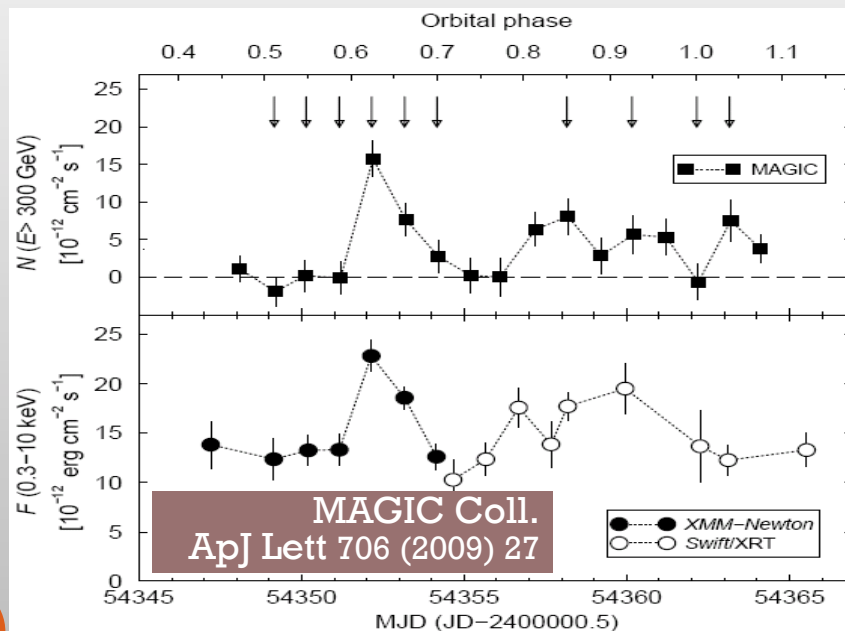


Low energy range
→ overlap with *Fermi*!

VHE γ -RAY EMISSION FROM BINARY SYSTEMS

LSI +61 303

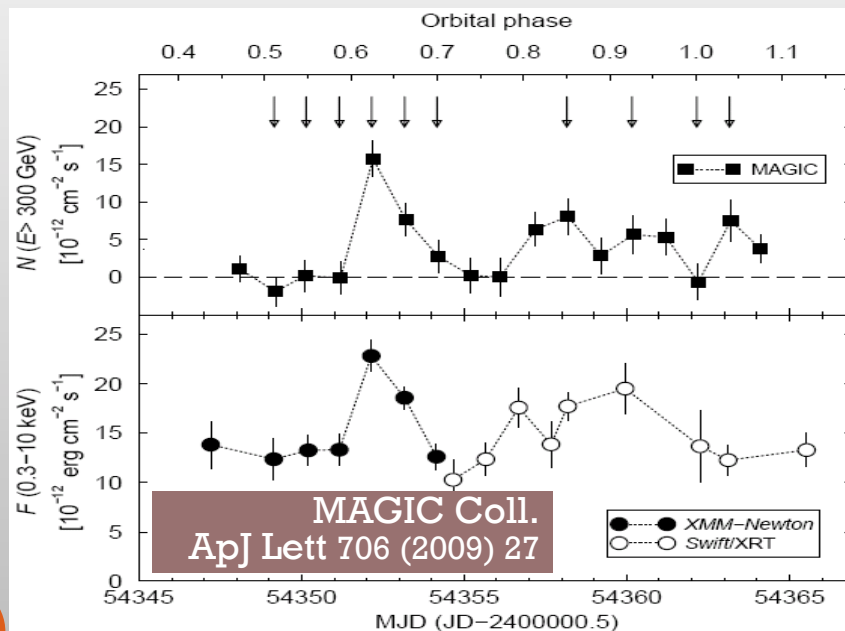
- Discovered by MAGIC in 2006
- Correlation between X and VHE γ emission
- Suggests **leptonic processes** are at work.



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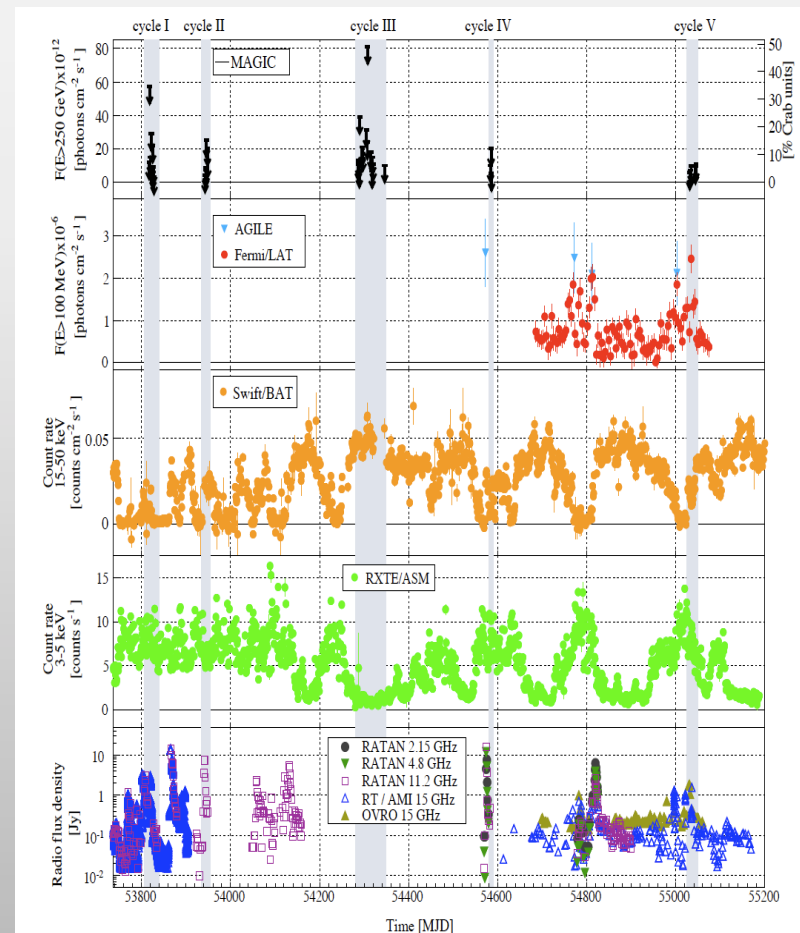
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Cyg X-3

MAGIC Coll.
ApJ 721 (2010) 843

- Large MWL efforts!
- MAGIC measured upper limits



HESS J0632+057

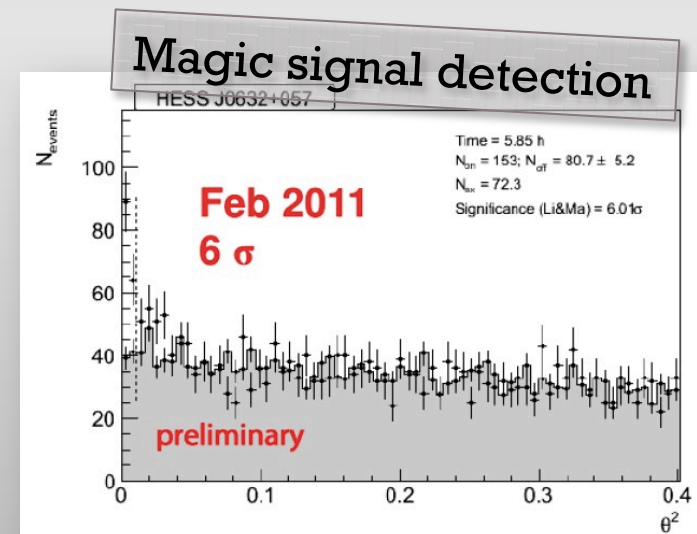
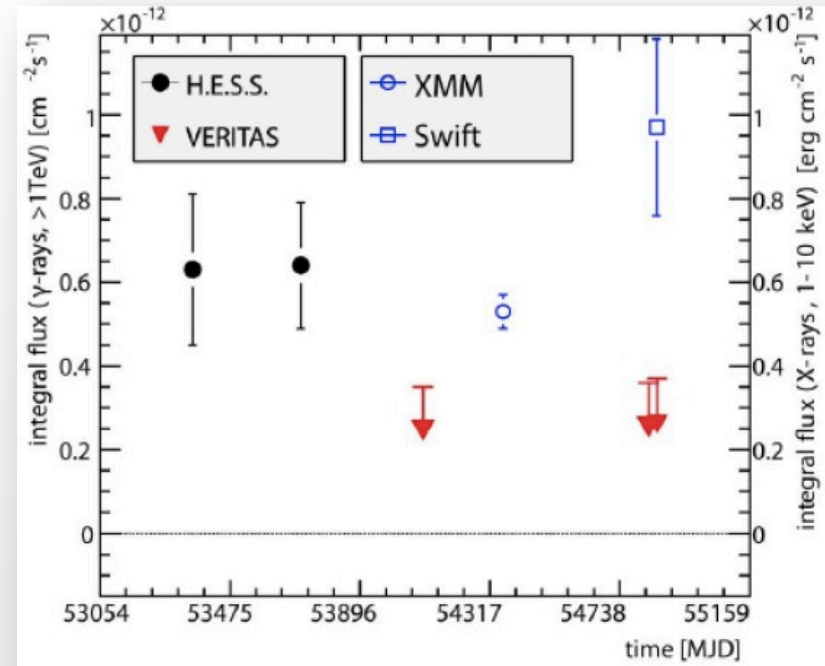
- Discovered by H.E.S.S
- VARIABLE (non detection by VERITAS)
- Possible binary system (compatible with VHE and X-ray sources)

January & February 2011:

INCREASED X-RAY ACTIVITY (Swift-XRT Atel) from Jan 23th 2011 on till at least Feb 6th

→ ToO observations:

- **VERITAS** (Atel #3153): 7&8 February
Flux 4% Crab > 400 GeV
- **MAGIC** (Atel #3161): 7-9 February
Flux 3.4% Crab > 200 GeV



PULSAR OBSERVATIONS: THE CRAB NEBULA

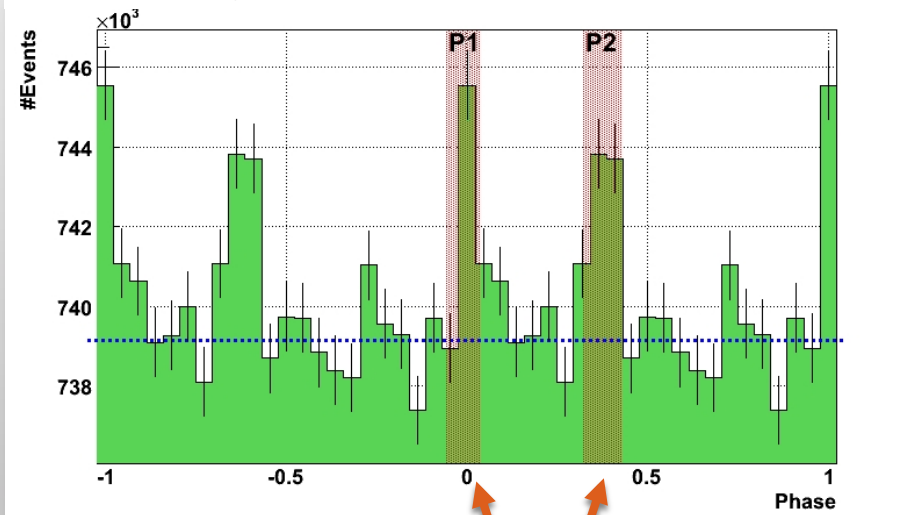


Pulsars: Energy cutoffs at few GeV → very difficult for IACTs

- MAGIC is the only Cherenkov telescope that has detected a pulsar:
 - Special **LOW-ENERGY** “Sum-Trigger” system
 - Lower threshold (but higher systematics)

Determinant to **CONSTRAIN MODEL**:
→ discards production mechanisms close to the pulsar surface, where the B-field is too high

Crab Nebula pulsar phaseogram
(Oct 2007 – Jan 2009)



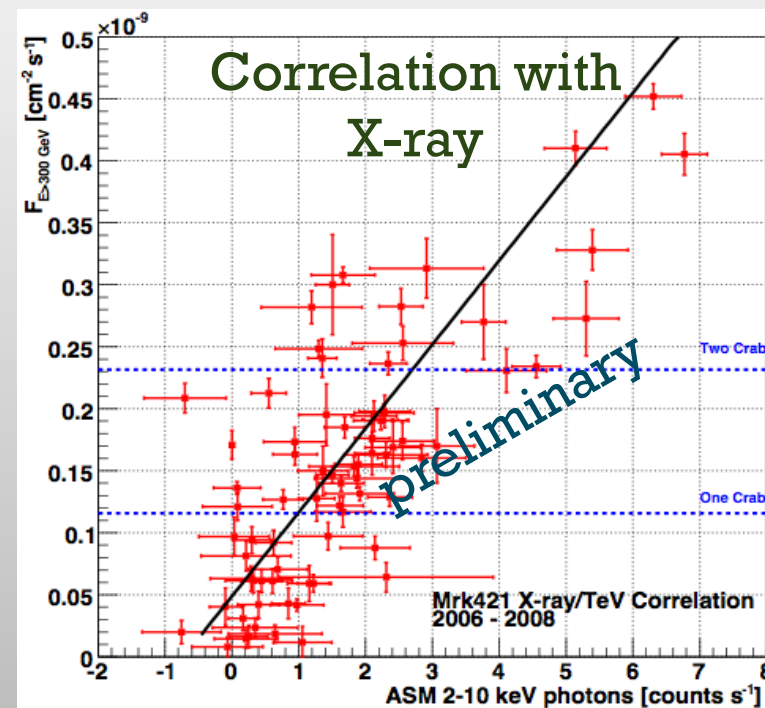
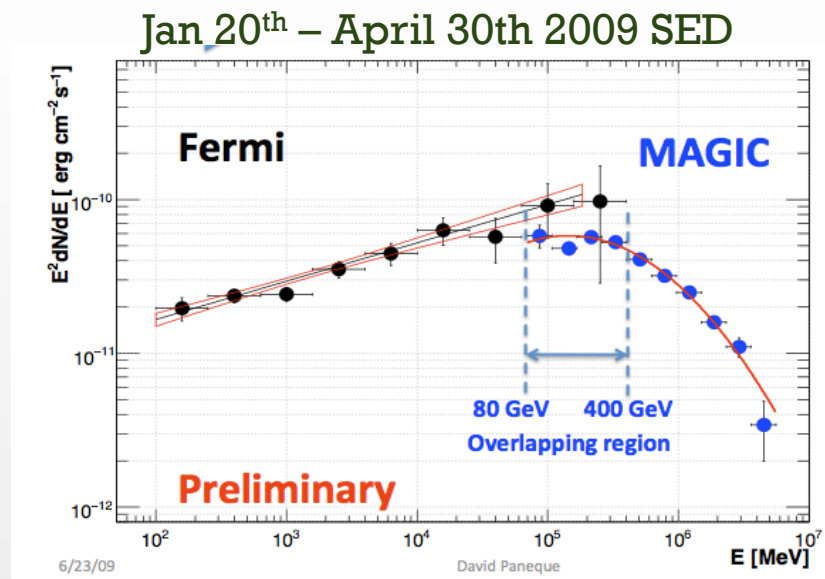
Clear signal

LONG TERM STUDY OF BRIGHT EXTRAGALACTIC SOURCES

- Mkn 421,
Mkn 501,
1ES 1959+650,
1ES 2344+514,
PG1553+113
- Strategies: MWL
campaigns, ToOs

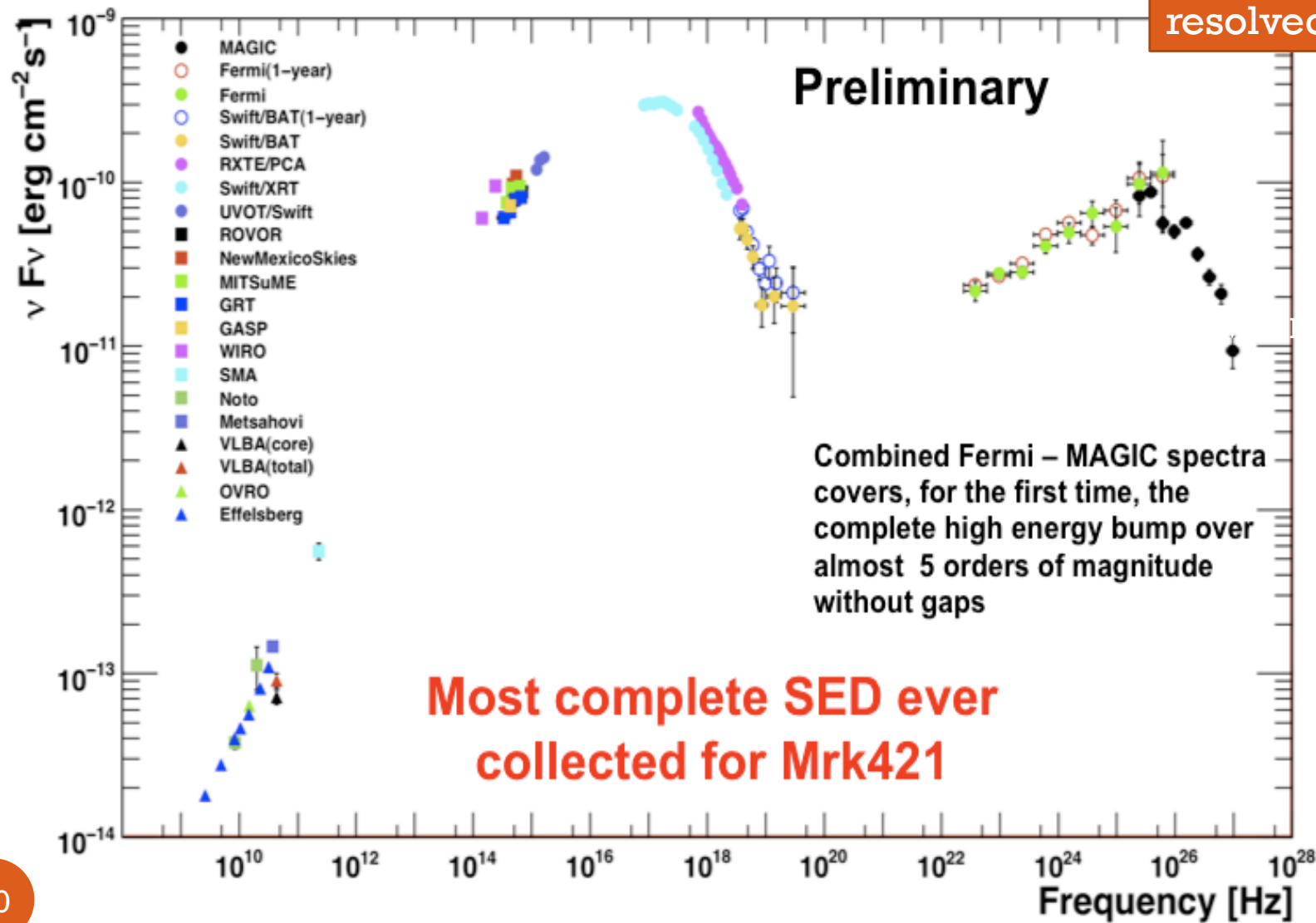
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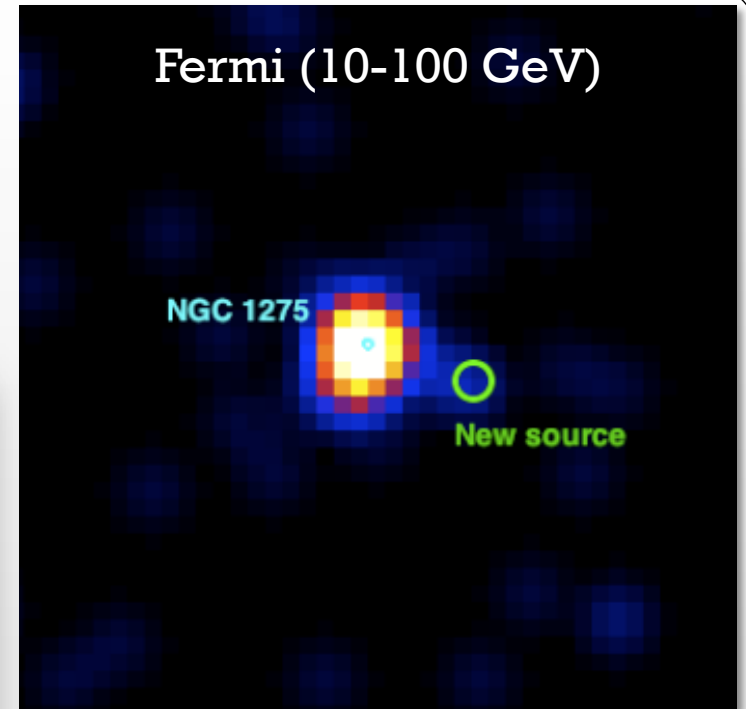
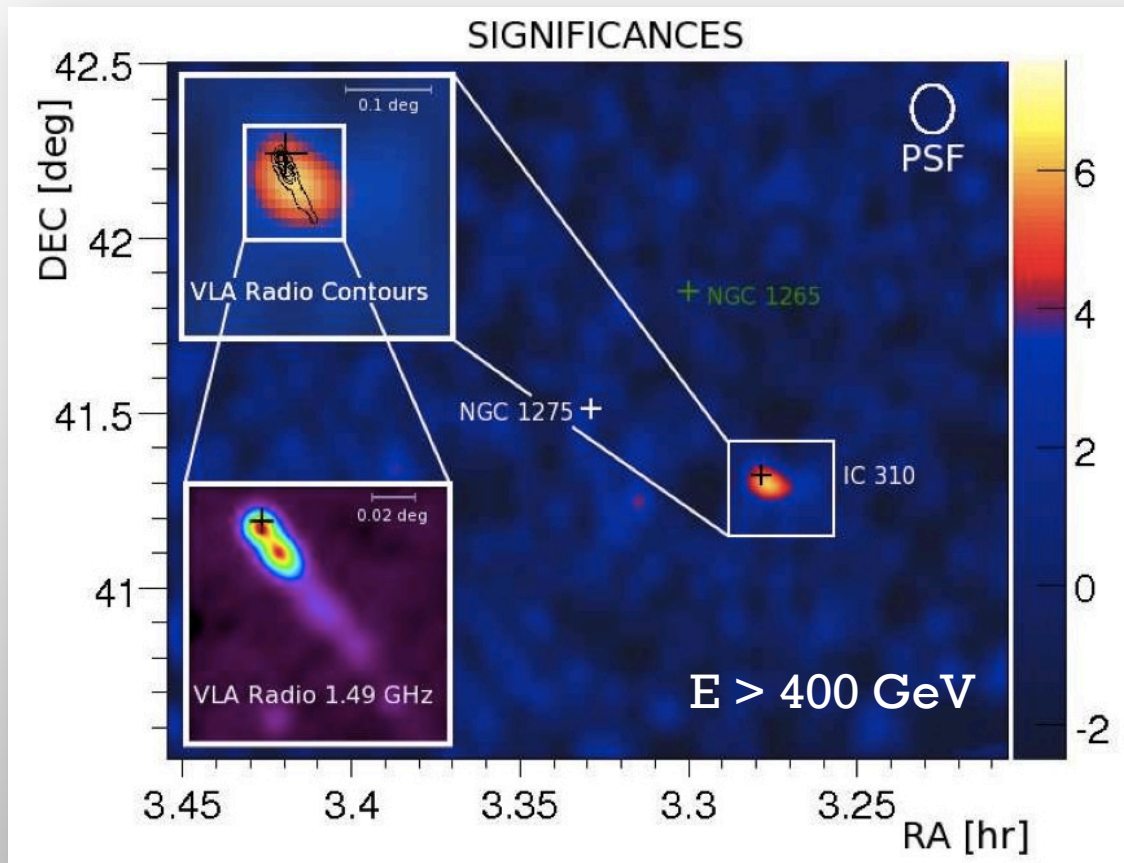


MKN 421 MWL VIEW

Both peaks are resolved!

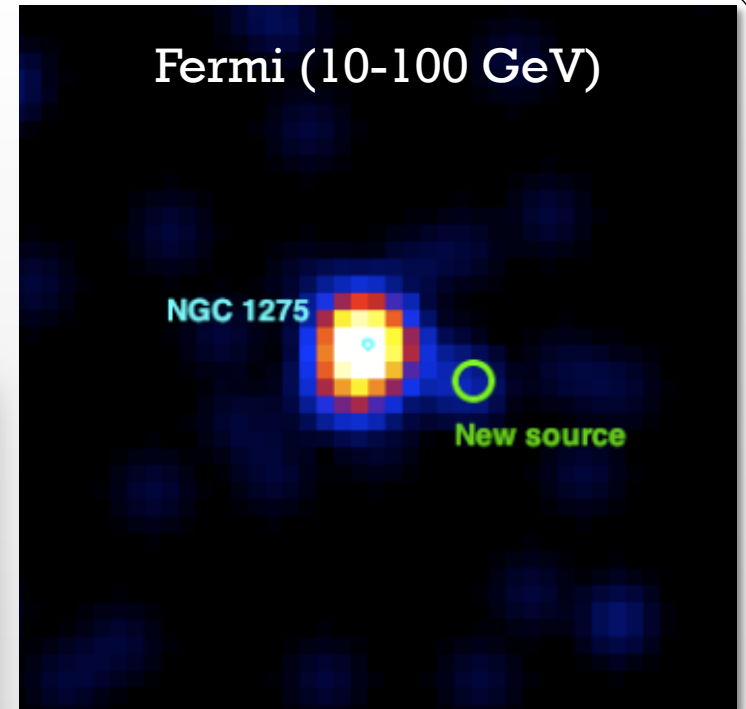
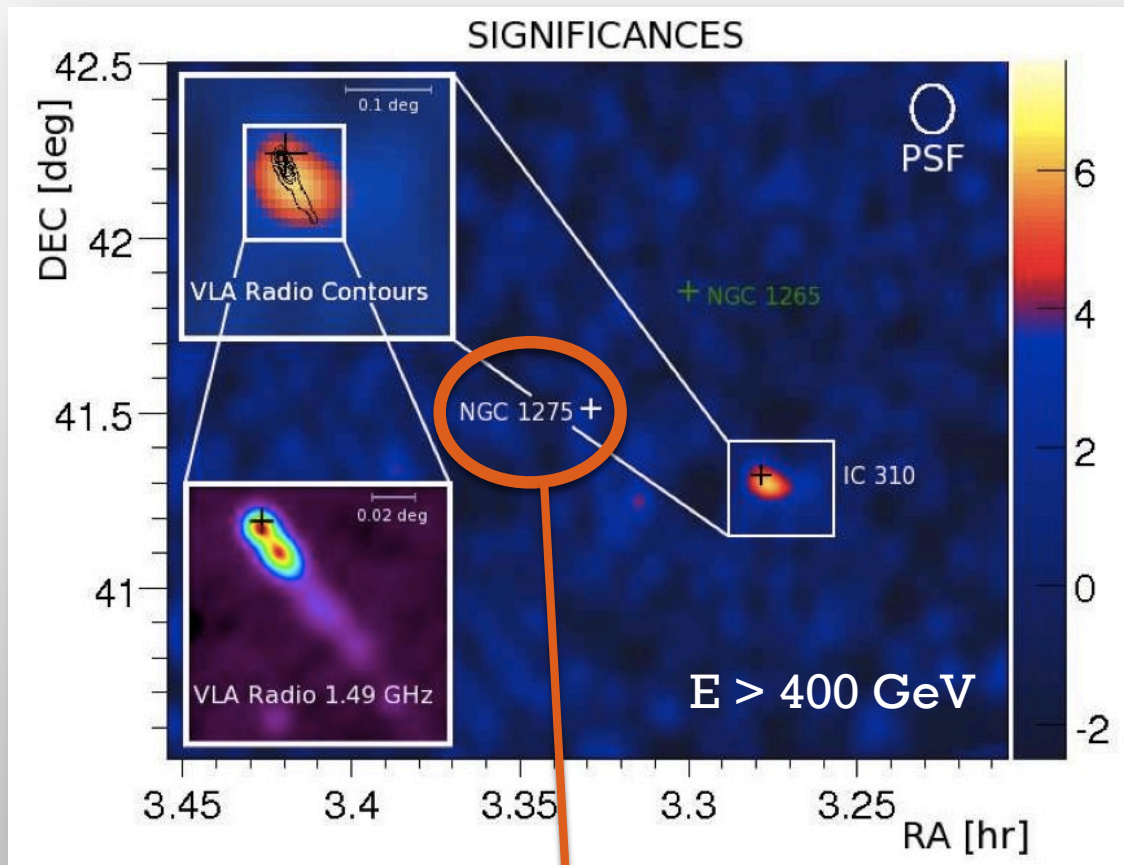


A RECENT DISCOVERY: IC 310 (MONO & STEREO)



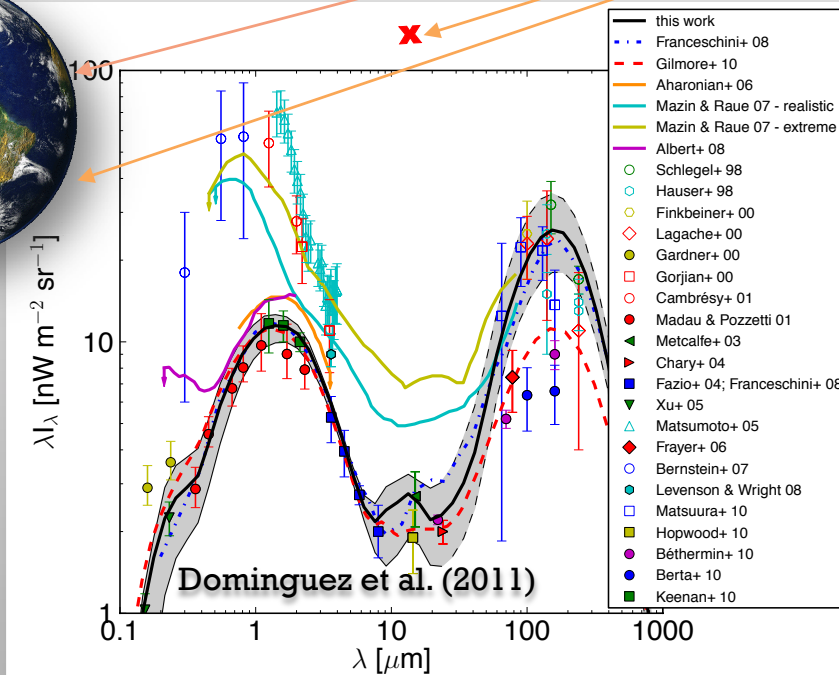
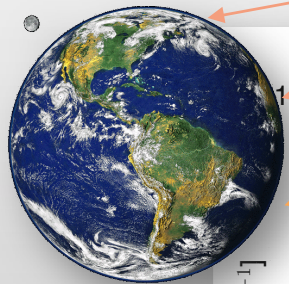
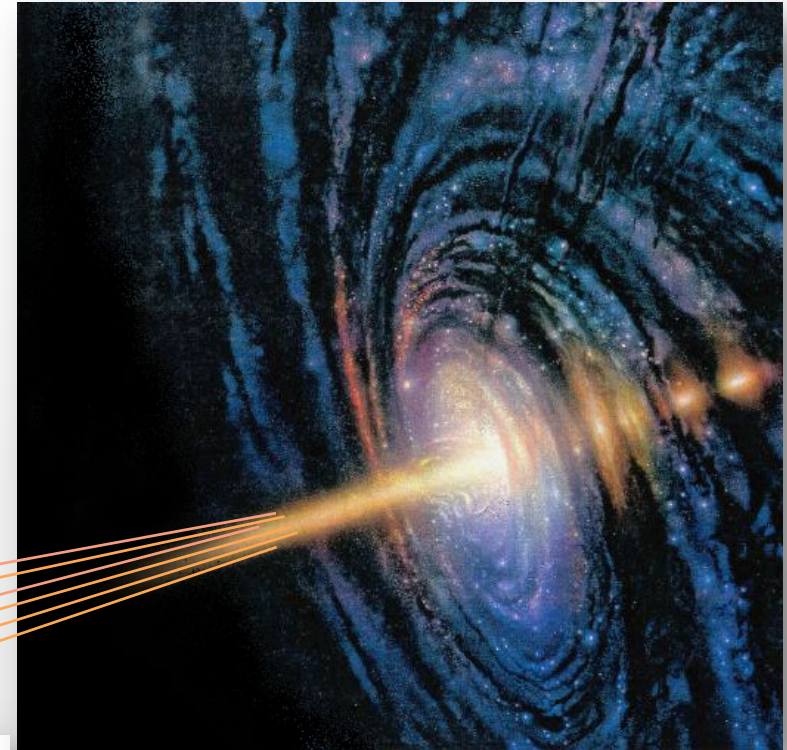
- Head tail radio galaxy
- Observation triggered by *Fermi* (hard spectra)
- Complex FoV
- Variable emission (since 2008)
- Inner jet emission location favored

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VHE PHOTONS ABSORPTION BY THE EXTRAGALACTIC BACKGROUND LIGHT



VHE photon + diffuse light
→ electron-positron pair
production



Absorption:

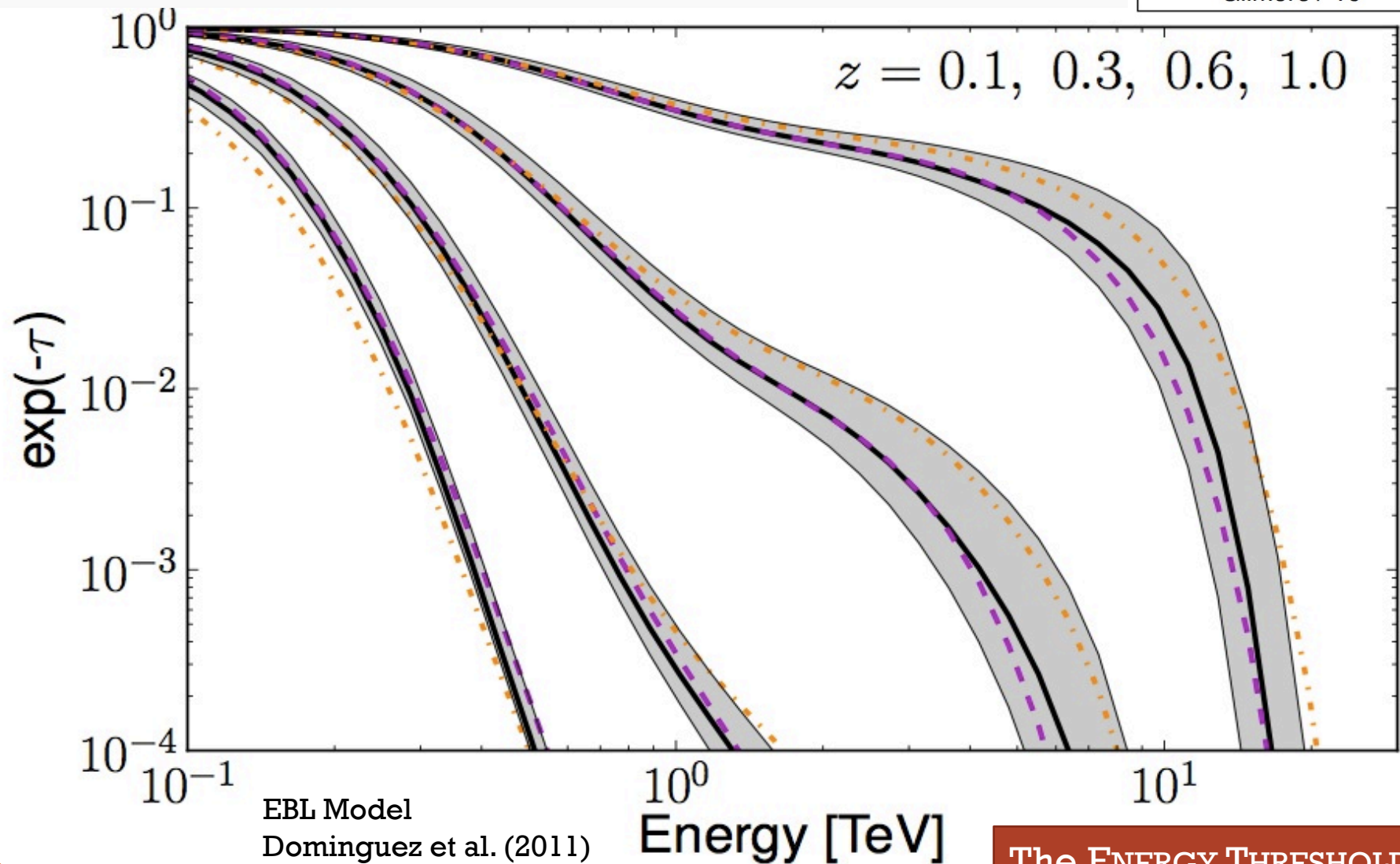
$$dF/dE_{\text{OBS}} = (dF/dE_{\text{EM}}) e^{-\tau}$$

γ - γ opacity

Absorption:

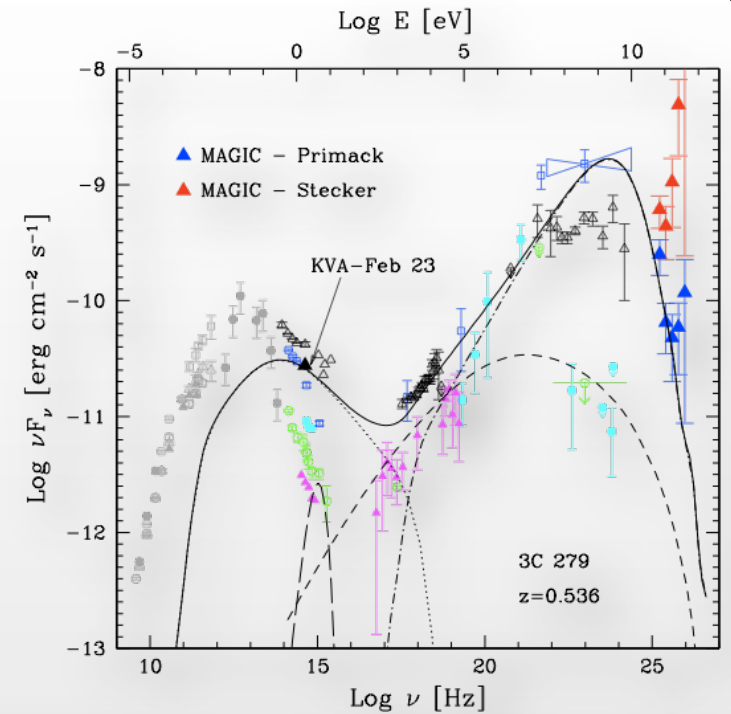
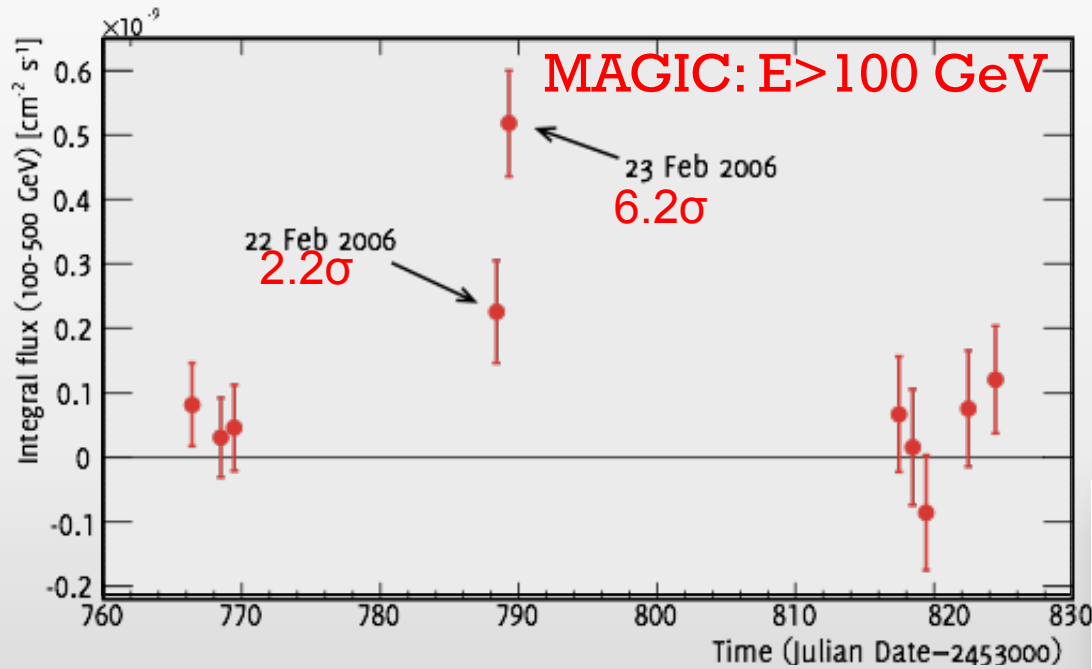
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- this work
- - Franceschini+ 08
- ... Gilmore+ 10

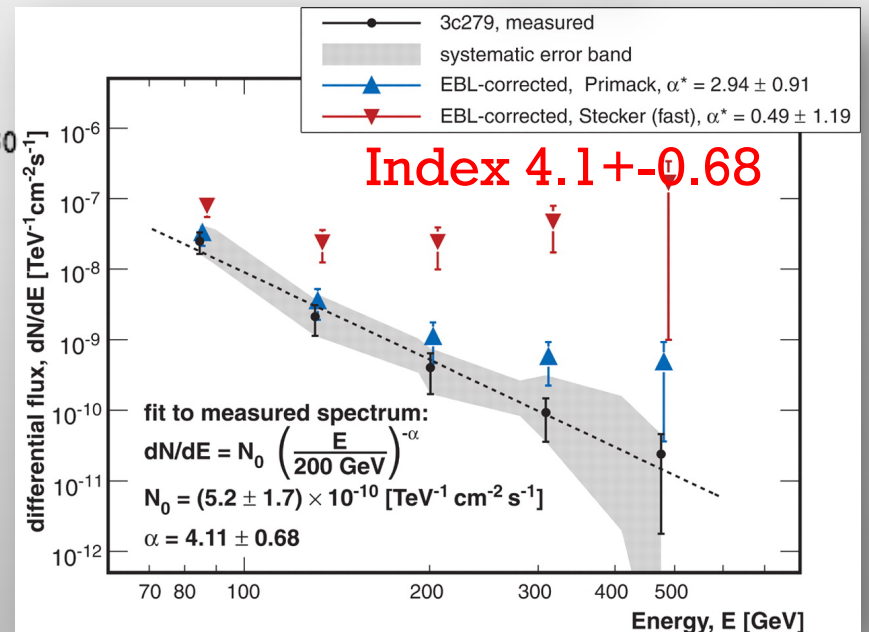


The ENERGY THRESHOLD
plays a key role!

3C 279 (JAN-APR 2006)

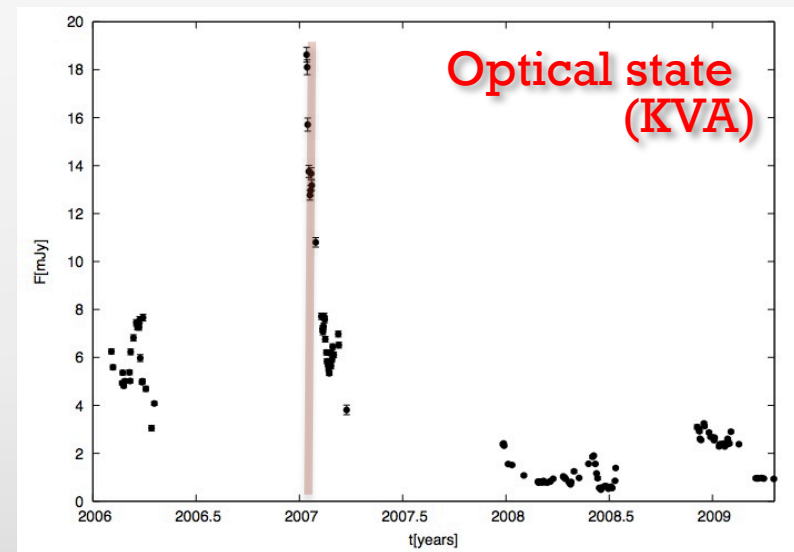


- The farthest TeV object (z=0.54)
- Modeling of 3C 279 non-trivial

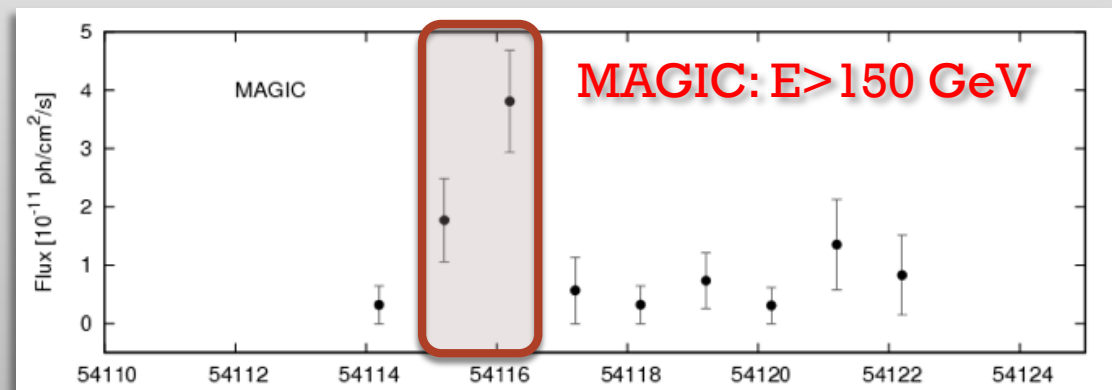


3C 279 (FOLLOW-UP OBSERVATIONS)

- 16th of January 2007:
another flare detected
(during a high optical state!)

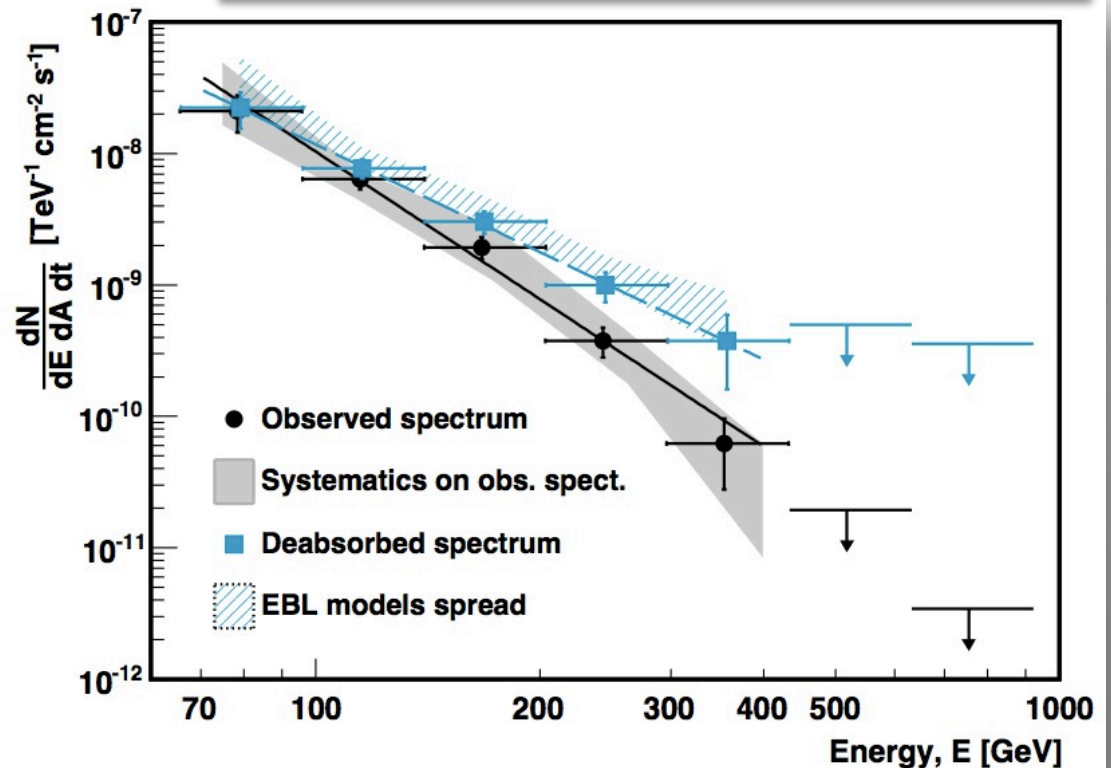
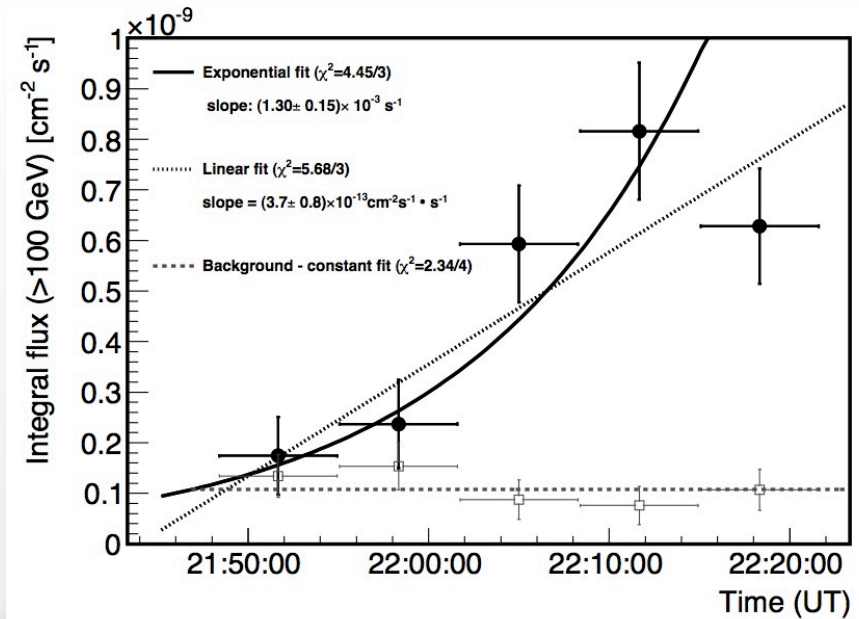


Confirms 2006 signal
and short timescale
variations



PKS 1222+21: MAGIC DISCOVERY!

- The second most distant TeV emitter ($z \sim 0.432$)
- FSRQ
- One night of detection:
 - 17th June 2010
- Rapid variations!
- No cut-off observed:
 - Emitting region constrained to lie outside the BLR

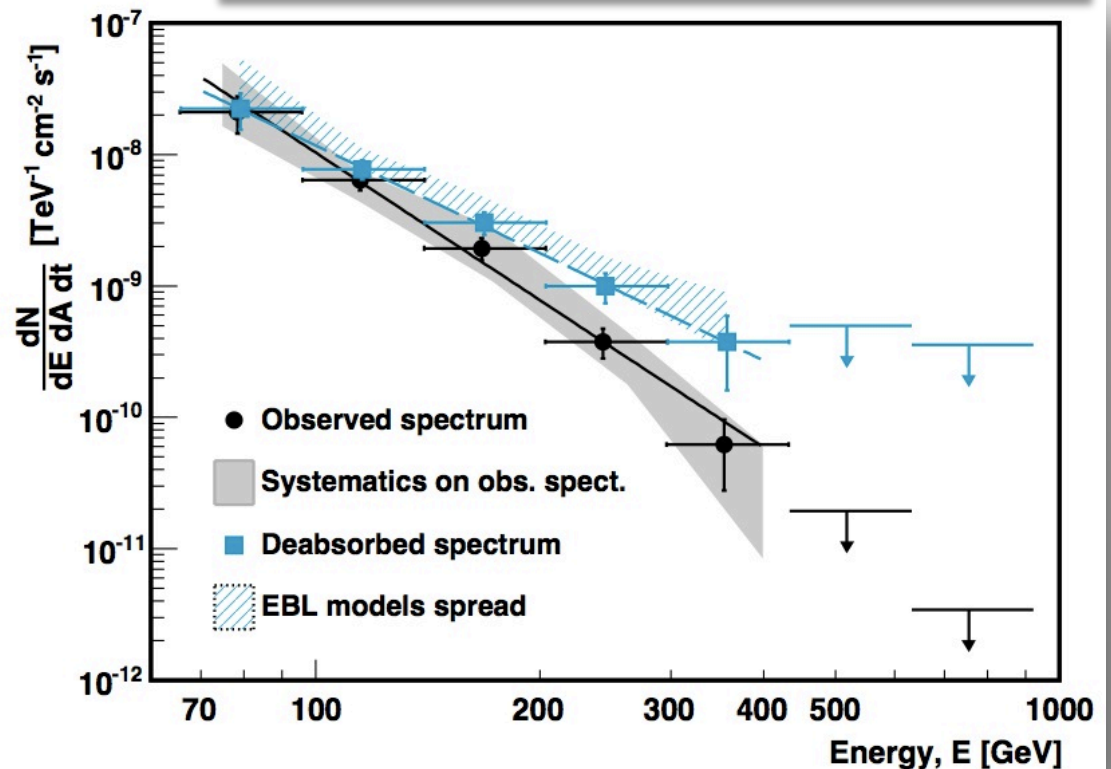
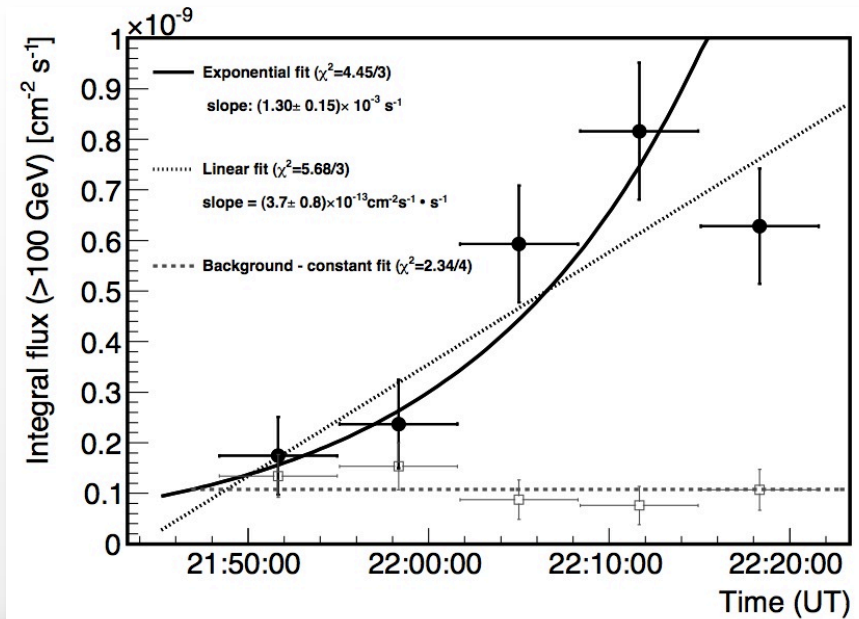


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Challenge for blazar emission models



DARK MATTER SEARCH WITH MAGIC

γ -RAYS FROM DM SELF-ANNIHILATION

Dwarf Galaxies (High mass-to-light ratio)

- MAGIC ULs from good candidates:

- Segue I MAGIC Coll, submitted to JCAP

- Willman I MAGIC Coll, ApJ 697, 1299 (2009)

- Draco MAGIC Coll, ApJ, 679, 428 (2008)

Galaxy clusters (~80% is DM)

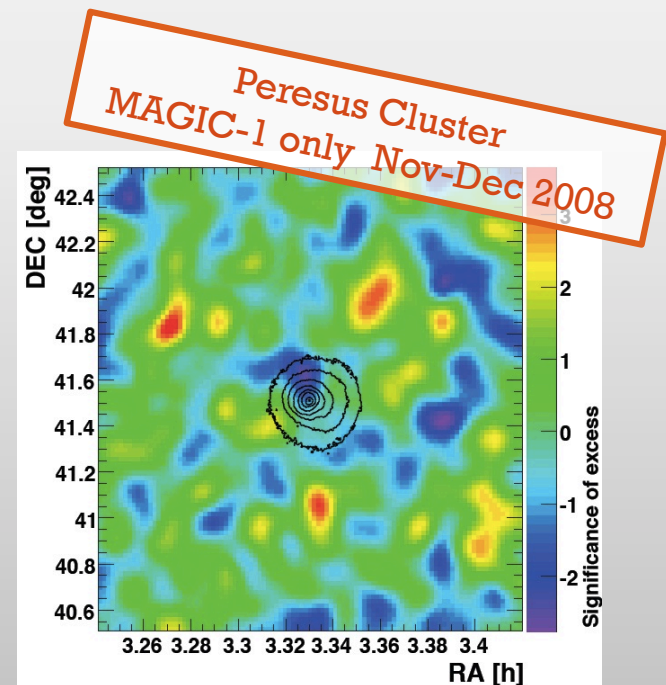
- Perseus ($z = 0.018$)

- Constraints on emission:

- from Cosmic Rays

- through Dark Matter annihilation

- from **NGC 1275 (Now detected at VHE)**



MAGIC Coll, ApJ 710 (2010) 634

MANY NEW DISCOVERIES...

1 YEAR OF A-TELS:

1. 25 February 2011: MAGIC OBSERVES A VERY HIGH ENERGY GAMMA-RAY FLARE FROM **1ES 0806+524**
2. 11 February 2011: MAGIC CONFIRMS VHE GAMMA-RAY EMISSION FROM **HESS J0632+057** BETWEEN 7-9 FEB 2011
3. 6 JANUARY 2011: DISCOVERY OF VERY HIGH ENERGY GAMMA-RAY EMISSION FROM **1ES 1215+303** BY MAGIC
4. 23 OCTOBER 2010: NO SIGNIFICANT ENHANCEMENT IN THE VHE GAMMA-RAY FLUX OF THE **CRAB NEBULA** MEASURED BY MAGIC IN SEPTEMBER 2010
5. 10 OCTOBER 2010: DISCOVERY OF VERY HIGH ENERGY GAMMA-RAY EMISSION FROM **NGC 1275** BY MAGIC
6. 7 October 2010: DISCOVERY OF VERY HIGH ENERGY GAMMA-RAY EMISSION FROM **B3 2247+381** BY MAGIC
7. 22 July 2010: Discovery of Very High Energy gamma-ray emission from **1FGL J2001.1+4351** by MAGIC
8. 19 June 2010: MAGIC DETECTS A VHE FLARE FROM **4C +21.35** (PKS 1222+21)
9. 9 April 2010: VERITAS AND MAGIC REPORT FLARING IN VERY HIGH ENERGY GAMMA RAYS FROM **M 87**
10. 25 MARCH 2010: MAGIC DETECTS VHE GAMMA-RAY EMISSION FROM **IC 310**

CONCLUSIONS

Strong points of MAGIC

- Low energy threshold
 - Overlapping with Fermi
 - Deep universe
- New stereoscopic system
- Fast repositioning (sensitivity to transients: GRB)
- Moon observations

Future plans

- MAGIC upgrade (IMPROVE LOW ENERGY SENSITIVITY):
 - M1 Camera
 - Trigger
 - Readout electronics →
- ... many new discoveries!!

Improved trigger acceptance and energy threshold

Less noise

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