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Univ. Dortmund

Status and latest results of the MAGIC telescope

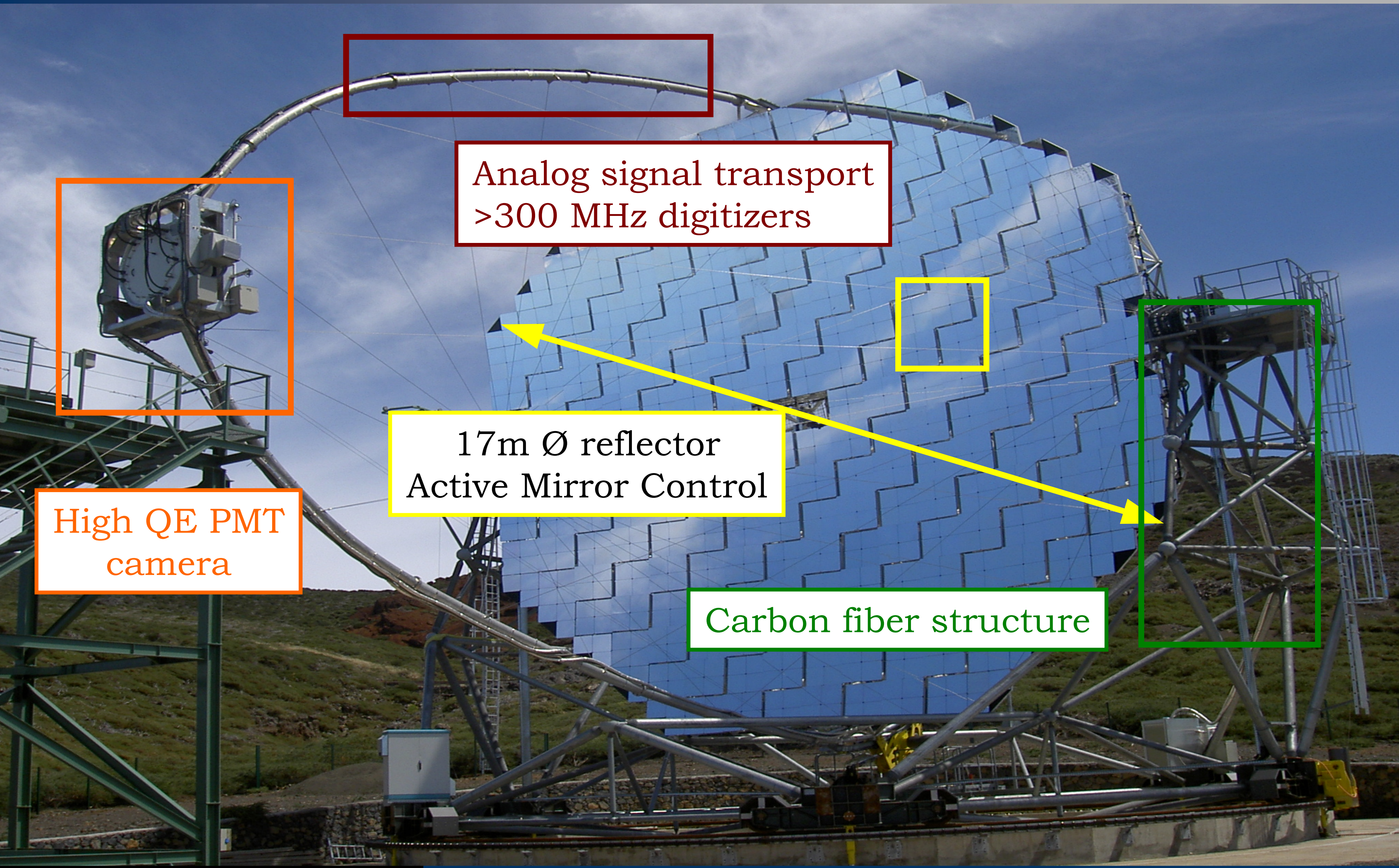
Juan Cortina

Summary

MAGIC-I and -II: the instruments

- Description of the instruments
- Technical developments
- Schedule of MAGIC-II

MAGIC-I: latest results


Analog signal transport
>300 MHz digitizers
High QE PMT
camera
17m Ø reflector
Active Mirror Control
Carbon fiber structure

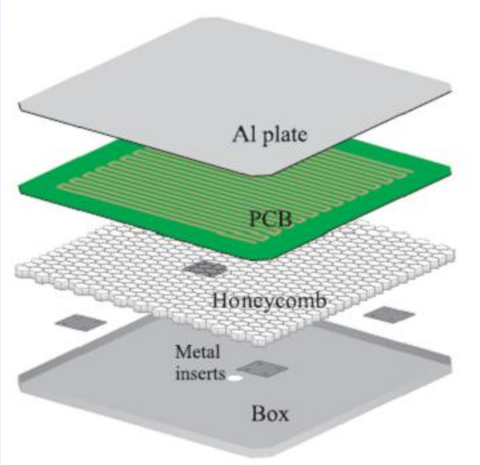
Description of the instrument

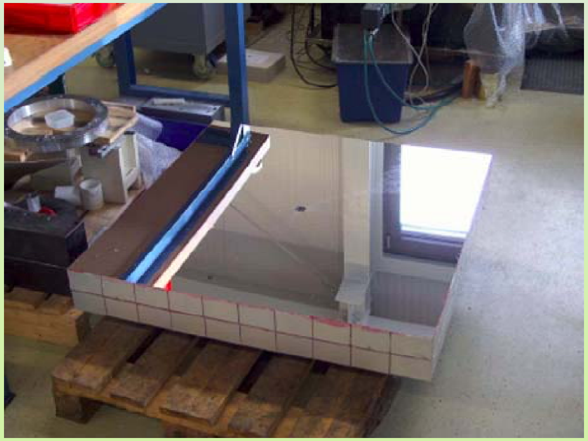
- MAGIC is an **Imaging Air Cherenkov** telescope operating in the energy range above **50 GeV**.
- Located at **Roque de Los Muchachos** observatory, Canary Islands, Spain, 28.8°N, 17.9°W, ~2200 m a.s.l..
- **Largest single-dish** (17 m Ø) $\Rightarrow$ lowest energy threshold

- 576 **high QE PMT** camera with 3.5° Ø FOV
- **Angular resolution (σ)** ~ 0.1°
- **Energy resolution** 20-30%
- **Flux sensitivity**: 2.5% Crab Nebula flux with 5σ in 50h
- **Fast repositioning** (<40s average) for GRB observation
- **Observations under moonlight possible $\Rightarrow$ 50% extra observation time**

Mirror technology: increasing size for MAGIC-II

- **Structure: sandwich of aluminium and honeycomb**
- **99 cm x 99 cm square**
- **Direct mounting on reflector frame.**
- **No need to align 4 mirrors inside panel.**
- **Even lighter weight: 18 kg vs 22 kg per m^2**
- **Cheap technology, reliable after years of operation.**
- **Testing large mirrors already in 1^{st} telescope.**

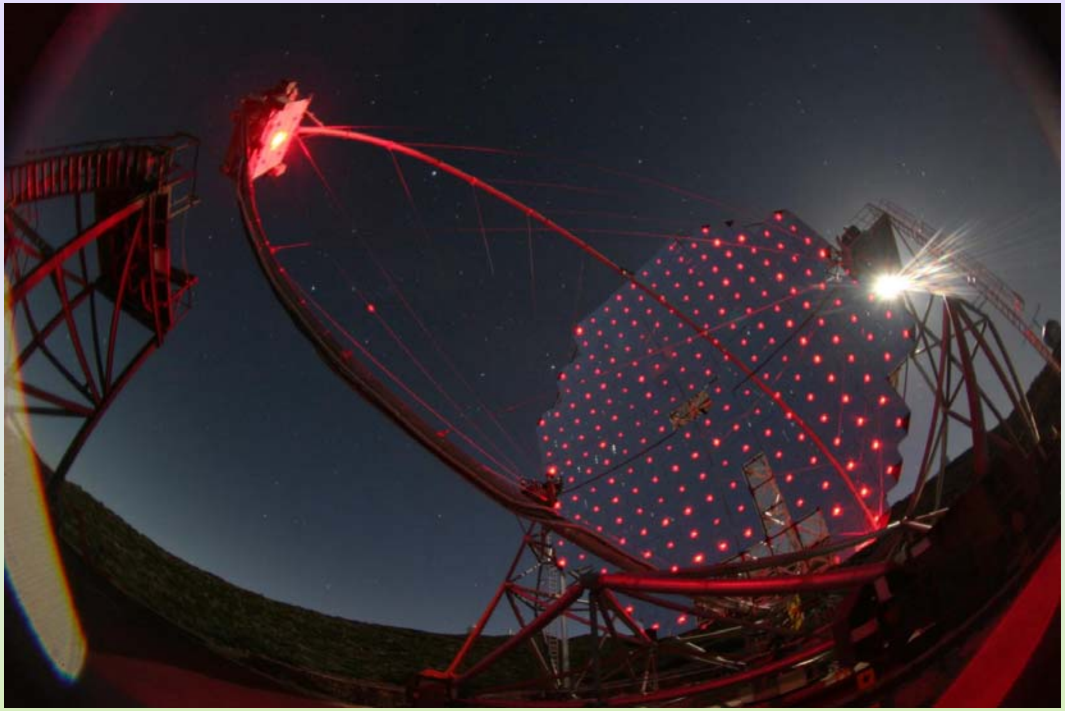




Carbon fiber mount & drive: good enough as it is...

- **Carbon fiber technology is now well tested in the first telescope (has survived some severe storms).**
- **Extremely easy to assemble: <1 month for 17 m ø frame.**
- **Ultralight: Dish & mirrors = 17 tons, whole telescope = 65 tons**
- **Fast positioning in <40 sec for GRB. Fully robotic procedure for moving the telescope to GRB position distributed via ethernet socket connections.**

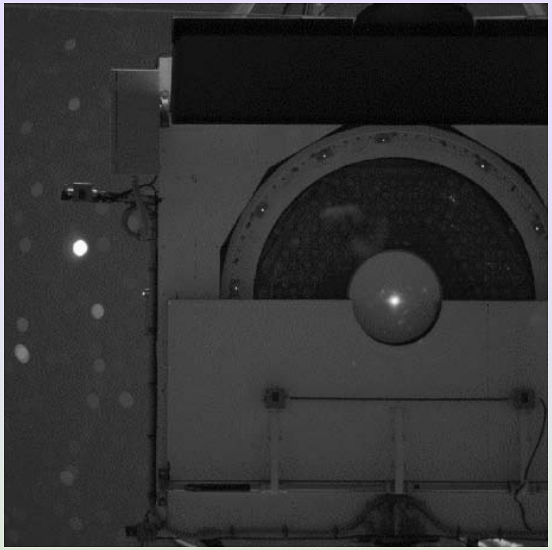
Active Mirror Control: constant improvement

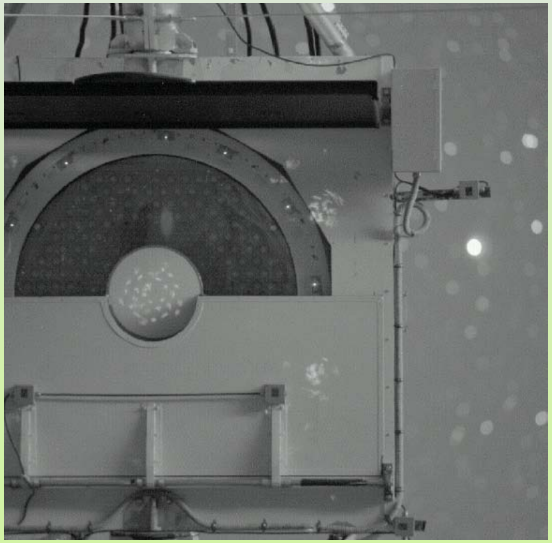


- Using red lasers to keep reference for mirror panel orientation.
- In fact we are right now using Look-Up Tables for normal operation and star images for table definition.

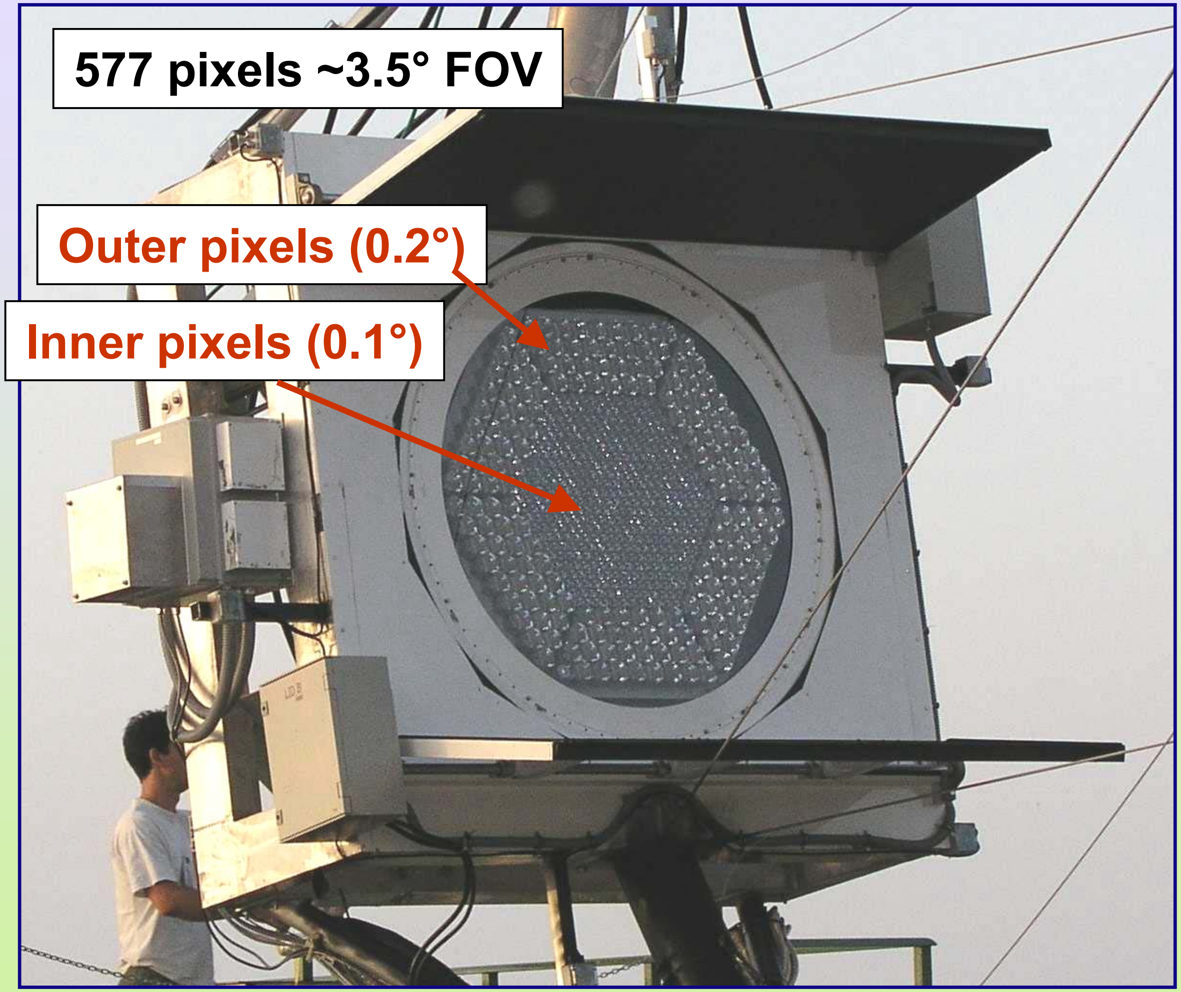
Active Mirror Control: constant improvement

- **Very sensitive CCD camera that allows to detect spots of individual mirror panels.**
- **We focus each panel and store step motor positions in Look-Up Tables (LUTs).**
- **During normal operation we use LUTs to re-focus reflector already as telescope moves to new position.**
- **Reflector ready for datataking even before taking data.**
- **Procedure may be used in future robotic telescopes (even if reflector is not fully active) for aligning the mirrors on a regular (~months) basis.**



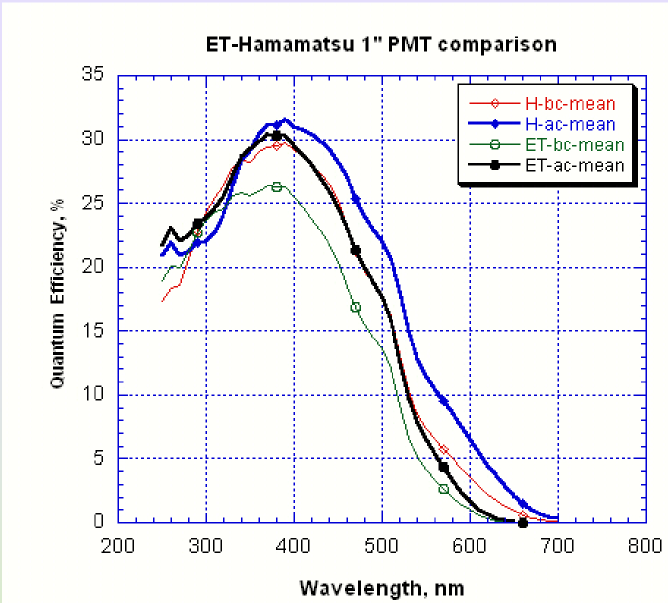


High QE cameras

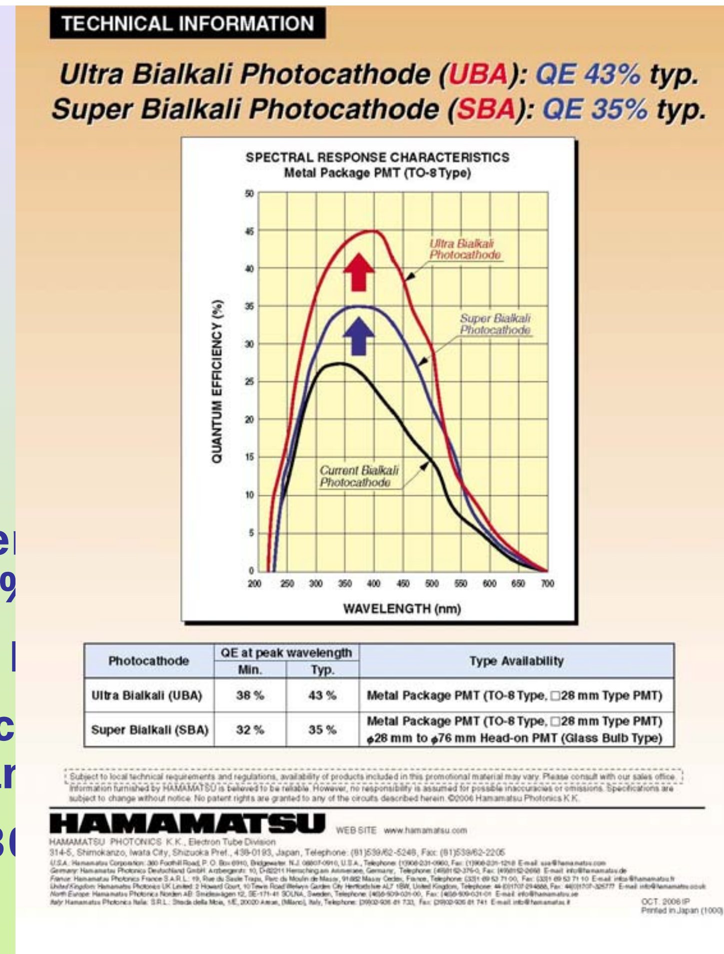


- We will probably install a 1100 PMT camera in the 2nd telescope.
- Trigger area was restricted to 2° FOV. Has been increased for MAGIC-II to almost 3°.

High QE cameras



Presented at the latest IEEE meeting in San Diego: Hamamatsu PMTs with peak QE~45%


TECHNICAL INFORMATION

Ultra Bialkali Photocathode (UBA): QE 43% typ.
Super Bialkali Photocathode (SBA): QE 35% typ.

Photocathode	QE at peak wavelength		Type Availability
	Min.	Typ.	
Ultra Bialkali (UBA)	38 %	43 %	Metal Package PMT (TO-8 Type, □28 mm Type PMT)
Super Bialkali (SBA)	32 %	35 %	Metal Package PMT (TO-8 Type, □28 mm Type PMT) ϕ28 mm to ϕ76 mm Head-on PMT (Glass Bulb Type)

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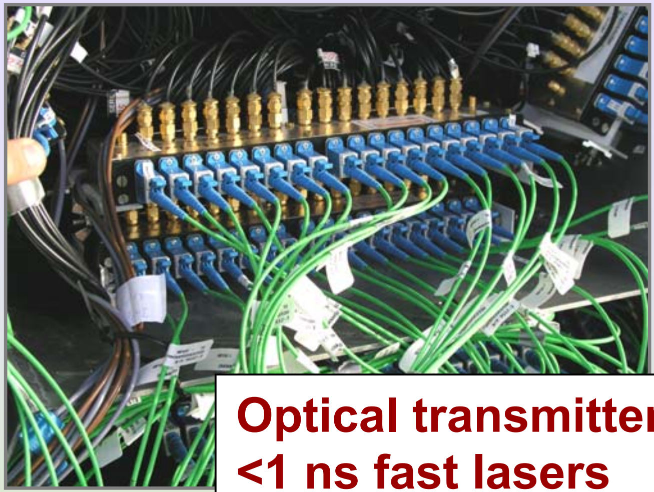
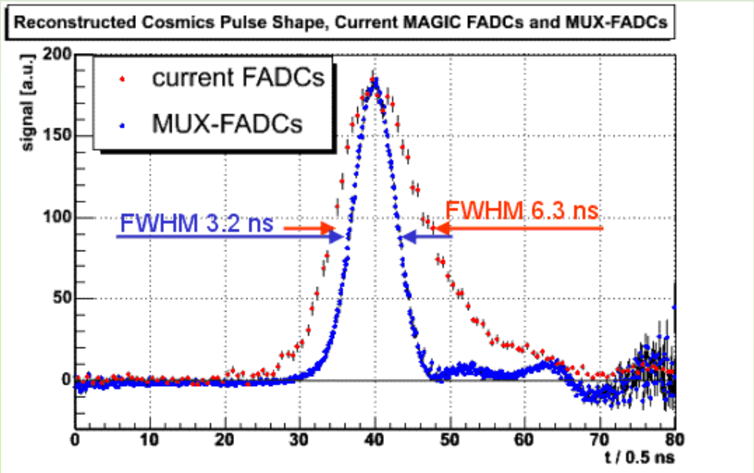
OCT. 2006 IP
Printed in Japan (1000)

- In MAGIC-I we applied a special lacquer … h increases the peak QE from 20% to 25%
- There is right now a new generation of …
- Development is happening now inside c… between Hamamatsu, Electron Tubes ar…
- We can count on PMTs with peak QE>3… higher.

Optical transmission and digitization: even faster



Optical transmitters: <1 ns fast lasers



- **Analog optical transmission using VCSELs has been working well for >2 years.**
- **Whole chain keeps very fast pulse: ~2 ns width.**
- **Needed to stretch pulse to digitize with 300 MHz FADCs!**
- **Now we are moving to ≥2 GHz FADCs for both telescopes.**
- **2 GHz FADCs for 1st telescope already under comissioning now.**
- **Allow to reduce night sky background contamination.**
- **May allow to discriminate γ's vs μ's or hadrons.**
- **Both VCSELs and FADCs are ready for new generation of telescopes.**

Observations under Moon Light: Motivation

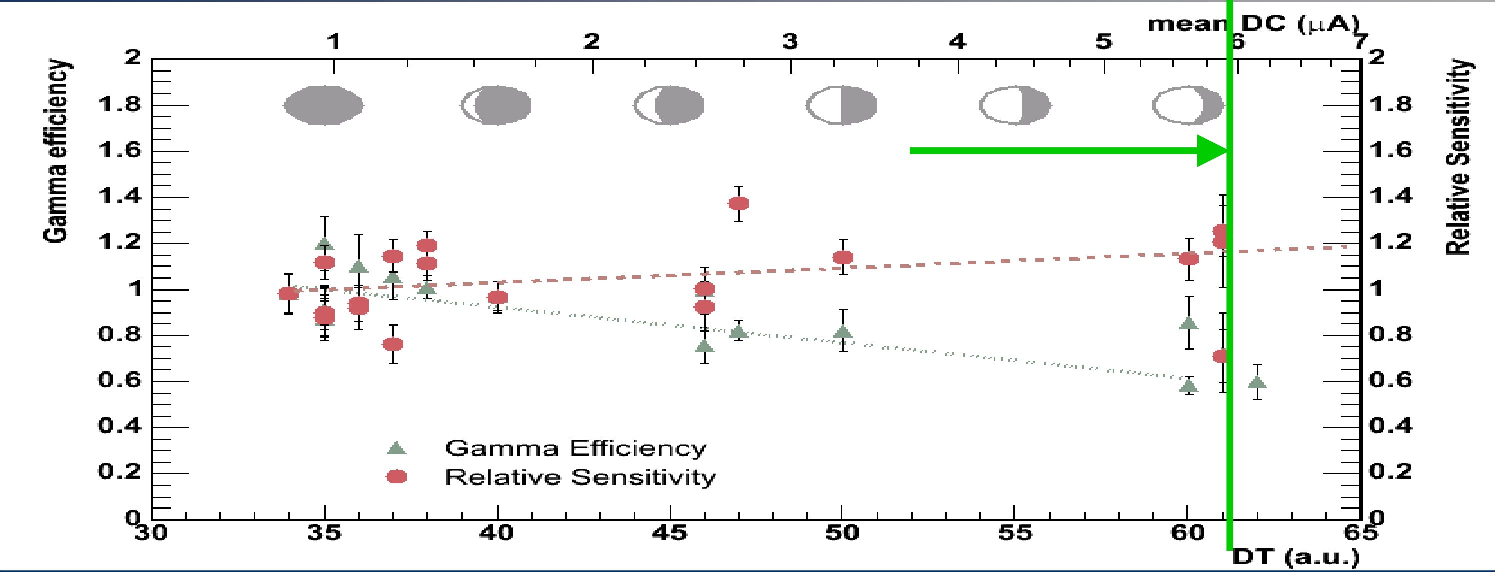
- **The duty cycle for operation of Cherenkov telescopes is limited by the light background.**
- **Traditional telescopes could only operate during strict dark time (no moon and no sun). The limitation is technical: in PMTs with standard amplifications around $10^8 \Rightarrow$ the light background generates currents that damage the last dynodes.**
- **HEGRA CT1 pioneered regular operation under moderate moonshine with reduced HV (Kranich et al, Astrop. Phys. 12, (1999) 65).**
- **This allowed to increase the operation time from ~1000 to 1500 hours/year.**
- **MAGIC is equipped with PMTs that run at a gain of $< 10^5$ so they are not damaged by operation under moderate moonlight.**
- **During Moon observations the trigger discriminator thresholds (DT) are increased to keep the cosmic ray accidental rate low.**

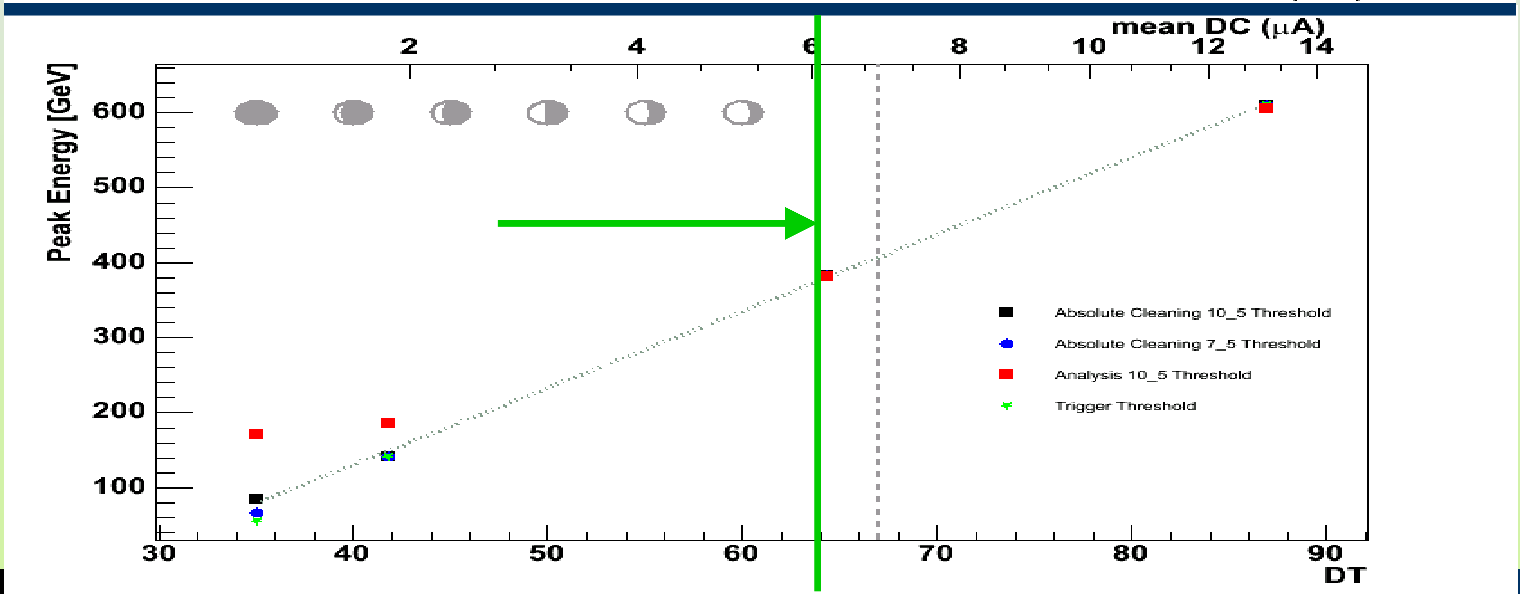
Evaluation of the effect of the Moon

- **We observed the Crab Nebula (standard candle) at different Moon illumination levels (i.e. different DT level / anode current in the PMTs).**
- **We calculate the loss of the gamma / hadron rate compare to Crab in dark conditions.**
- **Hillas Parameters do not show significant discrepancies for different moon illuminations.**

Results

Up to here: +50% more observation time





Moon Analysis Conclusions

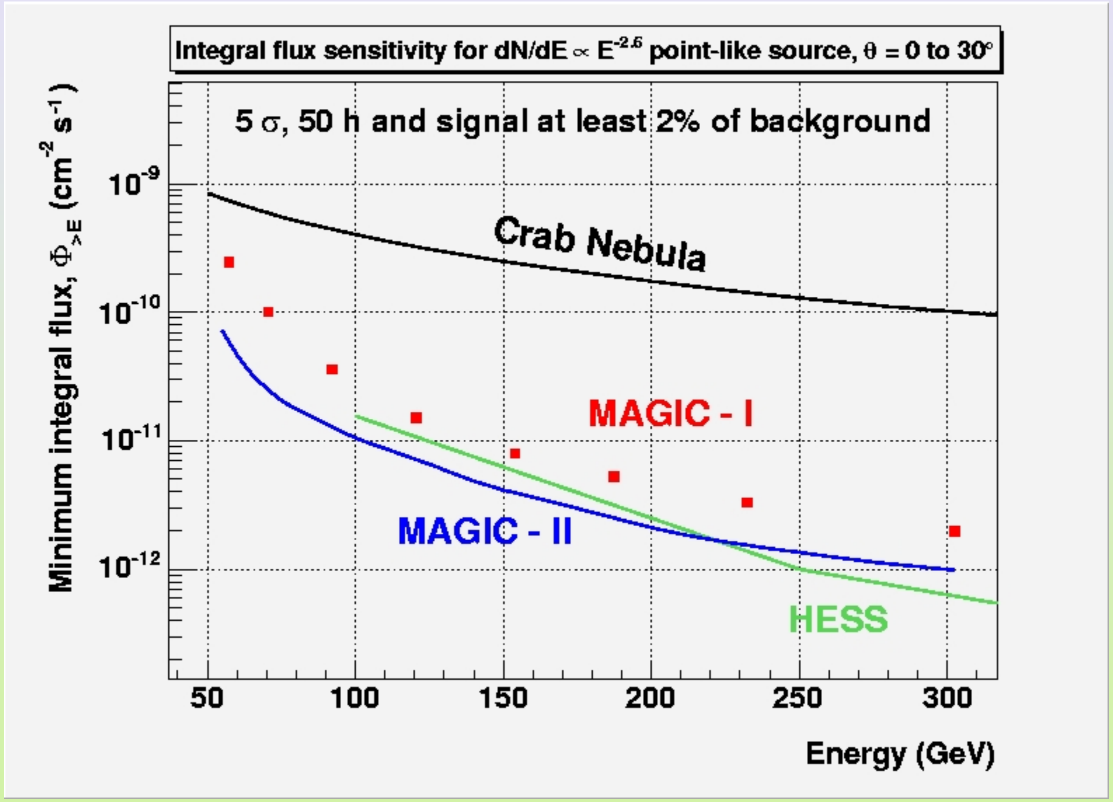
- **Sensitivity is not very much affected (at maximum illumination the sensitivity degrades from 2.5% to 2.9% Crab)**
- **The (standard) analysis energy threshold increases by a factor 2 for a strong camera illumination.**
- **Future telescopes should allow for high illuminations to increase the duty cycle using moon observations.**

MAGIC-II: schedule

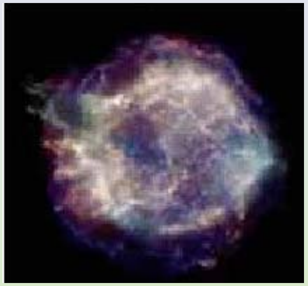
- Foundation, rails, frame, motors and drive equipment are already in place.
- Entering production for mirrors and electronics.
- Expect to start comissioning in Fall 2007, synchronous with GLAST.

MAGIC-II: expected performance

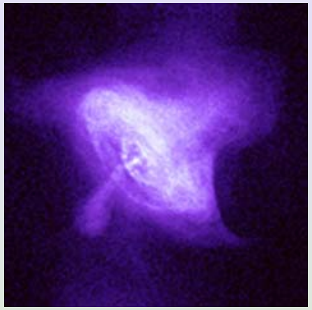
- **Expect a factor 2 better sensitivity.**
- **Gain may be larger below 100 GeV, i.e., effectively reduced analysis threshold.**



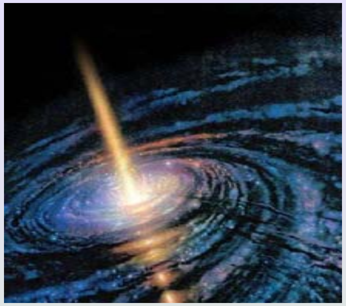
MAGIC Latest Results



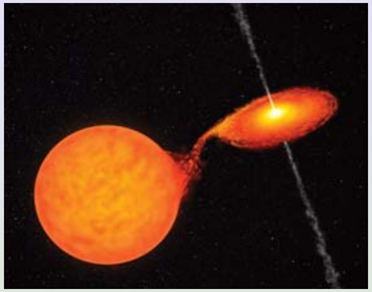
SNRs



Pulsars, PWNs



AGNs



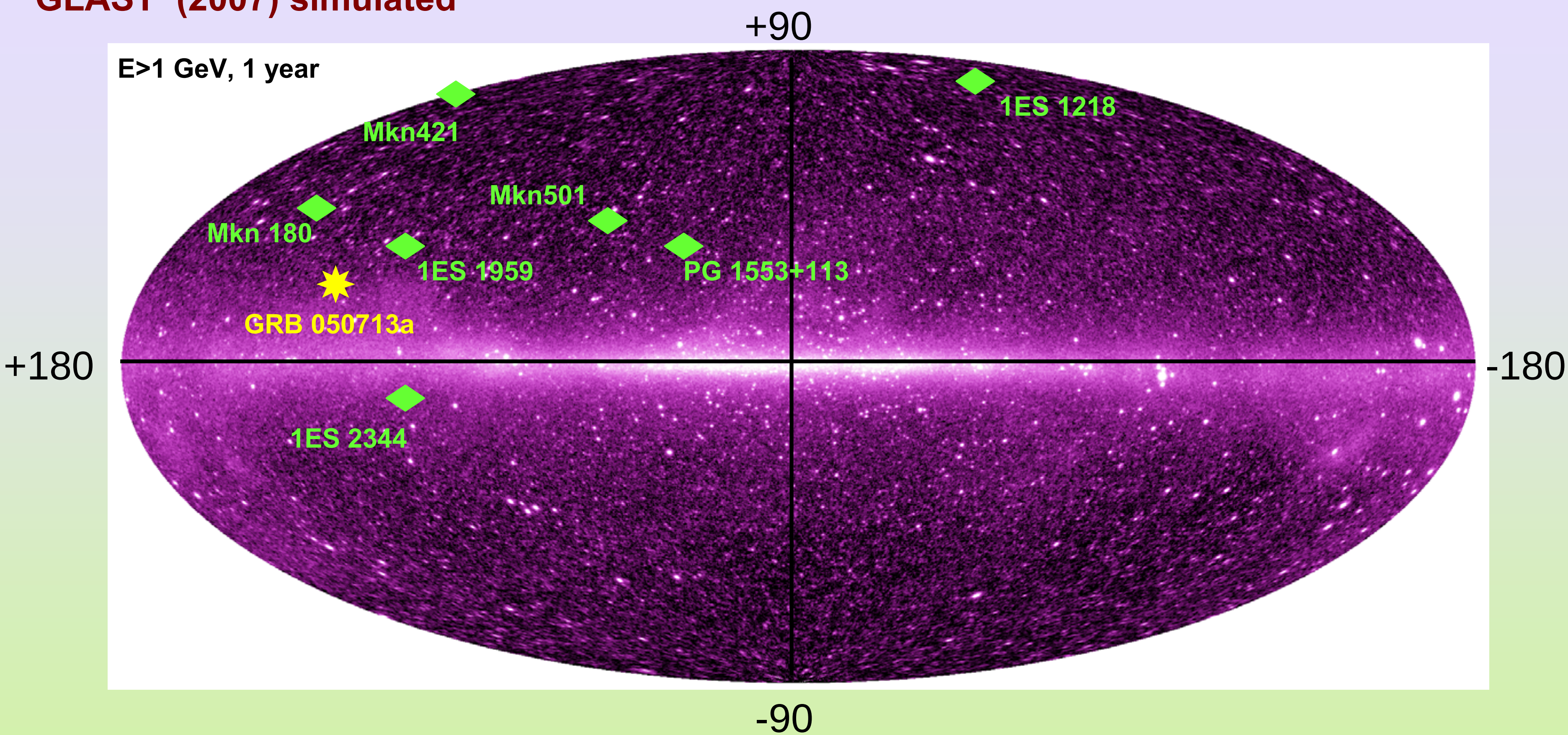
X-ray Binaries

Starburst regions

...

Extragalactic Sources

GLAST (2007) simulated



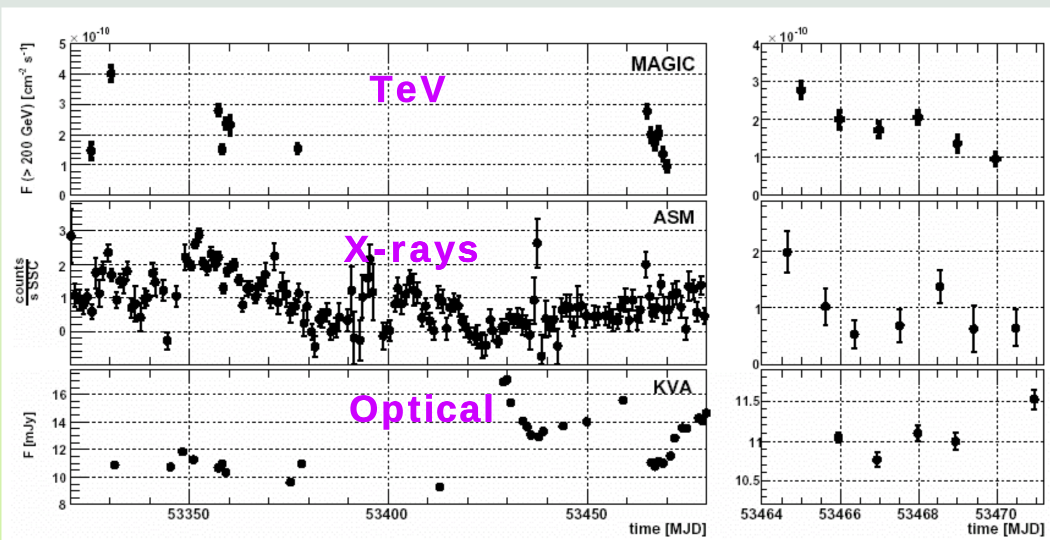
MAGIC Published sources

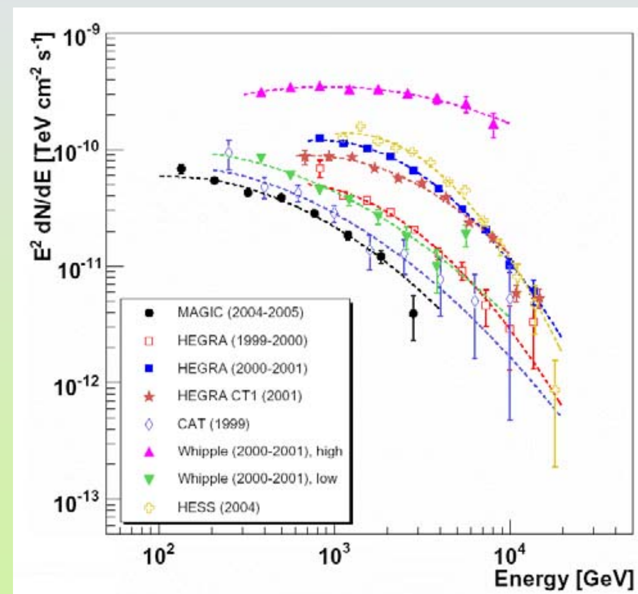
Extragalactic Souces Results

Name	Observation time(h)	Flux (>200 GeV, % Crab)	Slope	z	Paper
Mkn 421	25.6 h	50 -200	-2.2	0.030	*J. Albert et al,. submitted to ApJ 2006*
Mkn 501	23.1	50 -200	-2.1 – -2.6	0.034	*R.M. Wagner, 2006, paper in preparation*
1ES 2344+514	27.4	10	-2.96	0.044	*J. Albert et al., to be submitted in a matter of days*
Mkn 180	11.1	11	-3.3	0.045	*J.Albert et al,.submitted to ApJ Letters in June 2006*
1ES 1959+650	6	20	-2.72	0.047	*J.Albert et al,. ApJ, 639 (2006), 761*
1ES 1218+304	8.2	13	-3.0	0.182	*J. Albert et al., ApJ Letters 642, L119 (2006)*
PG 1553+113	18.8	2	-4.21	>0.09	*J.Albert et al,.submitted to ApJ Letters in May 2006*
GRB 050713a	36 min	---	---	0.4-2.6	*J. Albert et al., ApJ Letters 641, L9 (2006)*

Mkn 421

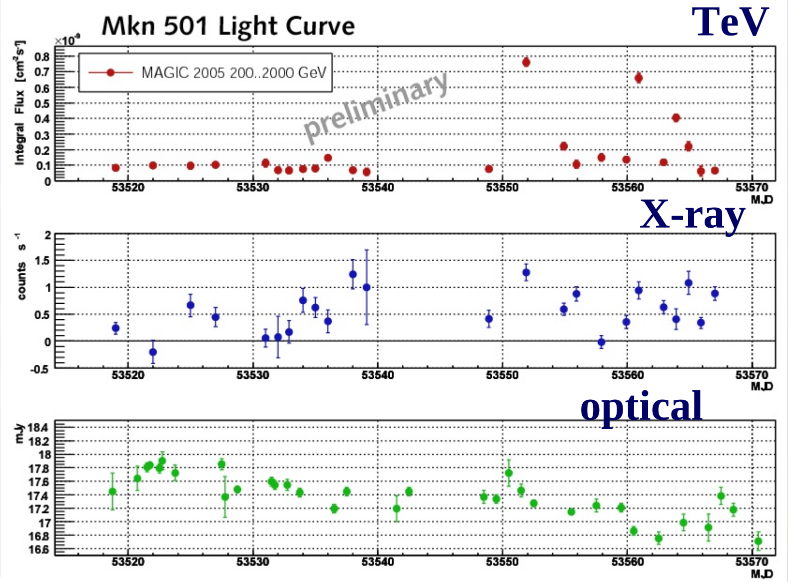
- Dec 2004- Apr 2005, 25.6 h.
- Variable flux from 0.5 to 2 crabs. Only from day to day, no intranight variability! Could it be that fast variability is associated with flaring state?
- De-absorbed SED compared to other observations. IC peak possibly at 100 GeV, i.e. lower than for higher states.

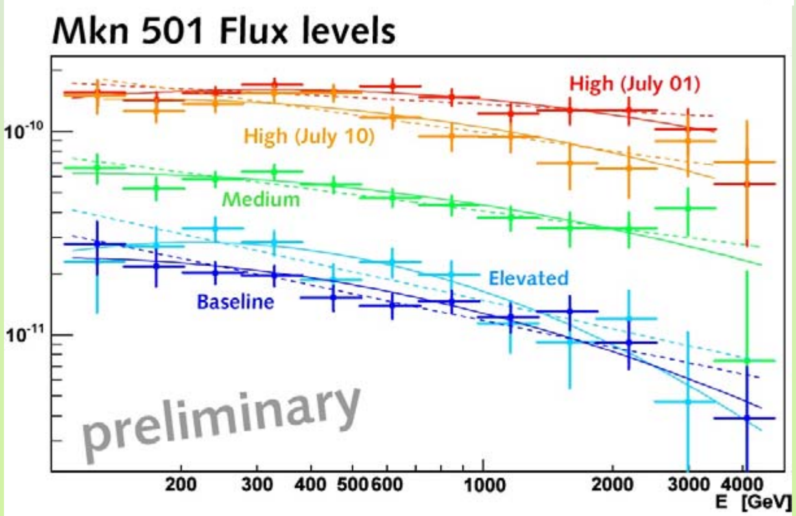




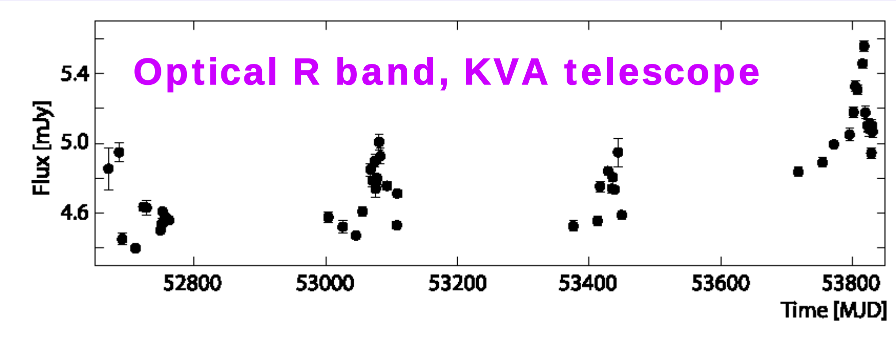
Mkn 501

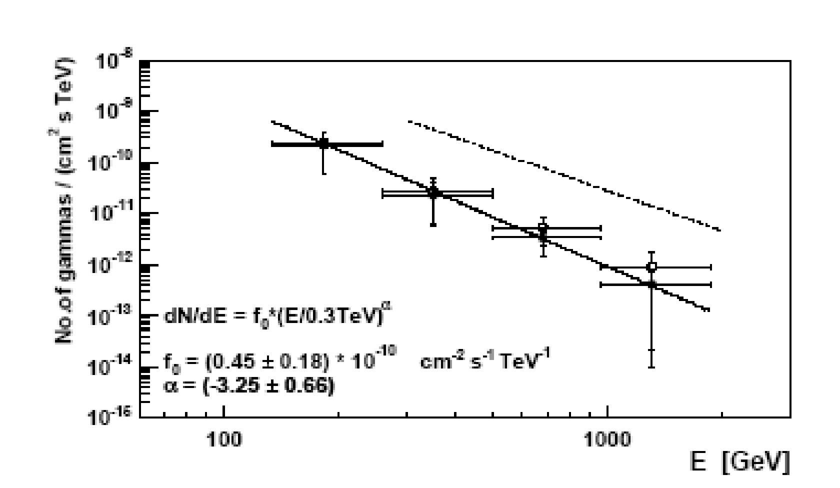
- June – July 2005
- 23.1 h, over 85 σ, over 14000 excess events,18h under moonlight.
- Evidence for fast intranight variability, at the scale of a few minutes.
- Evidence for change of spectral index depending on emission level.
- About to submit publication.





Mkn 180

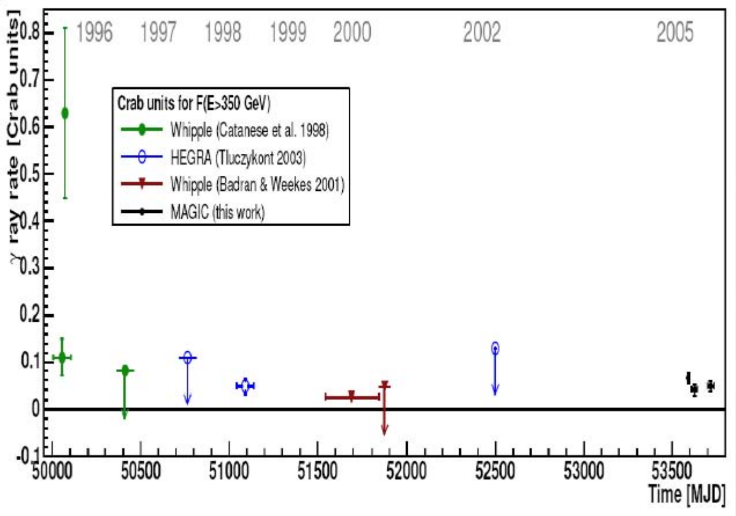


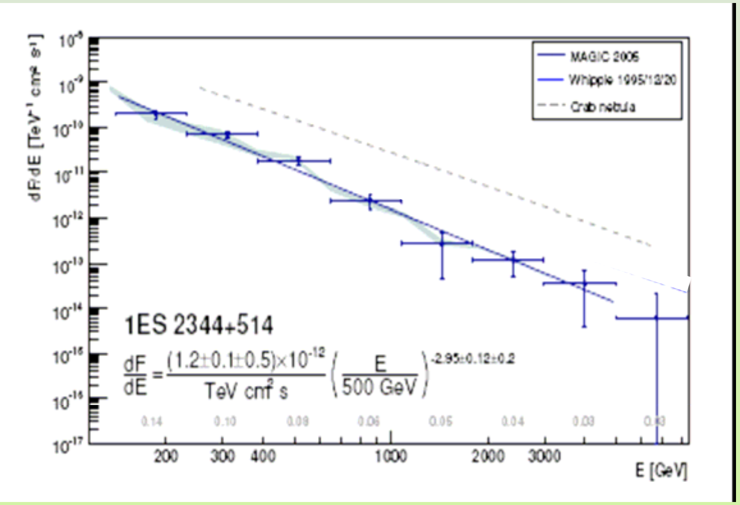


- **New AGN discovery**
- **Nearby, z=0.045.**
- **Upper limits with Whipple and HEGRA.**
- **Observation triggered by our optical telescope: 50% flux increase in galaxy core.**
- **11.1 h, 5.5 σ, 11% Crab.**
- **No evidence for variability.**
- **Very soft spectrum: α= 3.3 (de-absorbed α= 2.8).**

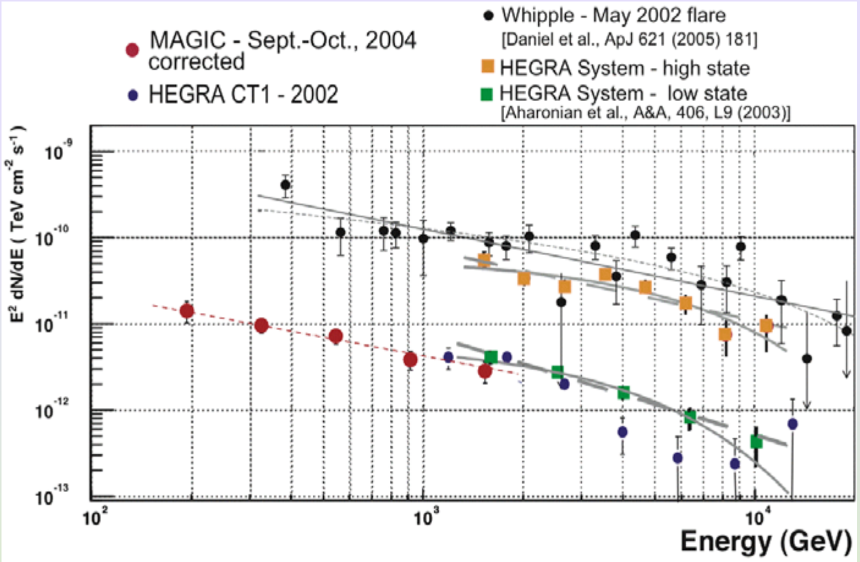
1ES 2344+514

- Whipple: Flare (95),F(>350GeV) = 63% Crab
- Subsequent Whipple observations: upper limits only, F(>350GeV) < 8% Crab in 96/97
- HEGRA 1997-2002: 4.4 σ F(>970GeV) = 3.3% Crab
- MAGIC 27.4 h, 8 σ, F(>350GeV) = 10% Crab
- No hint of flux variation.
- Publication to be submitted this week.





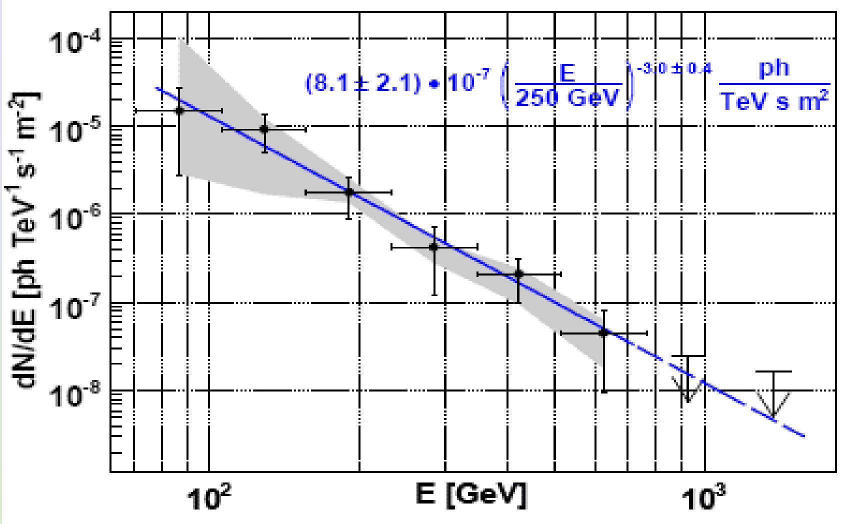
1ES 1959+640



- Blazar famous for the orphan flare in 2002
- MAGIC: 6h, 8.2 σ
- Flux level compatible with HEGRA low state
- Quiescent state?

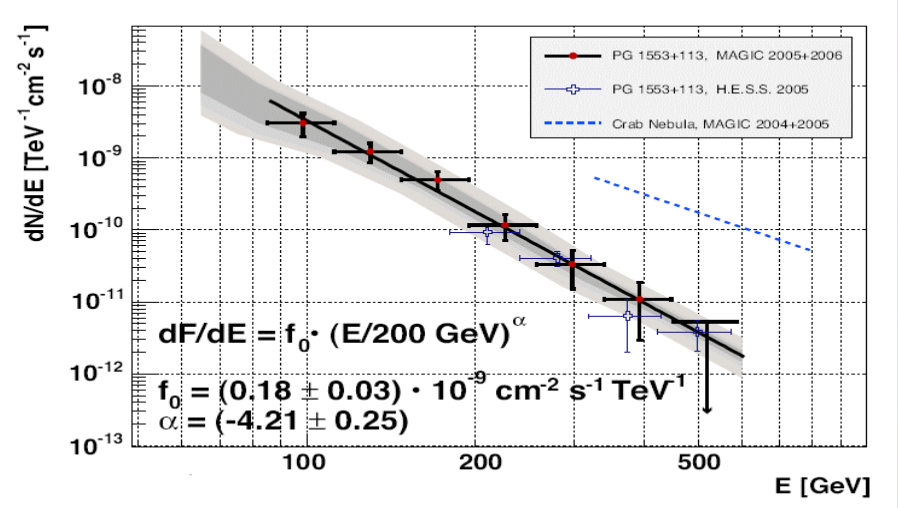
1ES 1218+304

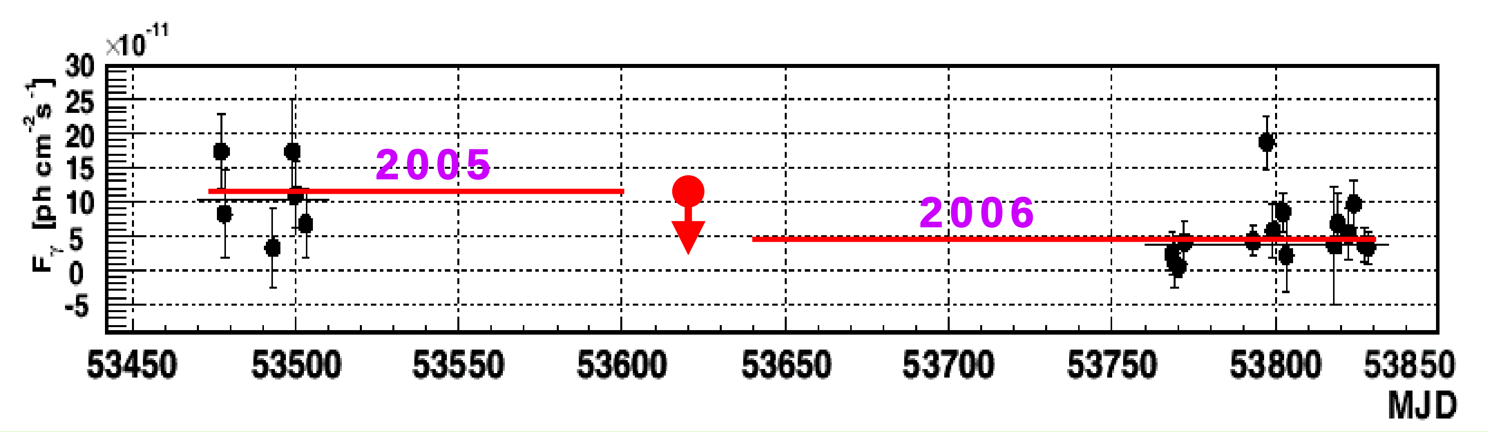
- **Upper limits with HEGRA y Whipple**
- **New AGN discovery**
- **Very far: z=0.18**
- **8.2h, 6.4 σ, 13% crab**
- **No hint of TeV variability. Simultaneous optical observations: no flare in optical.**
- **Steep spectral index α=3.0.**



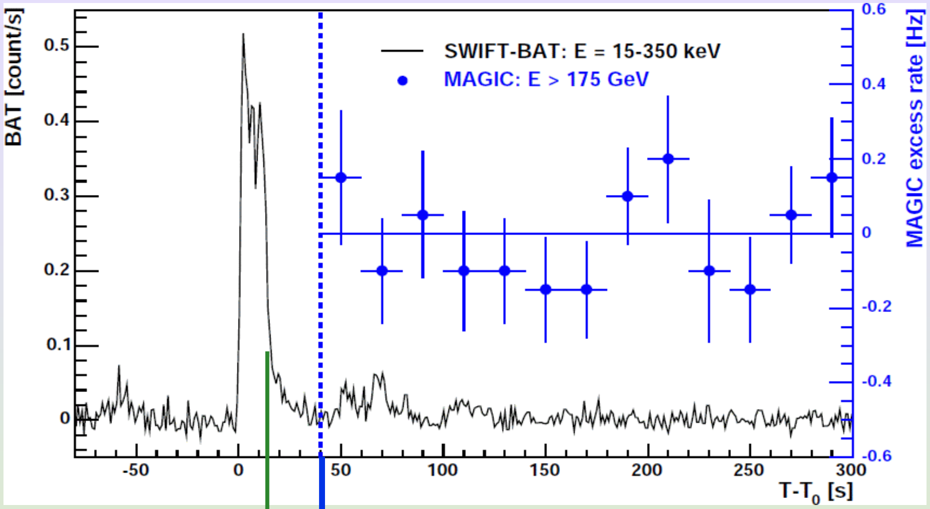
PG 1553+113

- Observed in 2005 (7h) and in 2006 (12h).
- H.E.S.S.: 4.0 σ evidence (A&A 448L (2006), 43)
- Redshift unknown!
- 18.8h , 8.8 σ, firm detection >6 σ both in 2005 and 2006.
- Flux decreases a factor 3 from 2005 to 2006.





GRB 050713a

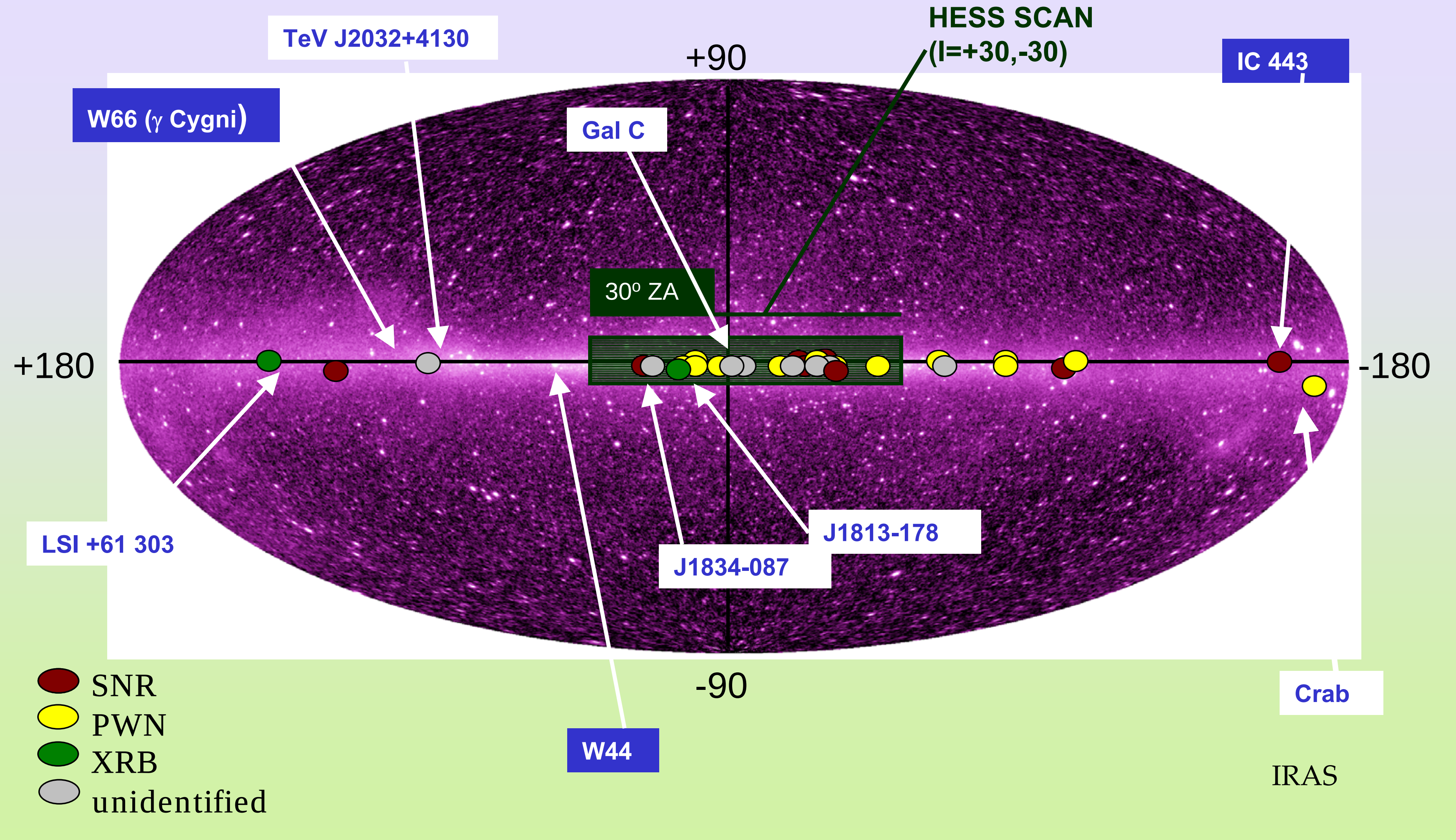


MAGIC starts data-taking

GRB-alarm from SWIFT

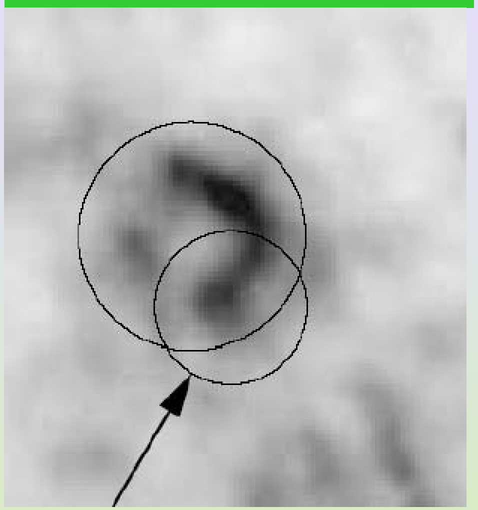
- 40 sec after the burst.
- No detection in VHE.
- E_{th} = 175 GeV
- E_{th} < 100 GeV more detailed analysis (M. Gaug, PhD)
- We are about to submit publication with upper limits to all GRB in first year of observation.

The galactic plane: TeV galactic sources



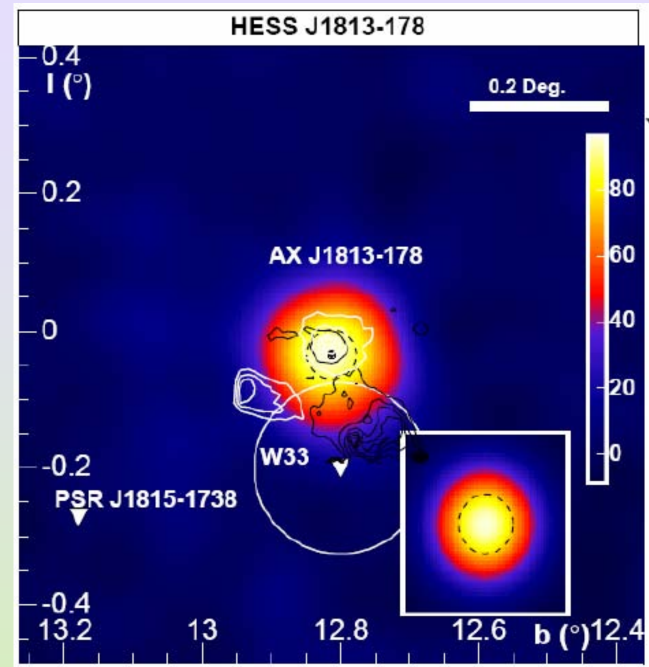
HESS/SNR Connection: HESS J1813 & HESS J1834

HESS J1813-178



After HESS discovery

- X-rays ASCA
- INTEGRAL
- RADIO VLA (SNR G12.8 0.0)



•Radio (20 cm VLA): White et al 2005, Brogan et al 2005
•Hard X-rays (Integral): Ubertini et al 2005.

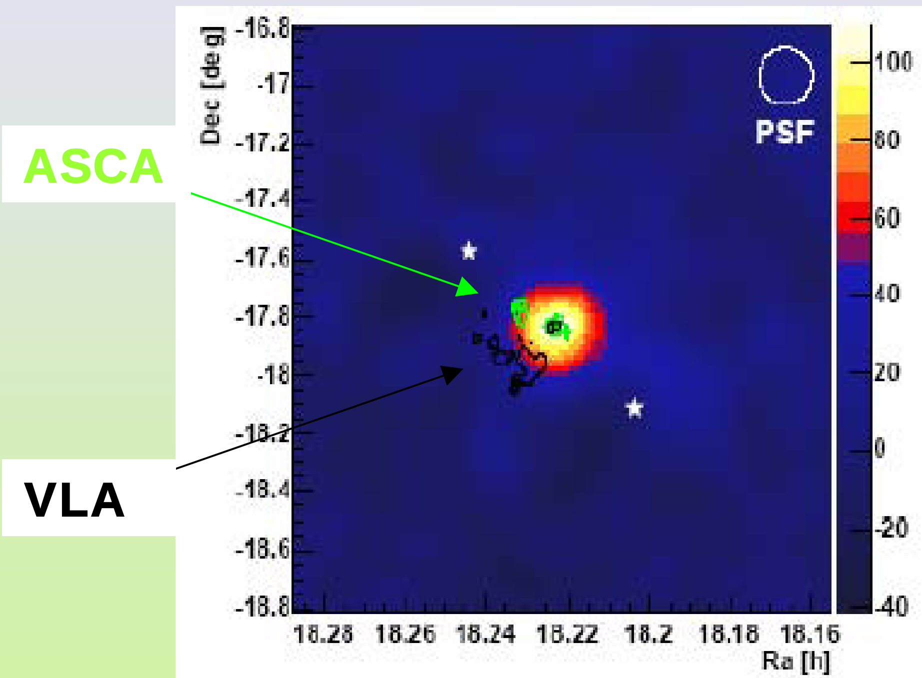
HESS/SNR Connection: HESS J1813 & HESS J1834

HESS J1813-178

MAGIC:

Section of shell spatially coincident with SNR G12.8-0.02

Zenith angle: 47°-54° – Threshold: 400 GeV – 25 hours



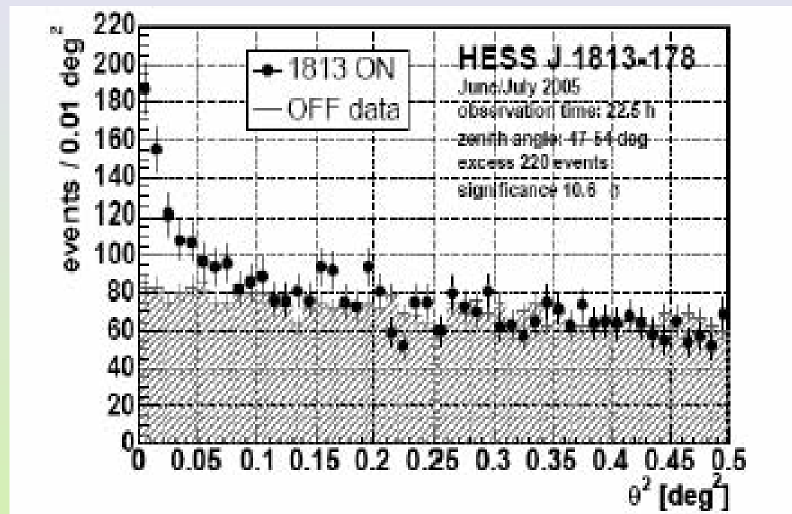
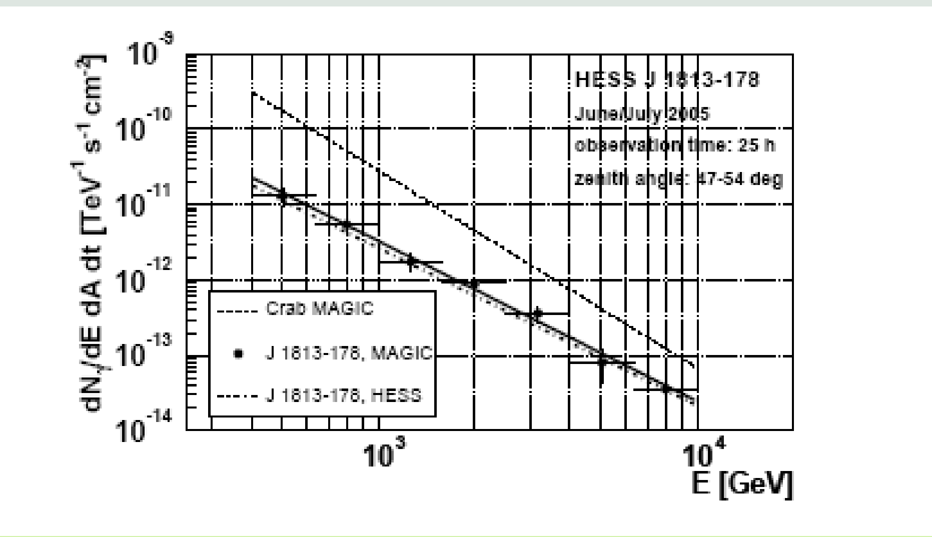


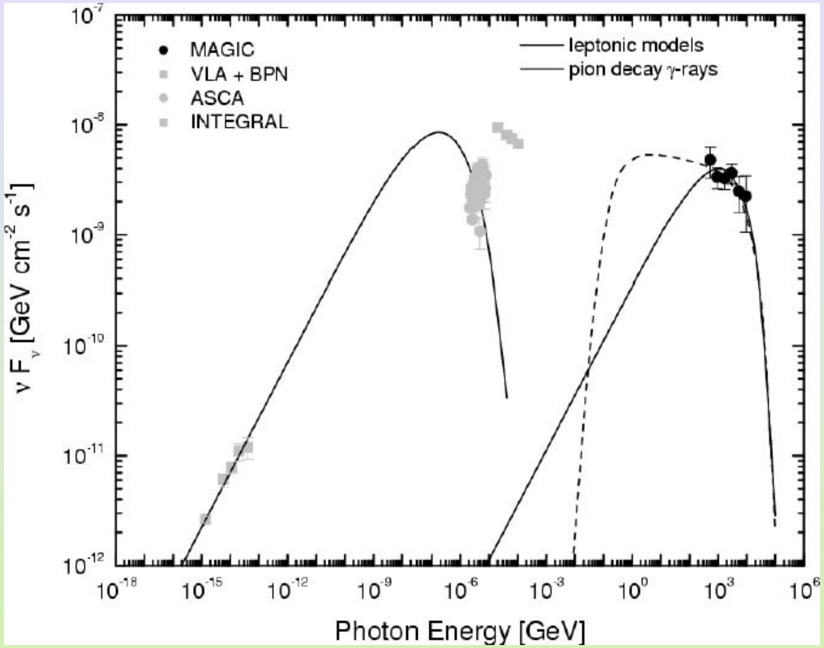
FIG. 2.— Distributions of θ^2 values for the source and anti-source, see text, for SIZE $\geq$ 600 ph. el. (corresponding to an energy threshold of about 1 TeV).

HESS/SNR Connection: HESS J1813 & HESS J1834

HESS J1813-178

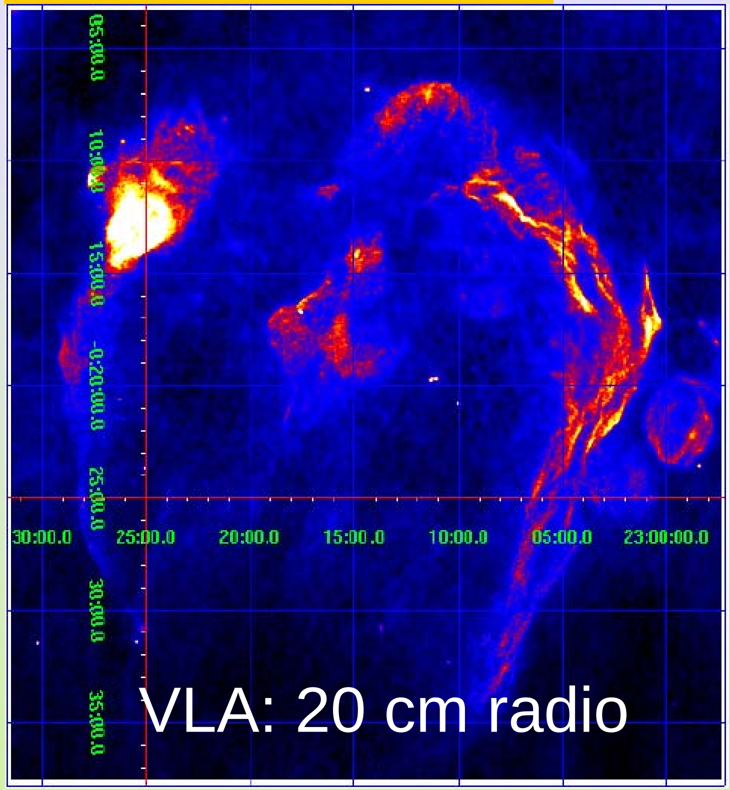
- Power law spectrum compatible with HESS flux level.
- SED can be fitted to hadronic or leptonic models.

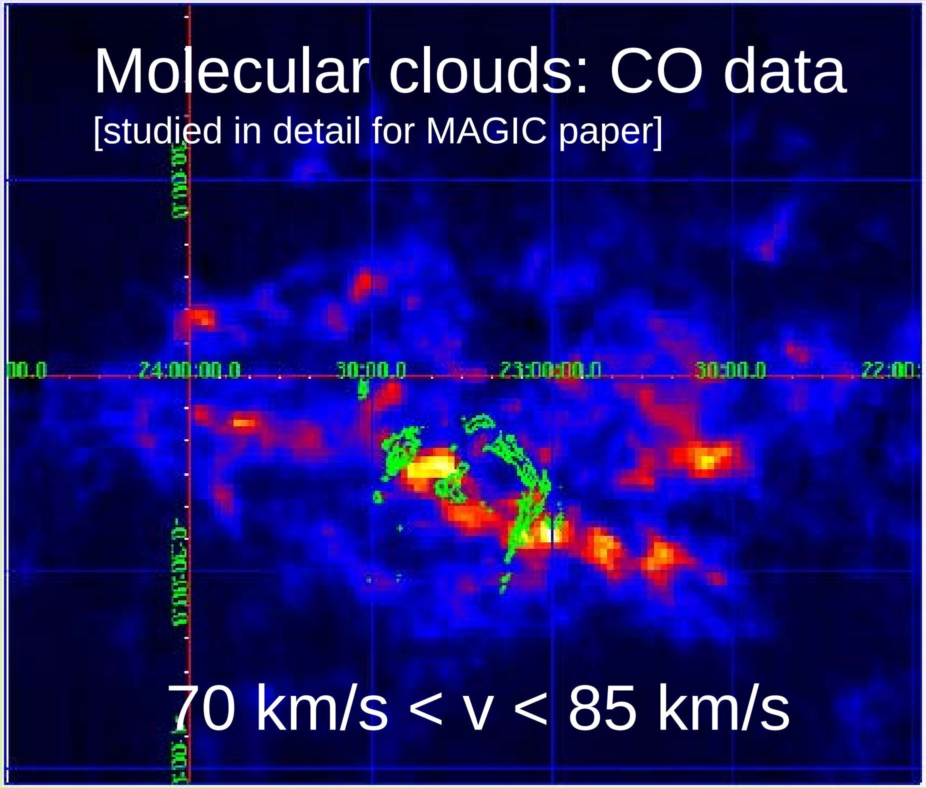




HESS/SNR Connection: HESS J1813 & HESS J1834

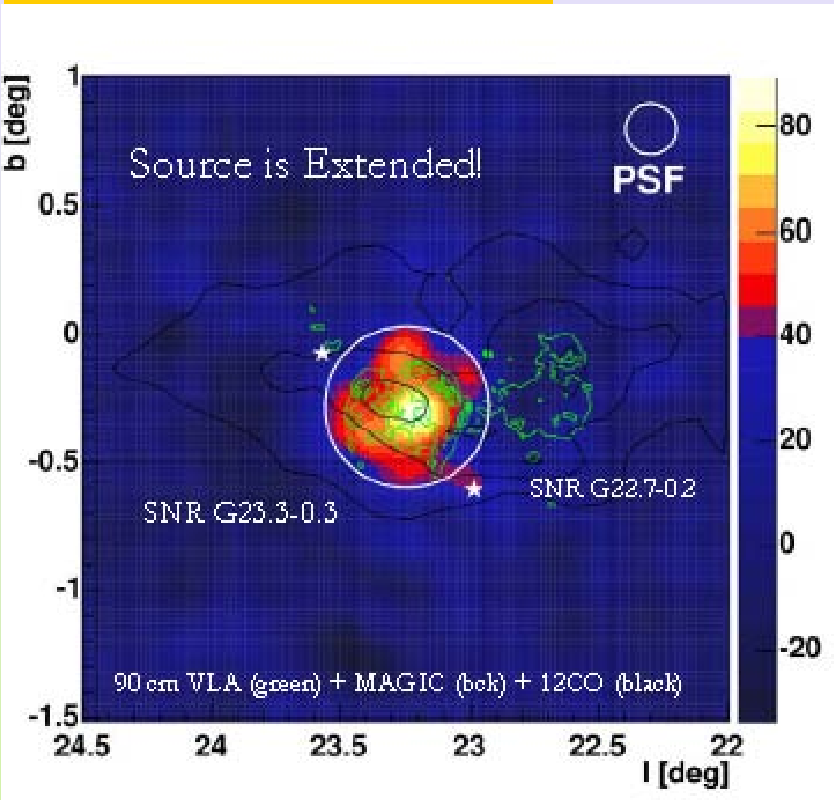
HESS J1834-087



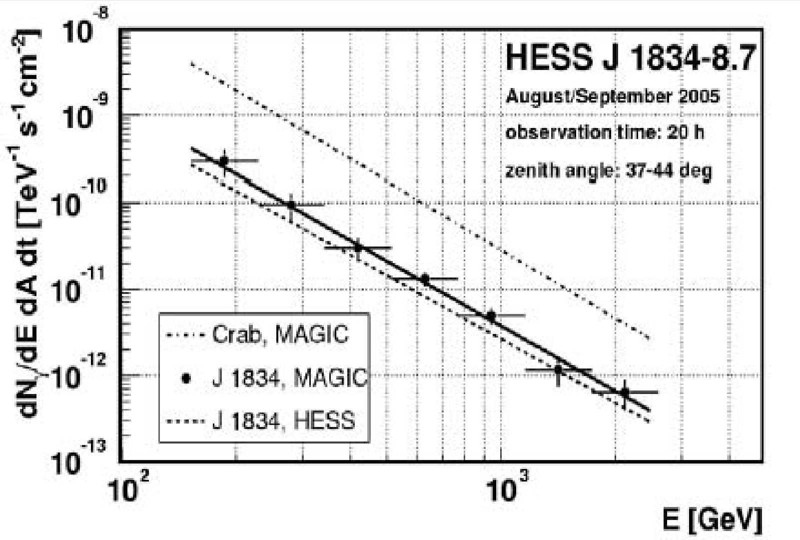


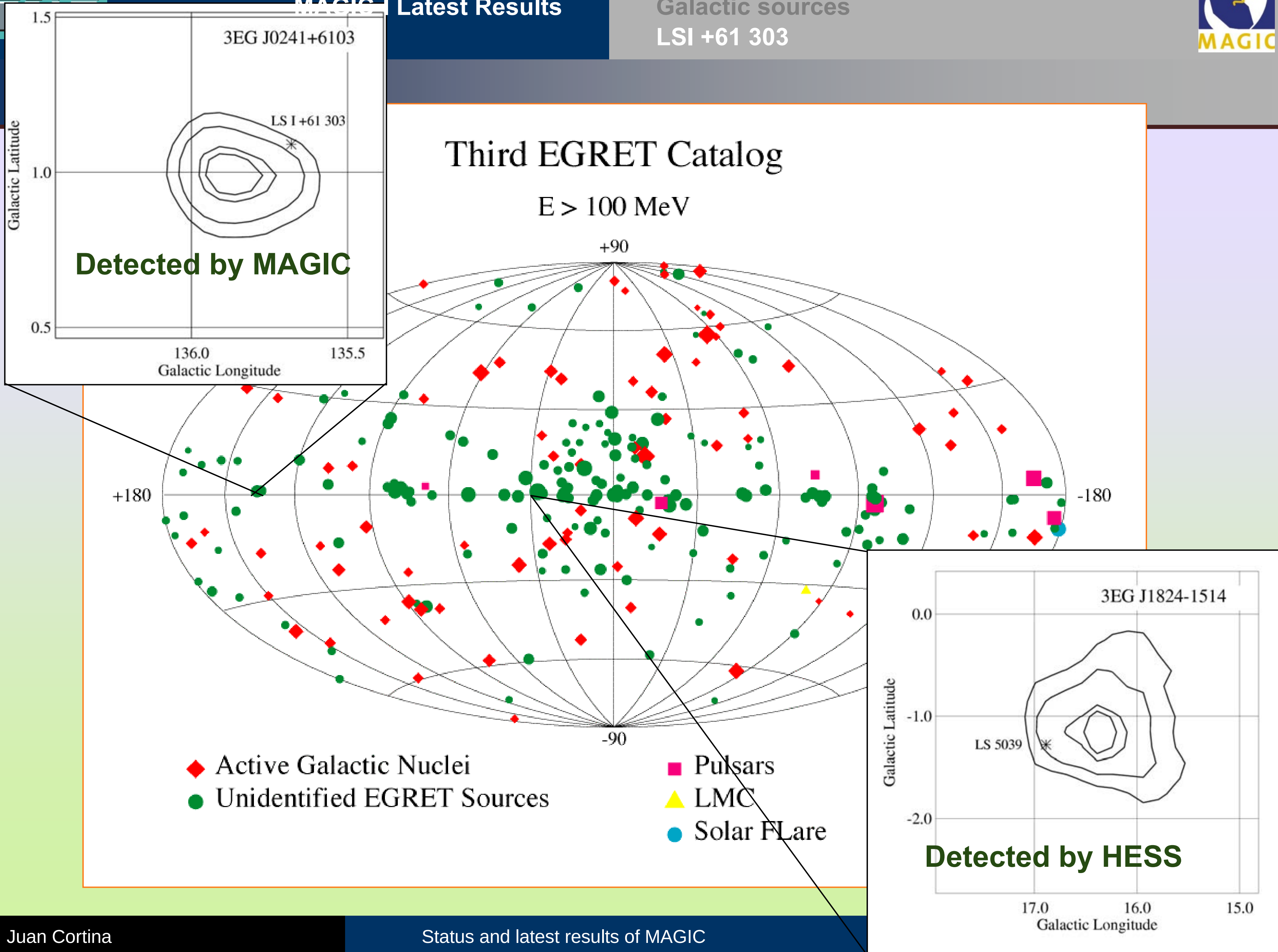
HESS/SNR Connection: HESS J1813 & HESS J1834

HESS J1834-087



- SNR G 23.3-0.3 (W 41)
- Zenith angle 37°-44°
- Threshold 150 GeV
- Existence of dense cloud reported by MAGIC (12 and 13CO)

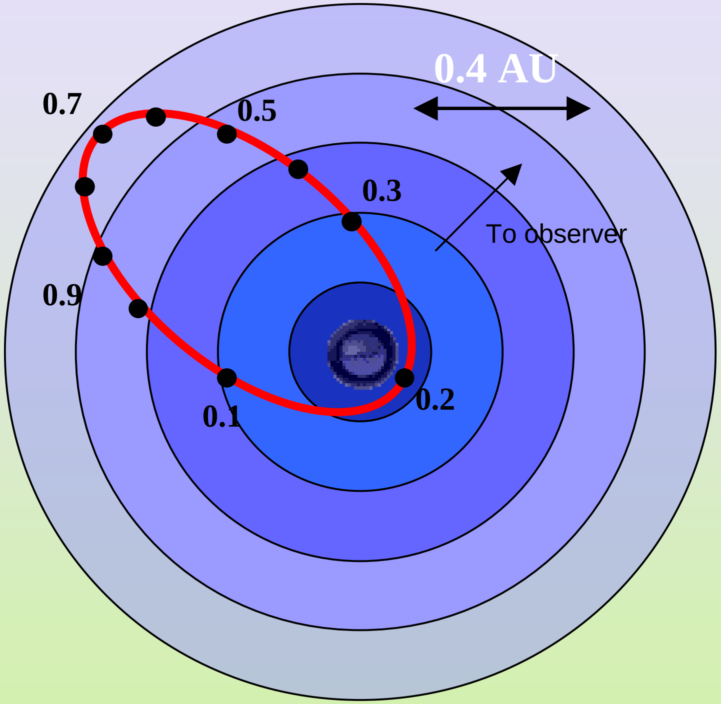



Third EGRET Catalog
E > 100 MeV
+90
-90
+180
-180
Active Galactic Nuclei
Unidentified EGRET Sources
Pulsars
LMC
Solar FLare
3EG J0241+6103
LS I +61 303
Galactic Latitude
Galactic Longitude
1.5
1.0
0.5
136.0
135.5
Detected by MAGIC
3EG J1824-1514
LS 5039
0.0
-1.0
-2.0
17.0
16.0
15.0
Detected by HESS

LSI +61 303

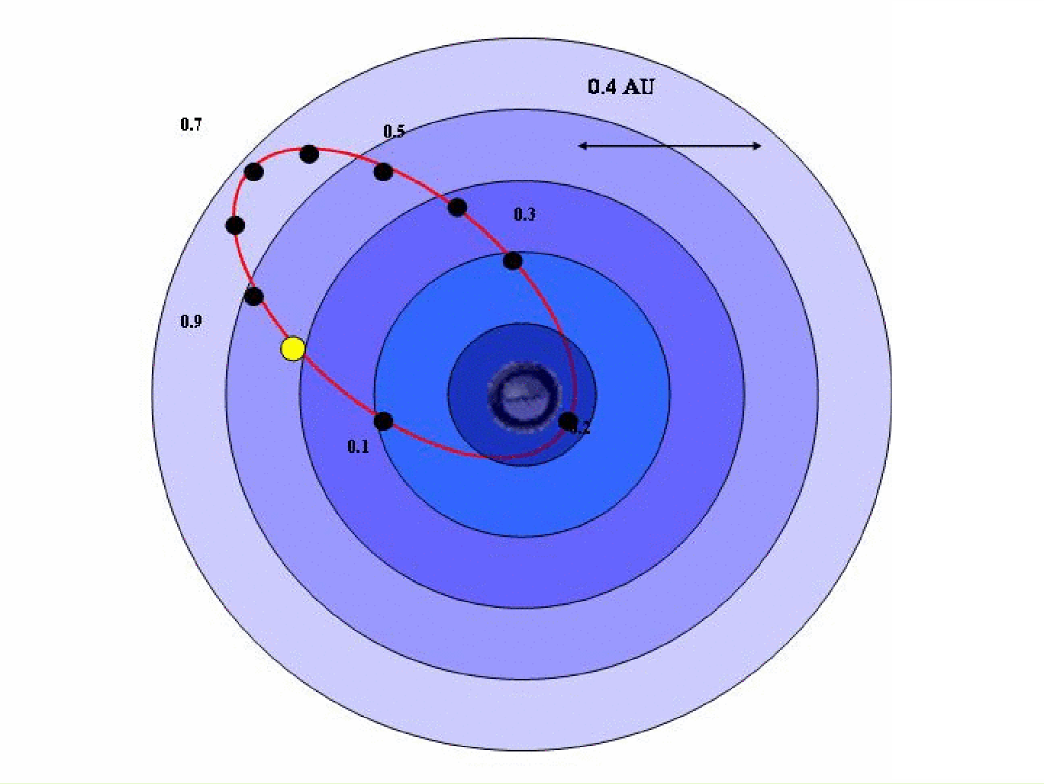
LSI +61 303

- High Mass X-ray binary at a distance of 2 kpc
- Optical companion is a B0 Ve star of 10.7^m with a circumstellar disc
- Compact object probably a neutron star
- High eccentricity or the orbit (0.7)
- Modulation of the emission from radio to X-rays with period 26.5 days attributed to orbital period

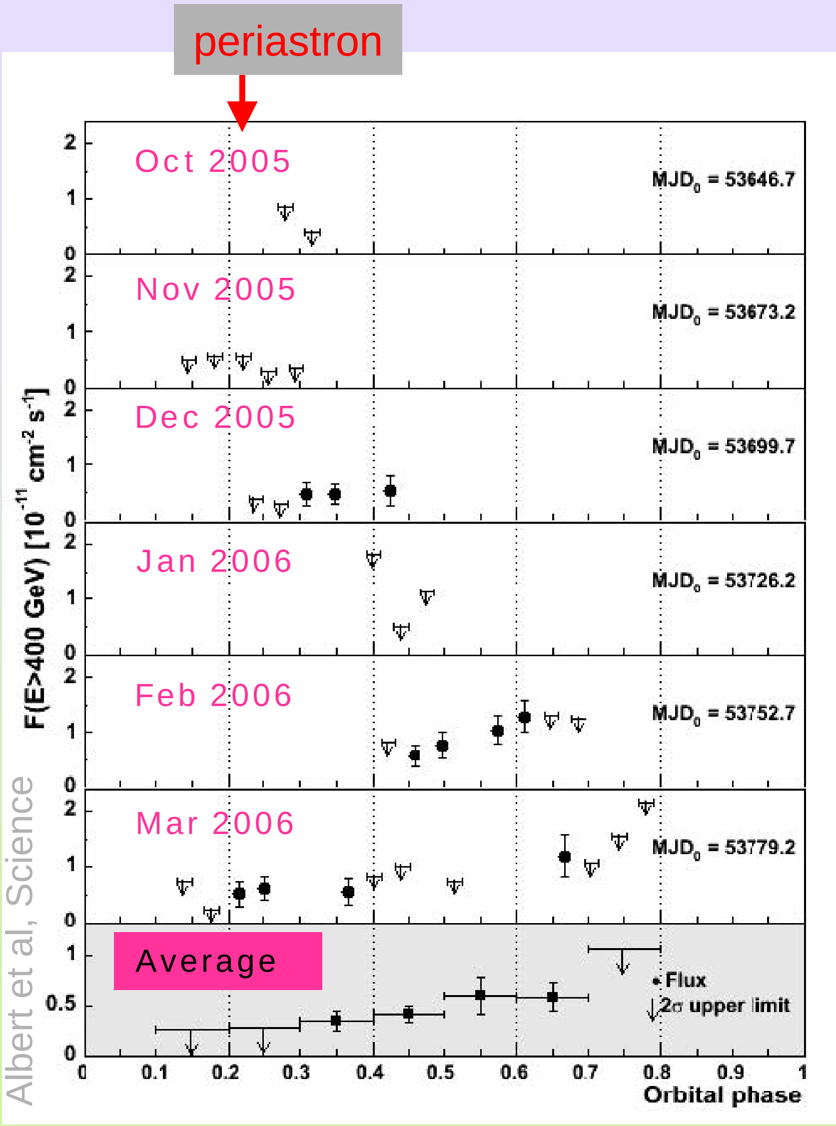


LSI +61 303

- MAGIC observed the source for six orbital cycles in 2005-2006.
- Albert et al, Science Express, 18 May 2006.
- Clear detection far from periastron (phases 0.4-0.7).



LSI +61 303



No significant emission close to periastron.

Hint at periodic emission

Maximum found for phase 0.6-0.7.

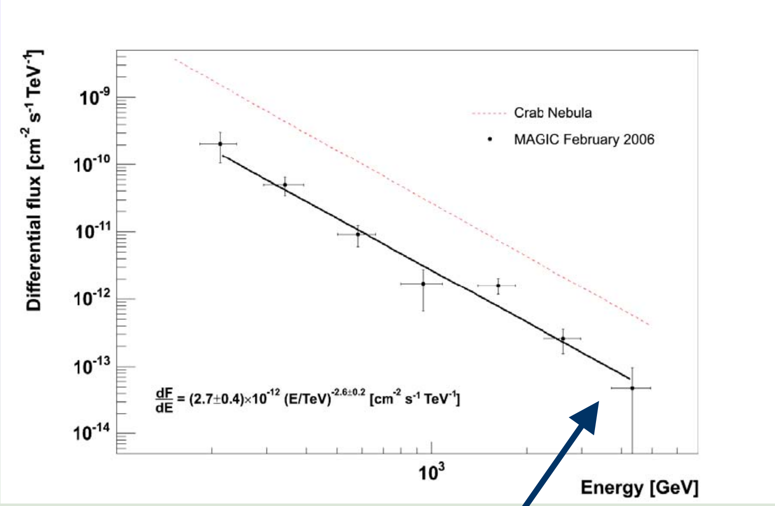
Flux at maximum 16% crab.

Maximum before periodic radio outburst at phase 0.7 (Ryle telescope).

LSI +61 303

Average Spectrum: straight power law spectrum from 400 GeV to 4 TeV:

α **= -2.6 ± 0.2 (stat) ± 0.2 (syst)**



No evidence for cutoff up to 5 TeV

Luminosity can be explained via wind accretion: Marti & Paredes A&A 298 (1995) 151.

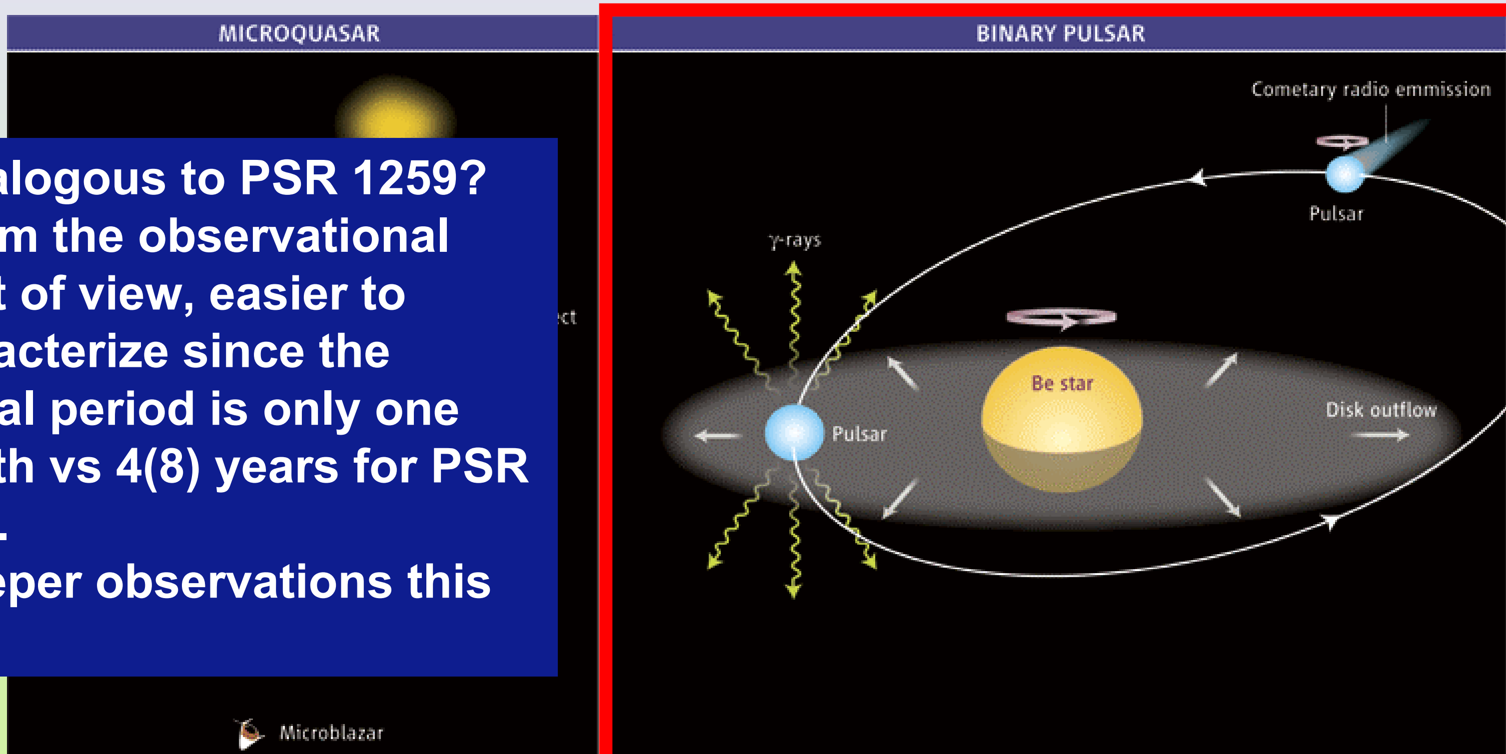
Non detection at periastron is puzzling. Could be due to absorption. Such strong absorption not predicted by most models, but see Bednarek MNRAS 368 (2006) 579.

Favors leptonic model because photon density dominates over matter density at apastron (?)

On the nature of LSI +61 303

Radio observations resolved a extended structure which was interpreted as a jet ⇒ microquasar?

BUT! Recent results show that the outflow could be produced by the interaction of a pulsar wind and the companion star's wind.



- **Analogous to PSR 1259?**
- **From the observational point of view, easier to characterize since the orbital period is only one month vs 4(8) years for PSR 1259.**
- **Deeper observations this year.**

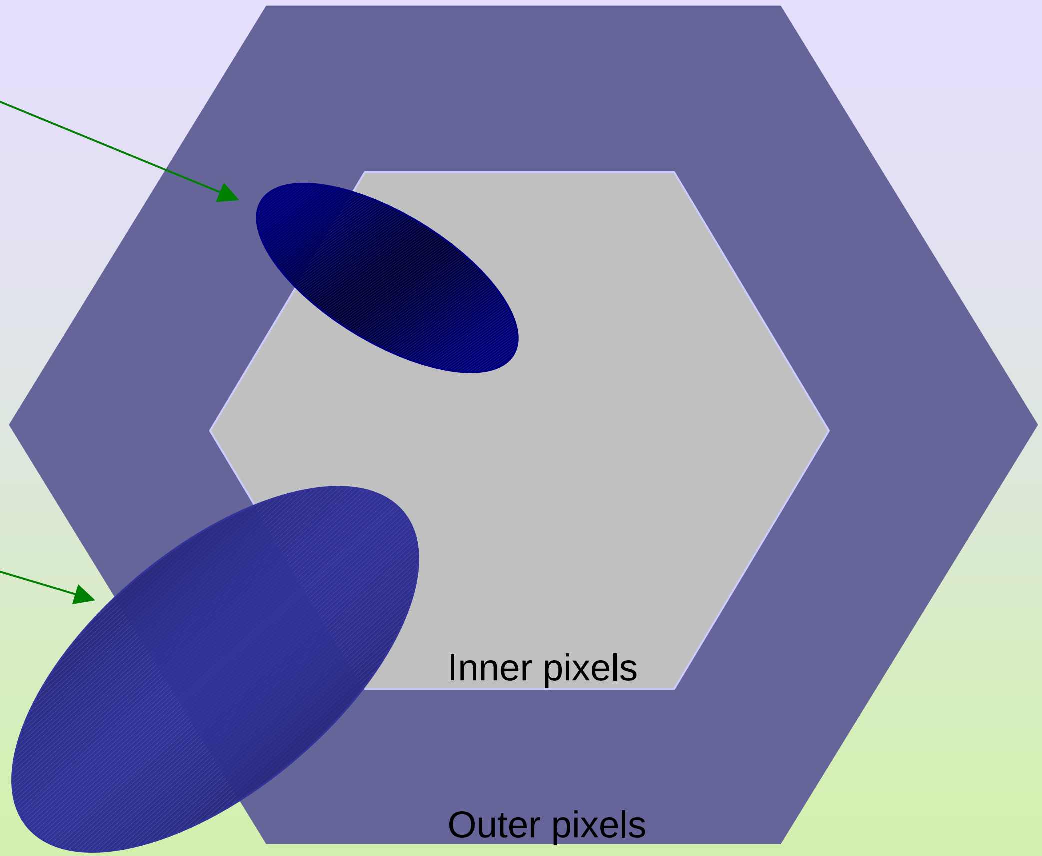
Conclusions

- **MAGIC is in its second year of regular observations.**
- **We are still improving our hardware. Many of the technological developments are now well proven and can be used in future telescopes.**
- **We are starting production of major elements of MAGIC-II. We aim at completion by Fall 2007.**
- **Extragalactic highlights: Mrk 421, Mrk 501, Mrk 180, 1ES1218, 1ES1959, 1ES2344, PG 1553, prompt observation of GRB050713a.**
- **Galactic highlights: variability of γ-ray binary LSI +61 303.**

MAGIC-I: high energy showers limited by camera

Low ENERGY shower: fully contained in camera (ø=3.5°), good energy reconstruction and Hillas reconstruction

High ENERGY shower: missing SIZE (“leakage”), truncated ellipse and poor Hillas reconstruction

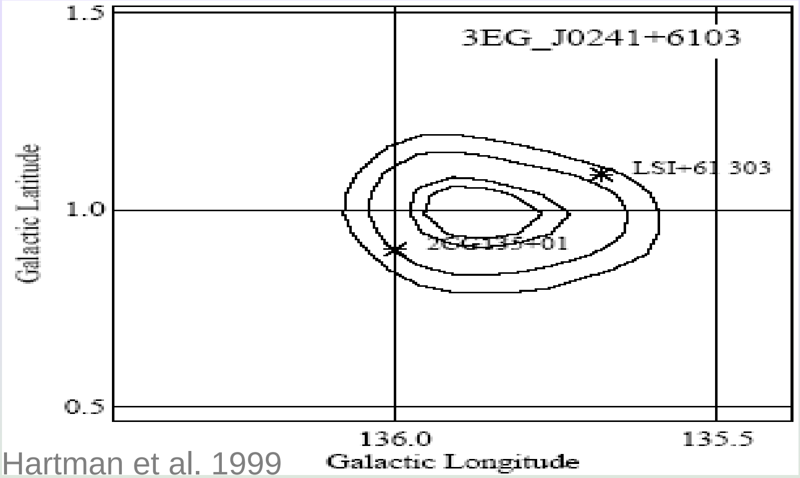


A good fraction of our showers above 1 TeV suffer from leakage. Need for larger camera FOV.

LSI +61 303

- **A HE γ-ray (100 MeV – 10 GeV) source detected by EGRET is marginally associated with the position of LS I +61 303.**
- **The emission is variable and peaking at periastron passage (ϕ=0.2) and ϕ ~ 0.4-0.6**

Interpreted as stellar photons upscattered (inverse Compton) by relativistic electrons in the jet



Hartman et al. 1999