

6. *Astronomia Gamma*

Corso “*Astrofisica delle particelle*”

Prof. Maurizio Spurio

Università di Bologna. A.a. 2011/12

Outline

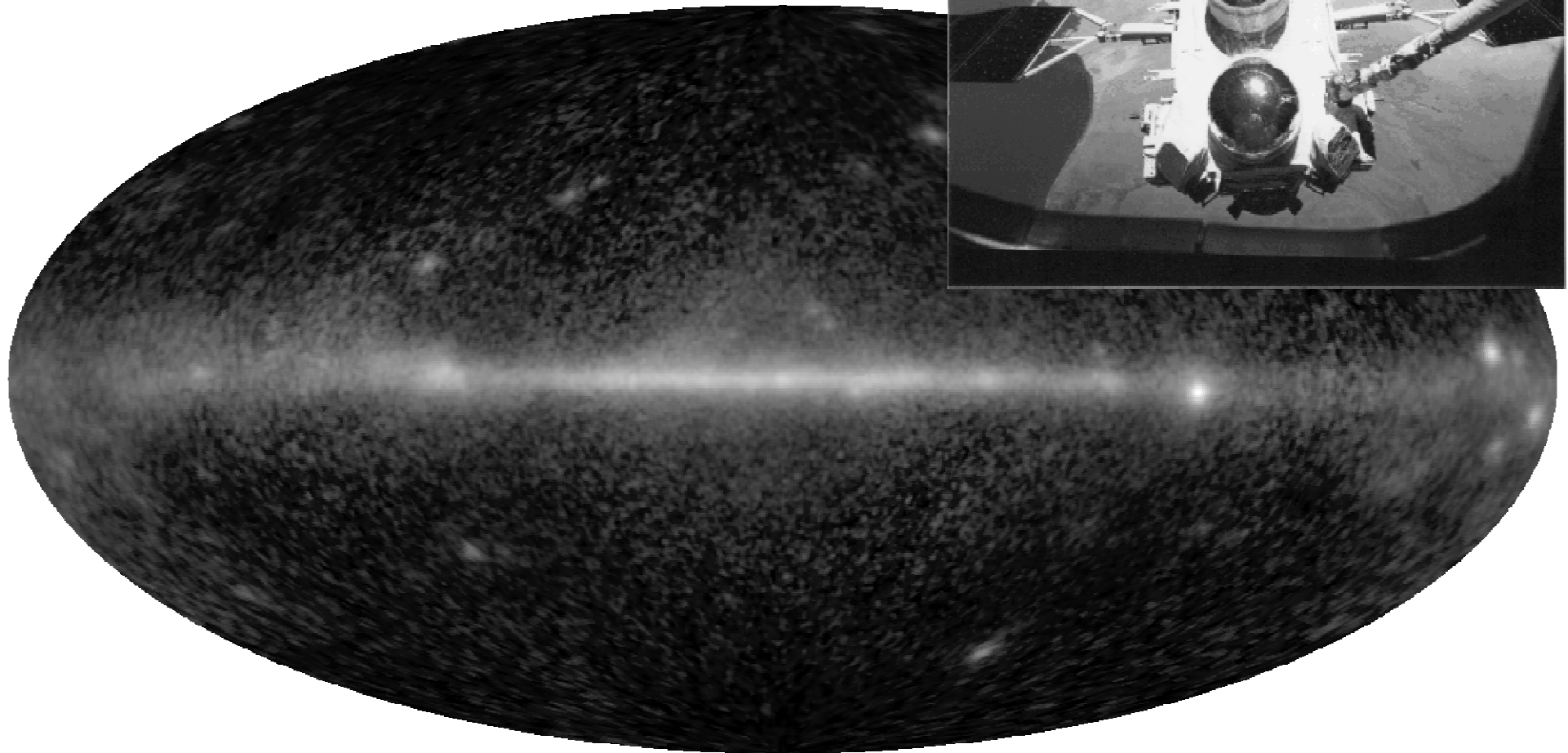
- Il cielo visto da EGRET (§6.1)
- FERMI-LAT
- Il fondo diffuso di raggi gamma (§6.2)
- Noto ed ignoto nel cielo Gamma (§6.3)
- I Gamma Ray Bursts (§6.4)
- Osservazioni sperimentali di acceleratori astrofisici nella Galassia: astronomia γ con telescopi Cherenkov (§6.5).
- γ dal piano galattico come indizio dei RC



100 GeV – decine di TeV

10

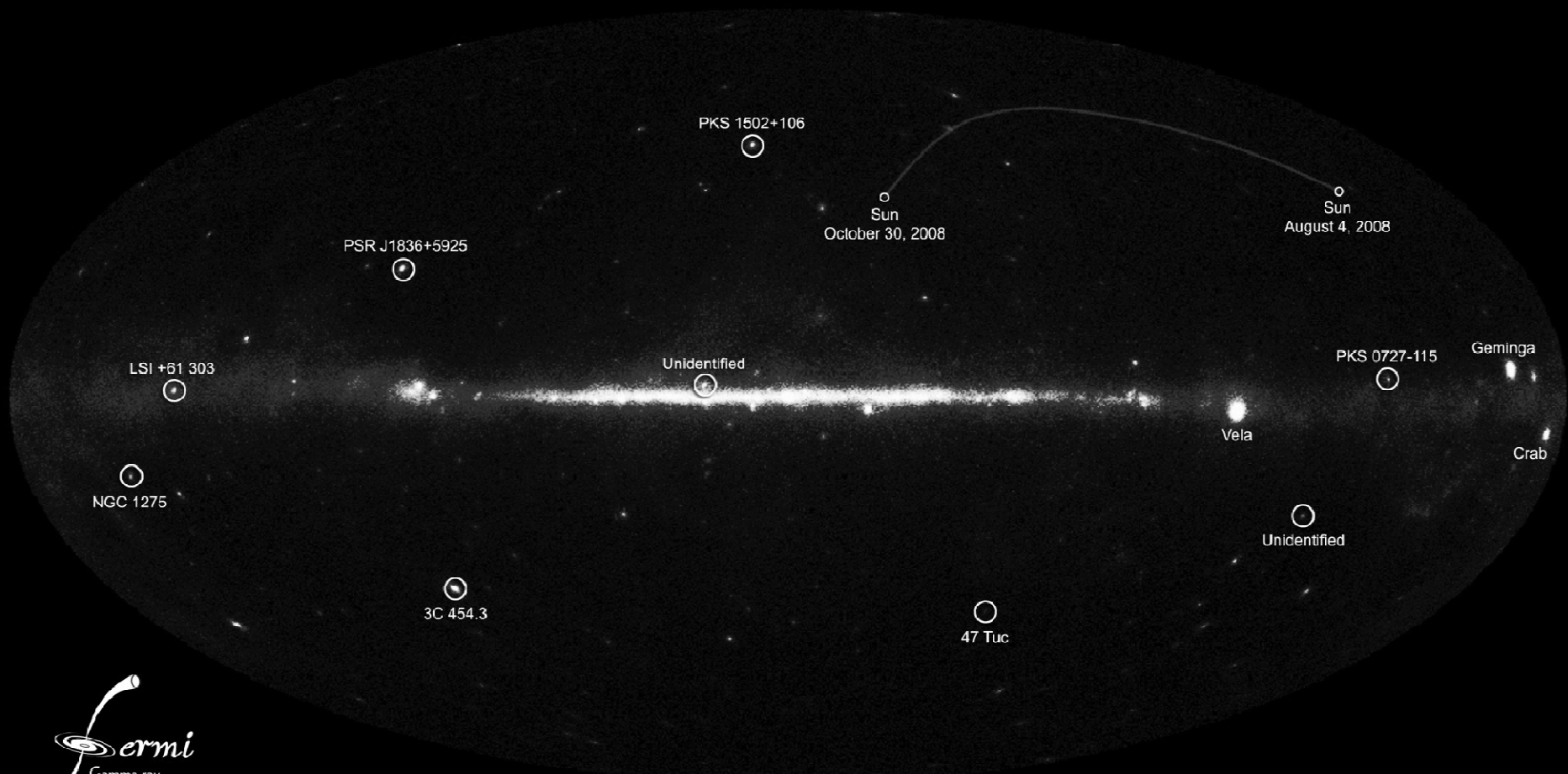
EGRET sky (DATA)



3rd EGRET Catalog: 270 sources, among them
93 blazars, 170 unid.

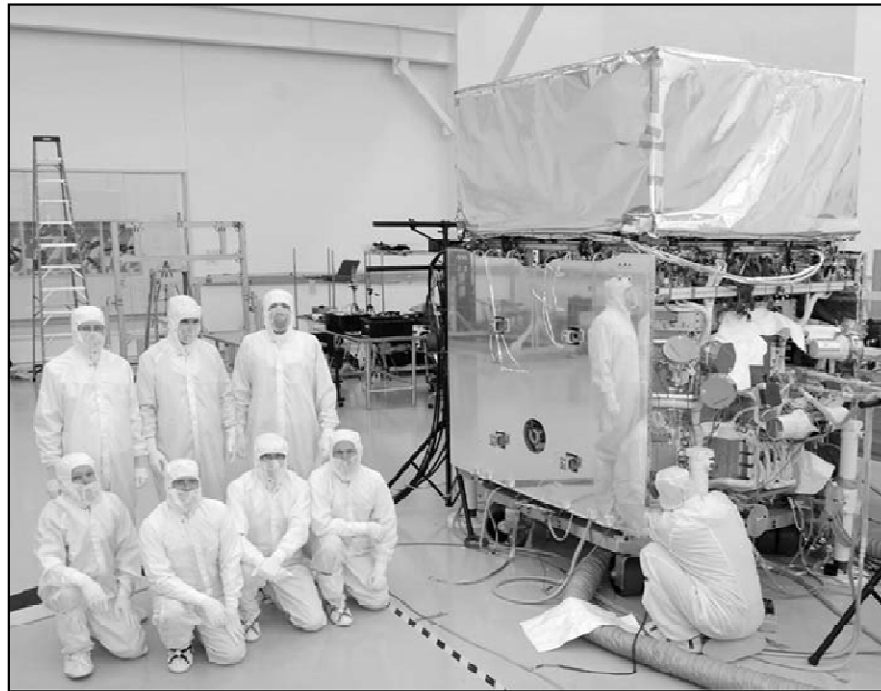
GLAST *skv* → FERMI-LAT

NASA's Fermi telescope reveals best-ever view of the gamma-ray sky



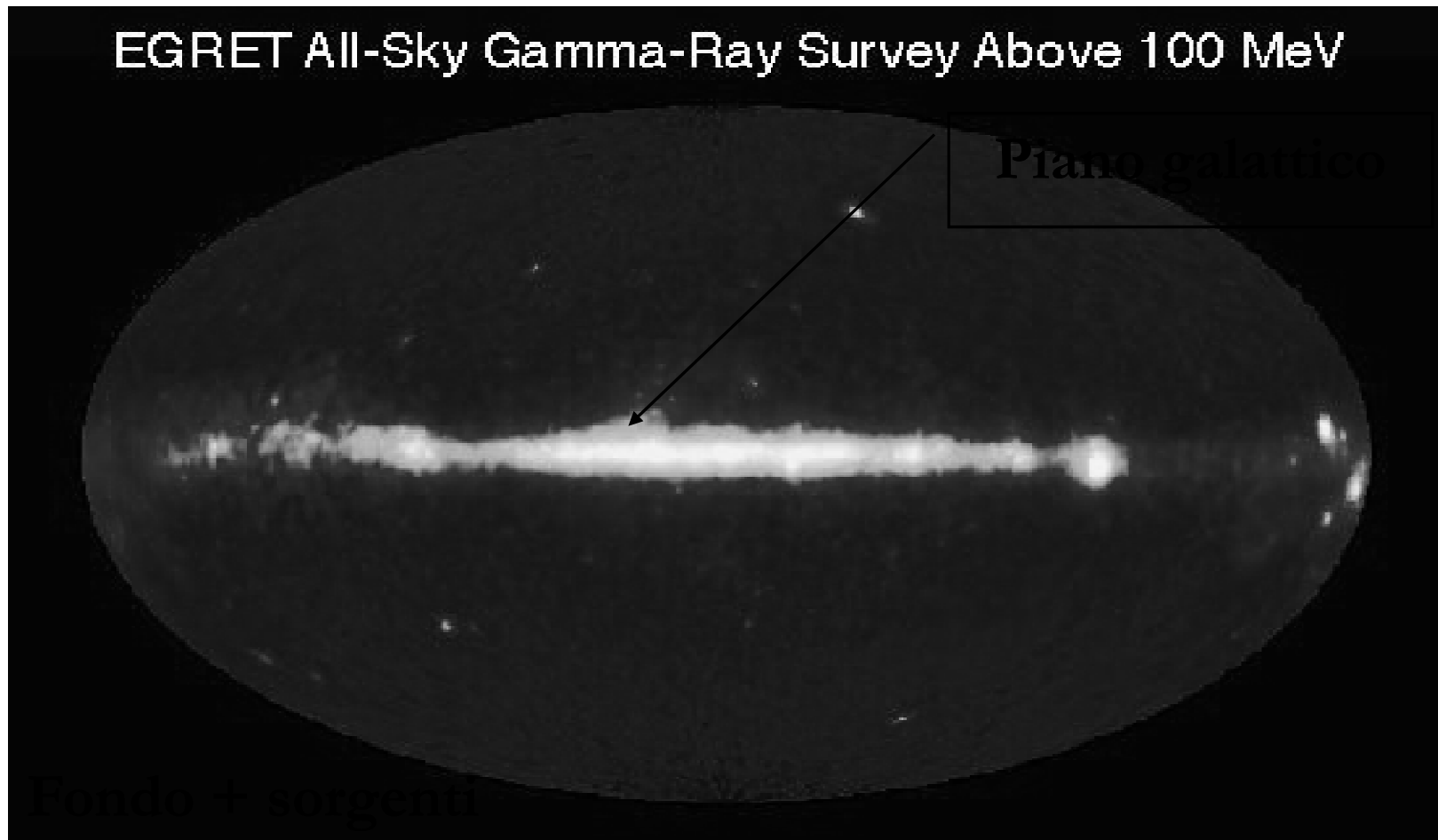
Credit: NASA/DOE/Fermi LAT Collaboration

Il rivelatore FERMI (ex GLAST)



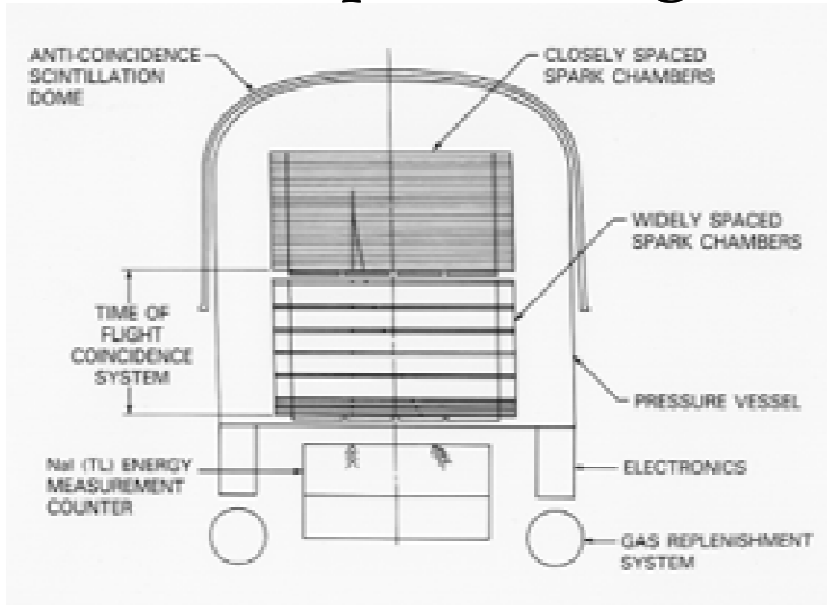
6.1 Il cielo visto dal satellite EGRET

$$20 \text{ MeV} < E_\gamma < 30 \text{ GeV}$$



Il satellite EGRET (α 1991- Ω 2000)

<http://coss.c.gsfc.nasa.gov/docs/cgro/egret/>

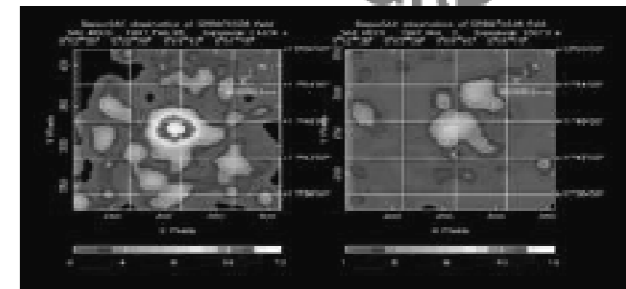
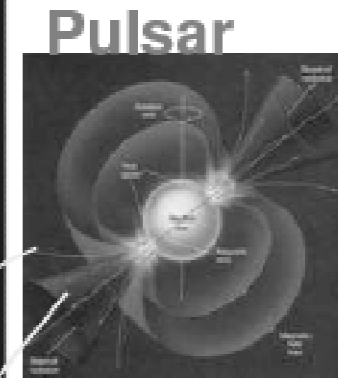
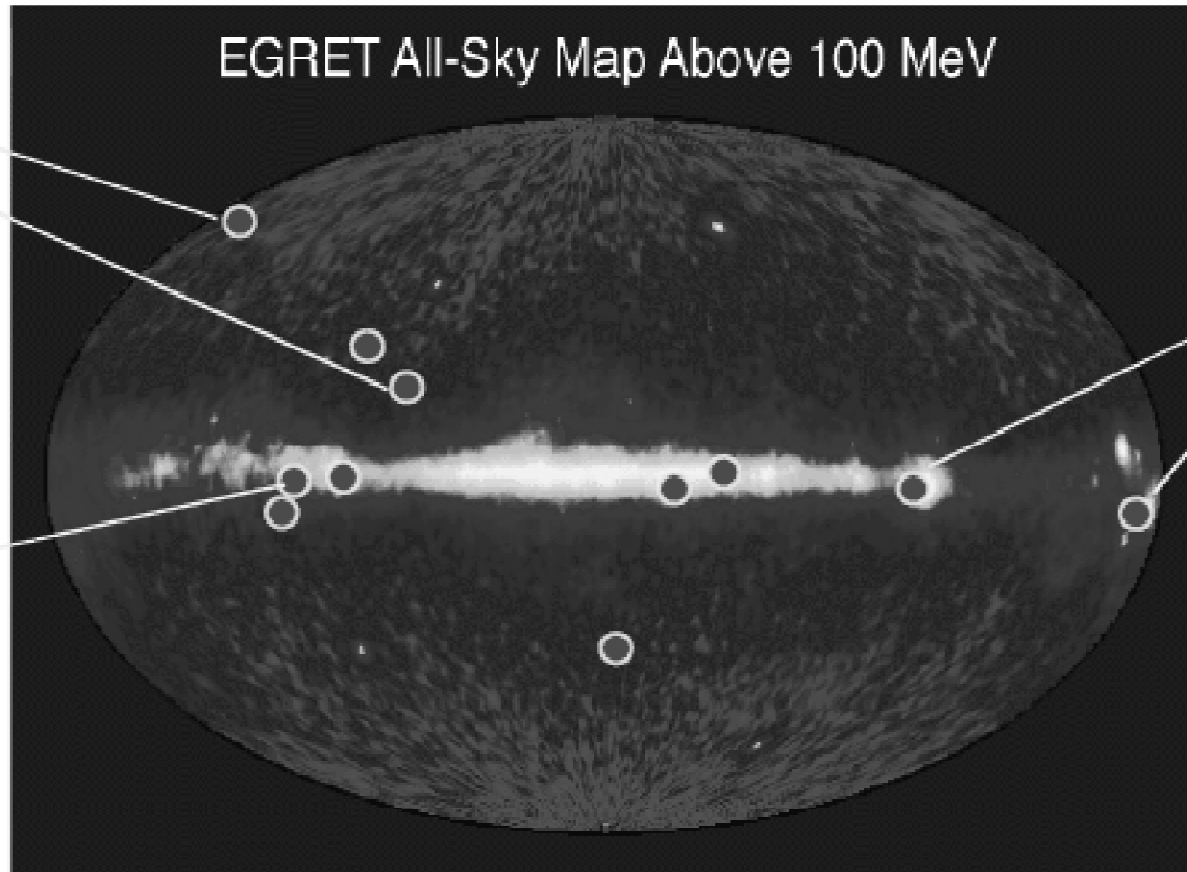
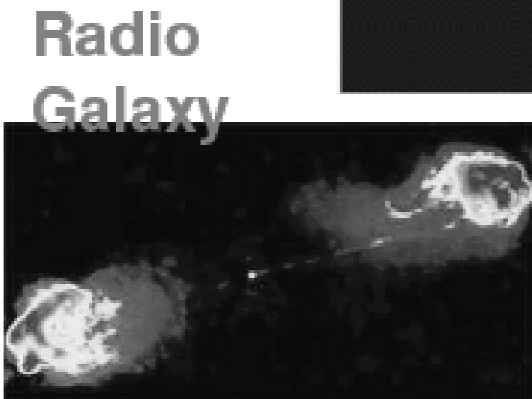
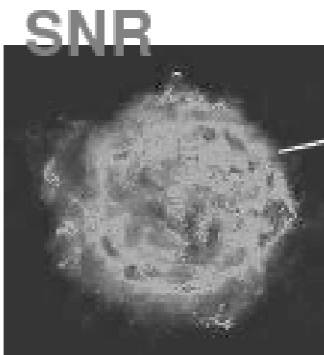
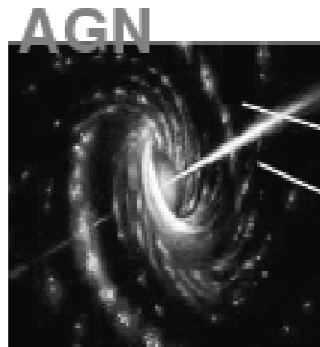


- EGRET = Energetic Gamma-Ray Experiment Telescope
- Era uno degli strumenti della missione CGRO Compton Gamma Ray Observatory (1991 - 2000) della NASA. Lancio: April 5, 1991 a bordo dello shuttle Atlantis. Compton è rientrato nell'atmosfera terrestre il 4/6/2000.
- EGRET ha rivelato $R\gamma$ tra 20 MeV-30 GeV .
- Aveva un campo di vista molto largo, circa 80° in diametro.
- Area: 1000 cm^2 tra 100 MeV e 3 GeV
- Precisione angolare dipendente dall'energia del $R\gamma$: 5.5° a 100 MeV, sino a 0.5° a 5 GeV;
- le sorgenti brillanti di $R\gamma$ potevano essere localizzate entro approssimativamente $10'$.

FONDO: Diffuse Galactic Gamma-Ray Emission (DG γ RE)

- L'emissione diffusa di raggi Gamma dal piano galattico (diffuse Galactic gamma-ray emission) è dominante nella rivelazione di raggi gamma di energia > 100 MeV.
- Le prime misure sono state effettuate dal *satellite* EGRET (sensibilità 20 MeV $< E_\gamma < 30$ GeV). Altre misure sono attualmente in corso, o nell'immediato futuro (Fermi).
- La DG γ RE è principalmente prodotta dalle interazioni elettromagnetiche ed adroniche di protoni ed elettroni dei raggi cosmici, che interagiscono col materiale interstellare nella loro propagazione nella Galassia.
- La distribuzione spaziale della DG γ RE osservata da EGRET può essere interpretata in termini della distribuzione di gas atomici e molecolari nel mezzo interstellare della nostra Galassia, utilizzando il modello di confinamento dei RC Galattici.
- Tuttavia, lo spettro della DG γ RE non è completamente spiegato in termini del solo modello di interazione dei RC col mezzo interstellare galattico: sono evidenti punti di accumulo (sorgenti).
- Il meccanismo di accelerazione dei RC da parte di onde di shock di Supernovae (cap. 4) può essere verificato dallo studio dell'emissione di raggi gamma dell'energia del TeV (*rivelatori Imaging Cerenkov di raggi gamma a terra*).

SORGENTI di $R\gamma$ (e di RC ?)

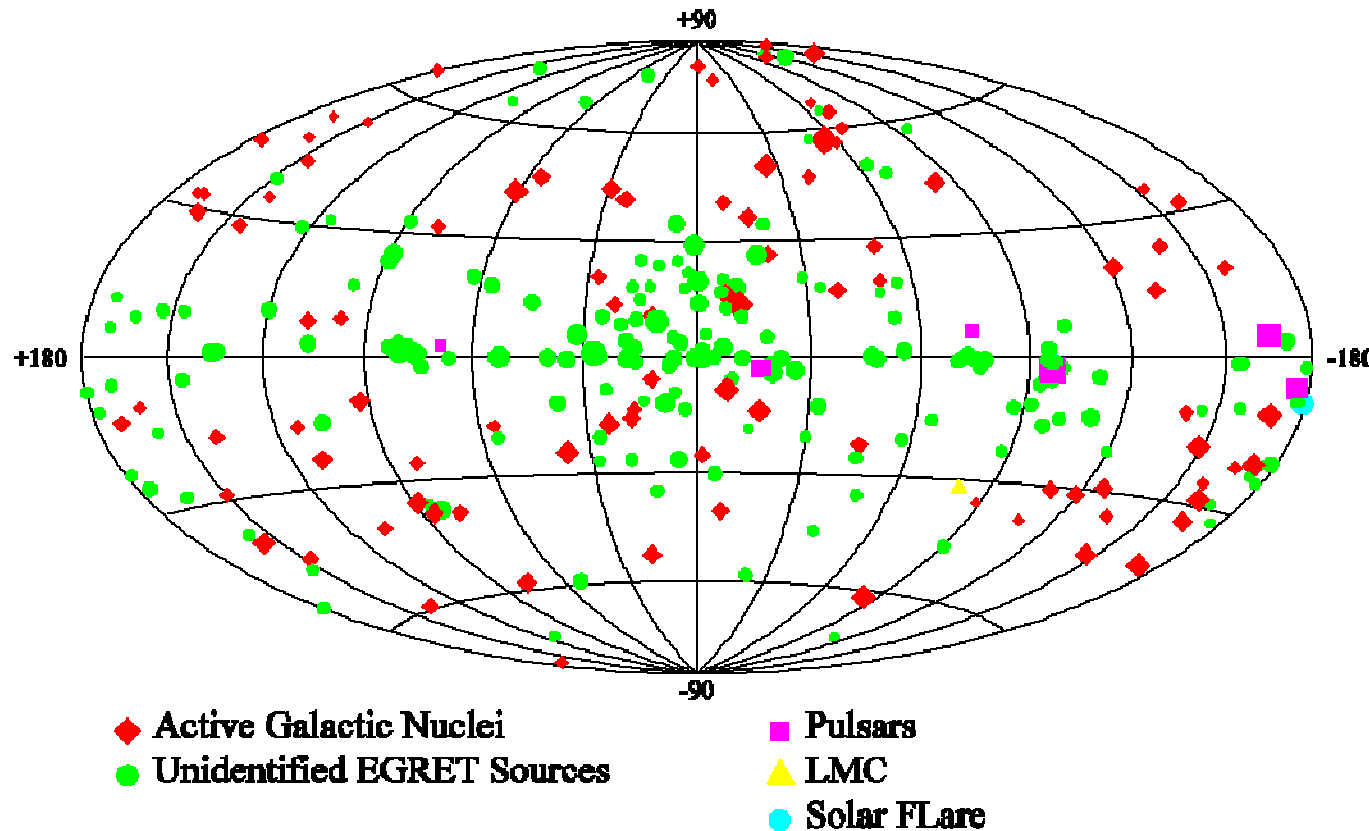


**3° Catalogo EGRET :
270 sorgenti, tra cui
93 blazars, 170 non
identificate.**

6.3 Noto ed ignoto da EGRET: segnale- fondo = *sorgenti*

Third EGRET Catalog

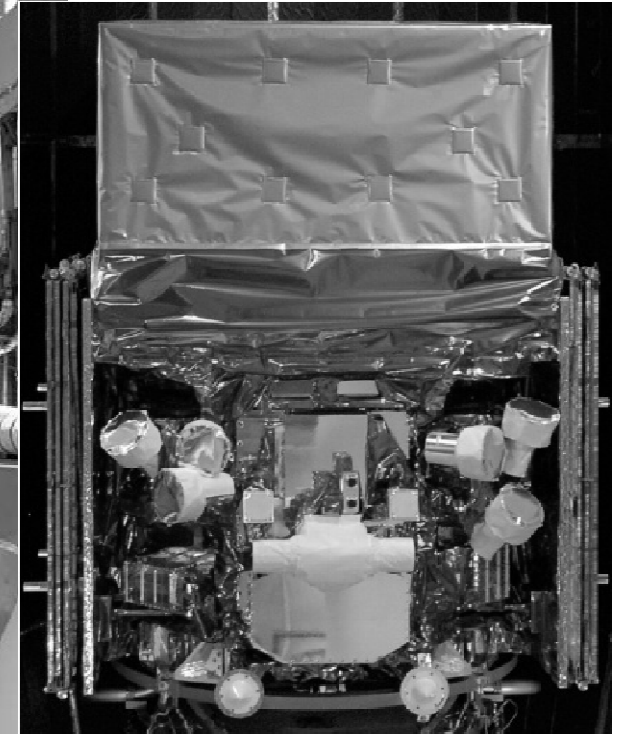
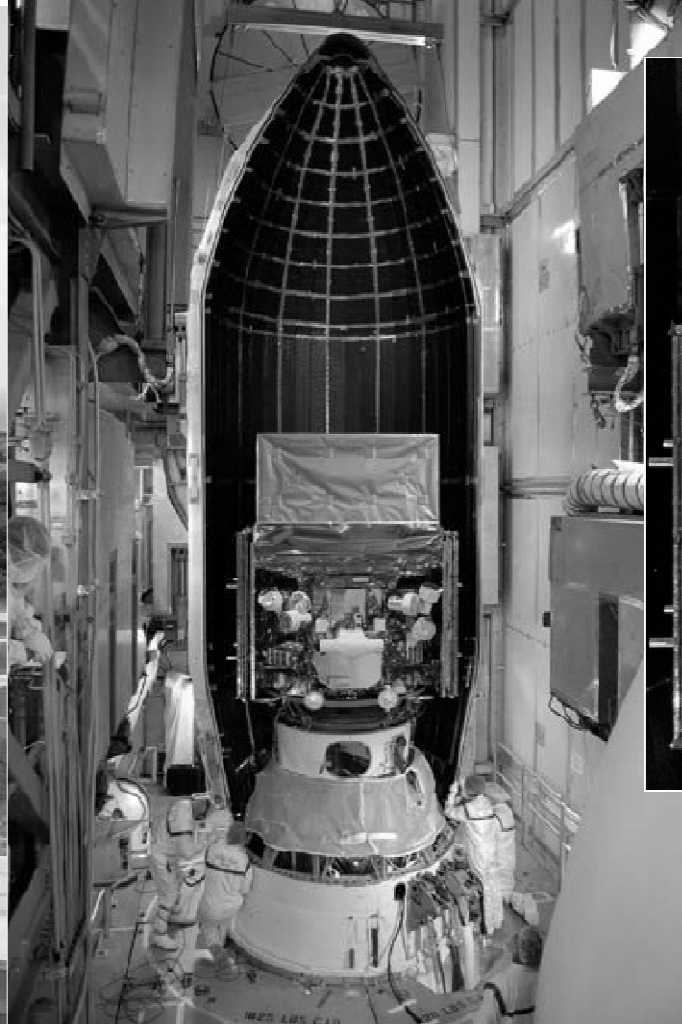
E > 100 MeV



- Circa il 50% delle sorgenti scoperte da EGRET sono state identificate (osservate anche in precedenza in altre lunghezze d'onda).
- Metà sono non identificate.
- Quali oggetti producono raggi gamma di alta energia, ed emettono anche nel radio?

Segnale ottenuto dopo la sottrazione del fondo galattico diffuso

Satellite FERMI (α 11/6/2008)



FERMI Large Area Telescope

■ The LAT is a pair-production telescope . The tracking section has 36 layers of silicon microstrip detectors to measure the tracks of charged particles, interleaved with 16 layers of tungsten foil (12 thin layers, 0.03 radiation length, at the top or front of the instrument, followed by 4 thick layers, 0.18 radiation length, in the back section) to promote γ -ray pair conversion. The tracker is followed by an array of CsI crystals to determine the γ -ray energy and is surrounded by segmented charged-particle detectors (plastic scintillators with photomultiplier tubes) to reject cosmic-ray backgrounds.

■ The LAT's improved sensitivity compared to EGRET stems from:

- a large peak effective area ($\sim 8000 \text{ cm}^2$, or ~ 6 times greater than EGRET's),

- large field of view ($\sim 2.4 \text{ sr}$, or nearly 5 times greater than EGRET's),

- good background rejection,

- superior angular resolution (68% containment angle $\sim 0.6^\circ$ at 1 GeV for the front section and about a factor of 2 larger for the back section),

- improved observing efficiency

LAT

Tracciatore al silicio (TKR)

Misura la direzione del fotone



Anticoincidenza Segmentata (ACD)

Rimuove il fondo di particelle cariche

Riduce il self-veto alle alte energie



HEP and astrophysics partnership

USA: US Dept. Of Energy, SU-SLAC, NASA GSFC, NRL

Italy: INFN, ASI, Inst. CR Res (IFC)

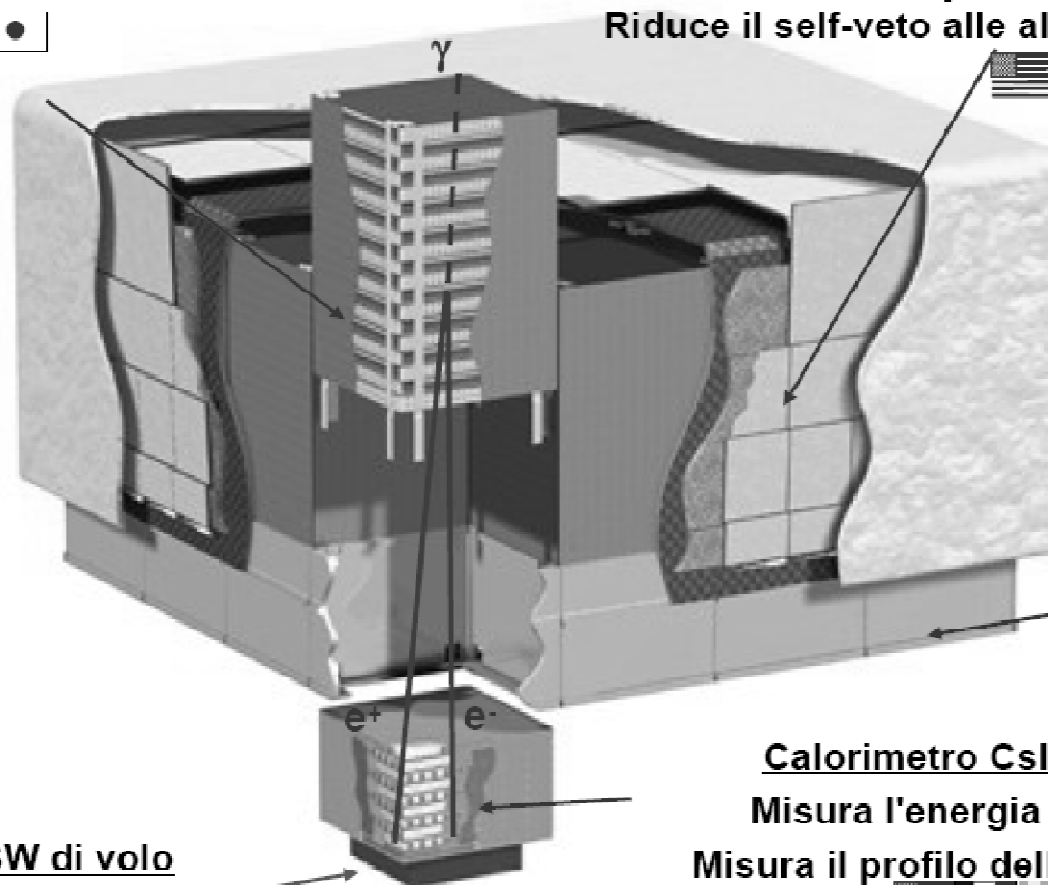
Japan: Univ. Tokyo, Univ. Hiroshima, Inst. Space Science, Inst. CR Res. (ICCR)

France: CEA, CNES, IN2P3

Sweden: Royal Inst. Tech., Univ. Stockholm

LAT:

modulare, 4 x 4
3000 kg, 650 W



GRID

“Spina dorsale”



Calorimetro Csi (CAL)

Misura l'energia dell'evento

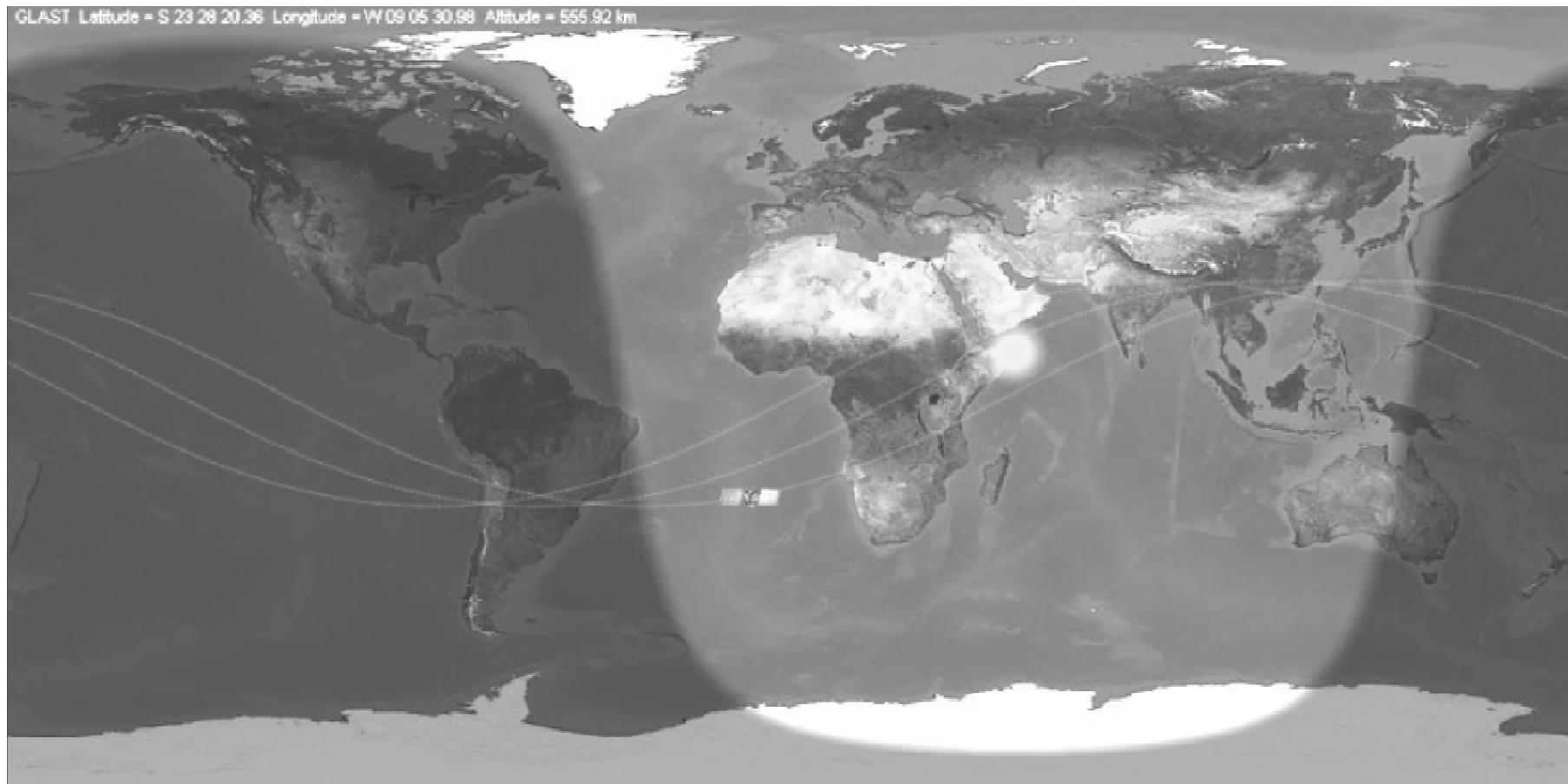
Misura il profilo dello sciame EM



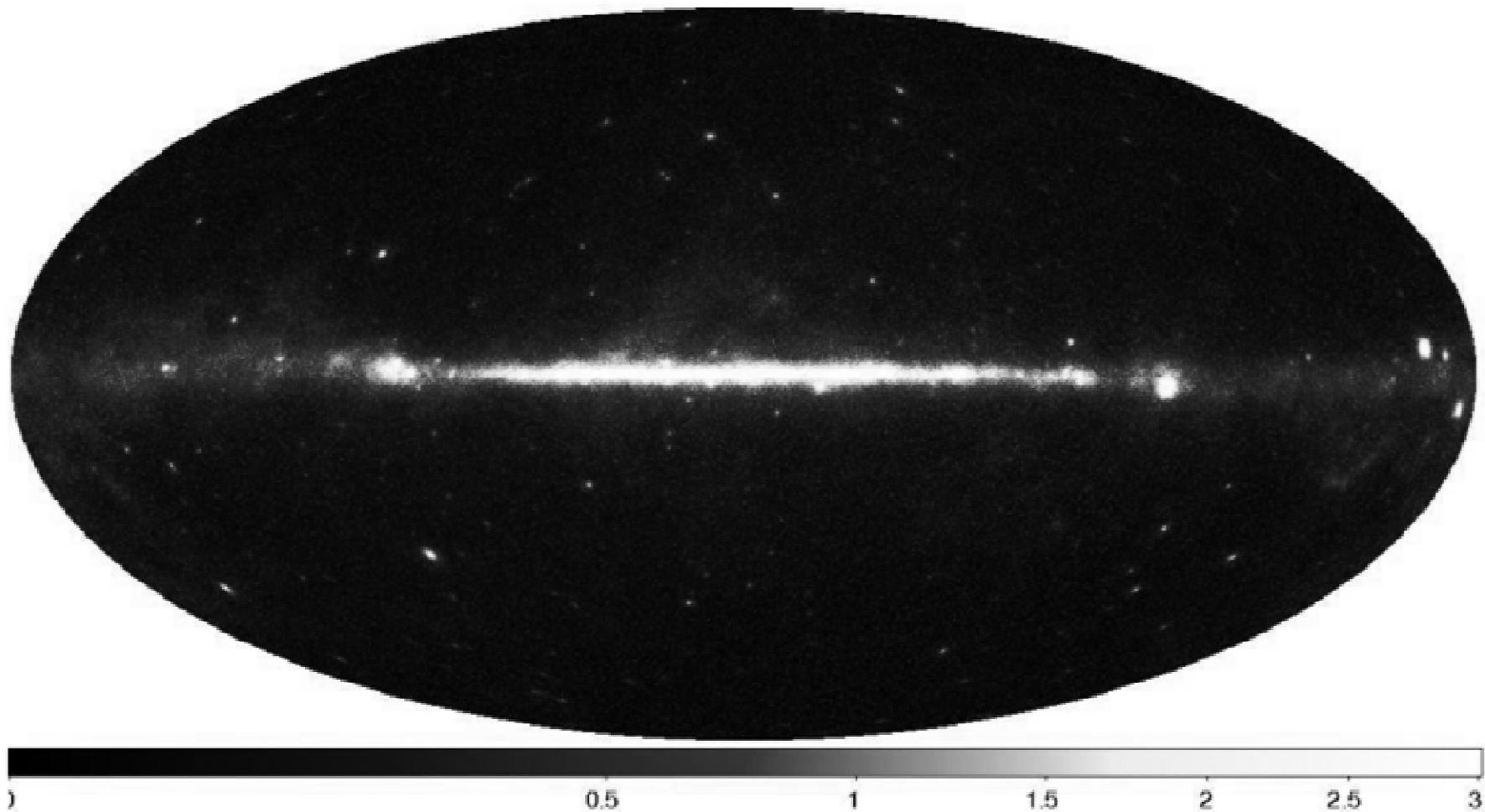
Elettronica e SW di volo

Sistema di presa dati



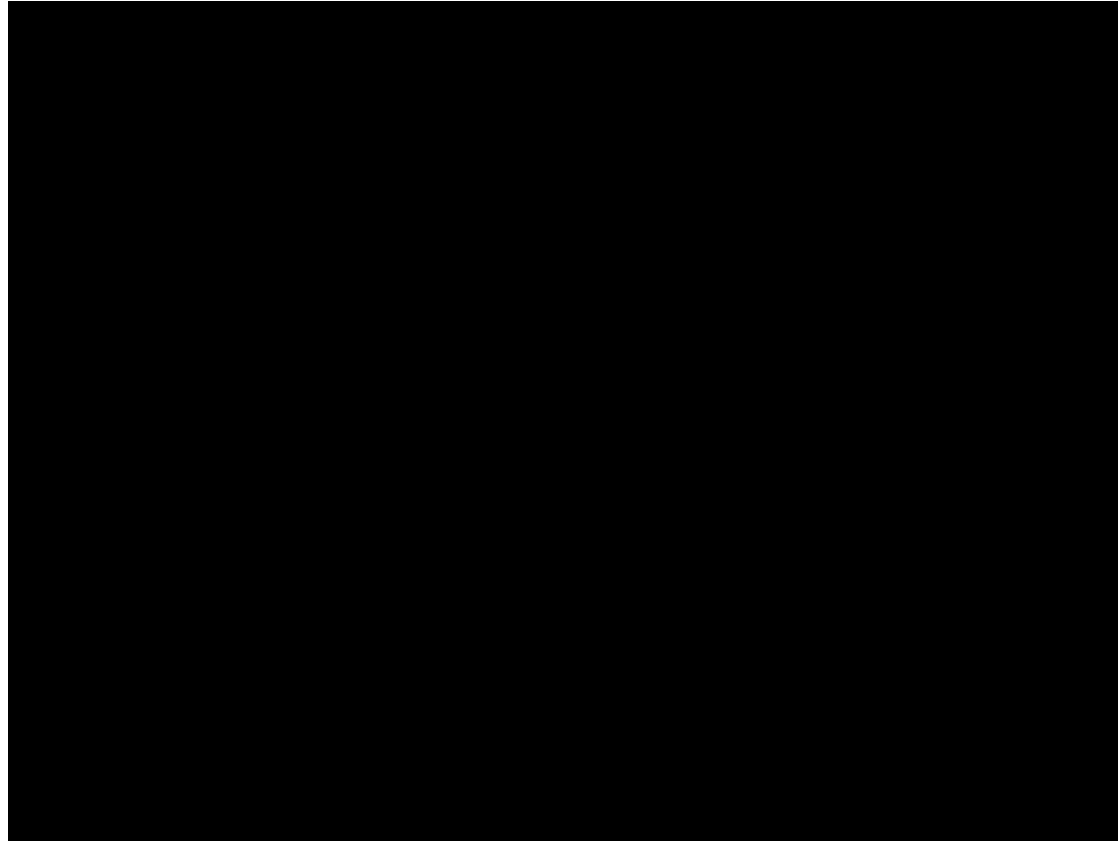


Orbita circolare, 565 km altitude (96 min periodo), 25.6 gradi inclinazione
Disattivato durante il transito nella SAA, comunque $S/N \sim 1/10^5$



- Sky map of the LAT data for the first 3 months, Aitoff projection in Galactic coordinates. γ -ray intensity for $E > 300$ MeV, in units of photons $\text{m}^{-2} \text{s}^{-1} \text{sr}^{-1}$.
- The list of sources was obtained after three steps which were applied in sequence: detection, localization, significance estimate.
- Source characteristics (flux in two energy bands, time variability) and possible counterparts

Aristotele sbagliava !



6.2 Osservazione di γ diffusi (DG γ RE) dal piano Galattico (EGRET, FERMI-Lat)

- Se I RC permeano la Galassia, le collisioni con il materiale IG attraversato (5 g cm^{-2}) produrranno sciame EM, in cui il decadimento dei π^0 produrranno fotoni di alta energia.
- Altre sorgenti di γ nel piano galattico sono:
 - la bremsstrahlung di elettroni di alta energia
 - Compton inverso di e di alta energia su fotoni (luce stellare)
- Possiamo stimare la luminosità attesa di fotoni dal piano galattico:
 - σ_{pp} = sezione d'urto inelastica = 50 mb
 - N = densità del mezzo IG = 1 p/cm^3
 - c = velocità della luce = $3 \cdot 10^{10} \text{ cm/s}$

FERMI LAT OBSERVATION OF DIFFUSE GAMMA RAYS PRODUCED THROUGH INTERACTIONS BETWEEN LOCAL INTERSTELLAR MATTER AND HIGH-ENERGY COSMIC RAYSA. A. Abdo *et al* 2009 *ApJ* **703** 1249-1256 doi: 10.1088/0004-637X/703/2/1249 (Help)

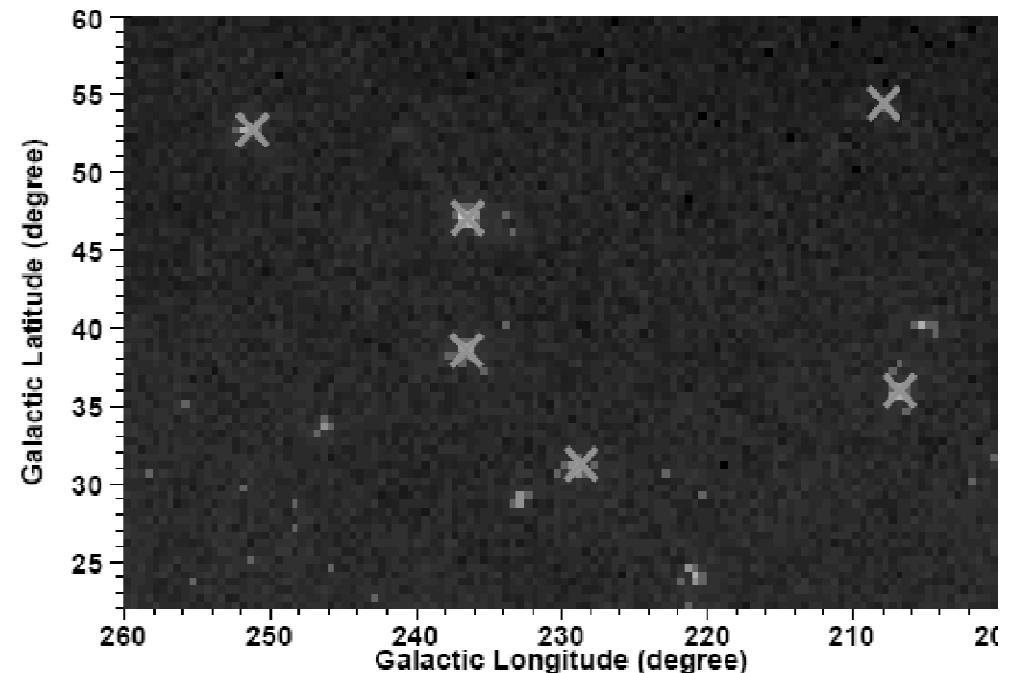
Full text

PDF (643 KB)

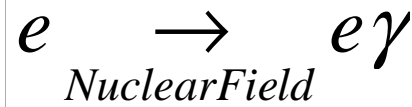
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References

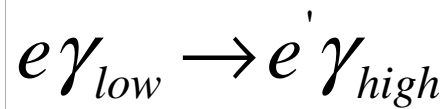
[A. A. Abdo](#)^{1,2}, [M. Ackermann](#)³, [M. Ajello](#)³, [W. B. Atwood](#)⁴, [M. Axelsson](#)^{5,6}, [L. Baldini](#)⁷, [J. Ballet](#)⁸, [G. Barbiellini](#)^{9,10}, [D. Bastien](#)^{11,12}, [B. M. Baughman](#)¹³, [K. Bechtol](#)³, [R. Bellazzini](#)⁷, [B. Berenji](#)³, [E. D. Bloom](#)³, [E. Bonamente](#)^{14,15}, [A. W. Borgland](#)³, [J. Bregeon](#)⁷, [A. Brez](#)⁷, [M. Brigida](#)^{16,17}, [P. Bruel](#)¹⁸, [T. H. Burnett](#)¹⁹, [G. A. Caliandro](#)^{16,17}, [R. A. Cameron](#)³, [P. A. Caraveo](#)²⁰, [P. Carlson](#)^{6,21}, [J. M. Casandjian](#)⁸, [C. Cecchi](#)^{14,15}, [Ö. Çelik](#)²², [A. Chekhtman](#)^{1,23}, [C. C. Cheung](#)²², [S. Ciprini](#)^{14,15}, [R. Claus](#)³, [I. Cohen-Tanugi](#)²⁴, [J. Conrad](#)^{6,21,25,52}, [S. Cutini](#)²⁶, [C. D. Dermer](#)¹, [A. de Angelis](#)²⁷, [F. de Palma](#)^{16,17}, [S. W. Digel](#)³, [E. do Couto e Silva](#)³, [P. S. Drell](#)³, [R. Dubois](#)³, [D. Dumora](#)^{28,29}, [C. Farnier](#)²⁴, [C. Favuzzi](#)^{16,17}, [S. J. Fegan](#)¹⁸, [W. B. Focke](#)³, [M. Frailis](#)²⁷, [Y. N. Gehrels](#)^{22,31}, [S. Germani](#)^{14,15}, [B. Giebels](#)¹⁸, [N. Giglietto](#)^{16,17}, [F. Giordano](#)^{16,17}, [T. Glanz](#), [L. Guillemot](#)^{28,29}, [S. Guiriec](#)^{24,32}, [Y. Hanabata](#)³⁰, [A. K. Harding](#)²², [M. Hayashida](#)³, [E. Hay](#), [W. N. Johnson](#)¹, [T. Kamae](#)³, [H. Katagiri](#)³⁰, [N. Kawai](#)^{33,34}, [M. Ken](#)¹⁹, [I. Knödlseder](#)³⁵, [M. M. Lemoine-Goumard](#)^{28,29}, [F. Longo](#)^{9,10,36}, [F. Loparco](#)^{16,17}, [B. Lott](#)^{28,29}, [M. N. Lovellette](#), [C. Meurer](#)^{6,25}, [P. F. Michelson](#)³, [W. Mitthumsiri](#)³, [T. Mizuno](#)^{1,30}, [A. A. Moiseev](#)^{31,37}, [C. P. L. Nolan](#)³, [J. P. Norris](#)³⁹, [E. Nuss](#)²⁴, [T. Ohsugi](#)³⁰, [A. Okumura](#)⁴⁰, [N. Omodei](#)⁷, [E. Orland](#), [M. Pepe](#)^{14,15}, [M. Pesce-Rollins](#)⁷, [F. Piron](#)²⁴, [M. Pohl](#)⁴³, [T. A. Porter](#)⁴, [S. Rainò](#)^{16,17}, [R. Re](#), [S. Ritz](#)²², [L. S. Rochester](#)³, [A. Y. Rodriguez](#)⁴⁵, [F. Ryde](#)^{6,21}, [H. F. W. Sadrozinski](#)⁴, [D. Sant](#), [C. Sgrò](#)⁷, [D. A. Smith](#)^{28,29}, [P. D. Smith](#)¹³, [G. Spandre](#)⁷, [P. Spinelli](#)^{16,17}, [I.-L. Starck](#)⁸, [F. W. H. Takahashi](#)³⁰, [T. Takahashi](#)⁴², [I. Tanaka](#)³, [J. B. Thayer](#)³, [J. G. Thayer](#)³, [D. J. Thompson](#), [Y. Uchiyama](#)^{3,42}, [T. L. Usher](#)³, [V. Vasileiou](#)^{22,37,49}, [N. Vilchez](#)³⁵, [V. Vitale](#)^{38,50}, [A. P. Wait](#)

¹ Space Science Division, Naval Research Laboratory, Washington, DC 20375, USA² National Research Council Research Associate, National Academy of Sciences, Wash

■ Bremsstrahlung



■ Compton Inverso



■ Decadimento π^0

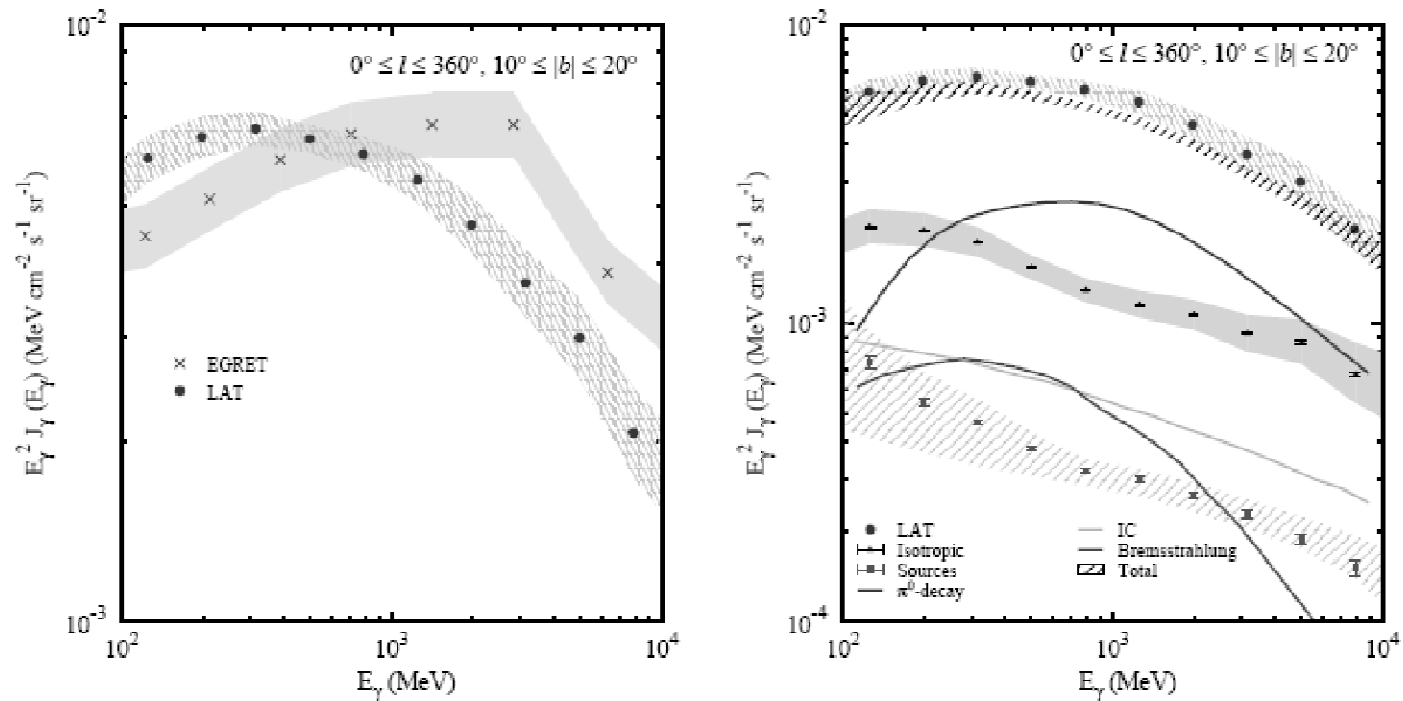
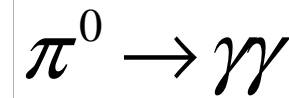


Fig. 1: *Left*: Preliminary diffuse emission intensity averaged over all Galactic longitudes for latitude range $10^\circ \leq |b| \leq 20^\circ$. Data points: LAT, red dots; EGRET, blue crosses. Systematic uncertainties: LAT, red; EGRET, blue. *Right*: Preliminary LAT data with model, source, and UIB components for same sky region. Model (lines): π^0 -decay, red; Bremsstrahlung, magenta; IC, green. Shaded/hatched regions: isotropic, grey/solid; source, blue/hatched; total (model + UIB + source), black/hatched.

Stima della correlazione tra “column density” e flusso

$L\rho$ (lunghezza \times densità numerica) = [cm⁻²]

$$P_{coll} = \sigma_{pp} \rho L = 5 \times 10^{-26} \rho L$$

Probabilità d'interazione di un RC nella
colonna di gas interstellare

$$\rho_E^{RC} = 0.6 \text{ eV} / \text{cm}^3 = 6 \times 10^{-7} \text{ MeV} / \text{cm}^3$$

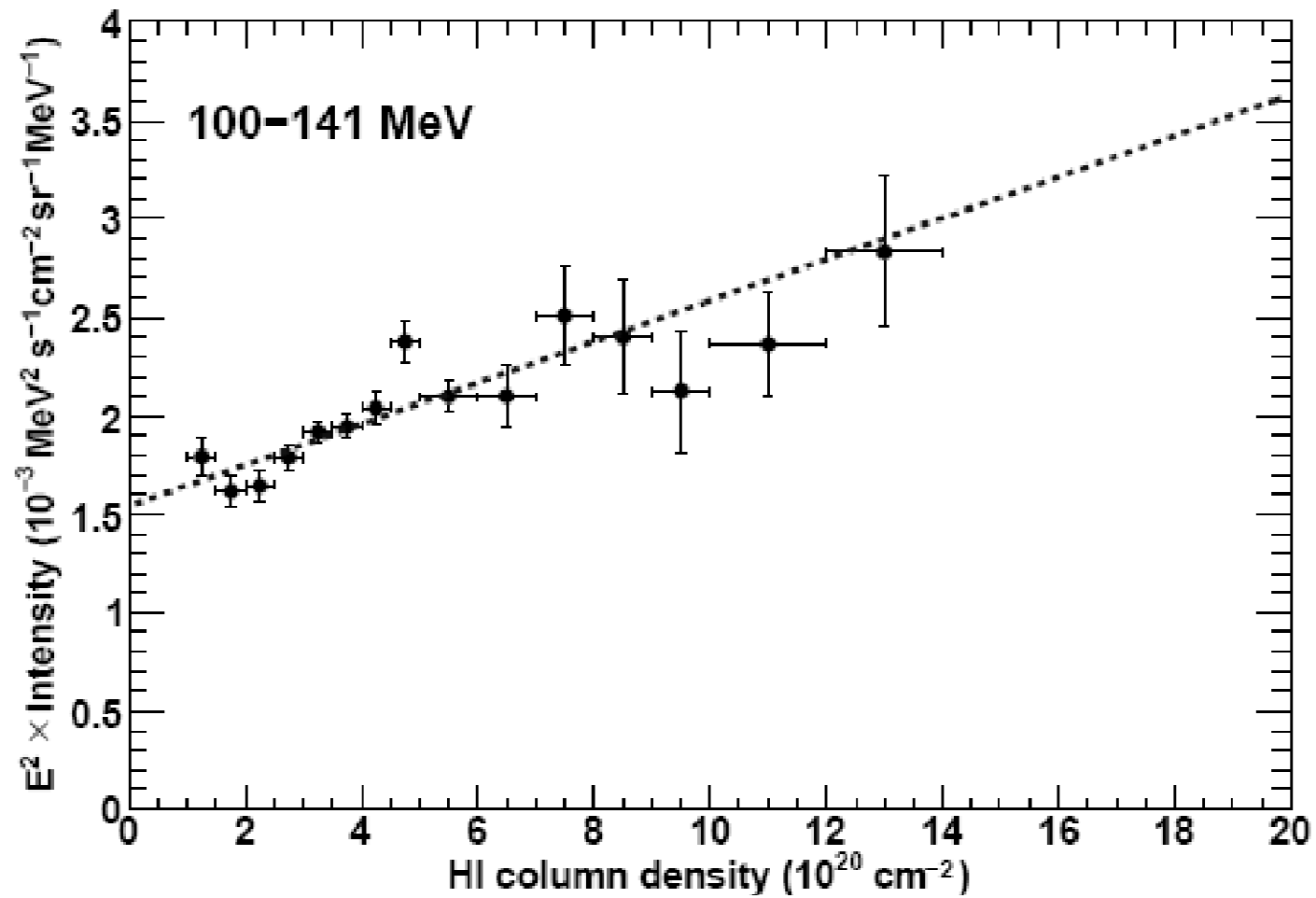
$$P_{coll} \rho_E^{RC} = 3 \times 10^{-32} \rho L$$

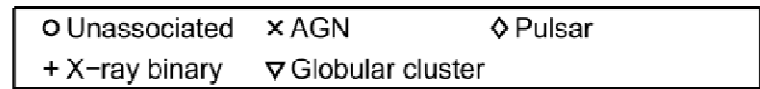
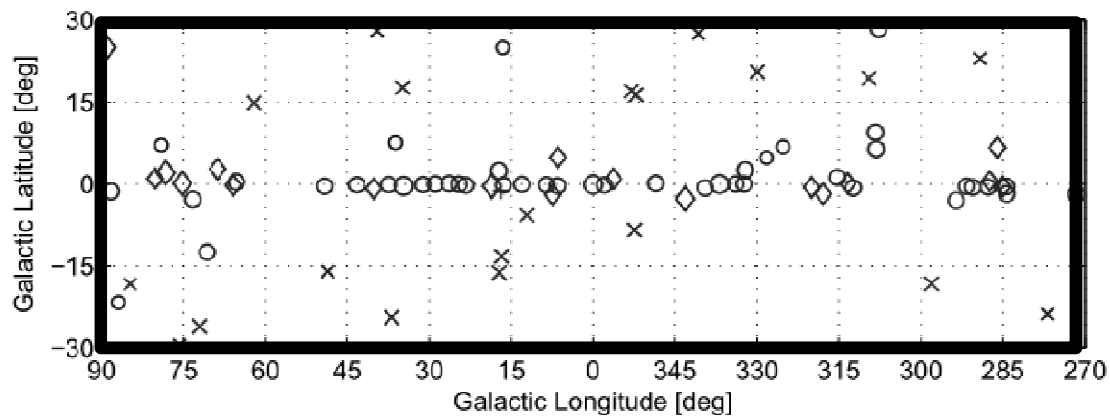
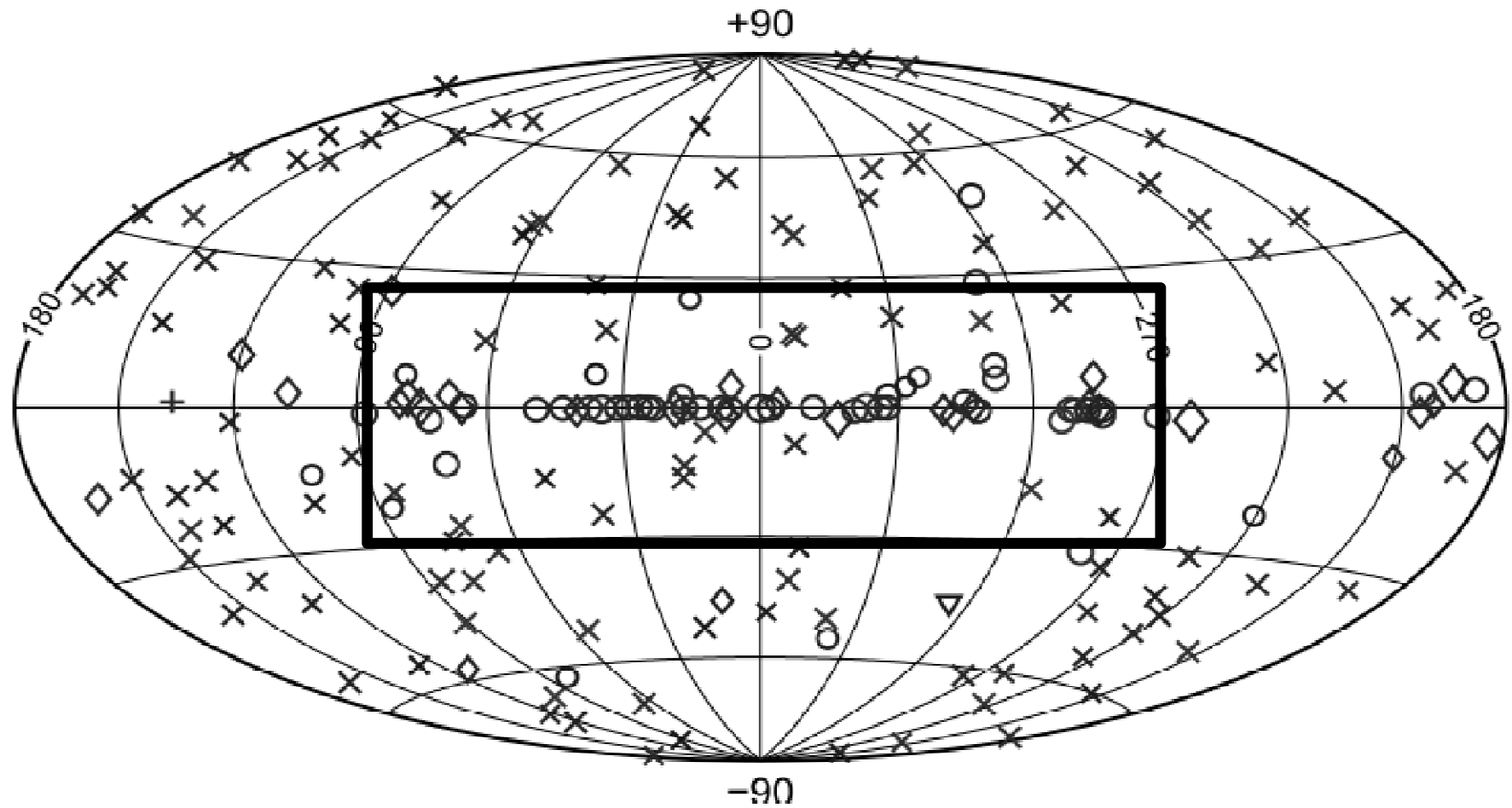
Energia rilasciata nella collisione dei RC
nella colonna. Solo 1/3 finisce in pioni neutri

$$\frac{c}{4\pi} \frac{1}{3} P_{coll} \rho_E^{RC} = 2 \times 10^{-23} \rho L \text{ (MeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}\text{)}$$

Da densità a flusso

Confrontate il valore con quello riportato in figura nella pagina seguente, ad
es. per $L\rho = 2 \cdot 10^{20} \text{ cm}^{-2}$.





- 205 FERMI Gamma LAT sources (0FGL)
- Both Galactic and extragalactic populations are visible. 73 sources are found within 10° of the Galactic Plane, where they exhibit a characteristic concentration in the inner Galaxy; 132 are seen at higher Galactic latitudes.
- 66 of the bright LAT sources show solid evidence of variability.
- Of the 205 0FGL sources, 60 have nearby counterparts in the EGRET catalogues
- The AGN class (121 members) is the largest source type identified
- Pulsars, including young radio, millisecond radio, and radio-quiet pulsars, form another well-defined class (29 members)

Submitted to Astrophysical Journal Supplement - Not Yet Refereed

Fermi Large Area Telescope Bright Gamma-ray Source List

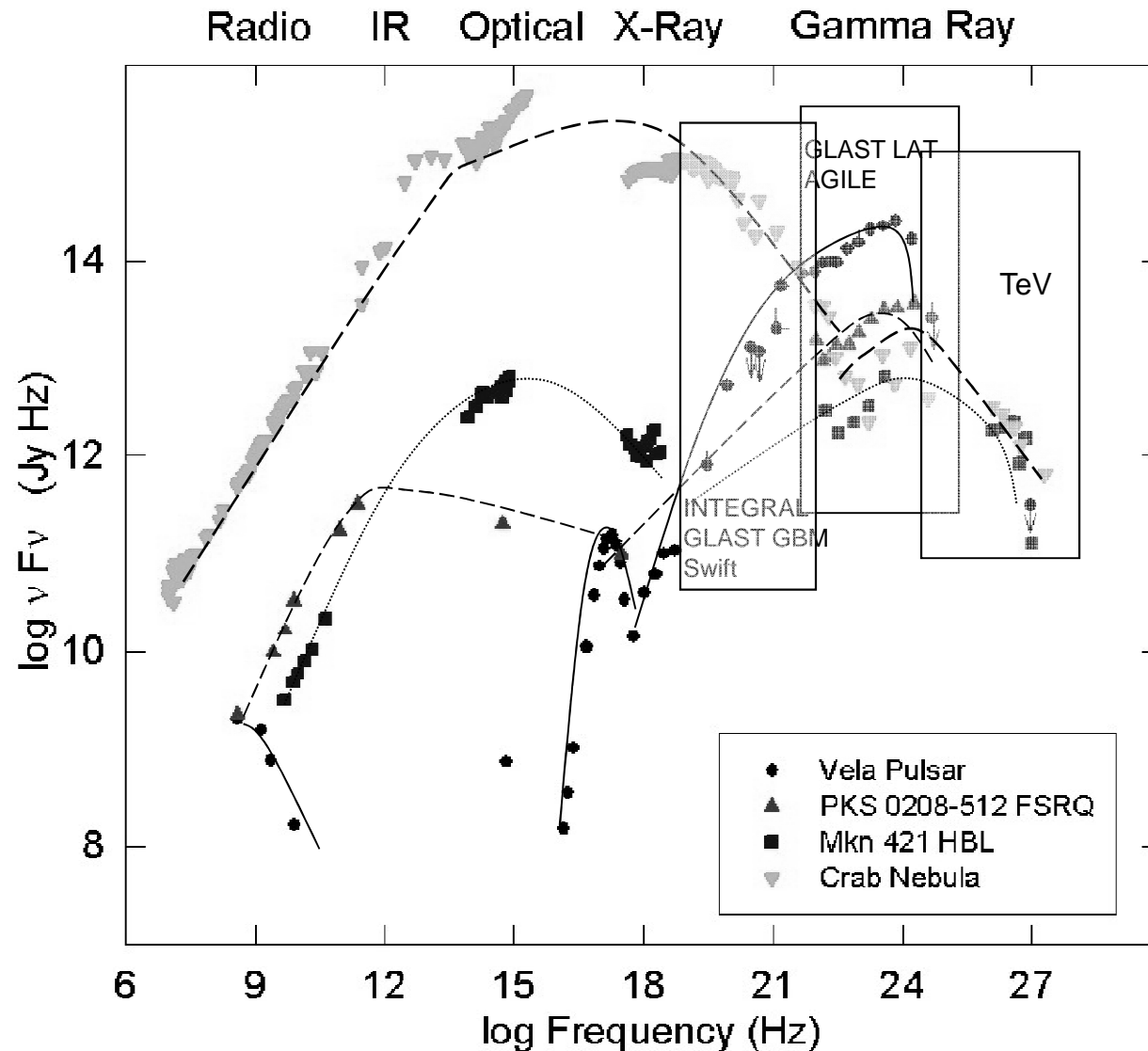
arXiv:0902.1340v1

LAT Bright Source List Source Associations

Class	Number
Radio/X-ray pulsar (PSR)	15
LAT gamma-ray pulsar (LAT PSR)	14
HMXB	2
BL LAC (bzb)	46
FSRQ (bzq)	62
Other blazar (Uncertain type, bzu)	11
Radio galaxy (rdg)	2
Globular Cluster (glb, see text)	1
LMC (see text)	1
† Special cases (see Table 2)	13
Unassociated	38

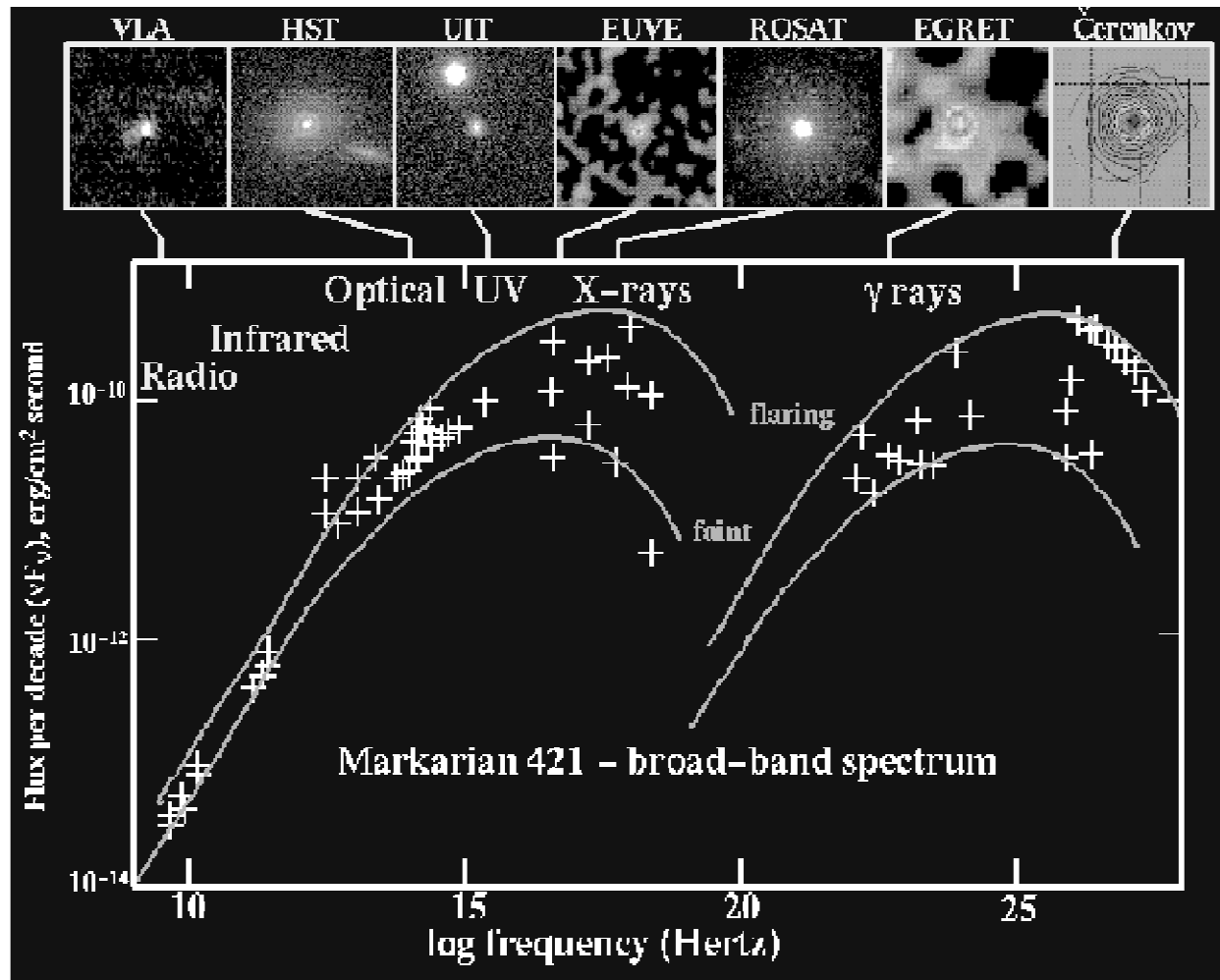
Modelli di emissione

Le sorgenti note di $R\gamma$ emettono anche nelle altre lunghezze d'onda

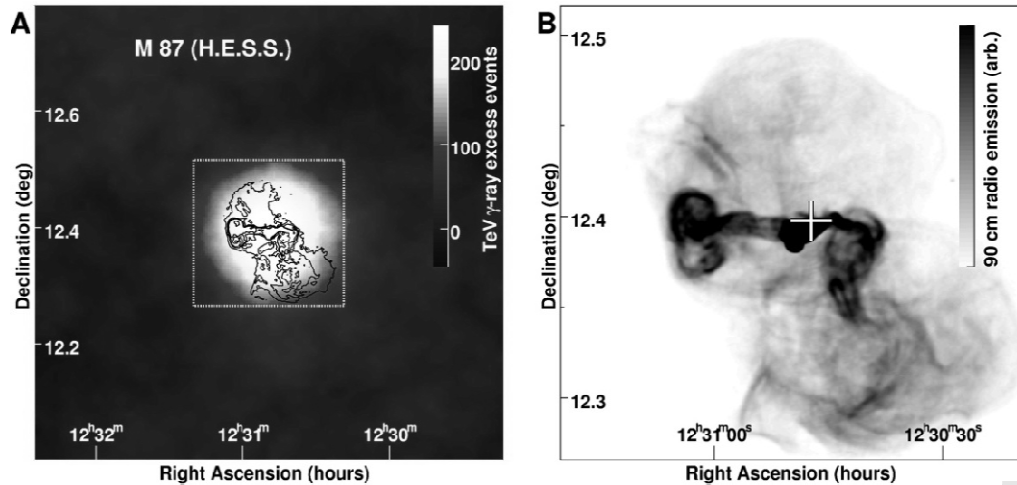


- Le sorgenti di $R\gamma$ sono non-termiche (ossia, non emettono uno spettro di corpo nero)
- I $R\gamma$ sono tipicamente prodotti dalle interazioni di particelle di alta energia
- Le classi di sorgenti di γ conosciute emettono (e sono rivelate) anche in altre lunghezze d'onda.

Mkn421 in different wavelength



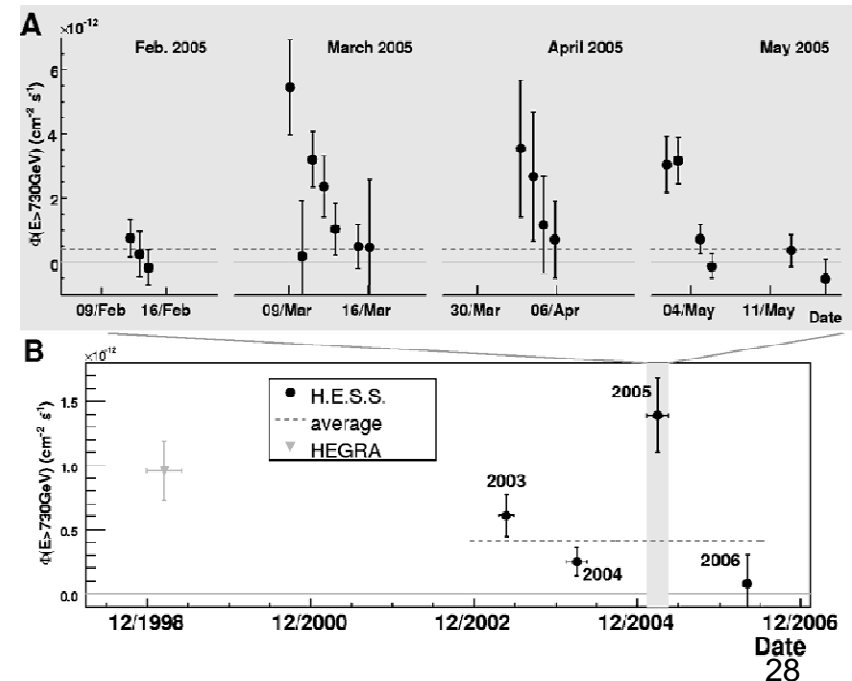
Esempi di sorgenti: Radio Galassie



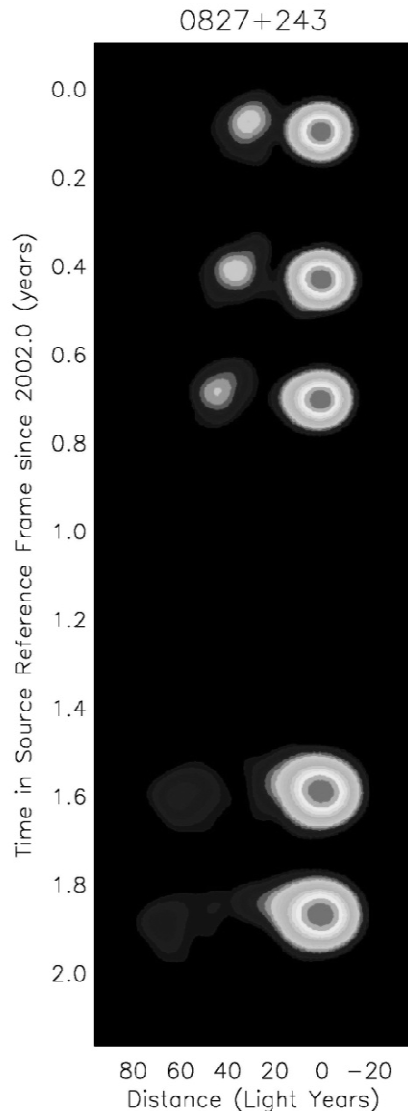
M87: Immagine da HESS (vedi:) tramite gamma del TeV; immagine radio. M87 è una delle più potenti radio galassie viste in raggi gamma.

Variabilità di M87 vista nel TeV

Is the gamma-ray variability related to changes in the jet? In the core?
What about fainter radio galaxies?



Esempi di sorgenti: Blazars



- **Le Blazars** sono Galassie nel cui centro è ospitato un Buco nero supermassivo.
- Le Blazars sono tra le principali sorgenti di $R\gamma$
- C'è evidenza di correlazione tra i getti di $R\gamma$ e l'emissione radio vista dai VLBI

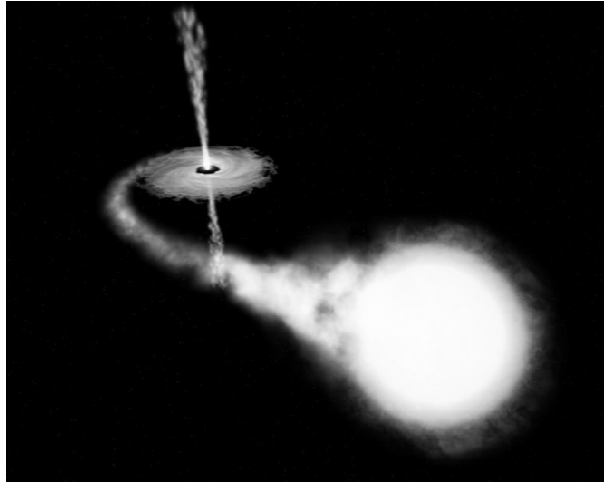
What do the combined radio/gamma-ray observations tell us about particle acceleration and interaction - processes, location?

What can this information reveal about jet formation and collimation?

Immagine da VLBI. Vedi

<http://web.whittier.edu/gpiner/research/index.htm>

Esempi di sorgenti galattiche: microquasars

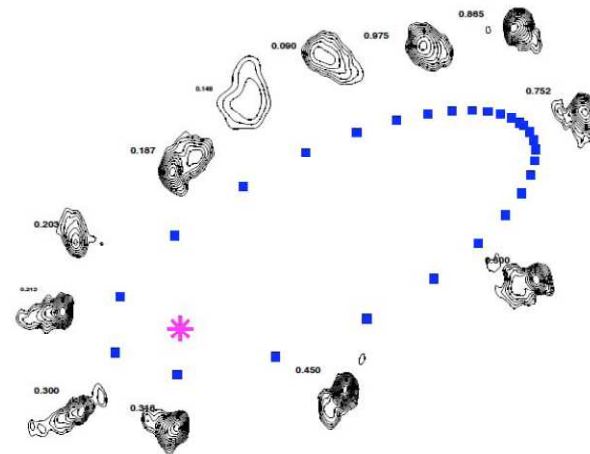


- Le **microquasar** sono dei corpi celesti simili alle quasar: le caratteristiche comuni sono: emissioni radio forti e variabili, spesso in getti, e un disco di accrescimento che circonda un buco nero.
- Nelle quasar, il buco nero è supermassiccio ($>10^6$ masse solari) mentre nelle microquasar, la massa del buco nero è di poche masse solari.
- Nelle microquasar, la massa di accrescimento deriva da una normale stella e il disco di accrescimento è molto luminoso nello spettro visibile e nei raggi X.

What sort of compact object?

How are the particles accelerated?

Are there different types of such high-mass binary systems?



6.4 Ancora sorprese: Gamma Ray Bursts

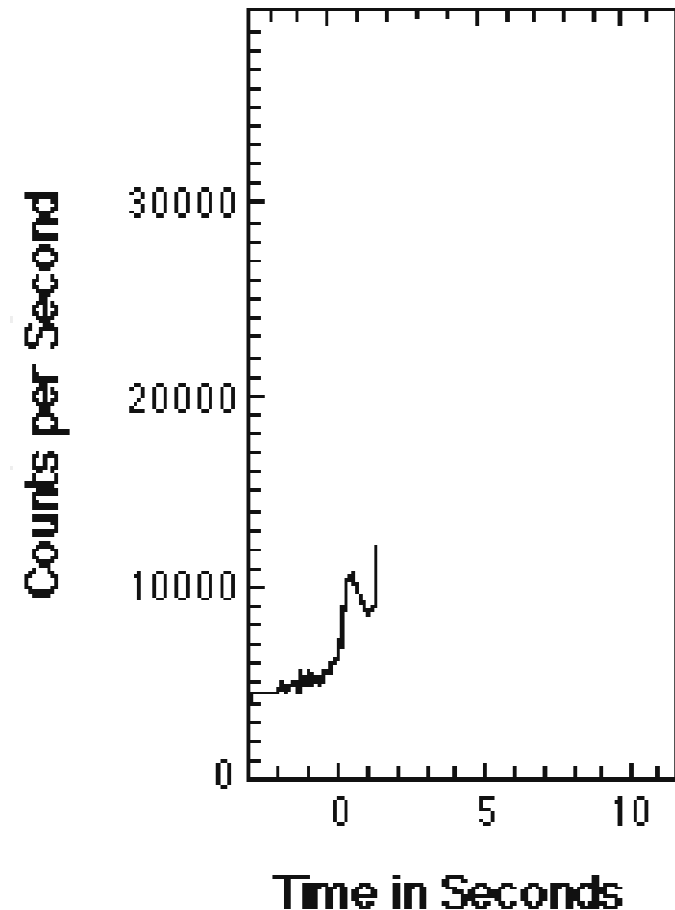
Scoperta di Sorgenti Transienti:

- GRB's (Gamma Ray Bursts)

- Non sappiamo *quando e dove* guardare!
- Indicazioni di una componente secondaria di alta energia



BATSE
on **CGRO**



- Origine Extragalattica. Possibili candidati di meccanismi di accelerazione per i RC di energia estrema.

VEDI: <http://imagine.gsfc.nasa.gov/docs/science/known/bursts.html>

■ Gamma-ray bursts are short-lived bursts of gamma-ray photons, the most energetic form of light. At least some of them are associated with a special type of supernovae, the explosions marking the deaths of especially massive stars.

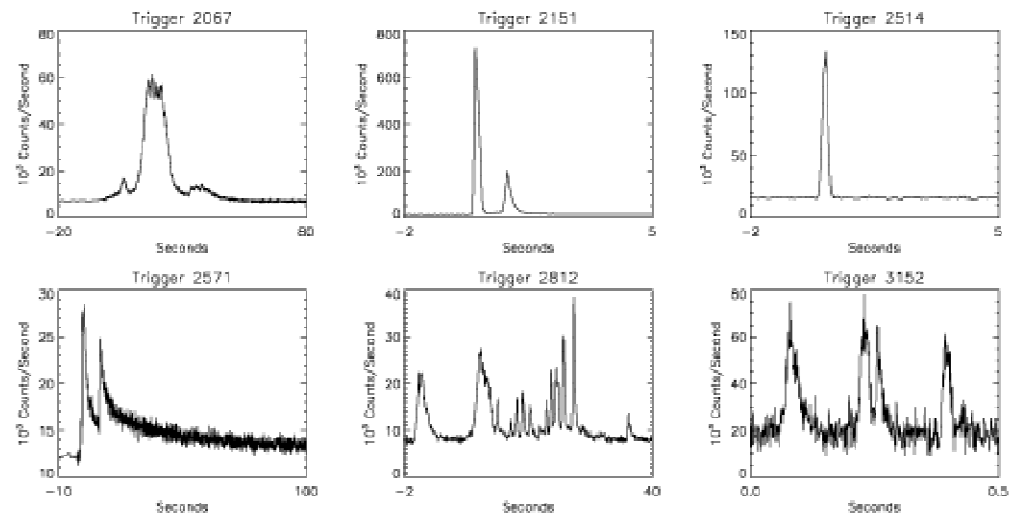
■ Lasting anywhere from a few milliseconds to several minutes, gamma-ray bursts (GRBs) shine hundreds of times brighter than a typical supernova and about a million trillion times as bright as the Sun, making them briefly the brightest source of cosmic gamma-ray photons in the observable Universe. GRBs are detected roughly once per day from wholly random directions of the sky.

■ Until recently, GRBs were arguably the biggest mystery in high-energy astronomy. They were discovered *serendipitously* in the late 1960s by U.S. military satellites which were on the look out for Soviet nuclear testing in violation of the atmospheric nuclear test ban treaty. These satellites carried gamma ray detectors since a nuclear explosion produces gamma rays.

■ As recently as the early 1990s, astronomers didn't even know if GRBs originated in our Milky Way Galaxy or incredibly far away near the edge of the observable Universe. (That is, they didn't know how far away GRBs were to within a factor of a few billion light years!) But now a slew of satellite observations, follow-up ground-based observations, and theoretical work have allowed astronomers to link GRBs to supernovae in distant galaxies

A sampling of the large variety of GRB time profiles, as detected from the CGRO satellite

- Gamma-ray bursts are separated into two classes: long-duration bursts and short-duration bursts. Long duration ones last more than 2 seconds and short-duration ones last less than 2 seconds
- Long and short duration GRBs are created by fundamentally different physical properties
- Working with large amounts of data collected over the past 15 years with special instruments aboard satellites, such as NASA's Compton Gamma-Ray Observatory and the joint **Italian-Dutch BeppoSAX** astronomers have developed a working model of the kind of star that produces a GRB.



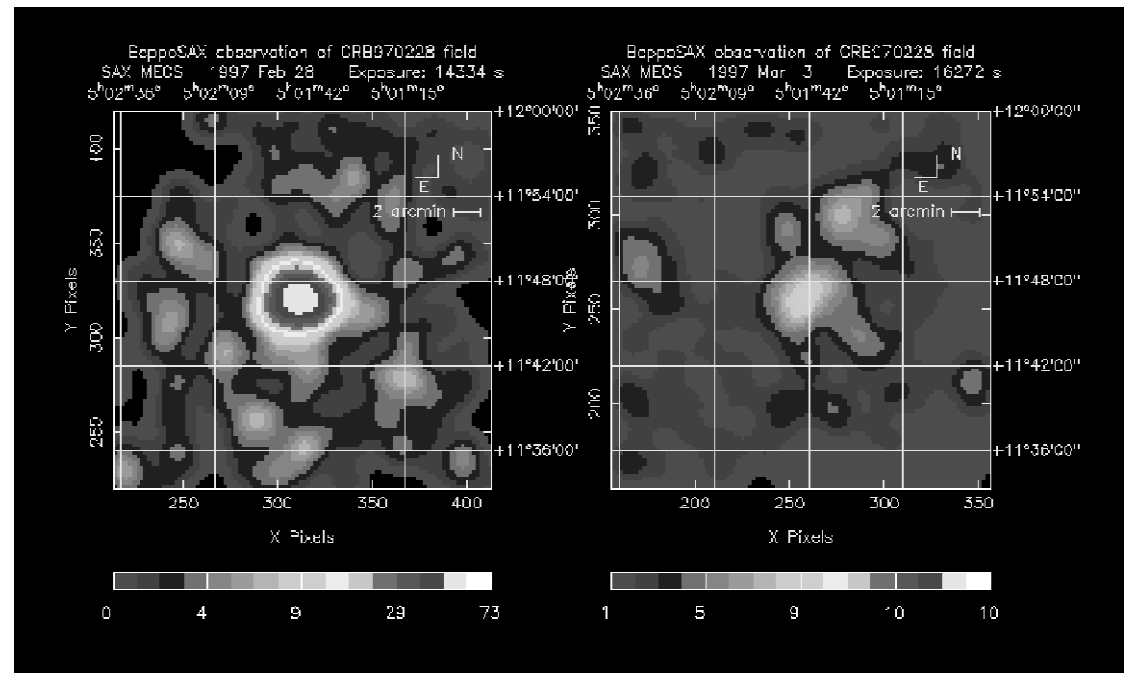
<http://bepposax.gsfc.nasa.gov/bepposax/italver.html>

- The model involves the collapse of the core of a special kind of very massive star. This core collapse occurs while the outer layers of the star explode in an especially energetic supernova (the “hypernova”, 100 times the SN).

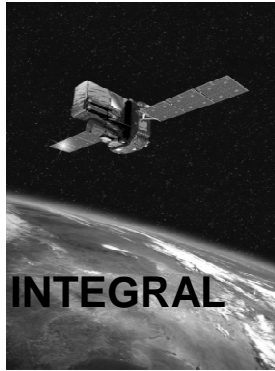
- The explosion originates at the center of these massive stars. While a black hole forms from the collapsing core, this explosion sends a blast wave moving through the star at speeds close to the speed of light. The gamma rays are created when the blast wave collides with stellar material still inside the star.
- Erupting through the star surface, the blast wave of stellar material sweeps through space, colliding with intervening gas and dust, producing additional emission of photons. These emissions are believed responsible for the "**afterglow**" of progressively less energetic photons, starting with X rays, visible light and radio waves
- BATSE detector catalogued 2,704 GRBs during the observatory's nine year lifetime (1991 - 2000), it was not equipped to make *afterglow* observations.

- The Italian satellite BeppoSAX was equipped with both a gamma ray and an X-ray detector. It spotted the X-ray afterglow signature associated with the gamma-ray burst on February 28, 1997

- **Discovery of the extragalactic origin of GRBs**



Altre (presenti o prossime) Gamma-ray Facilities



GLAST



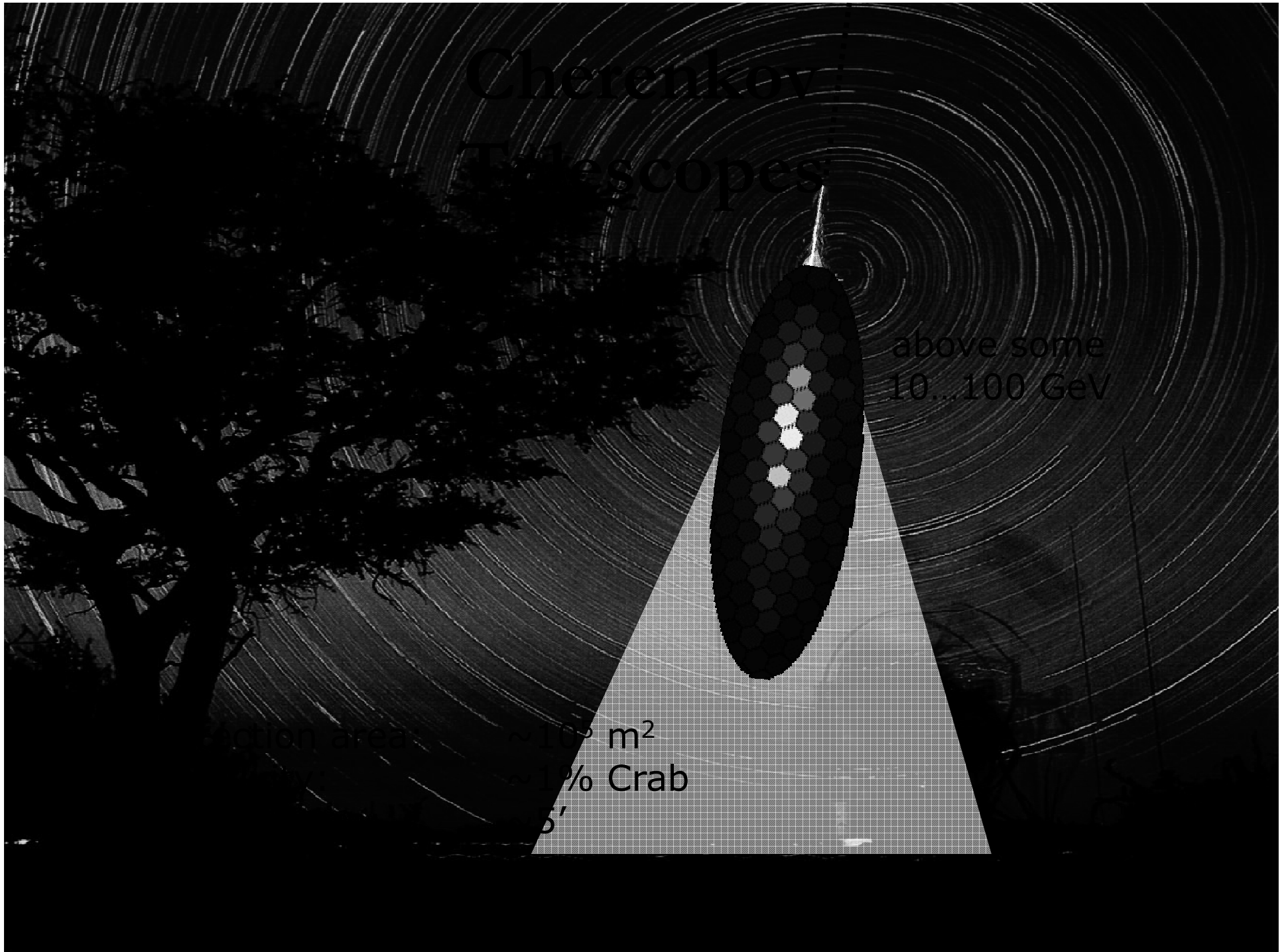
6.5 Osservazioni sperimentali di acceleratori astrofisici nella Galassia: astronomia γ (TeV) con telescopi Imaging Cherenkov

- *Cos'è un telescopio Cherenkov?* Un riflettore ottico con un fotomoltiplicatore (PMT) nel fuoco + elettronica veloce (ns)
- Perché “imaging”? Perché permette di ricostruire i parametri dello sciame di particelle:
 - Informazione sulla direzione di arrivo
 - Possibile separazione di sciami di adroni da quelli di fotoni
 - Largo Field of view (FoV), ossia area di raccolta
- Energia di soglia: 1 TeV

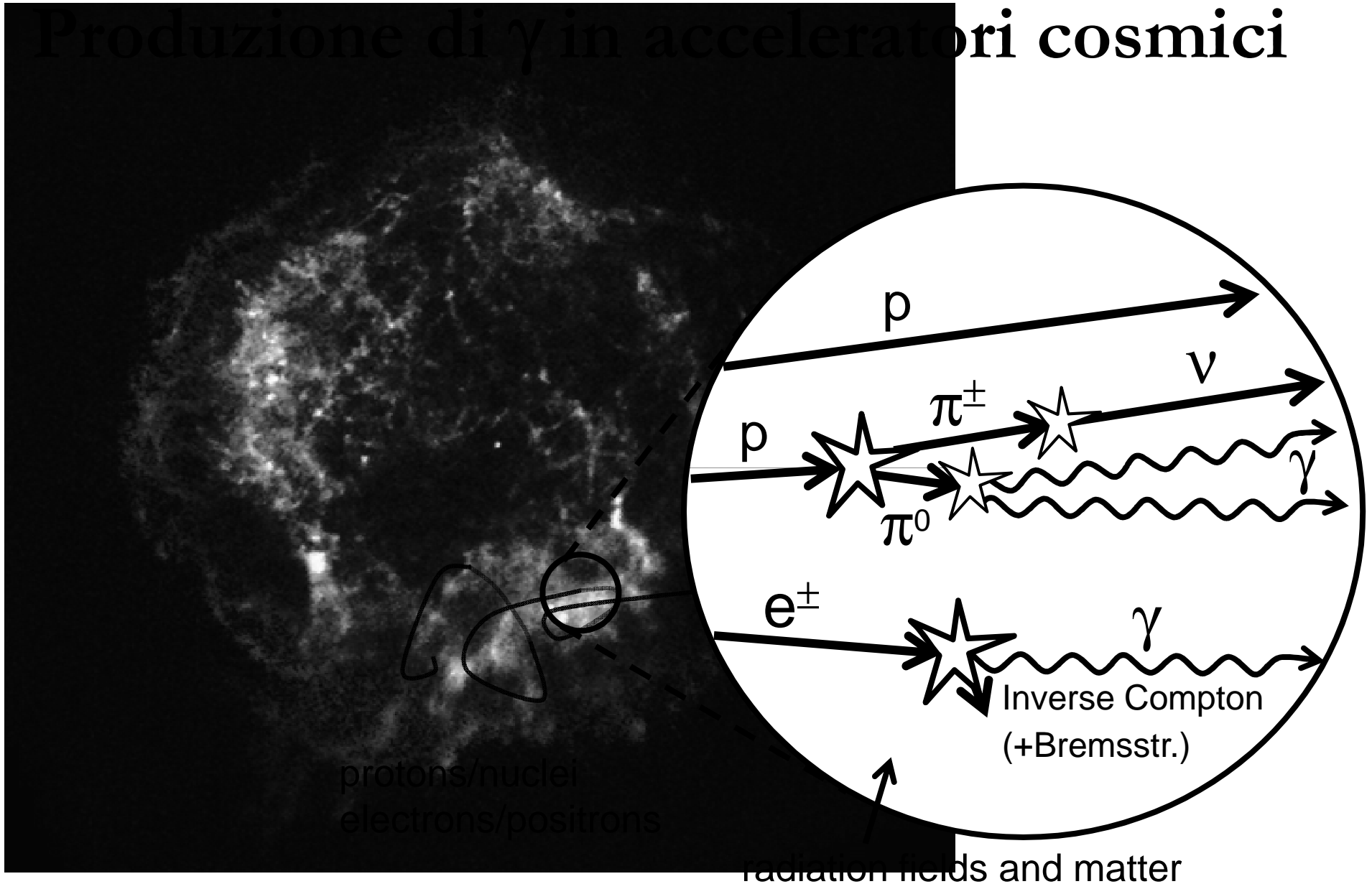
Cherenkov Telescopes

above some
10...100 GeV

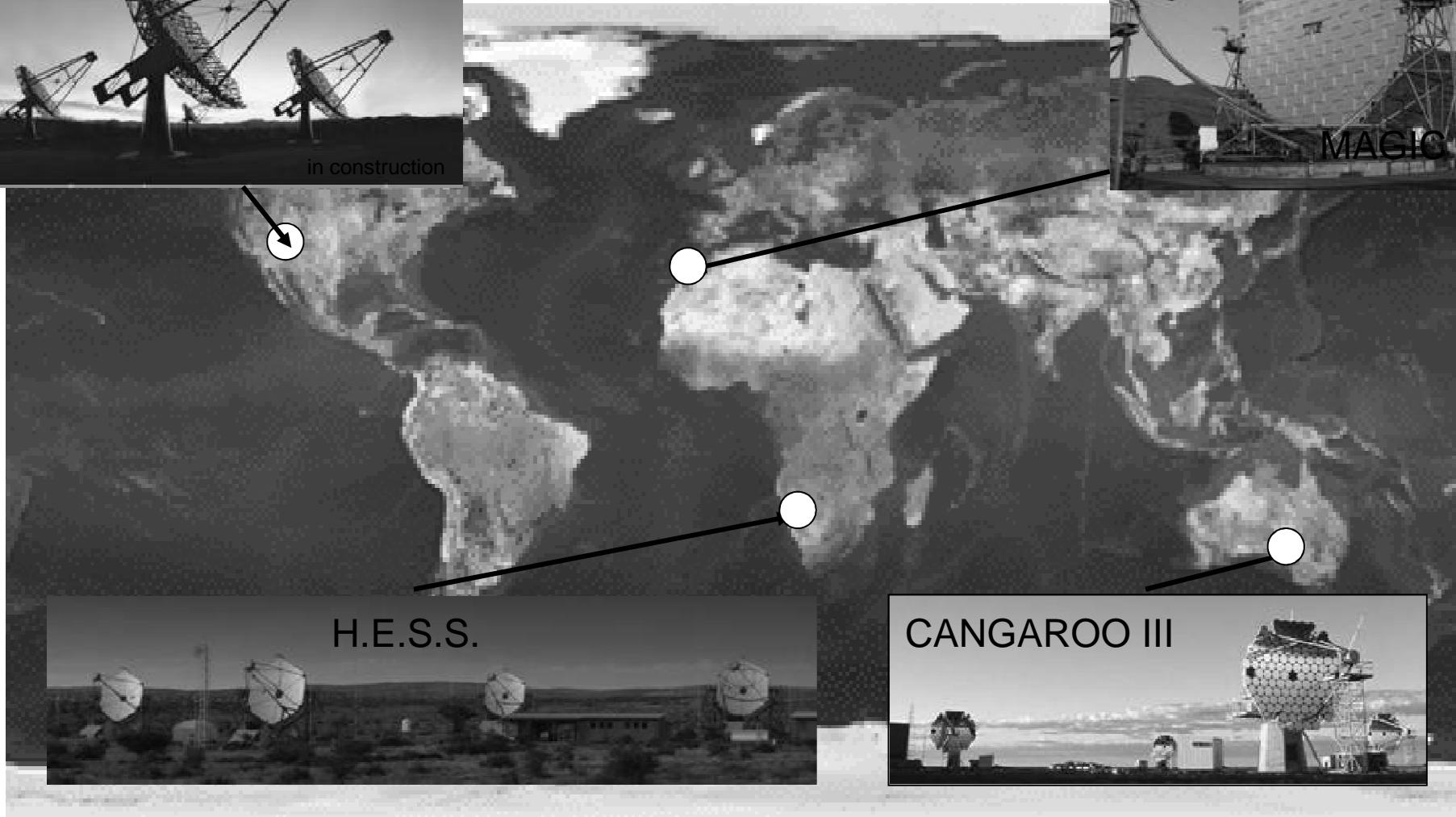
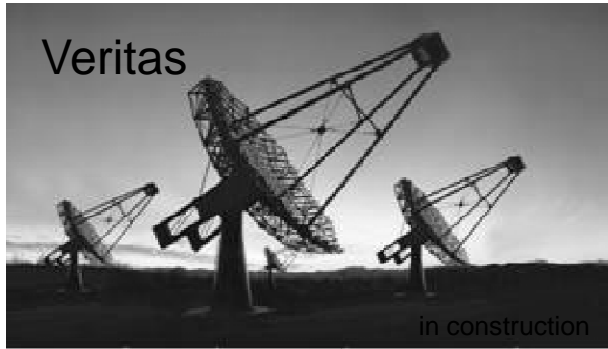
10000 m²
10% Crab
5'



Produzione di γ in acceleratori cosmici

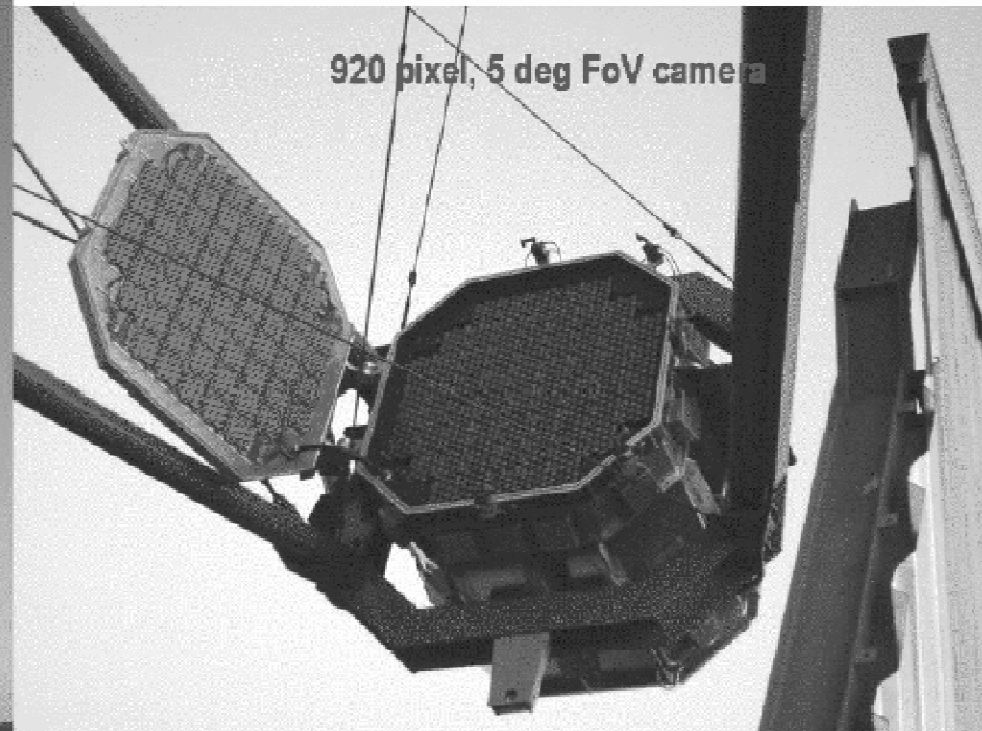
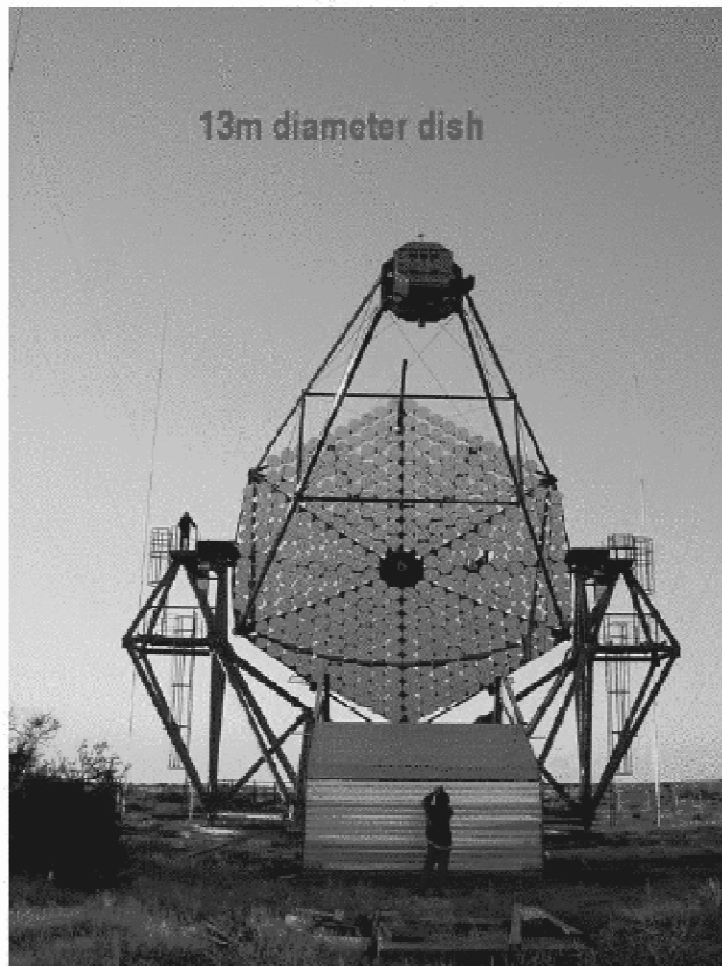


Cherenkov Telescopes (3rd Generation)



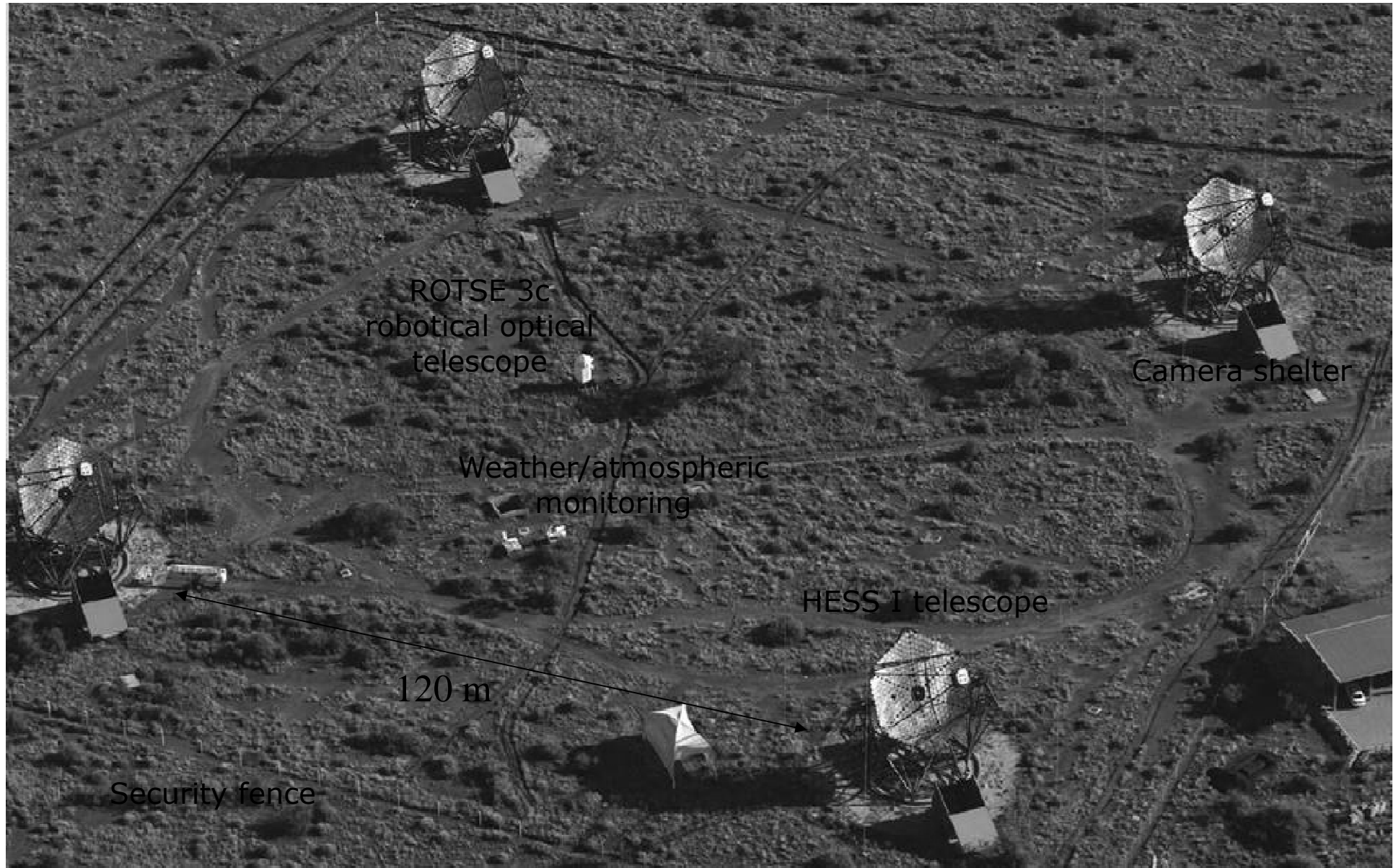
Il telescopio HESS

H.E.S.S. - *High Energy Stereoscopic System*



4 telescopi

HESS



- **MAGIC** Telescope is a large atmospheric imaging Cherenkov telescope
- mirror surface = 236 m² with photomultiplier tubes of optimal efficiency.
- It has been operated since 2004. Under construction is a second MAGIC telescope, on the same site (MAGIC II)



MAGIC on La Palma:
Largest dish, rapid slewing

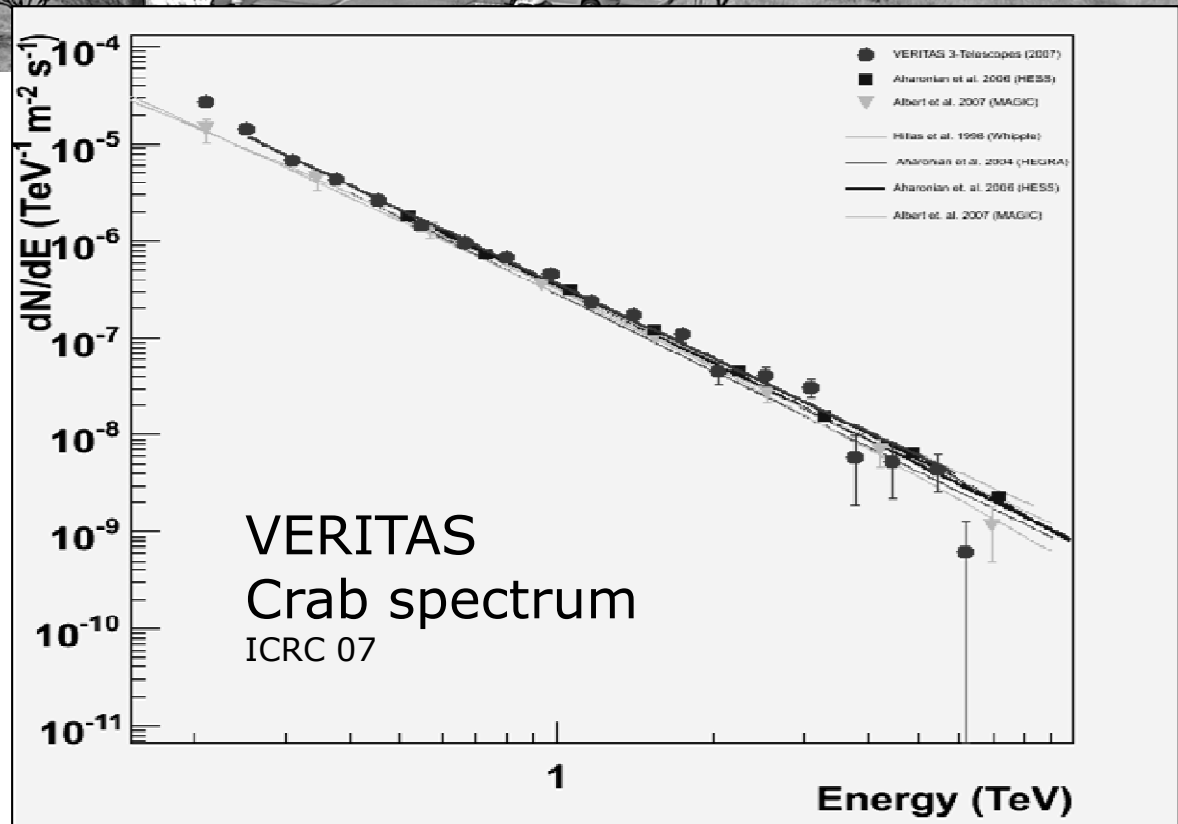
<http://wwwmagic.mppmu.mpg.de/>

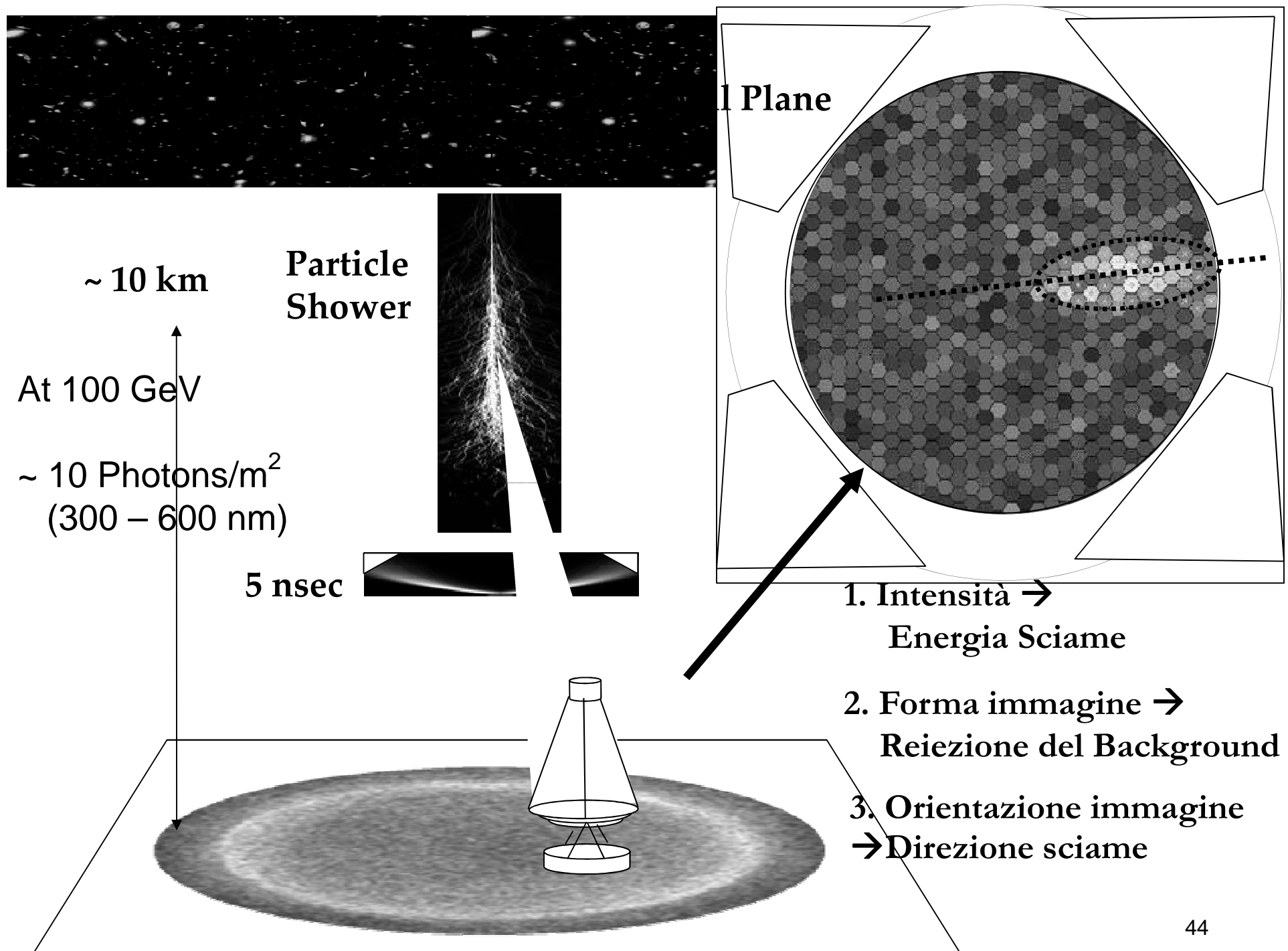
VERITAS-4: News



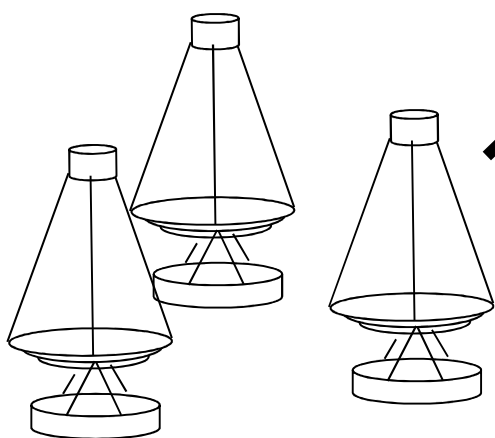
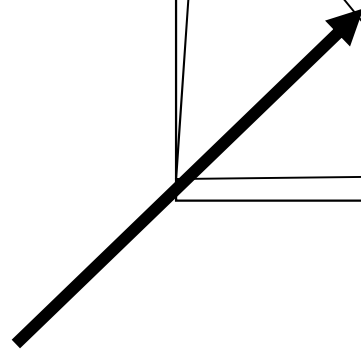
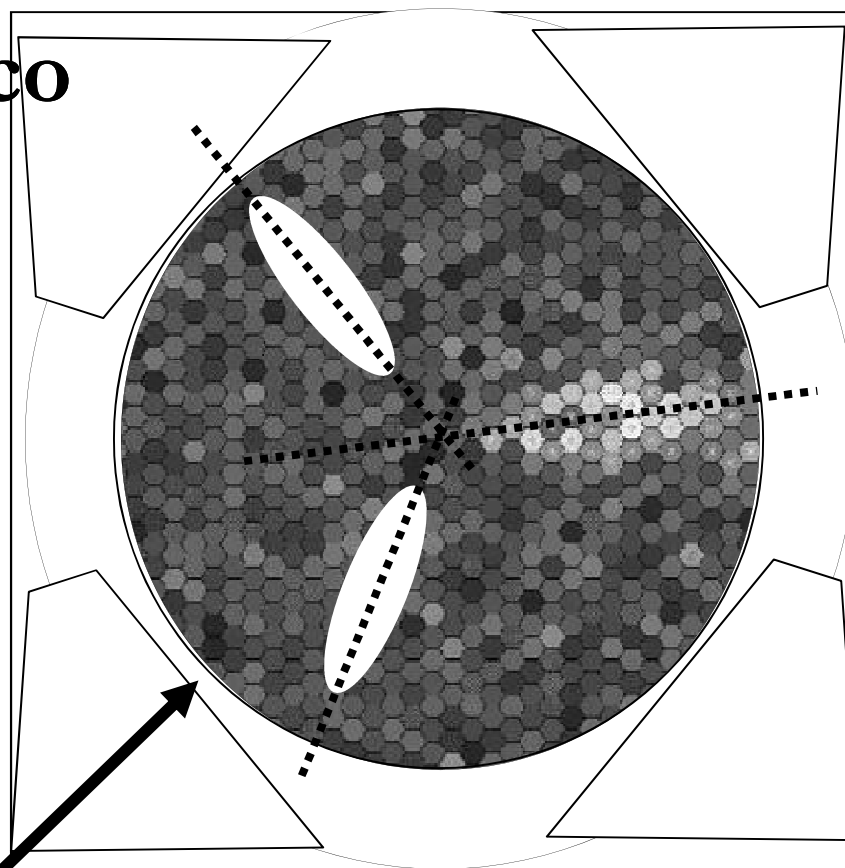
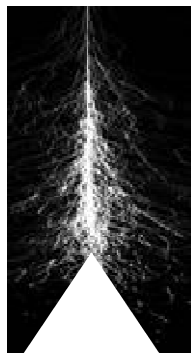
VERITAS
operational

Sensitivity
1% Crab in 50 h

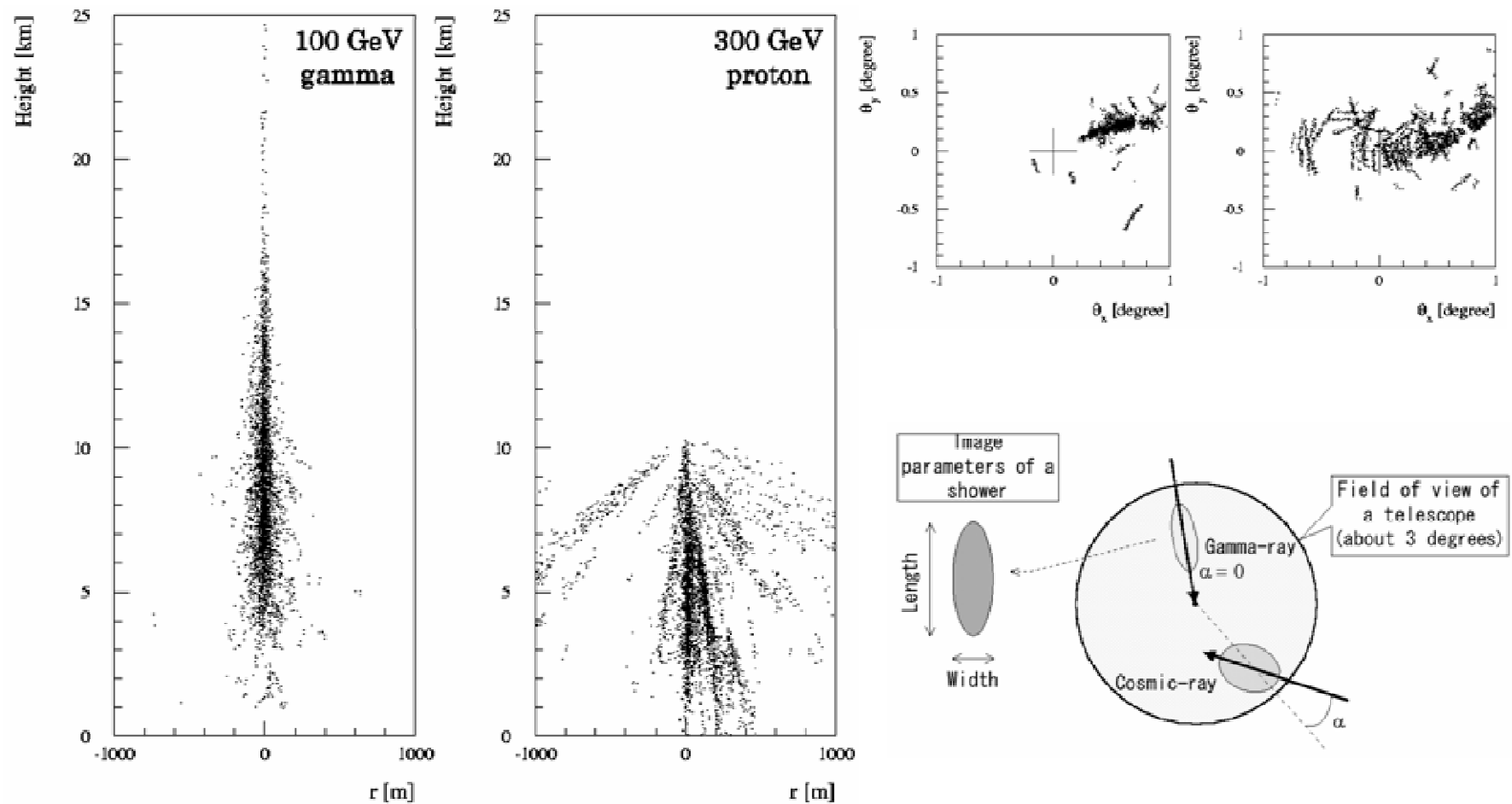




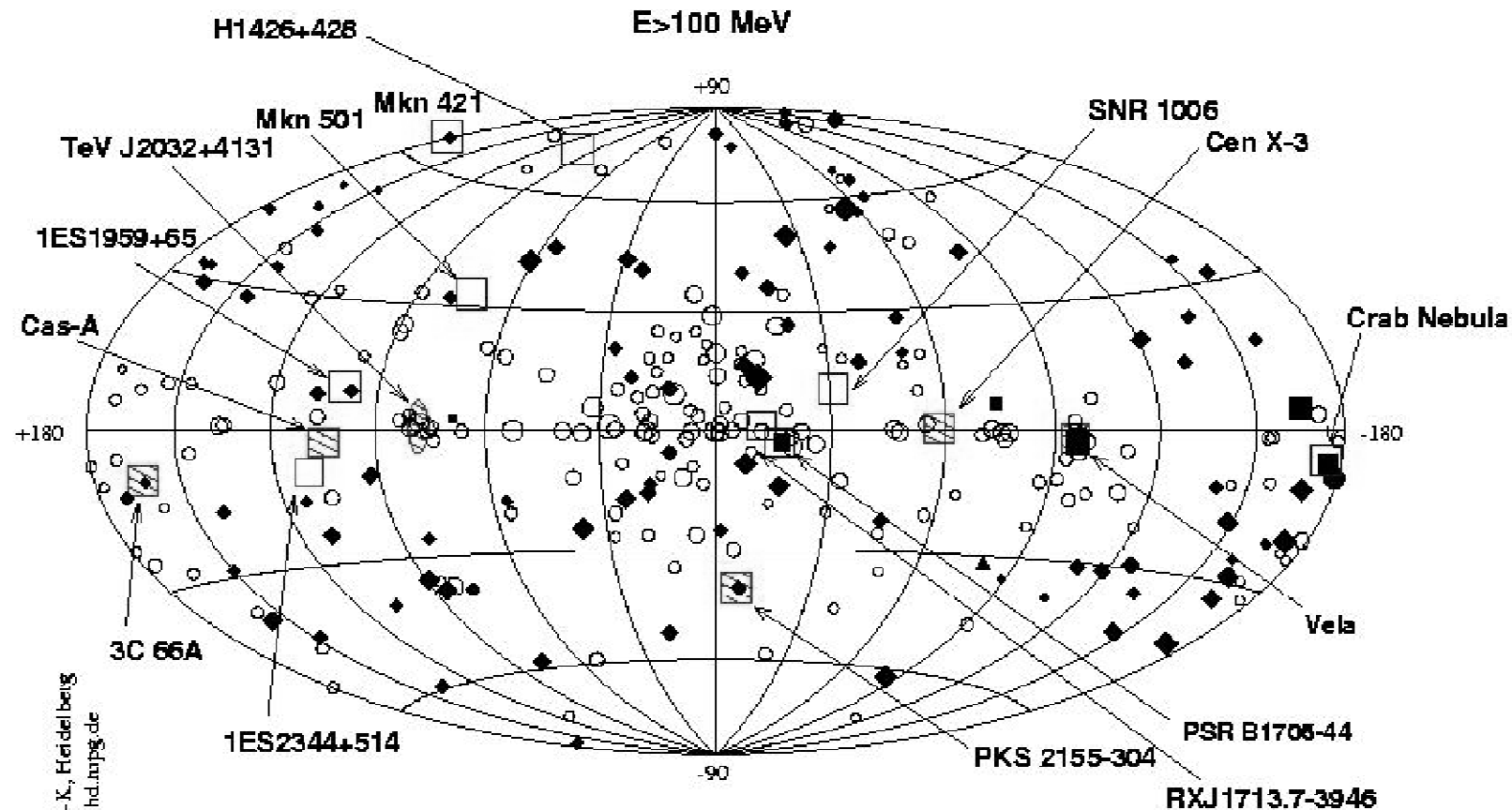
Approccio stereoscopico



Background: separazione gamma-protoni



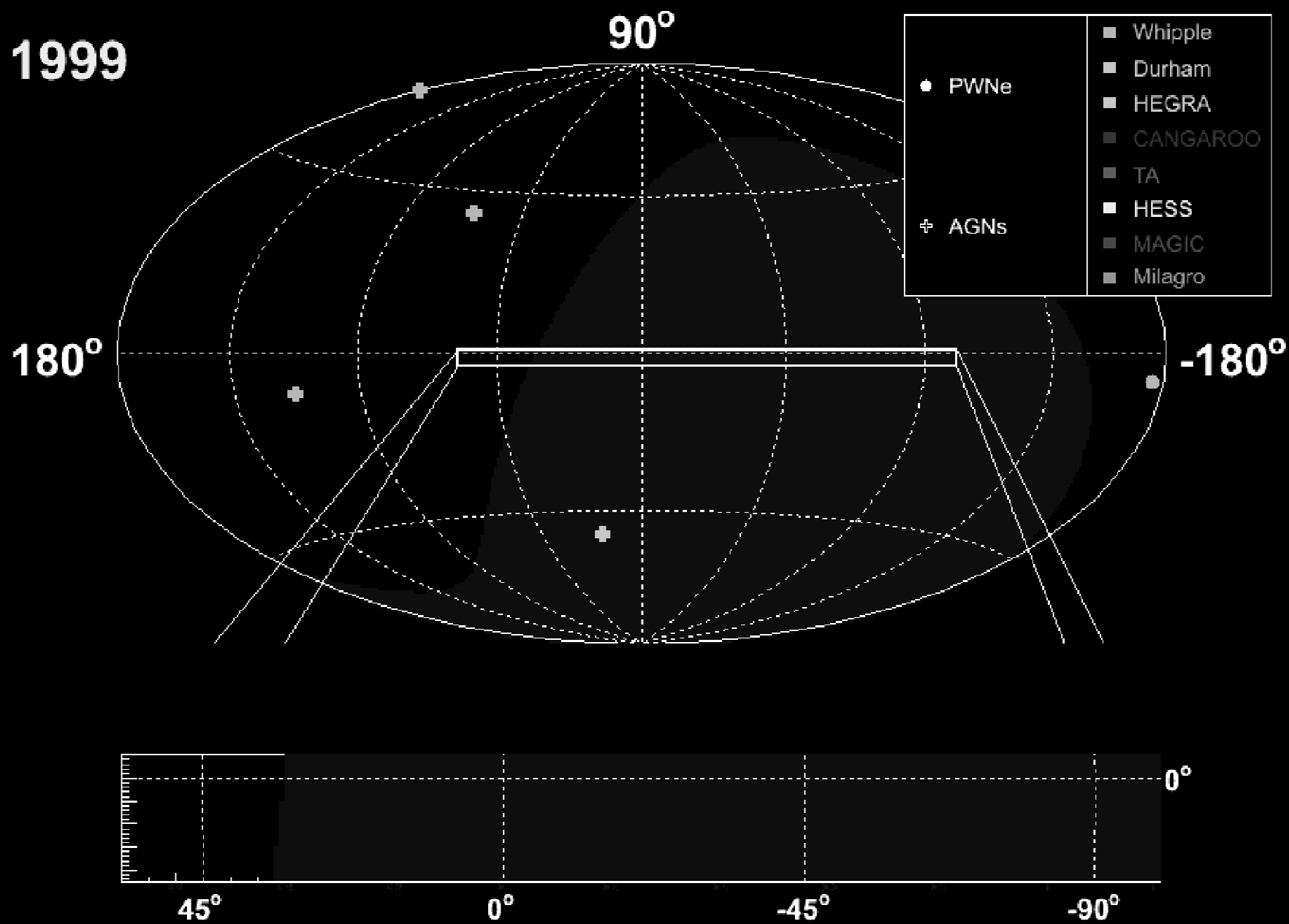
The emerging VHE gamma-ray sky



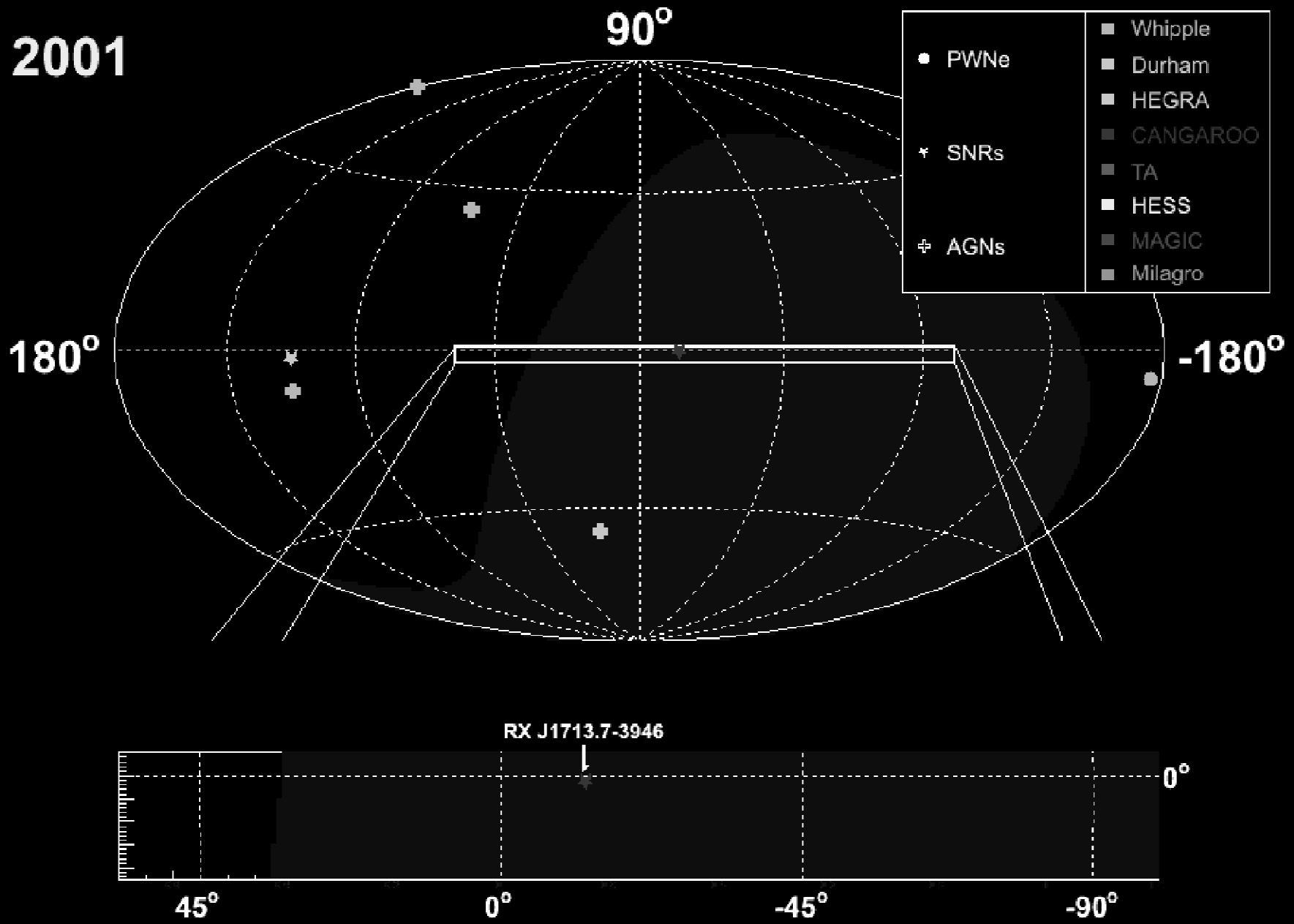
Dietel, Horns, MPI-K, Heidelberg
 dietel.horns@mpi-hd.mpg.de

3rd EGRET catalogue:		Ground based detections:	
◆ AGN	■ Pulsars	□ TeV sources (confirmed)	
○ Unidentified EGRET sources	▲ LMC	▨ TeV sources (not confirmed)	
● solar flare		◌ Unidentified TeV source (not conf.)	

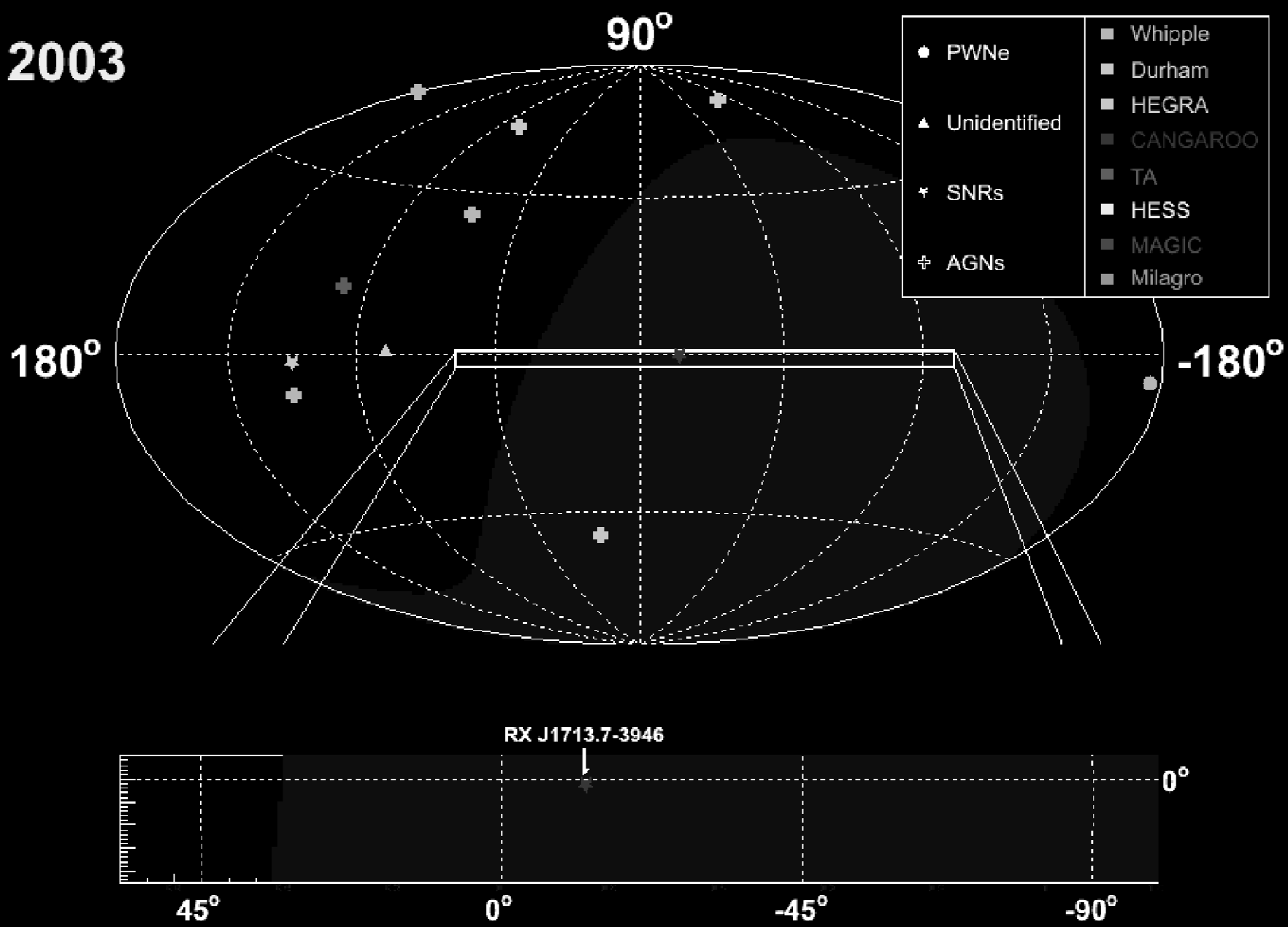
1999



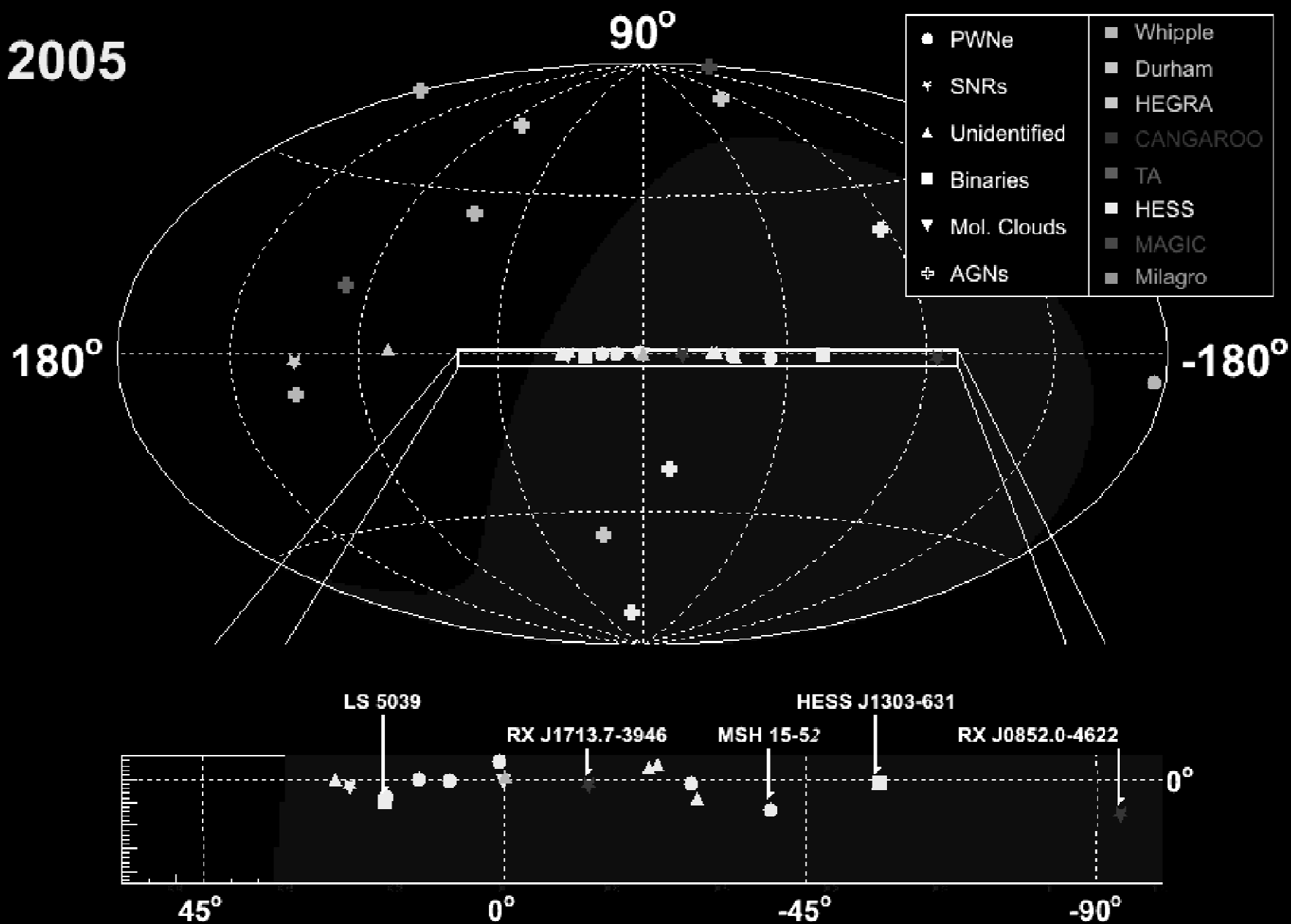
2001



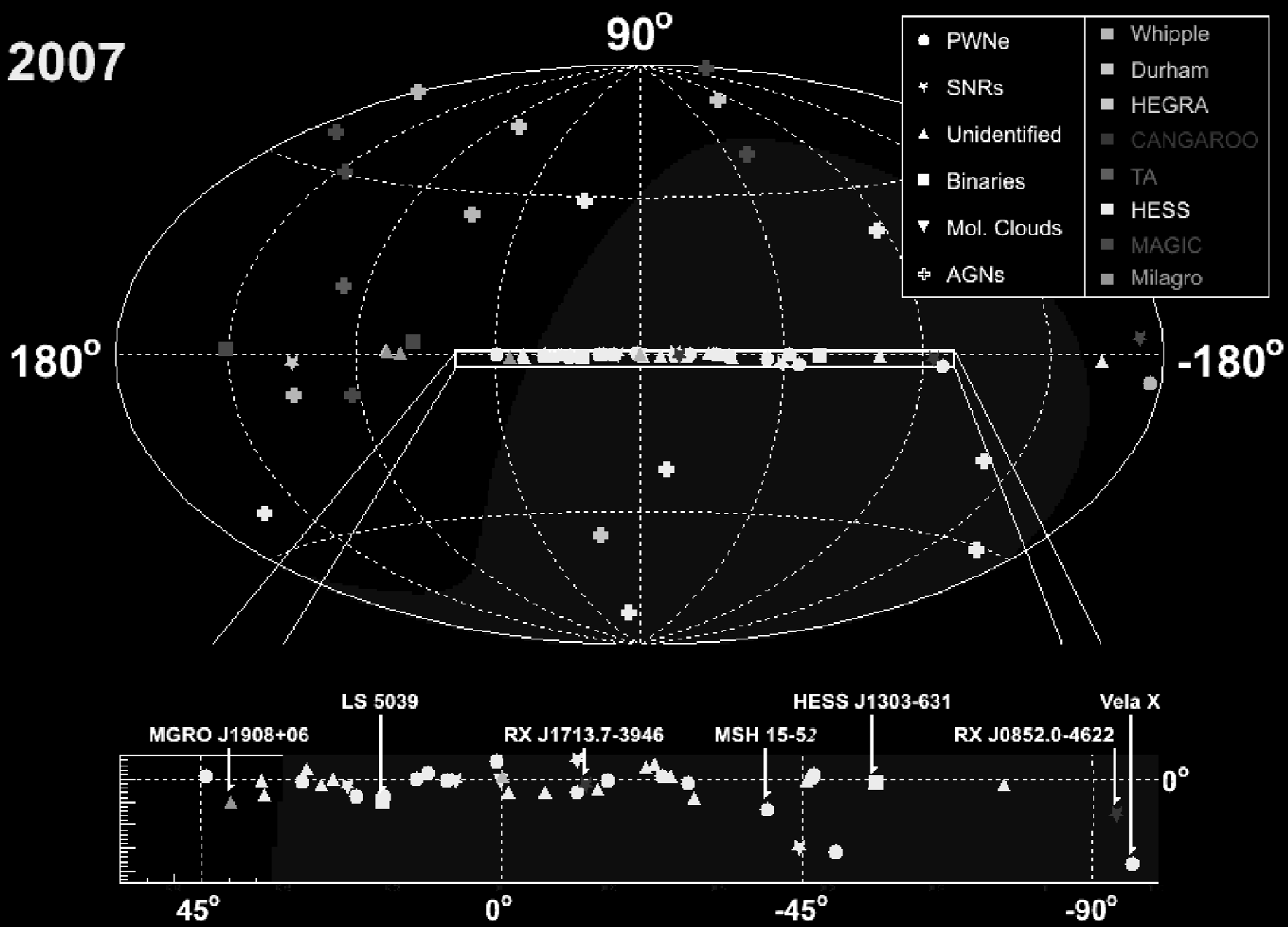
2003



2005

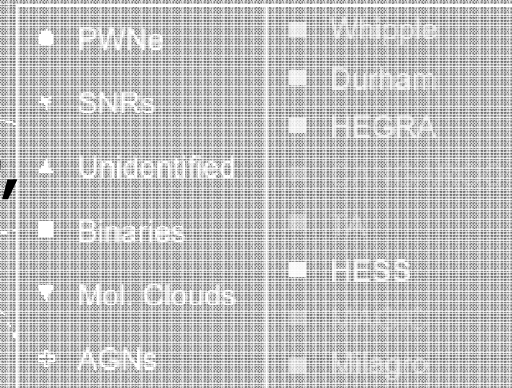


2007



2007

**71 VHE sources -
each a cosmic particle accelerator,
where gamma rays trace
primary electrons or nuclei**



Supernova Remnants (SNR)	7
Pulsar Wind Nebulae (PWN)	18
Unidentified Galactic Sources	21
Diffuse Sources	2
Binary systems	4
Active Galactic Nuclei (AGN)	19

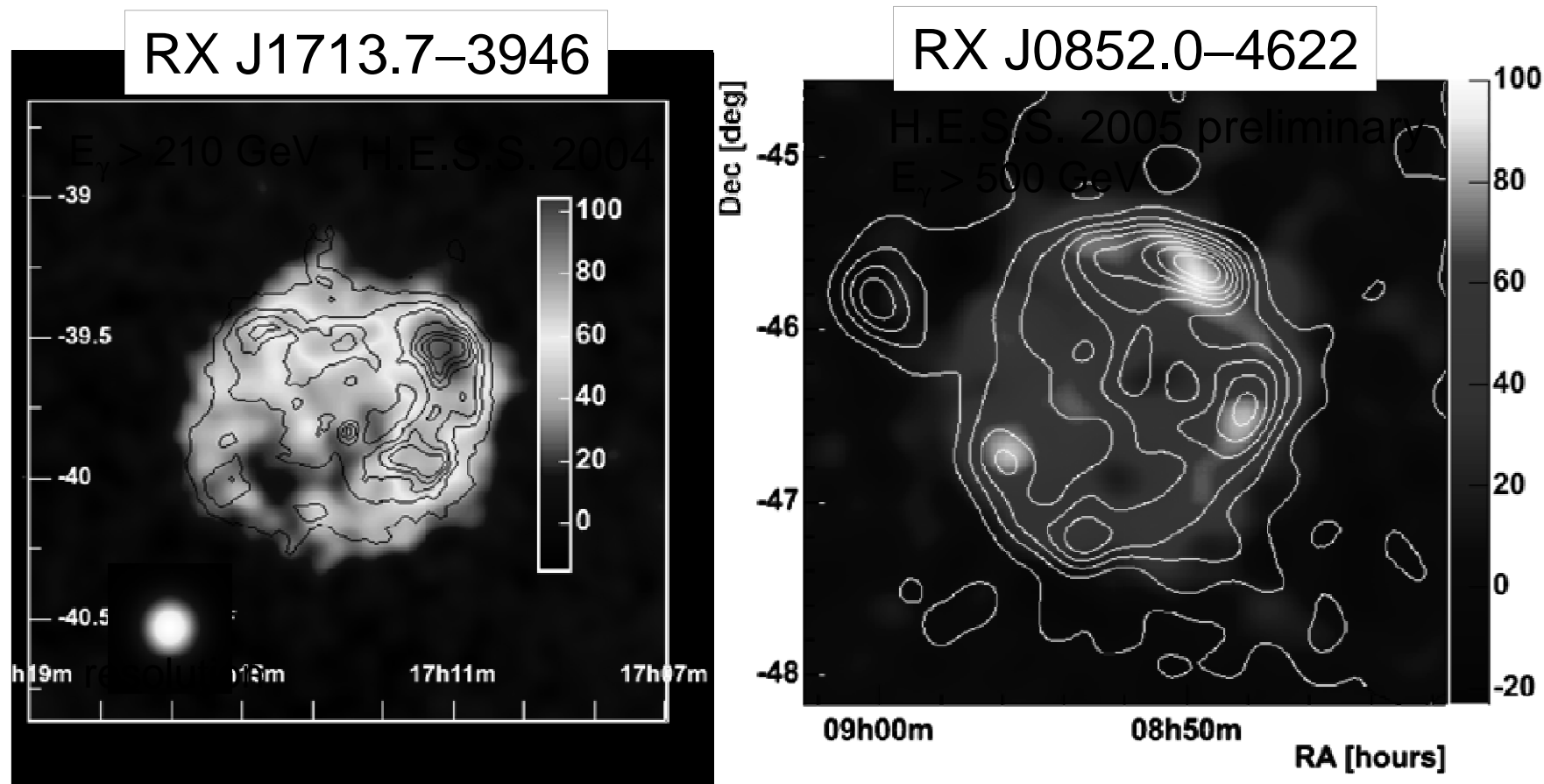
(Hinton, ICRC 2007)

Want to know:

- ▶ **Nature of primary particles**
- ▶ **Their spatial and momentum distribution**
- ▶ **Acceleration mechanism**
- ▶ **Propagation characteristics**

ICRC 2007

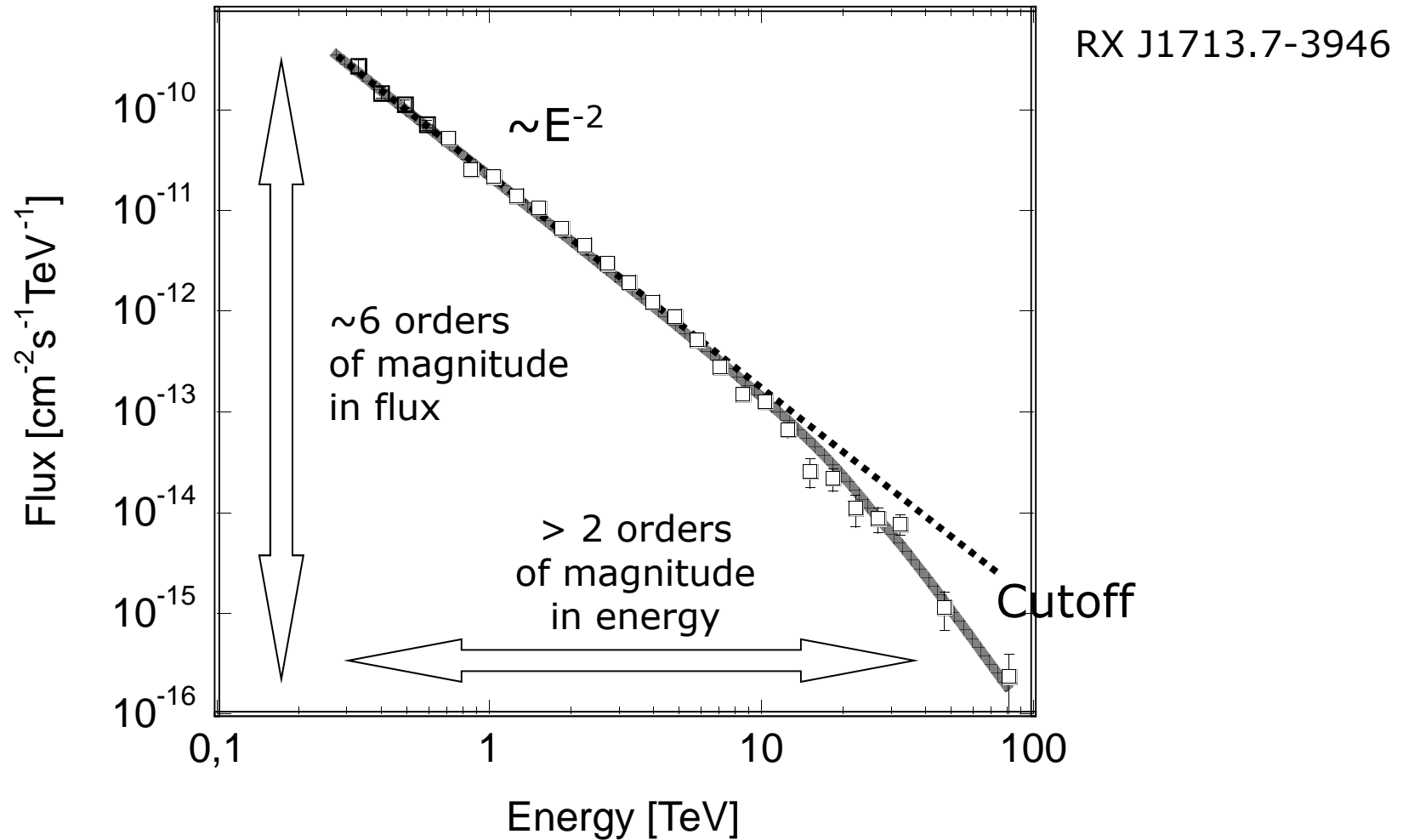
Supernova Shells: Acceleratori di RC?



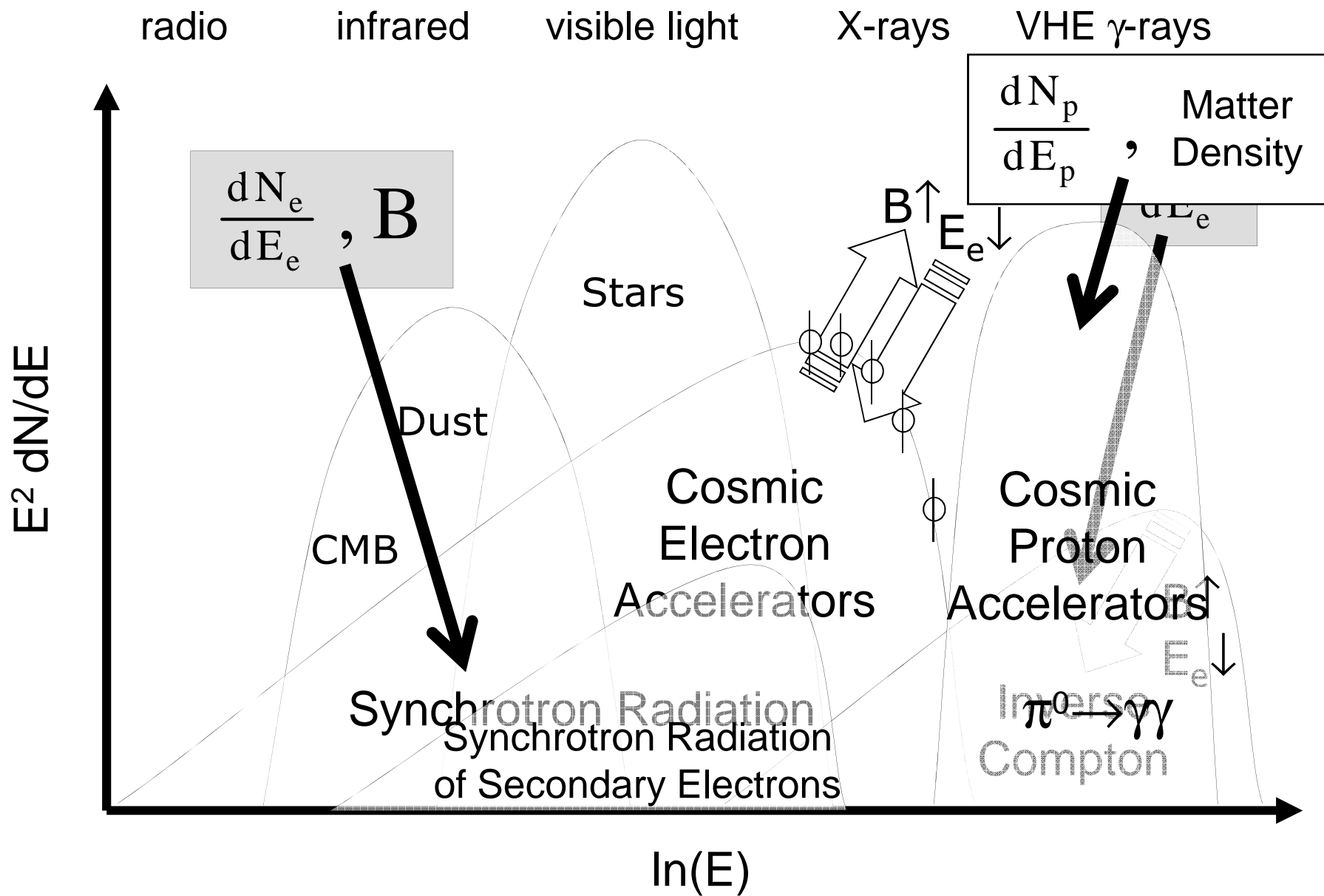
Strong Correlation with X-ray Intensities

- SN-Shells sono acceleratori di particelle sino almeno 100 TeV
- Ma le particelle sono protoni/nuclei o elettroni?

Spettro energetico RX J1713.7-3946

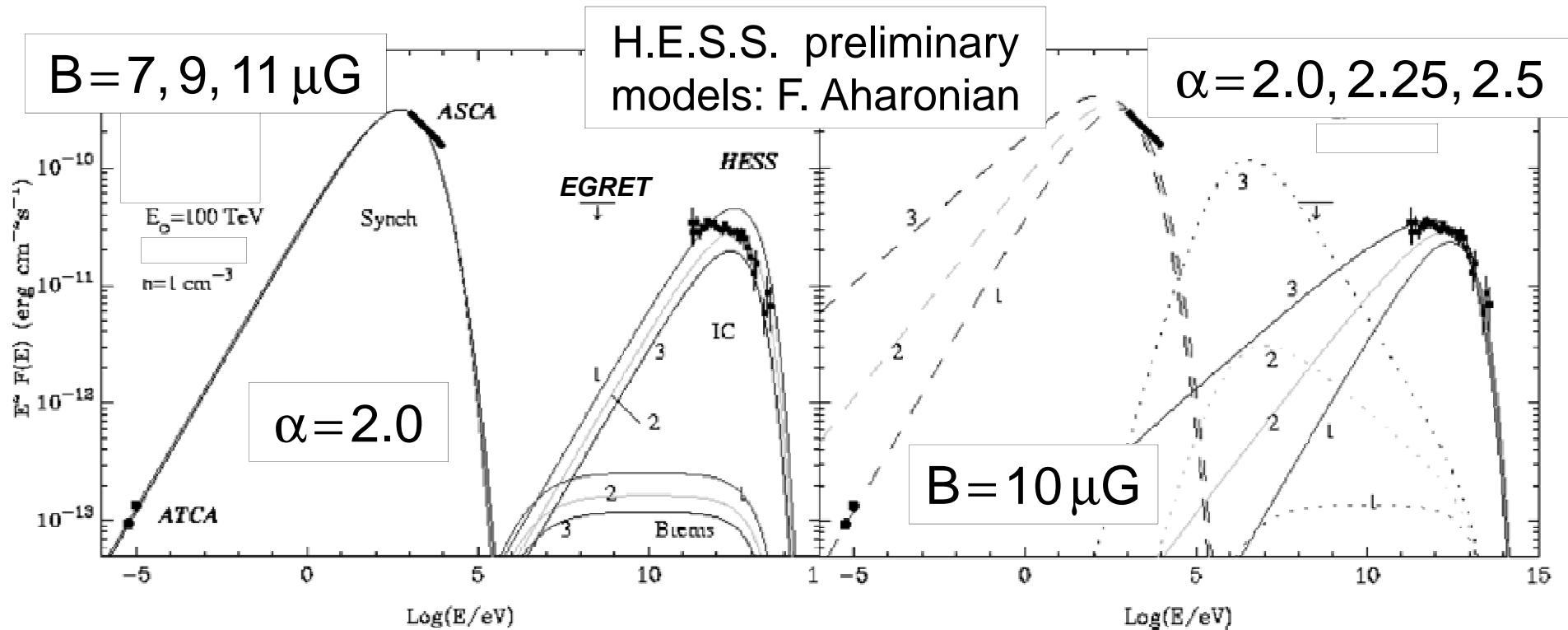


Electron or Hadron Accelerator?



Electron accelerator fits for RX J1713.7–3946:

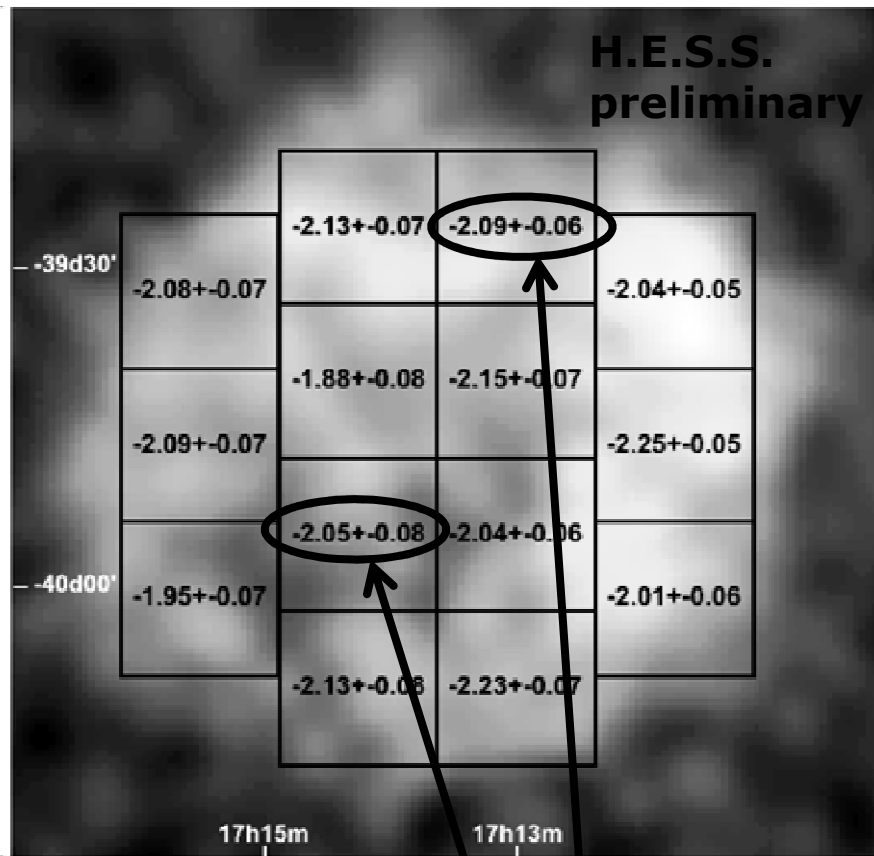
- Continuous electron injection over 1000 years
- Injection spectrum: power law with cutoff



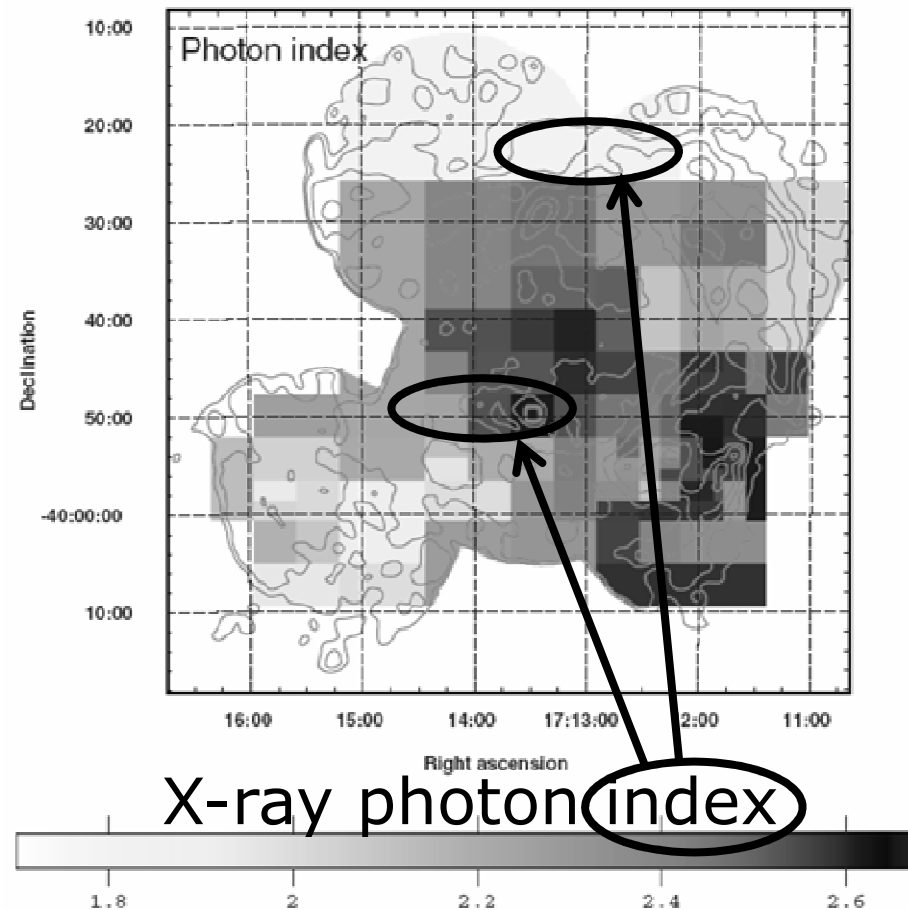
- IC peak not well described
- B-field low for SNR shell

- large α & injection rate \Rightarrow bremsstrahlung important
- needs tuning at low E

Spatially resolved spectra of RX J1713.7–3946



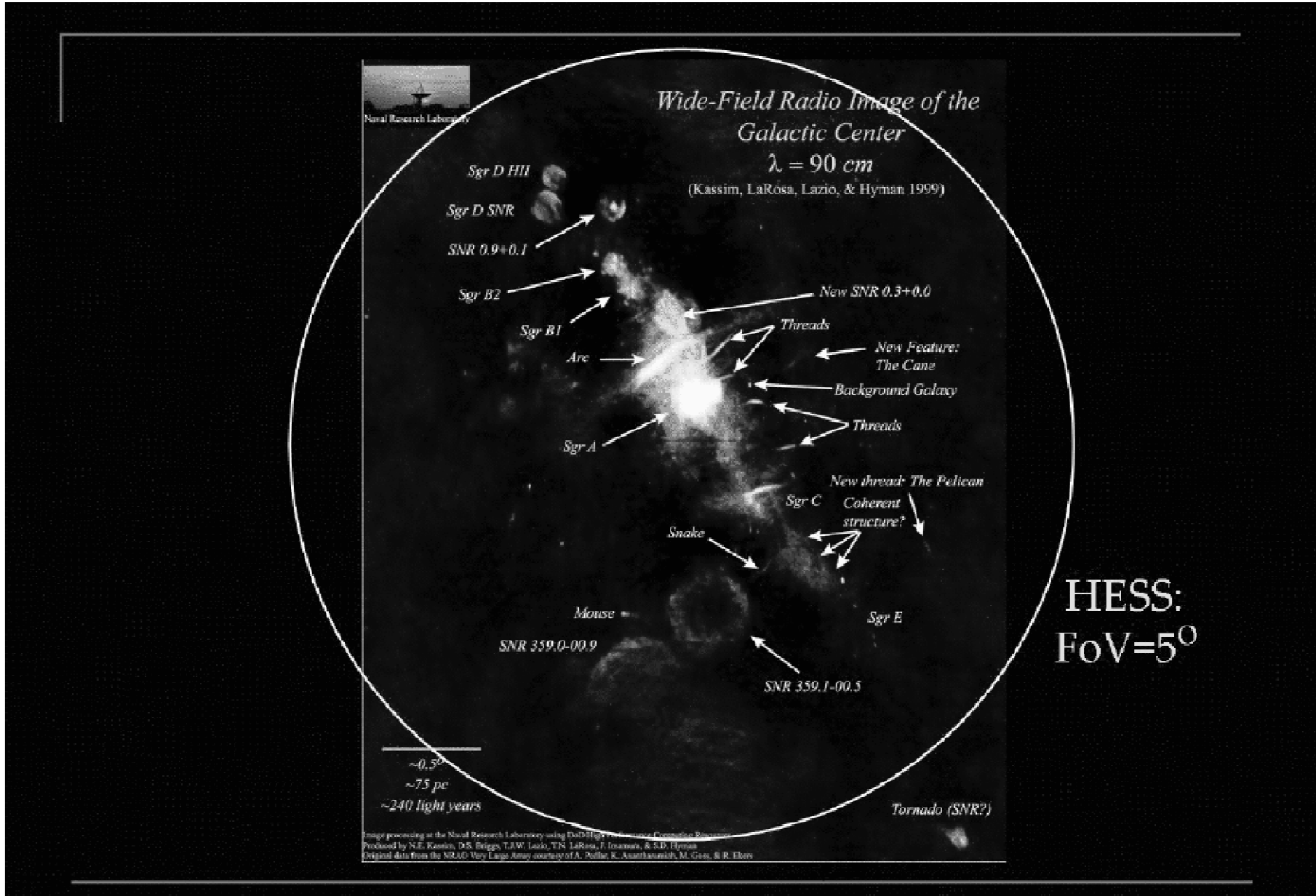
TeV photon index \approx const



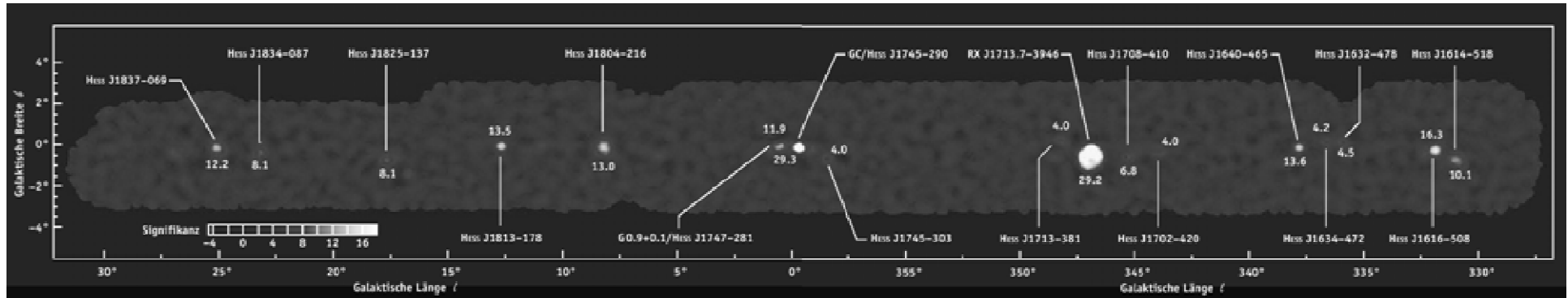
G. Cassam-Chenaï A&A 427, 199 (2004)

TeV / X-ray intensities correlate, but NOT the spectral shapes
 \Rightarrow very hard to understand for pure electron accelerator !

Il centro della Galassia



Il centro della Galassia in TeV (come visto da Hess)



- diffuse galactic plane emission: cosmic ray source distribution, D.M.
- shell-type SNR: spectroscopic imaging, multi- λ , cosmic ray origin
no conclusive evidence that SNRs are source of C.R.
- X-ray binaries (microquasars)
 - flux and spectral variability
 - assoc. with orbital period of binary system
 - γ -ray absorption inside source (size of source)
 - leptonic vs. hadronic origin
- Galactic center, PWN (SNR), unidentified TeV sources:

Alcuni esempi di indici spettrali

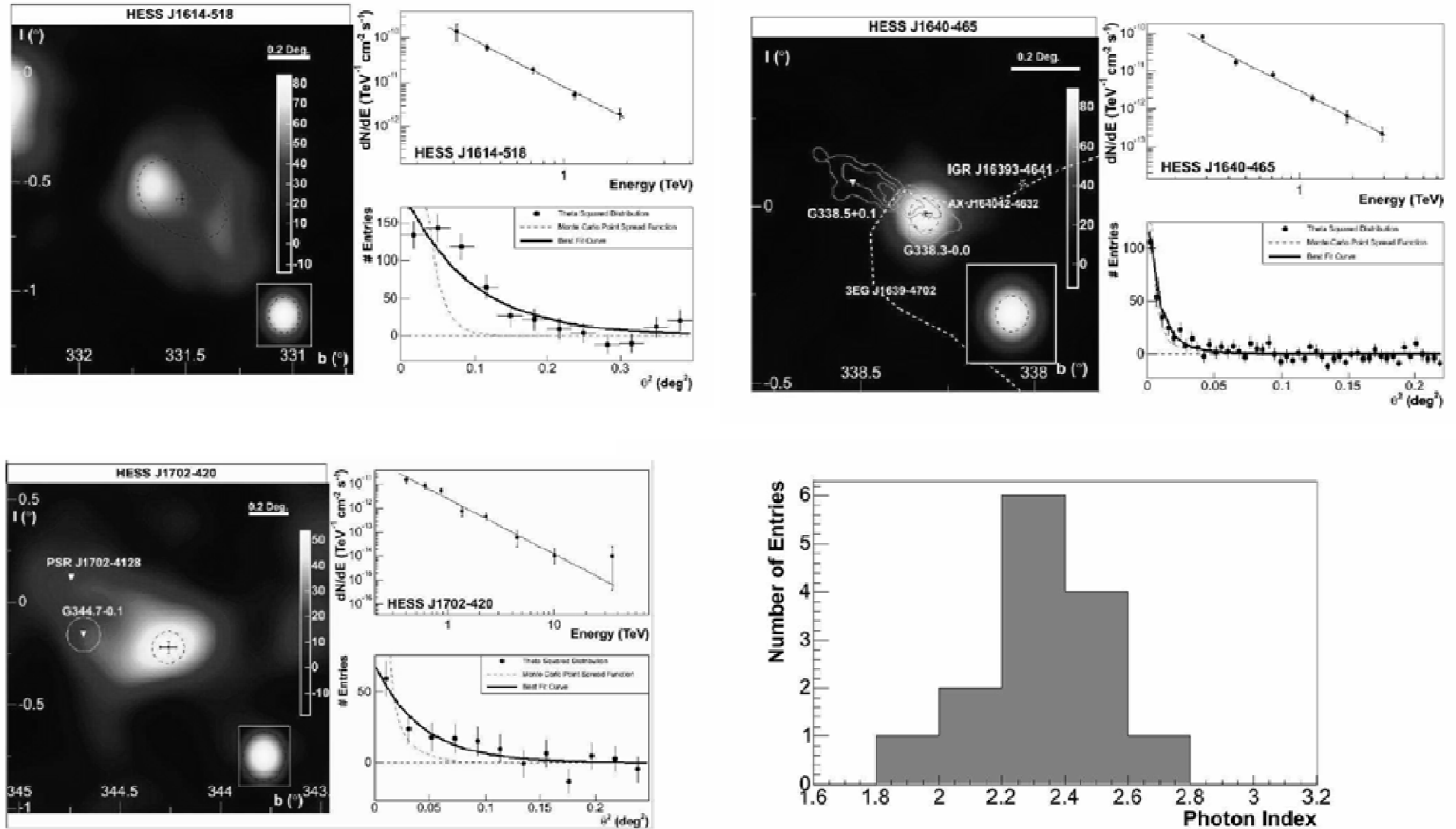


Fig. 8. — Distributions of the photon index of the new sources. The mean photon index is 2.32 with an RMS of 0.2.

Possibili approfondimenti

- Osservazioni di γ dal piano galattico dopo EGRET
- I GRB: modelli teorici ed osservazioni sperimentali
- Emissione di bremstrahlung;
- Compton inverso;
- Rivelazione di fotoni (TeV) a Terra.
-