# Linking GLAST Science Prospects with CTA

Olaf Reimer

Hansen Experimental Physics Labs
Kavli Institute for Astroparticle Physics & Cosmology

Stanford University

# Outline

The Unavoidable

Get familiar with your upcoming γ-ray observatory!

The Anticipation

What GLAST might do…

The Complementarity

What GLAST might not do…

} exemplified on a few individual scientific topics

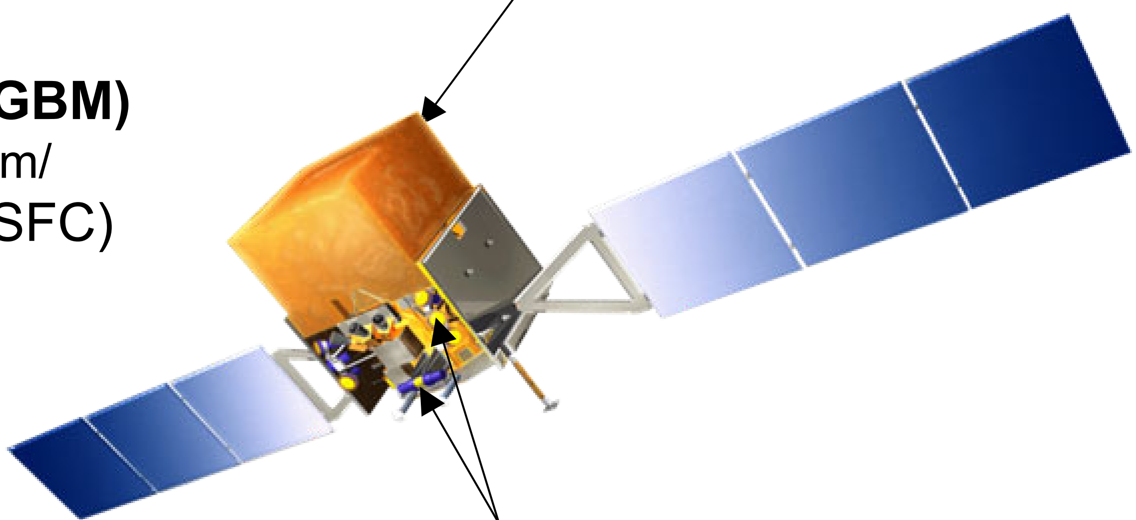
The Proximity of GLAST & CTA

# What is GLAST?

Two Instruments:

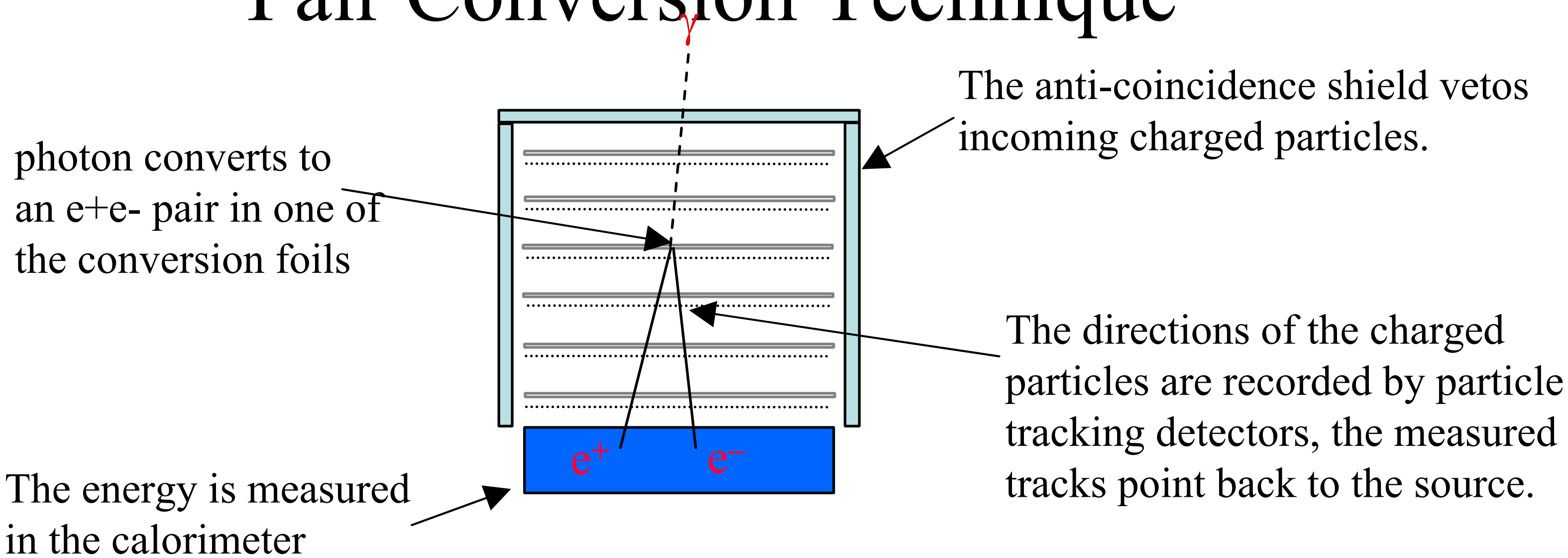
**Large Area Telescope (LAT)**
http://glast.stanford.edu/
PI: P. Michelson (Stanford University)
20 MeV - 300 GeV
>2.5 sr FoV

**GLAST Burst Monitor (GBM)**
http://f64.nsstc.nasa.gov/gbm/
PI: C. Meegan (NASA/MSFC)
8 keV – 30 MeV
9 sr FoV




Launch: Nov 2007 – Feb 2008
Lifetime: 5 years (req), 10 years (goal)

# Pair Conversion Technique




**BASIC DESIGN CRITERIA**

**Tracker: angular resolution is determined by:**

multiple scattering (at low energies) => many thin layers

position resolution (at high energies) => fine pitch detectors

**Calorimeter:**

Sufficient $X_0$ to contain shower, capability of shower leakage correction.

**Anticoincidence detector:**

High efficiency for rejecting charged particles, but not veto gamma-rays

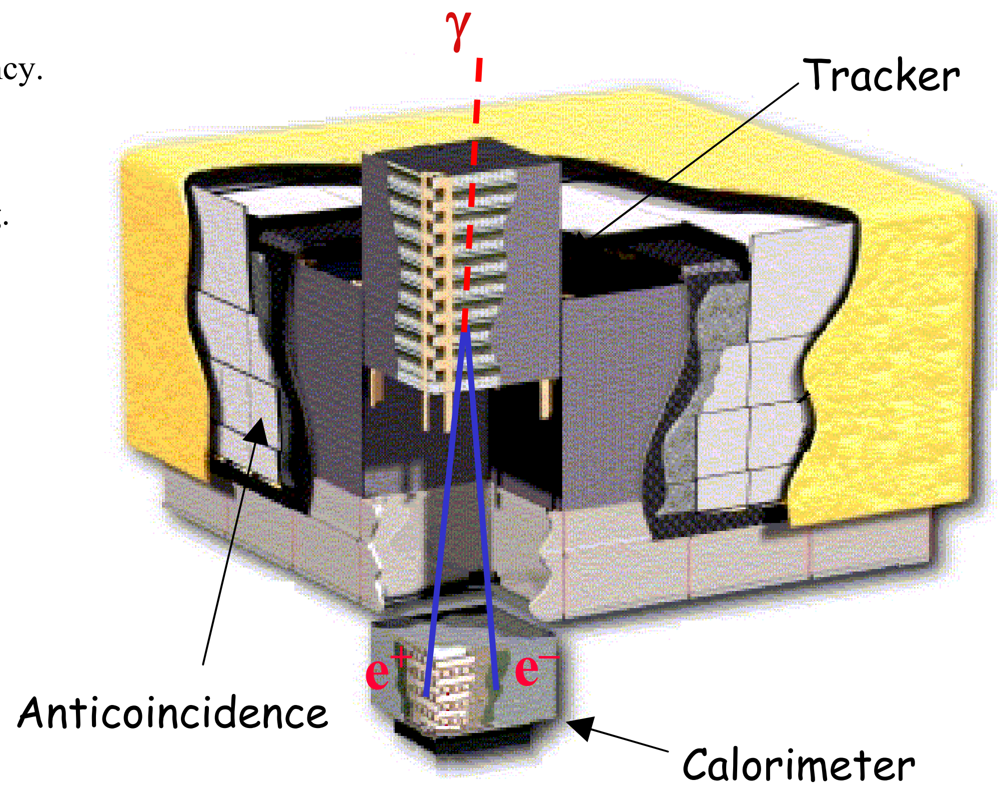
# The GLAST Large Area Telescope

- **Precision Si-strip Tracker (TKR)**
  18 XY tracking planes. 228 µm pitch). High efficiency. Good position resolution (ang. resolution at high energy)

  12 x 0.03 $X_0$ front end => reduce multiple scattering.
  4 x 0.18 $X_0$ back-end => increase sensitivity >1GeV

- **CsI Calorimeter(CAL)**
  Array of 1536 CsI(Tl) crystals in 8 layers.
  Hodoscopic => Cosmic ray rejection.
  => shower leakage correction.
  8.5 $X_0$ => Shower max contained <100 GeV

- **Anticoincidence Detector (ACD)**
  Segmented (89 plastic scintillator tiles)
  => minimize self veto




Height/Width = 0.4
-> large field of view

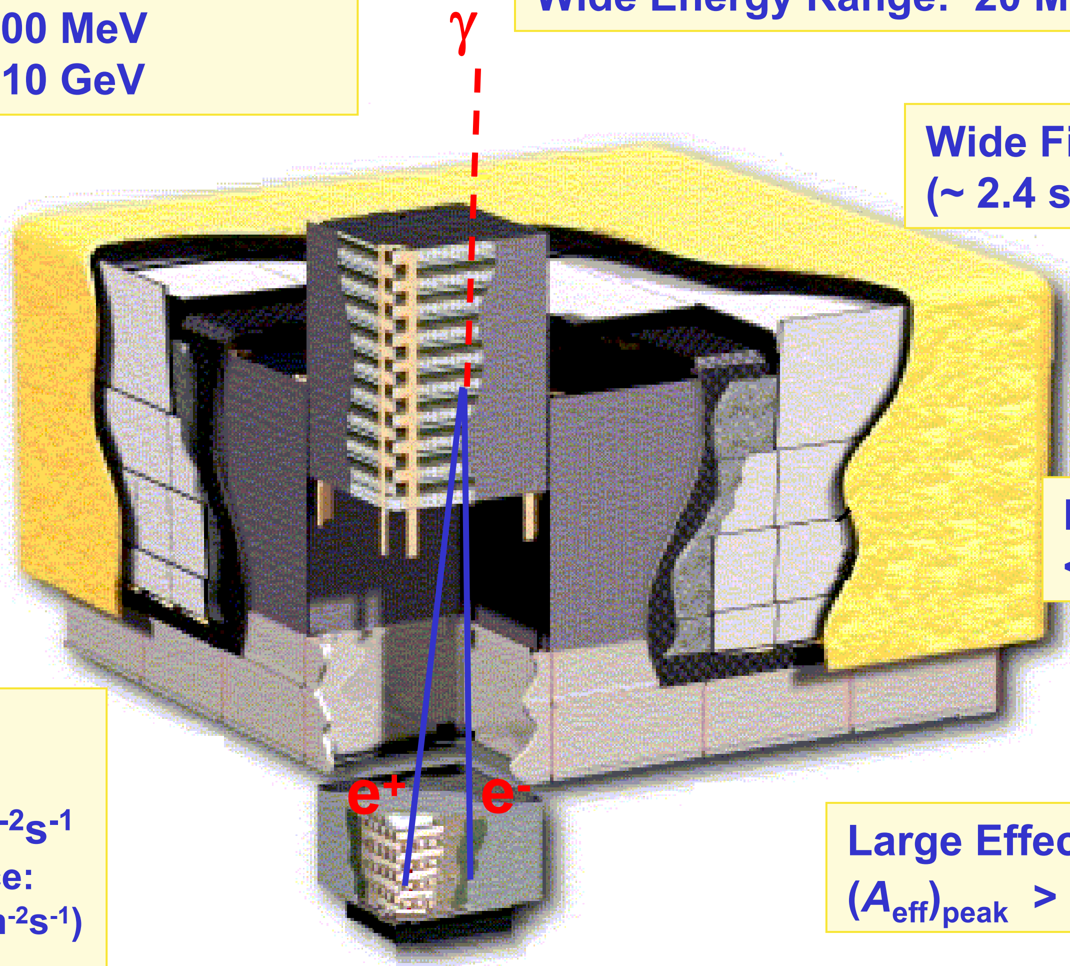
**Single Photon Angular Resolution**
3.5° @ 100 MeV
0.15° @ 10 GeV

**Wide Energy Range: 20 MeV … ~300 GeV**

**Wide Field of View**
(~ 2.4 sr)

**~40 x EGRET's sensitivity and extends energy range well into hundreds of GeV**

**Low dead time:**
< 100 μs/event



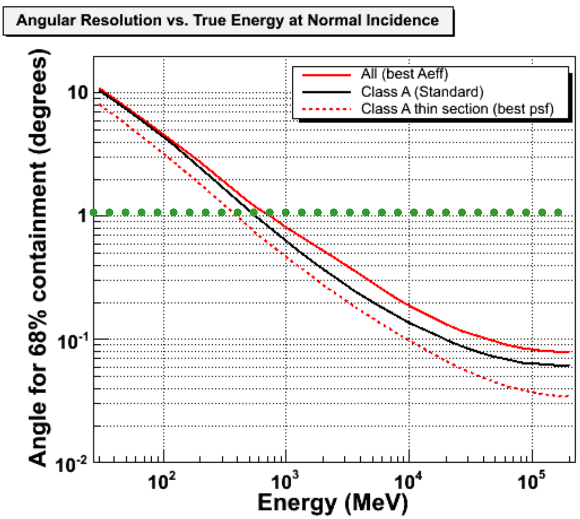

**Point Source Sensitivity:**
$< 6 \times 10^{-9}$ ph $cm^{-2}s^{-1}$
(est. performance:
$< 3 \times 10^{-9}$ ph $cm^{-2}s^{-1}$)

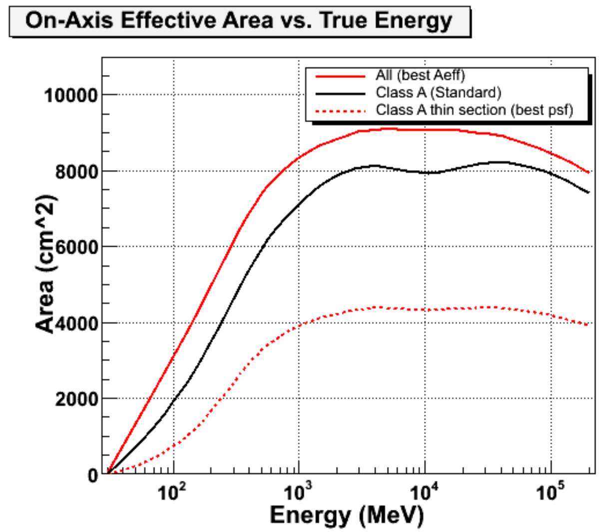
**Source Localization:**
0.3' – 1'

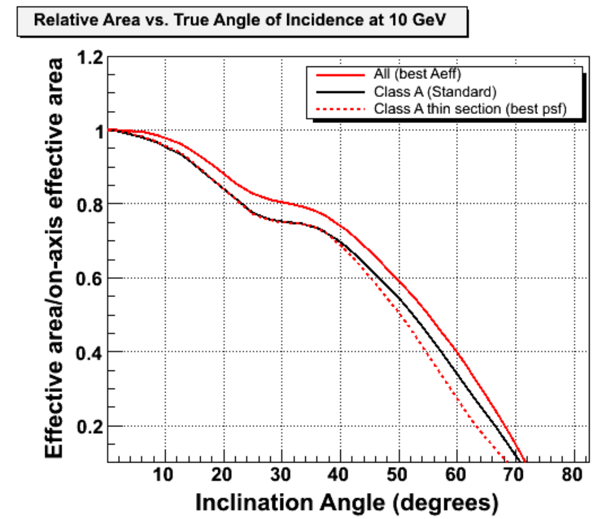
**Large Effective Area**
$(A_{eff})_{peak} > 8{,}000$ $cm^2$

**Good Energy Resolution**
$\Delta E/E \sim$ 10%; 100 MeV – 10 GeV
~ < 20%; 10 GeV – 300 GeV

# LAT Performance (as of Feb 2007)



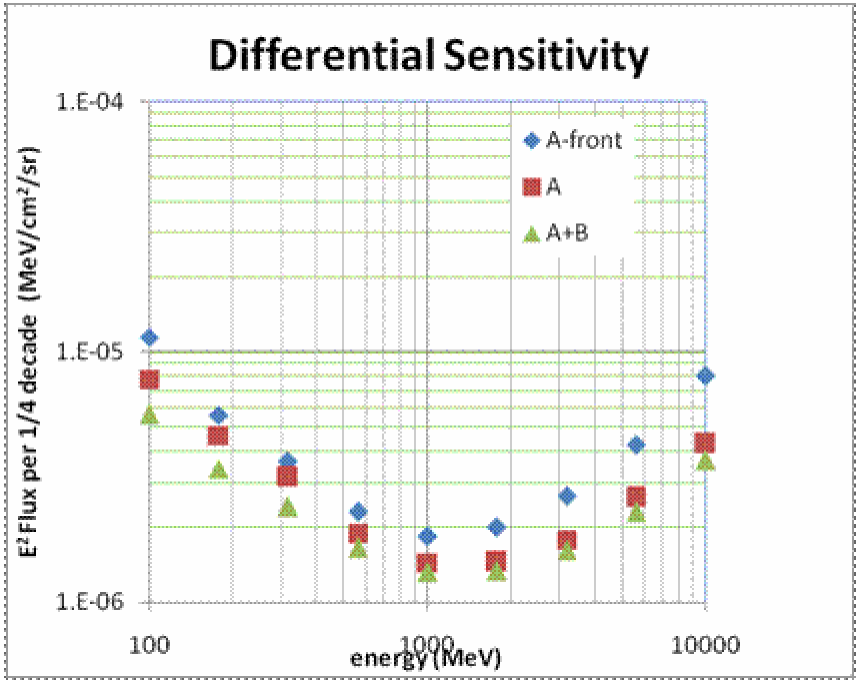



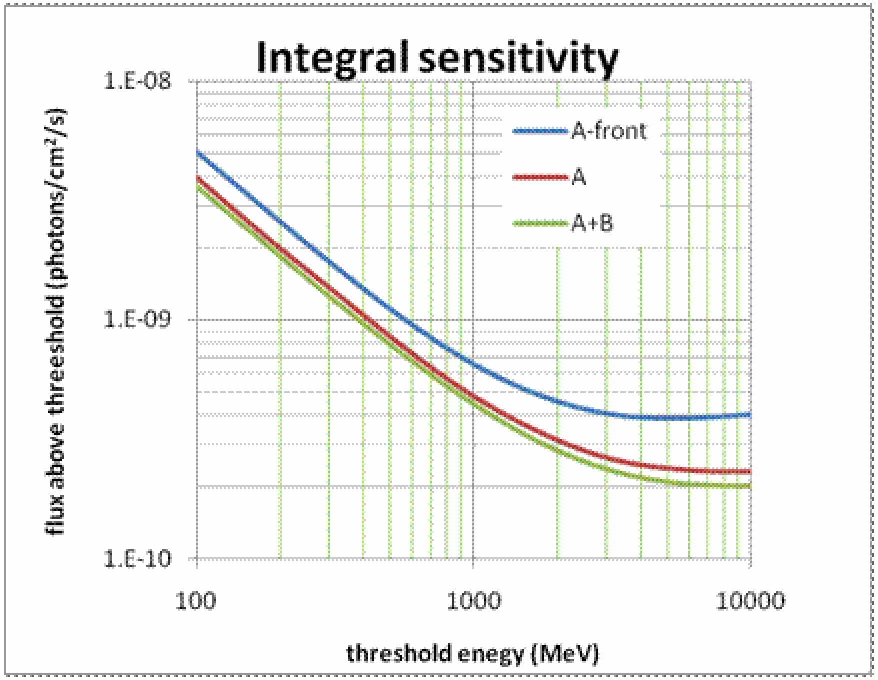




| | GLAST/LAT | EGRET |
|---|---|---|
| Energy Range | 20 MeV … 300 GeV | 30 MeV … 10+ GeV |
| Energy Resolution | 0.1 | 0.1 |
| Effective Area | 9000 cm$^2$ | 1500 cm$^2$ |
| Field of View | 2.2 sr. | 0.5 sr. |
| Angular Resolution | 3.5 @ 100 MeV<br>0.1@10 GeV | 5.8@100 MeV<br>0.5@10 GeV |
| Sensitivity (>100 MeV) | 3x10$^{-9}$ cm$^{-2}$ s$^{-1}$ | ~10$^{-7}$ cm$^{-2}$ s$^{-1}$ |
| Deadtime | 27 μs | 100ms |

http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm

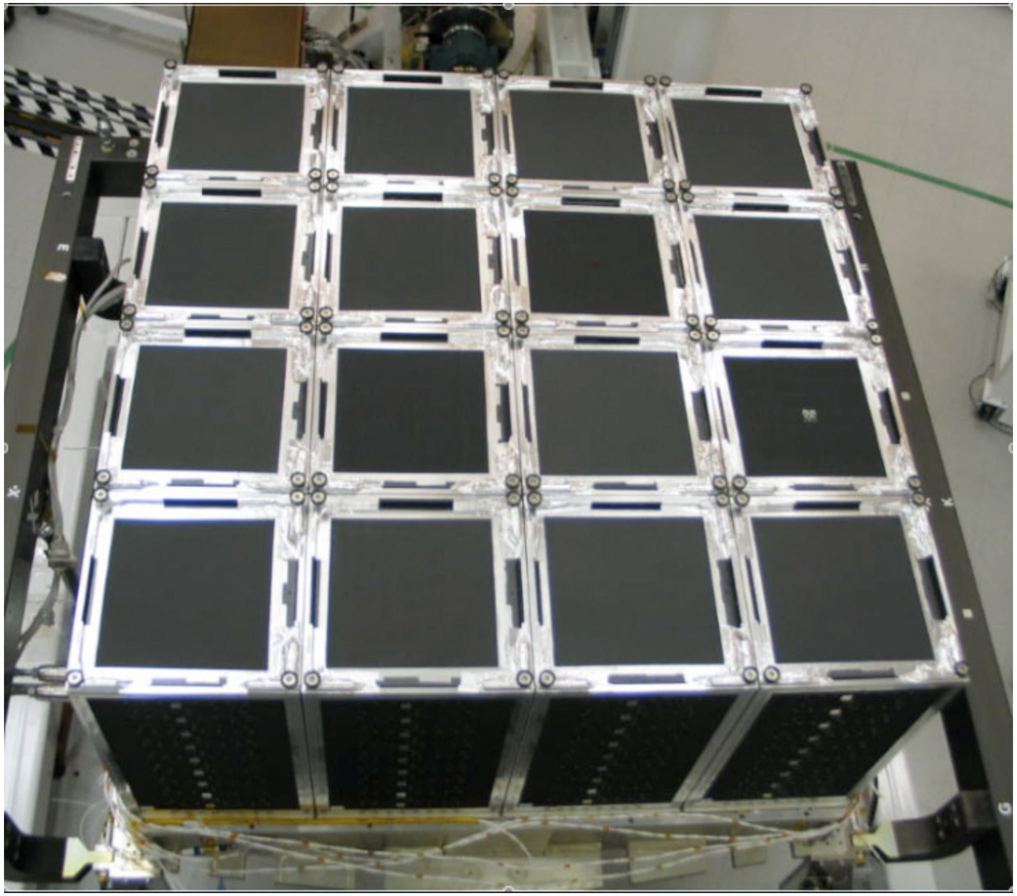
# LAT Performance (as of Feb 2007)




These are the performance characteristics justifying the scientific expectations in GLAST.

# It's being build…



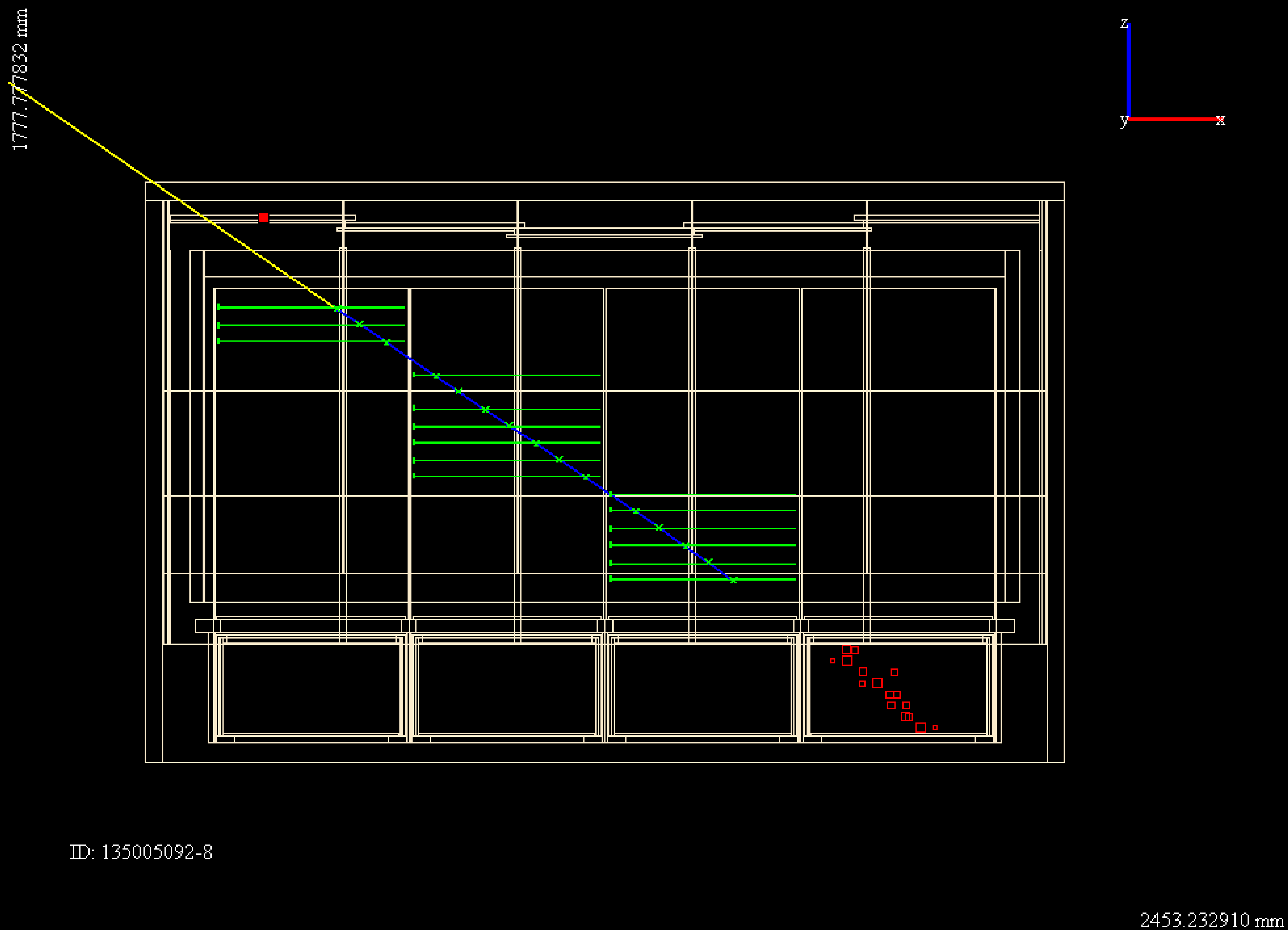
Tracker/Calorimeter/Electronics integration finished (May'06).

# …and integrated!

Schedule:

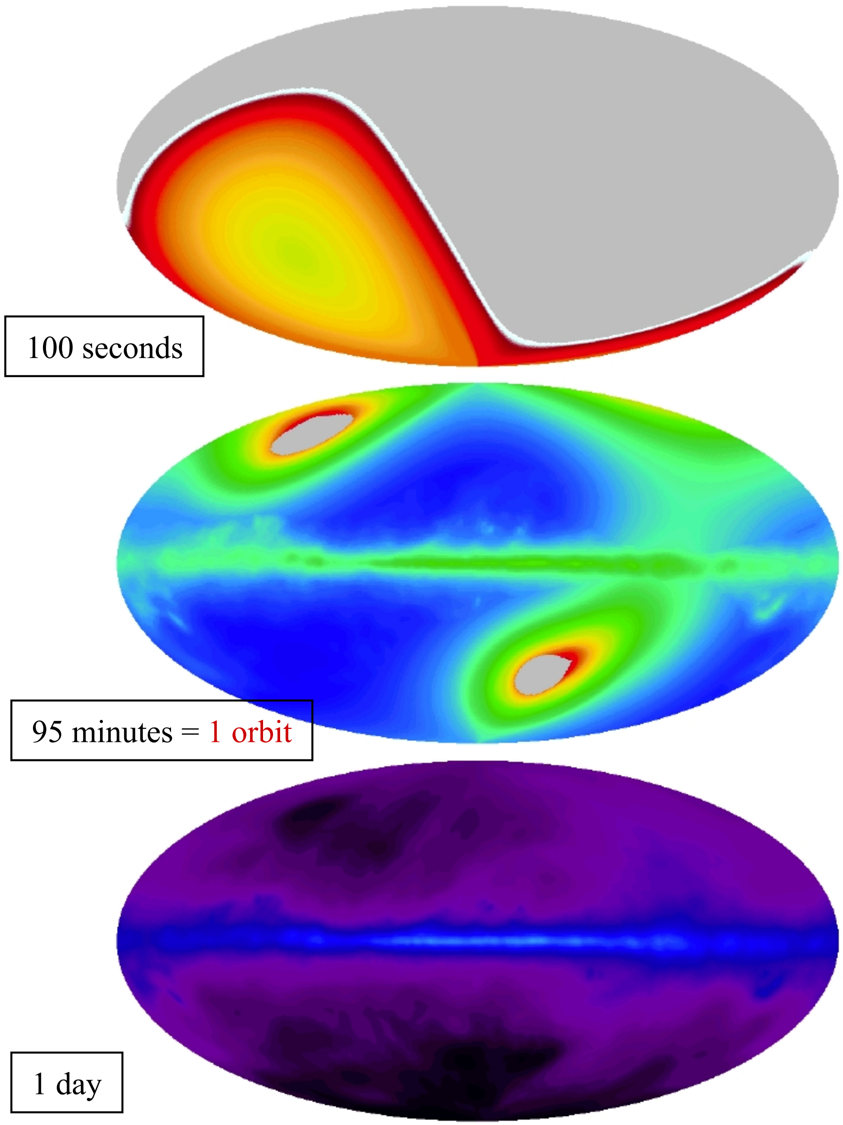
- now: Observatory pre-environmental review
- Observatory level testing Sept 2007.
- Launch site operations Sept-Oct 2007.
- Launch Nov'07+

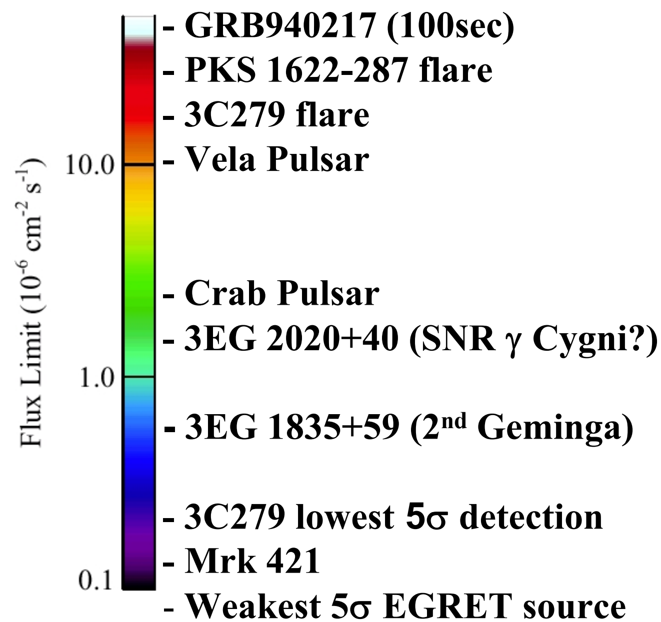
# It’s taking (ground) data!



# GLAST-LAT regular science operation mode

- Autonomous re-pointing for GRB (default)
- Continuous sky survey in rocking mode (default)
- Data on transients instantaneous released (AGN flares, GRB alerts).
- Data on ~20 selected sources released (source list reviewed and updated periodically by the GLAST Users Committee).
- Pointed observations driven by guest observer proposals selected by peer review (generally: hard to justify the gain in pointed vs. rocking mode obs)
- Extraordinary ToOs supported, DDTs via Project Scientist
- All data publicly released within 72 hours through GSSC, although level of sophistication presently undetermined
- In-depth analysis and key projects continued by LAT collaboration (2y, 5y cat, diffuse model updates, large-scale population studies etc.)



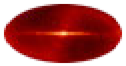




- We're confident that LAT will have sufficient sensitivity after one day to detect (5σ) the weakest EGRET sources.

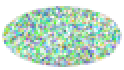
- Anticipated location accuracy will principally enable their individual MWL identification.

# Physics/Astrophysics at high-energy γ-rays

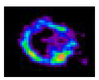
Active Galactic Nuclei



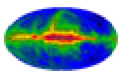
Extragalactic Background Light



Gamma Ray Bursts



Supernova Remnants



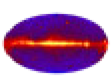
Galactic Diffuse Emission, Molecular Clouds

Pulsars

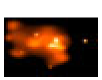
Plerions

Binary Systems (μQSOs, XRBs, PSRs, colliding wind systems)

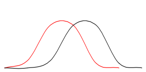
Extended Extragalactics
(Local Group Galaxies, Starburst Galaxies, Galaxy Cluster)



* Discovery Science hidden in Unidentified Sources

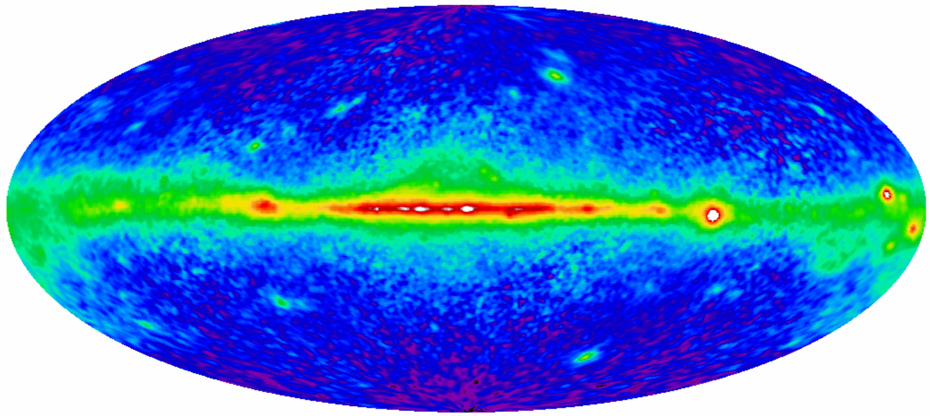


* Dark Matter Signatures



* Lorentz symmetry violation (Quantum Gravity)

# Science opportunities for the LAT



**EGRET (>100 MeV)**

**75% galactic diffuse emission**

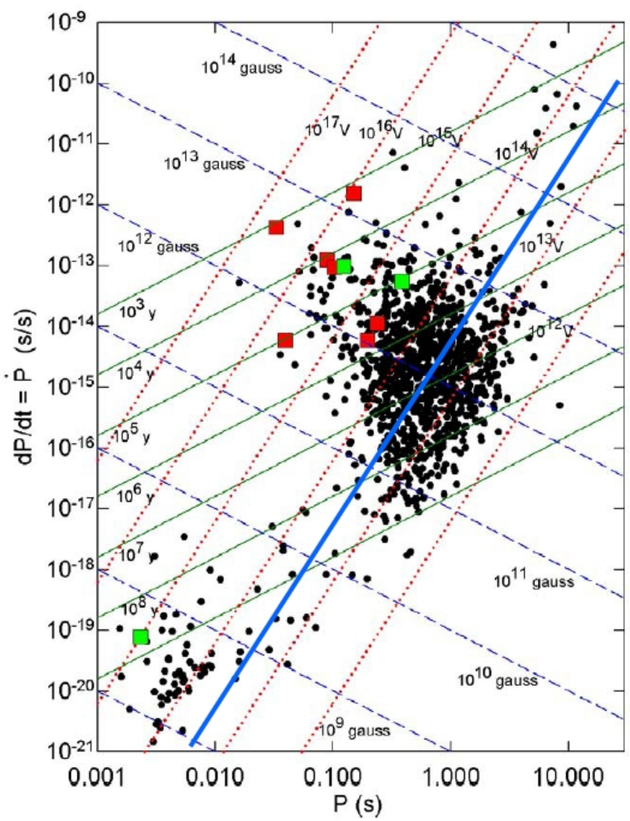
**15% isotropic emission**

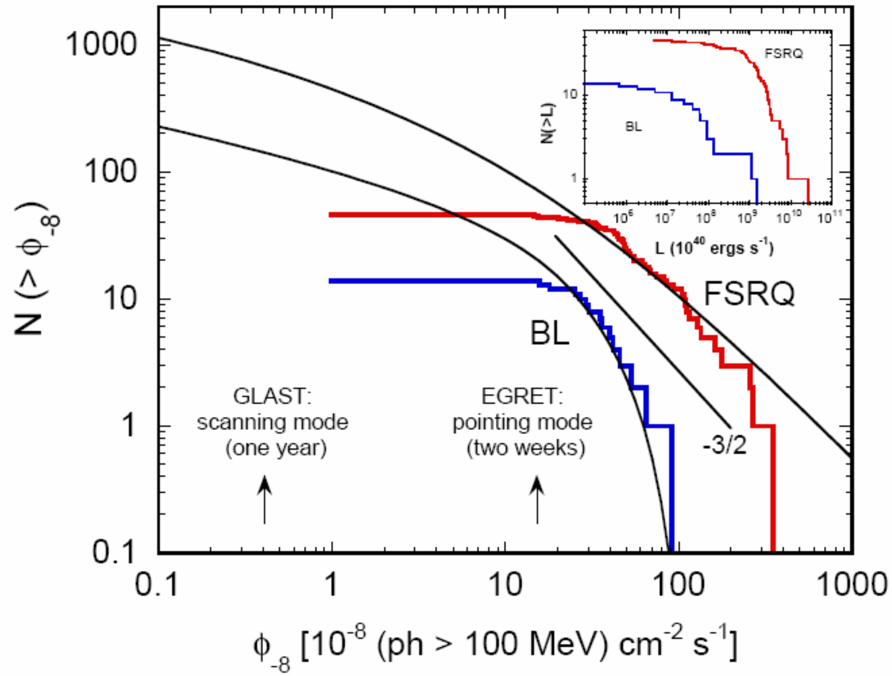
**10% point sources**

- determine the origin(s) of the high-energy extragalactic diffuse background
- measure extragalactic background starlight to $z > 3$
- detect γ-ray emission from clusters of galaxies; cosmic-ray acceleration and confinement on large scales
- detect γ-rays from Ultra-Luminous Infrared Galaxies; cosmic ray acceleration efficiency and star formation rate
- detect high-latitude Galactic Inverse-Compton emission and thereby measure TeV-scale CR electrons in the Galaxy
- study high-energy emission from Galactic pulsars and their birth places
- the unknown!

# A guaranteed science case: AGN & PSRs

An excurse into numbers:




Blazar detections under consideration of evolutionary aspects (Dermer 2006)

(tricky since blazar evolution itself is to be studied)

Current limit for PSR detections (Thompson 2005)

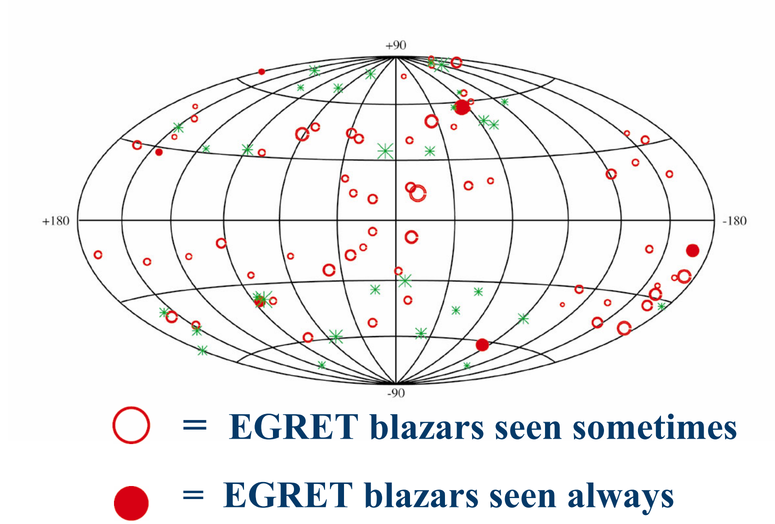
(rather an observationally driven *accessibility* limit)

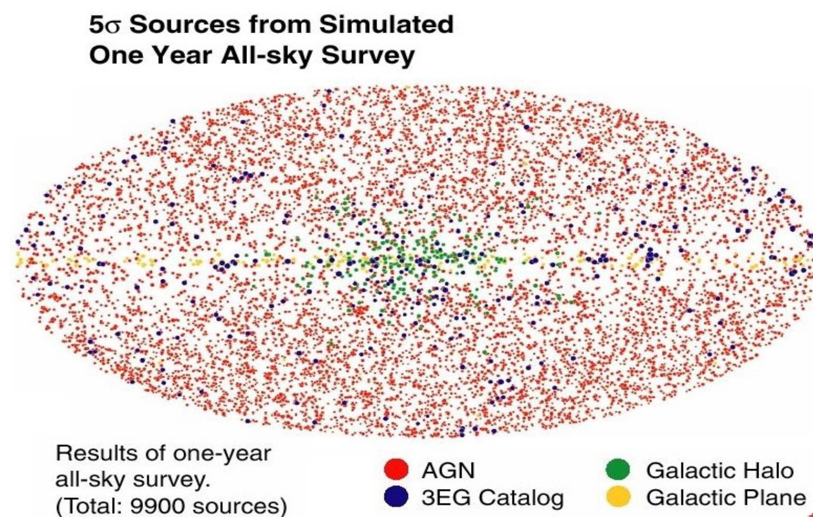
→ vastly different numbers,
but significantly larger for the already established source populations

# Gamma Ray Blazars

- The EGRET context
  - Discovered flaring from > 60 AGN
    - BL Lacs and FSRQs, Cen A
    - Radio loud, jet orientation
  - Highly variable
    - Timescale ~ day, but limited by sensitivity,
  - Multiwavelength variability
  - Note: now there are more than a dozen blazars at TeVs

- GLAST expectation
  - Predict detection of several thousand blazars
    - Population studies!
  - Sensitivity to monitor variability on hour timescales from bright flares
    - Time resolved spectra from 20 MeV to a few hundred GeV

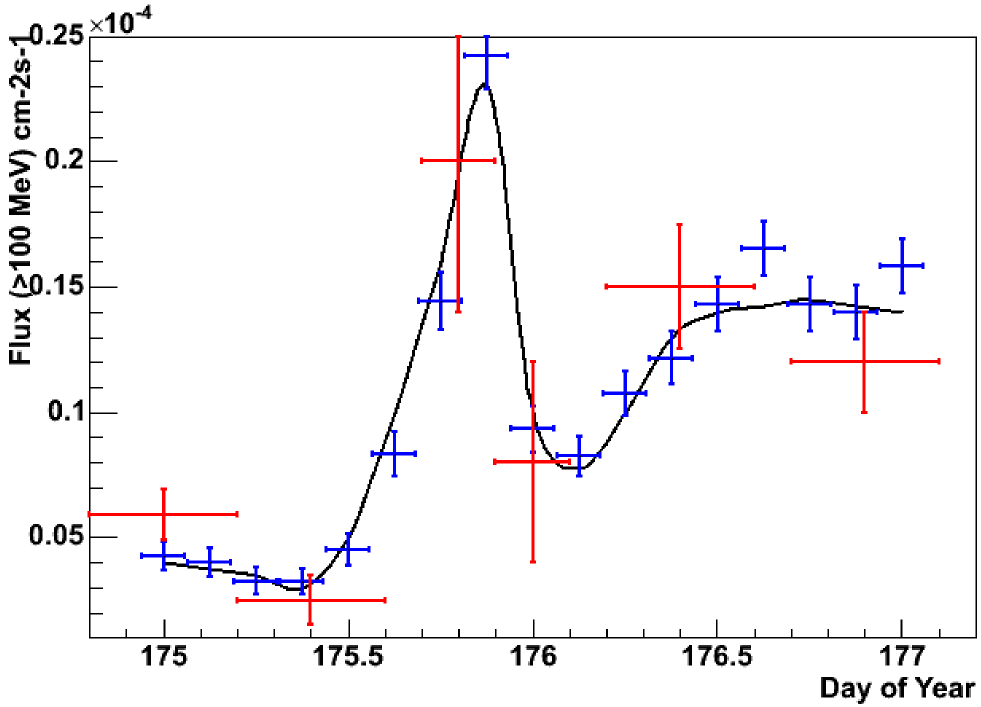


# Flares and variability

Larger effective area translates immediately into shorter variability timescales.

A ***photon, not background*** limited detector → bunches, patterns will matter

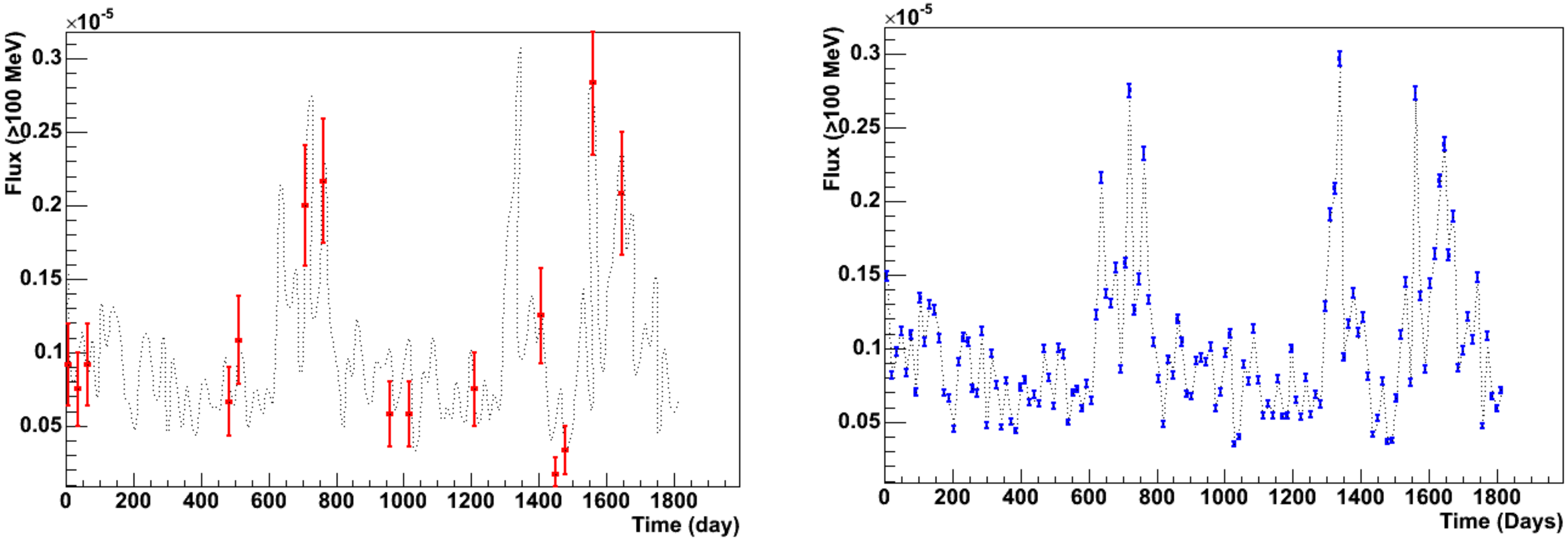



EGRET observations (red points) of a flare from PKS 1622-297 in 1995 (Mattox et al), the black line is a lightcurve consistent with the EGRET observations, and the blue points are simulated LAT obs.

**The LAT will detect a flare like this from any location in the sky at any time!**

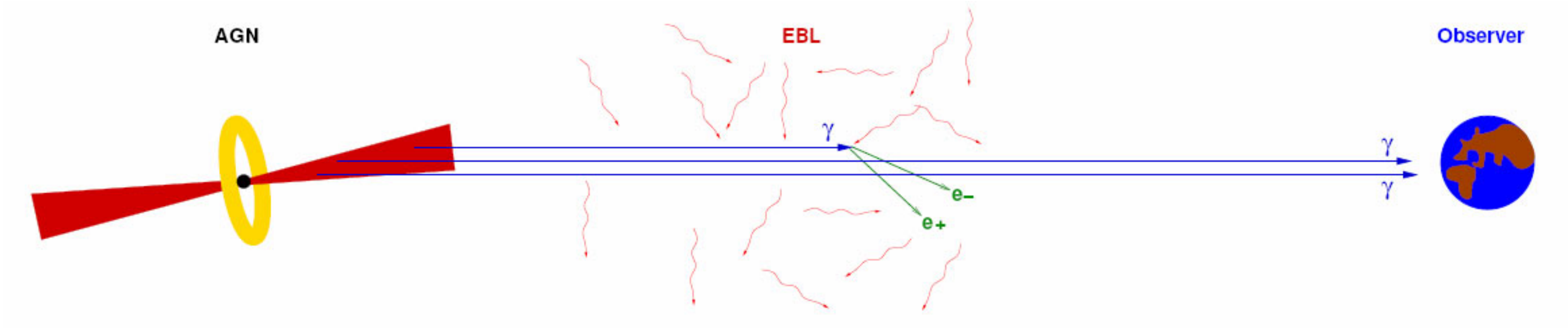
# Flares and variability

Simulated 5 year AGN lightcurve with simulated EGRET **(red)** and LAT **(blue)** observations (underlying power-law density spectrum was chosen to be consistent with that derived from X-ray observations of HBL – to avoid excitement as for 3C279).




- LAT will provide uniform (= unbiased) sampling of the lightcurves of a large number of gamma-ray bright objects on a wide range of timescales.
- Gamma-ray data will be available for all objects in the sky, MWL campaigns involving GLAST will be limited only by the ability to coordinate the observations at **other** wavebands.

# Probing Extragalactic Background Starlight with Blazars




- *diffuse EBL contains unique information about the epochs of formation and the evolution of galaxies*
- *direct EBL measurements require accurate model-based subtraction of bright foregrounds (e.g., zodiacal light)*
- *alternative approach: extract imprint of EBL absorption, as function of redshift, from high-energy spectra of extragalactic sources*

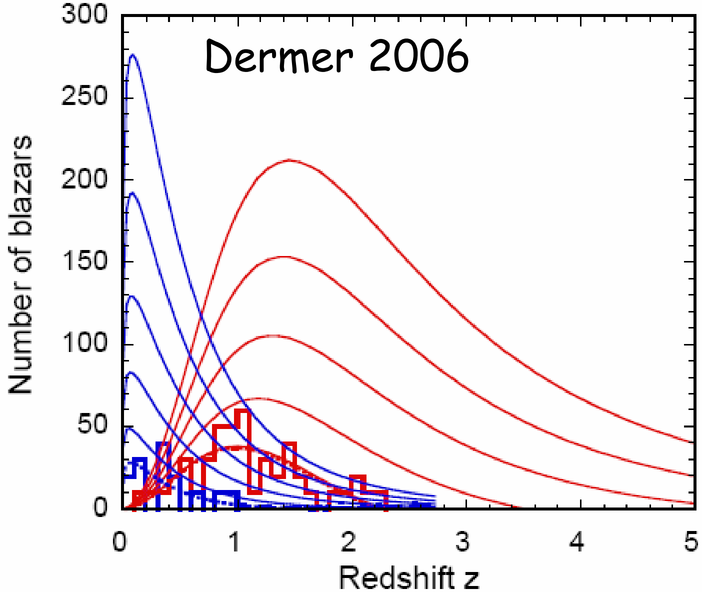
$\gamma\gamma \rightarrow e^+e^-$ , *maximum when*

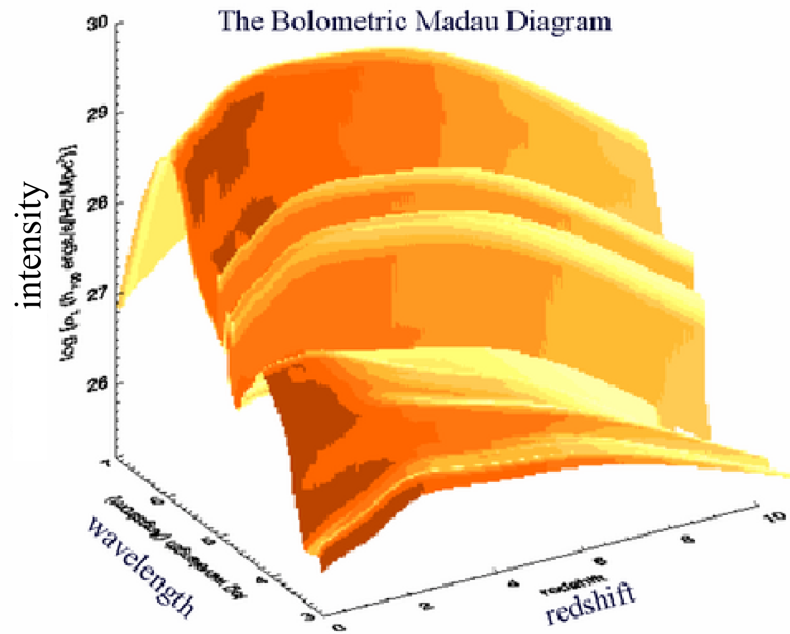
$$\varepsilon_{\mathrm{EBL}} \cong 2.94 \frac{m_e^2 c^4}{E_\gamma} \sim \frac{3}{4} \frac{1000\ \mathrm{GeV}}{E_\gamma}\ \mathrm{eV}$$

# Probing Extragalactic Background StarLight with Blazars

- measure the redshift dependence of the EBL as a function of redshift and wavelength
- GLAST will sample high-z blazars

**sensitive to optical-UV EBL**



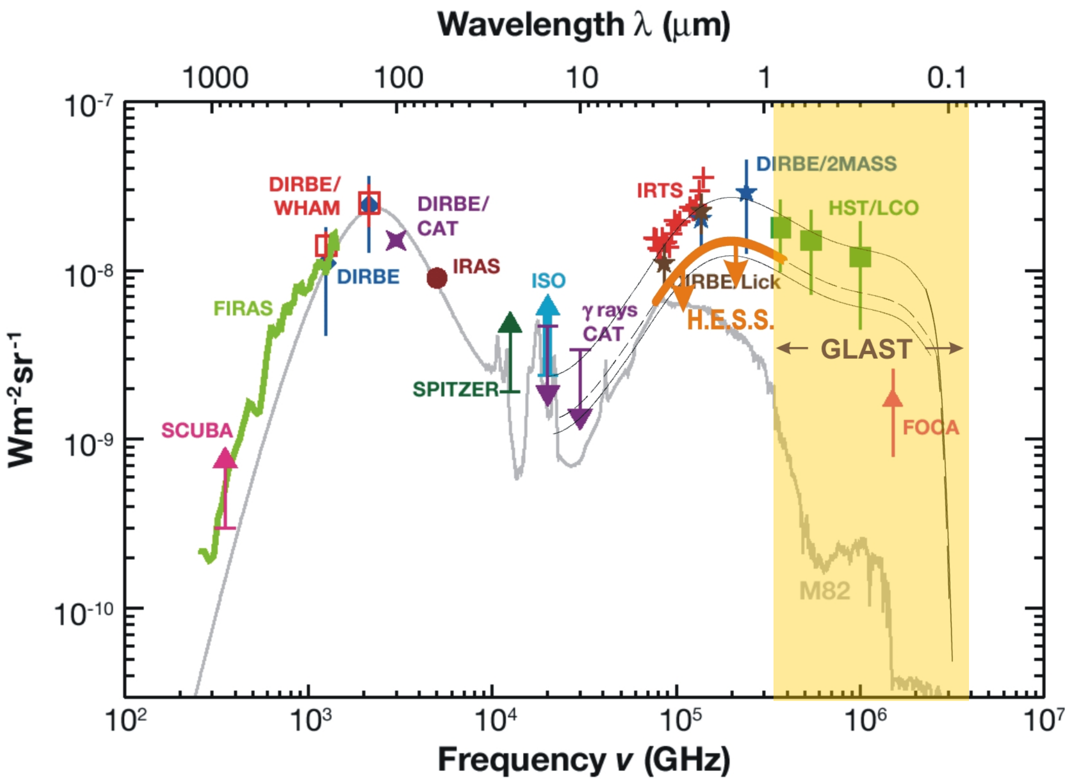

*70% of EGRET sources (|b|>10°) are blazars*

*4.8 GHz radio survey; chose bright flat-spectrum sources*

*95% of radio-selected sources are blazars*

# Contrasts the TeV (HESS) blazar constraints on EBL

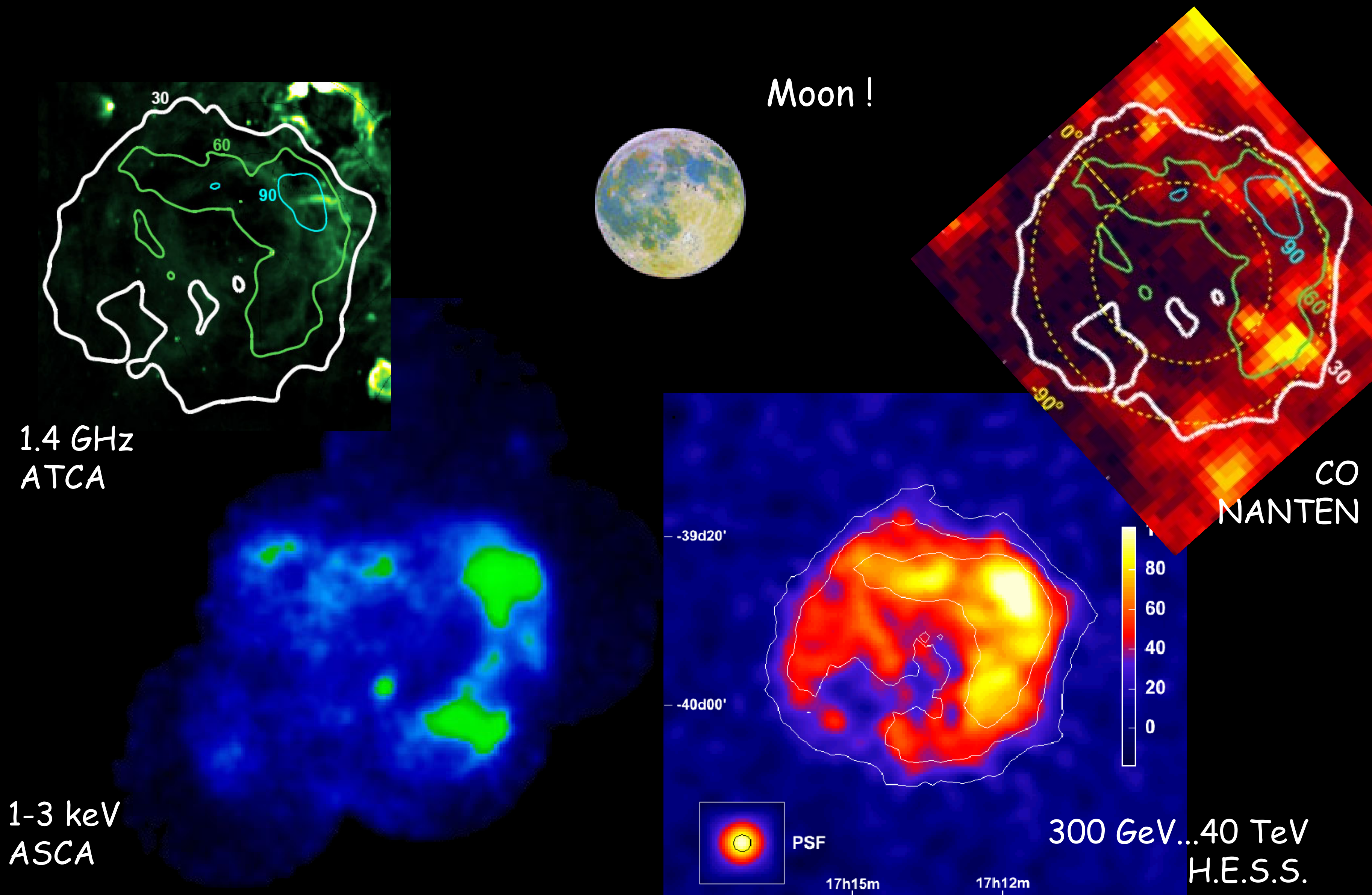
*EBL spectral energy distribution*



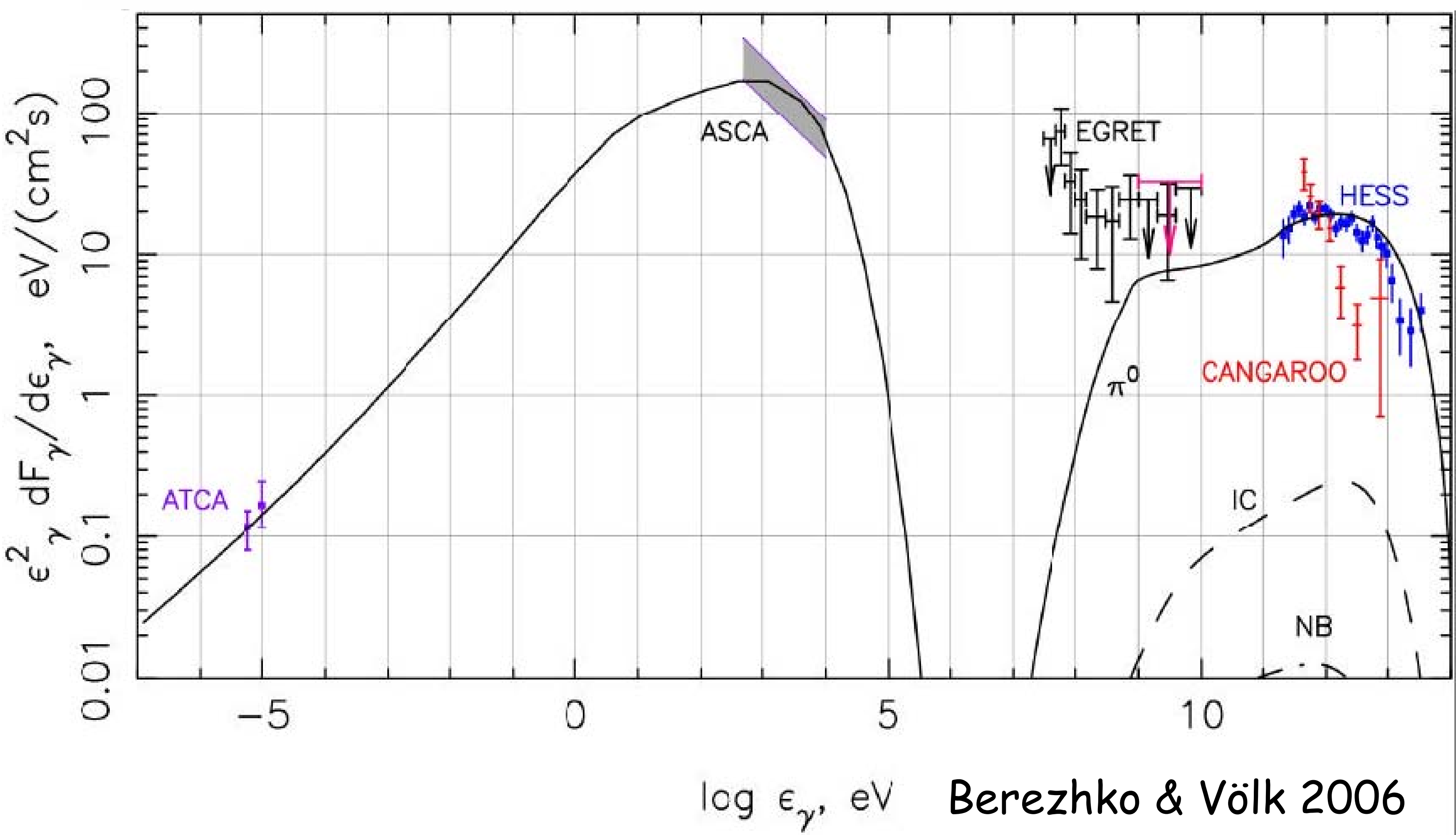

GLAST will continue in studying EBL absorption in the regime of **high-z blazars**, predictably constraining the EBL at sub-μm wavelength

- *lower limits on HST galaxy counts combined with HESS upper limit on EBL imply that any unresolved component is no more than ~1/3 of the total.*

# RXJ1713.7-3946 has become the archetypal SNR in the quest for hadronic particle acceleration

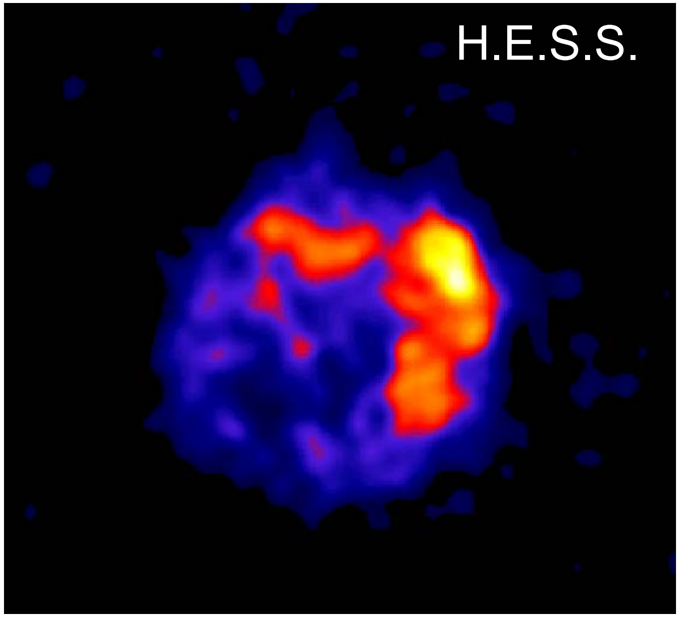


# Where are we now ?



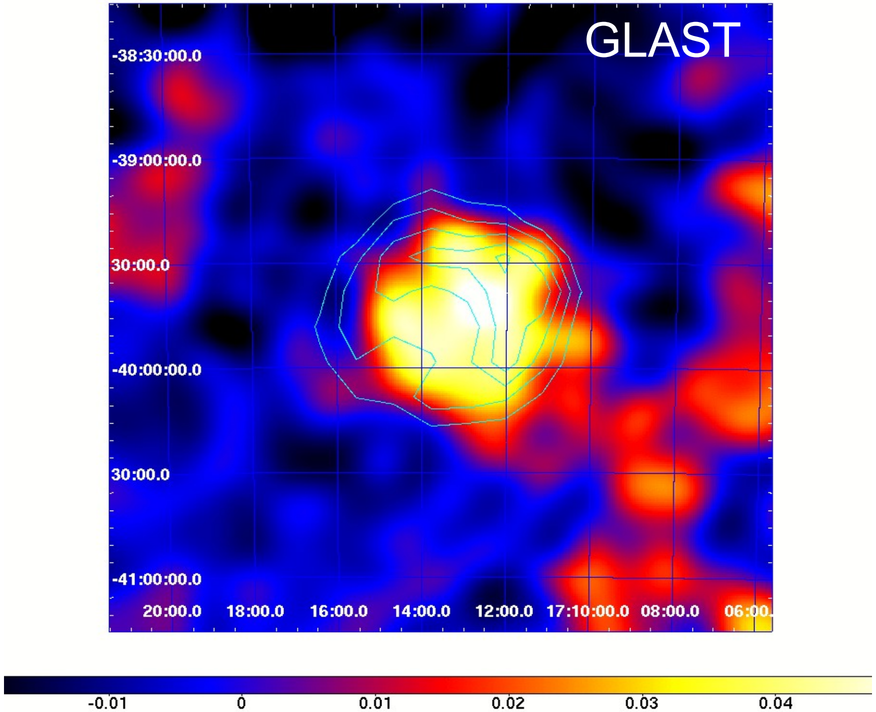

Berezhko & Völk 2006

# Where are we now ?




## GeV-Imaging of RXJ1713?

## Maybe, maybe not



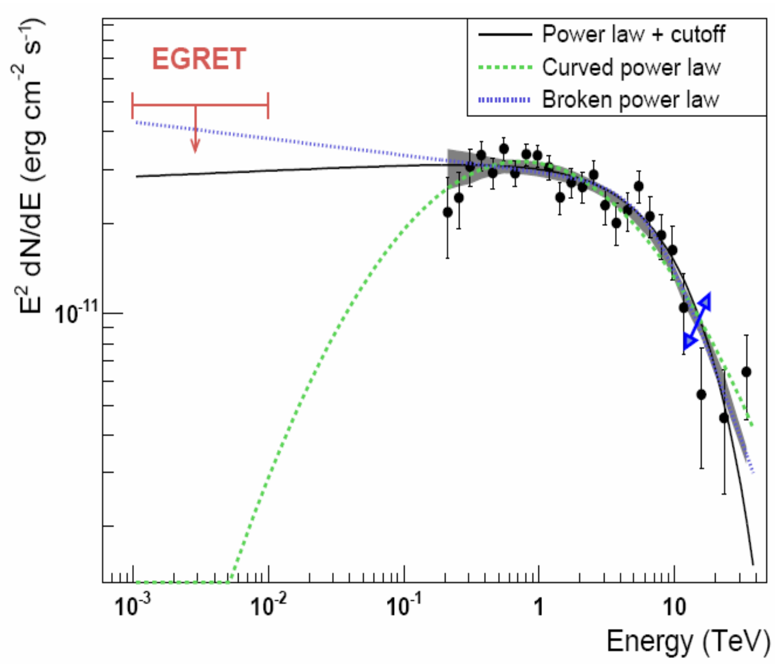

Assumptions on 3EGJ1714 made, underlying: 5 year exposure, E > 3 GeV

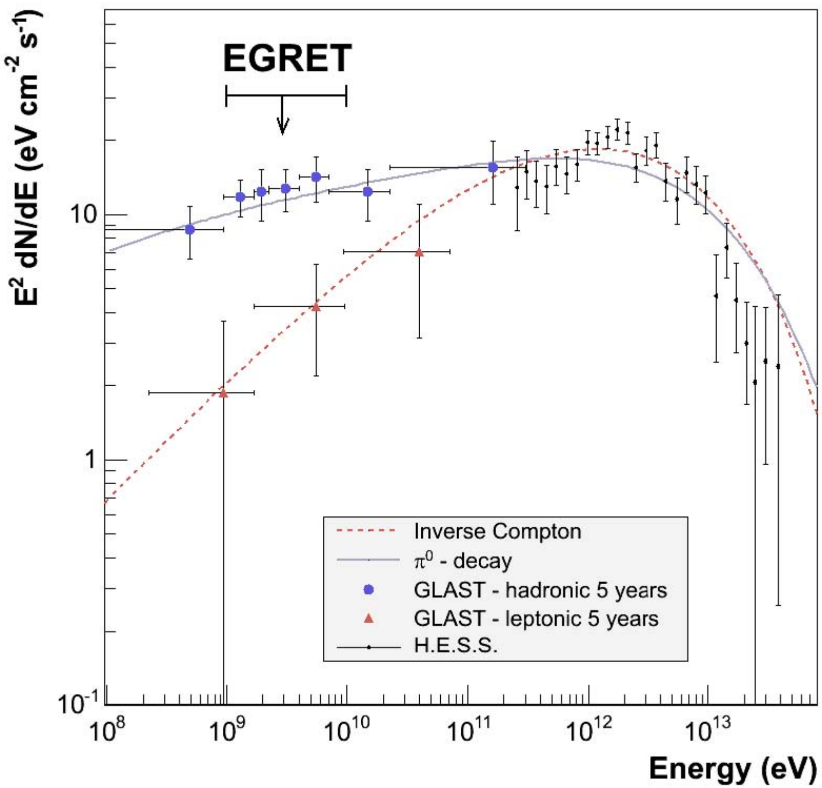
(Funk et al. 2006)

# Where are we now ?

## GeV-Spectrum of RXJ1713?

## Yes (in b/w perspective)



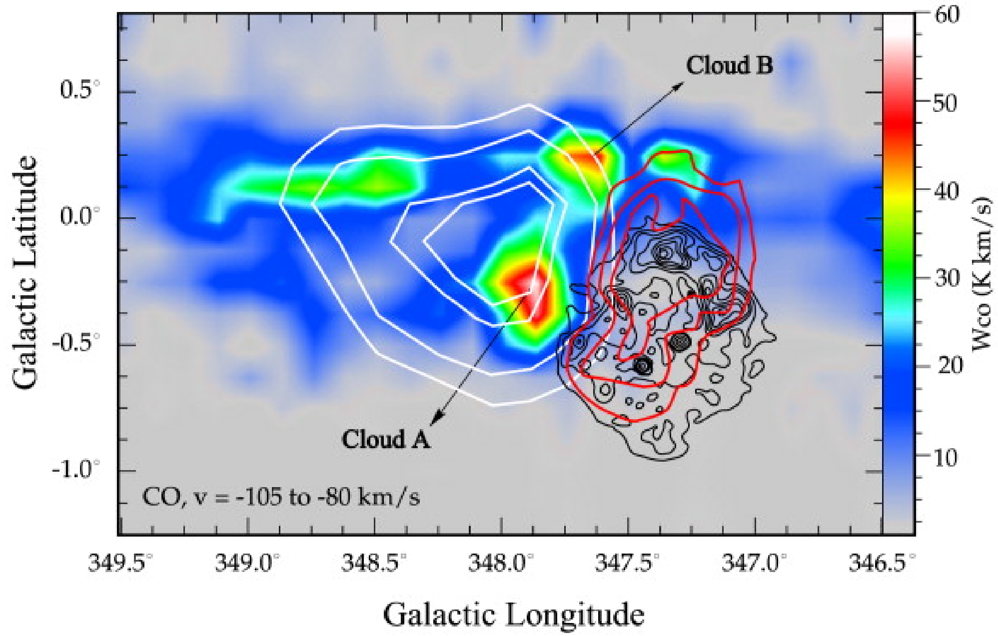



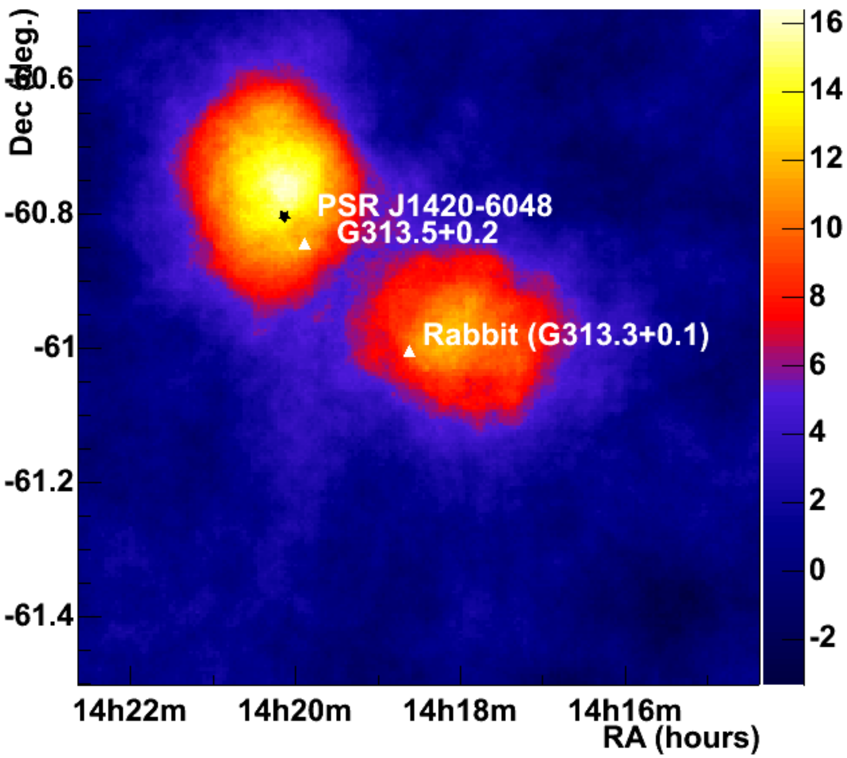
# A guaranteed science case: The remaining freedom in the interpretation of data will be constraint by E < 100 GeV data!

*(a) 3EGJ1714 will be refined/disentangled from RXJ1713.*
→ Molecular Cloud interaction → CfA & Nanten CO surveys

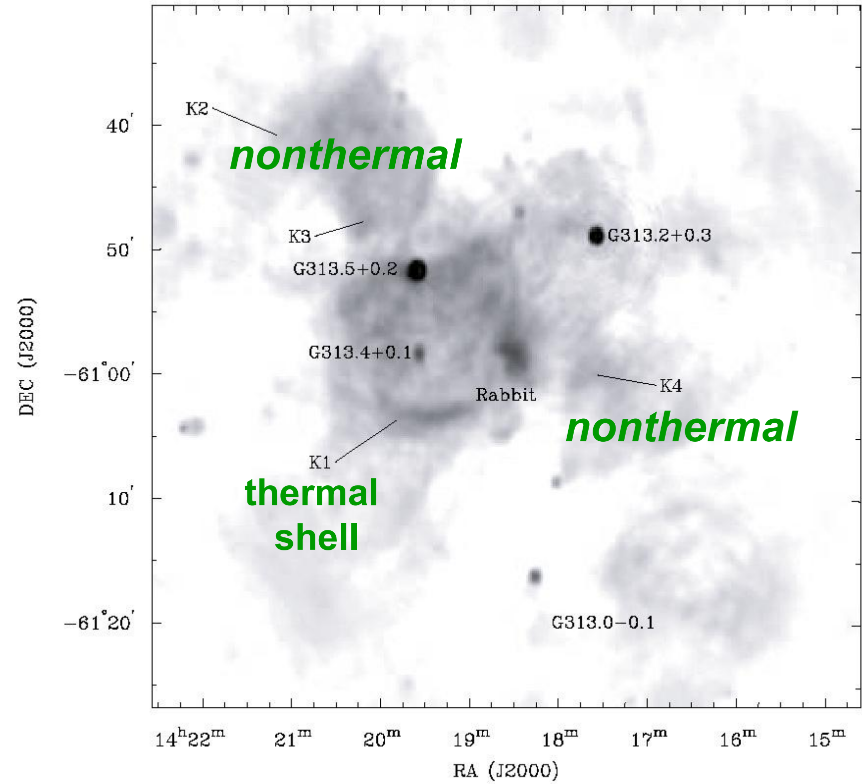
(b) GeV emission from RXJ1713 will be detected or an u.l. will be truly sensitive → *sanity check for the leptonic models/hadronic models* →
**SNR ACCELERATION SITE FOR HADRONS OR NOT ?**

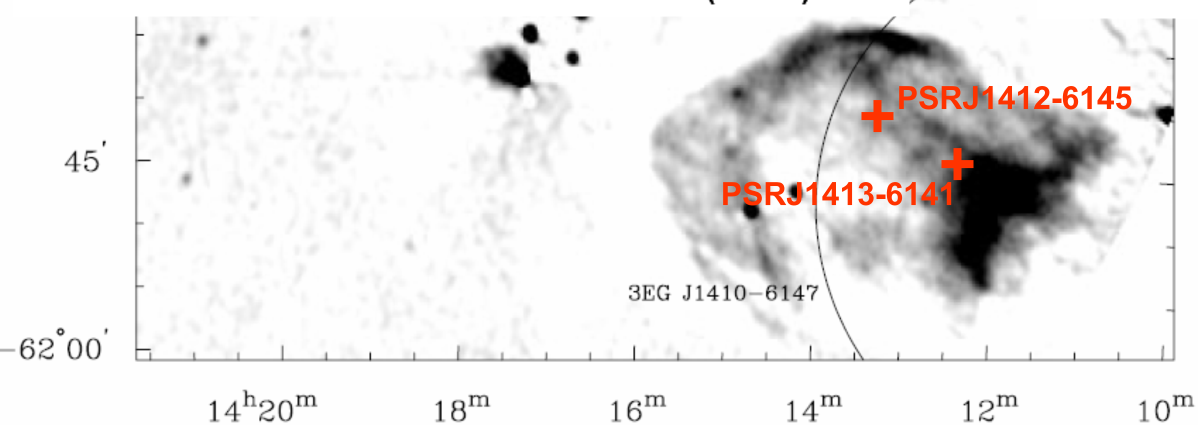
(c) *Nature of **1WGA** J1713.4-3949 ?* Compact object? Progenitor??





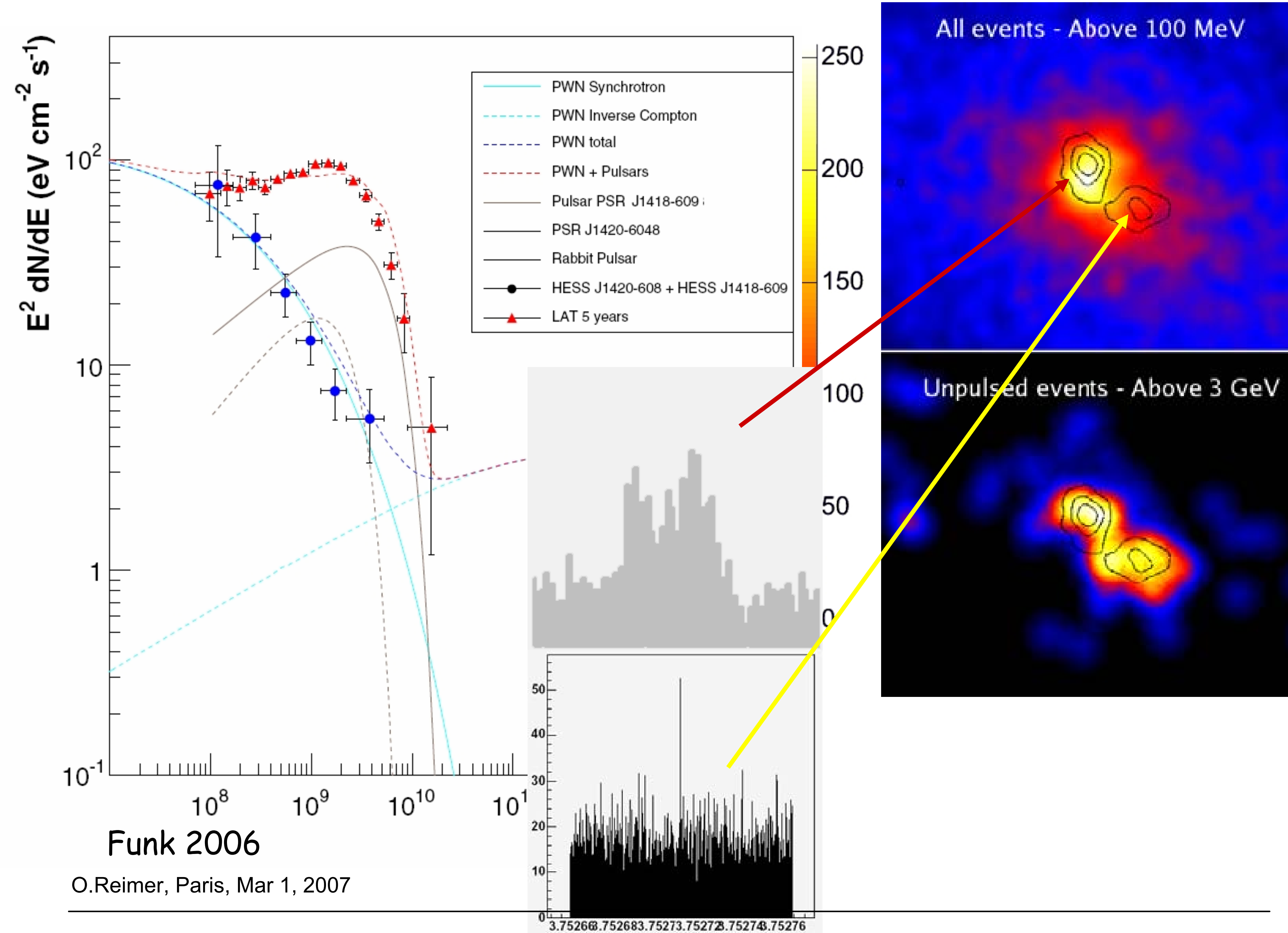

*ATCA 20 cm*




The case of a prime PSR/PWN connection

# It has it all (for performance studies conc. galactic objects)!

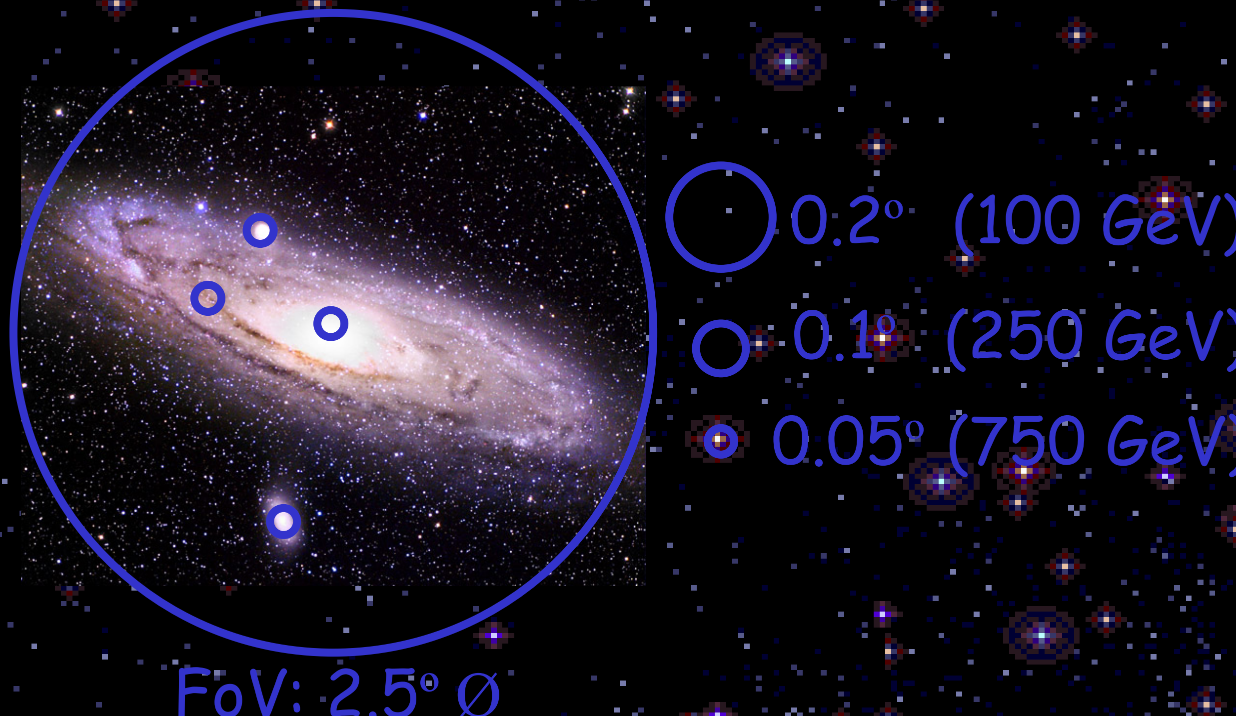


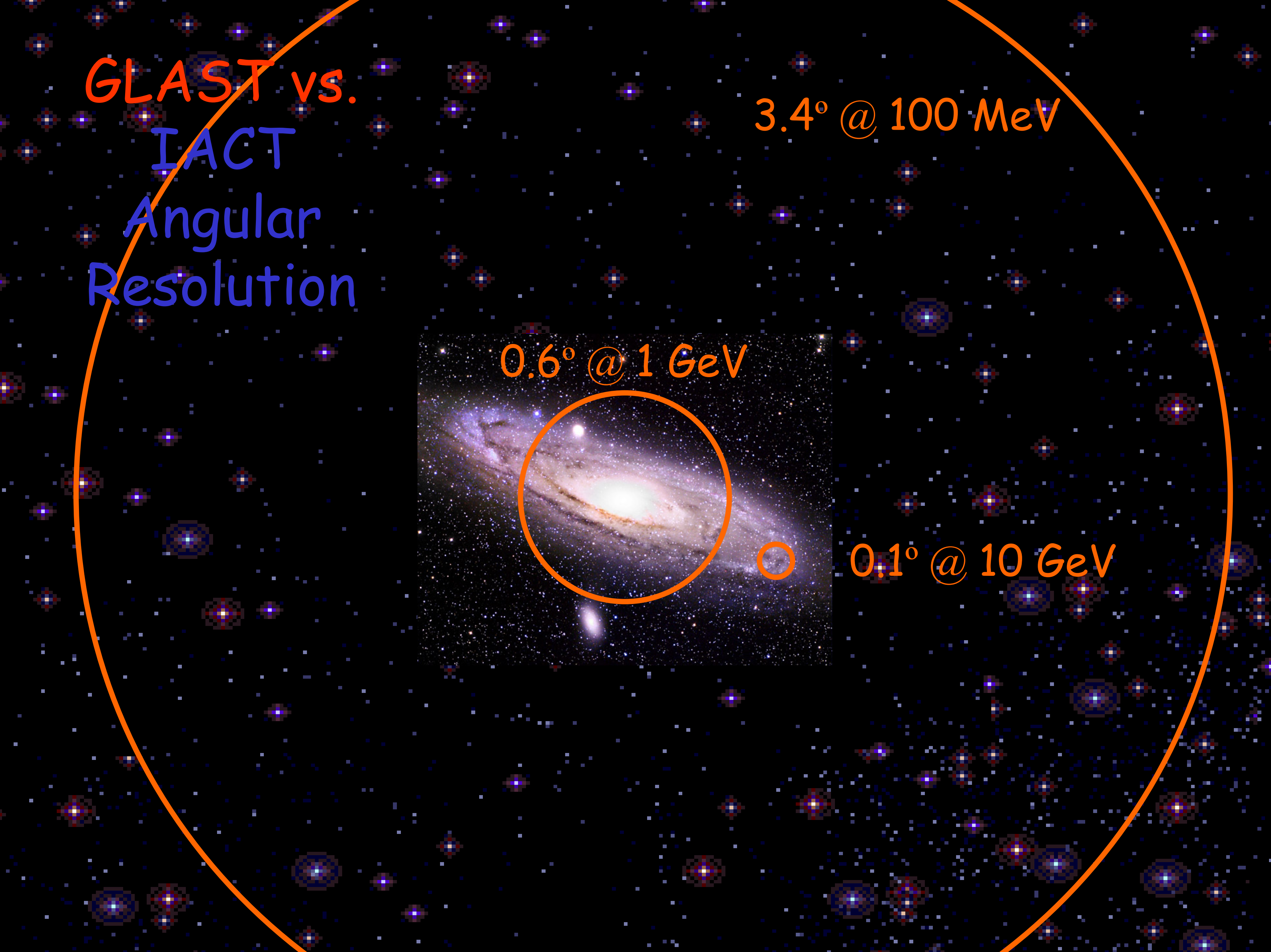
# GLAST vs. IACT Angular Resolution

..towards extended extragalactics

(be it local group, starburst galaxies or galaxy clusters)

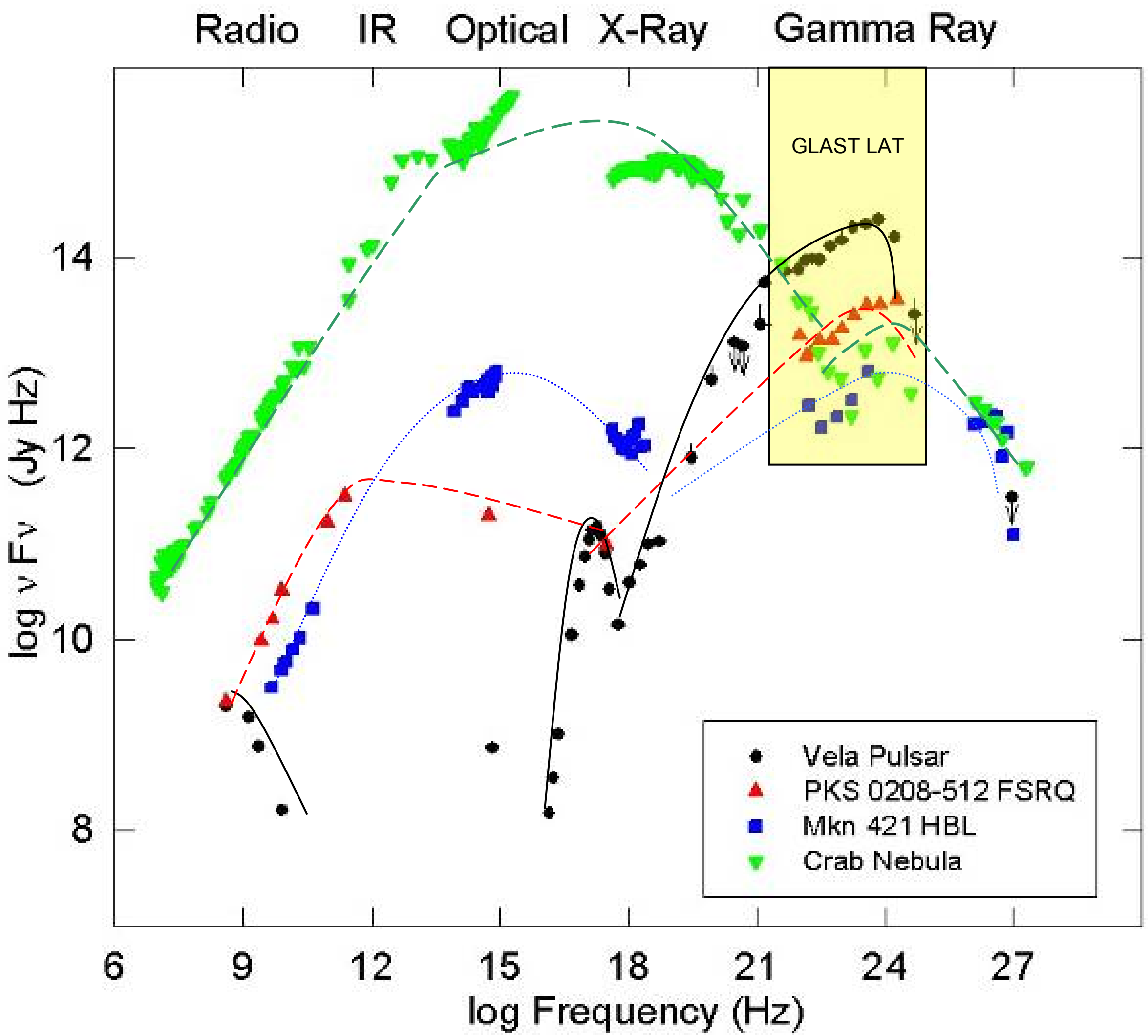
# GLAST vs. IACT Angular Resolution




GLAST vs.
IACT
Angular
Resolution
3.4° @ 100 MeV
0.6° @ 1 GeV
0.1° @ 10 GeV

# Gamma-ray Sources: Inherently Multiwavelength

Sources are non-thermal: produced by interactions of energetic particles




- Nature rarely produces mono-energetic particle beams. Broad range of particle energies leads to broad range of photon energies.
  - *example: $\pi^0$ production*
- Charged particles rarely interact by only one process. Different processes radiate in different energy bands.
  - *example: reprocessed IC*
- High-energy particles needed to produce gamma rays can radiate in lower-energy bands as they lose energy.
  - *example: gamma-ray burst afterglows*

# Gamma-Ray Astrophysics 2008+ will decisively benefit from the extended energetic coverage

Lots to be learned from measuring *high energy cutoffs*
(acceleration mechanisms, radiation and magnetic fields at the source)

Ground-based and space based gamma-ray instruments will overlap in energy coverage.

**"the regime of GeV cutoffs"**

GLAST: photon-limited, but best instrumental performance characteristics
ACTs: background-dominated, image reconstruction challenging

**-> "prospects for intercalibration at 50-200 GeVs"**
**-> more beneficial for ACTs than GLAST**

# Gamma-Ray Astrophysics 2008+ will decisively benefit from all-sky coverage: Towards populations!

Questions for CTA-Physics:

- PSRs in cutoff – the brightest PSRs, PSR/PWN systemts are gone!
  Cutoffs at low GeV energies will be addressed by GLAST.
  *What is the fundamental new quality in measuring PSR cutoffs beyond that?*

- VHE-Binaries – LSI 61 303 and LS5039 have COS-B ($10^{-6}$ $cm^{-2}$ $s^{-1}$) and EGRET counterparts ($10^{-7}$ $cm^{-2}$ $s^{-1}$). Only PSR B1259 not (yet).

- INTEGRAL binaries – Do not connect even to the EGRET energies nicely, GLAST will settle this!
  *Even if not each and any individual flare is resolved, the continuous exposure will put this in range (analog to EGRET AGNs).*

**A clear lack: sub-hour time resolution for individual flares at weaker flux levels!**

# Gamma-Ray Astrophysics 2008+ will decisively benefit from observatory status

Questions for CTA-Physics:

- More sensitivity … towards weaker sources ?
  Why? Physics cases in the archetypal sources more valueable!
  The cream of the known sources is gone!

- More sensitivity… angular resolution will aim on what's still unresolved ?
  Construct cases where it matters: CRs (SNRs, Mol. Clouds), IDs

- More sensitivity…what's guaranteed and what's not?
  At a certain sensitivity level, the Galactic diffuse emission problem will hit the ACTs, too – natural complication/limit for the physics case in weaker sources
  In particular the EGDB might be seen only in connection with the Galactic Diffuse.

# Gamma-Ray Astrophysics 2008+ will decisively benefit from unanticipated GLAST discoveries

Questions for CTA-Physics:

- UHECRs point sources (correlation studies), DM clumps in Milky Way halo, dwarf spherical etc. face primarily the problem of unambiguous identification

**A clear lack: sub-arcmin angular resolution for gamma-ray sources will crucial for definitive source identification!**

- DM annihilation lines in 30 – 200 GeV range – gone by then!
  New level of sophistication in modeling the Galactic Diffuse – DM claim at current level (EGRET GeV-excess) gone by then!
  Clarify on offset of GC source in GeV – NFW profiles still applicable by then?

- More sensitivity…what's guaranteed and what's not?