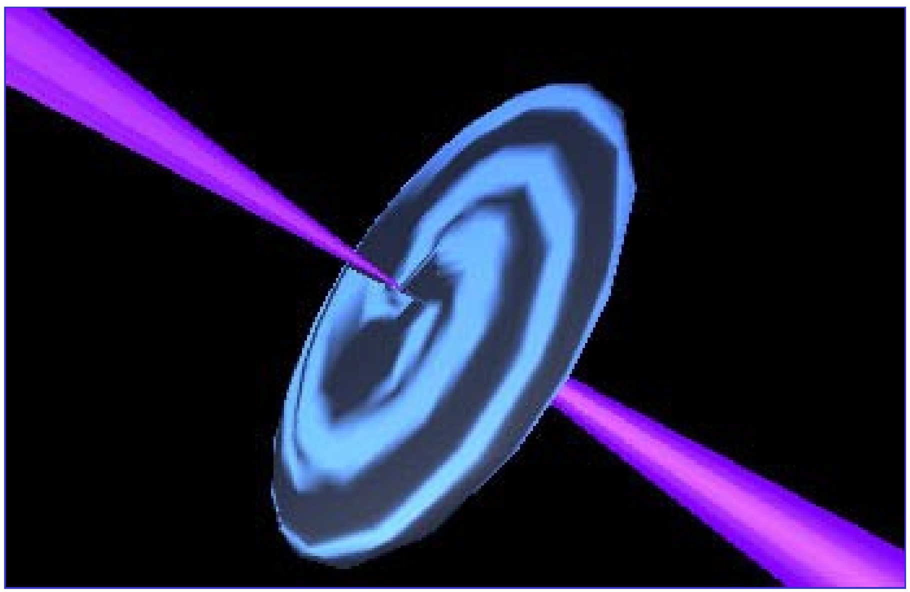
GLAST :

Exploring the High Energy Universe where Particle Physics and Astrophysics Collide



Prof. Lynn Cominsky

Sonoma State University

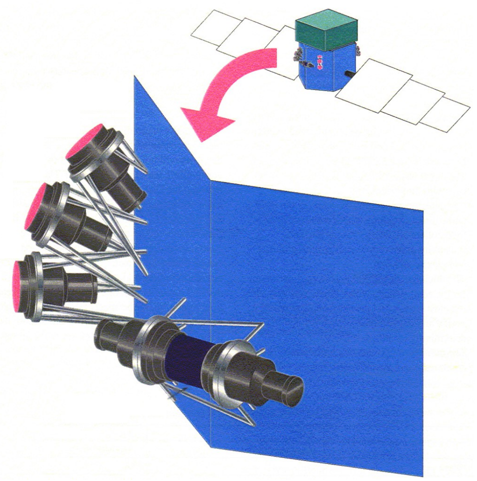
GLAST Education and Public Outreach

Mission

- First space-based collaboration between astrophysics and particle physics communities
- Launch expected in 2006
- First year All-sky Survey followed by…
- Competitive Guest Observer Program
- Expected duration 5-10 years

GLAST Burst Monitor (GBM)

- PI Charles Meegan (NASA/MSFC)
- US-German secondary instrument
- 12 Sodium Iodide scintillators
  - Few keV to 1 MeV
  - Burst triggers and locations
- 2 bismuth germanate detectors
  - 150 keV to 30 MeV
  - Overlap with LAT
- http://gammaray.msfc.nasa.gov/gbm/

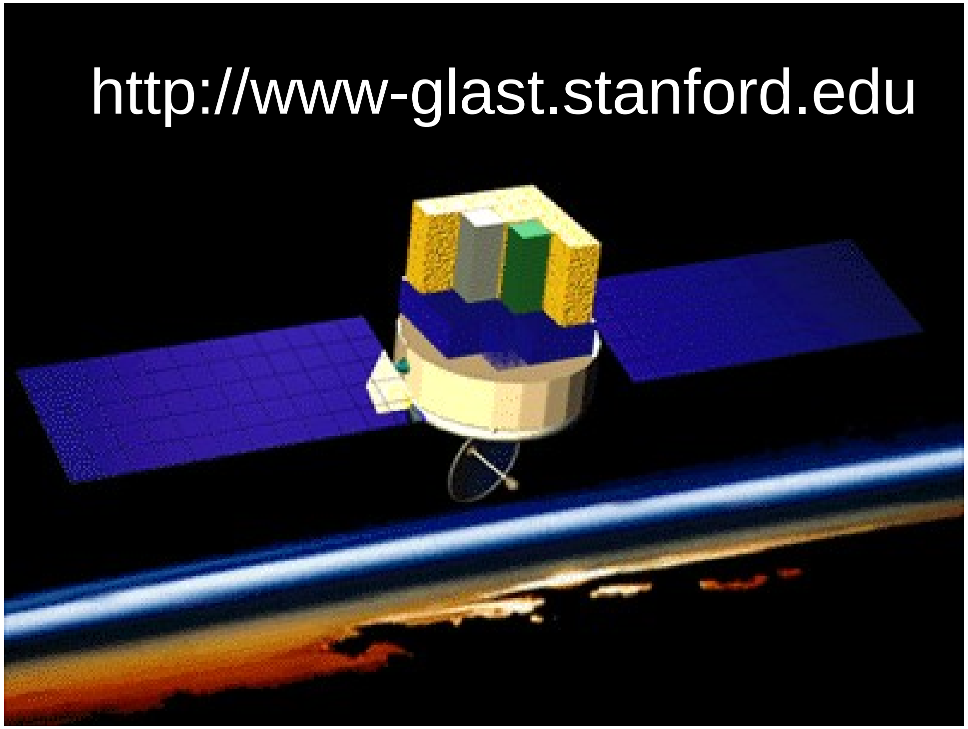


Large Area Telescope (LAT)

- PI Peter Michelson (Stanford)
- International Collaboration: USA NASA and DoE, France, Italy, Japan, Sweden

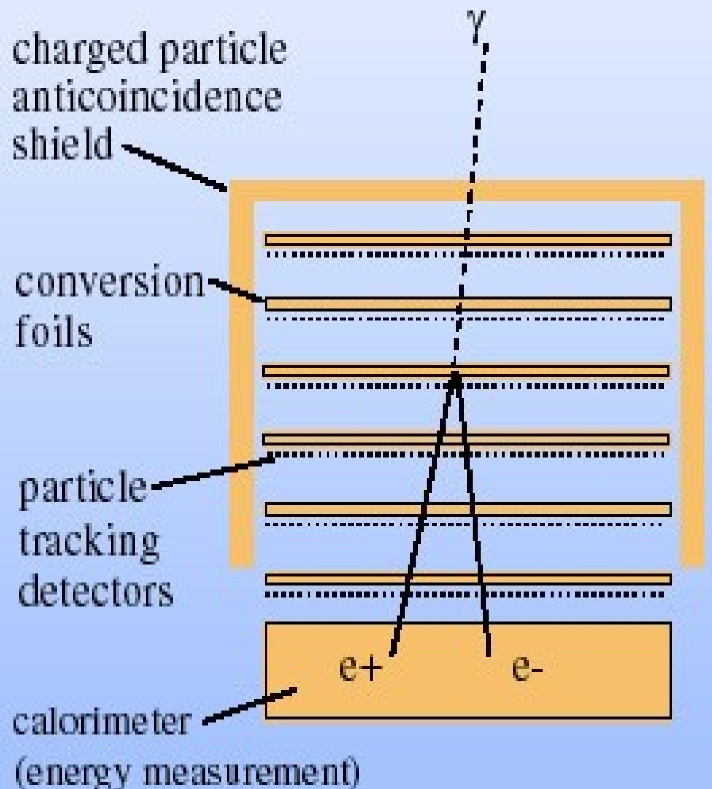
- LAT is a 4 x 4 array of towers

- Each tower is a pair conversion telescope with calorimeter



Pair Conversion Telescope

elements of a pair-conversion telescope



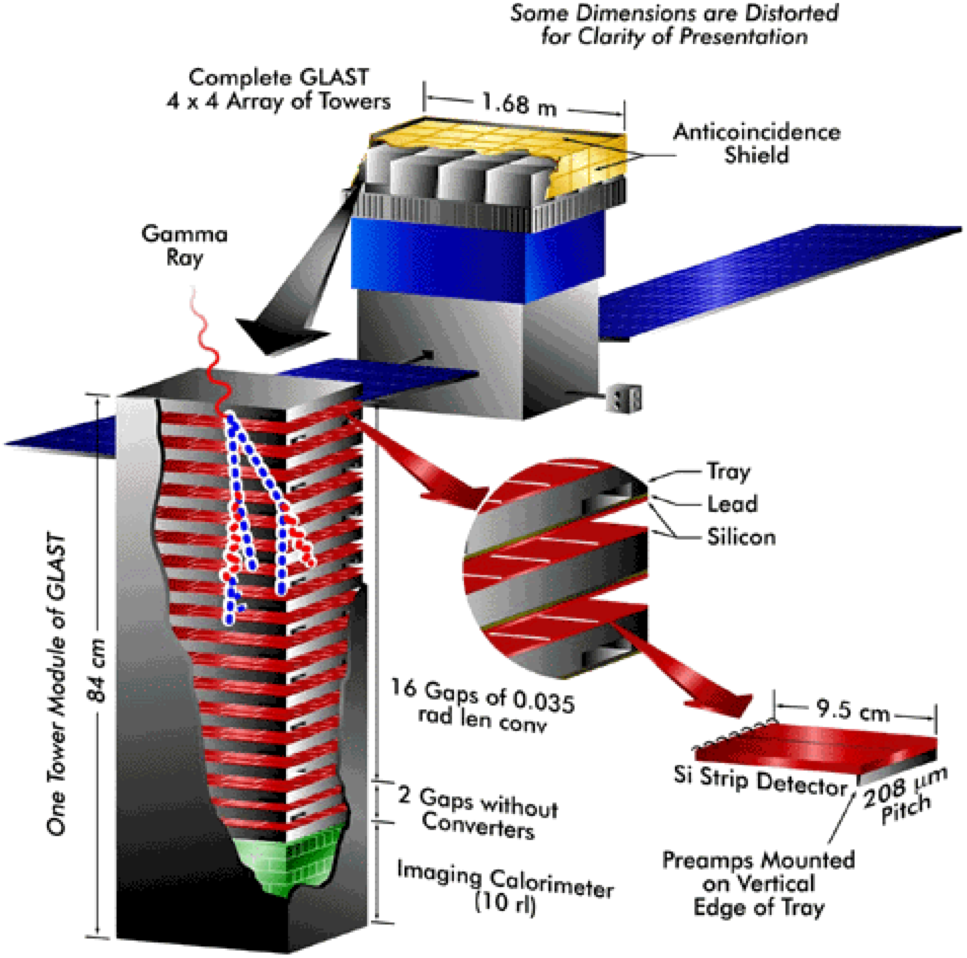
- photons materialize into matter-antimatter pairs:

  $$E_\gamma \text{ --> } m_{e+}c^2 + m_{e-}c^2$$

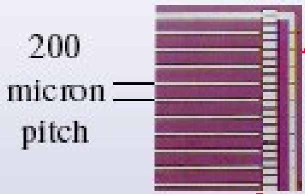
- electron and positron carry information about the direction, energy and polarization of the γ-ray

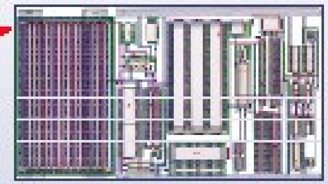
LAT Schematic

- Tiled Anticoincidence Shield
- Silicon strip detectors interleaved with Lead converter
- Cesium Iodide hodoscopic calorimeter



New Technologies



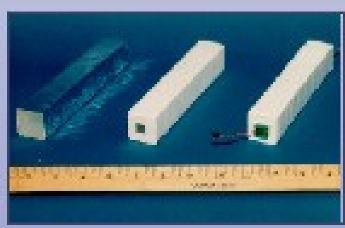


Low-Power Megachannel VLSI Readout Electronics

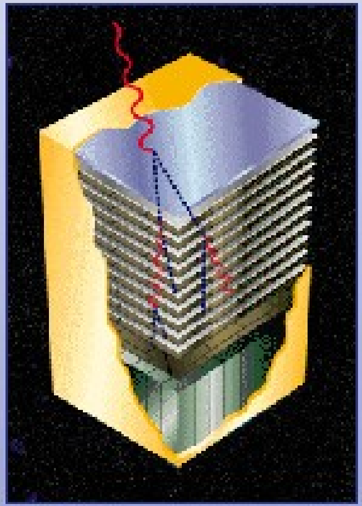
CHALLENGES:

- Largest silicon strip detector array ever assembled (1.5 million channels from total of 90 m^2 of silicon detectors)
- On-board data system sophistication: distributed, adaptable, programmable trigger

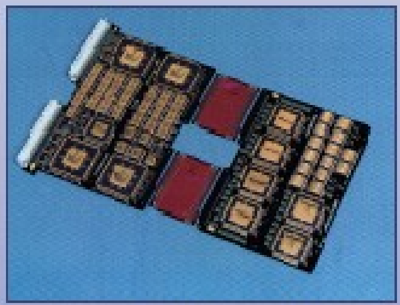
Silicon Strip Detector Tracker Plane



Cesium Iodide Imaging Spectrometer Elements



GLAST Telescope Module



32-bit Radiation-Hard Processor

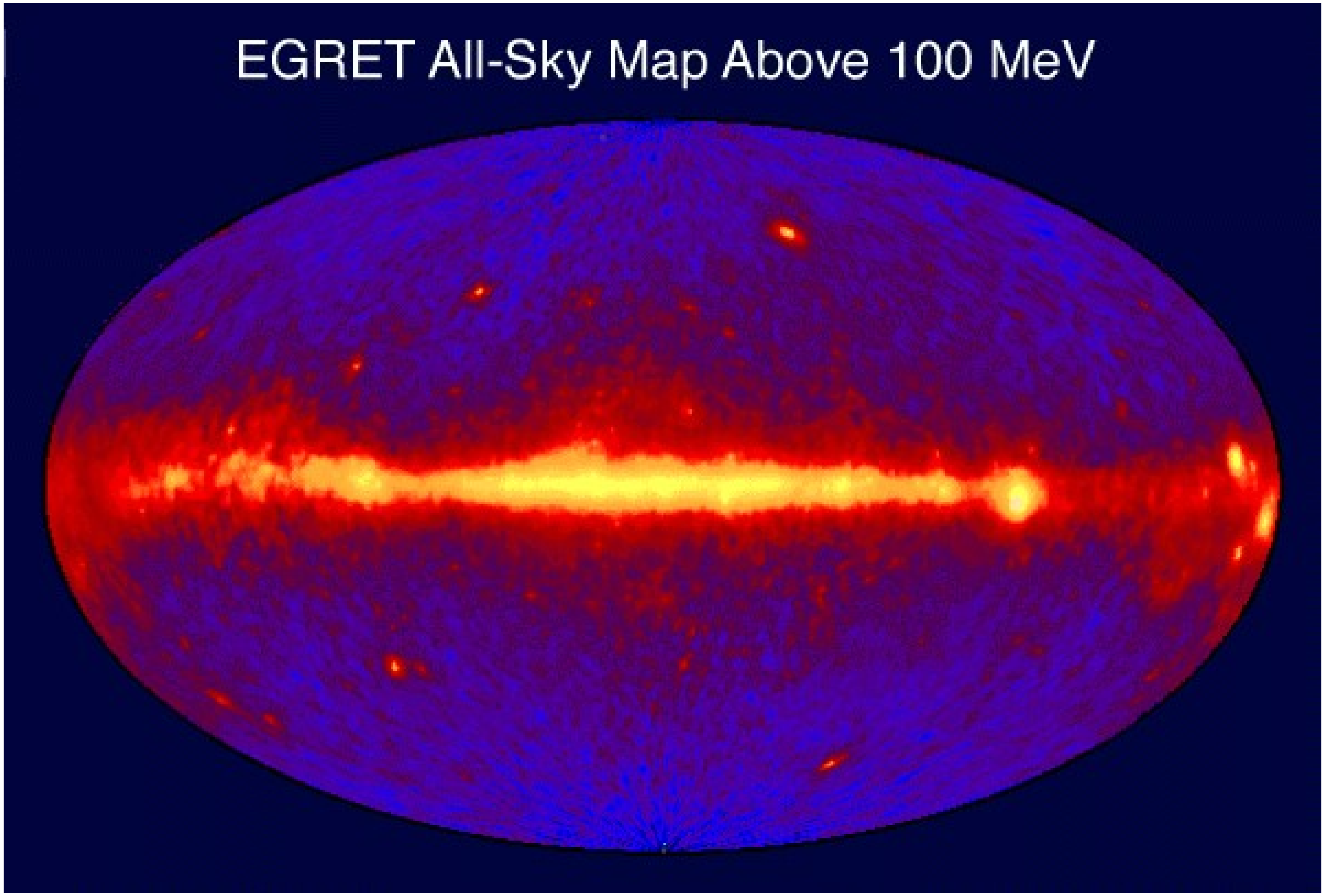
EGRET vs. GLAST LAT

	EGRET	GLAST LAT
Energy Range	20 MeV - 30 GeV	20 MeV -300 GeV
Energy Resolution	10%	10%
Effective Area	1500 cm^2	8000 cm^2
Field of View	0.5 sr	> 2 sr
Angular Resolution	5.8^o @ 100 MeV	~ 3^o @ 100 MeV
		~ 0.15^o > 10 GeV
Sensitivity	~ 10^{-7} cm^{-2} s^{-1}	<6 x 10^{-9} cm^{-2} s^{-1}
Source Location	5 - 30 arcmin	0.5 - 5 arcmin
Lifetime	1991 - 1997	2006 - 2011

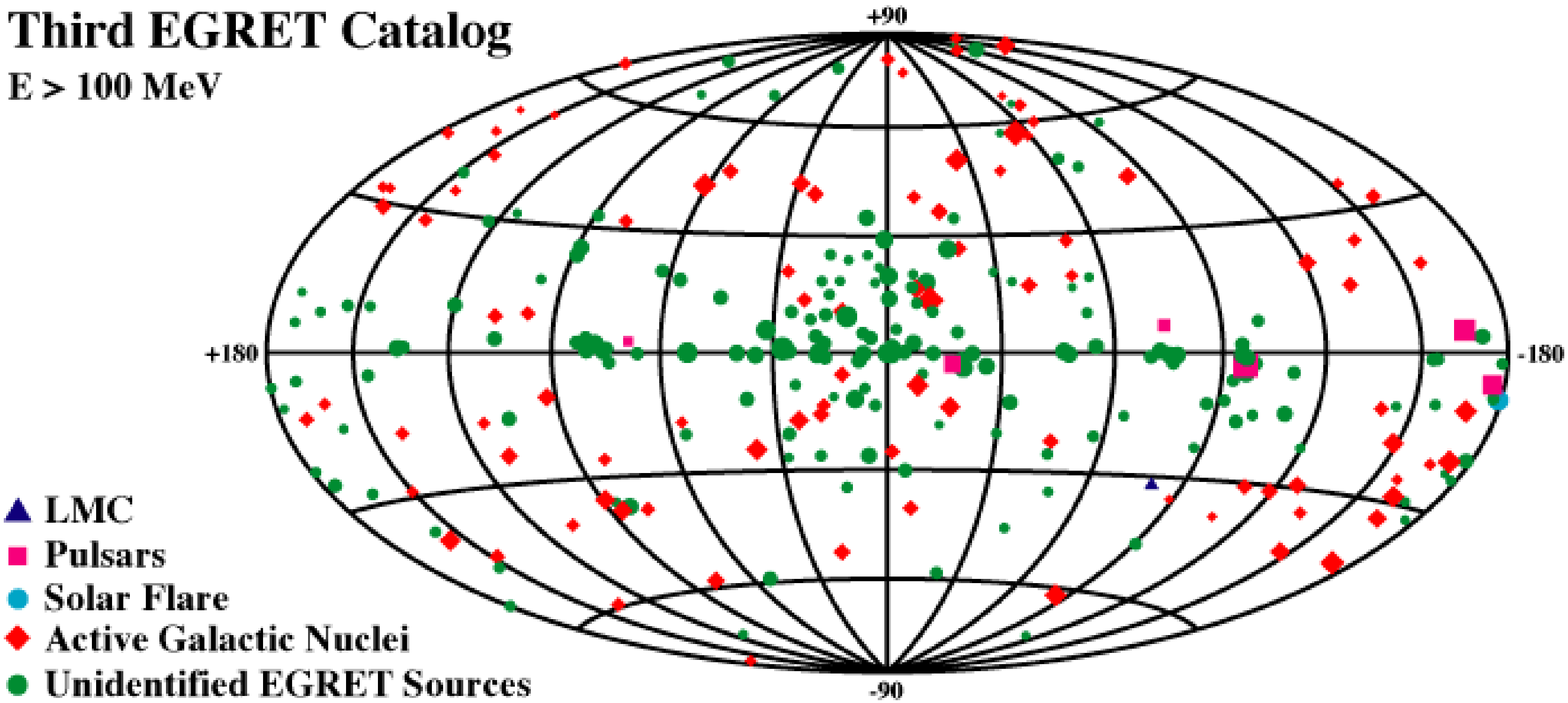
EGRET's Legacy

- Established blazars as largest class of extra-galactic γ-ray emitters
- Observed many blazar flares, some <1 day
- > 60% of ~270 sources are unidentified
- Measured extra-galactic γ-ray background
- Discovered gamma-rays from 4 pulsars
- Showed $E<10^{15}$ eV cosmic rays are galactic
- Detected solar flares and some γ-ray bursts at E>1 GeV

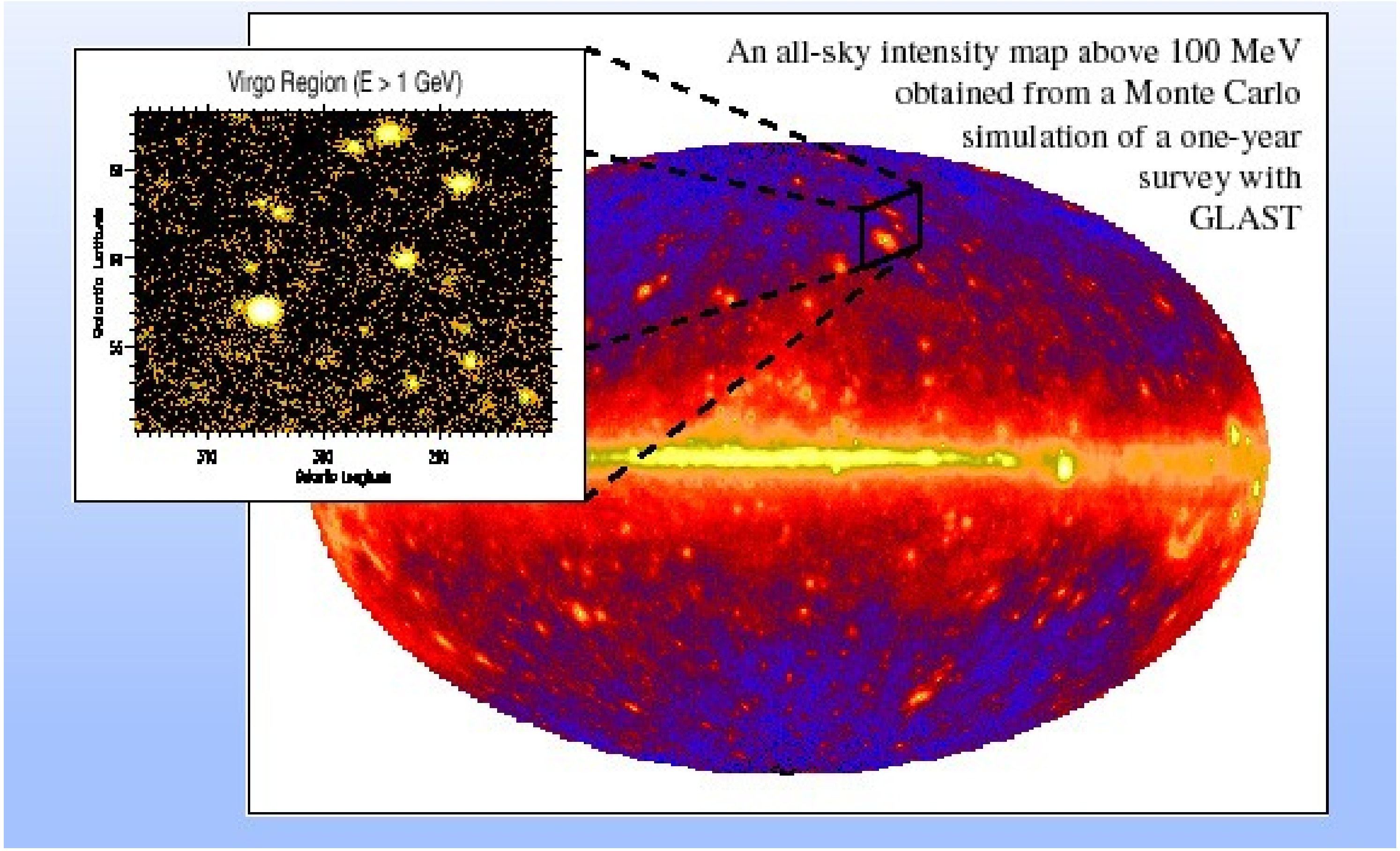
EGRET All-Sky Map



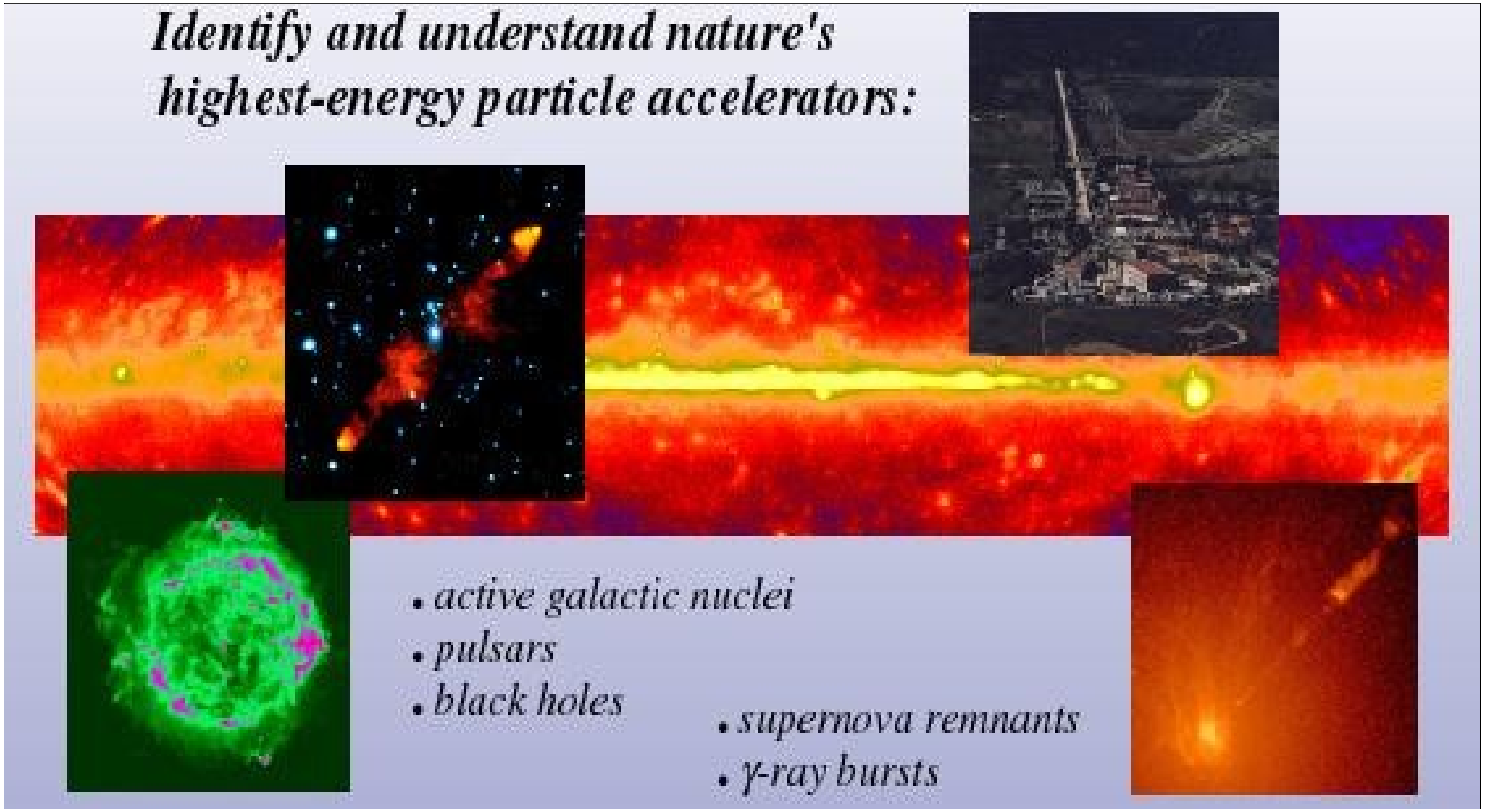
3rd EGRET Catalog



Simulated LAT all-sky map

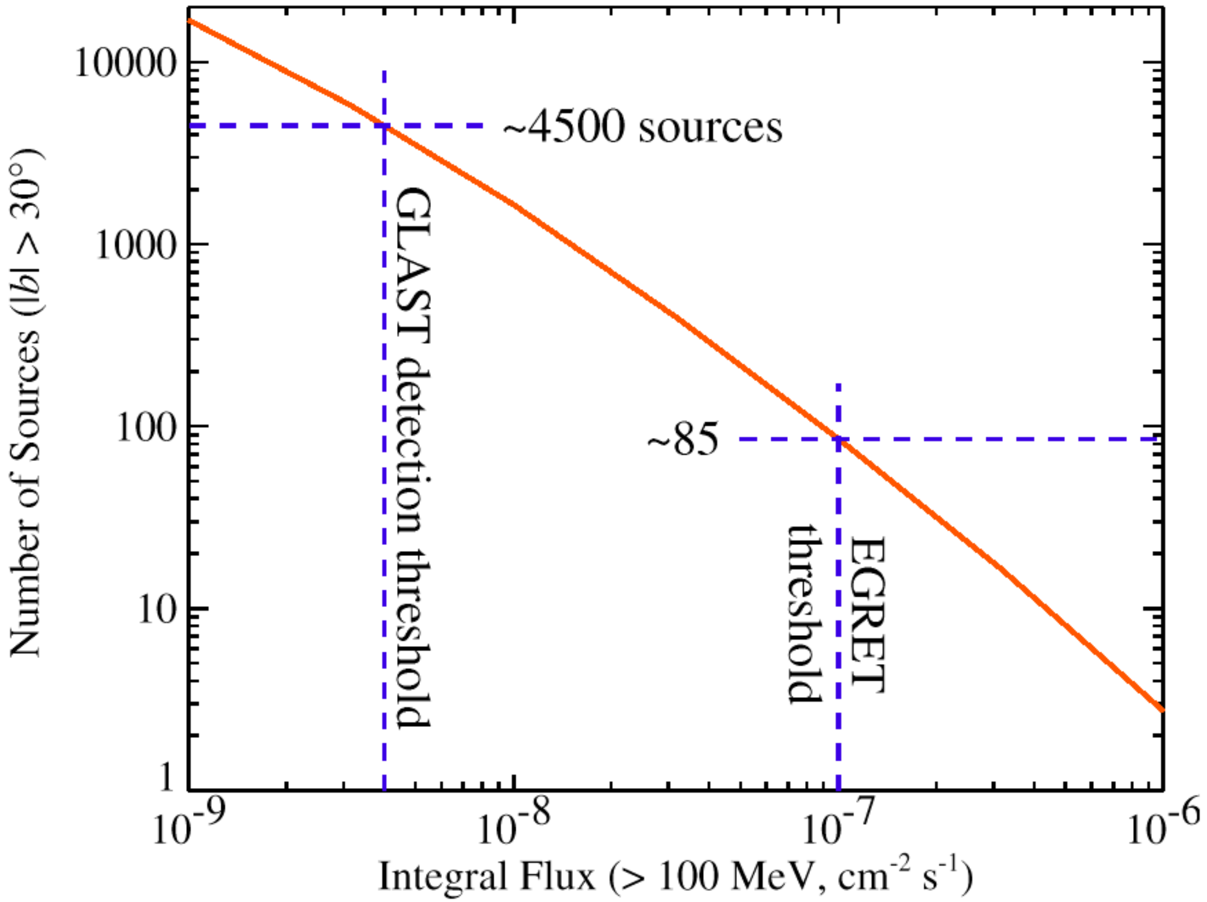


LAT Science Overview



LAT Log N vs. Log S

LAT should detect thousands of gamma-ray sources



Unidentified Sources

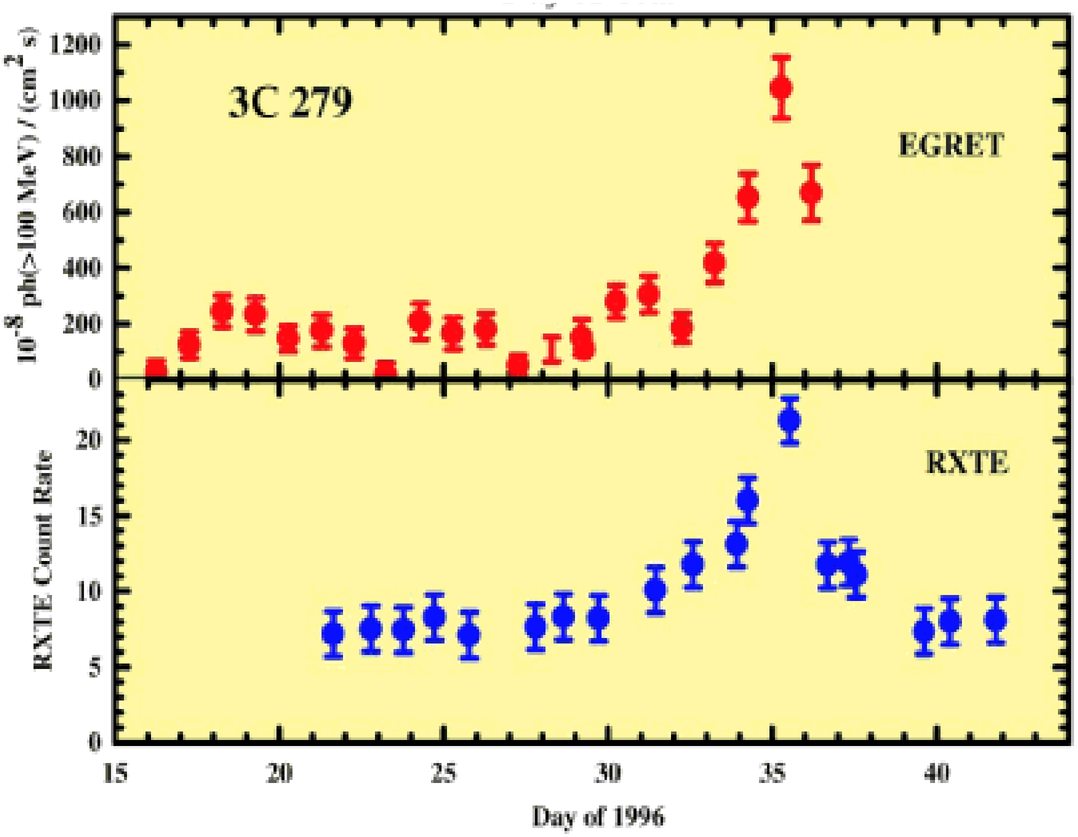
- 170 of the 270 sources in the 3rd EGRET catalog have no counterparts at longer wavelengths
- Variable sources appear at both low and high galactic latitudes
- High-latitude sources appear to be both extra-galactic and galactic
- Steady medium latitude sources may be associated with Gould’s belt (star forming region)

Possible Unidentified Sources

- Radio-quiet pulsars: Geminga-like objects can be found with direct pulsation searches
- Previously unknown blazars: flaring objects will have good positions, helping IDs
- Binary systems: shocked winds between companions will show time variability
- Microquasars: time variability, X/γ correlation
- Clusters of galaxies: steady, high-latitude sources should show shock spectra

EGRET Blazars

- 3C279 is brightest AGN at high energies
- Multi-wavelength coverage essential to understand flare mechanism



Blazar questions/LAT Answers

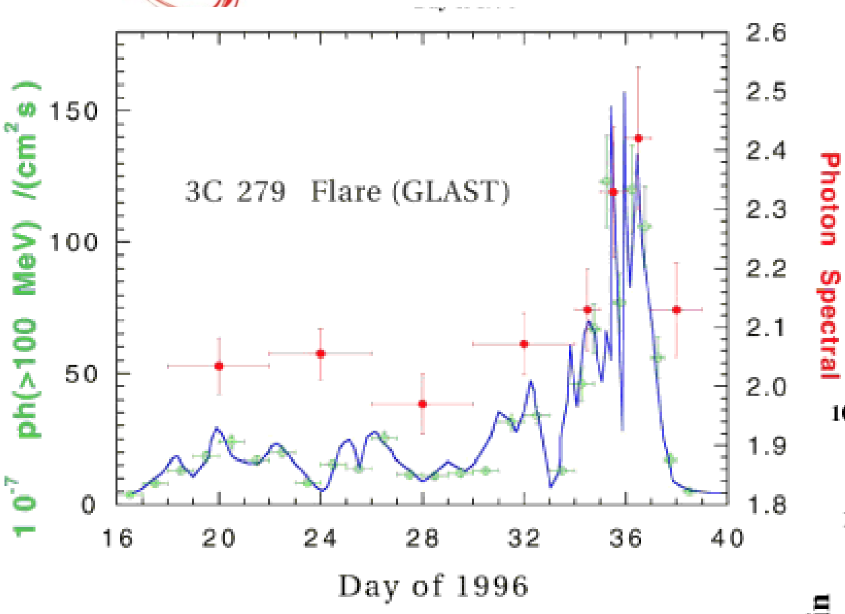
- Where are the acceleration and emission sites in blazar jets? Multi-wavelength campaigns from radio to TeV
- How do galaxies "cool their jets"? Study X/γ
- Are jets leptonic or hadronic? Study H-α/γ to distinguish between leptonic models. Study X/γ to distinguish leptonic/hadronic models

→ *All require energy and time-resolved spectra of blazars during flares and quiescence*

Blazar questions/LAT Answers

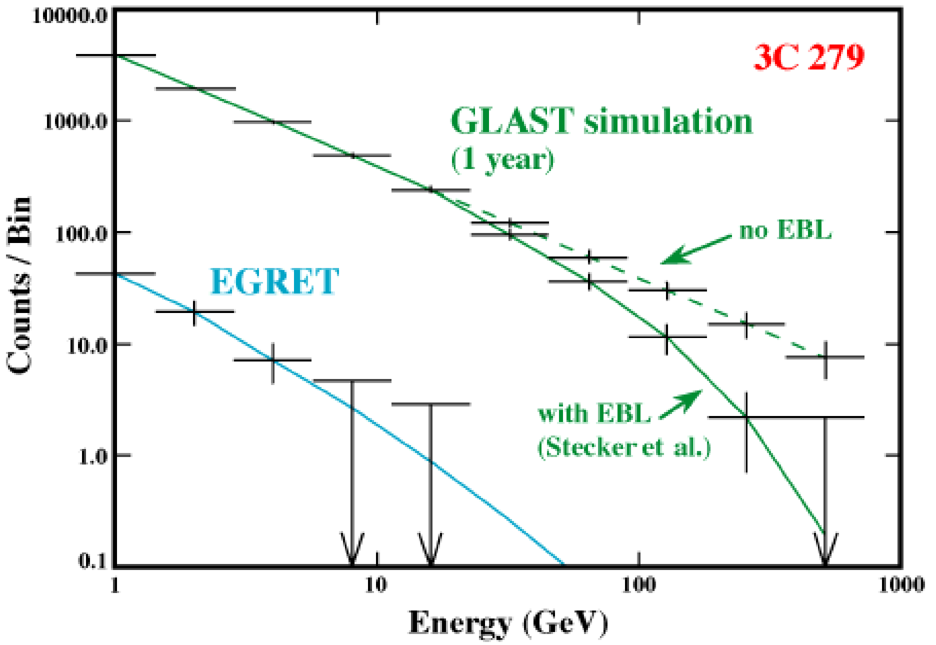
- Are radio galaxies also HE γ-ray sources? Seyferts? Increased sensitivity by 10^2
- How do blazars evolve? Detect 10^3 sources
- Is extra-galactic γ-ray background truly diffuse? Or is part due to annihilation or decay of exotic particles? Detect $>10^3$ sources
- Is AGN cutoff intrinsic or due to EBL? Study AGN spectra above 10 GeV

LAT studies 3C79



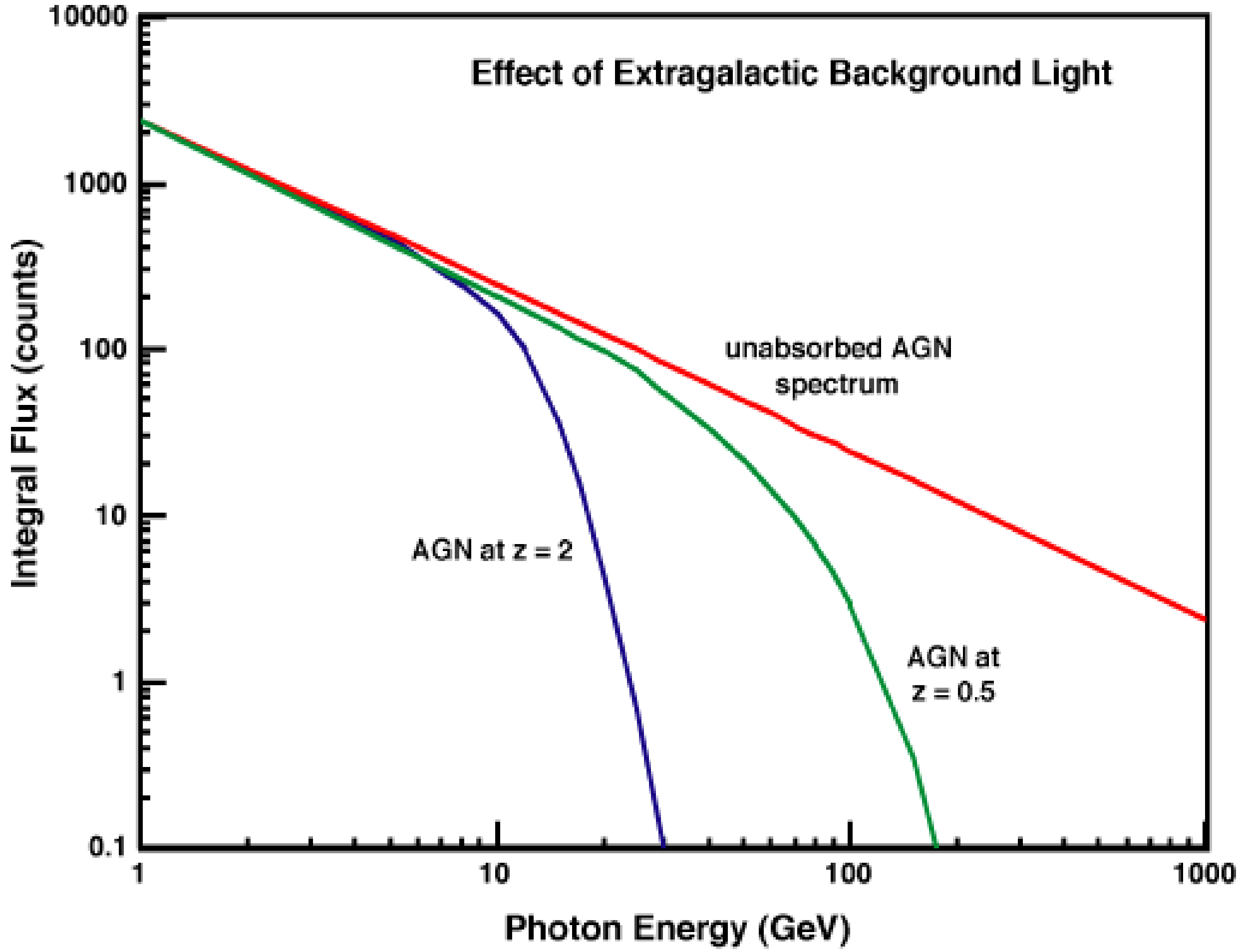
1996 flare

Spectral cutoff



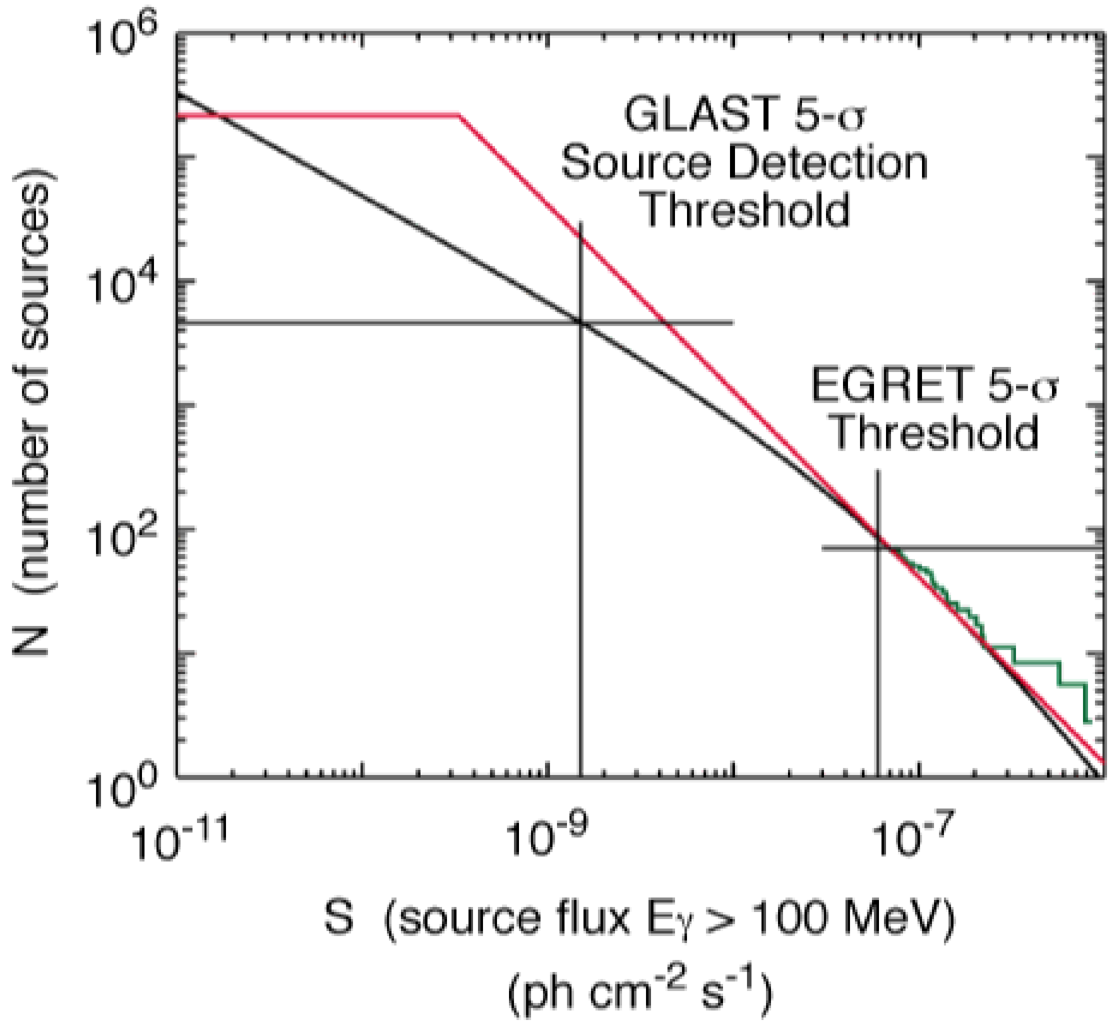
LAT studies EBL cutoff

Probe history of star formation to z ~4 by determining spectral cutoff in AGN due to EBL

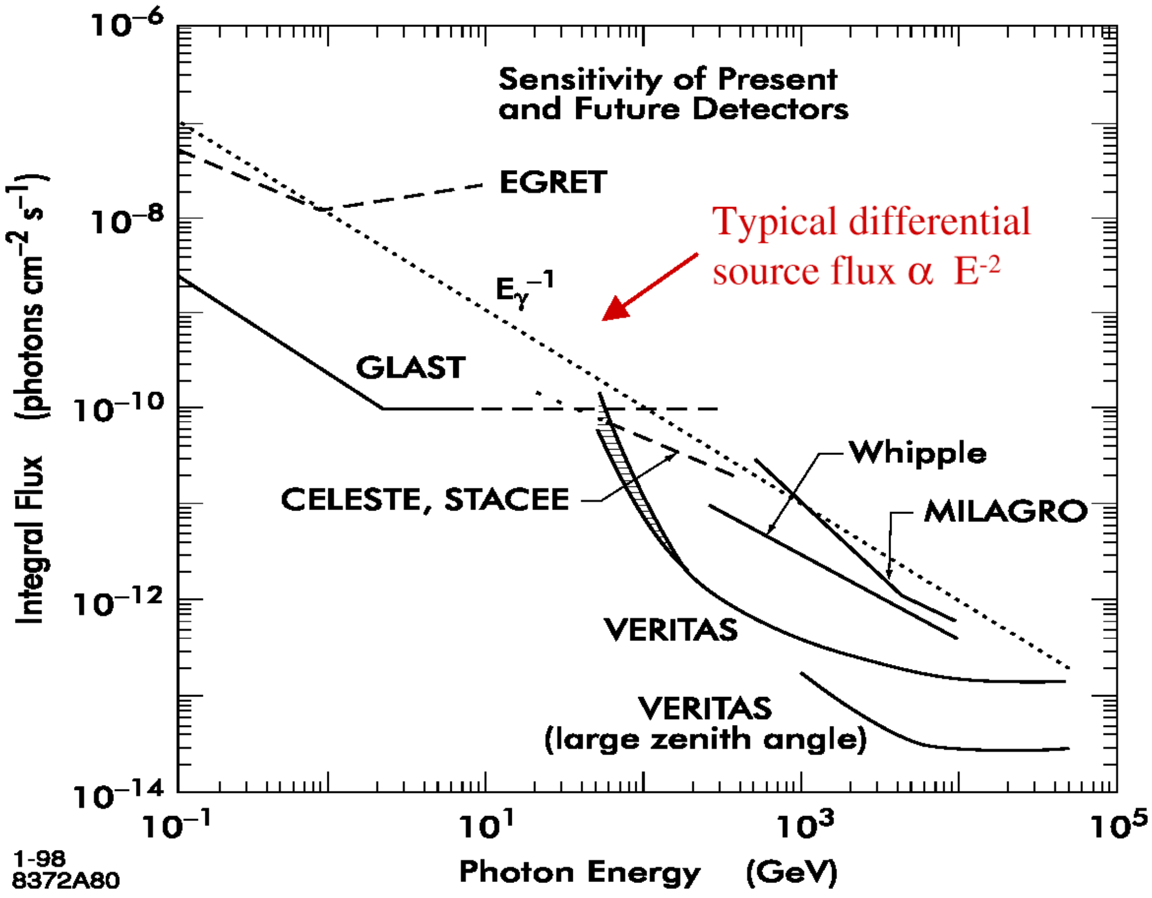


AGN Log N vs. Log S

- LAT should detect 3 x10^3 blazars
- Set limits on diffuse extra-galactic background → limits on decay or annihilation of exotic particles



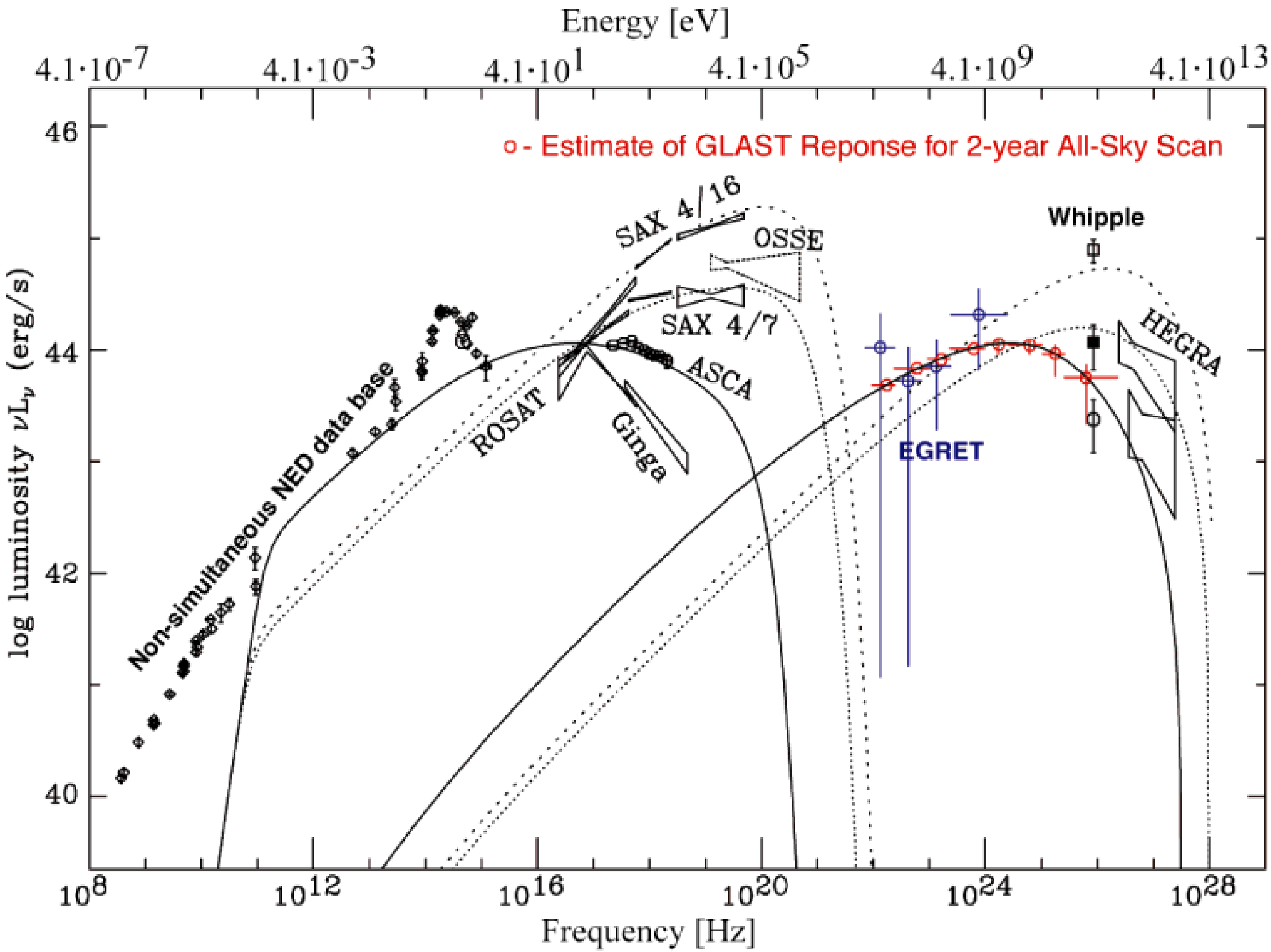
LAT vs. Ground-based HE Arrays



Ground-based HET Arrays

- HETs have detected 7+ sources at E > 250 GeV
  - 3 pulsar nebulae, 4 AGN, 1 possible SNR
- New HETs will reach down to ~50 GeV
- HETs have good sensitivity to flares of 15 min, & source localization to 10-30 arcmin
- Major limitations are <5^0 FOV, low-duty cycles and calibration uncertainties
- GLAST LAT can alert HETs to flaring objects & provide cross-correlation to calibrate spectra in overlap region

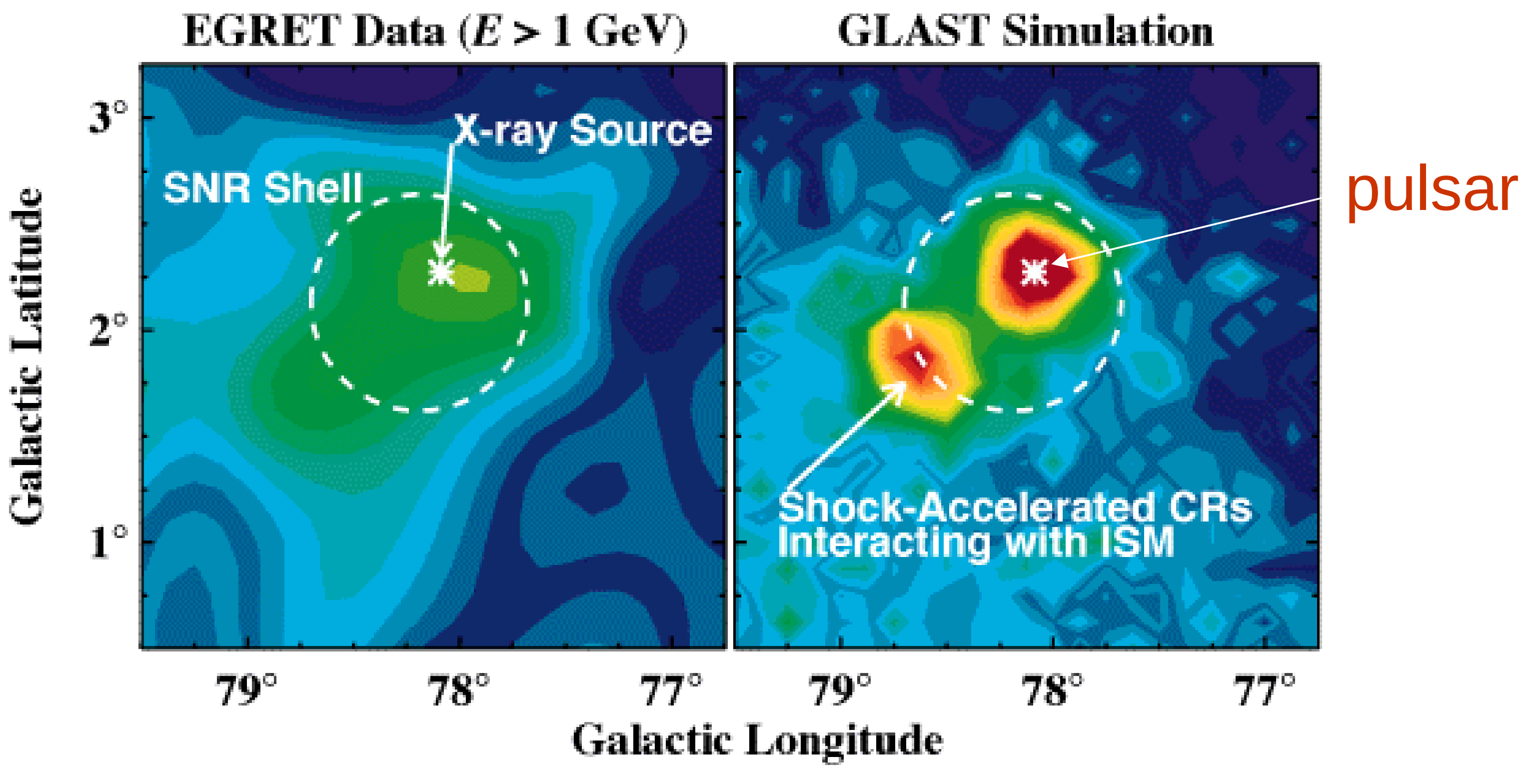
Multi-wavelength Mkn 501



Supernovae and Cosmic Rays

- Most scientists believe that Galactic CR are accelerated in SNR shocks
- EGRET detected π^0 bump at 68 MeV → direct evidence of nucleon-nucleon interactions
- EGRET detected γ–rays from LMC but not SMC → CR production varies
- Some EGRET sources could be SNRs, but poor resolution prevented confirmation
- X-ray and TeV observations of SN1006 show shocked electrons accelerated to CR-energies

LAT studies Supernova Remnants

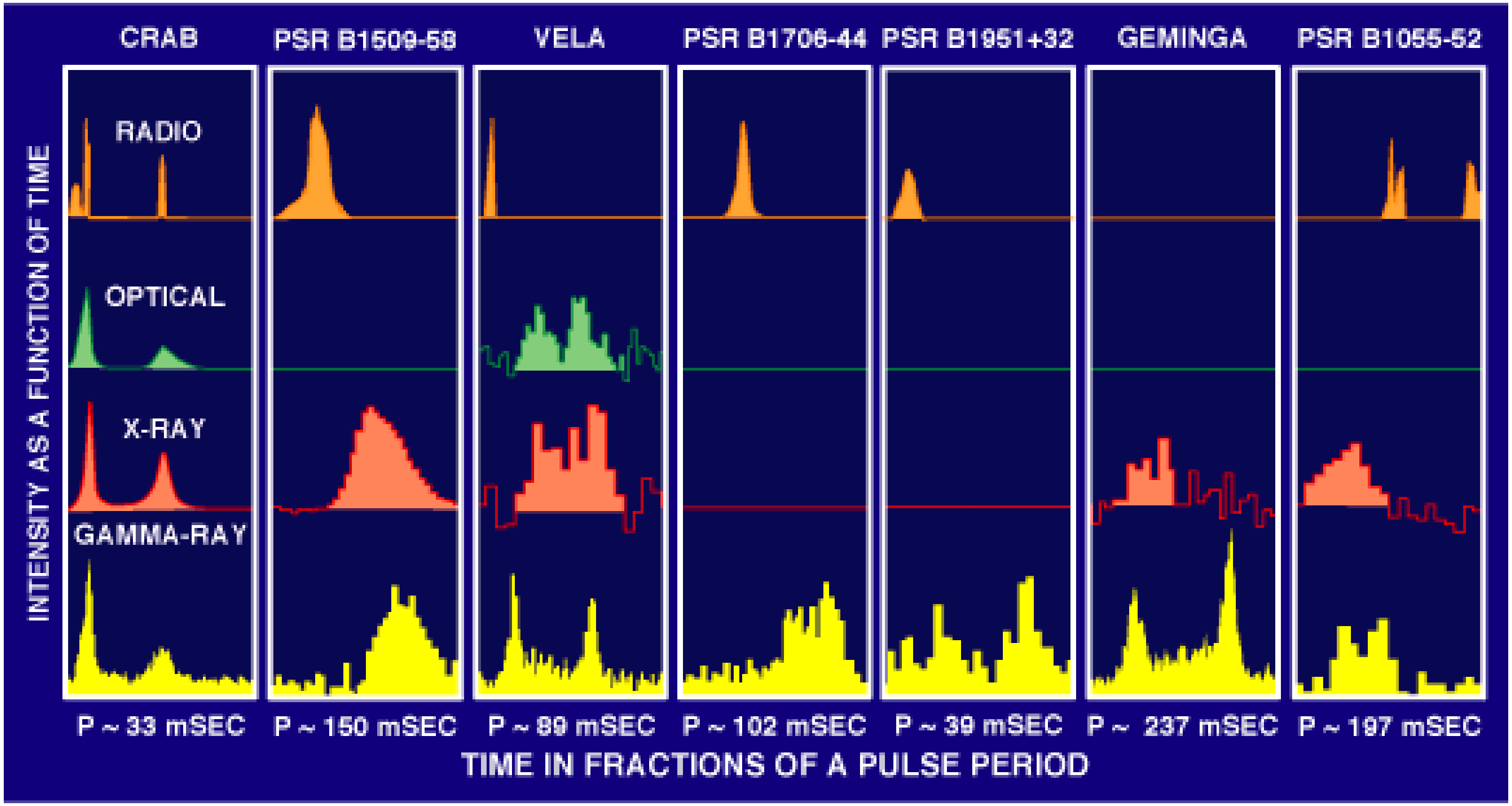


EGRET observations could not distinguish between pulsar (X-ray source) and shocked regions

LAT studies SNR and CRs

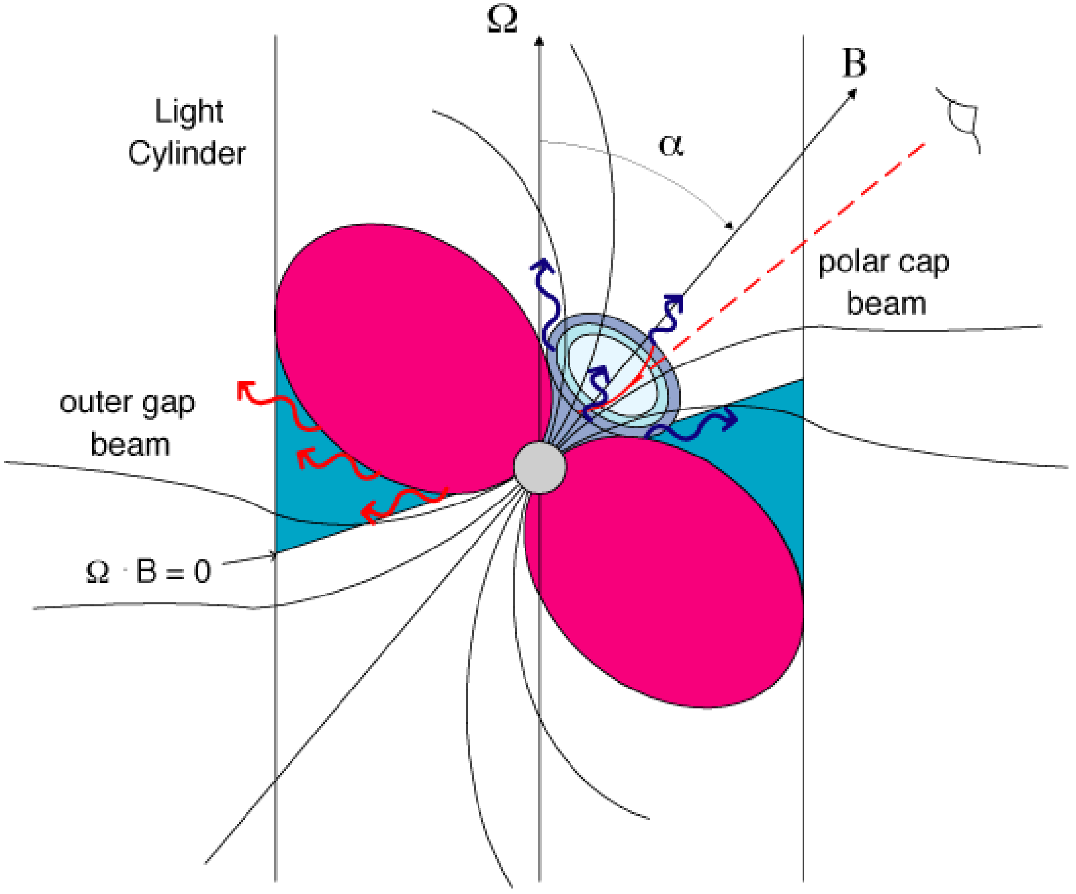
- Spatial separation of shocked acceleration regions from pulsar component
- Detect π^0 bump in SNR spectra from accelerated nuclei (on top of electron acceleration signatures – inverse Compton and bremsstrahlung)
- Determine relative number densities of electrons and nucleons in CRs
- Study CR production in other galaxies
- Improve H_2 measurements by mapping γ–rays

EGRET pulsars



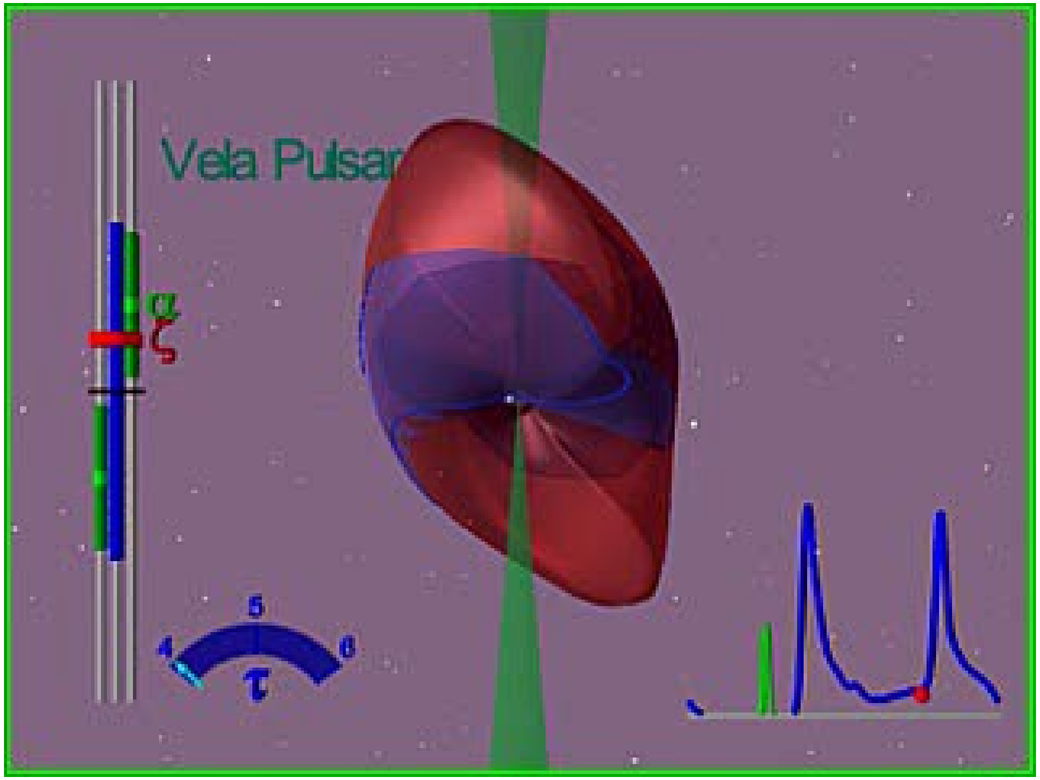
Outer gap vs. polar cap models

- Where are particles accelerated?
- How is particle beam energy converted into photons?
- What is shape of pulsar beam?
- How many pulsars are there? Birth rate?
- Where is most of the energy?



Vela pulsar outer gap model

- Green is radio
- Blue is gamma-ray
- Red is closed magneto-spheric surface

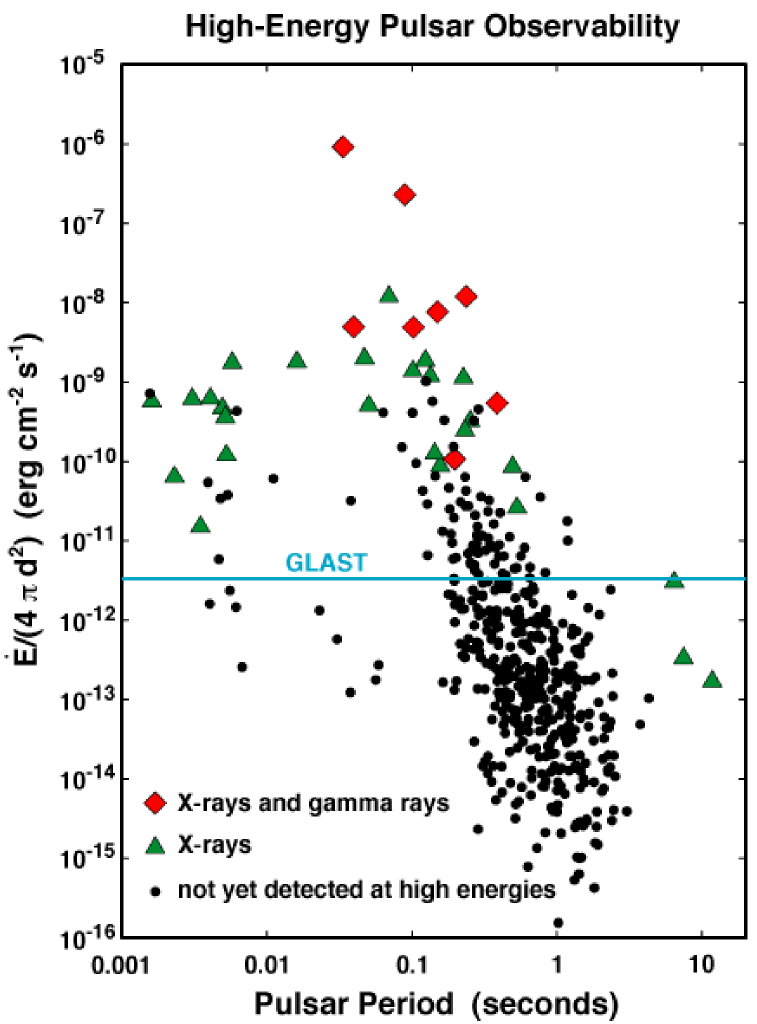


Yadigaroglu and Romani 1995

LAT studies pulsars

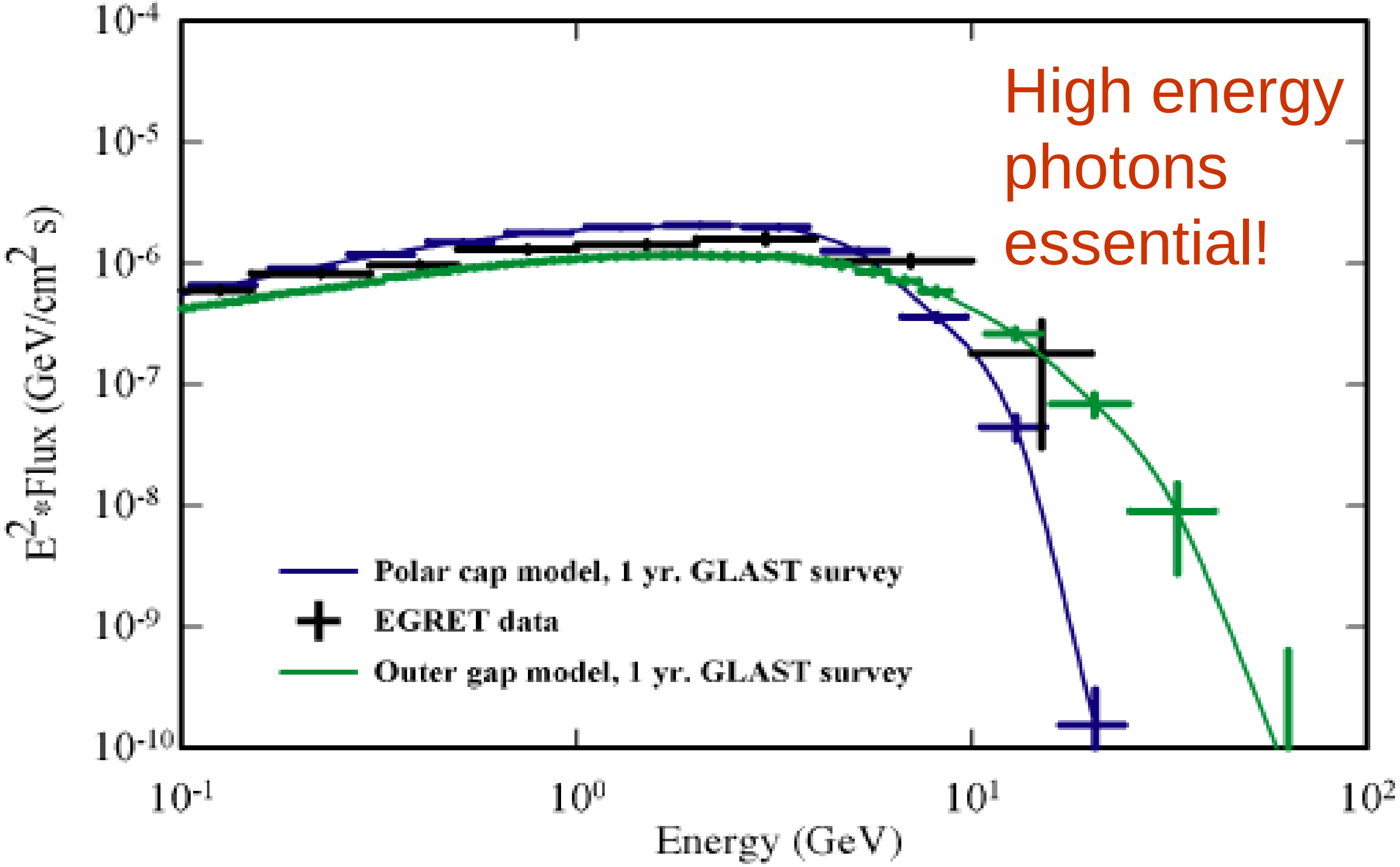
Up to 250 pulsars will be detectable, with half previously unknown in radio

(McLaughlin and Cordes 2000)



LAT studies pulsars

High quality phase-resolved spectra for 10^2 pulsars



Dark Matter – a short review

- Evidence:
  - Rapidly moving galaxies in clusters
  - Rotation curves of galaxies
  - Hot gas in galaxy clusters
  - Gravitational lensing
  - Stability of rotating spiral galaxies
- Types:
  - Baryonic vs. non-baryonic
  - Cold vs. Hot

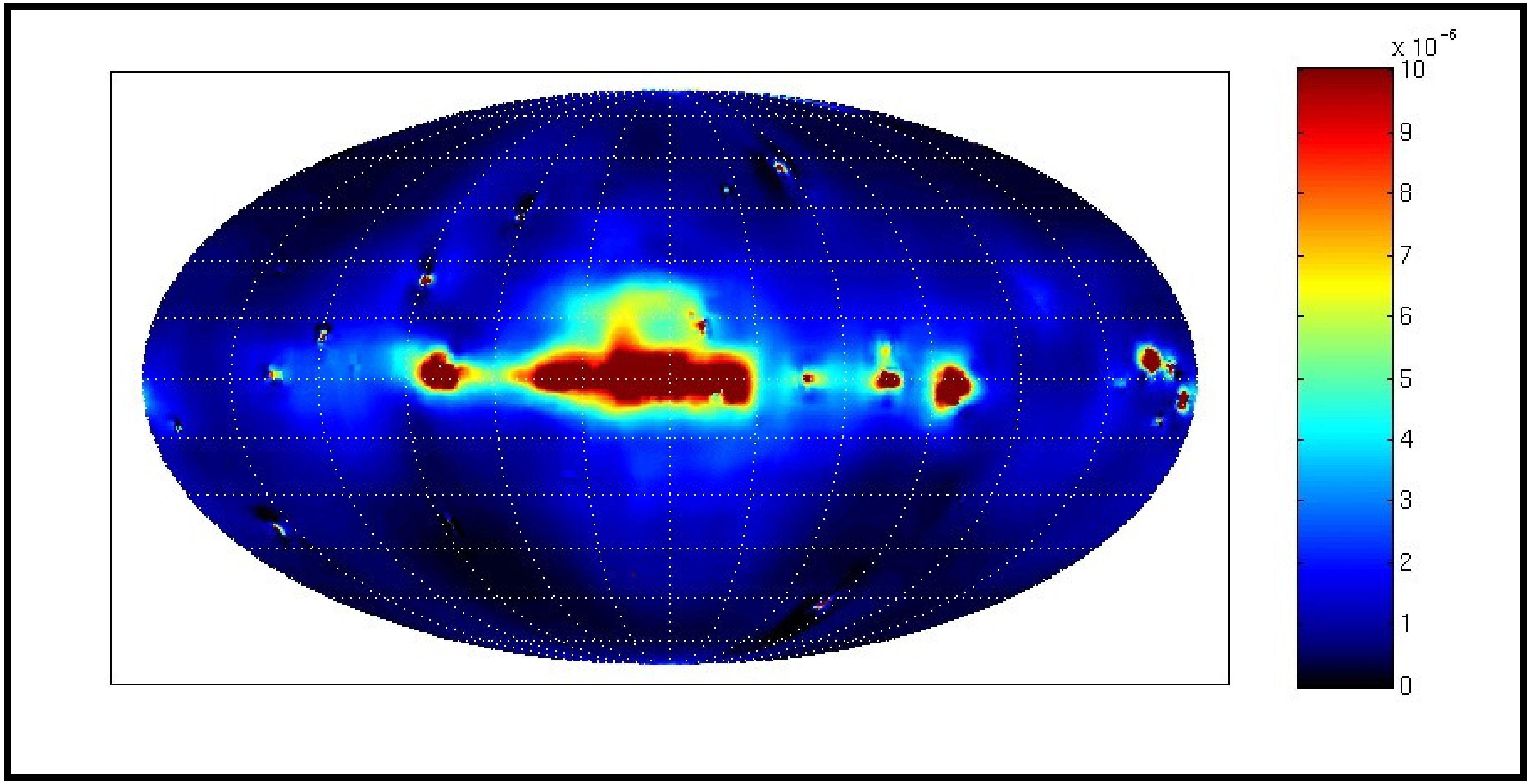
Hot gas in Galaxy Cluster

Searching for dark matter

- The lightest supersymmetric particle χ is a leading candidate for non-baryonic CDM
- It is neutral (hence neutralino) and stable if R-parity is not violated
- It self-annihilates in two ways:
  - $\chi\,\chi \rightarrow \gamma\gamma$ where $E\gamma = M\chi\, c^2$
  - $\chi\,\chi \rightarrow Z\gamma$ where $E\gamma = M\chi\, c^2(1 - M_z^2/4M_\chi^2)$
- Gamma-ray lines possible: 30 GeV - 10 TeV

First Light from Dark Matter?

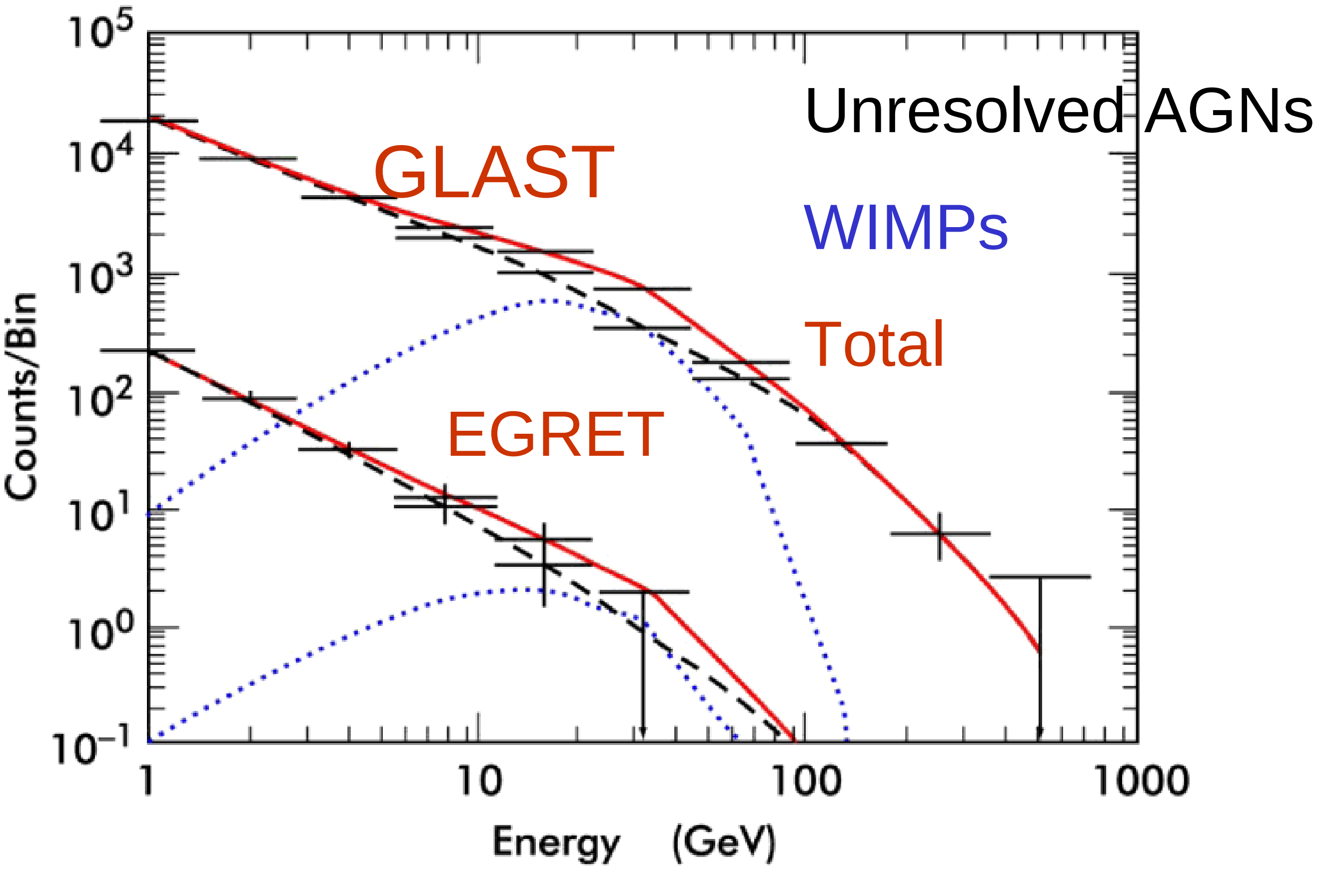
EGRET evidence for > 1 GeV excess



Courtesy of D. Dixon, University of California, Riverside

Diffuse emission from Relic decay

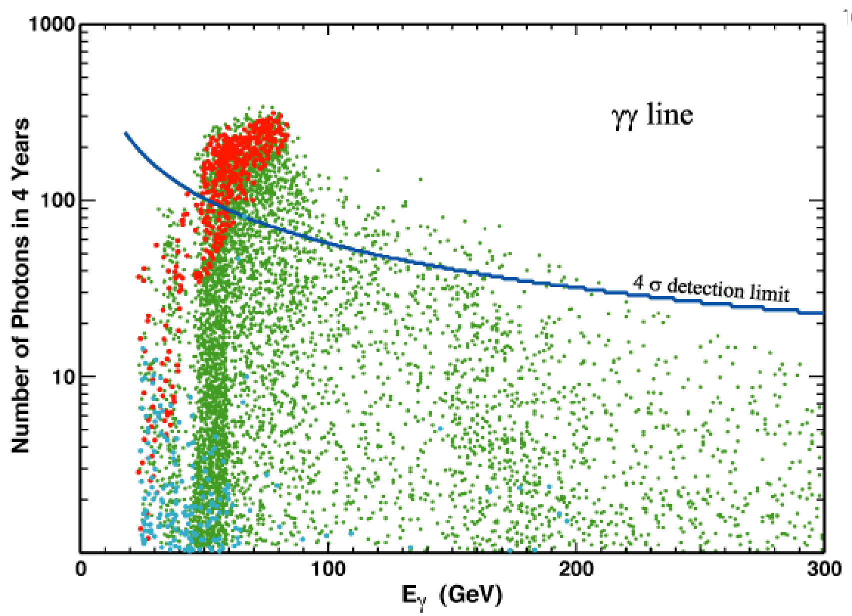
- Set limits on relic mass, density and lifetime

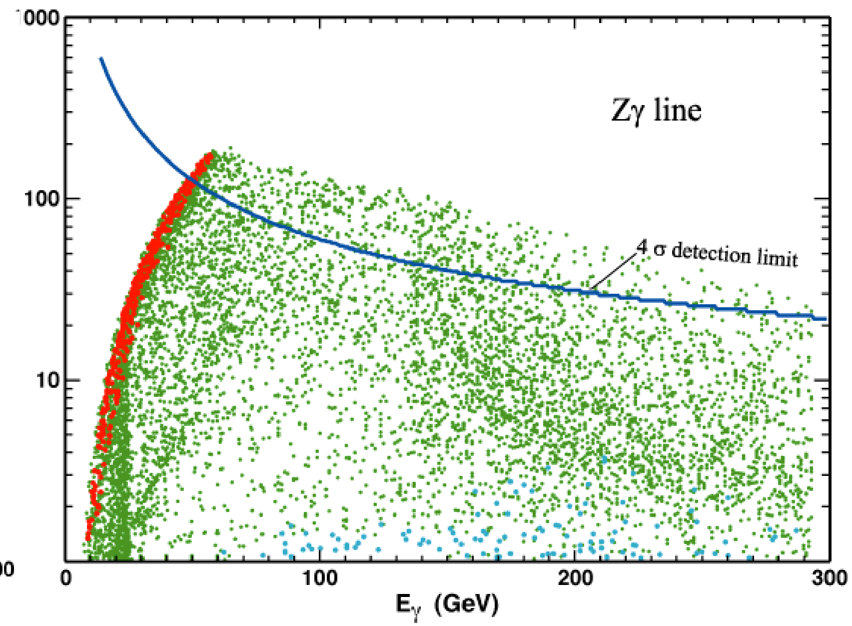


WIMP line detectability

∀ γ–γ line

∀ Z–γ line





Supersymmetry model calculations by Bergstrom, Ullio and Buckley 1998 – assume enhanced density near Galactic Center (Navarro, Frenk and White 1996)

Conclusions

- GLAST will open new areas of investigation at the boundary of astrophysics and particle physics
- GLAST is the first of many missions that will combine resources from astrophysics and particle physics

• GLAST will show us the connection between the smallest sub-atomic particles and the largest structures in the Universe

• Connections….from Quarks to the Cosmos!

For more information:

The GLAST Science Document (GSD)
GLAST: Exploring Nature’sHighest Energy Processes with the Gamma-ray Large Area Space Telescope
(Seth Digel, editor) may be downloaded from

ftp://lheaftp.gsfc.nasa.gov/pub/myersjd

The GLAST outreach web site:

http://www-glast.sonoma.edu

The GLAST LAT web site:

http://www-glast.stanford.edu

For more information:

Figures are from the Gamma-ray Image Gallery:

http://cossc.gsfc.nasa.gov/images/epo/gallery/index.html

For more information on the Connections program:

http://www.quarkstothecosmos.org

For more information on NASA's Cosmic Journeys:

http://journeys.gsfc.nasa.gov

For a copy of this talk:
http://perry.sonoma.edu/materials

LAT Studies Blazars

- Constrain jet acceleration and emission models
  - hadronic vs. leptonic
- Measure spectral cut off with distance to redshift z > 4 → star formation history of universe
- Statistically accurate calculation of blazar contribution to the high energy diffuse extragalactic background → diffuse limits
- Blazar evolution
- New types of gamma-ray emitting AGNs