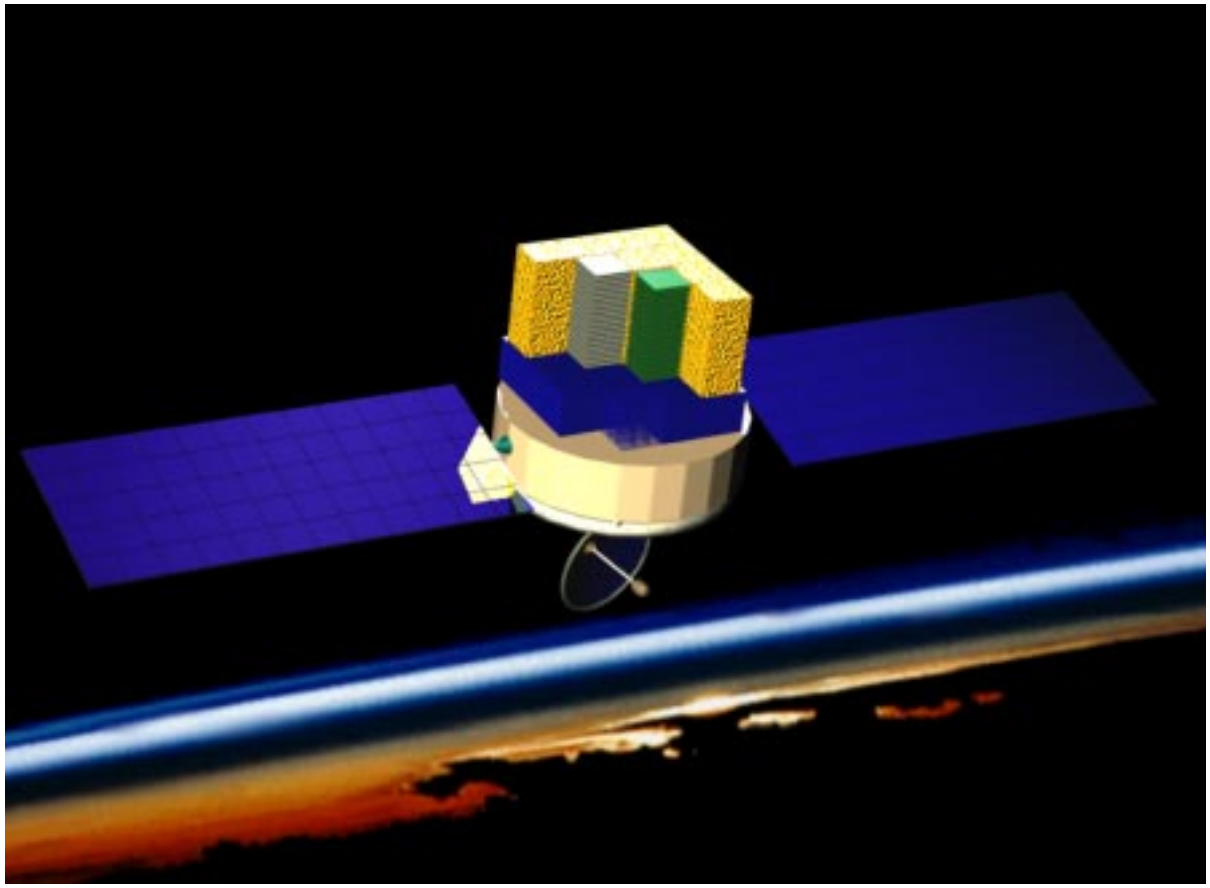
# GeV Gamma Ray Astronomy in the GLAST Era



**Neil Gehrels**

**June 26, 2000**

# Recent Development in U.S.

## Astronomy and Astrophysics in the New Millennium
## NRC 10-year Report

**Table 1.1** Prioritized Initiatives and Estimated Federal Costs for the Decade 2000-2010.

| Ground Based | Cost ($M) | Space Based | Cost ($M) |
|---|---|---|---|
| **Major Initiatives** | | | |
| Giant Segmented-Mirror Telescope (GSMT) | 350 | Next Generation Space Telescope (NGST) | 1000 |
| Expanded Very Large Array (EVAL) | 140 | Constellation-X Observatory | 800 |
| Large-aperture Synoptic Survey Telescope (LSST) | 170 | Terrestrial Planet Finder (TPF) | 200 |
| | | Single-Aperture Far Infra Red (SAFIR) Observatory | 100 |
| **Moderate Initiatives** | | | |
| Telescope System Instrumentation Program (TSIP) | 50 | **Gamma-ray Large Area Space Telescope (GLAST)** | 300 |
| Advanced Solar Telescope(AST) | 60 | Laser Interferometer Space Antenna (LISA) | 250 |
| Square Kilometer Array (SKA) Technology Development | 22 | Solar Dynamics Observatory (SDO) | 300 |
| Combined Array for Research in Millimeter-wave Astronomy (CARMA) | 11 | Energetic X-ray Imaging Survey Telescope (EXIST) | 150 |
| Very Energetic Radiation Imaging Telescope Array System (VERITAS) | 35 | Advanced Radio Interferometry between Space and Earth (ARISE) | 350 |
| Frequency Agile Solar Radiotelescope (FASR) | 26 | | |
| South Pole Submillimeter-wave Telescope (SPST) | 50 | | |

# Gamma Ray Large Area Space Telescope

**Theme: Exploring Sites of Particle Acceleration in the Universe**

- **Launch in 2005**
- **20 MeV to 300 GeV**
- **Wide-field imaging telescope**
- **NASA cost is $326 M**
- **http://glast.gsfc.nasa.gov/**

# Mission Parameters

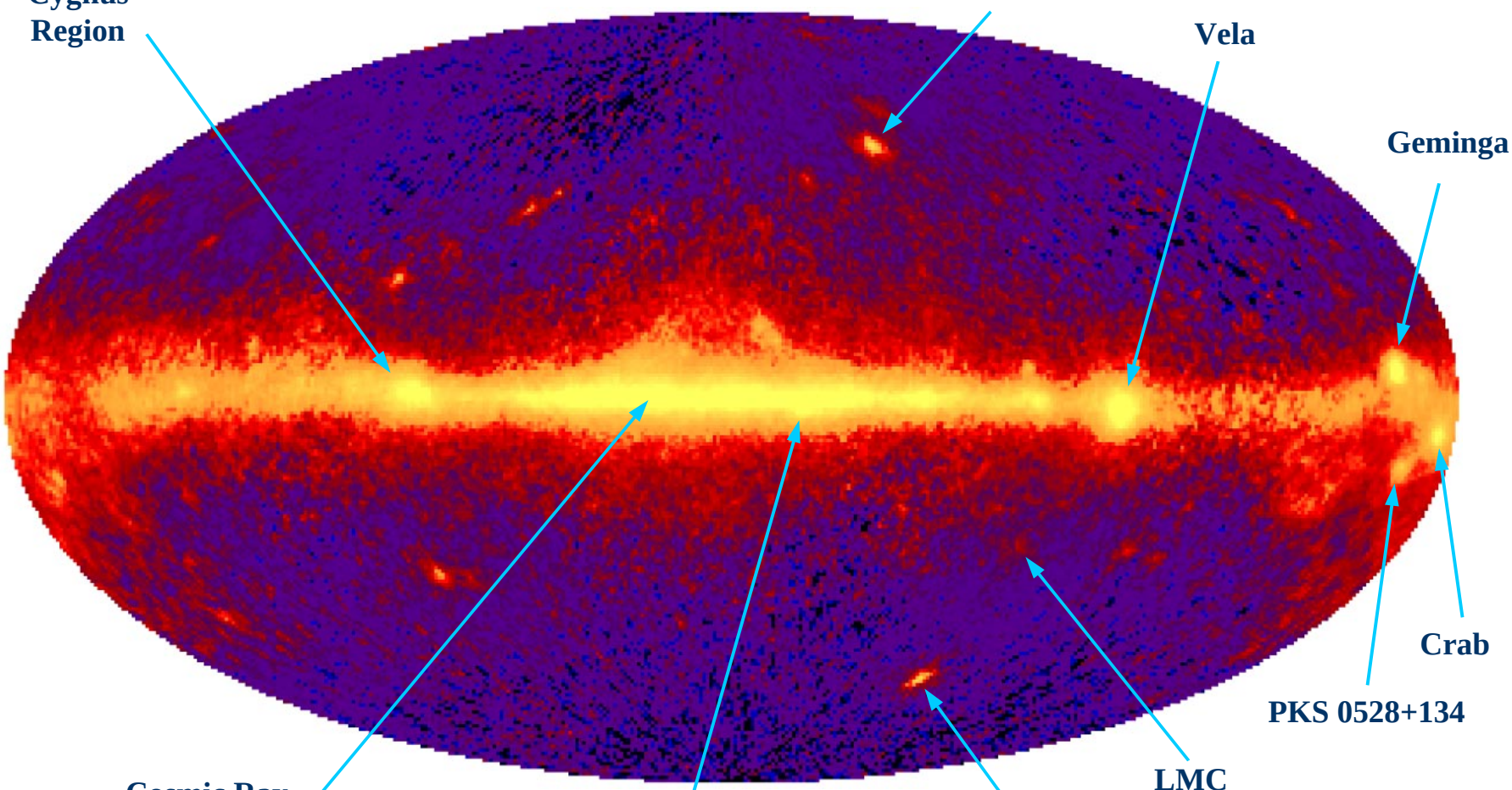
| | EGRET | AGILE | GLAST |
|---|---|---|---|
| Energy Range | 20 MeV - 30 GeV | 30 MeV - 50 GeV | 20 MeV - > 300 GeV |
| Energy Resolution ($\Delta E/E$) | 0.1 | 1 | 0.1 |
| Effective Area (peak) | 1500 $cm^2$ | 700 $cm^2$ | 12000 $cm^2$ |
| Field of View | 0.5 sr | ~ 3 sr | 2.5 sr |
| Angular Resolution | 5.8° @ 100 MeV<br>0.5° @ 10 GeV | 4.7° @ 100 MeV<br>0.2° @ 10 GeV | ~ 3.5° @ 100 MeV<br>~ 0.1° @ 10 GeV |
| Sensitivity (> 100 MeV)* | ~ $10^{-7}$ $cm^{-2}$ $s^{-1}$ | $5 \times 10^{-8}$ $cm^{-2}$ $s^{-1}$ | ~ $2 \times 10^{-9}$ $cm^{-2}$ $s^{-1}$ |
| Mass | 1810 kg | 60 kg | 3000 kg |
| Lifetime | 1991 - 1997 | 2002 - 2005 | 2005 - 2010 |

* 2 year survey at high latitudes

# GLAST Capabilities

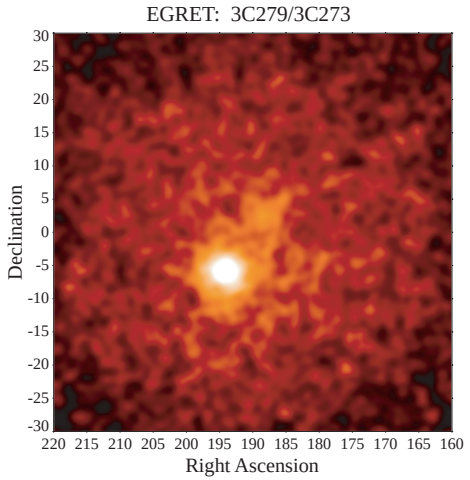
- **Huge FOV (> 20% of sky)**
- **Broadband (4 decades in energy, including unexplored region > 10 GeV)**
- **Unprecedented PSF for gamma rays (factor > 3 better than EGRET)**
- **No expendables ➞ long mission without degradation**
- **Large area (factor > 7 better than EGRET)**
- **Results in factor > 30 improvement in sensitivity**

# EGRET All Sky Map (>100 MeV)

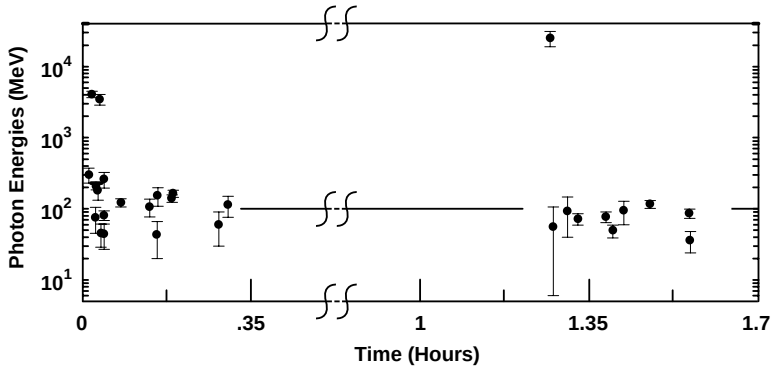


# EGRET Discoveries

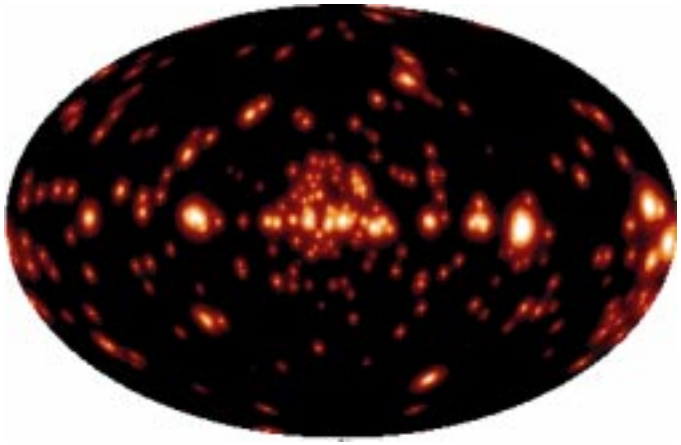
## Gamma Ray Blazars



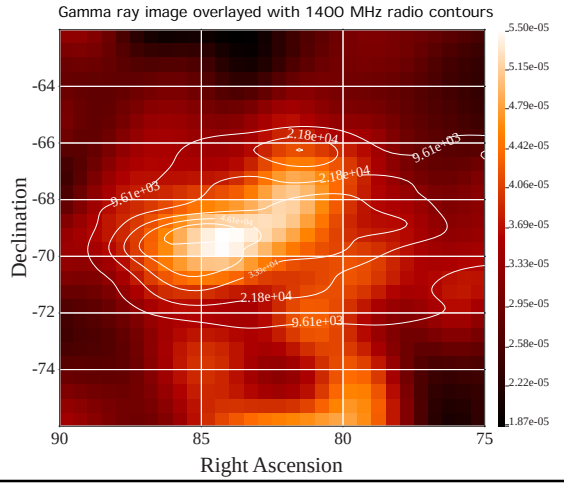

## Prolonged GeV Emission from GRBs




## 170 Unidentified Sources



## LMC Detection

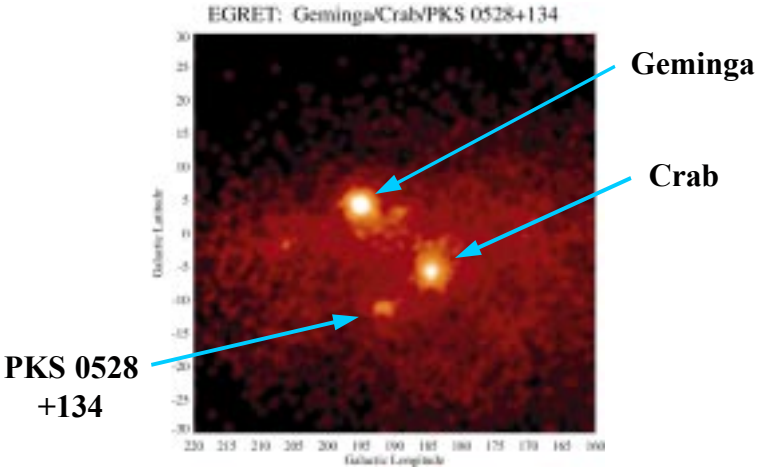


# EGRET Discoveries cont.

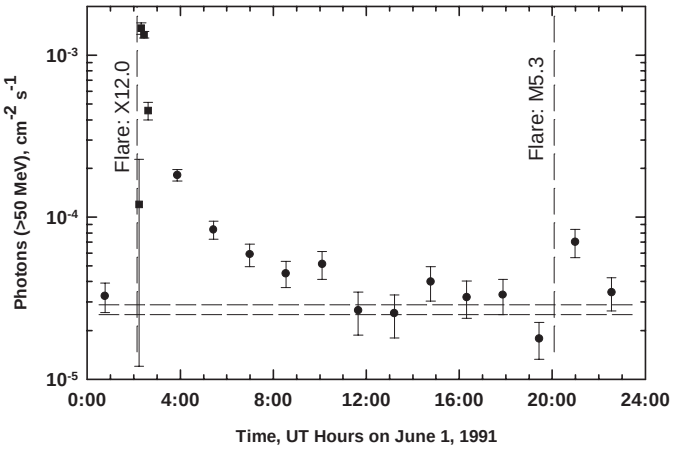
## 5 New Pulsars

| | |
|---|---|
| Crab | 1706-44 |
| Vela | 1055-52 |
| | Geminga |
| | 1951+32 |
| | 0656 +14 |

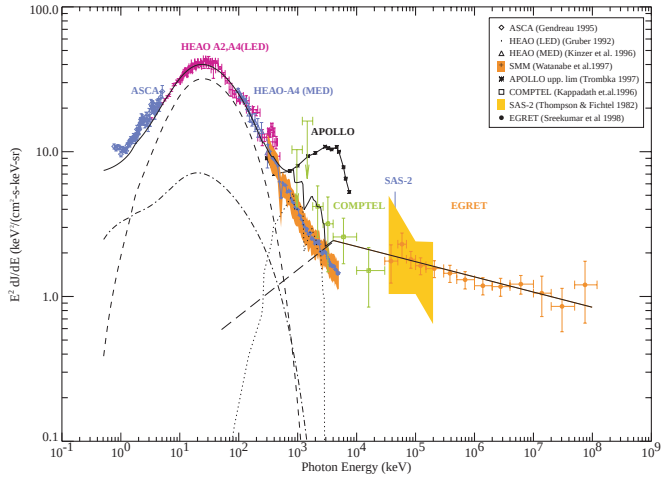
## Geminga Radio-Quiet Pulsars




## Prolonged GeV Emission from Solar Flares

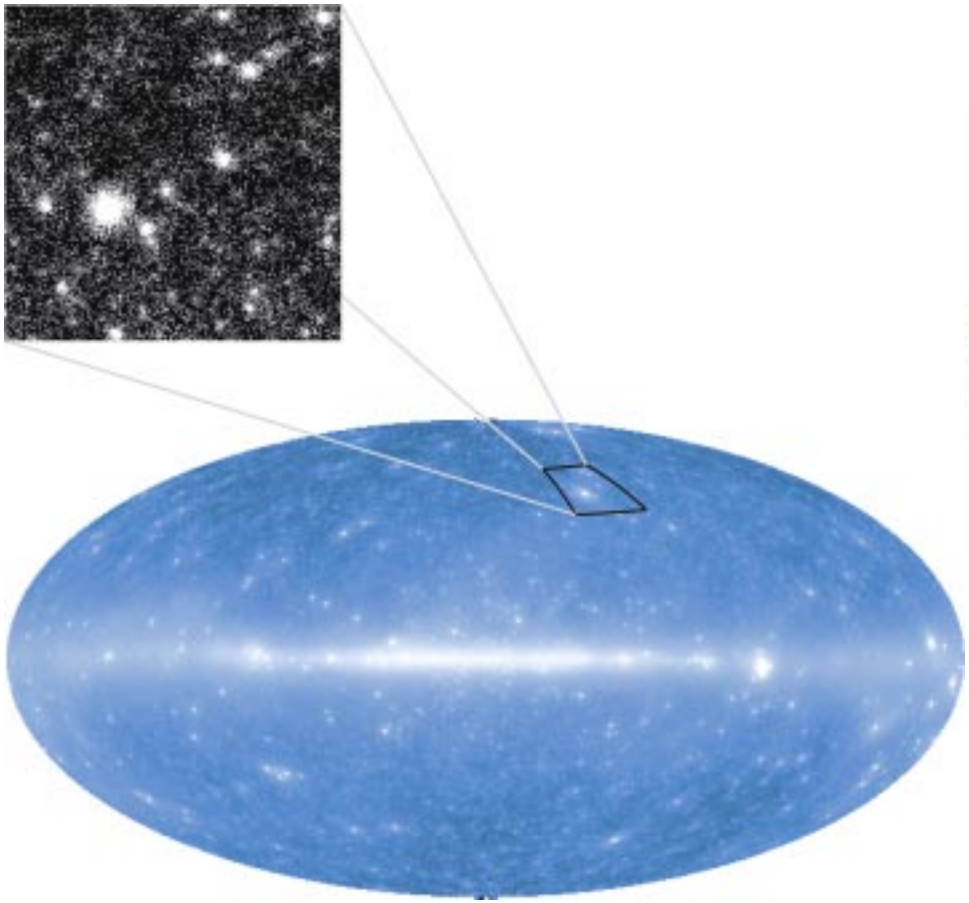



## Cosmic Diffuse Background

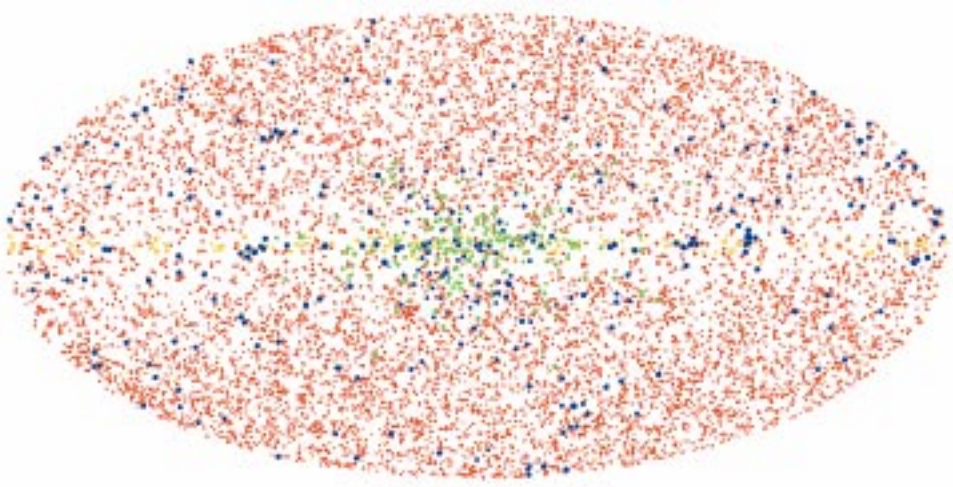


# GLAST versus EGRET: All-Sky Surveys

Virgo Region (E > 1 GeV)



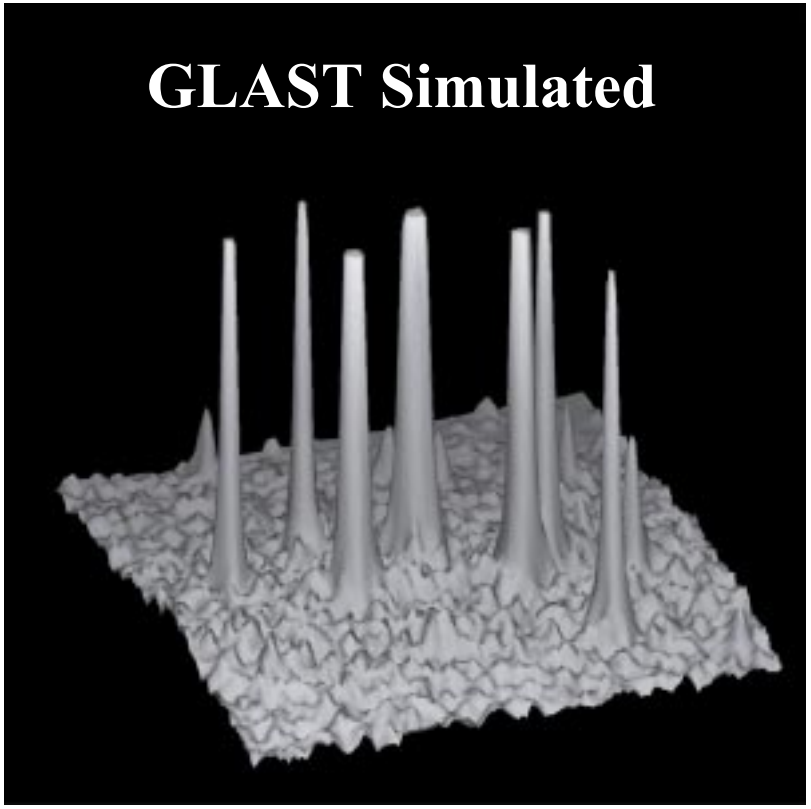
Simulated GLAST One-Year All-Sky Map (E > 100 MeV)



5σ Sources from Simulated One-Year All-Sky Survey

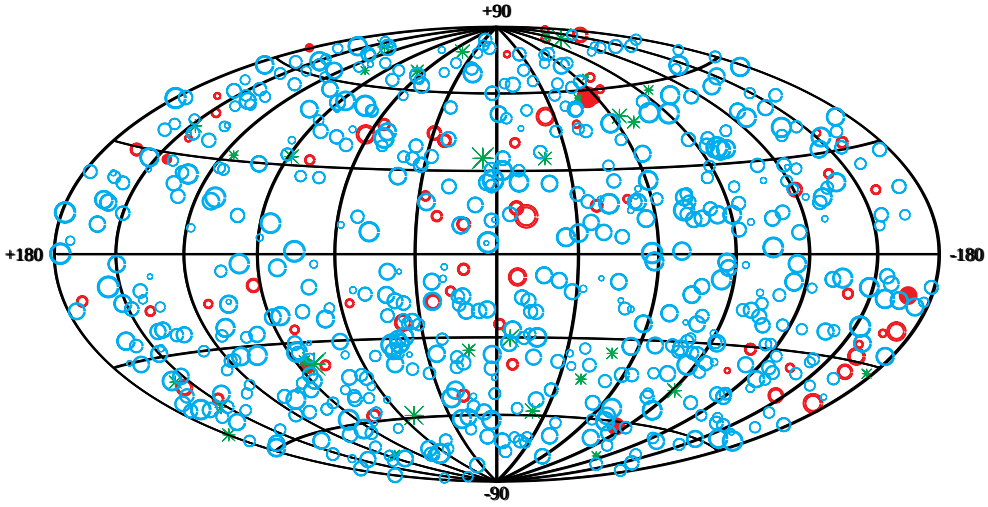
- AGN
- 3EG Catalog
- Galactic Plane
- Galactic Halo

# Cygnus Simulation



# Gamma-Ray Quasars

- **EGRET sees most blazars only when they flare**
- **What is the population of high-energy blazars?**
- **What is the nature of the quiescent emission?**
- **What is the relation to radio luminosity and variability?**
- **What are the high-latitude unidentifieds?**



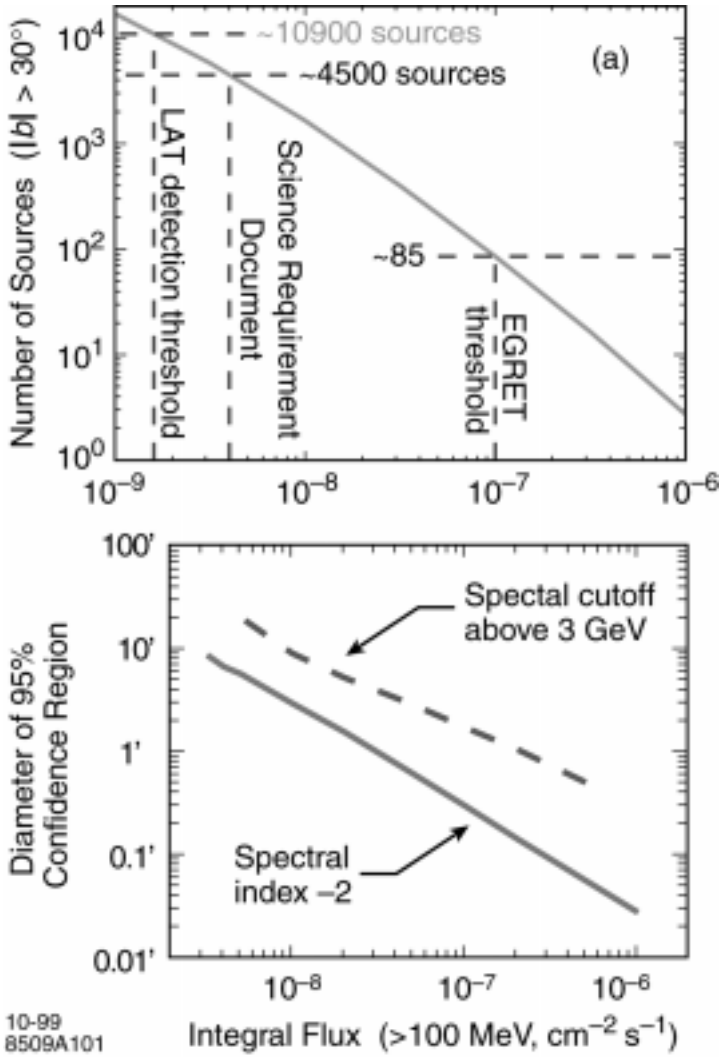

○ = **EGRET blazars seen sometimes**

● = **EGRET blazars seen always**

✳ = **EGRET unidentified high-latitude variables**

○ = **Simulated GLAST 20σ AGN detections**

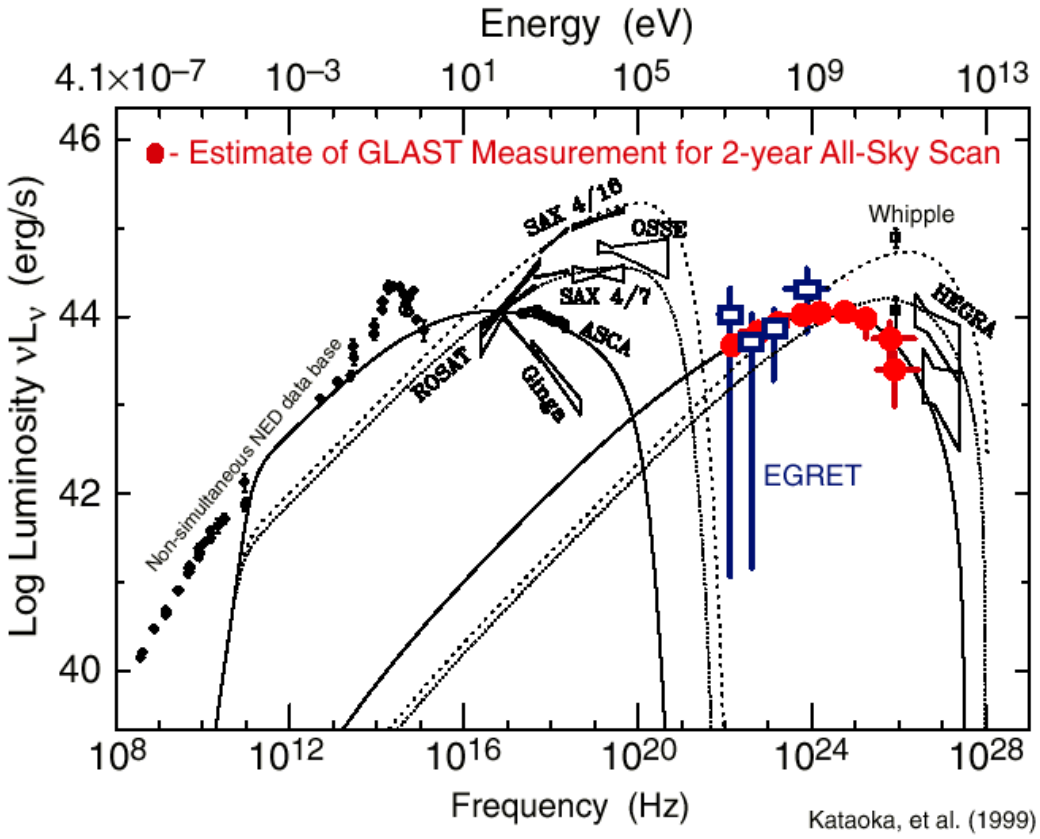
# Number and Localization of GLAST AGN



# Blazar Spectra

- **GLAST combined with TeV observatories will probe the complex spectra of blazars**

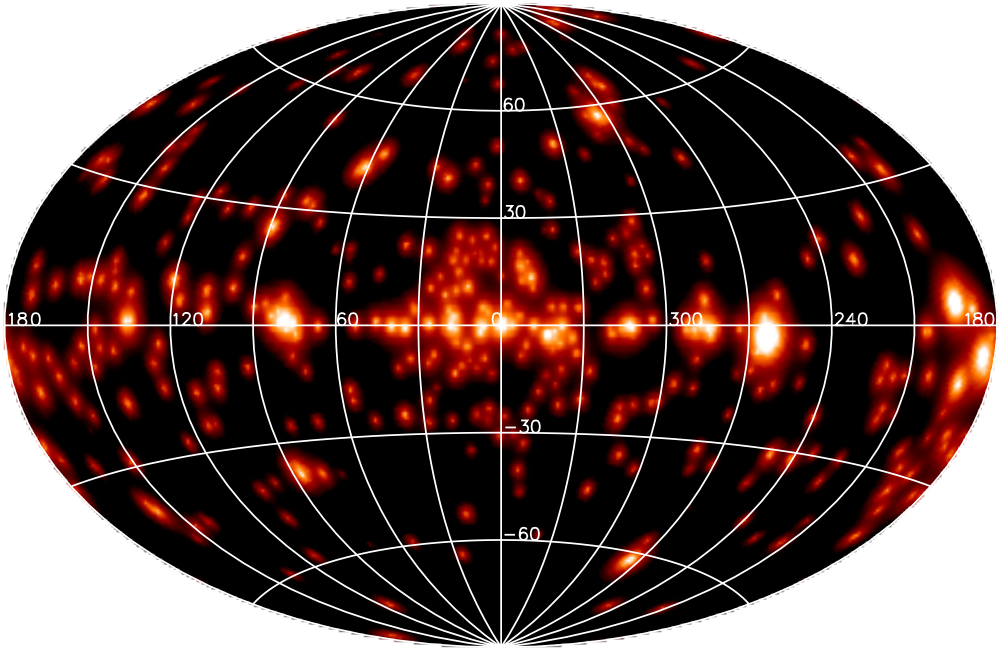
**Mrk 501**



# Unidentified Sources

- 172 unidentified sources in 3rd EGRET catalog
- Mystery of unidentifieds since 1970s
- Galactic unidentifieds may be SNRs, Gemingas, massive stars, molecular clouds, or new phenomenon!
- Mid-latitude sources are separate population from low-latitude sources (Nature, March 23rd issue)

## Sources in Third EGRET Catalog



# Solving the Mystery of Unidentifieds With GLAST

- EGRET source positions are ~ 0.5$^{o}$ in size, too large for counterpart searches
- GLAST will provide much more accurate source positions, 30 arcsec to 5 arcmin

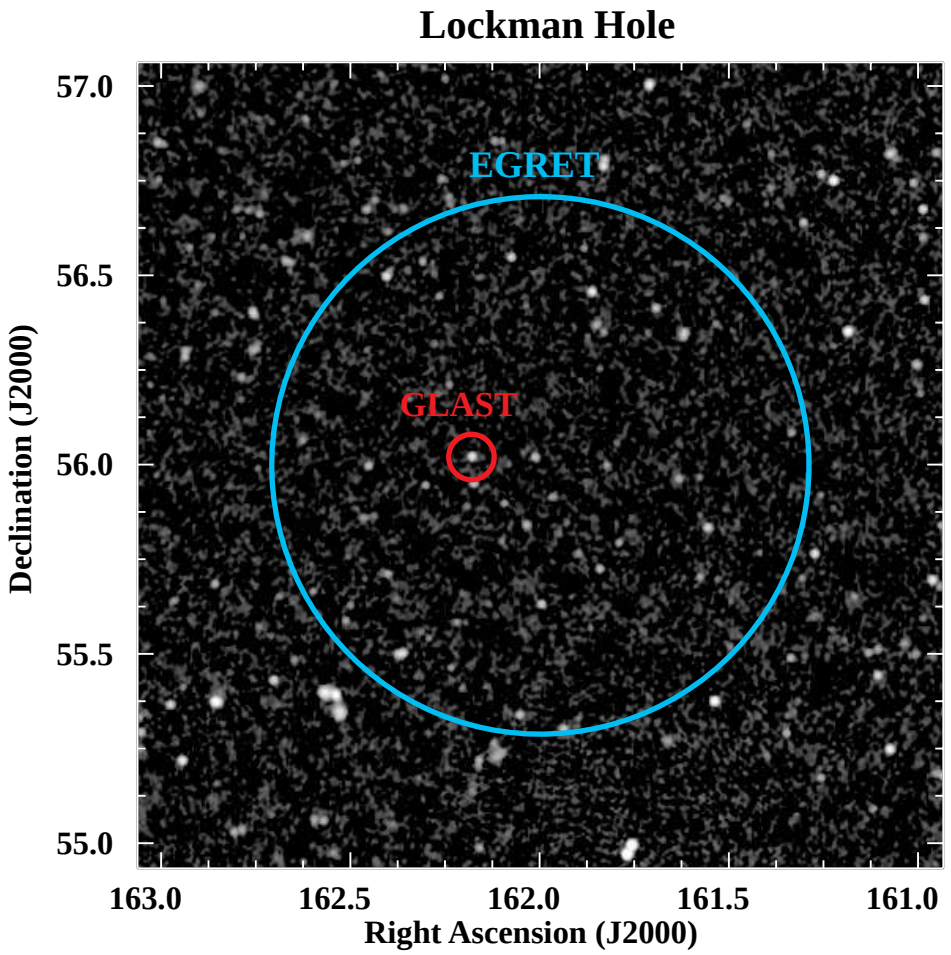
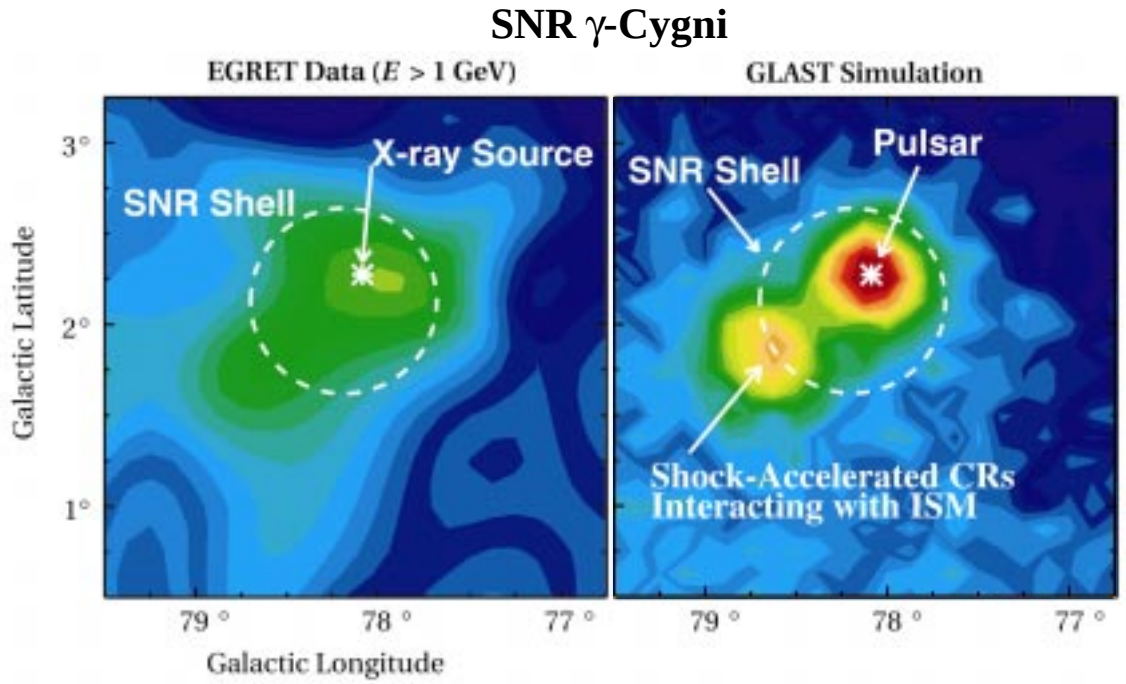


Image from NVSS 1.4 GHz survey, Condon et al. (1998)

# SNR Origin of Cosmic Rays

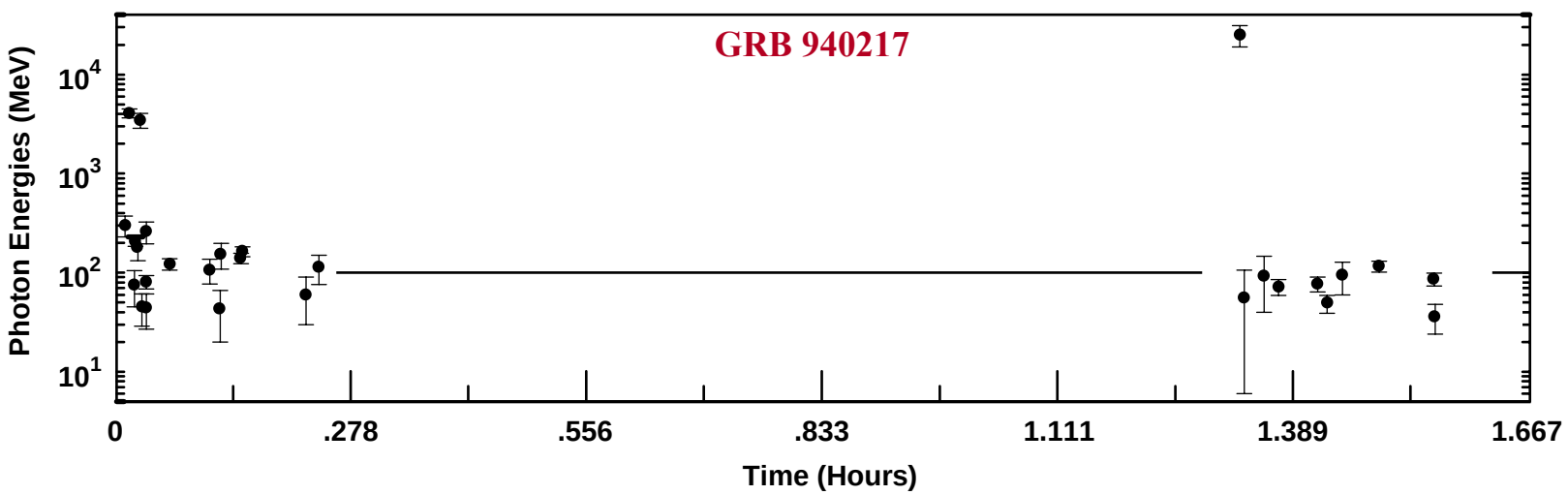
- **Supernova shock acceleration models predict correct spectra and energetics**
- **Evidence of TeV electrons in non-thermal X-ray emission and ground-based gamma-ray observations**



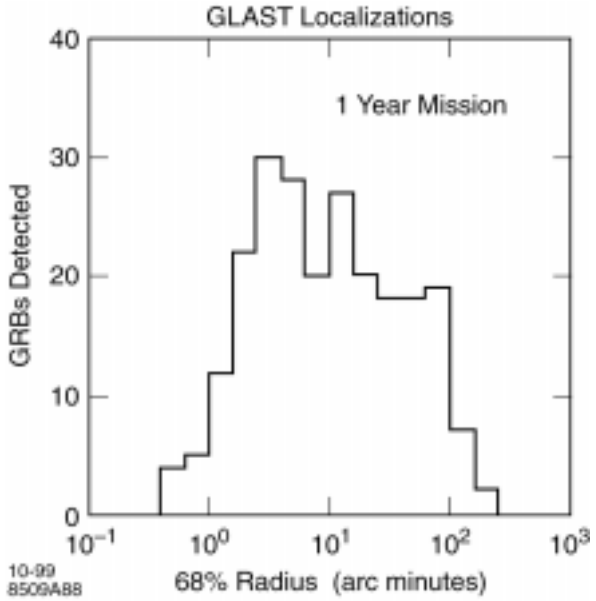

- **Smoking gun would be an extended gamma-ray source, such as an interstellar cloud, located next to a SNR, which may be the case for Gamma Cygni**
- **This would provide proof that nuclei as well as electrons are accelerated as predicted**

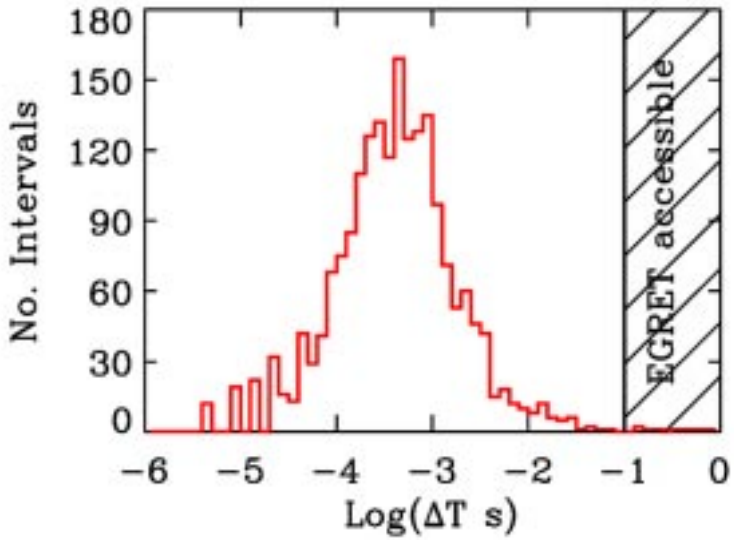
# Gamma Ray Bursts

## EGRET:




## GLAST:



# GLAST Instrument and IDS Selection

- **GLAST instruments & InterDisciplinary Scientists (IDS's) selected.**
  - **Large Area Telescope (LAT), PI: P. Michelson, Stanford**

    **Si Tracker: Stanford, UCSC, Japan, Italy**

    **CsI Calorimeter: NRL, France**

    **Anticoincidence: GSFC**

    **Data Acquisition System: Stanford, NRL**
  - **GLAST Burst Monitor (GBM), PI: C. Meegan, MSFC**

    **Detectors: MPE**

    | | |
    |---|---|
    | **NaI** | **5 keV - 1 MeV** |
    | **BGO** | **150 keV - 30 MeV** |
  - **IDS's**

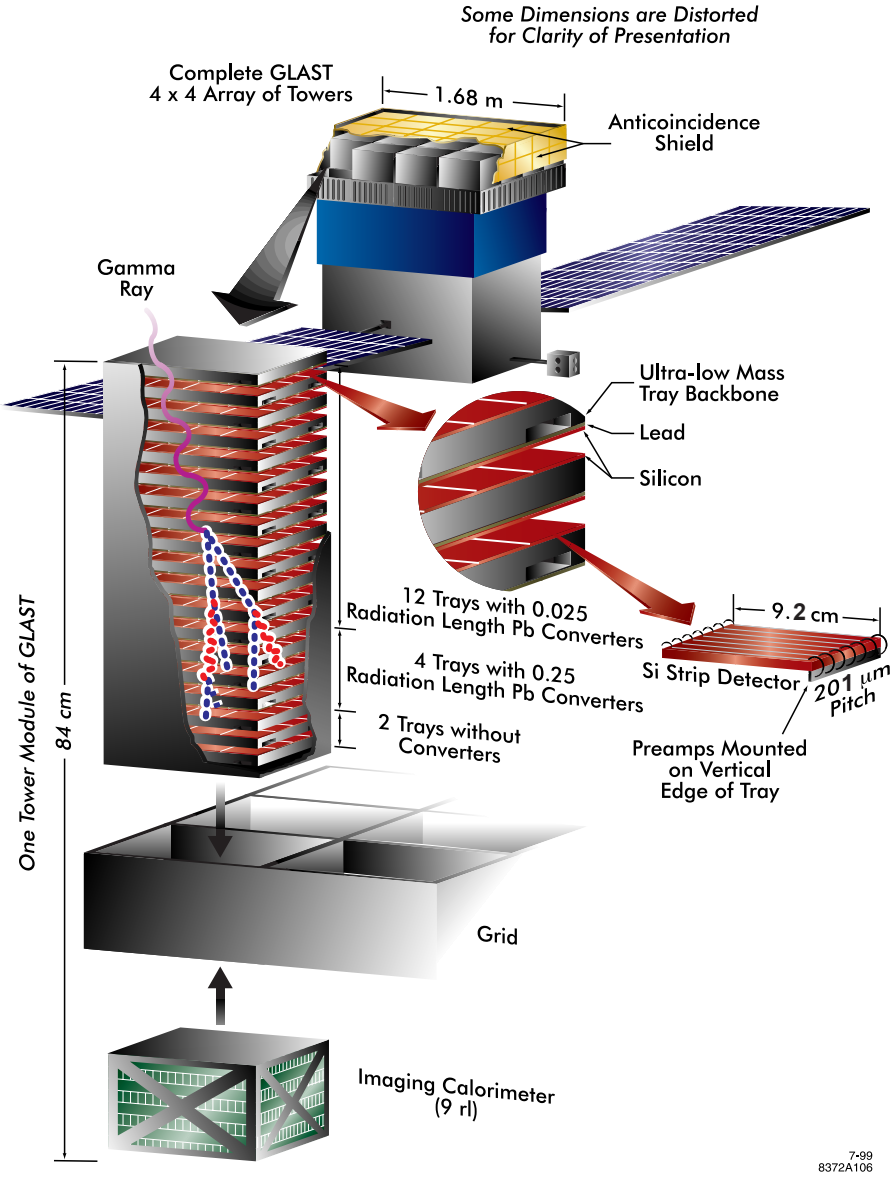
    **C. Dermer (NRL) - non-thermal universe**

    **B. Dingus (Wisconsin) - transients**

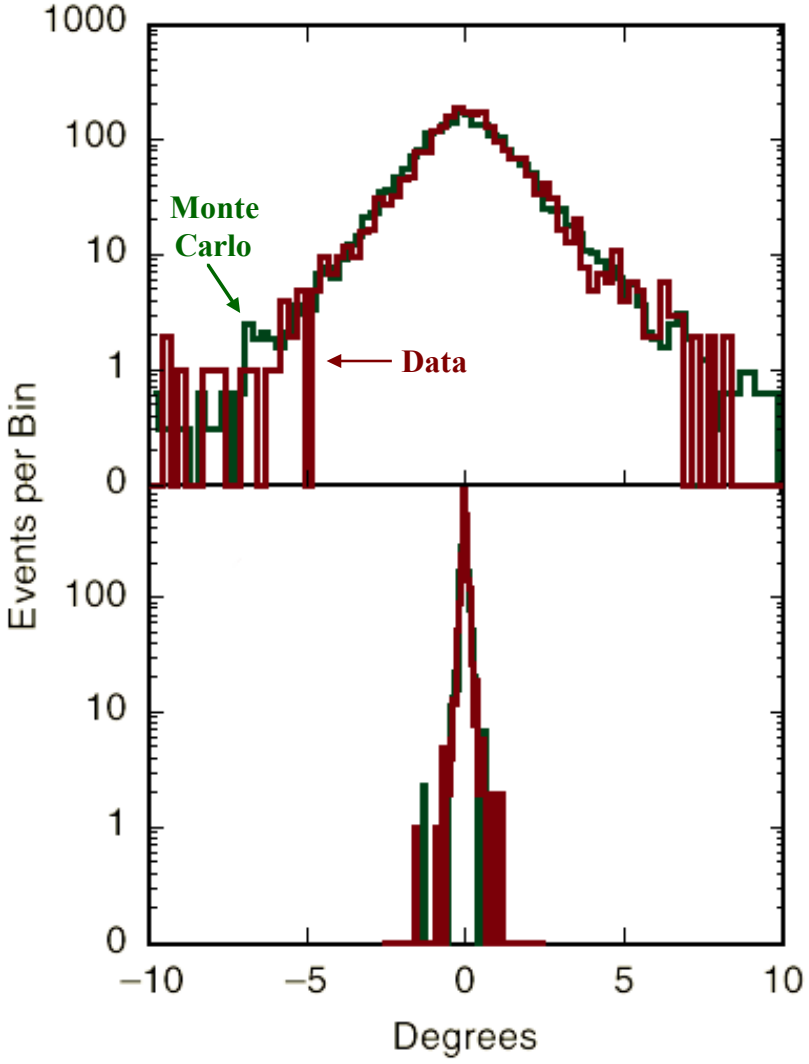
    **M. Pohl (Ruhr U.) - diffuse galactic**

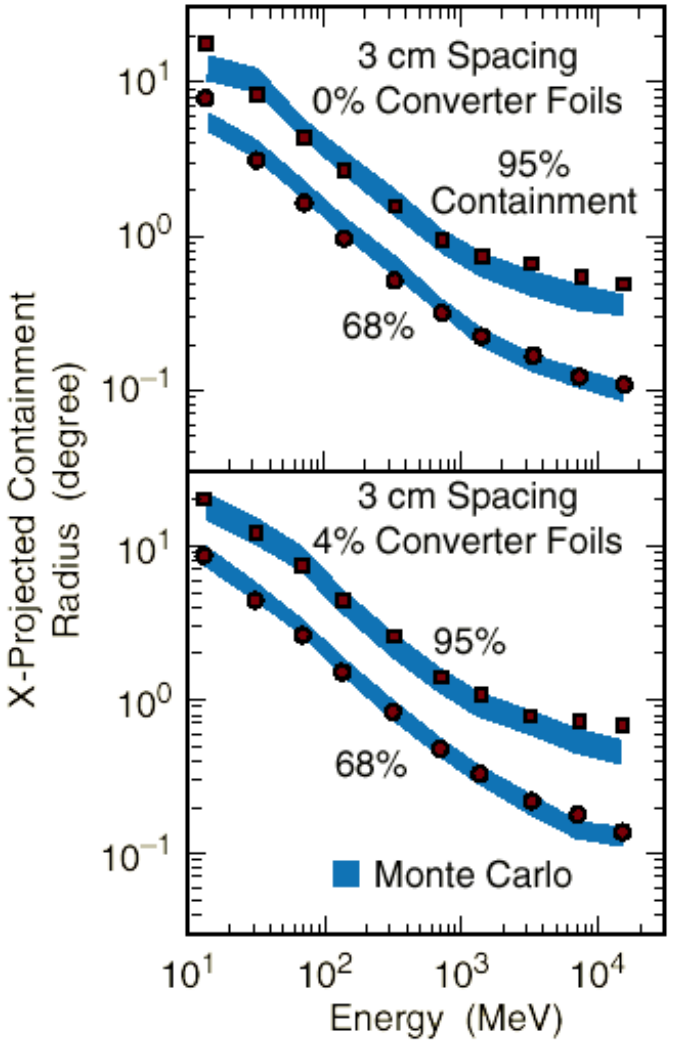
    **S. Thorsett (UCSC) - pulsars**

# GLAST LAT

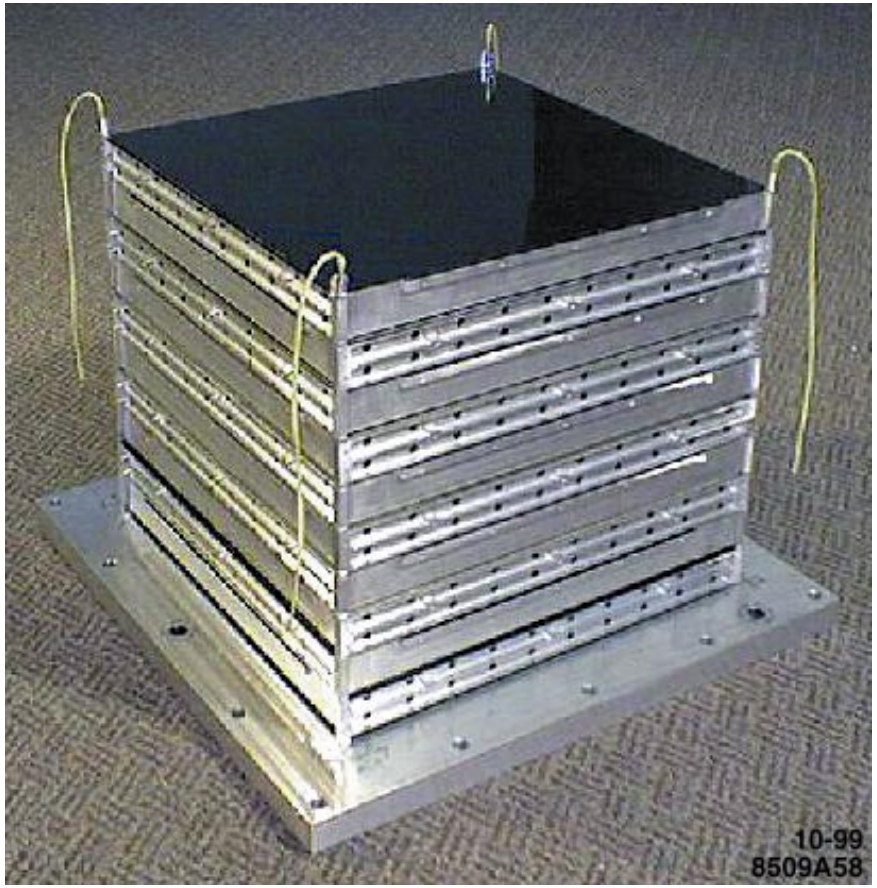

Some Dimensions are Distorted
for Clarity of Presentation
Complete GLAST
4 x 4 Array of Towers
1.68 m
Anticoincidence
Shield
Gamma
Ray
Ultra-low Mass
Tray Backbone
Lead
Silicon
12 Trays with 0.025
Radiation Length Pb Converters
4 Trays with 0.25
Radiation Length Pb Converters
2 Trays without
Converters
9.2 cm
Si Strip Detector
201 μm
Pitch
Preamps Mounted
on Vertical
Edge of Tray
One Tower Module of GLAST
84 cm
Grid
Imaging Calorimeter
(9 rl)
7-99
8372A106

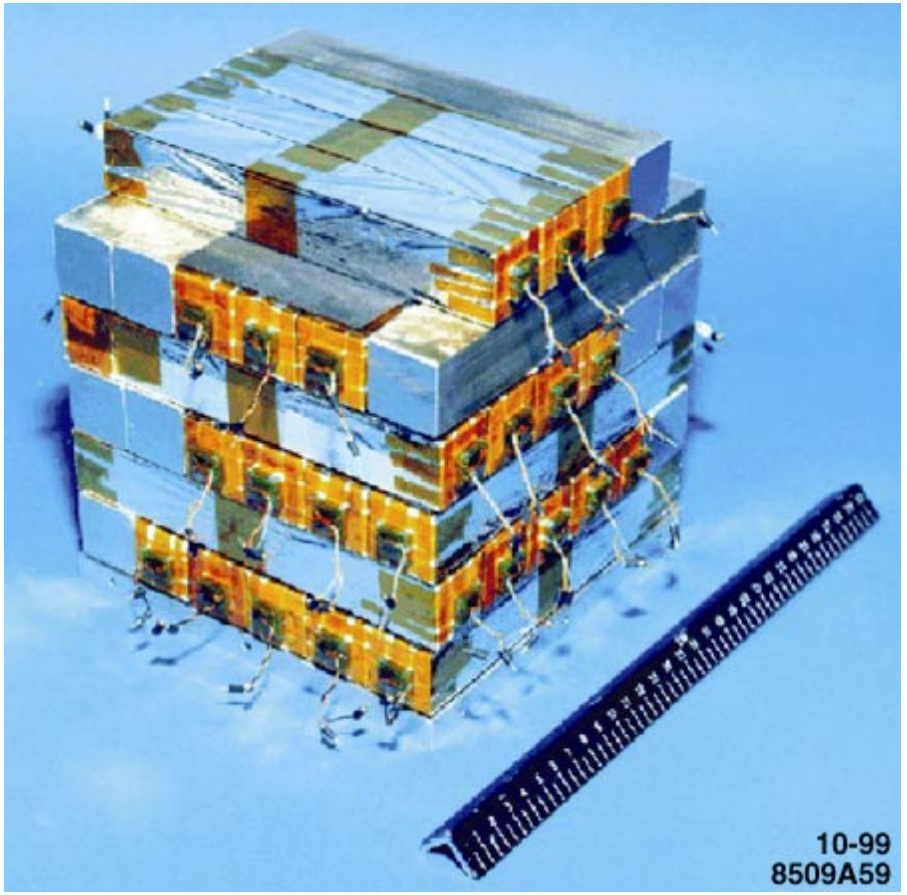
# LAT Beam Test Verification



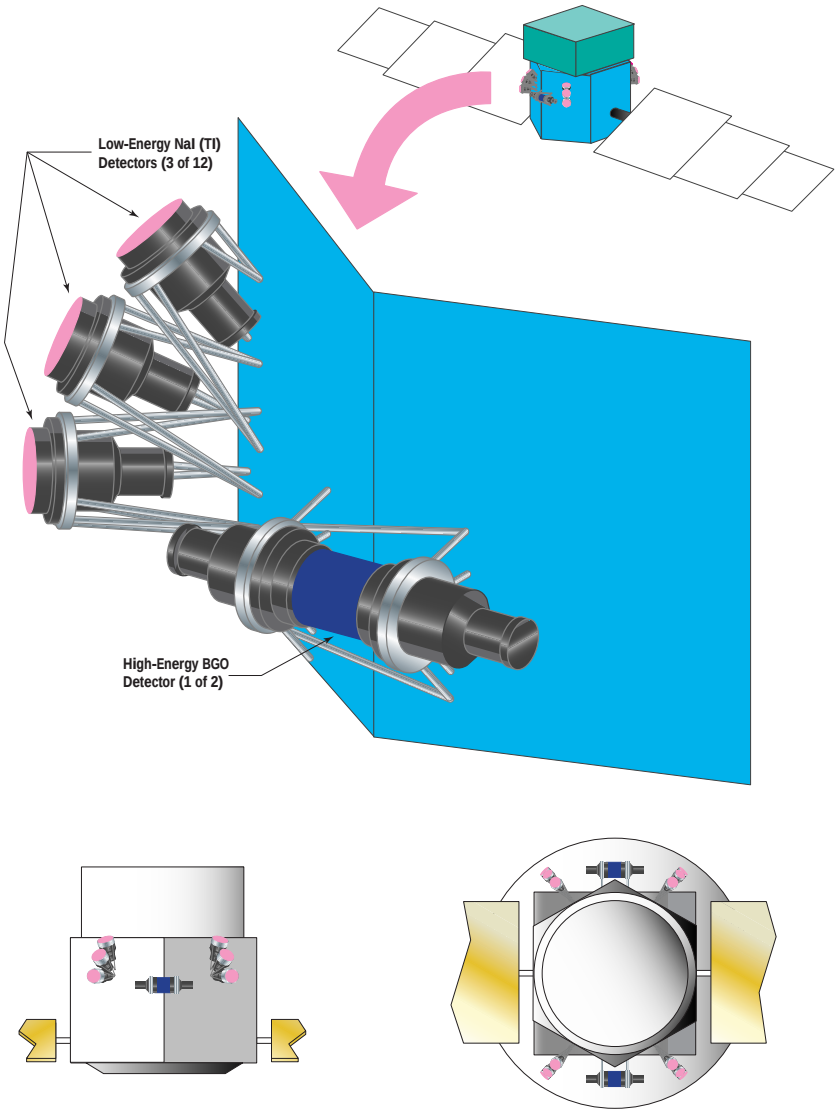



# LAT Hardware

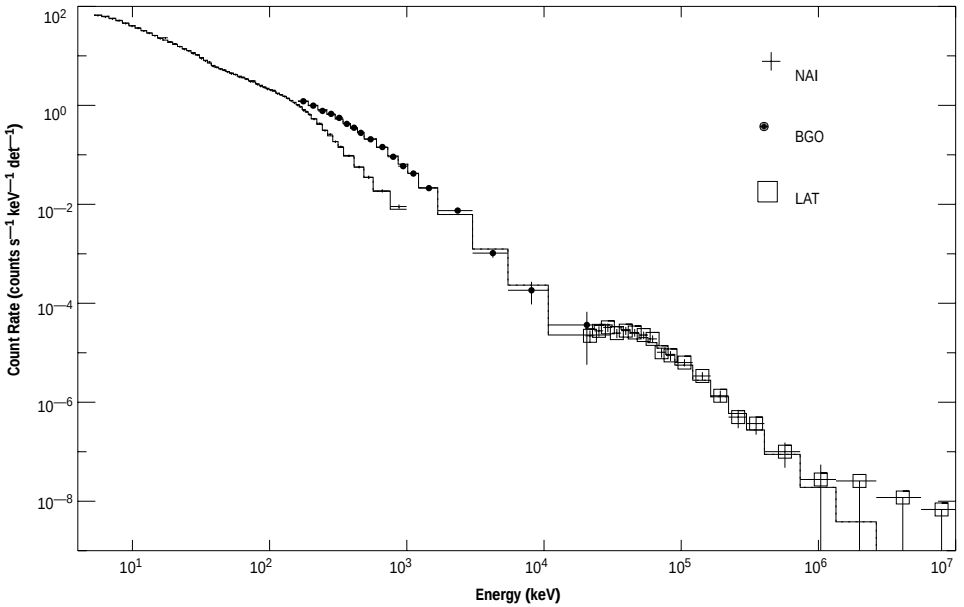


# GLAST GBM




## GRB 940217

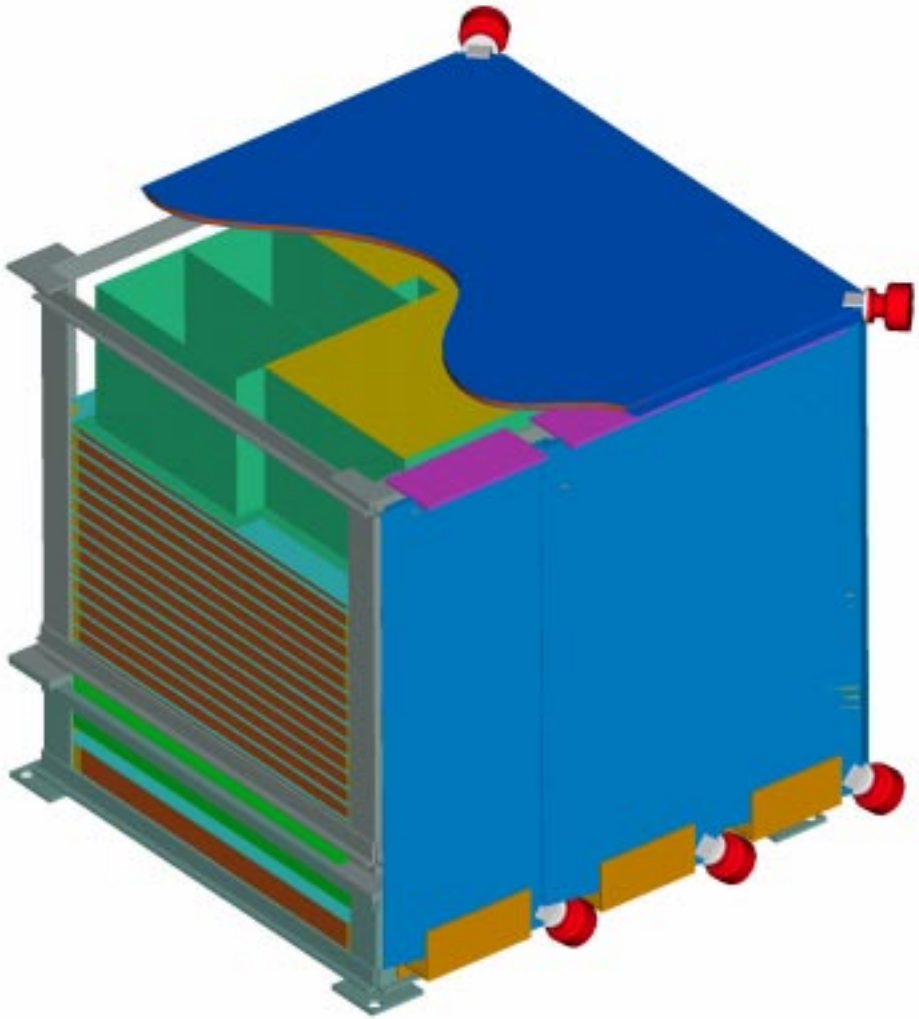



LAT and GBM simulation.

# GBM vs. BATSE

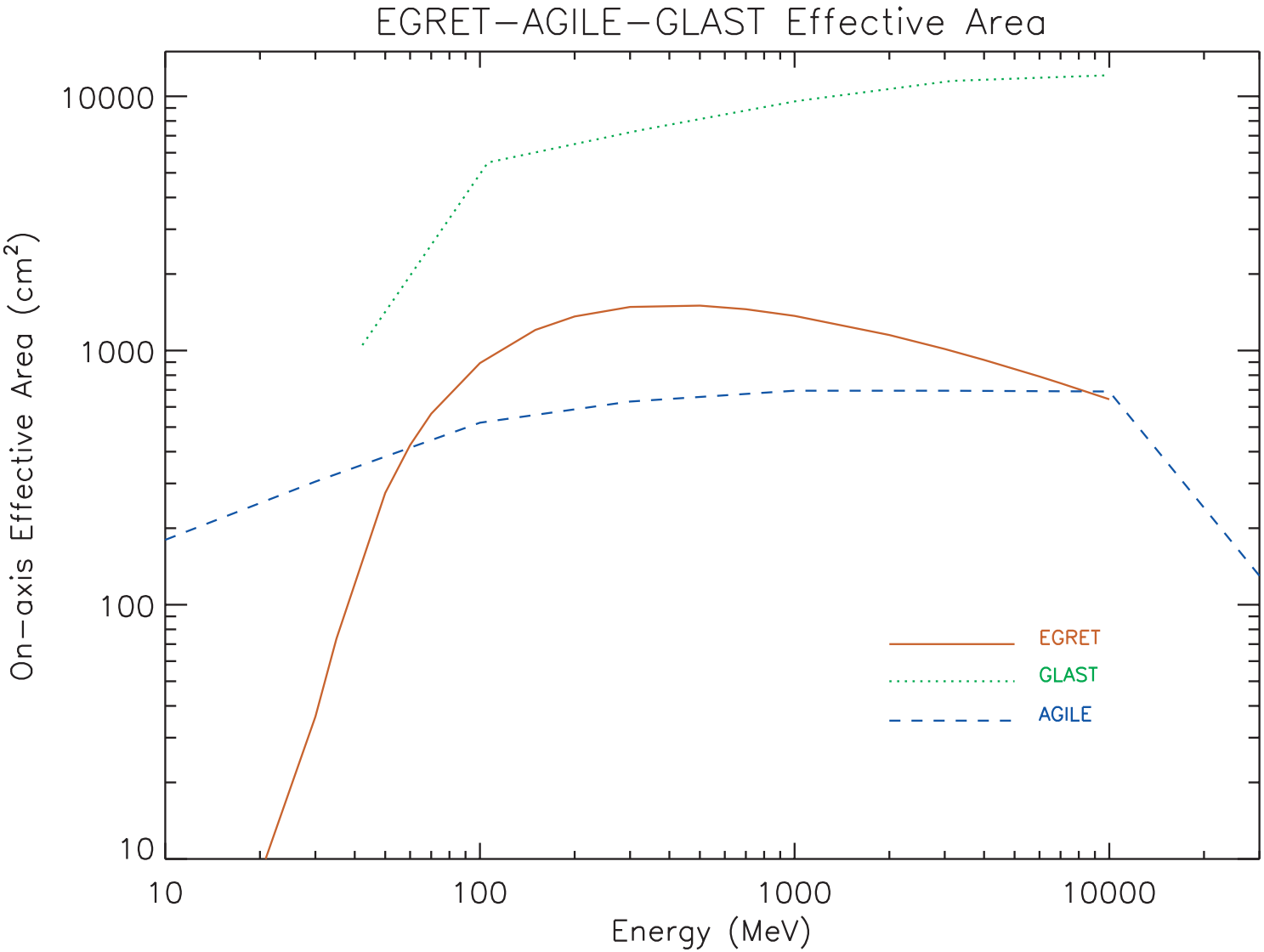
| Parameter | BATSE | GBM |
|---|---|---|
| Energy Range | 25 keV - 1.9 MeV (LAD)<br>7 keV - 10 MeV (SD) | 5 keV - 1 MeV (LED)<br>150 keV - 30 MeV (HED) |
| Detectors | NaI | NaI/BGO |
| FOV | Full Sky | 8.6 sr |
| Location Accuracy | 2° - 5° | 1.5° - 3° |
| Burst Sensitivity | 0.2 ph $cm^{-2}$ $s^{-1}$ | 0.6 ph $cm^{-2}$ $s^{-1}$ |

# AGILE

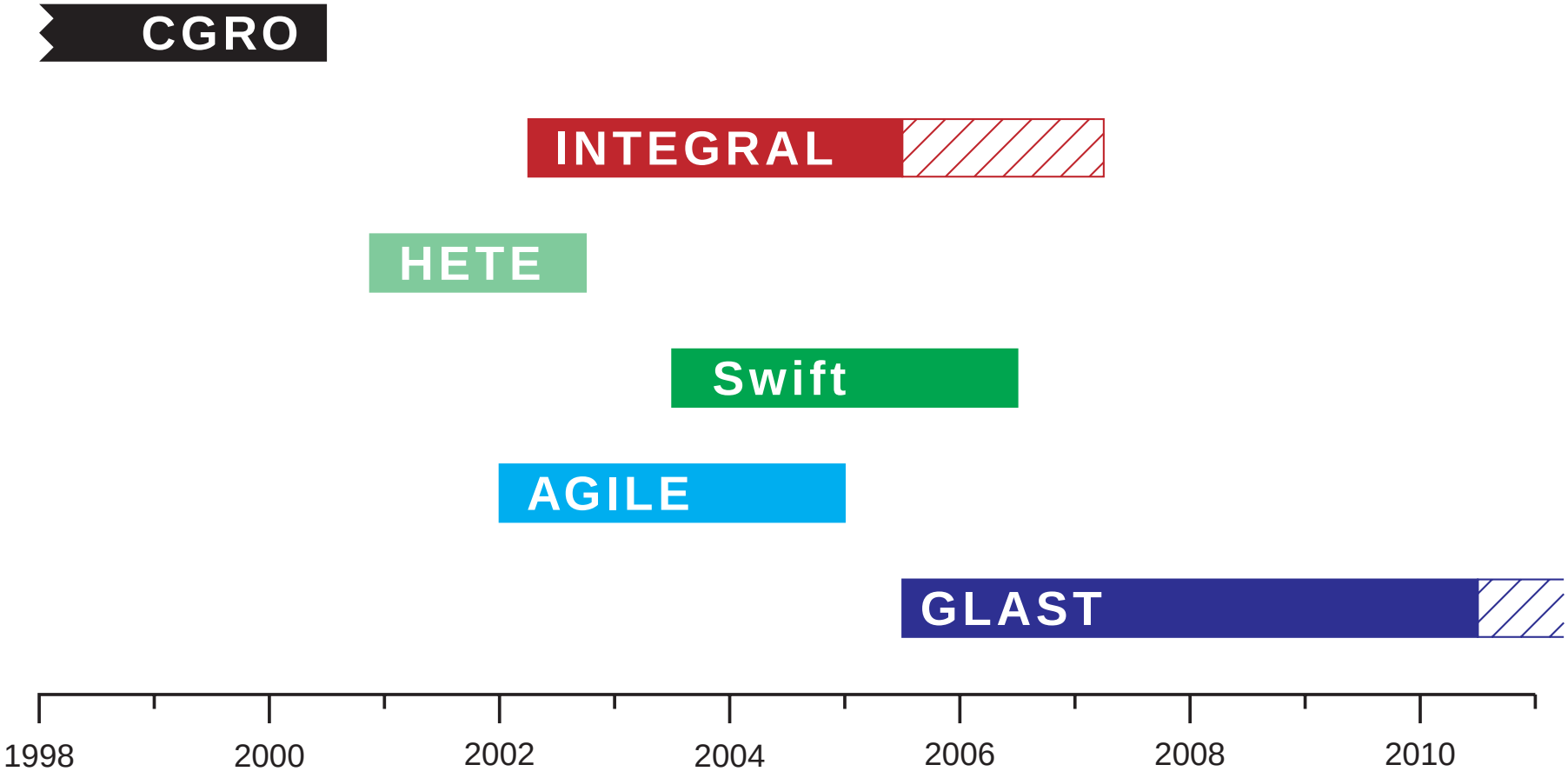


| Spacecraft and Satellite Characteristics | |
|---|---|
| Optimal orbital parameters | Equatorial orbit, 550 km |
| Possible ground station | Malindi (Kenya) |
| Spacecraft + payload mass | 180-200 kg |
| Payload required power | ~60 W |
| Downlink telemetry rate | ~500 kbit/sec |
| Pointing configuration | 3 - axes |
| Pointing accuracy | 0.5 - 1 degree |
| Satellite expected life | >~ 3 years |

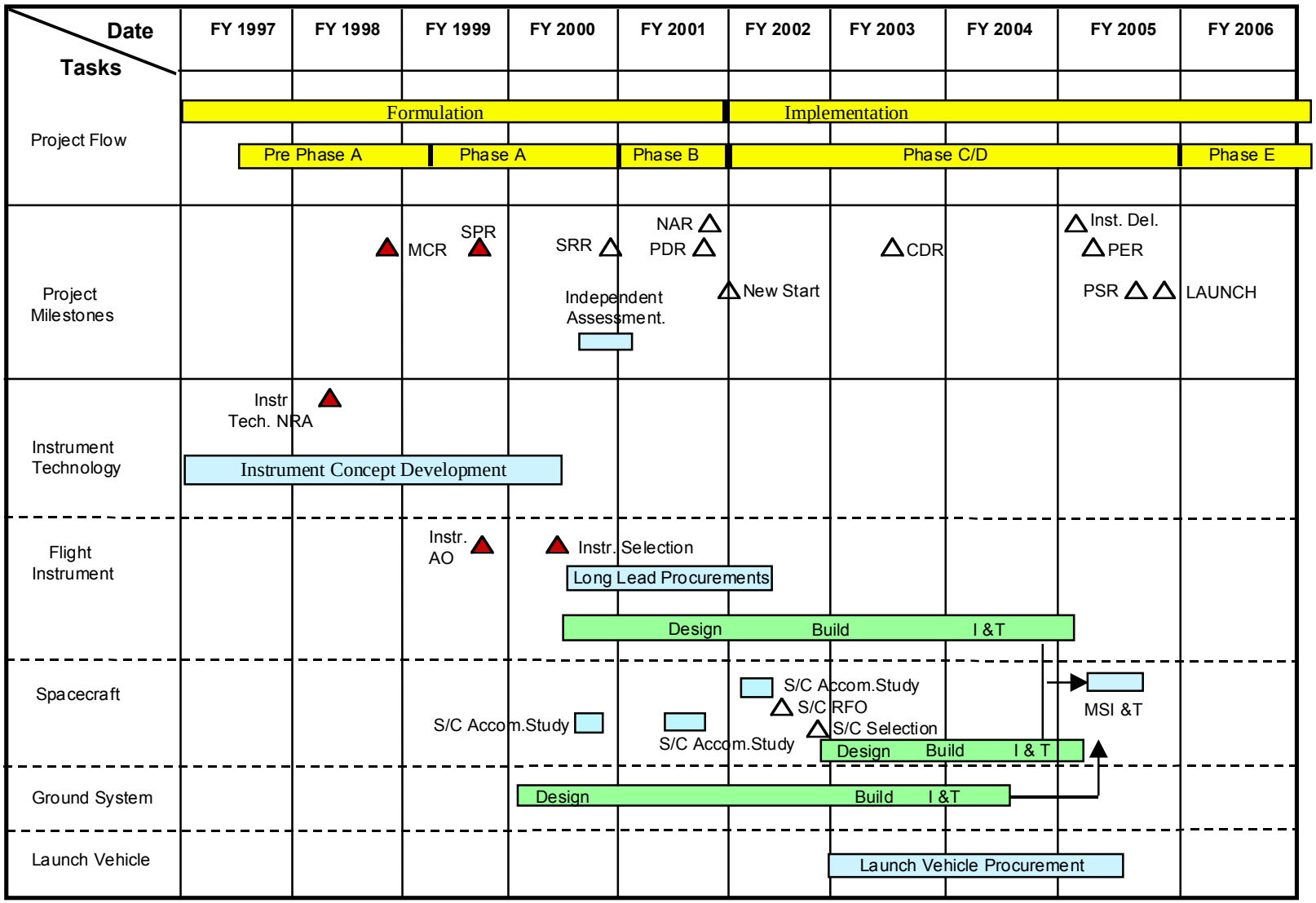
# AGILE and GLAST Performance



# Space Gamma Ray Astronomy



# GLAST Long-Term Schedule




Revised
12/20/99