Exploring the Extreme Universe with ~~GLAST~~ Fermi

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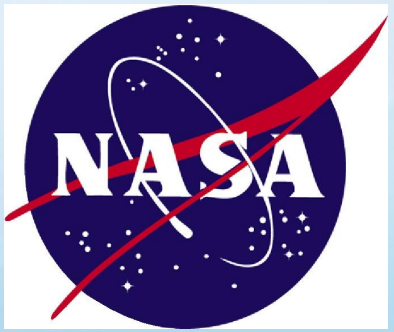
Sonoma State University
GLAST Education and Public Outreach

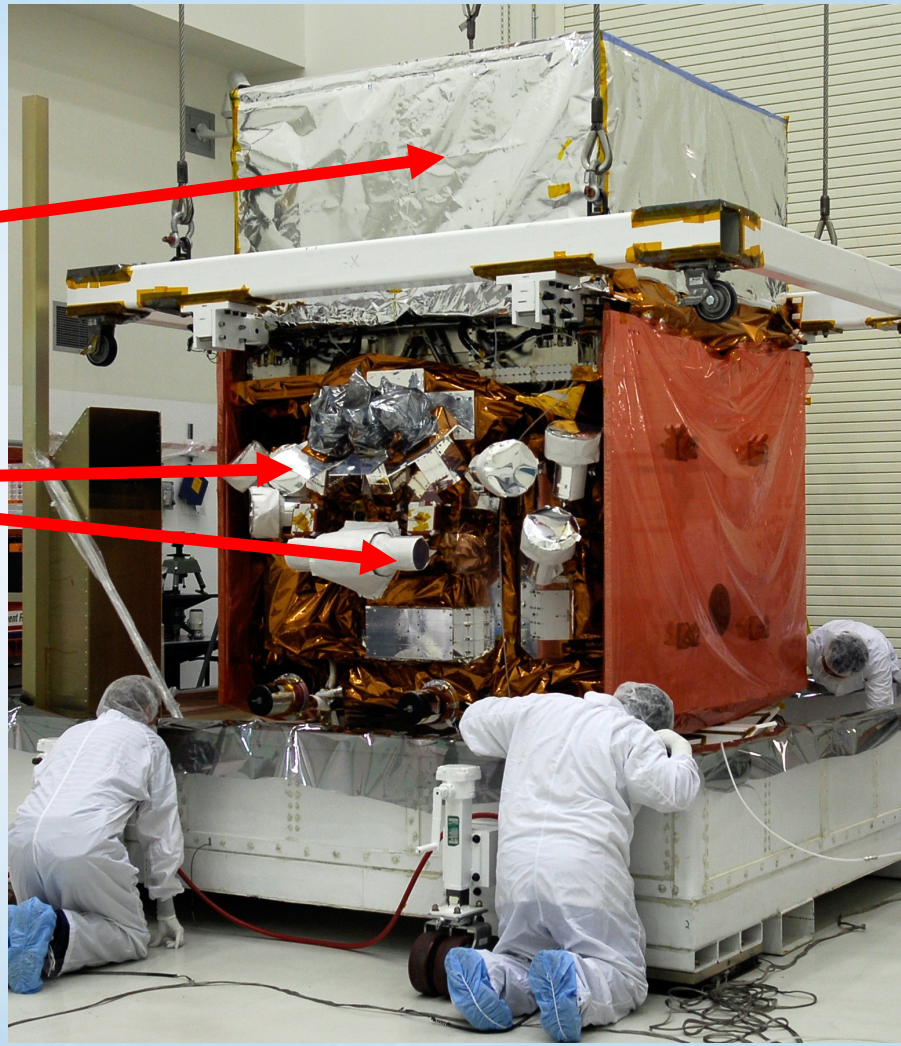
Mission

- First space-based collaboration between astrophysics and particle physics communities
- Launched June 11, 2008
- First year All-sky Survey followed by…
- Competitive Guest Observer Program
- Expected duration 5-10 years



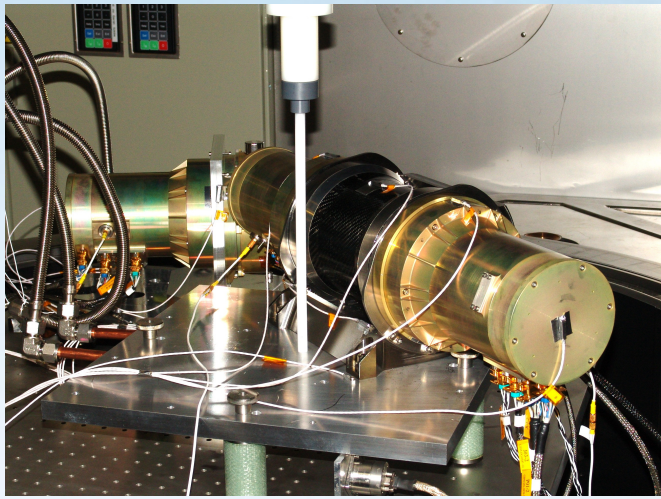
Before launch

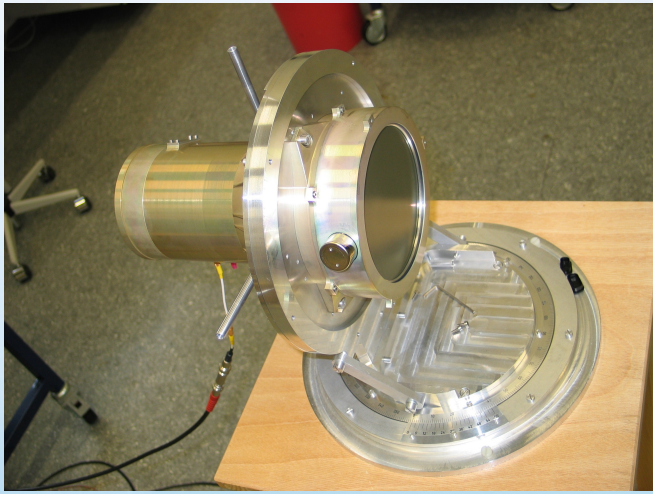
- Large Area Telescope
- GLAST Burst Monitor



GLAST Burst Monitor (GBM)

- PI Charles Meegan (NASA/MSFC)
- US-German secondary instrument
- 12 sodium iodide scintillators
  - 10 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/**



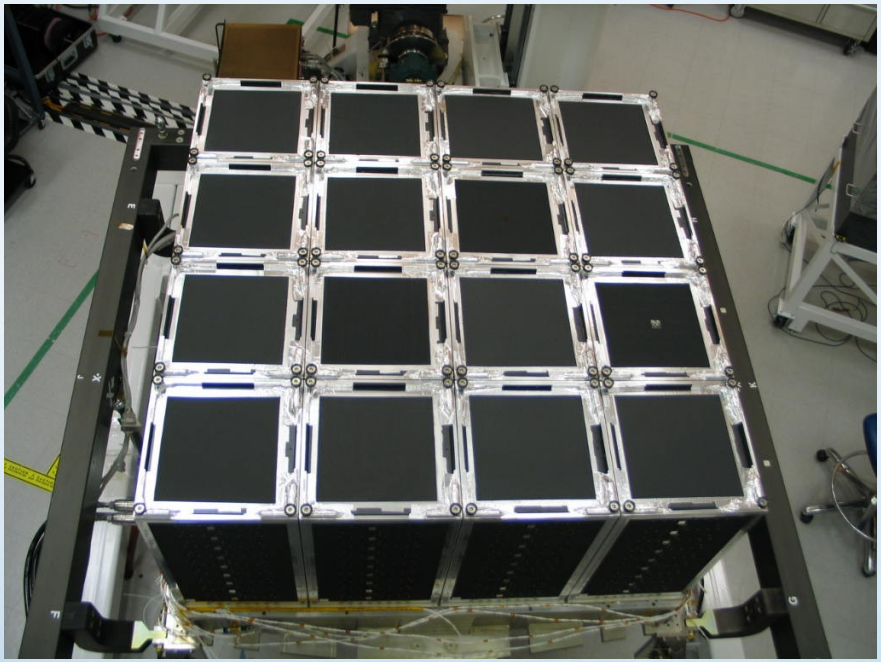


Large Area Telescope (LAT)

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

- LAT is a 4 x 4 array of towers

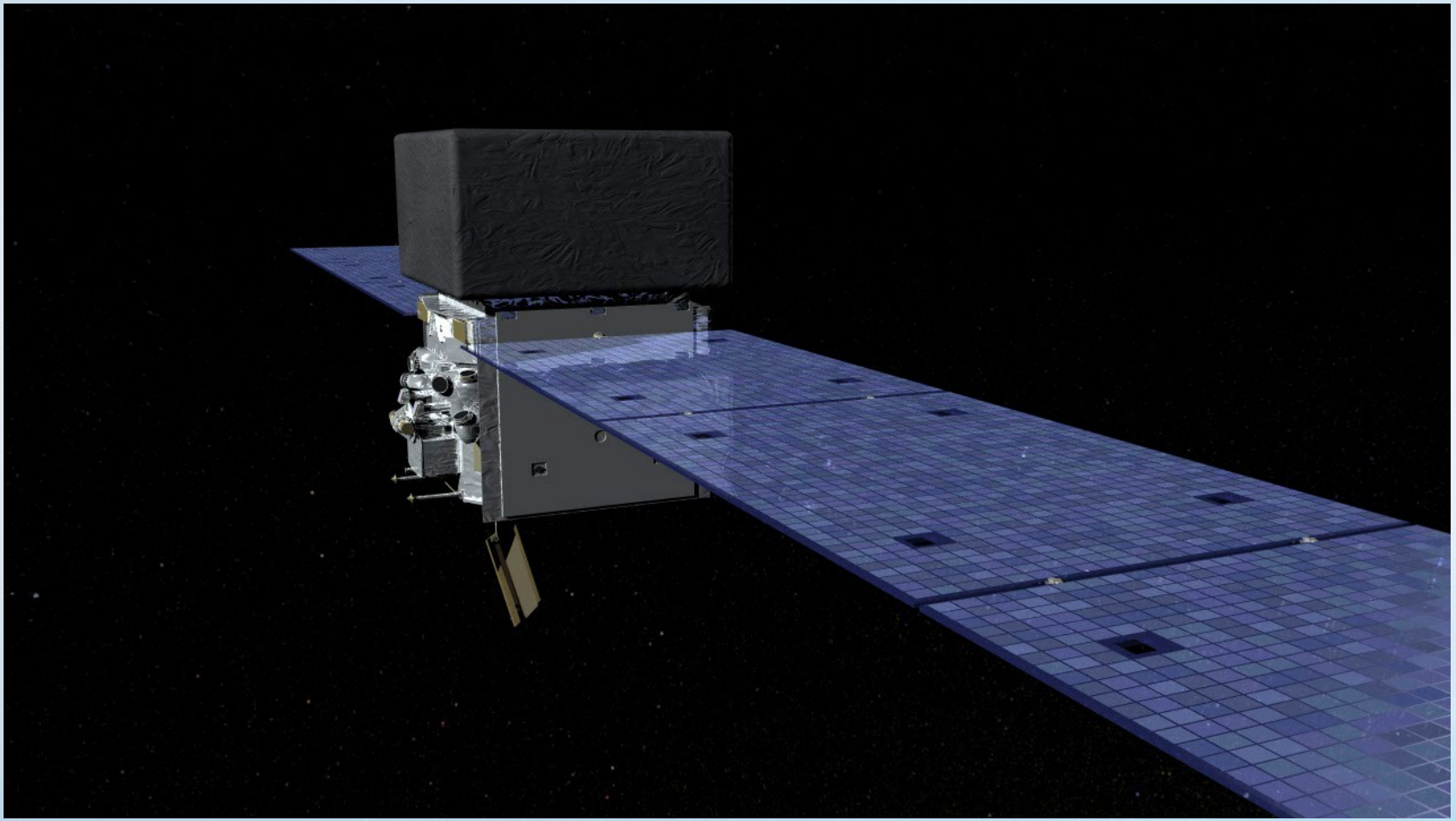
- Each tower is a pair conversion telescope with calorimeter



- http://glast.stanford.edu

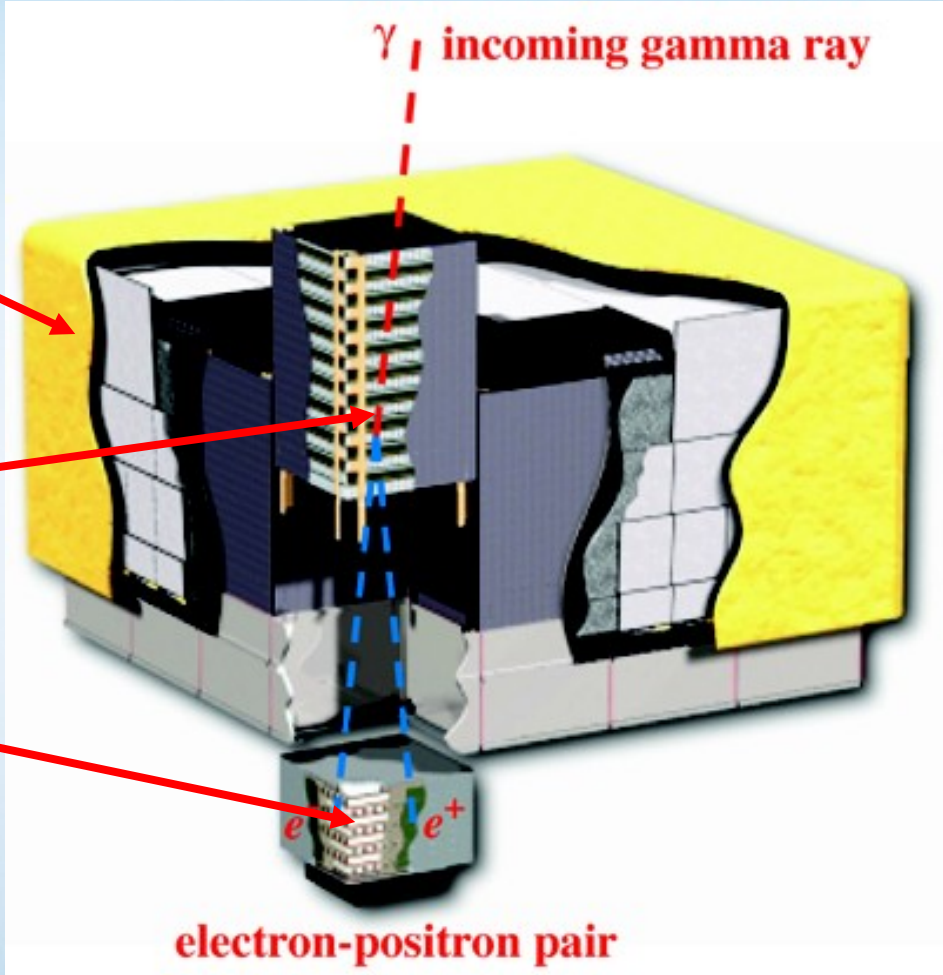
Fermi
Gamma-ray
Space Telescope

Pair Conversion Telescope

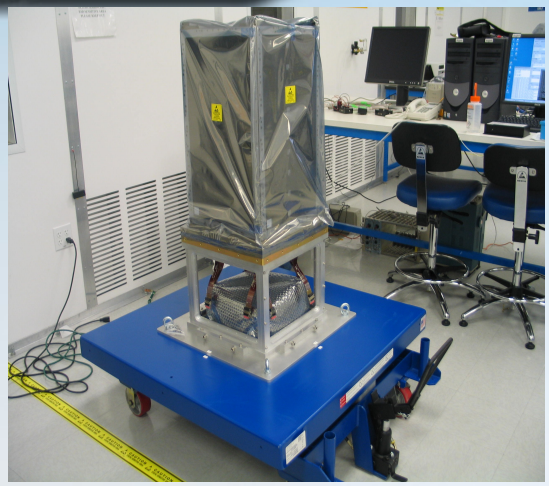


LAT Schematic

- Tiled Anticoincidence Detectors
- Silicon strip detectors interleaved with Tungsten converter
- Cesium Iodide hodoscopic calorimeter

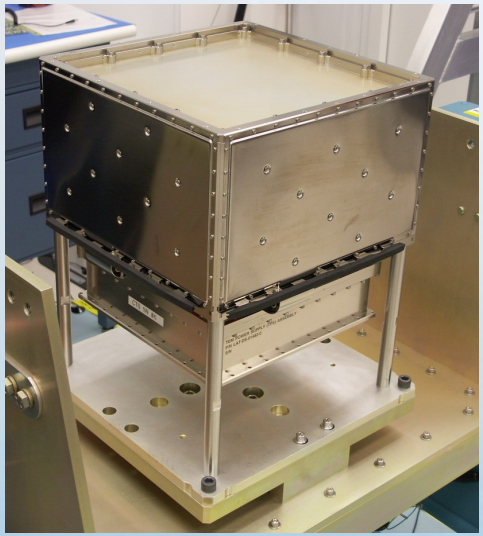


LAT Hardware

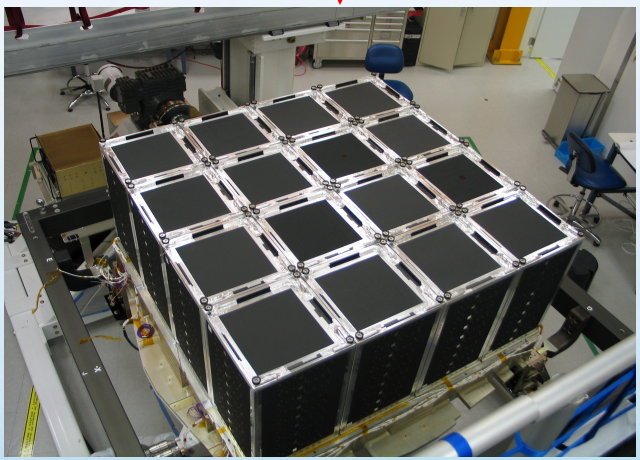


Trackers

Grid Structure



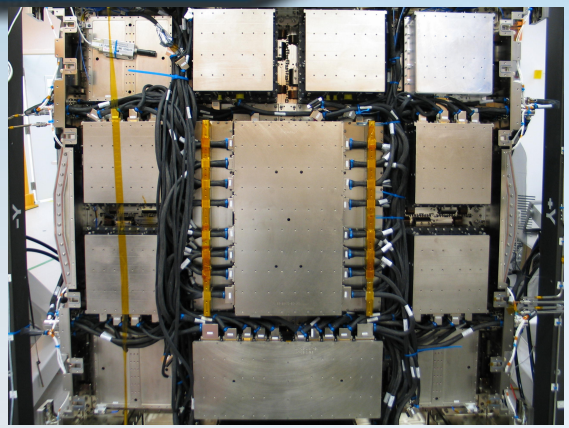
Calorimeters

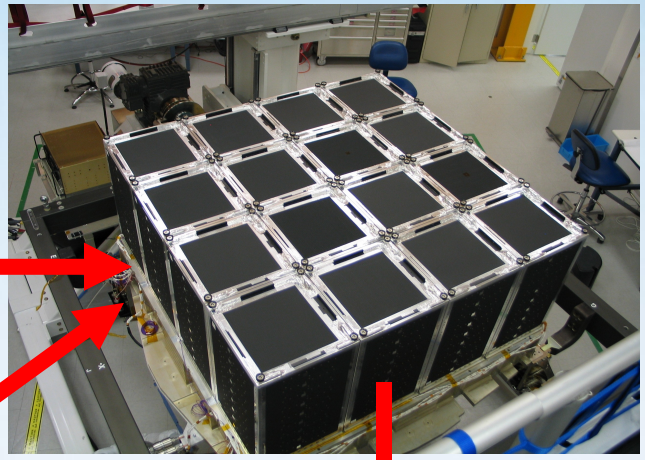


16 Towers

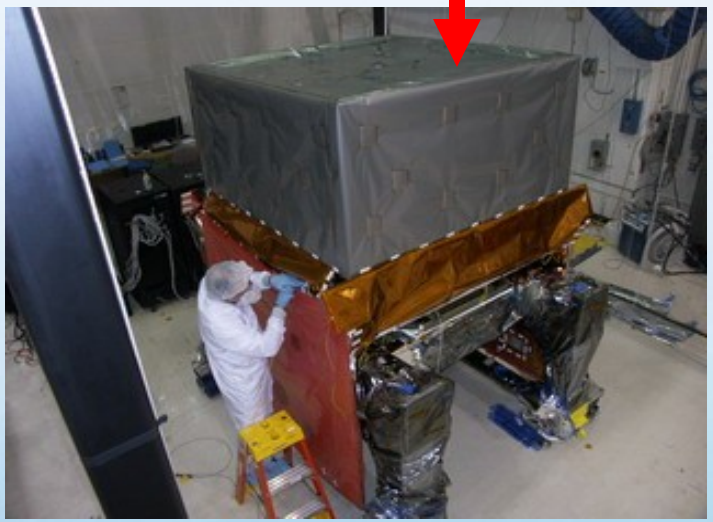
LAT Hardware

16 Towers





Global Electronics



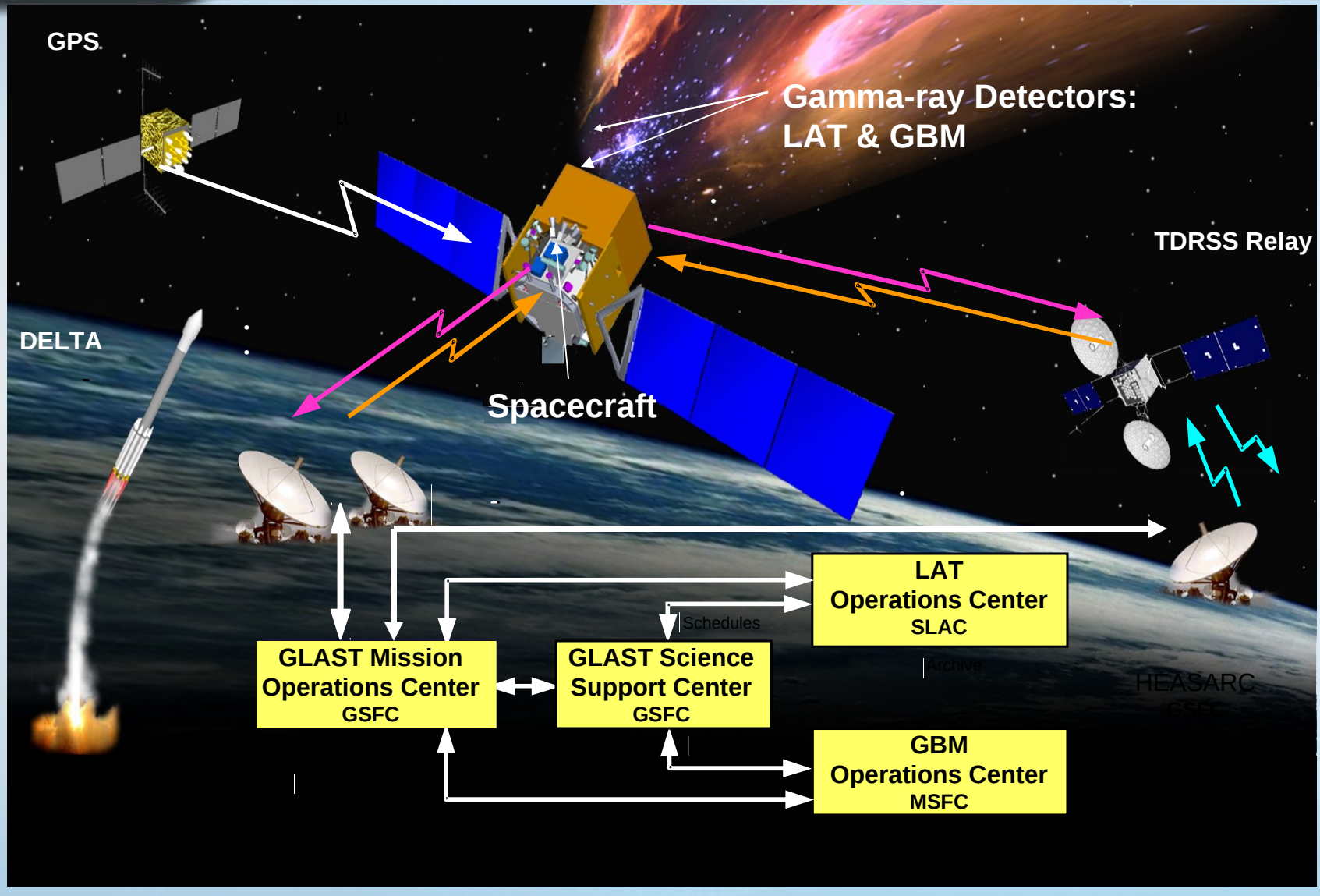
Anticoincidence Detectors

Integrated LAT with radiators

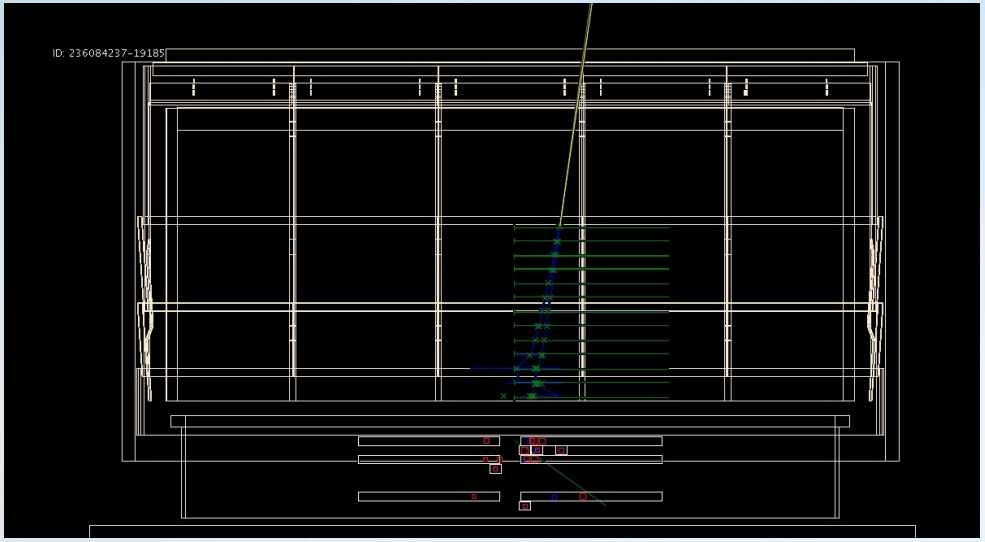
Launched!

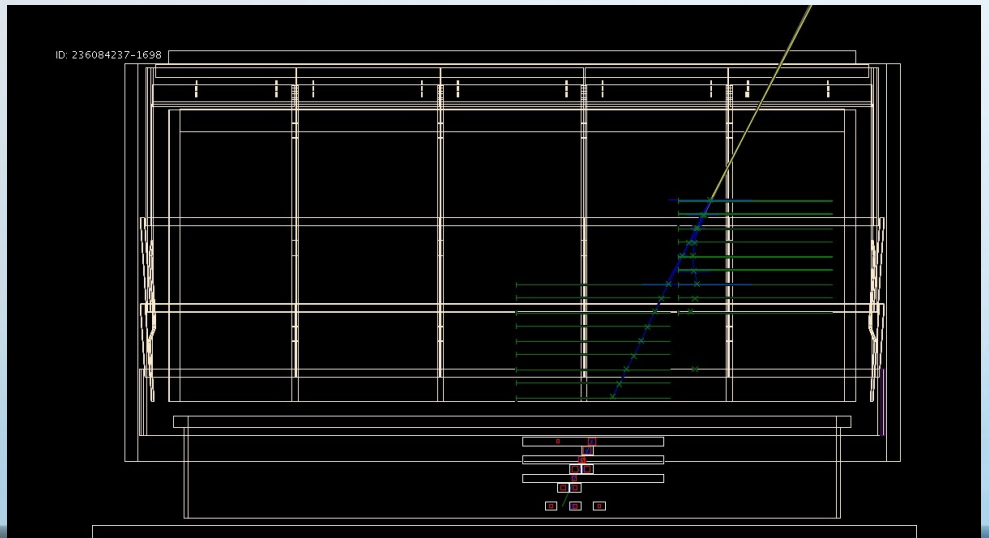
- June 11, 2008
- Delta II Heavy (9 solid rocket boosters)
- Mass is 4300 kg
- 555 km circular orbit
- 1500 W total power
- 40 Mb/sec downlink

Mission Data Relay



LAT Single GR Event Displays





green = charged particles

blue = reconstructed track

yellow = gamma-ray estimated direction

red = energy depositions in the calorimeter

First Light Press Conference

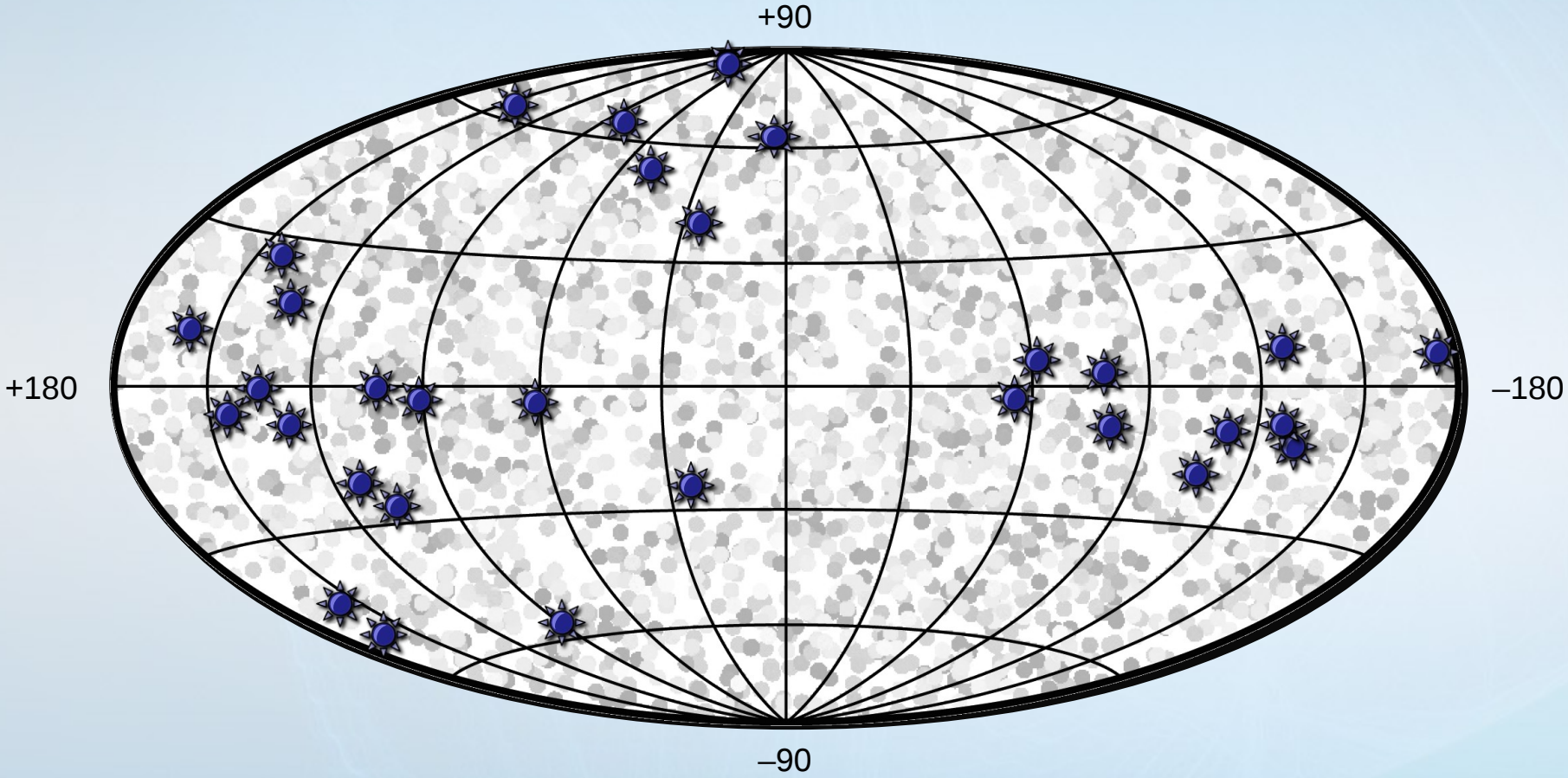
- Results were announced yesterday!

Enrico Fermi

1901-1954

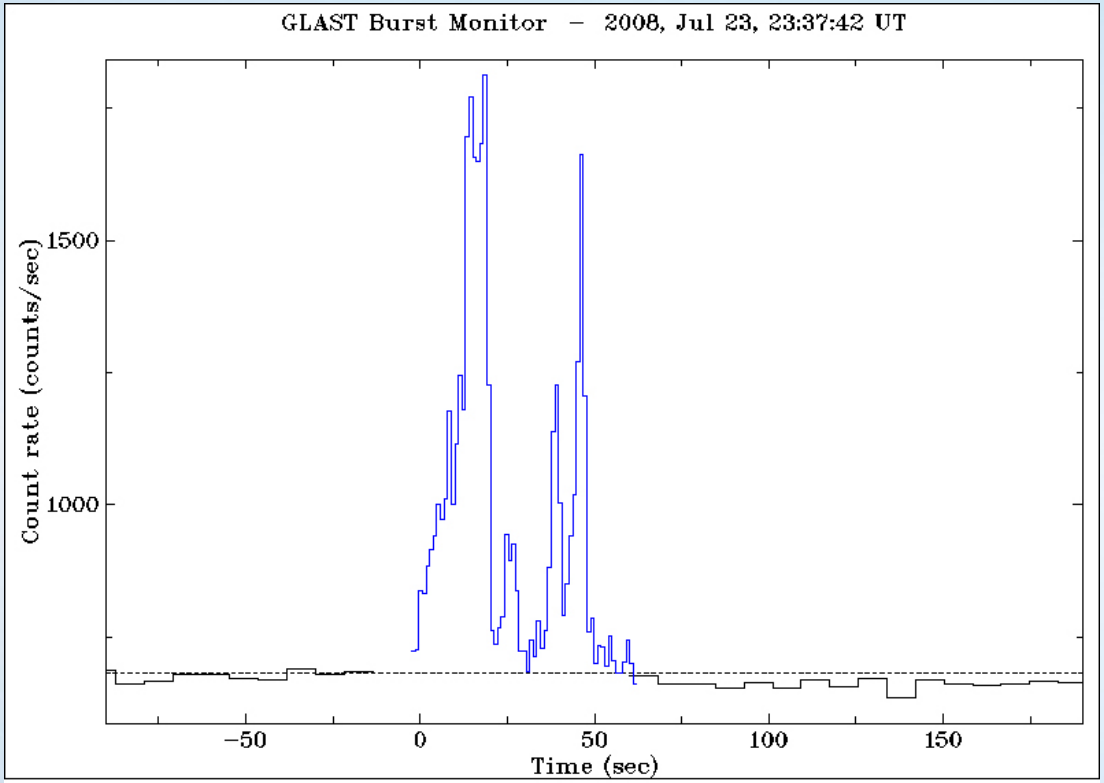
Nobel in 1938

GBM Bursts in first month



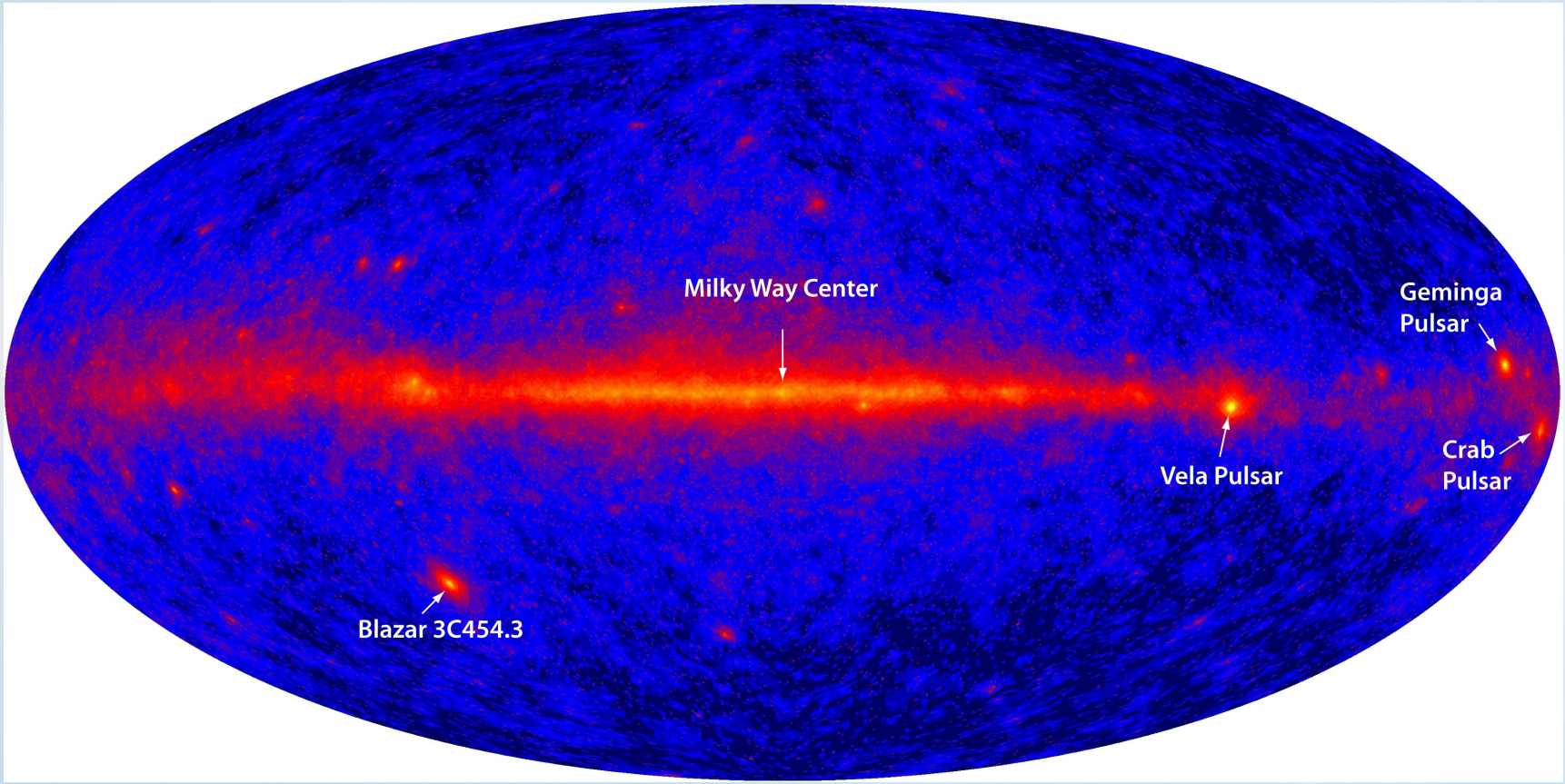
- About one burst per day

Typical strong GRB seen by GBM



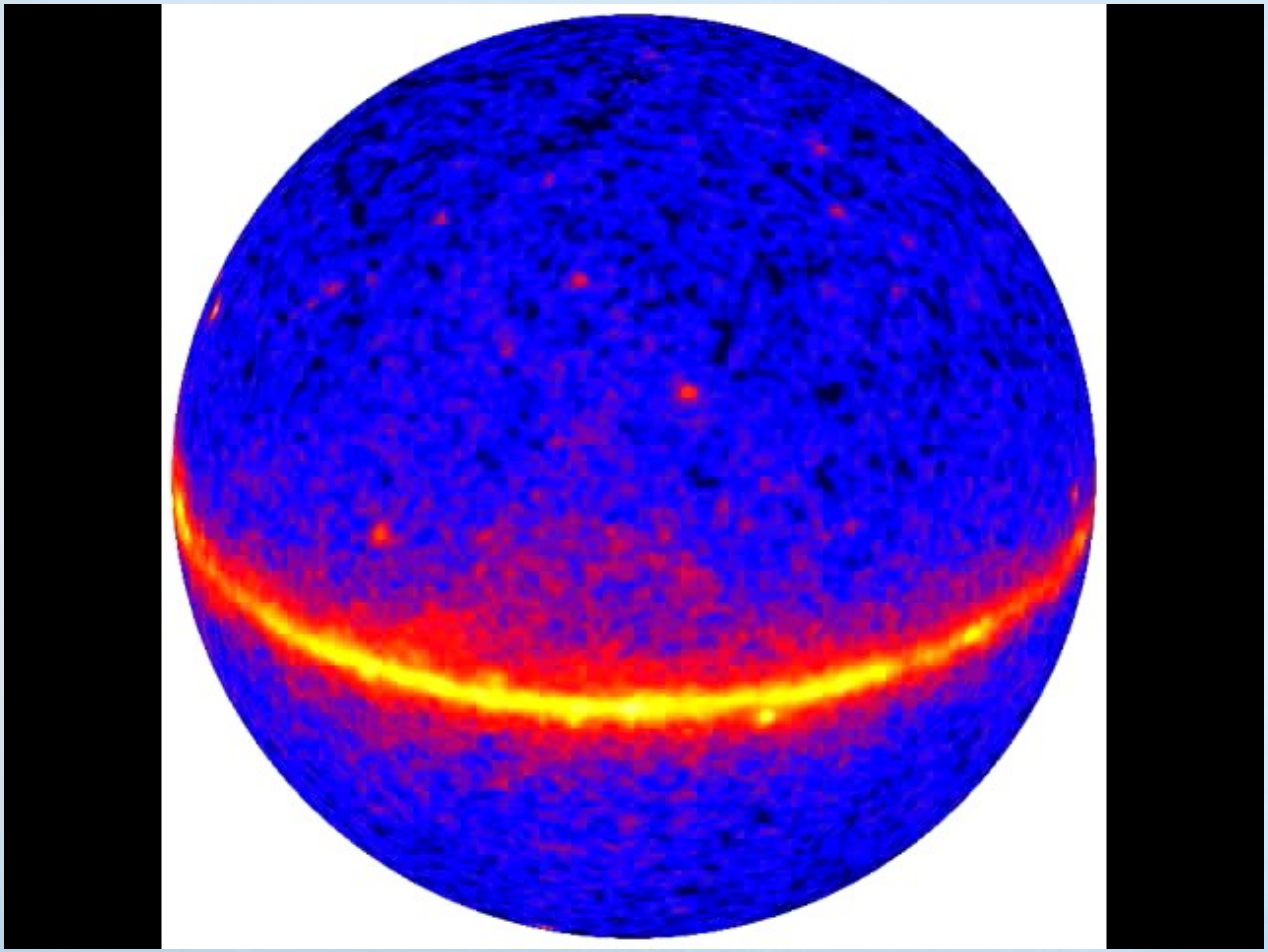
- No joint LAT-GBM bursts yet
- Several GBM bursts also seen by Swift

First Light LAT Skymap



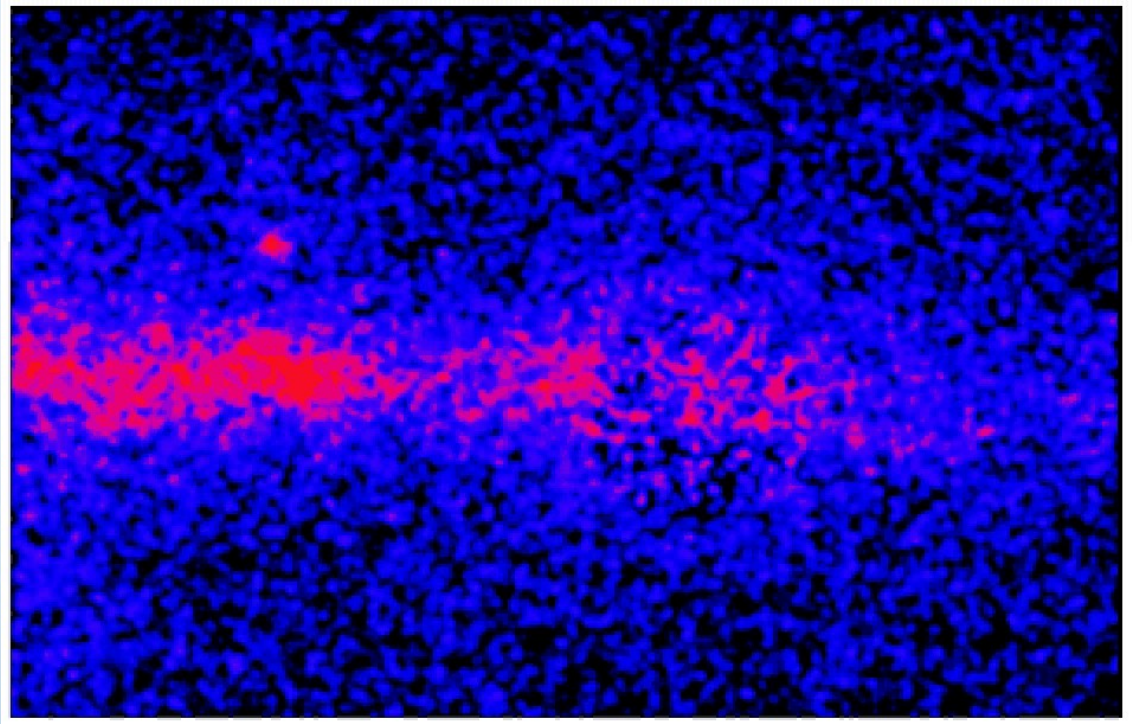
95 hours of LAT data = about 1 year of EGRET sensitivity

Orthographic projection



Vela pulsar

- LAT has detected all 7 EGRET pulsars



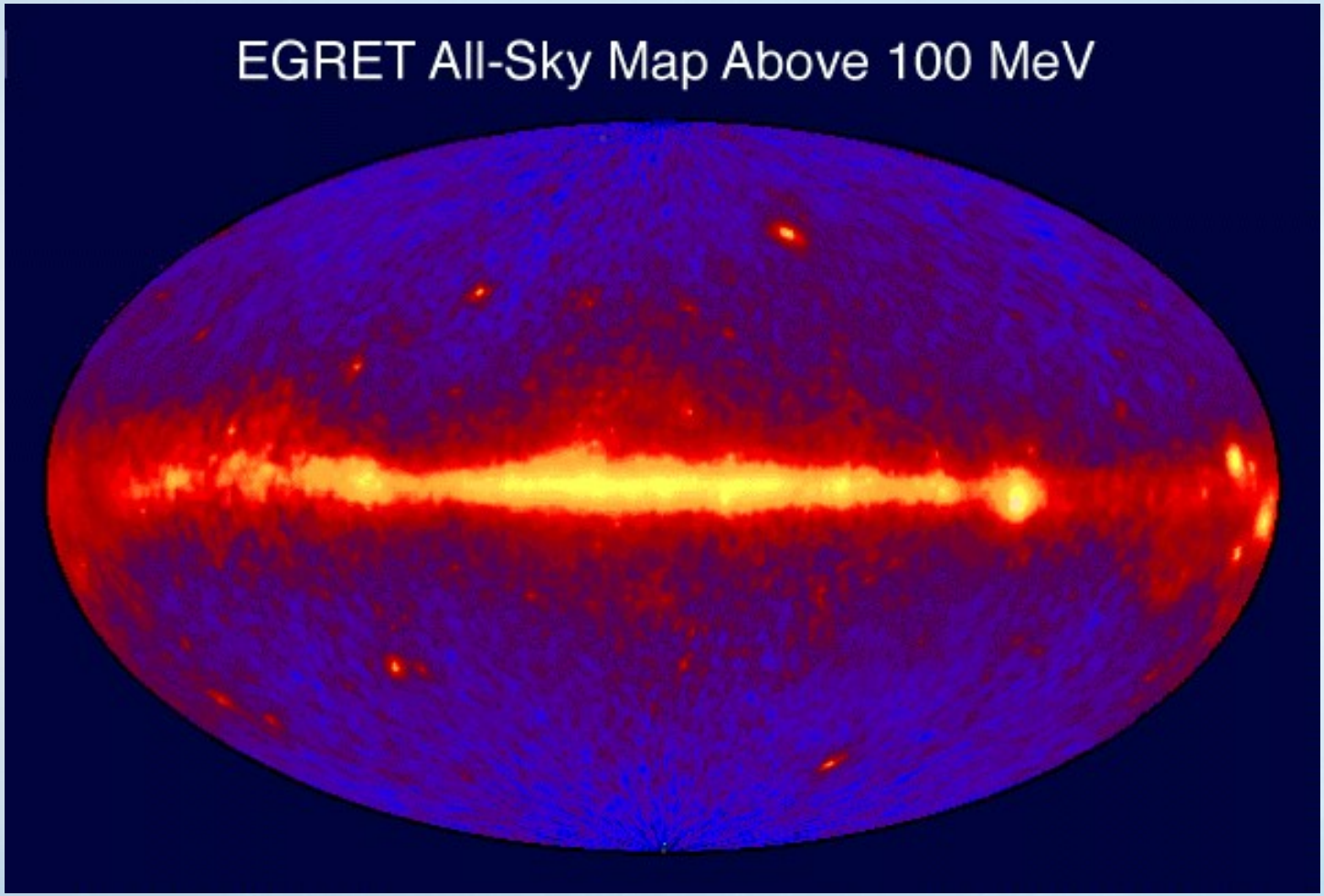
EGRET vs. Fermi LAT

	EGRET	Fermi 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	< 3.5^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 arcmin
Lifetime	1991 - 1997	2008 – 2013+

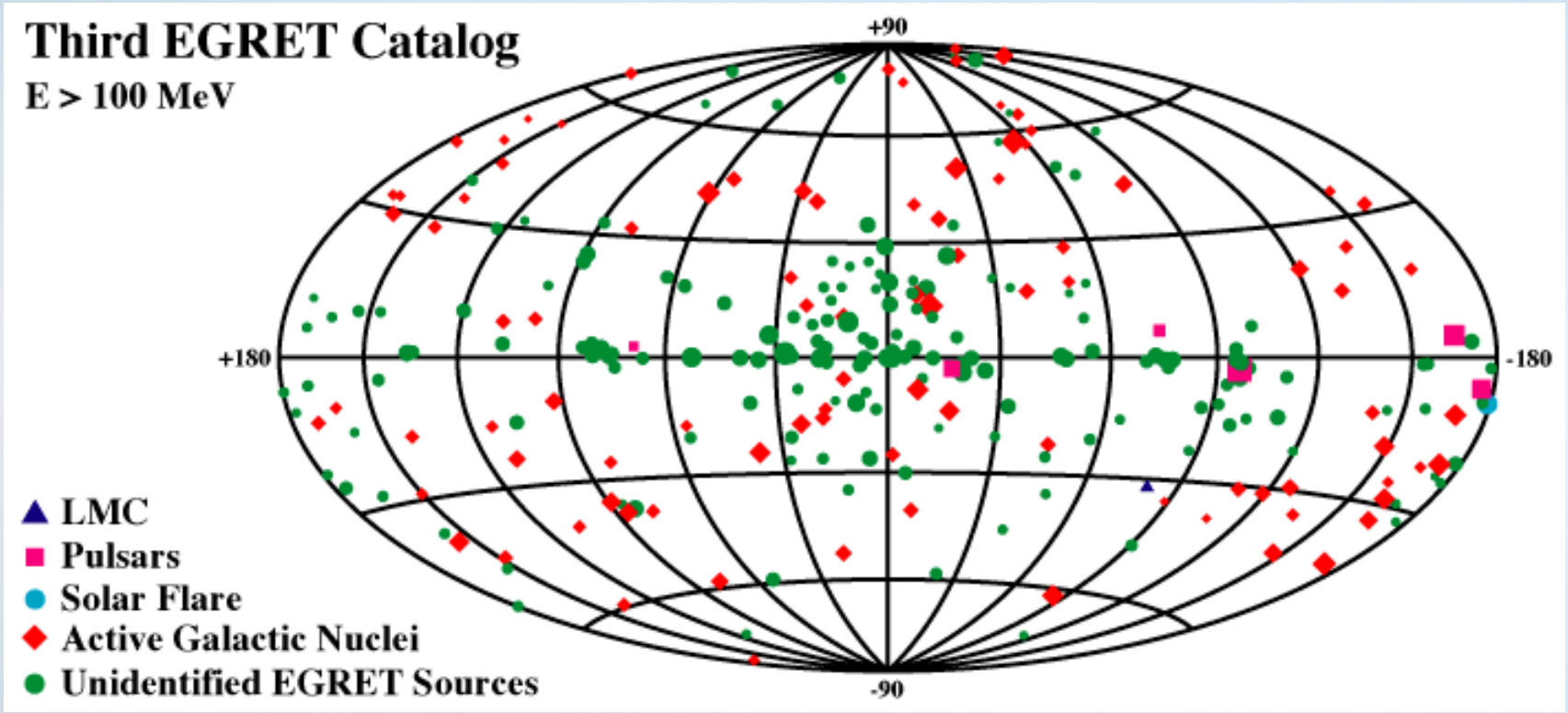
EGRET's Legacy

- 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

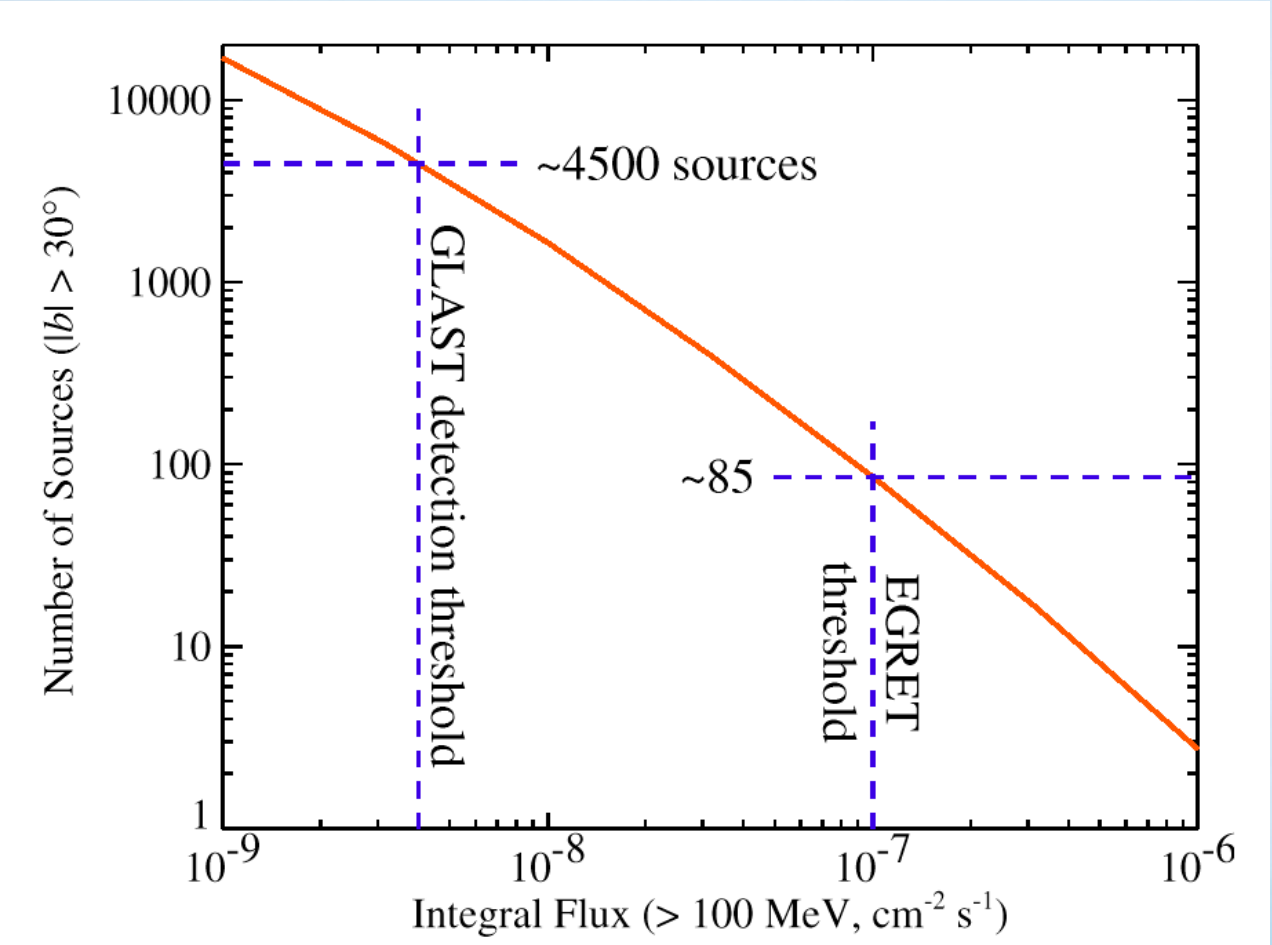


3rd EGRET Catalog



- LAT should detect thousands of sources

LAT Log N vs. Log S



Unidentified Sources

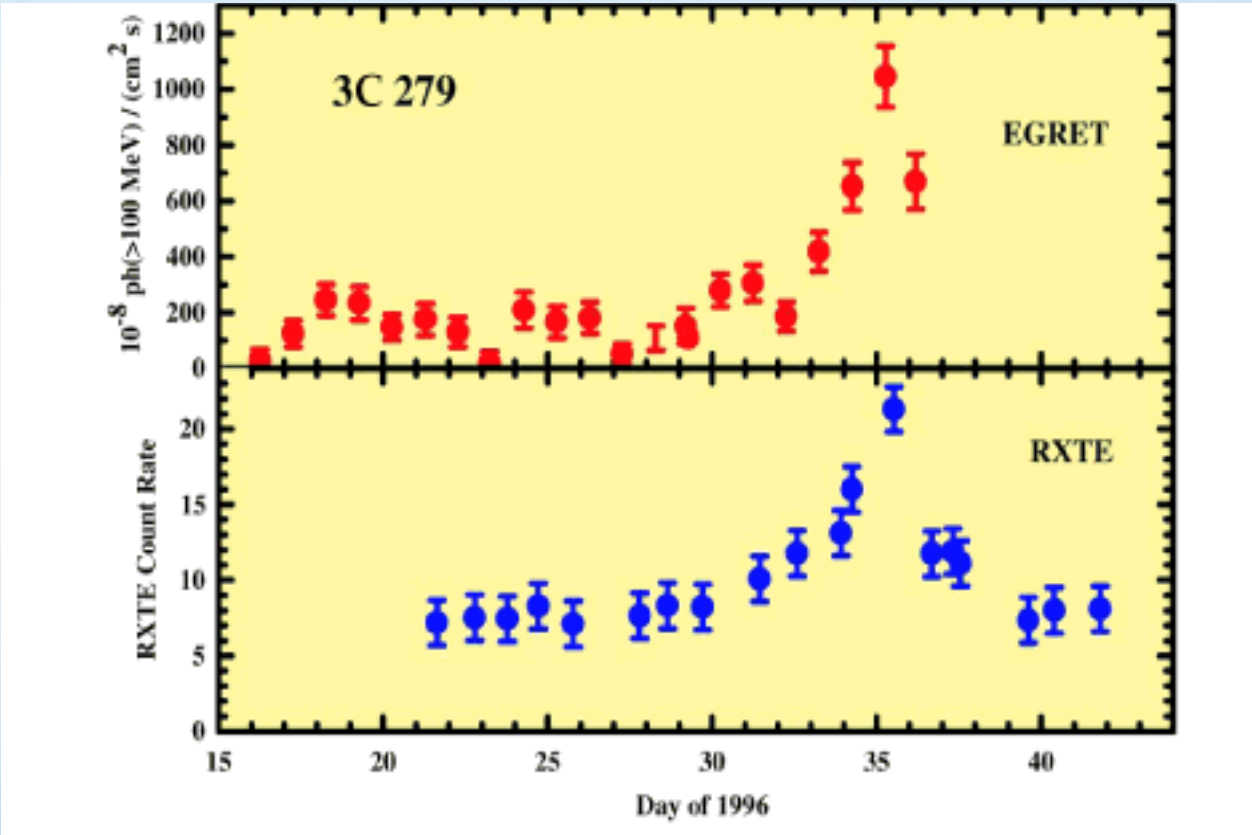
- 170 of the 270 sources in the 3rd EGRET catalog have no counterparts at longer wavelengths
- Variable sources appear at both low and high galactic latitudes
- High-latitude sources appear to be both extra-galactic and galactic
- Steady medium latitude sources may be associated with Gould's belt (star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



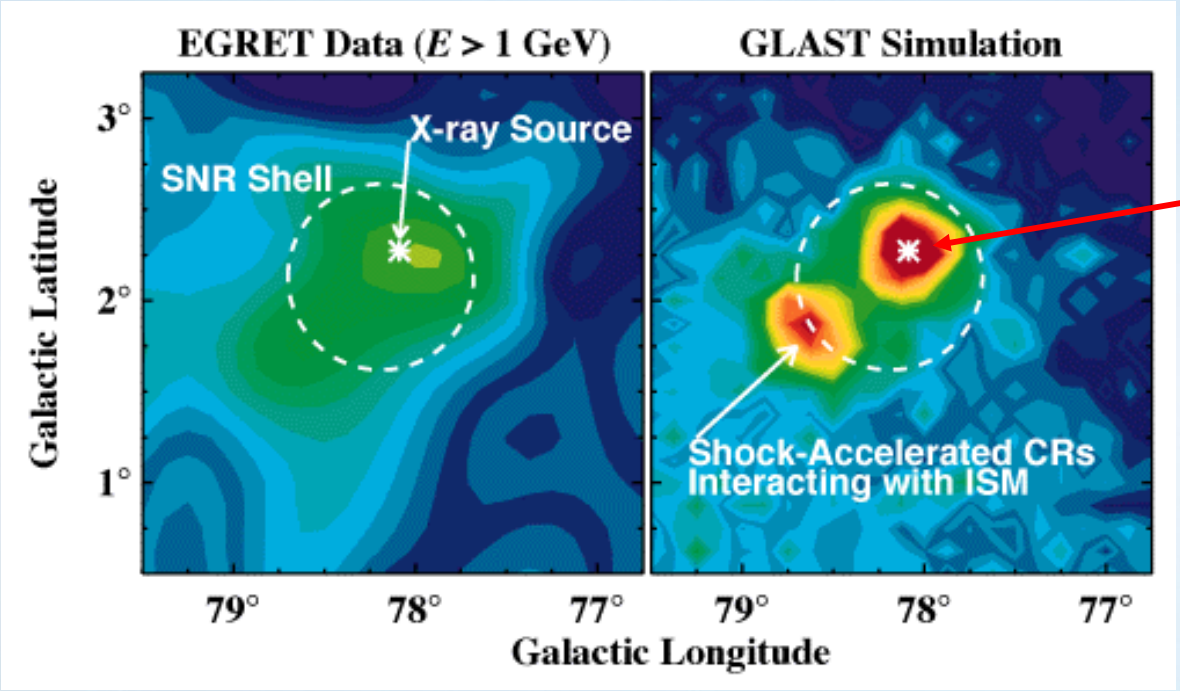
Blazar questions/LAT Answers

- Where are the acceleration and emission sites in blazar jets? Multi-wavelength campaigns from radio to TeV
- 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? Detect $>10^3$ sources
- Is AGN cutoff intrinsic or due to EBL? Study AGN spectra above 10 GeV

Supernovae and Cosmic Rays

- Galactic CR are most likely 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



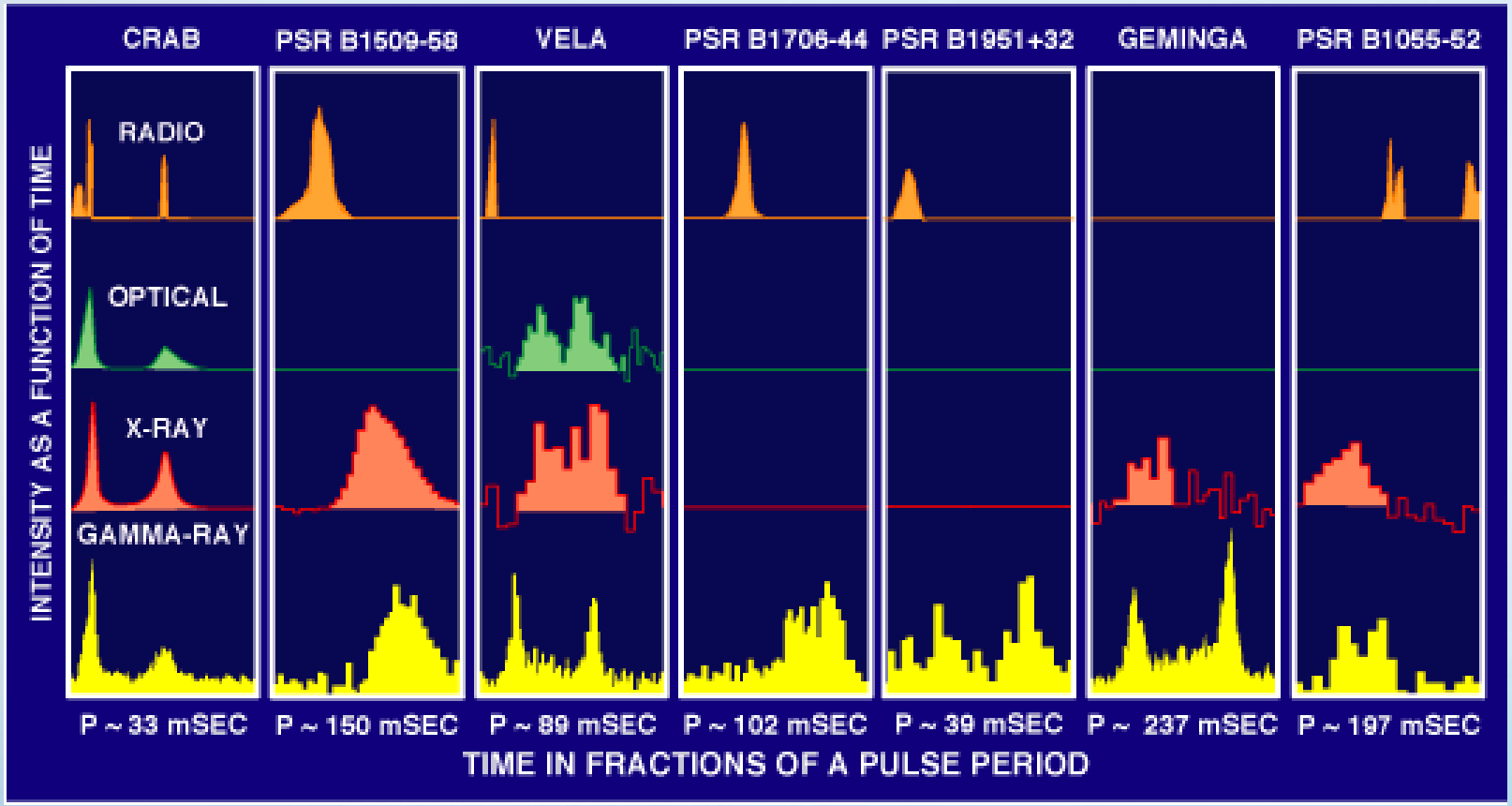
pulsar

- EGRET observations could not distinguish between pulsar (X-ray source) and shocked regions → LAT should provide first resolved GR images!

LAT studies SNR and CRs

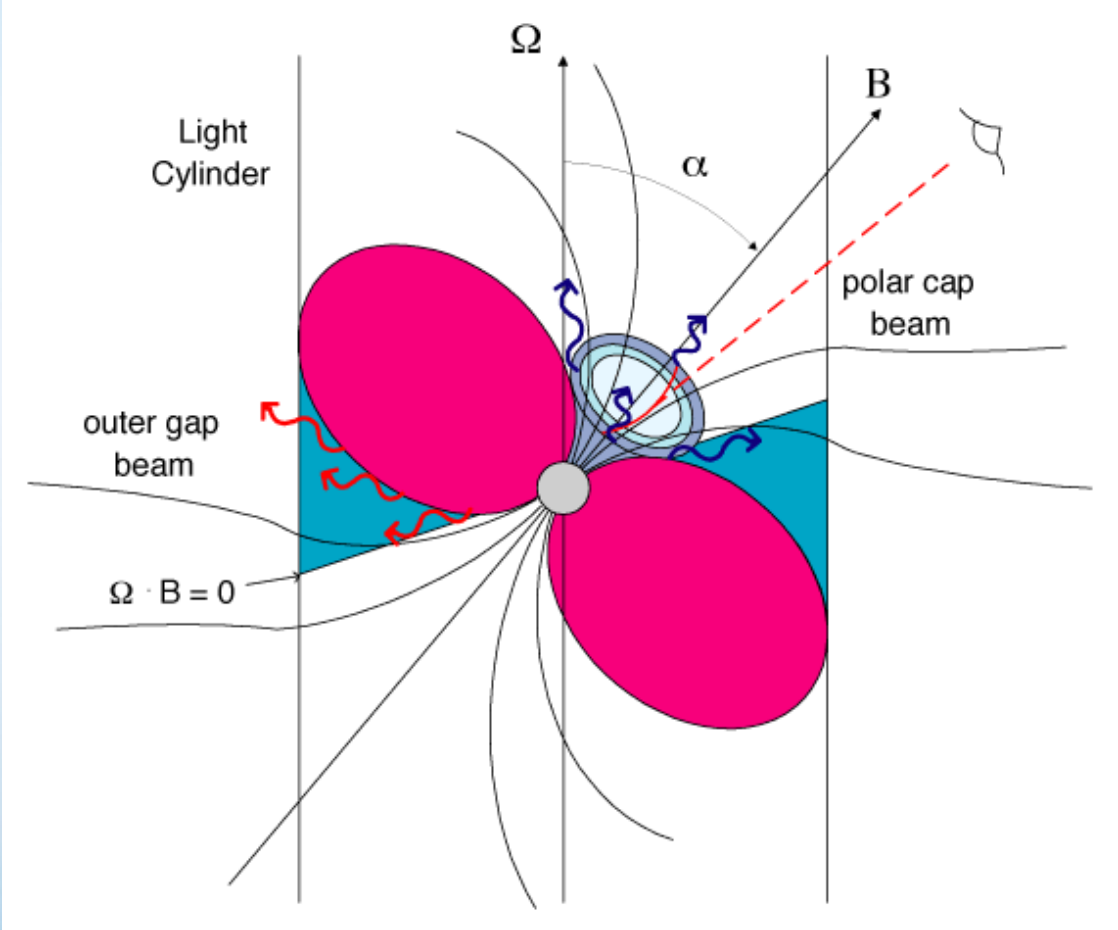
- Spatial separation of shocked acceleration regions from pulsar component
- Detect π^0 bump in SNR spectra from accelerated nuclei (on top of electron acceleration signatures – inverse Compton and bremsstrahlung)
- Determine relative number densities of electrons and nucleons in CRs
- Study CR production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

EGRET pulsars



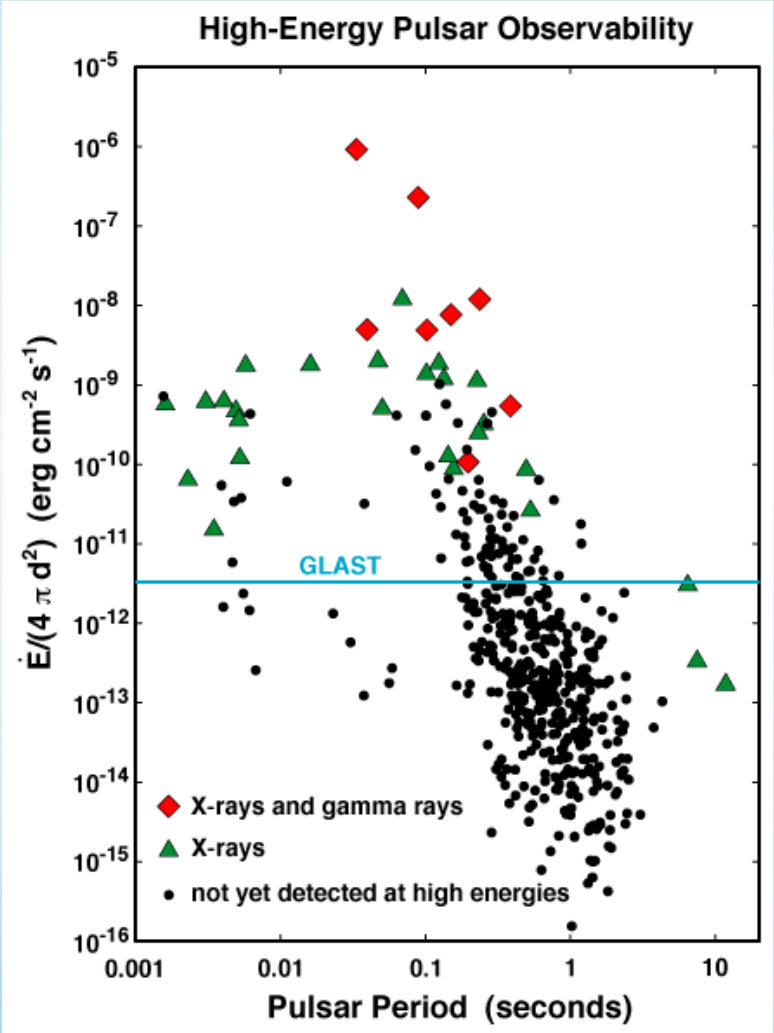
Outer gap vs. polar cap models

- 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?



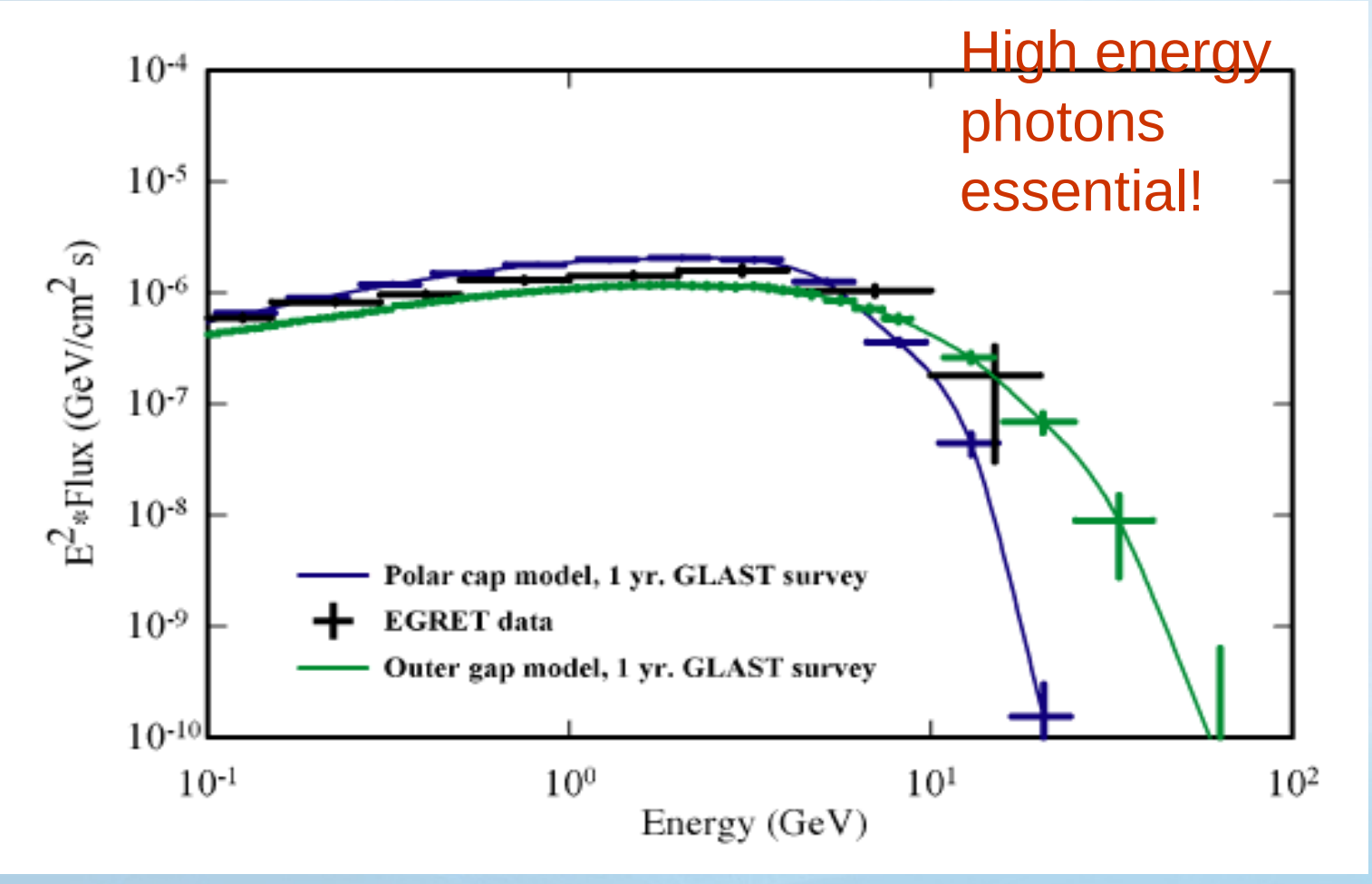
LAT studies pulsars

- Up to 250 pulsars will be detectable, with half previously unknown in radio (like Geminga)
- LAT will discover pulsars in gamma rays (first!)



LAT studies pulsars

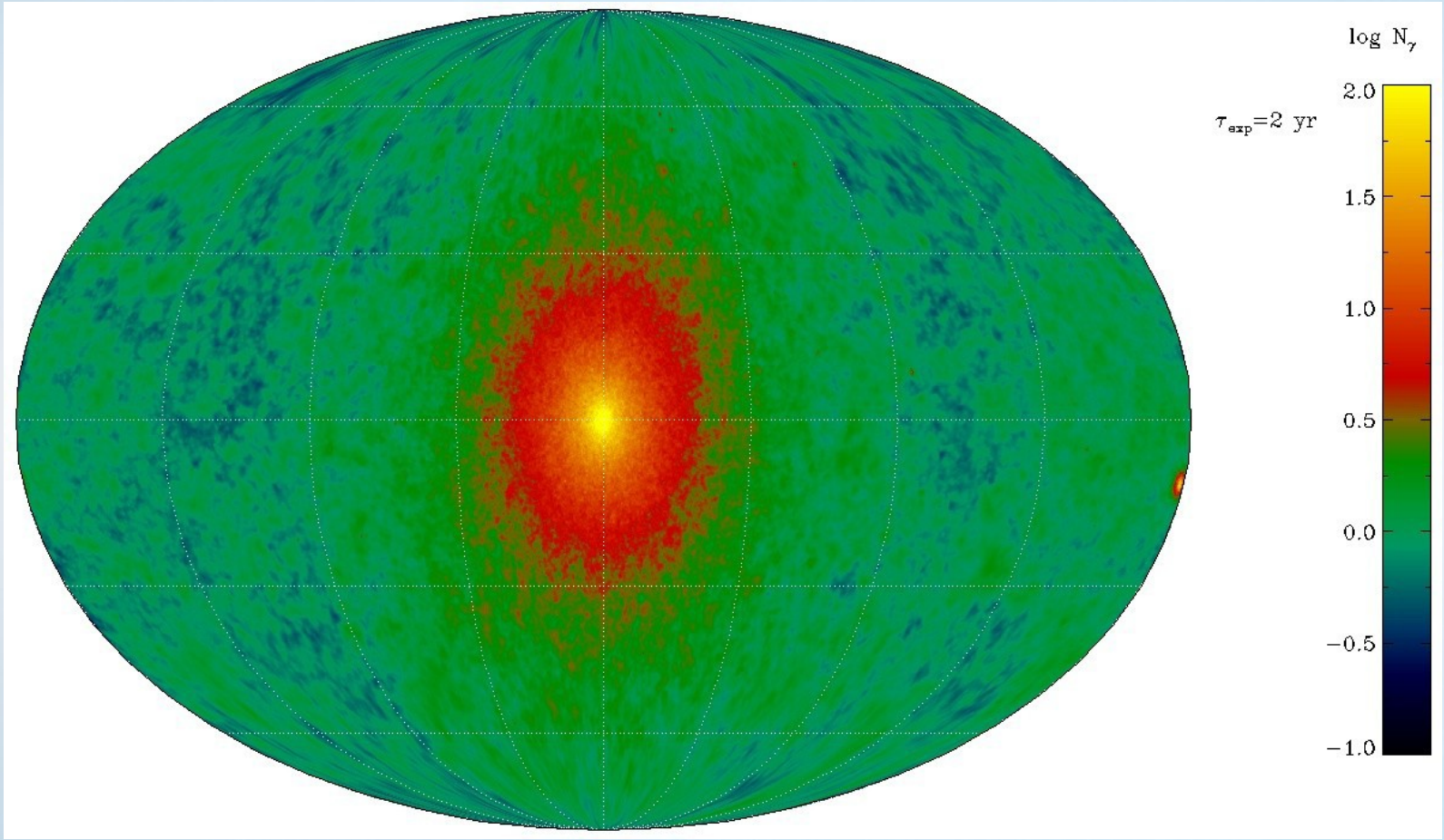
High quality phase-resolved spectra for 10^2 pulsars



Searching for dark matter

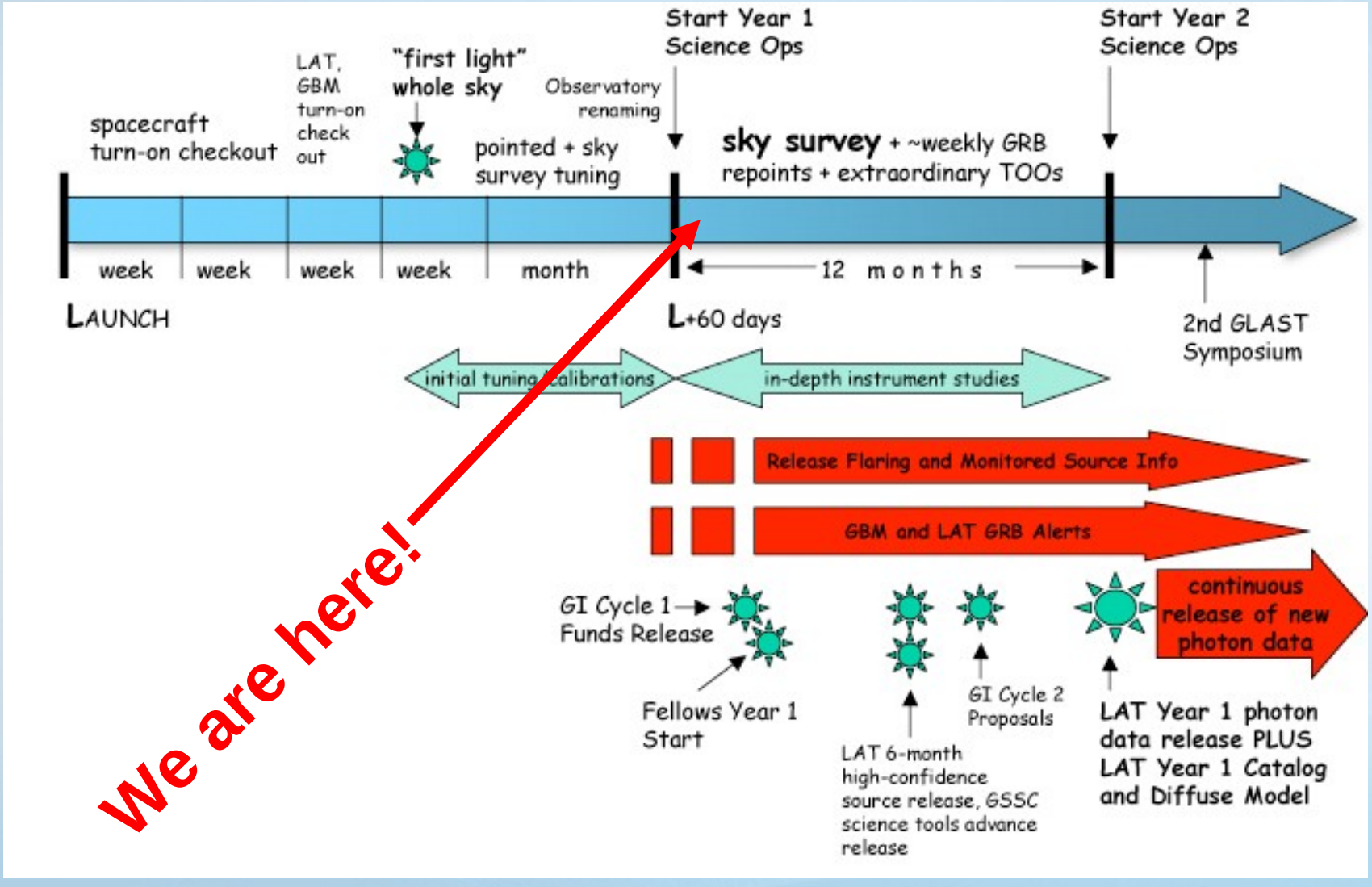
- The lightest supersymmetric particle χ is a leading candidate for non-baryonic CDM
- It is neutral (hence neutralino) and stable (if R-parity is not violated)
- It self-annihilates in two ways:
  - $\chi\,\chi \rightarrow \gamma\gamma$ where $E\gamma = M\chi\, c^2$
  - $\chi\,\chi \rightarrow Z\gamma$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

Galactic halo WIMP detectability



2 years of simulated data – detectable galactic center halo from Kuhlen, Diamand and Madau 2007

First year timeline



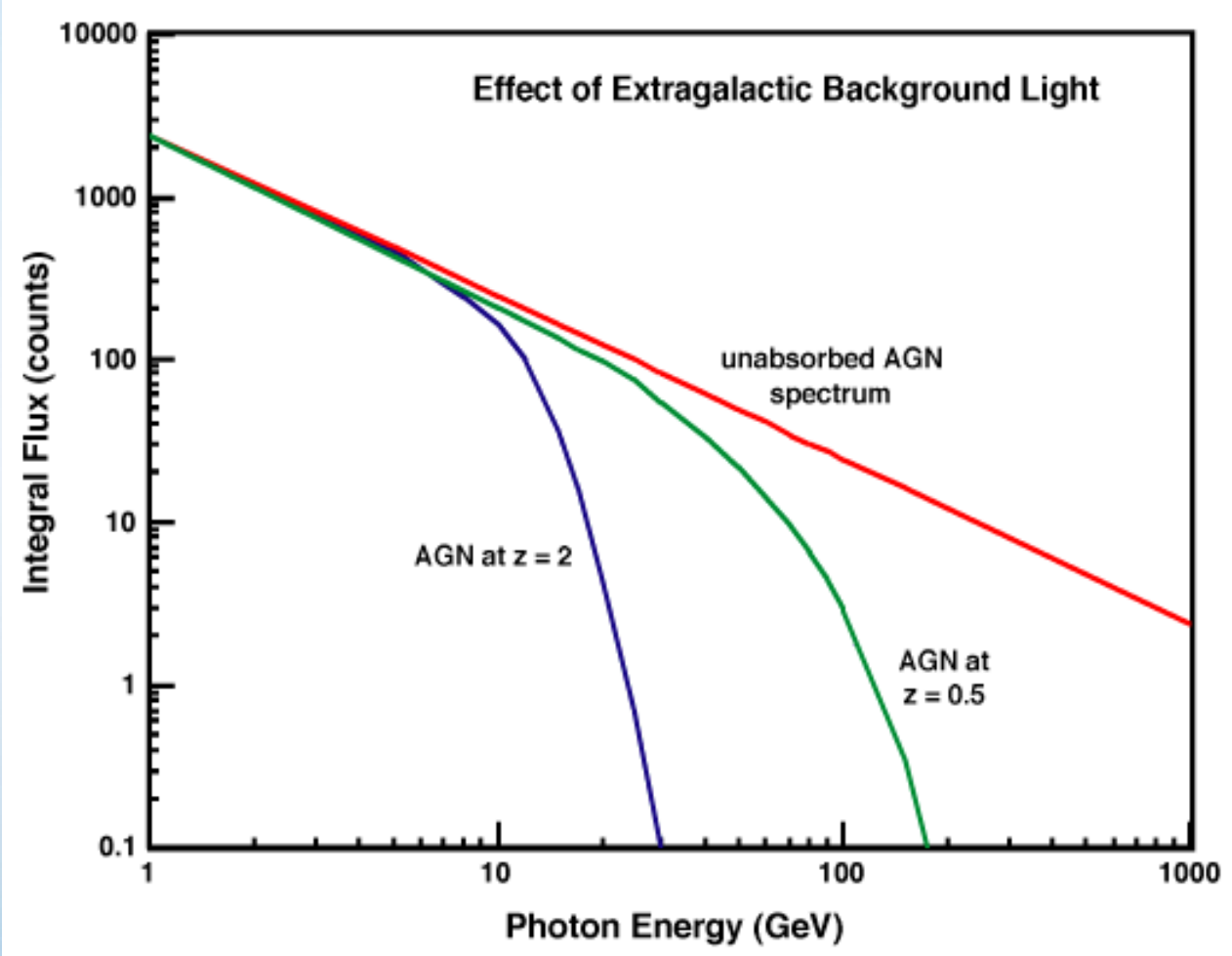
Conclusions

- In just a few days, Fermi has reached the sensitivity of EGRET and is starting to discover new sources of high-energy gamma rays
- Fermi is opening wide a new window on the Universe – which may show us connections between the infinite and the infinitesimal
- Stay tuned – the best is yet to come!
- For more info: http://www.nasa.gov/glast (soon to be http://www.nasa.gov/fermi)

Backups Follow

LAT studies EBL cutoff

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



LAT vs. Ground-based HE Arrays