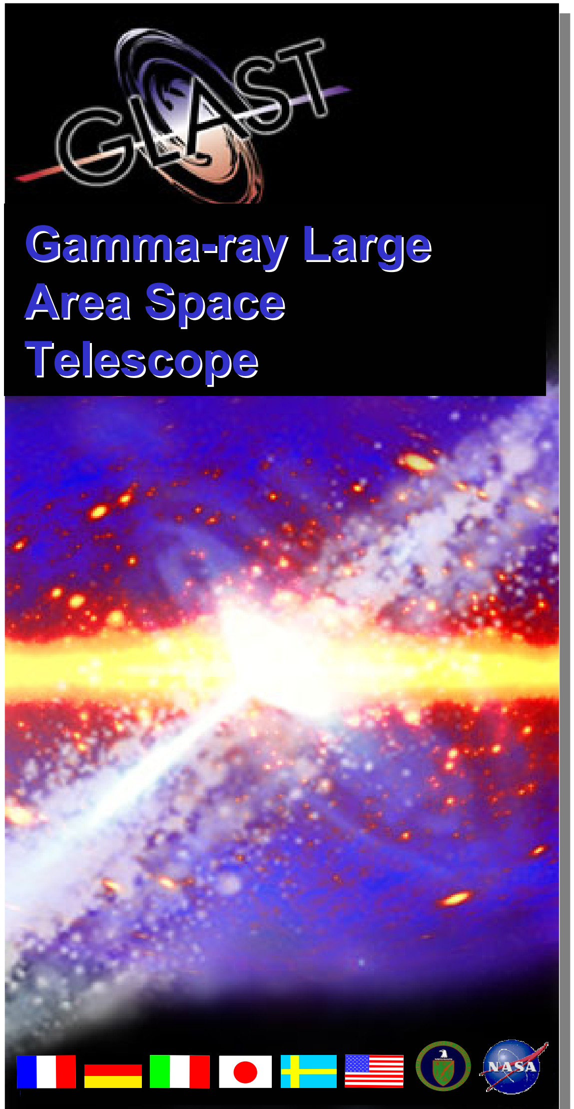


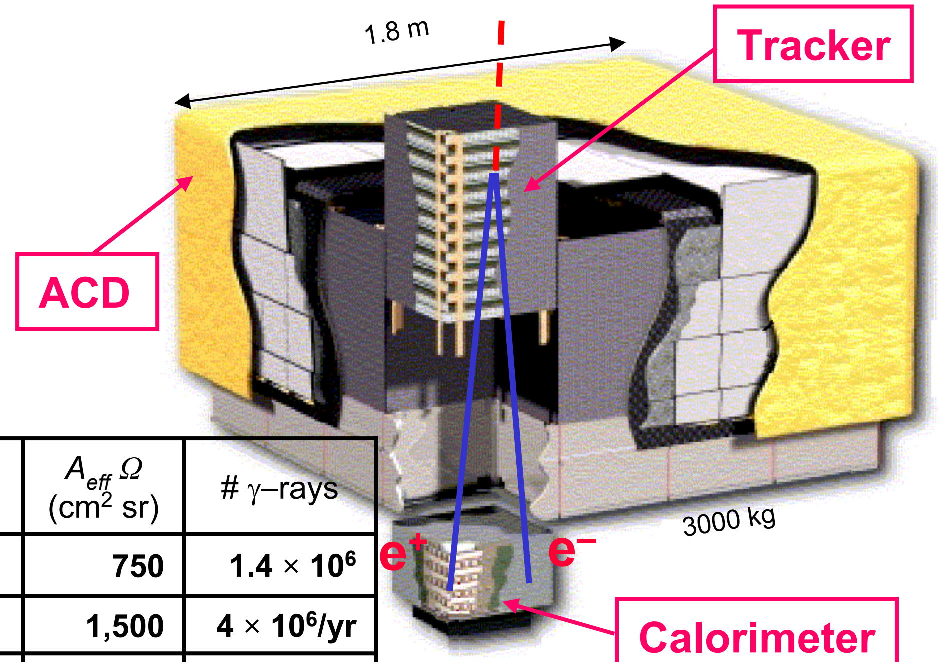
Science with the Large Area Telescope on GLAST

DOE HEP Physics Program Review

S. W. Digel
Hansen Experimental Physics Laboratory, Stanford Univ.

GLAST Large Area Telescope (LAT)

- **LAT is a pair conversion telescope with solid state (Si strip) technology**
- **Within its first few weeks, the LAT will double the number of celestial gamma rays ever detected**
- **5-year design life, goal of 10 years**



	Years	Ang. Res. (100 MeV)	Ang. Res. (10 GeV)	Eng. Rng. (GeV)	$A_{eff}\,\Omega$ (cm^2 sr)	# γ–rays
EGRET	**1991–00**	**5.8°**	**0.5°**	**0.03–10**	**750**	**1.4×10^6**
AGILE	**2005–**	**4.7°**	**0.2°**	**0.03–50**	**1,500**	**4×10^6/yr**
AMS	**2005+?–**	**–**	**0.1°**	**1–300**	**500**	**2×10^5/yr**
GLAST LAT	**2007–**	**3.5°**	**0.1°**	**0.02–300**	**25,000**	**1×10^8/yr**

Derived LAT Capabilities

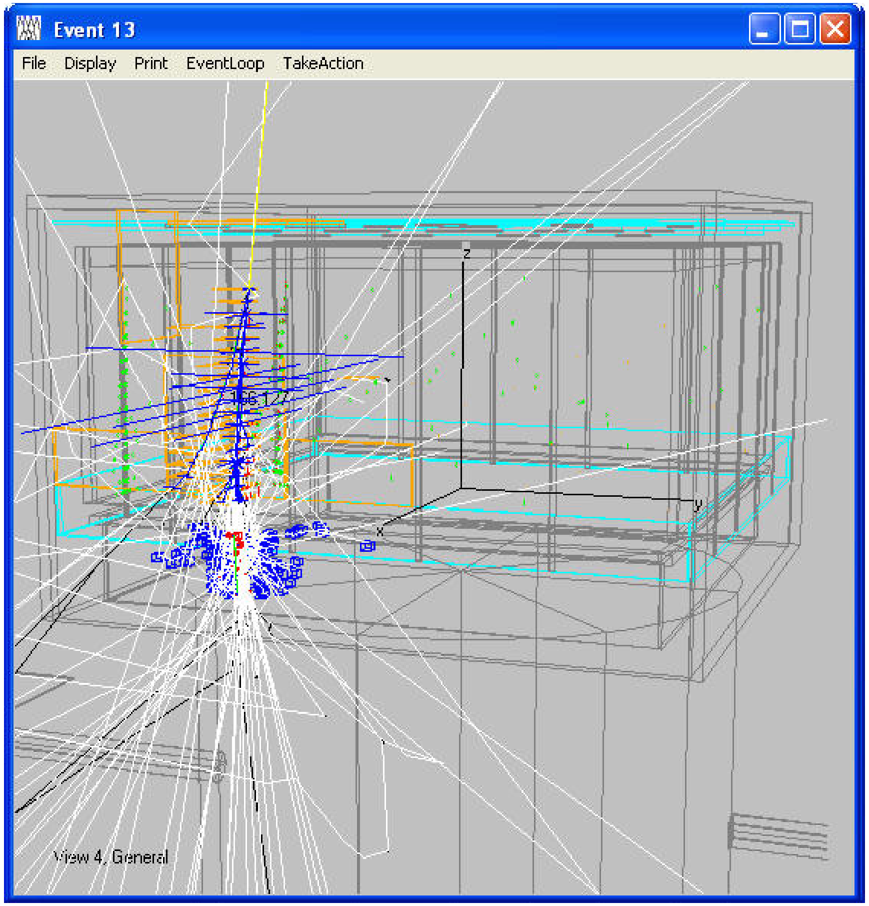
	EGRET	LAT
Point Source Sensitivity (5σ, >100 MeV)	~5×10^{-8} cm^{-2} s^{-1}	3×10^{-9} cm^{-2} s^{-1} (at high gal. latitude for 1-year sky survey, for photon index of -2)
Source Location Determination	15′	0.4′ (1σ radius, flux 10^{-7} cm^{-2} s^{-1} >100 MeV, 1-year sky survey, high *b*)
Splitting 1×10^{-7} cm^{-2} s^{-1} sources	75′	6′
Resolving 5×10^{-7} cm^{-2} s^{-1} extended sources	90′ min (7.5° max)	5′

For flaring or impulsive sources the relative effective areas (~6x greater for LAT), FOV (>4x greater for LAT), and deadtimes (>3 orders of magnitude shorter for LAT) are relevant as well

More fine print: E^{-2} sources, EGRET: 2-week pointed obs. on axis, LAT: 1-year sky survey, flat high-latitude diffuse background

Nature of the LAT Data

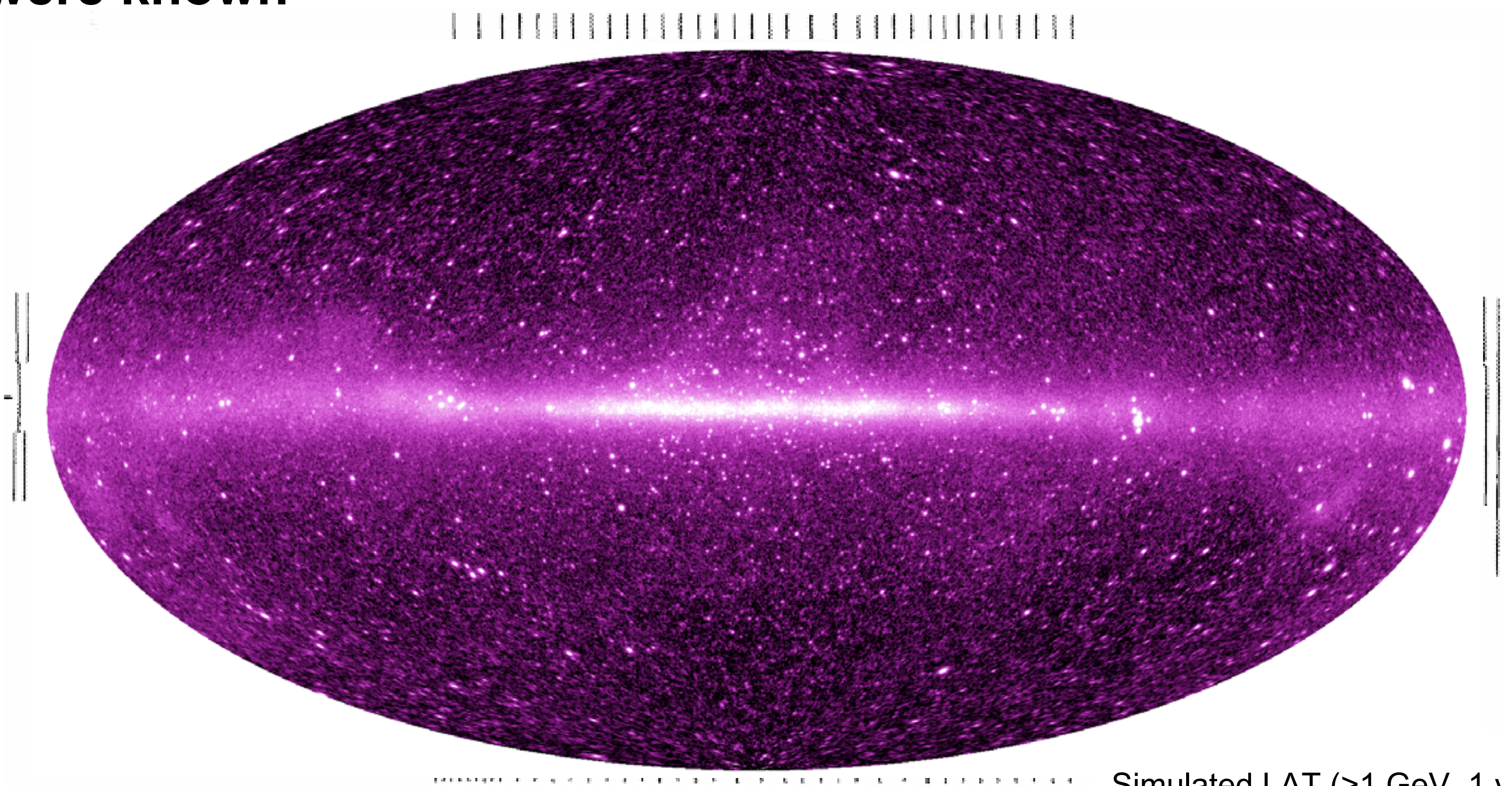
- Events are readouts of TKR hits, TOT, ACD tiles, and CAL crystal energy depositions, along with time, position, and orientation of the LAT
- Intense charged particle background & limited bandwidth for telemetry → data are extremely filtered
  - ~3 kHz trigger rate
  - ~300 Hz filtered event rate in telemetry
  - ~13 Gbyte/day raw data
  - ~2 × 10^5 γ-rays/day



T. Usher (SLAC)

Do we understand the gamma-ray sky?

- Gamma-ray astronomy and astrophysics is, relatively speaking, a very young field of study
- First detection of a source (the Milky Way) was ~30 years ago (OSO-III) and even 15 years ago fewer than 2 dozen sources were known



Simulated LAT (>1 GeV, 1 yr)

Celestial sources of high-energy gamma rays

- **A few classes of sources are established now; many others are plausible but have not been detectable before**

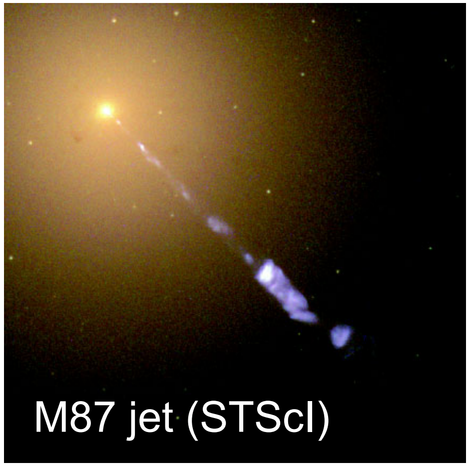
- **Even for known source classes – e.g., blazars and pulsars – improved sensitivity will fundamentally clarify understanding of the physical processes at work**

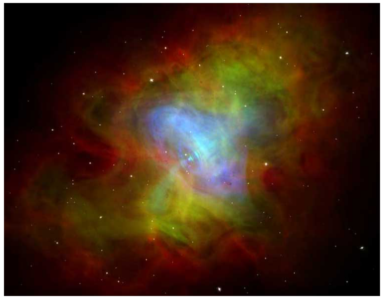
Celestial sources of high-energy gamma rays

Astrophysical γ-ray sources

Non-thermal processes: particle acceleration and γ-ray emission from jets and shocks

- Extragalactic
  - Blazars
  - Other active galaxies – Centaurus A
  - Local group galaxies – Large Magellanic Cloud + starburst
  - Galaxy clusters
  - Isotropic emission (blazars vs. relics from Big Bang)
  - Gamma-ray bursts
- In the Milky Way
  - Pulsars, binary pulsars, millisecond pulsars, plerions
  - Supernova remnants, OB/WR associations, black holes?
  - Microquasars, microblazars?
  - Diffuse – cosmic rays interacting with interstellar gas and photons
- In the Solar system
  - Solar flares
  - Moon…


M87 jet (STScI)


Crab pulsar & nebula (CXC)

Astroparticle physics

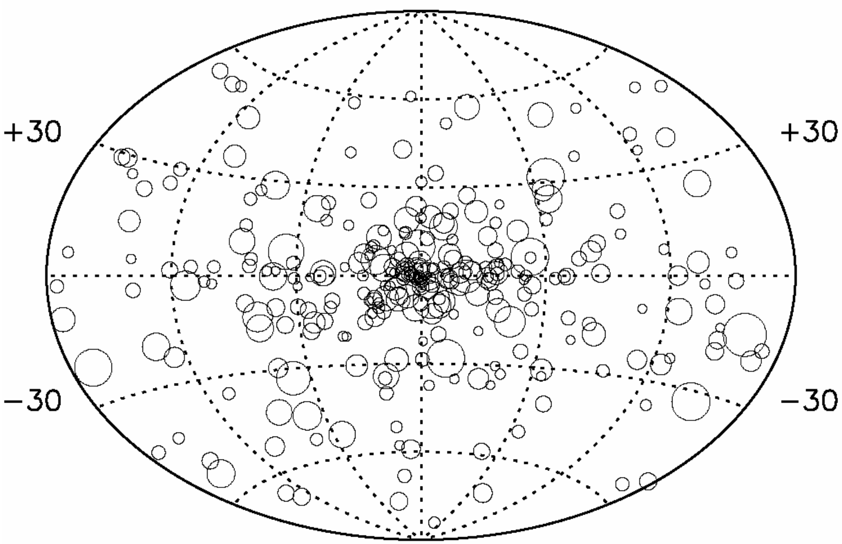
- WIMP annihilation?
- Relics from Big Bang?

Already known
Potential LAT discoveries

Example of LAT Science: Baryonic dark matter

- **Assumptions:**
  - **Galactic dark matter is cold gas (i.e., not seen in emission – or absorption somehow – and stable against collapse)**
  - **CDM-type clustering model clustering of the dark matter into 'mini-halos'**
- **Consequences:**
  - **Clumps will be gamma-ray sources (although not necessarily optically thin to cosmic rays)**
  - **Many would be EGRET point sources (i.e., detected but not resolved)**
  - **Sources would be steady & without counterparts (although might be detectable in thermal microwave emission)**
  - **Not strongly concentrated in the plane**

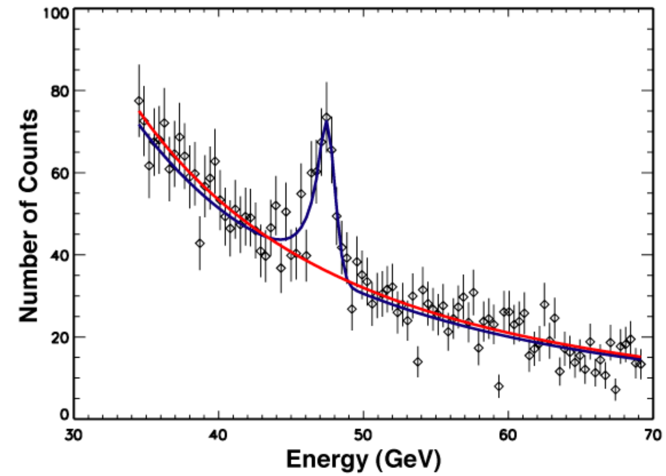
Simulated Cold Dark Gamma-Ray Sources

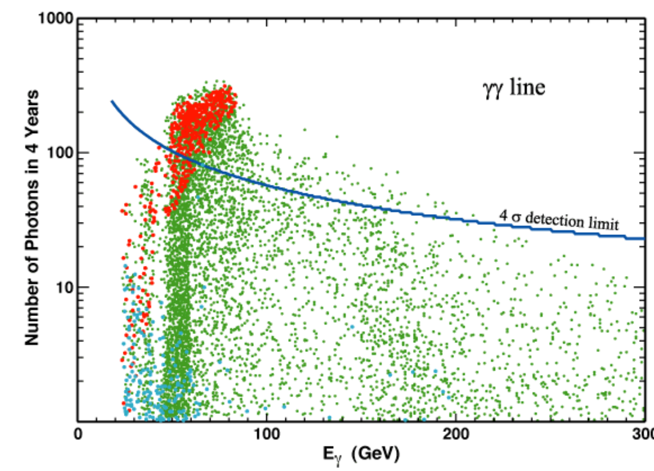


Walker et al. (2003)

Example: Nonbaryonic dark matter

- Some N-body simulations of the distribution of dark matter in the halo of the Milky Way predict a very cuspy distribution (e.g., Navarro et al. 1996)
- If the dark matter is the Lightest Supersymmetric Particle χ, the mass range currently allowed is 30 GeV-10 TeV
- Calculations of the annihilation processes
  $\chi\,\chi \rightarrow \gamma\gamma$ and $\chi\,\chi \rightarrow \gamma Z$
  (e.g., Bergström & Ullio 1998) indicate some chance for detection by GLAST
  - Observations can apparently cover an interesting range of the 7-dimensional parameter space for MSSM.
- EGRET apparently didn't see a source coincident with the Galactic center, but also is not very sensitive in the >10 GeV range

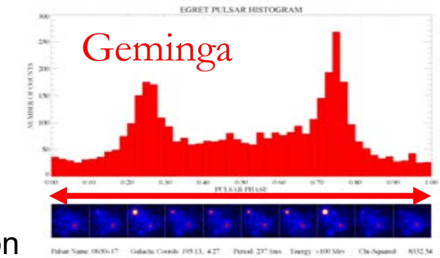




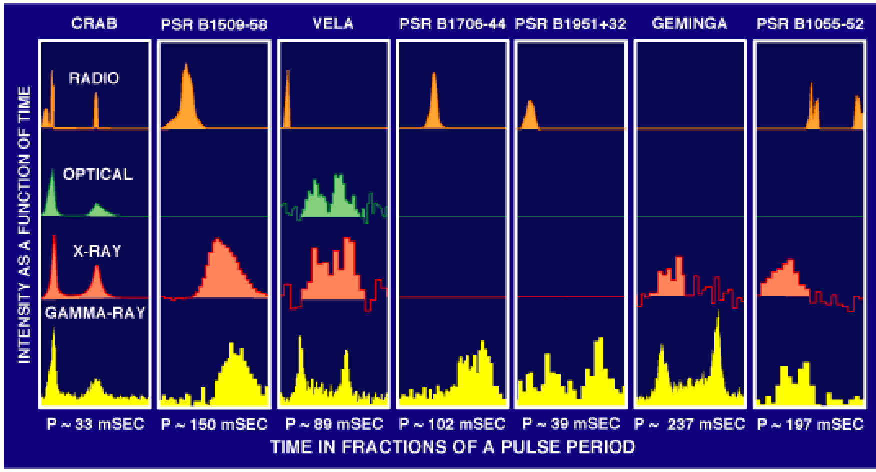
D. Engovatov

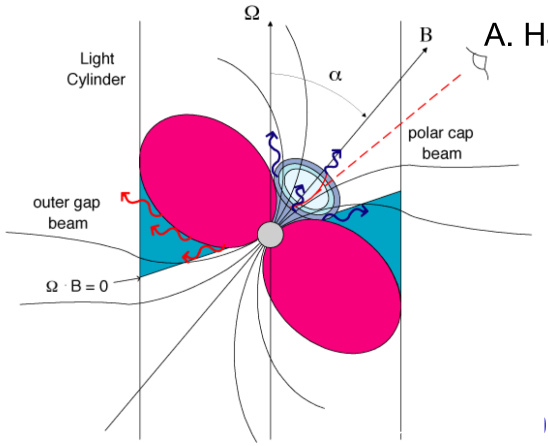
More: Rotation-Powered Pulsars

- Rapidly rotating magnetized neutron stars (and *B* not parallel to *Ω*)
- ~8 detected pulsating by EGRET
  - Steady (averaged over a period) sources, and not necessarily seen pulsating at other wavelengths
- Potential acceleration mechanisms are well modeled (Polar Cap and Outer Gap models)
  - ~$10^{35\text{-}36}$ erg s^{-1} luminosities means can see them for a few kpc



D. Thompson

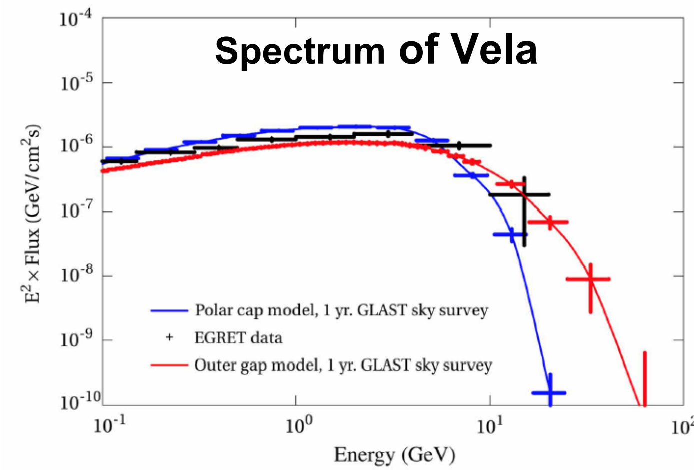




A. Harding

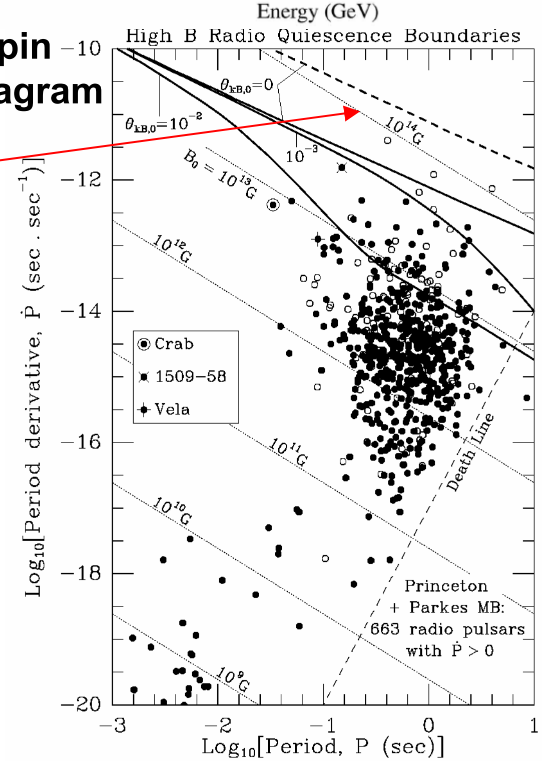
Pulsars (continued)

- Pulsars have spectral breaks in the GeV range; the already-low GeV fluxes prevented distinguishing between the models with EGRET
- 'Death line' for rotation-powered pulsars when cannot accelerate particles enough to induce pair cascades
  - Recent evidence suggests that *magnetic photon splitting* ($\gamma \rightarrow \gamma\gamma$) may also kill extremely high field pulsars (>~10^{14} G) as radio sources
  - These could still be γ-ray emitters
  - The large area and excellent coverage of the LAT will greatly advance blind period searching for γ-ray pulsars



A. Harding/R. Romani/D. Thompson

Pulsar spin down diagram

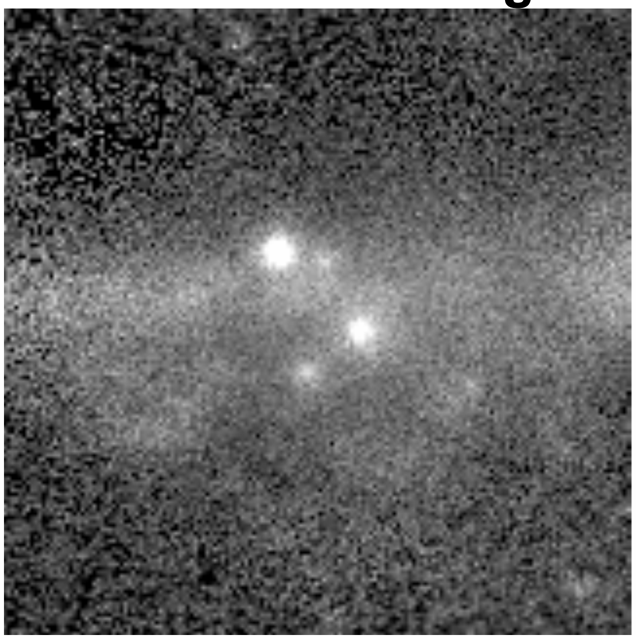


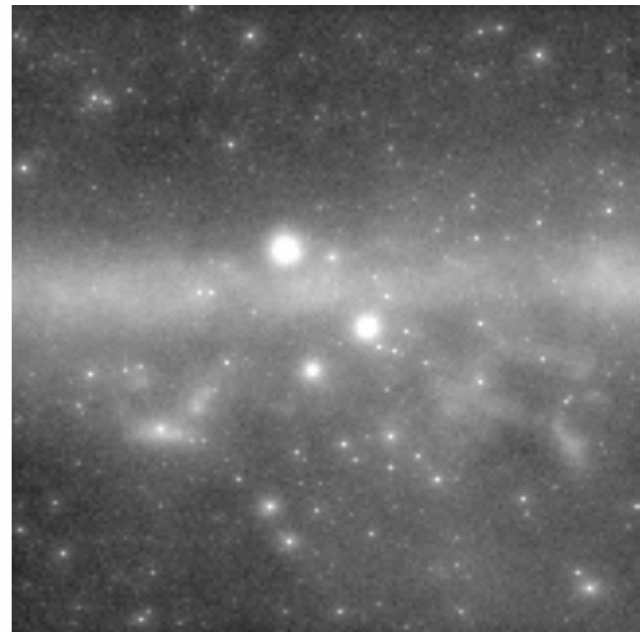
Baring et al.

Summary

- The γ-ray sky is diverse and dynamic; observations of high-energy gamma rays provide unique or complementary data relative to other wavelengths

EGRET
Phases 1-5





LAT
Sim. 1-yr

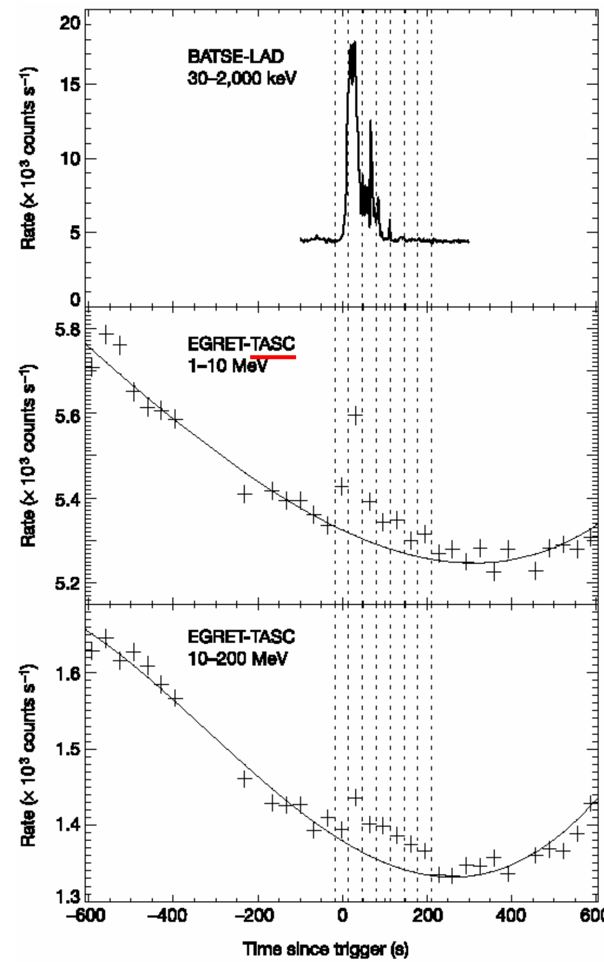
- We can anticipate many ways that the LAT on GLAST will advance astro and astroparticle physics
- We aren't smart enough to anticipate all advances

Backup slides follow

Another example: Gamma-ray bursts

- Something bad (hypernova?) happens at cosmological distances
  - Internal shocks and external shocks → pulses and afterglows
- Primarily hard X-ray, although several have been seen at high energies (~100 MeV) with EGRET
  - Recent result shows high-energy component may trace a different particle population, or indicate a proton component
- Quantum gravity effect? Amelino-Camelia et al. (1998) dispersion ~10 ms GeV^{-1} Gpc^{-1}
  - LAT will have orders of magnitude shorter deadtime than EGRET

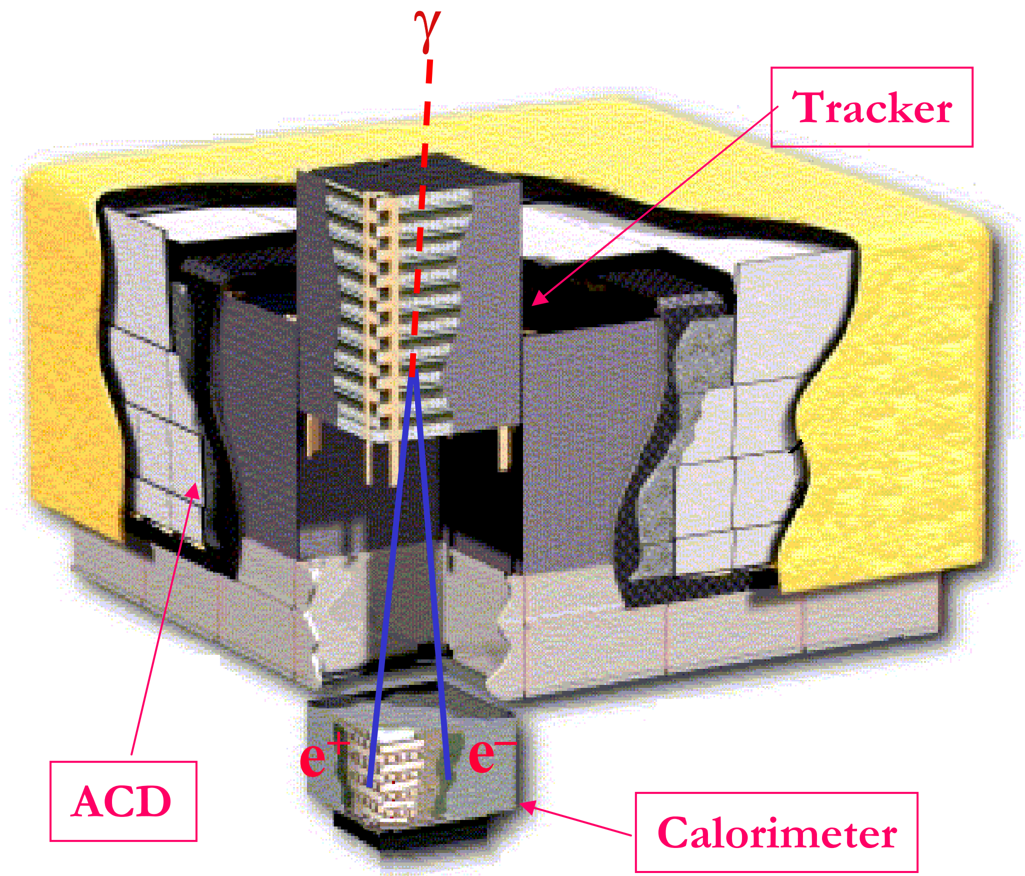
GRB940217



González et al. (2003)

Design of the LAT for gamma-ray detection

- **Tracker** 18 XY tracking planes with interleaved W conversion foils. Single-sided silicon strip detectors (228 μm pitch). Measure the photon direction; gamma ID.
- **Calorimeter** 1536 CsI(Tl) crystals in 8 layers; PIN photodiode readouts. Image the shower to measure the photon energy.
- **Anticoincidence Detector** 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation limits self-veto at high energy.

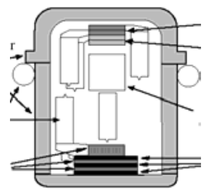


- **Electronics System** Includes flexible, robust hardware trigger and software filters. ~800 k channels, 600 W

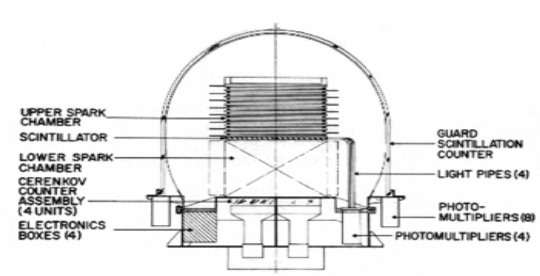
Brief History of Detectors

- 1967-1968, OSO-3 detected Milky Way as an extended γ-ray source, 621 γ-rays
- 1972-1973, SAS-2, ~8,000 celestial γ-rays
- 1975-1982, COS-B, orbit resulted in a large and variable background of charged particles, ~200,000 γ-rays.
- 1991-2000, EGRET, large effective area, good PSF, long mission life, excellent background rejection, and >1.4 × 10^6 γ-rays

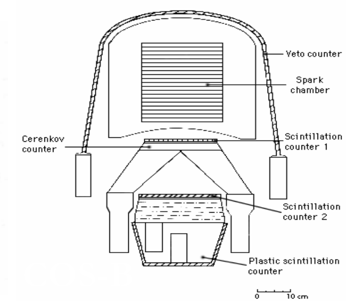
OSO-3



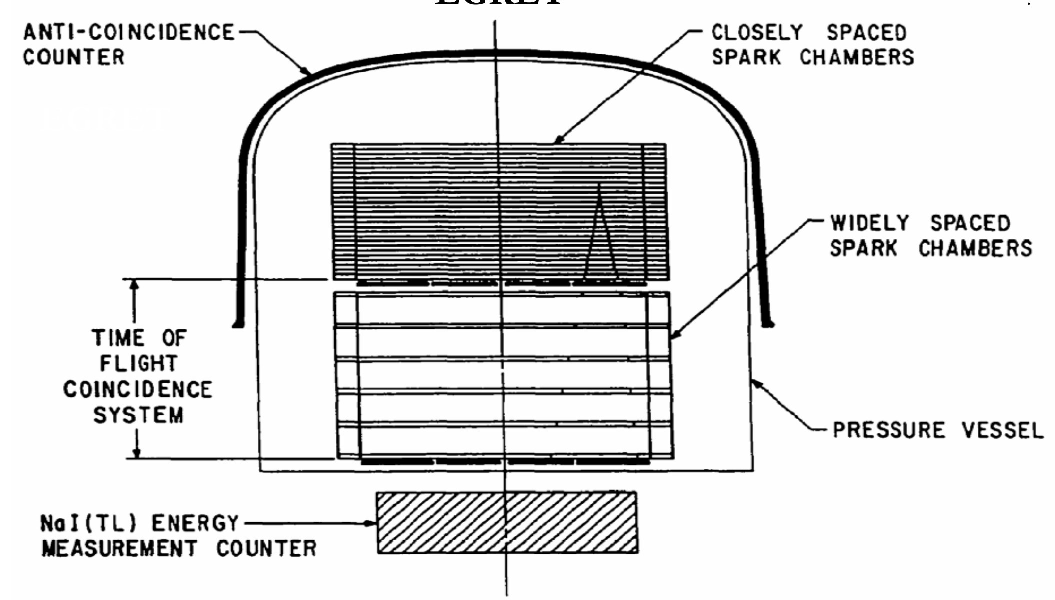
SAS-2



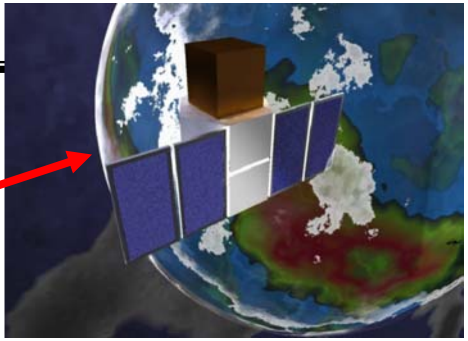
COS-B



EGRET



Future Missions



- AGILE (Astro-rivelatore Gamma a Immagini LEggero)
  - ASI small mission, late 2005 launch, good PSF, large FOV, short deadtime, very limited energy resolution
- AMS (Alpha Magnetic Spectrometer)
  - International, cosmic-ray experiment for ISS, will have sensitivity to >1 GeV gamma rays, *scheduled for 16th shuttle launch once launches resume*
- GLAST…