GLAST

The Gamma-ray Large Area Space Telescope

Science Goals, Observation Capabilities, and Operations
GSFC Workshop
17 January 2007

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GLAST Project Scientist

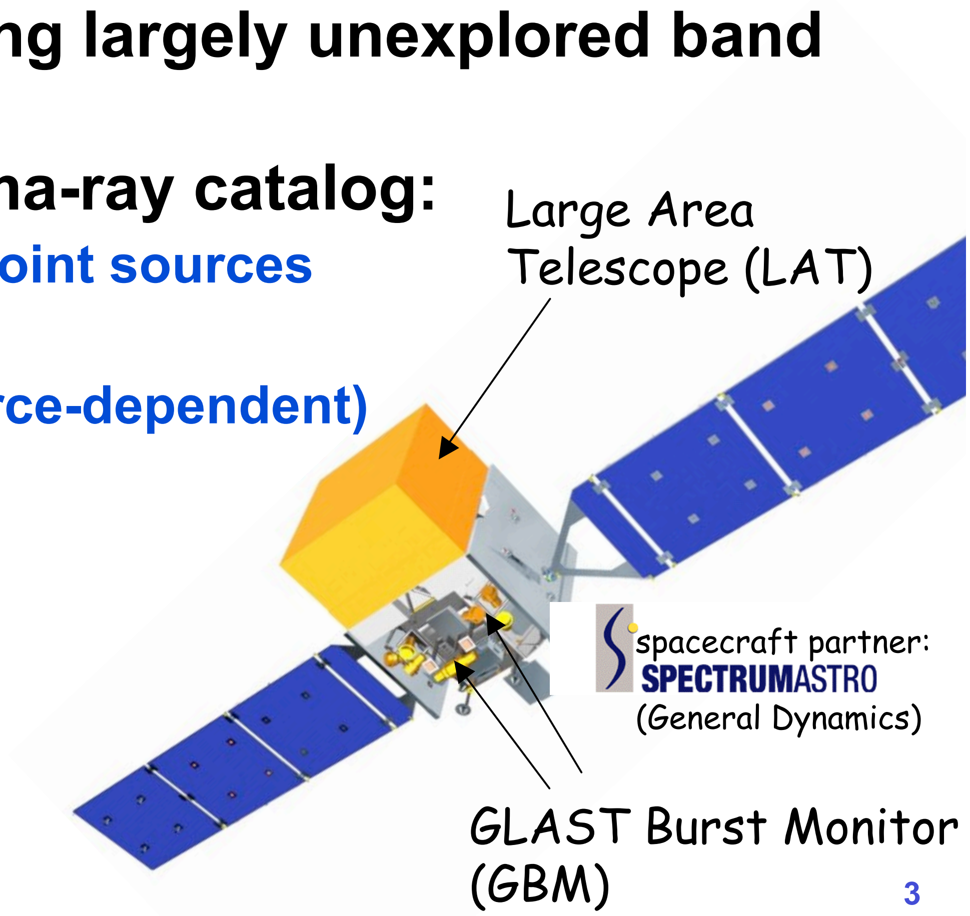
for the GLAST Mission Team

Topics

- Context, Key Features, Science Goals
  - a few examples for illustration
- Instruments (LAT & GBM)
  - capabilities, status
- Operations phases, data
- Guest Investigator Opportunities
- GLAST Users Committee (GUC)
- Summary

GLAST Key Features

- **Huge field of view**
  - **LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.**
- **Huge energy range, including largely unexplored band 10 GeV - 100 GeV**
- **Will transform the HE gamma-ray catalog:**
  - **by > order of magnitude in # point sources**
  - **spatially extended sources**
  - **sub-arcmin localizations (source-dependent)**



<u>Two GLAST instruments</u>:

LAT: 20 MeV – >300 GeV

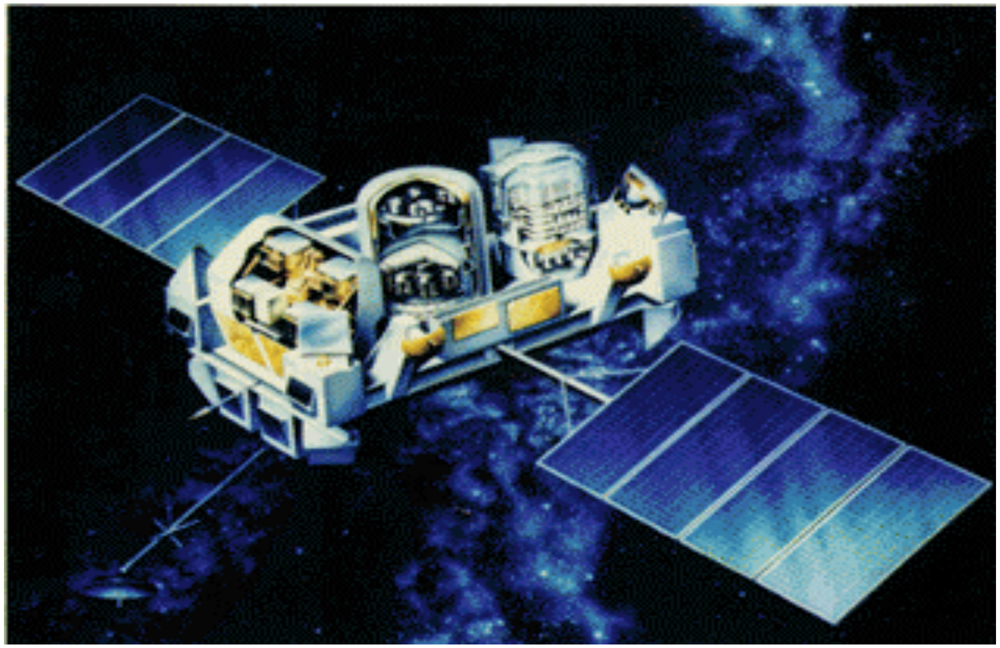
GBM: 10 keV – 25 MeV

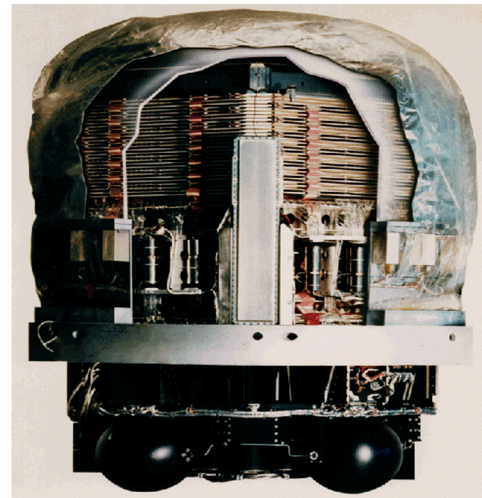
Launch: 2007

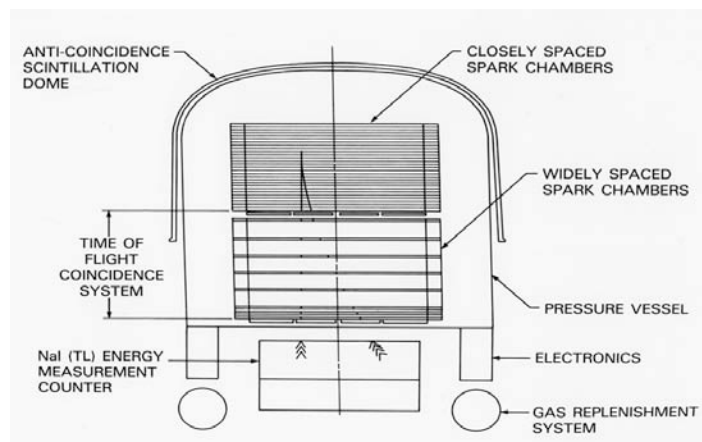
5-year mission (10-year goal)

EGRET

The high energy gamma ray detector on the Compton Gamma Ray Observatory (20 MeV - ~20 GeV), 1991-2000







GLAST LAT High Energy Capabilities

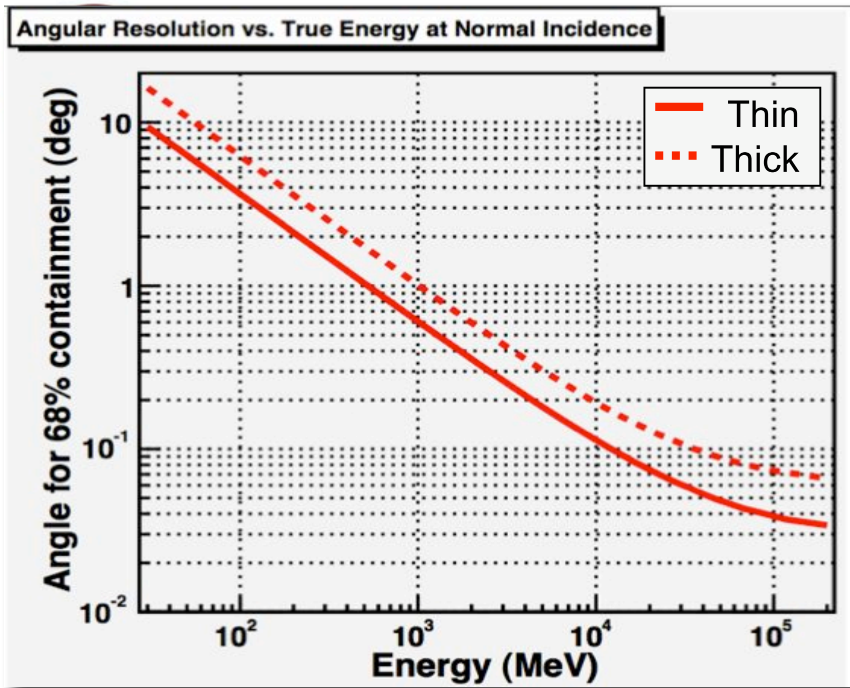
EGRET on GRO firmly established the field of high-energy gamma-ray astrophysics and demonstrated the importance and potential of this energy band.

GLAST is the next great step beyond EGRET, providing a huge leap in capabilities:

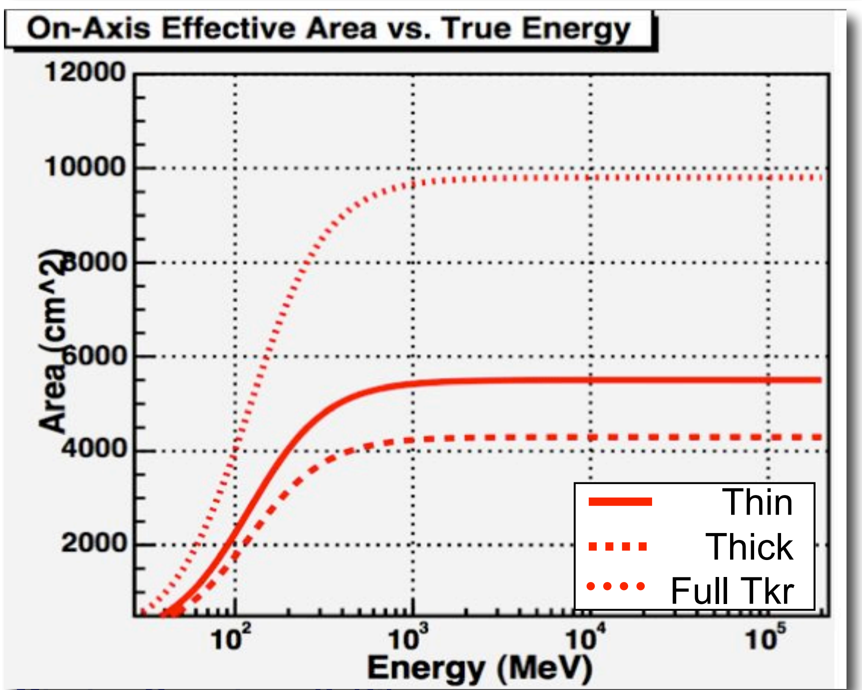
- *Very large FOV (~20% of sky), factor 4 greater than EGRET*
- *Broadband (4 decades in energy, including unexplored region E > 10 GeV)*
- *Unprecedented PSF for gamma rays (factor > 3 better than EGRET for E>1 GeV)*
- *Large effective area (factor > 5 better than EGRET)*
- *Results in factor > 30 improvement in sensitivity*
- *Much smaller deadtime per event (27 microsec, factor 4,000 better than EGRET)*
- *No expendables → long mission without degradation*

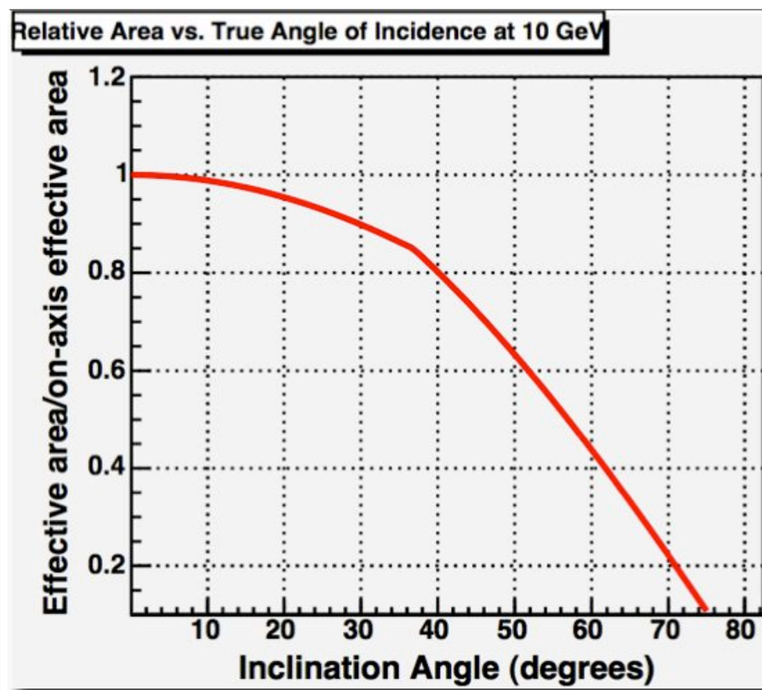
GLAST/LAT performance

(look for updates later this year)

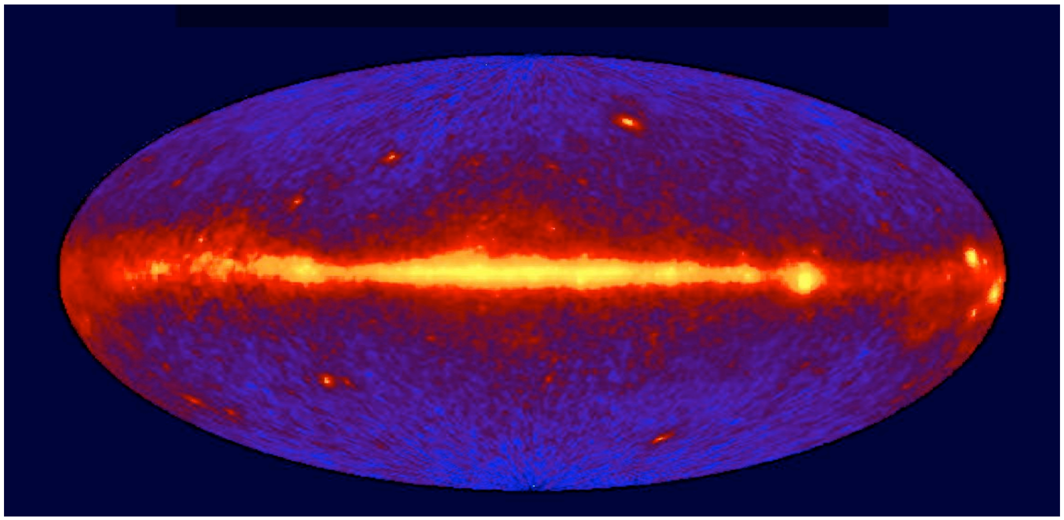


Energy Resolution: ~<10% (~5% off-axis)
PSF (68%) at 10 GeV ~ 0.1^{o}
Point Source sens. (>100 MeV): 4x10^{-9} cm^{-2} s^{-1}
Deadtime per event: 27 microsec





Features of the gamma-ray sky



EGRET all-sky survey (galactic coordinates) E>100 MeV

diffuse extra-galactic background (flux ~ 1.5×10^{-5} $cm^{-2}s^{-1}sr^{-1}$)

galactic diffuse (flux ~O(100) times larger)

high latitude (extra-galactic) point sources (typical flux from EGRET sources O(10^{-7} - 10^{-6}) $cm^{-2}s^{-1}$

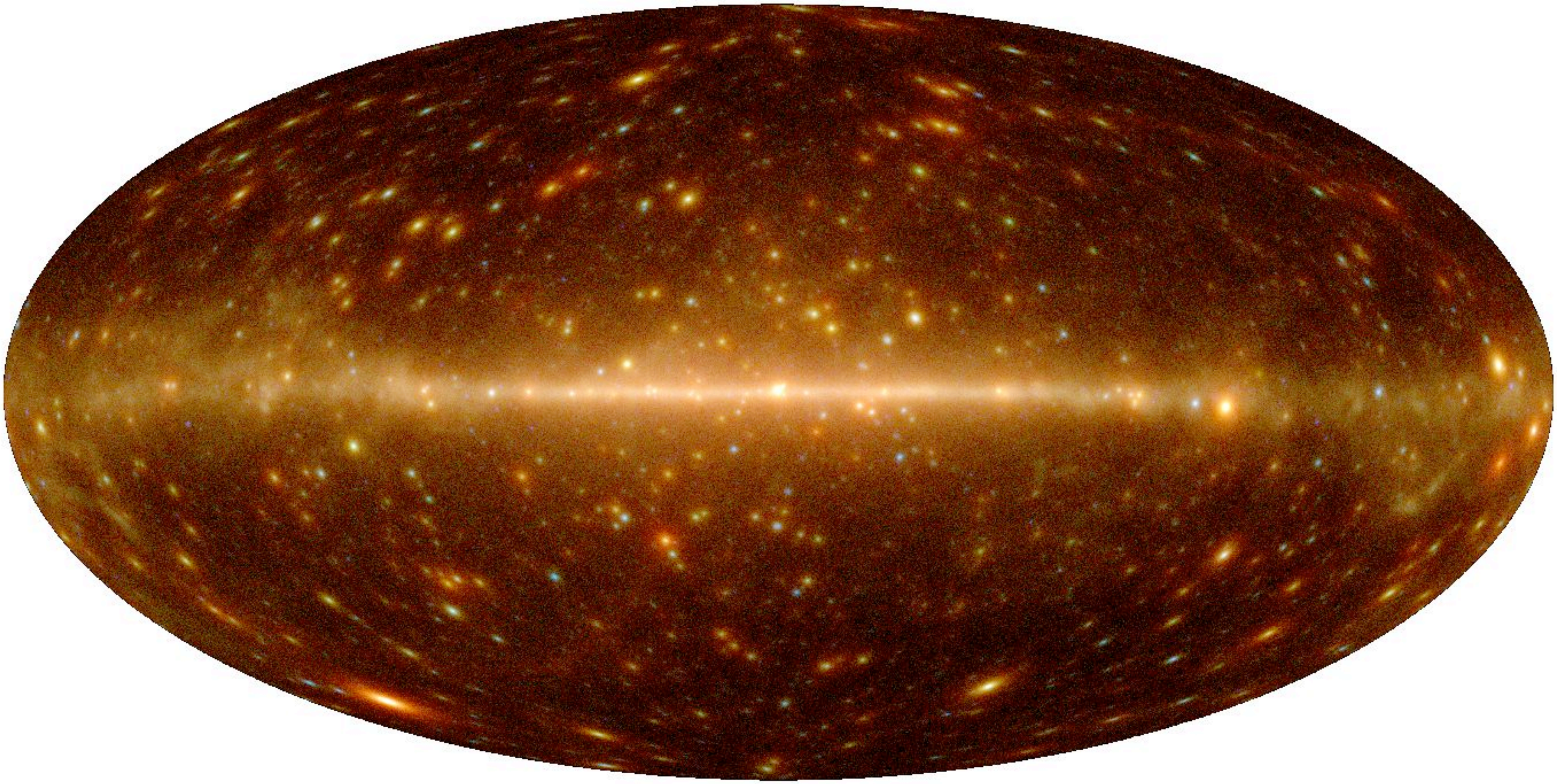
galactic sources (pulsars, un-ID'd)

An essential characteristic: VARIABILITY in time!

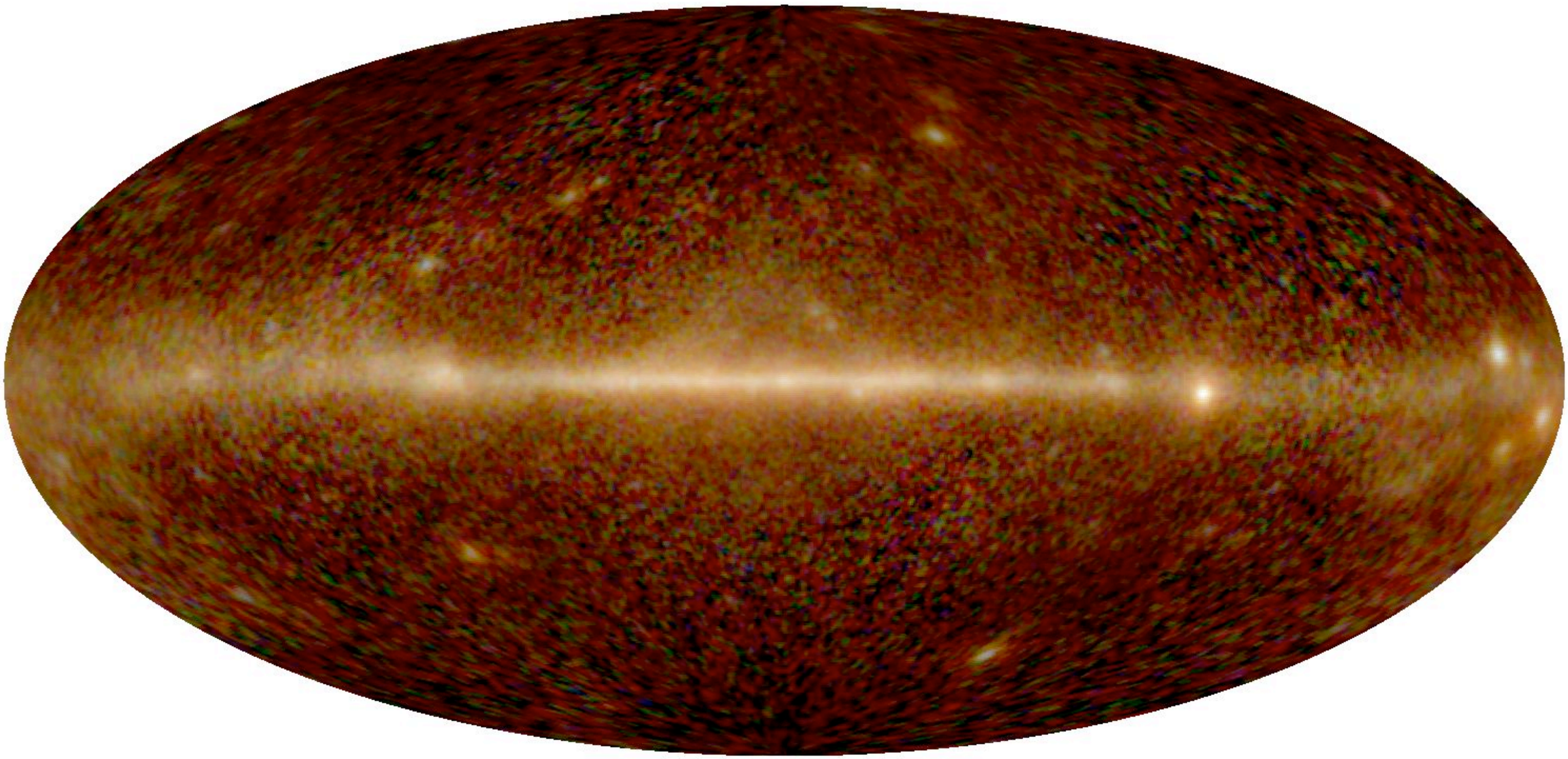
Field of view important for study of transients.

In sky survey mode, GLAST will cover the entire sky every 3 hours, with each region viewed for ~30 minutes.

GLAST One-year Service Challenge Simulation

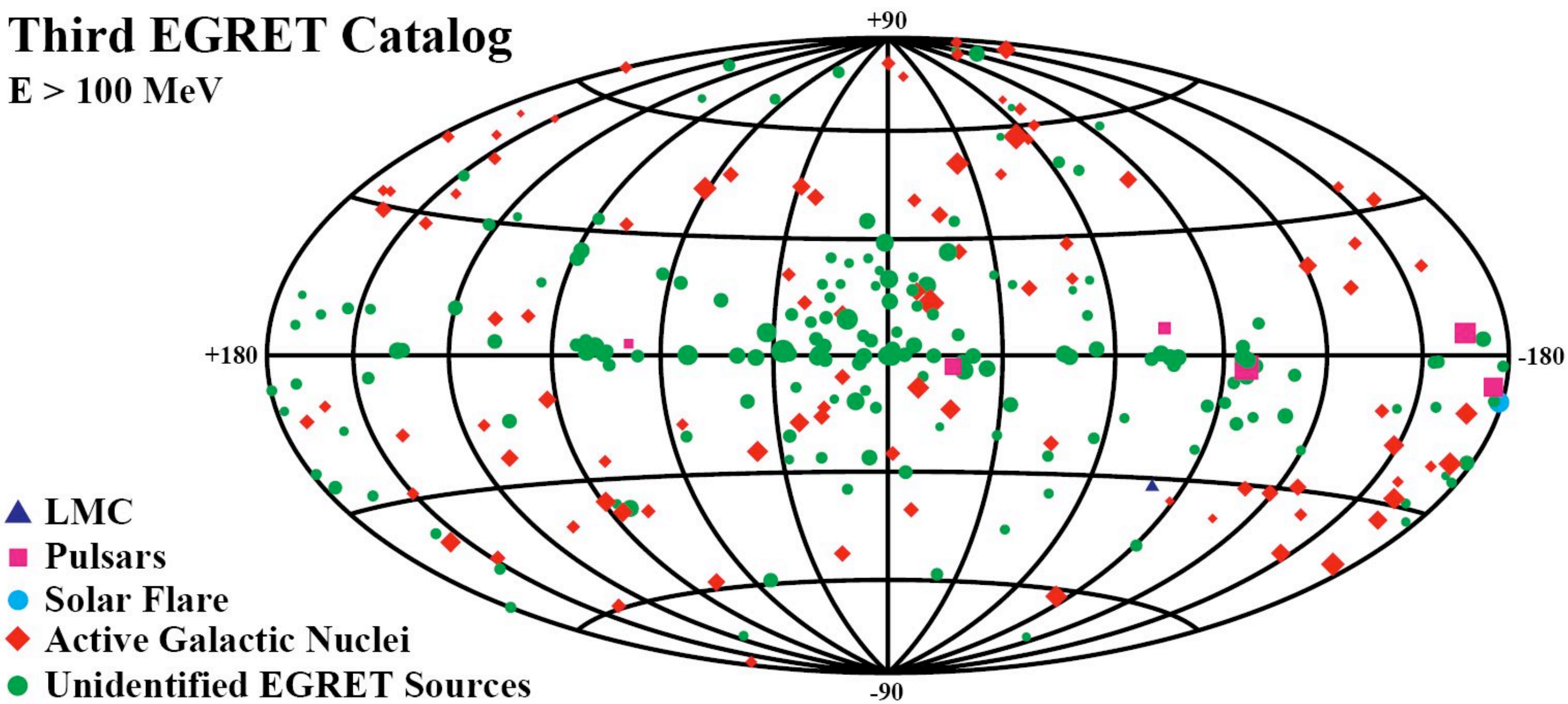


EGRET



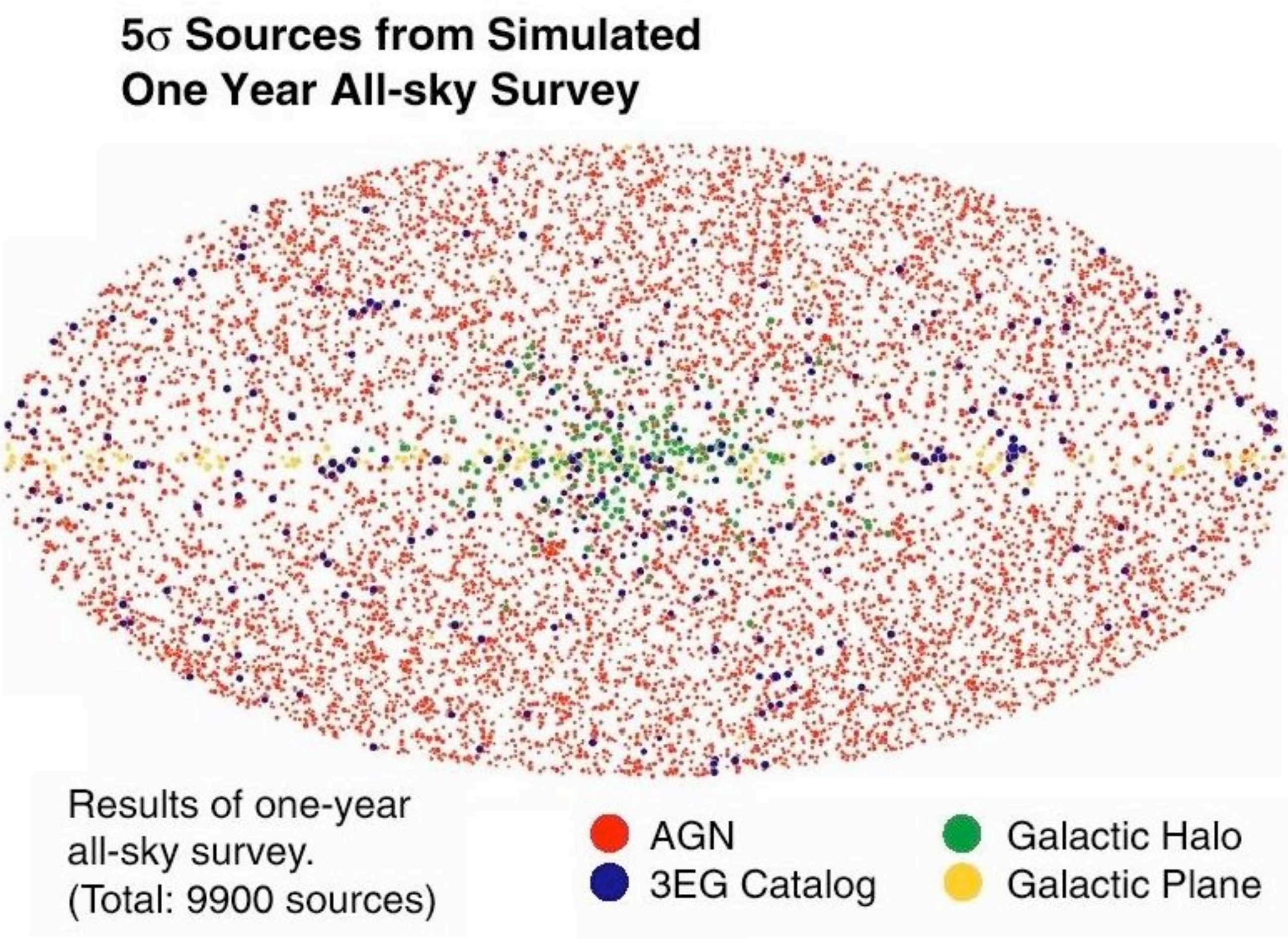
Sources

EGRET 3rd Catalog: 271 sources



Sources

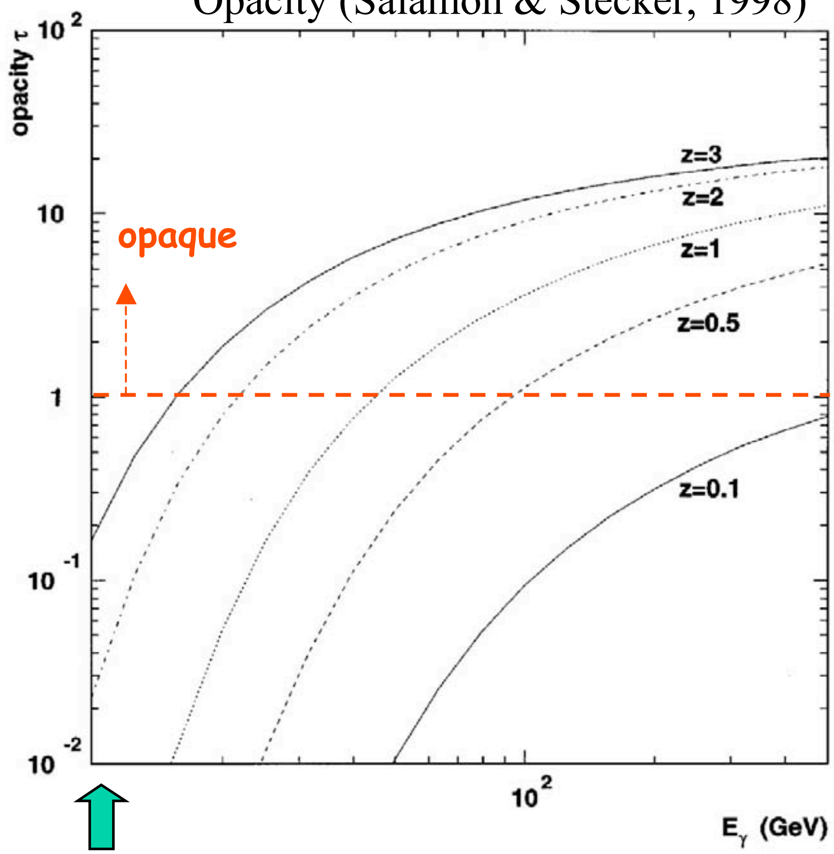
LAT 1st Catalog?



An Important Energy Band

Photons with E>10 GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL)

Opacity (Salamon & Stecker, 1998)



No significant attenuation below ~10 GeV.

only $e^{-\tau}$ of the original source flux reaches us

EBL over cosmological distances is probed by gammas in the 10-100 GeV range. Important science for GLAST!

In contrast, the TeV-IR attenuation results in a flux that may be limited to more local (or much brighter) sources.

A dominant factor in EBL models is the time of galaxy formation -- attenuation measurements can help distinguish models.

GLAST Science

GLAST will have a very broad menu that includes:

- Systems with supermassive black holes (Active Galactic Nuclei)
- Gamma-ray bursts (GRBs)
- Pulsars
- Solar physics
- Origin of Cosmic Rays, SNRs, PWNs, …
- Probing the era of galaxy formation, optical-UV background light
- Solving the mystery of the high-energy unidentified sources
- Discovery! New source classes. Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance.

Huge increment in capabilities.

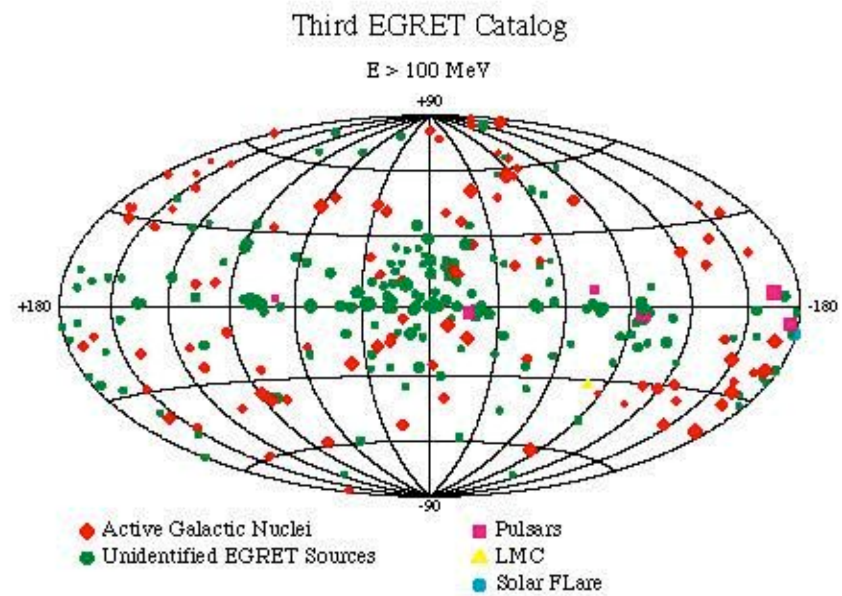
See *http://glast.gsfc.nasa.gov/science/multi/*

for MW campaigners information, coordination.

GLAST will provide unique information across a large range of science topics.

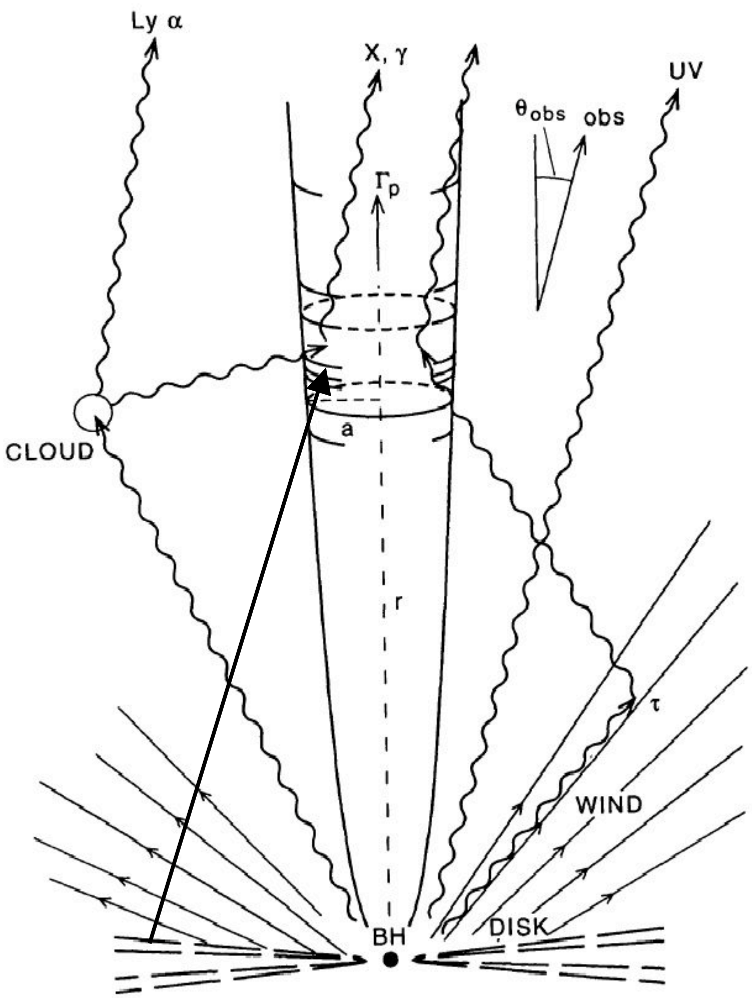
A surprise from EGRET:

detection of dozens of AGN shining brightly in γ-rays -- Blazars

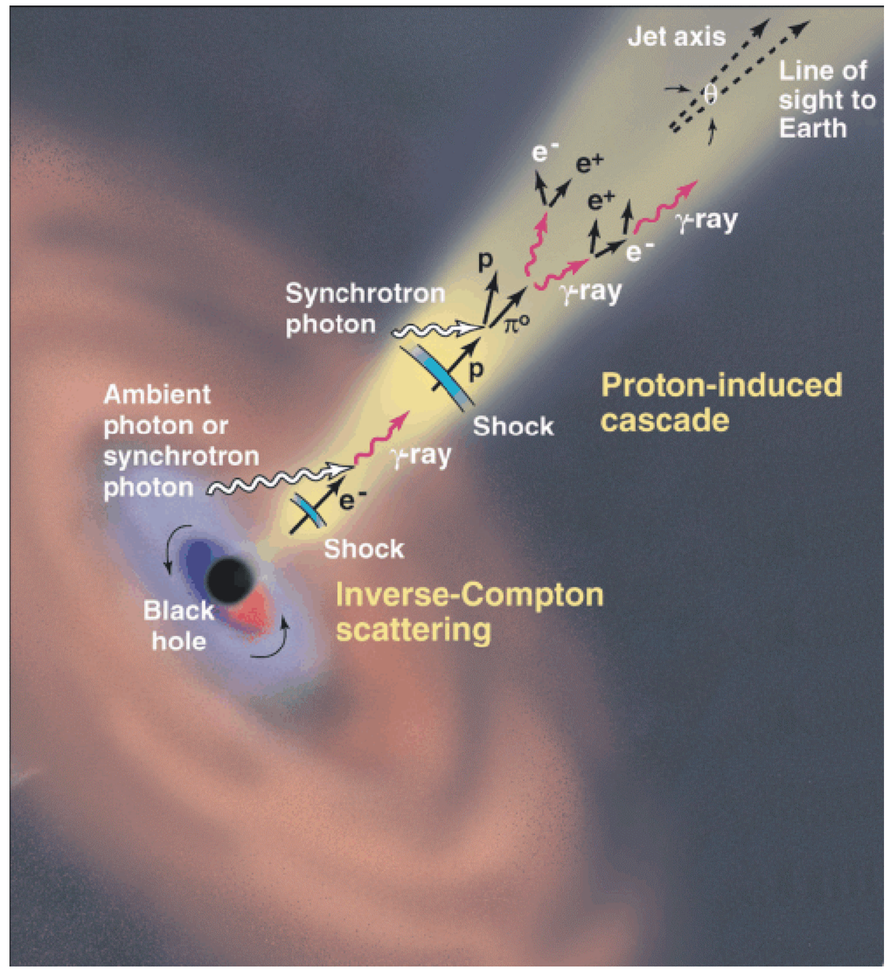


- a key to solving the longstanding puzzle of the extragalactic diffuse gamma flux -- is this integrated emission from a large number of unresolved sources?
- blazars provide a source of high energy γ-rays at cosmological distances. The Universe is largely transparent to γ-rays (any opacity is energy-dependent), so they probe cosmological volumes.

Models of AGN Gamma-ray Production



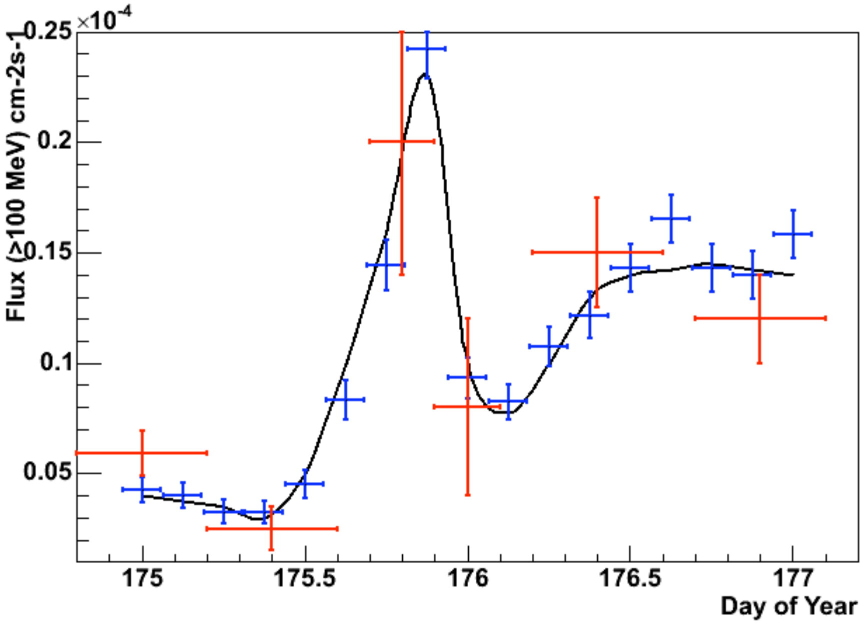
(from Sikora, Begelman, and Rees (1994))



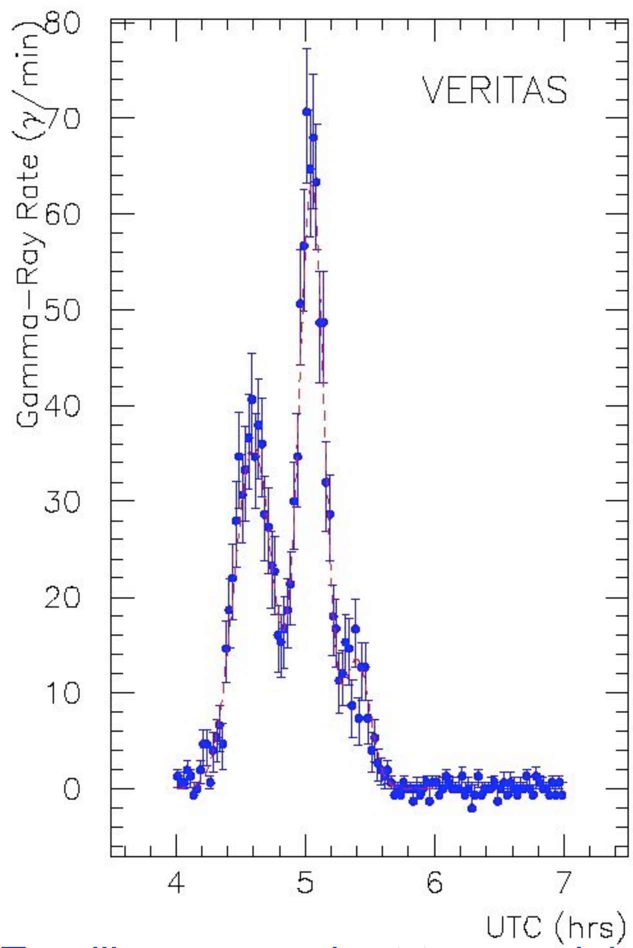
(credit:J. Buckley)

Flares and variability

Large effective area key for studying variability (geometry, dynamics)



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 observations. (J.Mc Enery)



Natural timescale for signal integration well matched to sky survey profile.

ACTs will measure short-term variability with dramatically better precision. GLAST will help guide them where to look.

GLAST Can Probe the Optical-UV EBL

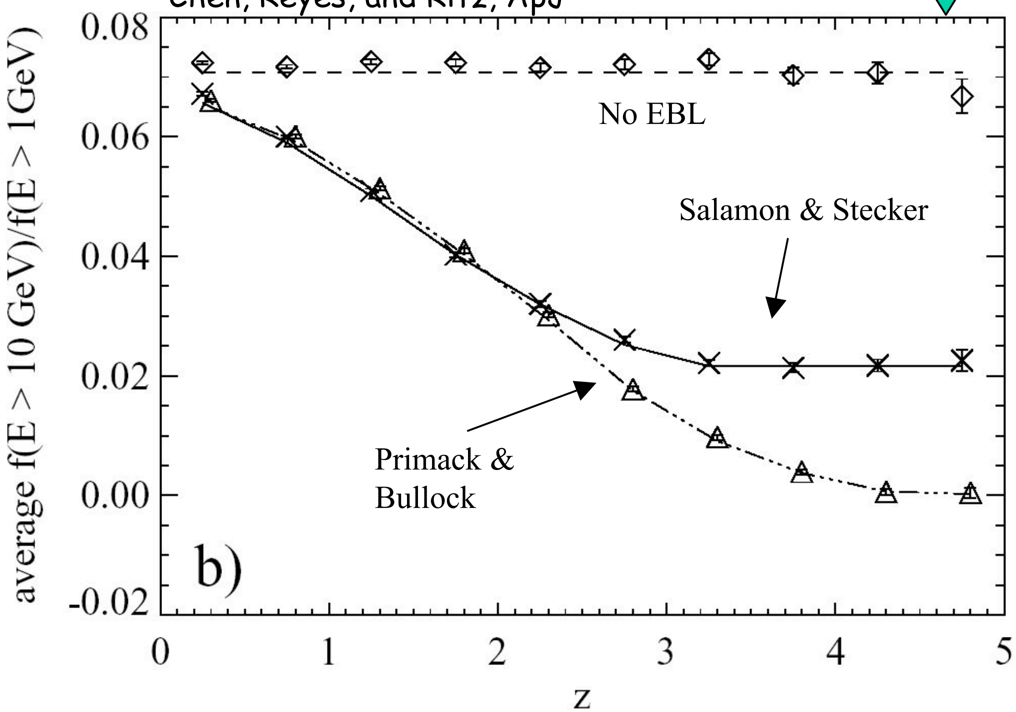
- **Important advances offered by GLAST:**

  (1) thousands of blazars - instead of peculiarities of individual sources, look for systematic effects vs redshift.

  (2) key energy range for cosmological distances (TeV-IR attenuation more local due to opacity).

- Effect is model-dependent (this is good):

Chen, Reyes, and Ritz, ApJ

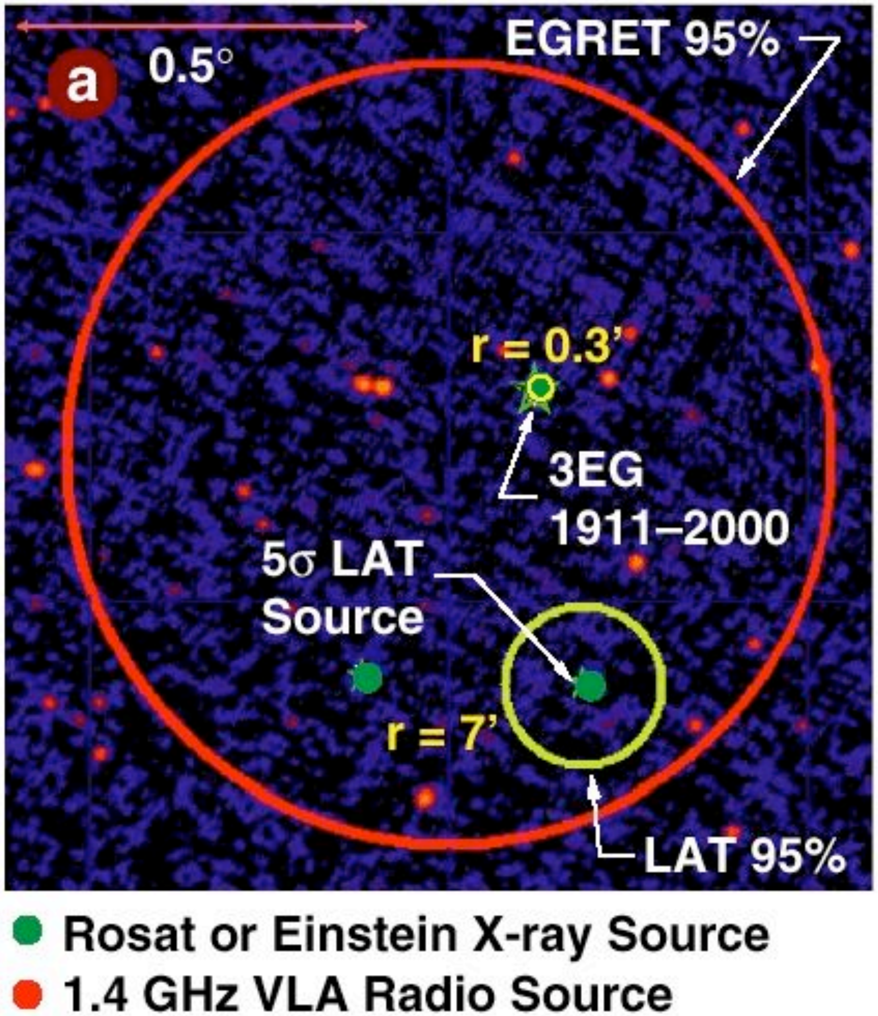


Caveats

- How many blazars have intrinsic roll-offs in this energy range (10-100 GeV)? (An important question by itself for GLAST!)
- What if there is conspiratorial evolution in the intrinsic roll-of vs redshift? More difficult, however there may also be independent constraints (e.g., direct observation of integrated EBL).
- Must measure the redshifts for a large sample of these blazars!

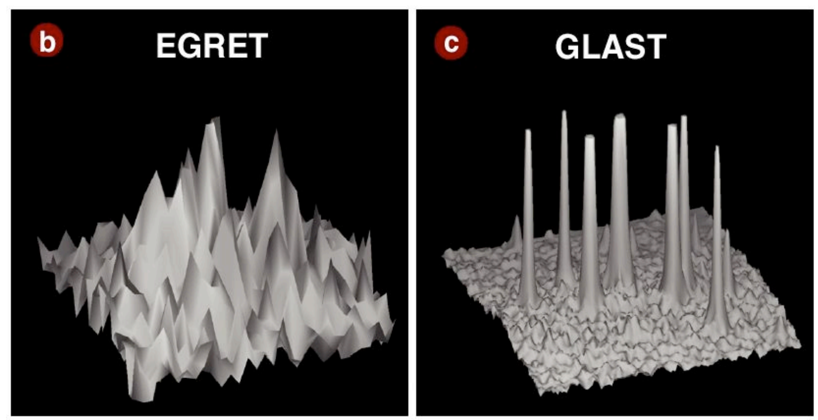
Unidentified Sources

172 of the 271 sources in the EGRET 3rd catalog are "unidentified"



EGRET source position error circles are ~0.5°, resulting in counterpart confusion.

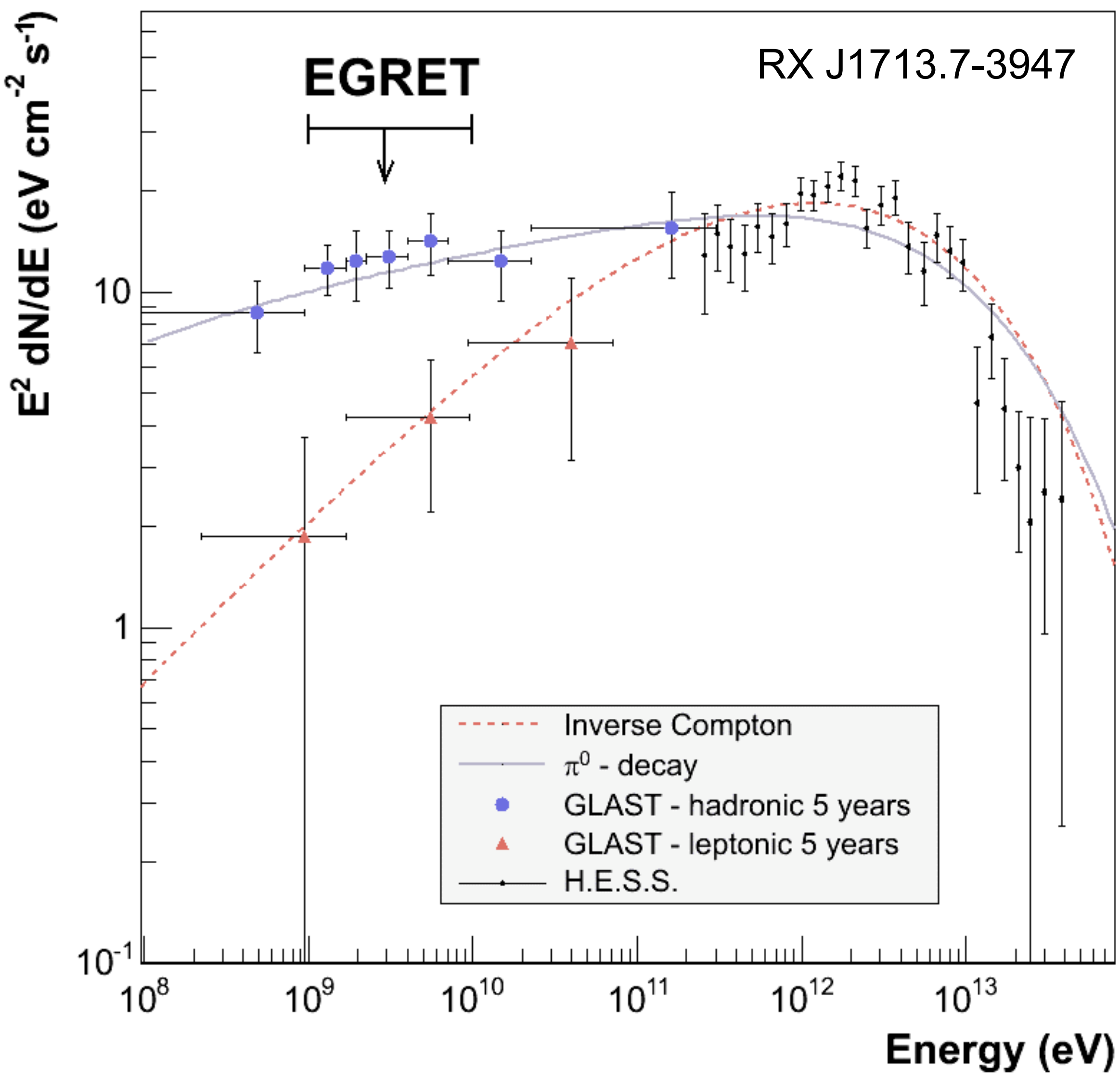
GLAST will provide much more accurate positions, with ~30 arcsec - ~10 arcmin localizations, depending on brightness.



Cygnus region (15x15 deg)

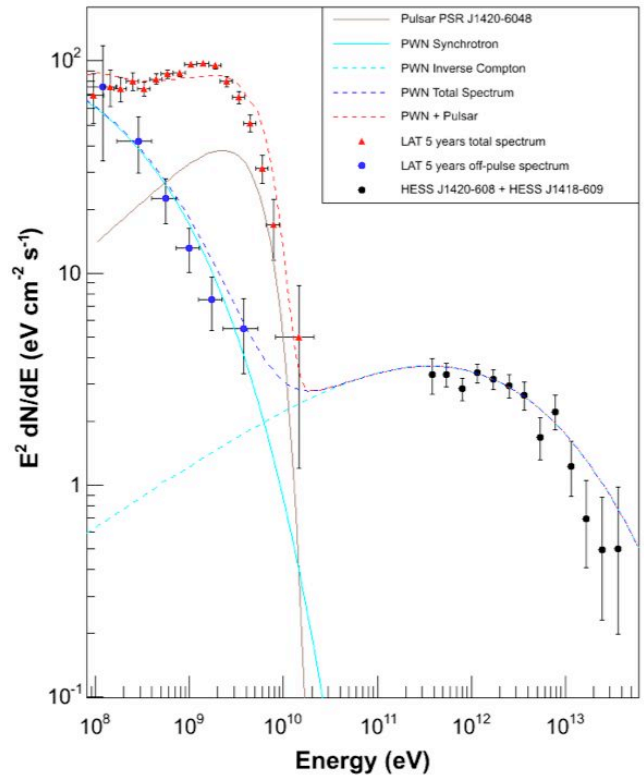
SNRs and Cosmic Ray Acceleration

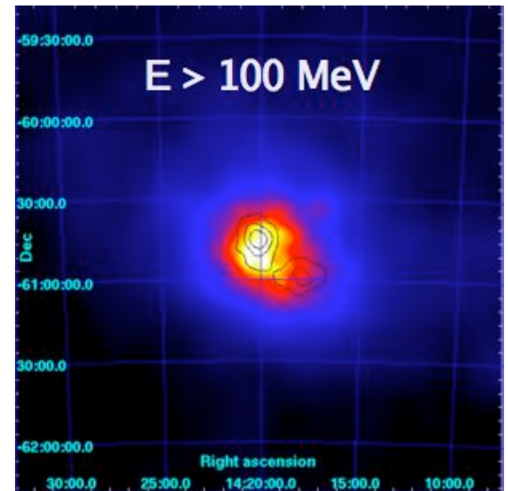
- **GLAST energy range key for proof that SNRs are the source of the HE cosmic ray protons.**

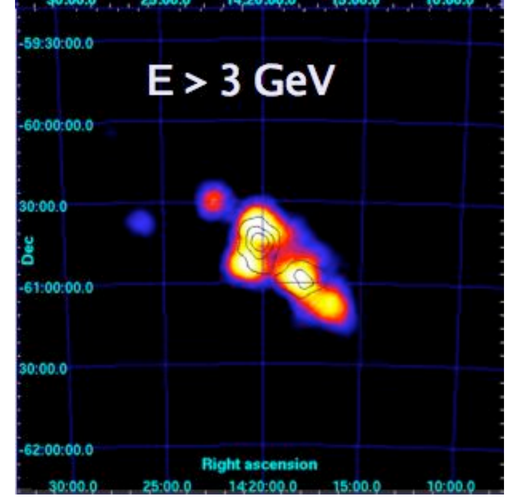


PWN

- **GLAST simulation of Kookaburra region**
- **Energy characterization:**
  - **lower energy: dominated by pulsed component, relatively poorer PSF**
  - **higher energy: better PSF for spatial resolution; determine pulsar cutoffs.**



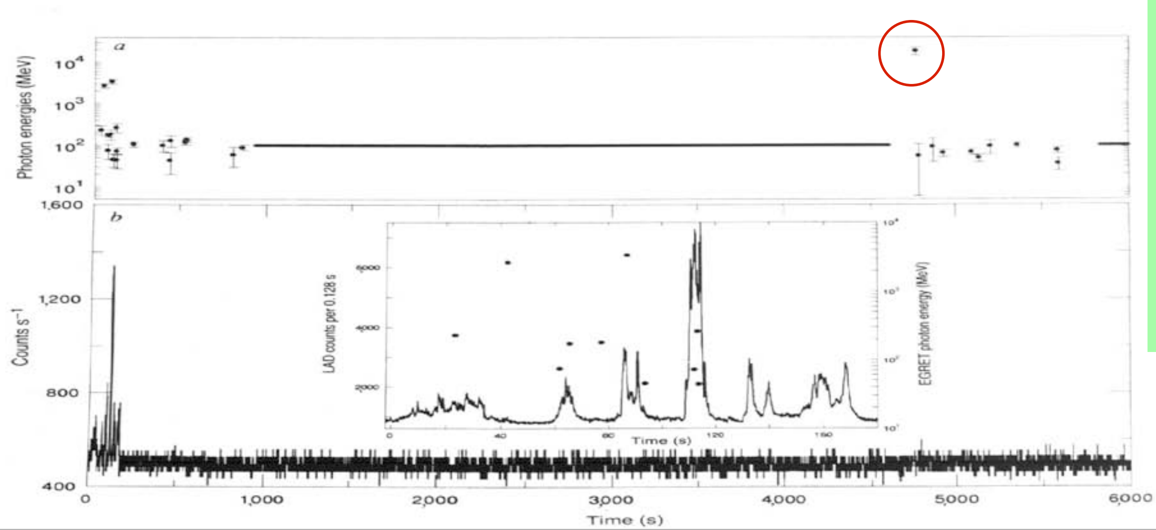




Gamma Ray Bursts

Highest-energy emission from bursts is intriguing:

EGRET detected a ~20 GeV photon ~75 minutes after the start of a burst:



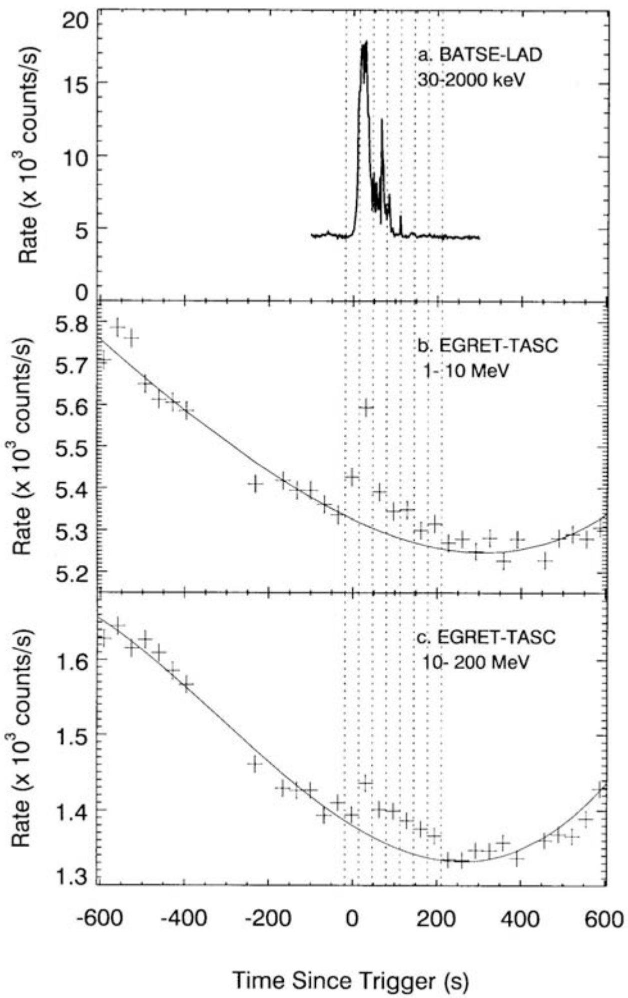
+ **Milagrito** evidence for TeV emission from GRB 970417 ApJ 533(2000)533.

Hurley et al., 1994

Future Prospects: GLAST will provide definitive information about the high energy behavior of bursts: LAT and GBM together will measure emission over >7 decades of energy. Place your bets on additional TeV burst detections!

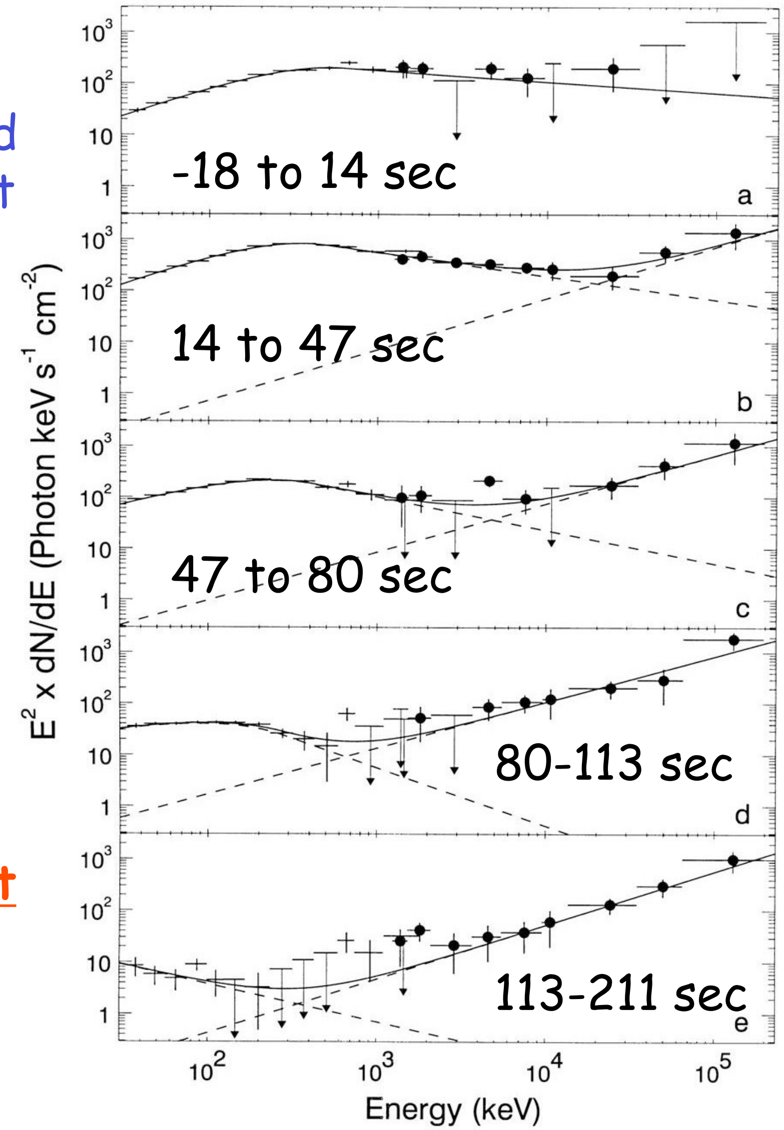
GRB941017

Gonzalez et al., published in Nature

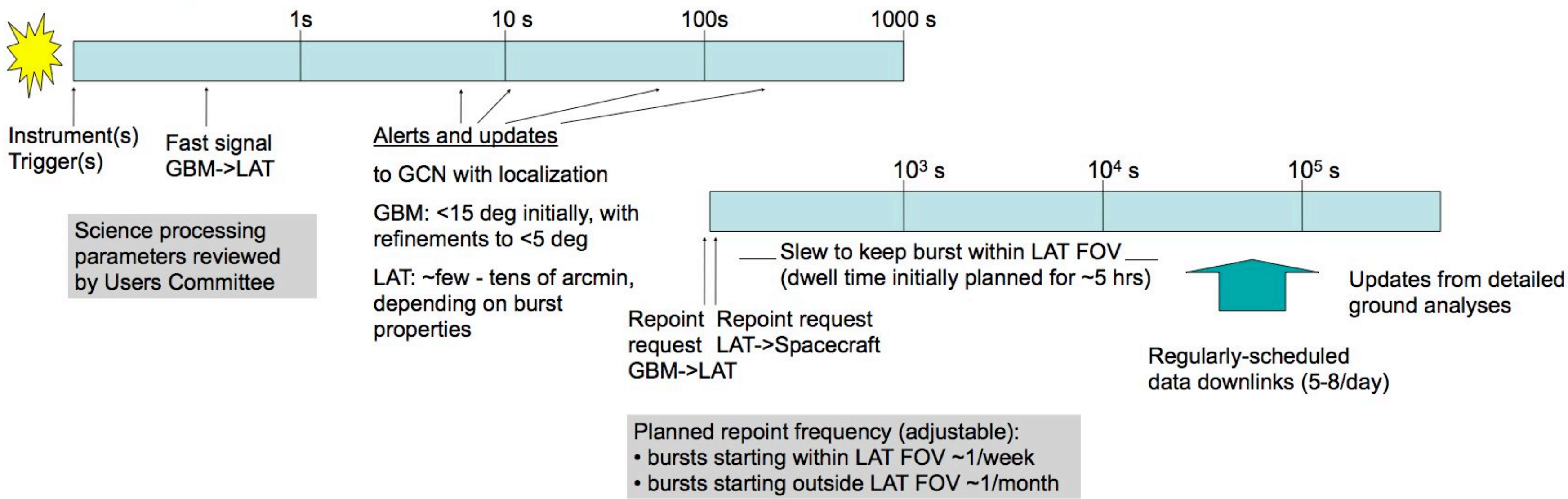


Compare data from EGRET and BATSE: Distinct high-energy component has different time behavior.
What is the high-energy break and total luminosity?
Need GLAST data!

Learn important lessons from the past.

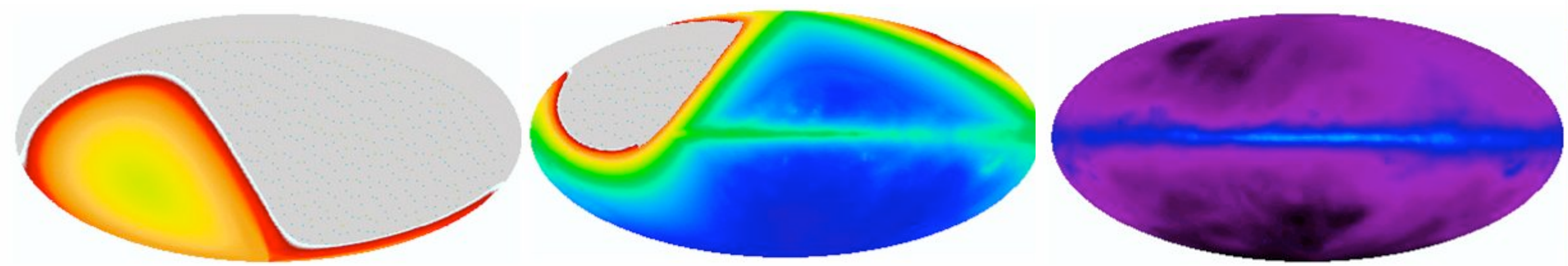


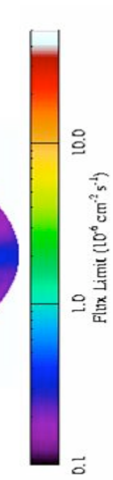
Typical GLAST GRB Timeline



Sky Survey Exposure, Sensitivity

Sensitivity maps for three exposure times

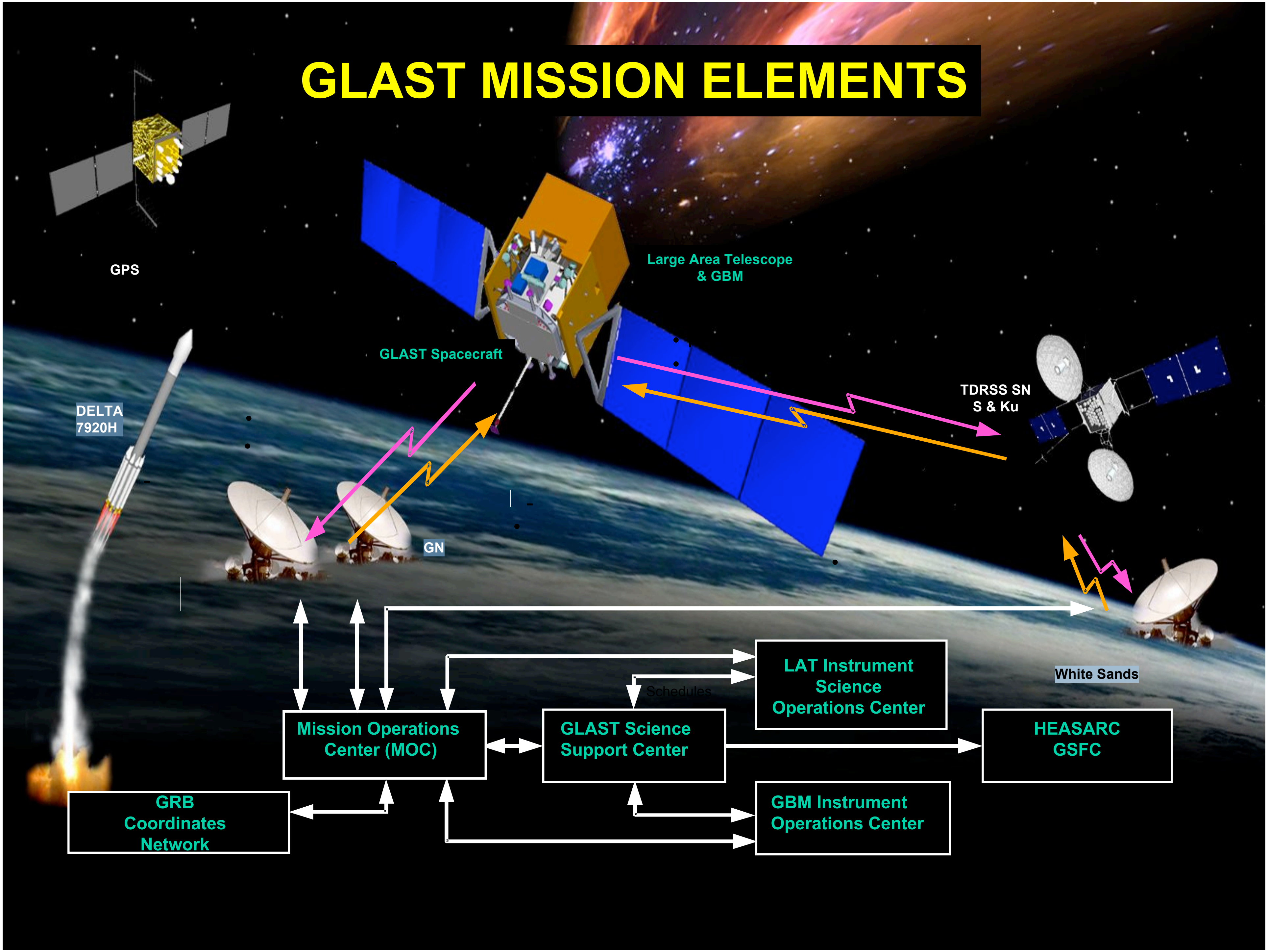




100 Seconds

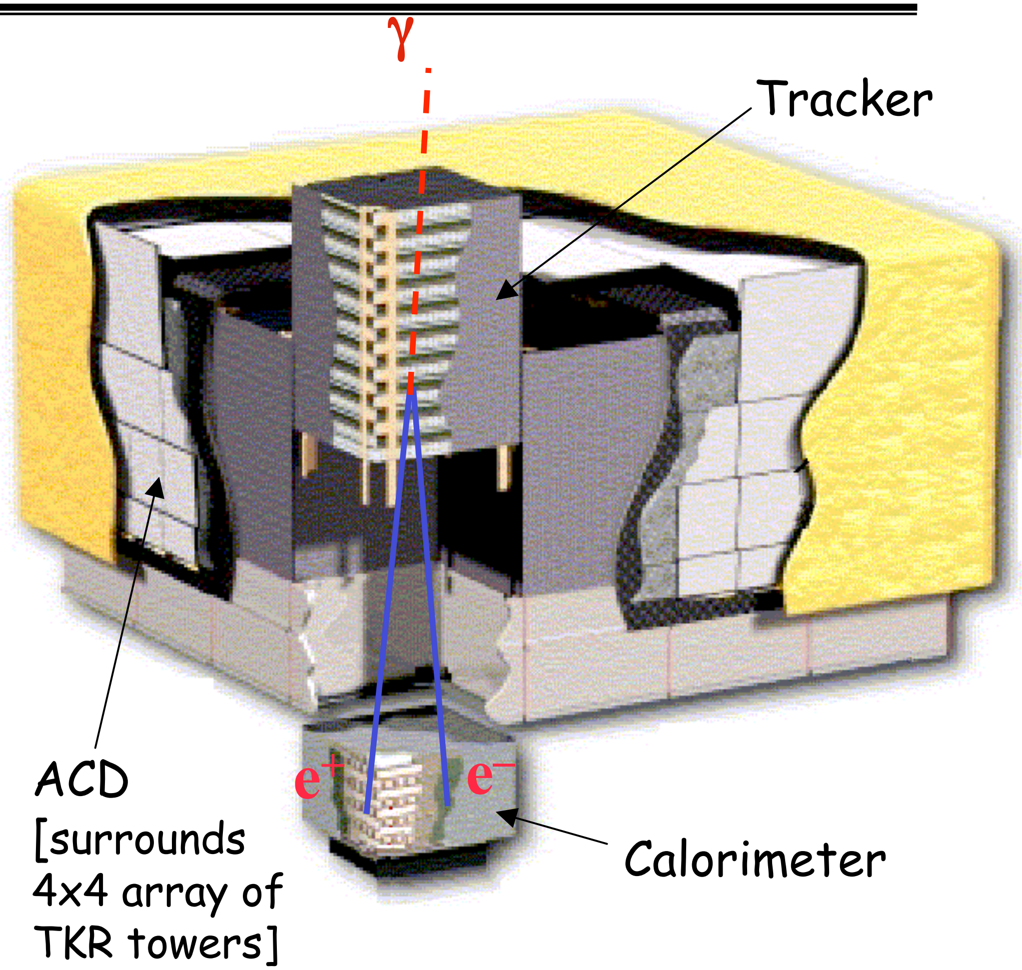
1 orbit (90 mins)

1 day


GLAST MISSION ELEMENTS
GPS
Large Area Telescope
& GBM
GLAST Spacecraft
DELTA
7920H
TDRSS SN
S & Ku
GN
White Sands
LAT Instrument
Science
Operations Center
Schedules
Mission Operations
Center (MOC)
GLAST Science
Support Center
HEASARC
GSFC
GRB
Coordinates
Network
GBM Instrument
Operations Center

Overview of LAT

- Precision Si-strip Tracker (TKR)
  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter(CAL)
  Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.



Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

GLAST LAT Collaboration

United States

- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Sonoma State University
- Stanford University (SLAC and HEPL/Physics)
- University of Washington
- Washington University, St. Louis

France

- IN2P3, CEA/Saclay

Italy

- INFN, ASI, INAF

Japanese GLAST Collaboration

- Hiroshima University
- ISAS, RIKEN

Swedish GLAST Collaboration

- Royal Institute of Technology (KTH)
- Stockholm University

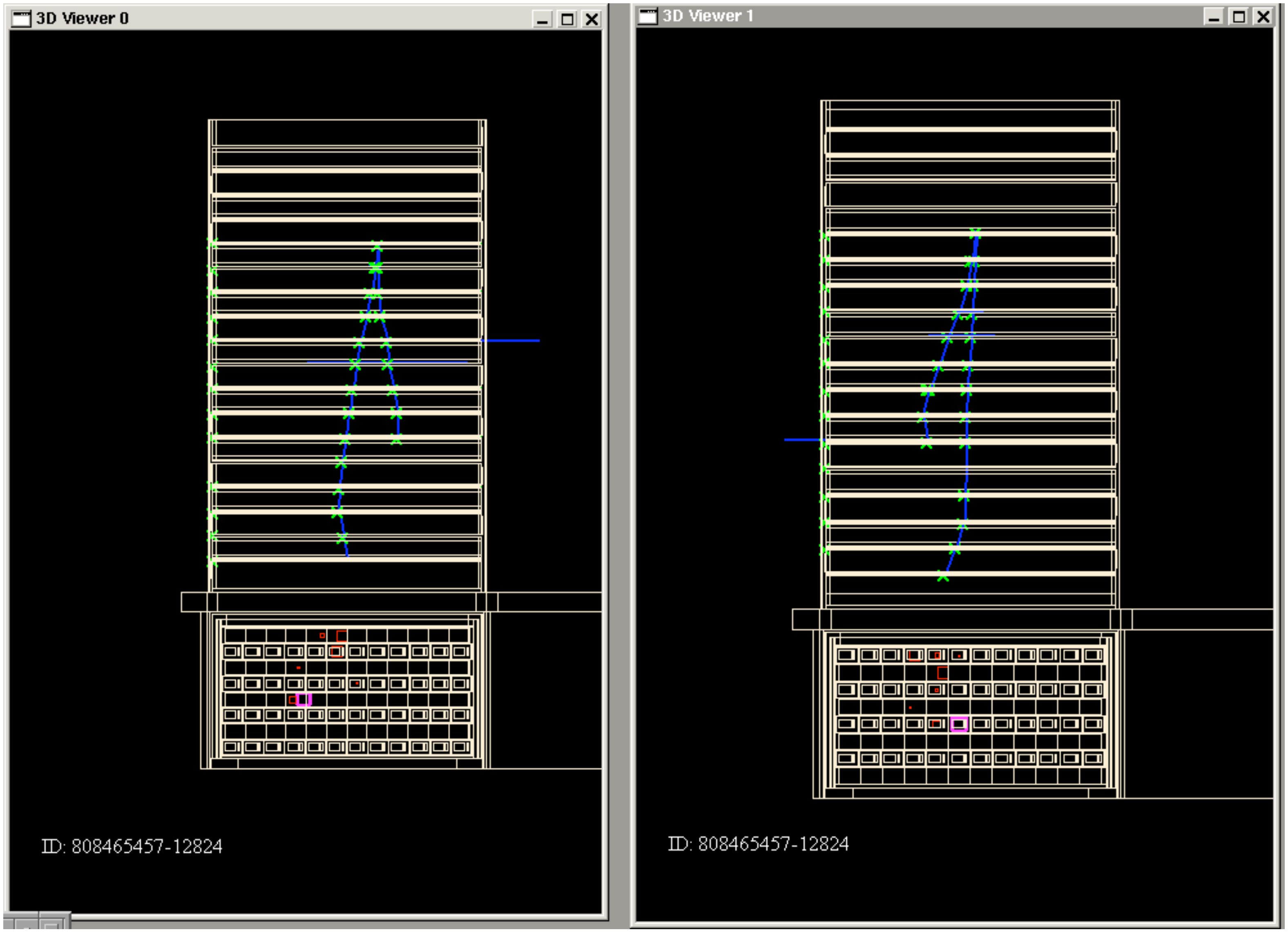
PI: Peter Michelson (Stanford & SLAC)

~230 Members (including ~84 Affiliated Scientists, plus 24 Postdocs, and 36 Graduate Students)

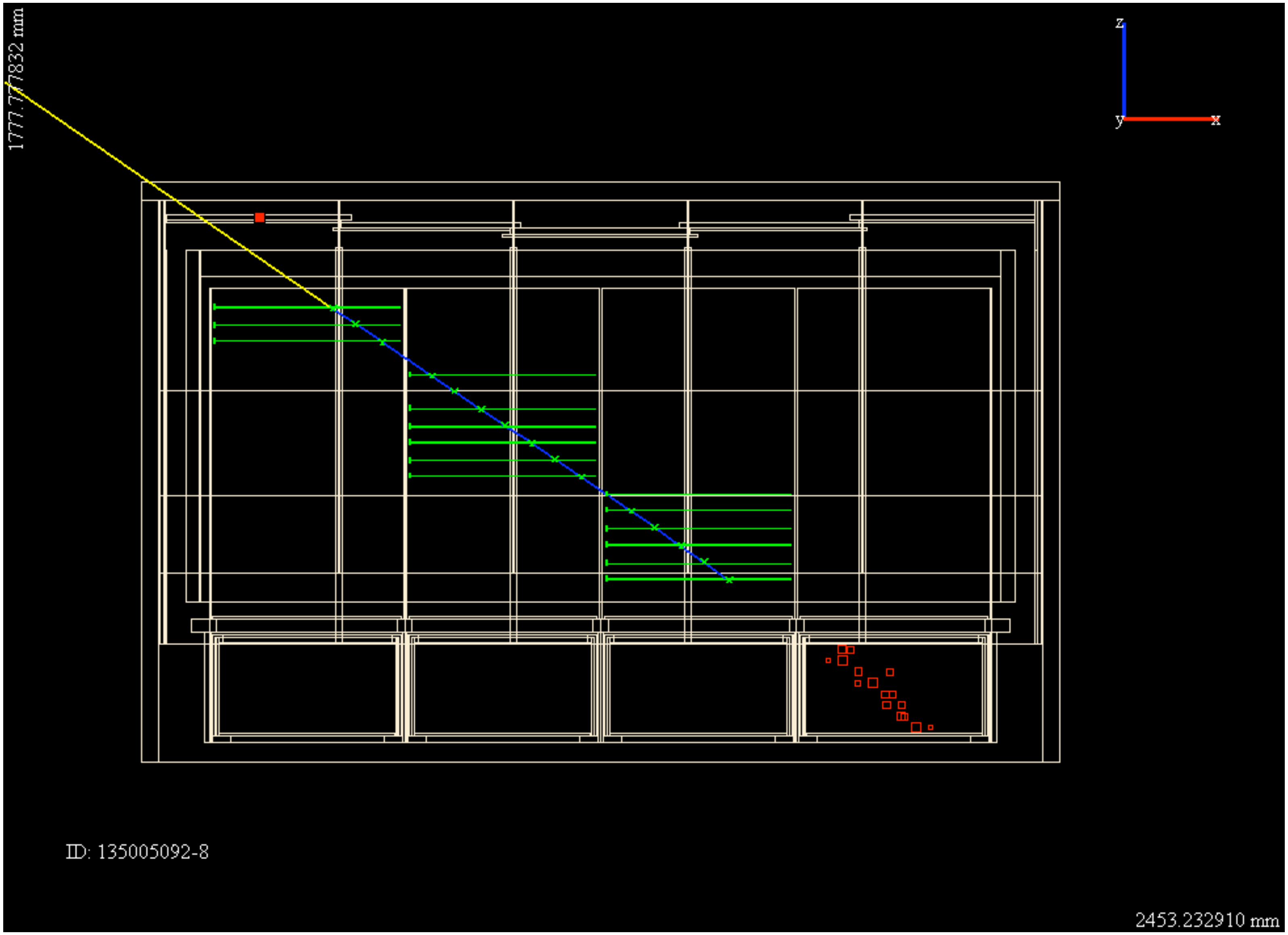
Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

Managed at Stanford Linear Accelerator Center (SLAC).

Gamma Candidate in First Integrated Tower!



16 Towers with ACD



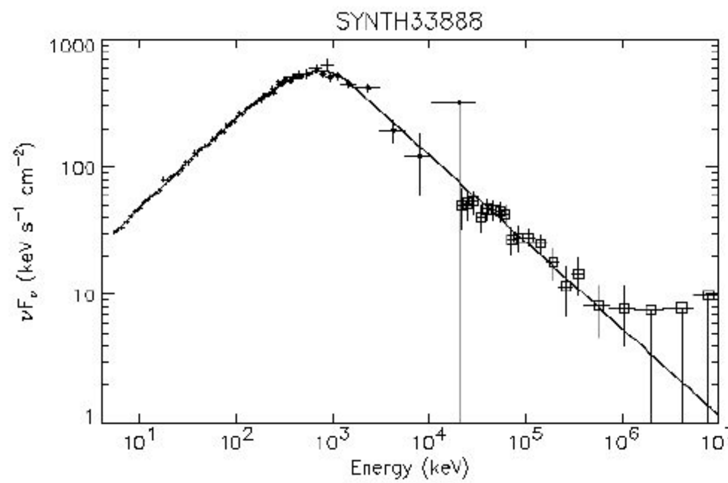
GBM

- **provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;**

Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

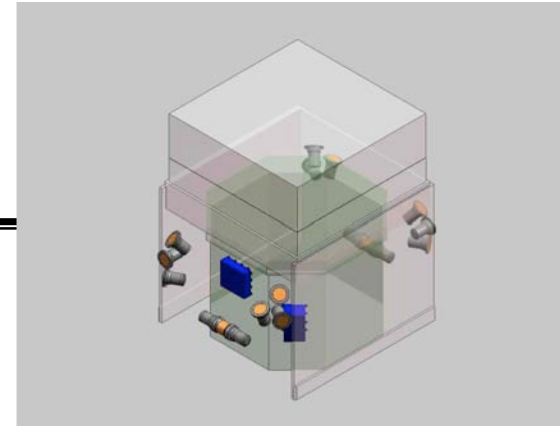
Spectral model parameters from CGRO wide-band fit

1 NaI (14 º) and 1 BGO (30 º)



- **provides wide sky coverage (>8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);**
- **provides burst alerts to the ground.**

GBM Collaboration



National Space Science & Technology Center

University of Alabama
in Huntsville

Michael Briggs
William Paciesas
Robert Preece
Narayana Bhat
Marc Kippen (LANL)

NASA
Marshall Space Flight Center

Charles Meegan (PI)
Gerald Fishman
Chryssa Kouveliotou
Robert Wilson

On-board processing, flight software, systems engineering, analysis software, and management

Max-Planck-Institut für
extraterrestrische Physik

Giselher Lichti (Co-PI)
Andreas von Keinlin
Volker Schönfelder
Roland Diehl
Jochen Greiner
Helmut Steinle

Detectors, power supplies, calibration, and analysis software

GBM Requirements

Parameter	Level 1 Requirements	Intra-Project Goals	Expected Performance
Energy range	10 keV – 25 MeV	5 keV – 30 MeV	8 keV – 30 MeV [1]
Energy resolution	10% (1σ; 0.1 – 1.0 MeV)	7% (1σ; 0.1 – 1.0 MeV)	<8% at 0.1 Mev [2] <4.5% at 1.0 Mev [3]
Effective area	NaI: >100 cm^2 at 14 keV BGO: >80 cm^2 at 1.8 MeV	NaI: >50 cm^2 at 6 keV BGO: none	NaI: 47.5 – 78 cm^2 at 14 keV BGO: >95 cm^2
On-board GRB locations	(none)	15° accuracy (1σ radius) within 2 seconds	<15°; 1.8 seconds (<8° for S/C <60° zenith)
GRB sensitivity (on ground)	0.5 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.3 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.47 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)
GRB on-board trigger sensitivity	1.0 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.75 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.71 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)
Field of view	>8 steradians	10 steradians	9 steradians

(1) Supported by measurements of window absorption
(2) Measured NaI-system resolution
(3) Measured BGO-system resolution

- **on-ground location accuracy: < ~few degrees**
- **expected burst-detection rate of the GBM:**
  - **~70 bursts/year in 55° FoV of LAT**
  - **~215 bursts/year will be detected in total**

Operations Phases, Guest Observers, Data

- After the initial on-orbit checkout, verification, and calibrations, the first year of science operations will be an all-sky survey.
  - every region of the sky viewed for ~30 minutes every 3 hours
  - burst alerts via GCN
  - first year LAT photon candidate event lists initially used for detailed instrument characterization, refinement of the alignment, and key projects (source catalog, diffuse background models, etc.) needed by the community
  - data on flaring sources, transients, and “sources of interest” will be released, with caveats (see following slide)
  - repoints for bright bursts and burst alerts enabled
  - extraordinary ToO’s supported
  - workshops for guest observers on science tools and mission characteristics for proposal preparation
- Observing plan in subsequent years driven by guest observer proposal selections by peer review -- default is sky survey mode. Public data released through the science support center (GSSC).

Year 1 LAT Data Releases

- Throughout year 1 and beyond, high-level data releases continuously:
  - on any flaring source (flux > 2×10^{-6} $cm^{-2}s^{-1}$, E>100 MeV), followed down to factor ~10 lower intensity. Time-binned spectra (or energy-binned light curves) and associated errors.
  - on approximately 20 sources of interest, time-binned spectra (or energy-binned light curves). List vetted through Users Committee. Posted on GSSC website.
  - information from GRBs detected both onboard and from ground-based analyses. For GBM bursts with no LAT detections, upper limits provided.
- At end of year 1, individual photon candidate event info released. All subsequent (year 2 and beyond) individual photon candidate events released immediately after processing.
- Approximately six months into year 1 (in advance of Cycle 2 proposals) a preliminary LAT source list of high-confidence sources will be released
  - position, avg flux, peak flux, spectral index, associated errors

GI Opportunities

- Yearly cycles, starting ~2 months after launch
- Cycle 1:
  - expect to fund ~50 investigations for
    - analyses of released data
    - GLAST-related MW observations
    - GLAST-related theory
    - GLAST-relevant data analysis methodology
- Cycle 2 and onward:
  - expect to fund ~100 investigations for all of the above plus detailed analyses of LAT photon candidate event lists.
  - may propose pointed observations
- GLAST Fellows Program
  - first call in 2007, for start in September 2008
  - three new Fellows selected each year, for three-year periods
- Tentative Schedule for Cycle 1 (2007)
  - NRA in ROSES January, proposals due in June, Cycle 1 funding starts in December

GLAST Science Support Center (GSSC)

- Supports guest investigator program
- Provides training workshops
- Provides data, software, documentation, workbooks to community
- Archives to HEASARC
- Joint software development with Instrument Teams, utilizing HEA standards
- Located at Goddard

see http://glast.gsfc.nasa.gov/ssc/

GLAST Users Committee (GUC)

- **Growing community eagerly anticipating GLAST data!**
- **Advises GLAST Project and NASA on NASA-funded Guest Investigator Program and Policies**
- **Most recent F2F meeting at Goddard in November, featuring a beta-test of the science tools.**
- **First-year source list vetting.**
- **See *http://glast.gsfc.nasa.gov/ssc/resources/guc/***

GLAST Users Committee Members

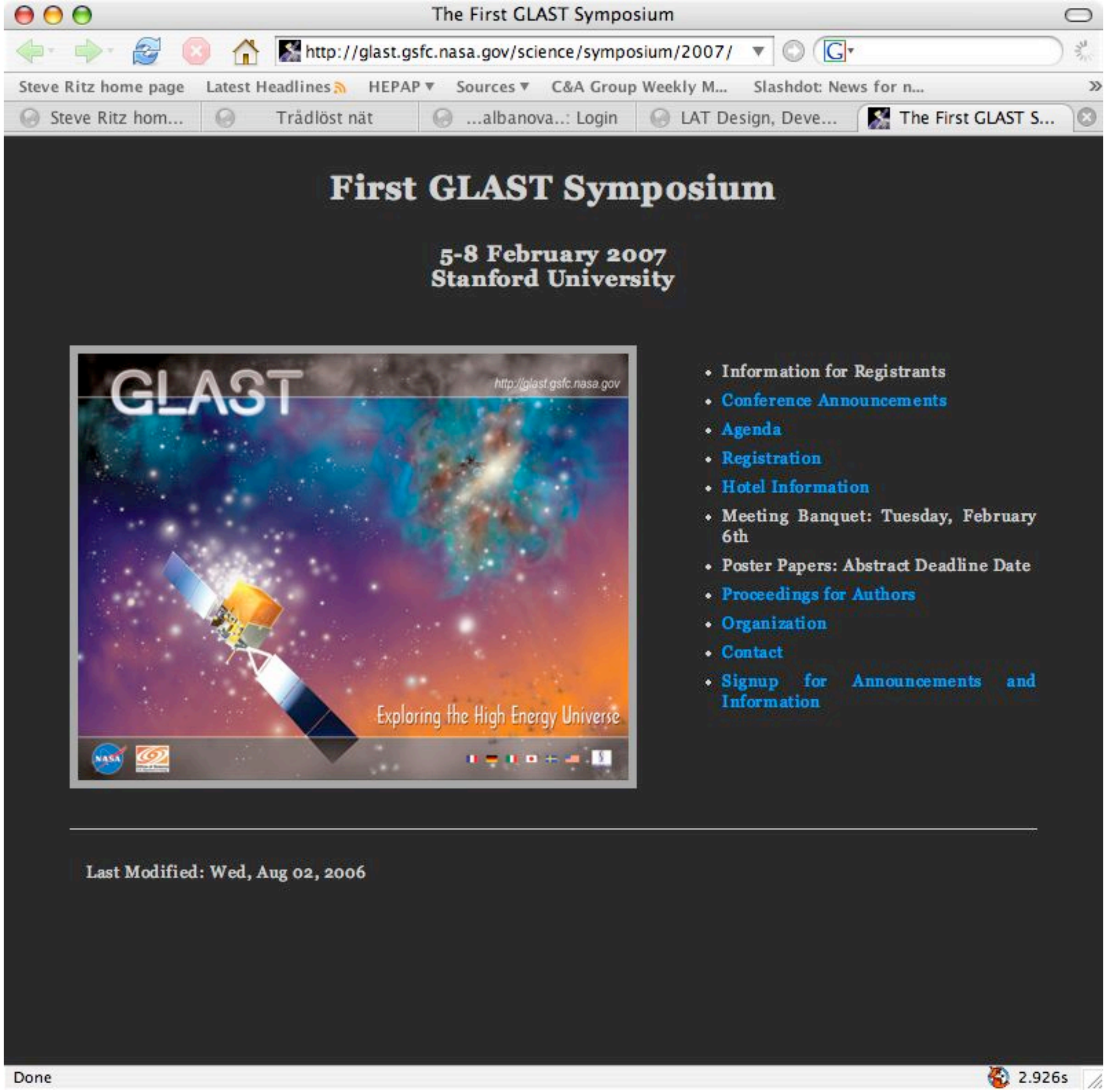
- Josh Grindlay (Chair)
- Roger Brissenden
- Jim Buckley
- Wim Hermsen
- Don Kniffen
- Jim Ling
- Alan Marscher
- Reshmi Mukherjee
- Rene Ong
- Luigi Piro
- Greg Stacy
- Mark Strickman
- Ann Wehrle

Plus

- David Band
- Neil Gehrels
- Rick Harnden
- Julie McEnery
- Chip Meegan
- Peter Michelson
- Steve Ritz
- Rita Sambruna
- Chris Shrader
- Kathy Turner
- Lynn Cominsky

http://glast.gsfc.nasa.gov/ssc/resources/guc/

First International GLAST Symposium



Starting monthly GLAST news email. Sign up!

Summary

- All the parts of GLAST are coming together:
  - the instruments are beautiful!
  - observatory integration is nearing completion
- Preparation for science and operations in full swing
  - good connections among all the elements
  - MW observations are key to many science topics for GLAST. See *http://glast.gsfc.nasa.gov/science/multi/*
  - First International GLAST Symposium 5-8 February at Stanford.
- Looking forward to launch in Fall 2007.

- Guest Investigator Program starts this year, with many opportunities for GIs. Join the fun!

Summary

- **GLAST will address many important questions:**
  - **How do Nature's most powerful accelerators work?**
  - **What are the unidentified sources found by EGRET?**
  - **What is the origin of the diffuse background?**
  - **What is the origin of cosmic rays?**
  - **What is the high energy behavior of gamma ray bursts?**
  - **When did galaxies form?**
  - **What else out there is shining gamma rays? New sources (*e.g.*, galaxy clusters)? Are there high-energy relics from the Big Bang? Are there further surprises in the poorly-measured energy region?**
- **Huge leap in key capabilities enables large menu of known exciting science and large discovery potential.**
- **Part of the bigger picture of experiments at the interface between particle physics and astrophysics.**