



GLAST

Gamma-ray Large
Area Space
Telescope



GLAST

The Gamma-ray Large Area Space Telescope

**GLAST Boston Workshop
21 June 2007**

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for the GLAST Mission Team

see <http://glast.gsfc.nasa.gov> and links therein



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 unoccluded sky at any time.**
- **Huge energy range, including 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)**

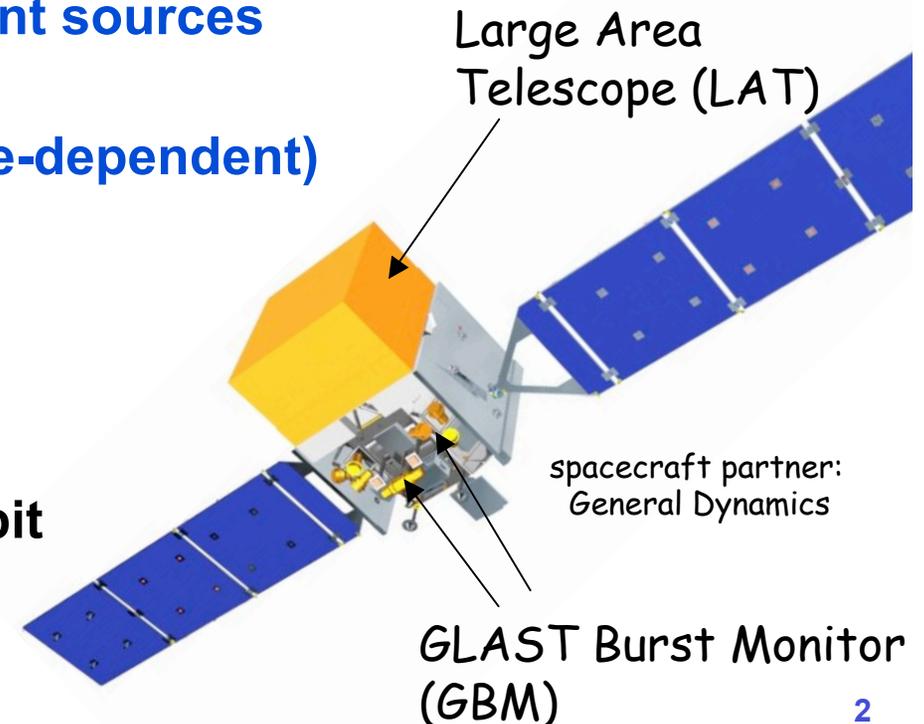
Two GLAST instruments:

LAT: 20 MeV – >300 GeV

GBM: 10 keV – 25 MeV

Launch: Jan 2008. 565 km, circular orbit

5-year mission (10-year goal)







Latest Picture of GLAST Observatory



<http://glast.gsfc.nasa.gov/public/resources/images/>



Google

Web Images Groups News Froogle LocalNew! more »

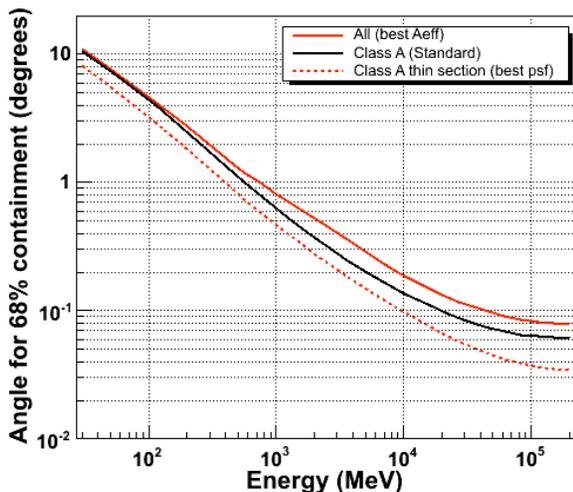
GLAST LAT performance

Search

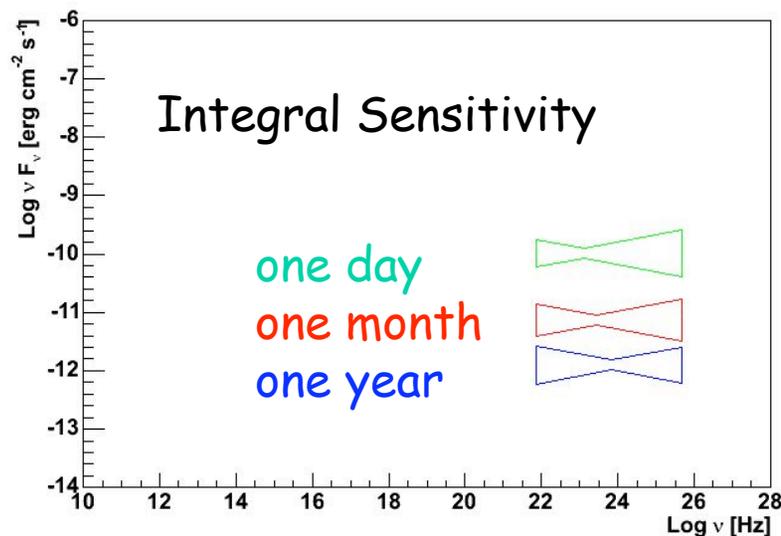
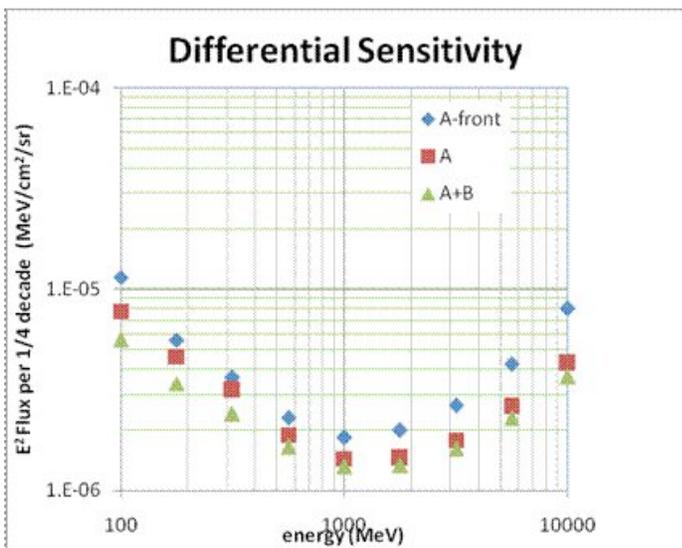
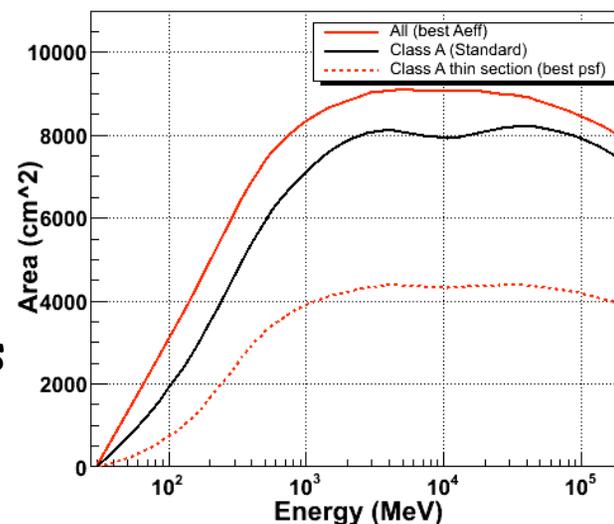
Advanced Search Preferences

Look for an update soon

LAT performance summary



⇒ sensitivity depends on source characteristics

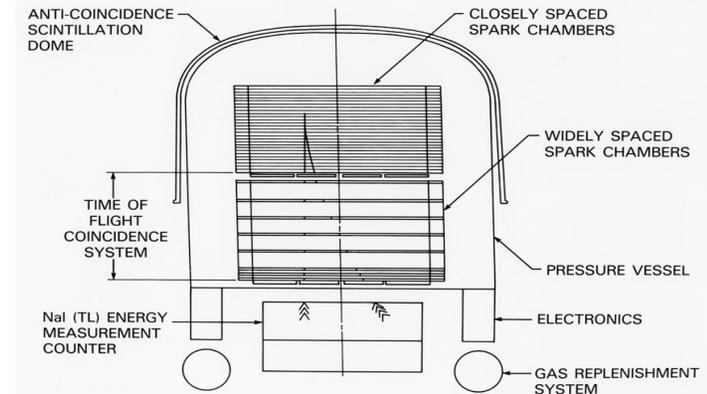
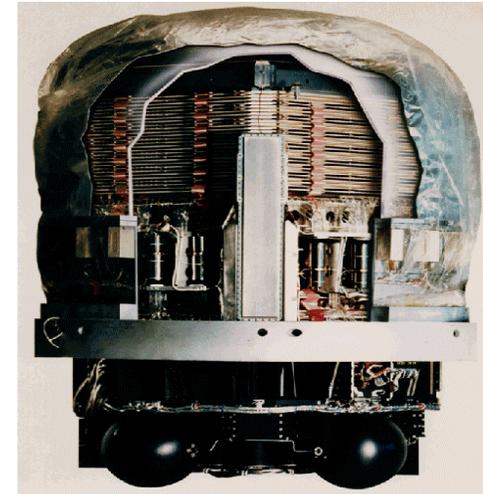
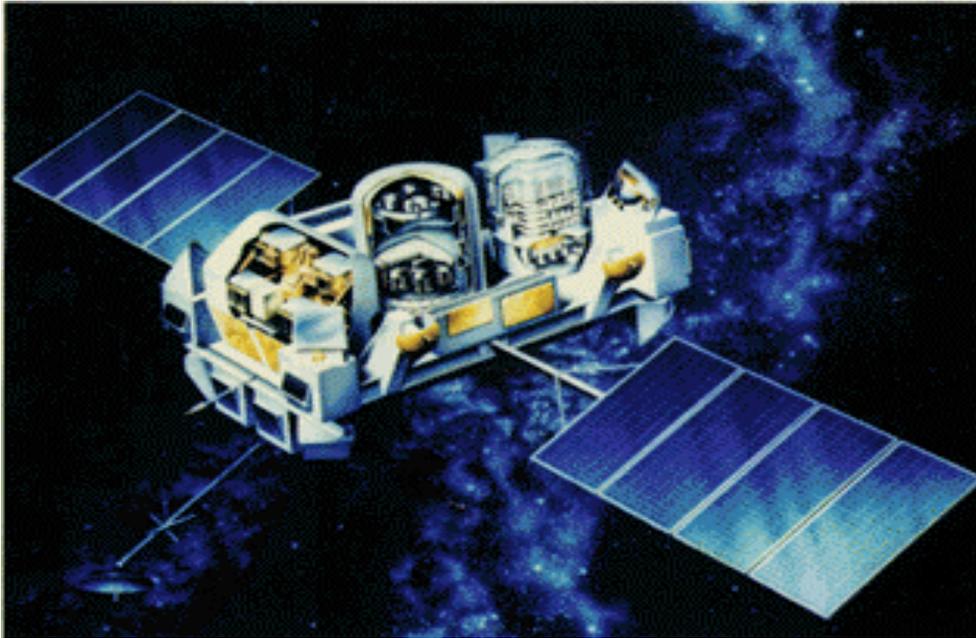


after 1 year, pt src sensitivity 4×10^{-9} cm⁻²s⁻¹ (E>100 MeV)



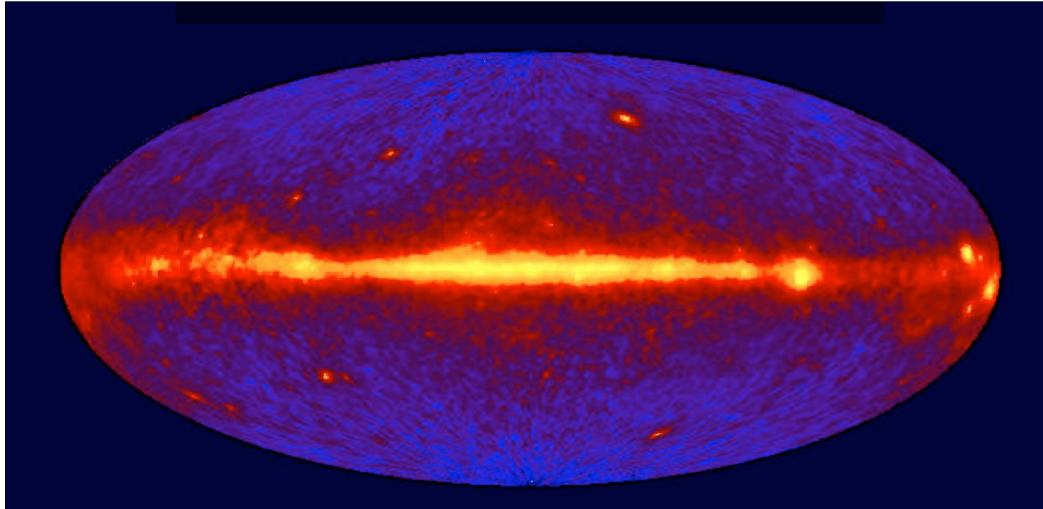
EGRET

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





Features of the gamma-ray sky



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

diffuse extra-galactic background
(flux $\sim 1.5 \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$)

galactic diffuse (flux $\sim O(100)$ times larger)

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

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 LAT High Energy Capabilities

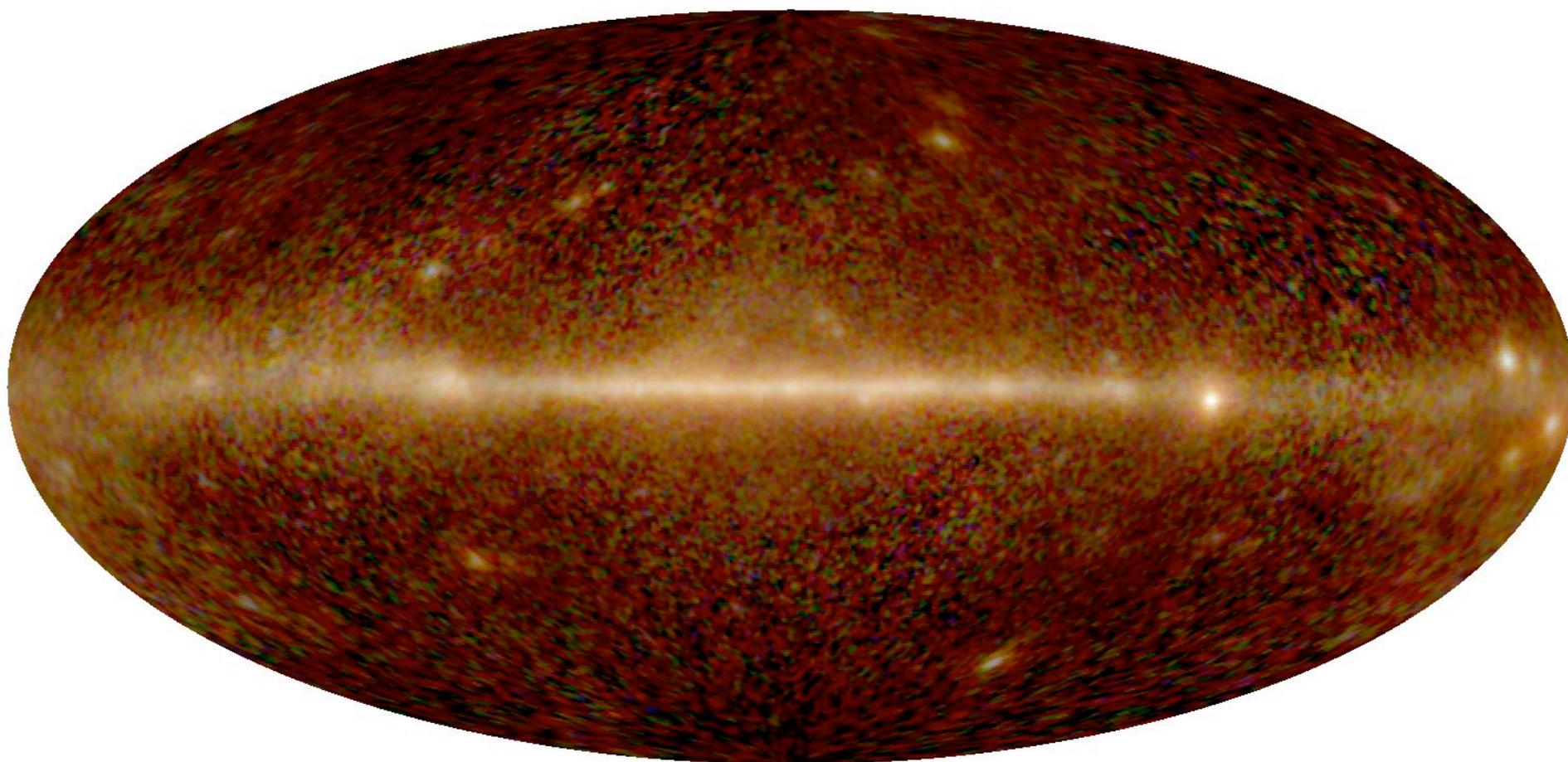
EGRET on GRO firmly established the field of high-energy gamma-ray astrophysics and demonstrated the importance and potential of this energy band.

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*

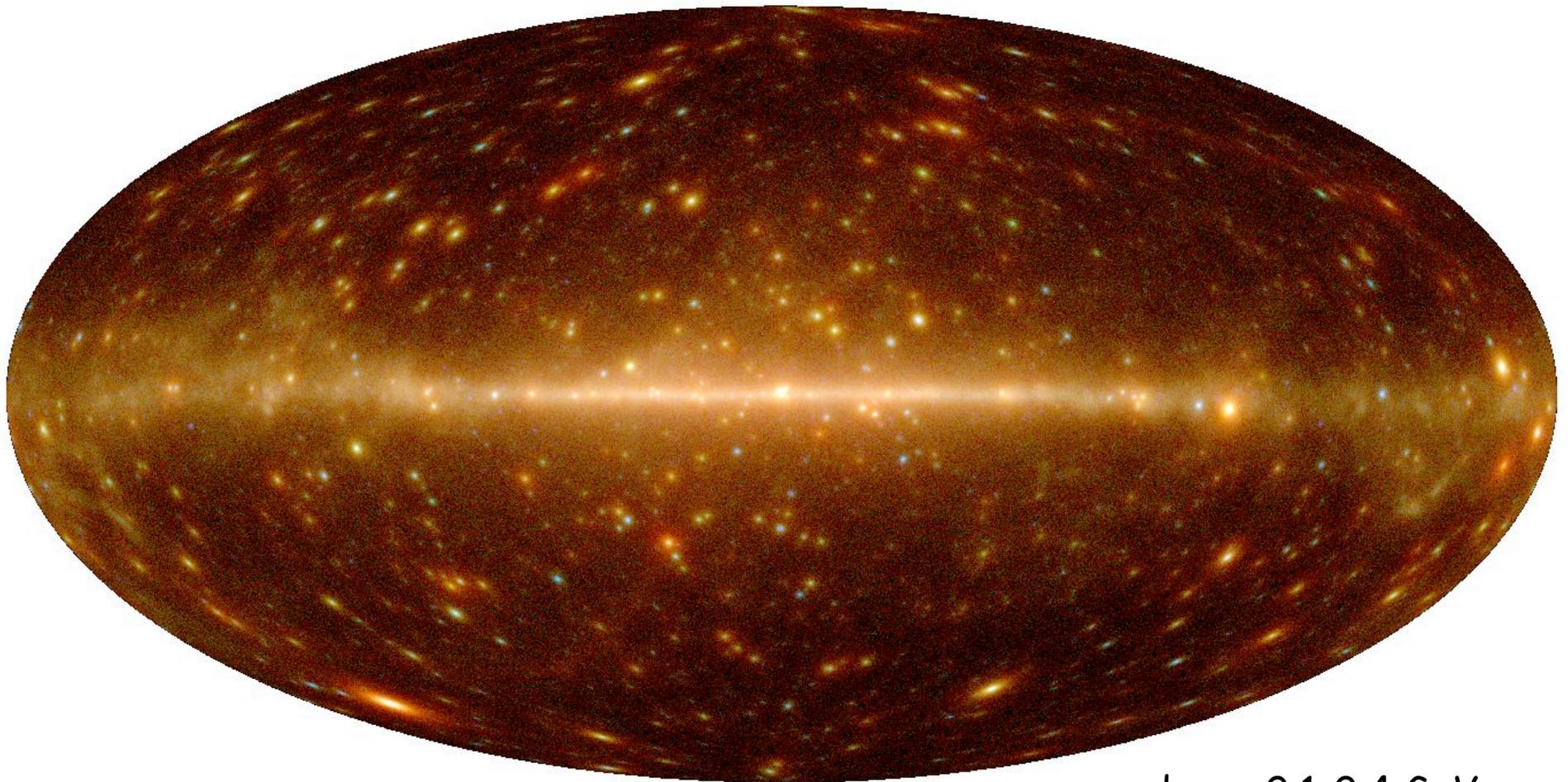


EGRET





GLAST One-year Service Challenge Simulation



red: 0.1-0.4 GeV
green: 0.4-1.6 GeV
blue: >1.6 GeV



Leap in Capabilities: Implications

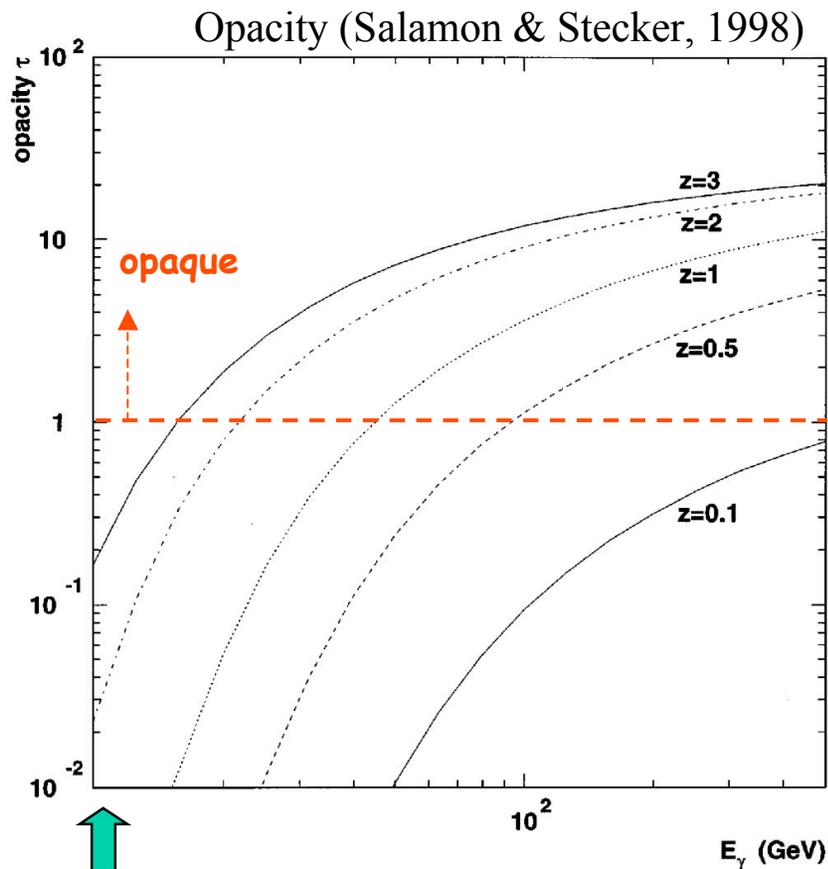
- **Dynamic Range Frontier; Variability Frontier** Whole-sky aperture for transients and variable sources: longterm, evenly sampled lightcurves; dynamic range of emission.
- **Depth Frontier** Deepening exposure over whole mission lifetime.
- **Energy Frontier** Discovering energy budgets and characteristics of wide variety of cosmic accelerator systems on different scales.
 - Getting to know 10 - 100 GeV sky
 - Connecting with TeV facilities: variability, spectral coverage
 - 7 decades of GLAST GRB energy coverage
- **Spatial Frontier** Breaking through to sub-arcmin point-source localizations (source dependent) -- ID the sources; PLUS starting to move beyond point sources: capabilities to resolve spatially ($> \sim 0.5^\circ$ features), spectrally, and temporally.
- **Timing Frontier** Transient and periodic pulse profiles, searches.
- **Measurement Frontier** A rich data set to mine, touching many areas of science. Sources we know (AGN, SNR, XRBs, pulsars, PWN, galaxy clusters, solar flares, moon,...) and those awaiting discovery.

Even greater multiwavelength/multimessenger needs and opportunities



An Important Energy Band

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



No significant attenuation below ~ 10 GeV.

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

EBL over cosmological distances may be 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 star formation rate -- 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**
- **Binary systems, microquasars**
- **Solar physics**
- **SNRs, Origin of Cosmic Rays, PWN**
- **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.

Multiwavelength/messenger cooperation will provide fundamentally new insights into these topics

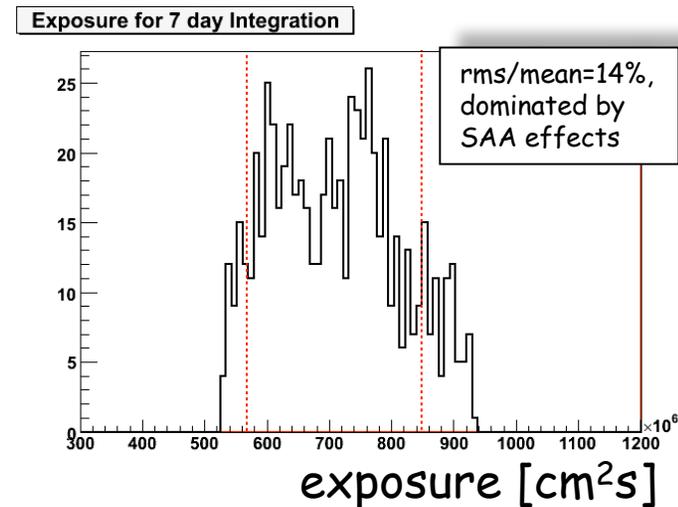
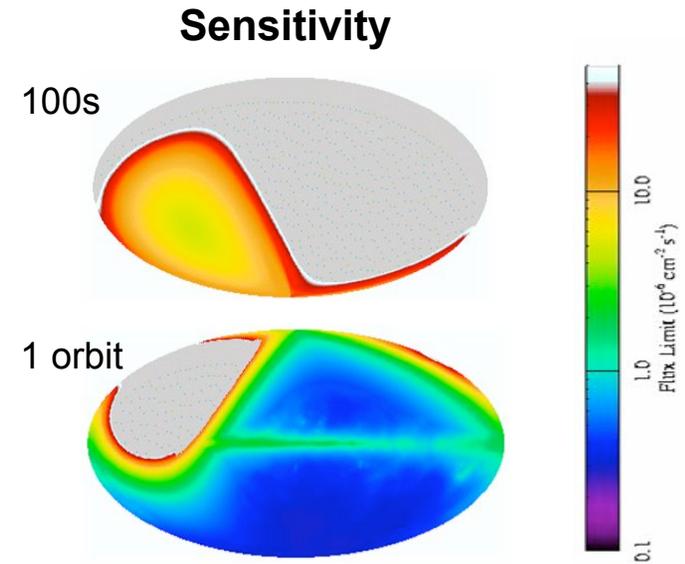


Sky Survey



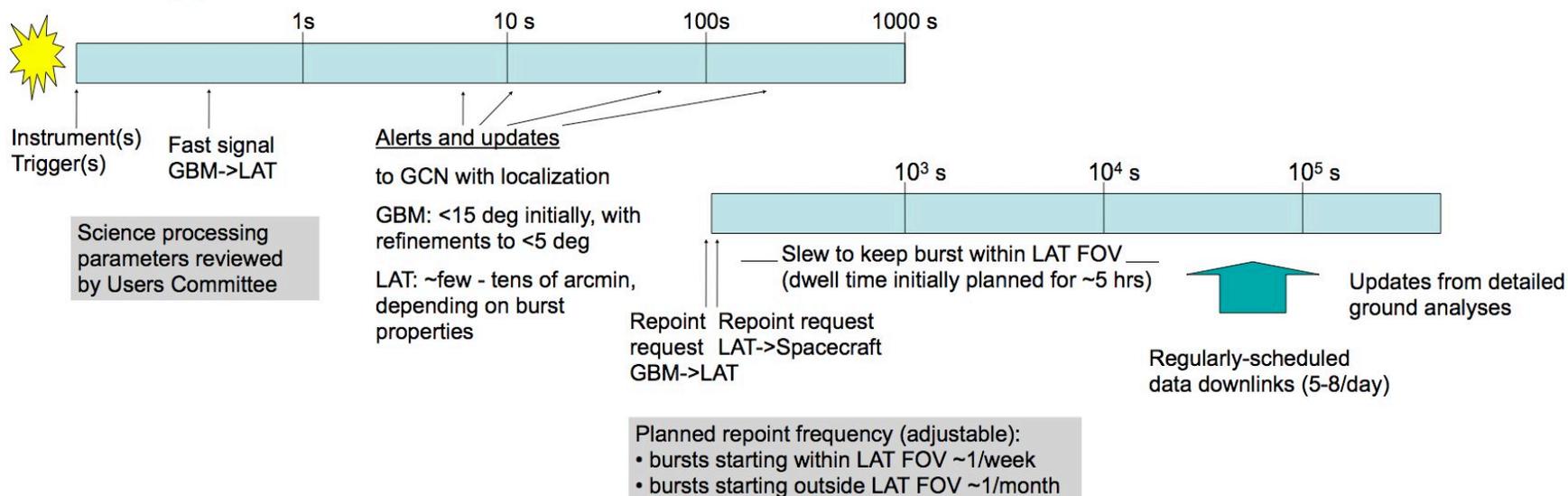
GLAST Operating Modes

- **Primary observing mode is Sky Survey**
 - Full sky every 2 orbits (3 hours)
 - Uniform exposure, with each region viewed for ~30 minutes every 2 orbits
 - Best serves majority of science, facilitates multiwavelength observation planning
 - Exposure intervals commensurate with typical instrument integration times for sources
 - **EGRET sensitivity reached in ~days**
- **Pointed observations when appropriate (selected by peer review) with automatic earth avoidance selectable. Target of Opportunity pointing.**
- **Autonomous repoints for onboard GRB detections in any mode.**

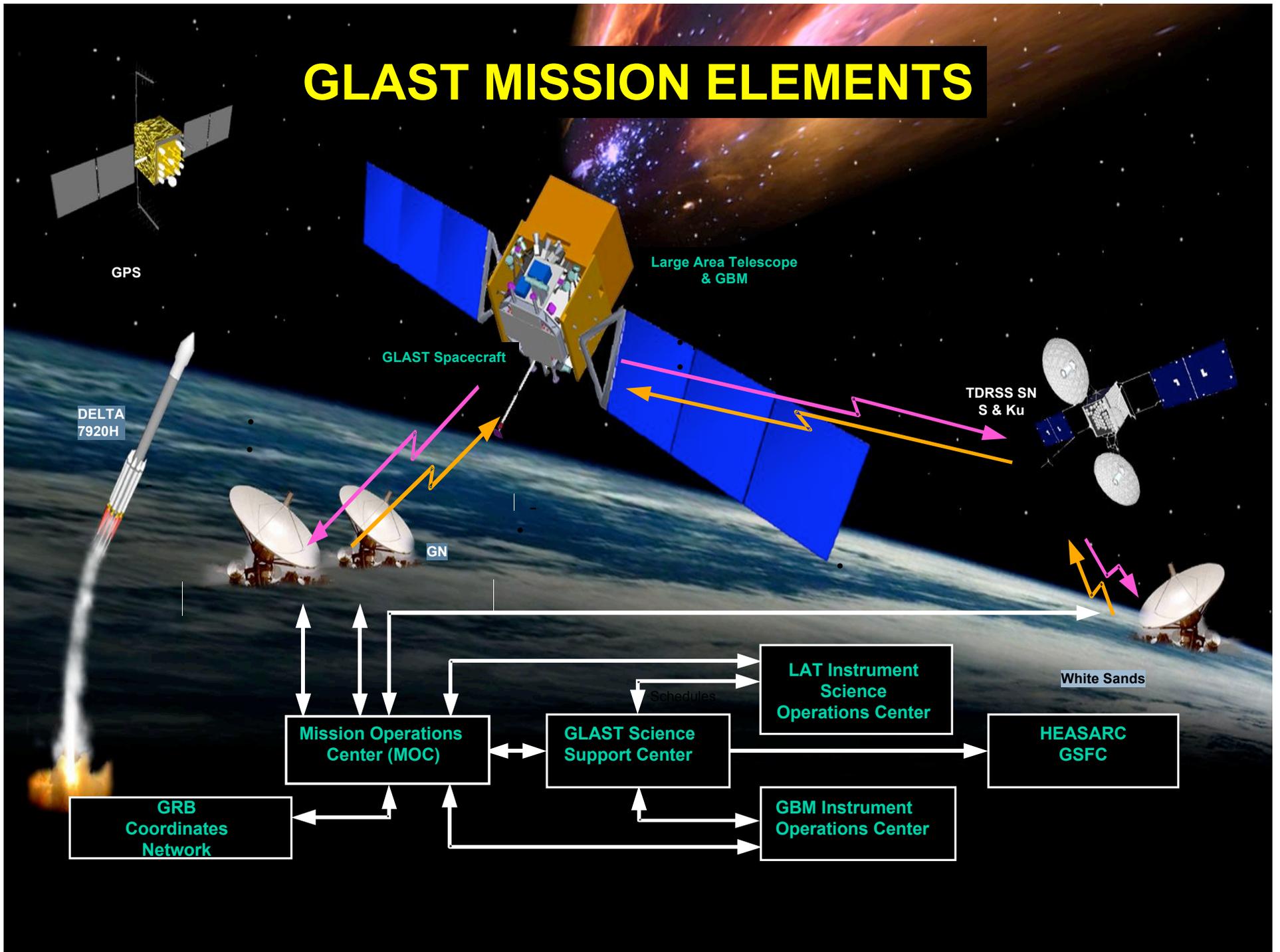




Typical GLAST GRB Timeline



GLAST MISSION ELEMENTS





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)

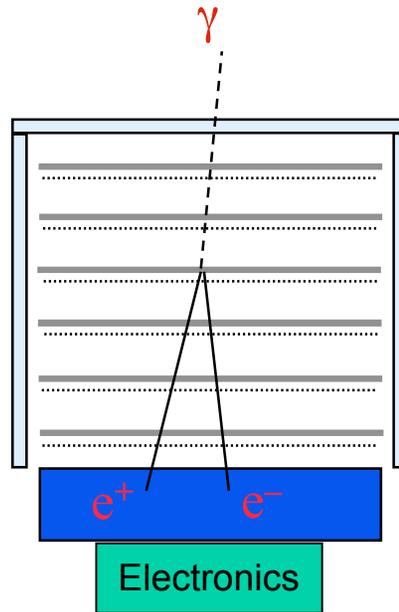
~230 Members (including ~84 Affiliated Scientists, plus 24 Postdocs, and 36 Graduate Students)

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

Managed at Stanford Linear Accelerator Center (SLAC).



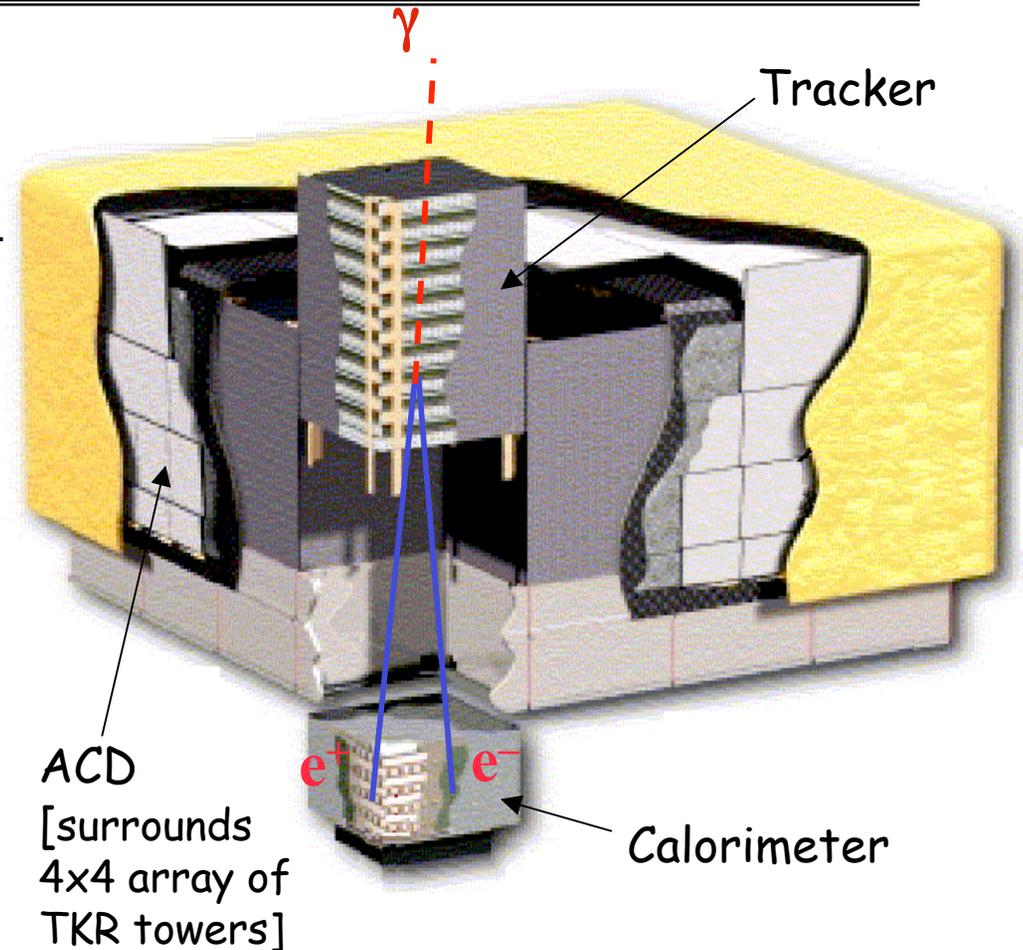
Pair Conversion Telescope





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.

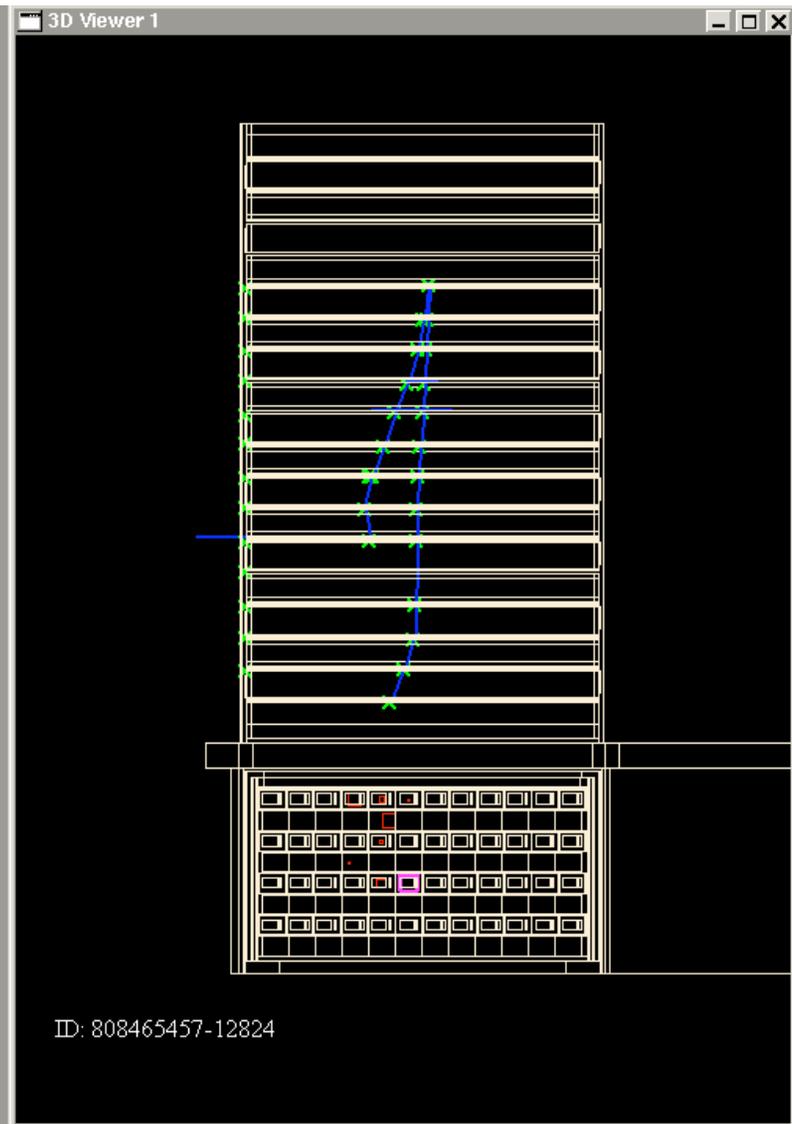
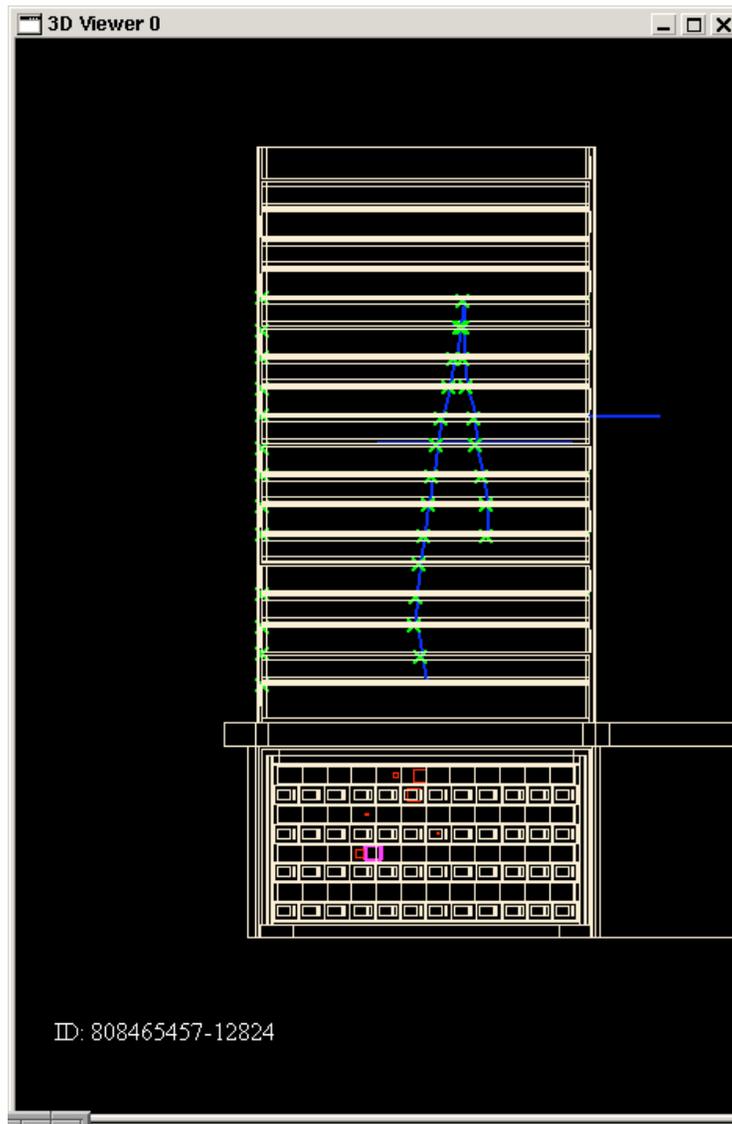


Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.



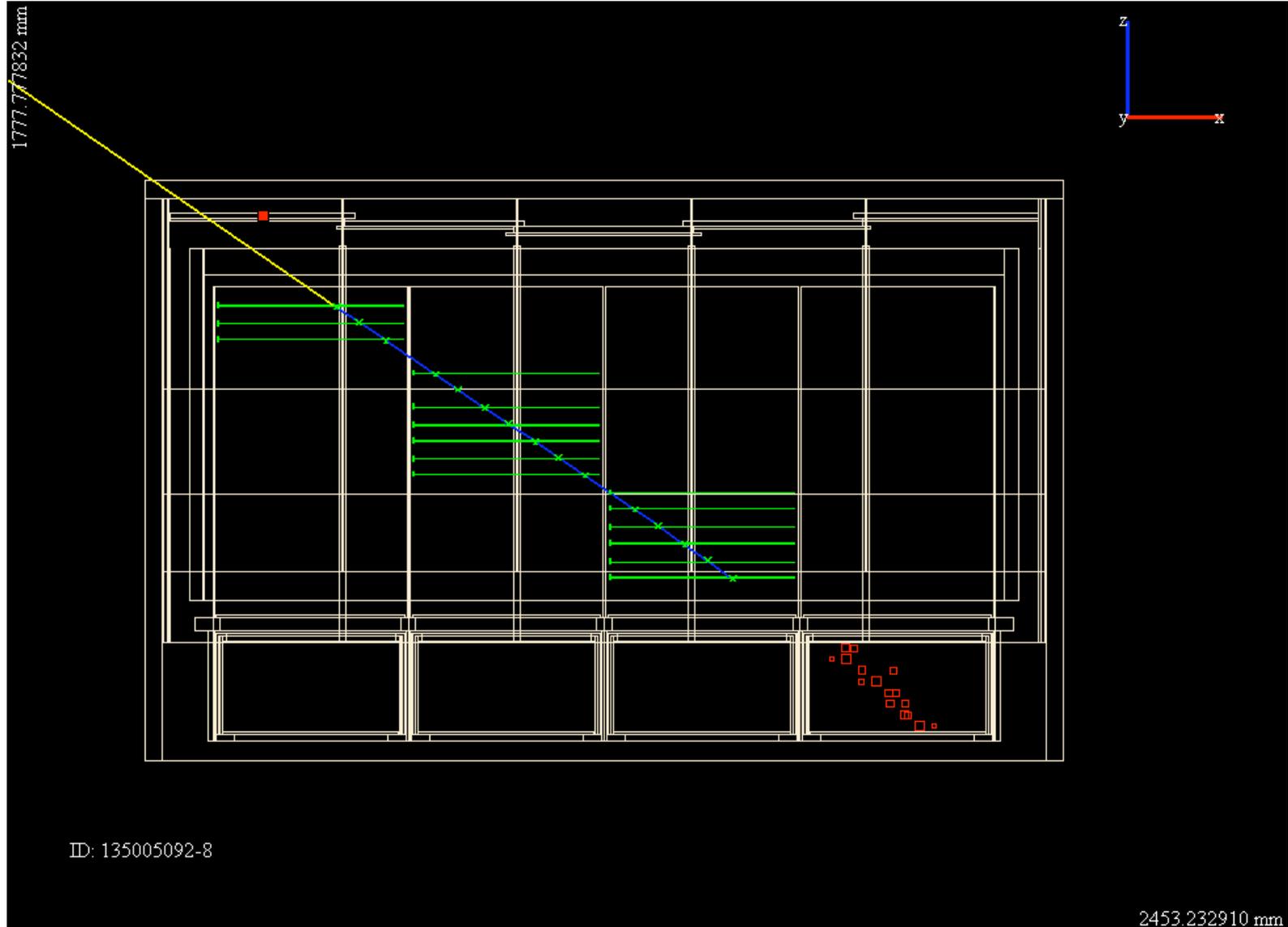


Gamma Candidate in First Integrated Tower!



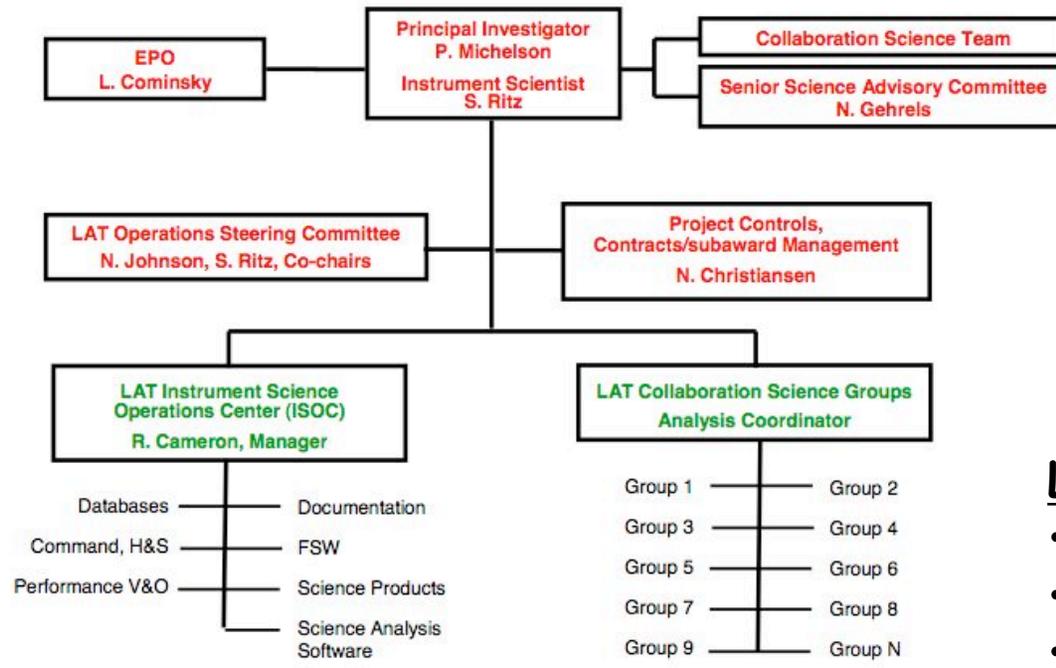


16 Towers with ACD





LAT Organization, Science Groups



see <http://www-glast.stanford.edu/>
and
<http://www-glast.slac.stanford.edu/>

LAT Science Group Coordinators

- Catalog: Grenier, Digel, Ballet
- Diffuse: Porter, Grenier
- Pulsars/SNR: Harding, Romani
- AGN: Tosti, Lott
- UNID: Caraveo, Reimer
- GRB: Omodei, Connaughton
- Solar: Longo, Share
- DM and New Physics: R. Johnson, Conrad
- Calibration and Analysis Methods: Bruel, Latronico

Group Coordinators report to Analysis Coordinator (J. McEnery)
each of these groups identifies MW needs and submits proposals and makes connections through LAT MW Coordinator (D.J. Thompson)

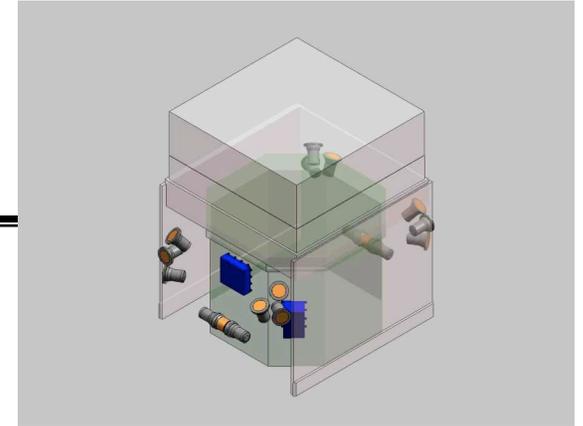


LAT Status

- **After integration at SLAC and environmental testing at NRL, shipped to General Dynamics/Spectrum Astro in September. Now integrated onto observatory.**
- **Beam tests of Calibration Unit (flight spare components) completed at CERN and at GSI.**
- **Pending flight software updates scheduled for bug fixes and to implement onboard science (GRB) algorithms.**



GBM Collaboration



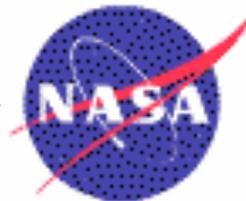
National Space Science & Technology Center



University of Alabama
in Huntsville

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

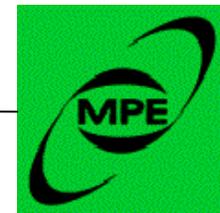
On-board processing, flight software, systems engineering, analysis software, and management



Marshall
Space
Flight
Center

NASA
Marshall Space Flight Center

Charles Meegan (PI)
Gerald Fishman
Chryssa Kouveliotou
Robert Wilson



Max-Planck-Institut für
extraterrestrische Physik

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

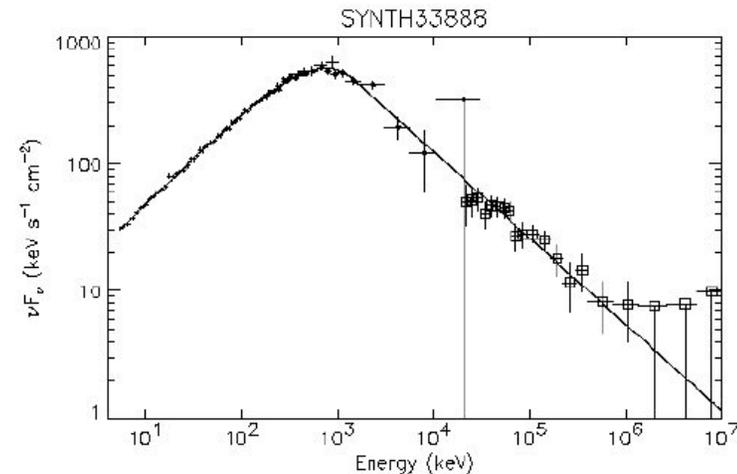
Detectors, power supplies, calibration, and analysis software



GBM

- 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 °) and 1 BGO (30 °)

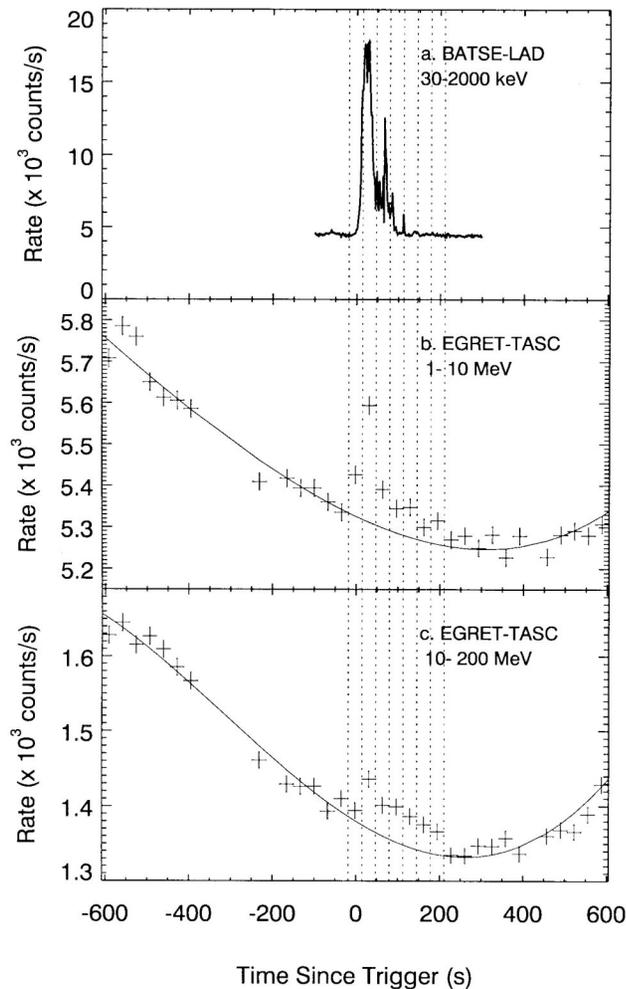


- provides wide sky coverage (>8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);
- provides burst alerts to the ground.



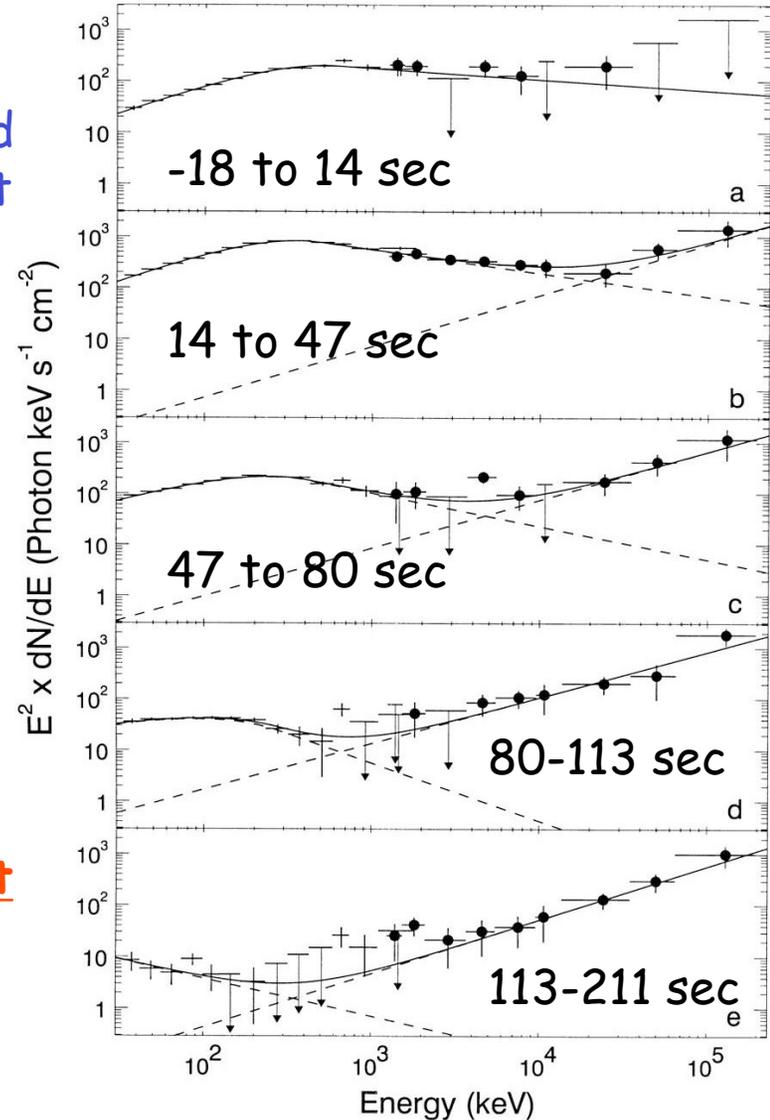
GRB941017

Gonzalez et al., published in Nature



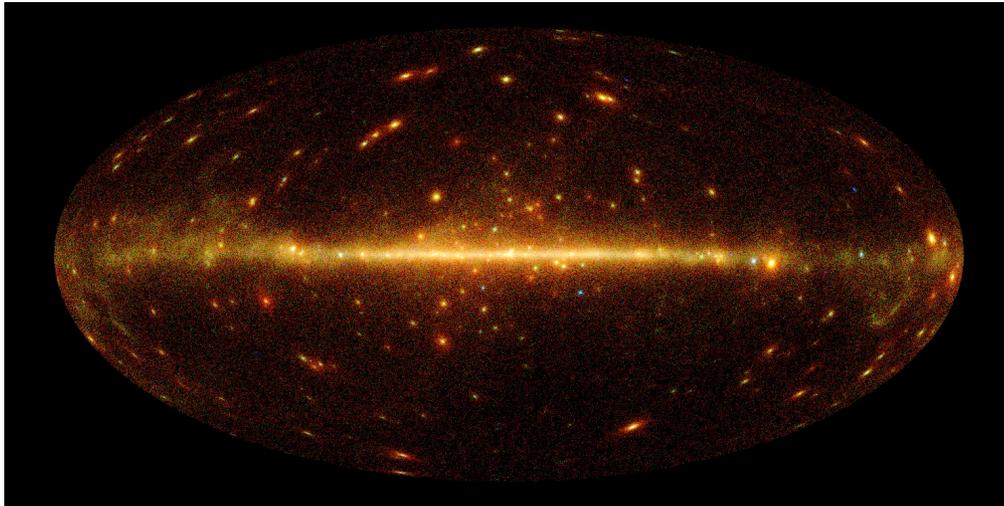
Compare data from EGRET and BATSE: Distinct high-energy component has different time behavior. What is the high-energy break and total luminosity? **Need GLAST data!**

Learn important lessons from the past.





Data Challenges



Data challenges provide excellent testbeds for science analysis software.

Full observation, instrument, and data processing simulation. Team uses data and tools to find the science. “Truth” revealed at the end.

- A progression of data challenges.
 - DC1 in 2004. 1 simulated week all-sky survey simulation.
 - find the sources, including GRBs
 - a few physics surprises
 - DC2 in 2006, completed in June. 55 simulated days all-sky survey.
 - first catalog
 - add source variability (AGN flares, pulsars). lightcurves and spectral studies. correlations with other wavelengths. add GBM. study detection algorithms. benchmark data processing/volumes.

+ Users
Committee
beta test of
the tools in
November



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.**
 - all GBM data released
 - LAT data on flaring sources, transients, and “sources of interest” will be released, with caveats (see following slide)
 - first-year LAT individual photon candidate events initially used for detailed instrument characterization, refinement of the alignment, and key projects (source catalog, diffuse background models, etc.) needed by the community. Individual photon data released at the end of year one. Subsequent photon data released immediately after processing.
 - burst alerts and repoints for bright bursts
 - 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. Data released through the science support center (GSSC).**



Year 1 LAT Data Releases

- **Main purpose: trigger MW observations for analysis of year 1 data**
- **Throughout year 1 and beyond, high-level data releases continuously:**
 - **on any flaring source (flux $> 2 \times 10^{-6} \text{ cm}^{-2}\text{s}^{-1}$, $E > 100 \text{ MeV}$), 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) or upper limits. 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 (best effort) into year 1, to support Cycle 2 proposals, a preliminary LAT source list of high-confidence sources will be released**
 - **position, avg flux, peak flux, spectral index, associated errors**



Preliminary LAT Year1 Monitored Source Release List

http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Monitored_Sources.html

plus 5 more:
 BL LAC
 OJ 287
 0235+163
 0716+714
 1510-089

| Source Type | Source Name | EGRET Name | Average or Min. Flux ($10^{-6} \gamma \text{ cm}^{-2} \text{ s}^{-1}$) | Galactic Latitude | Redshift | TeV Source |
|---|-------------------------|----------------|--|-------------------|----------|------------|
| Blazar | 0208-512 | 3EGJ0210-5055 | 85.5 ± 4.5 | -61.9 | 1.003 | |
| | PKS 0528+134 | 3EGJ0530+1323 | 93.5 ± 3.6 | -11.1 | 2.060 | |
| | 0827+243 | 3EGJ0829+2413 | 24.9 ± 3.9 | 31.7 | 2.046 | |
| | Mrk 421 | 3EGJ1104+3809 | 13.9 ± 1.8 | 65.0 | 0.031 | Yes |
| | W Com 1219+285 | 3EGJ1222+2841 | 11.5 ± 1.8 | 83.5 | 0.102 | |
| | 3C 273 | 3EGJ1229+0210 | 15.4 ± 1.8 | 64.5 | 0.158 | |
| | 3C 279 | 3EGJ1255-0549 | 74.2 ± 2.8 | 57.0 | 0.538 | |
| | 1406-076 | 3EGJ1409-0745 | 27.4 ± 2.8 | 50.3 | 1.494 | |
| | H 1426+428 | NA | | 64.9 | 0.129 | Yes |
| | PKS 1622-297 | 3EGJ1625-2955 | 47.4 ± 3.7 | 13.4 | 0.815 | |
| | 1633+383 | 3EGJ1635+3813 | 58.4 ± 5.2 | 42.3 | 1.814 | |
| | Mrk 501 | NA | | 38.9 | 0.033 | Yes |
| | 1730-130 NRAO 530 | 3EGJ1733-1313 | 36.1 ± 3.4 | 10.6 | 0.902 | |
| | 1ES 1959+650 | NA | | 17.7 | 0.048 | Yes |
| | PKS 2155-304 | 3EG2158-3023 | 13.2 ± 3.2 | -52.2 | 0.116 | Yes |
| 3C 454.3 | 3EGJ2254+1601 | 53.7 ± 4.0 | -38.3 | 0.859 | | |
| 1ES 2344+514 | NA | | -9.9 | 0.044 | Yes | |
| HMXB | LSI+61 303 2CG135+01 | 3EGJ0241+6103 | 69.3 ± 6.1 | 1.0 | | Yes |
| any source (except Crab, Vela, and Geminga pulsars) | | | monitor if flux exceeds 2×10^{-6} $\text{cm}^{-2} \text{ s}^{-1}$ then reported down to $2 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1}$ | | | |



GI Opportunities

- Annual cycles; typical range \$50-\$100k/investigation
- Cycle 1:
 - expect to fund ~40 investigations for
 - analyses of released data
 - GLAST-related MW observations
 - NRAO MOU signed! Provides joint observing time through the regular GLAST GI program. See GSSC site.
 - 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, as well as ensured sky-survey periods (expect <20% time on pointed observations)
- Tentative Schedule for Cycle 1 (2007)
 - NRA in ROSES released, proposals due in September, Cycle 1 funding starts in 2008. See <http://glast.gsfc.nasa.gov/ssc/>.



Cycle 1

- **NRA in ROSES released**
 - See <http://glast.gsfc.nasa.gov/ssc/>
- **Notice of intent (optional):**
 - due 13 July
 - <http://glast.gsfc.nasa.gov/ssc/proposals/cycle1/noi>
- **Proposals due 7 September**
- **Two-stage proposal process: first science evaluation, then budget**
 - first stage proposal must contain a stated budget maximum
- **Two proposal classes:**
 - (1) Regular proposals with research plans that can be completed in one year (anticipate funding ~40)
 - (2) Large proposals whose research plans are more expansive and may take up to three years to complete (anticipate funding ~4)
 - Page limit for the central Science-Technical-Management section of Phase 1 proposals is 4 pages for Regular proposals and 6 pages for Large proposals.



Workshops

- **promote the GI program, describe GLAST capabilities, data plan, how to propose**
- **sessions on potential science studies with GLAST. Help connect people who have common science interests.**
- **Next one in D.C. area in August.**
- **Previous ones in the Washington, DC area (at GSFC), Chicago area (at ANL), and Southern CA region (at UCLA).**



GLAST Fellows Program Plan

- **Similar to other observatory Fellows programs**
- **Tentative schedule:**
 - **first call for proposals Fall 2007, selections announced early 2008, start in September 2008**
- **Three new Fellows selected each year, for three-year periods**



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/>

and help desk

<http://glast.gsfc.nasa.gov/ssc/help/>



GLAST Users Committee (GUC)

- **Advises GLAST Project and NASA HQ on NASA-funded Guest Investigator Program and Policies**
- **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)**
- **Matthew Baring**
- **Roger Brissenden**
- **Wim Hermsen**
- **Buell Januzzi**
- **Don Kniffen**
- **Henric Krawczynski**
- **Reshmi Mukherjee**
- **Luigi Piro**
- **Jim Ulvestad**
- **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/>



SWG Activities

- **Membership includes international representatives from LAT and GBM, along with four Interdisciplinary Scientists (IDS)**
 - **Chuck Dermer, Brenda Dingus, Martin Pohl, Steve Thorsett**
- **SWG scientific review of the expected performance (LAT, GBM, Observatory) relative to the Science Requirements. See**
<http://glast.gsfc.nasa.gov/science/swg/feb07/>



MW Info and Coordination

- **Multiwavelength observations are key to many science topics for GLAST.**
 - **GLAST welcomes collaborative efforts from observers at all wavelengths**
 - **For campaigners' information and coordination, see <http://glast.gsfc.nasa.gov/science/multi>**
 - **To be added to the Gamma Ray Multiwavelength Information mailing list, contact Dave Thompson, djt@egret.gsfc.nasa.gov**
- **GI Program will support correlative observations and analysis**
 - **See <http://glast.gsfc.nasa.gov/ssc/proposals>**



Summary

- **All the parts of GLAST are coming together:**
 - **the instruments are beautiful!**
 - **observatory integration is nearing completion; environmental testing about to start**
- **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/>
- **Looking forward to launch at end of this year.**
- **Guest Investigator Program starting soon, with many opportunities for GIs. Join the fun!**

Started periodic GLAST news email. Sign up by sending email to majordomo@athena.gsfc.nasa.gov
(you can leave the subject line blank)

In the body of the message, please write the following:

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