GLAST

Progress and Plans as of March 2003

Jonathan Ormes, Project Scientist,

on behalf of the GLAST team

and the Large Area Telescope Collaboration

Presented at the High Energy Astrophysics Divisional Meeting
Mt. Tremblant, March 23-25, 2330

GLAST is an International Mission

NASA - DoE Partnership on LAT

LAT is being built by an international team

- **Si Tracker:** Stanford, UCSC, Japan, Italy
- **CsI Calorimeter:** NRL, France, Sweden
- **Anticoincidence:** GSFC
- **Data Acquisition System:** Stanford, NRL

GBM is being built by US and Germany

- **Detectors:** MPE

Sweden

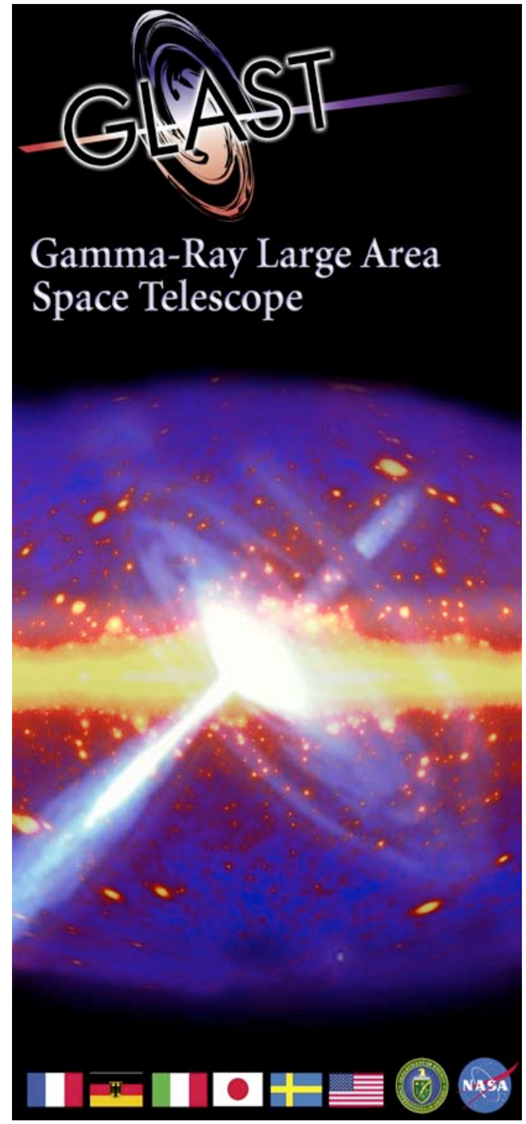
Italy

France

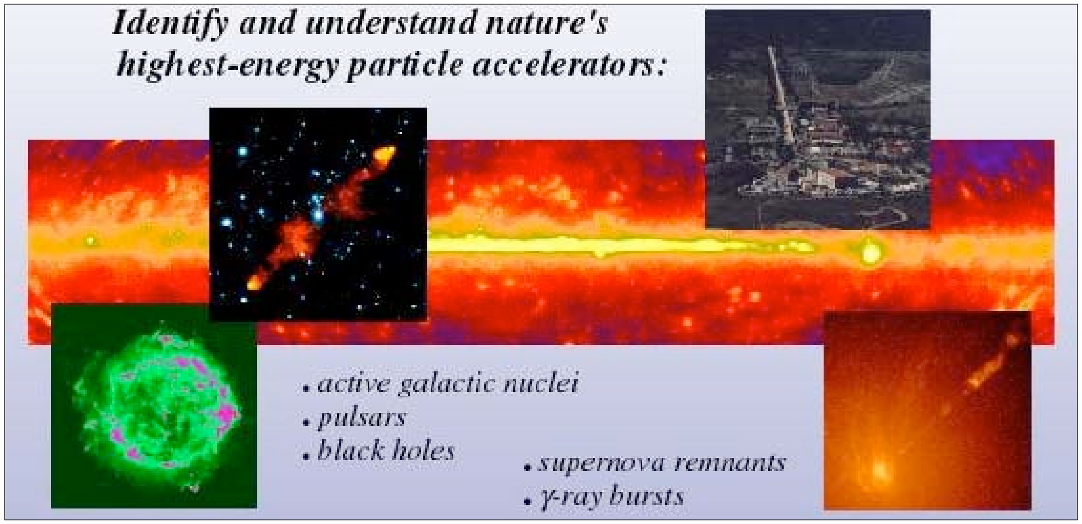
Germany

USA

Japan



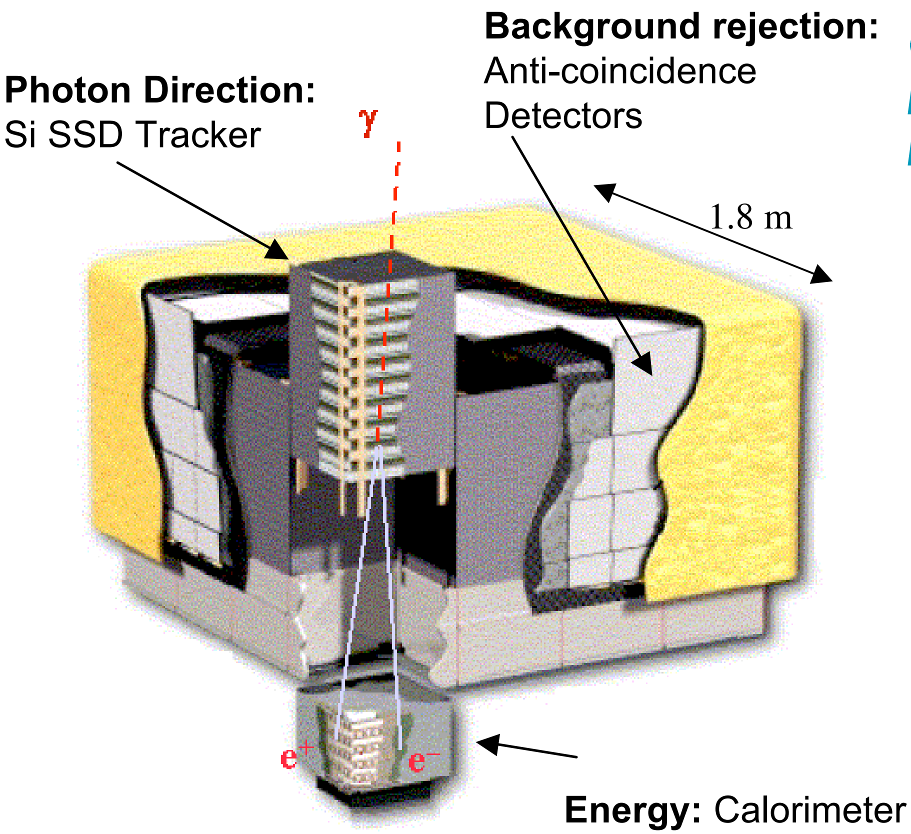
Mission Objectives



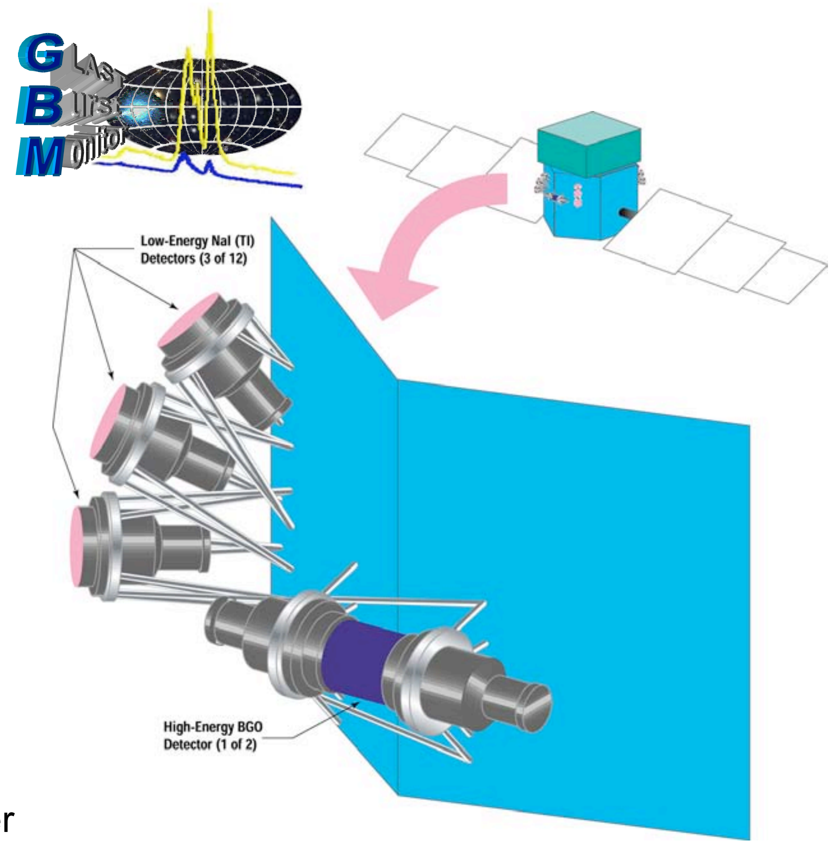
- Understand the mechanisms of particle acceleration in astrophysical environments such as active galactic nuclei, pulsars and supernova remnants
- Determine the high energy behavior of gamma-ray bursts and other transients
- Resolve and identify point sources with known objects
- Probe dark matter and the extra-galactic background light in the early universe

GLAST Instruments

Large Area Telescope (LAT)
PI: Peter Michelson
Stanford University



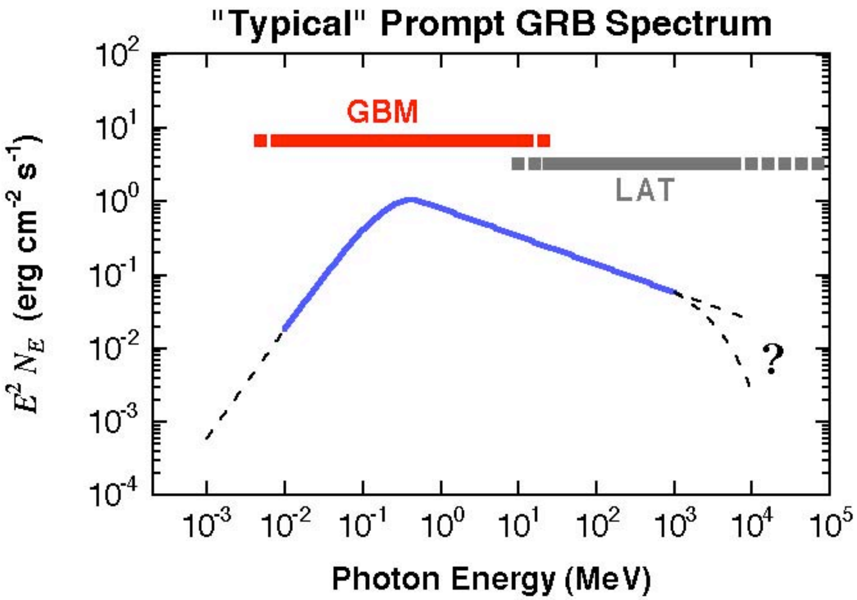
GLAST Burst Monitor (GBM)
PI: Charles Meegan
Marshall Space Flight Center

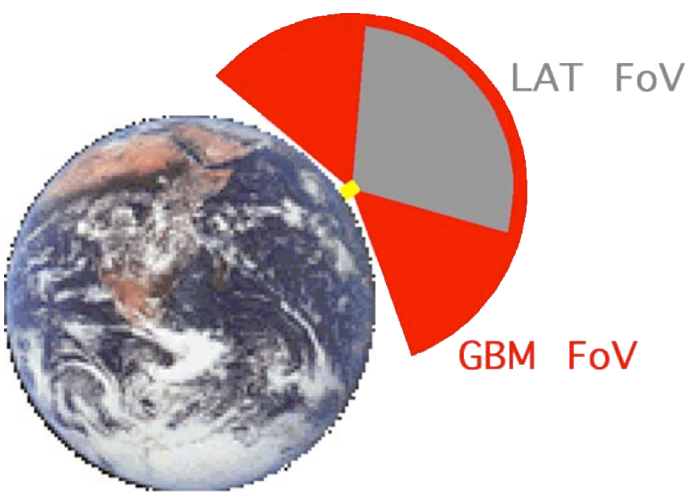


GLAST Burst Monitoring

- **LAT and GBM work synergistically to make new GRB observations**

- **GBM provides low-energy context measurements with high time resolution**
  - Broad-band spectral sensitivity
  - Contemporaneous low-energy & high-energy measurements
  - Continuity with current GRB knowledge-base (GRO-BATSE)



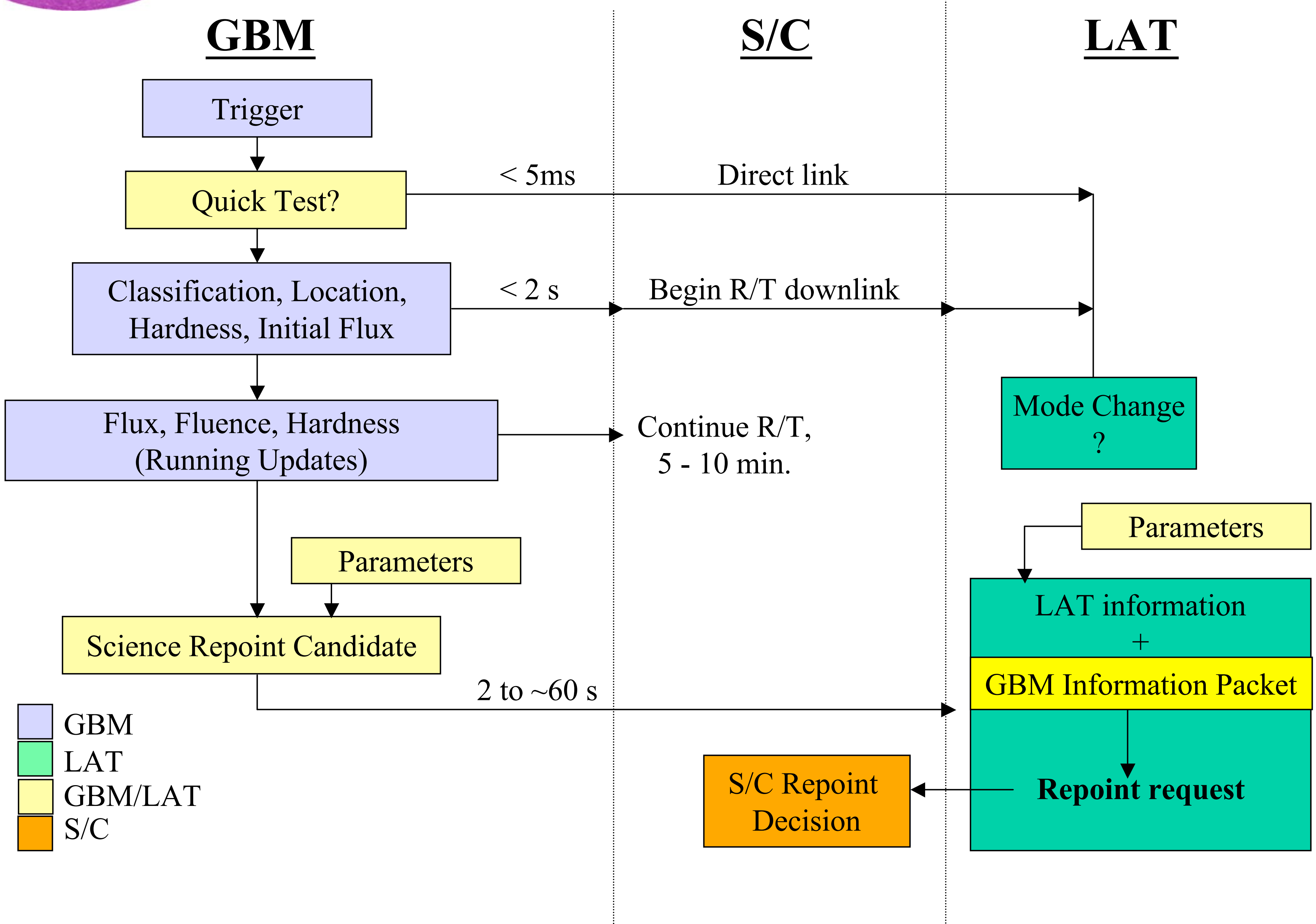


- **Provides rapid GRB timing & location triggers w/FoV > LAT FoV**
  - Improved sensitivity and response time for weak bursts
  - Follow particularly interesting bursts for afterglow observations
  - Provide rapid locations for ground/space follow-up

GBM Capabilities

	BATSE	GBM - Requirement	GBM - Current Design
Energy Range	**25 keV – 10 MeV**	**<10 keV – >25 MeV**	**6 keV - 30 MeV**
Field of View	**All sky not occulted by Earth**	**>8 sr**	**8.7 sr**
Energy Resolution	**<10%**	**<10% (0.1-1.0 MeV, 1σ on-axis)**	**7% (100 keV) 5% (1 MeV)**
Deadtime		**< 10 μs/event**	**2.5 μs/event**
Burst Sensitivity - Ground (5σ, 50-300 keV)	**0.2 cm^{-2} s^{-1}**	**<0.5 cm^{-2} s^{-1}**	**0.45 cm^{-2} s^{-1}**
Burst Sensitivity - On-board (5σ, 50-300 keV, 50% efficiency)		**<1.0 cm^{-2} s^{-1}**	**0.78 cm^{-2} s^{-1}**
GRB Alert Location	**~25°**	**-**	**<15°**
GRB Final Location	**1.7°**	**-**	**<1.5°**
GRB Notification Time to Spacecraft		**<2s**	**2s (arbitrarily selectable, trade-off between speed & accuracy)**

Burst Alerts



Mission Repointing Plan for Bursts

<u>Summary of plan</u>

- Detection a sufficiently significant burst
- Interrupt the scanning operation
- Remain pointed at the burst region for 5 hours (TBR).

There are two cases:

1. <u>The burst occurs within the LAT FOV.</u>

   For moderately bright bursts.
   Set threshold to occur approximately once per week.

2. <u>The burst occurs outside the LAT FOV.</u>

   For exceptionally bright bursts.
   Set threshold to occur a few times per year.

Reevaluate strategy based on what has been learned about delayed high-energy emissions.

the brightness criterion

the stare time

GLAST

LAT Instrument

Tracker: 18 xy planes

Si-strips: fine pitch: 228 μm, high efficiency

12 x 0.03 X_0 front-end → reduce multiple scattering

4 x 0.18 X_0 back-end → increase sensitivity > 1 GeV

2 blank planes to locate calorimeter entry location

Calorimeter: 1536 CsI(Tl) crystals in 8 layers

CsI: wide energy range 0.1-100 GeV

hodoscopic → cosmic-ray rejection

→ shower leakage correction

8.5 X_0 → shower max contained < 100 GeV

Anti-Coincidence Detector

segmented [89 tiles] plastic scintillator

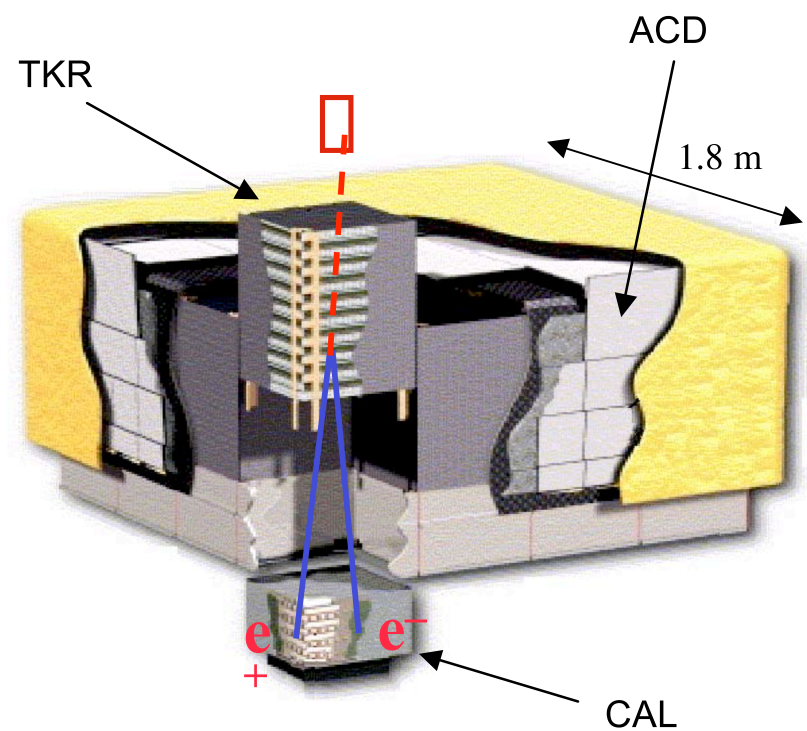
→ minimize self-veto

> 0.9997 efficiency & redundant readout

16 [4x4] towers → modularity

height/width = 0.4

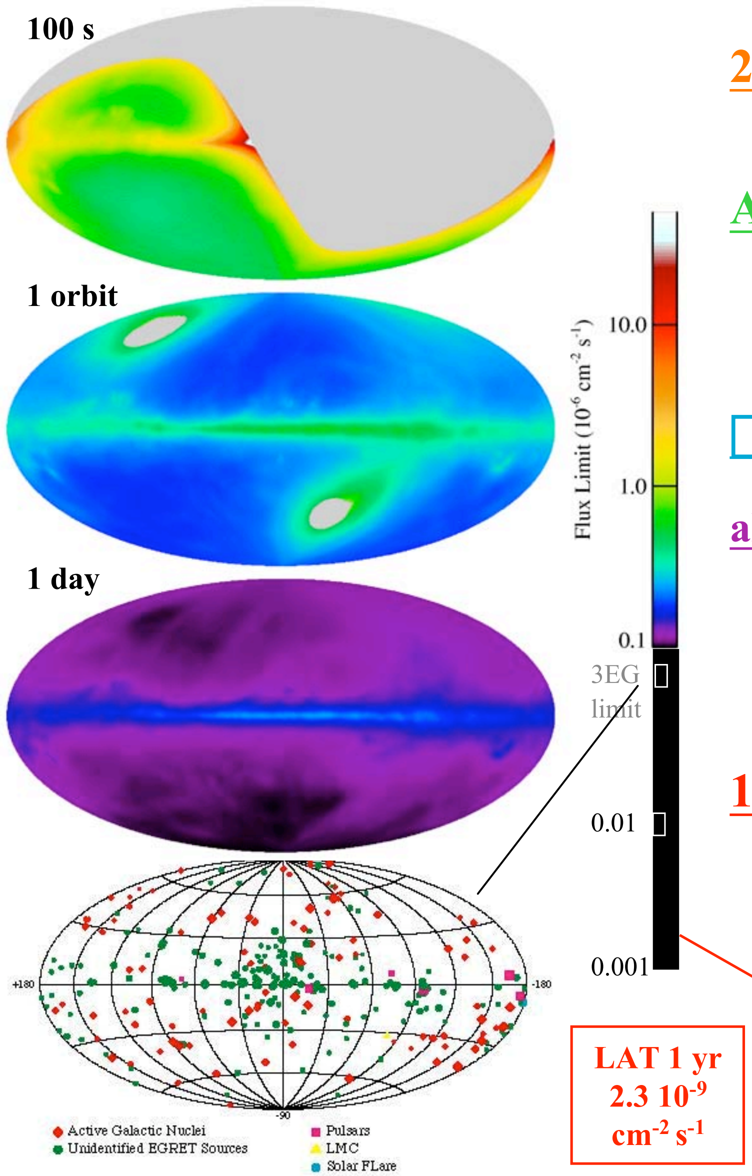
→ large field-of-view



LAT Capabilities

	EGRET	LAT - Requirement	LAT - Current Design
Energy Range	**20 MeV – 30 GeV**	**20 MeV – 300 GeV**	**20 MeV - 300 GeV**
Energy Resolution	**10 %**	**<10%, 0.1–100 GeV (1σ, on-axis)**	**~9%, 0.1–100 GeV**
Effective Area	**1500 cm^2**	**>8000 cm^2 (maximum value, 1-10GeV)**	**10,000 cm^2 at 10 GeV**
Point Source Sensitivity (5σ, >100 MeV)	**~1 $\times 10^{-7}$ cm^{-2} s^{-s}**	**<6 $\times 10^{-9}$ cm^{-2} s^{-2} (at high gal. latitude for 1-year sky survy, for photon index of -2)**	**3 $\times 10^{-9}$ cm^{-2} s^{-2}**
Angular Resolution	**5.8° (100 MeV)**	**<3.5° (100 MeV) <0.15° (>10 GeV)**	**3.4° (100 MeV) 0.086° (>10 GeV)**
Source Location Determination	**15 arcmin**	**<0.5 arcmin (1σ radius, flux 10^{-7} cm^{-2} s^{-1} at 100 MeV, high gal latitude)**	**0.4 arcmin**
Field-of-view	**0.5 sr**	**>2 sr**	**2.4 sr**
Timing Accuracy	**100 μs**	**<10 μs**	**TBD**
Deadtime	**100 ms/event**	**<100 μs/event**	**TBD**
GRB Location Accuracy On-Board		**<10 arcmin**	**5 arcmin**
GRB Notification Time to Spacecraft		**<5 s**	**TBD**

LAT Sensitivity



<u>200 γ bursts per year</u>

- prompt emission sampled to > 20 μs

<u>AGN flares > 2 month</u>

- time profile + ΔE/E ⇒ physics of jets and acceleration

<u>γ bursts delayed emission</u>

<u>all 3EG sources + 80 new in 2 days</u>

- periodicity searches (pulsars & X-ray binaries)
- pulsar beam & emission vs. luminosity, age, B

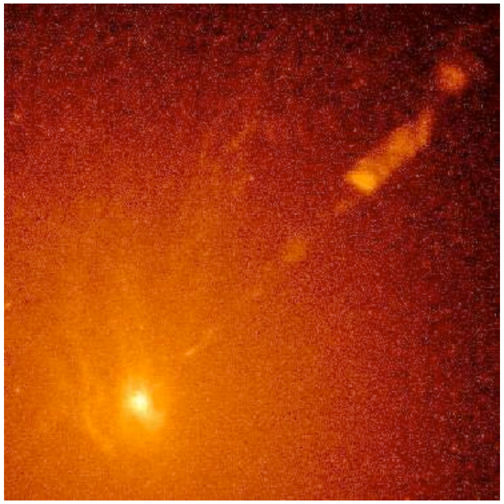
<u>10^4 sources in 1-yr survey</u>

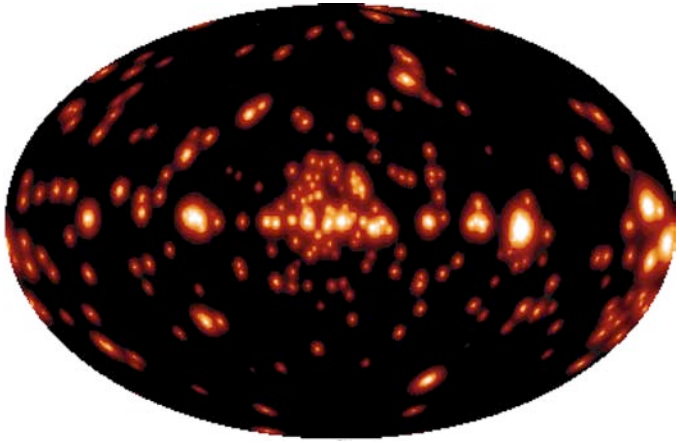
- AGN: logN-logS, duty cycle, emission vs. type, redshift, aspect angle
- extragalactic background light (γ + IR-opt)
- new γ sources (μQSO,external galaxies,clusters)

GLAST

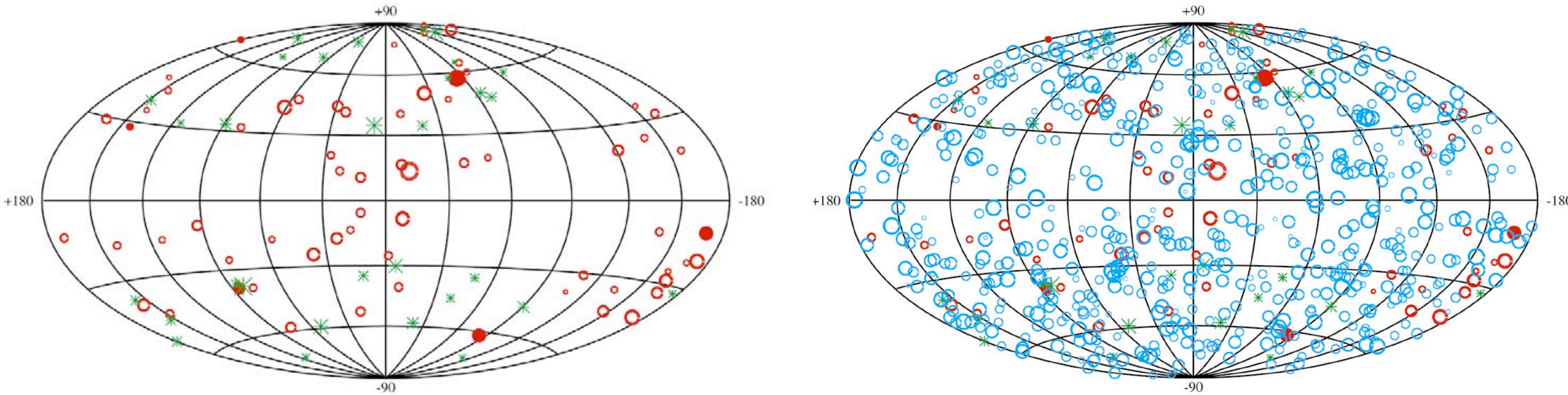
Science Topics

- Active Galactic Nuclei
- Isotropic Diffuse Background Radiation
- Cosmic Ray Production:
  - Molecular Clouds
  - Supernova Remnants
  - Normal Galaxies
- Endpoints of Stellar Evolution
  - Neutron Stars/Pulsars
  - Black Holes
- Unidentified Gamma-ray Sources
- Dark Matter
- Solar Physics
- Gamma-Ray Bursts





From EGRET to GLAST



○ = EGRET blazars seen sometimes

● = EGRET blazars seen always

✳ = EGRET unidentified high-latitude variables

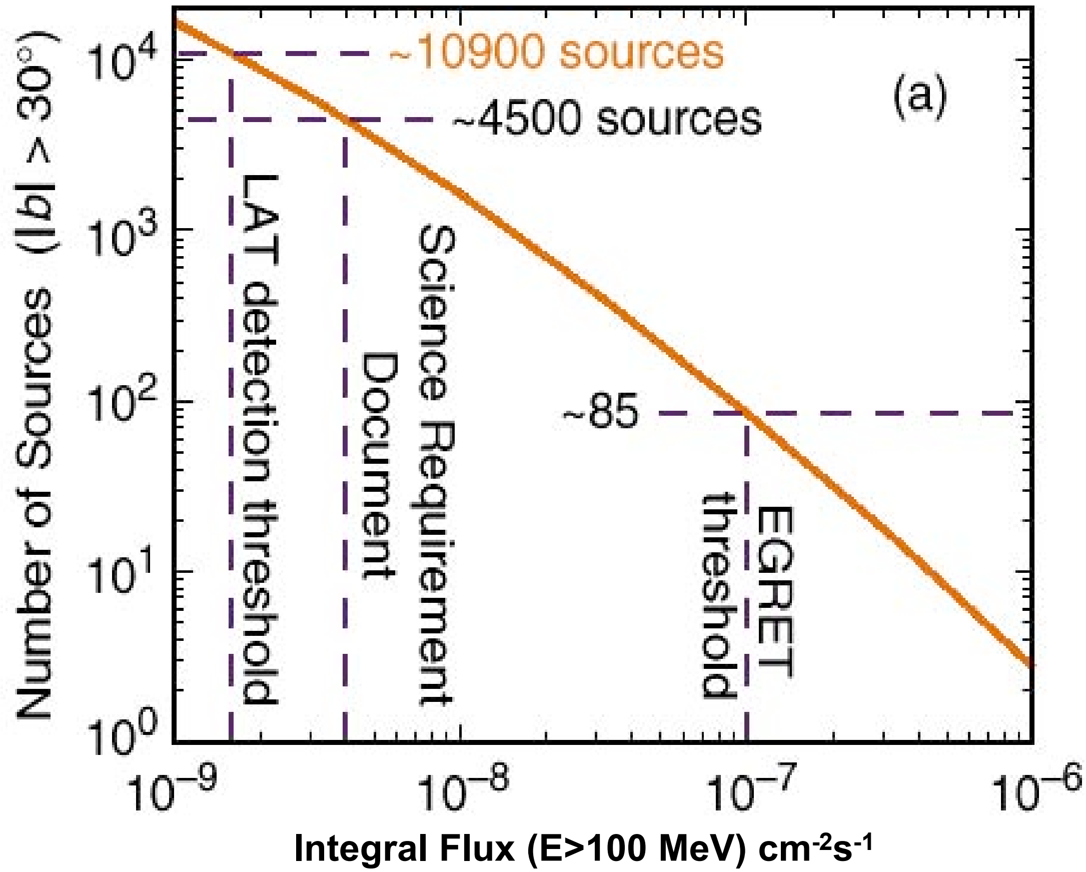
○ = Simulated GLAST 20□ AGN detections

AGN: What GLAST will do

- EGRET detected ~ 70-90 AGN. Extrapolating, GLAST should expect to see dramatically more – many thousands.

- The GLAST energy range is broad, overlapping those of ground-based experiments for good multiwavelength coverage.

- The wide field of view will allow GLAST to monitor AGN for time variability on many scales.

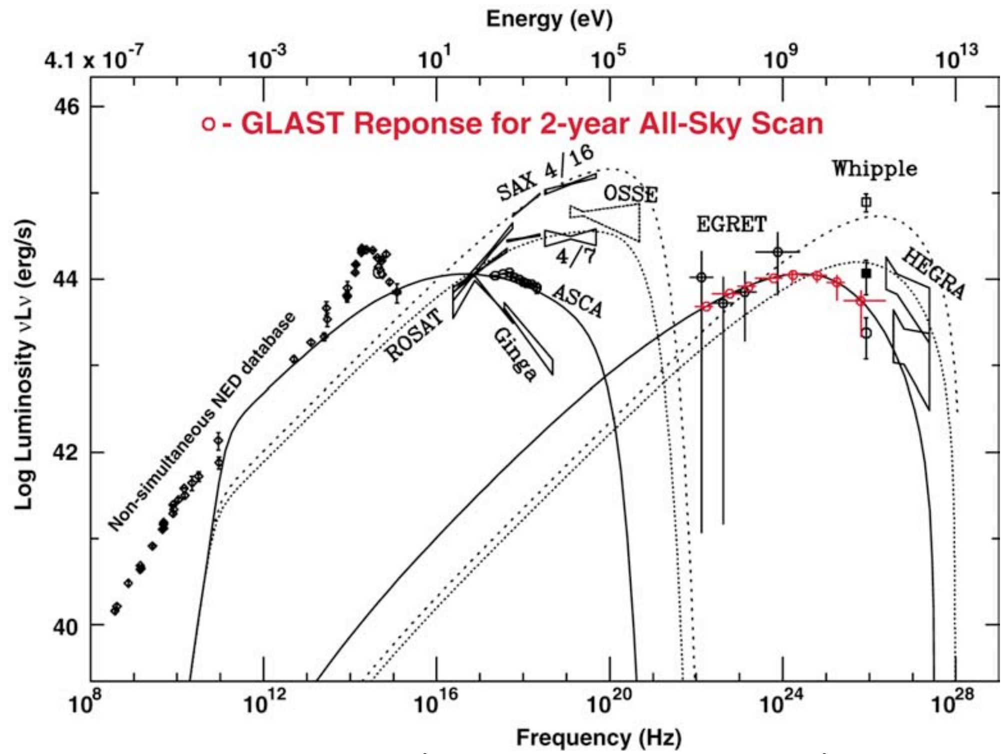


Joining the unique capabilities of GLAST with other detectors will provide a powerful tool.

Blazar Spectra

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

Mrk 501



synchrotron

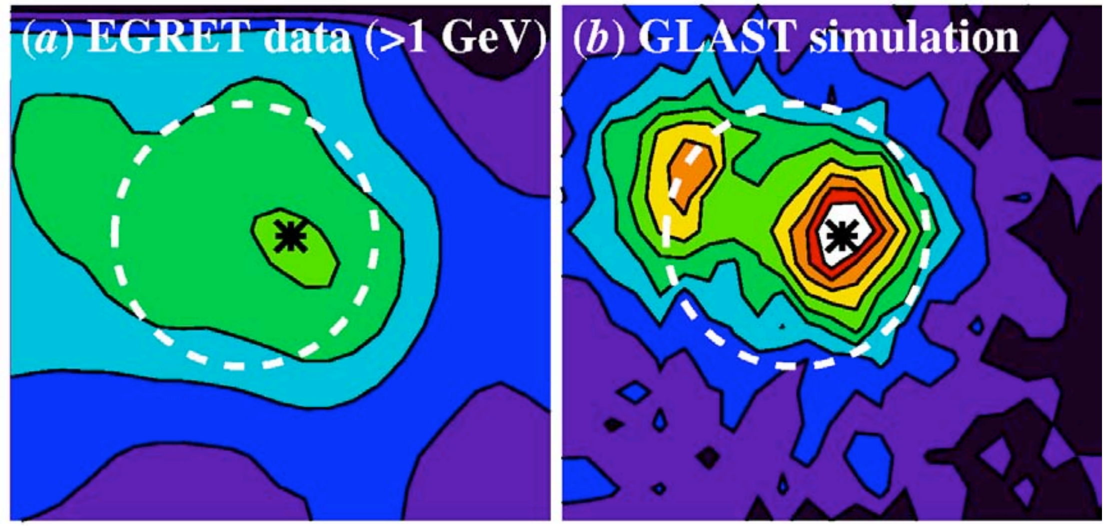
inverse compton

SNR: Spatial Resolution by GLAST

• For SNR candidates, the LAT sensitivity and resolution will allow mapping to separate extended emission from the SNR from possible pulsar components.

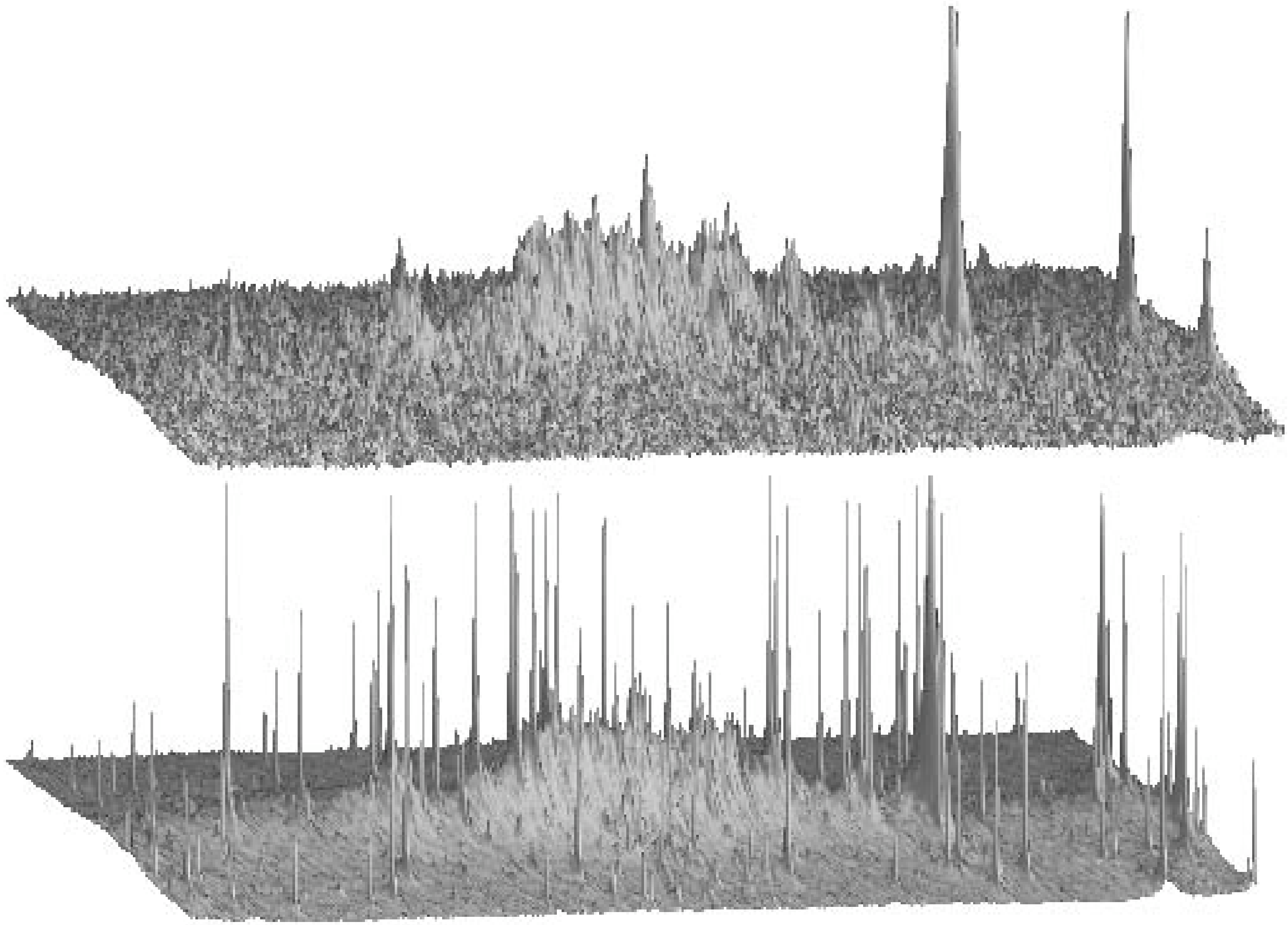
• Energy spectra for the two emission components may also differ.

• Resolved images will allow observations at other wavelengths to concentrate on promising directions.



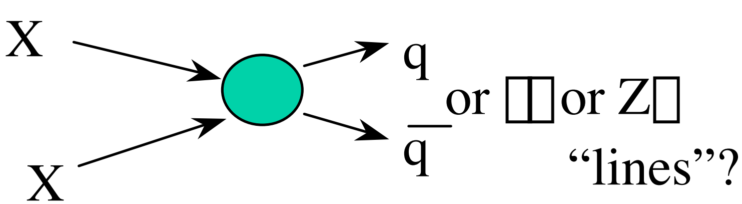
(*a*) Observed (EGRET) and (*b*) simulated LAT (1-yr sky survey) intensity in the vicinity of **_-Cygni** for energies >1 GeV. The coordinates and scale are the same as in the images of _-Cygni in the box at left. The dashed circle indicates the radio position of the shell and the asterisk the pulsar candidate proposed by Brazier et al. (1996).

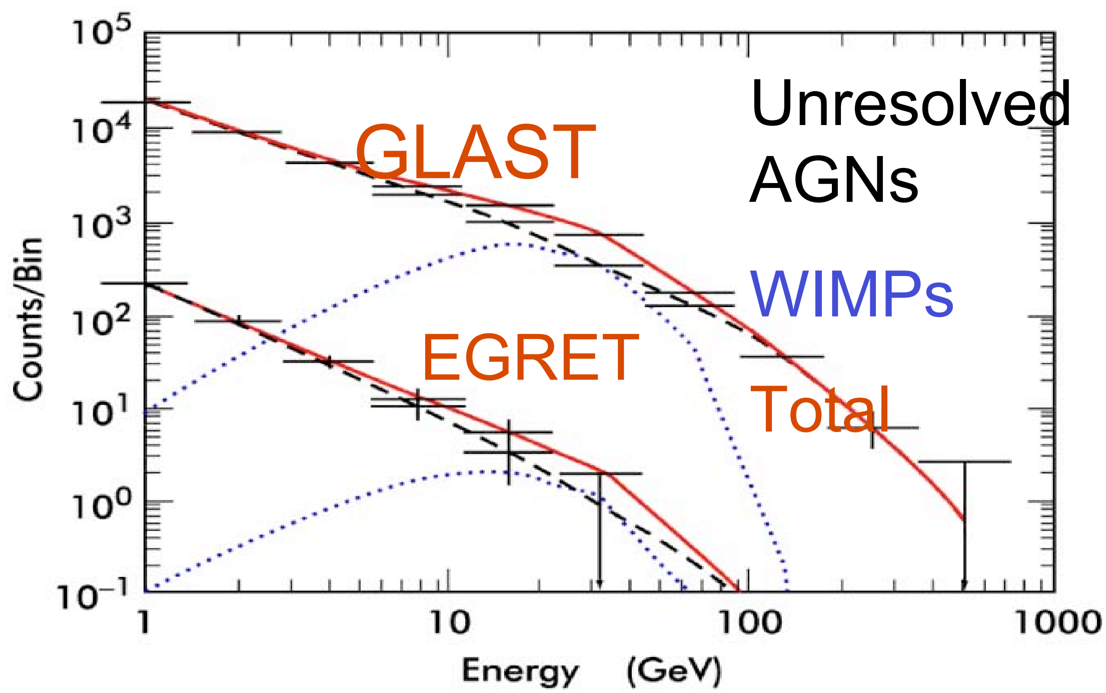
EGRET to GLAST: galactic diffuse gamma rays



Searching for dark matter

- The lightest super-symmetric 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





Mission Requirements and Observing Plan

- Spacecraft
  - Pointing knowledge < 10 arcseconds (1 □)
  - Observatory is designed to "point anywhere, anytime"
    - Operate without pointing at the Earth
    - Reorient quickly and autonomously to follow a transient
  - 3 normal operational modes
    - Scan (baseline)
    - Inertial pointing
    - Scan pointing - takes advantage of the wide field of view to optimize time on sky
- Mission Lifetime 5 years, Goal 10 years
  - Observatory checkout 30-60 days
  - First year is scanning to make all sky survey
    - Planned observations subject to interruption for extraordinary transients
  - Second year and beyond - operational mode driven by competitive proposals

GLAST Project Master Schedule

- Instrument preliminary Design Reviews completed
- Spacecraft contractor selected: Spectrum-Astro
  - S/C PDR March 2003
  - S/C CDR fall 2003
- Critical Design Reviews for instruments will be April or May this year
- Instrument deliveries in 2005
  - GBM spring
  - LAT summer
- Launch in 2006
  - September (“God willin’ and the creek don’t rise.”)

Guest Investigator Program

- GI program starts during the survey
  - 10-15 GIs
- Will grow to ~100 Guest Investigations funded by NASA each year.
- GLAST Fellows program

- Continue Interdisciplinary Scientist (IDS) Program

  C. Dermer (NRL) - non-thermal universe

  B. Dingus (Wisconsin) - transients

  M. Pohl (Ruhr U.) - diffuse galactic

  S. Thorsett (UCSC) - pulsars

- Program of Education and Public Outreach continues throughout the mission

Transient policy

- The GLAST instrument teams have the duty to release data on transient gamma ray sources to the community as soon as practical. The decisions on which data are to be released will be based on advice from scientists analyzing the data and an evaluation of the scientific interest that the data might generate. They will follow the general guidelines suggested below:
- 1) Gamma-ray bursts: All data on gamma-ray bursts that trigger either the LAT or GBM will be released. The prompt data release will include direction, fluence estimate and other key information about the burst immediately on discovery. Individual photon data and technical information for their analysis will be released as soon as practical.
- 2) Blazars and some other sources of high interest: 10-20 pre-selected sources from the 3rd EGRET catalog will be monitored continuously and the fluxes and spectral characteristics will be posted on a publicly accessible web site. Another 10-20 scientifically interesting sources will be added to this list during the survey. The list will include some known or newly discovered AGN selected to be of special interest by the TeV and other communities as well as galactic sources of special interest discovered during the survey.
- 3) New transients: The community will be notified when a newly discovered source goes above an adjustable flux level of about (2-5) x 10^{-6} photons (> 100 MeV) per cm^2 s for the first time; the flux level is to be adjusted to set the release rate to about 1-2 per week. A source exhibiting unusual behavior that is detectable on sub-day timescales, such as a spectral state change or a large flux derivative while the source is at elevated flux levels, will also trigger an alert to the community.

Multi-wavelength campaigns

- Science requires broad band (radio to gamma-rays) study of these celestial sources. Therefore, following the survey, the observing program will be determined entirely by the astronomical and high energy physics communities based on proposals submitted.
    - LAT and GBM team members can compete, but cannot win additional funding.
    - Non-US investigators may apply
    - Selection is based on peer reviewed proposals.

  – The community will interface to the GLAST data through the GLAST Science Support Center.
    - SSC mirror sites in Italy (LAT and GBM may have others)

GLAST

Gamma-ray science requires multi-wavelength approach

In the MeV range and above, sources are non-thermal
$\Rightarrow$ produced by interactions of energetic particles

- Nature rarely produces mono-energetic particle beams. Broad range of particle energies leads to a broad range of photon energies.
  - Example: π^o production
- Charged particles rarely interact by only one process. Different processes radiate in different energy bands.
  - Example: synchrotron-Compton processes
- High-energy particles, as they lose energy, can radiate in lower-energy bands.
  - Contrast: non-thermal X-ray source can have high-energy cutoff

Due to variability on short time scales, AGN require <u>simultaneous</u> multiwavelength observations for maximum scientific return.

For other science, the time scale for variability is long (e.g. SNR, plereons); therefore simultaneity is not critical for multiwavelength observations.

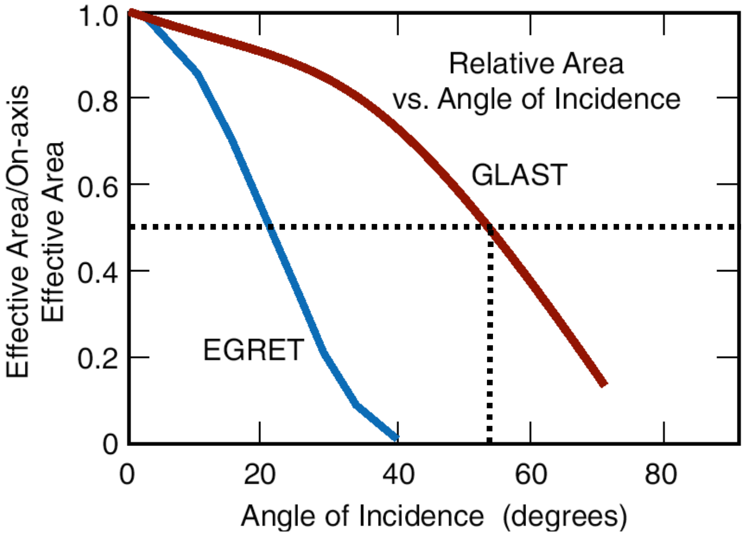
For transients or other variable unidentified gamma-ray sources, having simultaneous observations may be the <u>only</u> viable means of positive identification.

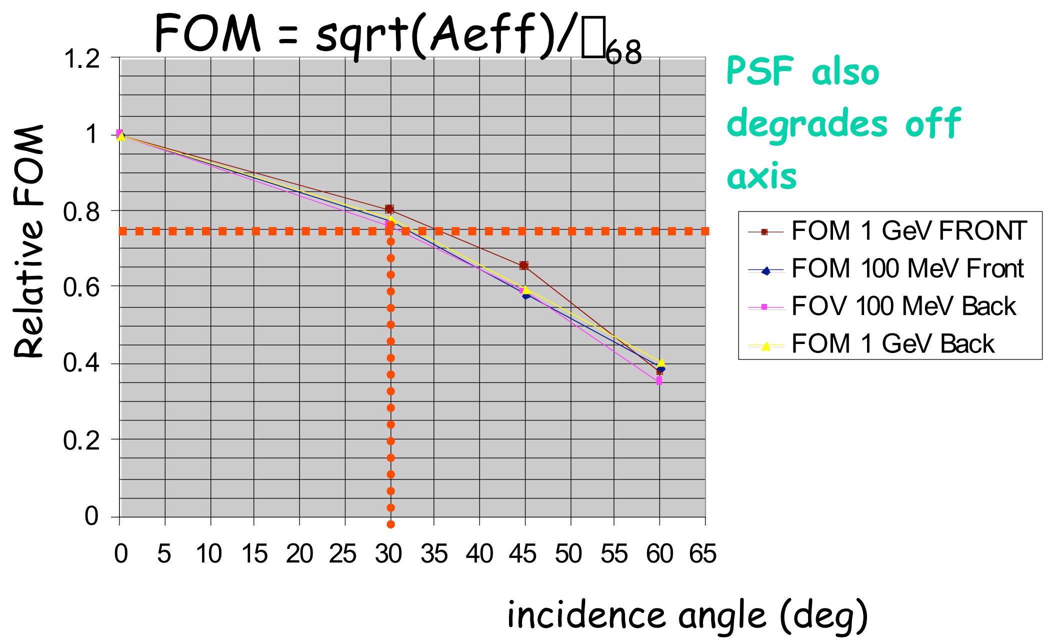
Data release policies

- All-sky survey during the first year.
  - LAT team to produce a point source catalog and an all sky map; formal release 90 days following completion of the survey.
- Transient source locations are made public immediately with photon data (light curves, improved positions, etc.) to follow as practical.
  - During first year photon data to include warning that the data may be unverified and uncalibrated
  - Best efforts to release preliminary catalogs in time for AOs
    - The first 3 months of observations will be delivered at 6 months
    - The full 12 months of observations will be delivered 1 month after the end of the sky survey
- Guest investigators may propose for source studies, associated theory or key projects
  - Data from these sources of interest are made available immediately to the GIs.
- Following the survey, it is being proposed that all GLAST data will be made public immediately.
  - Comments on this policy may be sent to Jonathan.F.Ormes@nasa.gov or Donald.A.Kniffen@nasa.gov
  - We plan to conduct workshops on how to propose for and how to the use the tools to analyze the GLAST data

What does "pointing" mean?

The LAT FOV is huge:

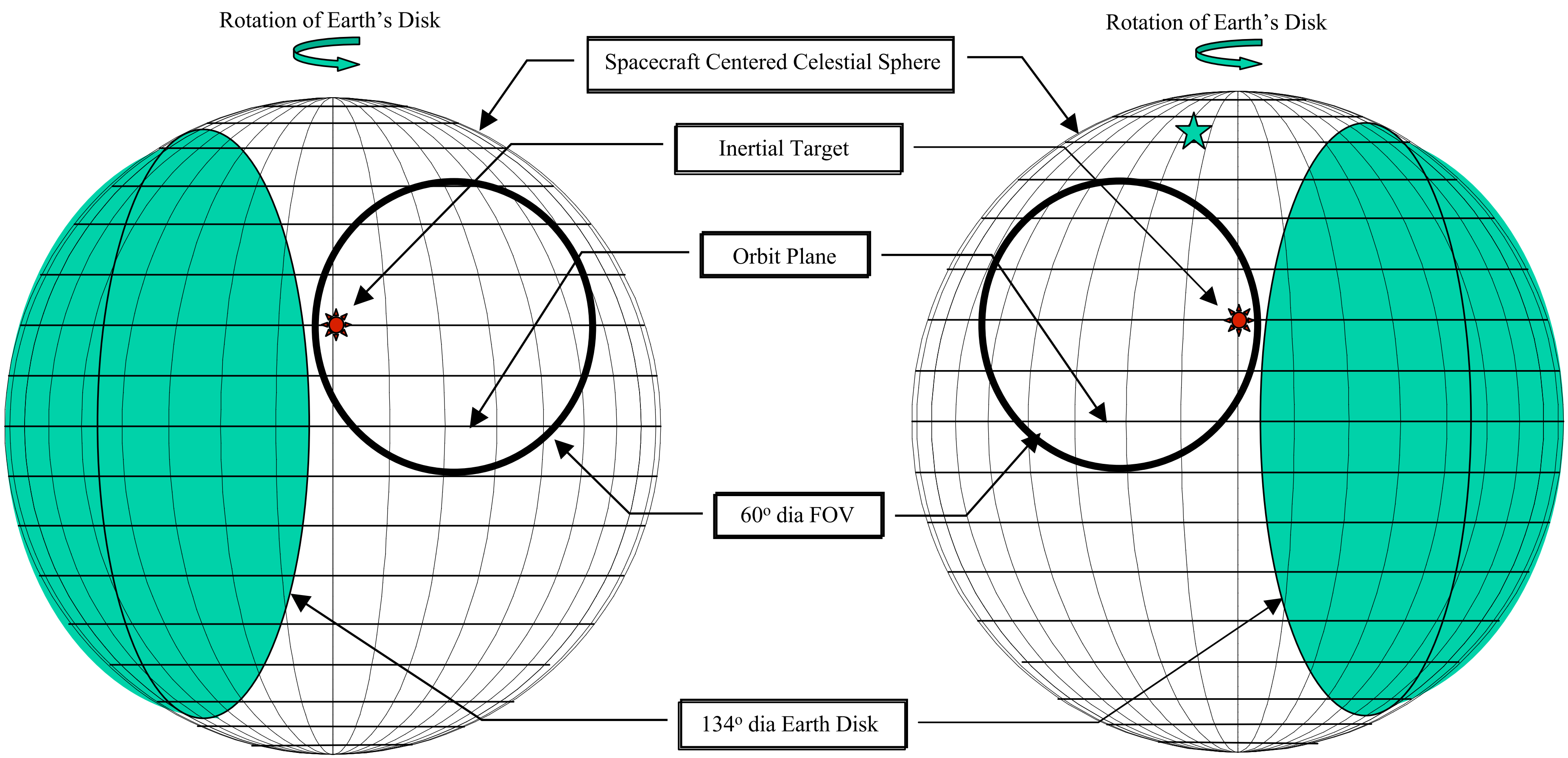




For the purposes of setting slew requirements define

- **LAT FOV: anything within ±55° (0.96 radian) (TBR) of normal incidence is within the LAT FOV.**
- **"Pointing": the target is within ±30° (0.52 radian) (TBR) of normal incidence. Individual targets may have a different criterion, depending on their characteristics.**

Earth Avoidance for Pointed Observations



Before Occultation

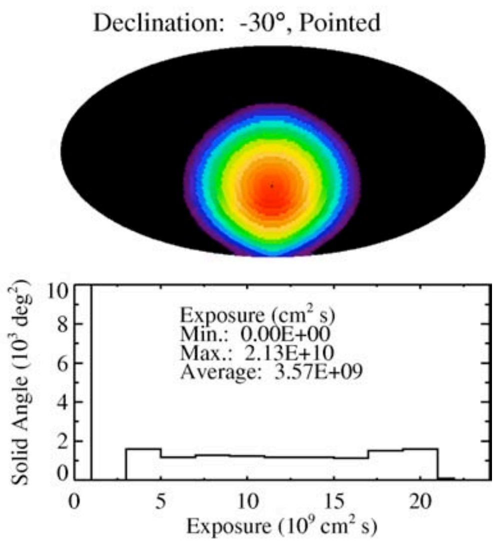
- Earth's disk is approaching from the left
- FOV is losing inertial target

After Occultation

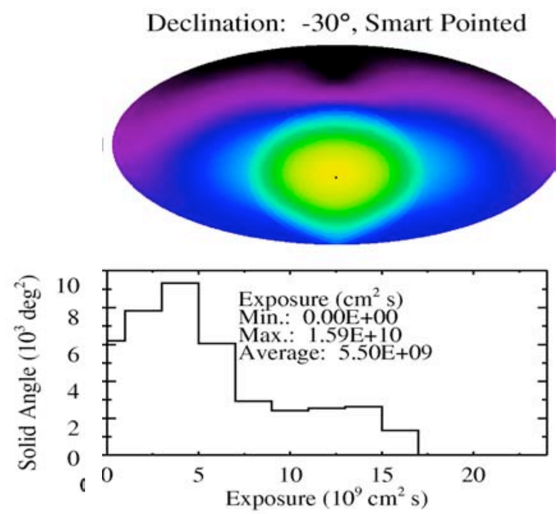
- Earth's disk is receding to the right
- FOV is picking up inertial target

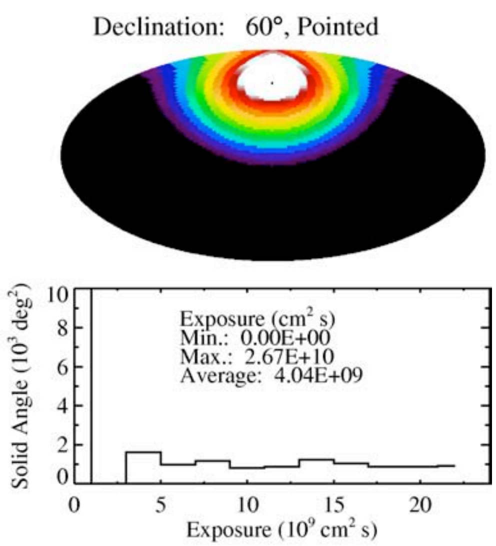
GLAST

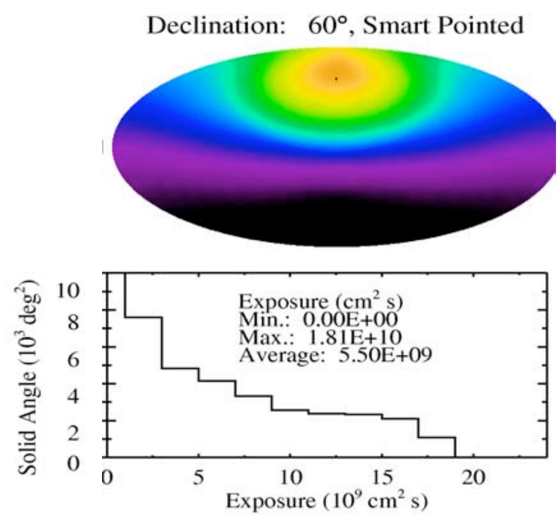
Scan Pointed Observations

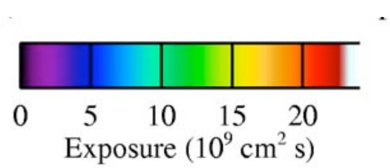


One day observation trade 20% exposure on source for sky coverage









GLAST Mission Overview