GLAST
Science Summary

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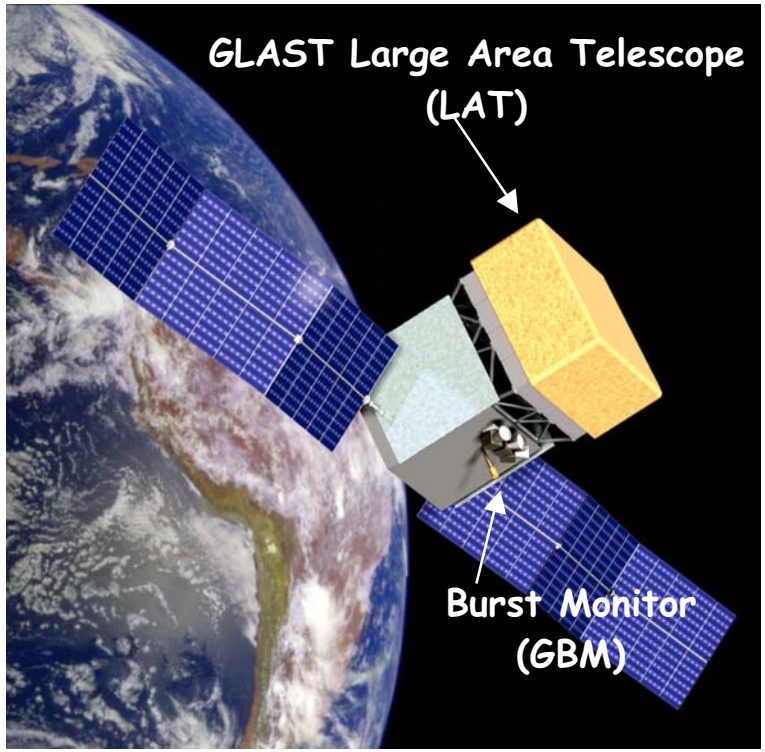
Why study γ's?

Gamma rays carry a wealth of information:

- *γ rays do not interact much at their source: they offer a direct view into Nature's largest accelerators.*
- *similarly, the Universe is mainly transparent to γ rays: can probe cosmological volumes. Any opacity is energy-dependent.*
- *conversely, γ rays readily interact in detectors, with a clear signature.*
- *γ rays are neutral: no complications due to magnetic fields. Point directly back to sources, etc.*

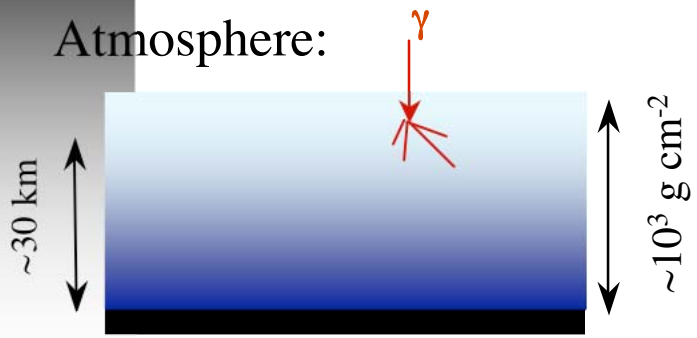


Two GLAST instruments:

LAT: 20 MeV – >300 GeV

GBM: 10 keV – 25 MeV

Cosmic γ-ray Measurement Techniques



For E_γ < ~ 100 GeV, must detect above atmosphere (balloons, satellites)

For E_γ > ~100 GeV, information from showers penetrates to the ground (Cerenkov, air showers)

Photon interaction mechanisms:

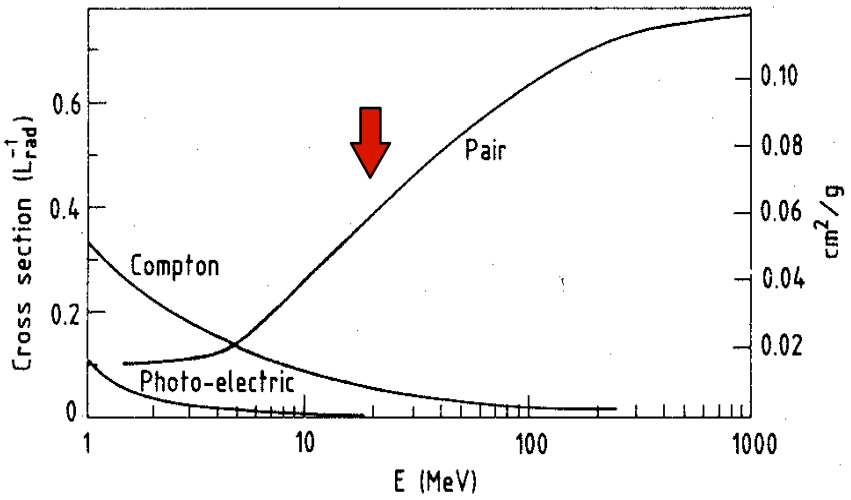


Fig. 2: Photon cross-section σ in lead as a function of photon energy. The intensity of photons can be expressed as $I = I_0 \exp(-\sigma x)$, where x is the path length in radiation lengths. (Review of Particle Properties, April 1980 edition).

Note:

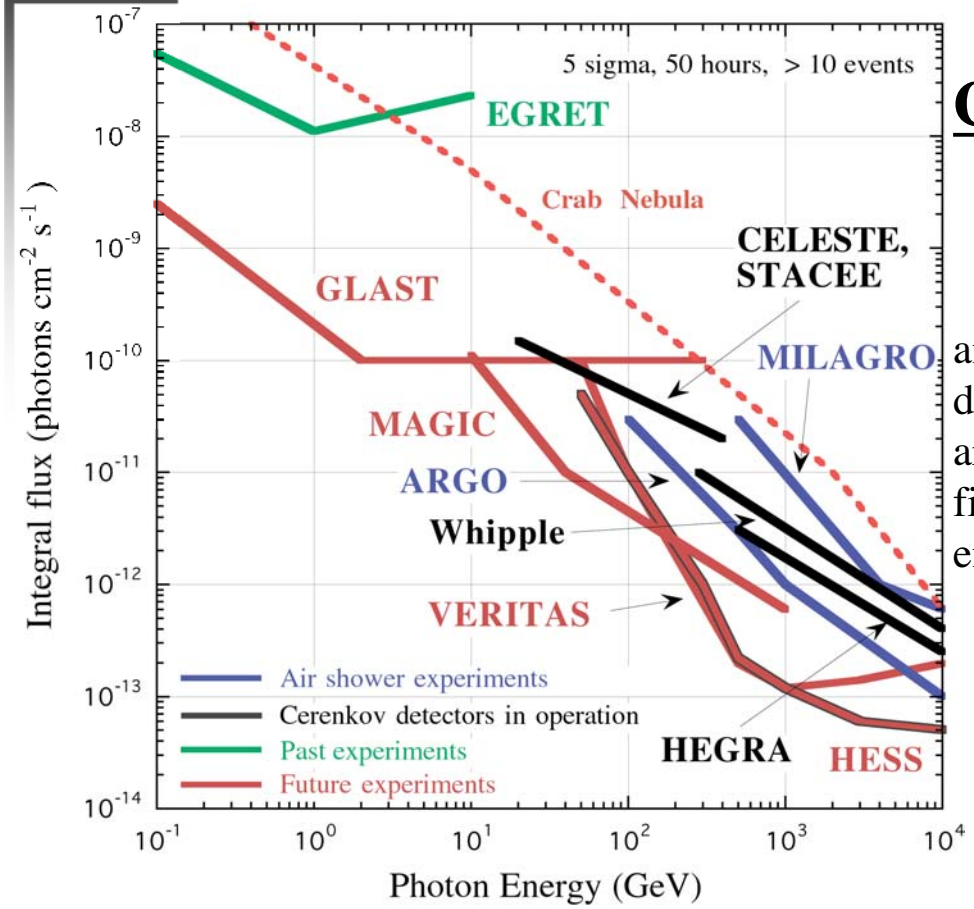
1 MeV=10^6 eV

1 GeV=10^9 eV

1 TeV=10^{12} eV

1eV=1.6x10^{-19} Joules

Gamma-ray Observatories

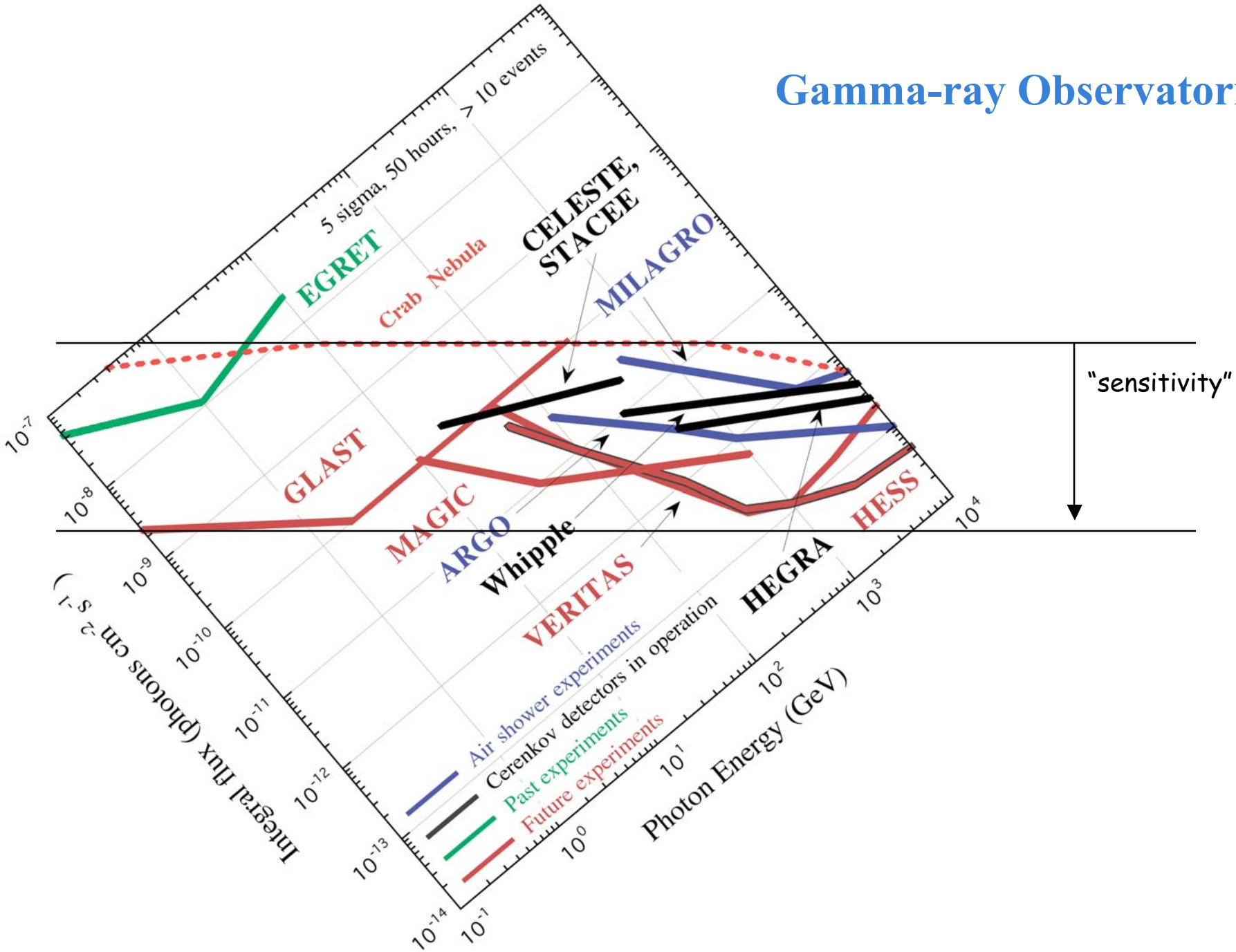


Complementary capabilities

	ground-based		space-based
	ACT	EAS	Pair
angular resolution	good	fair	good
duty cycle	low	high	high
area	large	large	small
field of view	small	large	large+can reorient
energy resolution	good	fair	good, w/ smaller systematic uncertainties

The next-generation ground-based and space-based experiments are well matched.

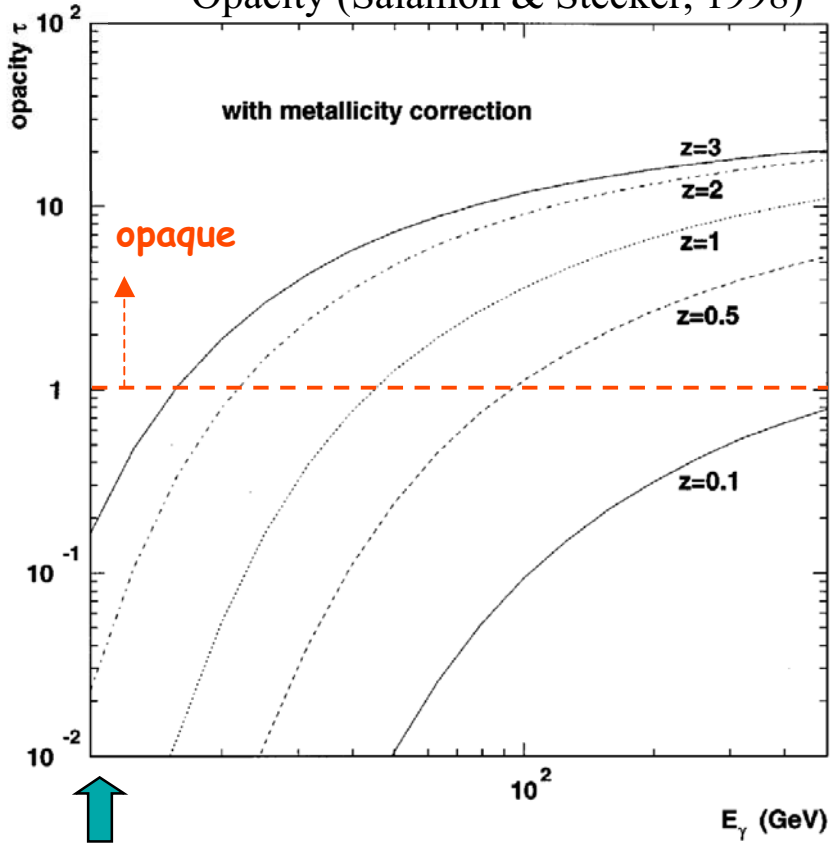
Gamma-ray Observatories



An Important Energy Band for Cosmology

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.

The Success of EGRET: Probing New Territory

History:

SAS-2, COSB (1970's-1980's) exploration phase: established galactic diffuse flux

EGRET (1990's) established field:

- increased number of ID'd sources by large factor;
- broadband measurements covering energy range ~20 MeV - ~20 GeV;
- discovered many still-unidentified sources;
- discovered surprisingly large number of Active Galactic Nuclei (AGN);
- discovered multi-GeV emissions from gamma-ray bursts (GRBs);
- discovered GeV emissions from the sun

GLAST will explore the unexplored energy range above EGRET's reach, filling in the present gap in the photon spectrum, and will cover the very broad energy range ~ 20 MeV - 300 GeV (→ 1 TeV) with superior acceptance and resolution. Historically, opening new energy regimes has led to the discovery of totally unexpected new phenomena.

GLAST Science

GLAST will have a very broad menu that includes:

- ***Systems with supermassive black holes***
- ***Gamma-ray bursts (GRBs)***
- ***Pulsars***
- ***Solar physics***
- ***Origin of Cosmic Rays***
- ***Probing the era of galaxy formation***
- ***Discovery! Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance. New source classes.***

Huge increment in capabilities.

GLAST draws the interest of both the High Energy Particle Physics and High Energy Astrophysics communities.

GLAST LAT High Energy Capabilities

- Huge FOV (~20% of sky)
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays (factor > 3 better than EGRET for E>1 GeV)
- Large effective area (factor > 4 better than EGRET)
- **Results in factor > 30-100 improvement in sensitivity**
- No expendables → long mission without degradation

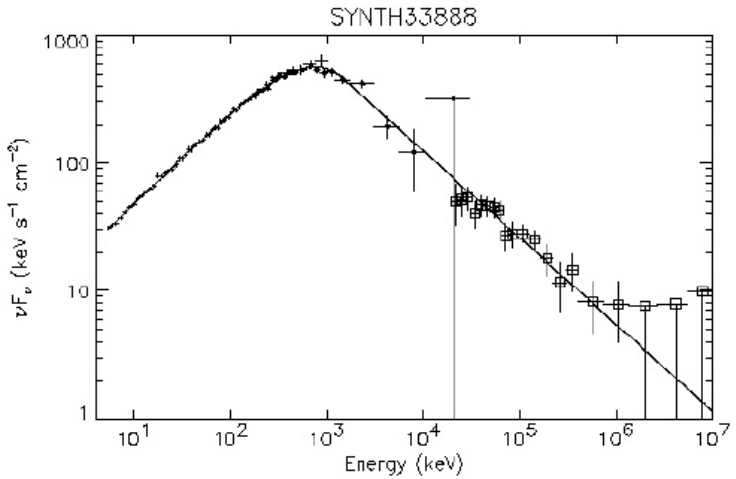
GBM

- ***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

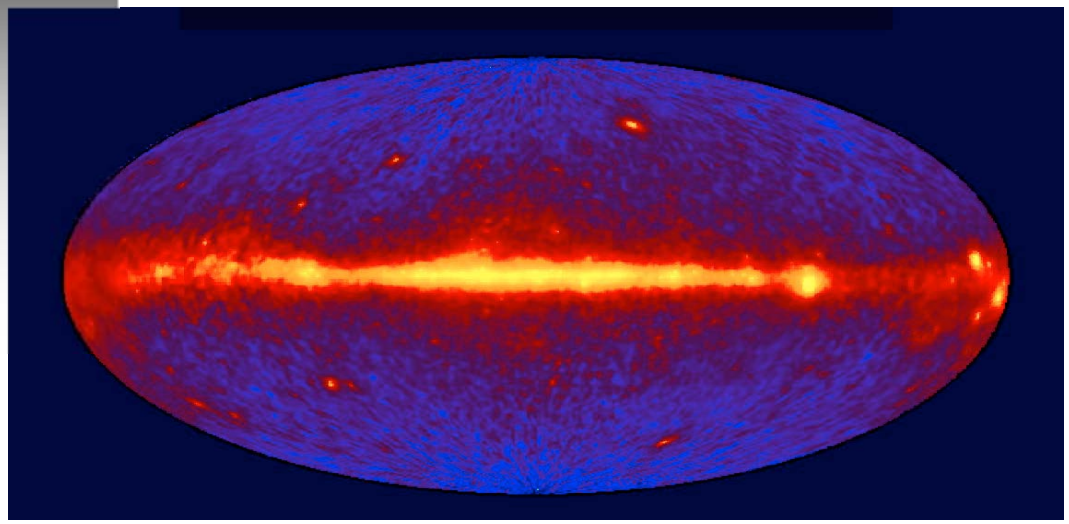
Spectral model parameters from CGRO wide-band fit

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.***

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)

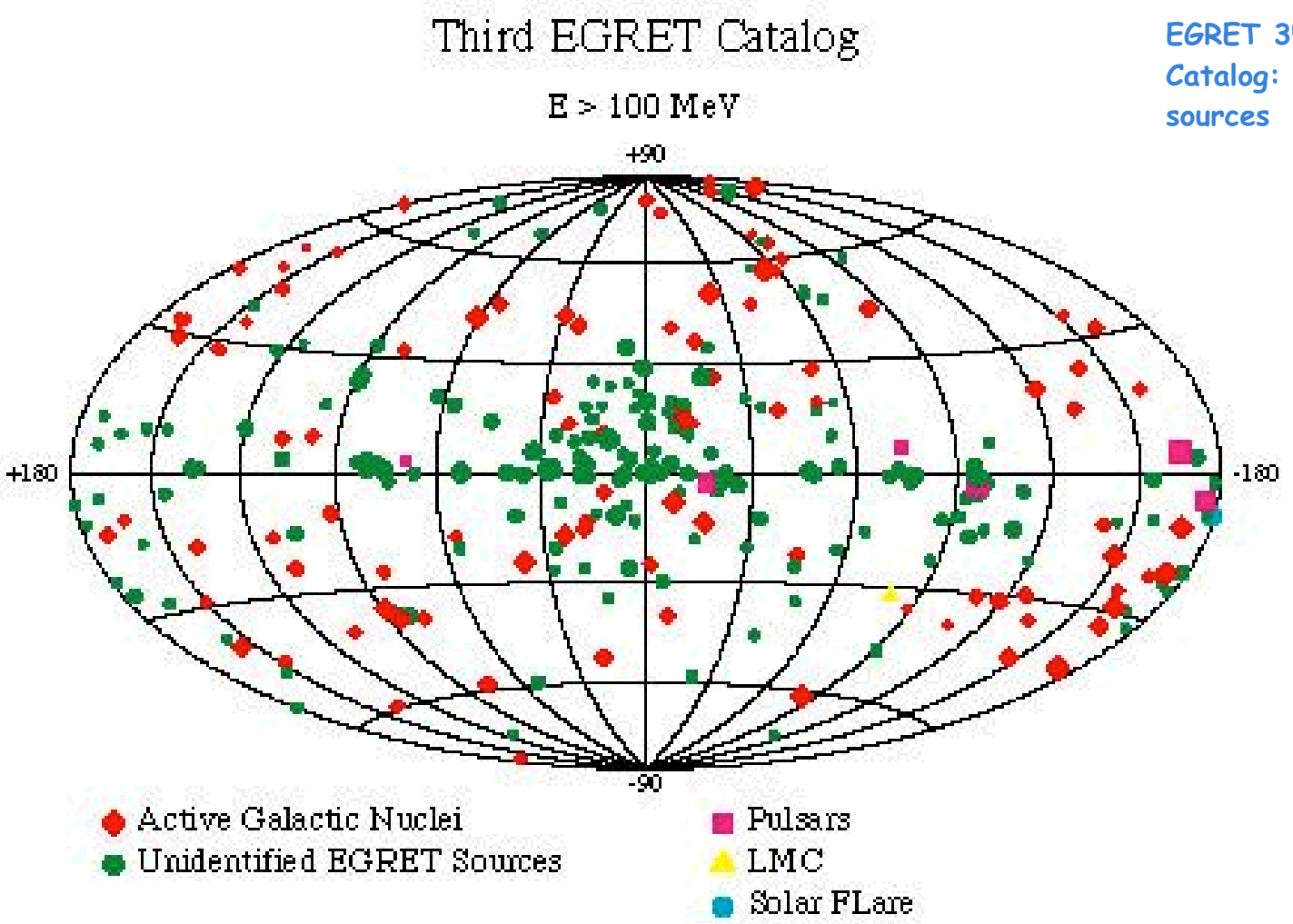
high latitude (extra-galactic) point sources (typical flux from EGRET sources O(10^{-7} - 10^{-6}) $cm^{-2}s^{-1}$

galactic sources (pulsars, un-ID'd)

An essential characteristic: VARIABILITY in time!

➡ Field of view, and the ability to repoint, important for study of transients (*e.g.*, AGN flares, Gamma-ray bursts).

Sources

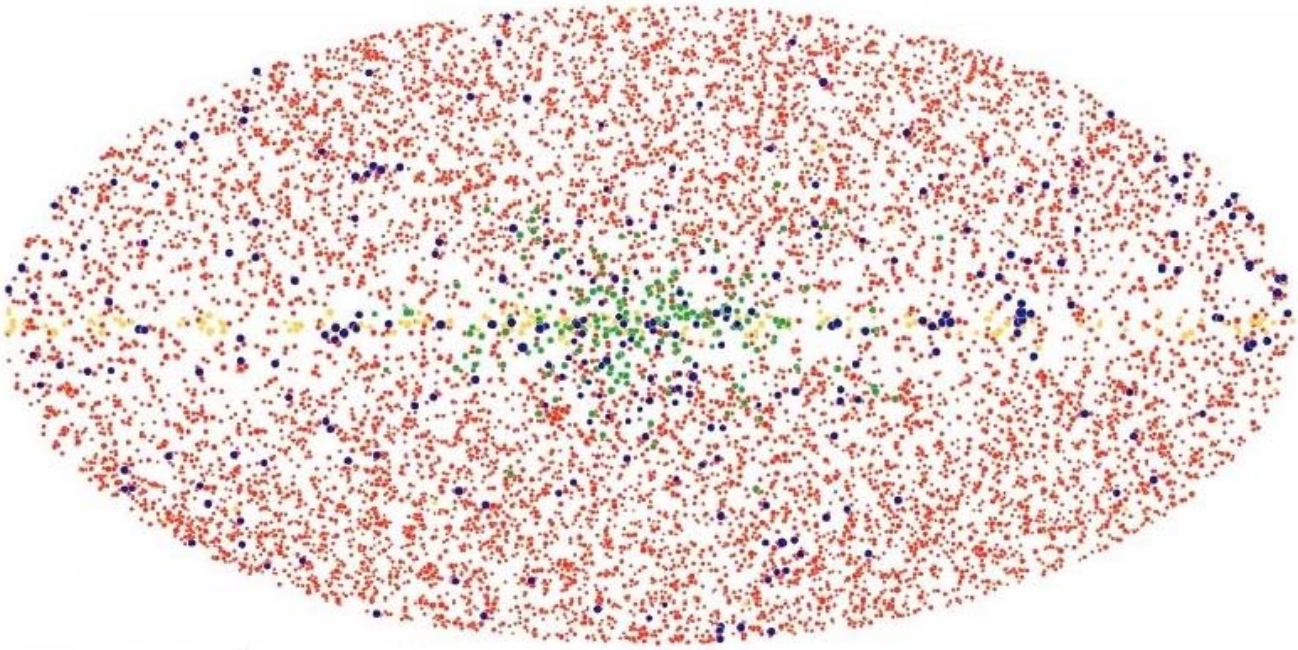


EGRET 3rd Catalog: 271 sources

Sources

LAT 1st Catalog:
>9000 sources
possible

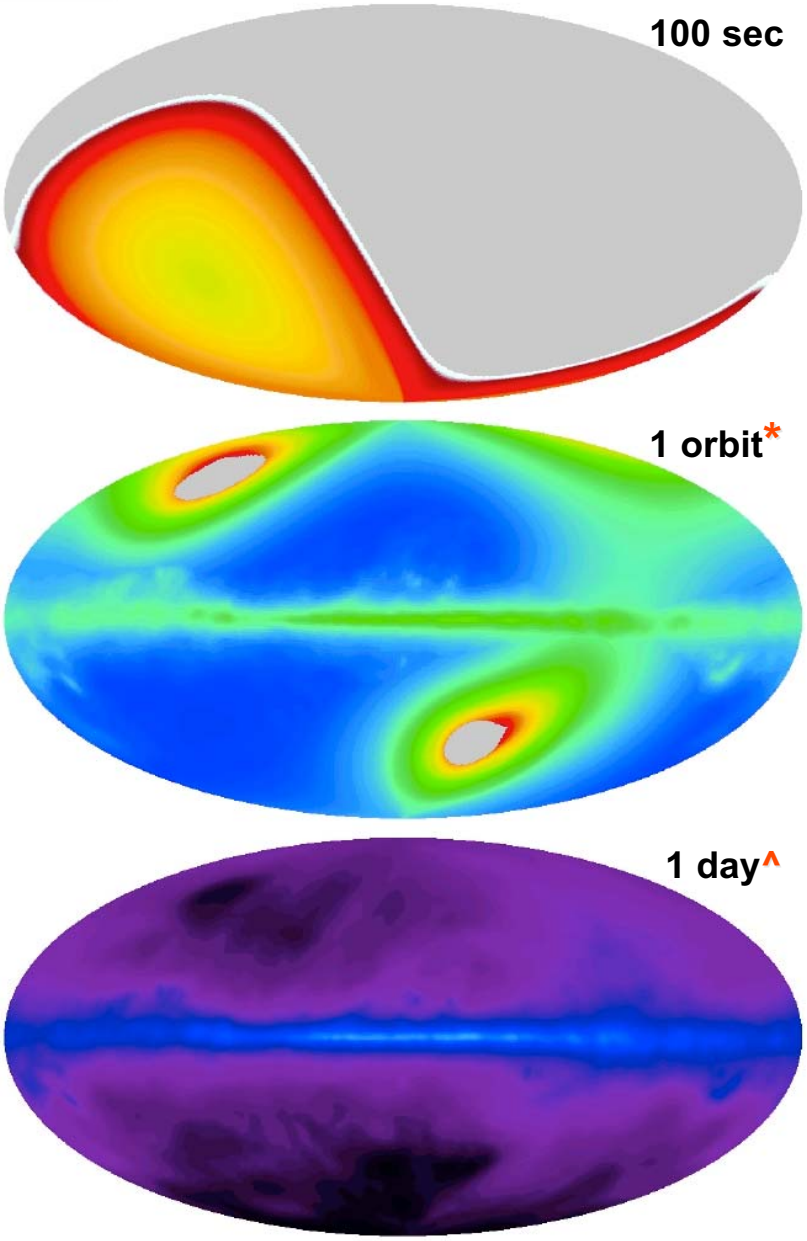
5σ Sources from Simulated One Year All-sky Survey

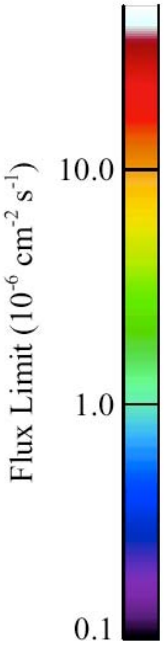


Results of one-year all-sky survey. (Total: 9900 sources)

AGN
3EG Catalog
Galactic Halo
Galactic Plane

High Energy Transients Sensitivity During All-sky Scan Mode





EGRET Fluxes

- GRB940217 (100sec)
- PKS 1622-287 flare
- 3C279 flare
- Vela Pulsar
- Crab Pulsar
- 3EG 2020+40 (SNR γ Cygni?)
- 3EG 1835+59
- 3C279 lowest 5σ detection
- 3EG 1911-2000 (AGN)
- Mrk 421
- Weakest 5σ EGRET source

During the all-sky survey, GLAST will have sufficient sensitivity after O(1) day to detect (5σ) the weakest EGRET sources.

*zenith-pointed

^"rocking" all-sky scan: alternating orbits point above/below the orbit plane

The GLAST Science Support Center

- ***To facilitate the multi-mission interpretation of the GLAST data, the GLAST SSC is located in Goddard's Laboratory for High Energy Astrophysics.***
- ***The SSC is responsible for:***
  - *the guest investigator program*
  - *the mission timeline (includes support for TOOs, commands)*
  - *providing data & analysis software to the scientific community*
  - *archiving data & software in the HEASARC*
  - *supporting (logistically & scientifically) the Project Scientist, the Science Working Group, and the Users' Committee*
  - *some data processing*
- ***The SSC and the instrument teams define the analysis software together. The instrument teams manage the software development, but SSC staff assists.***

Project Science Working Group

- ***Chaired by Project Scientist (Jonathan Ormes). Membership includes the Interdisciplinary Scientists and delegates from the instrument teams.***
- ***Having bimonthly telecons and ~biannual sit-down meetings.***
- ***Sit-down meetings have included daylong topical meetings directly involving the various communities: AGN (4/01 Baltimore, adjacent to GAMMA2001); Pulsars (12/01 UCSC); Bursts (9/02 Huntsville); Diffuse emissions (9/03 Rome).***
- ***Working groups on topics as needed, including observing planning (inputs to spacecraft design), GRB coordination, transient definition.***
- ***see http://glast.gsfc.nasa.gov/science/swg/ for meeting minutes and activities***
- ***GLAST science sessions at major conferences. Outreach for multiwavelength coordination with other observatories.***

Science Summary

- ***GLAST Science is exciting!***
  - *Highest-ranked mid-size mission in the most recent National Academy of Sciences "Decadal Survey" of Astronomy and Astrophysics.*
  - *Positively peer-reviewed by Particle Physics community*
- ***GLAST will address many important questions:***
  - *What is going on around black holes? How do Nature's most powerful accelerators work? (are these engines really black holes?)*
  - *What are the unidentified sources found by EGRET?*
  - *What is the origin of the diffuse background?*
  - *What is the high energy behavior of gamma ray bursts?*
  - *What else out there is shining gamma rays? Are there further surprises in the poorly measured energy region?*
  - *When did galaxies form?*
- ***Large menu of "bread and butter" science, and Large discovery potential.***

We expect the gamma-ray community to grow enormously during the GLAST era!