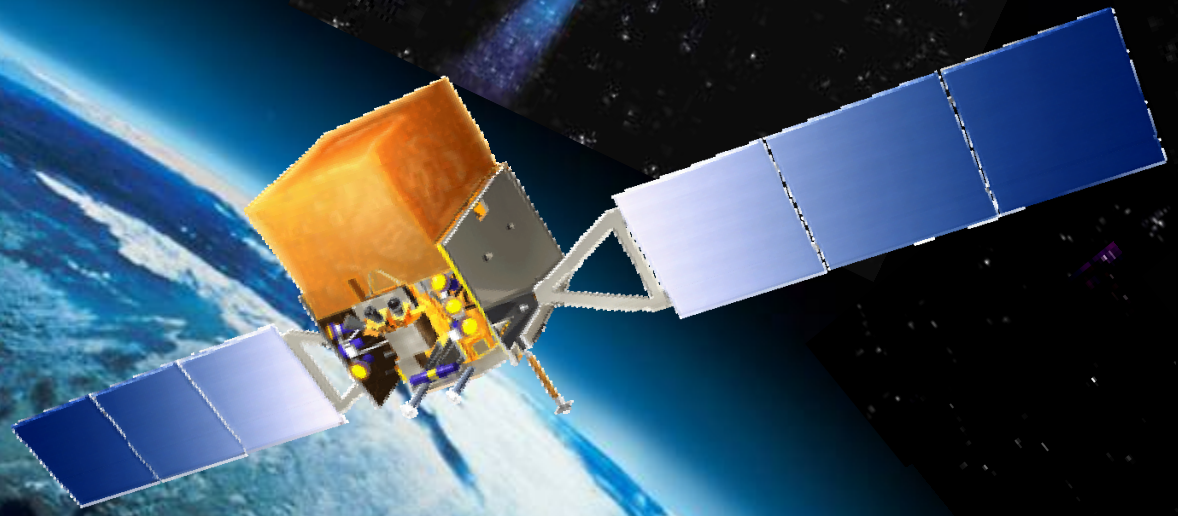
GLAST

Project Overview,

Collaboration Status,

Overview of Science Analysis Groups



Peter F. Michelson
GLAST LAT Spokesperson
Stanford University
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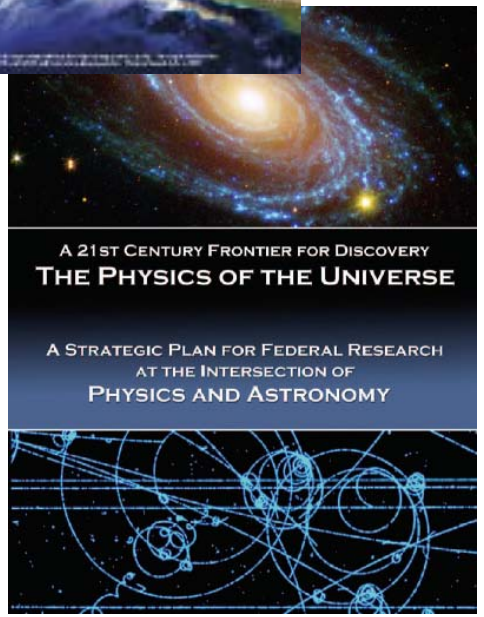
GLAST LAT International Finance Committee
October 17, 2005

GLAST LAT Status

- ***Instrument Development has turned the corner! Integration & Test of instrument proceeding smoothly (Tkr, Cal, ACD subsystems complete)***
  - *collaboration fully involved in instrument. Science Verification and Analysis (SVAC); a collaboration-wide activity.*
  - *beam test planning underway; very likely we will take advantage of capabilities of CERN test beams; also a collaboration-wide activity (coordinators: Ronaldo Bellazzini, Eduardo do Couto é Silva, Benoit Lott)*

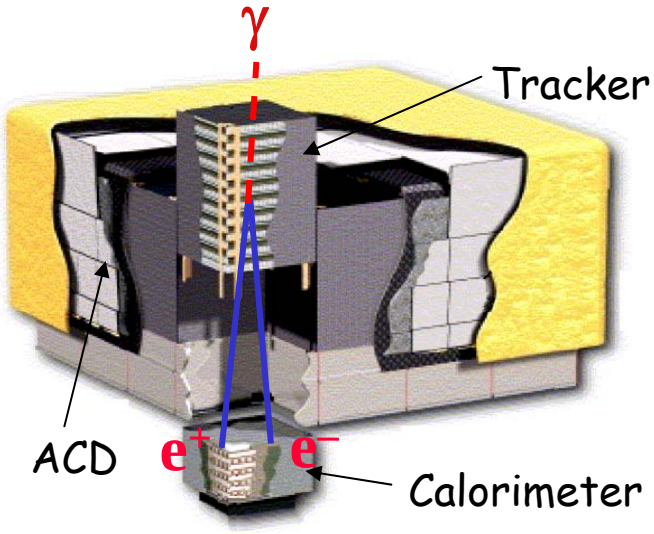
- ***LAT Collaboration very actively engaged in science analysis preparation; was focus of Collaboration meeting in August***
  - *9 science analysis groups formed and active;*
  - *preparations for Data Challenge II underway, will start early next year;*
  - *multiwavelength observing plans advancing*



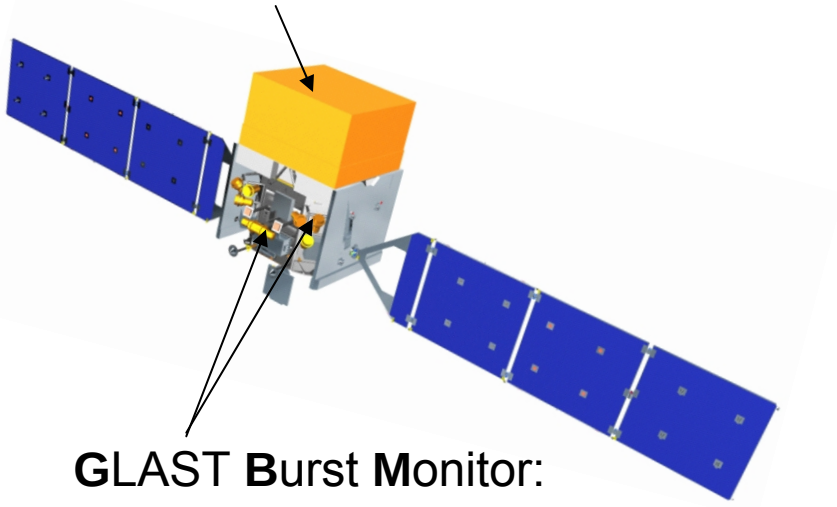
".. GLAST will focus on the most energetic objects and phenomena in the universe…"

GLAST development status

- ***all mission elements completing hardware fabrication phase and in integration phase***
- ***LAT delivery for observatory integration – Spring 2006***
- ***Observatory integration and test – Spring 2006 through Summer 2007***
- ***launch – September 7, 2007***



Large **A**rea **T**elescope:
20 MeV – >300 GeV



GLAST Burst Monitor:
10 keV – 25 MeV

LAT: jointly supported by France (CEA, IN2P3), Italy (ASI, INFN), Japan, Sweden, and USA (DOE, NASA); Stanford-SLAC host for LAT ISOC

GBM: US and Germany

Spacecraft, Observatory integration: General Dynamics, C-4 division

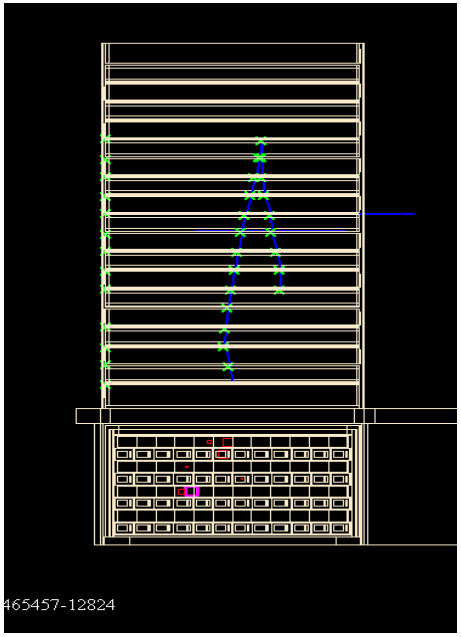
Mission management/observatory operations: Goddard Space Flight Center

LAT status

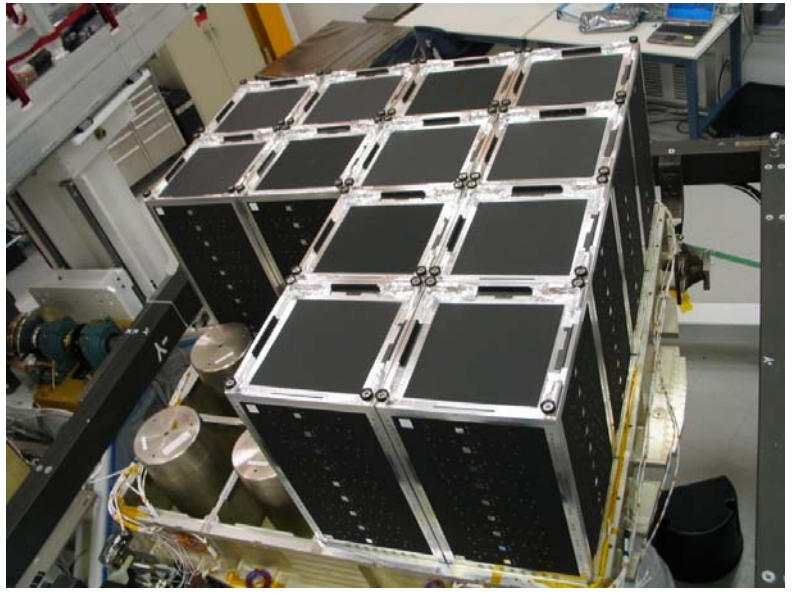
- ***flight hardware integration well underway and proceeding towards June 2006 RFI to observatory***

LAT is possible because of partnership between

- ***scientists:*** ***particle physicists & astrophysicists,***
- ***laboratories:*** ***SLAC, GSFC, and collaborating labs***
- ***agencies and institutes***

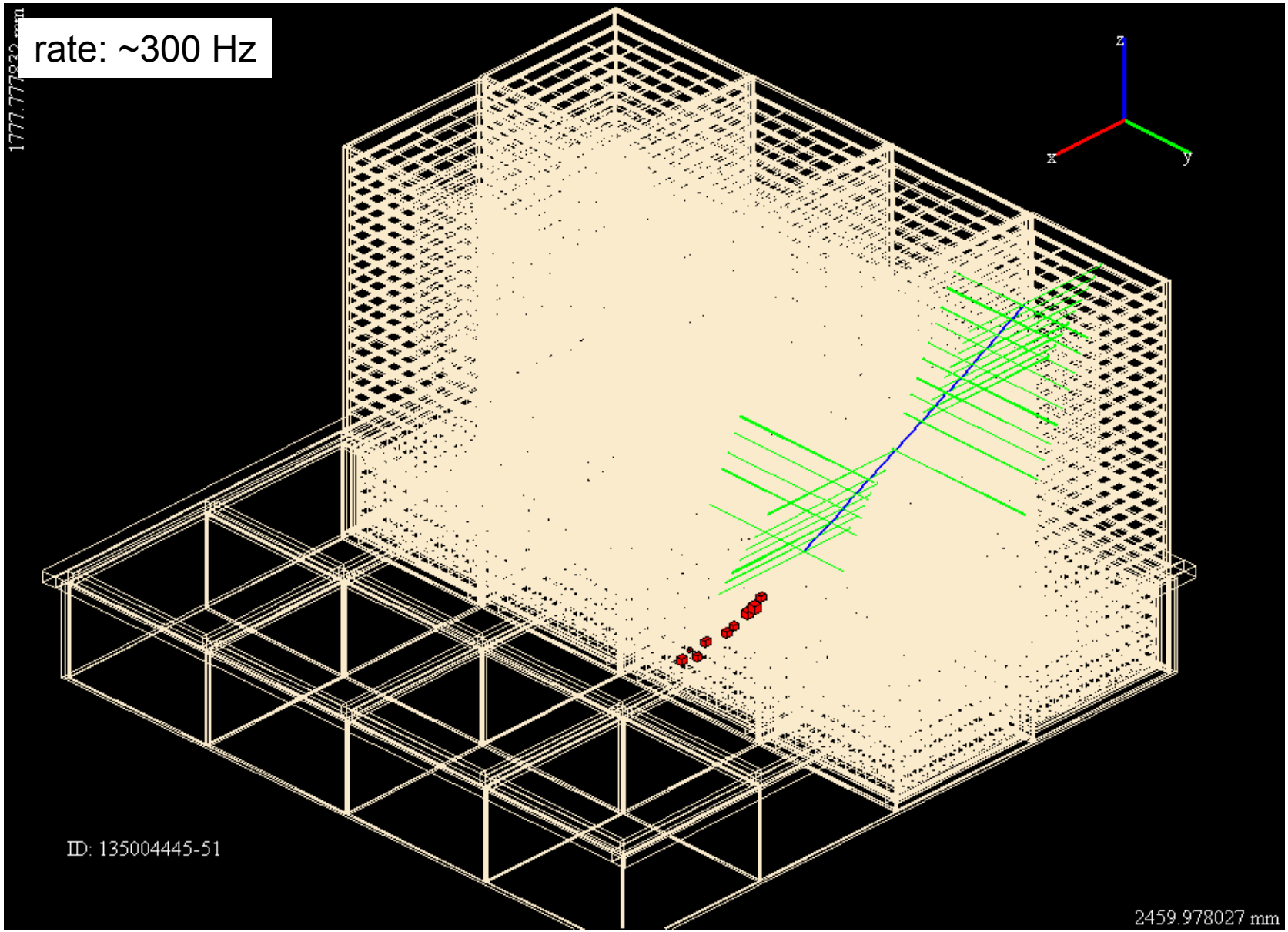


γ-ray event in 1st tower (1 of 16)

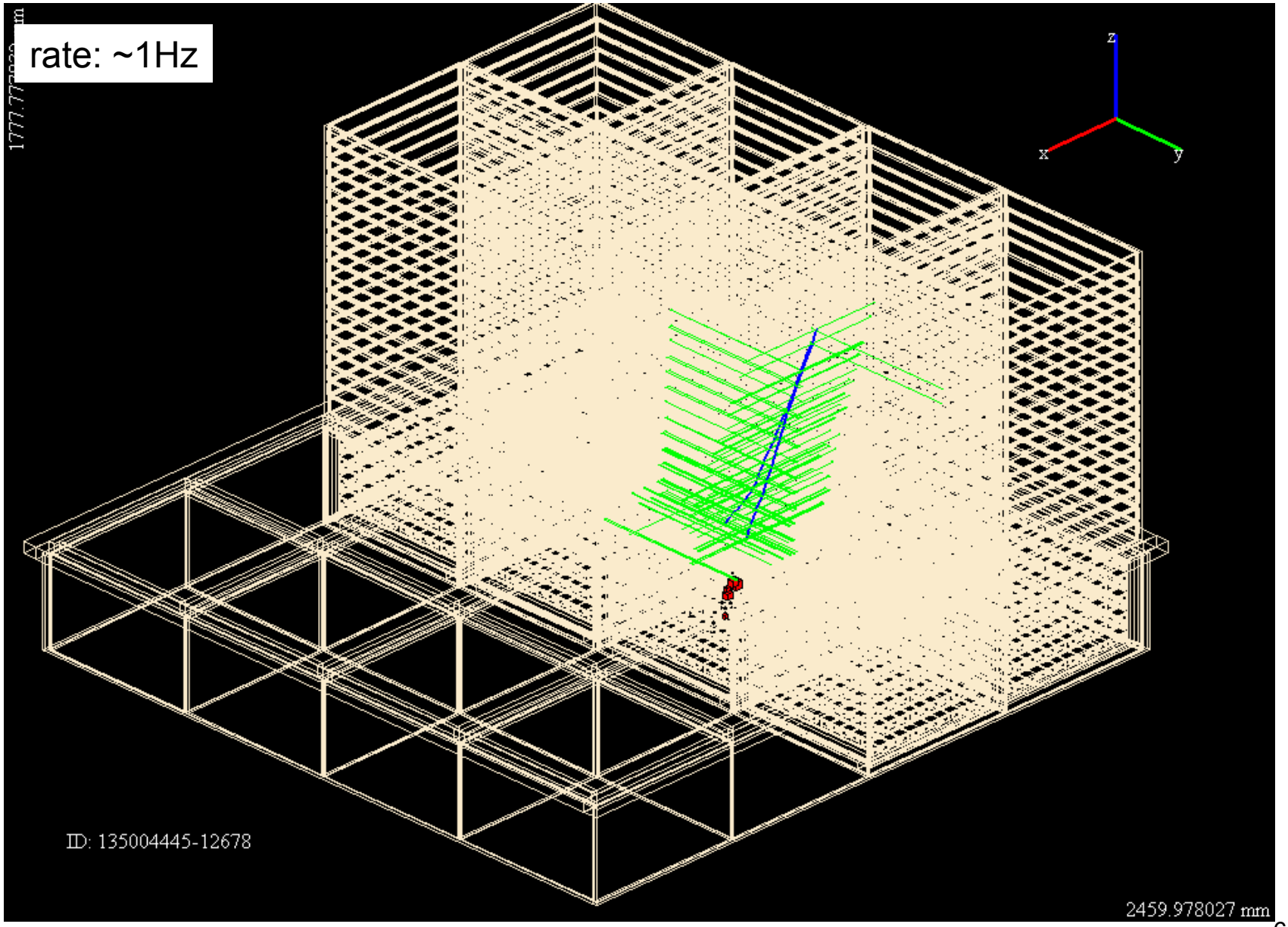


I&T facility at SLAC / Stanford University

8-tower movie – muon events



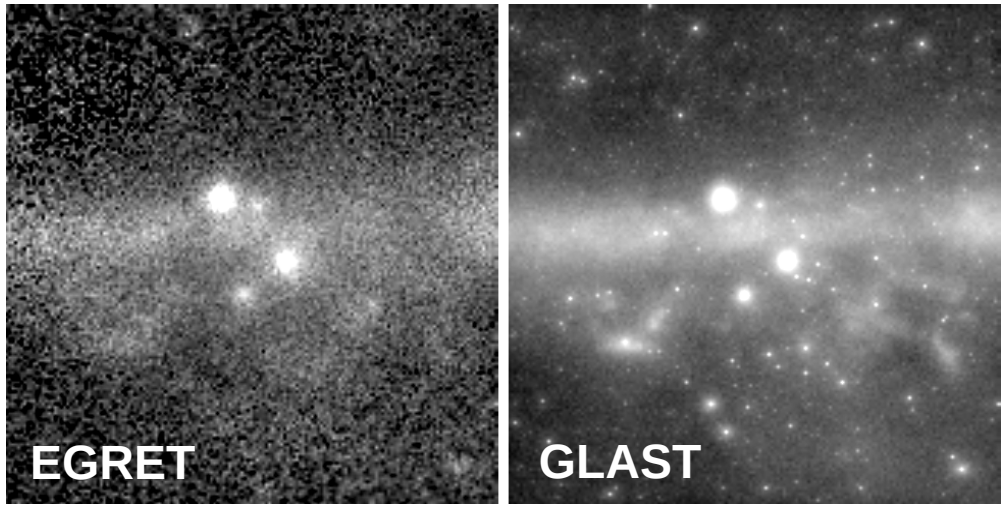
8-tower movie – photon events



Science preparation:

- science opportunities
- collaboration science analysis groups
- multiwavelength planning and needs

Science opportunities



anti-center region
(E > 100 MeV)

Many opportunities for exciting discoveries:

- *origin(s) of the high-energy extragalactic diffuse background*
- *extragalactic background starlight to z > 3*
- *new physics & the unknown! (e.g. dark matter, extra dimensions, Lorentz invariance violation)*
- *γ-ray emission from clusters of galaxies; cosmic-ray acceleration and confinement on large scales*
- *γ-rays from Ultra-Luminous Infrared Galaxies; cosmic ray acceleration efficiency and star formation rate*
- *high-latitude Galactic Inverse-Compton emission and thereby measure TeV-scale CR electrons in the Galaxy*
- *high-energy emission from Galactic pulsars and their birth places*

Status of Science Groups

- ***9 Science Groups formed and active***
  - *Coordinators identified*
  - *websites established and linked to Collaboration webpage*
  - *periodic meetings of groups; face-to-face meeting prior to August Collaboration meeting*

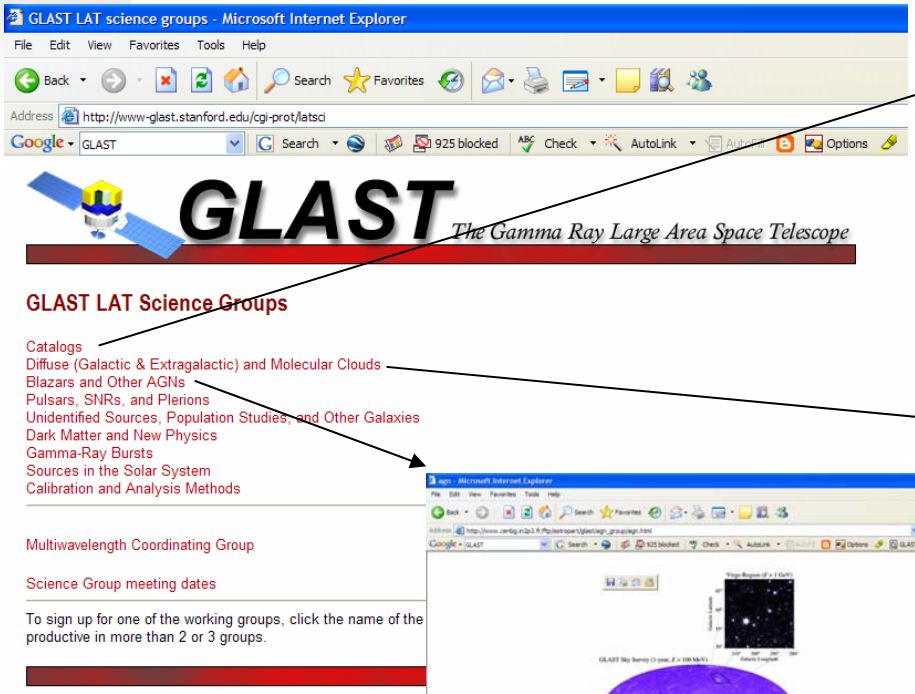
Group	Coordinators	# participants
Catalog	S. Digel, I. Grenier	16
Diffuse Radiation	S. Digel, I. Grenier	28
Blazars & AGNs	P. Giommi, B. Lott	40
Pulsars, SNRs, & Plerions	R. Romani, D. Thompson	42
Unidentified Sources, Population Studies, and Other Galaxies	P. Caraveo, O. Reimer	33
Dark Matter & Exotic Physics	E. Bloom, A. Morselli	37
Gamma-Ray Bursts	J. Norris, N. Omodei	46
Solar	G. Share	9
Calibration & Analysis Methods	W. Atwood, S. Ritz	55

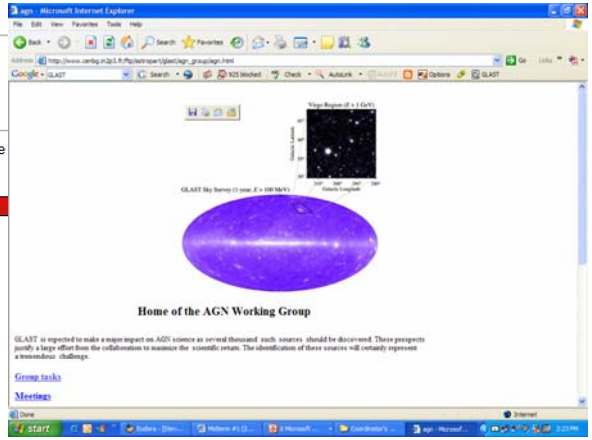
Collaboration demographics

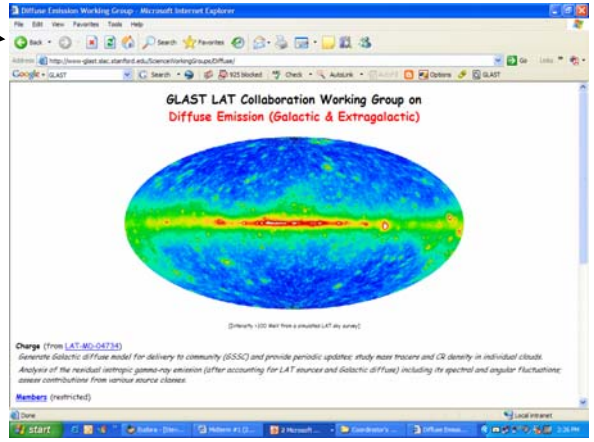
Country	membership category		
	Member	Affiliated	Postdoc
France	13	5	
Germany		3	
Italy	14	24	12
Australia		1	
Japan	5	2	
Sweden	1	5	
USA	53	27	3
Total	86	67	15

Science Group interactions

- *groups typically meet (via VRVS) weekly or bi-weekly*
- *periodic (~monthly) teleconference meetings of science analysis coordinators*
- *extensive use of Web pages: e.g. confluence*

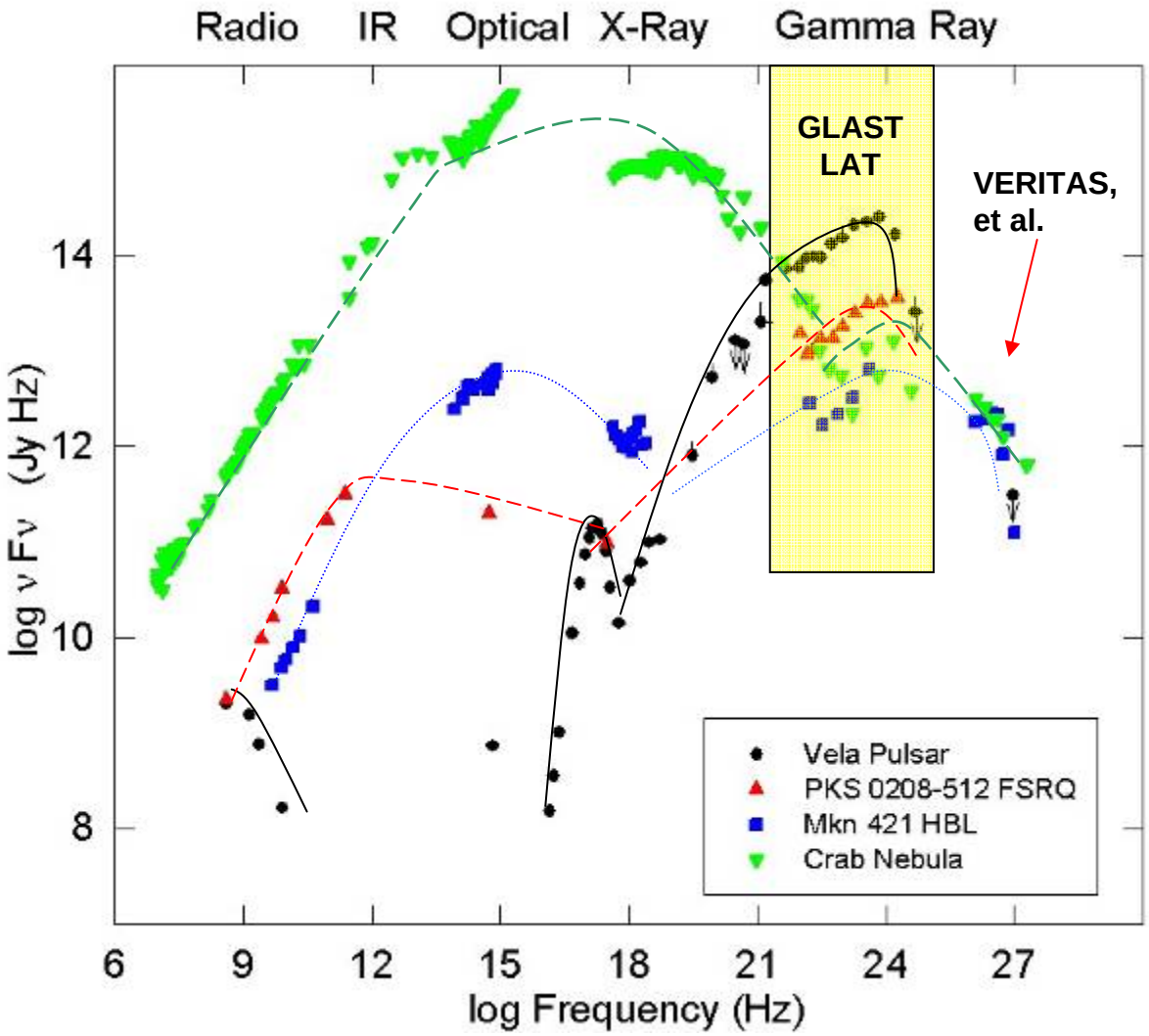






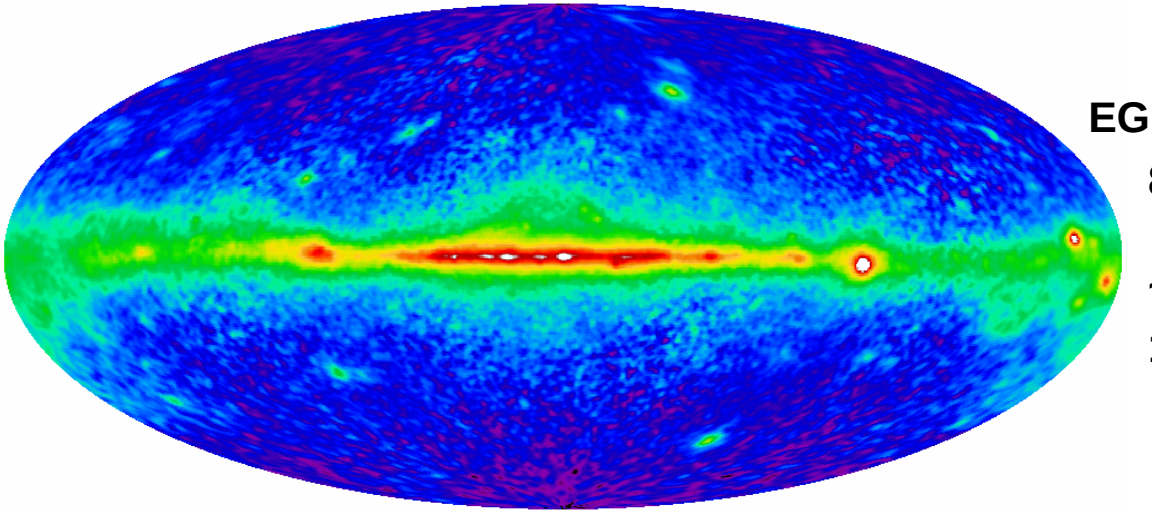
Understanding γ-ray Sources: multiwavelength needs

radiation produced by high-energy particles



- *Nature rarely produces mono-energetic particle beams. Broad range of particle energies leads to broad range of photon energies.*
  - *example: π^0 production*
- *Charged particles rarely interact by only one process. Different processes radiate in different energy bands.*
  - *example: synchrotron-Compton processes*
- *High-energy particles producing gamma rays radiate in lower-energy bands as they lose energy.*
  - *example: gamma-ray burst afterglows*

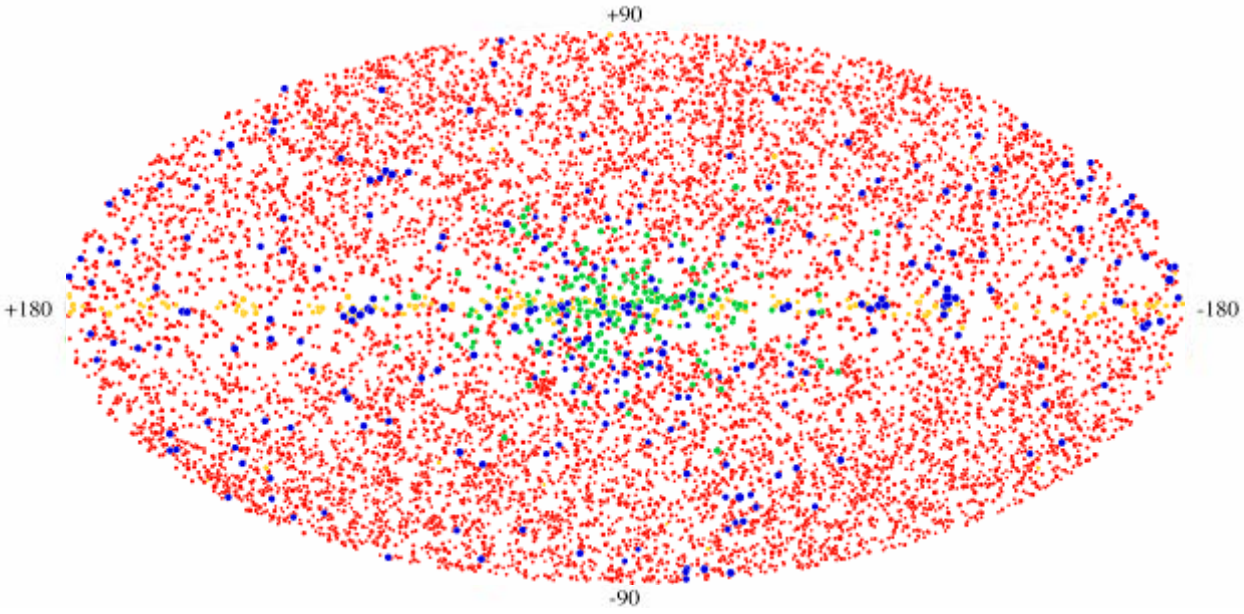
Science opportunities & multiwavelength needs



EGRET (>100 MeV)

- **85% galactic diffuse emission**
- **~5% isotropic emission**
- **10% point sources**

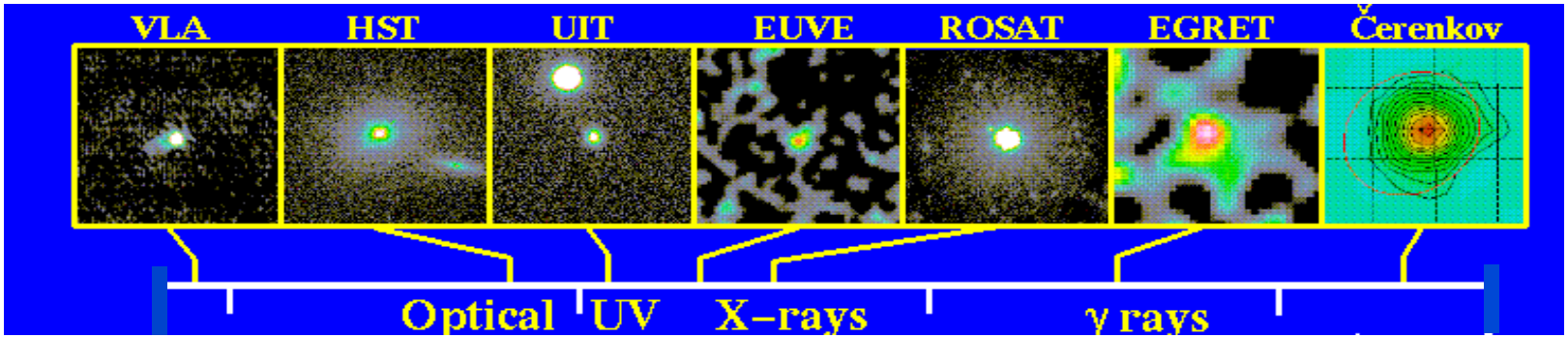
GLAST all-sky survey
(~10^4 sources)



Multiwavelength observations are important for GLAST

- *Multiwavelength observations needed for*
  - *understanding the high-energy diffuse emission of the Milky Way*
  - *source identification and population studies*
  - *intensive exploration of the brightest and most variable sources that will allow deep study of the source physics*
  - *rapid follow-up on transients (e.g. GRBs, blazar flares)*
    - *GLAST mission designed to support rapid notification for follow-up*

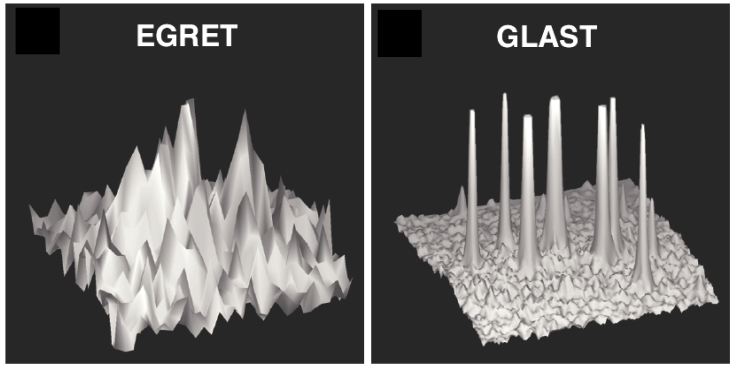
example: Markarian 421



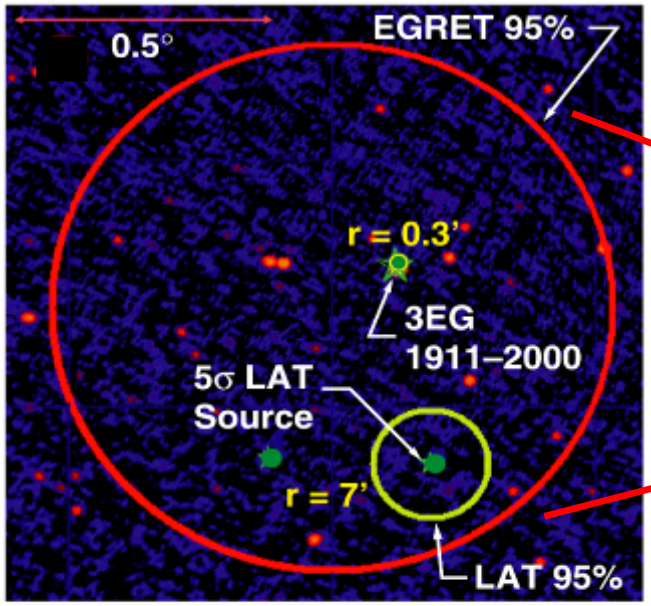
γ-ray source localization

multi-wavelength approach to γ-ray source identification:
- **localization**
- **variability**

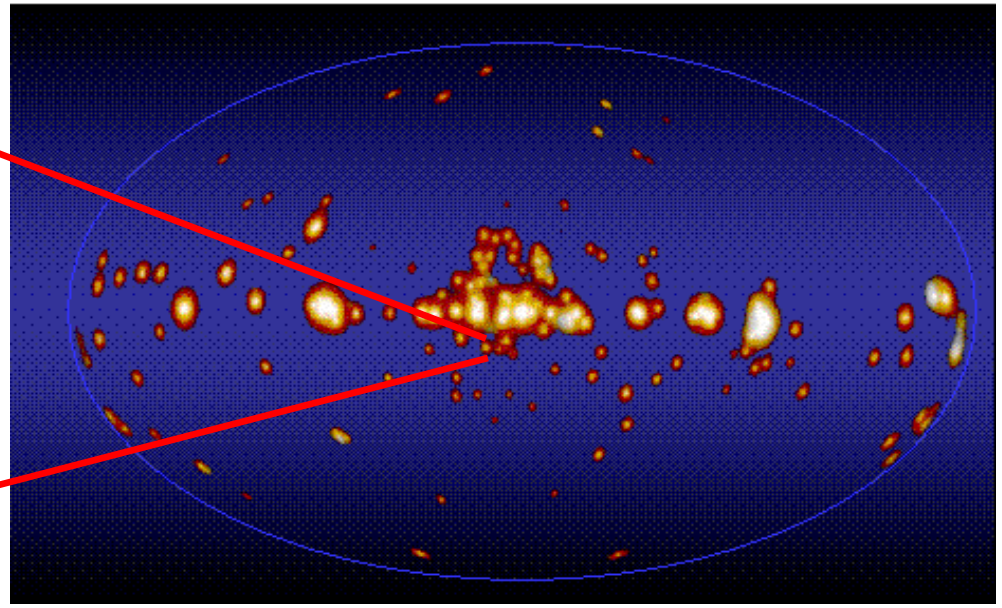
source localization (68% radius)
- *γ-ray bursts: 1 to tens arcminutes*
- *unid EGRET sources: 0.3' – 1'*



Cygnus region (10° x 10°)



● Rosat or Einstein X-ray Source
● 1.4 GHz VLA Radio Source

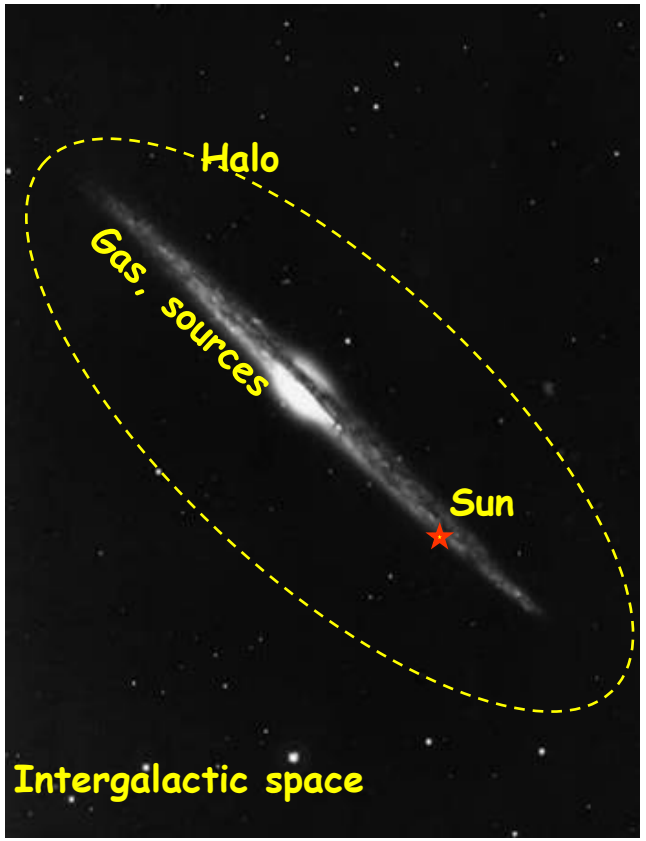


Unidentified EGRET sources

Diffuse γ-ray emission from the Milky Way

85% of the celestial gamma-ray emission

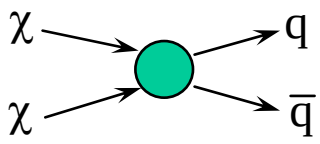
- *This foreground needs to be well characterized for analysis of LAT data, much more so than for EGRET, owing to vastly better statistics and better angular resolution*
- *The origin is cosmic-ray interactions with interstellar gas and the interstellar radiation field*
- *Fundamental questions remain from EGRET with results limited by knowledge of the diffuse emission; e.g.*



–What is the contribution of particle dark matter?
–What is the EGRET source in the galactic center region?
–What is the origin(s) of the isotropic γ-ray background?

particle dark matter

- *The lightest supersymmetric particle is a plausible dark matter candidate, most likely with mass > ~50 GeV*
- *Annihilation channels produce γ-ray lines and continuum*



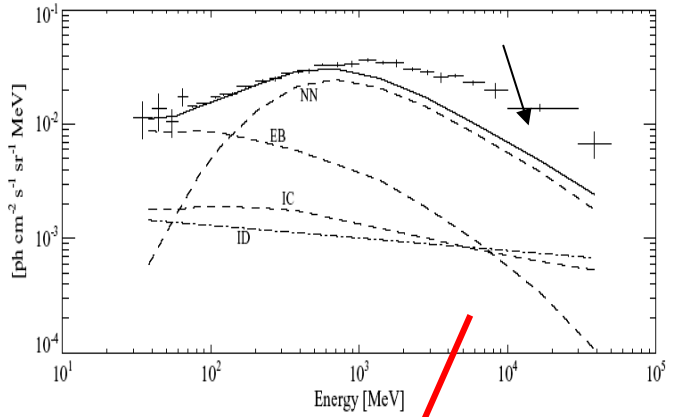
inclusive continuum flux,

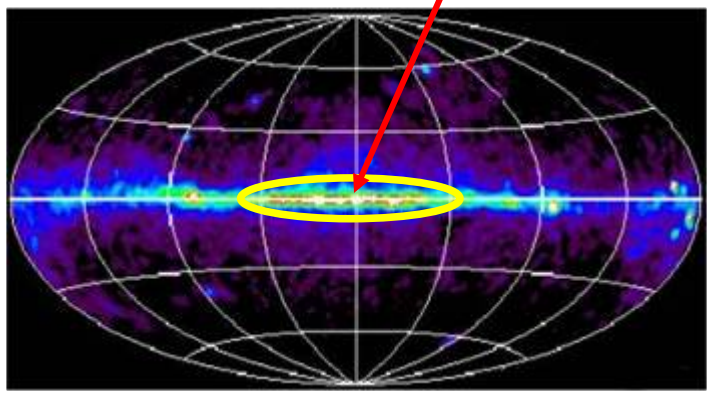
or $\gamma\gamma$ or $Z\gamma$ "lines"?

- *WIMPs would be distributed in a Galactic halo, with a central density enhancement of uncertain cuspiness;*

most likely the halo will have significant substructure, which is important as the annihilation rate ~ρ^2

EGRET GeV "excess"





two different explanations possible:

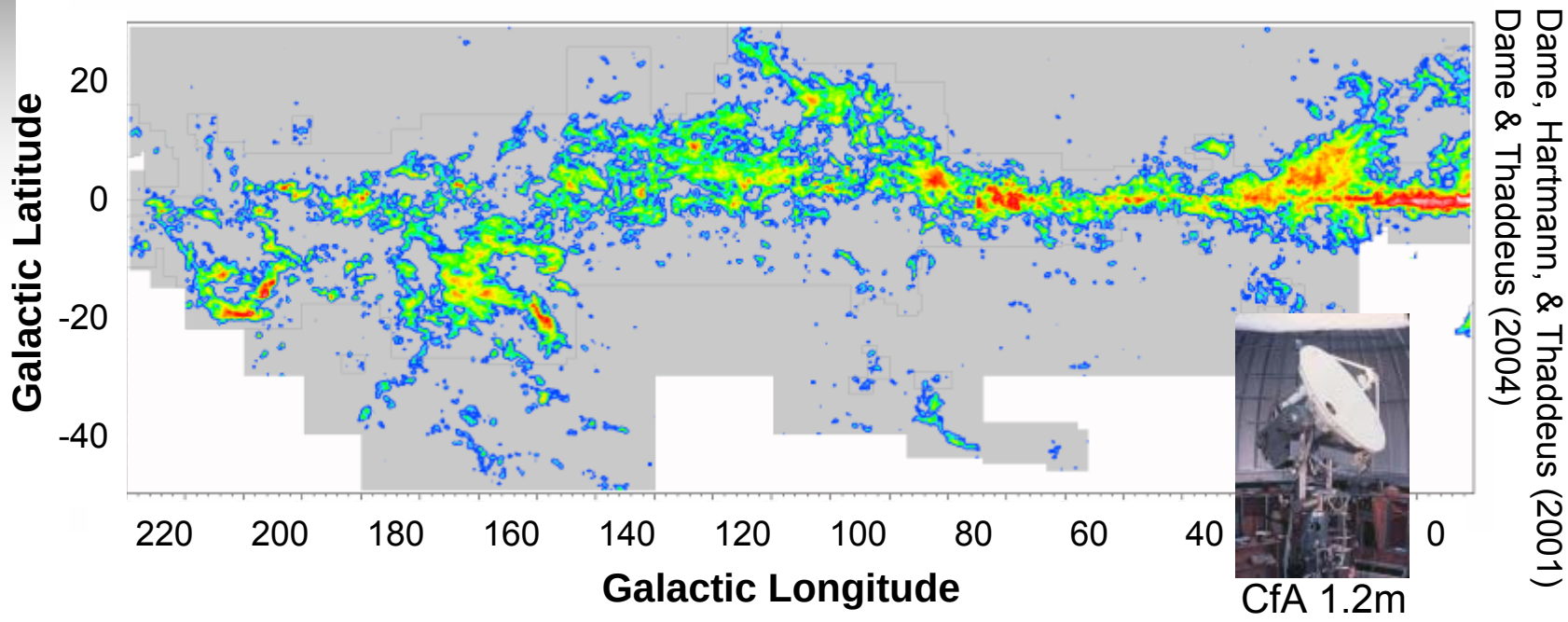
- CR spectral variations
- dark matter

Modeling diffuse emission of the Milky Way

- ***Nature has given us some breaks***
  - *Radiative transfer is simple – once γ-rays are produced, they propagate without scattering or absorption*
  - *CRs tend to be much more smoothly distributed than the interstellar gas*
  - *Good tracers of the gas exist for most regions, with Doppler shift measurements obviating to a large extent the disadvantage of our in-plane perspective*

Modeling diffuse emission: need for new data

- ***Extend CO surveys to high latitudes***
  - *newly-found small molecular clouds will otherwise be interpreted as unidentified sources, and clearly limit dark matter studies*



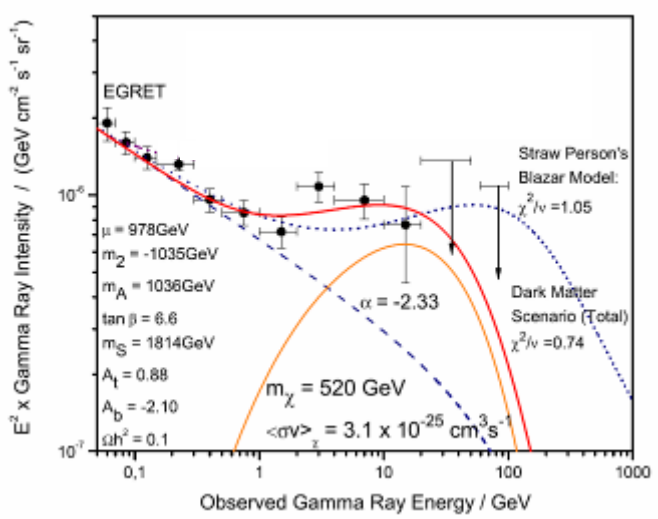
- **$C^{18}O$ *observations (optically thin tracer) of special directions (e.g. Galactic center, arm tangents)***
  - *assess whether velocity crowding is affecting calculations of molecular column density, and for carefully pinning down the diffuse emission*

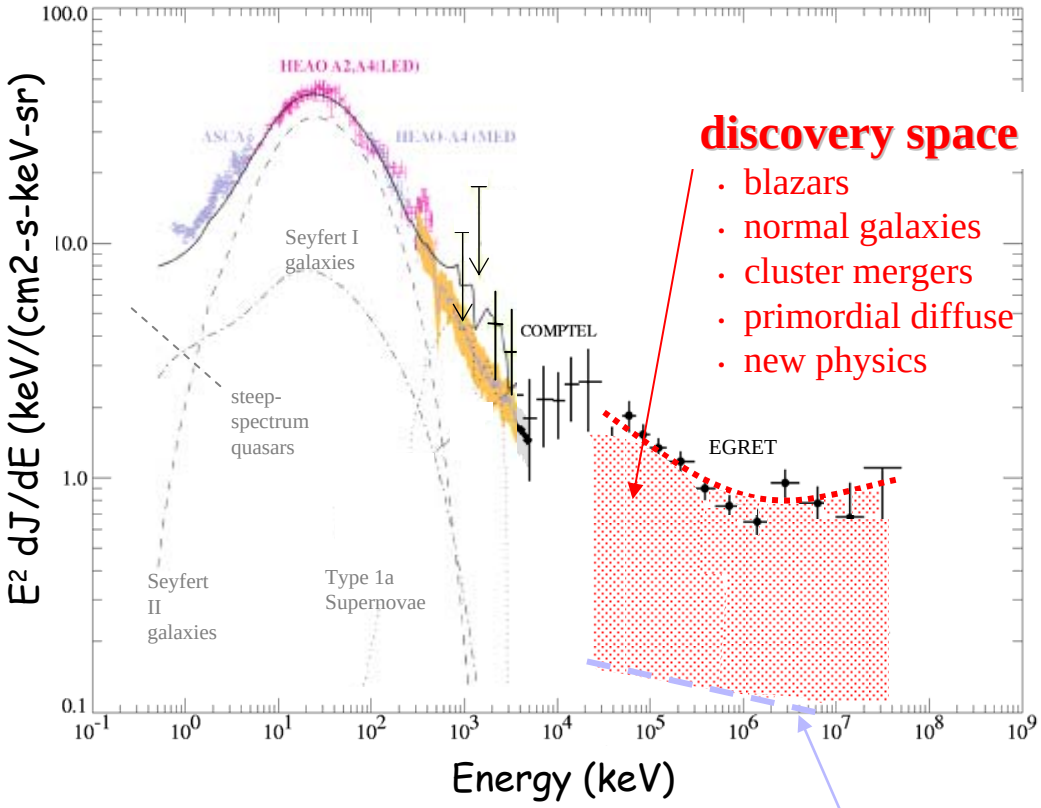
Extragalactic γ-ray background

- ***origin is a mystery; either sources there for GLAST to resolve (and study!) OR there is a truly diffuse flux from the early Universe***

EGRET constrains blazars to be > 25% of diffuse;

annihilation of cosmological neutralinos has, in principle, a distinctive spectral signature





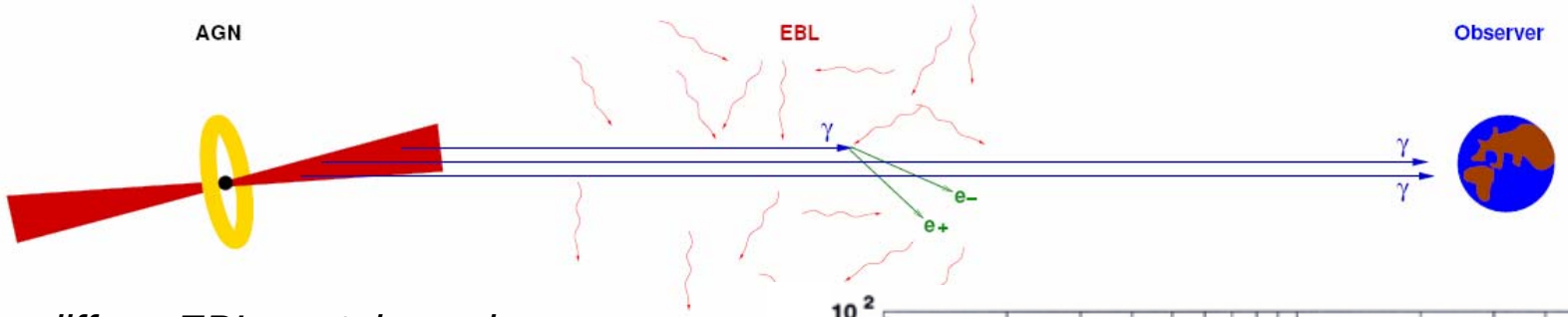
discovery space

- blazars
- normal galaxies
- cluster mergers
- primordial diffuse
- new physics

LAT baseline background limit

Elsässer & Mannheim, Phys. Rev. Lett. (2005)

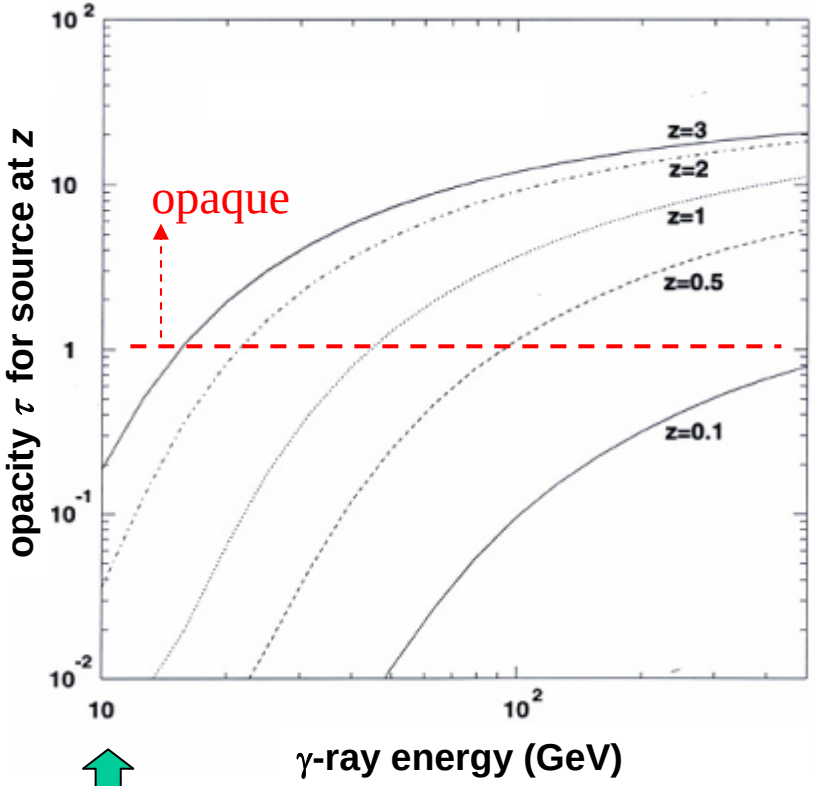
Probing Extragalactic Background StarLight with Blazars



- *diffuse EBL contains unique information about the epochs of formation and the evolution of galaxies and in what environments the stars of the universe formed*
- *direct EBL measurements require accurate model-based subtraction of bright foregrounds (e.g., zodiacal light)*
- *alternative approach: extract imprint of EBL absorption, as function of redshift, from high-energy spectra of extragalactic sources*

  $\gamma\gamma \rightarrow e^+e^-$, *maximum when*

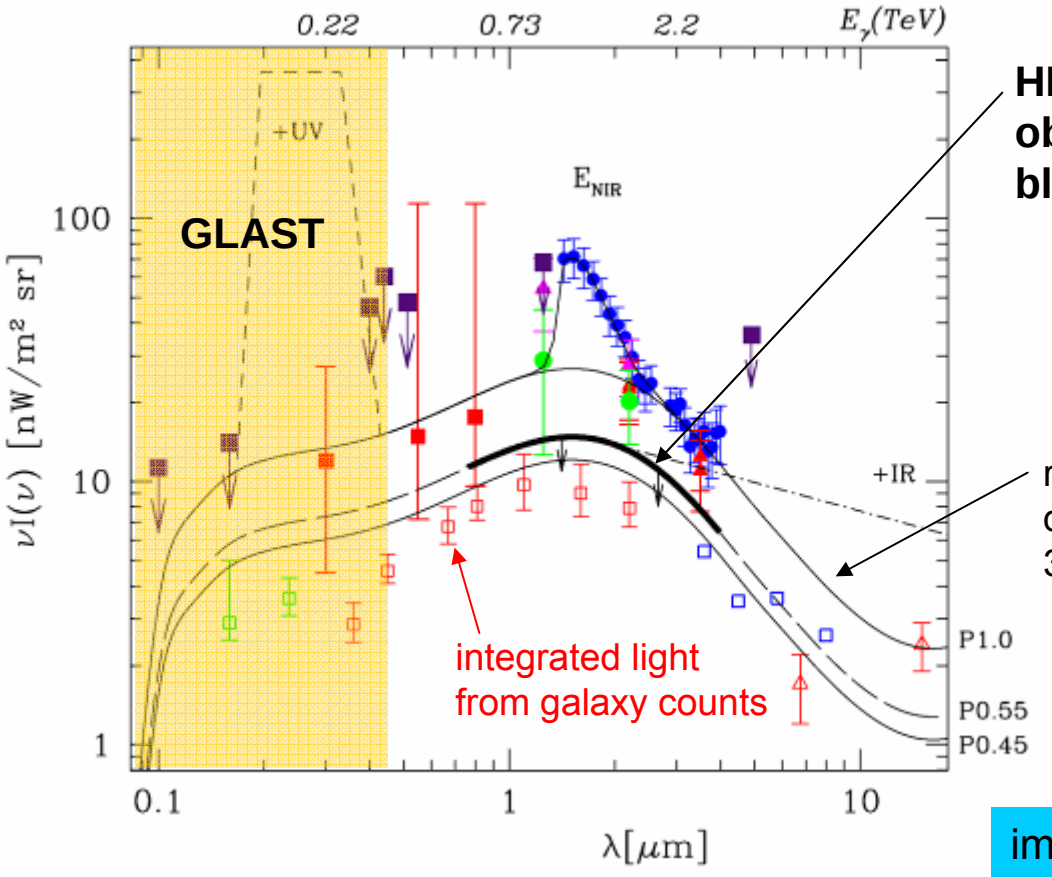
  $\varepsilon_{EBL} \sim ½ \text{ (1000 GeV / } E_\gamma\text{) eV}$



No significant attenuation below 10 GeV

Blazar constraints on EBL

EBL spectral energy distribution



HESS upper limit derived from observed hard spectra of blazars at z = 0.165 and 0.186

reference EBL SED, matches direct measurements at 2.2 and 3.5 μm.

important science for VERITAS, HESS, Magic, and GLAST

- *lower limits on HST galaxy counts combined with HESS upper limit on EBL imply that any unresolved component is no more than ~1/3 of the total.*

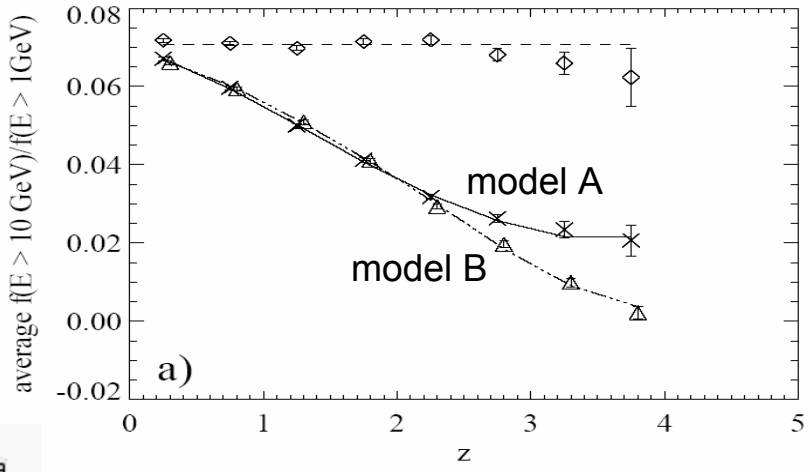
Probing Extragalactic Background StarLight with Blazars

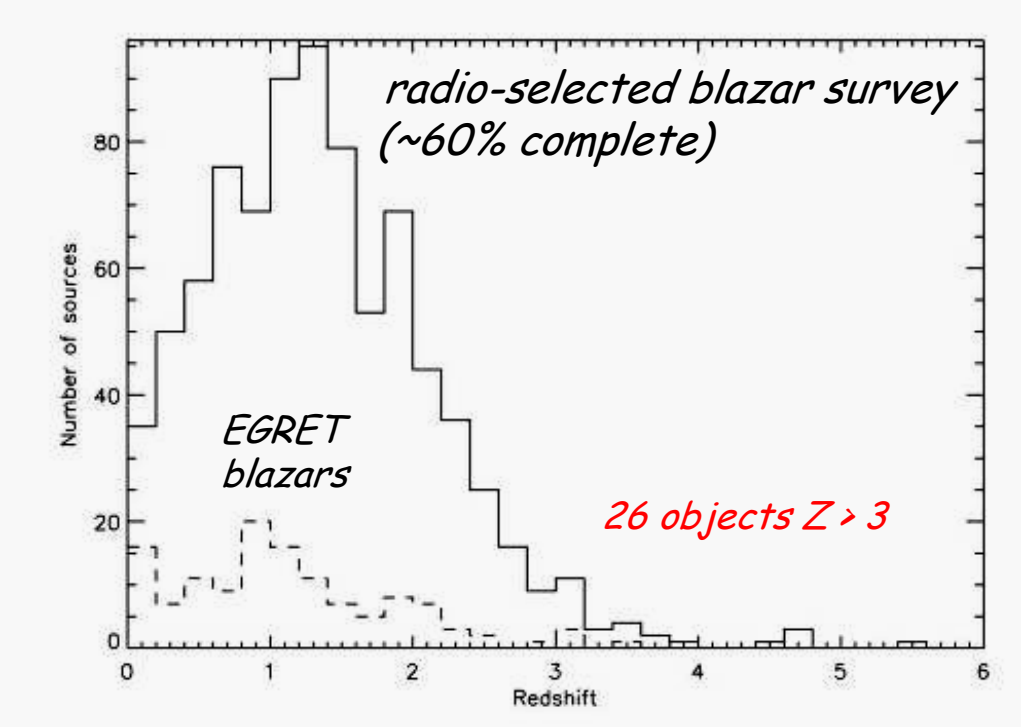
- *measure redshift dependence of flux attenuation above 10 GeV*
- *GLAST will sample high-z blazars*

sensitive to optical-UV EBL;

complements TeV measurements of nearby blazars that constrain the optical-NIR EBL

measure flux E>10 GeV/flux E>1 GeV





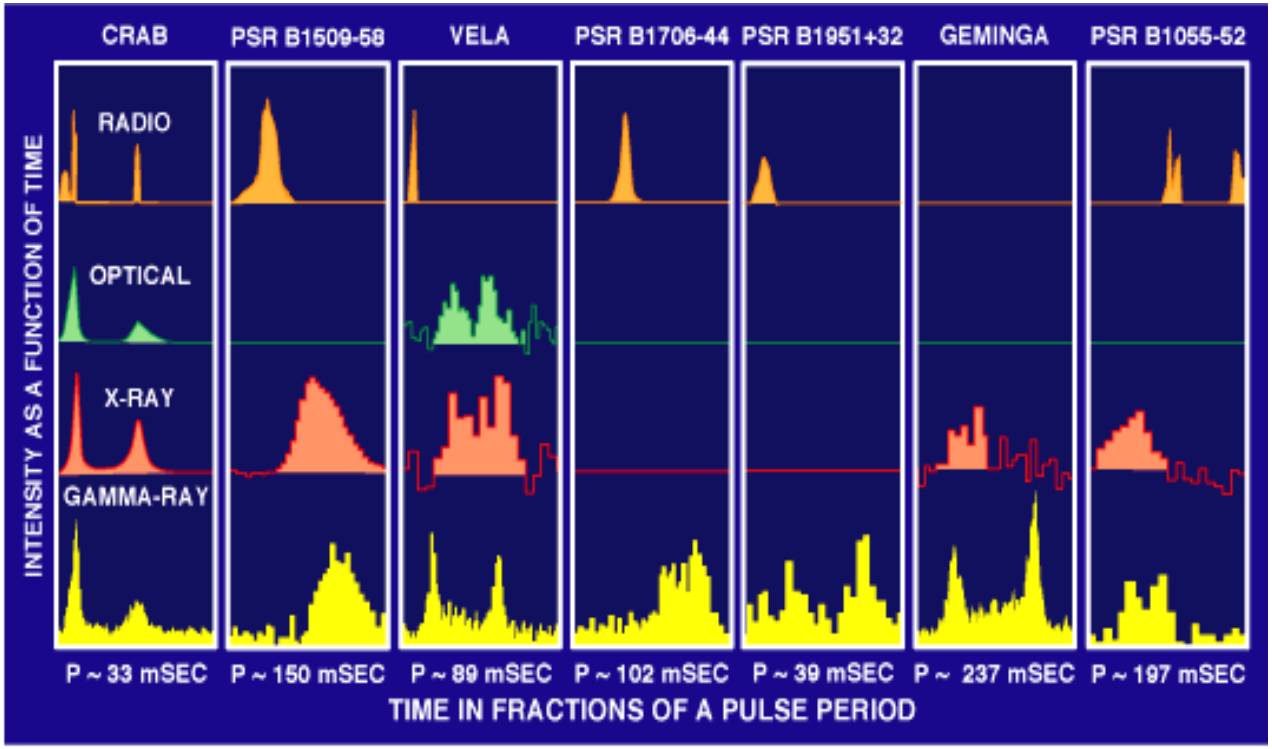
70% of EGRET sources (|b|>10°) are blazars

4.8 GHz radio survey; chose bright flat-spectrum sources

95% of radio-selected sources are blazars

Physics in the Extreme Environments of Pulsars

- ***sites of interactions in extreme gravitational, electric, and magnetic fields.***
- ***key to deciphering these extreme conditions is having accurate, absolute timing data for many pulsars.***
- ***with the exception of a few X-ray pulsars, radio band provides the needed timing information. A sizeable radio timing program is beyond the scope of routine radio pulsar programs.***



Multiwavelength light curves of gamma-ray pulsars

- their diversity shows the need for a larger sample with better detail, including phase-resolved spectra at all wavelengths.

Summary of Important Multiwavelength Needs

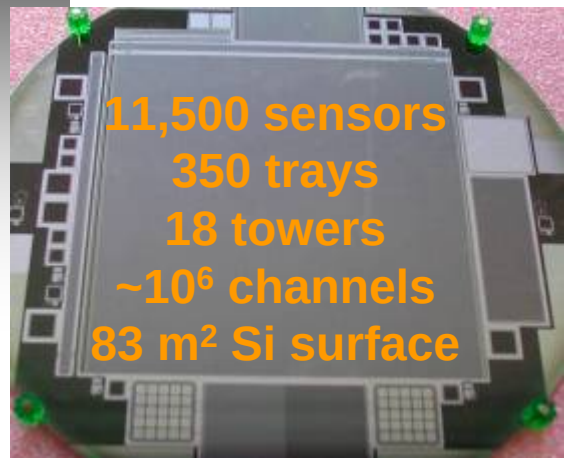
Science Objective	GLAST provides	multi-λ requirements
Differential measurement (vs *Z*) of extragalactic background light to *Z* ~5.5	Measurement of blazar spectra in band where cutoffs are expected from $\gamma + \gamma_{ebl} \rightarrow e^+ + e^-$	Broadband contemporaneous / simultaneous spectral measurements (radio, optical, X-ray, TeV) of blazar spectra, particularly around the synchrotron peak;
Resolve origin of particle acceleration and emission mechanisms in systems with relativistic jets, supermassive black holes	All-sky monitoring coverage of blazar flares and GRBs	radio and optical surveys of flat-spectrum radio sources to extend blazar catalogs
Reliable model of Milky Way diffuse emission required for accurate source localization and to facilitate search for dark matter	Mapping of cosmic ray interactions with all forms of interstellar matter.	Extend CO surveys to high galactic latitude; survey special directions (eg. spiral arms, galactic center) with optically thin tracer (e.g. $C^{18}O$)
Understand particle acceleration and emission mechanisms in extreme environment (gravity, electric and magnetic fields) of rotating neutron stars	Spectra and light curves resulting from primary interactions of the most energetic particles.	Contemporaneous radio and X-ray pulsar timing observations

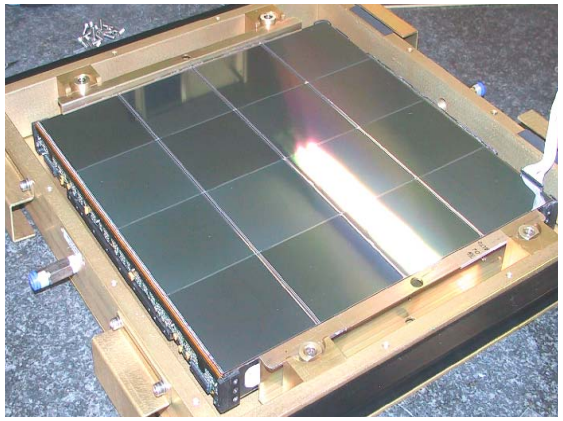
Summary

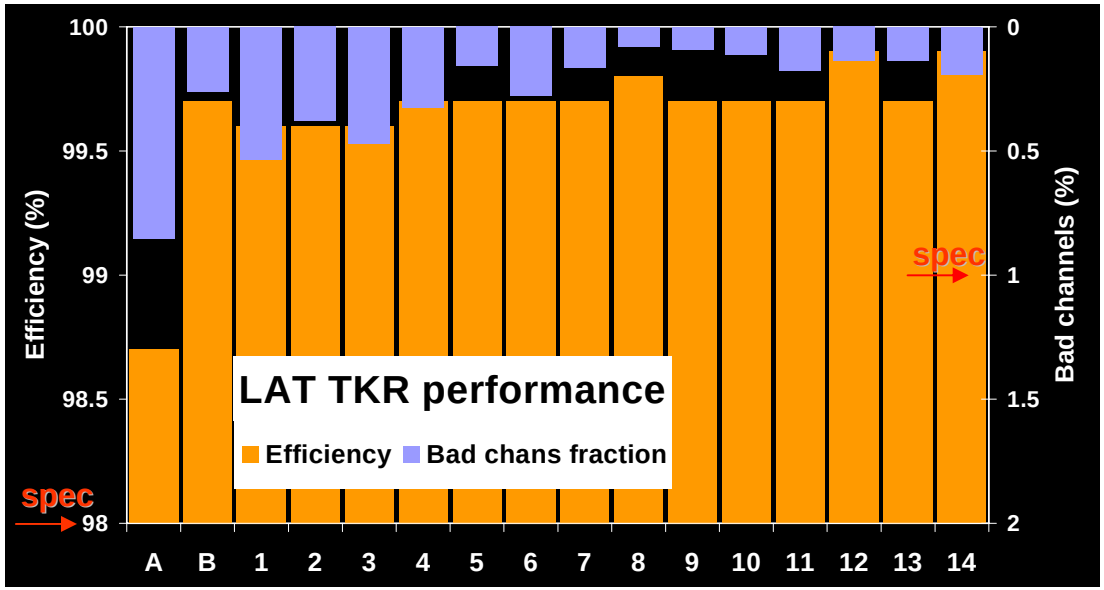
- ***LAT is coming together***
  - ***International partnership a success. THANKS TO ALL !***
- ***GLAST will provide a major new capability for addressing important science questions***
  - *extensive coordinated and, in some cases, simultaneous observations from radio to TeV energies, are needed to fully exploit GLAST data*
- ***Collaboration looking forward to launch of GLAST and beginning of science operations in September 2007***
  - *beam test planning underway*
  - *science analysis groups very active*

LAT Silicon Tracker

team effort involving physicists and engineers from Italy (INFN & ASI), Japan, and the United States

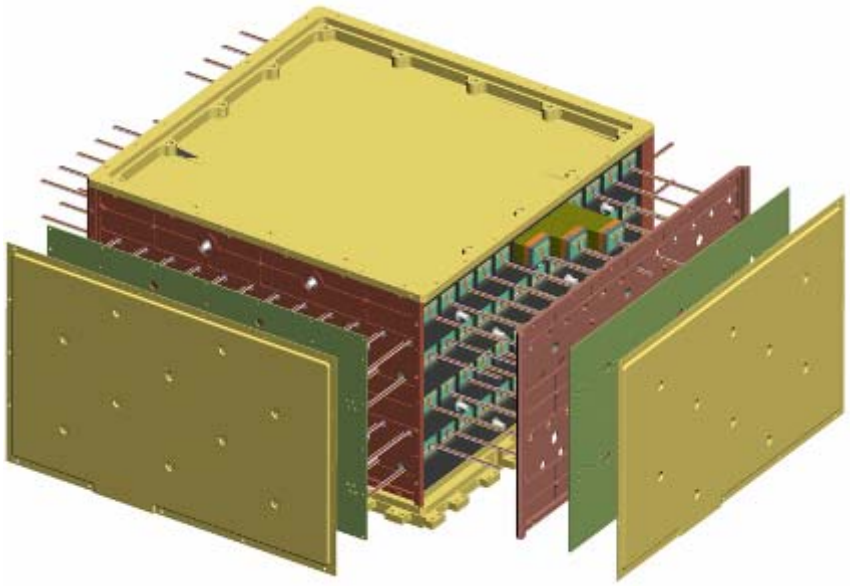


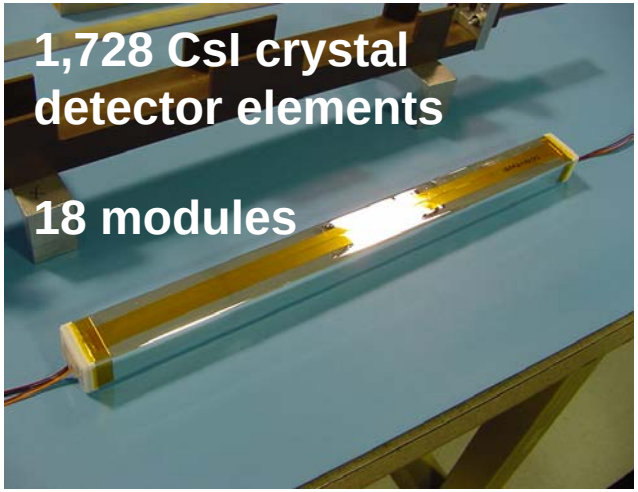


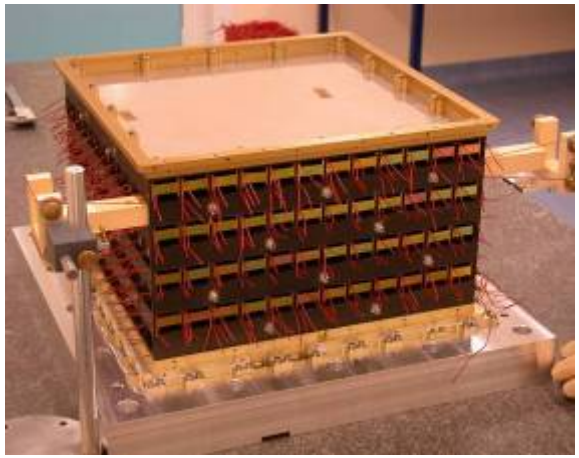


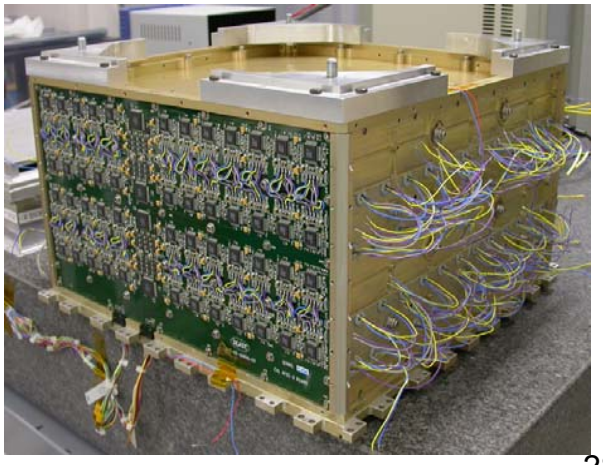
LAT Calorimeter

team effort involving physicists and engineers from the France (IN2P3 & CEA), Sweden, and the United States





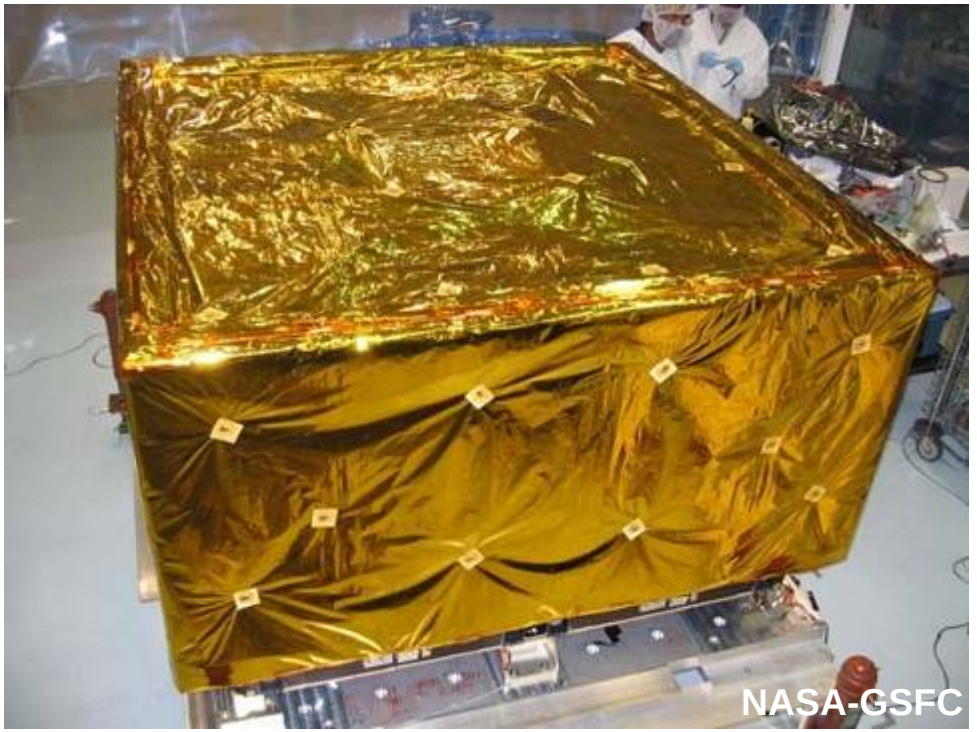




LAT Anti-Coincidence Detector

team effort involving physicists and engineers from Goddard Space Flight Center, SLAC, and Fermi Lab

ACD before installation of Micrometeoroid Shield



ACD with Micrometeoroid Shield and Multi-Layer Insulation (but without Germanium Kapton outer layer)