GLAST - Exploring the high-energy gamma-ray Universe

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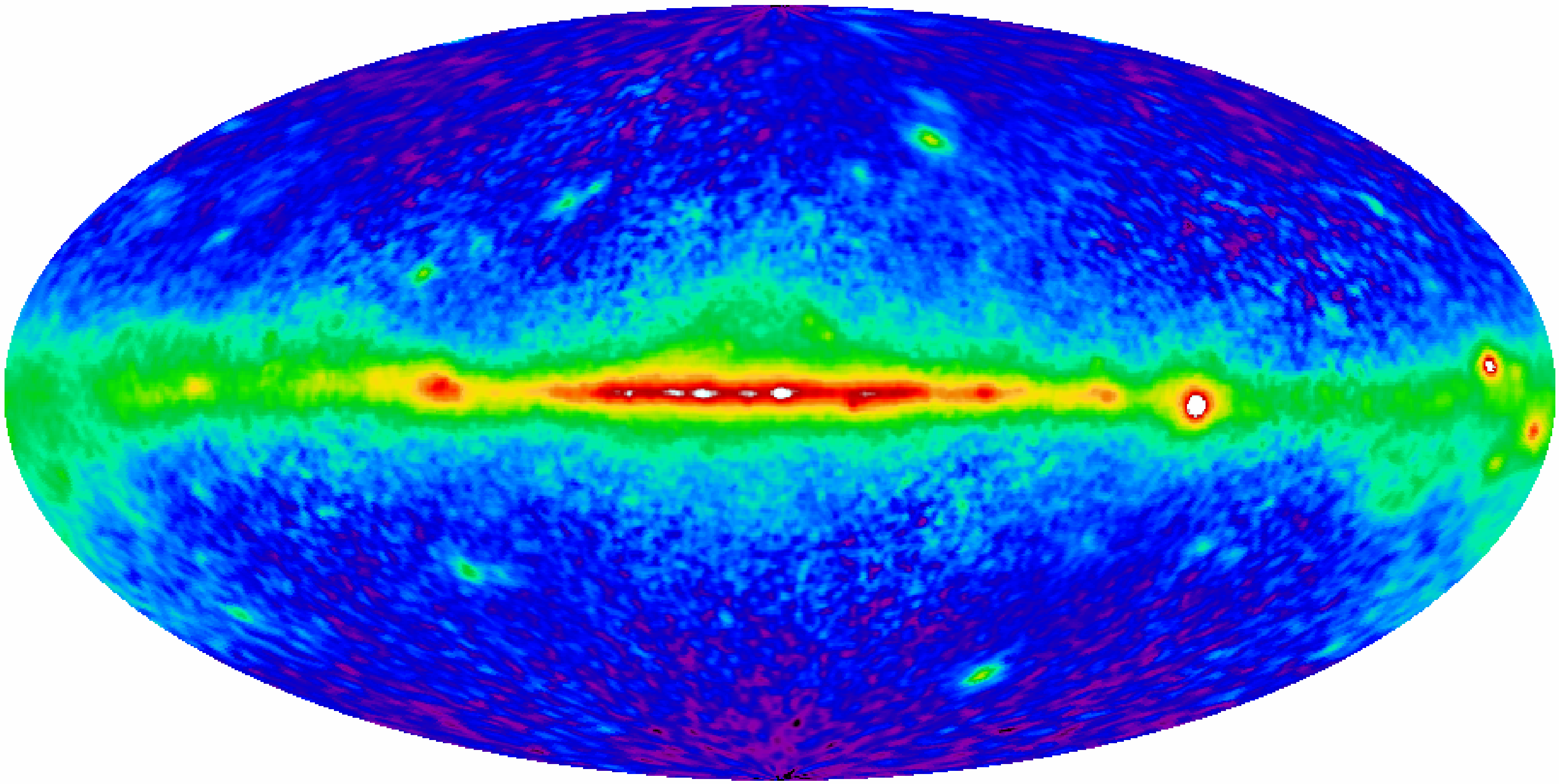
(many thanks to the members of the LAT DM&NP working group for figures and suggestions for this talk)

Outline

- The High Energy Gamma-ray sky
- Prospects for Dark Matter Searches
- GLAST
  - Instruments and performance
- Conclusions

The high-energy gamma-ray sky

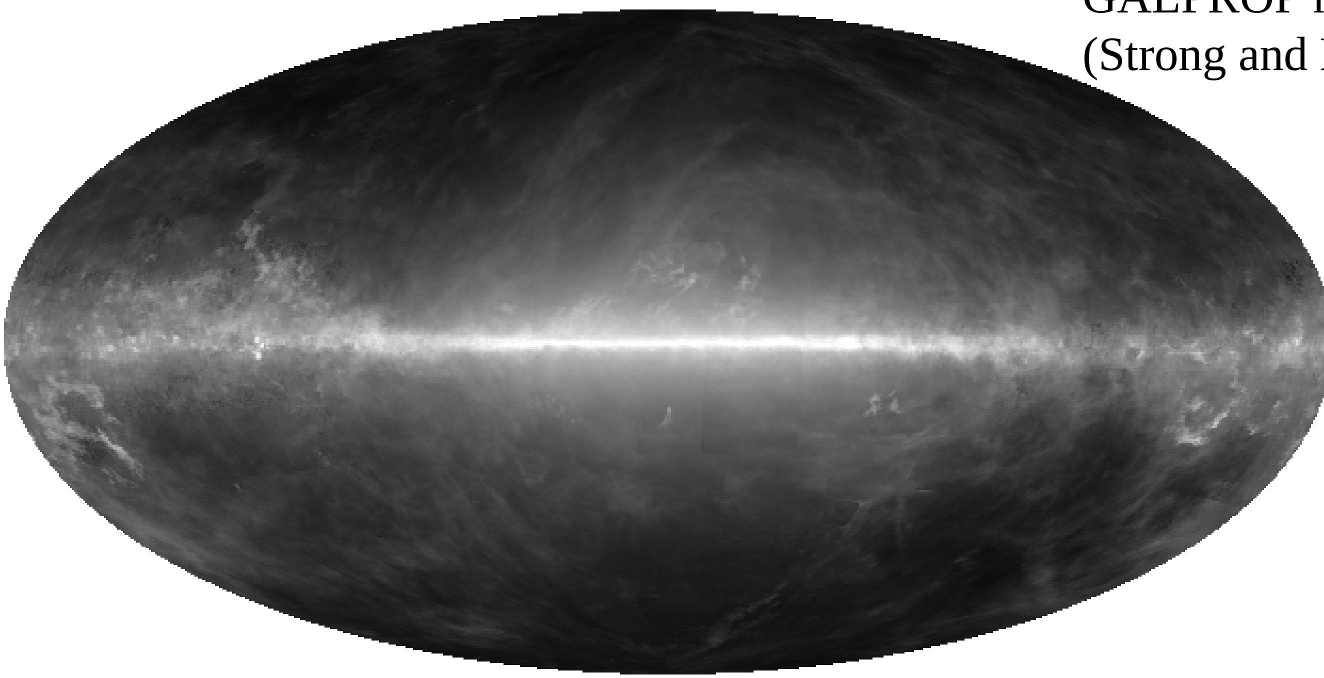
- **EGRET sky map (>100 MeV)**



Galactic Diffuse emission

- **Interaction of cosmic-rays with interstellar gas and radiation fields in our Galaxy**

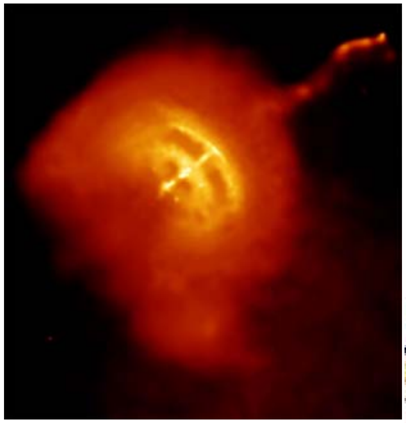
GALPROP model
(Strong and Moskalenko)

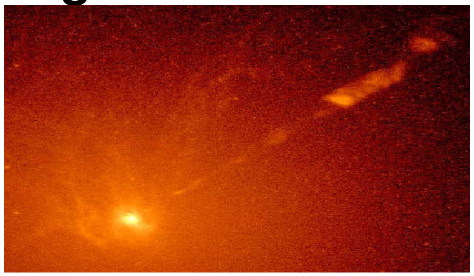


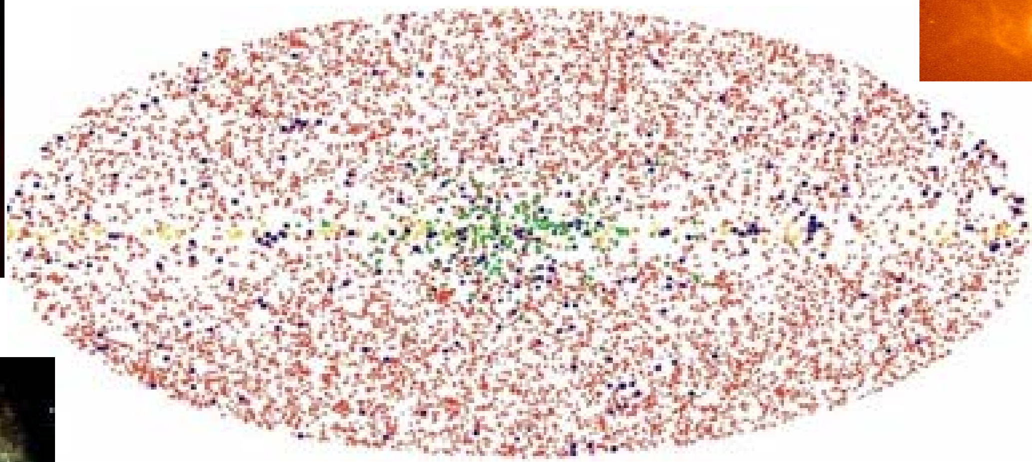
Dominant source of high energy gamma-rays (>80% of total)

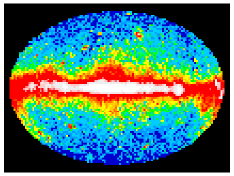
Discrete sources

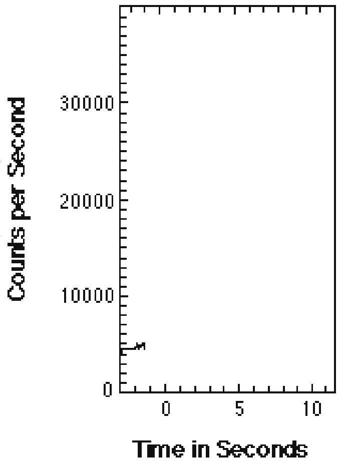
- **Pulsars, Active Galactic Nuclei, supernova remnants, gamma-ray bursts and more - Where the energetic things are!**







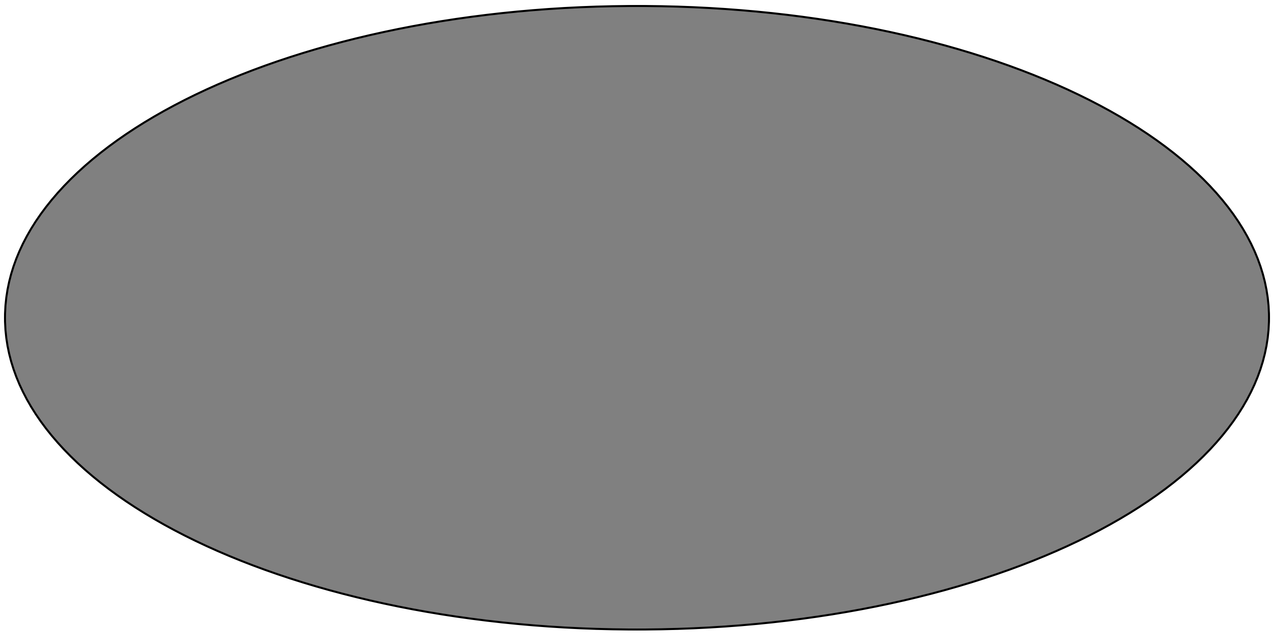




Julie McEnery

Isotropic/extragalactic diffuse emission

- **Unresolved sources - AGN, GRB, galaxies etc**
- **Truly diffuse/extended components - cascading TeV photons, UHECRs etc.**

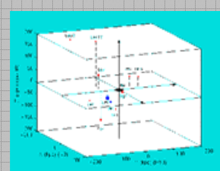
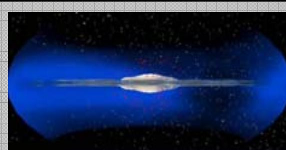


Other proposed sources of extragalactic diffuse emission

- **Structure formation in the intergalactic medium**
  - **Electrons accelerated at shock waves induced by gravity during formation of large scale structure scatter CMB photons to gamma-ray energies (e.g. Loeb and Waxman 2000, Gabici and Blasi 2002): 10%-75% of the EGRB**
- **Hadronic interactions in Galaxy clusters (e.g. Ensslin et al, 1997)**
- **Phase of baryon-antibaryon annihilation (Stecker et al 1971, Gao et al 1990, Dolgov and Silk 1993)**
- **Evaporation of primordial black holes (Hawking 1974, Maki, Mitsui and Orito 1996)**
- **Annihilation of dark matter particles (e.g. Ando and Komatsu 2006, Ullio 2002, Elsaesser and Mannheim 2005, Oda et al 2006, Jungman et al 1996)**
- **Kpc scale jets in FR1 radio galaxies (Stawarz et al, 2006)**
  - **Magnetic fields must be less than 10 μG on average as otherwise the extragalactic gamma-ray background would be overproduced.**

- **Signatures of dark matter may be found in any of these 3 components.**
  - **Need to both detect gamma-rays from particle dark matter and have enough information to recognize what we have detected.**

Prospects for dark matter searches

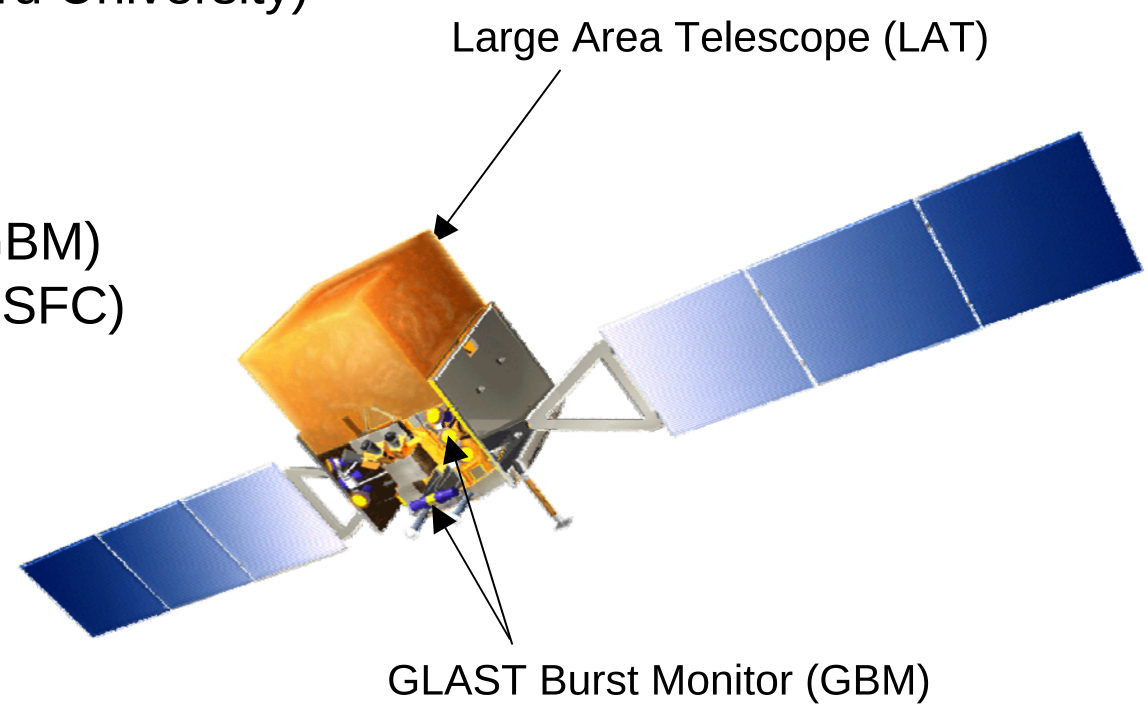
Search Technique	advantages	challenges
Galactic center 	Good Statistics	Source confusion/Diffuse background
Satellites, Subhalos, 	Low background, Good source id	Low statistics
Milky Way halo 	Large statistics	Galactic diffuse background
Extra-galactic	Large Statistics	Astrophysics, galactic diffuse background
Spectral lines	No astrophysical uncertainties, good source id	Low statistics

GLAST - The next step forward

Two Instruments:
Large Area Telescope (LAT)
PI: P. Michelson (Stanford University)
 20 MeV - >300 GeV
 >2.5 sr FoV

GLAST Burst Monitor (GBM)
PI: C. Meegan (NASA/MSFC)
 8 keV – 30 MeV
 >9 sr FoV

Launch: Early 2008
Lifetime: 5 years (req)
 10 years (goal)



GLAST LAT Collaboration

United States

- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Astroparticle Physics Laboratory
- 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)

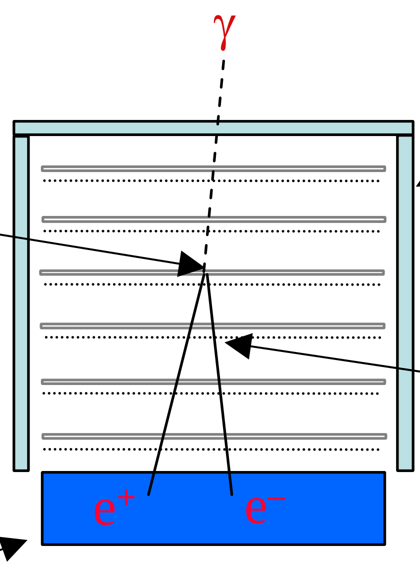
Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

Managed at Stanford Linear Accelerator Center (SLAC).

Pair Conversion Technique

photon converts to an e+e- pair in one of the conversion foils

The anti-coincidence shield vetos incoming charged particles.



The directions of the charged particles are recorded by particle tracking detectors, the measured tracks point back to the source.

The energy is measured in the calorimeter

Tracker: angular resolution is determined by:
multiple scattering (at low energies) => Many thin layers
position resolution (at high energies) => fine pitch detectors

Calorimeter:
Enough X_0 to contain shower, shower leakage correction.

Anti-coincidence detector:
Must have high efficiency for rejecting charged particles, but not veto gamma-rays

The GLAST Large Area Telescope

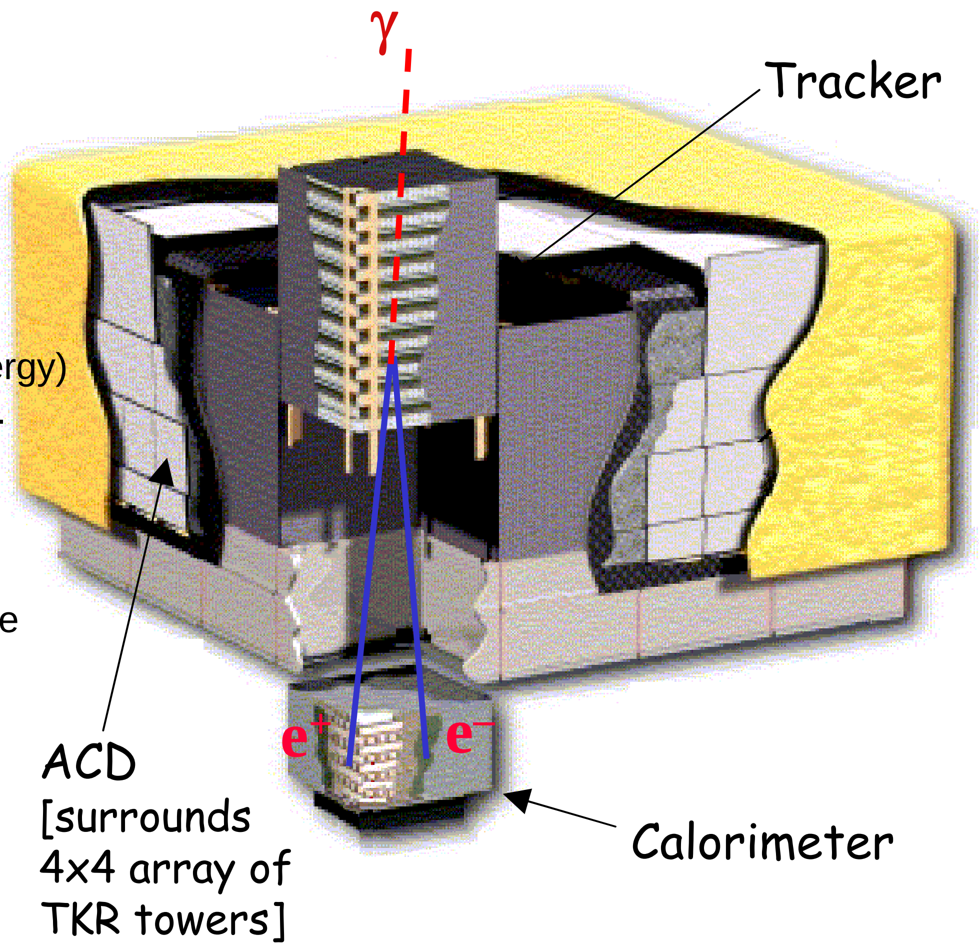
Overall LAT Design:

- 4x4 array of identical towers
- 3000 kg, 650 W (allocation)
- 1.8 m × 1.8 m × 1.0 m

- **Precision Si-strip Tracker (TKR)**
  18 XY tracking planes. 228 μm pitch).
  High efficiency.
  Good position resolution (ang. resolution at high energy)
  12 x 0.03 X0 front end => reduce multiple scattering.
  4 x 0.18 X0 back-end => increase sensitivity >1GeV

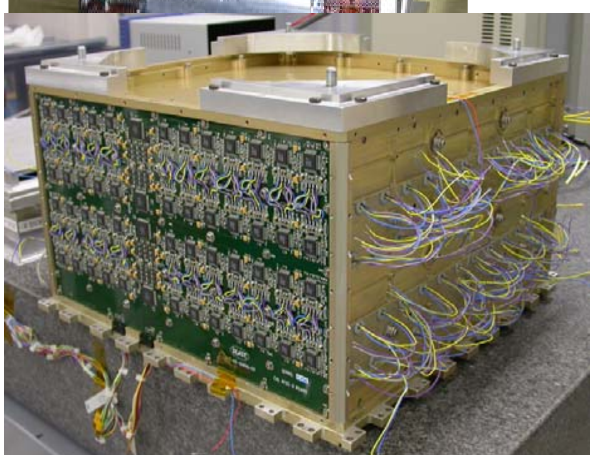
- **CsI Calorimeter(CAL)**
  Array of 1536 CsI(Tl) crystals in 8 layers.
  Hodoscopic => Cosmic ray rejection, shower leakage correction.
  8.5 X0 => Shower max contained <100 GeV

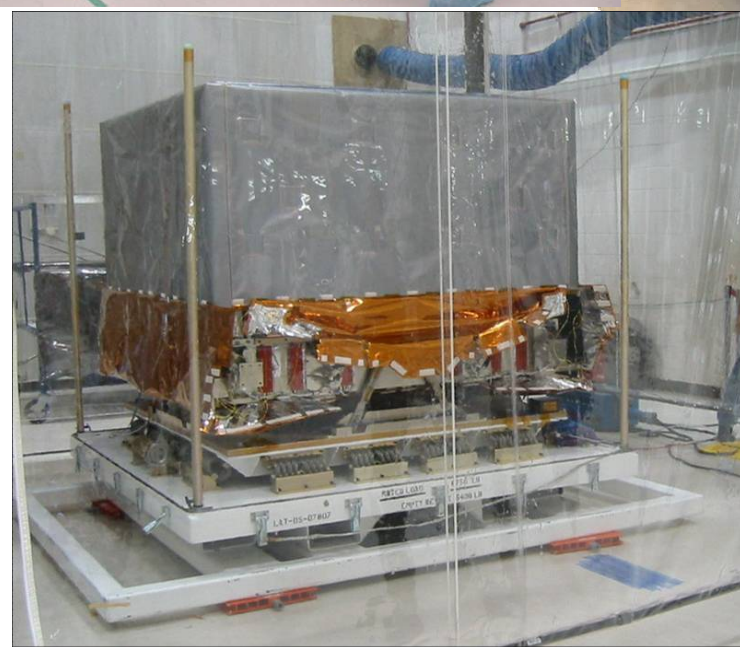
- **Anticoincidence Detector (ACD)**
  Segmented (89 plastic scintillator tiles)
  => minimize self veto



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

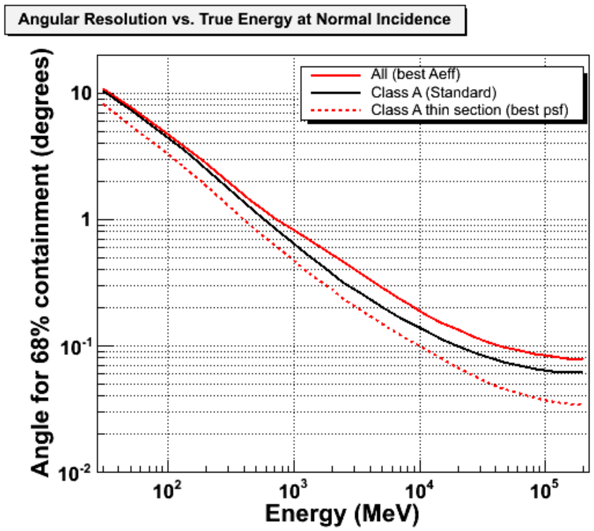
LAT Construction

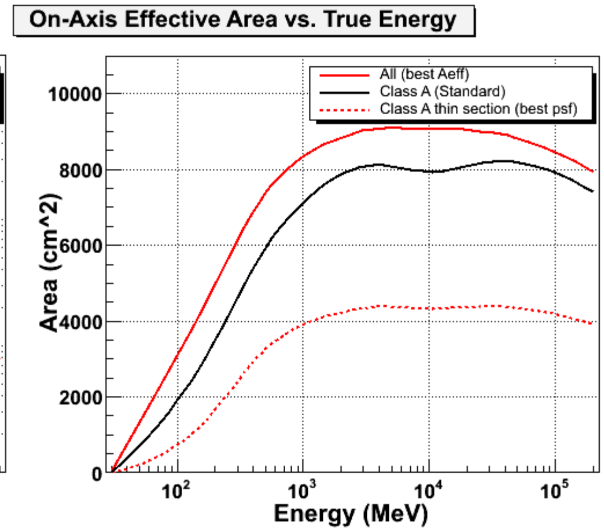


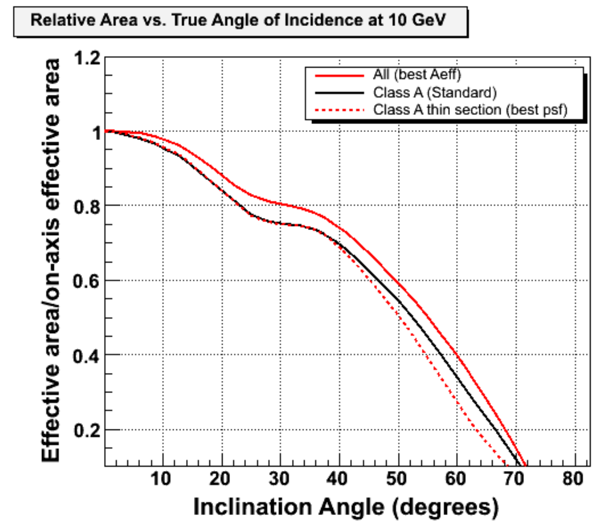


An Observatory

LAT Performance



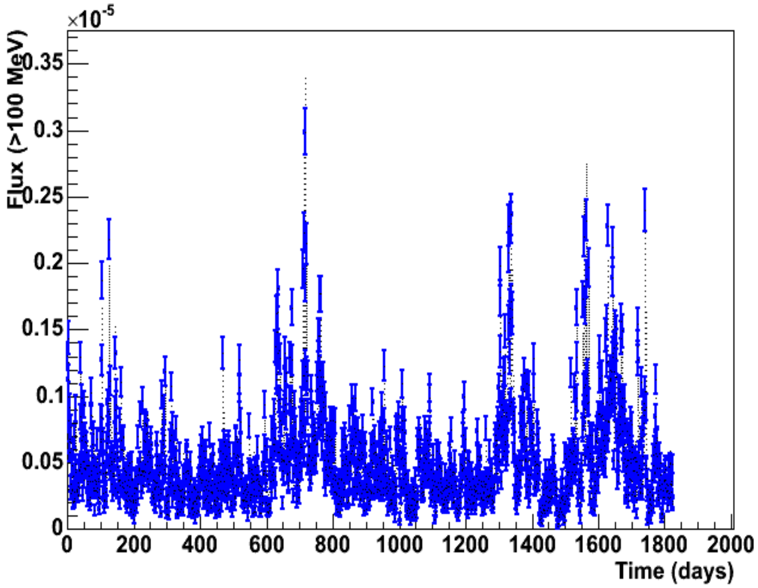


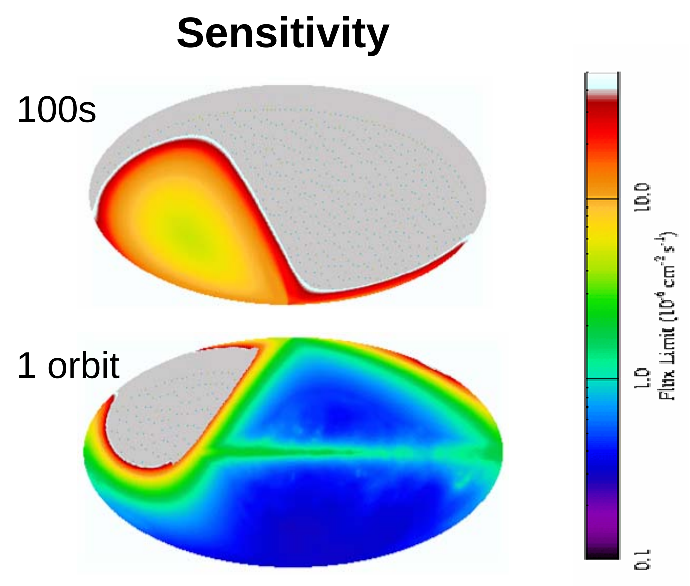


Apply cuts to make event selections optimized for specific science goals.

	GLAST/LAT	EGRET
Energy Range	20 MeV - >300 GeV	30 MeV – 30 GeV
Energy Resolution	0.1	0.1
Effective Area	>8000 cm^2	1500 cm^2
Field of View	>2.2 sr.	0.5 sr.
Angular Resolution	3.5 @ 100 MeV 0.1@10 GeV	5.8@100 MeV 0.5@10 GeV
Sensitivity (>100 MeV)	$3x10^{-9}$ cm^{-2} s^{-1}	$\sim 10^{-7}$ cm^{-2} s^{-1}
Deadtime	27 μs	100ms

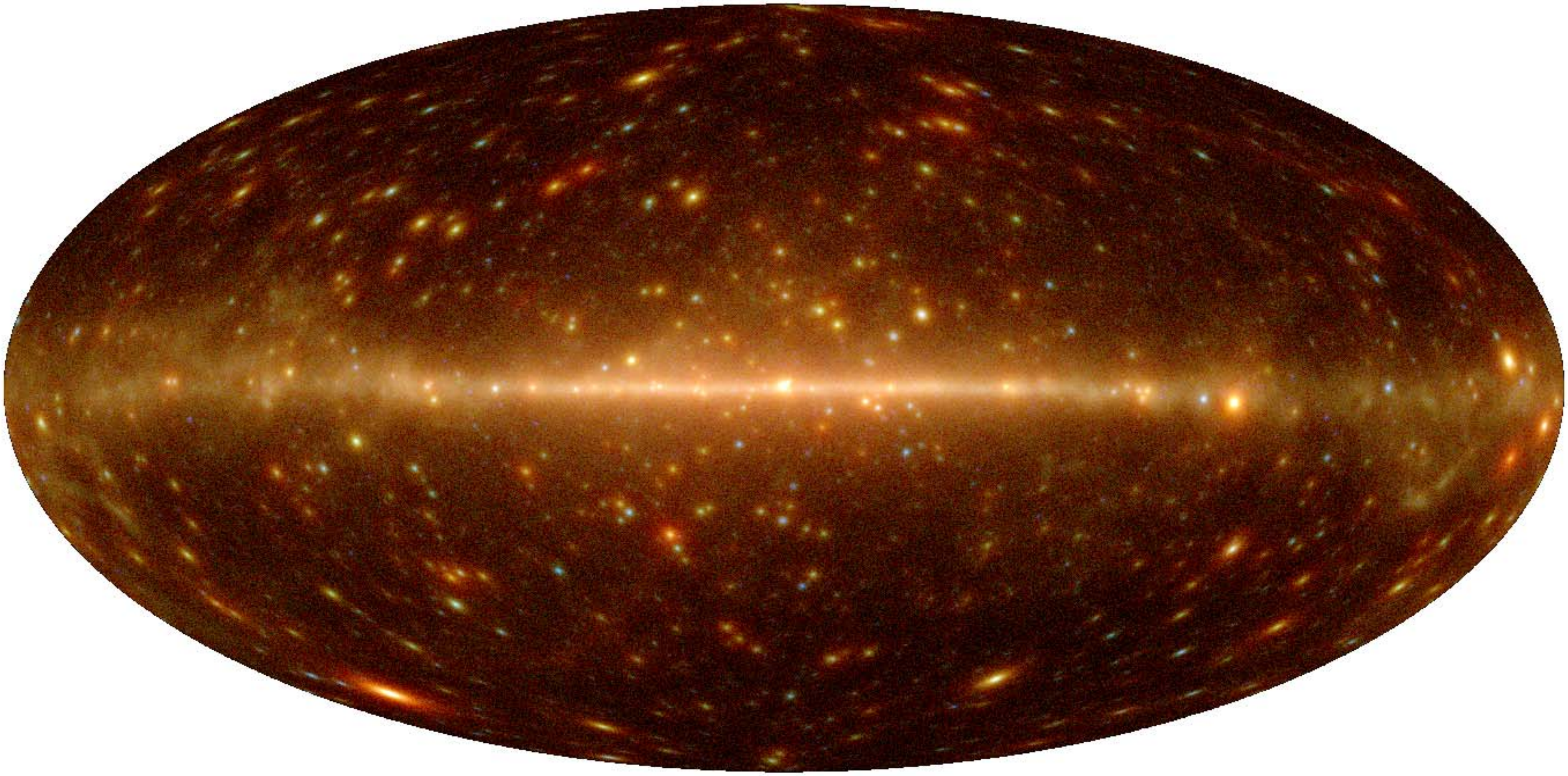
Operating mode





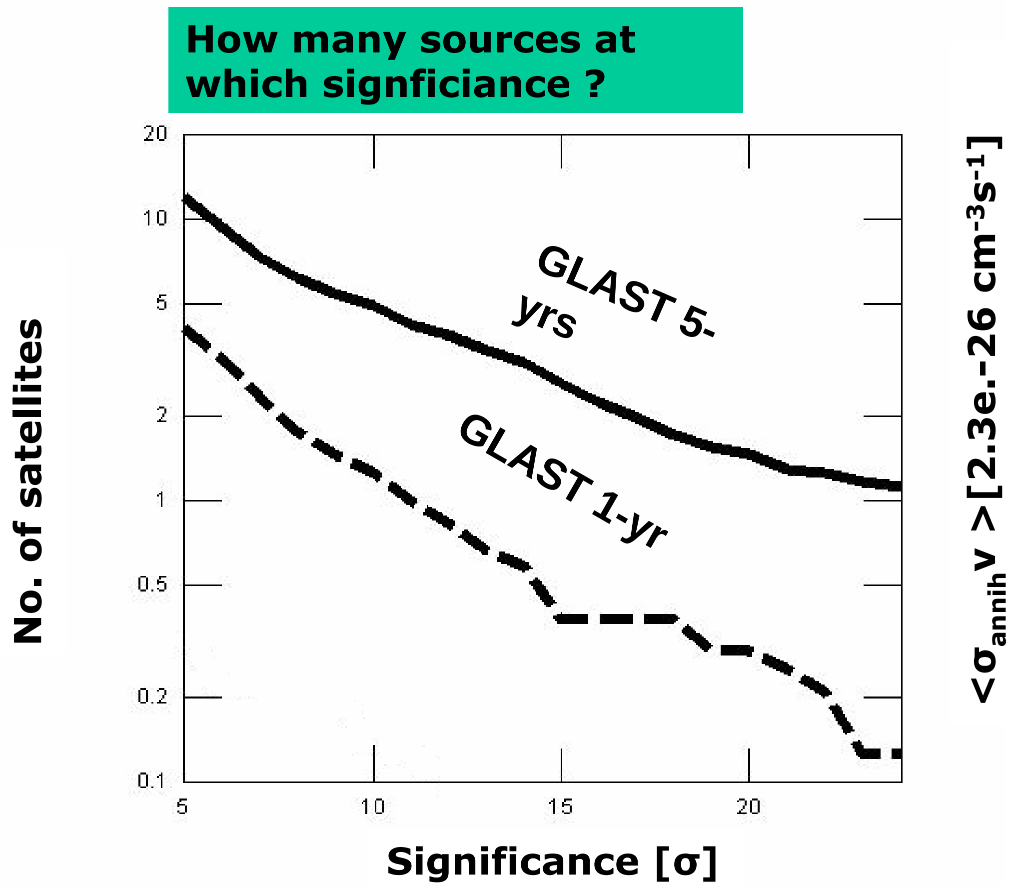
- **LAT has a huge field of view >20% of the sky (>2.5 sr)**
  - **Excellent for "catching" transients (GRB/Solar flares)**
- **Efficient observing -- we don't waste time looking at the Earth.**
- **In survey mode, the LAT observes the entire sky every two orbits (~3 hours), each point on the sky receives ~30 mins exposure during this time.**
- **The LAT will be able to monitor variability over a wide range of timescales - minutes to years.**

From EGRET (all years) to GLAST (1 year)



Dark Matter satellites/sub-halo ("generic" WIMP Model)

Improved sensitivity means that we can detect things that were previously invisible!

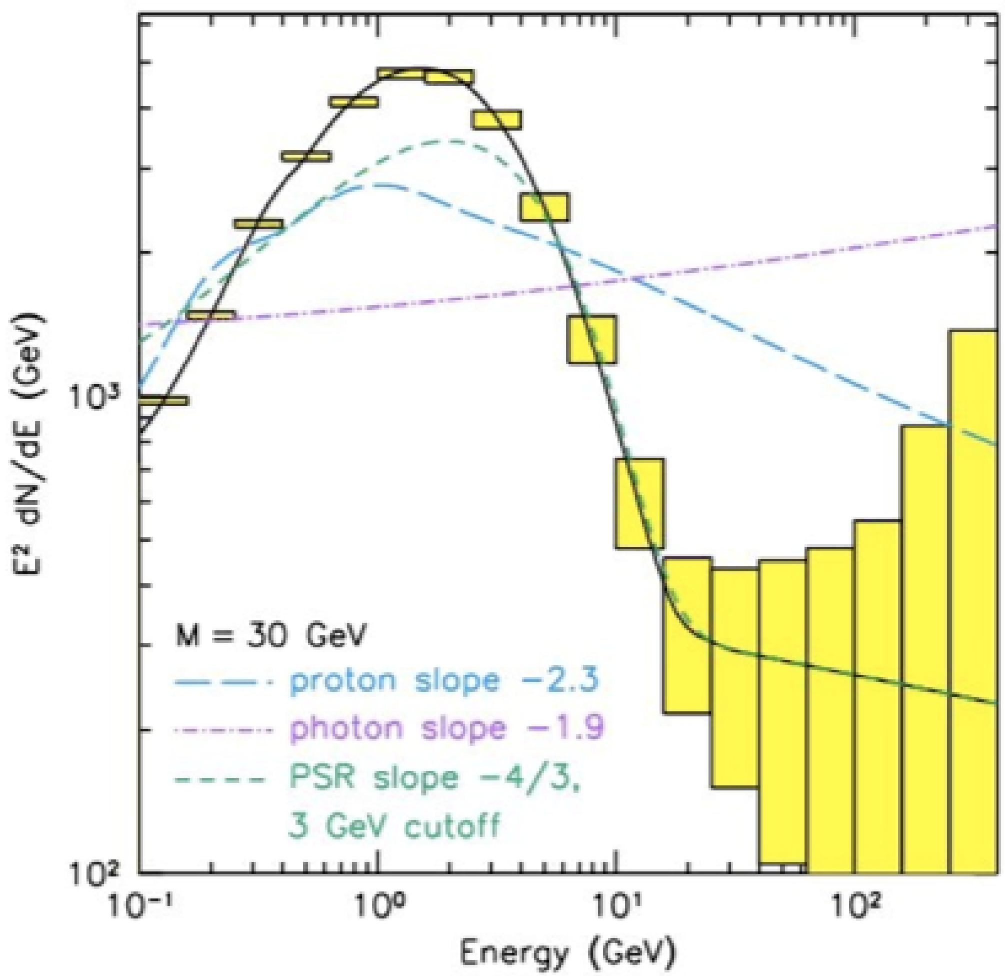


- Semi-analytic models of halo substructure from Taylor & Babul, 2004, MNRAS
- Background estimate using EGRET above 1 GeV (point source subtracted) from Cillis & Hartman 2005.
- WIMP mass = 100 GeV

P. Wang et al, First Glast Symposium, 2007

Energy Range - Satellites/sub-halos

- The LAT covers a large energy range 20 MeV - >300 GeV
- This provides a wide lever-arm to identify unique or characteristic spectral shapes.
- Plot shows a spectrum from a dark matter satellite/clump (mass = 30 GeV) compared with spectra from typical astrophysical sources.



Baltz, Taylor and Wai (2006)

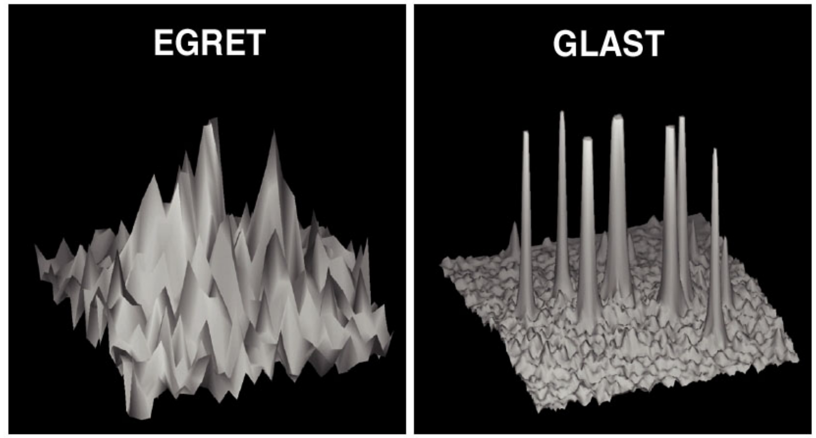
Angular resolution

- Source resolution and localisation will be greatly improved (1 - few 10s arcmin typically).

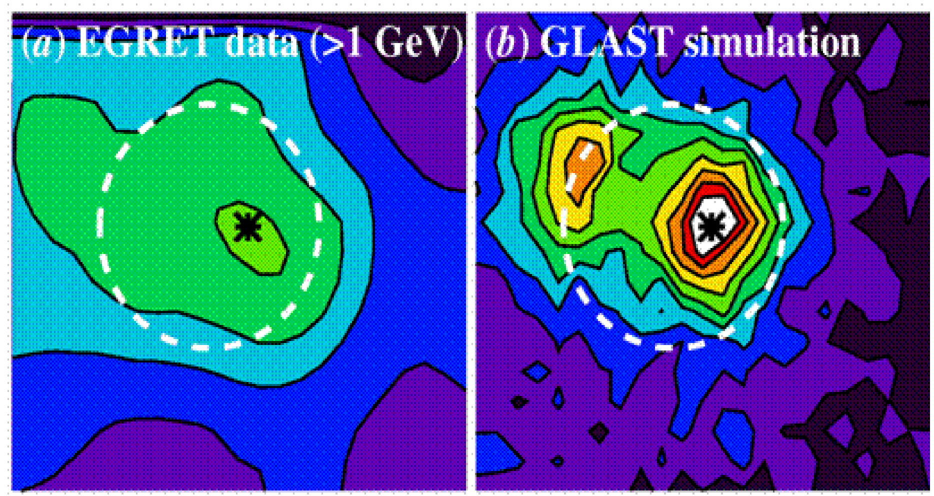
- Follow-up observations at longer wavelengths can confirm (or refute) a hypothesis that a gamma-ray source is a dark matter candidate.

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

- Everything gets better once we know what we are looking at!



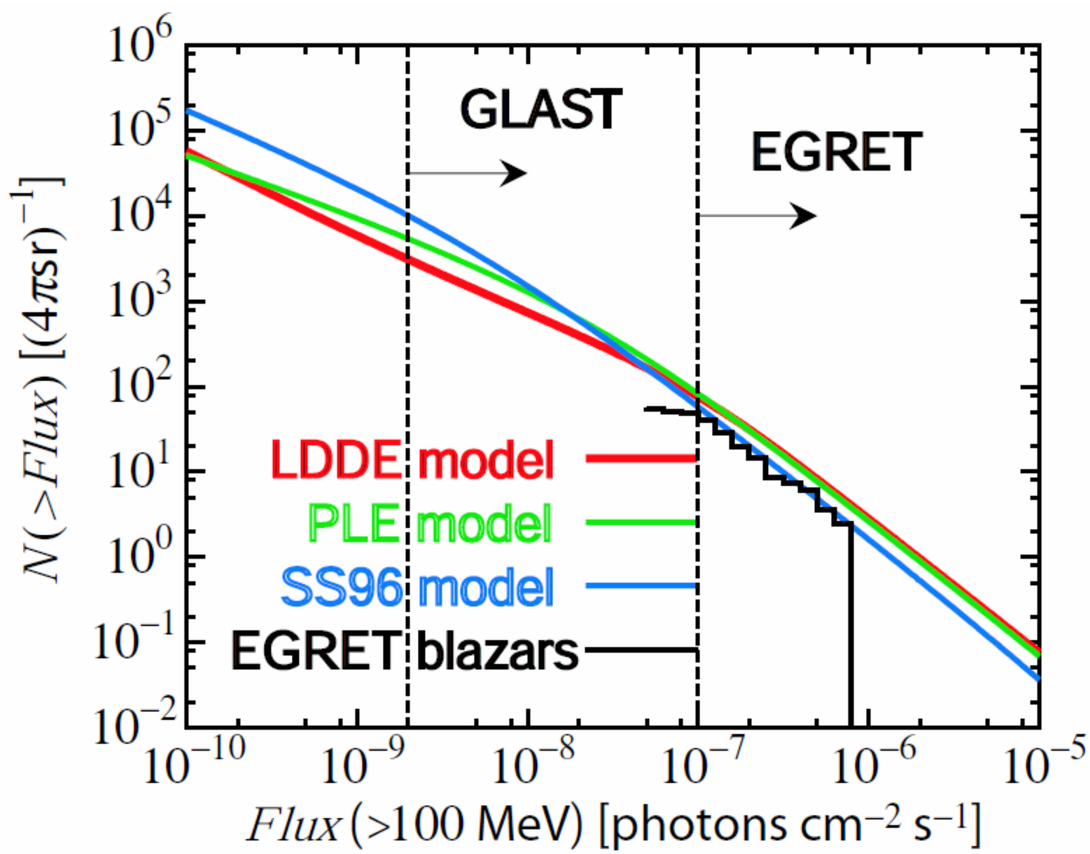
>1 GeV simulation of the cygnus region



γ-cygni simulation (SNR+pulsar)

GLAST AGN - how many?

- **Blazar luminosity function and its evolution can be constrained from the number count of GLAST blazars.**



Narumoto and Totani 2006

The number of blazars detectable by GLAST is

3000 - LDDE (~20% of EGRB)

5250 - PLE (~40% of EGRB)

10000 - SS96

c.f. ~70 with EGRET

The flux from these detected blazars will no longer be part of the extragalactic gamma-ray background (EGRB)

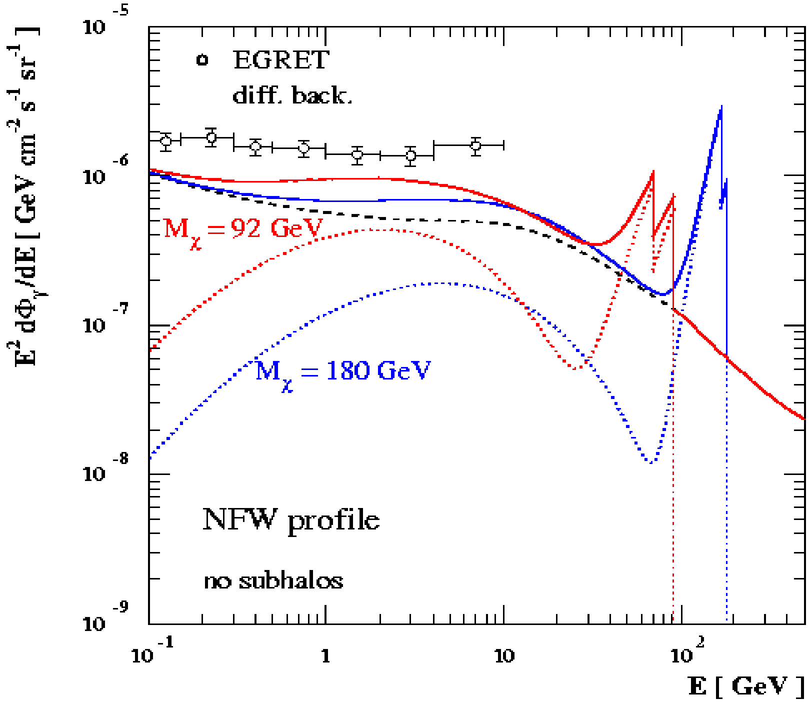
GLAST and the EBL at high energies

- **GLAST has excellent background rejection, large effective area and wide field of view and will provide well measured diffuse spectrum up to several hundred GeV.**
- **Point source contributions above ~100 GeV will be determined by ground based gamma-ray telescopes (CANGAROO, H.E.S.S., MAGIC, VERITAS and Milagro/HAWC).**

Measure the shape of the EBL from 10 GeV to 300 GeV - information about the cosmological distribution of extragalactic high energy gamma-ray sources and UV-optical-IR radiation fields.

Increasing the energy range and resolving point sources (decreasing limits on truly diffuse component) opens up window for new discoveries.

Ullio, Bergstrom & Edjso 2002



Conclusions

- **The launch of GLAST in early 2008 will open substantial new areas of discovery space.**
  - **Improved sensitivity and broad energy range may result in detections of dark matter sources**
  - **Improved angular resolution, energy range and flux monitoring provide us with the tools we need to characterize these sources.**
  - **Diffuse emission in the Galaxy will be measured to higher energy and to finer spatial scales (allowing for more detailed comparisons with models)**
- **GLAST LAT team is pursuing several complementary searches for signals of dark matter.**
- **In addition to all of this, GLAST will also detect and study thousands of the most interesting astrophysical sources in the sky at gamma-ray energies.**