Gamma-ray Large Area Space Telescope

X-ray Opportunities with GLAST

Julie Mc Enery

NASA/GSFC

What is GLAST

Two Instruments:

Large Area Telescope (LAT)

http://glast.stanford.edu/

PI: P. Michelson (Stanford University)

  20 MeV - 300 GeV

  >2.5 sr FoV

GLAST Burst Monitor (GBM)

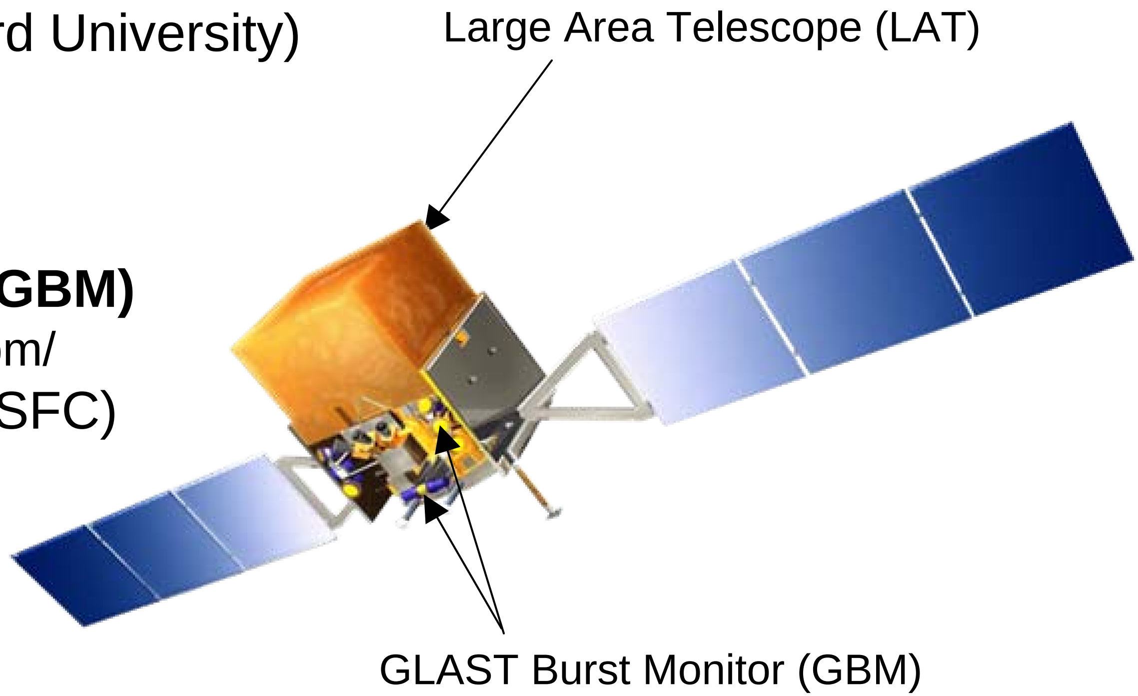
http://f64.nsstc.nasa.gov/gbm/

PI: C. Meegan (NASA/MSFC)

Co-PI: J Greiner (MPE)

  8 keV – 30 MeV

  9.5 sr FoV

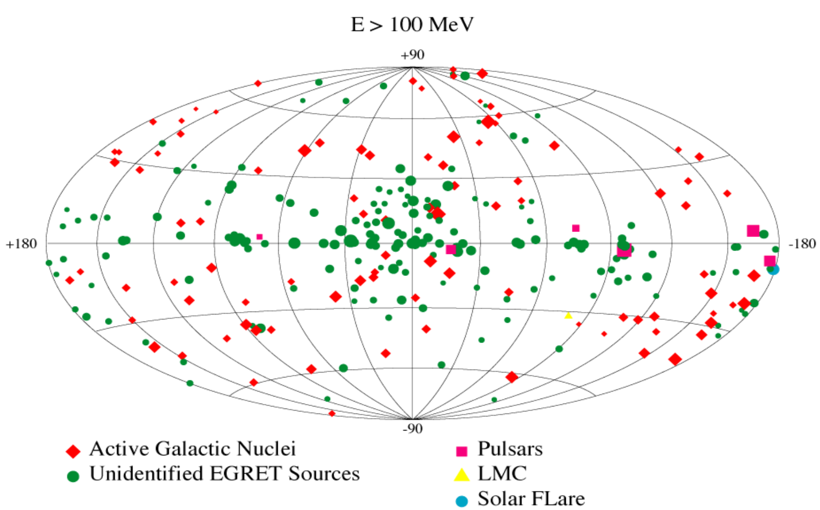


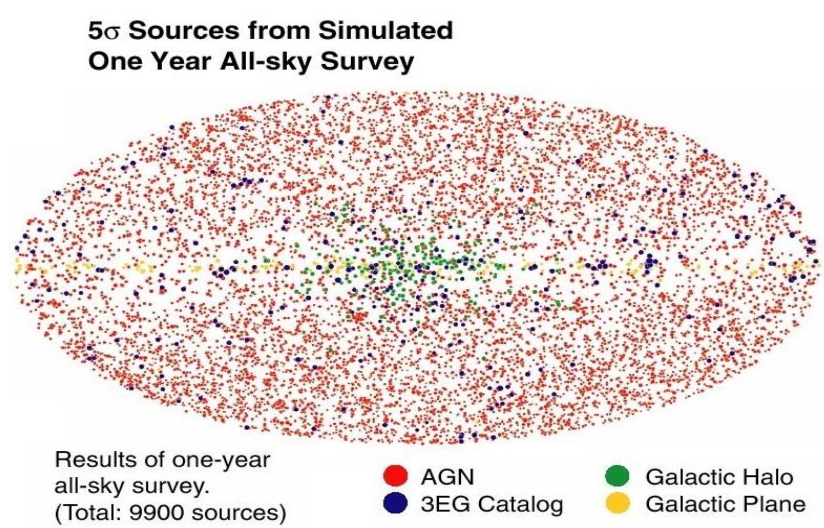
Launch: Spring 2008

Lifetime: 5 years (req), 10 years (goal)

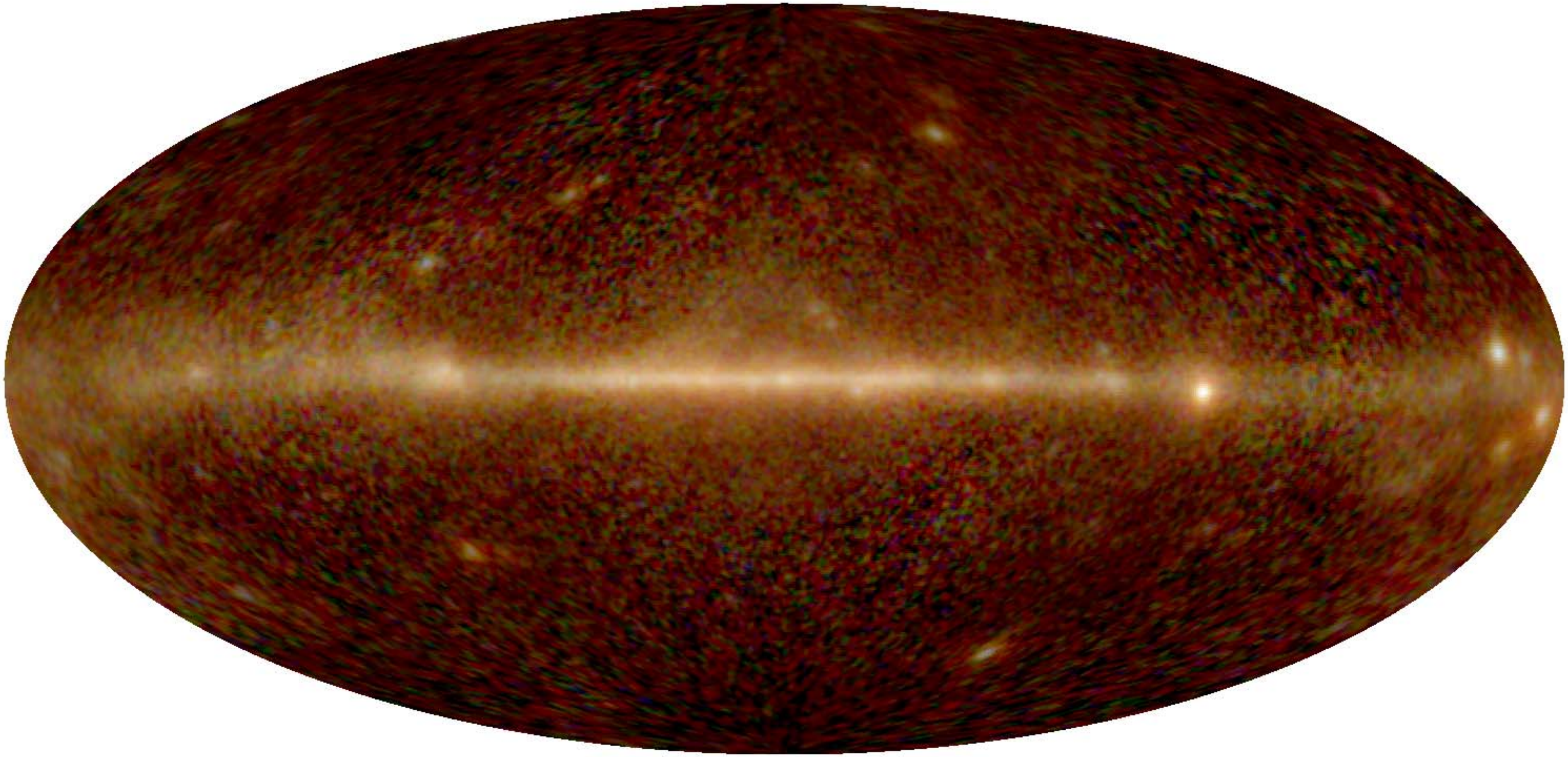
Why should you care about GLAST?

- High energy gamma-rays explore nature's accelerators - "Where the energetic things are"
- Huge improvement over previous missions in this waveband
  - Huge field of view, optimized for sky survey
    - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours.
  - Huge energy range, including largely unexplored 10 GeV - 100 GeV band
  - Will transform the HE gamma-ray catalog:
    - By > order of magnitude in number of point sources
    - Sub-arcmin localizations (source-dependent)
    - Map spatially extended sources



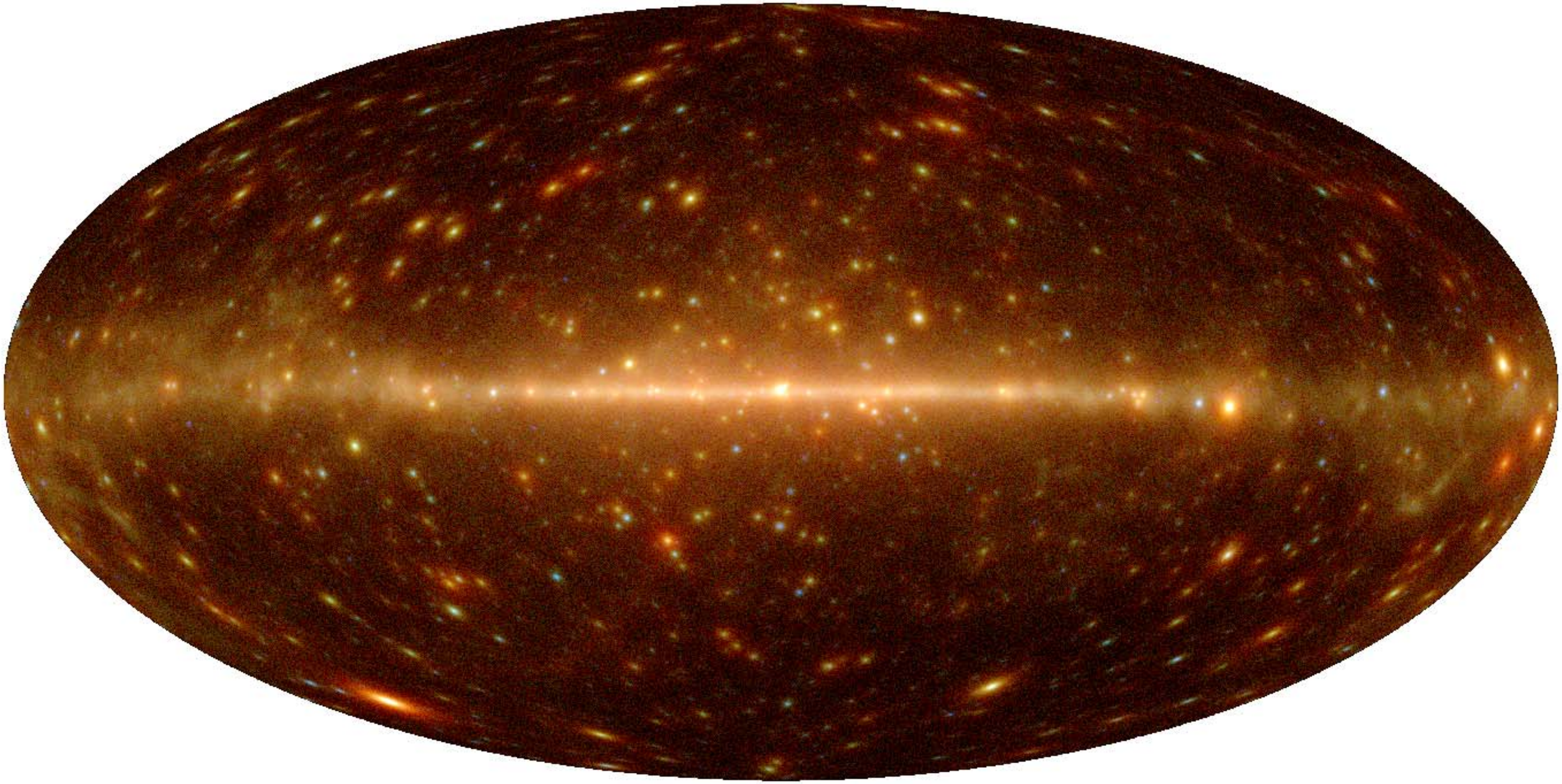


From EGRET (all years) to GLAST



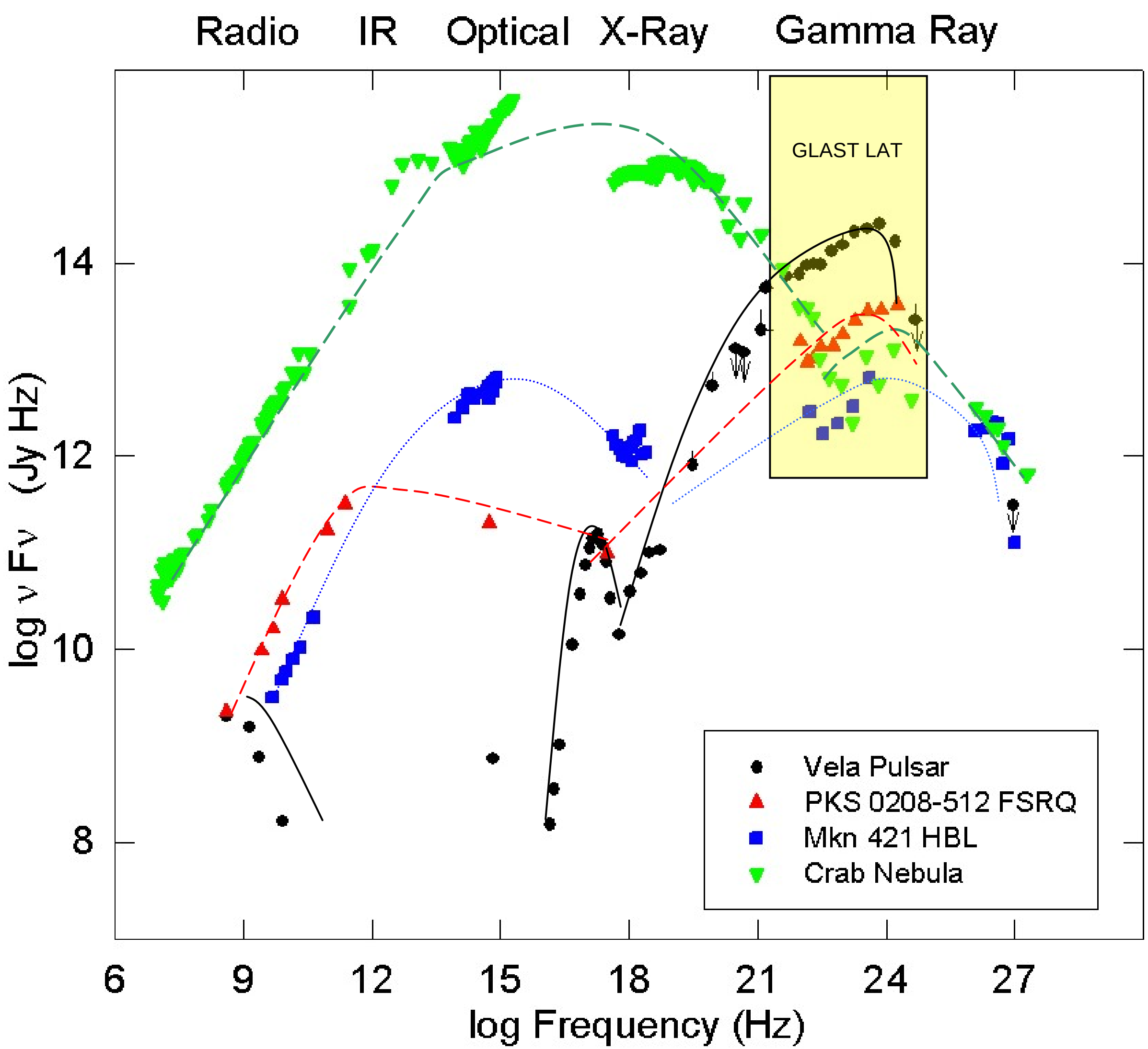
E>100 MeV

From EGRET to GLAST (1 year)



E>100 MeV

Multiwavelength gamma-ray sources



- Gamma-ray sources and non-thermal, typically produced by interactions of high energy particles.
- Known classes of gamma-ray sources are multiwavelength objects seen across much of the spectrum

What do MW observations provide?

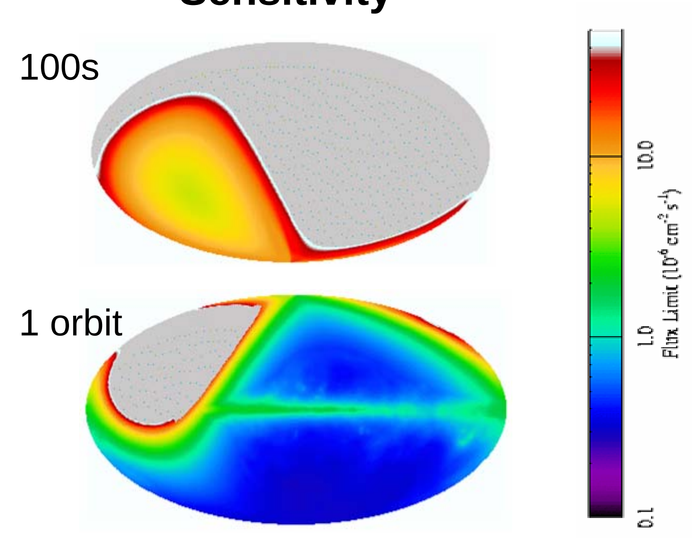
- View the same region via different emission mechanisms
- Broad band spectra and spectral evolution

- However, MW observations provide much more….
- Spectroscopy
  - Abundances and conditions near the emission region
  - distance
- Polarimetry
  - explore magnetic fields
- Complementary capabilities
  - Spatial resolution
  - Temporal resolution
- Timing - provide timing solutions for pulsars
- Source Identification - Guaranteed discovery!

Operating mode

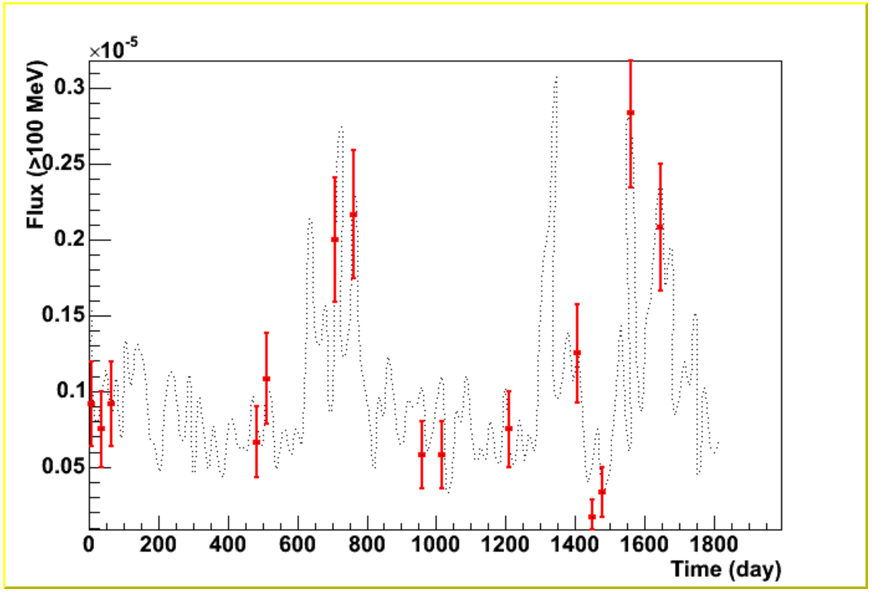
QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

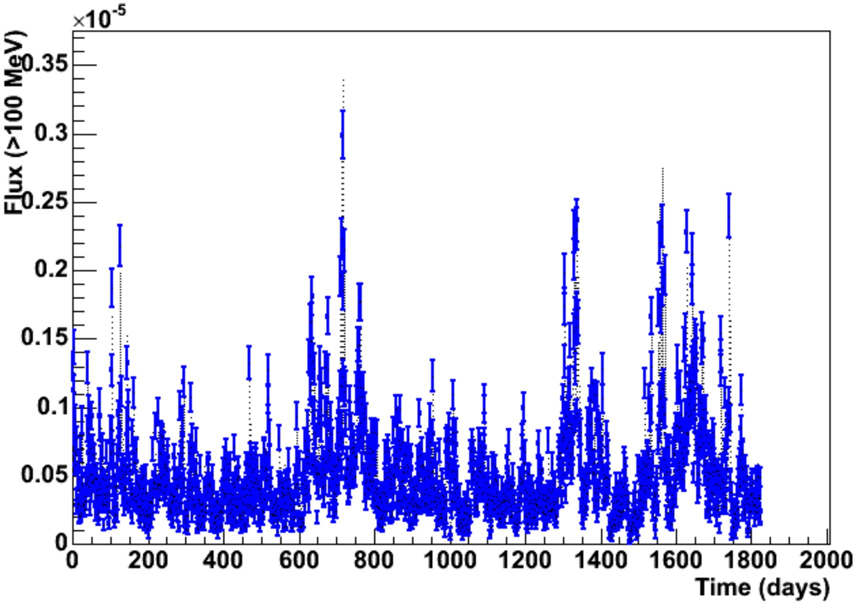
Sensitivity



- **LAT has a huge field of view >20% of the sky (>2.5 sr)**
  - **Excellent for "catching" GRB**
- **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.**
- **Whatever source you are interested in, the gamma-ray data will be there!**

Survey mode - Source monitoring



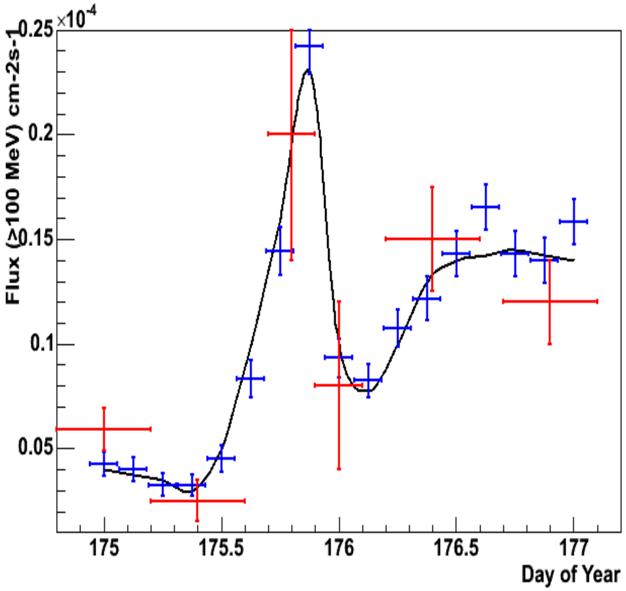


- The LAT will provide long evenly sampled lightcurves for all sources all the time.
- Relate long term properties of AGN with behaviour at other wavebands - eg gamma-ray flares and radio blob ejections or mm band outbursts
  - Good match for long term monitoring at other wavebands
- Multiwavelength campaigns are limited only by the ability to coordinate observations at other wavebands.

Survey mode observations

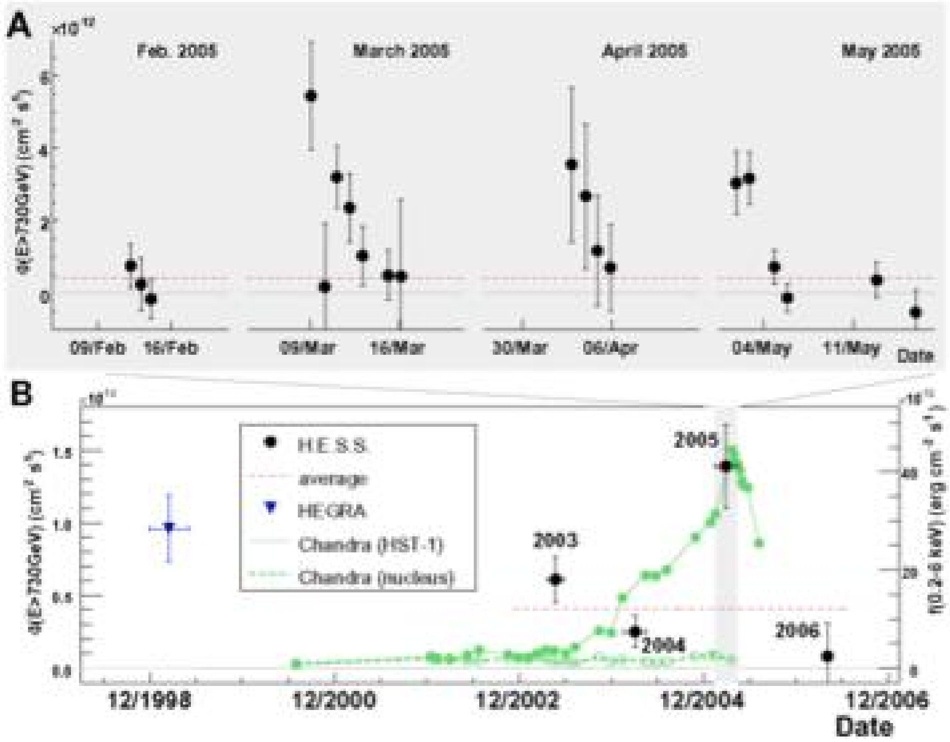
- Survey mode observations will allow us to "catch" the brightest things in the sky.
- Increased effective area will allow us to resolve variability to shorter timescales (which would have been photon limited with previous instruments)

EGRET observations (red points) of a flare from PKS 1622-297 in 1995 (Mattox et al), the black line is a lightcurve consistent with the EGRET observations and the blue points are simulated LAT observations. **In survey mode, the LAT would detect a flare light this from any point in the sky at any time!**



- TOO observations at other wavebands triggered by GLAST
- Identify bright blazars for detailed studies at other wavebands - i.e. soft X-ray observations of blazars to probe WHIM.

Identifying the Gamma-Ray Emission region



M87: Suggestion of correlated variability between Chandra (x-ray) and HESS (gamma-ray) observations of HST1

- **Illustrates the value of joint observations!**
- **A much more conclusive analysis could be done if the gamma-ray and X-ray lightcurves were differently sampled.**

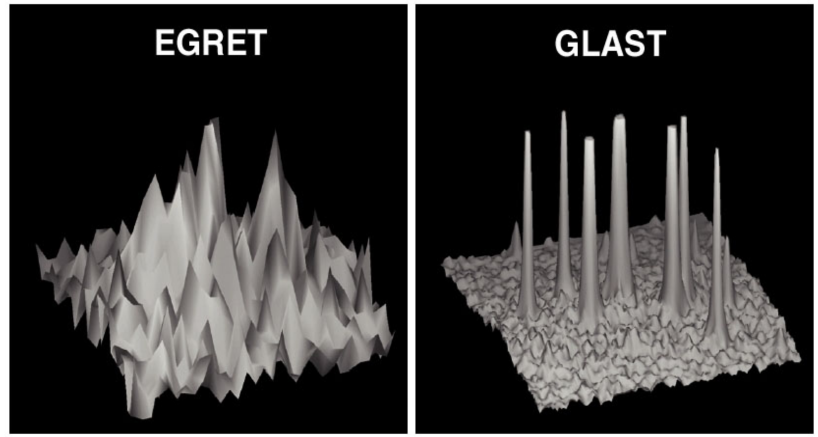
LAT Capabilities - angular resolution

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

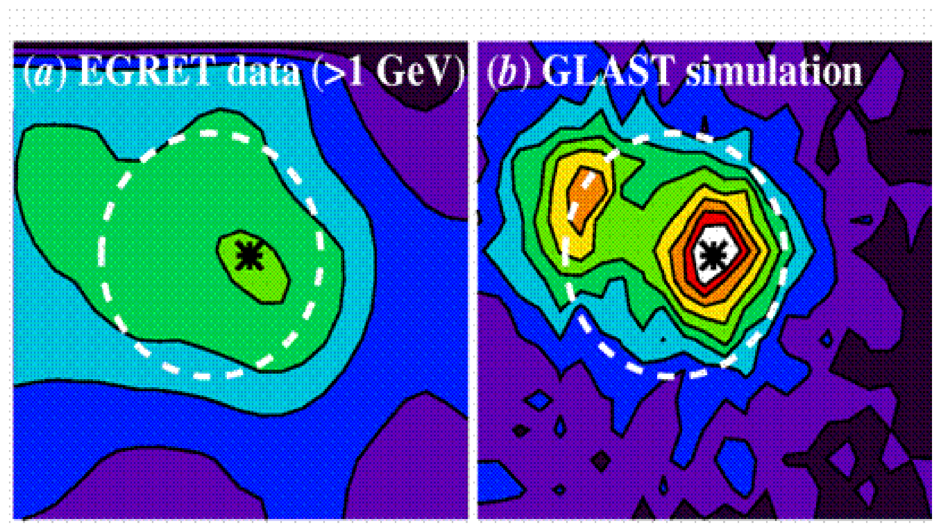
- A large fraction of EGRET sources were “unidentified”, not because there were no plausible counterparts but because it was not clear which source was the source of the gamma-rays

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

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



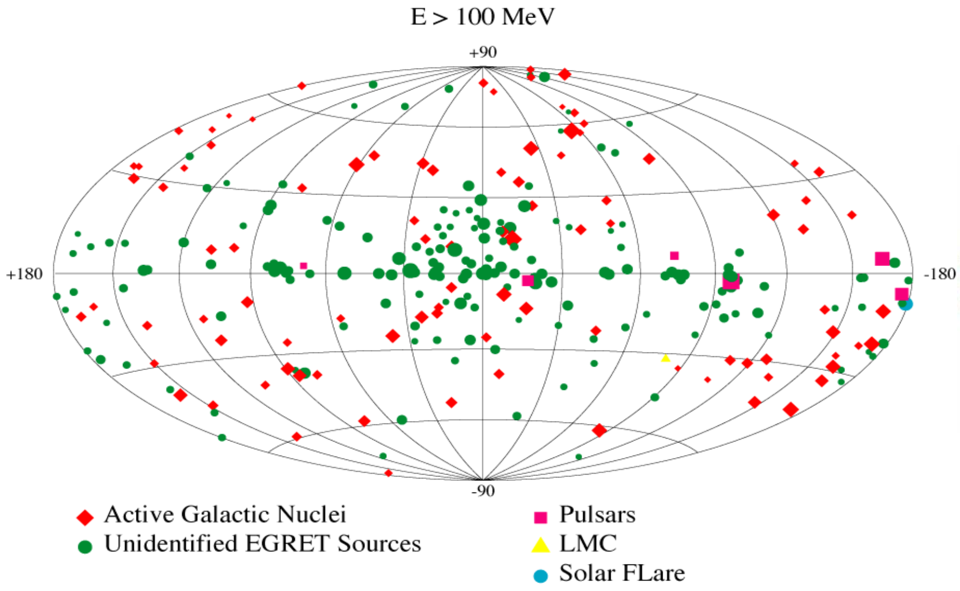
>1 GeV simulation of the cygnus region

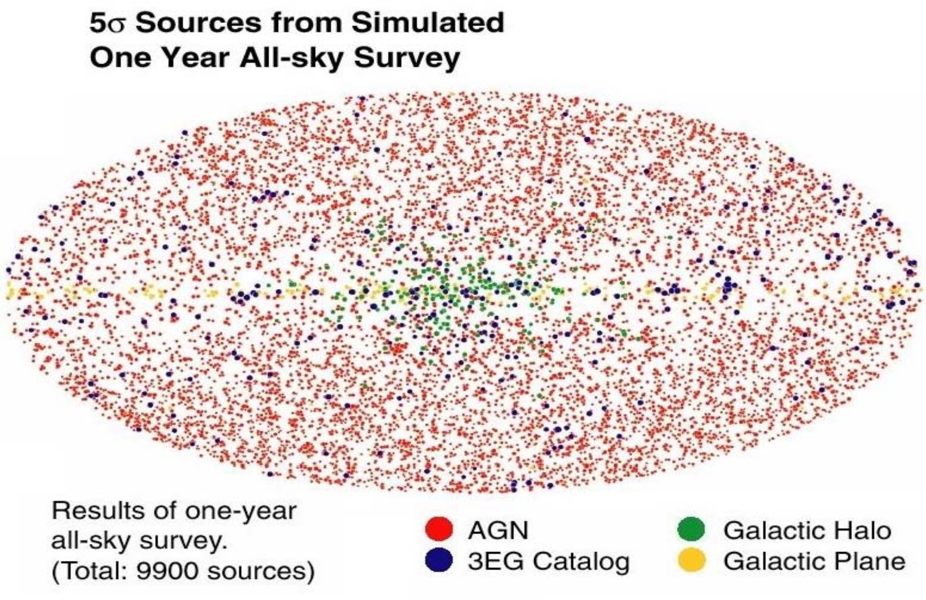


γ-cygni simulation (SNR+pulsar)

LAT Capabilities - Sensitivity

- **GLAST will detect thousands of sources and is likely to detect new classes of GeV gamma-ray sources.**
- **Gamma-ray objects are likely to become relevant to a much larger group of people**

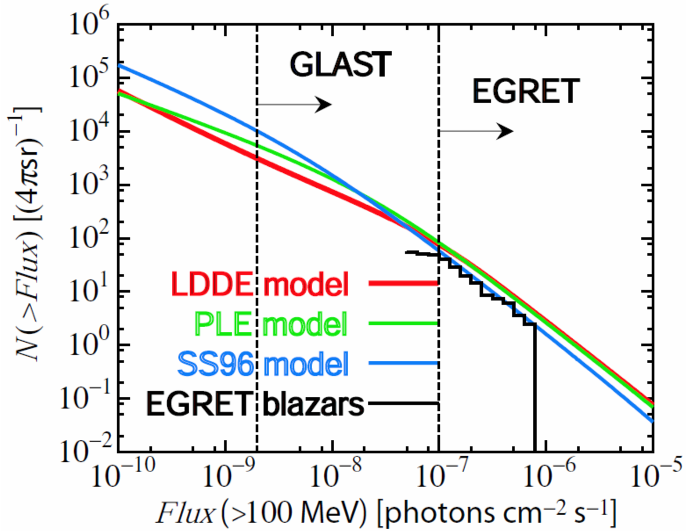




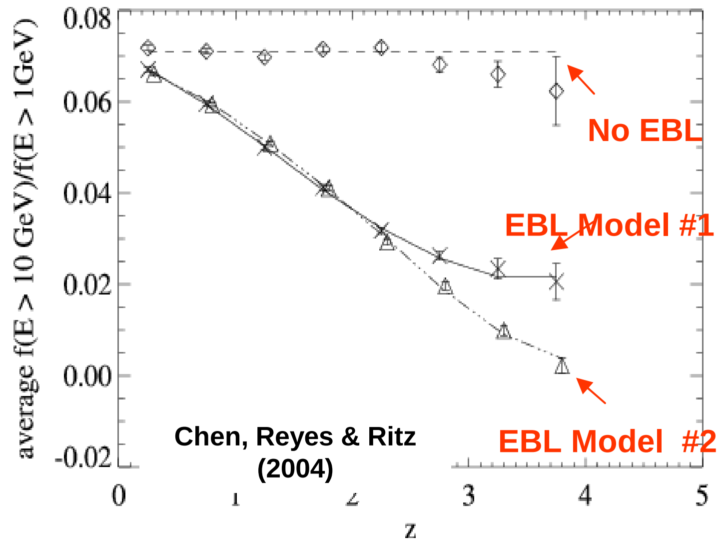
Population Studies

- **Predict that GLAST will detect several thousand blazars.**
  - **Likely that many will not at first be identified as blazars**
  - **To best study these as a population we will need to know the properties at other wavelengths.**

Narumoto and Totani 2005



  - **To use AGN as a probe of the optical-UV extragalactic background light, we will need (a) redshifts and (b) MW data (particularly X-ray) to predict the intrinsic gamma-ray spectrum.**

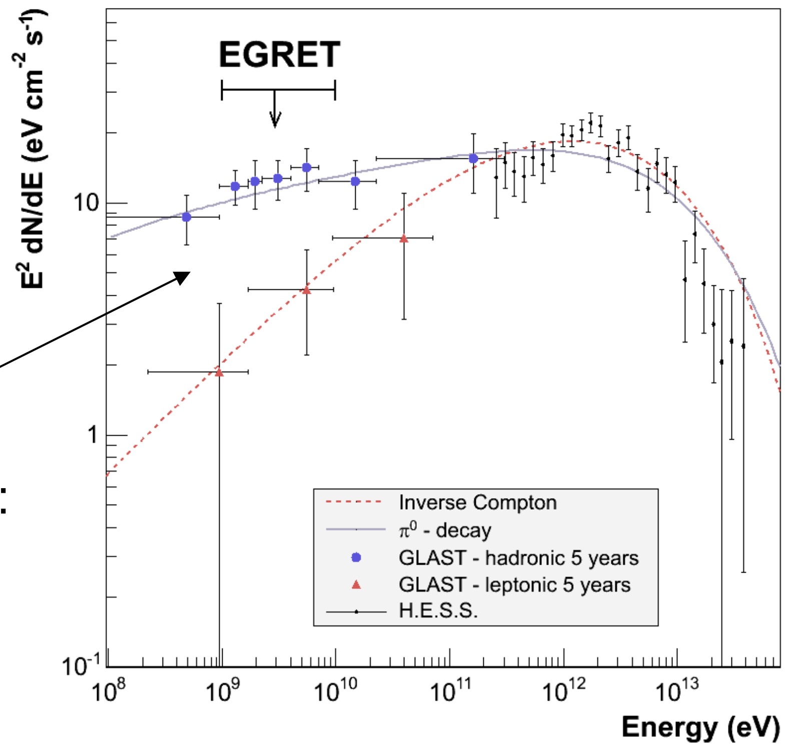


LAT Energy Range

The LAT has an extremely broad energy range (20 MeV - 300 GeV)

• First time that space-based and ground-based telescopes overlap.

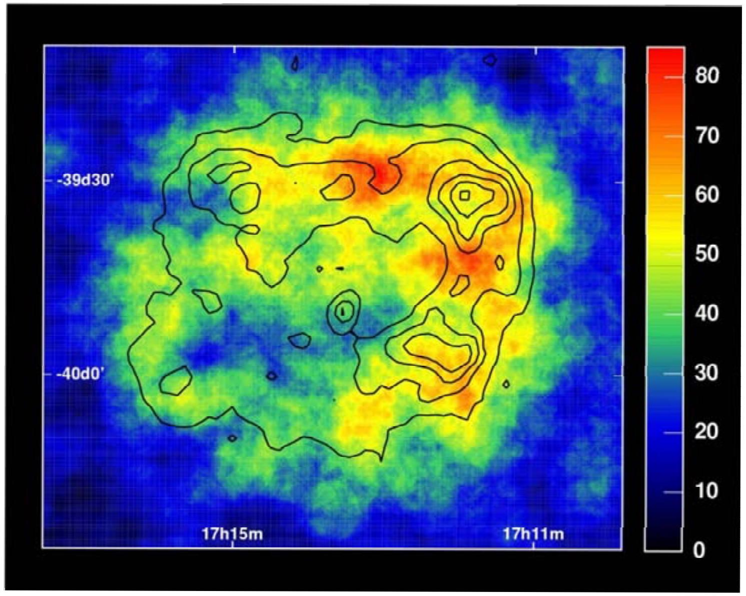
• Lots to be learned from measuring high energy cutoffs (acceleration mechanisms, radiation and magnetic fields at the source)



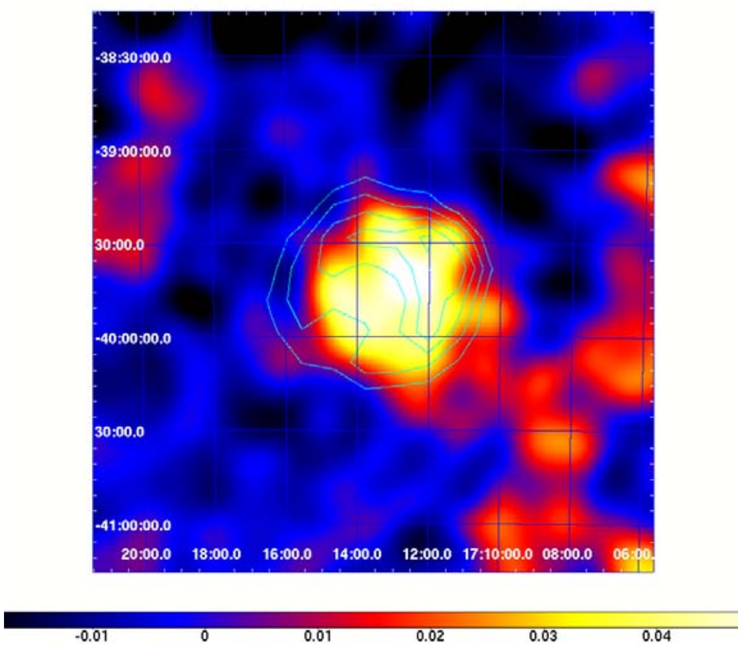
RXJ1713.7-3946, showing different models for the gamma-ray emission: hadronic (blue) and leptonic (red)

Resolving extended sources

- **Observations at other wavelengths can provide more detailed gamma-ray maps of extended sources discovered by GLAST.**



HESS image of SNR RXJ 1713.7-3946.

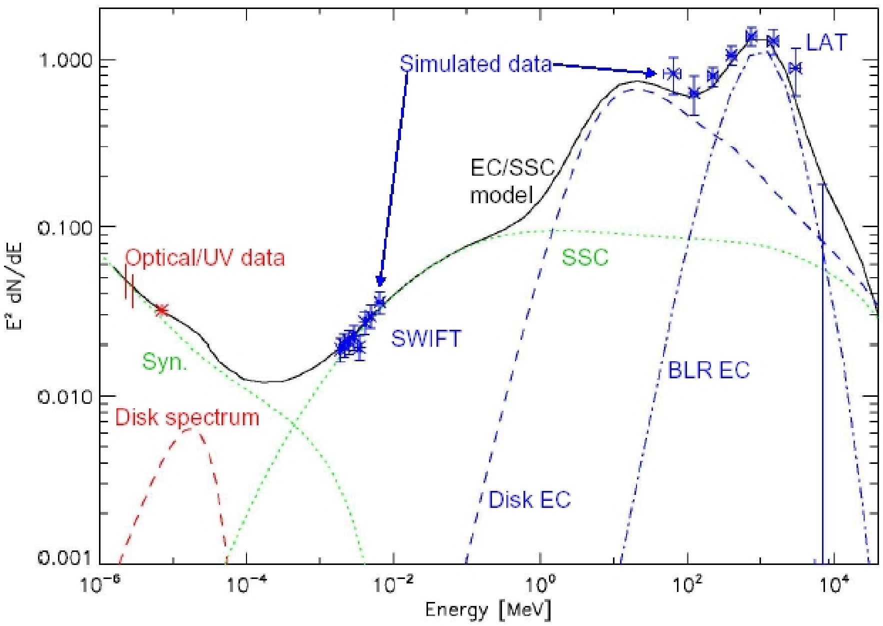


Simulated 5-year LAT image of SNR RXJ 1713.7-3946. The SNR diameter is about 1 degree.

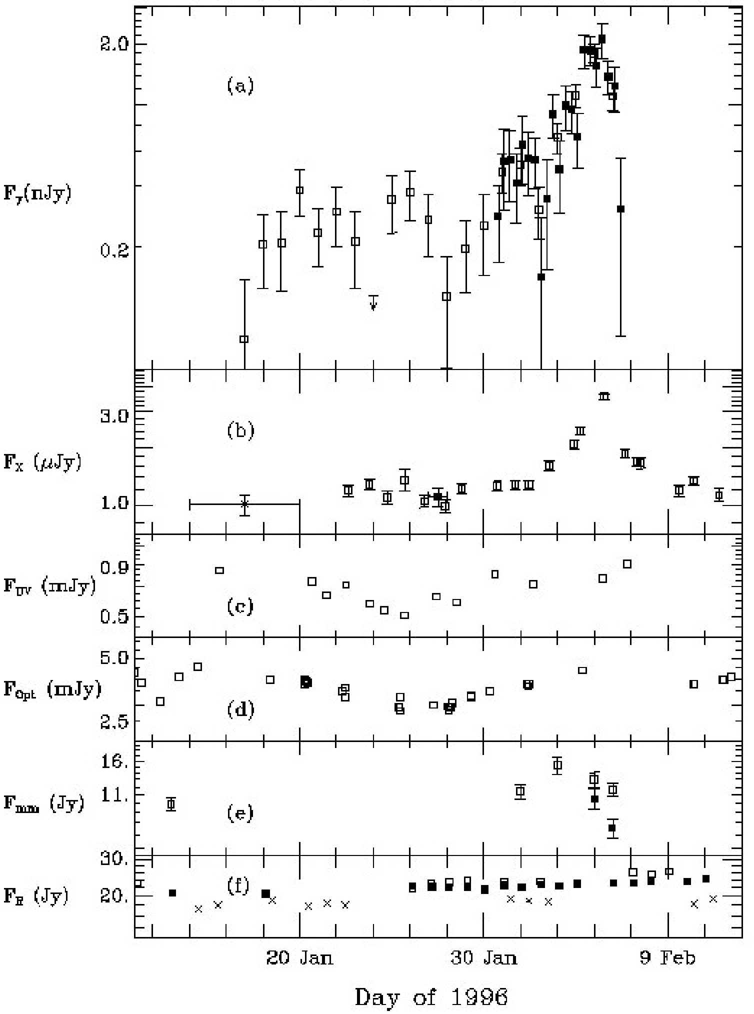
Time resolved gamma-ray spectra

- **GLAST observations of flaring blazars could trigger observations at other wavelengths**

3C279 simulations of a flare: optical/X-ray data constrain the underlying electron distribution, LAT data probe the optical/UV radiation fields in the emission region.



Wehrle etc al 1995



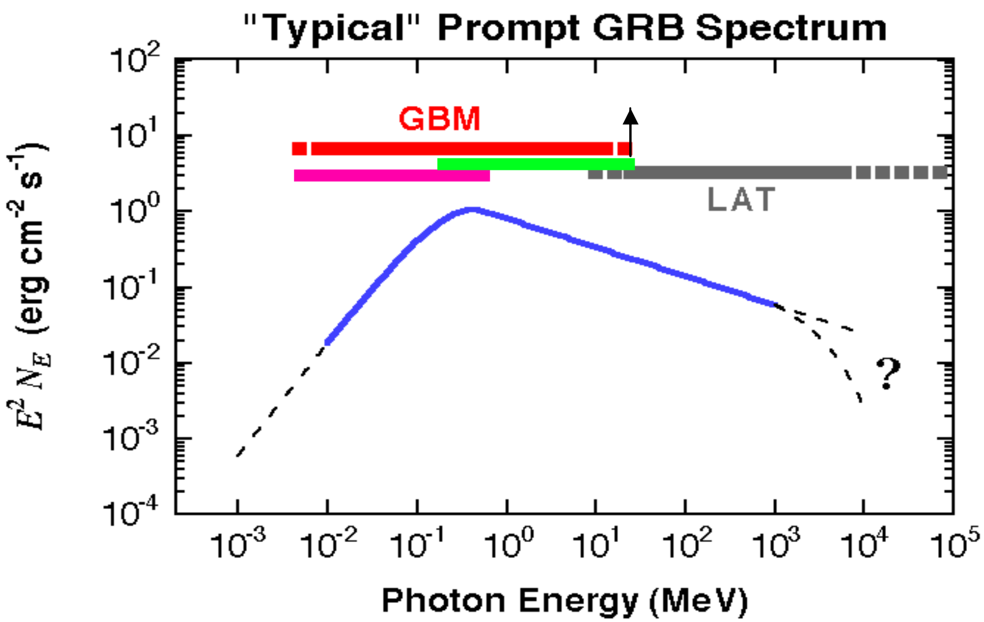
Julie McEnery

Gamma-Ray Bursts with GLAST

GLAST will provide superb prompt GRB spectra over a wide energy range (8 keV - 300 GeV)

Spacecraft can autonomously slew to the GRB location to allow measurement of high energy afterglows.

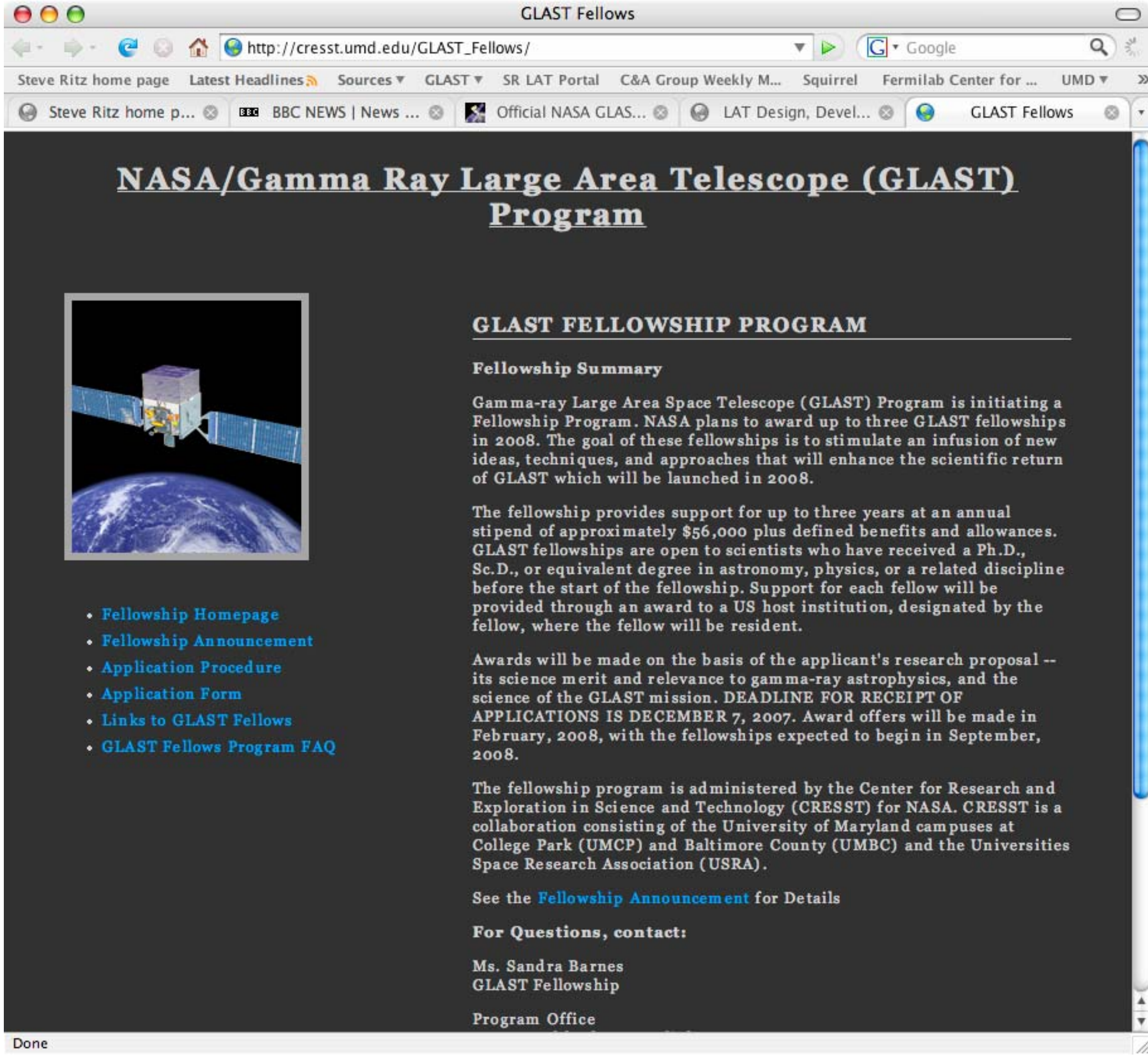
GBM will trigger on ~200 GRB per year of which ~80 will lie within LAT FoV.



- **Multiwavelength follow up observations** are crucial
  - This will be challenging for GRB detected in the GBM only (position uncertainty of a couple degrees)
  - GRB detected by the LAT will have much better measured locations (10s arcmin)
  - Optimally a GRB is triggered in both Swift and GLAST: GLAST will provide good prompt spectra and high energy afterglow measurements, Swift will provide good location and afterglow observations.

GLAST Fellows Program

- Similar to other observatory Fellows programs
- First call for proposals is out, selections announced early 2008, start in September 2008
  - see http://cresst.umd.edu/GLAST_Fellows/
- Three new Fellows selected each year, for three-year periods



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 -- <u>default is sky survey mode</u>. Data released through the science support center (GSSC).

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 supports correlative observations and analysis**
  - **See** *http://glast.gsfc.nasa.gov/ssc/proposals*

Observatory Status

- Dynamics testing just completed.
- Ship to NRL for thermal-vac testing in mid-November

Launch Spring 2008!

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

Conclusions

- **GLAST will provide a huge leap in capabilities compared with previous high energy gamma-ray missions.**
  - **Lots more gamma-ray sources**
  - **More classes of gamma-ray sources**
  - **Lots more details on the gamma-ray properties of these sources**
    - **Gamma-ray observations will become relevant to a lot more people.**
- **Multiwavelength observations are crucial to make the most of the gamma-ray data.**
- **See http://glast.gsfc.nasa.gov/ for more information on the mission and on guest investigator support.**

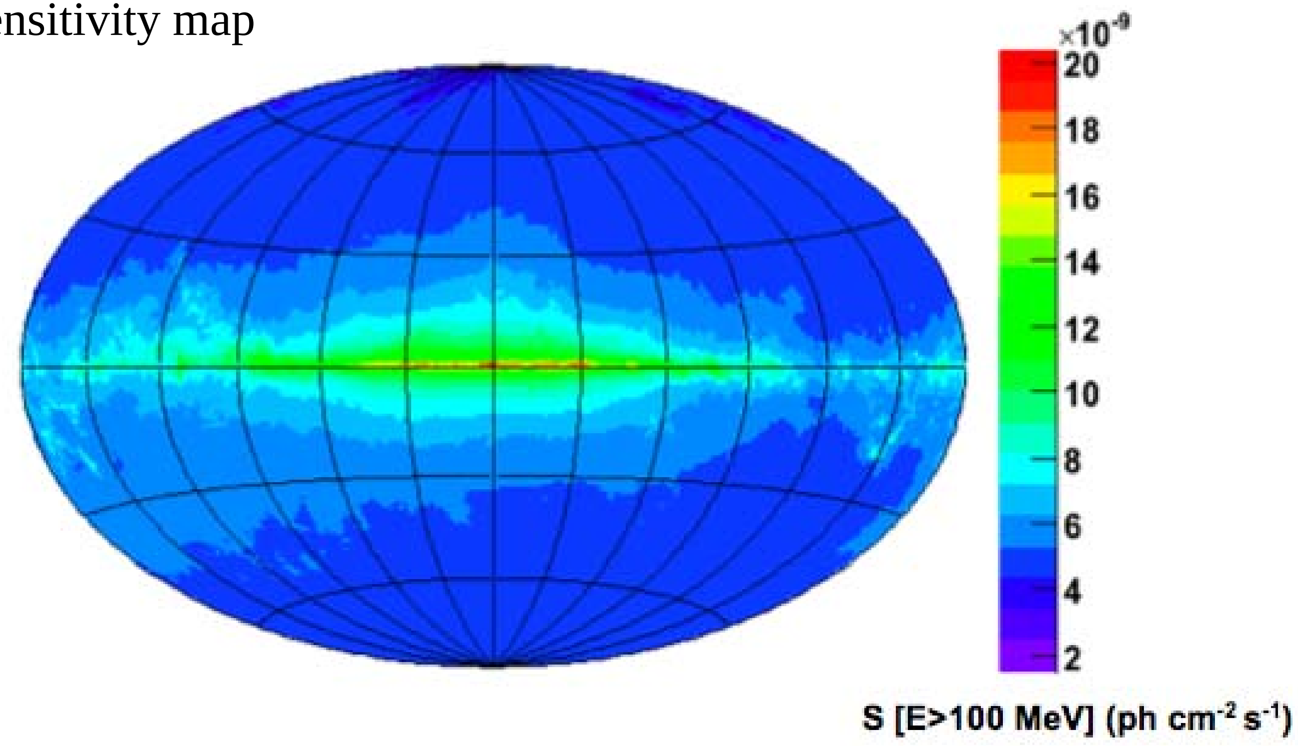
Some Questions GLAST Will Address

- How do super massive black holes in Active Galactic Nuclei create powerful jets of material moving at nearly light speed? What are the jets made of?
- What are the mechanisms that produce Gamma-Ray Burst (GRB) explosions? What is the total amount of energy produced?
- What is the origin of the cosmic rays that pervade the galaxy?
- How does the Sun generate high-energy gamma-rays in flares?
- How has the amount of starlight in the Universe changed over cosmic time?
- What are the unidentified gamma-ray sources found by EGRET?
- What is the mysterious dark matter?

Survey mode

- **Survey mode observations will produce uniform exposure on the sky -> minimize biases in population studies. Make it easier to compile unbiased gamma-ray selected samples.**

1-year 5 sigma sensitivity map



GLAST LAT and Other Observatories – Common Scientific Interests

Gamma rays are nonthermal, so sources of interest are those that have hard, nonthermal spectra.

Blazars – LAT will quickly announce flares that can be correlated with data at other wavelengths or used as TOO triggers.

Radio galaxies, galaxy clusters, starburst galaxies, and luminous IR galaxies are potential LAT sources.

Pulsars – a known Galactic gamma-ray source class.

Microquasars, pulsar wind nebulae, and supernova remnants are likely LAT Galactic source classes. Stellar Winds in WR-Binaries and OB associations are potential LAT sources.

As soon as a new source class is <u>suggested</u> in LAT data, the LAT scientists will come looking for cooperative efforts – maybe yours.

GLAST Burst Monitor

- Similar to BATSE (same technique); >9.5sr FoV (~ entire unocculted sky)
- 200 GRB/year (triggered onboard): ~80 within 65° of LAT boresight
- 8 keV - 30 MeV (broader energy range than BATSE)
  - Measure E_{peak} for all GLAST detected GRB (needed to calculate pseudo-redshifts)
  - Overlap with LAT energy range (connects ground-breaking LAT observations with "traditional" GRB range)
- Onboard GRB trigger
  - More flexible trigger algorithm compared with BATSE -> improved sensitivity to very short GRB and to long soft GRB.
  - Onboard trigger classifications (solar flare, particle event, GRB etc)
  - Provides repoint recommendation to allow high energy afterglow observations with the LAT
  - Provide rapid alert to GRB afterglow observers (via GCN)
- Localization of GRB by GBM
  - <15 degrees initially (calculated onboard within 2 s)
  - Refinements to <5 deg (ground analysis within ~15-30 mins of GRB trigger)

Large Area Telescope (LAT)

- Efficient observing mode (don't look at Earth)
- Wide FoV (useful GRB observations out to 65 half angle, 3.6 sr)
- Low deadtime (27μs c.f. 100ms for EGRET)
- Large effective area
- Good angular resolution
- Increased energy coverage (to few hundred GeV)

Many GRB

More photons detected from each GRB

Good GRB locations

Very major improvements in capabilities for GRB observations compared to previous missions in this energy range.

More photons - study high energy lightcurves, good detection sensitivity

Study the *population* of MeV-GeV bright bursts

Measure spectra out to hundreds of GeV - how common are the high energy components such as that seen in GRB 941017?

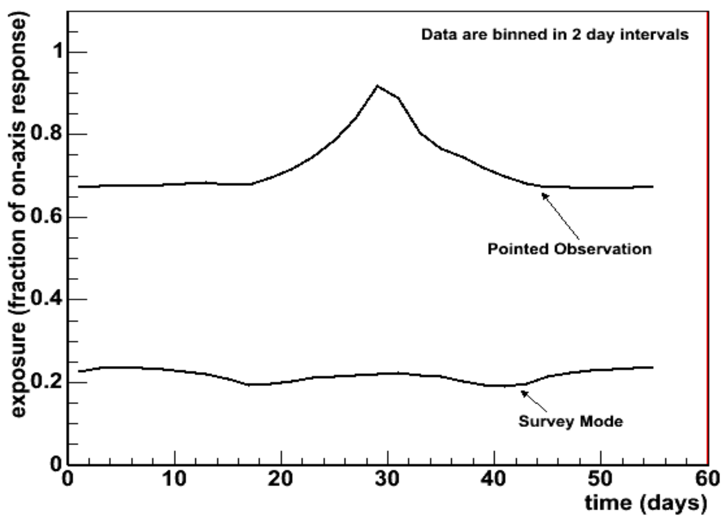
Year 1 LAT Data Releases

- 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 > $2x10^{-6}$ $cm^{-2}s^{-1}$, E>100 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

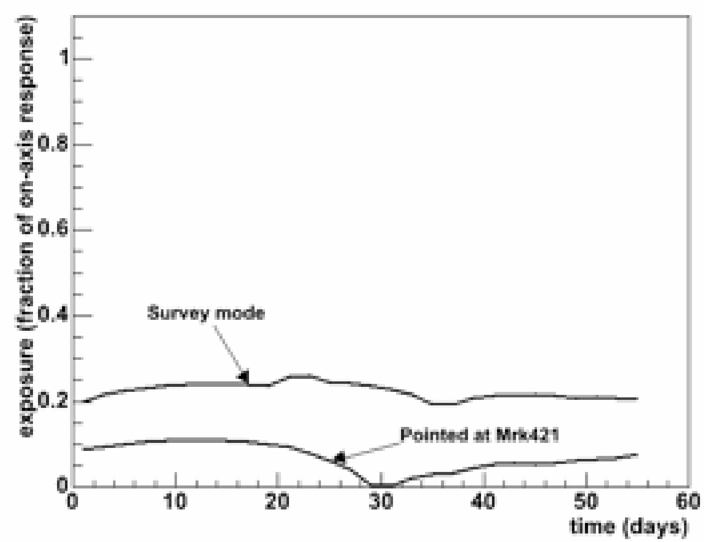
Survey mode observations

- **Survey mode is designed to provide uniform coverage over as short a timescale as possible**
  - **Thus also provides continuous uniform temporal coverage down to short timescales.**

Mrk 421



PKS 1622-295



Some Suggestions

- Multiwavelength possibilities for year 1 proposals
  - Monitor one of the sources in the first year source list.
  - Plan ToO follow up observations of flaring sources
    - Follow variability to shorter timescales
  - Observe any source, or population of objects likely to be LAT sources (this applies to all objects, not just AGN).
    - Search for candidate GLAST blazars, measure redshifts, SEDs
    - Monitor large samples of blazars (forming a baseline prior and during LAT observations).
    - Pulsar timing
- Additional suggestions
  - Map extended sources
  - Multiwavelength observations of unid sources.
- Remember: whatever sources you choose to observe, LAT data will be available!

High-Energy Gamma-Ray Statistics

Except for gamma-ray bursts, none of the sources are bright enough to produce statistically-significant detections of very short time variations.

Time estimates

Source	l (deg)	b (deg)	z	Flux*/index	Time**
BL Lac	92.6	-10.44	0.069	11.1 /2.60 39.9/2.60	20 d 2 d
3C273	289.9	64.4	0.158	15.4/2.58	5.5 d
3C279	305.10	57.06	0.536	74.2/1.96 1000/2	4 h 9 min
PKS0528+134	191.4	-11.01	2.06	93.5/2.46 300/2.21 30/2.5	11 h 1.4 h 3 d
PKS2155-304	17.73	-52.25	0.116	13.2/ 2.35	5 d
1ES1959+650	98.0	17.7	0.047	13.3/2.45	9.5 d

* [E>100 MeV] 10^{-8} ph $cm^{-2}s^{-1}$
** to achieve 5 σ

Estimates of times for source detections with LAT.