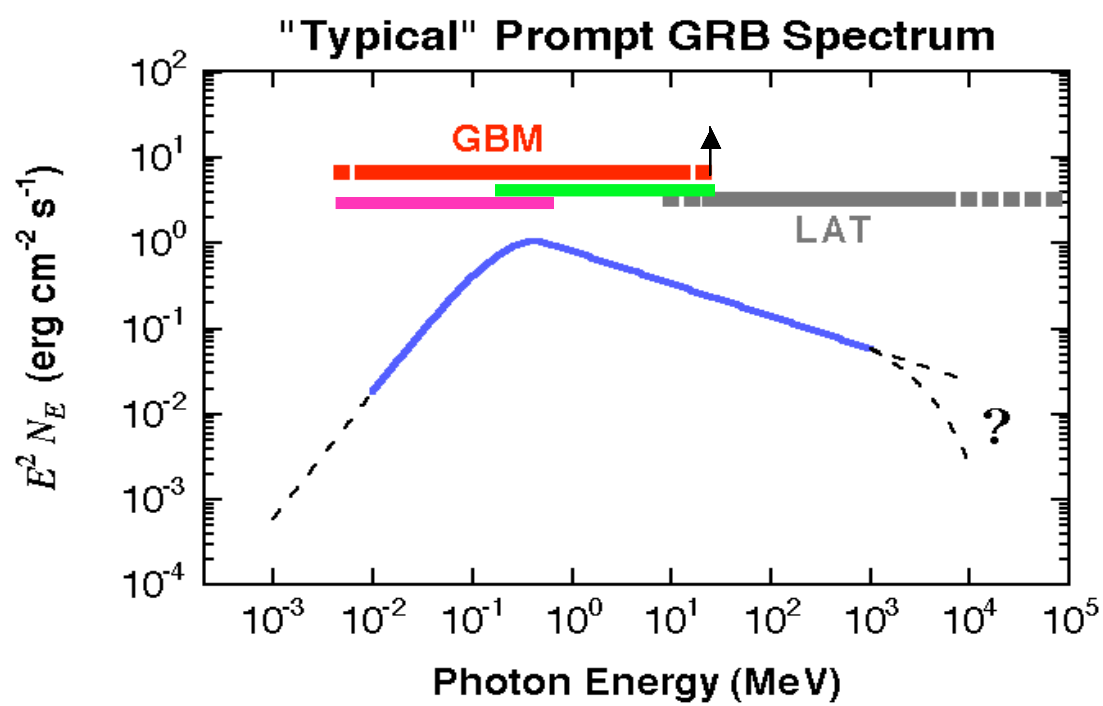
GLAST: GRB operations and science and multiwavelength possibilities with a new mission

Julie Mc Enery

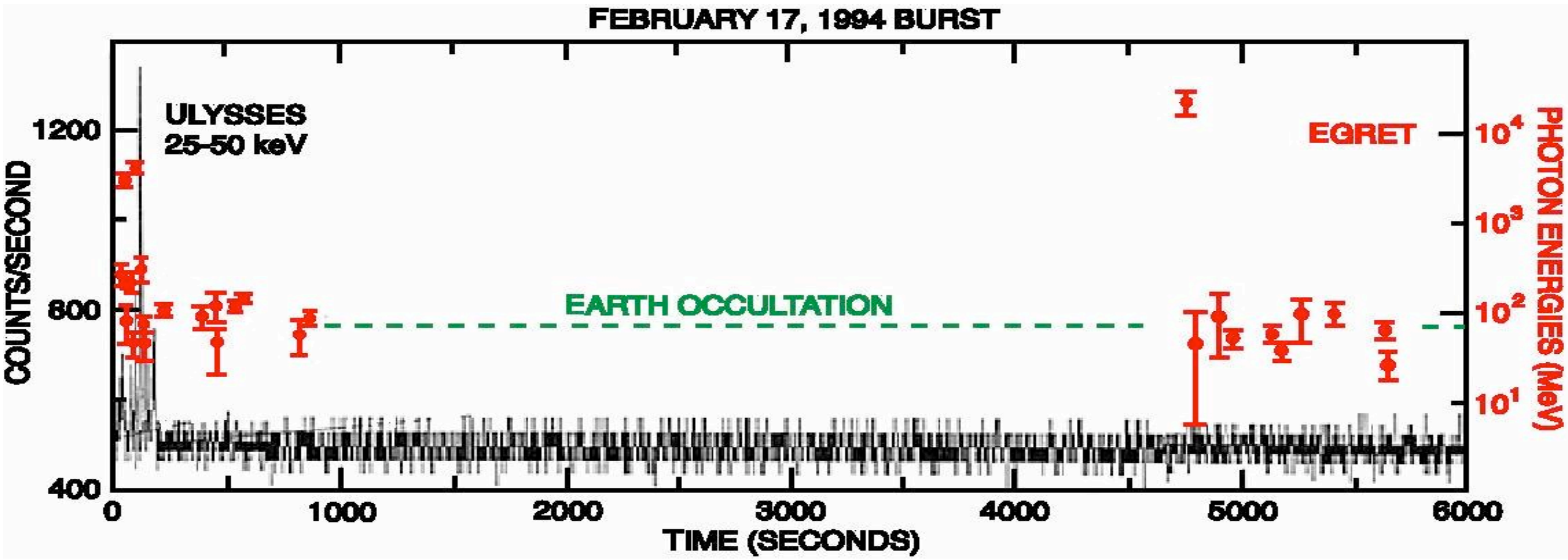
GLAST and GRB

- LAT: <20 MeV to >300 GeV. With both onboard and ground burst triggers.
- GBM: 12 NaI detectors— 8 keV to 1 MeV. Used for onboard trigger, onboard and ground localization, spectroscopy: 2 BGO detectors— 150 keV to 30 MeV. Used for spectroscopy.
- Total of >7 energy decades!
- ~200 GRB/year with observations from 8 keV to 30 MeV, ~80 GRB/year with observations from 8 keV to 300 GeV (# high energy detections is unknown)

Exceptionally good spectral observations of the prompt phase of lots of GRB



High Energy Afterglow



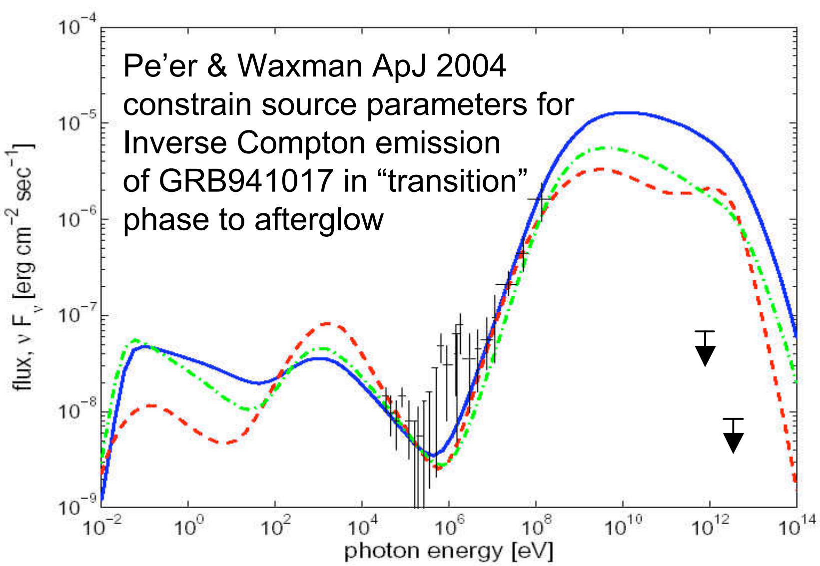
- EGRET detected 4 GRB in its pair conversion telescope.
- In one GRB, EGRET observed emission above 30 MeV for more than an hour after the prompt emission.
- 18 GeV photon was observed (the highest ever seen by EGRET from a GRB).

Unlike optical/X-ray afterglows, gamma-ray luminosity did not decrease with time -> additional processes contributing to high energy emission?

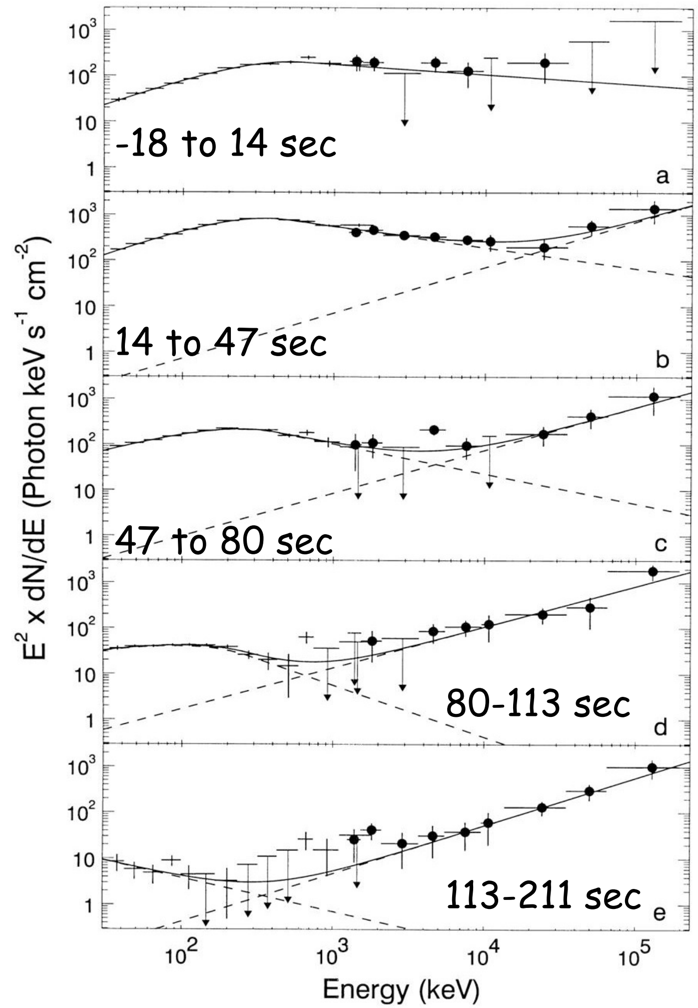
Joint EGRET-BATSE observations

Analysis using EGRET TASC data

- **Classic sub-MeV component observed in BATSE data which decays by factor of 1000 and Epeak moves to lower energies**
- **Higher Energy component observed within 14-47 seconds by EGRET and at later times by both BATSE and EGRET detectors**
- **Higher Energy Component has**
  - **$dN_\gamma/dE = kE^{-1}$**
  - **lasts ~200 seconds**
  - **Increases total energy flux by factor of 3**



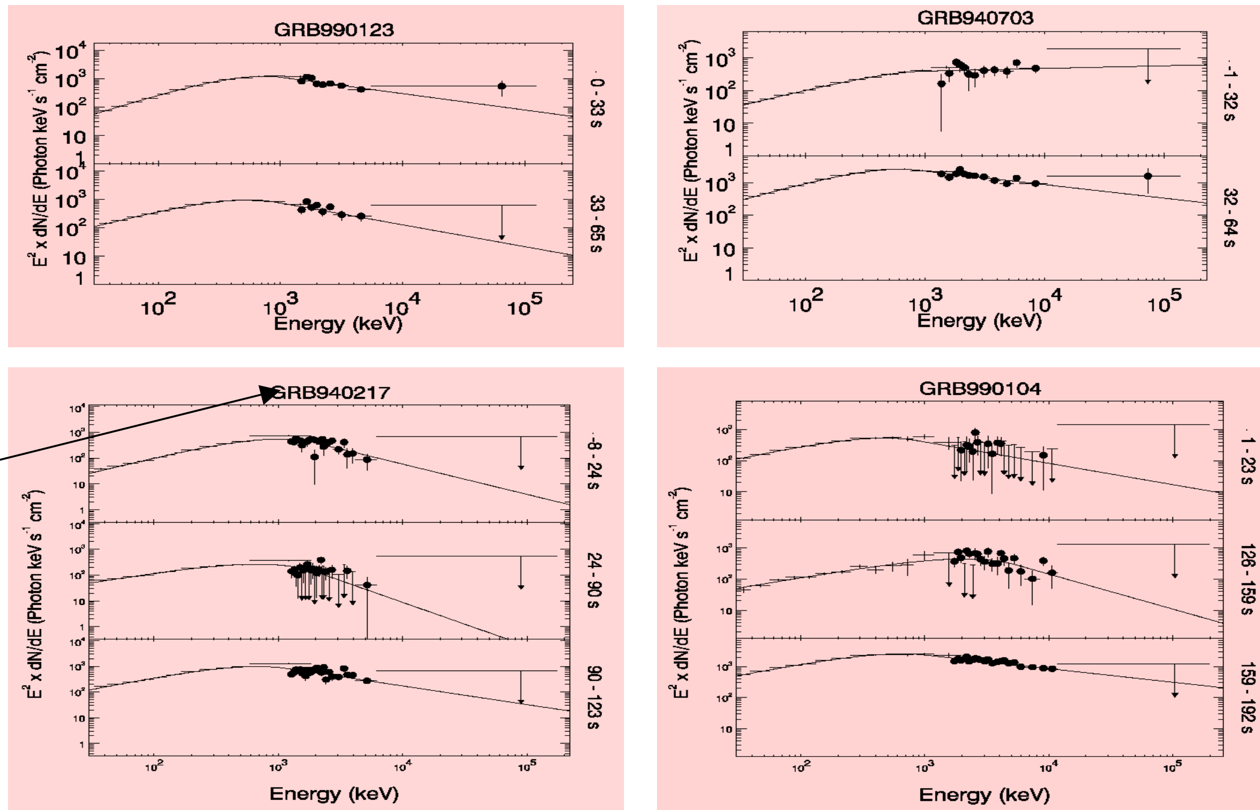
GRB941017



Joint EGRET-BATSE observations

- **High energy component not always present in EGRET TASC observations.**

Note this GRB



- **Above 100 MeV, spark chamber observations were much more sensitive than TASC observations (albeit with smaller FoV)**

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.

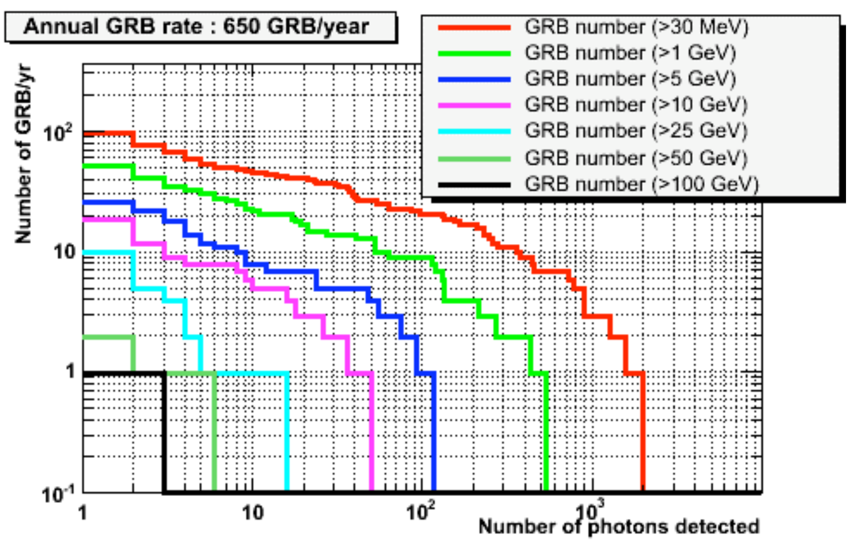
More photons - study high energy lightcurves, good detection sensitivity

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?

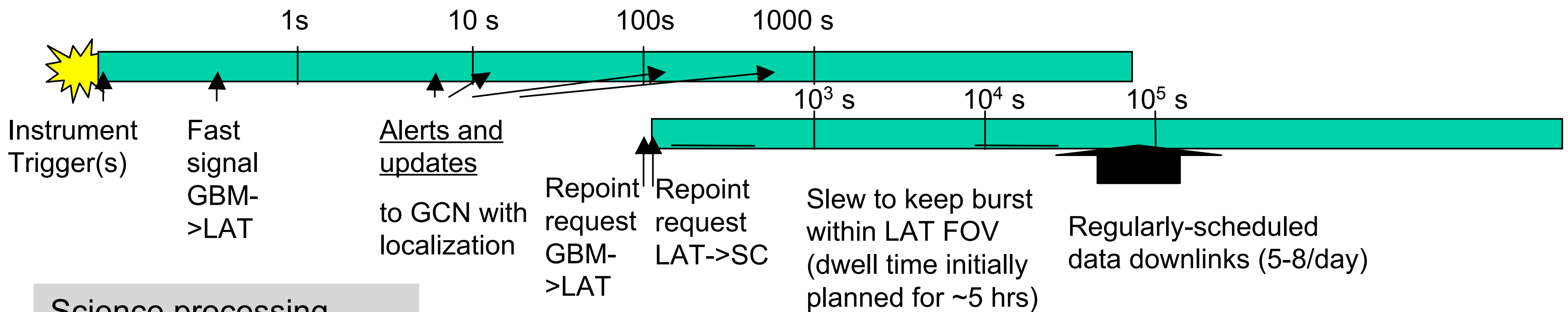
How many LAT detected GRB?

- ~80 GBM detected GRB will lie within the LAT FoV
- Fraction that will be detected by the LAT is unknown. We can make a estimate by assuming that GRB properties measured at low energy (by BATSE) extrapolate to LAT energies.
  - Ignores evidence from EGRET that there are additional high energy components
  - Ignores the possibility of intrinsic cutoffs (from reaching the end of the particle energy distribution, or from internal opacity)



For a trigger criterion of 10 photons above 30 MeV, the LAT would detect ~50 GRB/year. Localizations will be between 1 min and 1 deg depending on flux and specrtra

Alerts and Data Flow



Science processing parameters reviewed by Users Committee

Planned repoint frequency (adjustable):
- bursts starting within LAT FOV ~1/week
- bursts starting outside LAT FOV ~1/month

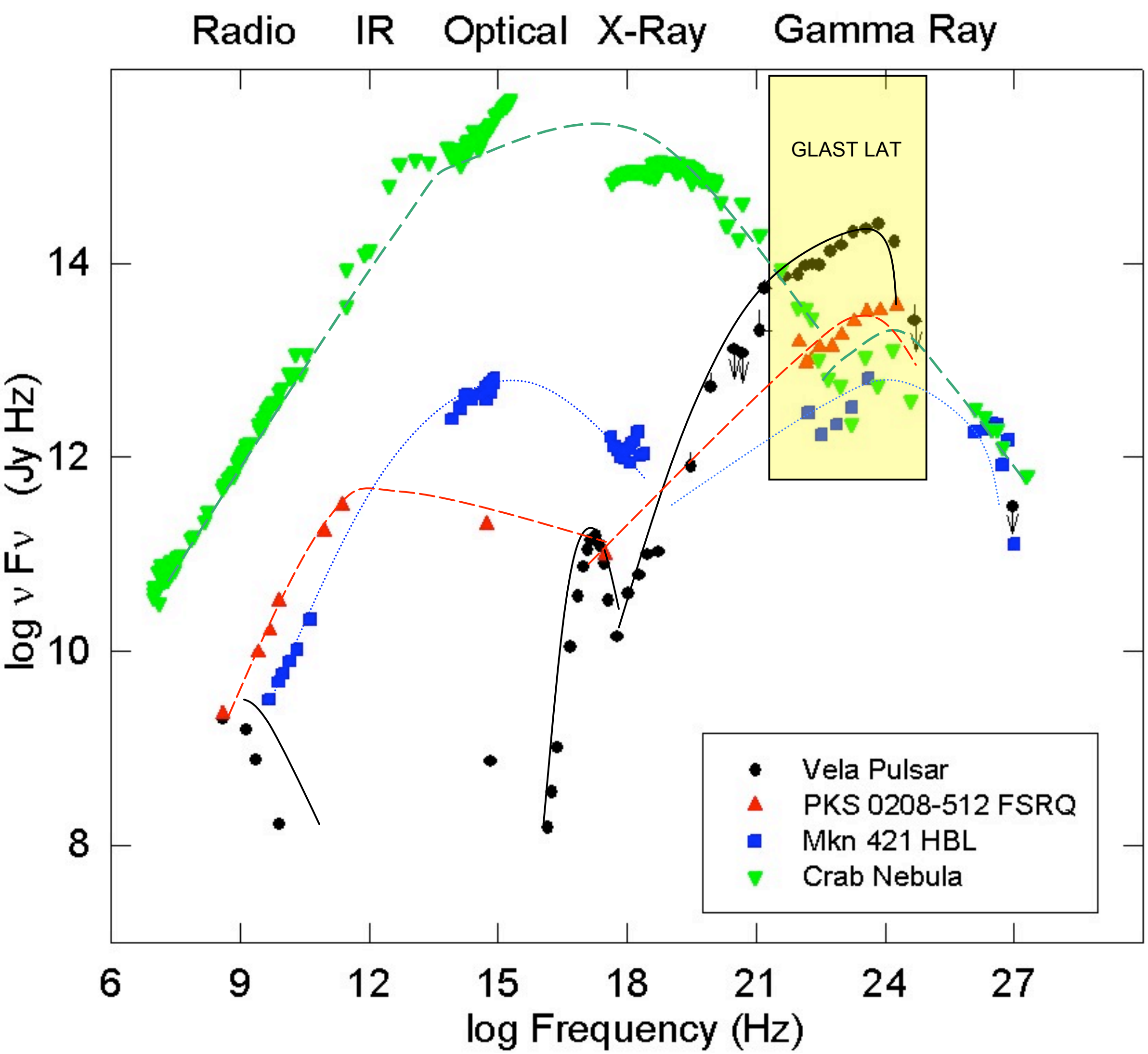
- Onboard processing - GCN alerts: location, intensity (cnts), hardness ratio, trigger classification etc
- Ground processing of prompt data (~15 mins): updated GBM location, preliminary GBM lightcurve
- LAT ground processing (5-12 hours): updated location, high energy spectrum, flux (or upper limit), afterglow search results
- Final ground processing (24-48 hours): GBM model fit (spectral parameters, flux, fluence), joint LAT-GBM model fit, raw GBM data available. Year 2 and beyond - LAT count data available.

Some proposal suggestions - GRB

- In the first year, all GBM data is released and processed LAT data on GRB (spectra, lightcurves etc) are released.

- Multiwavelength Follow up observations of GRB
- Population studies using LAT and/or GBM measured properties.
- Time series analysis studies
- Spectral analysis
- Theory/modeling

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!

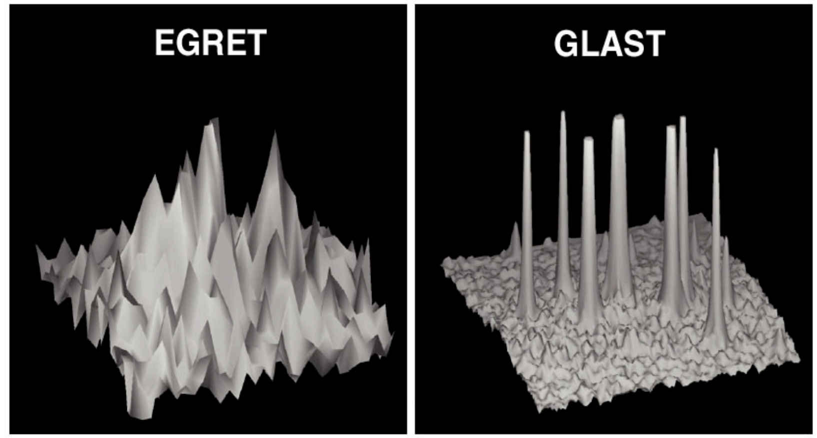
LAT Capabilities - angular resolution

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

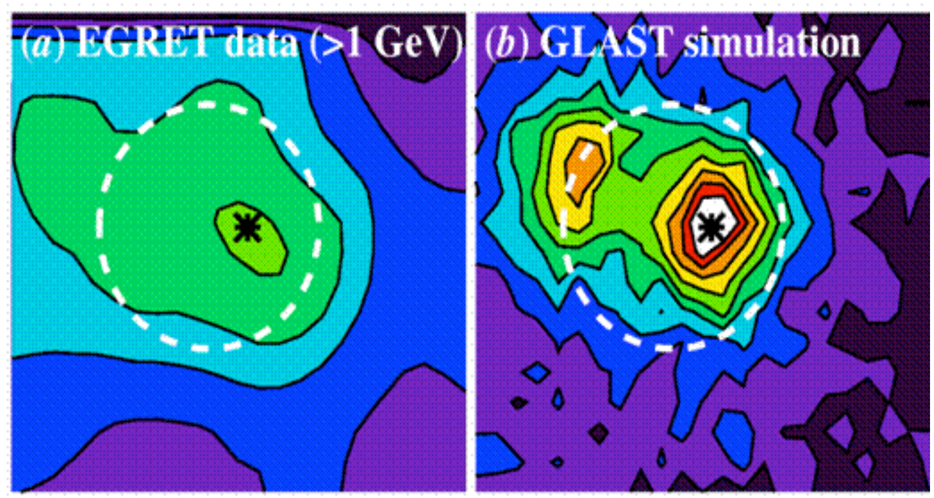
•A large fraction of EGRET sources were "unidentified", not because there were no plausible counterparts but because it was not clear which source was the source of the gamma-rays

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

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



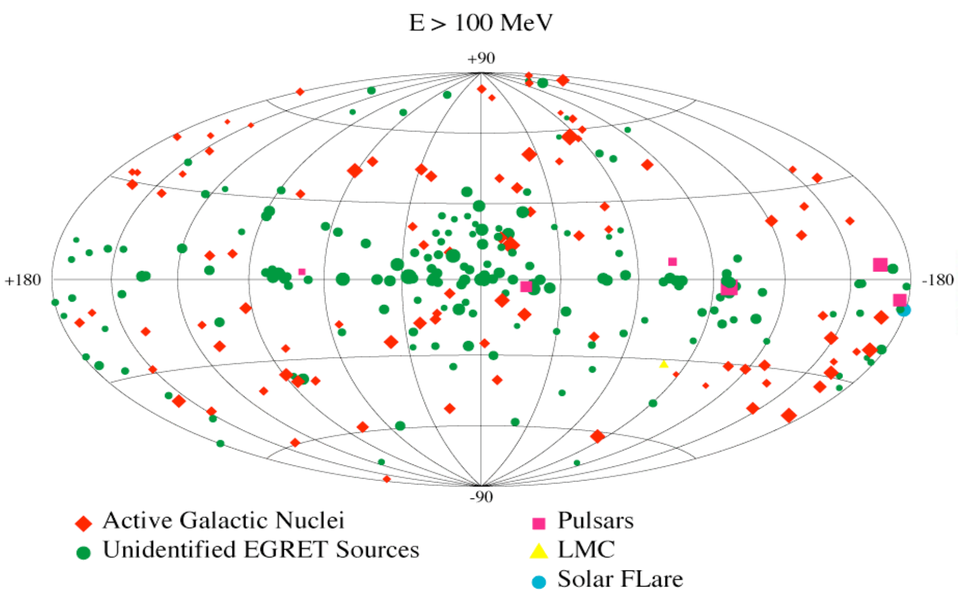
>1 GeV simulation of the cygnus region

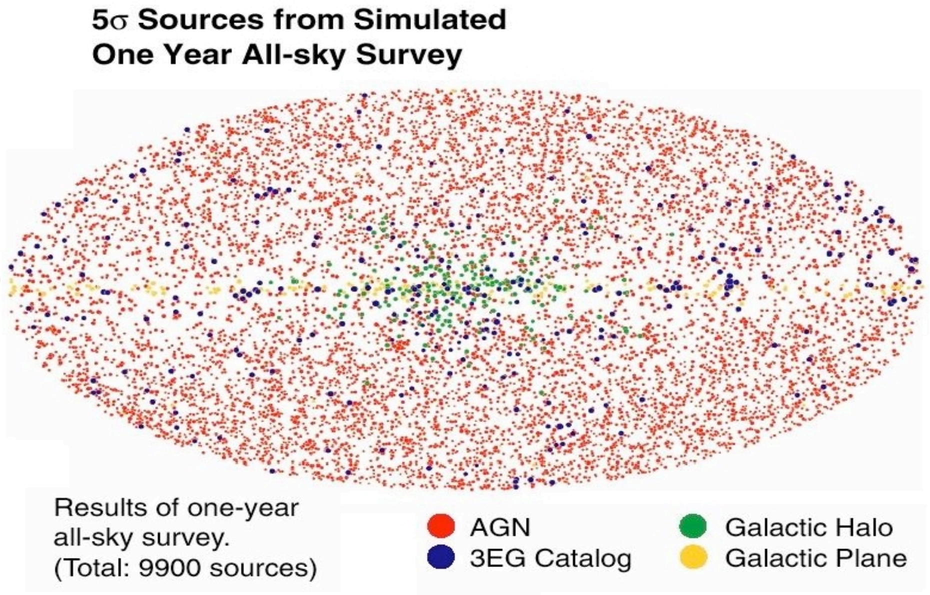


γ-cygni simulation (SNR+pulsar)

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

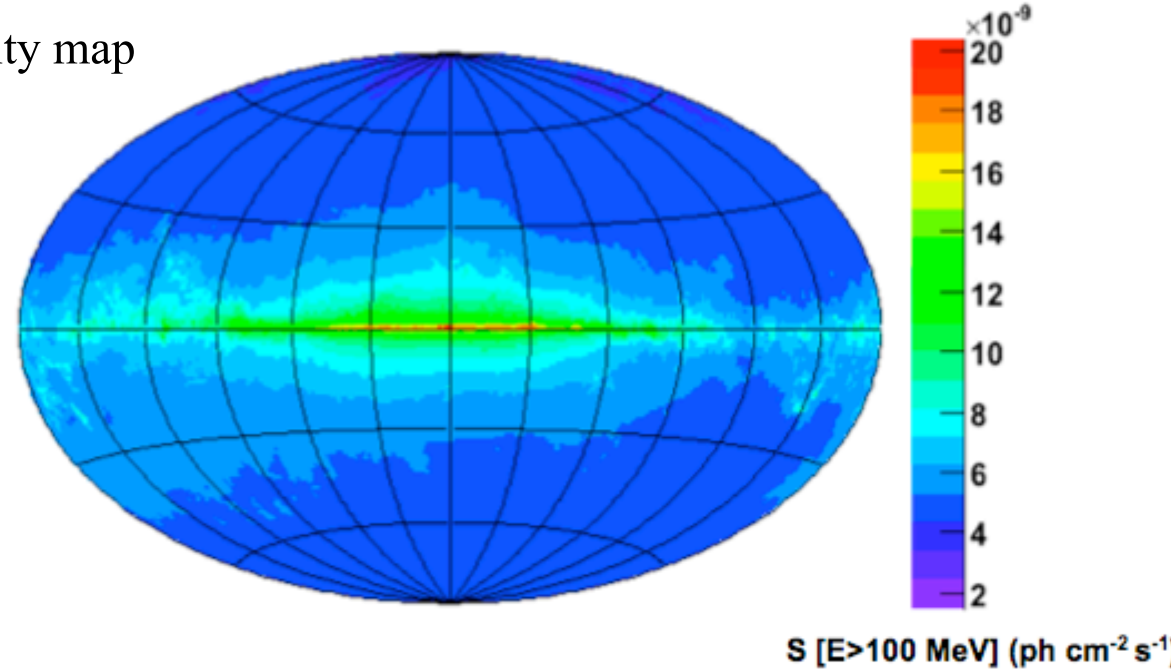




Survey mode

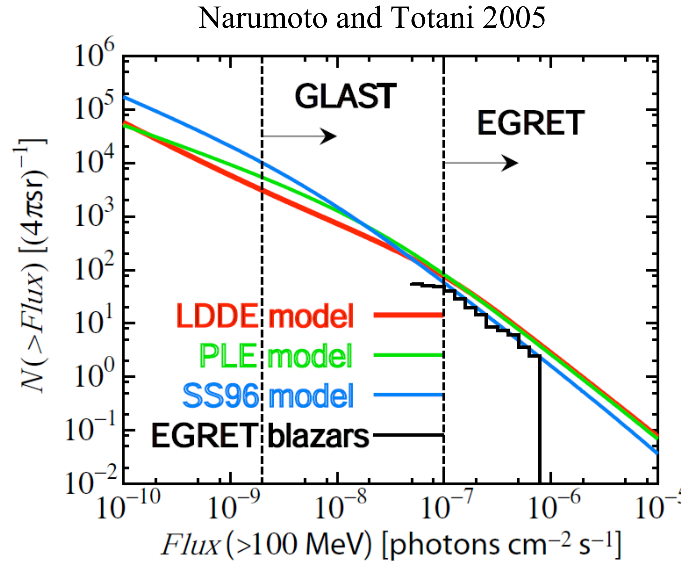
- **Survey mode observations will produce uniform exposure on the sky -> minimize biases in population studies. Make it easier to compile unbiased gamma-ray selected samples.**

1-year 5 sigma sensitivity map

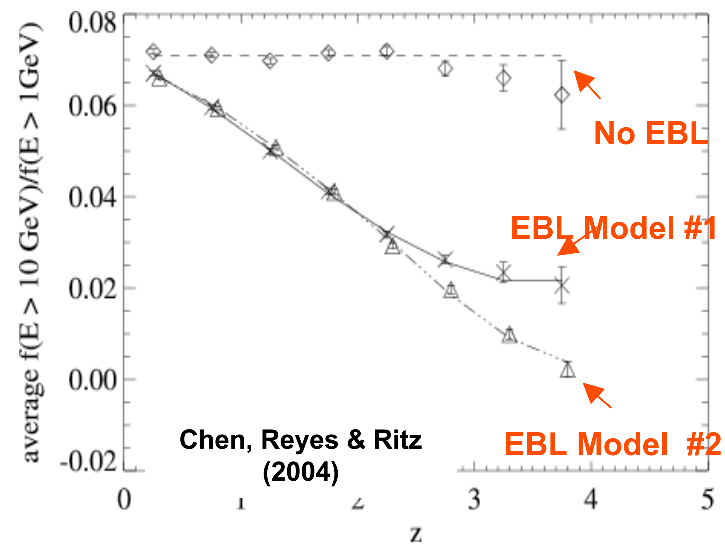


Population Studies

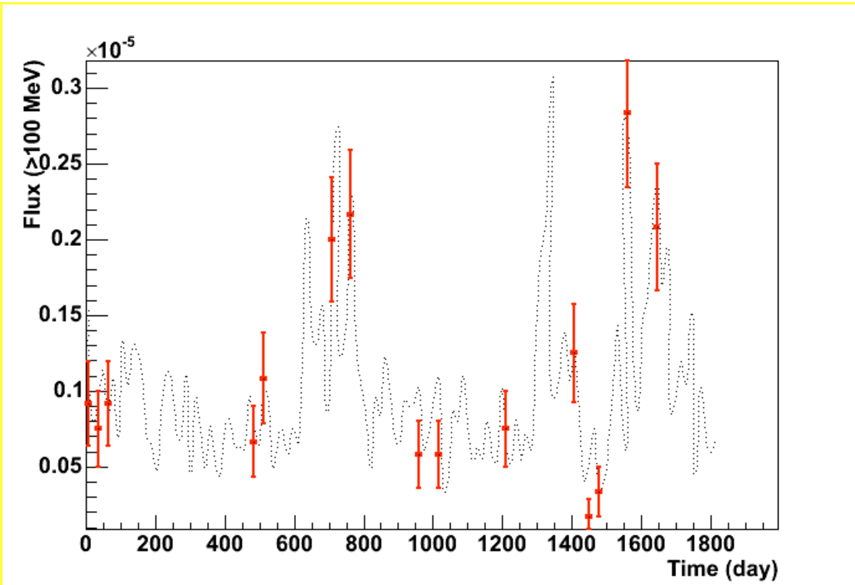
- **Predict that GLAST will detect several thousand blazars.**
  - **Likely that many will not at first be identified as blazars**
  - **To best study these as a population we will need to know the properties at other wavelengths.**

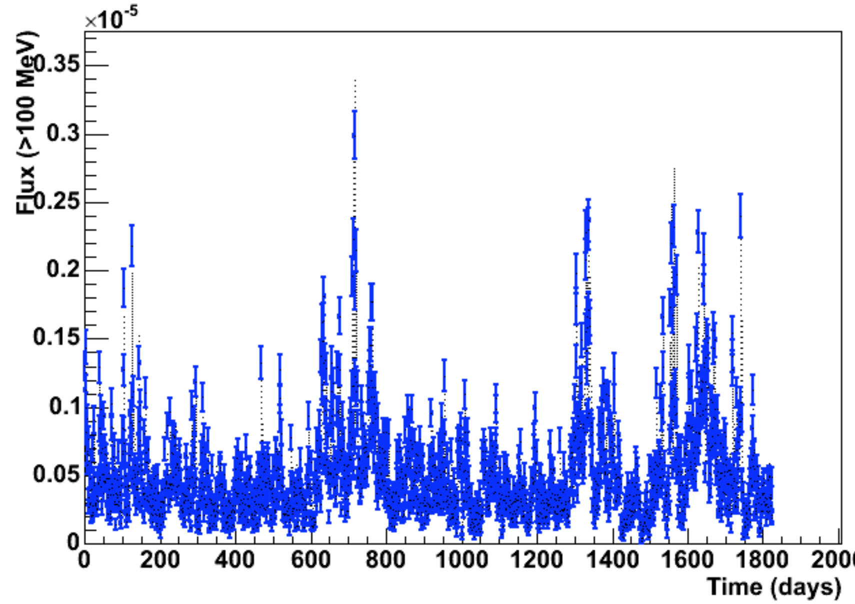


  - **To use AGN as a probe of the extragalactic background light, we will need redshifts.**



Survey mode - Source monitoring



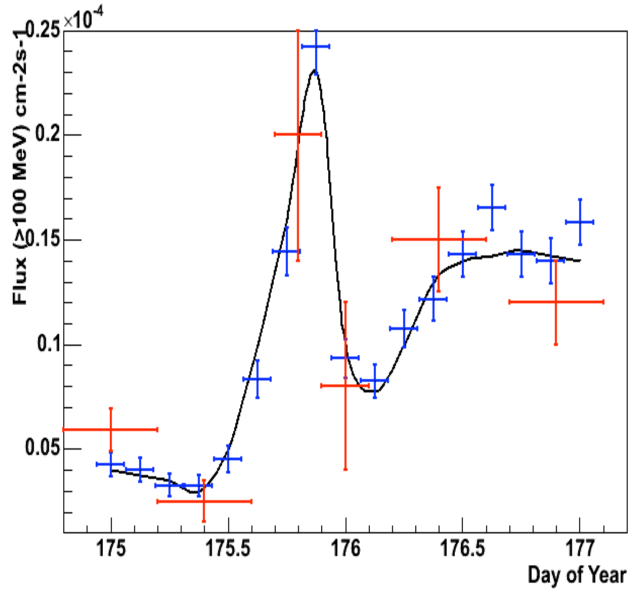


- The LAT will provide long evenly sampled lightcurves for all sources all the time.
- Relate long term properties of AGN with behaviour at other wavebands - eg gamma-ray flares and radio blob ejections or mm band outbursts
  - Good match for long term monitoring at other wavebands
- Multiwavelength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

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!**

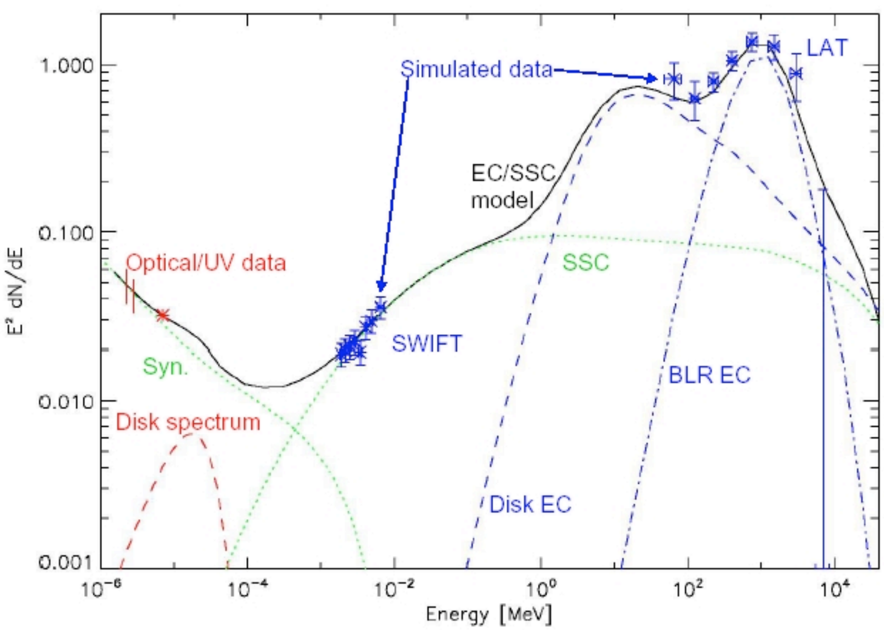


- **TOO observations at other wavebands triggered by GLAST**
- **Identify bright blazars for detailed studies at other wavebands - i.e. soft X-ray observations of blazars to probe WHIM.**

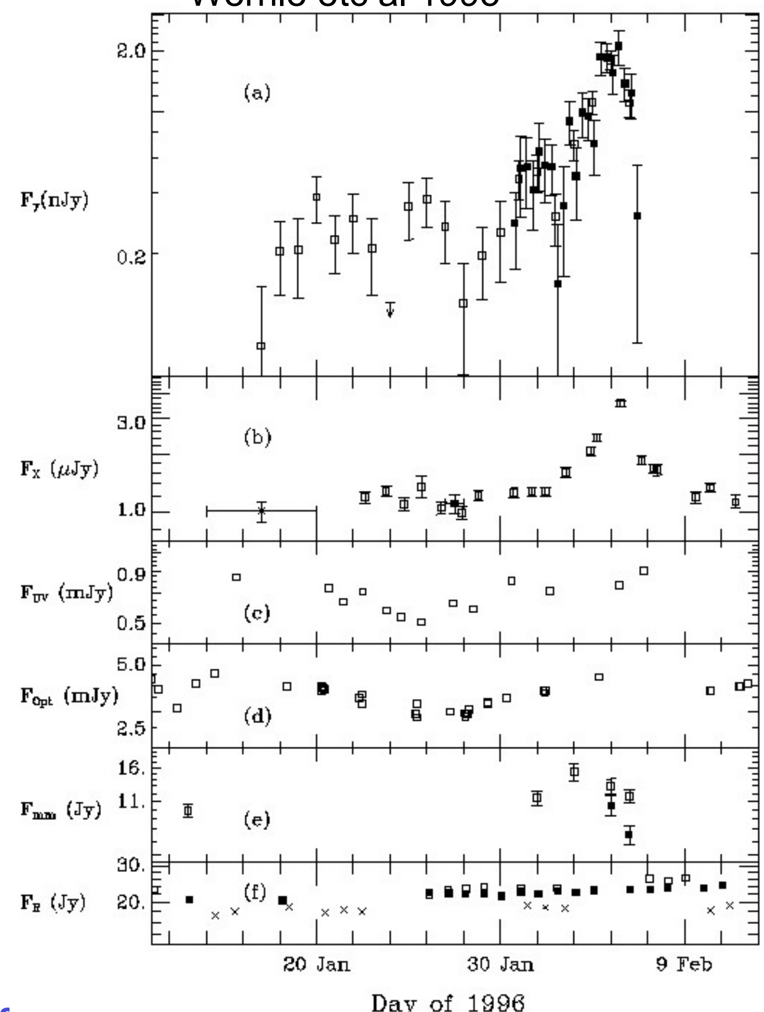
Time resolved gamma-ray spectra

- **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.



Werhle etc al 1995



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.

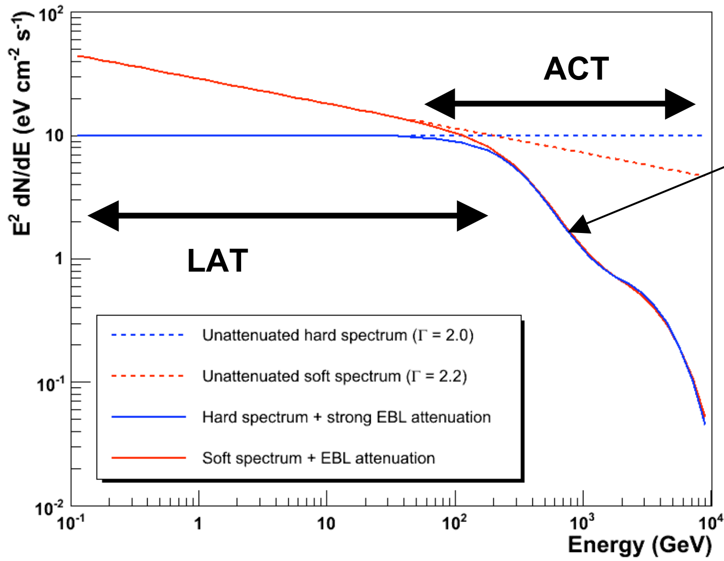
Time estimates

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

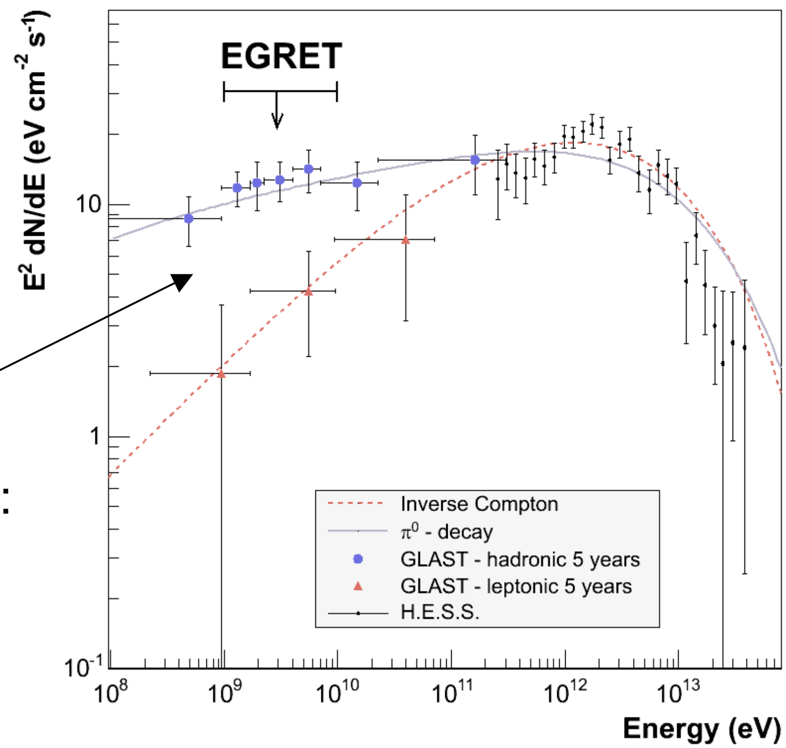
* [E>100 MeV] 10^{-8} ph $cm^{-2}s^{-1}$
** to achieve 5 σ

Estimates of times for source detections with LAT.

Overlap with ground-based gamma-ray Telescopes



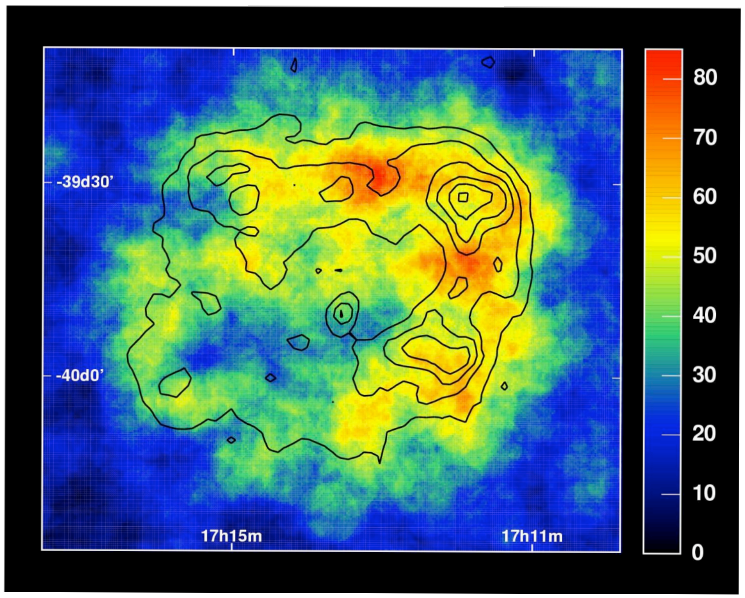
Two spectral indices (2.0 and 2.2), for a redshift of 0.2 convolved with nominal EBL (Primack et al 2005) and EBL*0.8.



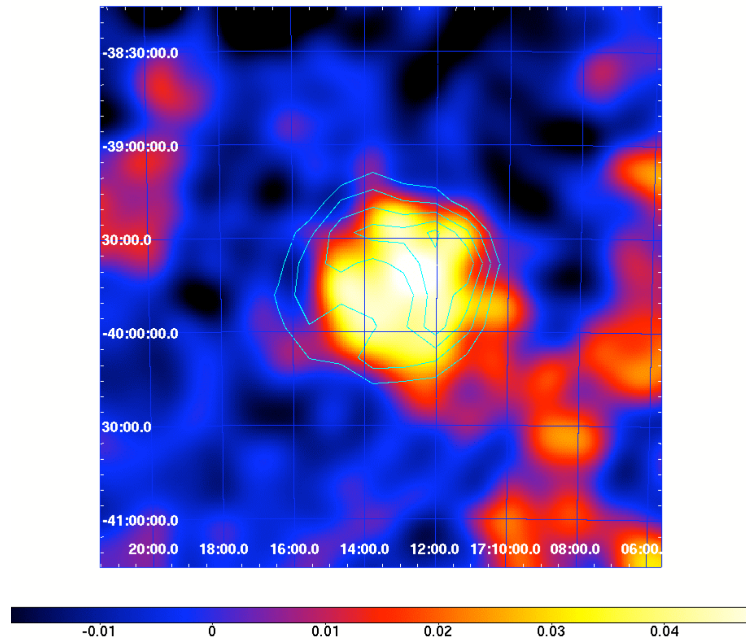
RXJ1713.7-3946, showing different models for the gamma-ray emission: hadronic (blue) and leptonic (red)

Resolving extended sources

- **Observations by ground based gamma-ray instruments 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.

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 (year 2 and beyond)**
  - Map extended sources
  - Multiwavelength observations of unidentified sources
- **Remember: whatever sources you choose to observe, LAT data will be available!**

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

Conclusions

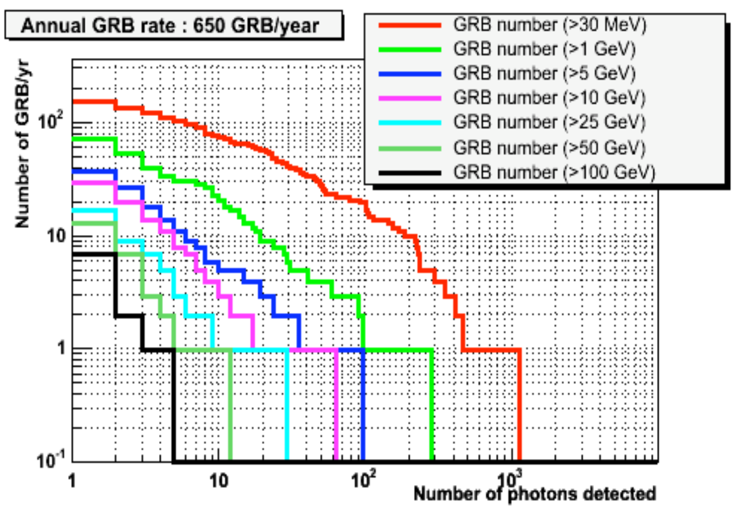
- GLAST will provide a huge leap in capabilities compared with previous high energy gamma-ray missions.
  - Lots more gamma-ray sources
  - More classes of gamma-ray sources
  - Lots more details on the gamma-ray properties of these sources
    - Gamma-ray observations will become relevant to a lot more people.
- GLAST will detect hundreds of GRB and will provide superb prompt spectral measurments.
- 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.

Scientific Questions

- Spectral-temporal components—characterization, origin
- Intrinsic spectral cutoffs—probe of particle acceleration
- Extrinsic spectral cutoffs—absorption by intervening photon fields (low-mid z OUV—Dwek, Stecker, high z Pop III—Kashlinsky)
- Quantum gravity—predictions of $c_{light}(E)$ can be tested by searching for energy-dependent lags
  - See Scargle et al. (2007)—astro-ph/0610571
- Redshift indicators—relations between burst properties turn bursts into standard candles
  - E.g., Firmani et al. (2006, MNRAS, 370, 185)
- Burst locations—afterglows, host galaxies, redshifts
  - Requires follow-up observations.

How well are LAT detected GRB localised?

- **The ability of the LAT to determine the location of a GRB is strongly determined by the flux and spectrum of the GRB (brighter, harder bursts are better localised)**



Consider 2 cases:

10 photons @ 100 MeV:
3.5/sqrt(10) ~ 1° loc. Accuracy

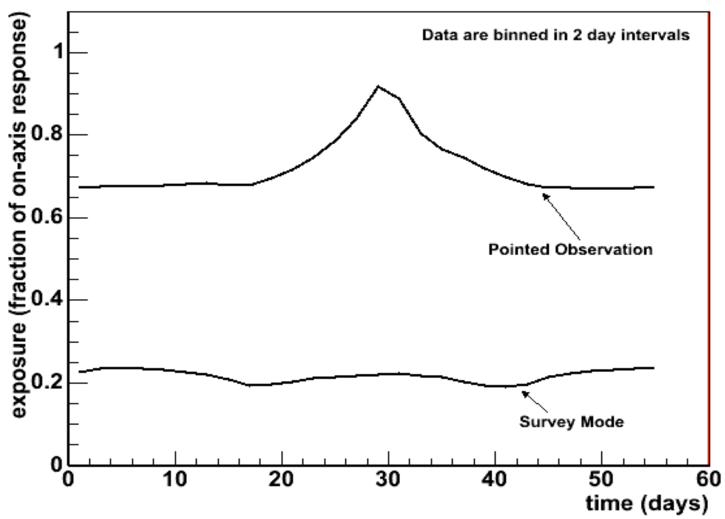
10 photons @ 10 GeV:
0.1/sqrt(10) ~ 1 arcmin loc. accuracy

- **Onboard trigger localisations:** The above discussion applies for ground-based analysis.
  - Onboard algorithms provides rough tracks, somewhat smaller FoV and higher background.
  - Will tend to trigger on brighter harder GRB.
  - Expect O(10)/year with <10 arcmin onboard localisations (to GCN within 15 s).

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