Transient Definition

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GLAST SWG, 10 February 2003

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Why do we need transient policy?

- Release data immediately
- Community alerts
- Premier GLAST science goals (scanning/pointing ToOs)
- Quicklook code design

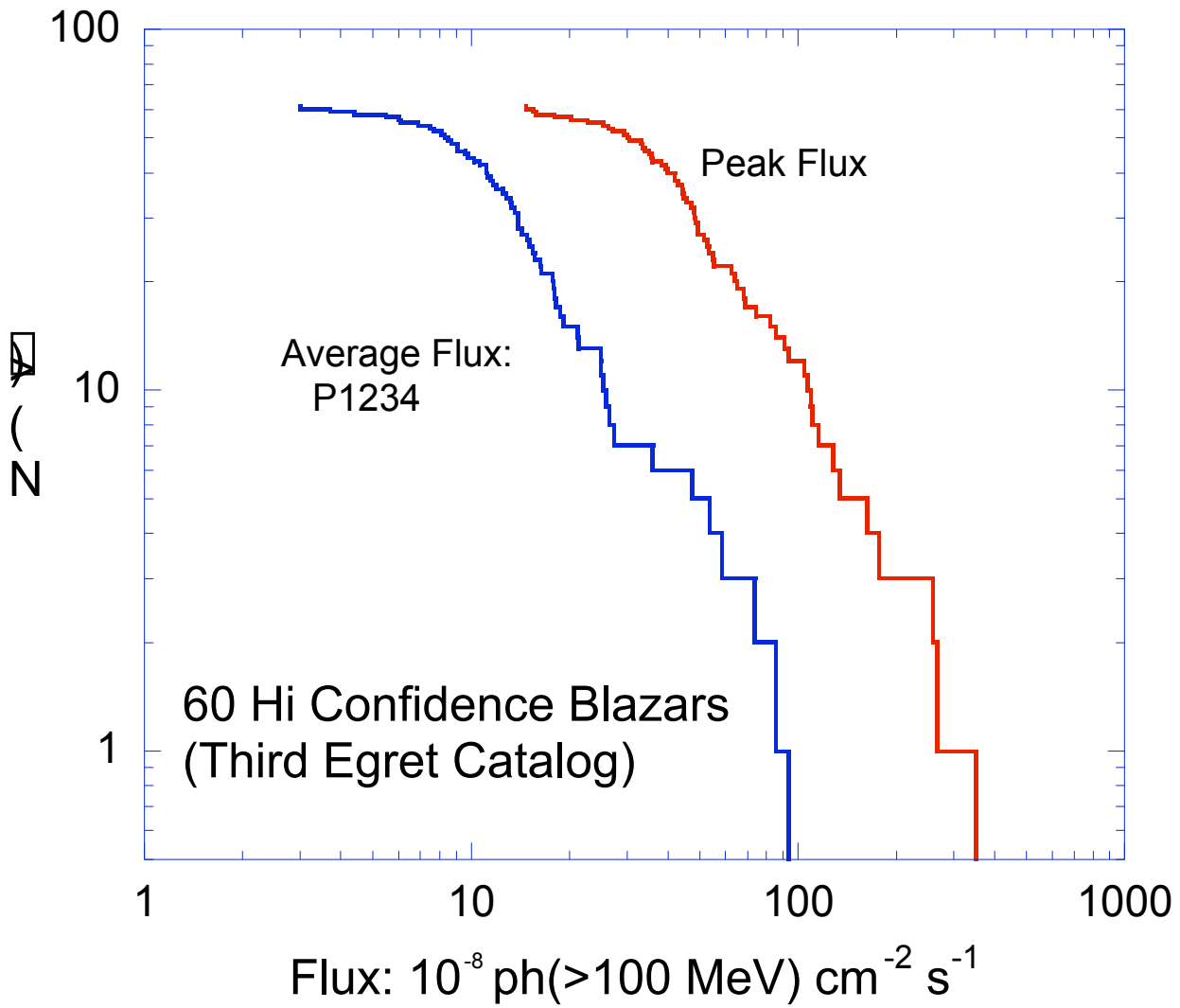
Expected Rates of Transients/Flares at different flux levels from

1. **Blazars**
2. **Unidentified Sources**
3. **GRBs**

Transient Policy

1. **AO (Phase 1)**
2. **Policy Proposed by Mattox, Thompson, Band and Ormes**
3. **Transient Policy Issues**

GLAST Blazars (Average and Peak Fluxes)

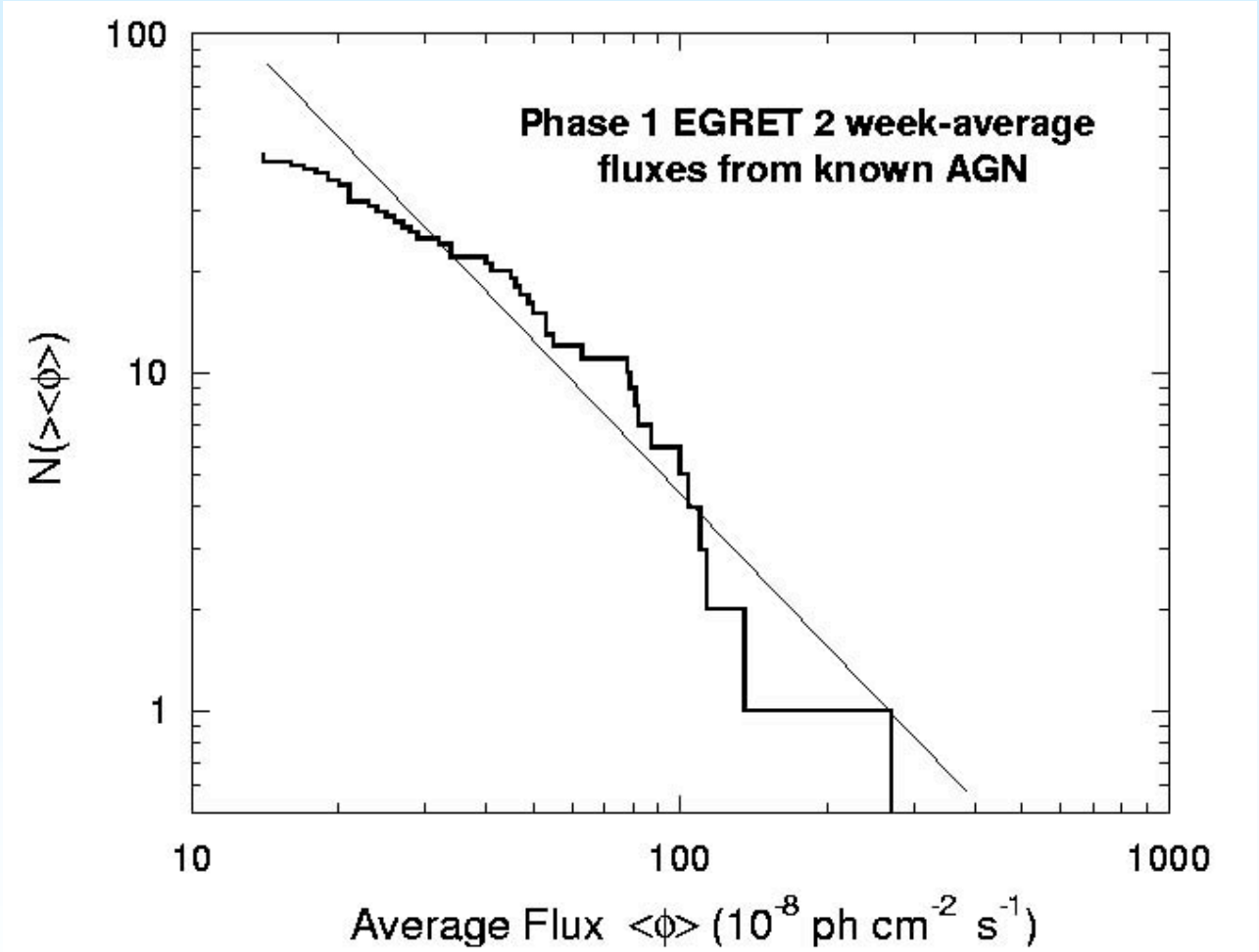


P1234: 1991 April 22-1995 October 3 (4.5 yrs)

Factor of 3-4 between (2 wk average) peak flux and average flux

Minimum peak flux on Two-week timescale: ~15×10^{-8} ph(>100 MeV) cm^{-2} s^{-1}

Frequency of Blazar Flare Occurrences



Phase 1: 1991 April 22-1992 November 17 (573 days)

44 high confidence detections of 25 different sources

Minimum peak flux on Two-week timescale: ~15x10^{-8} ph(>100 MeV) cm^{-2} s^{-1}

The size distribution of blazar 2-week average fluxes < □ > measured during the Phase 1 EGRET all-sky survey (Fichtel et al. 1994)

GLAST Characteristics

$$(E > E_{100} = 100\ MeV)$$

On-axis Point Spread Function:

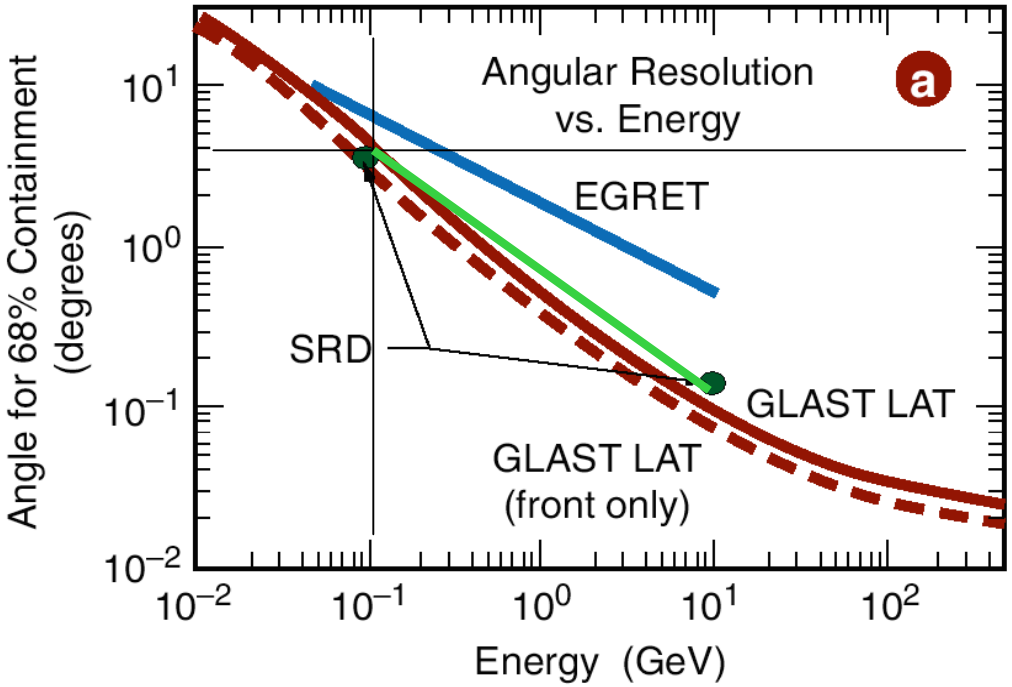
$$\theta = 3.5^\circ \left(\frac{E}{E_{100}}\right)^{-2/3}$$

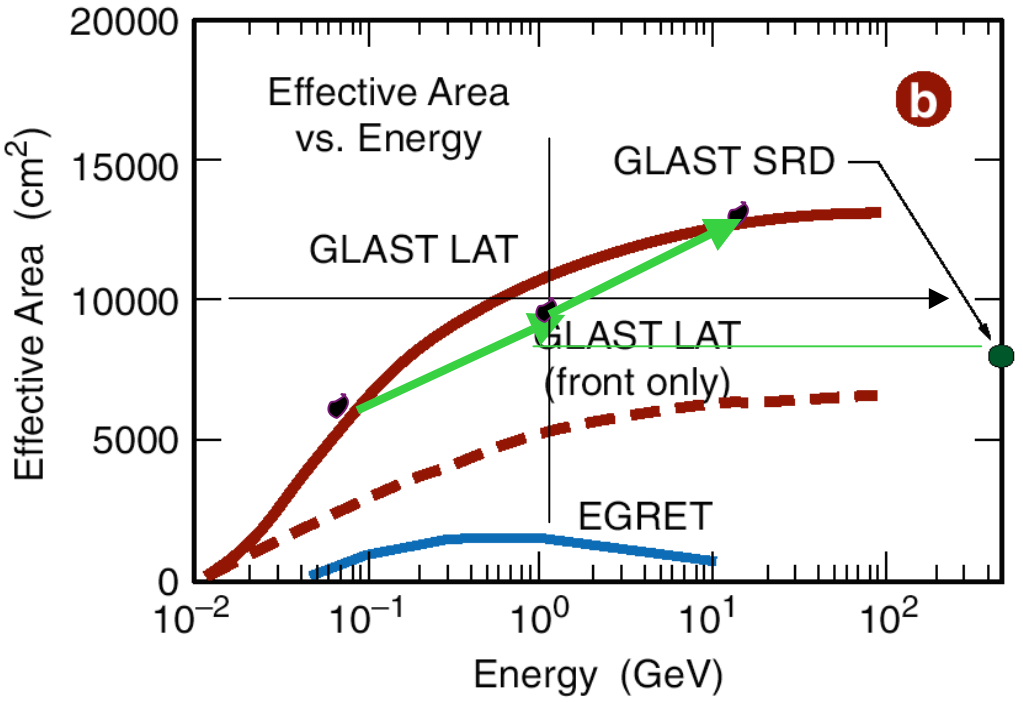
Effective Area

$$A(E,\theta) = A_0 u(\theta) \left(\frac{E}{E_{100}}\right)^{a(\theta)}\ cm^2$$

On-Axis Effective Area

$$A = 6200 \left(\frac{E}{E_{100}}\right)^{0.16}\ cm^2$$





High Latitude Background Calculations with GLAST

$$\dot{B} = \int_{E_1}^{E_2} dE\, A[E,\theta(t),\phi(t)]\, \Phi_B(E,\Omega)$$

Diffuse Extragalactic Background Flux

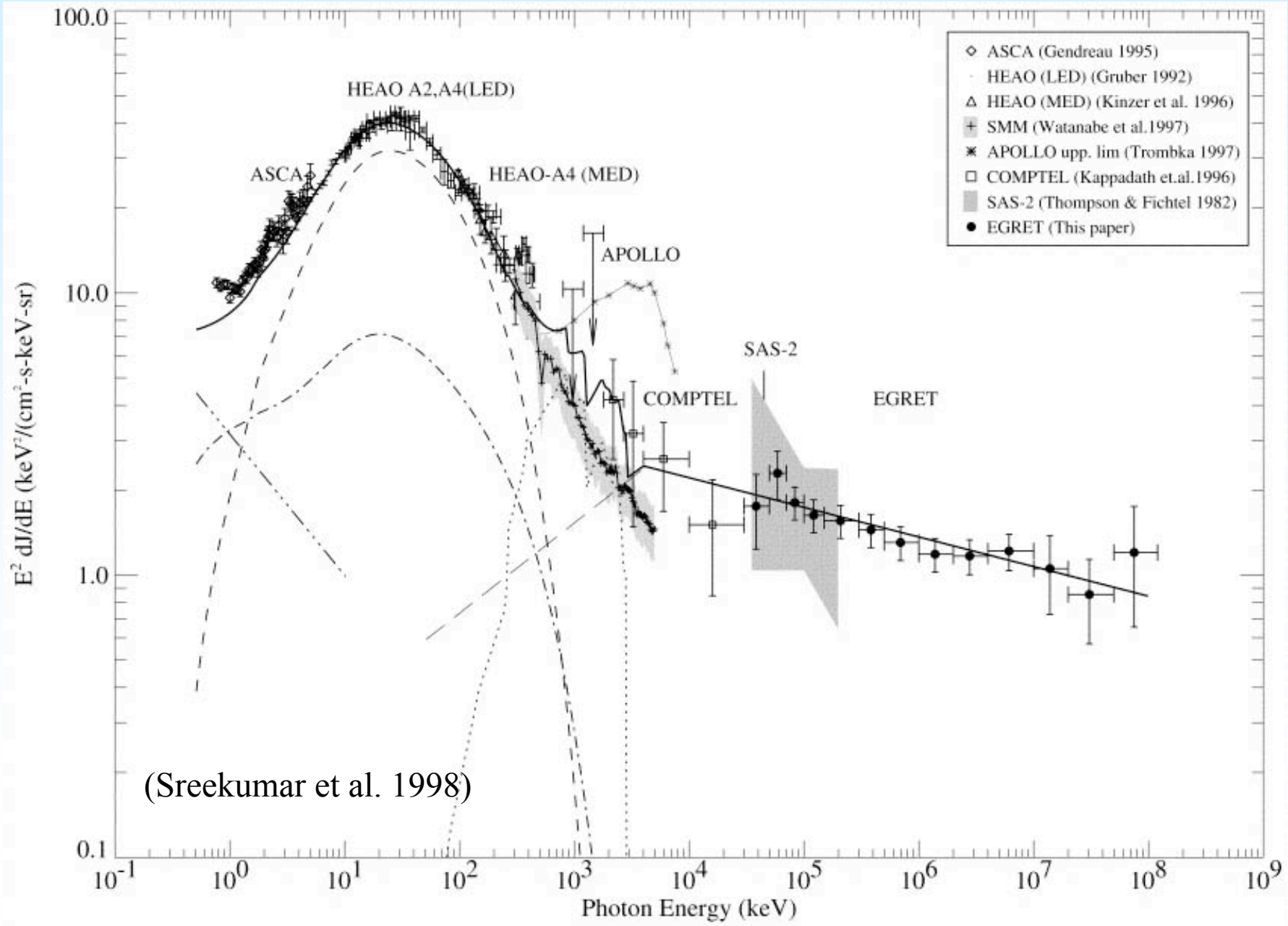
$$\Phi_B(E,\Omega) = K_B \left(\frac{E}{E_{100}}\right)^{-\gamma_B}$$

$$K_B = 1.72(\pm 0.08) \times 10^{-7}\ ph\ cm^{-2}\ s^{-1}\ sr^{-1}\ MeV^{-1}$$

$$\gamma_B = 2.10(\pm 0.03)$$ (Sreekumar et al. 1998)

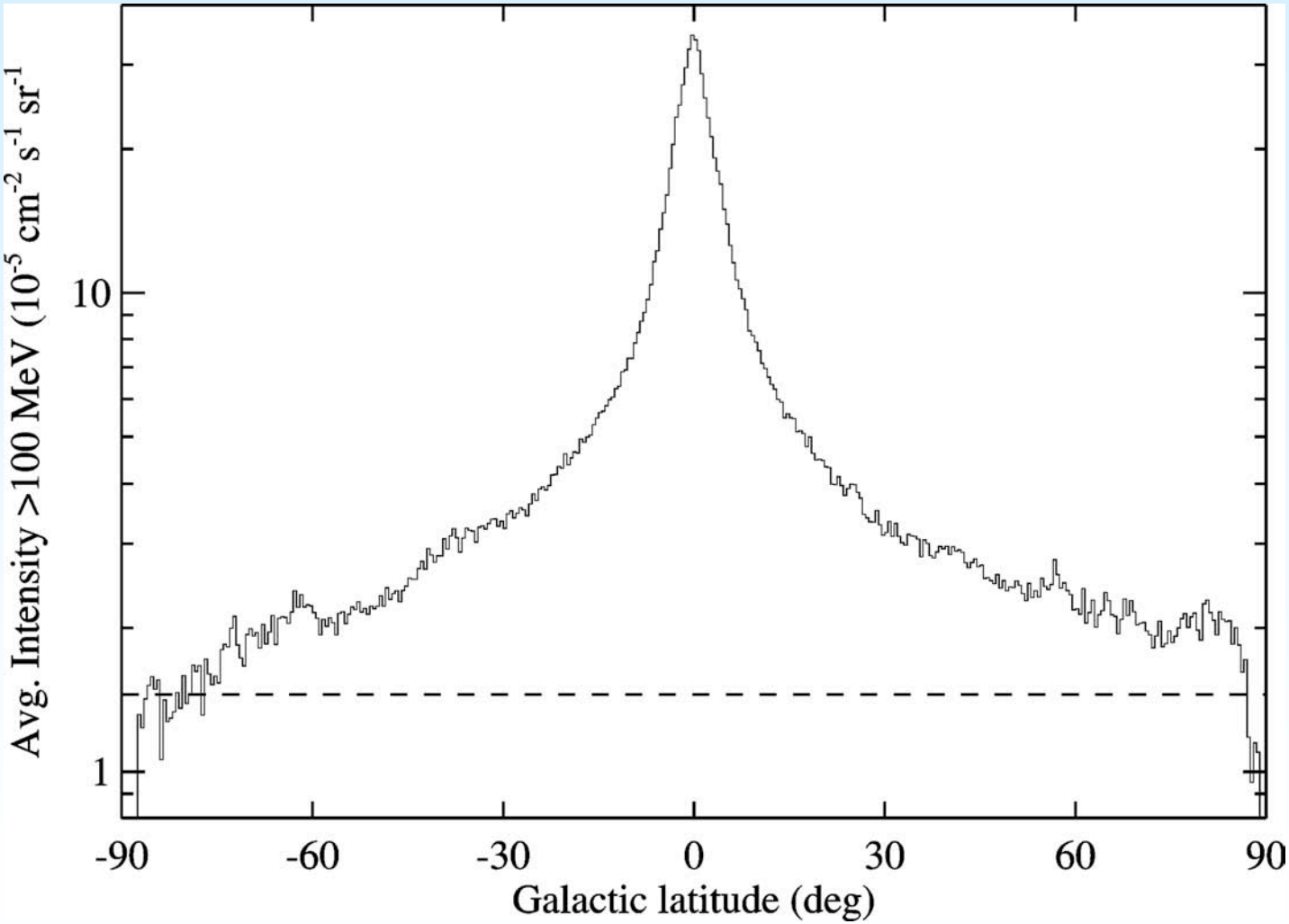
$$B(>E) = \frac{(\Delta\Omega) A_0(\theta t) K_B E_{100}}{\gamma_B - a_0 - 1} \left(\frac{E}{E_{100}}\right)^{1+a_0-\gamma_B}$$

Diffuse High-Latitude Extragalactic Diffuse Background



(Sreekumar et al. 1998)

Diffuse Galactic Emission



Credit: Digel (2001)

Sensitivity of GLAST for High Latitude AGN Detection

Source F_ν Flux $\quad F_\nu = 10^{-10} f_{-10} \left(\frac{E}{E_{100}}\right)^{-\Gamma} \; ergs\ cm^{-2}\ s^{-1}$

Source Counts $\quad S = \frac{39}{0.84 - \Gamma} X t_4 f_{-10} \left(\frac{E}{E_{100}}\right)^{-0.84+\Gamma} \quad (> 5)$

$Total\ observing\ time = 10^4 t_4$ sec, $X = 0.2 : occulting\ factor$

Diffuse Extragalactic Background Counts

(Acceptance cone = psf)

$B = 13.3\ X t_4 \left(\frac{E}{E_{100}}\right)^{-2.27}$

Sigma $\quad \sigma = \frac{S}{\sqrt{2B}} = \frac{7.6}{0.84 - \Gamma} \sqrt{X t_4} f_{-10} \left(\frac{E}{E_{100}}\right)^{-\Gamma+0.29} \quad (> 5)$

High Latitude Point Source Detection Requirements

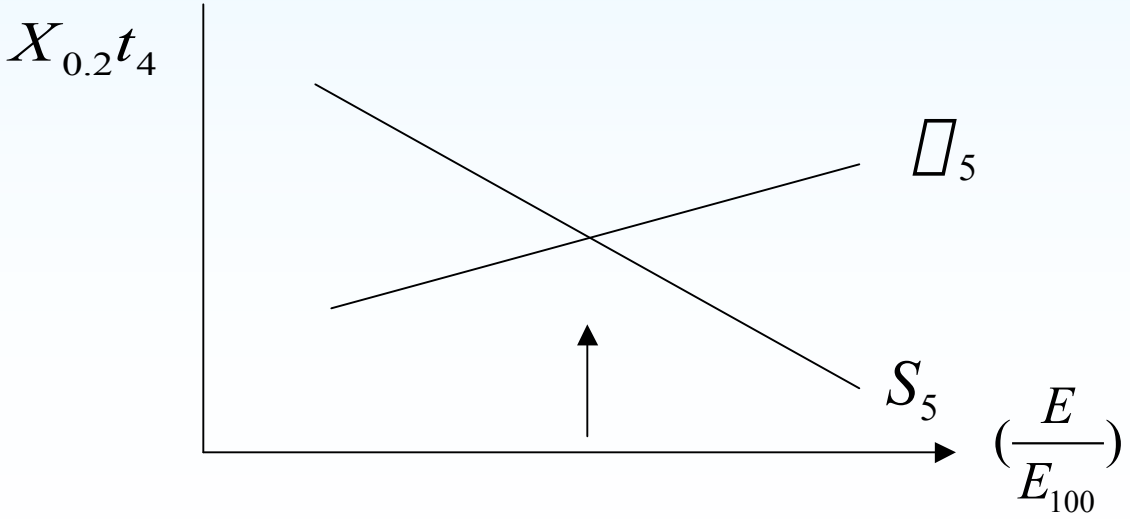
Source Counts

$$S \propto \frac{8}{0.84\,\Gamma_{\gamma}} X_{0.2} t_4 f_{\gamma 10} \left(\frac{E}{E_{100}}\right)^{\Gamma_{\gamma}+0.84} \quad (\geq 5)$$

Sigma

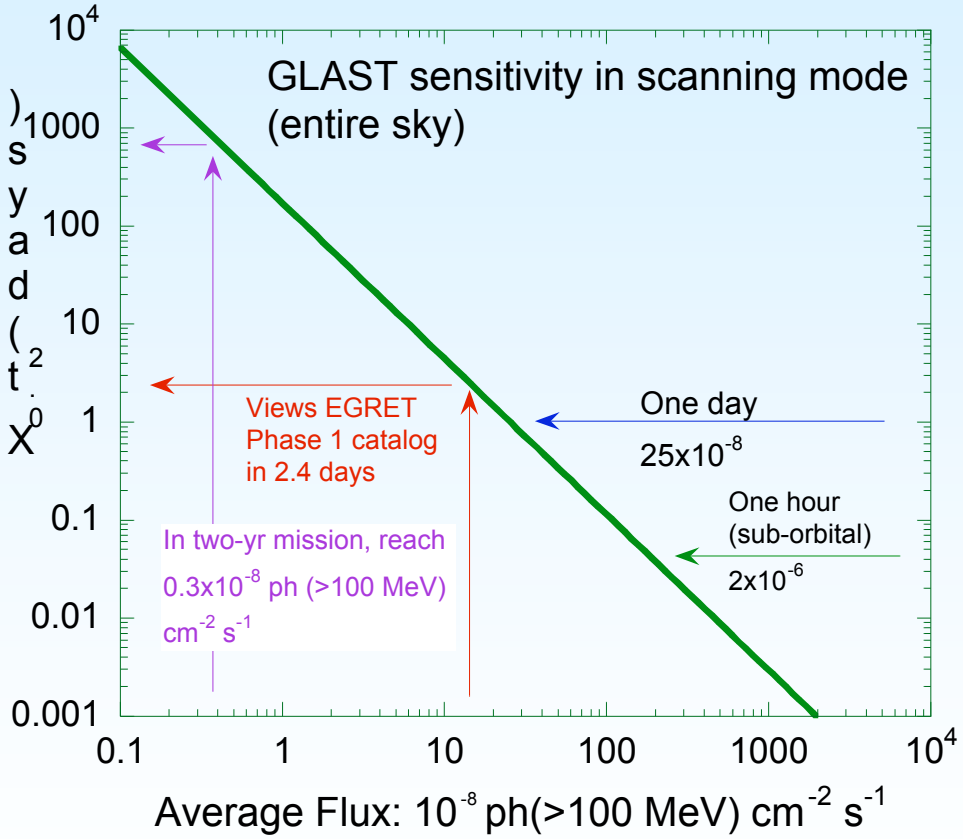
$$\sigma = \frac{S}{\sqrt{2B}} \propto \frac{3.4}{0.84\,\Gamma_{\gamma}} \sqrt{X_{0.2} t_4} f_{\gamma 10} \left(\frac{E}{E_{100}}\right)^{\Gamma_{\gamma}+0.29} \quad (\geq 5)$$

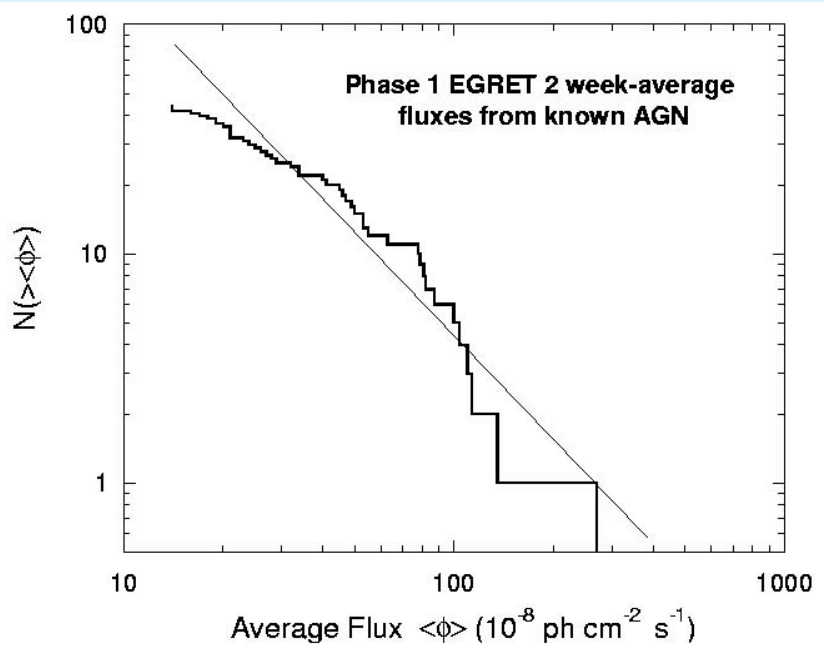
Determine energy at which observing time is smallest to satisfy 5σ, 5 count criterion



Rate of Blazars Detected with GLAST

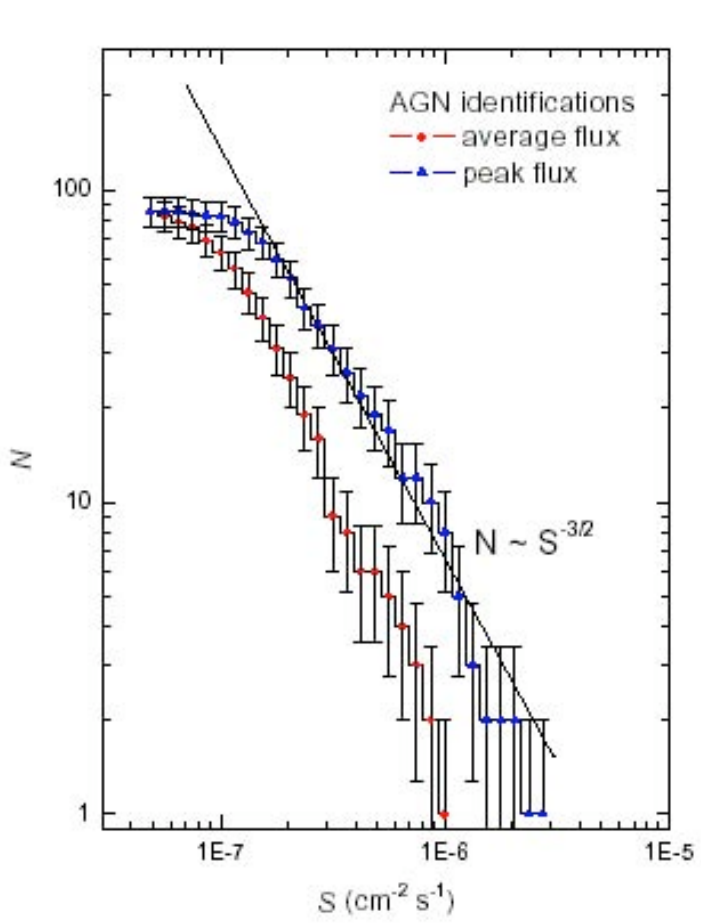
EGRET saw blazars to a level of 15×10^{-8} ph(>100 MeV) cm^{-2} s^{-1} in a two week pointing (background limited)

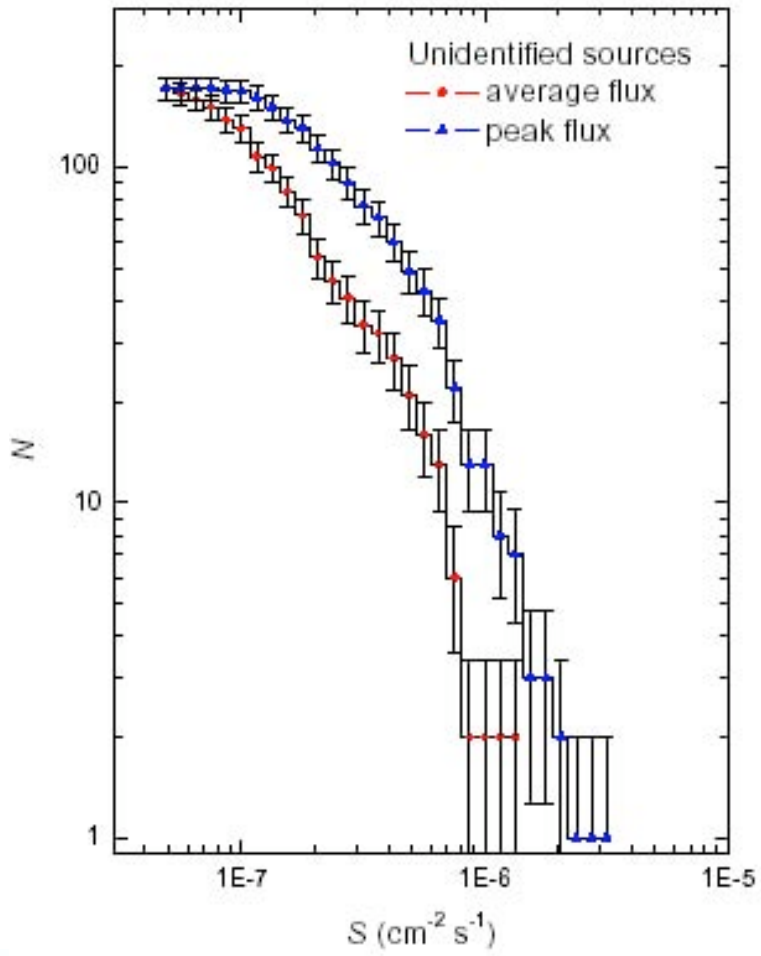




GLAST, in scanning mode, will reach EGRET's threshold sensitivity for a 2-week pointing in ~ 2.4 days. But instead of seeing 1/24th of the sky, GLAST will have surveyed the whole sky

Unidentified Sources

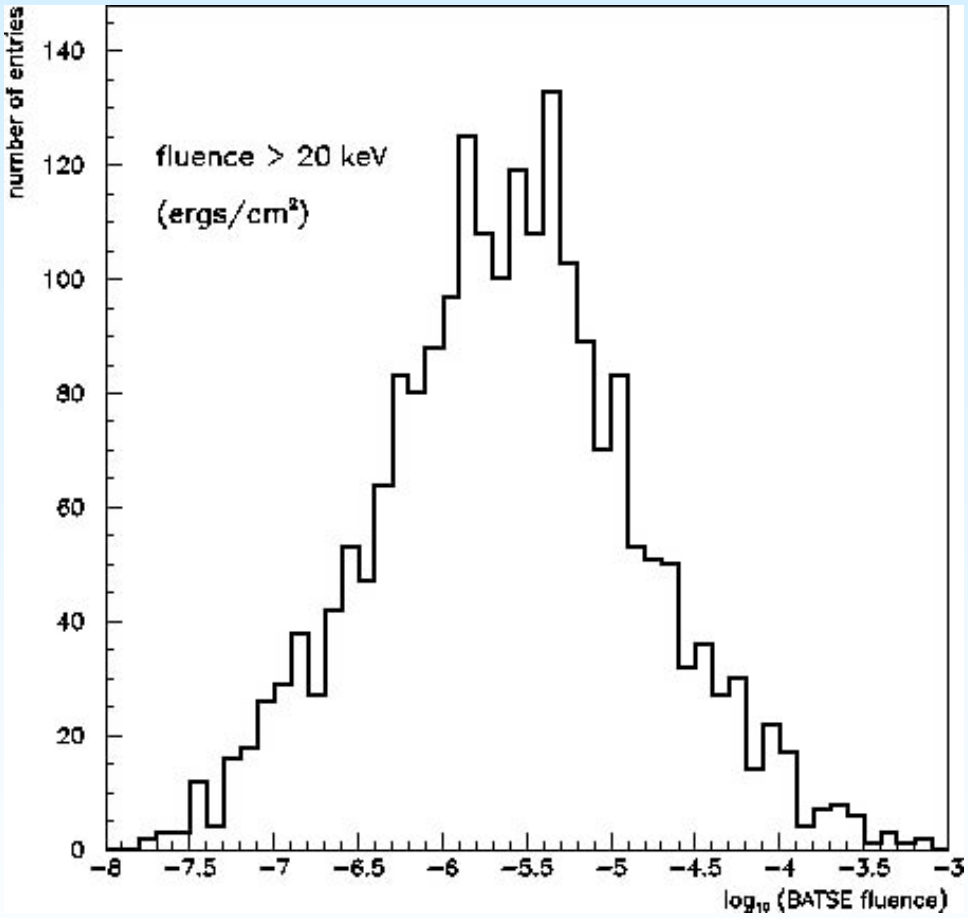




(Reimer and Thompson 2001)

More unidentified sources; comparable number of bright AGNs and unidentified sources

Detection Rate of GRBs with GLAST



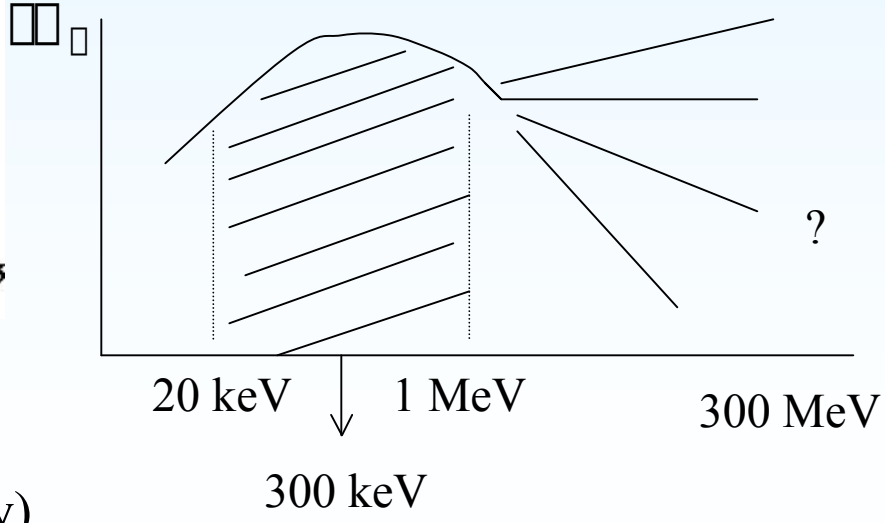
GRB fluence (> 20 keV) distribution for 2135 BATSE GRBs from BATSE 4B catalog (McCullough 2001) 600 GRBs/yr (full sky)

Number of photons detected with GLAST =

$$\frac{\Phi_{GLAST}(ergs\,cm^{-2})}{ergs/ph} A_{GLAST}$$

$$\frac{\Phi_{BATSE}(ergs\,cm^{-2})\,8000cm^2}{1.6\times10^{-6}\times300MeV/ph}\left(\frac{\Phi_{GLAST}}{\Phi_{BATSE}}\right)$$

$$\Phi_{BATSE}\,(1000)^{\Gamma-1} \geq 5$$



GLAST GRB Detection Rate

α	$\phi_{BATSE,min}$(ergs cm^{-2})	#(>ϕ)	#/day	GLAST GRBs/day*
0	3×10^{-7}	1700	1.3	0.26
0.5	10^{-5}	400	0.3	0.06
1	3×10^{-4}	8	0.006	0.0012

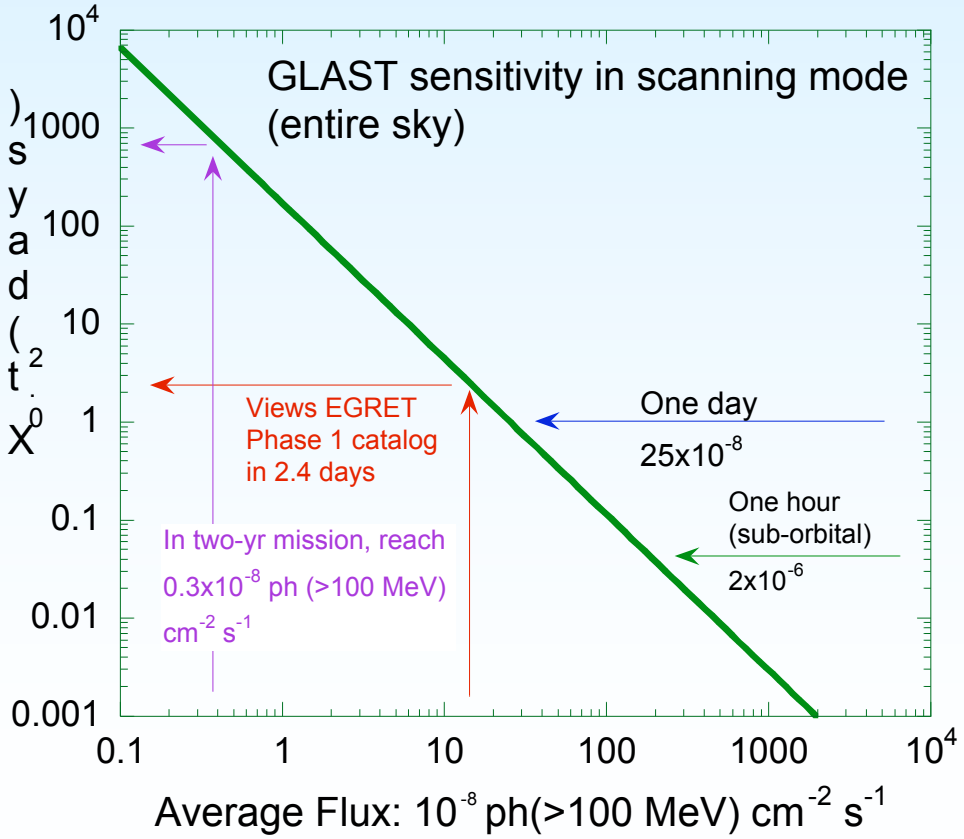
*Assumes GRB duration < 20 minutes

TASC Observations of 15 GRBs $\Rightarrow$ $\langle\alpha\rangle \approx 0.2$
(median value is $\alpha = 0.02$) (Catelli and Dingus 1998)

$\Rightarrow$ $\approx$100 GRBs/yr detectable in LAT

Goal of Transient Policy

1. **Satisfy Mandates of AO**
2. **Adopt a Policy of Fairness and Simplicity**
3. **Maximize Science Return from GLAST**



TRANSIENT POLICY OF THE AO

"During the first twelve months of science operations, data from specific sources of interest to qualified individual researchers will be made available upon request to the Guest Observer Facility. Note that large projects, i.e., those involving large number of sources and/or very long observing times, will not be permitted by outside researchers during this period. At all times, including the first twelve months of science operations, the data from transient sources discovered or detected by GLAST will immediately be made publicly available. During the first twelve months of operations, the instrument may not have been completely calibrated, and, thus, any data made available may be unvalidated and unverified."

AO 99-OSS-03, p. 13

Definition of Transient

tran•sient (tr_n$h_nt), *adj*. **1.** passing with time, not lasting or enduring; transitory. 2. Lasting but for a time; temporary; *transient authority*. 3. remaining only for a short time, as a guest at a hotel.

(The American College Dictionary)

Transient Source ≠ Time Variable Source

GRBs; Evaporating Black Holes; Newly Discovered Flaring Sources

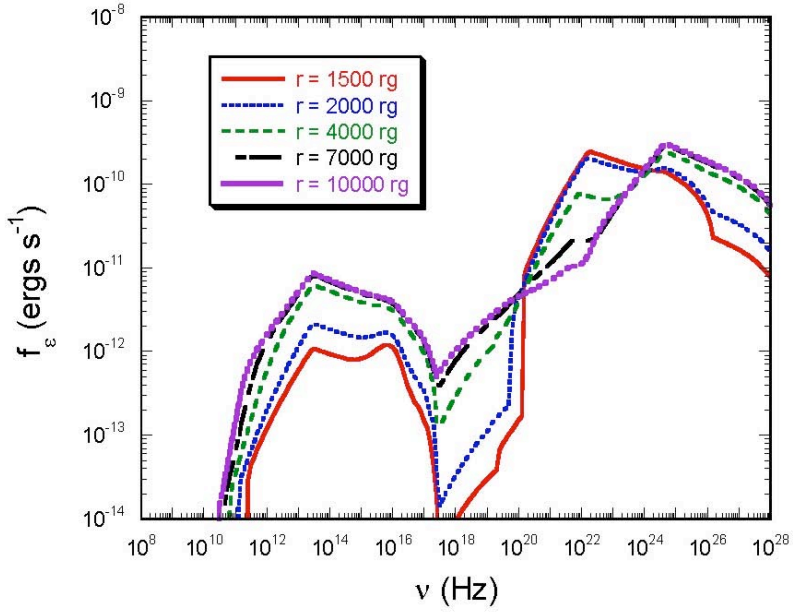
But is the flaring emission the transient, or is the source the transient?

Transient Source = Time Variable Source

Motivation for Blazar Transient Alerts

Draft of GLAST Transient Policy by Band, Mattox, Thompson, Ormes, et al.

- **"…multiwavelength monitoring is expected to be of greatest value when the blazar flux is sufficient to resolve flux variations on time scales of interest."**
- **Monitor spectral changes of different physical components in the source**
- **Multiwavelength campaigns to establish dominant physical processes**
- **Blazars are moderately bright before flares; look for gamma-ray characteristics to alert multiwavelength community**



Draft Policy: Gamma-Ray Bursts

Immediate release of GBM Level 1 transient (GRB) data throughout mission

- **GMB – LAT GRB: Release LAT Level 1 data**
- **GBM – (No LAT) GRB: do not release LAT Level 1 data**
- **GBM – (LAT ?) GRB: Policy undefined**
- **(No GBM) – LAT GRB/hard transient: burst trigger coded into flight software**

Definitely release to community: discovery potential for clean fireballs, evaporating black holes, or new phenomenon

Policy on Other GBM transients?

Immediate release of GBM Level 1 transient data throughout mission

- **Solar flares**
- **Electron precipitation events**
- **TGFs**
- **Occultation emergences of strong sources**
- **Fluctuations in strong sources (Cyg X-1)**
- **SGRs**
- **Other**

Draft Policy for Release of Blazar Data

Every bright EGRET blazar is variable

The following policy is proposed:

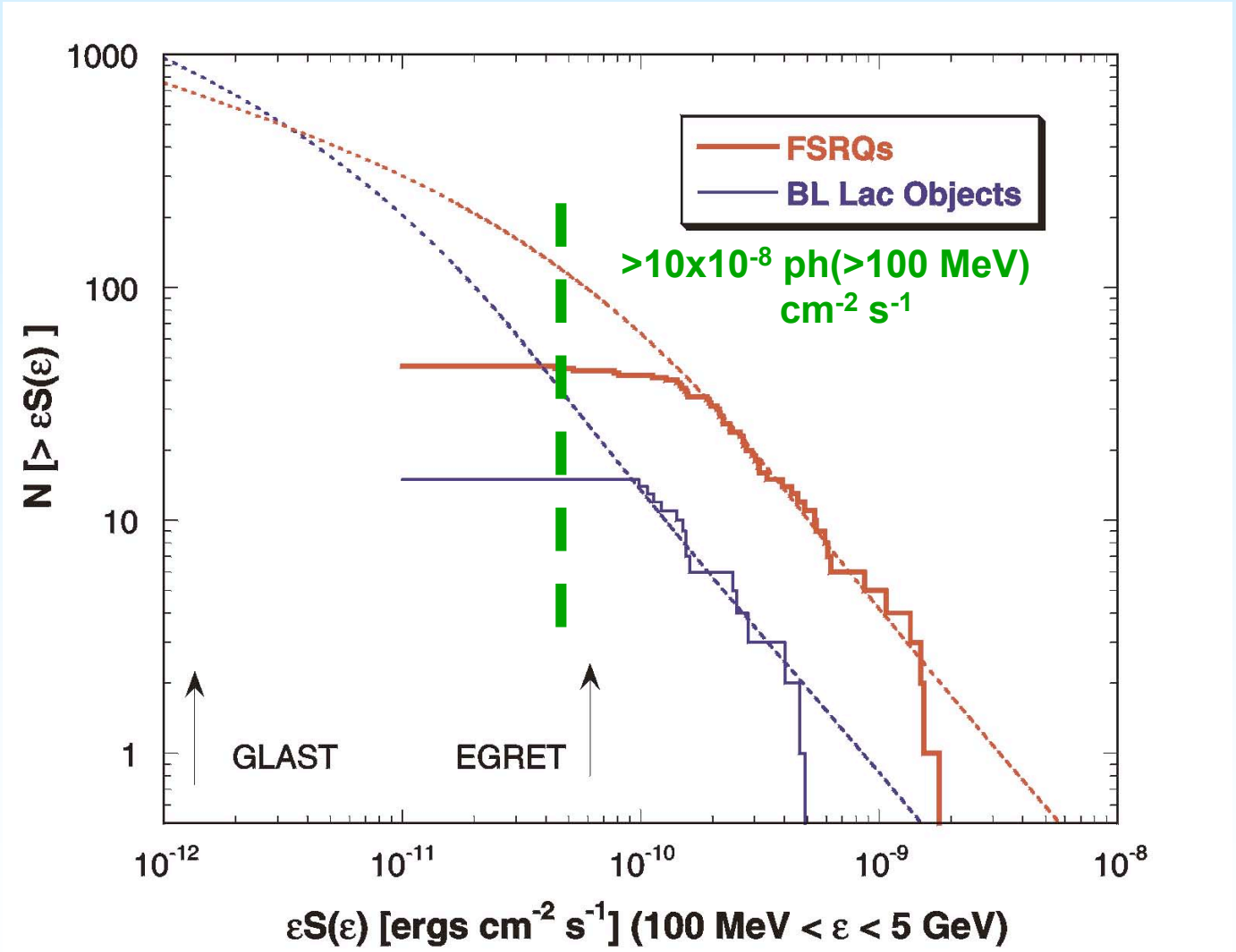
1. **Update weekly on a public web page all blazars with weekly average fluxes exceeding 10×10^{-8} ph(>100 MeV) cm^{-2} s^{-1} (~90 blazars)**

   List all blazars that have ever exceed 10×10^{-8} ph(>100 MeV) cm^{-2} s^{-1} this flux: expect several thousand after several years.

Include low flux TeV blazars

Most blazars will never exceed this flux level; majority of GLAST blazars require integration over full year (or more) (depends on duty cycle)

GLAST Blazars (Peak Fluxes)



Proposed Policy for Release of Blazar Data

2. Issue IAU circular when blazar fluxes exceeds 10^{-6} ph(>100 MeV) cm^{-2} s^{-1} for the first time and post data for 7 consecutive days. If it subsequently exceeds 10^{-6} ph(>100 MeV) cm^{-2} s^{-1}, release the data through a GCN notice

IAU circulars should be abandoned. They may freeze out the Amateur Astronomers who do not subscribe to them for financial reasons.

GCN (or a GCN-type immediate-release network) should be used.

There would be many IAU circulars in the early phase of the mission when blazars first reach flux level above 10^{-6} ph(>100 MeV) cm^{-2} s^{-1}

Several blazars and several unidentified sources will be above this level every day

Proposed Policy for Release of Blazar Data (cont.)

3. **Announce data for blazars exceeding LAT flux of 5×10^{-6} ph(>100 MeV) cm^{-2} s^{-1}, and with a logarithmic time derivative > 1/day, through IAU circular.**

$3\text{-}5 \times 10^{-6}$ ph(>100 MeV) cm^{-2} s^{-1} are rare events, and should trigger alert

But it may turn out that these events always originate from the same few sources

Hidden assumption that the brighter the blazar, the more interesting it is.

For X-ray selected BL Lac objects, it might be just the opposite. Other anti-correlations might affect detectability with joint INTEGRAL/GLAST observations. [Automation depends on quick-look analysis software]

The "d ln Delta(counts)/ d ln time > 1/day => IAU Circular" policy too liberal.

GLAST will view EGRET's Phase 1 all-sky catalog (~ 40 blazars) in about 2.4 days. During this time, several to ~10 of these blazars will be bright enough to show sub-day time scale variability. We don't want to be sending out several IAU (or GCN) notifications per day. [Only previously unknown sources]

Draft Policy: Non-Burst, Non-Blazar Transients

Transients that should trigger a full release of LAT Level 1 Data

- **Proposed policy: Release an IAU circular for newly discovered bright, non-blazar sources that reach a level of > 30×10^{-8} ph(>100 MeV) cm^{-2} s^{-1}, and exhibit 5□ transient behavior within one week**

  Release level 1 LAT data
  - **for region large enough to do likelihood analysis**
  - **beginning 1 week prior to reaching >30×10^{-8} ph(>100 MeV) cm^{-2} s^{-1} until flux drops below this level for seven days**

- **May have to wait one week before determining whether criterion is met**
- **Flux levels may bias policy toward high-latitude sources**
  GRO J1838-04 flared to 400×10^{-8} ph(>100 MeV) cm^{-2} s^{-1} (Tavani et al. 1997)
- **Assumes that flux is most important criterion for notification**
- **Different quick-look analysis for known and newly discovered sources**

Transient Policy Issues

Maximizing Scientific Return

1. **Cannot (simply) automate transient policy; it is a bootstrapping procedure**

2. **Flux or flaring rate is not the only crucial variables; source type is more important than either**
   - **Seeing a micro-blazar in the GLAST energy range at low flux levels could be more important than seeing the 6th flare from 3C 279 at a flux level of 10^{-6} ph(>100 MeV) cm^{-2} s^{-1} ; establishing a new class of variable gamma-ray sources is most important scientifically**

3. **The "scientific community" is disparate and has differing interests and capabilities**

4. **Requires a scientist in the loop to make decisions on when to issue alert**

Source Types

1. *Blazars previously detected at gamma-ray energies

2. *Blazars not previously detected at gamma-ray energies but expected to exhibit episodes of gamma-ray brightness on the basis of standard gamma-ray blazar properties (flat radio spectra; superluminal motion; optical variability, etc.).

3. *Blazars and AGN not expected to be gamma-ray bright and variable (e.g., radio galaxies [aka misaligned blazars], steep spectrum radio quasars, radio-quiet AGN), but which could surprise us.

4. GRBs detected by GBM and/or LAT

5. Non-recurring fast gamma-ray transients (clean fireball GRBs or evaporating black holes) not detected by the GBM.

* indicate sources for which a source catalog exists or could be developed for GLAST studies

Source Types (cont.)

6. *Previously catalogued unidentified gamma-ray sources

7. Newly catalogued unidentified gamma-ray sources (which may start their lives as fast gamma-ray transients, but move to this category if they persist beyond several hours or days. They would then move to category 6 if they persist beyond a week).
   Trigger alert if they exceed 10^{-6} ph(>100 MeV) cm^{-2} s^{-1}

8. *Sources of Interest: These would especially include microquasars and the Galactic Center, but also X-ray binaries, pulsars, plerions, and supernova remnants (these last three categories would include sources that are persistent gamma-ray emitters which could--though are not expected to--flare at gamma-ray energies).

9. Solar flares (?)

* indicates sources for which a source catalog exists or could be developed for GLAST studies: update source catalog/watch list at least once/day

Observer Communities

Different communities of observers have different interests (e.g., high-redshift FSRQs would be of little interest to Whipple; GRB communities)

Geographical locations

Does Solar community requires notification?

Transient Strategy

- Post light curves of N (= 30?) blazars from quick-look analysis on web
- Issue ~ 1/week GLAST alerts (which would then generate many follow-up e-mails)
- Issue automated alert for source that reach > 2x**10^{-6} ph(>100 MeV) cm^{-2} s^{-1}**

Summary of Policy Issues

- Satisfying mandates of AO: depends on what the definition of is is
- Automated and “fair” process: could lose important science without rigorous examination of criteria on a source-type by source-type basis
- Maximize GLAST science return:

Two-prong policy of posting fluxes/count rates and sending alerts

Need a fully informed, cognizant scientist to decide which GLAST detections warrant an alert to the community.