The Burst Populations Swift Will Detect

David Band (GLAST SSC—GSFC/UMBC)

Useful Background

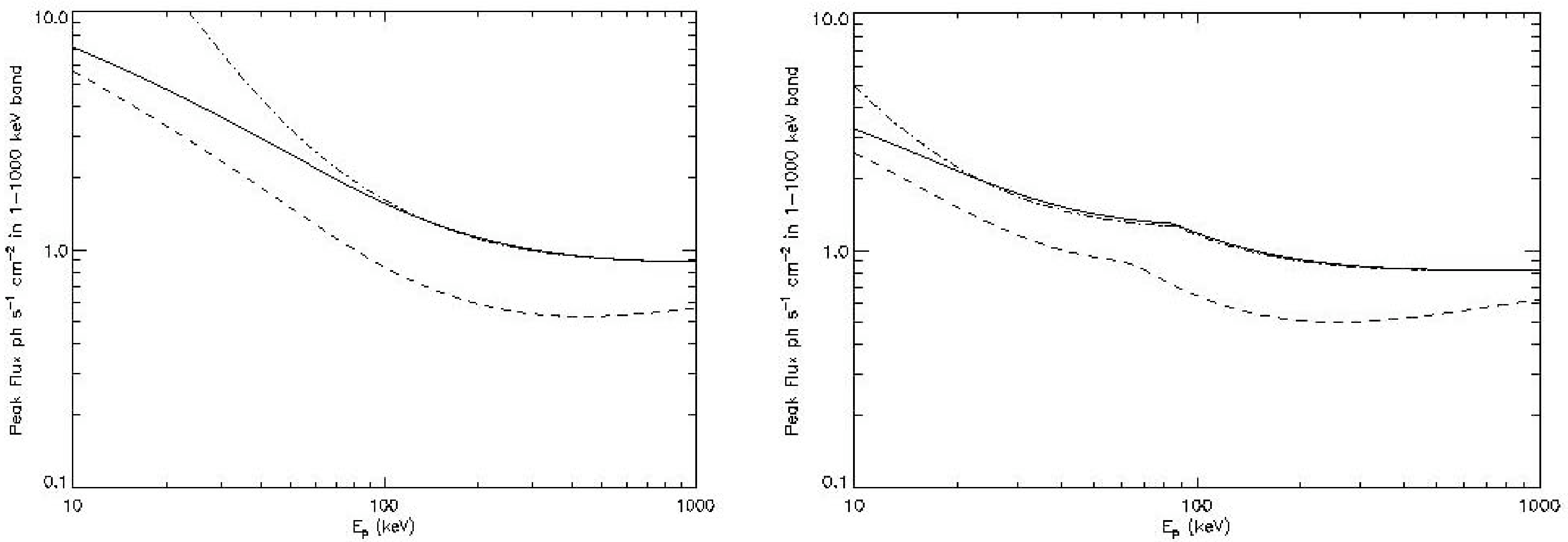
- Burst spectra can be characterized by

$$N(E) \propto E^{\alpha} e^{-E/E_0} \quad \text{at low energy} \quad (\alpha \sim -1)$$
$$\propto E^{\beta} \quad \text{at high energy} \quad (\beta \sim -2)$$
$$E_p = (2+\alpha)E_0 \quad \text{(energy of maximum } \nu F_\nu\text{)}$$

- Rate triggers search for a significant increase in the counts accumulated over Δt and ΔE. Swift will use a variety of rate triggers followed by imaging to verify a new point source has appeared. My analysis focuses on rate triggers only.

- To compare the sensitivity of detectors with different energy ranges to bursts with different spectral properties, consider the F_T-E_p plane, where F_T=1-1000 keV flux. Bursts live in this plane, allowing detector and burst population studies.

BATSE (left) and Swift (right)



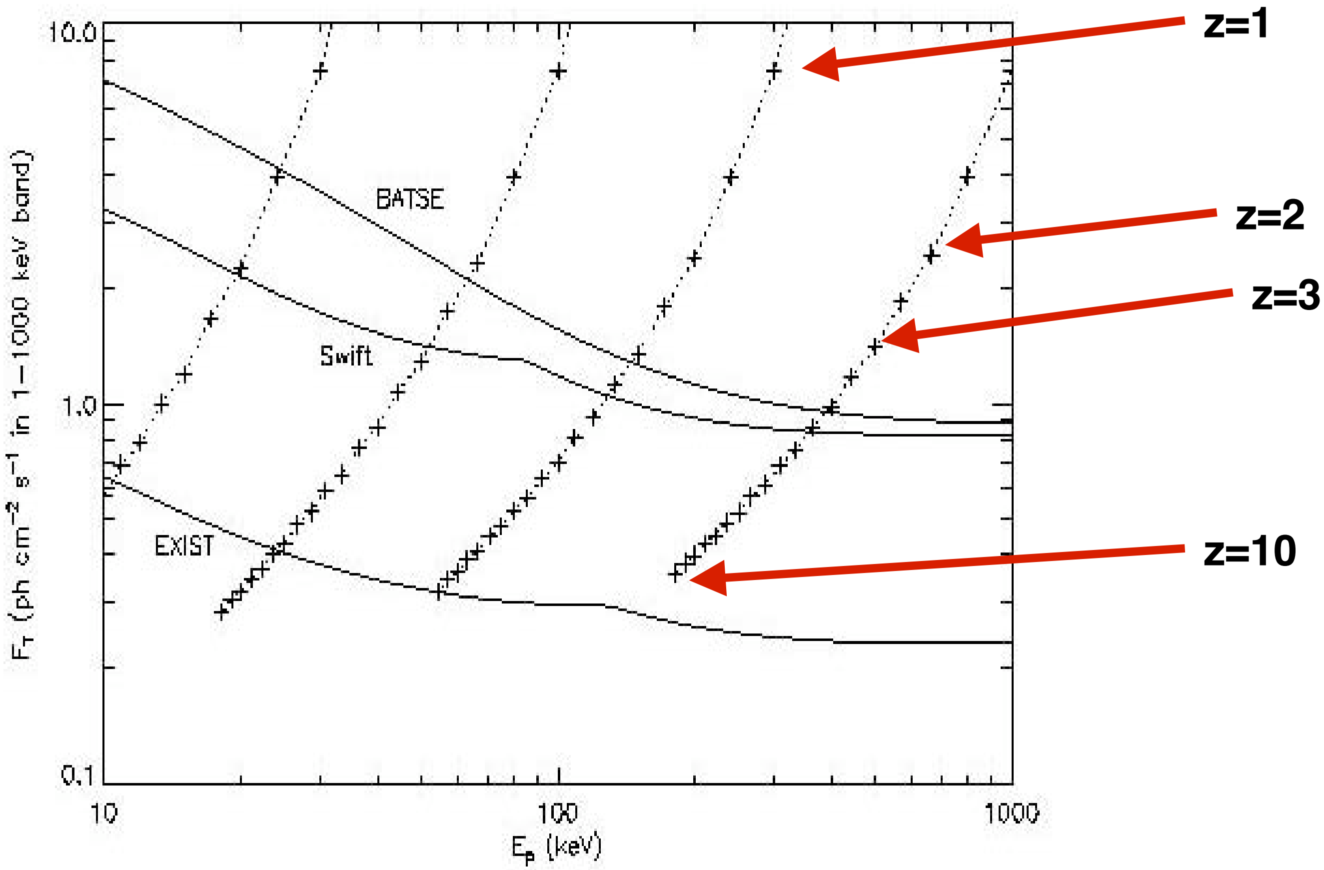
Swift and BATSE have comparable sensitivities for E_p>100 keV, but Swift is much more sensitive for E_p<100 keV.

Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.

Swift's Burst Detection Rate

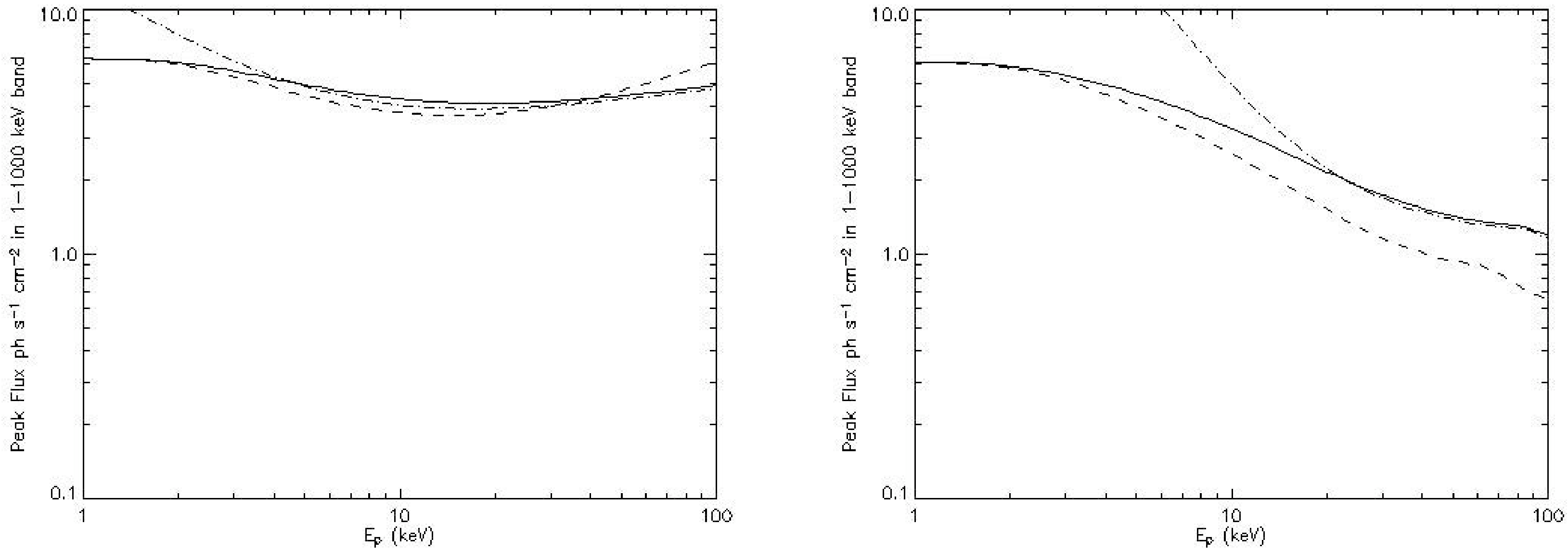
- BATSE: 550 bursts/yr/sky ($\phi \geq 0.3$ ph cm^{-2} s^{-1}, $\Delta t=1.024$ s, $\Delta E=50$-300 keV).
- Assume logN-logϕ has an index of -0.8 at the low end.
- Model the Swift FOV
- Result: ~100 bursts per year
- The actual number will probably be ~50% larger because of:
  - XRFs (X-ray Flashes—faint soft bursts) for detectors with low energy sensitivity
  - Multiple trigger times (particularly long ones)

High Redshift Bursts—Faint and Soft



Each track corresponds to a burst with F_T=7.5 ph cm^{-2} s^{-1}@ z=1; the tracks differ by E_p @ z=1; symbols are spaced by Δz=1/2.

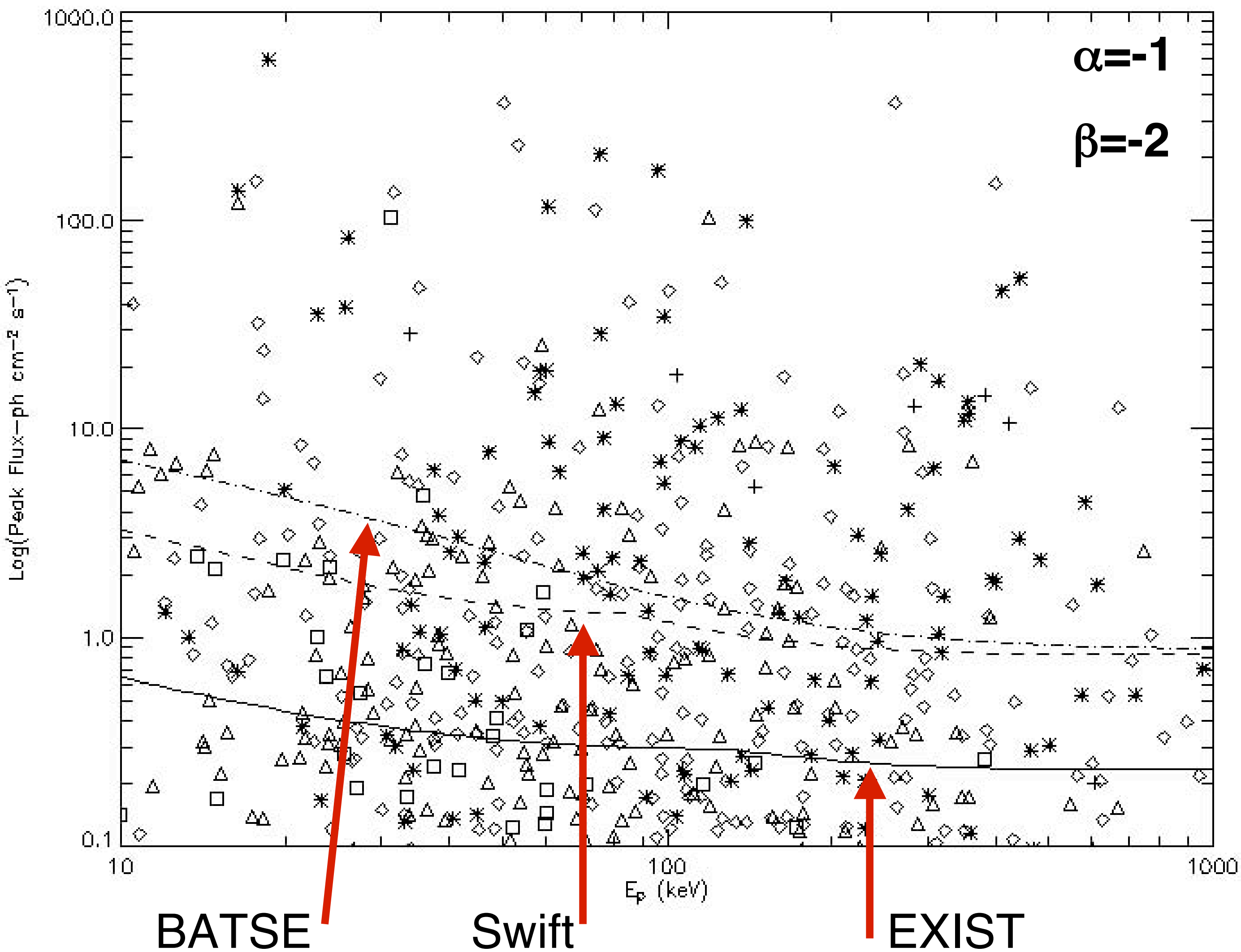
HETE II's WXM (left) and Swift (right)



Swift will be significantly more sensitive than HETE's WXM except for E_p<10 keV (particularly for β<-2).

Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.

Population Modeling



+ = z≤0.5

* = 0.5<z≤1.5

◊ = 1.5<z≤3

_ = 3<z≤6

_ = 6<z

Models for:

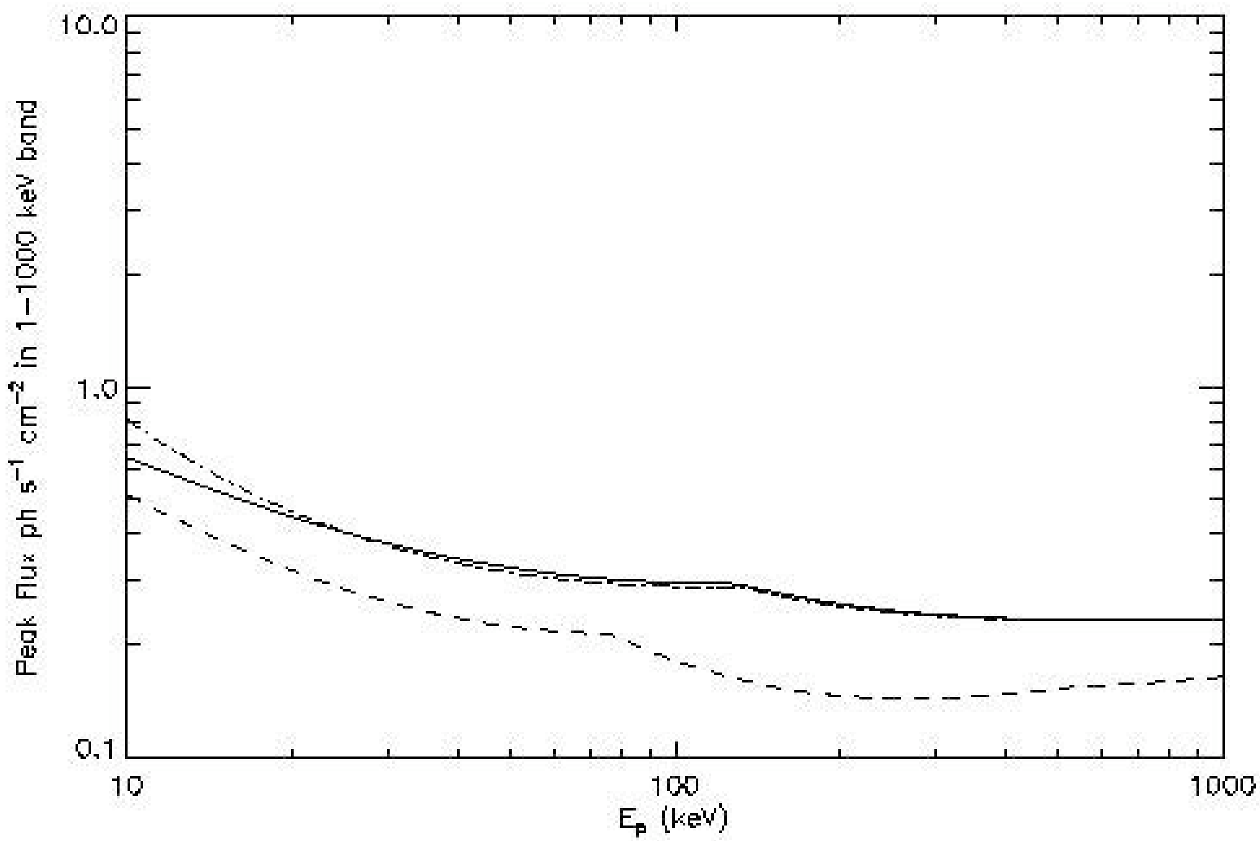
E_p, E_{iso}, z, t_{char}

Summary

- Swift will be more sensitive than BATSE for soft bursts.
- Swift will be more sensitive than HETE's WXM except for the very softest bursts (low E_p, β), leaving the WXM a niche in the Swift era!
- High redshift bursts should be faint and soft.
- Swift will probably detect ~150 bursts per year.
- Burst populations can be modeled can compared to the sensitivity of different detectors.

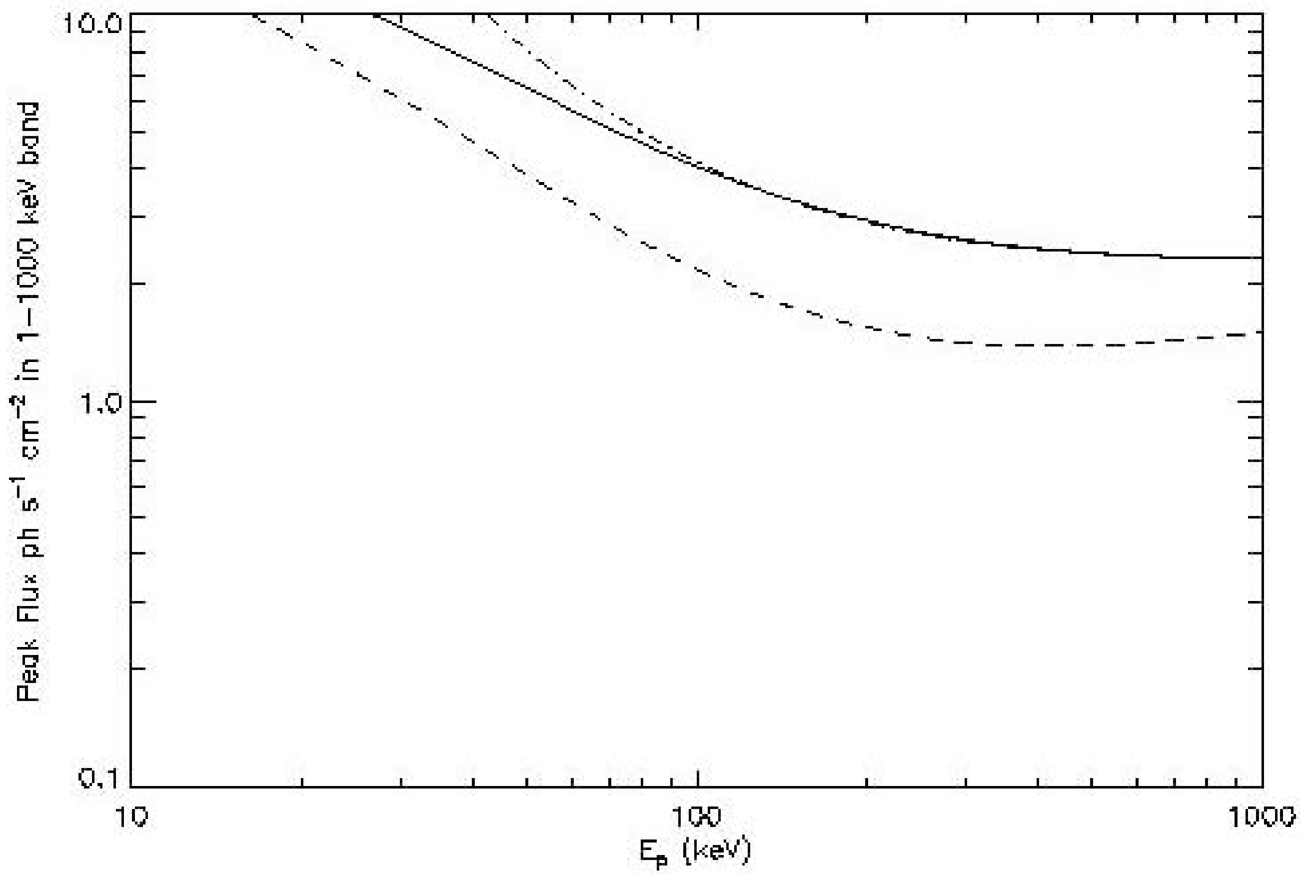
ADDITIONAL SLIDES

EXIST, 5mm CZT



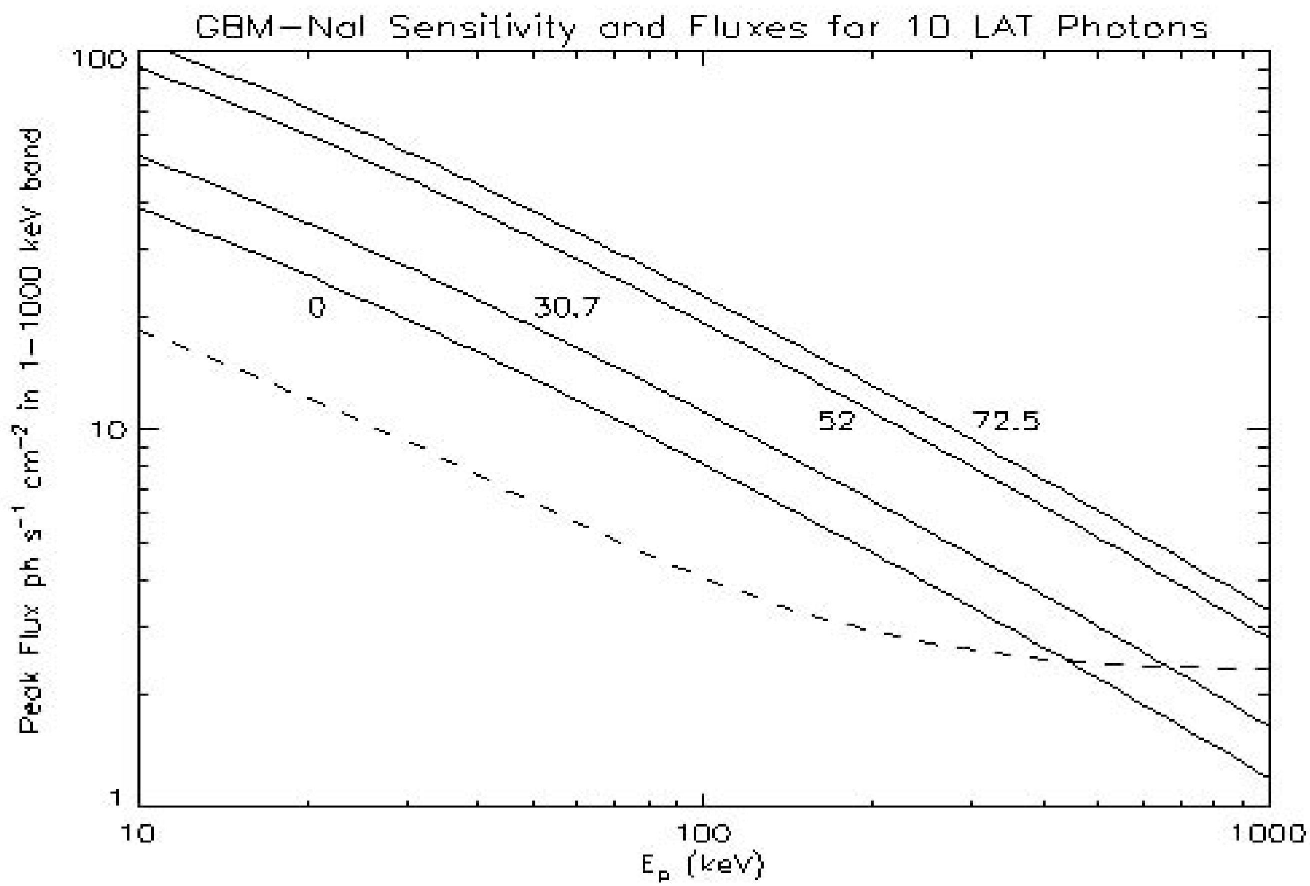
Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.

GBM NaI(*Tl*)



Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.

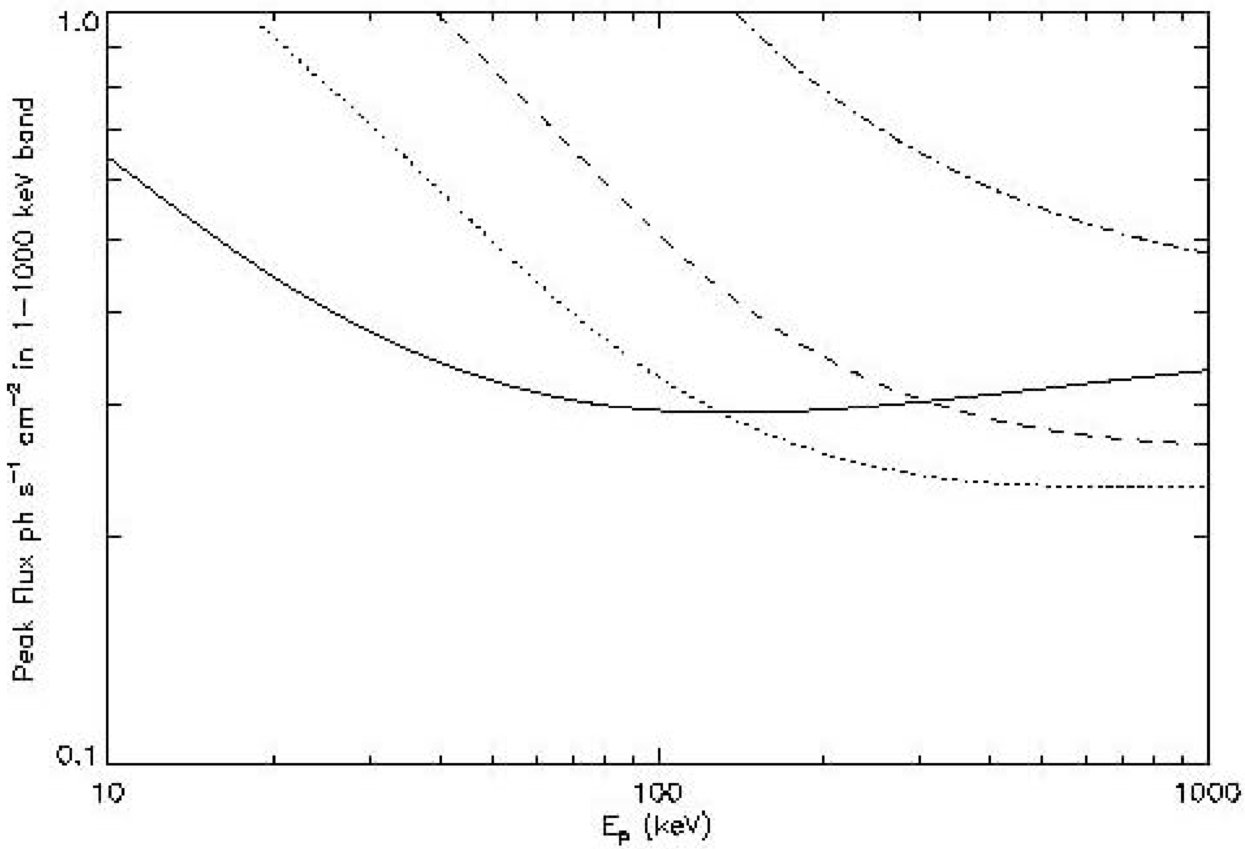
GBM as GLAST's GRB Trigger



Dashed line—α = -1, β = -2.

Solid lines—fluxes for 10 LAT photons, labeled by inclination angle.

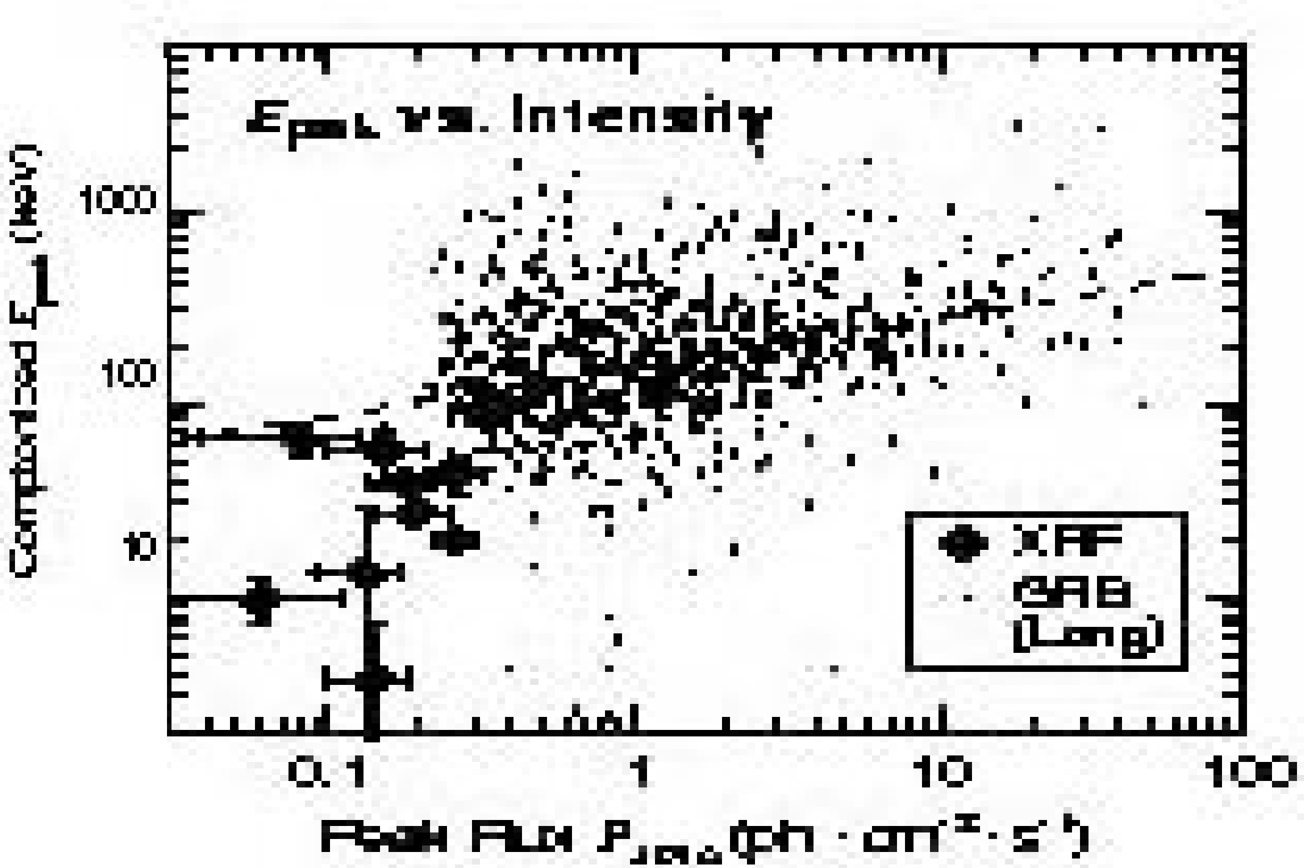
Sensitivity to Trigger Band--EXIST



α = -1, β = -2: Solid—10-70 keV; dotted—40-200 keV;

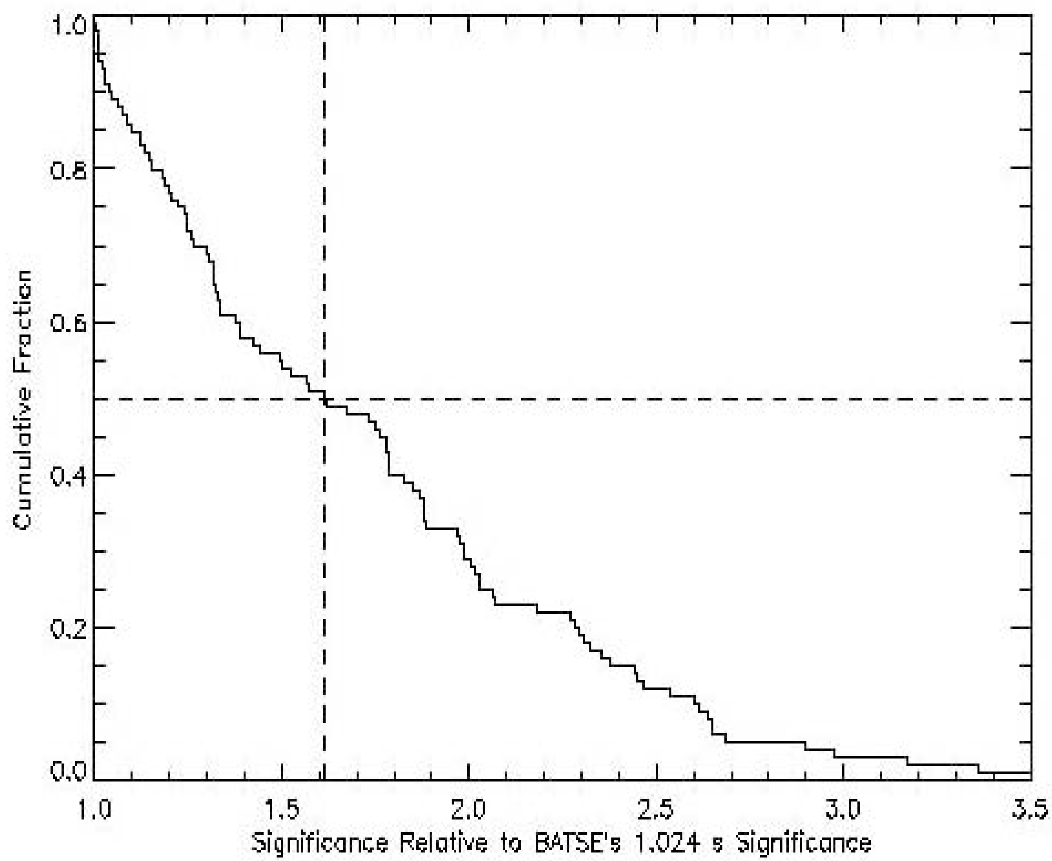
Dashed—70-350 keV; dot-dashed—100-1000 keV

Bursts in the E_p-F Plane



Kippen *et al.*, 2002, Woods Hole GRB Workshop. Note that F and E_p are reversed.

The Dependence On Δt



Based on a study of the 100 brightest BATSE bursts using all Δt:

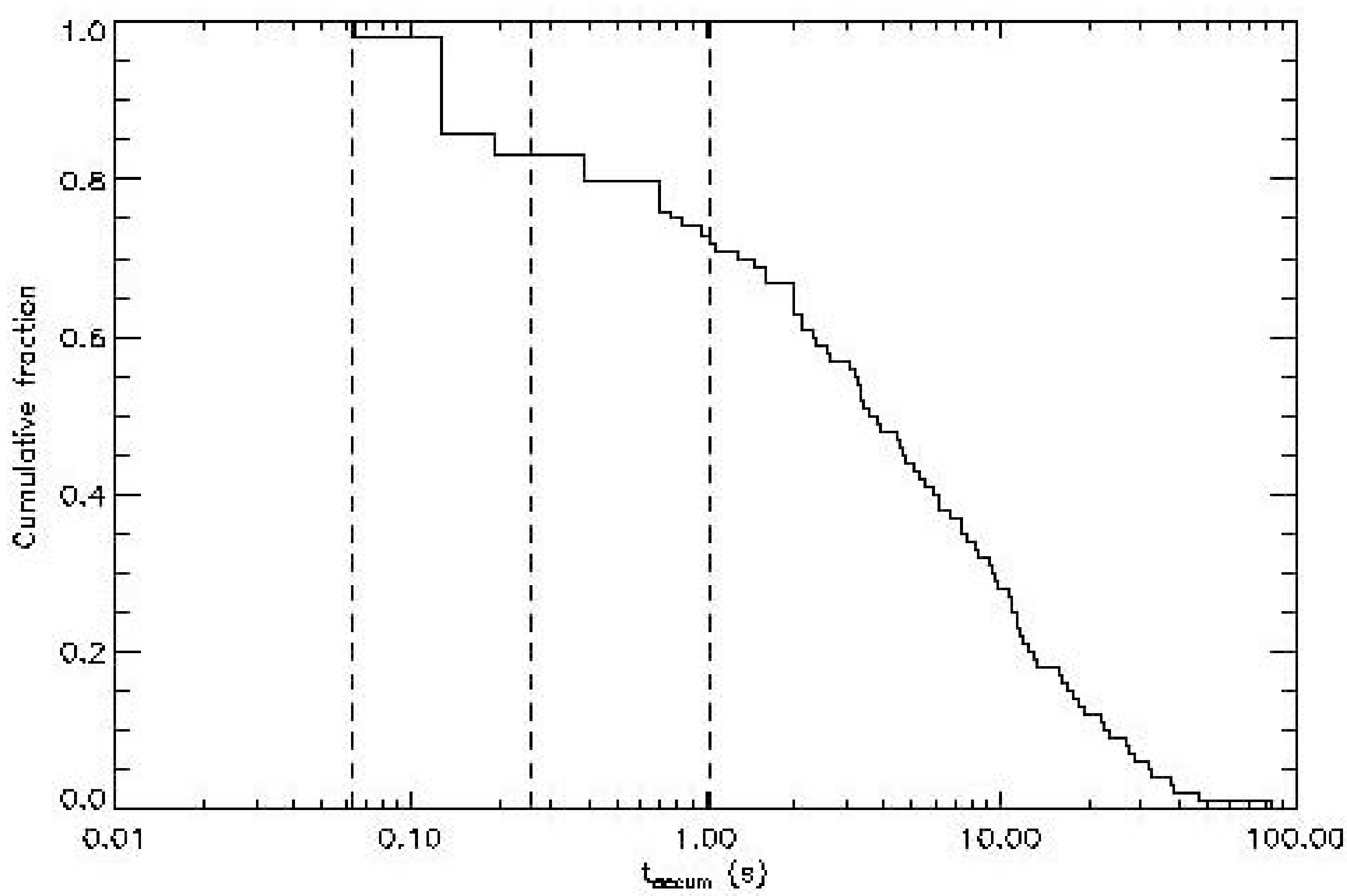
The average increase in sensitivity relative to Δt=1 s is only ×1.6!

Modeling Detector Sensitivity

$$F = \frac{n_\sigma}{<\varepsilon> f_{mask}} \sqrt{\frac{B\Delta E}{A f_{\mathrm{det}} \Delta t}}$$

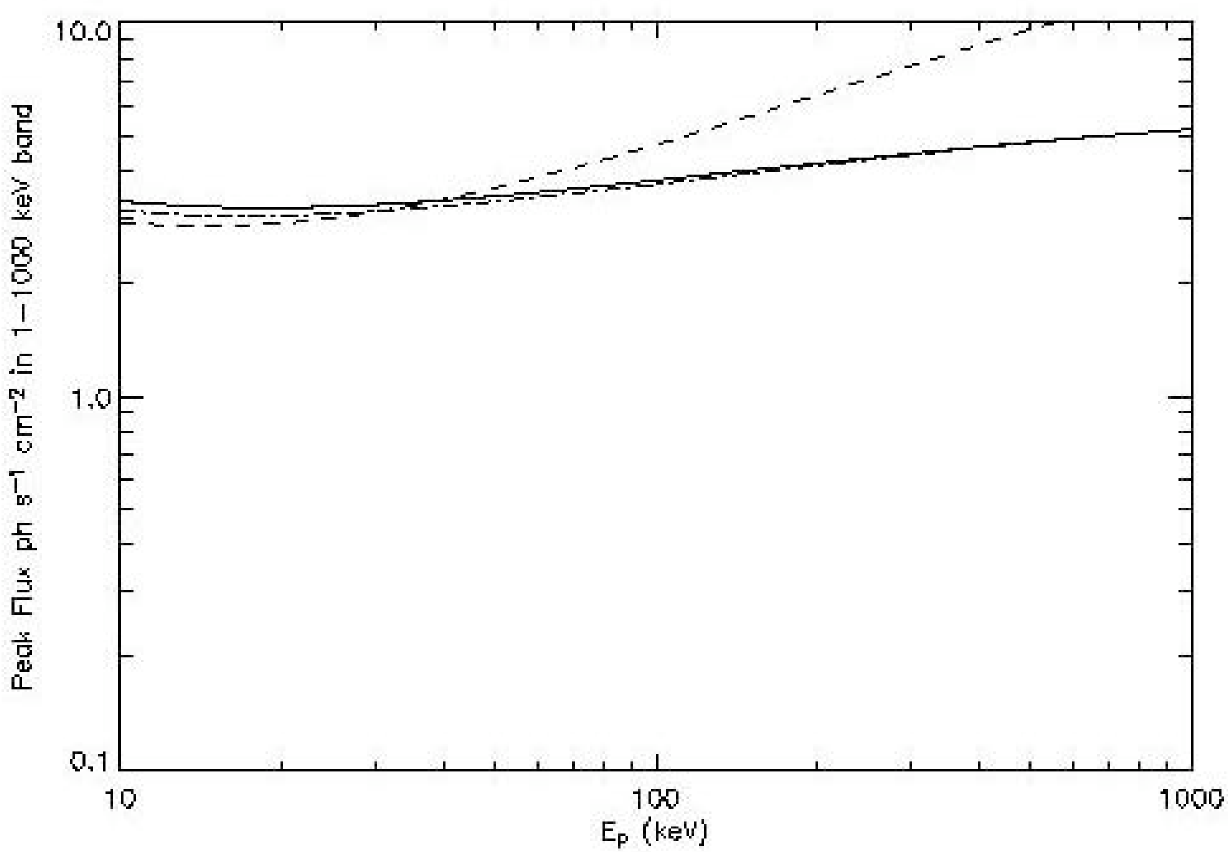
- n_σ—number of "sigma" for a trigger
- $<\varepsilon>$—average efficiency (no downscatter), dependent on burst spectrum
- B (cts/area/time/energy)—background, modeled as aperture flux+constant. Aperture flux $\propto$ Ω (average sky solid angle the detector plane "sees"). Detector efficiency considered.
- A—area of detector plane.
- f_{mask}—fraction of mask that is open
- f_{det}—the fraction of the detector plane that is active
- ΔE—the trigger band
- Δt—trigger time. For my comparisons Δt=1s.

Δt Of Maximum Sensitivity



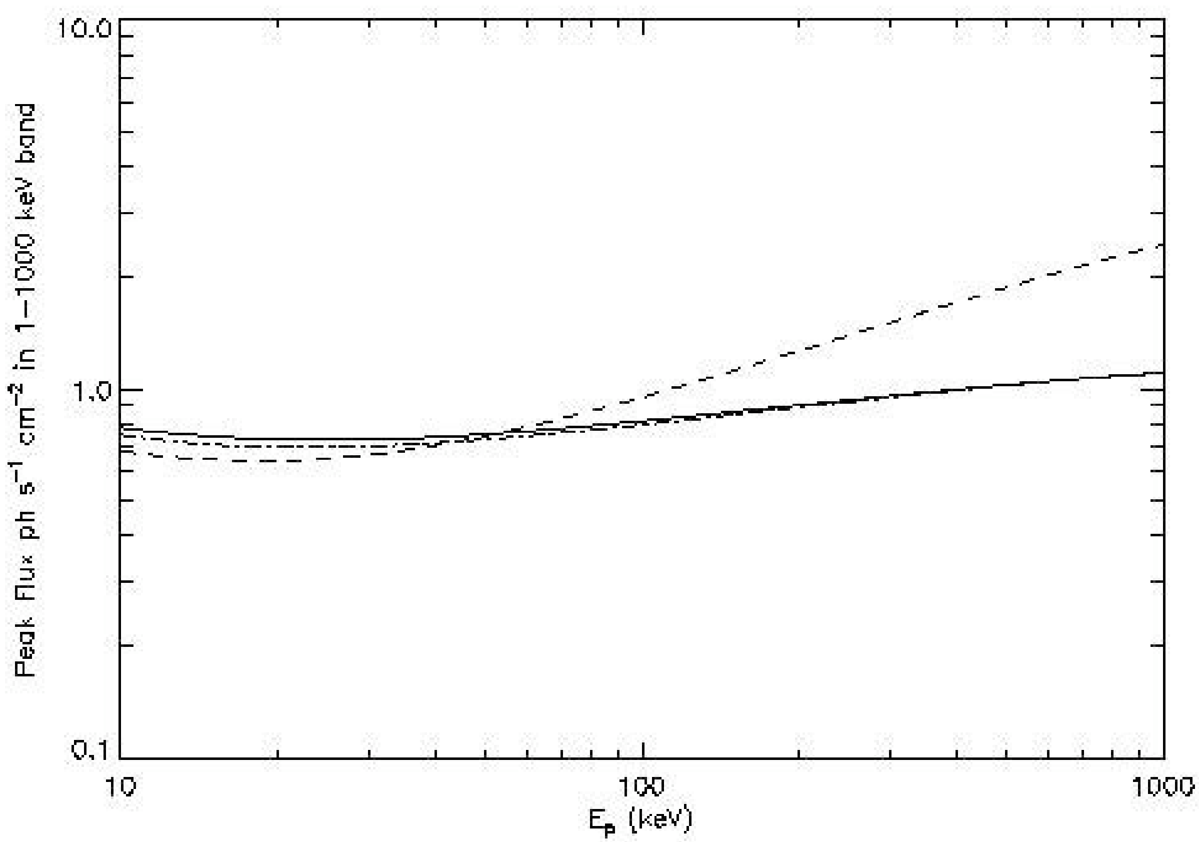
There were not a large number of bursts where the greatest sensitivity was for small Δt.

WXM--HETE



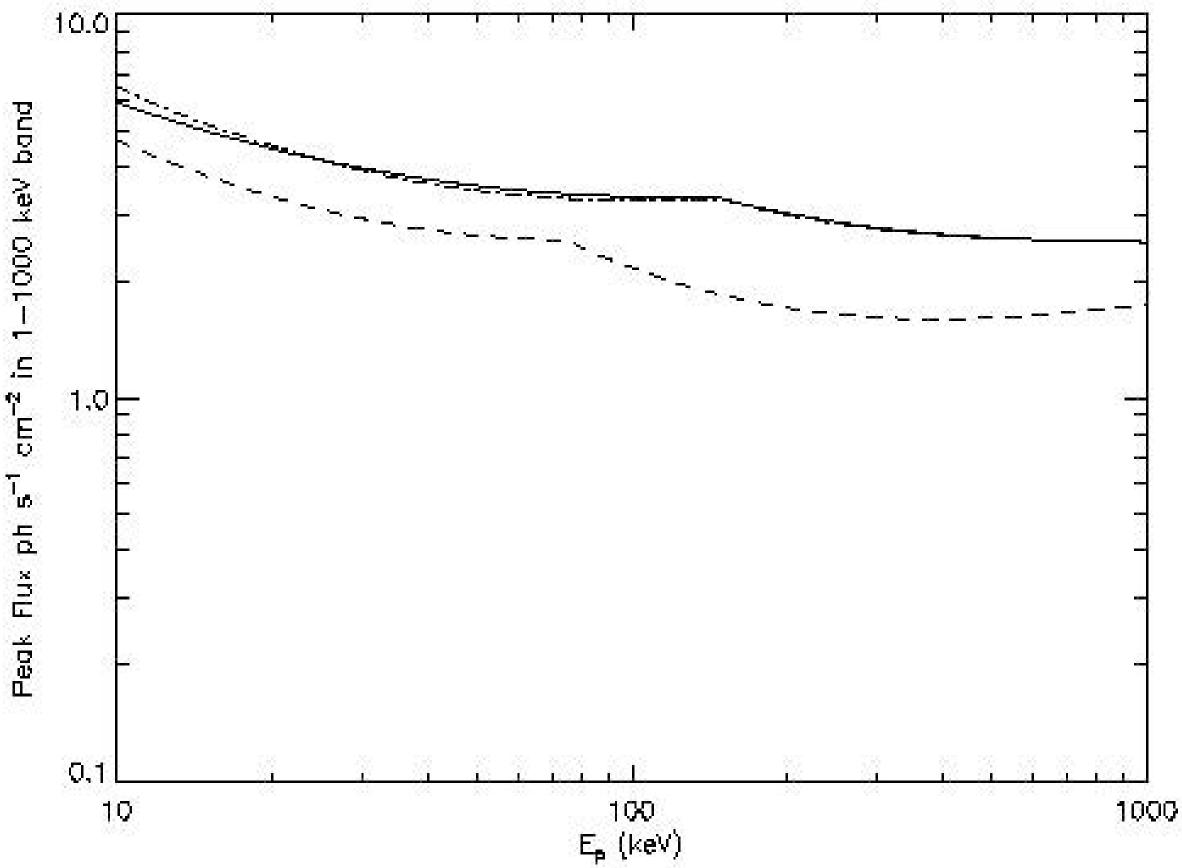
Solid line—$\alpha = -1$, $\beta = -2$; dashed line—$\alpha = -0.5$, $\beta = -2$; dot-dashed line—$\alpha = -1$, $\beta = -3$.

WFC--*Beppo*SAX



Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.

FREGATE--HETE



Solid line—α = -1, β = -2; dashed line—α = -0.5, β = -2; dot-dashed line—α = -1, β = -3.