Observed GRB Properties

G.J. (Jerry) Fishman

GLAST SWG Meeting

Huntsville, Sept. 2002

GRBs - Topics *not* Covered in this Talk:

- GRB Afterglow Observations (Kouveliotou)
- Populations of GRBs (Band)
- High Energy GRB Observations, Incl. Delays (Dingus, McEnery)
- Lag-Luminosity Relationship (Norris)
- GRB Theory (Salmonson, Barbiellini, Preece, Dermer, Hartmann, Meszaros)

GRBs - Topics Covered in this Talk:

- Burst Profiles & Morphology
- Duration of GRBs
- Spectral Characteristics
- Correlations between Intensity, Spectral Evolution, etc.
- Afterglows in Gamma Rays (Med. En.)

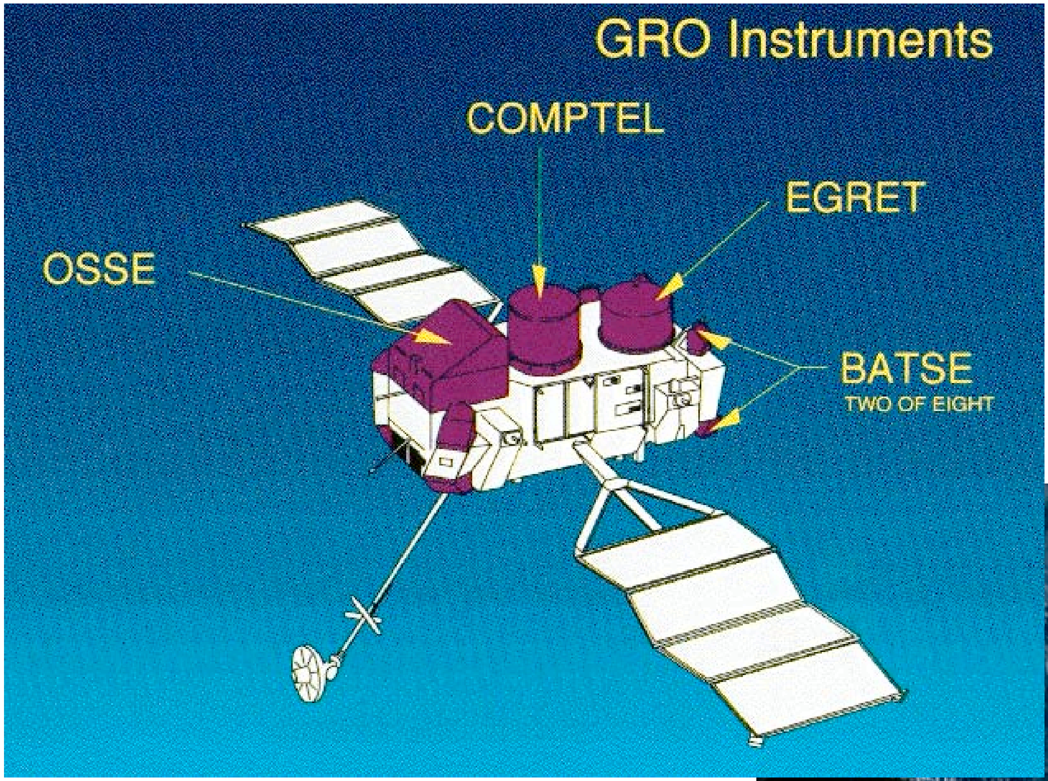
Some Properties of GRBs

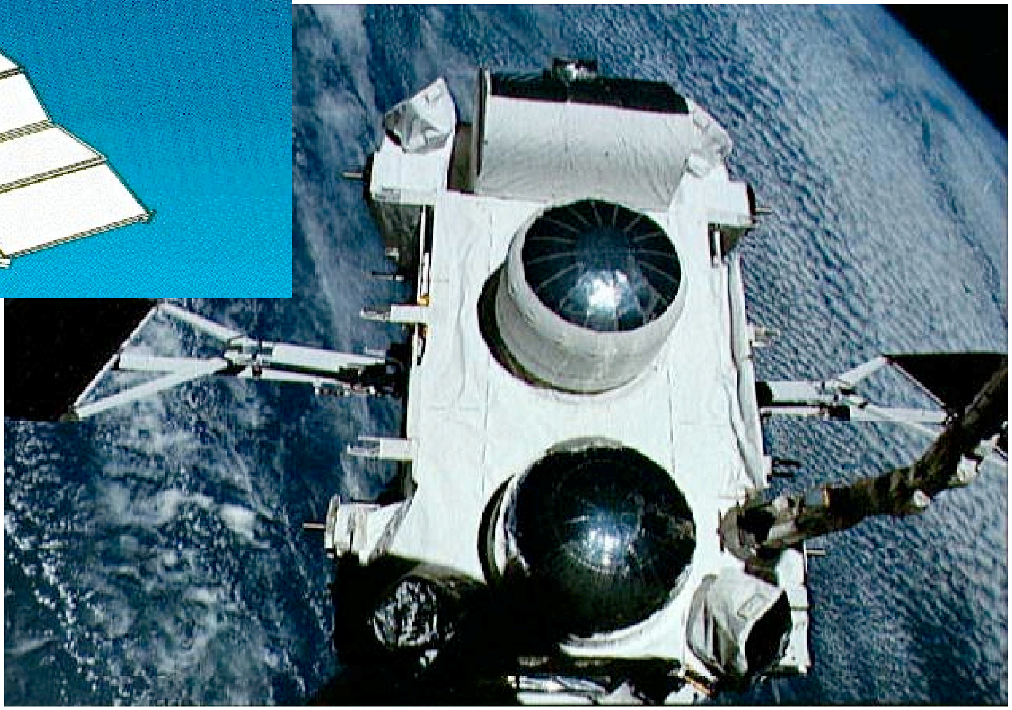
- Most durations range from ~10ms to hundreds of seconds.
- Double-peaked duration distribution
- Extremely diverse profiles on all timescales
- Spectra are non-thermal
  - energy flux peaks ~100 keV to 1 MeV
- A few generalizations can be made regarding time/spectral correlations

BATSE

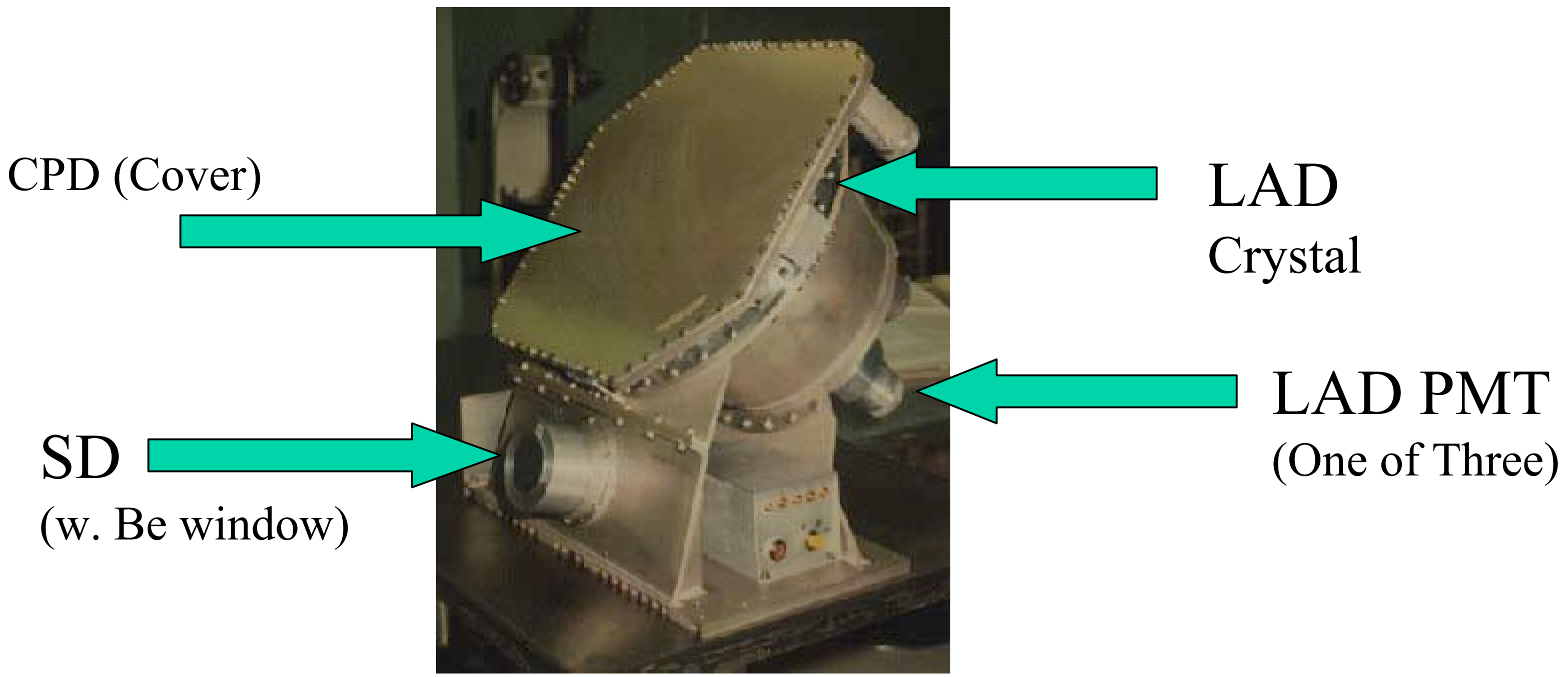
- **Eight modules, each consisting of a Large Area Detector (LAD) and a Spectroscopy Detector (SD)**
- **NaI Scintillation Detectors**
- **LADs are positioned on the faces of an octahedron**

Compton GRO





BATSE Detector Module



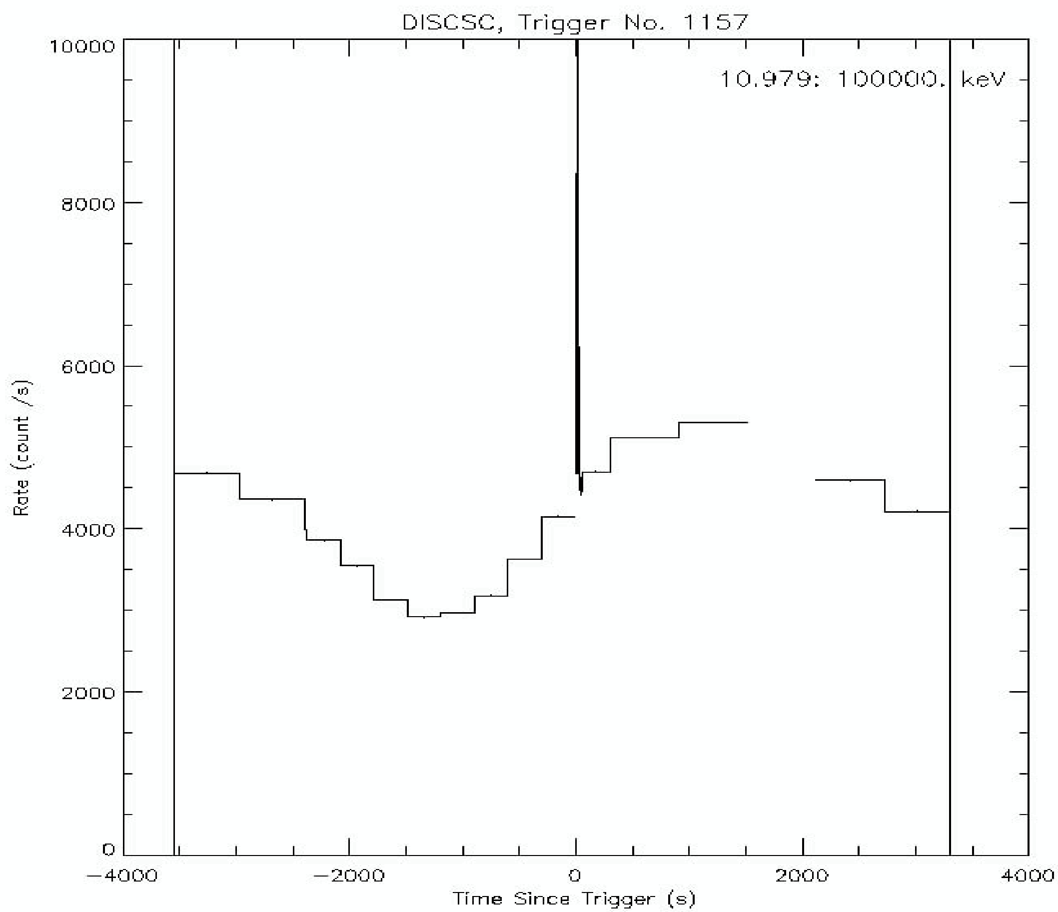
Large Area Detectors (LADs)

- Thin, flat, and large (2000 cm^2 _ 1.27 cm)
- Energy range: 25keV-1800 keV
- Designed to detect and locate bursts

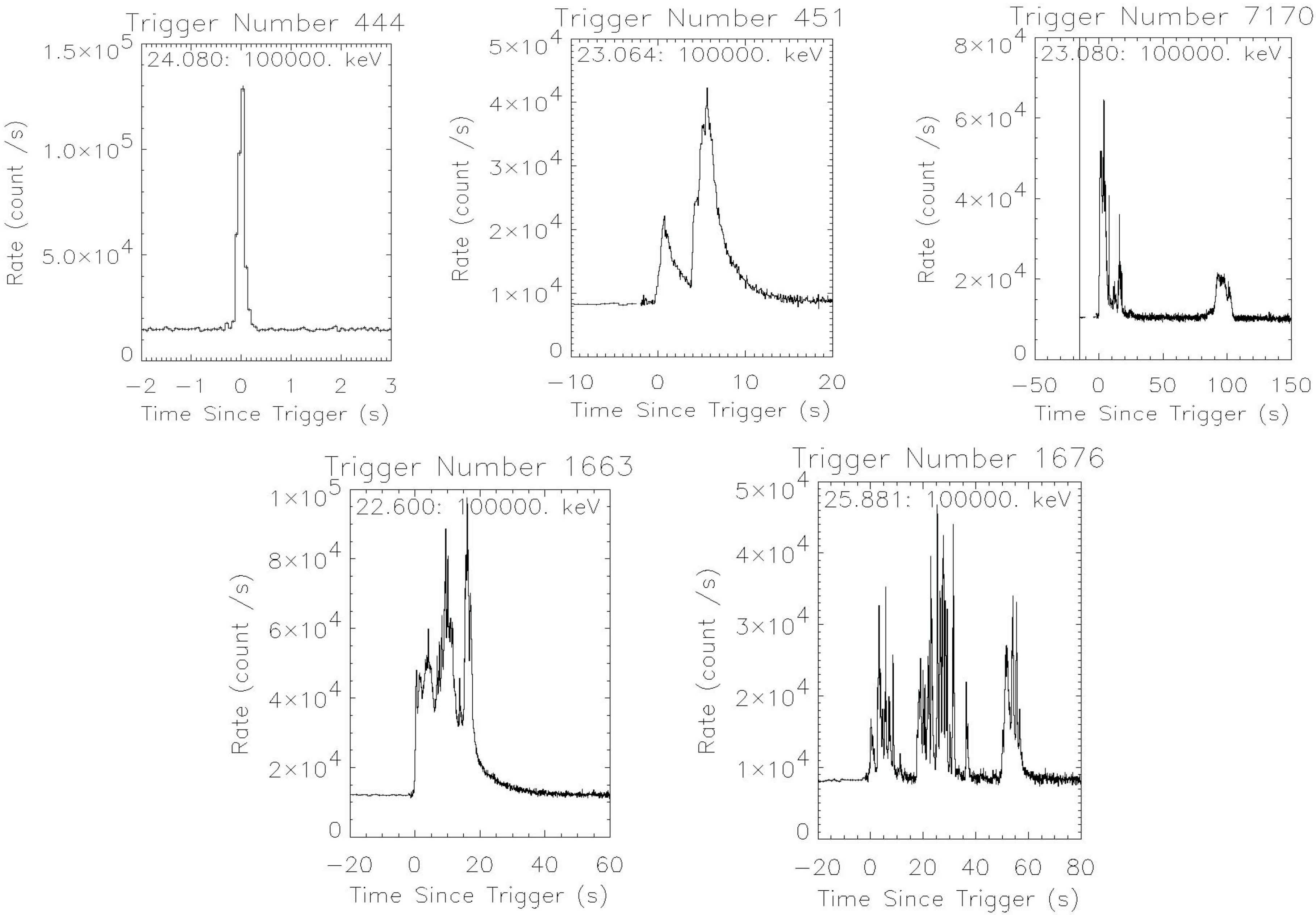
Spectroscopy Detectors (SDs)

- Designed for better energy resolution and larger energy span
- Small and thick (127 cm^2 _ 7.2 cm)
- Energy Range: ~10keV to 10 MeV

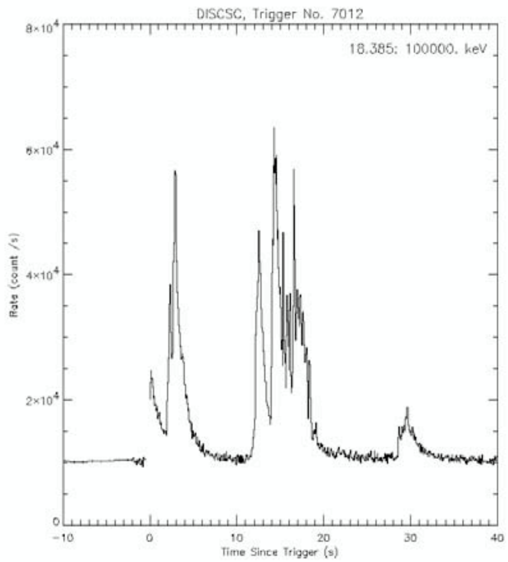
BATSE
Orbital Bkgnd Variations

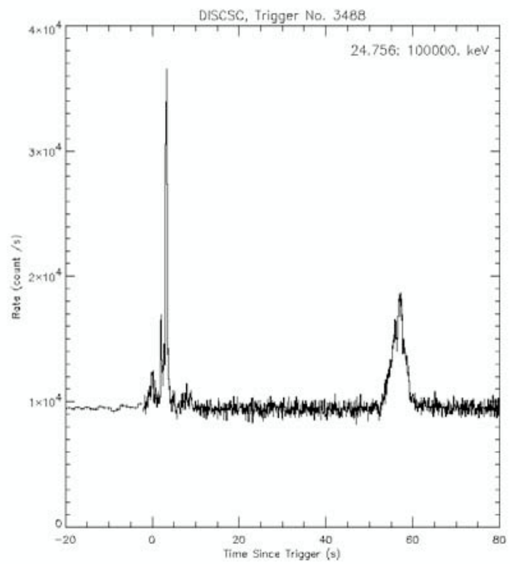


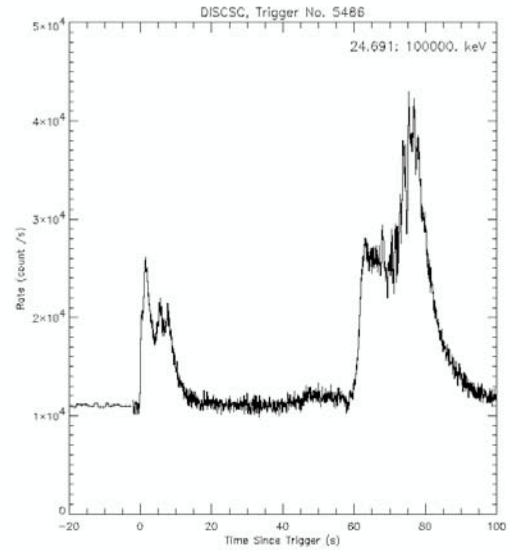
Diversity of GRB Profiles



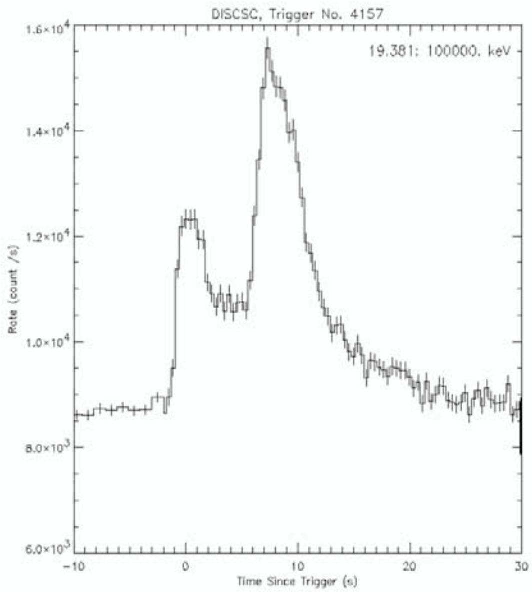
Multiple-Episode Bursts

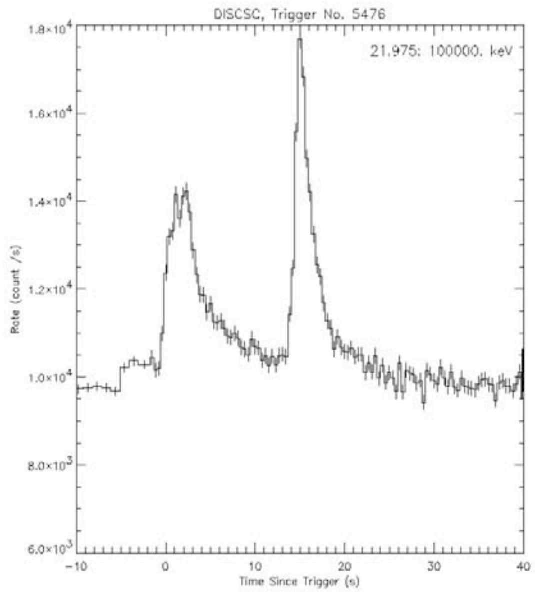


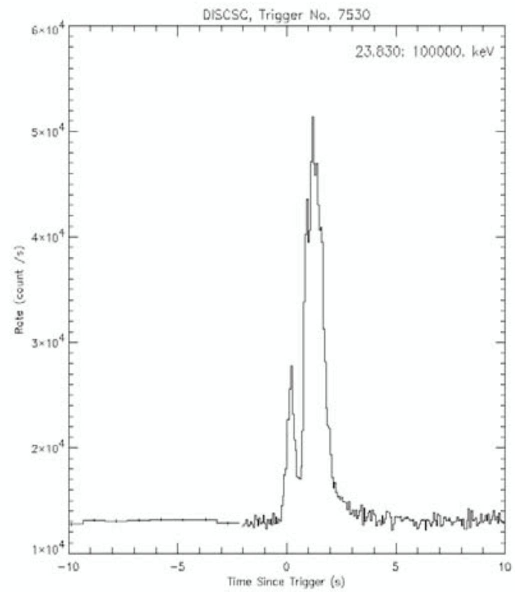




Examples of Double-Peaked GRBs







- from Lee, Bloom and Petrosian; ApJSupp 2000 Lee, et al 2000 & other papers :

- Pulses *usually* have shorter rise times than decay times

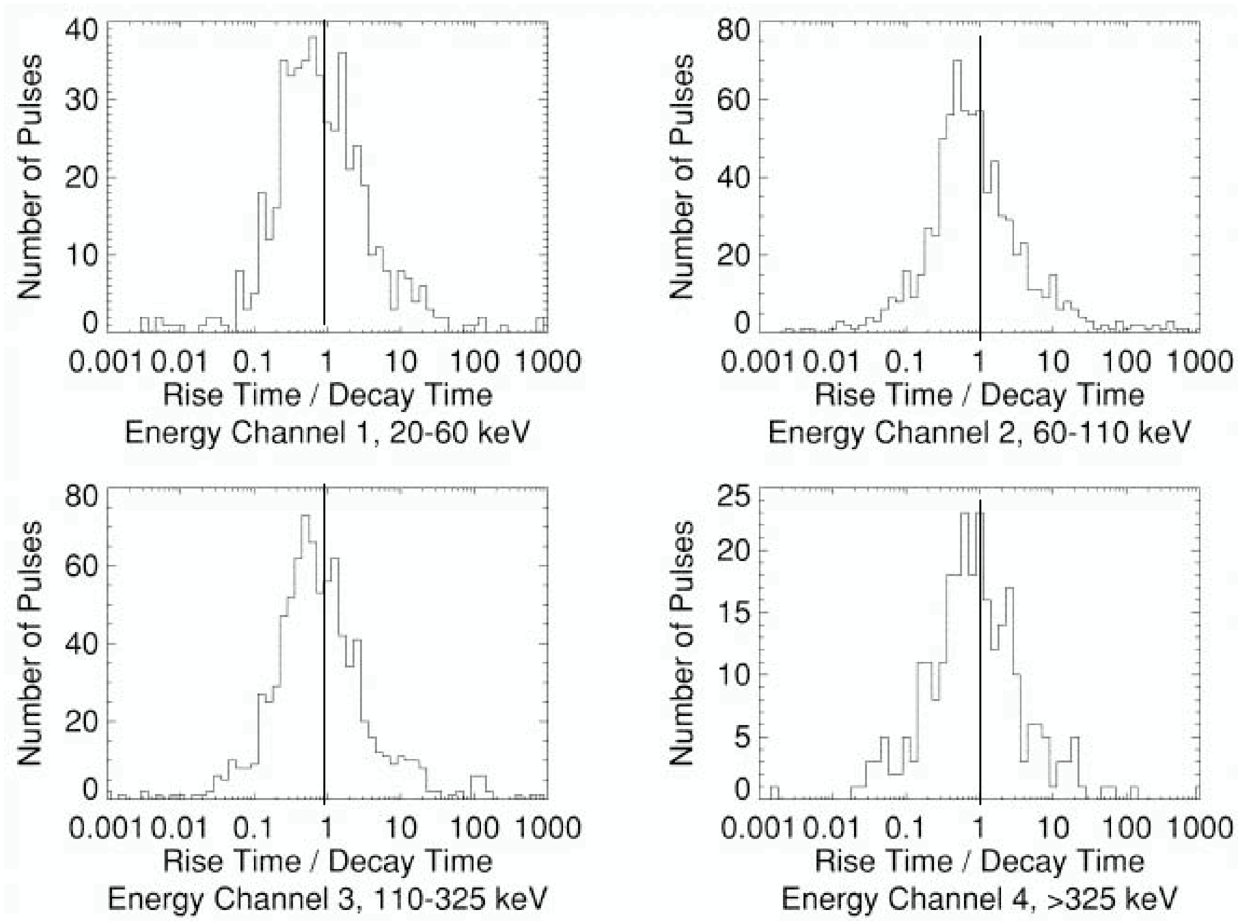
- Pulses *are* narrower and peak earlier at higher energies

- Pulse brightness, pulse width, and pulse hardness ratios *do not* evolve monotonically within bursts

- Ratios of pulse rise times to decay times *tend* to decrease with time within bursts

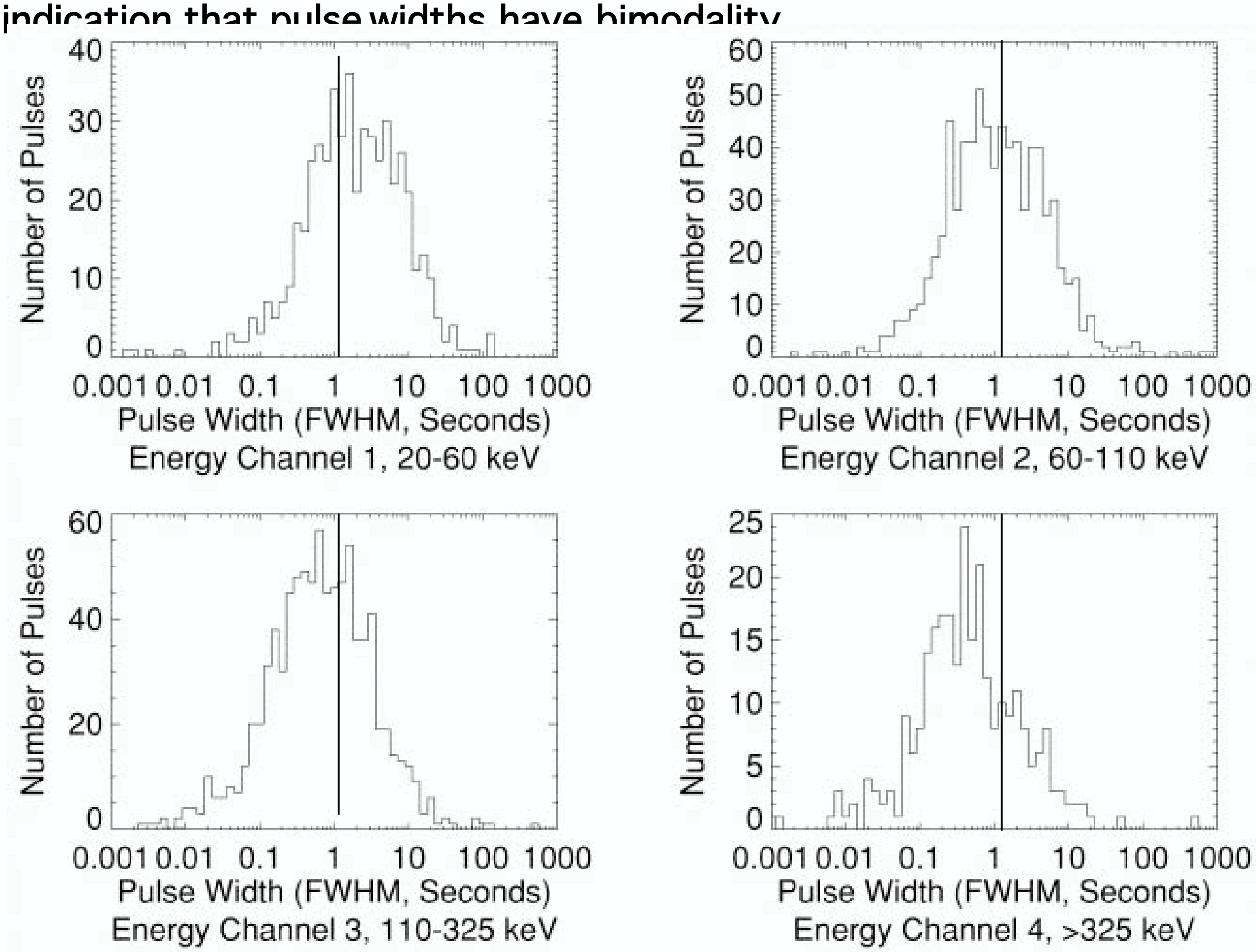
Asymmetry ratios from many pulses within bursts, by energy channel

- Risetimes < Falltimes, at *all* energies - Lee et al. 2000

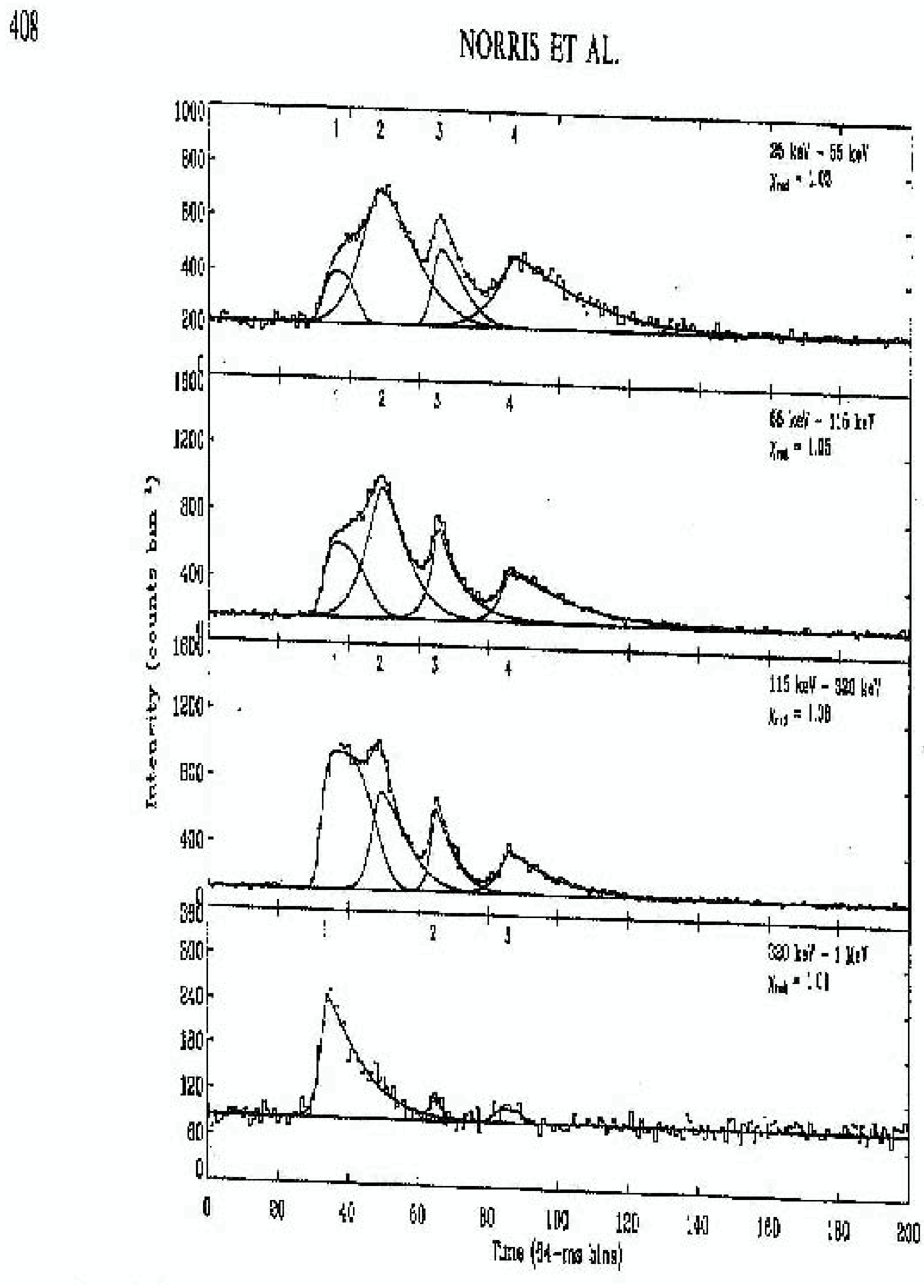


- Distribution of pulse widths (FWHM) for pulses from bursts, by energy channel

- No indication that pulse widths have bimodality



Andrew Lee, Elliott D. Bloom, Vah_ Petrosian; ApJSupp 2000



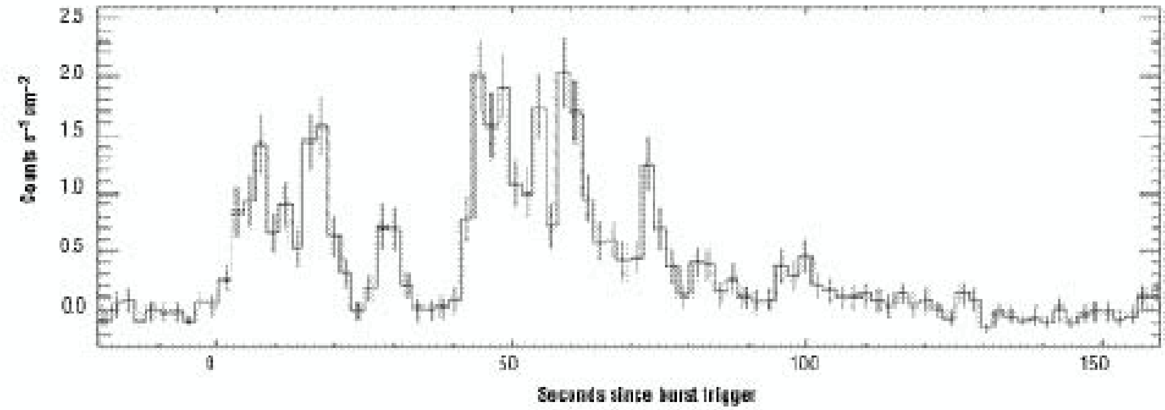
Chan 1
25-55 keV

Chan 2
55-110 keV

Chan 3
110- 300 keV

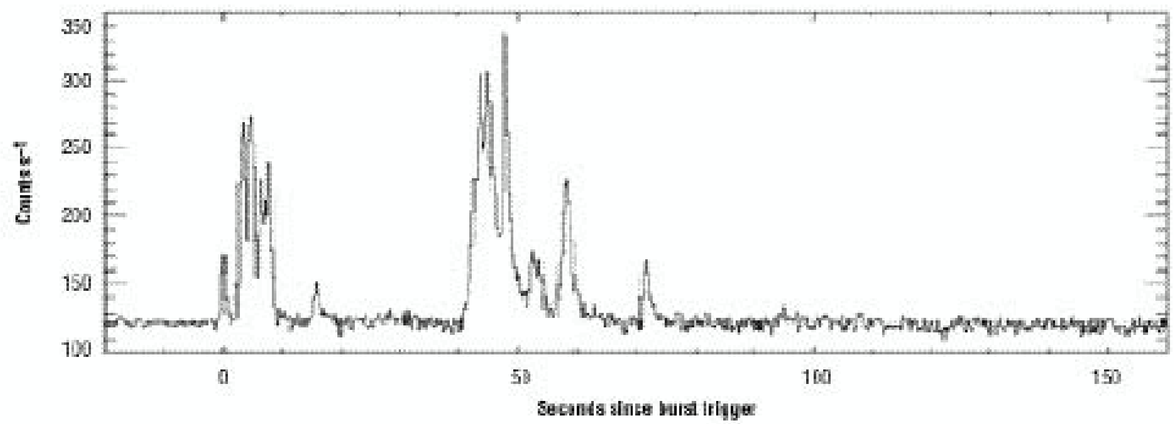
Chan 4
>300 keV

- Note softness of 2nd pulse



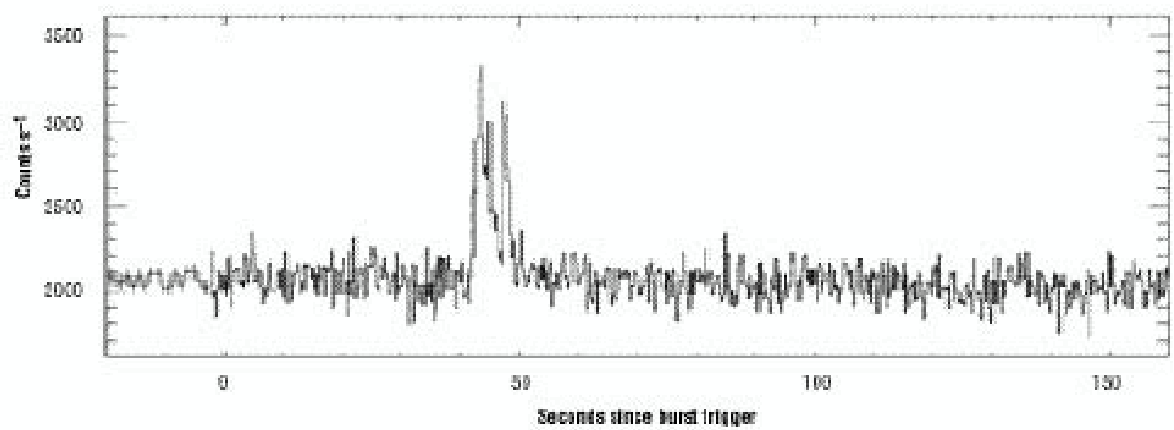
5-9 keV

(WFC/BeppoSAX)



20-60 keV

(BATSE)

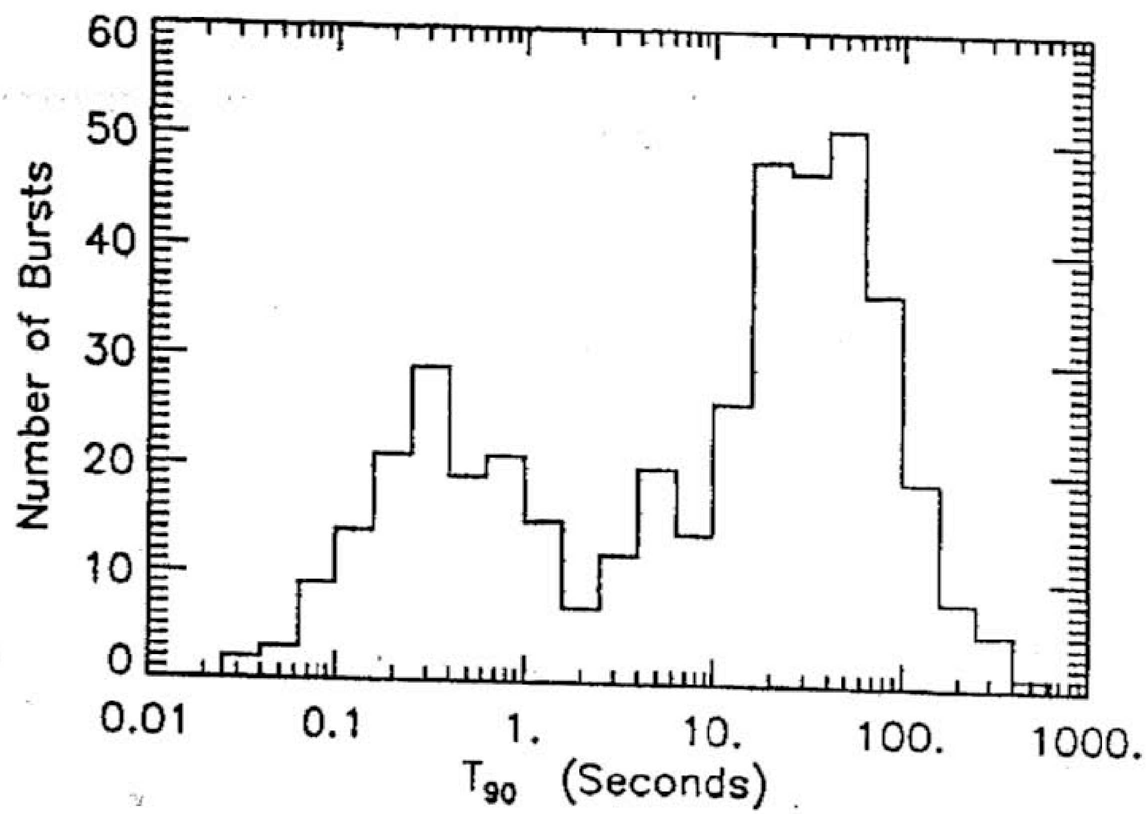


>300 keV

(BATSE)

Duration Distribution of GRBs - BATSE 3B Catalog

Meegan, et al. 1996



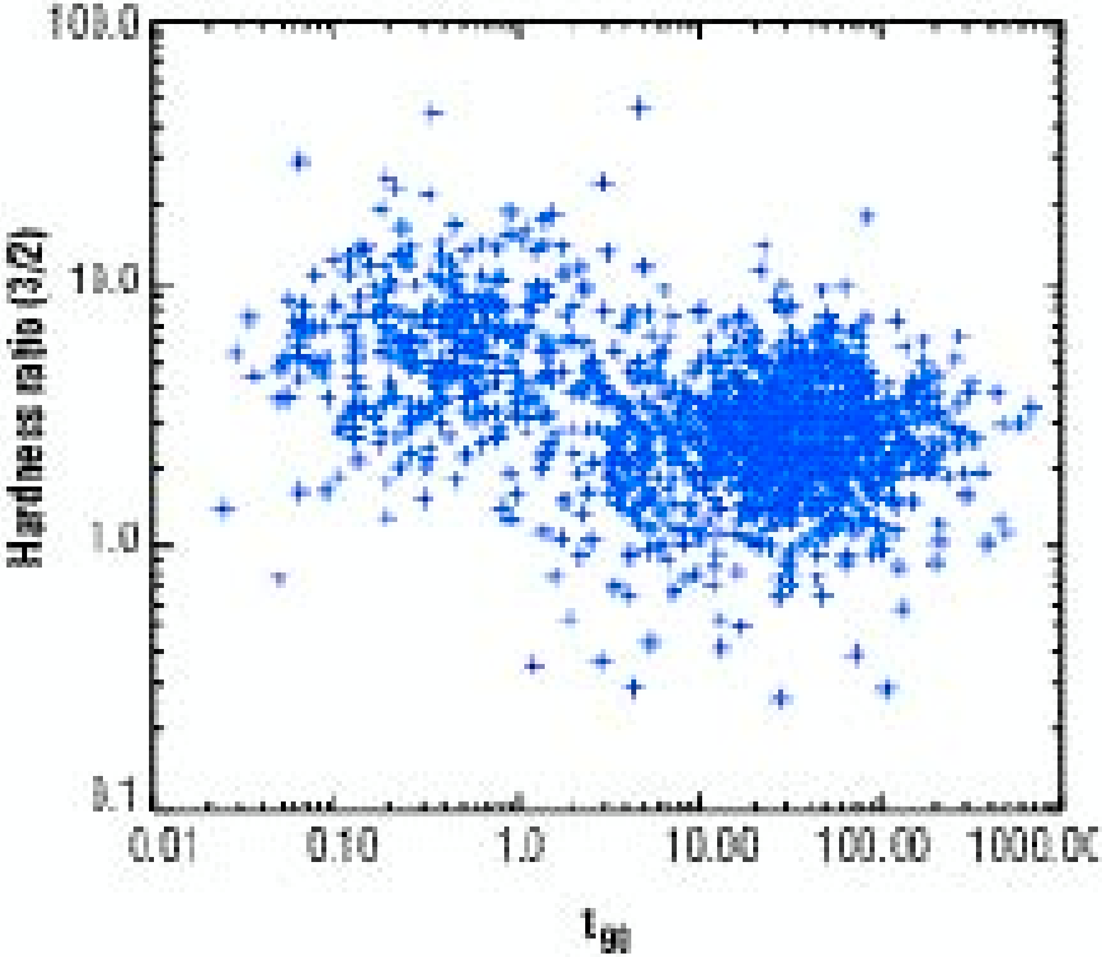
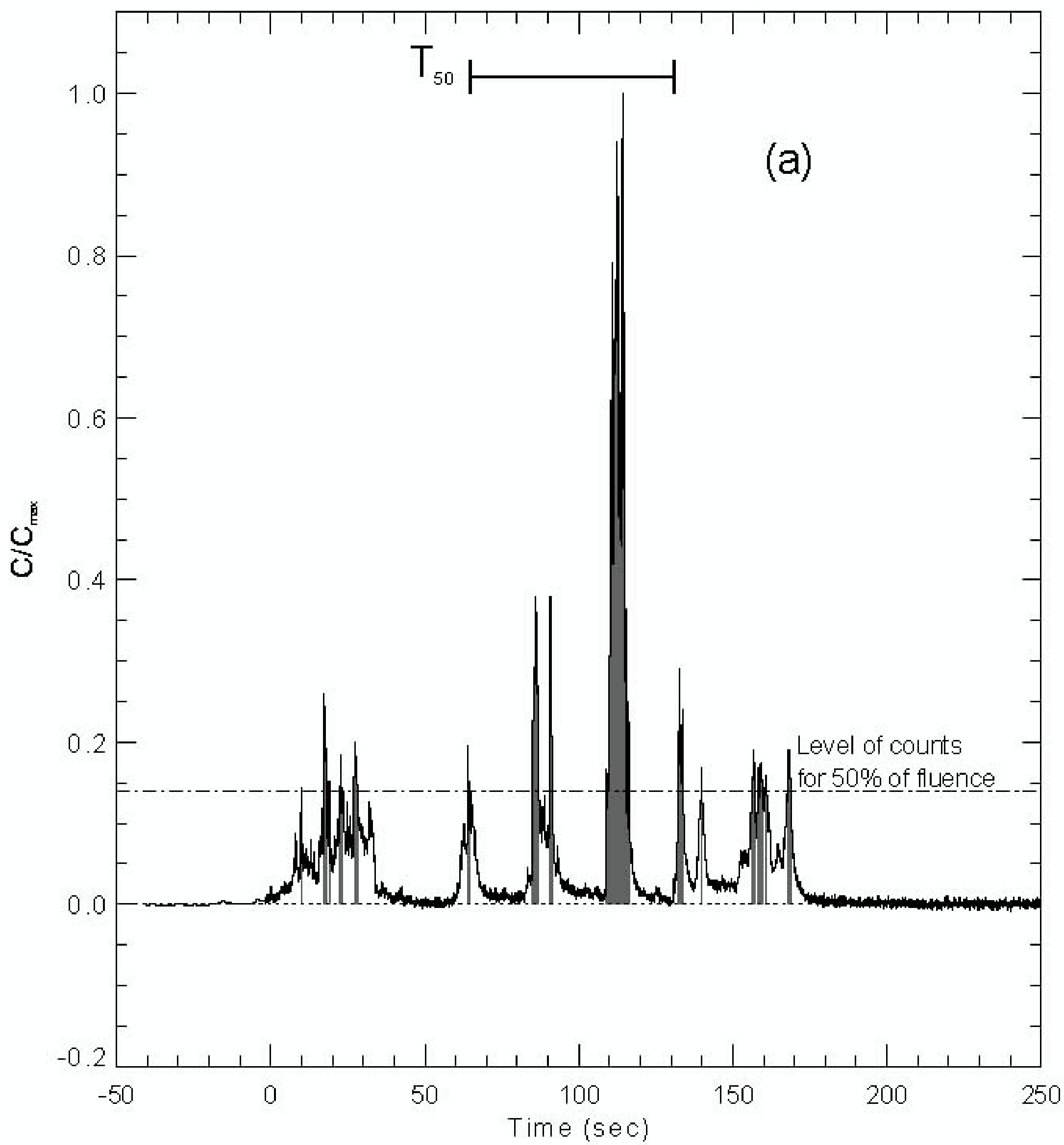
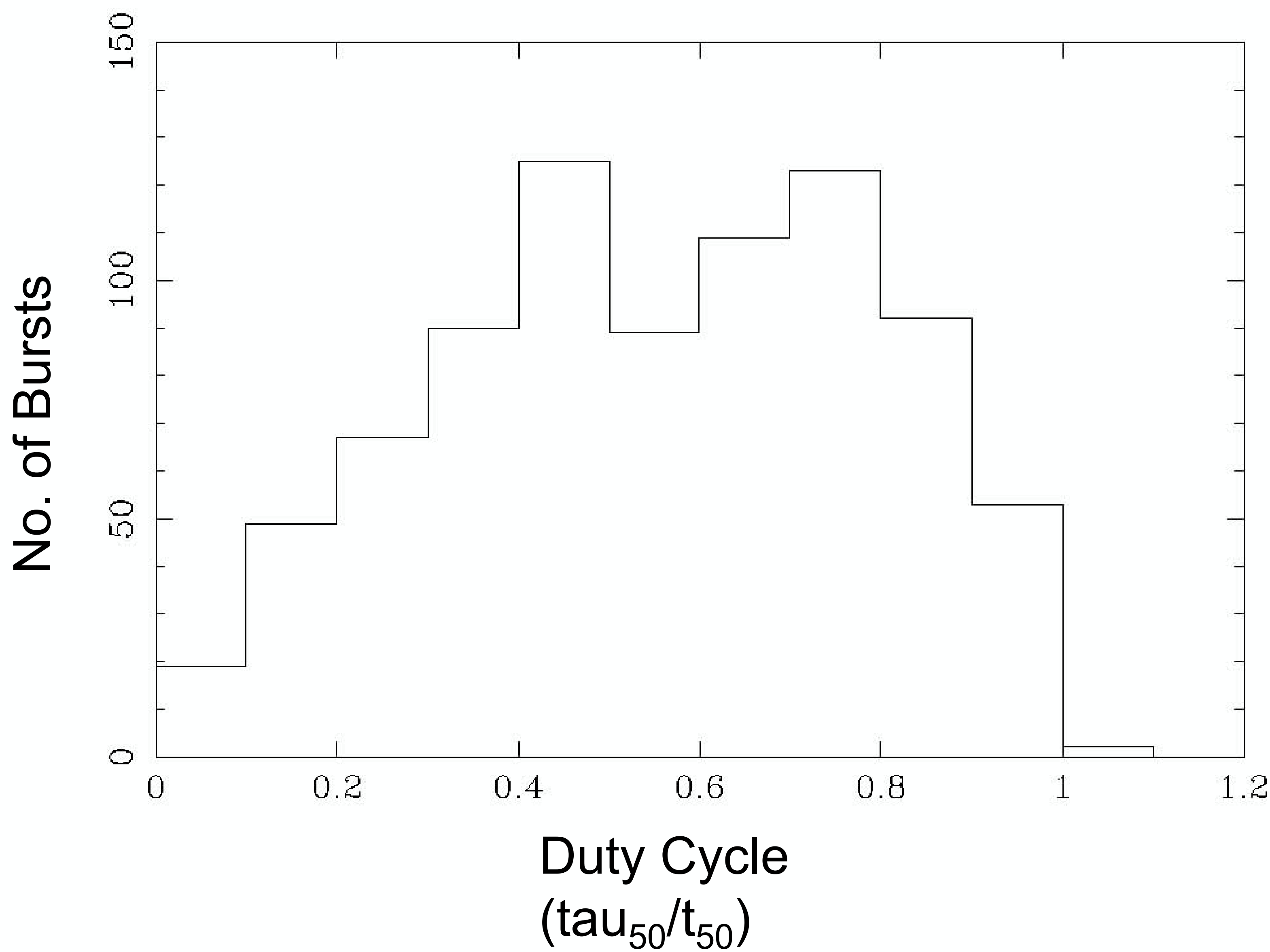


Figure 4.—Hardness-ratio and duration characteristics of GRB's. When GRB's are plotted against hardness ratio and duration, two classes become evident: short/hard and long/soft.



T50
(a)
Level of counts
for 50% of fluence
C/Cmax
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-50
0
50
100
150
200
250
Time (sec)



No. of Bursts
0
50
100
150
0
0.2
0.4
0.6
0.8
1
1.2
Duty Cycle
(tau_{50}/t_{50})

Band GRB Spectrum:

$$f(E) = A\left(\frac{E}{100}\right)^{\alpha} e^{\frac{-E(2+\alpha)}{E_{peak}}} \qquad \text{for} \quad E < \frac{(\alpha-\beta)E_{peak}}{2+\alpha}$$

$$f(E) = A\left[\frac{(\alpha-\beta)E_{peak}}{100(2+\alpha)}\right]^{(\alpha-\beta)} e^{(\beta-\alpha)}\left(\frac{E}{100}\right)^{\beta}$$

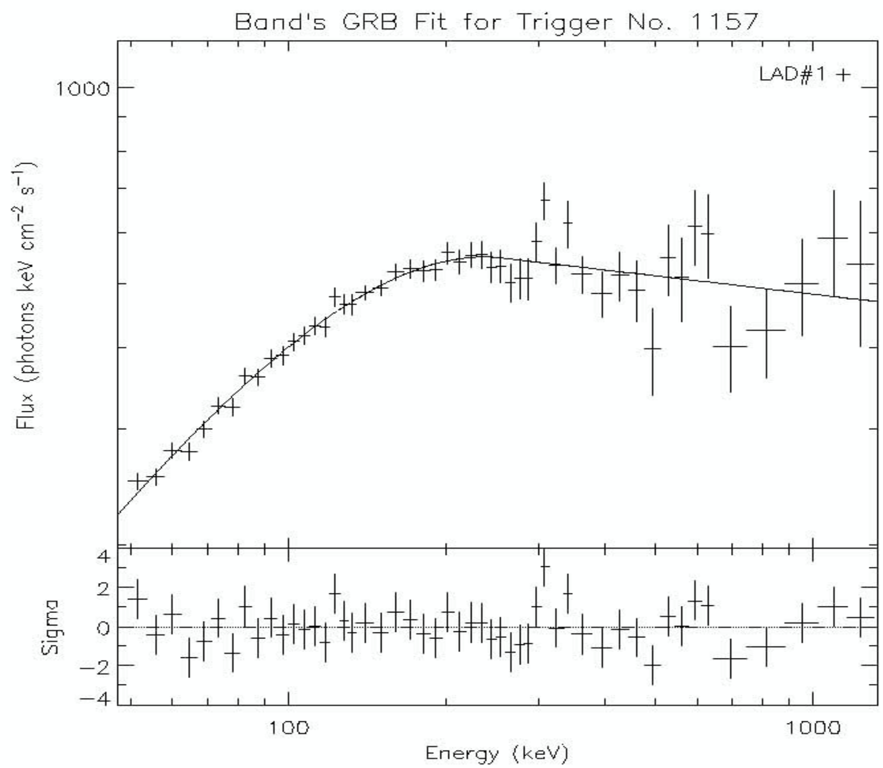
$$\text{for} \quad E \geq \frac{(\alpha-\beta)E_{peak}}{2+\alpha}$$

Band GRB Parameters

- E_{peak} : peak of the νF_ν spectrum
- α : low energy spectral index
- β : high energy spectral index

- A : Amplitude (photons s^{-1} cm^{-2} keV^{-1})

Fitting a GRB Spectrum



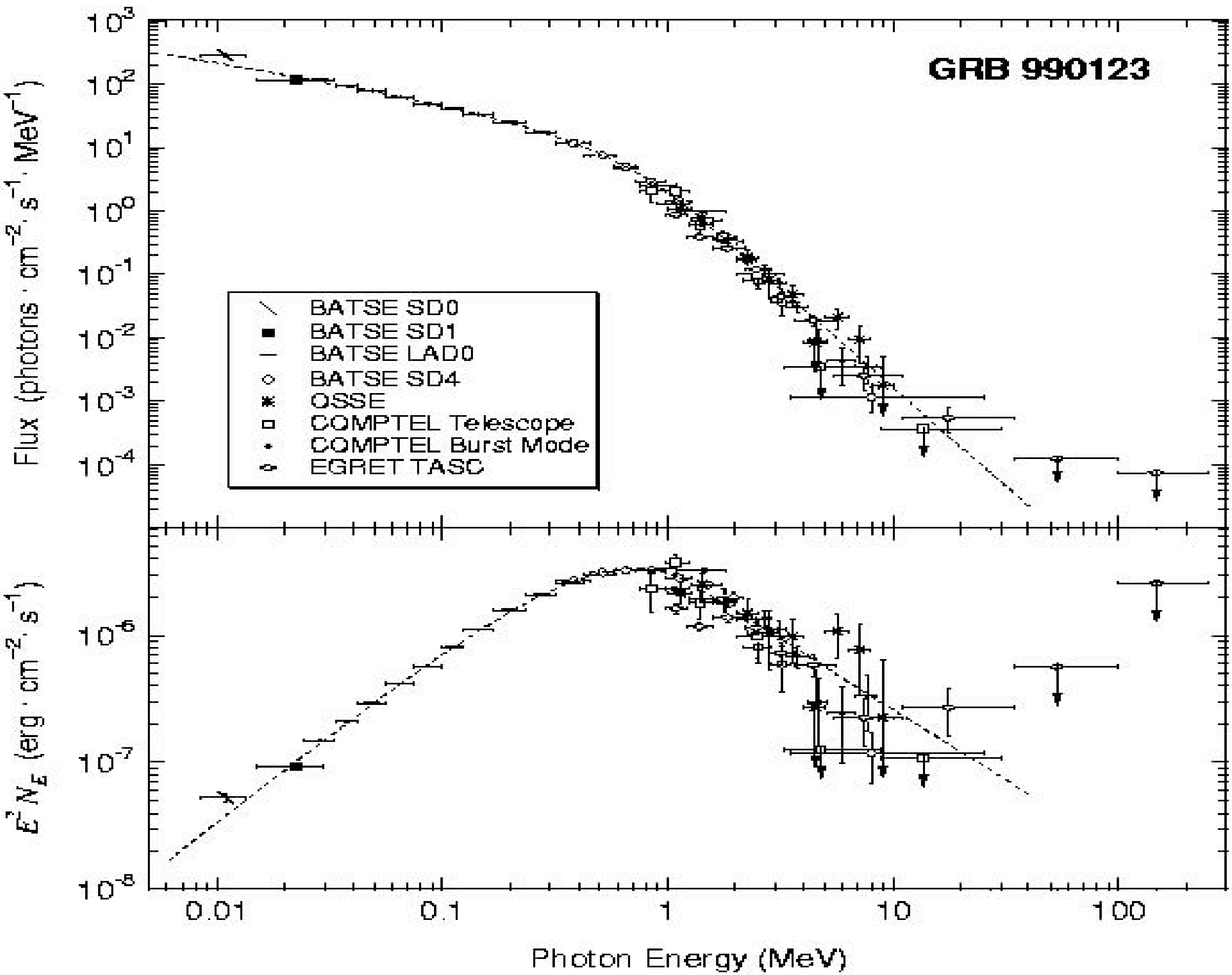
RMFIT – spectral fitting program; Preece et al.

E_{peak} = 235 +/- 15.1 keV

α = -0.8772 +/- 0.0753

β = -2.093 +/- 0.0465

χ^2 per dof = 0.8820



Briggs, et al. 1999

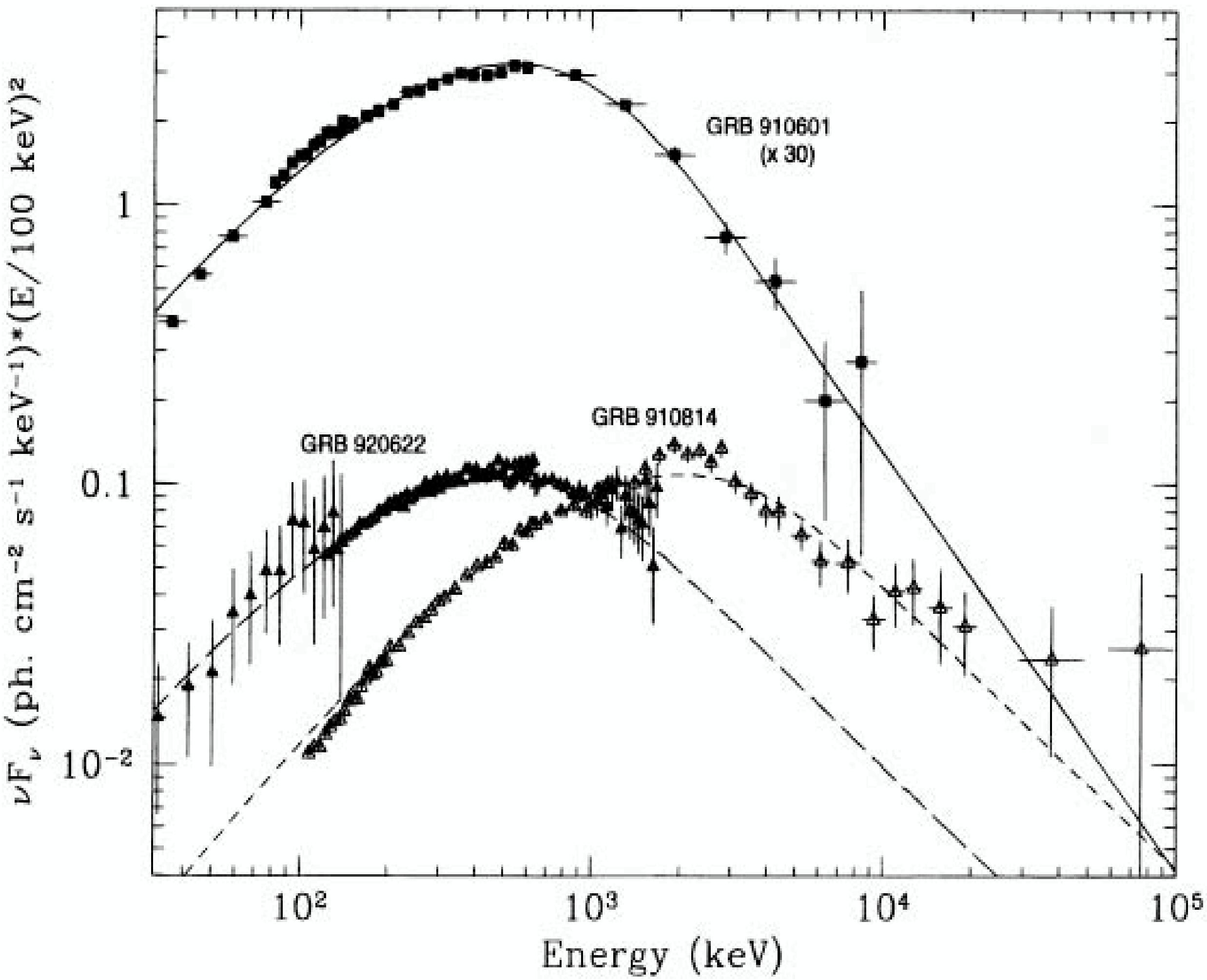
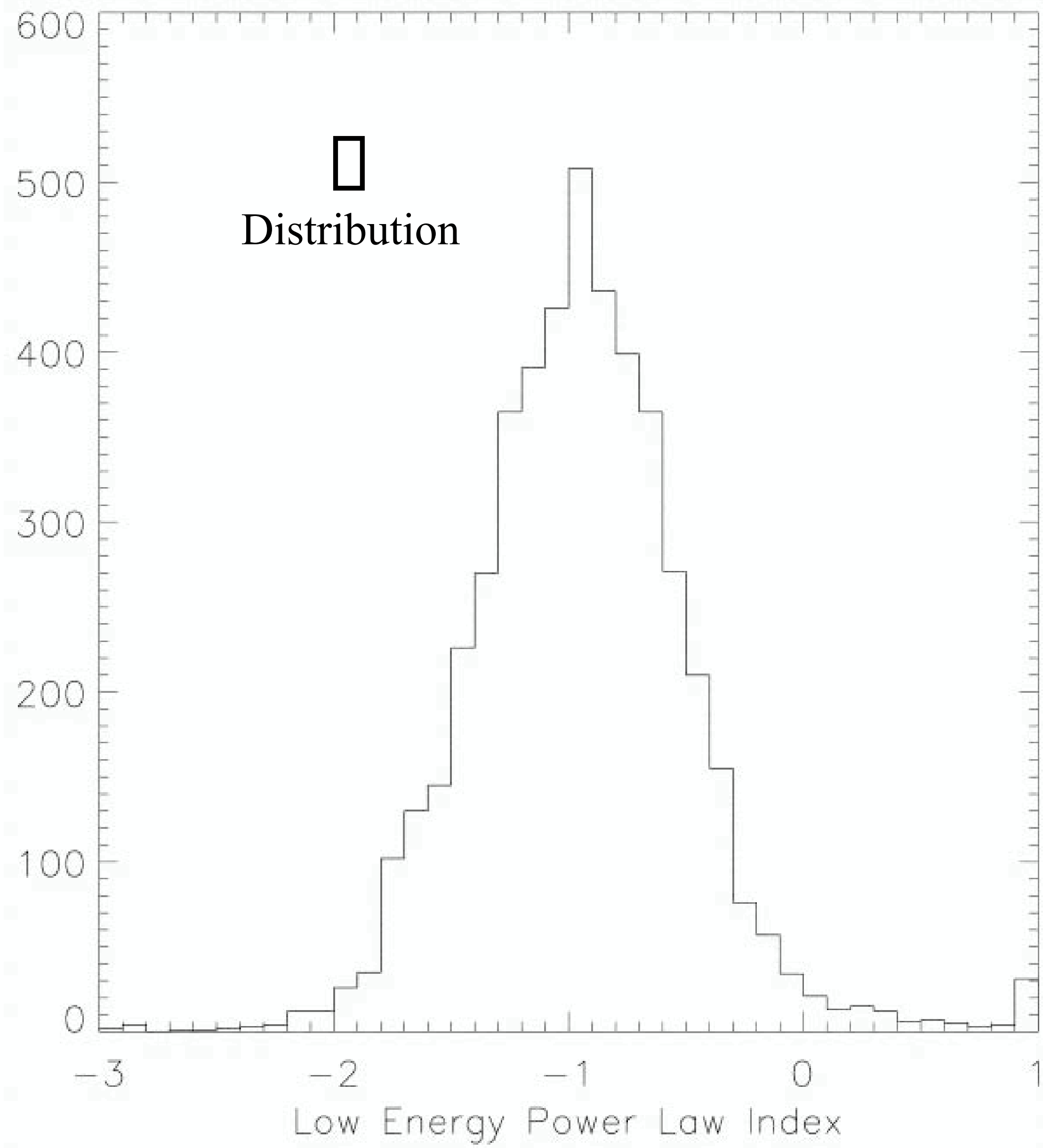


FIG. 5.—Observed composite (*CGRO* multi-instrument) νF_ν spectra of GRBs 910601, 920622, 910814, and best fit calculated νF_ν spectra (see Table 1). Data are from Schaefer et al. (1994a), Schaefer (1995), and Greiner et al. (1995). The observed GRB spectra are marginally "obliging" in the low-energy range in the sense of Fenimore et al. (1981), and the overall spectral shape is not strongly sensitive to spectral deconvolution (Schaefer et al. 1994a).

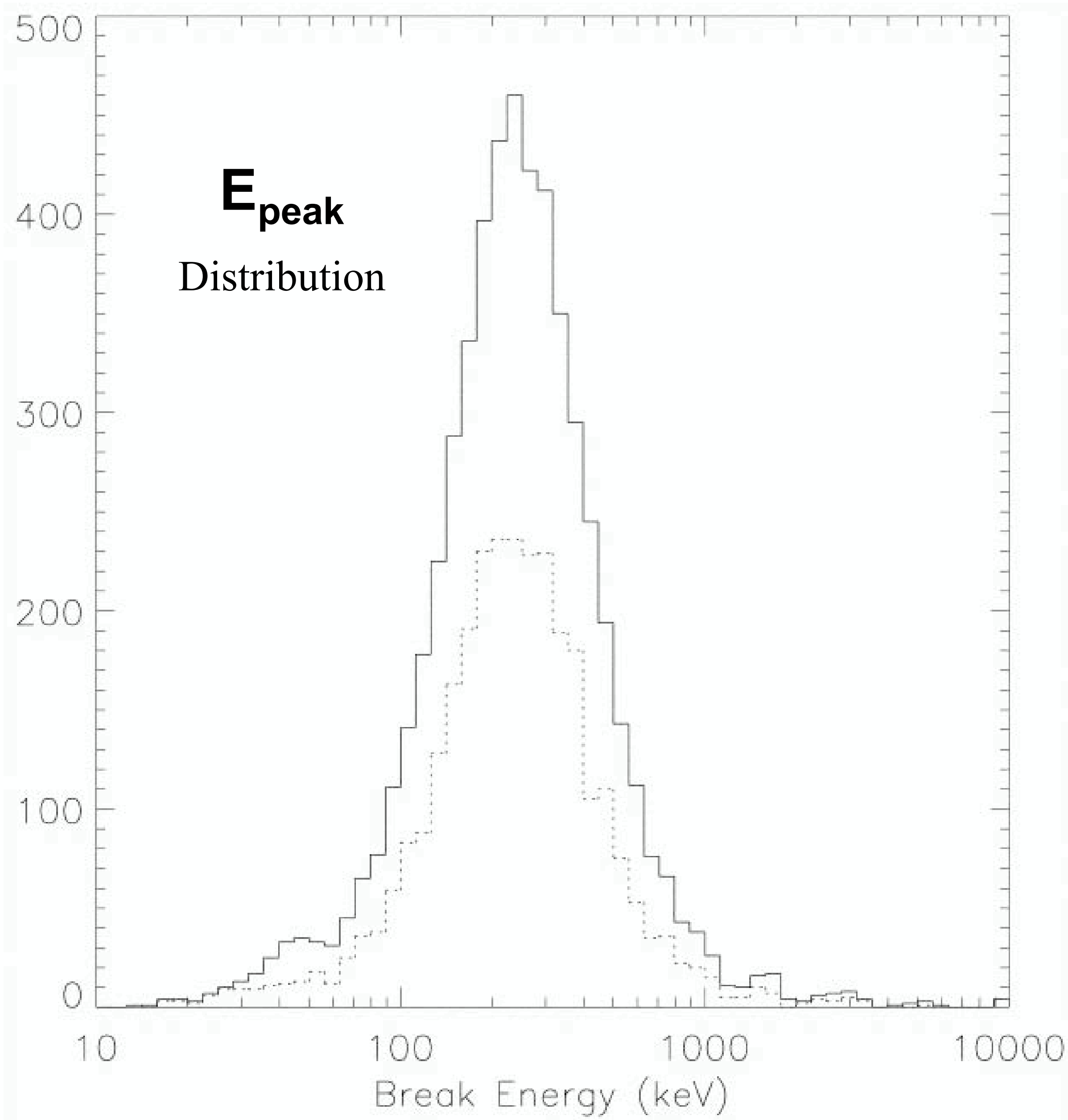
The Astrophysical Journal Supplement Series, 126:19-36, 2000 January

The BATSE Gamma-Ray Burst Spectral Catalog.
- High Time Resolution Spectroscopy of Bright Bursts Using High Energy Resolution Data

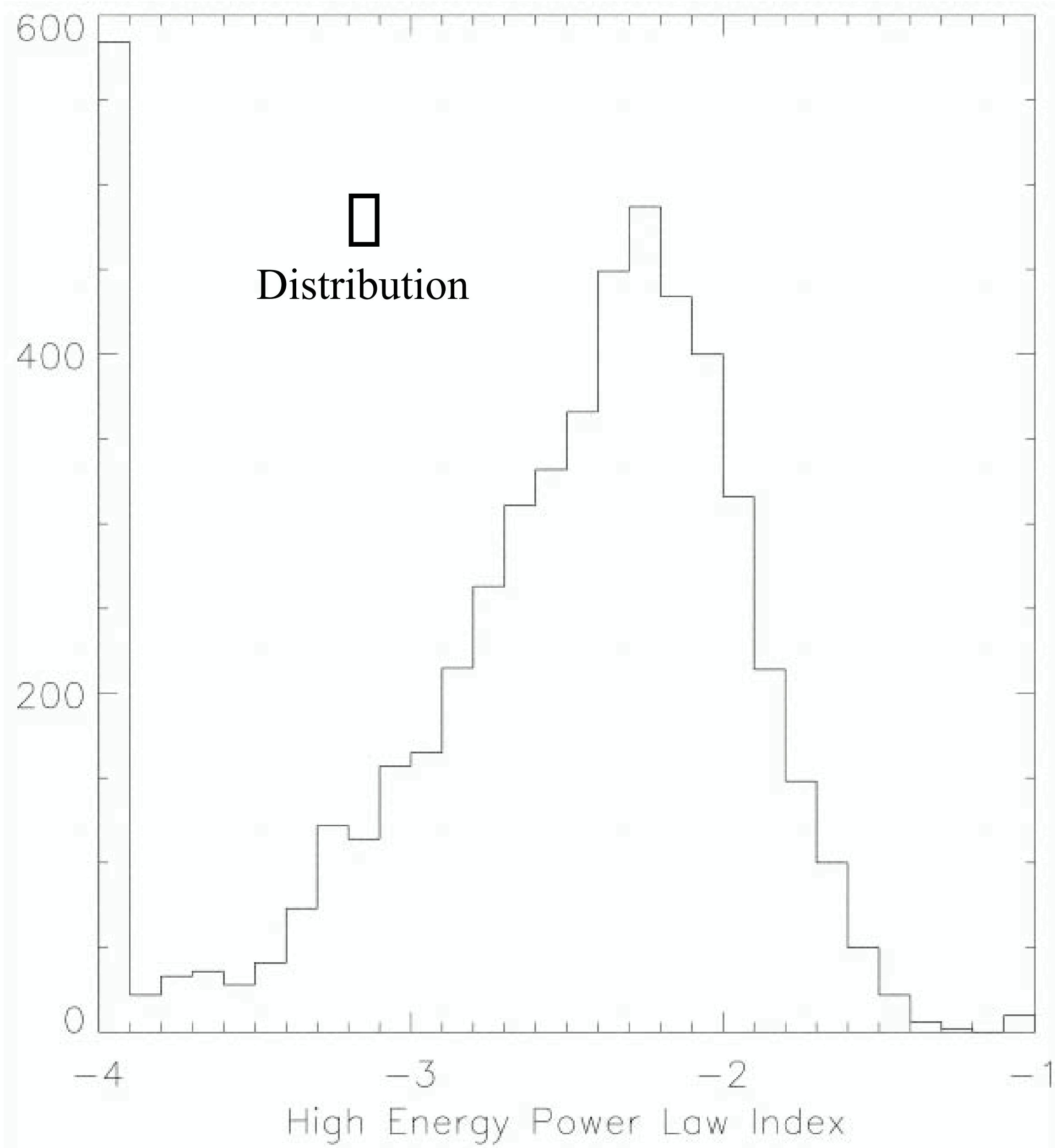
R. D. Preece , M. S. Briggs , R. S. Mallozzi , G. N. Pendleton , and W. S. Paciesas
Department of Physics, University of Alabama, Huntsville, Huntsville, AL 35899
and
D. L. Band
Center for Astrophysics and Space Sciences, Code 0424, University of California, San Diego, La Jolla, CA 92093



Distribution
600
500
400
300
200
100
0
−3
−2
−1
0
1
Low Energy Power Law Index



E_{peak}
Distribution
500
400
300
200
100
0
10
100
1000
10000
Break Energy (keV)


Distribution
600
400
200
0
−4
−3
−2
−1
High Energy Power Law Index

Correlations

HIC : Hardness-Intensity Correlation [Golenetskii et al. (1983)]

A common behavior is a tracking between the intensity, **N(*t*),** and the hardness, $\boldsymbol{E_{pk}}$**,** first noted by Golenetskii, who described it quantitatively as a power-law relation between the instantaneous luminosity (the energy flux) and the peak energy.

N(*t*) is the photon flux at time *t* (photons cm^{-2} s^{-1})

E_{pk} : peak energy of the spectrum, defined as the photon energy where the power output is the largest, i.e., the maximum of the E^2N_E spectrum, where *E* is the photon energy in units of keV and N_E is the specific photon flux (photons cm^{-2} s^{-1} keV^{-1})

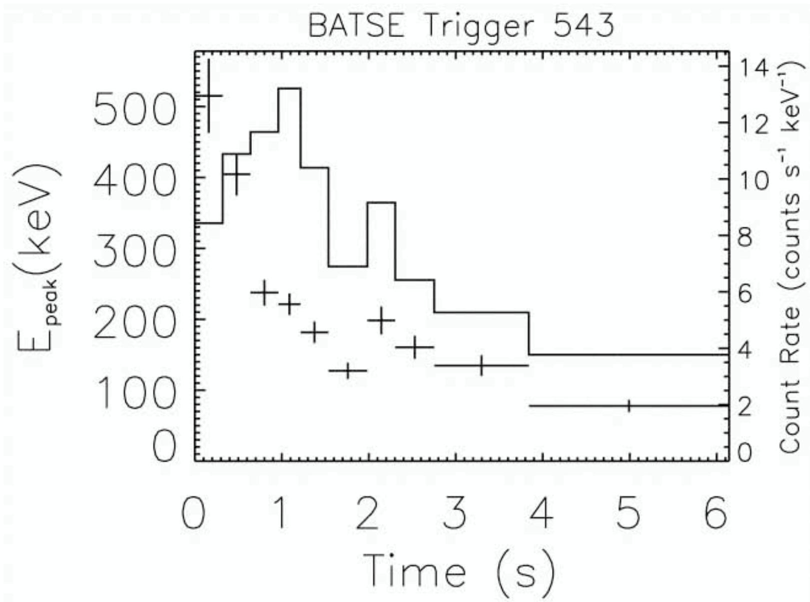
HFC : Hardness-Fluence Correlation

[Liang & Kargatis (1996); Crider et al. 1999]

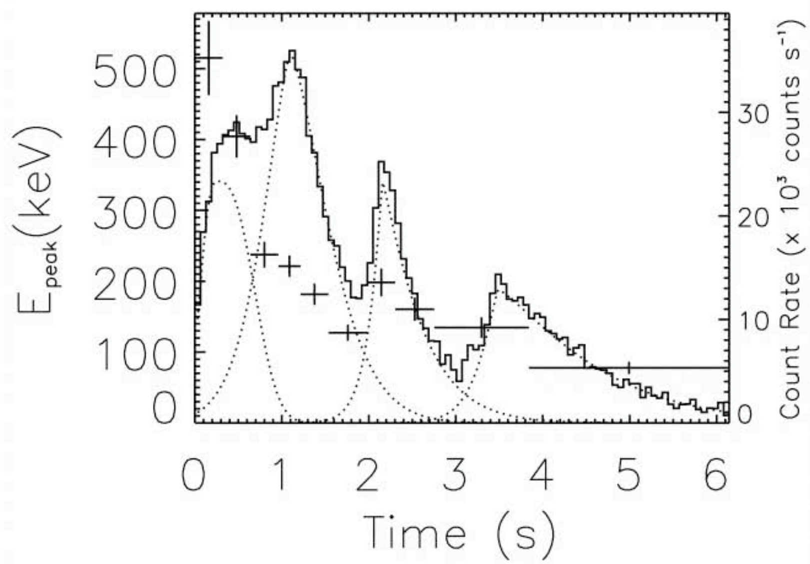
The discovery that E_{pk} often decays exponentially in bright, long, smooth BATSE GRB pulses *as a function of photon fluence* provided a new constraint for emission models
The HFC function:

$$E_{pk}(t) = E_{pk(0)} \exp\left[-\Phi(t)/\Phi_0^{LK}\right] \quad (1)$$

HFC



(*top*) coarse time resolution



(*bottom*) 64 ms resolution.

The fits of the Norris function to these pulses are plotted here as dotted lines.

Crider et al. 1999

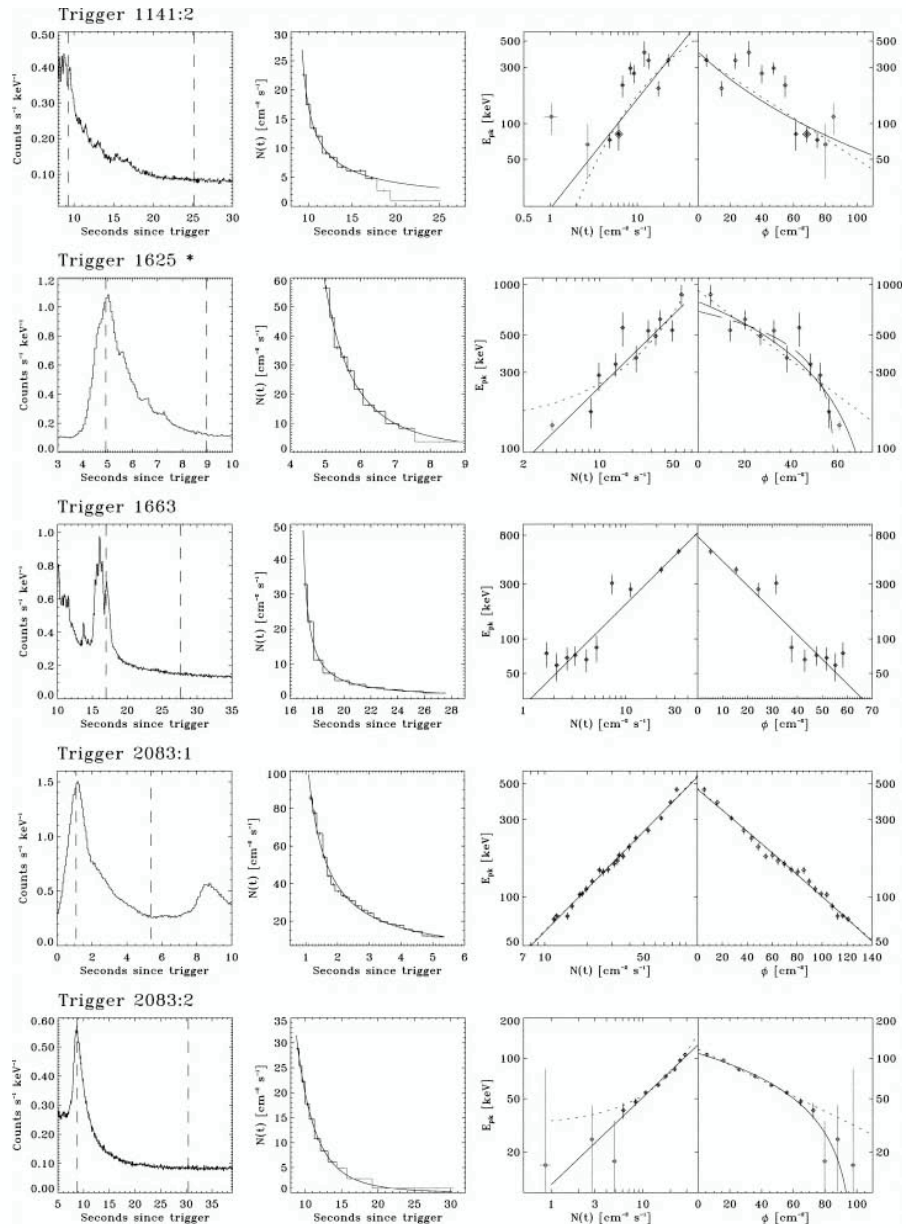
Felix Ryde [1]
Center for Space Science and Astrophysics, Stanford University, Stanford, CA 94305
and
Roland Svensson
SCFAB, Stockholm Observatory, SE-106 91 Stockholm, Sweden

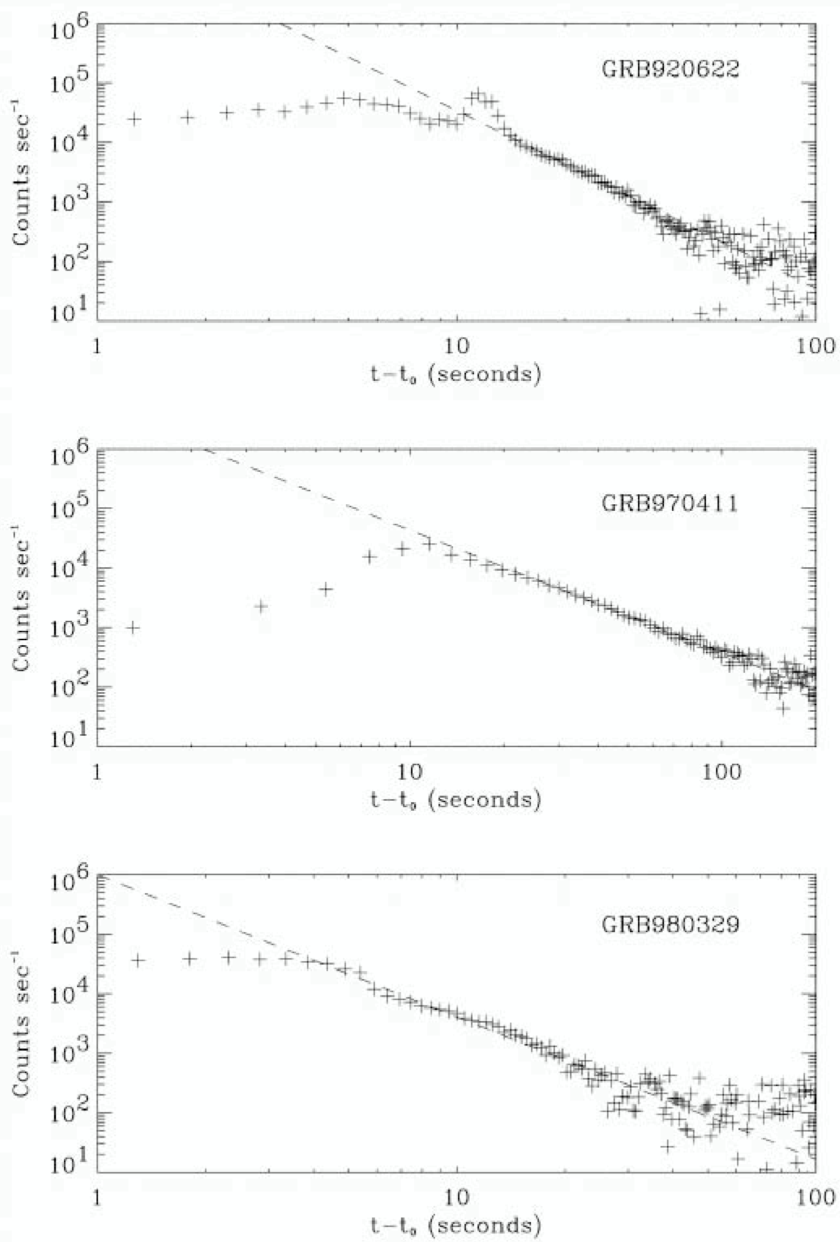
Ap.J. 2002

A Sample of 5 GRBs -

HIC: $E_{pk}(N)$ (panel 3)

HFC: E_{pk}(Phi) (panel 4)





Gamma-ray Afterglows

Time histories of three events in the 25 - 300 keV range. The dashed line is the best-fit power-law model for each burst.

(Most power-law decay indices range from -1.7 to -2.2)

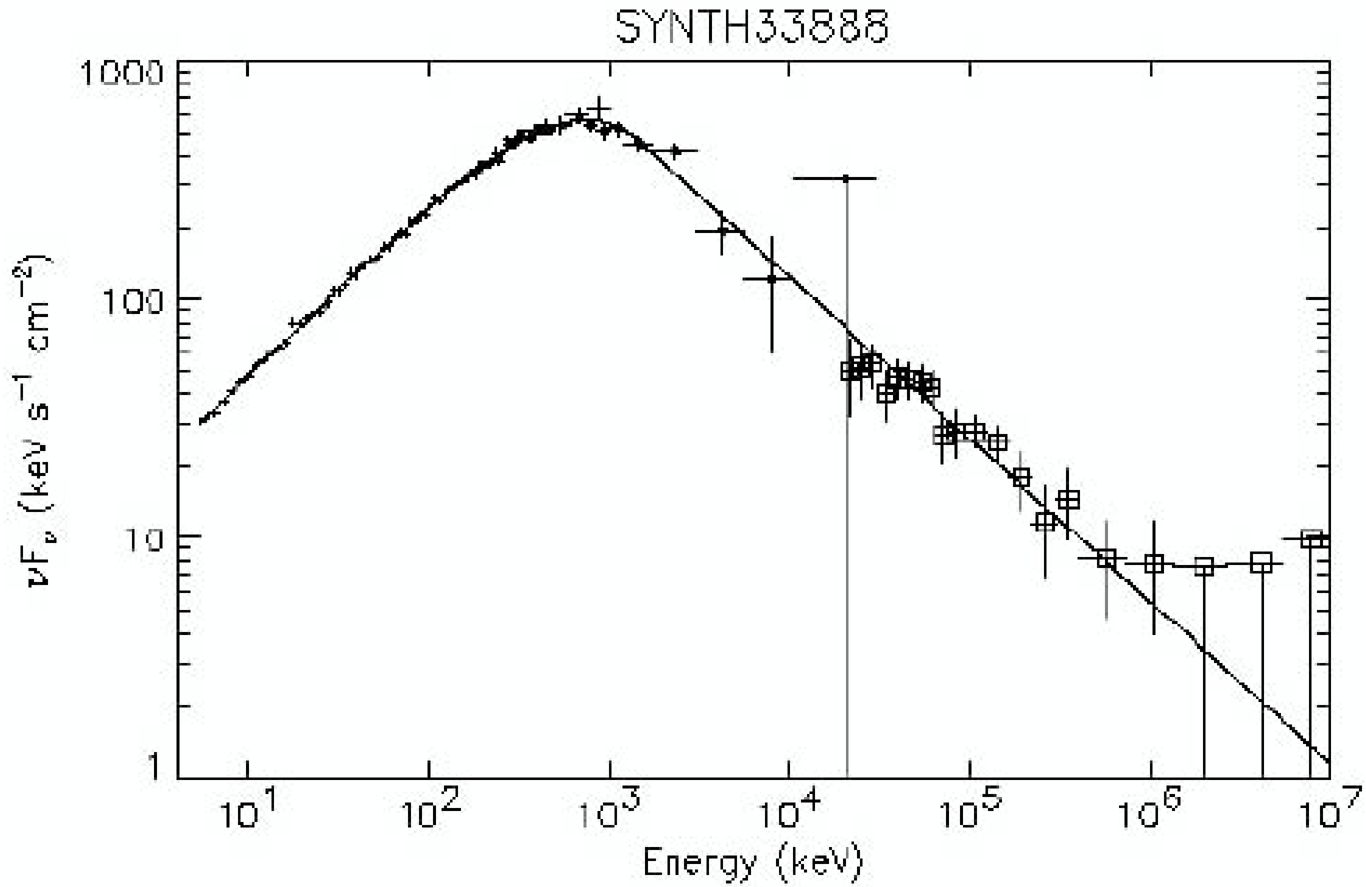
Giblin, et al. 2002

- see also

Connaughton 2000

Simulated GRB Spectrum

LAT + GBM



GLAST

-Time Resolved Spectra