Discovery of a Distinct Higher Energy Spectral Component in GRB941017

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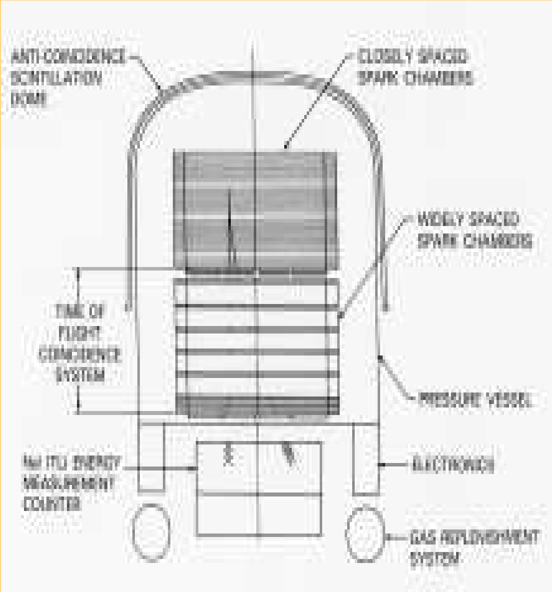
- **43 BATSE Triggers were analyzed.**

- **These 43 bursts were bright above 300keV and have flux>10 ph/cm^2/s**

- **Combine BATSE and EGRET-TASC data to characterize the synchrotron component and its temporal evolution when possible.**

❧**This analysis is especially important when the synchrotron component peaks >~1MeV where BATSE has poor sensitivity.**

Comptel Gamma Ray Observatory

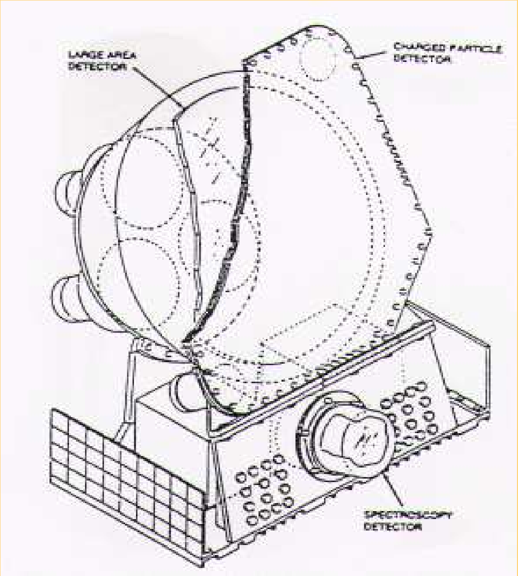


EGRET-TASC

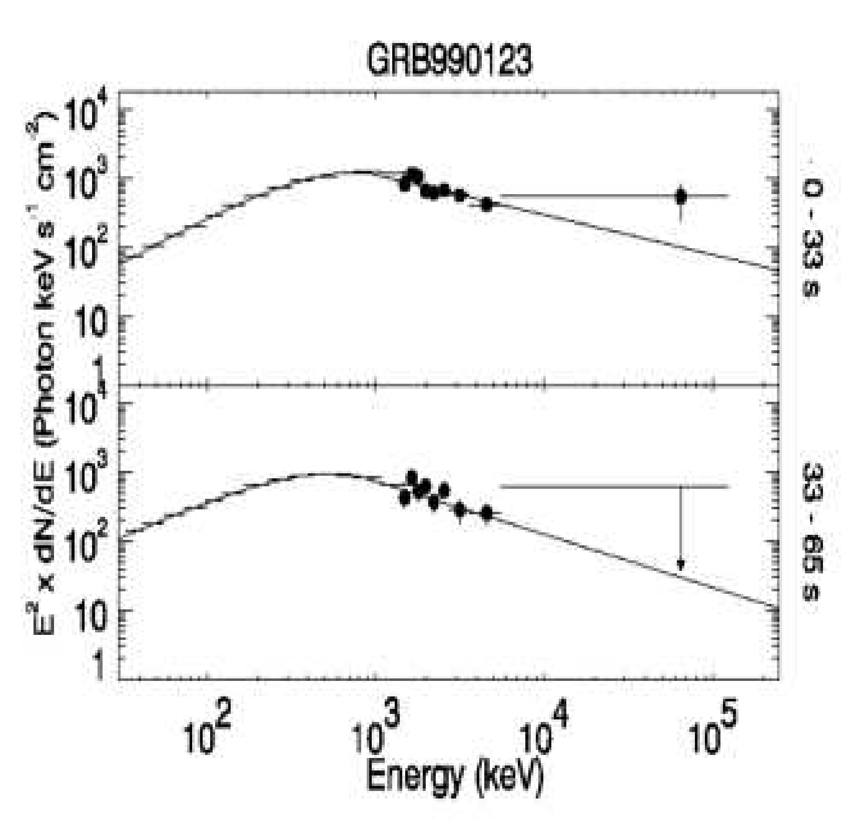
- NaI calorimeter, 6400cm^2 x 8r.l.
- No self-trigger
- Sensitive to all directions.
- E= 1-200MeV
- 1, 2, 4, 16, 32.7s time resolution
- 65% dead time

BATSE

- trigger
- direction of the burst
- E= 25keV-2MeV
- 16-64 msec time resolution

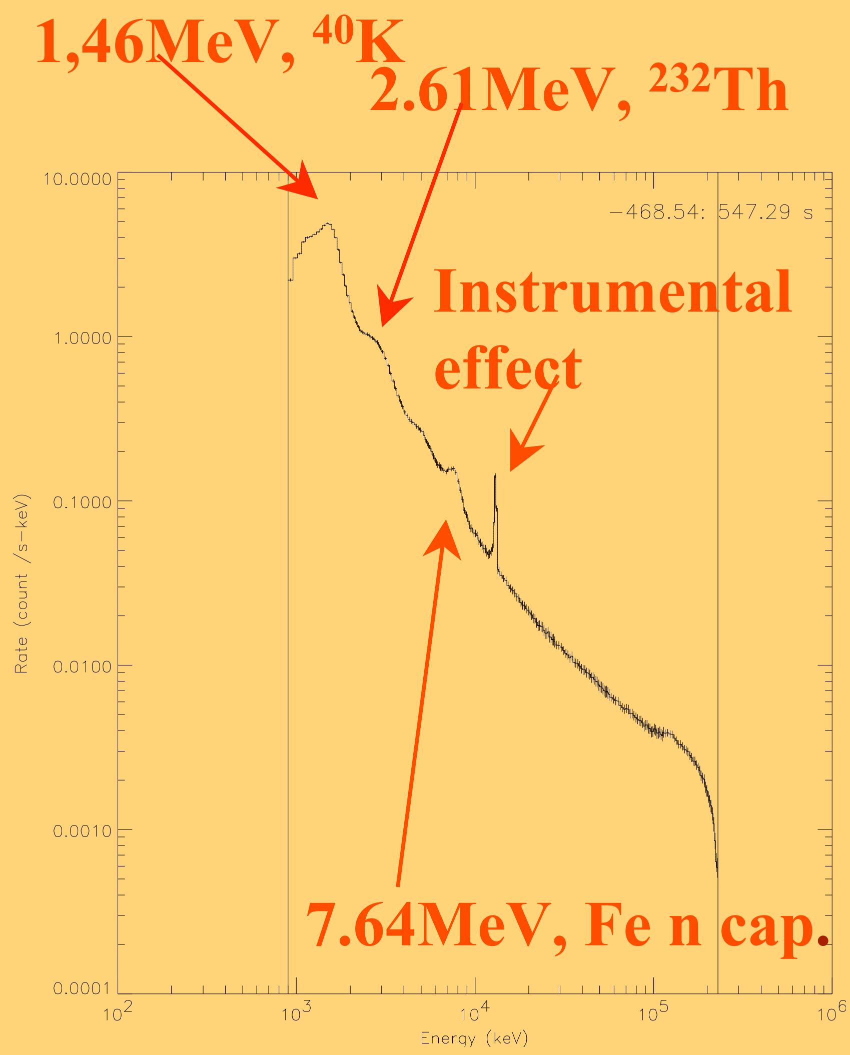


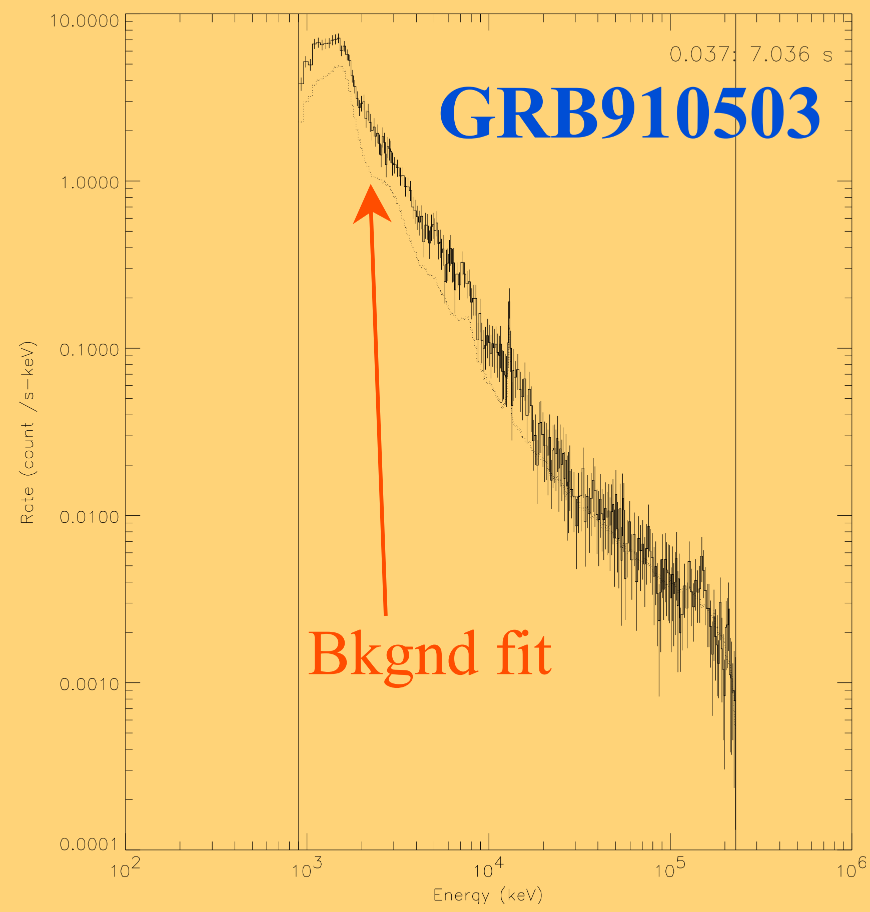
- Fit background using rate before and after the burst.
- Calculate detector response for the known burst direction.
- Use RMFIT spectral fitting program written for BATSE in IDL environment that combine both sets of data.
  - Different photon models are possible
  - Normalization factor between BATSE & EGRET is added



- 26/43 with detected by TASC
- 16/43 have significant detection in more than 1 time interval in TASC.
- 25/26 are consistent with an extension of the synchrotron emission

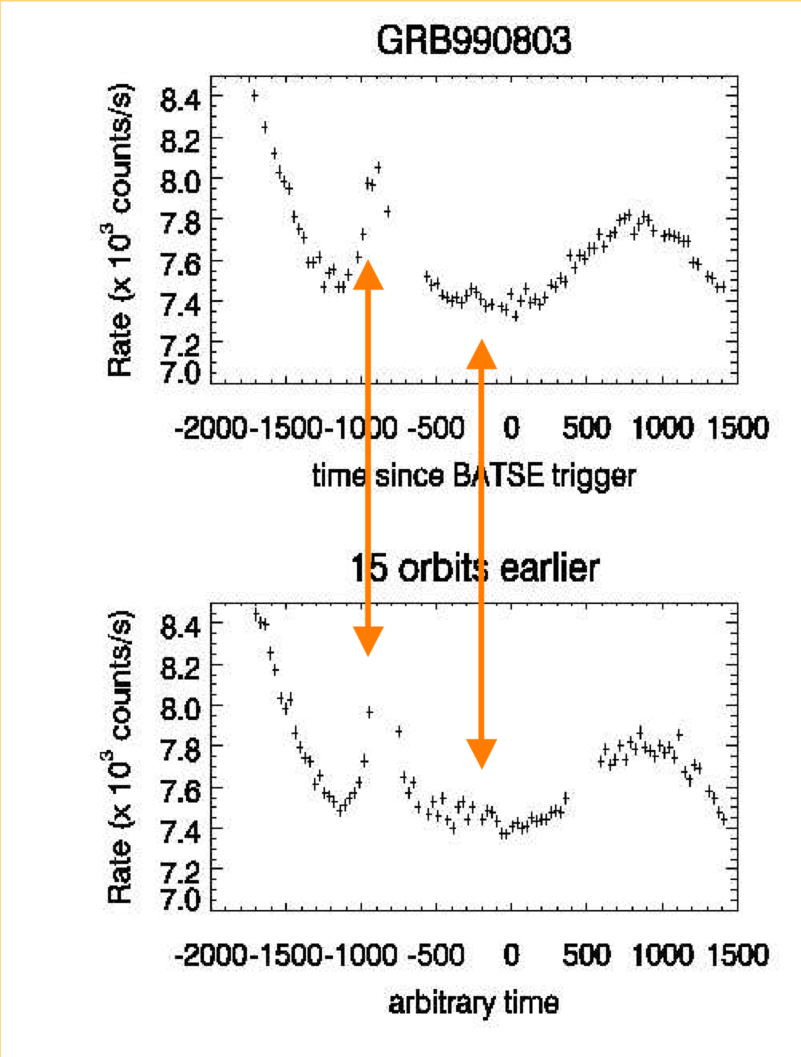
TASC spectrum



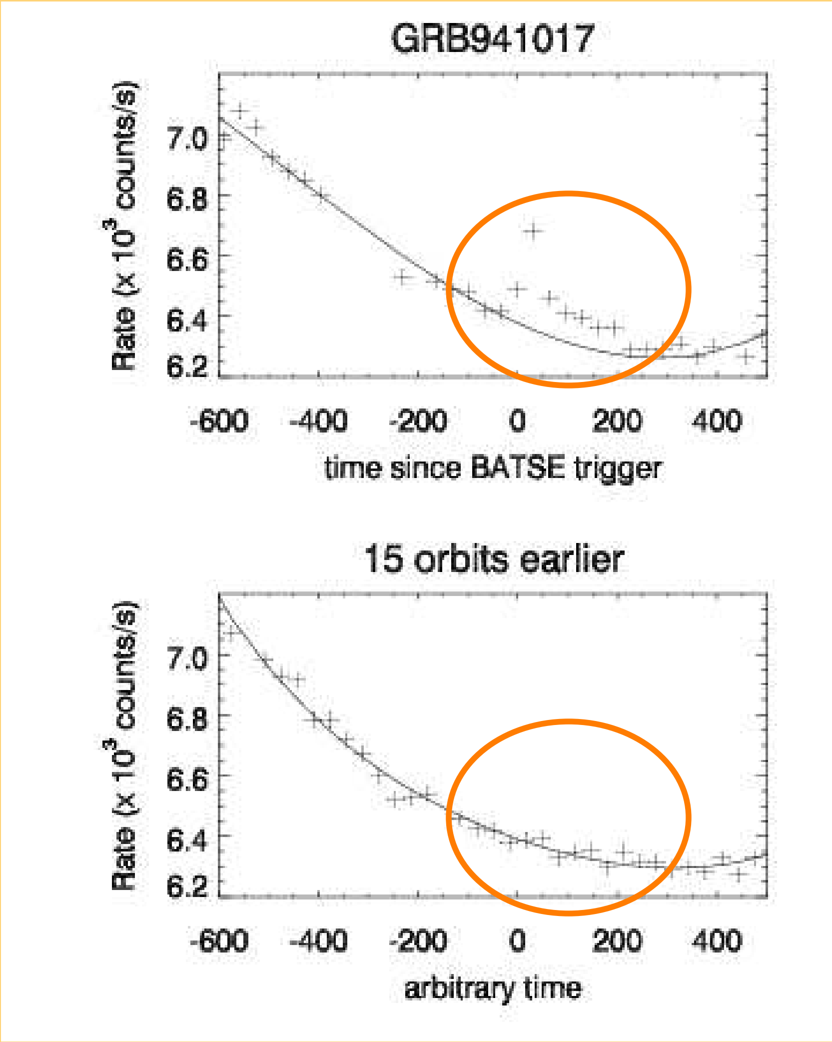


Background Check

15 orbits earlier = same position relative to Earth's magnetic field

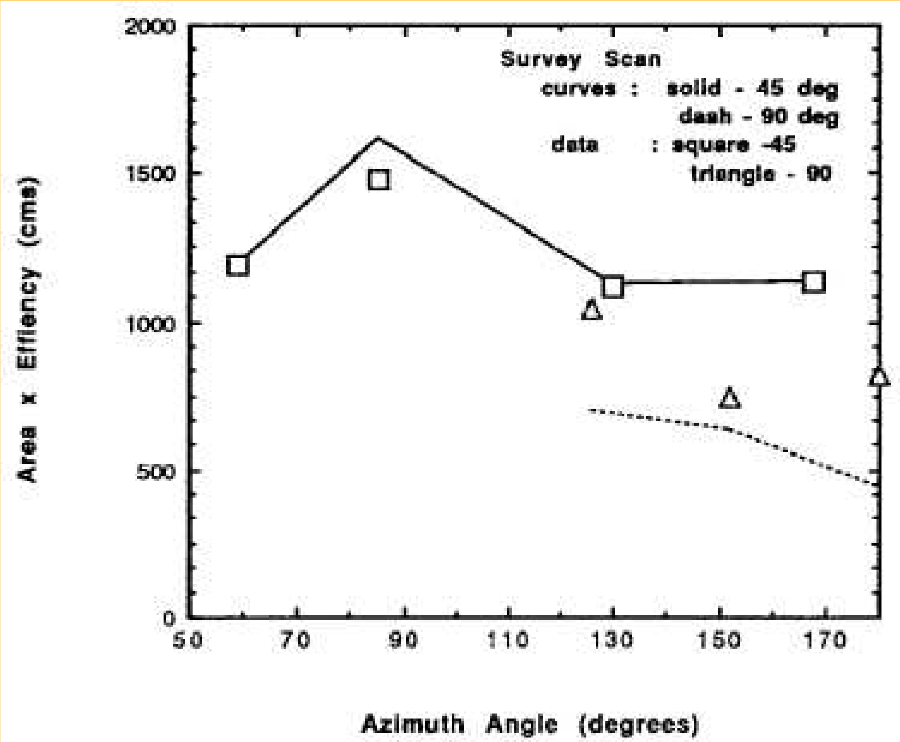


No TASC Detection

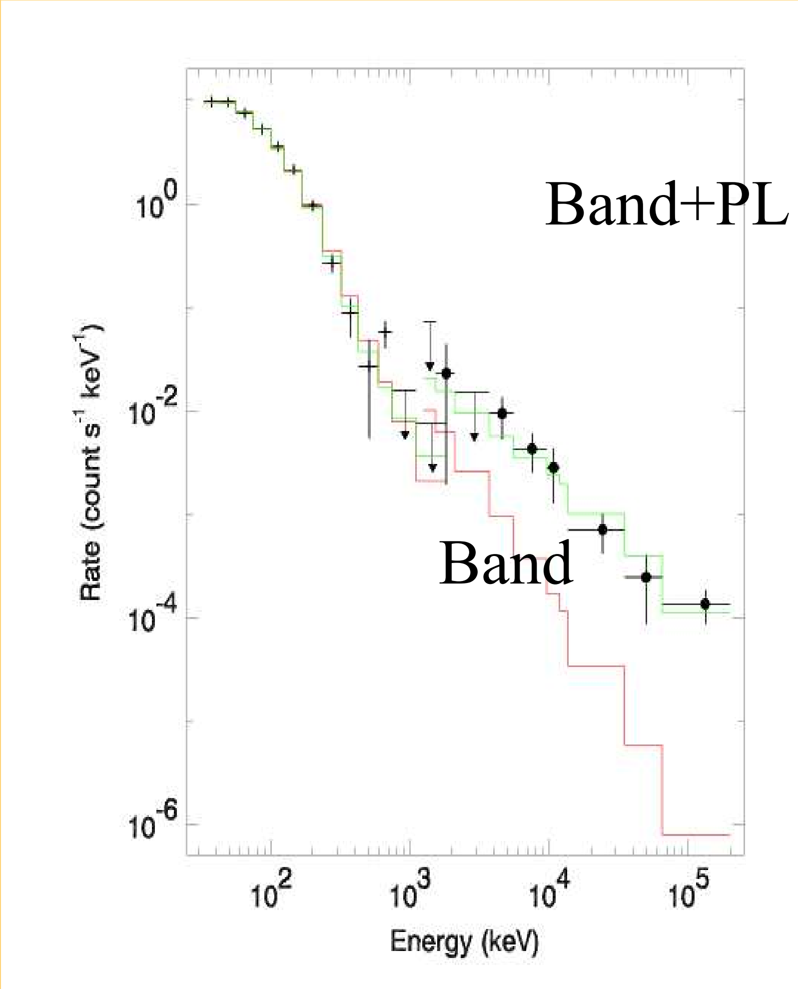


Yes TASC Detection

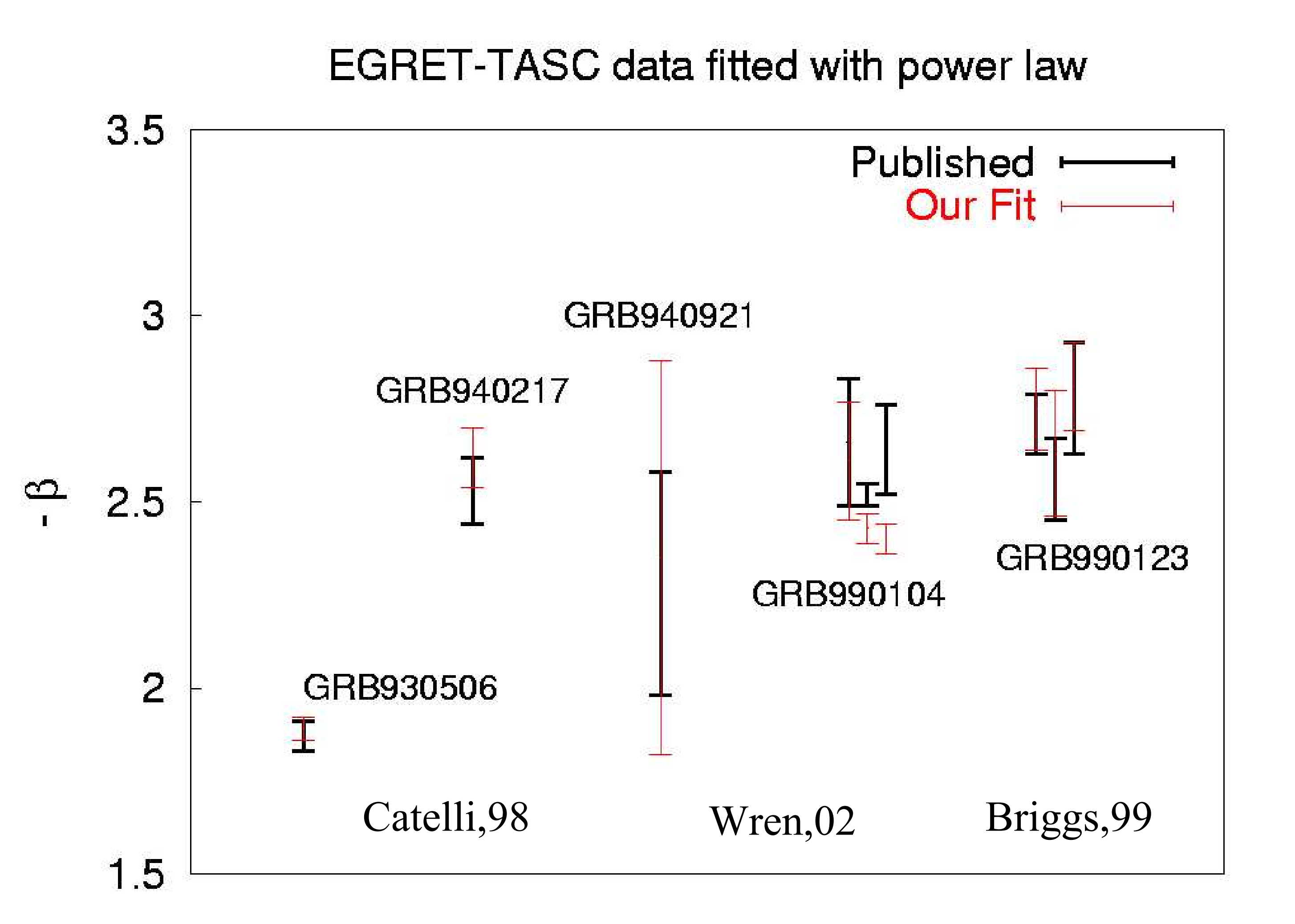
GRO mass model + Monte Carlo EGS
=> Response Matrix



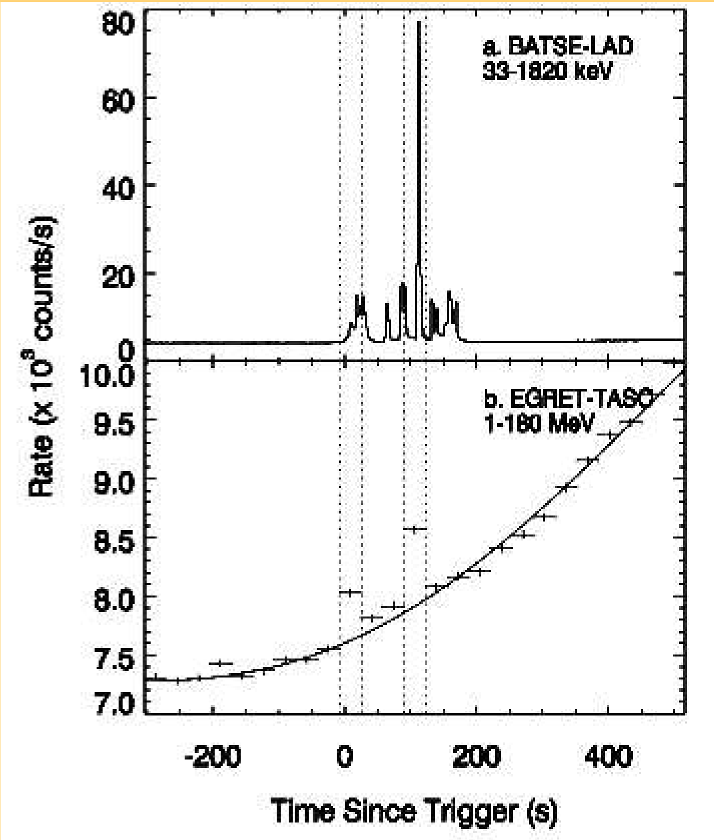
Response Matrix + Counts spectrum
=> Energy Spectrum

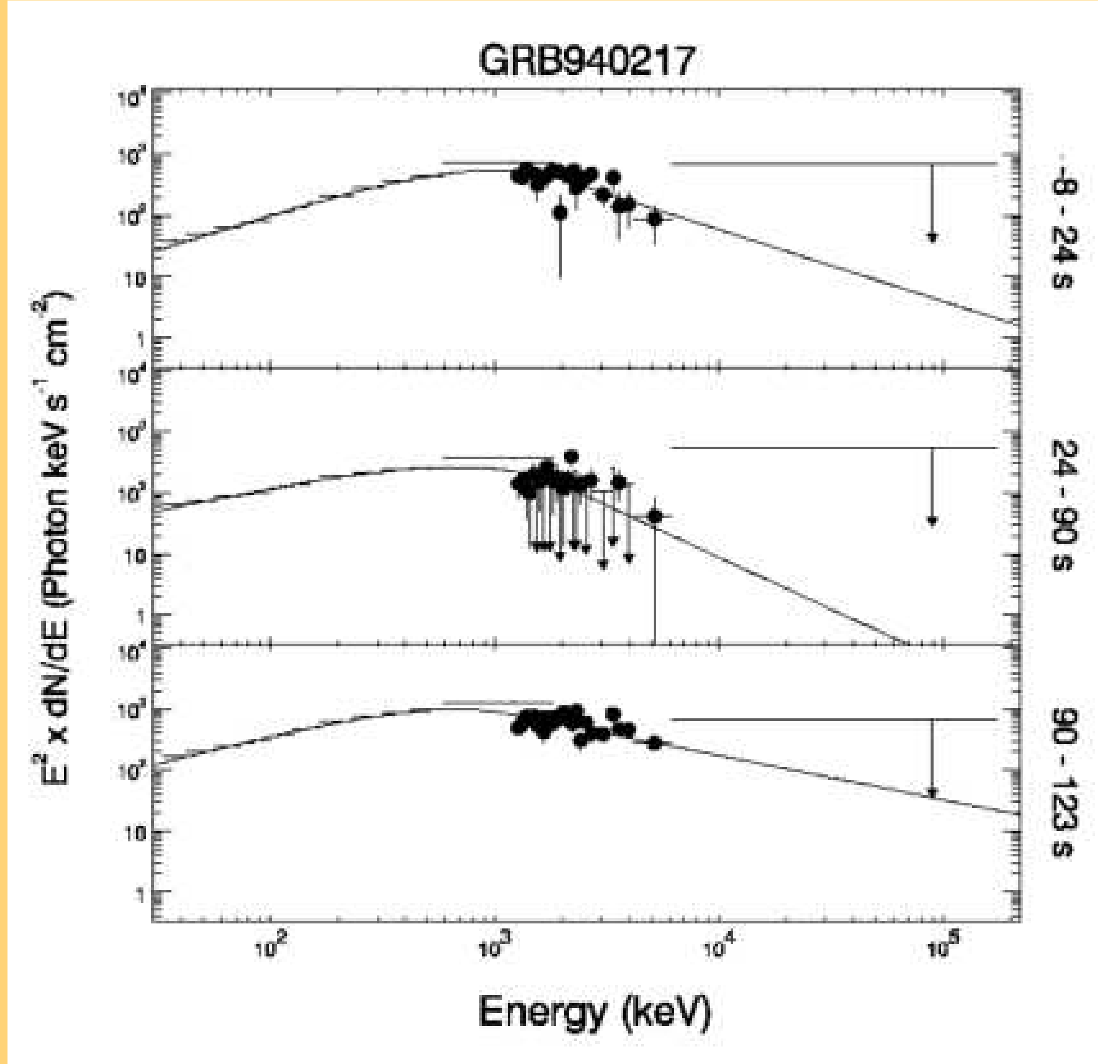


Comparison of Spectral Fit with Previous Analysis Algorithms and BATSE's RMFIT Program



GRB940217



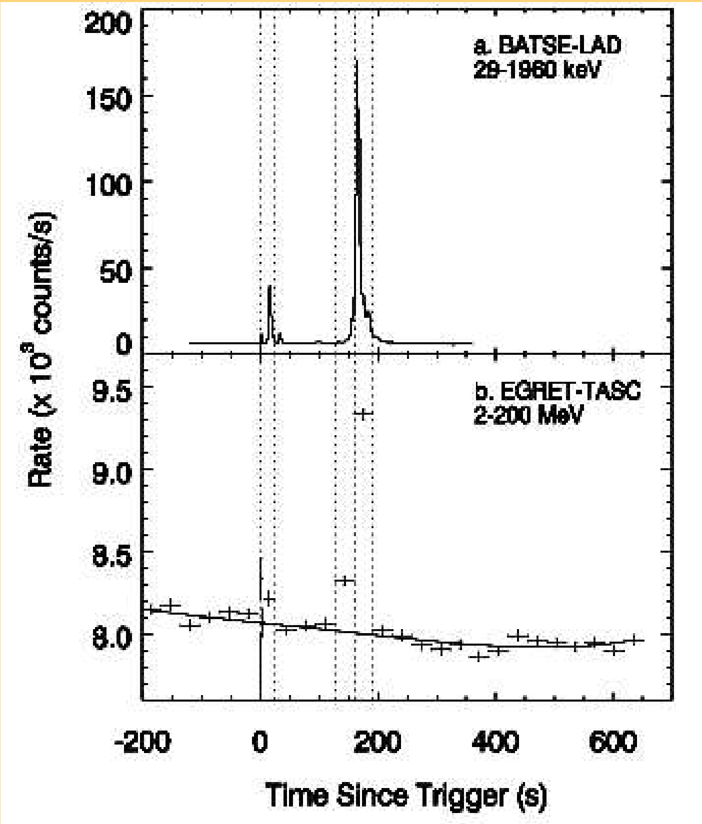


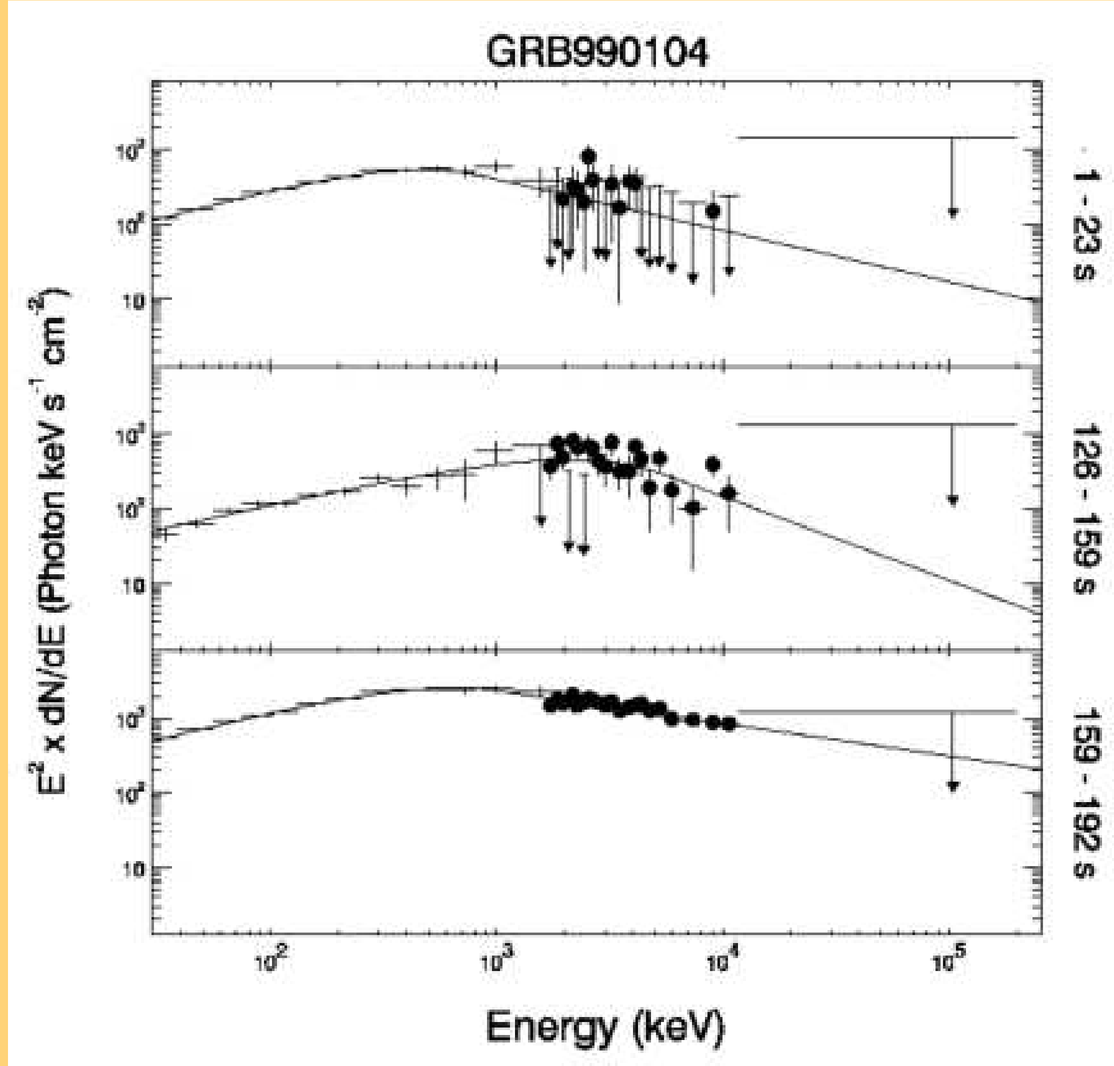
GRB940217

N=0.6, E=0.03-177MeV

Time after BATSE trigger (s)	−8-25	25-90	90-123
A($x10^{-3}$ ph/cm^2-s-keV)	11.2±0.1	12.9±0.1	40.2±0.2
Epeak(keV)	1017±32	675±26	676±14
α	−0.79±0.02	−1.21±0.01	−1.03±0.01
β	−3.17±0.25	−3.69±0.90	−2.73±0.00

GRB990104



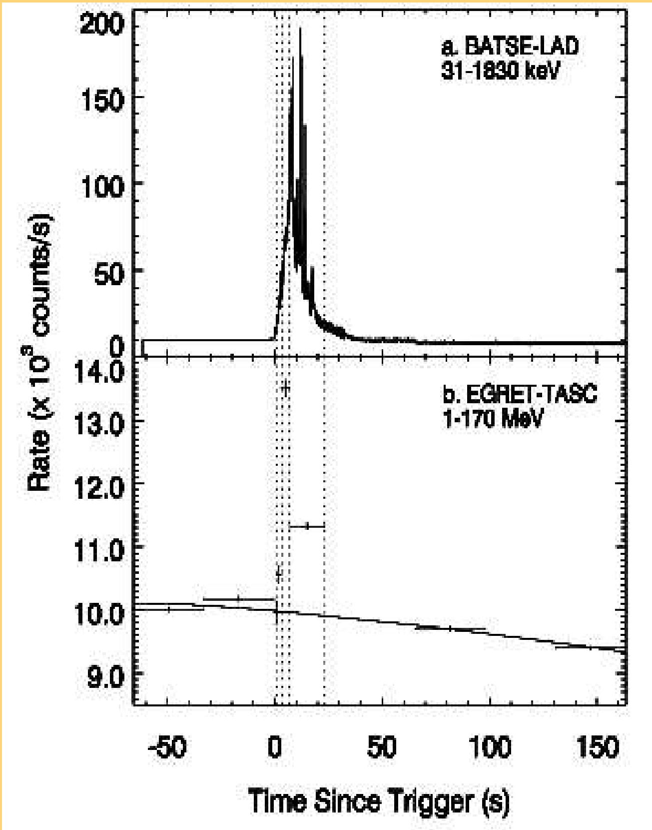


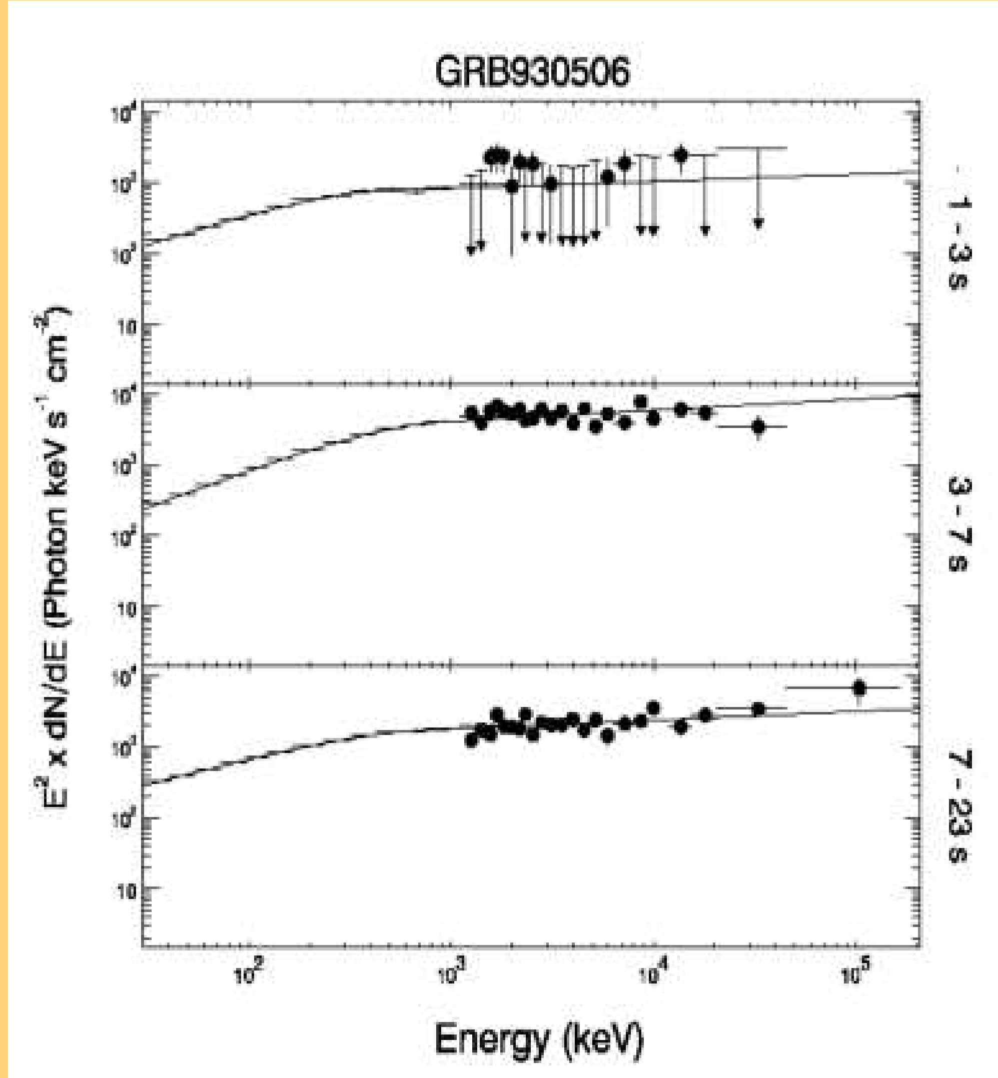
GRB990104

N=0.3, E=0.03-201MeV

Time after BATSE trigger (s)	1-23	127-159	159-192
A($\times 10^{-3}$ ph/cm^2-s-keV)	33.2±0.8	11.4±0.4	131.0±1.2
Epeak(keV)	476±35	2083±289	648±27
α	−1.14±0.03	−1.33±0.06	−1.22±0.01
β	−2.69±0.15	−3.13±0.61	−2.44±0.02

GRB930506



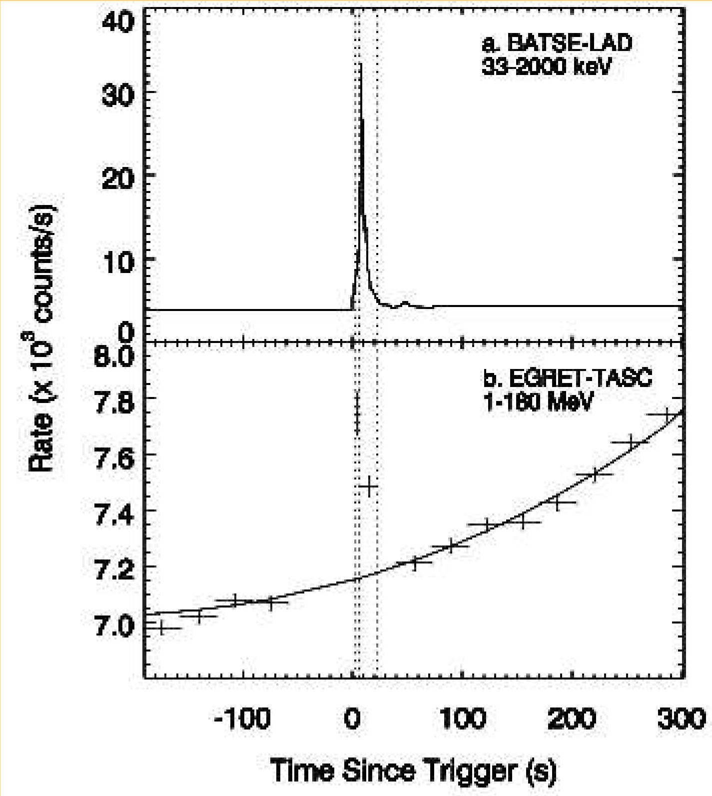


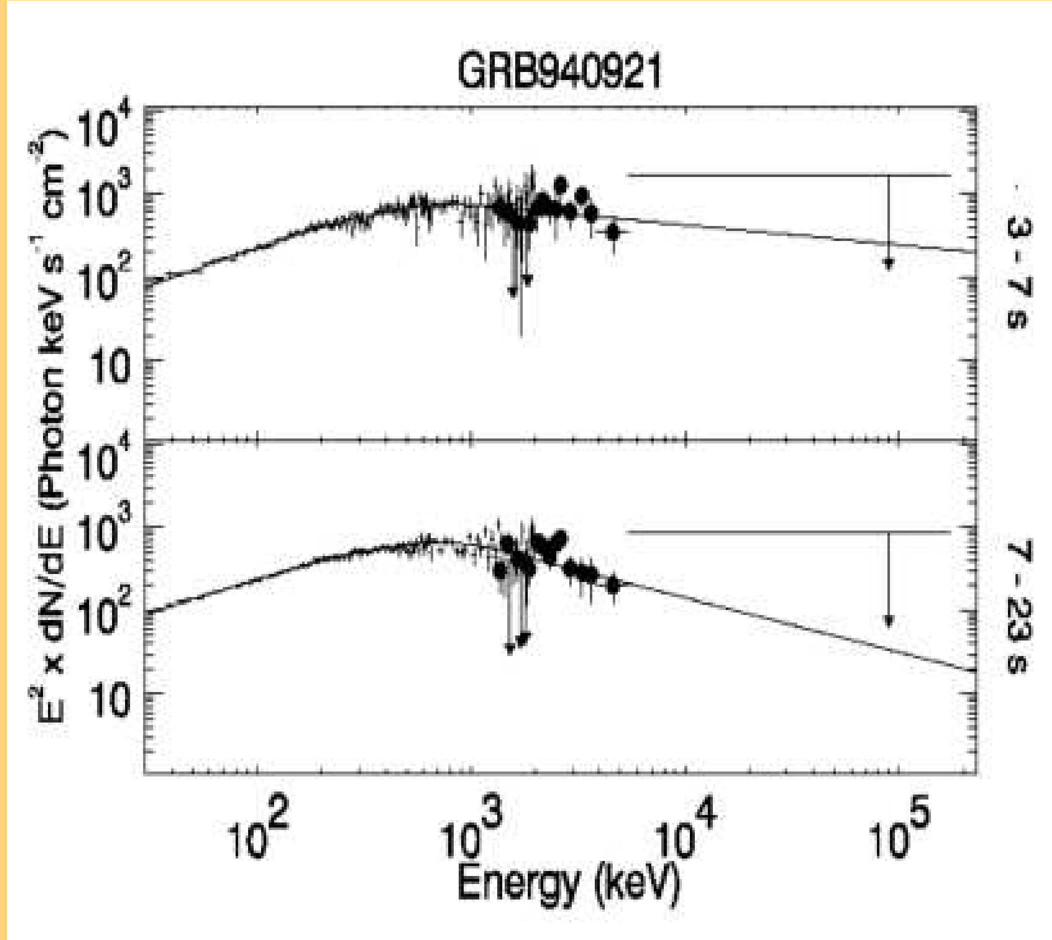
GRB930506

N=0.6, E=0.03-167MeV

Time after BATSE trigger (s)	1-3	3-7	7-23
A($\times 10^{-3}$ ph/cm^2-s-keV)	41.5±1.4	91.9±0.6	72.8±0.4
Epeak(keV)	540±58	1064±38	850±32
α	−1.06±0.04	−0.89±0.01	−1.24±0.01
β	−1.90±0.06	−1.84±0.02	−1.87±0.01

GRB940921



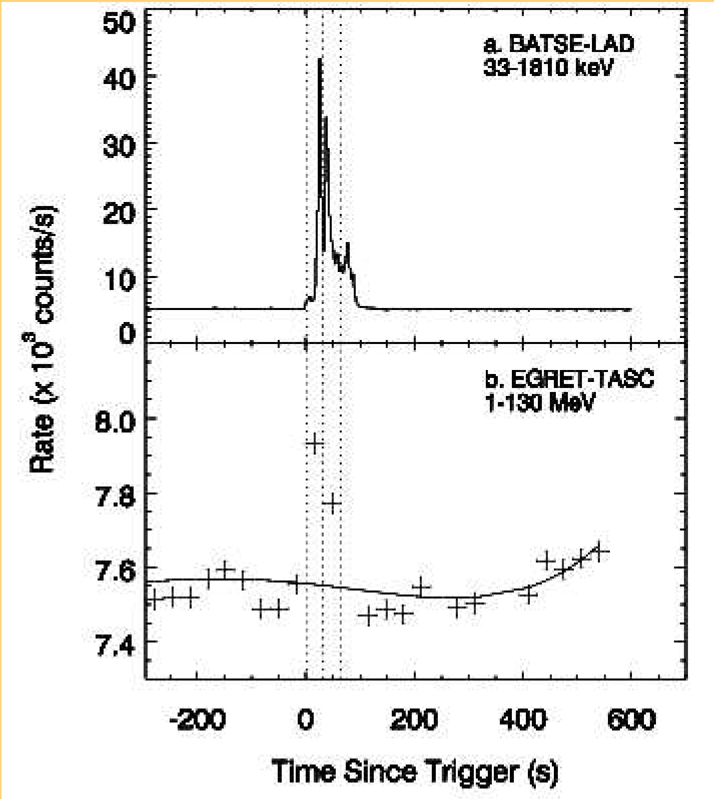


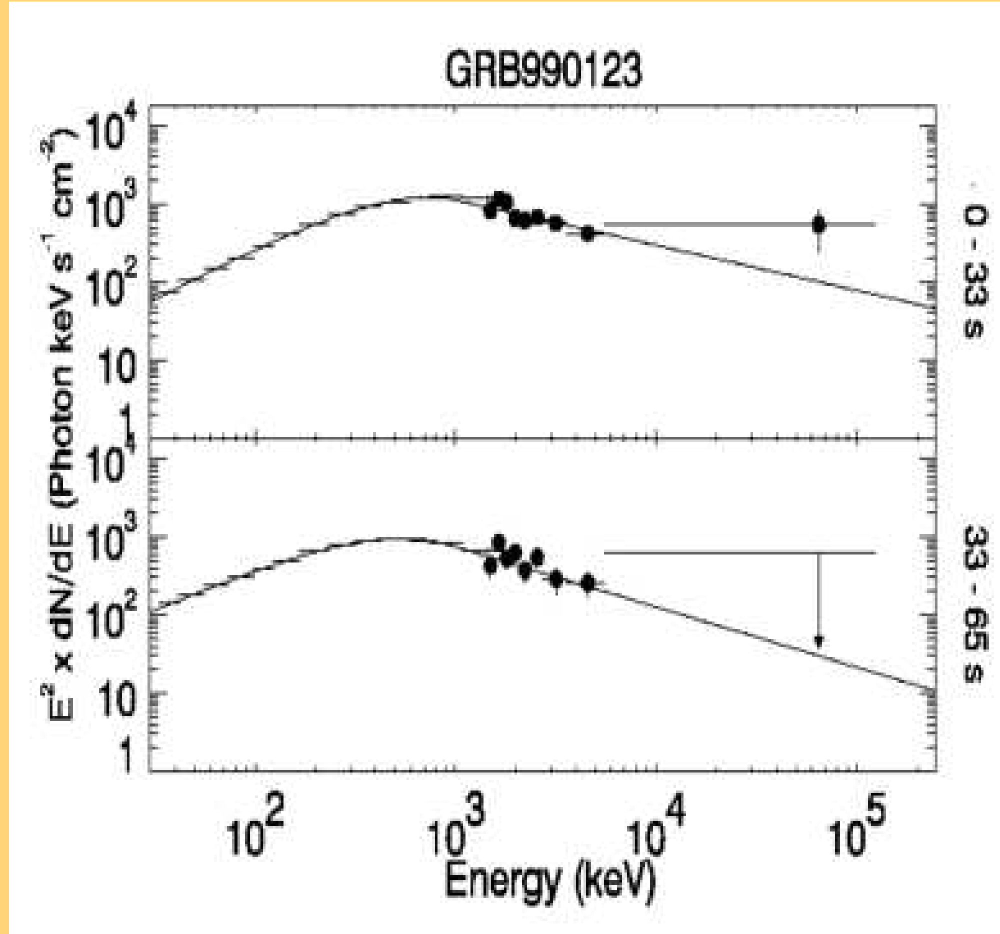
GRB940921

N=0.6, E=0.03-178MeV

Time after trigger (s)	3-7	7-23
A($x10^{-3}$ ph/cm^2-s-keV)	25.4±0.5	27±0.3
Epeak(keV)	814±71	732±30
α	−1.01±0.03	−1.11±0.01
β	−2.24±0.08	−2.66±0.12

GRB990123



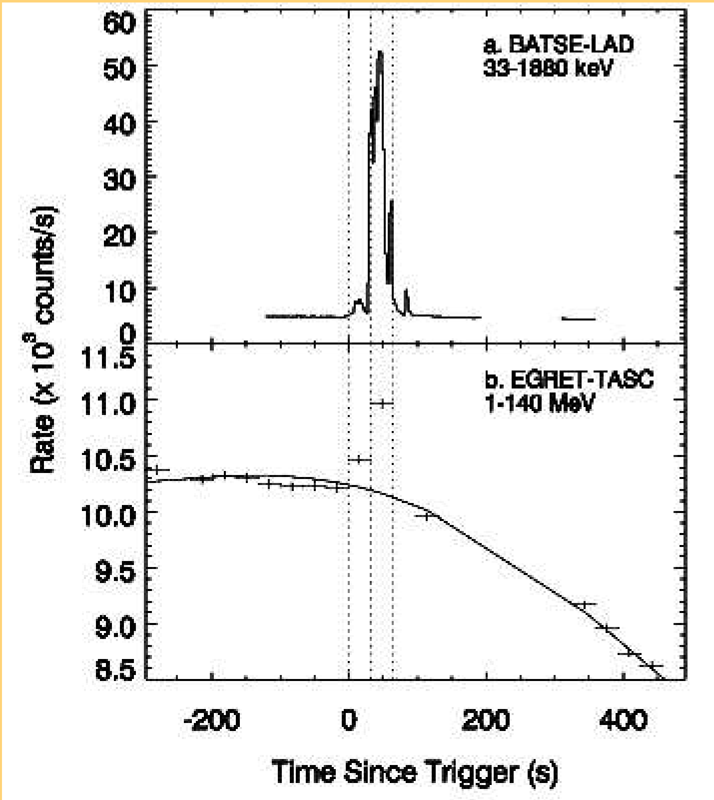


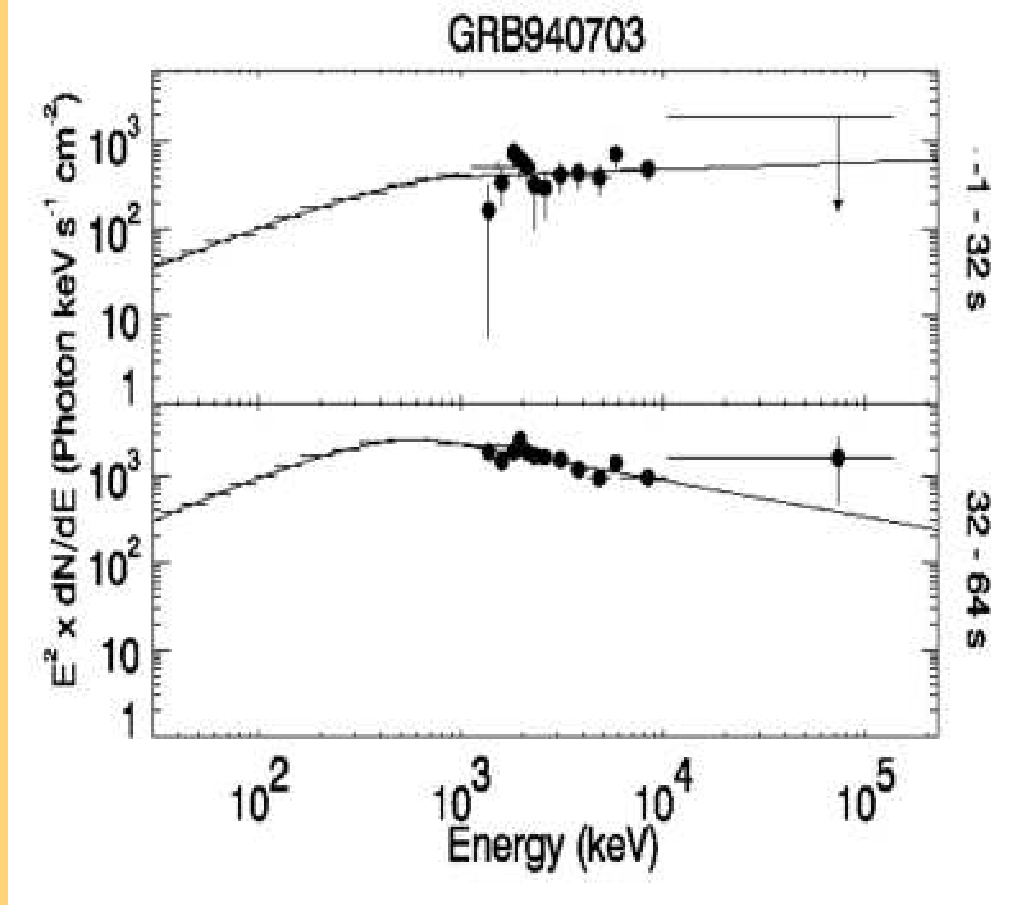
GRB990123

N=0.7, E=0.03-128MeV

Time after trigger (s)	0-33	33-66
A($x10^{-3}$ ph/cm^2-s-keV)	30.7±0.2	44.5±0.3
Epeak(keV)	734±13	543±10
α	−0.62±0.01	−0.88±0.01
β	−2.58±0.06	−2.77±0.08

GRB940703



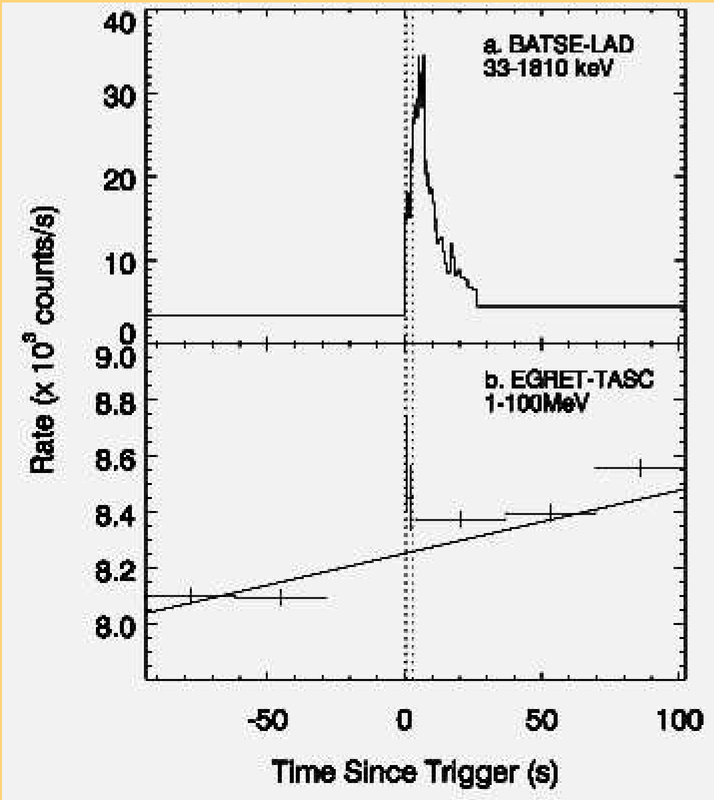


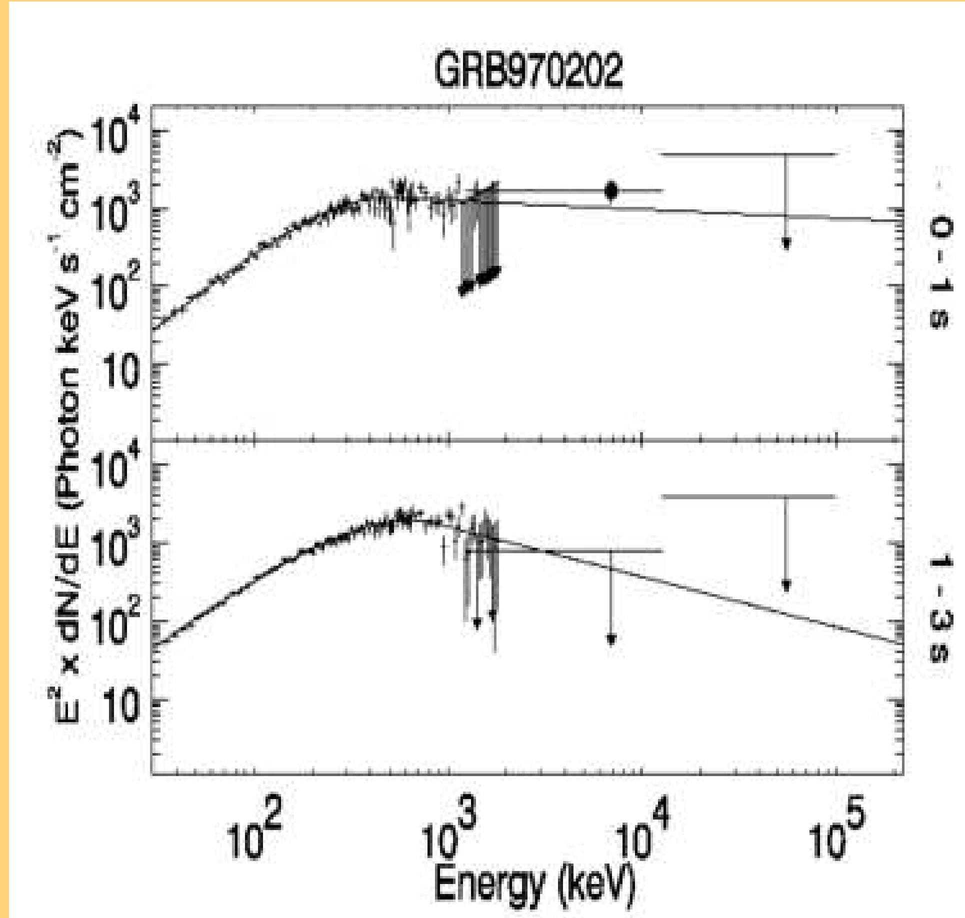
GRB940703

N=0.3, E=0.03-139MeV

Time after trigger (s)	−1-32	32-64
A($x10^{-3}$ ph/cm^2-s-keV)	11.1±0.2	110.6±0.5
Epeak(keV)	1120±135	613±9
α	−1.09±0.03	−0.96±0.01
β	−1.92±0.06	−2.42±0.03

GRB970202





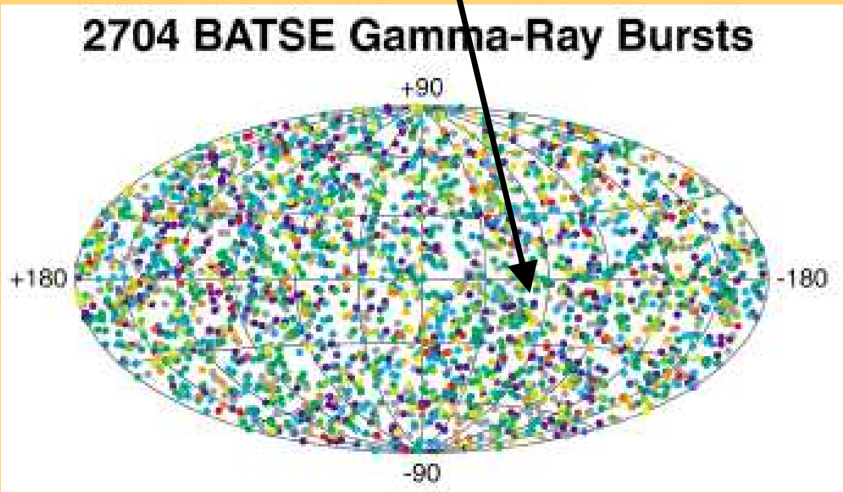
GRB970202

N=0.6, E=0.03-100MeV

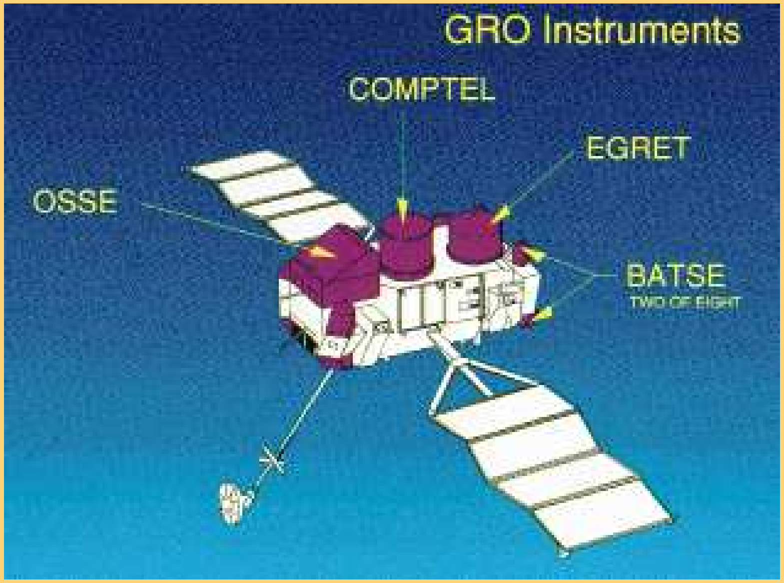
Time after trigger (s)	0-1	1-3
A(x10^{-3} ph/cm^2-s-keV)	39.5±2.1	42.4±1
Epeak(keV)	487±32	630±27
α	0.11±0.08	−0.19±0.04
β	−2.12±0.09	−2.64±0.17

GRB941017

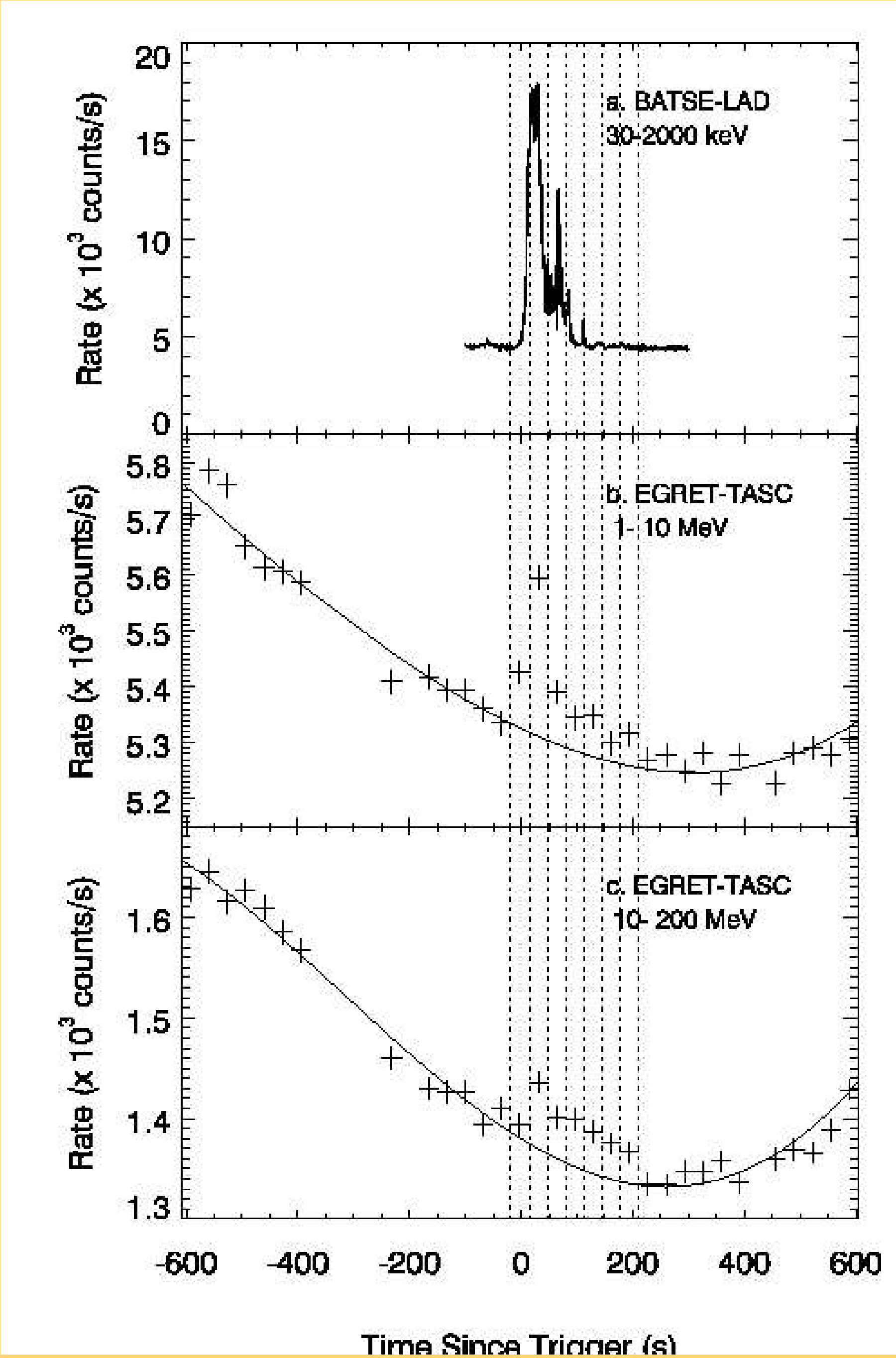
l= 50.0, b= -11.7



zang=65.6 azi=102.2



- 11th brightest in BATSE Catalog
- T90 = 77s
- BATSE; Preece 00 , Briggs 98
- COMPTEL detected light curve
- TASC; Catelli 98



GRB941017

- Correlation in light curves. Brightest bin in TASC corresponds to peak in BASTE.

- BATSE light curve :
  - precursor 90s before trigger
  - tail 113-211s is 17σ.

- TASC light curve:
  - detection in 113-211s is 6σ in E=10-200 MeV

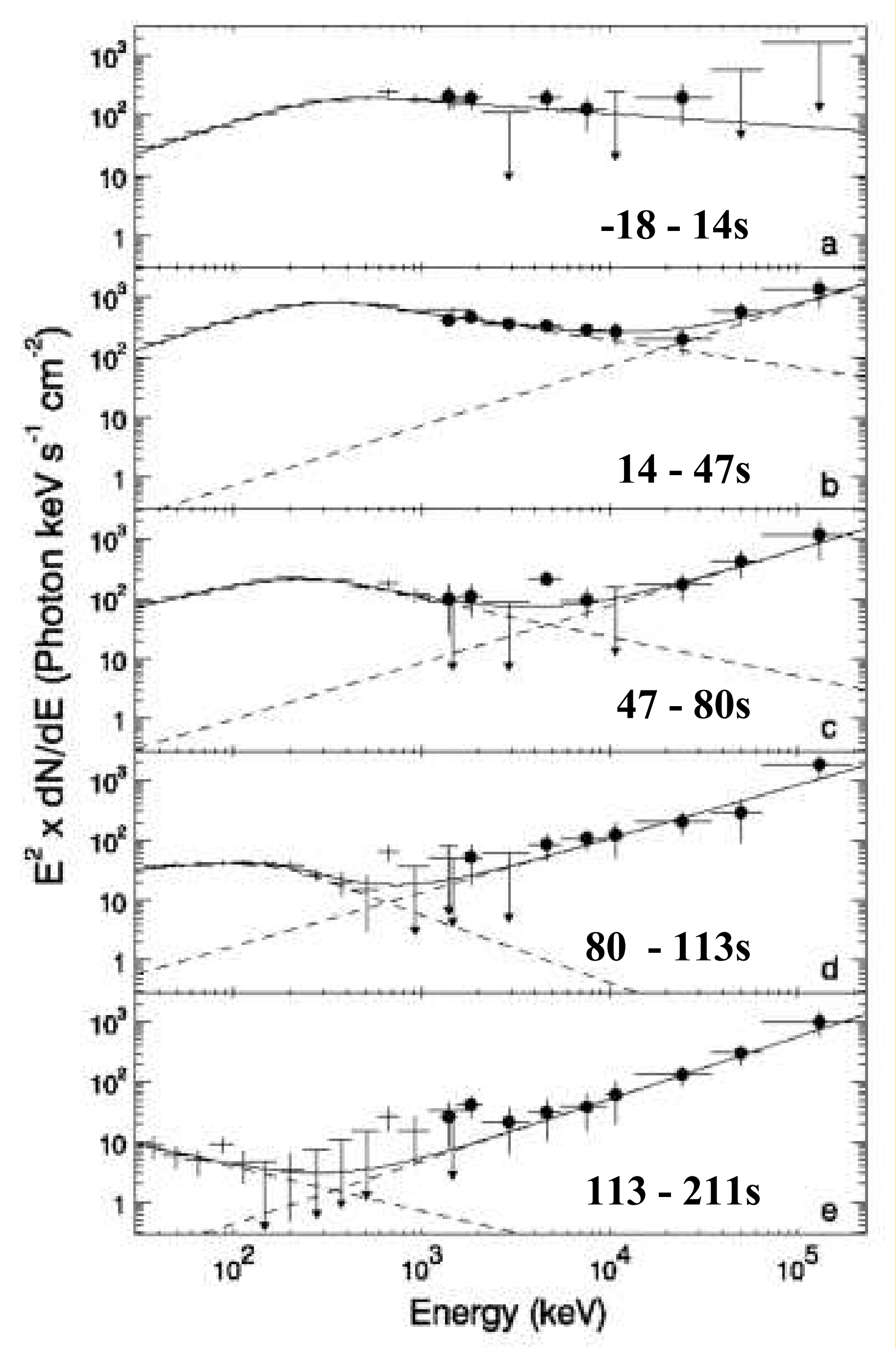
GRB941017 shows a new spectral component !!!

- Both components observed by both detectors.

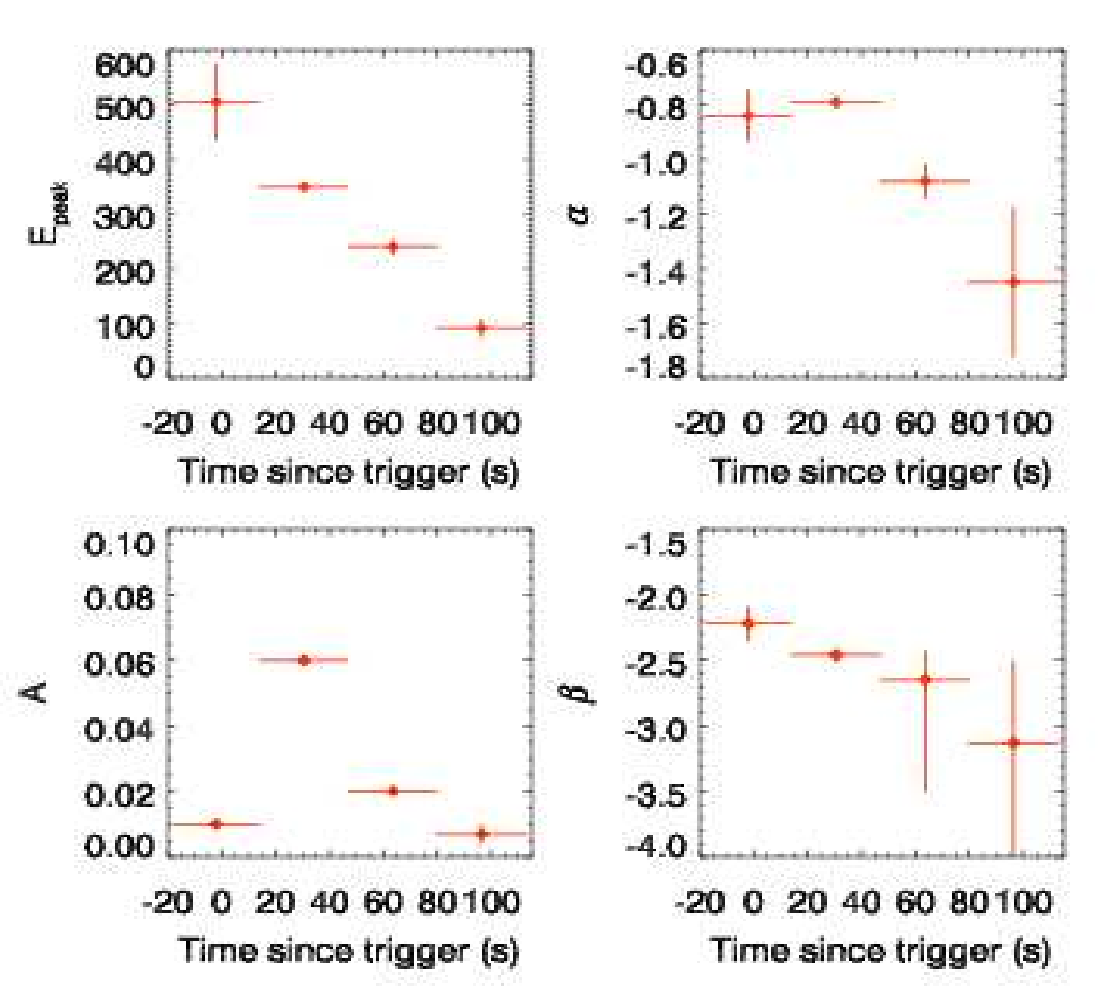
- BATSE-LAD and TASC data joint nicely describing the synchrotron component in first time intervals => Correct Normalization factor (=0.45) & good background fit.

- For last time intervals BATSE detection consistent with second component.

- Broad energy range => separate both components & identify different temporal evolution.



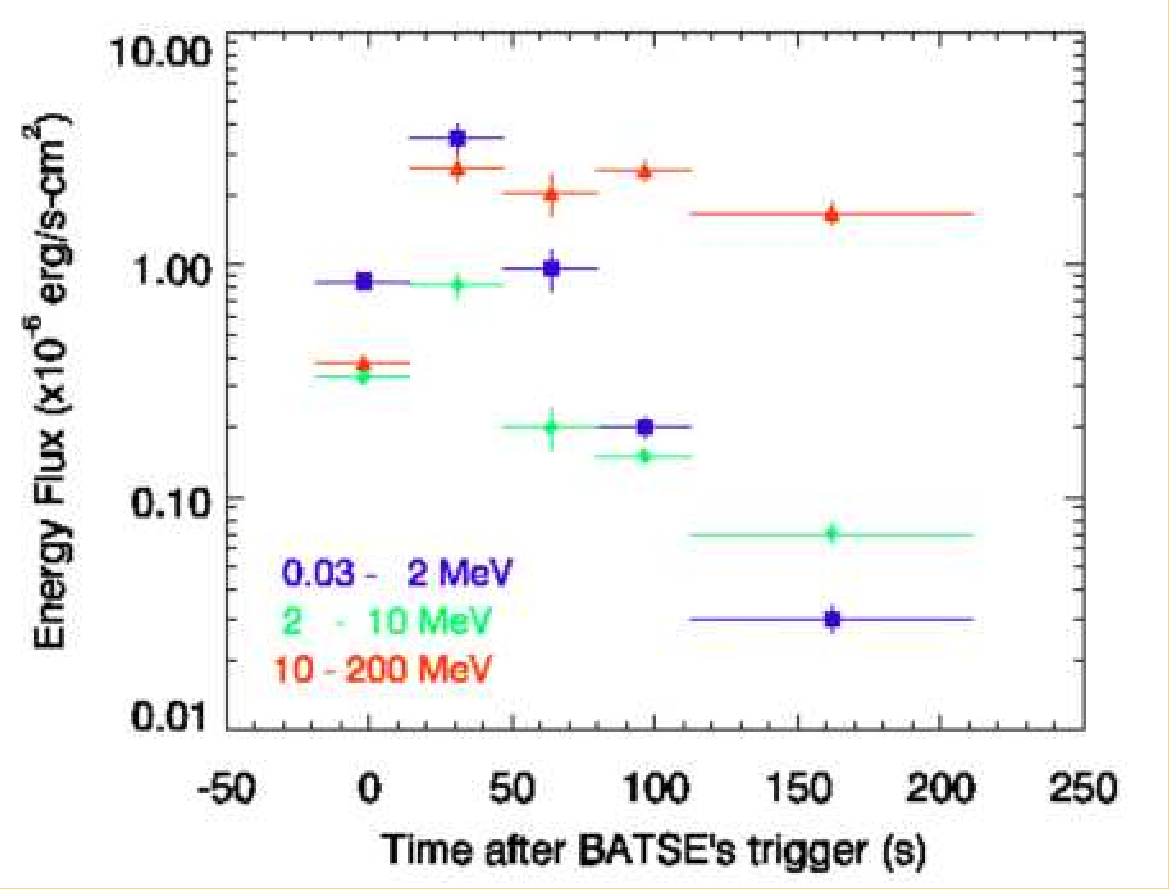
Low Energy Component fitted with a Band Function



- **Hard to soft evolution of synchrotron component as observed in other BATSE bursts.**

- **Synchrotron comp. dims with time.**

- **Differential Photon Spectral index for second component is constant and =-1.**



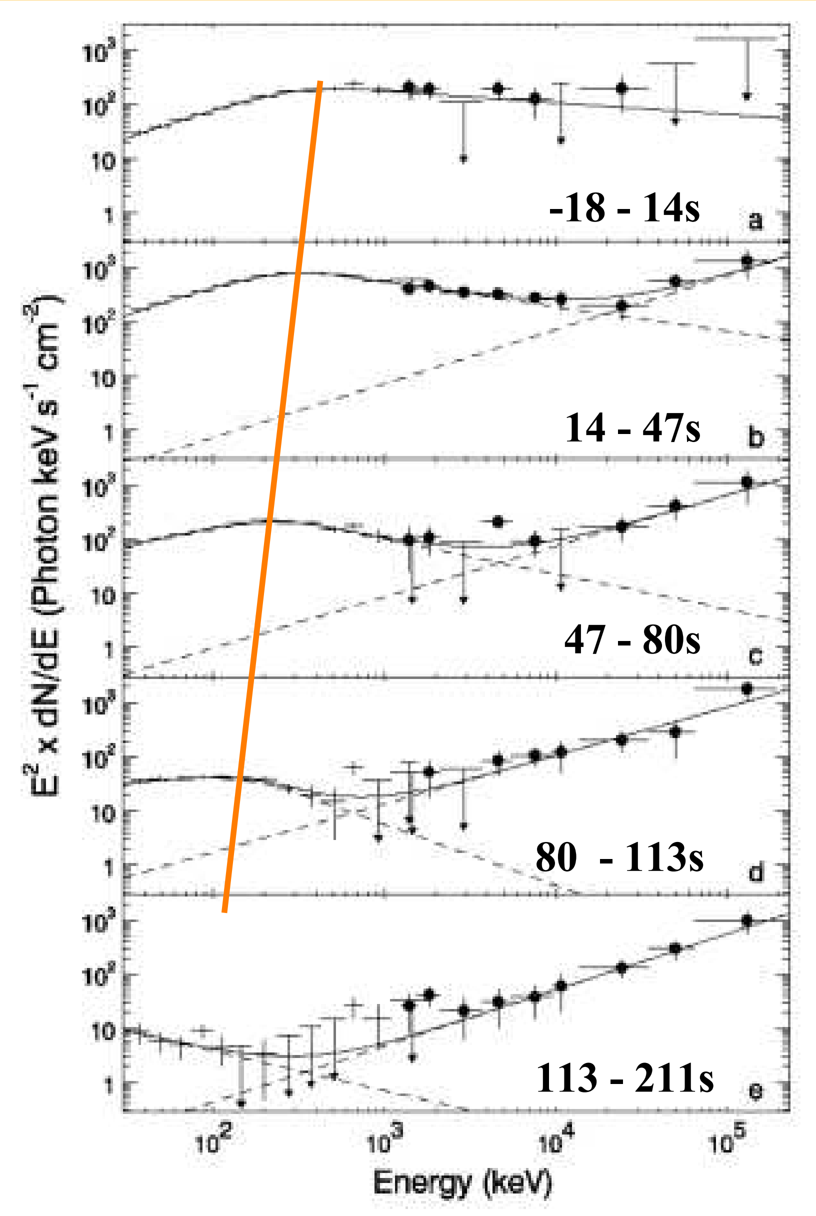
- **Decay of Energy fluxes are described by a power law with indices for the different energy ranges are: -2.8(0.03-2 MeV), -1.45(2-10 MeV) and -0.2(10-200 MeV).**

- **$Fluence_{total} > 3*Fluence_{BATSE}$**

CONCLUSIONS

GRB941017 shows a new spectral component !!!

- Duration ~150 seconds
- Photon spectral index ~ -1.
- Peak flux at > 200 MeV
- Fluence > 3*Fluence$_{BATSE}$
- Temporal evolution different from the lower energy (synchrotron?) component
- Difficult for standard inverse Compton models—maybe reverse shock or hadrons (i.e ultra-high energy cosmic rays)



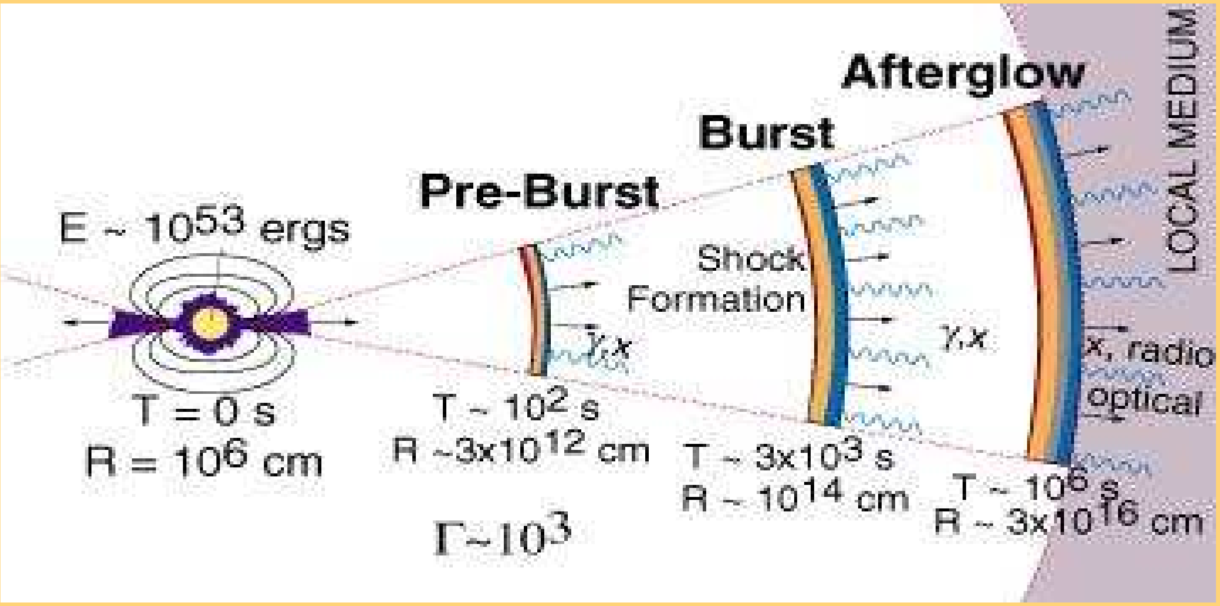
Reverse Shocks

Granot & Guetta 8 Sept 2003 astroph submission

Higher Energy Component due to Synchrotron Self Compton of Reverse Shock

Lower Energy Component due to Synchrotron Self Compton of Forward Shock in contrast with most GRBs that are believed to be due to synchrotron not SSC

"… find that it is hard to explain. Most models fail badly.,,



GLAST Expectations

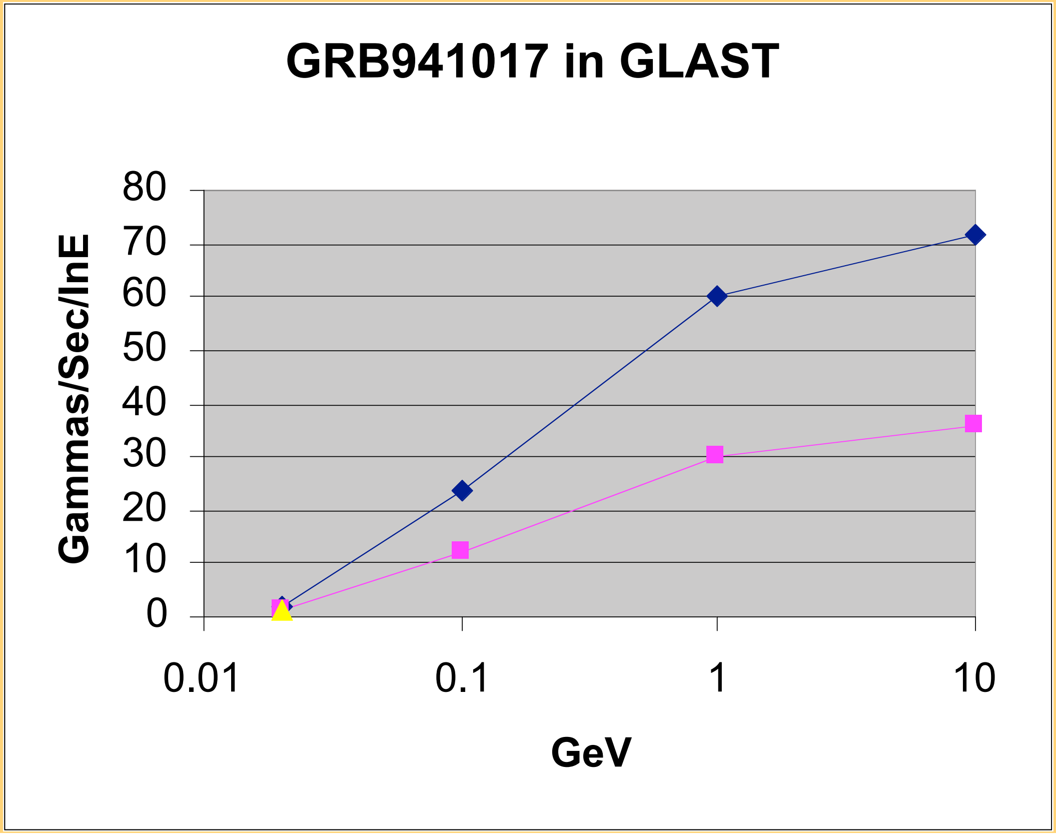
GRB941017's high energy component is described by

$dN/dE = 2x10^{-7} (E/3x10^{4}keV)^{-1}$ □/(cm^2 sec keV)

E dN/dE= dN/d(lnE) so

$dn_{obs}/d(lnE)=6$ x (Area/1000cm^2) □/sec

Using VERY preliminary Effective Area



On Axis

60^o Off Axis

Xpdf: /disk03/people/magda/MAGDA/TALKS/grb2003_SantaFe/nature01869_r.pdf

Table 1 **Spectral fitting parameters of the differential photon flux**

Time from BATSE trigger (s)	−18 to 14	14 to 47	47 to 80	80 to 113	113 to 211
Band GRB function parameters					
A (photons $cm^{-2} s^{-1} keV^{-1}$)	0.01 ± 0.0005	0.06 ± 0.001	0.02 ± 0.001	0.007 ± 0.003	$0.05^{+0.04}_{-0.02}$
E_{peak} (keV)	505 ± 69	350 ± 8	240 ± 14	91 ± 15	10 fixed
α (low-energy spectral index)	-0.84 ± 0.09	-0.79 ± 0.02	-1.08 ± 0.06	-1.45 ± 0.27	−1.00 fixed
β (high-energy spectral index)	-2.22 ± 0.13	-2.46 ± 0.05	$-2.65^{+0.22}_{-0.85}$	$-3.13^{+0.63}_{-\infty}$	-2.73 ± 0.55
High-energy power law parameters					
A_{PL} ($\times 10^{-7}$ photons $cm^{-2} s^{-1} keV^{-1}$)	NA	2.4 ± 0.6	2.4 ± 1.0	3.2 ± 0.7	1.8 ± 0.5
γ (highest-energy spectral index)	NA	−1.00 fixed	$-1.06^{+0.70}_{-0.44}$	$-1.10^{+0.32}_{-0.17}$	$0.96^{+0.36}_{-0.17}$
Probability	NA	1.40×10^{-4}	3.71×10^{-4}	6.49×10^{-8}	1.44×10^{-7}
Energy flux for different energy ranges ($\times 10^{-6}$ erg $s^{-1} cm^{-2}$)					
0.03–2 MeV	0.85 ± 0.02	3.52 ± 0.46	0.96 ± 0.19	0.20 ± 0.02	0.03 ± 0.004
2–10 MeV	0.33 ± 0.008	0.82 ± 0.11	0.20 ± 0.04	0.15 ± 0.01	0.07 ± 0.007
10–200 MeV	0.38 ± 0.009	2.63 ± 0.35	2.03 ± 0.40	2.54 ± 0.25	1.67 ± 0.18

The first six rows contain the best spectral fit parameters for the five time intervals shown in Fig. 2. The seventh row shows the probability that the improvement in χ^2 from the addition of the high-energy power law in the fit is due to chance, as determined by the χ^2 test. The last three rows contain the energy fluxes for three different energy ranges. For the first interval, the high-energy power law was not required to fit the spectrum. For the second and last intervals, poorly determined parameters were fixed at values that are either consistent with those determined for later time intervals (γ in 14–47 s) or assumed to be reasonable (E_{peak} and α in 113–211 s). The temporal fit of the energy fluxes (F) in the last four time intervals when described by $F = At^{-\phi}$, yields $\phi = 2.8$, 1.45 and 0.2 for the energy ranges of 0.03–2, 2–10 and 10–200 MeV, respectively. Thus the temporal energy flux decay of the higher-energy component is much slower than the typical energy flux decay of afterglows. NA, not applicable.

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