The Solar Flare on 15 June 1991

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this report can be accessed at http://wwwgro.unh.edu:8080/users/grank/GROUP/groupdocu.html

We report on the results of a joint analysis of COMPTEL telescope data and GAMMA-1 data.
Work is done in collaboration with:
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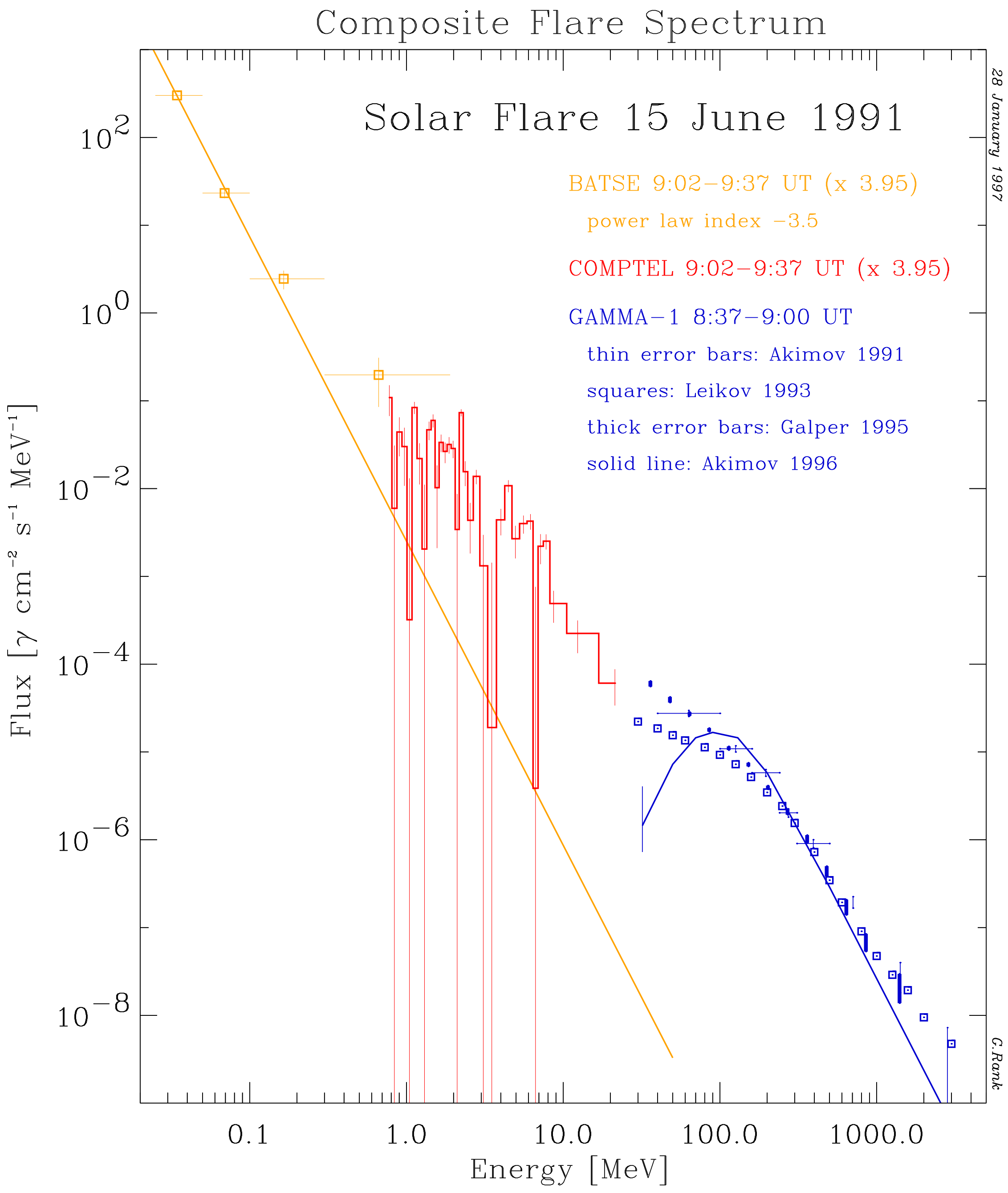
Combined Gamma-Ray Spectrum

Combination of spectra obtained by BATSE, COMPTEL and GAMMA-1 allowes to construct a HXR/γ-ray spectrum that extends from 25 keV to 5 GeV:
BATSE: 25–1900 keV; COMPTEL: 0.75–30 MeV; GAMMA-1: 30 MeV–5 GeV

Data from the BATSE-LADs are available from GSFC. We use a background that is constant during the observation period and check this by sampling data from 15 and 16 orbits before the flare. A weighted effective area is used to deconvolve the data.
The method works well, except for the highest energy channel (300–1900 keV), which depends too critical upon the background model. As we are interested in a bremsstrahlung fit, we include only the three lowest channels in the analysis.

GAMMA-1 spectra have been published by various authors. As CGRO and GAMMA measure at different time intervals, the 9.1 GHz microwave data from Zimeki station are used to align both datasets.

Result:
The bremsstrahlung continuum from BATSE fits the COMPTEL spectrum quite well, although it appears somewhat low. The COMPTEL data show clear emission in the 8-30 MeV band. This flux fits more smoothly to the higher GAMMA-1 values given in the range from about 50-100 MeV. The sharp turnover in the spectrum given by Akimov *et al.* (1996) is not supported by the high energy COMPTEL data points.


Composite Flare Spectrum
Solar Flare 15 June 1991
BATSE 9:02−9:37 UT (x 3.95)
power law index −3.5
COMPTEL 9:02−9:37 UT (x 3.95)
GAMMA−1 8:37−9:00 UT
thin error bars: Akimov 1991
squares: Leikov 1993
thick error bars: Galper 1995
solid line: Akimov 1996
Flux [γ cm⁻² s⁻¹ MeV⁻¹]
Energy [MeV]
0.1
1.0
10.0
100.0
1000.0
10^2
10^0
10^−2
10^−4
10^−6
10^−8
28 January 1997
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Investigating the Accelerated Proton Spectrum

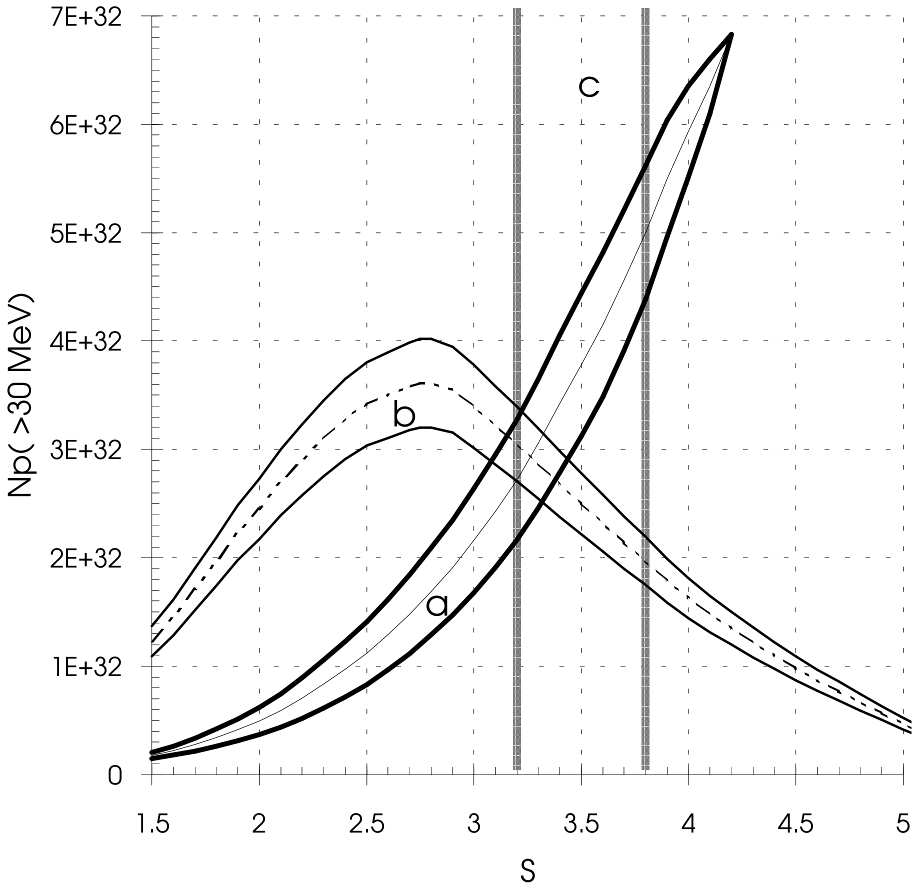
We investigate the accelerated proton spectrum which is assumed to be of the form $N_P \propto E^{-S}$. The following methods are probing proton energies in the range of 10–200 MeV.

• 10–100 MeV Neutrons
The measured neutron spectrum depends on both N and S. However, as the neutron spectrum at these energies flattens out, it is not very sensitive on S. The obtained values span a wide range with $S < 4.2$.
Sensitiv to proton energies of 20–200 MeV

• Fluence of the 4–7 MeV band
The emission in the 4–7 MeV energy band is dominated by prompt nuclear lines. By comparing with theoeatical models of nuclear emission (Ramaty et al.,1993) we determine the combinations of N and S that can explain the observed fluence.
Sensitiv to proton energies of 10–20 MeV

• Fluence ratio between 2.2 MeV line and 4–7 MeV band
This ratio sets rather narrow limits on the spectal index. It does provide no information on the absolute number of protons. For the extended phase of June 15 flare, we find a ratio of 0.8 ± 0.15. For isotropically interacting protons, this refers to $S = 3.3 \pm 0.2$. Sensitiv to proton energies of 10–100 MeV

Results for the spectral hardness obtained by 3 different methods:



(a) 10-100 MeV neutron measurements
(b) fluence in the 4–7 MeV band
(c) 2.2 MeV line / 4–7 MeV band fluence ratio

We obtain a best-fit proton spectrum with an index of $S = 3.3 \pm 0.1$ and a number of interacting protons of $N_P(> 30\text{MeV}) = (2.9 \pm 0.4)10^{32}$.

The power law spectrum obtained for the 10–200 MeV protons is not compatible with the GAMMA-1 observations of > 100MeV γ-rays. When this unbroken power law is assumed, the expected γ-ray fluence from pion decay is larger than the measured value.
To explain both measurements, we assume a broken power law of the form

$$N_P \propto E^{-S} \quad \text{for} \quad E < 300\text{MeV}$$

$$N_P \propto E^{-(S+D)} \quad \text{for} \quad E > 300\text{MeV}$$

From spectral studies of GAMMA-1 data alone, a hard spectrum ($S = 3$) seems to be required for γ-energies above 1 GeV (Galper et al., 1995).

One possible explanation is a two-component spectrum: One is the broken power law, producing γ-rays with energies below 1 GeV and neutrons; The other an unbroken $S = 3$ power law, that takes over at above 1 GeV.