Composite Solar Flare Spectra:
Combining BATSE, COMPTEL and GAMMA-1 Data

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The Solar Flare on 15 June 1991 was observed by the orbiting high-energy missions CGRO and GAMMA.

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
(it is for the first time, that a measured spectrum of this whole energy range is shown!)

What can be studied additionally when we combine the datasets?

- We can test, if the extrapolated flux values obtained from different instruments are matching. This validates the process of our data analysis and the spectral deconvolution.

- The low energy datapoints determine the shape of the bremsstrahlung continuum. Besides studying variations of the spectral index, it also allows to specify the contribution from the electronic emission in the nuclear line region.

- Different interpretations of the GAMMA-1 measurements have been presented. A combination of COMPTEL and GAMMA-1 data can help to clarify the shape of the spectrum at the lower end of the GAMMA-1 region.

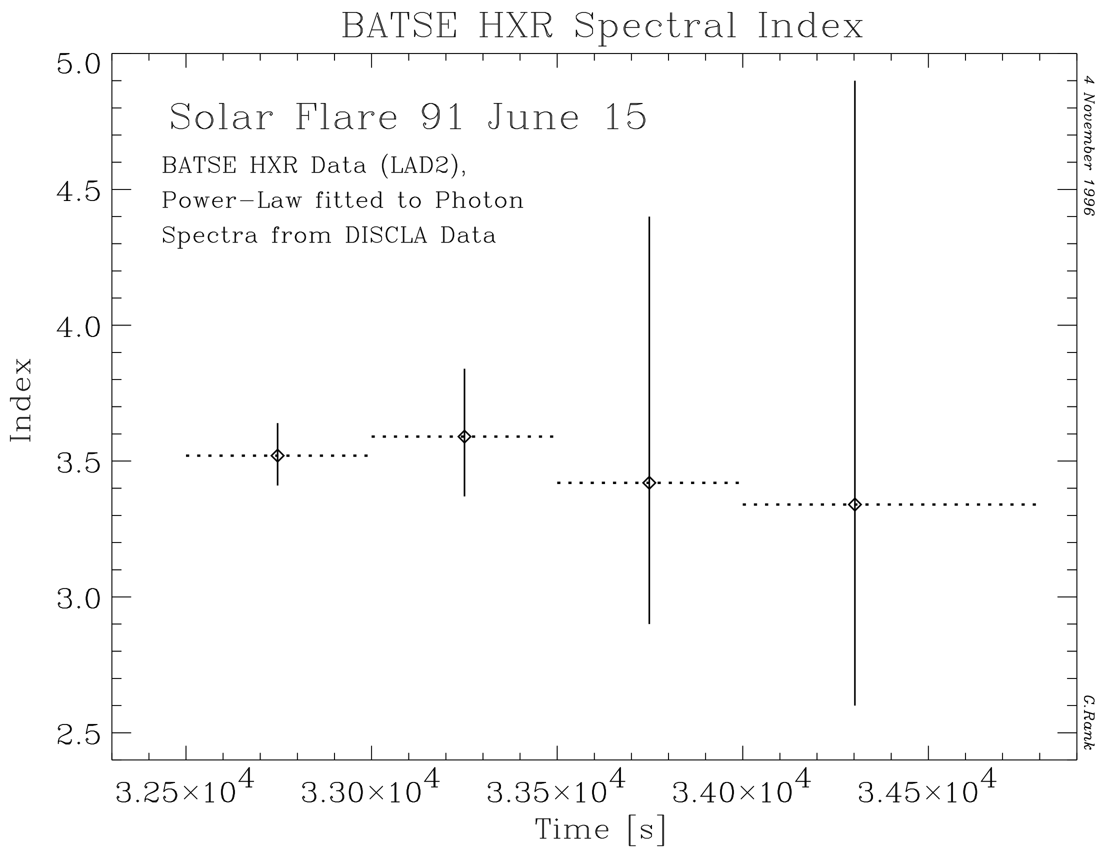
- The true extend of the γ-radiation emitted from secondary electrons (=electrons from the decay of charged pions) to energies below 100 MeV is not well known. It could contribute significantly to the nuclear lines at 4-7 MeV.

- Comparison of the emission in the nuclear lines and the pion-induced emission allowes to determine the spectral hardness of the accelerated proton spectrum.

Data from the **BATSE-LADs** are available from GSFC, corrected for counter overflow, livetime and cosine of the Sun's position. The data are not background corrected.

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 needs a more sophisticated background model. (excluded from this analysis)



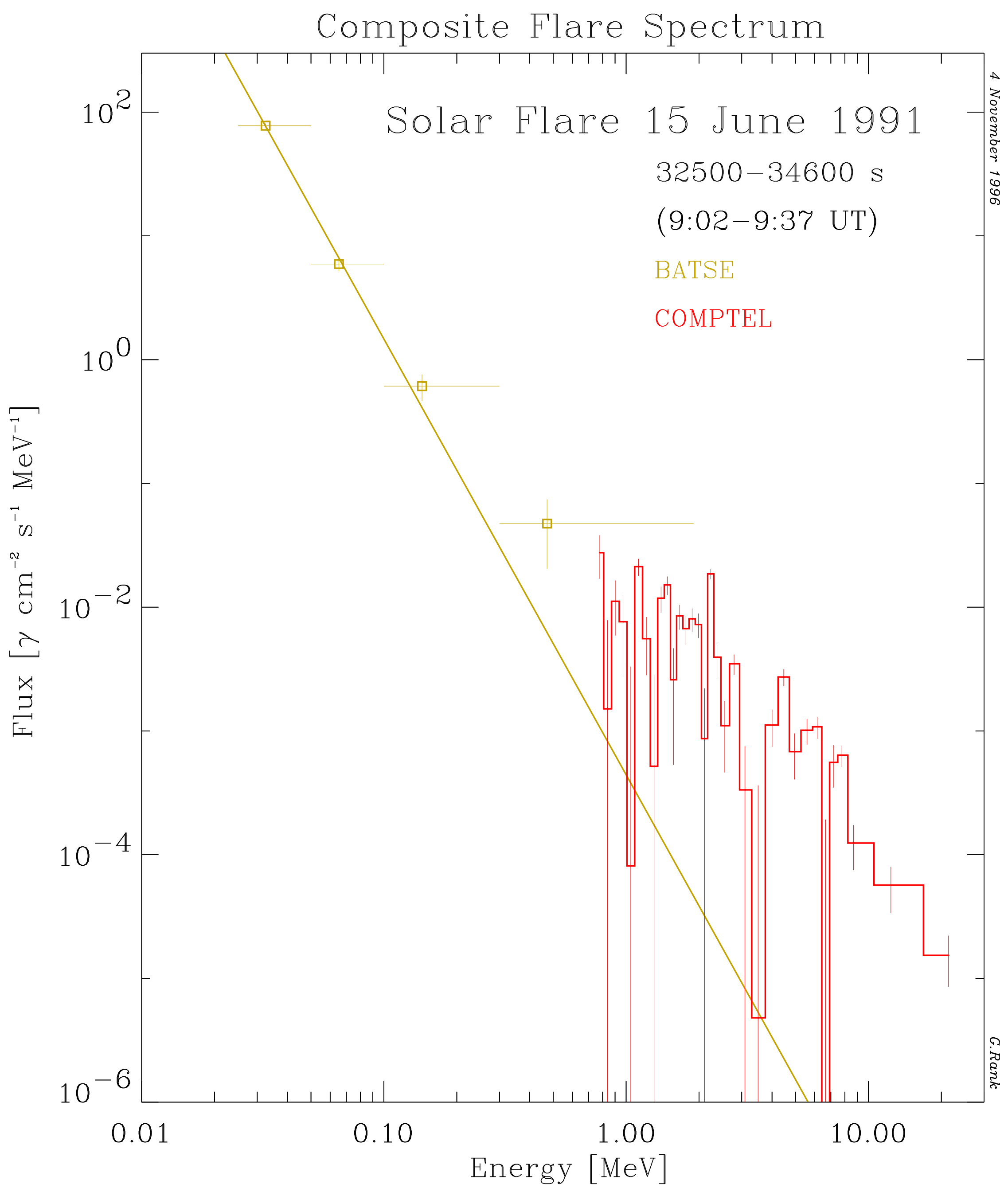
The plot shows the power law index fitted to the datapoints of the most sunward facing LAD detector. The spectral index of the bremsstrahlung does not show temporal variations during the observation period.

The data from **GAMMA-1** have been published by various authors. The deconvolved spectra do not agree with each other in all cases:

(A) Akimov *et al.* (1994, 1996):
The authors use analytical models and fit the foreward-folded spectra to the measured data points. Results: The assumption of a single power law is not supported by the data. A good representation of the measured data is obtained with a double power law. It is important that the function at low energies is increaing, causing a distinct roll-over of the spectrum.

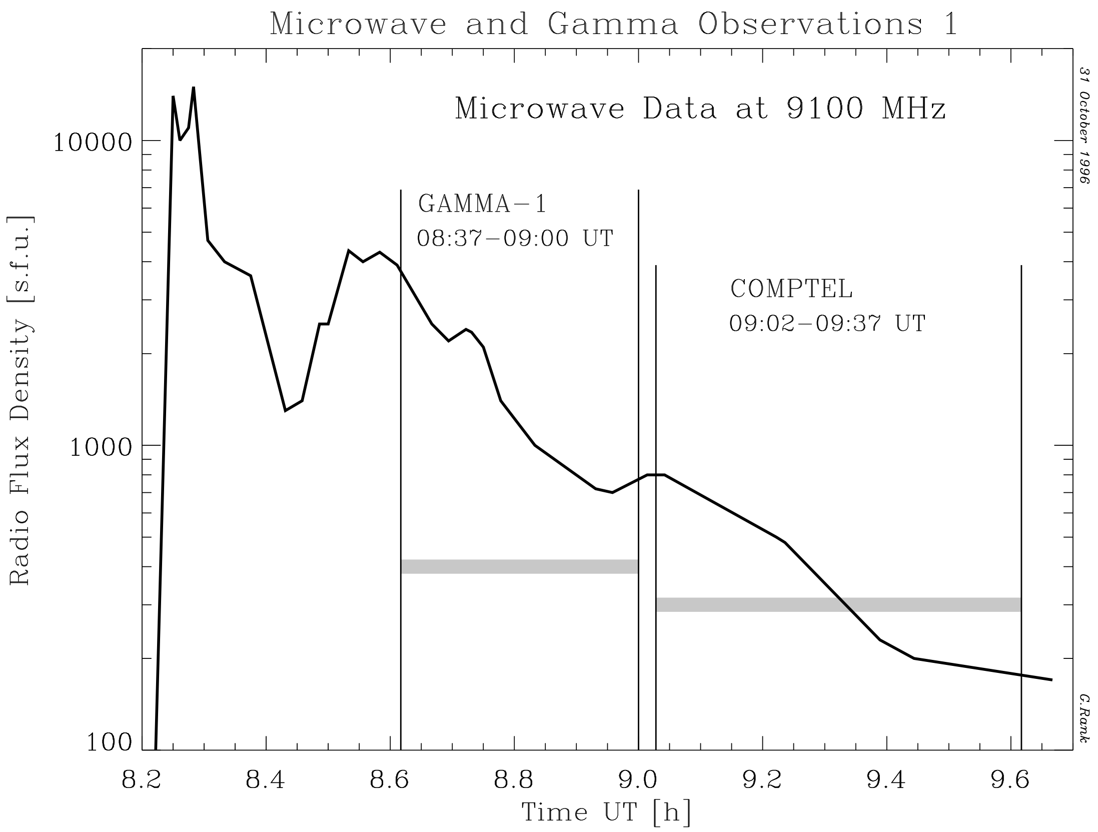
(B) Kocharov *et al.* (1994) / Akimov *et al.* (1991):
Kocharov et al. support a deconvolution that has been done earlier by Akimov et al. It agrees with the best fit model given above, but differs for energies below $\sim$100 MeV.

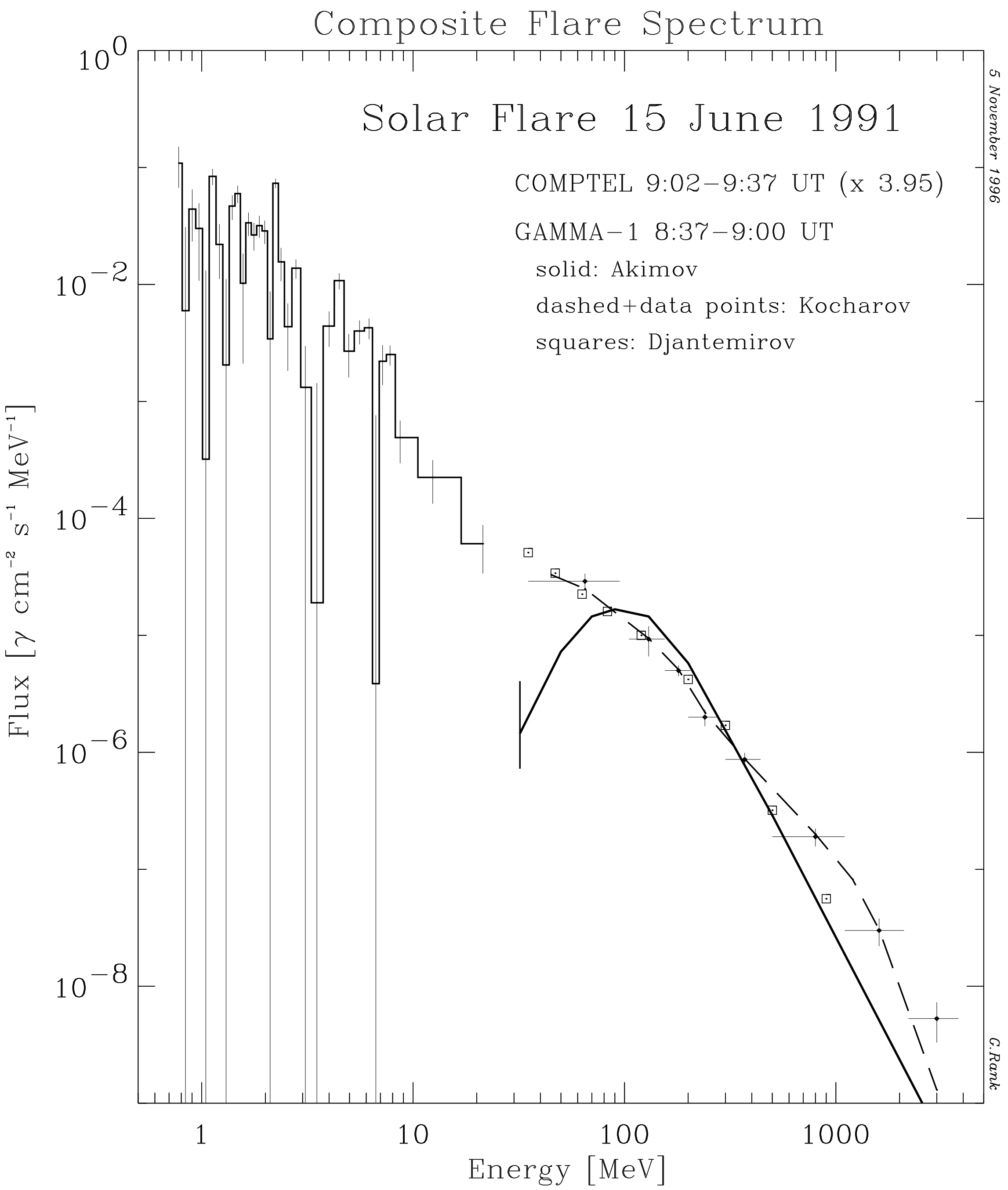
(C) Djantemirov *et al.* (1995)
This approach is based on an untraditional iterative method to derive the photon spectrum. It is important to note, that this algorithm a priori assumes a representation by a monotonously decreasing function. It is in good agreement with Kocharov's spectrum, but again differs from Akimov's spectrum for energies below $\sim$100 MeV.



Composite spectrum using BATSE and COMPTEL data. The bremsstrahlung continuum fits the COMPTEL spectrum quite well, although it is somewhat low. The high energy data point of BATSE is too high, but we know that the background subtraction does not work very well here.

The measurements of COMPTEL and GAMMA-1 have been obtained during different time periods. Therefore, the spectra of both instruments cannot be compared directly. To enable a comparison we use the microwave data, that resemble the time profiles of the gamma-radiation very well, and integrate the microwave flux over the time intervals that refer to the GAMMA-1 and COMPTEL observation periods. We obtain a ratio of 3.95 for the intervals indicated in the figure.
The method assumes that the γ-ray flux in the energy range from 0.75 MeV to 4 GeV and the microwave flux at 2100 MHz show the same time profile, at least at time scales of about ten minutes. Further, the combination of both datasets is only meaningful under the assumption that the spectra shape does not change during the time periods of interest.





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.