TRACKING DOWN THE SPECTRAL DATA FROM THE SGR1806-20 GEANT FLARE WITH THE IREM INSTRUMENT ON INTEGRAL

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ABSTRACT

The main spike of the giant flare from the Soft Gamma Repeater (SGR) SGR1806-20 on 27 Dec 2004 [1] released enormous energy that saturated all X-ray detectors onboard satellites. Only small instruments dedicated mainly for charged particle detection could gather reliable data. We briefly present the analysis of the main spike performed with the data provided by the ESA Standard Environment Radiation Monitor (SREM) onboard of the INTEGRAL satellite [2]. The monitor contains three Si Surface Barrier Detectors coupled to fifteen fast discriminators and counters. Effective sensitivity range of the instrument for rough spectroscopy extends from 85 keV up to about 1 MeV. Experimental data as well as Monte Carlo simulations of the monitor response are presented. The necessity of including the satellite mass model is underlined. The data are described using different spectral models and found fit parameters are discussed.

1. INTEGRAL AND IREM

The ESA International Gamma-Ray Astrophysics Laboratory INTEGARL was launched on 17 Oct 2002 into a highly elliptical orbit. Its primary goal is to study the universe with instruments sensitive from visible wavelengths - like the optical camera (OMC) up to hard X-rays and gamma-rays - like the gamma ray spectrometer (SPI) and imager (IBIS). The satellite is also equipped with a small support instrument responsible for permanent measurements of protons and electrons along the orbit. It is the INTEGRAL Radiation Environment Monitor (IREM) [3] adapted from the ESA SREM batch – see Fig. 1. In addition to the IREMs monitoring role the instrument also sends radiation level flags to the on-board data handler as well as to the main payload instruments. It alerts them against increased levels of the particle fluxes e.g. when the satellite enters the Earth Radiation Belts or during the Solar Energetic Particle events. IREM collects the data during 60 sec long intervals while the alarm flags are issued every 8 sec. Another ESA satellite with an identical SREM instrument onboard is the Project for On-Board Autonomy PROBA1 launched in October 2001 into the Low Earth Orbit. PROBA1 SREM data is collected using 30 sec long intervals. Mission payload includes in addition a star tracker, high resolution optical cameras as well as debris detector and yet another radiation monitor.

SREMs contain three commercial Si Surface Barrier Detectors with a thickness of 300 μm and active areas of about 65 mm^2 (D1, D3) and 100 cm^2 (D2). Two detectors are enclosed into the same housing making a telescope. The detector housings are made of an outer layer of 5 mm thick Aluminium and an inner layer of 4 mm thick Tantalum. The field of view for both sensor sets is equal to ±22.5°. Entrance windows are made of Aluminium with the thickness of 0.5 mm for the single detector and 2.0 mm for the telescope.

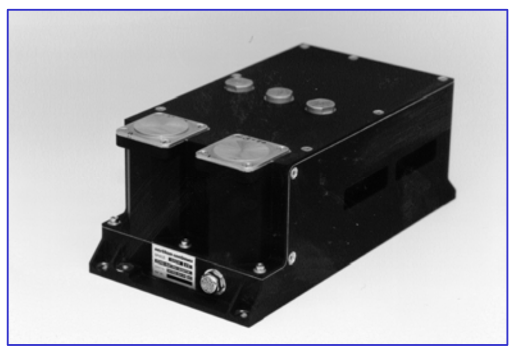

Fig. 1. INTEGRAL Standard Radiation Environment Monitor IREM. The front side exhibits two detector heads with three Si sensors inside.

IREM electronic chain consists of fast discriminators (FD) instead of slower analogue to digital converters to assure the high speed readout. Discriminators are coupled with 15 counters allowing for rather rudimentary spectroscopy of protons and electrons along the orbit. Four counters are incremented by the coincidence events from the telescope what is useful for proton-electron discrimination and high energy

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observations. The FD energy thresholds are equal to 85, 250, 600, 750, 2000 and 3000 keV.

SREM was constructed by the Contraves Space AG in collaboration with ESA and PSI. The instrument was fully calibrated using the PSI Proton Irradiation Facility (PIF) and well as the electron (^{90}Sr) and gamma (^{60}Co) radiation sources [4]. The SREM mass model was constructed using GEANT3 code from CERN and its computer response was verified and fine tuned with the help of the calibration data.

2. INITIAL SPIKE RAW DATA

During the giant flare emitted by the SGR1806-20 on 27th Dec 2004, 21:30 UT, the INTEGRAL was far away from the radiation belts. It made possible a good detection of the event in the stable conditions of the low level background from the cosmic rays – see Fig. 2. As it is seen the detection was still visible at energies above 600 keV while there were no counts in the 2000 keV channel. After the main peak there were no significant counts seen above the background. It reveals too small sensitivity of the detector for detection of the oscillating part of the giant flare

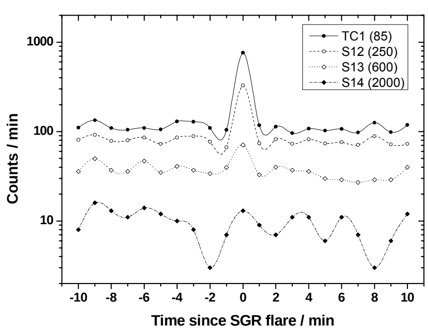

Fig. 2. Count rate vs. time for four IREM counters of the detector 1. The peak from the prompt emission of the SGR is clearly seen at time=0. Numbers in brackets contain energy thresholds of the counters in keV.

The event was detected by all three Si-detectors as it is seen in the TC1, TC2 and TC3 IREM counters – see Fig. 3. No events have been seen in the coincidence channels between detector 1 and 2 (C1 – C4). The total number of counts with energies above 85 keV is equal to 2711. The duration of the main peak was about 1 sec as measured with other detectors e.g. onboard of the RHESSI satellite [5]. The period of the highest flux was equal to about 250 msec but it still made the dead time corrections of the IREM fully negligible. The ratio of detector rates up to 20% resembles the ratio of their active areas (D1 – 67 mm^2, D2 – 105 mm^2 and D3 67 mm^2) indicating almost no shadowing between them. The incoming flux direction in the IREM coordinate system was (Θ, φ) ≈ (165°, 4°). For such orientation the satellite itself shielded the SGR and the photons passed through the whole service module to the data handling panel with IREM. Lower rates in the counters higher than TCi ones (e.g. 250 vs. 85 keV) imply fast decrease of the flare flux with energy.

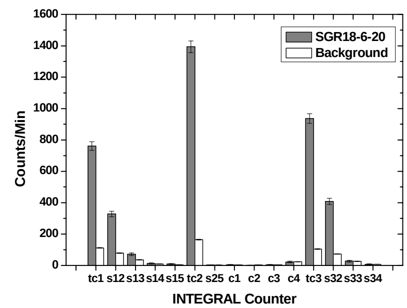

Fig. 3. Count rate in IREM counters for detection of the SGR1806-20 and for the background measurement.

The flare was also detected by the SREM monitor onboard of the PROBA1 mission just shortly before entering the radiation belt. Counts from both SREM instruments are shown after background subtraction and normalization to the sensor sensitive area in Fig. 4. All identical energy channels from three Si-detectors are averaged. As it is seen, the data points at 2000 keV and 3000 keV are consistent with the background level. Higher counting rate in the PROBA1 SREM indicates different direction of this monitor with respect to the SGR and its more preferable orientation for detection of the incoming photons.

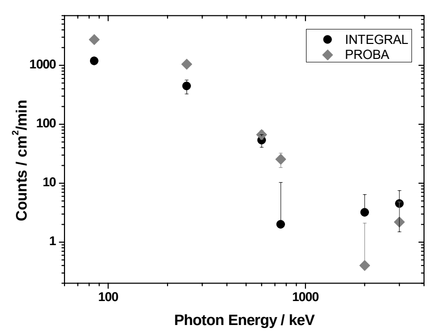

Fig. 4. Normalized counts from the SGR flare on 27 Dec 2004 measured by IREM and SREM instruments.

3. SPECTRAL ANALYSIS

Response calculations for IREM on INTEGRAL were carried out with the GEANT3 code from CERN. In addition to the full mass model of the monitor, the whole satellite was also incorporated into the Monte Carlo simulations. As it is seen in Fig. 5 the IREM is mounted in the lower left corner of the Data Handling and Telecommunication panel of the INTEGRAL. The detector heads point to the outer space and are not covered by a thermal mantel.

Fig. 5. INTEGRAL with IREM onboard. The end of the arrow shows location of the radiation monitor

The response was generated for spacecraft orientation as it was during the transient event and with photons coming from the SGR direction. As the INTEGRAL was far away from the outer Earth radiation belts the possible Earth scattering of the SGR photons was not taken into account during response calculations.

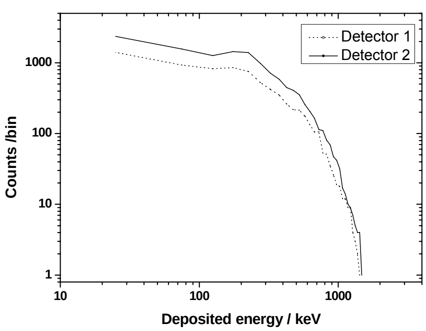

Fig. 6. Energy depositions in the response matrix for the uniform photon spectrum from 70 to 2500 keV.

Simulations were performed using a flat incoming spectrum in the energy range from 70 to 2500 keV. Photons illuminated the detector using a uniform beam spot with a diameter twice as large as the IREM envelope. The response matrix is showed in Fig. 6 for two detectors (D1 and D2) that form the telescope. As the incoming photons are almost parallel to the detector z-axis, they must pass through the full rear shielding of the instrument (Al-Ta bi-layer). Such thick internal shielding together with the satellite mass bulk strongly reduces the effective sensitivity of the detectors. It is especially well seen at lower energies for which the detection efficiency is very small – see Fig 7.

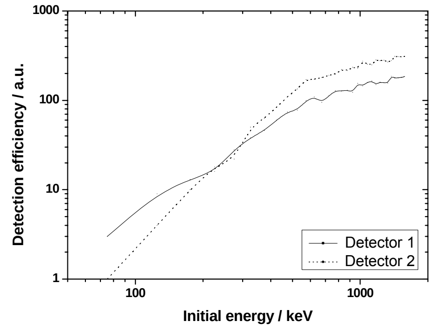

Fig. 7. IREM response matrix displayed as a function of the initial photon energy.

In addition, the maximum thickness of the Si-waver of about no more than 10 mm, makes the detector useful for rough spectroscopy only at lower γ–ray energies. The response sensitivity as a function of deposited energies (Fig. 6) decreases quickly at energies reaching region around 1000 keV.

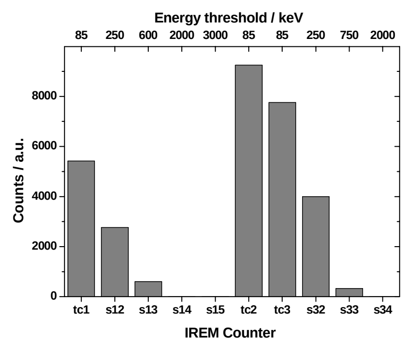

Fig. 8. Response matrix as a function of the counter energy threshold for the uniform input spectrum.

It means that for higher energies IREM acts only as a radiation counter. It is well illustrated by its high energy counters in Fig. 8 in which the response matrix is shown as a function of the counter energy threshold.
Although IREM contains fifteen distinct counters, already four of them are used for coincidences. For the rest their FD threshold values partially overlap. It leaves only four independent energies that can be used to extract potential spectroscopic information from the SGR observations: 85, 250, 600 and 750 keV. Such limited number of points does not allow any strict determination of the SGR spectrum. Nonetheless one can examine how the experimental data is described by different spectral models and try to put limits on their characteristic parameters like a total energy flux or

temperature. For this purpose the modelled spectra were convoluted with the instrument response matrix and transformed into the number of counts in the IREM counters. The fit procedure was applied in which the distinctive model parameters were modified in order to minimize the difference between computed values of the counters and the data. Spectral fits were performed for the following functions: power laws, cooling blackbody and thermal bremsstrahlung. The choice was motivated by previous analysis performed with other instruments onboard of Wind and RHESSI [5], geosynchronous [6], Geotail [7] and Coronas-F [8] satellites. The authors describe their observations using different spectral functions. Finding the most preferable one requires more data from new instruments. The energy range in the fit was limited by the intrinsic sensitivity of IREM to about 1500 keV. This condition requires that any contribution to the counters from the SGR spectrum should become negligible for energies higher than the sensitivity limit.

4. RESULTS

The preliminary results of the fit for three spectral models are shown in Fig. 9 [9]. For the power law and the exponential power law the spectra had very hard photon indexes between 1 and 2. In order to explain the data the photon fluence was of the order of hundreds of ergs/cm^2. A strong dependence was also found on the energy range applied for the fit.

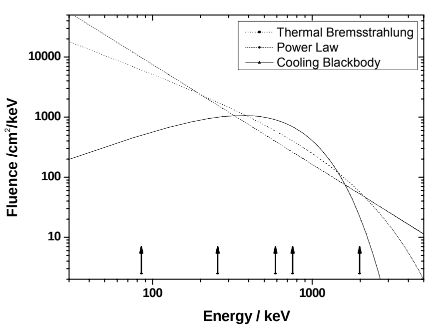

Fig. 9. SGR initial peak spectra for three different models. Arrows show IREM energy threshold.

Thermal bremsstrahlung resulted in temperatures of about 1000 keV and fluences of the order of 1 erg/cm^2 (g-factor was neglected). The cooling blackbody fit gave the most meaningful physical parameters that also agreed with other measurements [5]: the temperature of 230±50 keV and the energy fluence of 1.0±0.5 erg/cm^2 – see Fig 10. Despite of less plausible parameters of other models, their agreement with the IREM counter data is just as good as for the blackbody one. Moreover, large discrepancies seen in the whole energy range from tens of keV to few MeV do not appear so big in the region covered by IREM (~ 100 – 1000 keV) – see Fig 9. All the results are also very susceptible to the uncertainties on both ends of the sensitivity region.

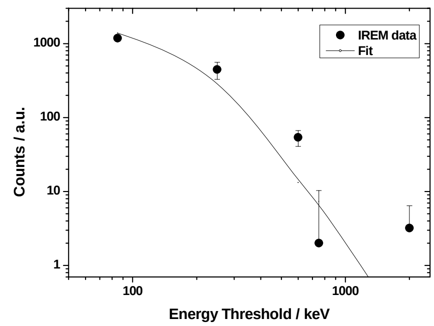

Fig. 10. IREM experimental data and best fit of the cooling blackbody spectrum.

The low energy response depends not only on the mass model accuracy of both IREM and INTEGRAL but also on the stability of the discriminator threshold – see Fig. 7. This can easily influence e.g. the total fluence in the power law fits. A high sensitivity was, as expected found to the last channels (600 and 750 keV). As these data points have rather low statistical accuracy – see Fig. 8, the final conclusion about the most preferential cooling blackbody model and parameters of other models still requires further studies.

SUMMARY

IREM particle monitor onboard of INTEGRAL detected the initial spike from the SGR1806-20 giant flare. Present analysis favors the cooling blackbody spectral shape (T=230±50 keV, F=1.0±0.5 erg/cm^2) consistent e.g. with the WIND mission results. Nonetheless other models cannot be categorically excluded due to the uncertainties on both ends of the IREM sensitive range. Further analysis and data e.g. from the SREM on PROBA1 mission are still required.

5. REFERENCES

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