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Standard Radiation Environment Monitor - data repository and web based data analysis tools

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Abstract: To date the Standard Radiation Environment Monitor SREM is the main instrument providing largest amount of the space radiation data for the European Space Agency. SREM was designed in collaboration between ESA, RUAG AG and PSI. Ten units were manufactured by RUAG and carefully calibrated and modeled by PSI. In this paper we describe the commonly accessible database developed for different SREM's at PSI. It contains crucial mission parameters as well as the count rates and electron and proton fluxes along the orbit.

Keywords: SREM, radiation monitor, radiation belts, solar particles, cosmic rays

1 Introduction

To date the Standard Radiation Environment Monitor SREM is the main particle detecting instrument providing largest amount of the space radiation data for the European Space Agency [1] . SREM was designed in collaboration between ESA, RUAG AG and PSI. Ten units were manufactured by RUAG AG and carefully calibrated and modeled by PSI. A common database containing count rates and electron and proton fluxes for the different SREM's has been developed at PSI. The data and spectrum unfolding models are publicly accessible via a web link to the database.

2 Missions and raw data

The current fleet of the Standard Radiation Environment Monitor SREMs consists of 7 flying units. They are placed onboard of several ESA missions such as Proba-1, Rosetta, Integral, Herschel, Planck and Giove B and the UK mission STRV1c. Each SREM contains three commercial sensors enclosed in a refined shielding. Two detectors are arranged as a telescope and optimized for detection of protons. The third sensor with a weaker shielding is more sensitive to electrons. Typical energy range for proton detection extends from 10 MeV up to mor ethan 300 MeV. The electrons are observed starting from energies of 500 keV. Particle energy spectra are measured indirectly from the partial energy depositions in the detector. The method relies on 15 fast discriminators coupled to the analogue readout electronics on one side and to the event counters on the digital one. The number of useful energy bins is limited by the total number of discriminators. In addition, certain threshold values favor detection of either electrons or protons. Heavy ions are mostly detected by one dedicated channel without any possibility for refining of their spectra. Nonetheless the Cosmic Rays are routinely detected by SREM and both their fluxes and a rough spectral information up to few hundred MeV is also possible. Single block of SREM data is related to the event counting time that extends from 60 seconds e.g. for Integral up to several minutes as for Rosetta. An example of the typical SREM counting rate curves is presented in Figure1.

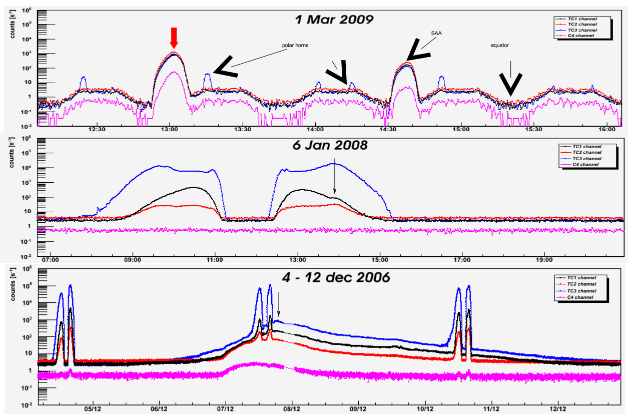

Figure 1: Typical radiation features along various SREM orbits: Radiation Belts, SAA, Solar Events and Forbush decreases.

The SREM common data base was initiated in 2002 coinciding with the launch of Integral and Proba1. The main server is located at PSI. The database contains proton, electron and cosmic ray measurements from such environments and events as radiation belts, solar energetic particles and Forbusch decreases. This primary database contains elementary information about collected events with crude spectral information from the simplest unfolding methods. In parallel, this simple data base is extended to a richer repository in which an extra relevant information related to this instrument was collected. The repository is populated with both the raw and preprocessed data. It also possesses the individual SREM response matrix including the spacecraft mass models as well as verification methods, individual calibration data sets and new laboratory measurements. The user will also find the tools for advanced data analysis including a number of elaborated methods for spectral unfolding.

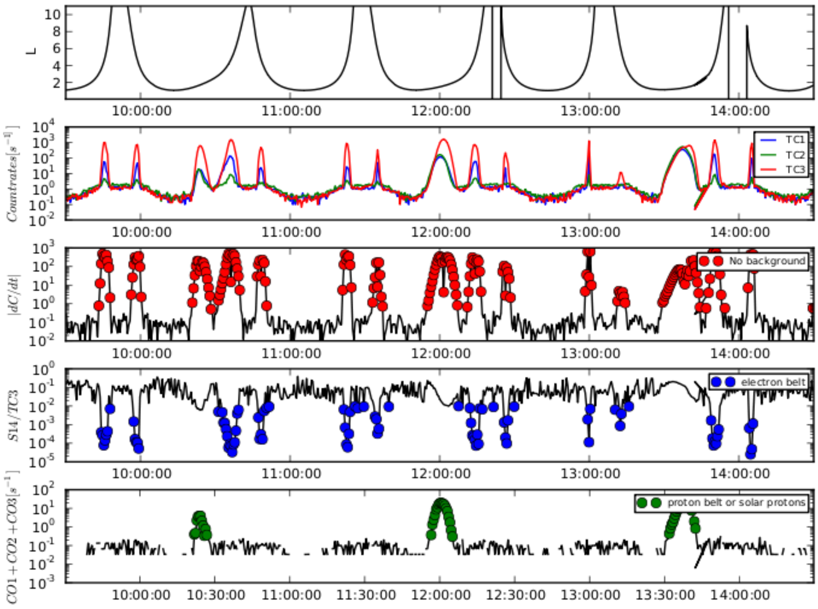

Figure 2: Data for pre-processing with detector rates monitoring and checking for environment conditions. Three lowest drawings show the criteria used for identification of the dominating particle environment.

3 Data repository and environment examination tools

Further refinement of the SREM data started recently and aimed for better and more elaborated processing of the measurement results. In one of the first steps several more accurate analytical methods and extended visualization tools were provided. They were used to verify existing models and observe environment, its variability and transient phenomena. The initial data pre-processing with applications of the particle identification criteria allows for distinguishing the type of environments e.g. electrons, protons or Cosmic Rays as showed in Figure2.

For best sensing of the environmental conditions a set of three selection criteria was introduced. They were carefully verified with various test fields: laboratory calibrations and tests, Monte Carlo simulations as well as typical space environmental data such as e.g. Electron Belts. Finaly, during the analysis, each data point is marked with a corresponding flag and such preprocessed data is displayed. One can see that the displayed plots contain the L-shell parameter variation, the rates in three main counters and the plots for verification of the three sensing conditions.

An example of the final environment unfolding result is showed in Figure3 for 4 hours measurement period from the SREM onboard of the Proba-1 satellite. Such indexed data curve is used by the spectral unfolding methods that are selected accordingly to the specific radiation environment.

In parallel, the simple data base is further enriched to the extended repository in which extra relevant information related to this instrument and its mission is collected. The repository is populated with both the raw and preprocessed monitor data. For each SREM unit it also possesses its individual monitor response matrix that for few missions includes the spacecraft mass model. In addition, the matrix verification methods, individual calibration data sets and new laboratory measurements are included. The user will

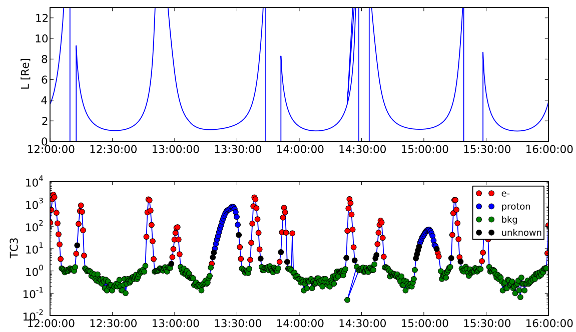

Figure 3: Processed data showed for TC3 counter with environment flags set to indicate regions with proton, electron or Cosmic Ray background. The L-shall values are plot for cross-correlation

also find the tools for advanced data analysis including a number of methods for spectral unfolding. In the simple data base one already finds the spectra approximation parameters: exponential for electron and power law for proton environments.

4 Data analysis with spectral unfolding methods

Two methods have been implemented for spectral unfolding: the neural network and chi2 minimization. They can be applied for either proton or electron environments. Usually, both methods are executed for extended time periods such as one orbit or single crossing of the radiation belt. The mixed space radiation environments can also be unfolded by either method though the fit quality is much less satisfactory.

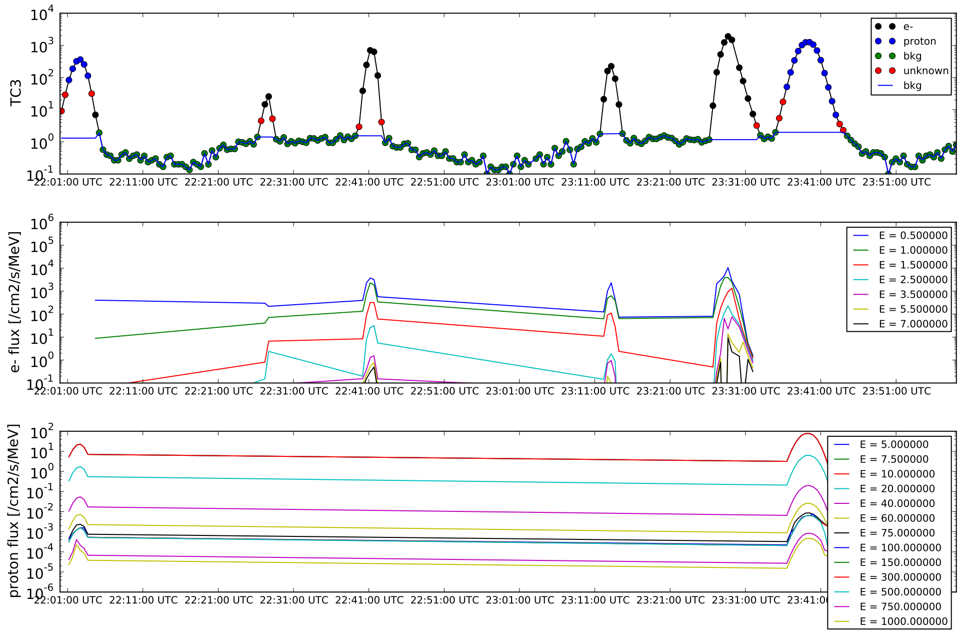

Figure 4: Example of the electron and proton fits in the radiation belts for Proba1.

It is due to such reasons as e.g. particle anisotropy . The spectra are approximated by step-like functions and the fluxes are computed for each energy bin.There are up to seven electron energy bins and up to thirteen proton energy bins. An example of such unfolding procedure is presented in Figure4. One can see the particle fluxes at each energy bin plotted as a function of time. Separate graphs are given for electron and for proton spectra. The plots indicate that in this particular data set there is no overlap between various particle environments and protons and electrons are clearly separated. In addition, especially for electrons one can observe various values of the spectral hardness. They depend on the local space weather conditions and on the crossing parameters through the electron belt.

5 Cross-comparison between SREMs and other monitors

The cross-comparison with different and even identical instruments in space is usually subjected to many uncertainties. First obstacle comes from obvious difficulties in having two monitors at the same space location at the same time. Usually even for the single instrument the observed environment changes from orbit to orbit despite of comparing it at the same B-L values. It reflects only natural dynamic changes of the environment. To some extend and with big precautions, the scale of them might be used to estimate uncertainty factors when comparing two instruments. In this paper however another comparison is presented using the Solar Energetic Particle event. Two SREM instruments are selected from the Integral (IREM) and ROSETTA ESA missions. As the third party particle detector the monitor onboard of the NASA GOES10 satellite is chosen. The proton rate curves are plotted for pre-selected energy bins as showed in Figure6. In general the agreement is very good and several specific features are well reproduced. Some discrepancies can be attributed to very large distances between Integral and Rosetta missions or different orientation (pointing) of the satellites or instruments as in case of Integral-IREM and GOES10. For higher energies the differences became as expected much smaller and the rate curves nearly overlap. It is also worth to mention that the best base for comparisons is provided in the laboratory during standard calibrations of the instrument with well known energetic beams of particles.

6 Comparison with radiation belt models

SREM capabilities are well illustrated by comparison of its unfolded data with the radiation belt models. Such analysis is very much simplified and user friendly when using PSI tools. They provide for example a direct link to the ESA SPENVIS suite. SPENVIS can compute modeled spectra for any pre-defined mission orbit. Two such plots are presented for Proba-1 data in Figure5; one for electrons and the other one for protons. Models used were the standard NASA electron AE8 and proton AP8 as well as the model based on the CRRES mission measurements. The comparison of the particle rates as measured in SREM counters with the folded rates from the belt models is given in form of the bar-plots for both proton and electron environments. As one can see on the bar-plots the fit quality is satisfactory but the discrepancies with models may be large. Such differences are frequently attributed to the static character of the models and large time lag between model construction and the time of the new measurement. It is further supported by discrepancies clearly observed between the AE8 and CRRES electron models. Further comparison of the SREM data, especially for these instruments that are still collecting data, is planned with the new AE9 and AP9 models of the trapped radiation. They have an advantage of taking into account both spacial and temporal environmental variations

The beta version of the AE9/AP9 was recently release and goes currently through the test phase.

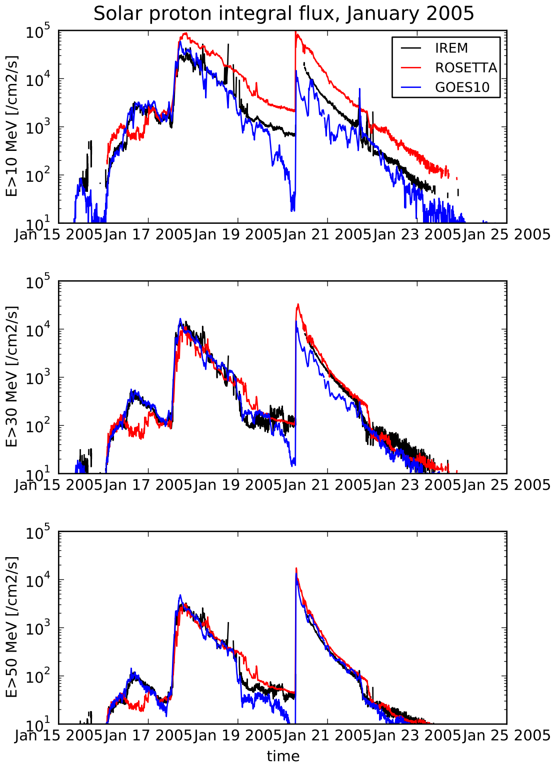

Figure 5: Comparison of the proton rate curves for three energy thresholds during solar proton event in January 2005. The data from two SREMs and GOES10 are presented

7 Summary

Extended database for the ESA Standard Radiation Environment Monitor SREM is created at PSI. SREM is to date the main particle monitor that provides large amount of radiation data from several ESA missions. Each of ten manufactured instruments was carefully calibrated and individually modeled to assure high detection accuracy. The database for different SREM units contains space measurements with count rates and electron and proton fluxes. Additional items such as the mission orbital parameters, spacecraft orientation , measured or computed magnetic fields are included. Moreover, calibration and cross calibration data and intercomparison analysis with other radiation monitors are also present. The data and spectrum unfolding models such as minimization and neural network are accessible via a web link. The access to the repository is open to the whole community and emphasis is given on providing a user-friendly interface.

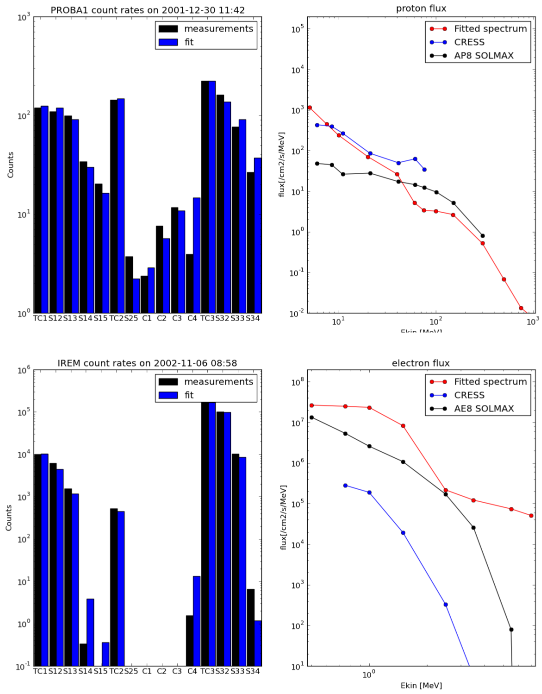

Figure 6: Example of the spectral unfolding of the Proba-1 data for protons (left) and electrons (right) and comparison with the radiation belt models: AP8/AE8 and CRRES.

References

[1] H.D.R. Evans, P. Buehler, W. Hajdas, E.J. Daly, P. Nieminen, A. Mohammadzadeh, Results from the ESA SREM monitors and comparison with existing radiation belt models, Advances in Space Research 42, 1527 (2008)