SPACECRAFT CHARGING MODELS IN ESA'S SPACE ENVIRONMENT INFORMATION SYSTEM (SPENVIS)

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Abstract

The ESA SPace ENVironment Information System (SPENVIS) provides standardized access to models of the hazardous space environment through a user-friendly WWW interface. The interface includes parameter input with extensive defaulting, definition of user environments, streamlined production of results (both in graphical and textual form), background information, and on-line help. The system can be accessed at the WWW site http://www.spenvis.oma.be/spenvis/. Intranet versions are also available. The results of a SPENVIS model run are presented in the form of reports and data files that can be downloaded by the user, and as a variety of plot types (line plots, maps and 3-D plots) in different graphics formats (GIF, PS, JPG, VRML, ...). Extensive help facilities are provided in SPENVIS: context-sensitive help pages provide information on the model parameters and usage, background pages contain in-depth material on the space environment and models, and a user guide and links to other sites are available as well. SPENVIS features a number of models and tools for evaluating spacecraft charging. The DERA DICTAT tool for evaluation of internal charging calculates the electron current that passes through a conductive shield and becomes deposited inside a dielectric, and predicts whether an electrostatic discharge will occur. SPENVIS has implemented the DERA EQUIPOT non-geometrical tool for assessing material susceptibility to charging in typical orbital environments, including polar and GEO environments. SPENVIS Also includes SOLARC, for assessment of the current collection and the floating potential of solar arrays in LEO. Finally, the system features access to data from surface charging events on CRRES and the Russian Gorizont spacecraft, in the form of spectrograms and double Maxwellian fit parameters.

1. Introduction

The planning of space missions requires an analysis of the complex space environment and its impact on space systems. Empirical or quasi-empirical models of this hazardous environment have been developed by different organizations, often independently of one another. As a consequence, the availability of existing models is not always known to potential users. In addition, the issue of updating models and acquiring up-to-date versions is not straightforward.

The SPace ENVironment Information System (SPENVIS) developed for ESA/ESTEC provides easy access to most of the recent models of the hazardous space environment, in combination with an orbit generator, via an integrated user-friendly World-Wide Web (WWW) interface. The interface includes parameter input with extensive defaulting, definition of user environments, streamlined production of results (both in graphical and textual form), background information and on-line help. The tools are harmonised with the European standard on the space environment.

Section 2 contains an overview of SPENVIS. The model suite implemented in SPENVIS is briefly described in Section 3, while Section 4 presents the spacecraft charging models and tools available in SPENVIS in some more detail.

2. General functionality

The SPENVIS system makes full use of the WWW facilities through the following features:

- access via computer networks to a centralized system;
- easy-to-use input facilities making extensive use of default values for the various input parameters, hierarchical structuring of input, and input validation;
- identification of users allowing for the creation of personalized environments, in which previous results and inputs are retained, even when leaving the system;
- automatic and user-specified generation of output, both tables and plots in downloadable graphical formats;
- extensive on-line help and links to in-depth documentation.

The URL of the SPENVIS system is
`http://www.spenvis.oma.be/spenvis/`.

At the heart of SPENVIS is the project concept. A project is defined as the collective input to and output from the SPENVIS system for a series of related runs. This approach ensures that all the inputs and the outputs of a run are conserved, so that an analysis can be performed over more than one session.

SPENVIS Is based on internationally recognised standard models and methods in many domains. It uses an ESA-developed orbit generator to produce orbital point files necessary for many different aspects of mission analysis, and also generates maps and profiles to study the geographical distribution of model parameters.

Extensive help facilities are provided in SPENVIS: context-sensitive help pages provide information on the model parameters and usage, background pages contain in-depth material on the space environment and models, and a user guide and links to other sites are available as well. The help pages are cross-referenced for fast navigation, which is further enhanced by a search engine.

3. SPENVIS Models

Most of the models implemented in SPENVIS require as input a set of points on a spacecraft trajectory or a user-defined set of geographic points. These sets of points are produced by two tools: the orbit generator and the coordinate grid generator. When running the orbit or grid generator, all outputs previously obtained with models that use the respective coordinate tool, are deleted. This is to ensure consistency between results, and to avoid errors in the plotting routines that produce the graphical output. The input parameters for the models are not deleted, so that they can be run again in the same way. The models in SPENVIS have been organised in packages, which are briefly described in the sections below. The spacecraft charging models are treated in more detail.

3.1. Radiation analysis

The radiation tools include:

- radiation belt models: the NASA models AP-8 and AE-8 (Vette, 1991), the AFRL models CRRESPRO (Meffert and Gussenhoven, 1994) and CRRESELE (Brautigam and Bell, 1995), and models developed recently in the framework of ESA TRP contacts (Lemaire et al., 1998) with data sets including SAMPEX/PET (Heynderickx et al., 1999) and CRRES/MEA (Vampola et al., 1992), and a model of the low-altitude trapped proton anisotropy (Kruglanski, 1996).
- solar proton models: JPL-91 (Feynman et al., 1993), JPL-85 (Feynman and Gabriel, 1990), King (1974);
- CREME (Adams, 1986) for cosmic rays.

The conversion of geographic to magnetic coordinates is done internally without interference from the user, ensuring consistency in the application of field models, often a source of confusion and error.

SPENVIS Contains the SHIELDOSE and SHIELDOSE-2 codes (Seltzer, 1980) for total dose assessment and EQFRUX (Tada et al., 1982) for solar cell damage-equivalent fluences (1 MeV electron equivalent). These tools have been augmented by a code for computing the Non-Ionizing Energy Loss (NIEL) or non-ionizing dose (Dale et al., 1993).

In conjunction with CREME and the trapped and solar proton models, the user can compute single event upset rates from cosmic and solar ions and trapped and solar protons. In computing all these parameters, spacecraft or solar cell coverglass shielding is taken into account. A sectoring tool to calculate shielding distributions for simple spacecraft geometries is available.

3.2. Magnetic field

The most commonly used internal and external magnetic field models have been implemented in SPENVIS. These models can be evaluated over a spacecraft trajectory or a coordinate grid. The output from the SPENVIS implementation of the models contains the (B, L) coordinates, the invariant coordinates (R, Λ), magnetic longitude and latitude, the magnetic field vector components, and the location of the footpoints. In addition, field line traces are plotted, and three-dimensional plots of drift shells are available. The magnetic field models and related utilities have been implemented using the UNILIB subroutine library developed by BIRA/IASB (available at http://www.magnet.oma.be/home/unilib/).

3.3. Atmosphere and ionosphere

Several neutral atmosphere and ionosphere models are implemented in SPENVIS: MSISE-90 (Hedin, 1991), MET (Hickey, 1988), DTM 78 (Barlier et al., 1979), HWM 93 (Hedin et al., 1991), IRI-90 (Bilitza, 1990). These models can be evaluated over a grid of points to produce world maps of densities or temperatures, over a coordinate range to produce density profiles, or over a range of one of the model parameters for one geographic point. In addition, number densities can be calculated along a spacecraft trajectory, and particle fluxes and fluences on an oriented surface can be determined.

3.4. Meteoroids and debris

The Grün (1985) meteoroid model and the NASA90 (Kessler et al., 1989) debris model are implemented, while the implementation of the NASA96 (Kessler et al., 1996) debris model is in progress, as well as of particle/wall penetration models for damage risk analysis.

3.5. Data base interface

SPENVIS features survey plots of satellite databases, in combination with geomagnetic indices and related parameters. Data from Meteosat, GOES, SAMPEX, UARS, AZUR, CRRES, and ISEE have been implemented, as well as radiation environment data from the REM instruments on MIR and STRV.

3.6. Integration with a standard on the space environment

The European Cooperation on Space Standards (ECSS) is a system of harmonised standards for the management and engineering of space projects. One of the standards is on Space Environment. SPENVIS Has allowed this standard to be made "active" so that it links to SPENVIS utilities when an engineer wishes to make use of a model or method referred to in the standard, and sits alongside the models so that the engineer can consult the standard in an efficient way for information. As further standards are prepared by ECSS in the areas of radiation effects and spacecraft charging, these will be similarly integrated.

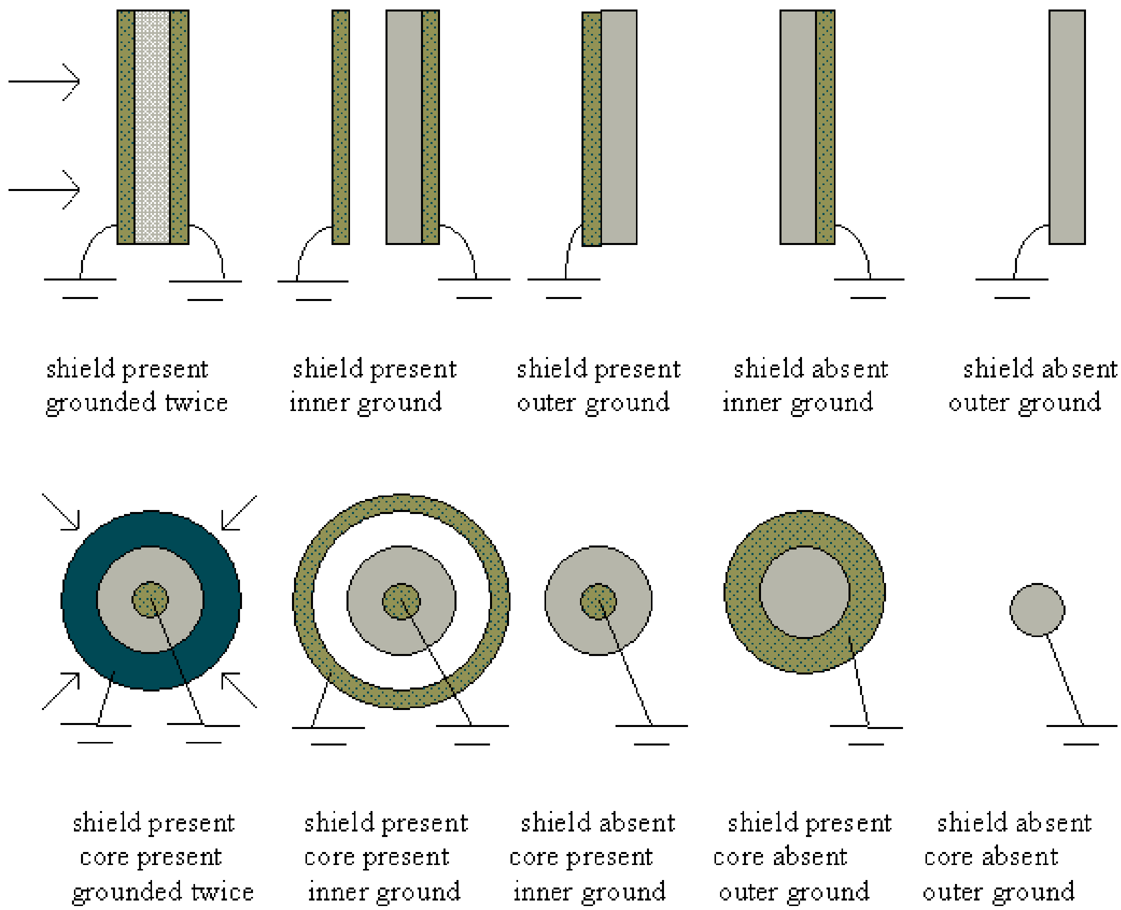


Figure 1. *DICTAT planar and cylindrical geometries*

4. Spacecraft charging

4.1. Internal charging

There has long been a lack of a tool for engineering level evaluation of the internal charging problem. This has recently been addressed by the development of the DICTAT tool (Rodgers, 1998) by DERA for ESA. Not only is there a lack of analysis tools but also of a method for specifying the hazard, which is addressed by DICTAT. DICTAT calculates the electron current, from an integrated electron environment model, that passes through a conductive shield and becomes deposited inside a dielectric. Planar and cylindrical geometries can be defined (see Fig. 1), and all relevant material properties can be specified by the user. From the deposited charge, the maximum electric field within the dielectric is found. This field is compared with the breakdown field for that dielectric to see if the material is at risk of an electrostatic discharge. The breakdown field can be a field deduced from beam irradiations, also with the help of the tool.

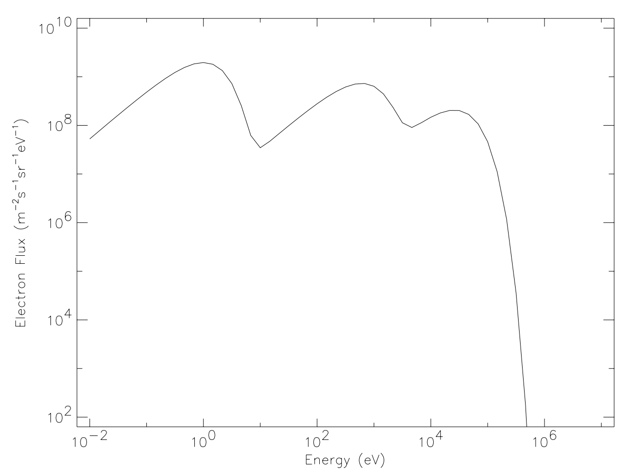
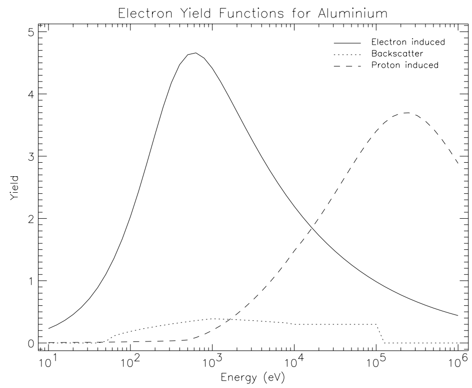


Figure 2. *EQUIPOT worst case (Mullen and Gussenhoven, 1982) electron spectrum*

4.2. Surface charging

While the standard tool for spacecraft charging assessment is the 3-D NASCAP code, SPENVIS has implemented the DERA EQUIPOT non-geometrical tool (Wrenn and Simms, 1990) for assessing material susceptibility to charging in typical orbital environments, including polar and GEO environments. While it does not treat geometry explicitly, it does model the charg-



SPENVIS 2.0 Date: Thu Apr 12 12:20:21 2001
Project: Test

Structure material: Aluminium
Incident distribution: isotropic
Secondary electron emission yield due to electrons: Dionne function
Maximum yield: 3.200
Energy for maximum yield: 0.350 keV
Secondary electron emission yield due to protons
Yield at 1 keV: 0.244
Energy for maximum yield: 230.000 keV
Backscatter yield
Atomic number: 13.0

Figure 3. *EQUIPOT electron yield functions for Al*

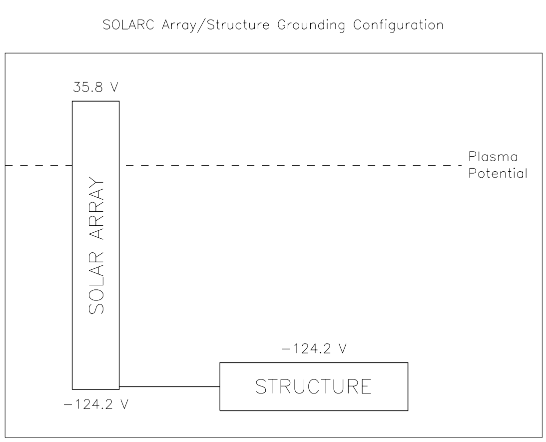


Figure 4. *SOLARC Solar array/structure grounding configuration*

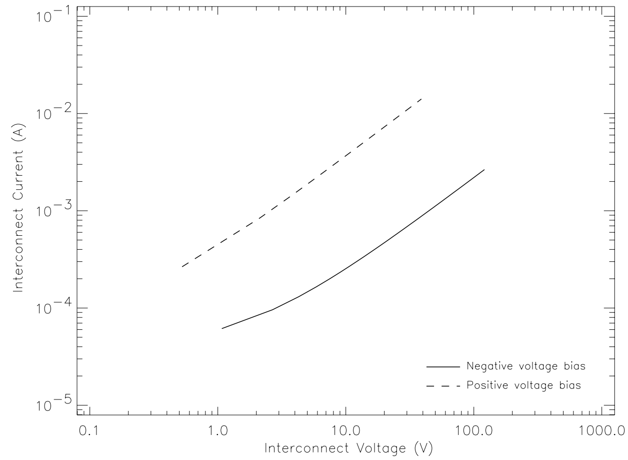


Figure 5. *SOLARC Solar array V/I characteristics*

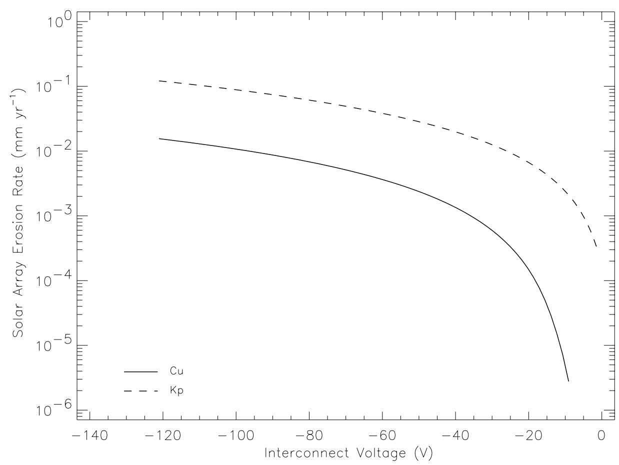


Figure 6. *SOLARC Solar array erosion rates*

ing behaviour of a patch-on-a-sphere model which is useful for investigating differential charging.

The ambient electron and ion environment can be fully specified by the user, or default environment specifications can be selected [e.g., Fig. 2 shows the high altitude worst case electron spectrum from Mullen and Gussenhoven (1982)]. All relevant material parameters for the sphere and patch can be defined by the user. The graphical output includes plots of the electron yield functions (see Fig. 3).

4.3. Solar arrays

SPENVIS Also includes SOLARC, for assessment of the current collection and the floating potential of solar arrays in LEO. The graphical output includes the solar array/structure grounding configuration, the solar array V/I characteristics and erosion rates (see Figs. 4, 5 and 6), and the ion and electron current collection models.

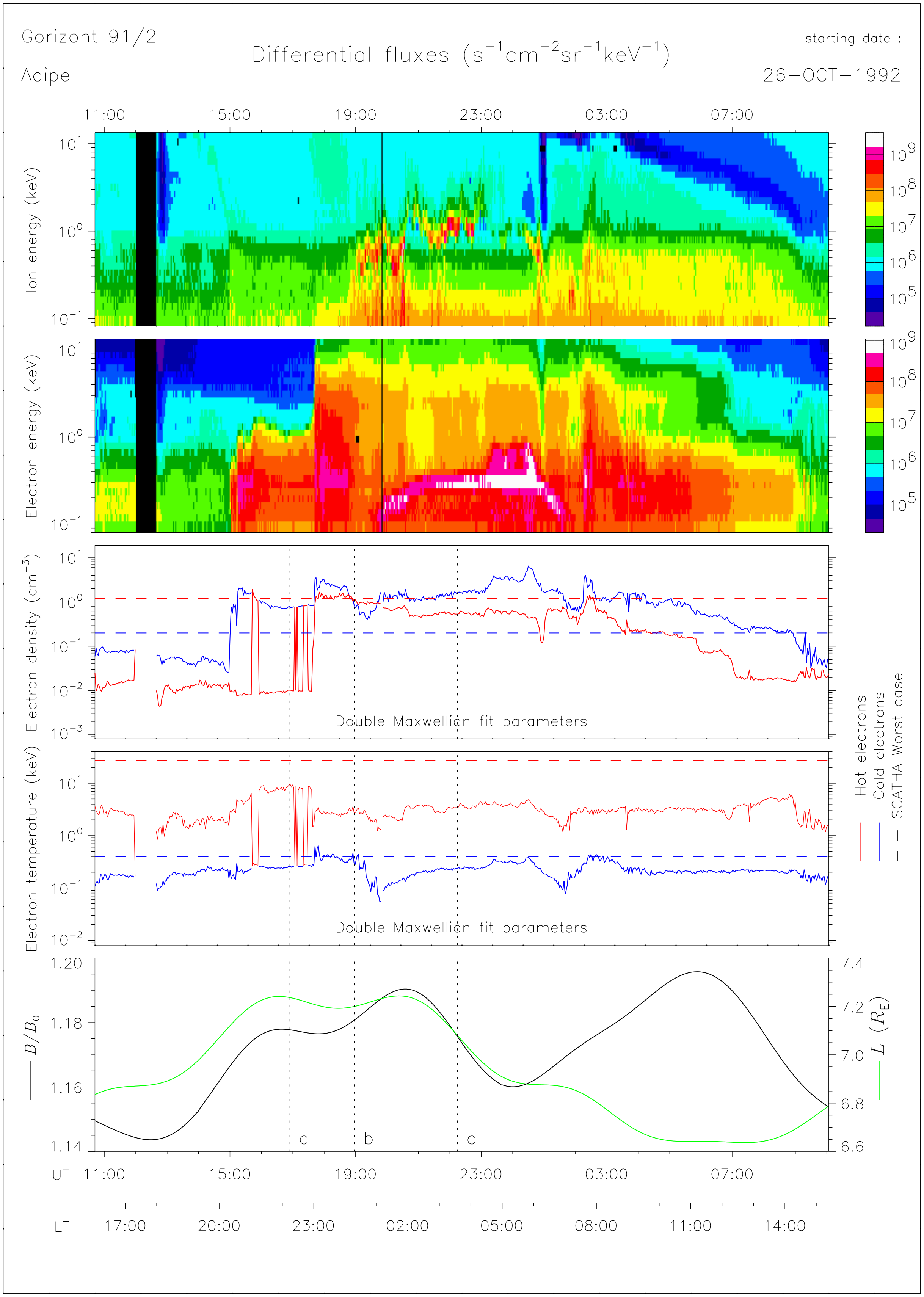


Figure 8. *Representation of the Gorizont/ADIPE electron charging event spectrum on 26 October 1992*

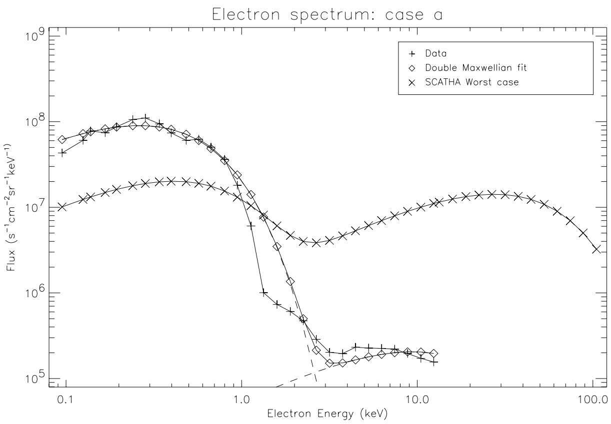


Figure 7. *Double Maxwellian fit to the Gorizont/ADIPE electron charging event spectrum of Fig. 8*

4.4. Data sets of charging events

The system features access to data from surface charging events on CRRES and the Russian Gorizont spacecraft, in the form of double Maxwellian fit parameters (Fig. 7) and spectrograms (Fig. 8).

Acknowledgments

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