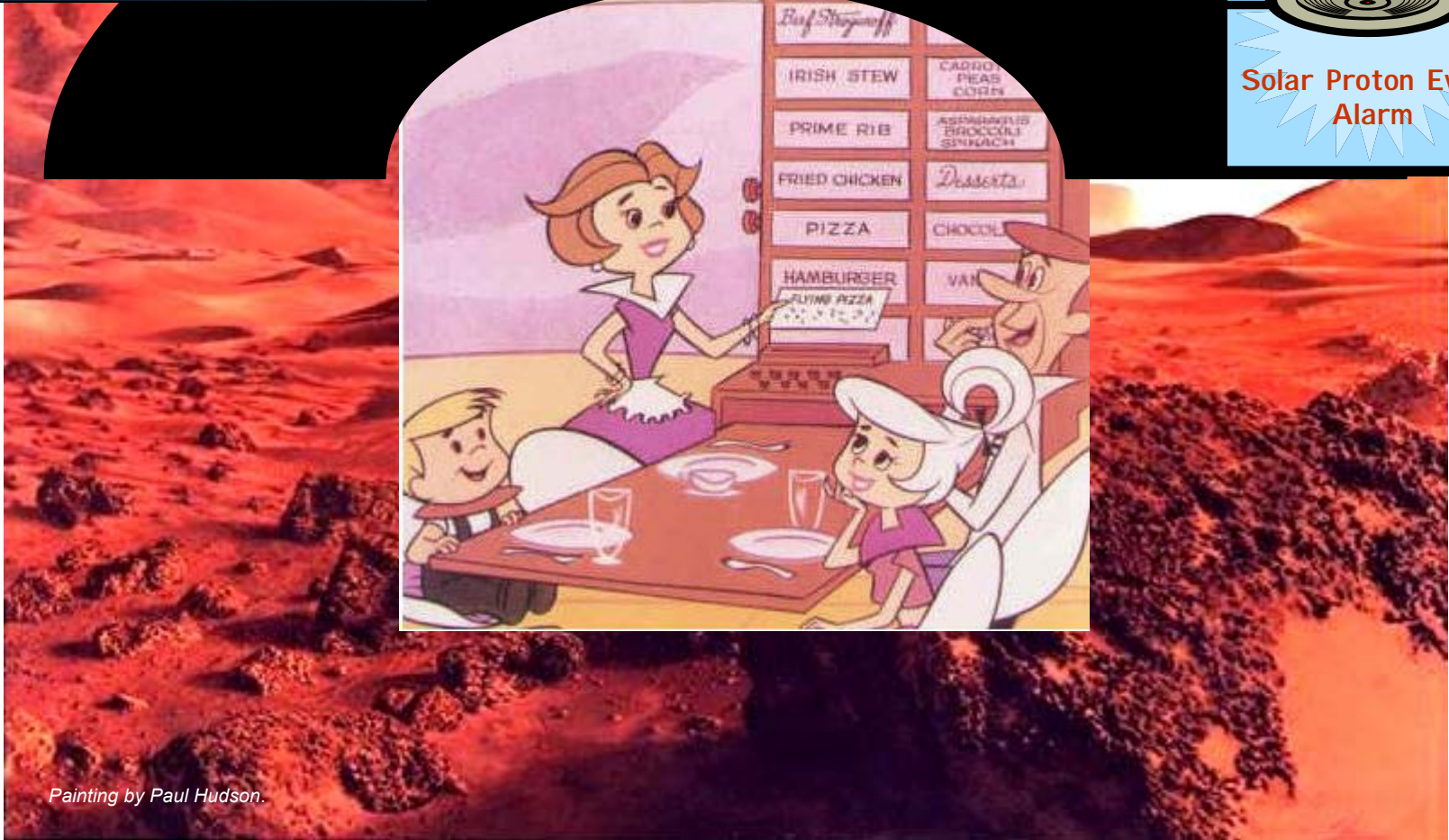
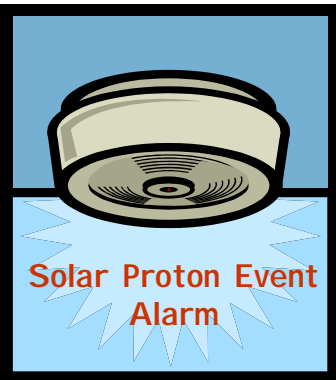


was originally supposed to take place
"one hundred years in the future" in the year 2062



Painting by Paul Hudson.

BISA Activities Related to Space Radiation



BISA = Belgian Institute for Space Aeronomie

BIRA
IASB



Belgisch Instituut voor Ruimte-Aëronomie
Institut d'Aéronomie Spatiale de Belgique
Belgian Institute for Space Aeronomy

>> Nederlands
>> Français
>> English

aeronomie.be

Norma B. Crosby



Welcome to BISA

Interplanetary Environment

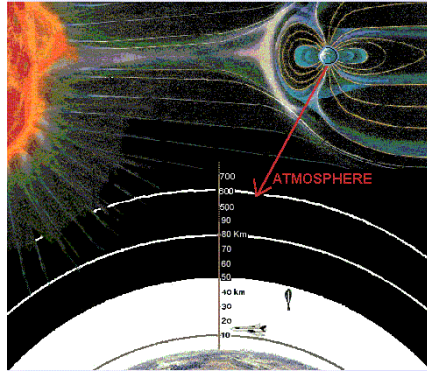
- Solar rays
- Solar wind
- Magnetosphere
- Aurora
- Radiation belts
- Ionosphere

System Earth

- Layers atmosphere
- Water
- Ozone
- UV index
- Aerosols
- Greenhouse effect
- Climate change

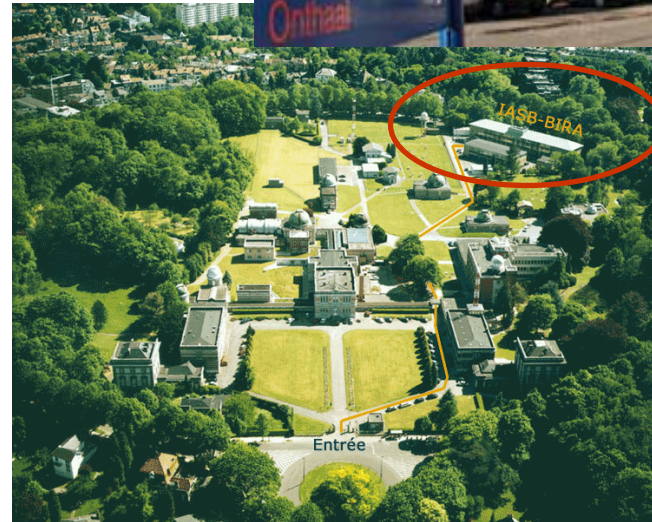
Planetary Atmosphere

- Mars
- Venus
- Planets
- Comets



1. Space Plasma
2. Atmosphere
3. Valorization & Exploitation

BISA is involved in many space weather service oriented projects and activities, especially in the space environment effects domain. This includes scientific research, and in particular the valorisation of this research towards users and services (e.g. aerospace, navigation, telecommunications).



<http://www.aeronomie.be/>



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OUTLINE

1. Interplanetary Radiation Environment
[mission to Mars scenario]

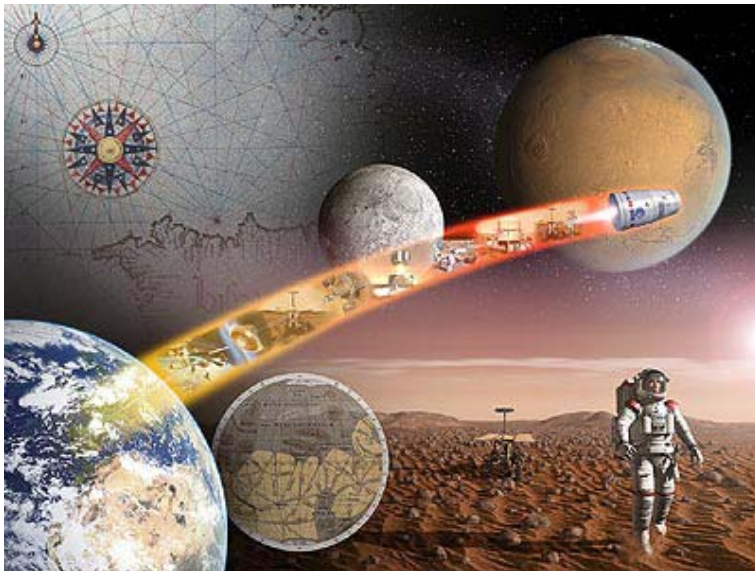
2. BISA Activities Related to Space
Radiation

3. Final Words



1. Interplanetary Radiation Environment

[mission to Mars scenario]



Credits: ESA

Major Radiation Environments in the Heliosphere.



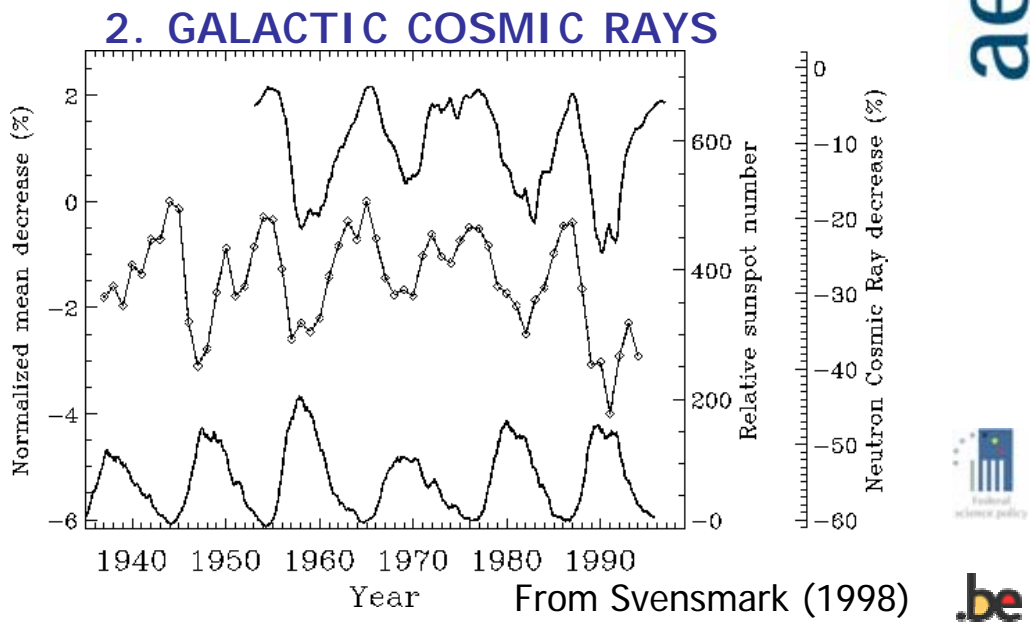
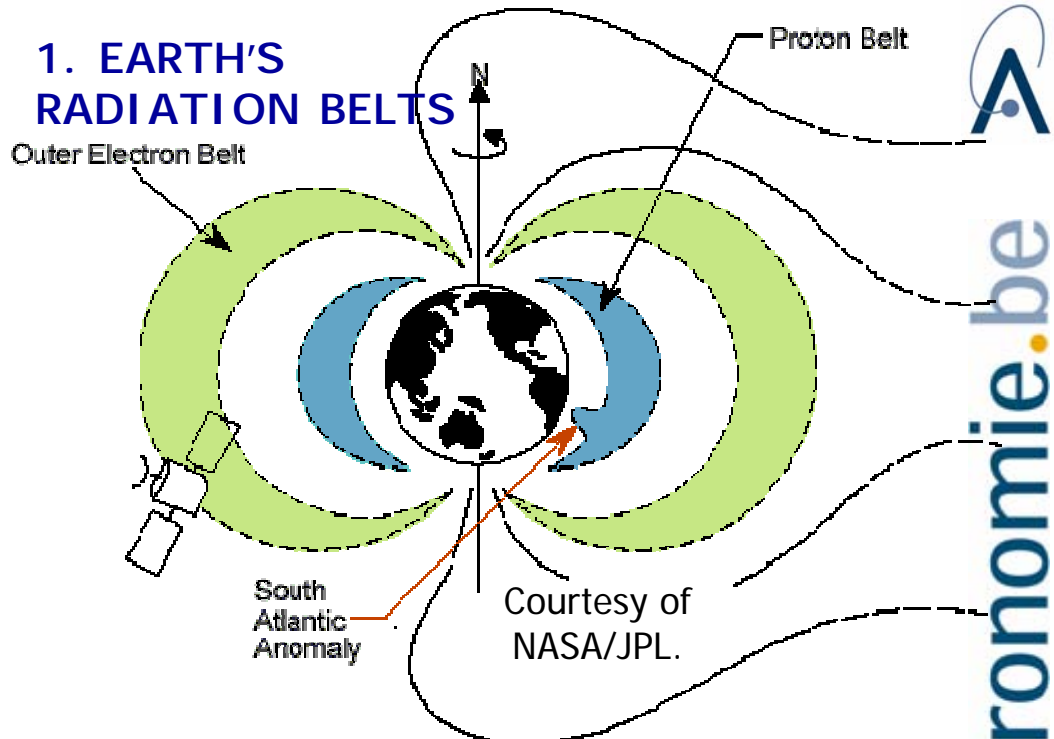
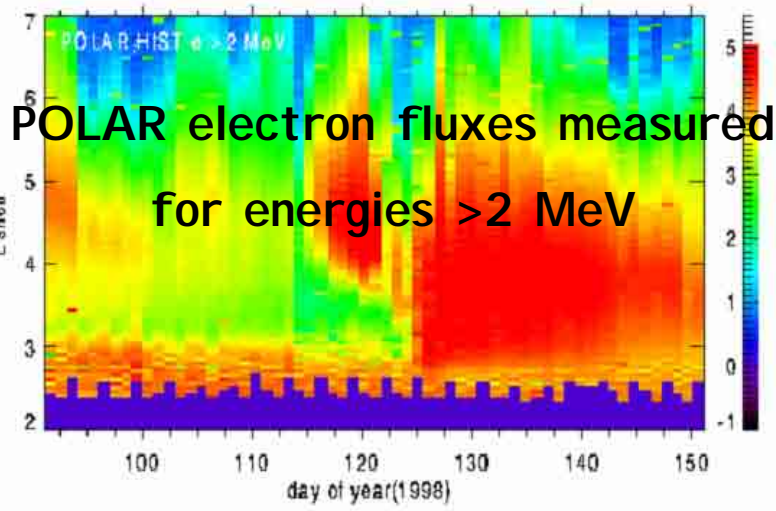
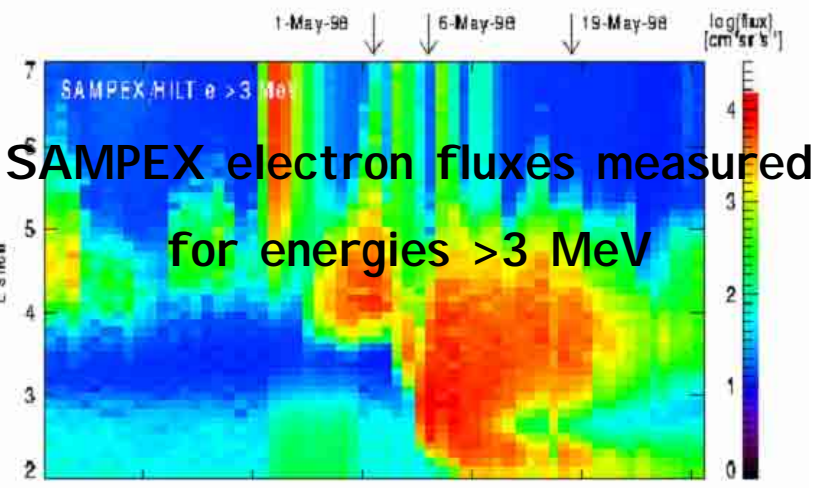
Particle Populations	Energy Range	Temporal Range	Spatial Range (first order)
Galactic Cosmic Rays	0.1 - 1000 GeV (the 100 to 1000 MeV fluxes constitute the largest contribution)	Continuous (factor 10 variation with solar cycle)	Entire heliosphere
Anomalous Cosmic Rays	< 100 MeV	Continuous	Entire heliosphere
Solar Energetic Particles	keV - GeV	Sporadic (minutes to days)	Source region properties (flare/CME sites and evolution) and bound to CME driven shock
Energetic Storm Particles	keV - (>10 MeV)	Hours-Day	Bound to shock
Corotating Interaction Regions	keV - MeV	Few days (recurrent)	Bound to CIR shock and compression region
Particles accelerated at planetary bow shocks	keV - MeV	Continuous	Bound to bow shock
Trapped Particle Populations	Tens keV - couple of hundreds of MeV (for protons) Tens keV - several MeV (for electrons)	Variations "minutes-years"	Variations "height-width"
CME: coronal mass ejection CIR: corotating interaction region			

Cosmic Rays

[super-thermal to more than 10^{21} eV]

Most cosmic rays are ionized atoms, ranging from protons, helium (α -particles), up to the iron nucleus and even beyond to heavier nuclei (e.g. uranium).

Cosmic rays also include high-energy electrons, positrons, and other subatomic particles.



Baker, D.N., J.H. Allen, S.G. Kanekal, and G.D. Reeves; EOS, 79, p. 477, 1998.

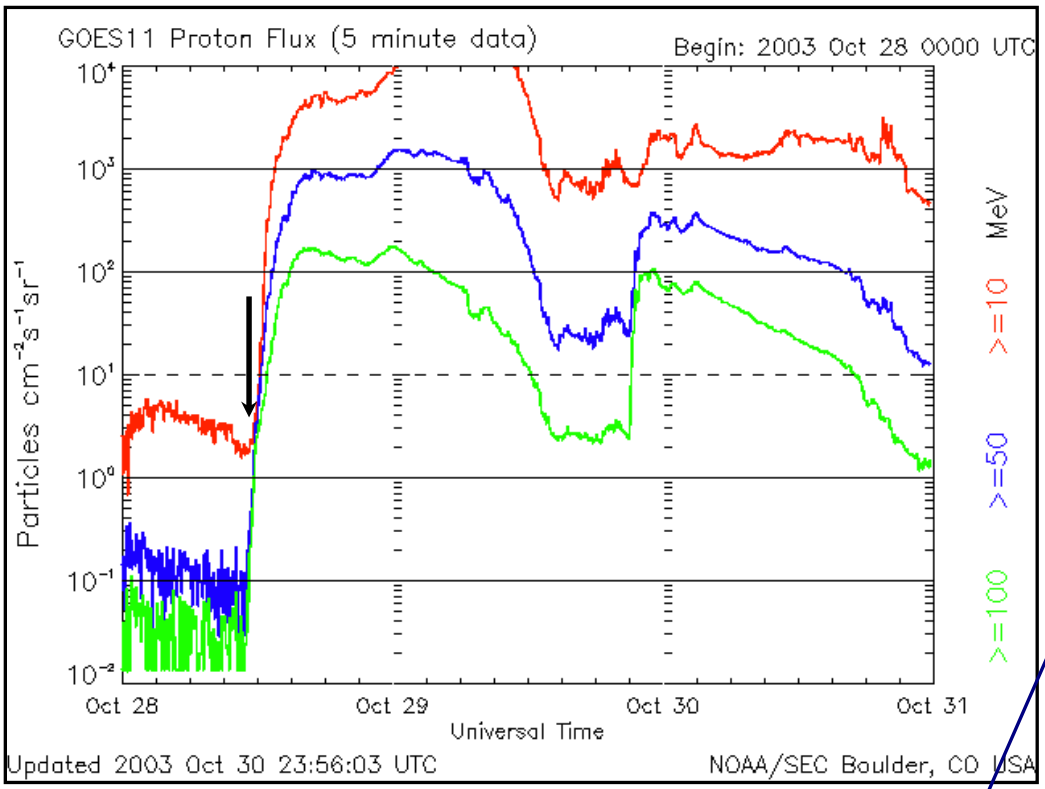


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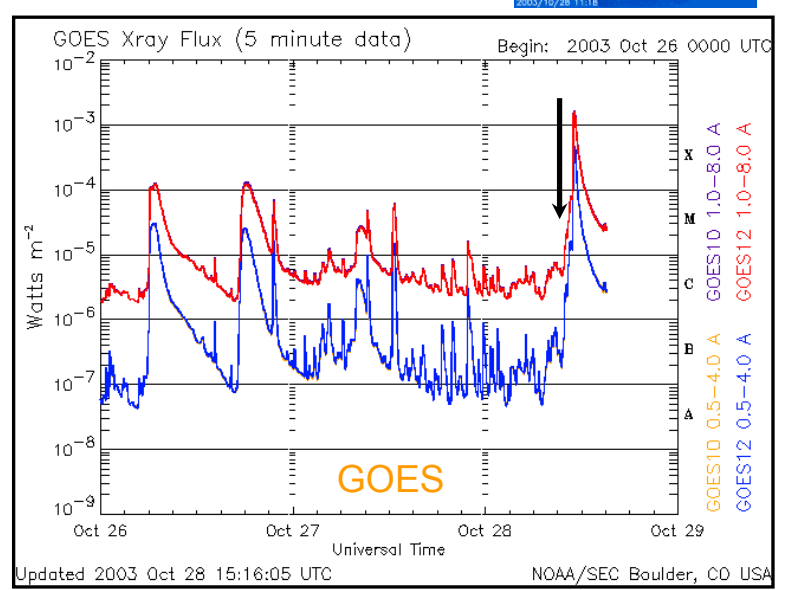
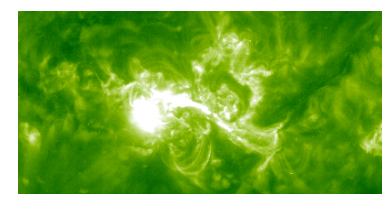
3. SOLAR ENERGETIC PARTICLE EVENTS



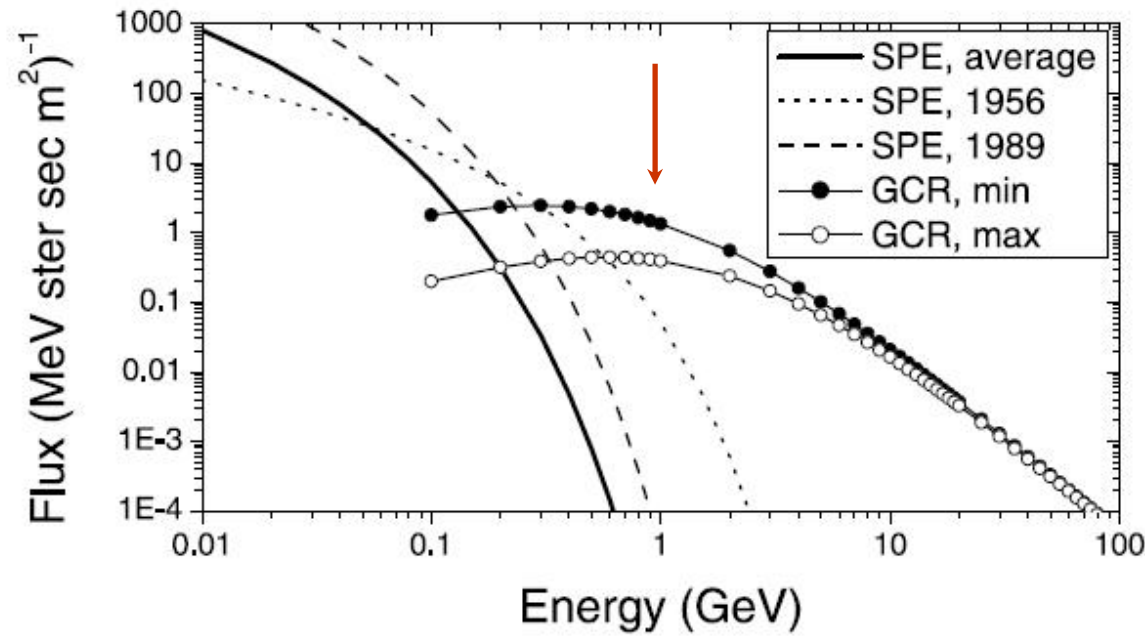
Coronal Mass Ejections



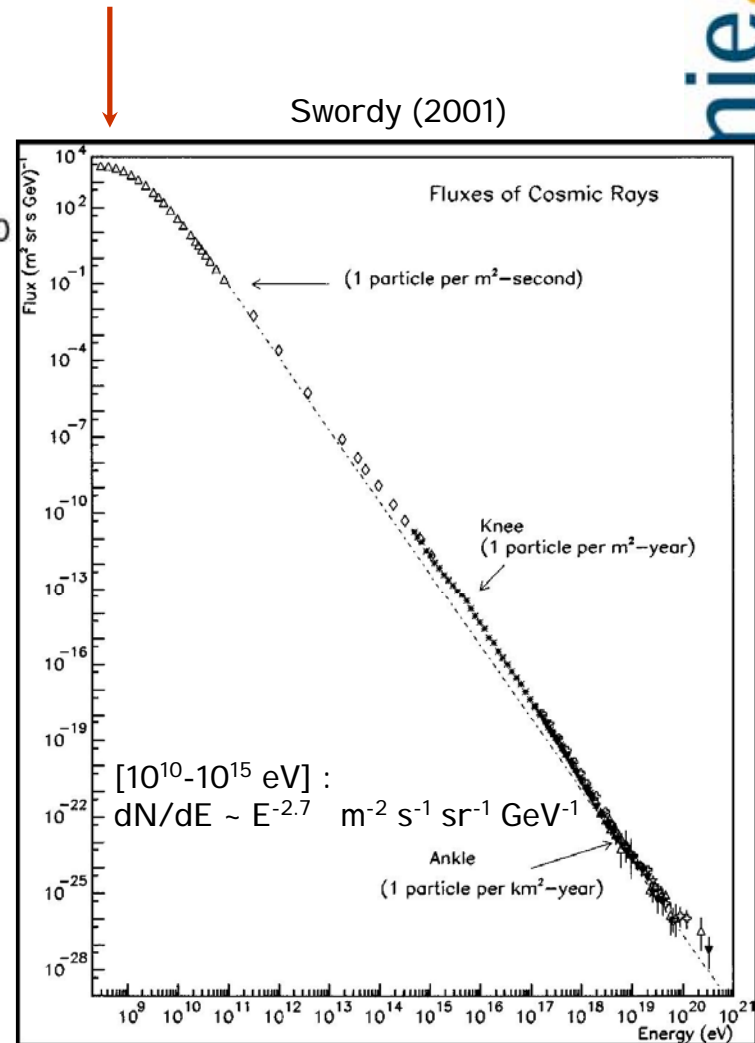
Solar Flares



SPECTRA - flux (s^{-1})



Usoskin et al. (2006)



Space Environment Hazards

Space hazard	Spacecraft charging		Single-event effects			Total radiation dose		Surface degradation		Plasma interference with communications	
	Surface	Internal	Cosmic rays	Trapped radiation	Solar particle	Trapped radiation	Solar particle	Ion sputtering	O ⁺ erosion	Scintillation	Wave refraction
LEO <60°	Not applicable	Not applicable	Relevant	Important	Not applicable	Important	Relevant	Relevant	Important	Important	Important
LEO >60°	Relevant	Not applicable	Important	Important	Important	Important	Relevant	Relevant	Important	Important	Important
MEO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
GPS	Important	Important	Important	Not applicable	Important	Important	Important	Relevant	Not applicable	Important	Important
GTO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
GEO	Important	Important	Important	Not applicable	Important	Important	Important	Relevant	Not applicable	Important	Important
HEO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
Inter-planetary	Not applicable	Not applicable	Important	Not applicable	Important	Not applicable	Important	Relevant	Not applicable	Relevant	Relevant



Important



Relevant



Not applicable

Space environment hazards for typical orbits. Key: LEO <60°—low Earth orbit, less than 60 degrees inclination; LEO >60°—low Earth orbit, more than 60 degrees inclination; MEO—medium Earth orbit; GPS—Global Positioning System satellite orbit; GTO—geosynchronous transfer orbit; GEO—geosynchronous orbit; HEO—highly elliptical orbit; O⁺—atomic oxygen.

Courtesy of the
Aerospace
Corporation



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Inter-
planetary



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2. BISA Activities Related to Space Radiation

- SPace ENVironment Information System (SPENVIS)
- Solar Energetic Particle Environment Modelling (SEPTEM)
- Martian Radiation Environment Models (MarsREM)
- European Space WEather Portal (ESWEP)
- Space Weather European NETwork (SWENET)

ESA's SPace ENVironment Information System (SPENVIS)



SPENVIS is a World Wide Web based interface to models of the space environment and its effects, including the natural radiation belts, solar energetic particles, cosmic rays, plasmas, gases, and 'micro-particles'. BISA is main contractor of the SPENVIS project.

With SPENVIS, one can generate a spacecraft trajectory or a coordinate grid (altitude, latitude, longitude).

The screenshot shows the SPENVIS website interface. On the left is a navigation menu with links: Home, Access, Register, Models, Help, Credits. The main content area includes a welcome message, a 'Please report any problems or bugs' section, 'System updates', 'Registration' information, and 'System requirements'. On the right, there is a vertical menu of services: Coordinate generators, Spacecraft trajectories, Geographical coordinate grids, Radiation sources and effects, Spacecraft charging, Atmosphere and ionosphere, Magnetic field, Meteoroids and debris, Data base queries, Miscellaneous, and ECSS Space Environment Standard. The ESA logo and 'The Space Environment Information System' text are visible at the top of the main content area.

- atmospheric and ionospheric densities and temperatures
- atomic oxygen erosion depths.

<http://www.spervis.oma.be/>

ESA's SPace ENVironment Information System (SPENVIS)



Trapped proton and electron fluxes

- ❑ AP-8/AE-8, CRRES, SAMPEX

Solar proton fluences

- ❑ JPL 9, ESP (total fluence, worst case event), King

-
- ❑ damage equivalent fluences for Si, GaAs and multi-junction solar cells

- ❑ Ionizing dose: SHIELDOSE and SHIELDOSE-2

- ❑ Non-ionizing energy loss (NIEL)

- ❑ Geant4 Monte Carlo analysis for doses and pulse height rates in planar and spherical shields

- ❑ a sectoring analysis for dose calculations in more complex geometries

- ❑ ion LET and flux spectra and single event upset rates (CREME)

Coordinate generators
Radiation sources and effects
Radiation sources
Trapped proton and electron fluxes
Trapped proton flux anisotropy
Solar proton fluences
Solar cell radiation damage
Damage equivalent fluences for solar cells
Radiation doses
Ionizing and non-ionizing dose models for simple geometries
Multi-Layered Shielding Simulation (Mulassis)
Sectoring analysis for more complex geometries
Single event effects
Ion energy and LET spectra
Single event upset rates
Spacecraft charging
Atmosphere and ionosphere
Magnetic field
Meteoroids and debris
Data base queries
Miscellaneous
ECSS Space Environment Standard

ESA's Solar Energetic Particle Environment Modelling (SEPTEM) Project

[BISA, K.U.Leuven, QinetiQ, Univ. of Barcelona, Univ. of Southampton]

SEPTEM will create new engineering models & tools to address future needs, in particular:

- taking advantage of new data and taking into account recent advances in understanding the generation mechanism
- enabling automatic model and tools update and establishing community consensus
- rather than producing only mission-integrated fluence for a given confidence level (for dose, solar array degradation), models and tools will be designed and developed to produce new types of user products (suitable for SEU rate, system impact and radiation background), including, but not limited to, peak flux statistics, durations of high or arbitrary flux periods, and corresponding error and uncertainty estimates
- integrating databases of ion species and their fluxes into tools for analysis (including SEU and background calculation) so that past events and future scenarios can be simulated
- examine (limited) available data and improve models to predict the expected event time profiles at non-Earth locations (near-Sun, Mercury, Venus, Mars,...) in order to obtain realistic models of the variation in peak flux and fluence with heliocentric location in order to avoid potentially over-severe environment specifications.

<http://www.oma.be/SEPTEM/>



ESA's Martian Radiation Environment Models (MarsREM) Project [QinetiQ, LIP, SpaceIT, BISA]

The primary objectives of MarsREM are:

- ❑ Design, develop, implement and validate engineering tools, based on Geant4, to predict the Martian radiation environment for orbital spacecraft, and Mars planetary and moon landers or habitats
- ❑ The tools shall be easy-to-use by mission designers and planners (rather than developed just for radiation experts), web-based and interfaced with existing radiation shielding and effects simulation tools at the SPENVIS web-site.

BISA's CONTRIBUTION: *WP2200 Definition Mars primary particle source*

“To define the primary particle environments at Mars before interactions with the Martian atmosphere or surface, or the surfaces of Phobos or Deimos.”

Major WP2200 Activities:

- Review existing data and models of galactic cosmic rays, solar energetic particles, solar UV and X-rays, and solar and Jovian electrons for the vicinity of Mars and Martian moons
- Extension of SAPRE to Mars orbits
- Create database of radiation data, and an interface to the database
- Derivation of “standard” spectra or models for use in the radiation transport codes
- Comparison of example spectra with flight data results

European Space WEather Portal (ESWEP)

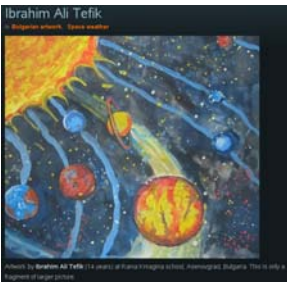
The ESWEP website is being developed and hosted by BISA.



<http://www.spaceweather.eu/>

Besides the functionalities (e.g. remote model and database access) intended for scientists and engineers, the ESWEP places a lot of emphasis on public outreach and has a specific section dedicated to this.

Introductory texts translated into many languages (e.g. English, French, Dutch, Russian, etc.), explain where space weather comes from and what its consequences can be.



When given a simple lecture on space weather, children from all over Europe produce beautiful artwork and are very proud to see their images on line.



Space Weather European NETwork (SWENET)



SWENET Contents

- Introduction
- SWENET Services
- Look for Services
- Latest Data
- Space Weather Data
 - Data Browsing
 - FTP Mirror
 - Latest SEC Plots
 - Latest Indices
- Statistics
- Daily Reports
- Message of the Day
- Report Browsing
- Resources
- Documentation
- Release Information
- WebService
- User Area
- Login
- Register

SWENET Services

- Ground Effects
- Ionospheric Effects
- Spacecraft Effects

IRI TEC Map

Previous 24 hours

Welcome to SWENET
Space Weather European Network

With the increasing importance of space weather aspects in space missions, it is important to provide industry and other users with the means to access space weather data and services. The Service Development Activities (SDA) being currently developed as part of ESA's Space Weather Applications Pilot Project will provide a series of applications, services and data products involving all space weather aspects for a wide range of users. The products resulting from these activities will form the Space Weather European Network - SWENET.

The SWENET Infrastructure is a central resource centre for space weather activities, providing interested users access to space weather data and services. To access the different sections of the SWENET Infrastructure use the menu on the left.

Geomagnetic field disturbance
Provided by GAFS (DMI)

Level of disturbance of the geomagnetic field expected over the next two days at Brorfolde (BFE) - Denmark.

	0-3 hrs	3-12 hrs	12-48 hrs
f_pos	quiet	quiet	quiet
f_neg	quiet	quiet	quiet
d_pos	quiet	quiet	quiet
d_neg	quiet	quiet	quiet
i_pos	quiet	quiet	quiet
i_neg	quiet	quiet	quiet

Solar Radio Indices
Provided by TSRS (INAF)

Predicted sum of lh and rh components in Solar flux units [10^{-22} W/m²/Hz] at 237, 327, 408, 610, 1420 and 2695 MHz.

Last update: 2007-09-03 13:33

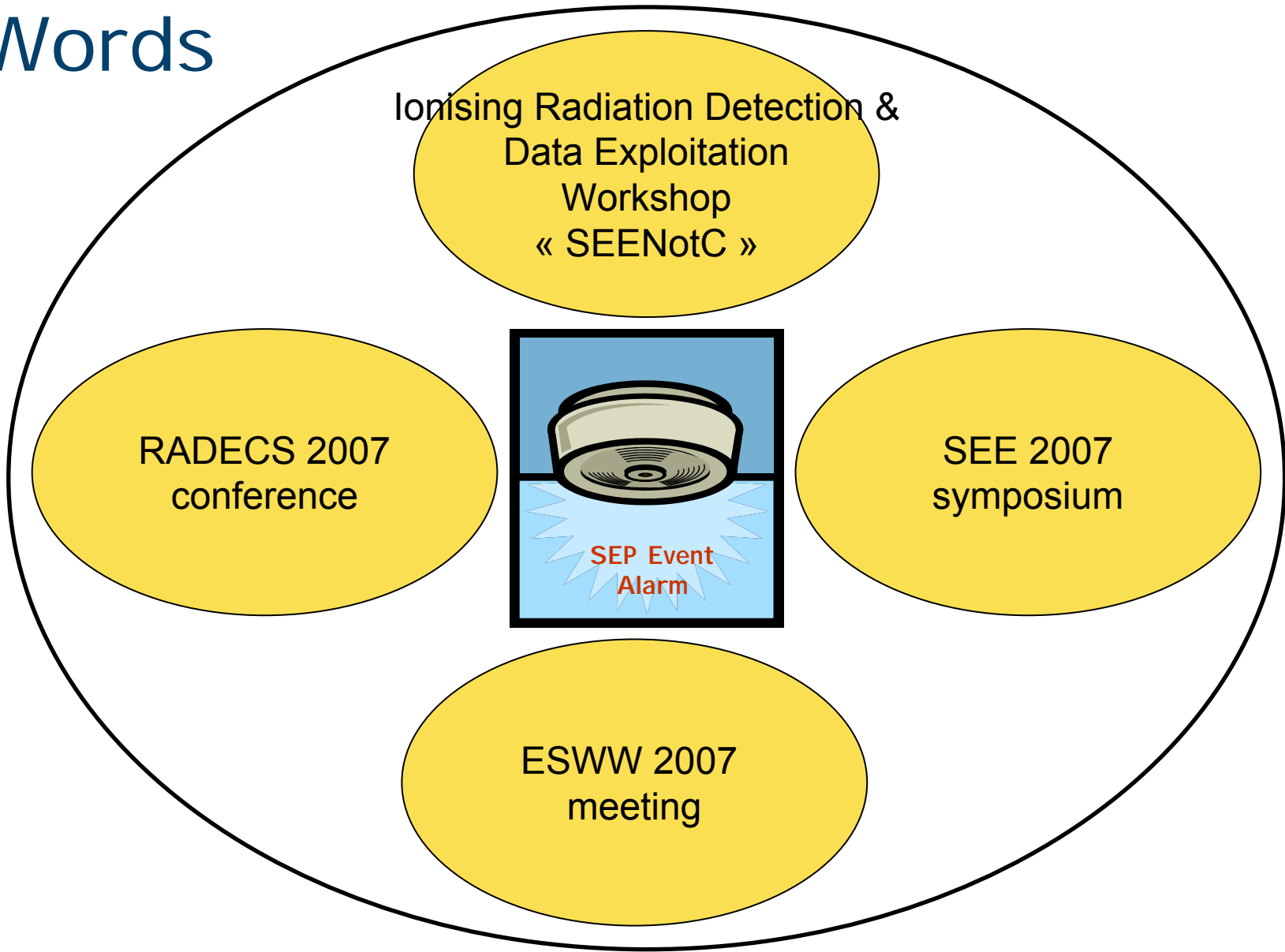
The SWENET Software Infrastructure is a web portal providing access to services and data related to the space environment and its effects.

Products include: 'Aurora Forecasting', 'Geomagnetic Activity and Geomagnetically Induced Currents Forecasting', 'Radio Communications Conditions', 'Quality of Satellite Navigation services' and 'Satellite Anomalies & Operational Support'.

SWENET has been developed in the frame of ESA's Space Weather Applications Pilot Project in order to support European users with information and services related to space weather effects. BISA has contributed to the development of the SWENET portal.

<http://esa-spaceweather.net/swenet/index.html>

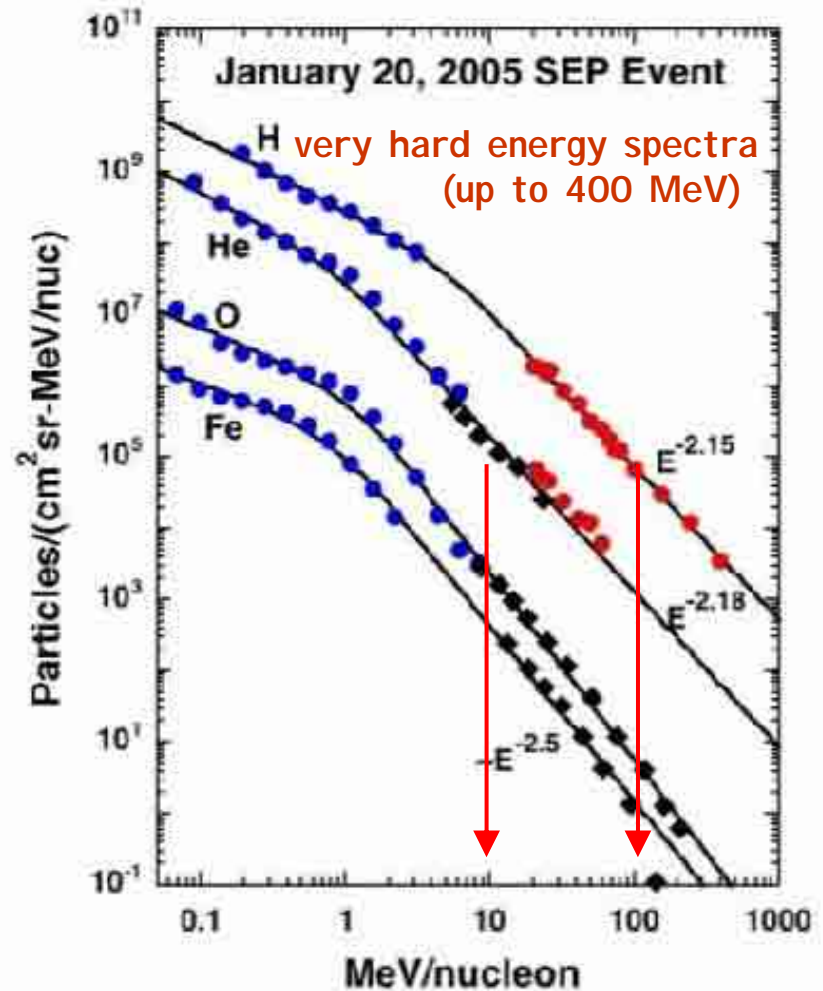
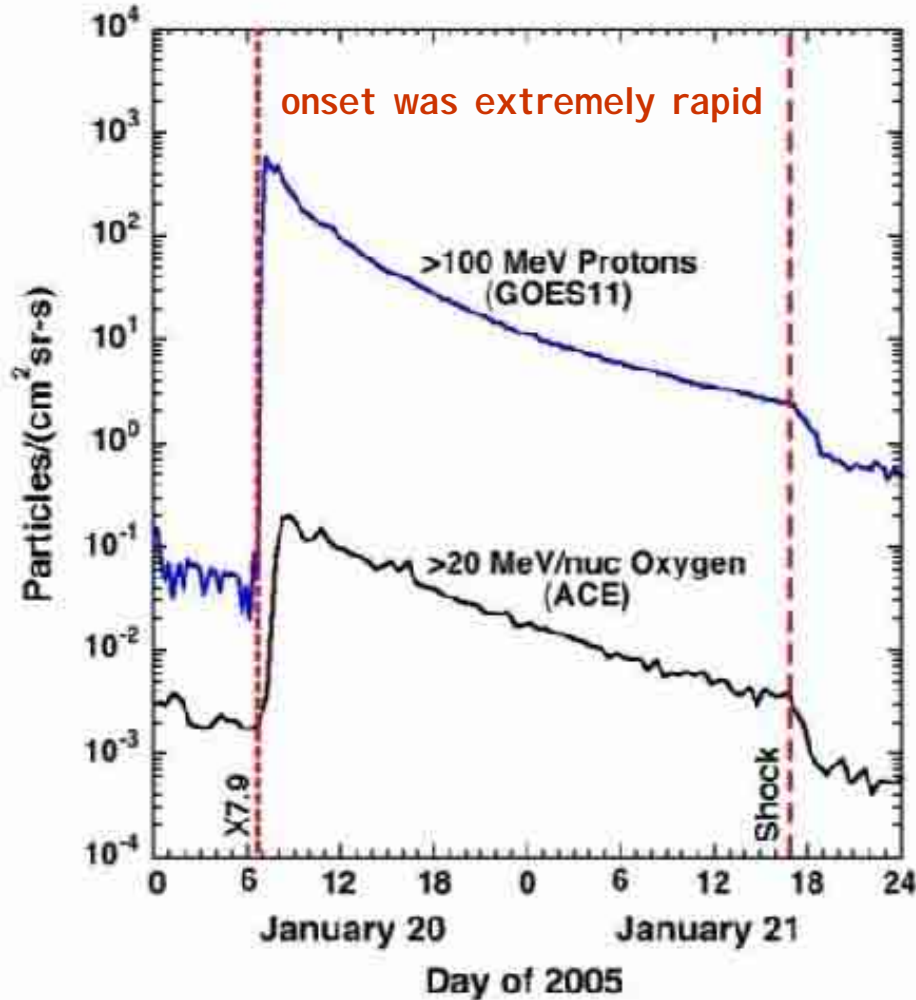
3. Final Words



X7.9 flare that began at 6:36 UT and associated CME.

ACE News #87 - Feb 23, 2005

Space Weather Aspects of the January 20, 2005 Solar Energetic Particle Event

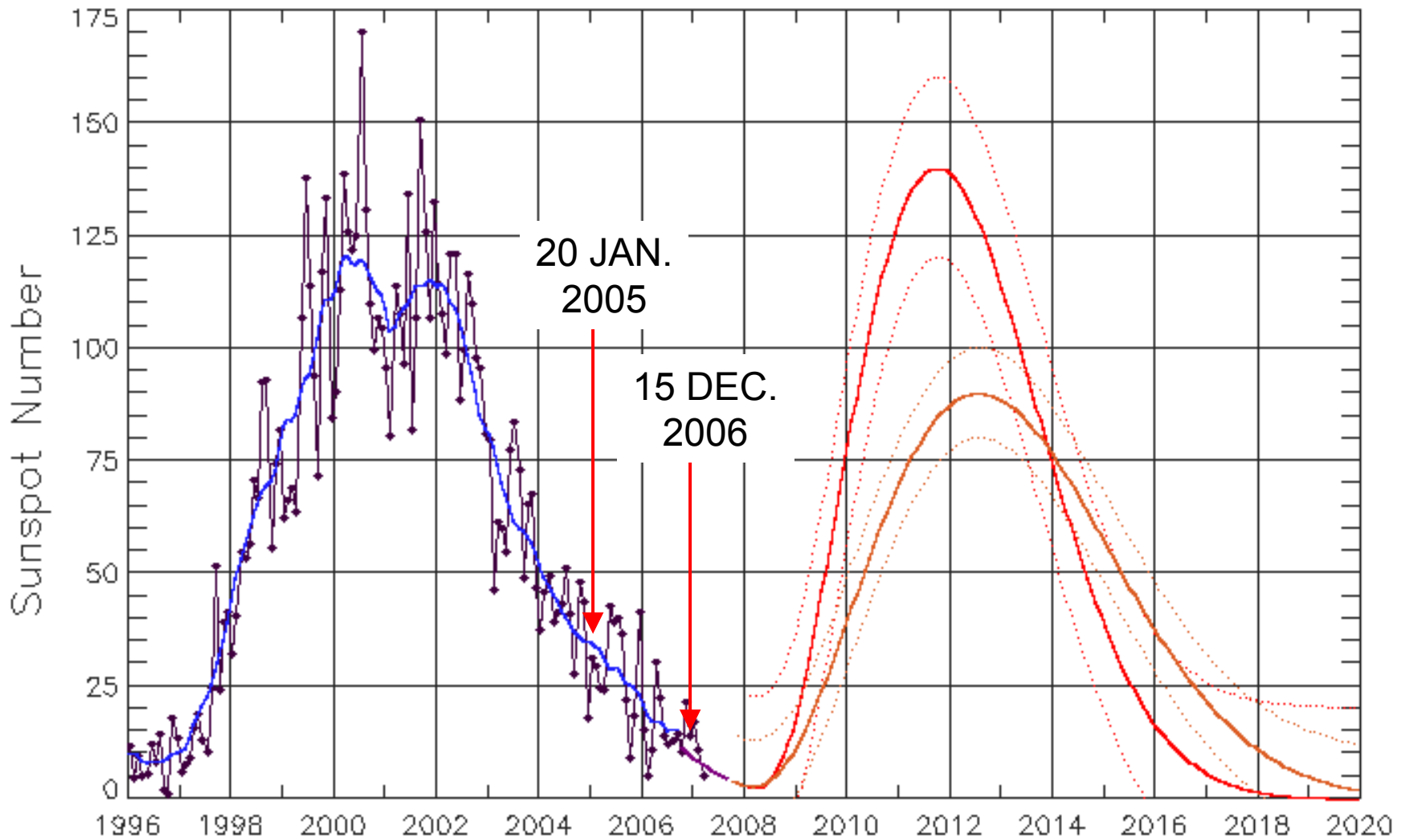


Solar Cycle 24 Sunspot Number Prediction

Data Through 31 Mar 07



aeronomie.be



— Low Prediction (Smoothed)
— Smoothed Monthly Values

— High Prediction (Smoothed)
— Monthly Values

..... 1-Sigma Error

Updated 2007 Apr 20

NOAA/SEC Boulder, CO USA



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