

Use of Spenvis and Web resources in the Space Weather Class at KU Leuven

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- To provide an overview of the current observational data on space weather;
- To provide insight in the basic physics of of space weather;
- To provide an overview of the current state-of-the-art modeling and forecasting activities for selected aspects of space weather, e.g. CME initiation and IP CME evolution, gradual SPE events, etc.
- To explore the effects of space weather on humans and on technology in space and on the ground.

- perswww.kuleuven.be/~u0052182/teaching.html

Class material: Space Weather

[Syllabus in wiki format](#)

1. [Lecture 1 \(HTML\)](#)
2. [Lecture 2 \(HTML\)](#)
3. [Lecture 3 \(HTML\)](#)
4. [Lecture 4 \(PDF\)](#)
5. [Lecture 5 \(PDF\)](#)
6. [Lecture 6 \(PDF\)](#)
7. [Lecture 7 - notes \(PDF\)](#)
8. [Lecture 7 - slides \(PDF\)](#)
9. [Lecture 8 \(PDF\)](#)
10. [Lecture 9-12 \(see Toledo\)](#)
11. [Lecture 13 \(PDF\)](#)

Homework

1. [Homework 1 \(PDF\)](#)
2. [Homework 2 \(PDF\)](#)
3. [Homework 3 \(PDF\)](#)
4. [Homework 4 \(PDF\)](#)

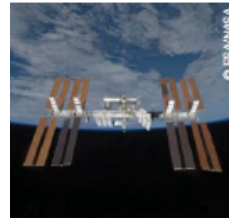
Class offered to:

- Master in Mathematics
- Master in Astrophysics
- Erasmus
- MaNaMa in Space Studies

POC: POC Wiskunde



KATHOLIEKE UNIVERSITEIT
LEUVEN



Master of Space studies

INTERUNIVERSITY PROGRAMME

Faculty of Science
Faculty of Engineering
Faculty of Medicine
Faculty of Law



Topics covered

MASTER OF SPACE STUDIES		60
COURSE		CREDITS
Mandatory courses		23
• Questions in Space Sciences		3
• Space Law and Space Policy		3
• Space Project Management		5
• Space Sciences and Exploration		3
• Life Sciences and Biology in Space		3
• Orbital Mechanics and Mission Design		3
• Spacecraft Design and Instrumentation		3
Major subject		22
<p>Students have to choose courses amounting to 22 credits from the list below and (for a maximum of 6 credits) from other Master's programmes at the universities of Gent and Leuven. Students with a Master's degree in the Humanities and Social Sciences are expected to choose these courses from list A below. Students with a Master's degree in Science, Engineering and Technology or Biomedical Sciences are expected to choose these courses from lists B and/or C.</p>		
A Space Law, Policy, Business and Management		
- The Law of International Organizations		6
- Introduction to Management and Strategy		4
- Space Business and Management		4
- Advanced Topics in Space Law and Space Policy		4
- Product Development and Innovation		4
B Space Sciences		
- Space Weather		4
- Advanced Topics in Life Sciences in Space		4
- Astrophysics from Space		4
- Remote Sensing of the Atmosphere		4
- Synchrotron Radiation Research in Earth and Planetary Sciences		4
- Plant Biology in Space: Life Support System Applications		4
- Global Change Monitoring and Coastal Processes		3
C Space Technology and Applications		
- Space Geodesy, Geophysics and Earth Observation		4
- Satellite and Space Communications		4
- Spacecraft Systems Design		3
- Spacecraft Technology and Space Environment		5
- Reliability of Space Systems		4
- Robotics		4
- Image Analysis and Understanding		6
Master's thesis		15

Master in Astrophysics and Master in Math

MASTER OF MATHEMATICS (120 credits)

MASTER OF ASTRONOMY AND ASTROPHYSICS

120 studiepunten

COURSE CREDITS

Compulsory courses 54

• Observational Techniques in Astronomy	6
• Research Projects I	3
• Binary Stars	6
• Theory of Nucleosynthesis	3
• Star Formation	6
• Interstellar Matter	6
• Physics of Planets	6
• Asteroseismology	6
• Specialised Topics in Astronomical Techniques	6

Students must choose two of the courses below.

• Stellar Structure Models	3
• Research Projects II	3
• Research Projects III	4

Elective courses 36

Students choose electives comprising at least 36 credits, either from the list below or from specialized courses included in other Master's programmes, particularly physical applied mathematics (Plasma Astrophysics) courses from the Master of Mathematics and physics courses from the Master of Physics.

• The Milky Way Galaxy	6
• Relativity	6
• Dynamics of Stellar Systems (UGent)	6
• Theoretical Seismology	6
• Capita selecta in Astronomy and Astrophysics	6
• Planetary Systems	6
• Computational Methods for Astrophysical Applications	6

Master's thesis 30

Introductory and General Section (30 credits)

In this section the student has to take courses from the K.U.Leuven curriculum adding up to 30 credits. These courses can be introductory and/or may be of general non-mathematical nature (e.g. dutch course). The programme director advises each student individually so that package of courses in this section is optimally tailored to the student's specific situation and needs. The chosen package has to be approved by the programme director.

Options (60 credits)

The student chooses one of the two options.

1. Option Pure Mathematics

The student chooses for (at least) 60 credits from the subgroups according to the rules specified in each subgroup.

Core Courses (at least two courses, choice)

Deepening Courses (at least two courses, choice)

Exchange Courses (at least one course, choice)

Advanced Courses (at least one course, choice)

Research Seminars (one seminar, choice being determined by the domain of the master thesis)

Elective Master Courses

(The student can choose up to three courses (max. 18 credits) from the option Applied Mathematics or from the Dutch master program)

2. Option Applied Mathematics

The student chooses for (at least) 60 credits from the subgroups according to the rules specified in each subgroup.

Physical Applied Mathematics (at least three courses, choice)

Numerical Mathematics (at least one course, choice)

Probability and Statistics (at least two courses, choice)

Exchange courses (the student can choose one course)

Advanced Courses (at least one course, choice)

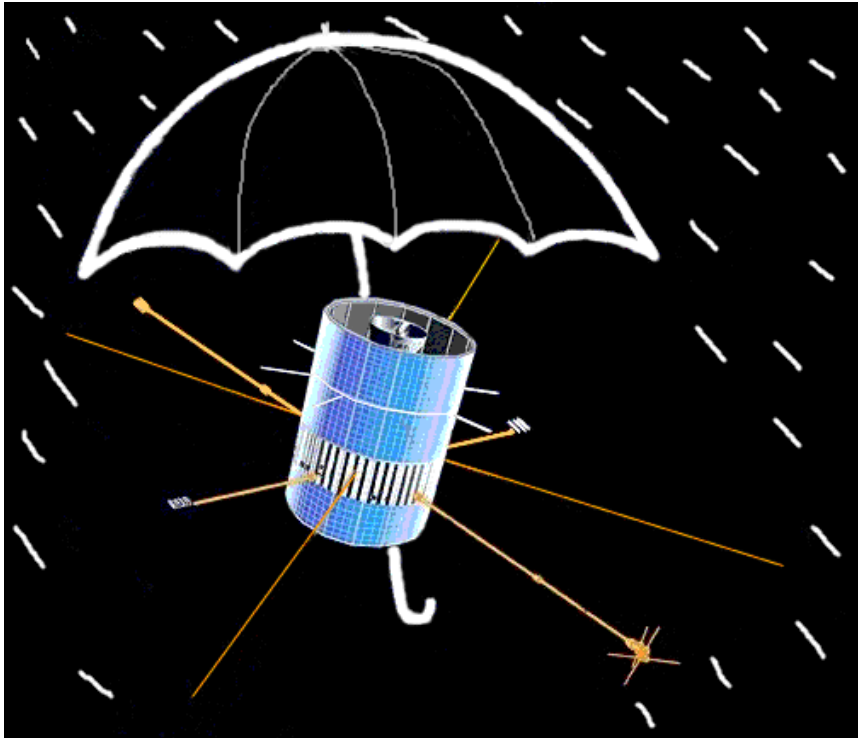
Research Seminars (one seminar, choice being determined by the domain of the master thesis)

Elective Master Courses

(The student can choose up to three courses (max. 18 credits) from the option Pure Mathematics or from the Dutch master program)

Master Thesis (30 credits, compulsory)

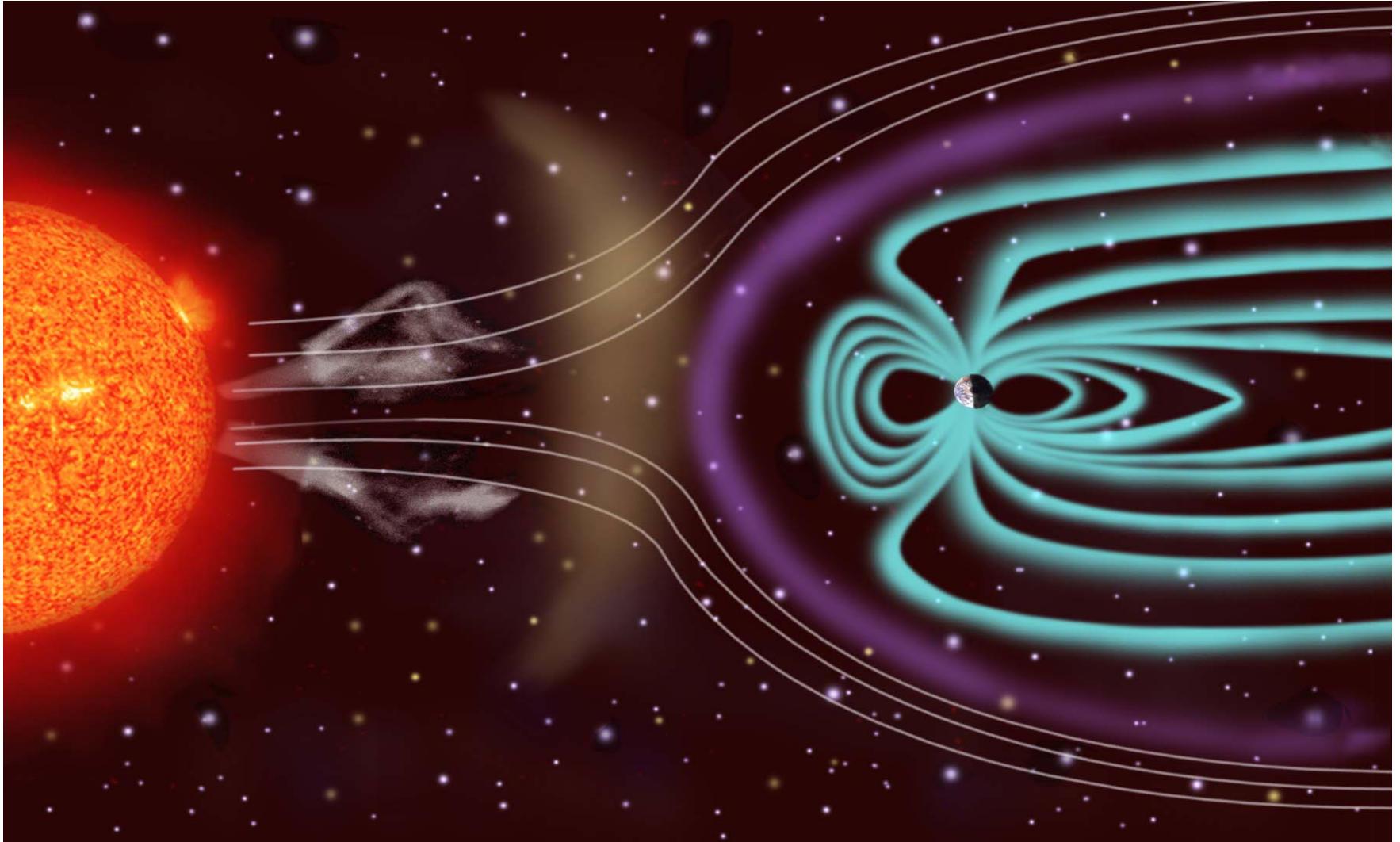
Overview of the space weather class



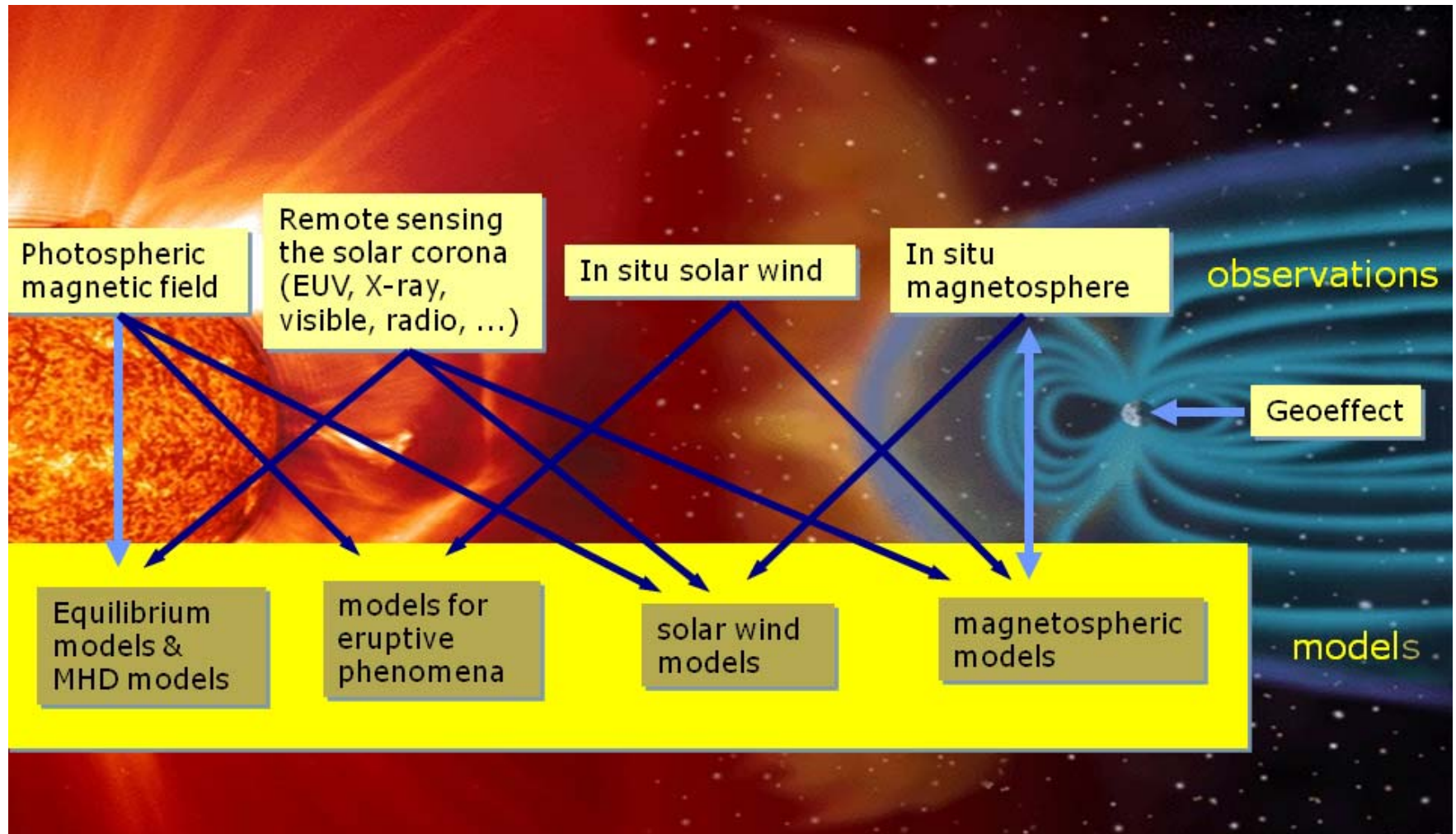
- Some students have little math and physics
- Most students do not know what a plasma is
- Or the structure of the solar system plasma
- Need to provide a short background on the "geography", mathematics and physics of space plasmas
- Regular Students: part A - introduction
- Advanced students: part B - project

- Descriptive Part
 1. Sun and Solar Wind
 2. Heliosphere and Magnetosphere
 3. Typical space weather events
 4. High Energy Particles
- Application Part
 1. Interaction of particles, fields and radiation with matter
 2. Biological impact of space weather
 3. Technological impact of space weather
- Modeling Part
 - Particles and Fields (ABC of plasma physics)
 - Kinetic approach: microphysics of space weather
 - Fluid approach: macrophysics of space weather
- Guest professors:
 - Johan De Keyser: inner magnetosphere and observations
 - Stefano Markidis: kinetic simulation

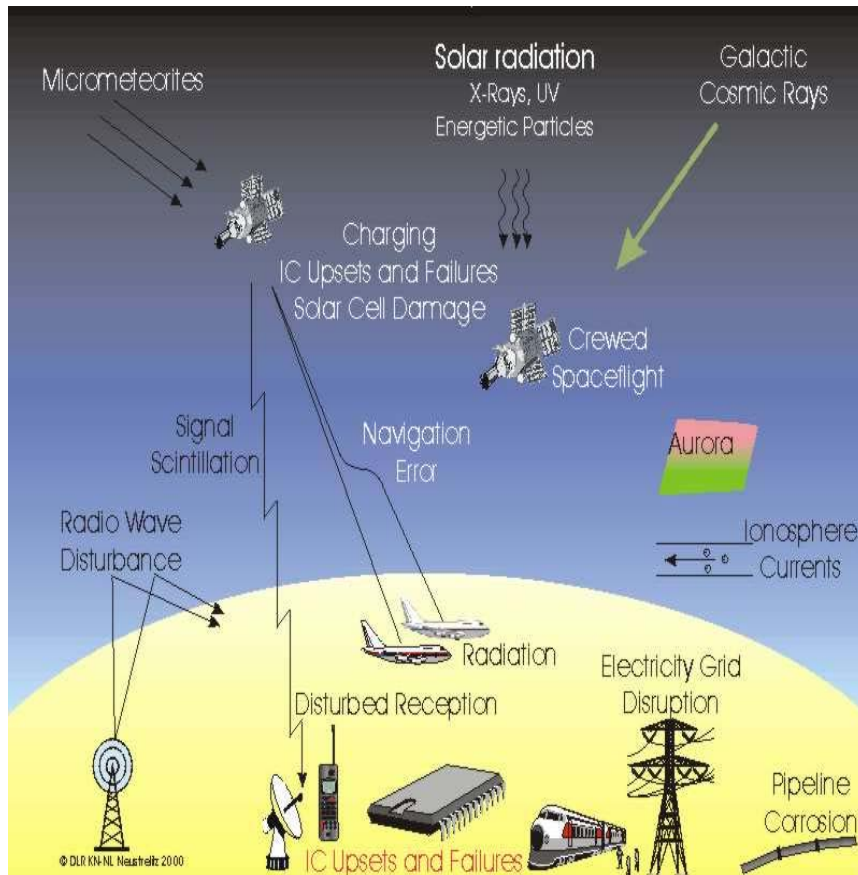
Descriptive part: The Sun-Earth coupling



Modelling part: processes to model



Effects of space weather

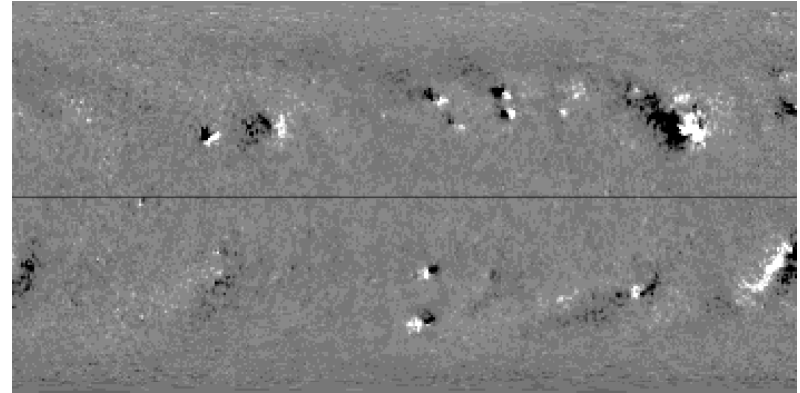


- NASA: Living With a Star, Sun-Earth Connection
- NSF: Cism, Integrated Space Weather Modeling, Geospace Environment Modeling
- NOAA, DOD,...
- Spaceweather.com
- JAPAN: Space Environment & Effects System
- ESA: new initiative SSA, swenet.eu
- In Belgium: ROB, BISA

Descriptive part

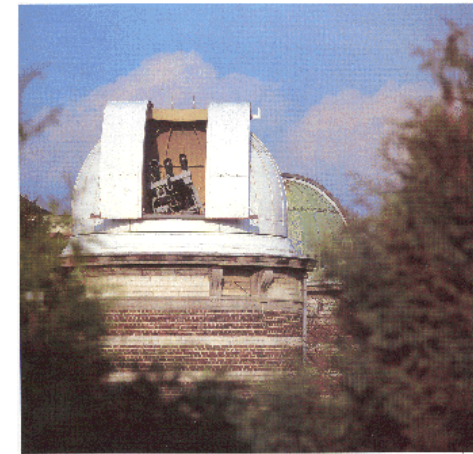
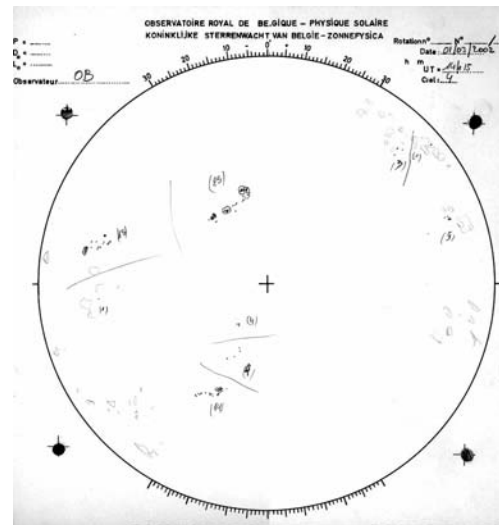
Solar - ground based:

- ROB (Brussel)
- Wilcox Observatory
- Mt Wilson
- GONG



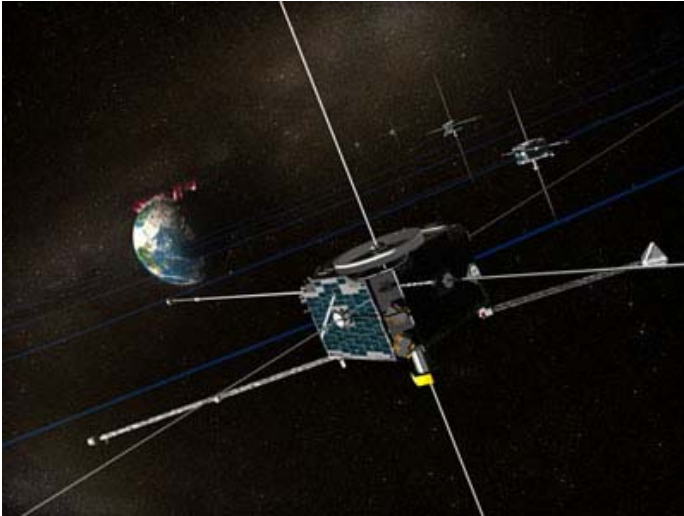
Solar - space based:

- SOHO
- STEREO
- TRACE
- Proba 2
- SDO

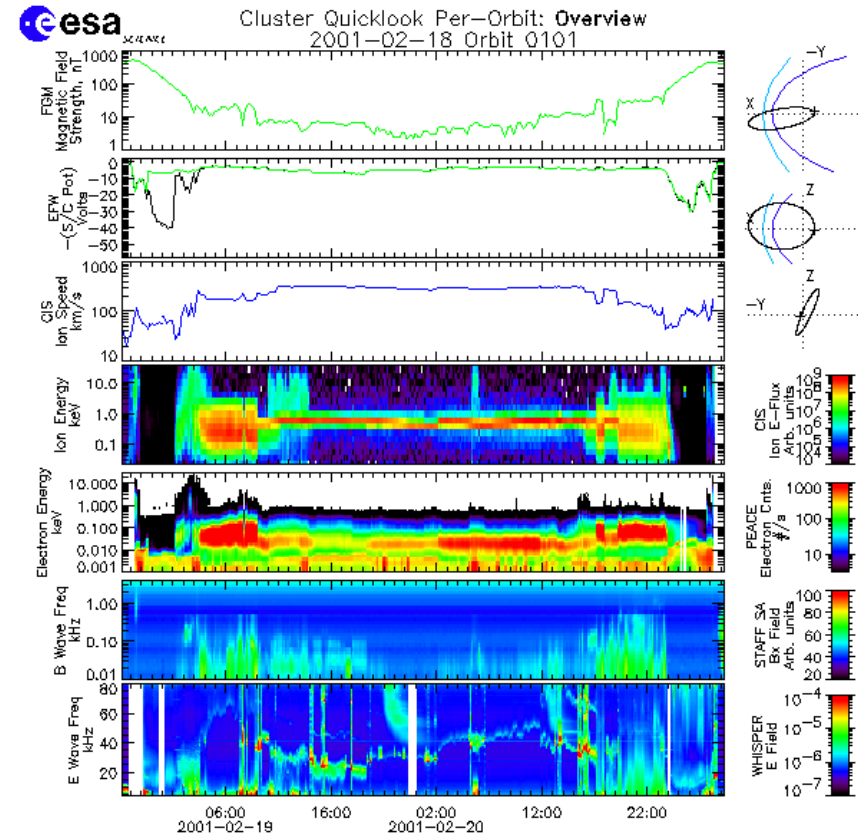


*A typical day for Professor David
(Berghmans)*

Space Missions



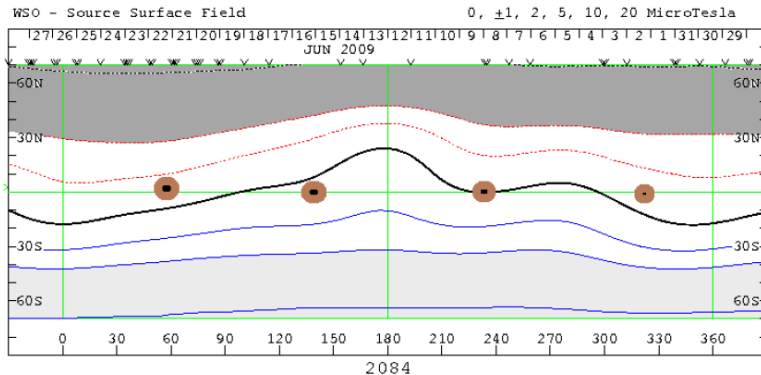
- We cover how to access and use data from probes:
- Themis
- Cluster



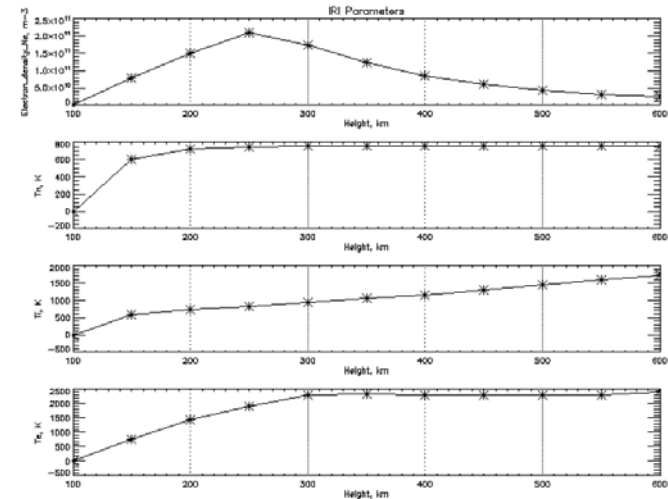
Last Updated: Fri Jun 1 19:04:02 2001

<http://www.cluster.rl.ac.uk/csdweb/>

Example of Tasks done by the students



- Use web resources and models learned in class to predict solar wind at the Earth in different days. From synoptic maps to comparison with ACE data



- Use web resources to study dependence of ionospheric parameter from day to night and with different indices of space weather activity

- A PIC code in
MATLAB

<https://perswww.kuleuven.be/~u0052182/teaching.html>

```
L=2*pi;
DT=.5;
NT=200;NTOUT=25;
NG=32;

N=1000;
WP=1;
QM=-1;
V0=0.2;
VT=0.0;

XP1=1;
V1=0.0;
mode=1;

Q=WP^2/(QM*N/L);
rho_back=-Q*N/L;
dx=L/NG;

% 2 Stream instability
xp=linspace(0,L-L/N,N)';
vp=VT*randn(N,1);
pm=[1:N]';pm=1-2*mod(pm,2);
vp=vp+pm.*V0;

% Perturbation
vp=vp+V1*sin(2*pi*xp/L*mode);
xp=xp+XP1*(L/N)*sin(2*pi*xp/L*mode);

p=1:N;p=[p p];
un=ones(NG-1,1);
Poisson=spdiags([un -2*un un],[-1 0 1],NG-1,NG-1);
```

```
for it=1:NT

    % aggiornamento xp

    xp=xp+vp*DT;
    out=(xp<0); xp(out)=xp(out)+L;
    out=(xp>=L); xp(out)=xp(out)-L;

    % proiezione p->g

    g1=floor(xp/dx-.5)+1;g=[g1;g1+1];
    fraz1=1-abs(xp/dx-g1+.5);fraz=[fraz1;1-fraz1];
        out=(g<1);g(out)=g(out)+NG;
        out=(g>NG);g(out)=g(out)-NG;

    mat=sparse(p,g,fraz,N,NG);
    rho=full((Q/dx)*sum(mat))'+rho_back;

    % calcolo del campo

    Phi=Poisson\(-rho(1:NG-1)*dx^2);Phi=[Phi;0];
    Eg=( [Phi(NG); Phi(1:NG-1)]-[Phi(2:NG);Phi(1)])/(2*dx);

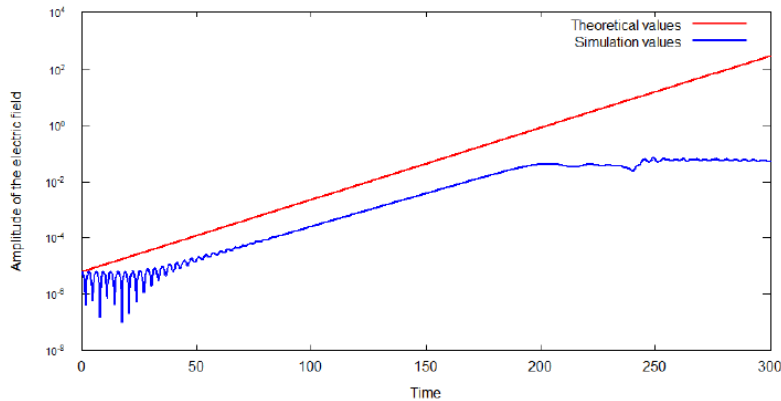
    % proiezione q->p e aggiornamento velocita'

    vp=vp+mat*QM*Eg*DT;

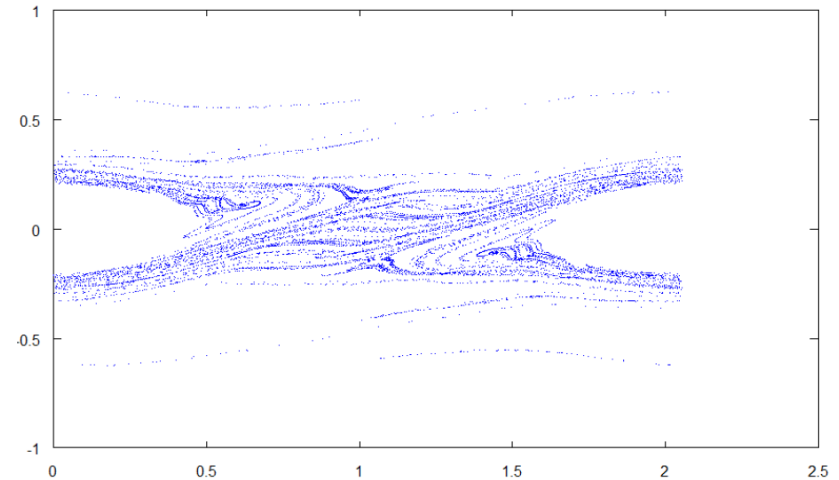
end
```

Runs in MATLAB (not free)
Or in OCTAVE (free)

Examples from student projects: relaxation via wave-particle interaction



Graph 5: Growth of the electric field



* Distribution of the particle velocities at a given time:

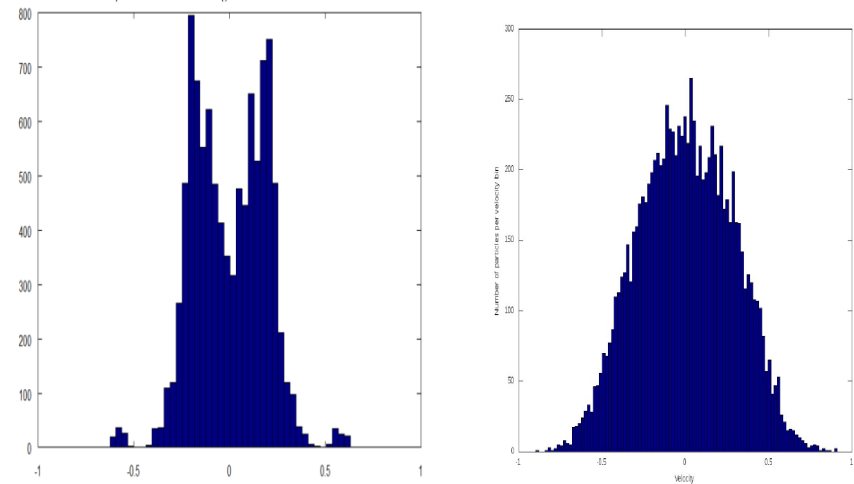
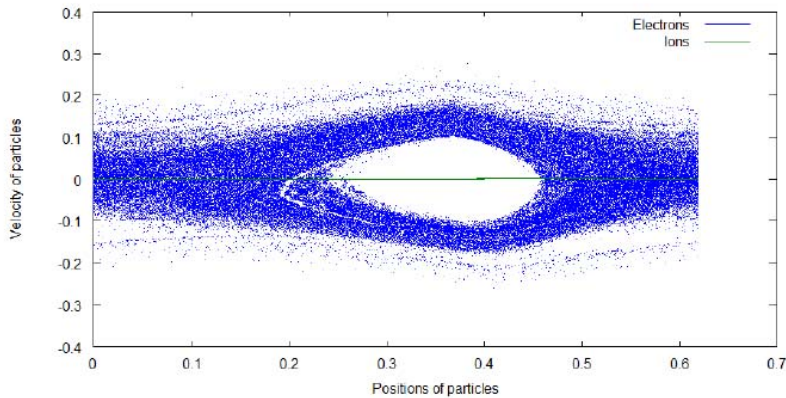


Figure 22: Velocity distribution function at timestep 6000.



Graph 4: Phase-space plot of the electrons after 300 plasma periods



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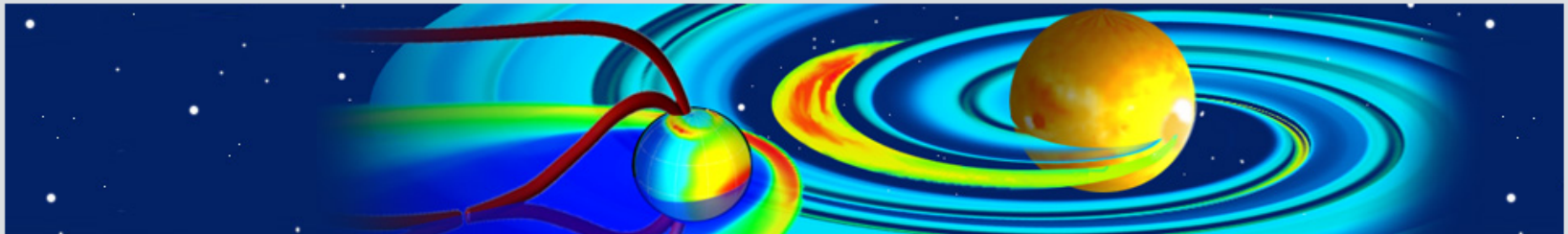
[Space Weather Models at CCMC](#)

[Request A Model Run](#)

[View Model Run Results](#)

[Instant Run](#)

[Experimental Real-Time](#)



CCMC Mission Statement

The CCMC is a multi-agency partnership to enable, support and perform the research and development for next-generation space science and space weather models.

CEDAR ETI Challenge

CCMC is supporting CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Modeling Challenge. The outcome of the preliminary round of model output comparisons will be discussed at the [CEDAR 2010 Workshop](#) (June 25, 2010, 10:30 - 12:30). To participate in this first round of the Challenge please submit your model results using CCMC on-line [submission interface](#) prior to June 1st, 2010.

[Find out more](#)

CCMC Services

- We provide, to the scientific community, access to modern space research models
- We test and evaluate models
- We support Space Weather forecasters
- We support space science education

Latest Additions to the CCMC Services

- [Integrated Space Weather Analysis System](#) is a web-based dissemination system for NASA-relevant space weather information.
- [Space Weather Awareness at NASA](#) space weather information portal.
- [LWS Supported Tools and Methods](#)
- [Kameleon software](#): model output from different

Sample of one project based on CCMC

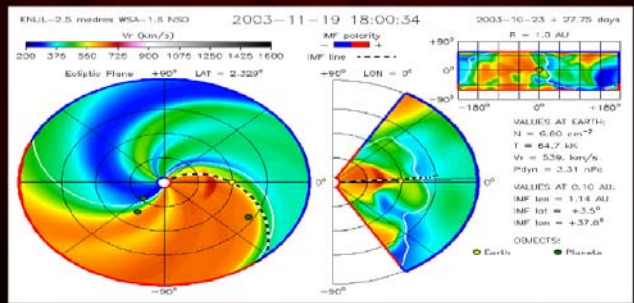
Modeling a space weather event:
Coronal Mass Ejection



Jan Deca
June 29, 2003
Space Weather
Centre for Plasma Astrophysics
Katholieke Universiteit Leuven

ENLIL: Heliosphere

✓ Velocity = Density = Pressure



ENLIL-2.5 method WSA-1.6 NSC 2003-11-19 18:00:54 2003-10-23 + 27.75 days
R = 1.0 AU

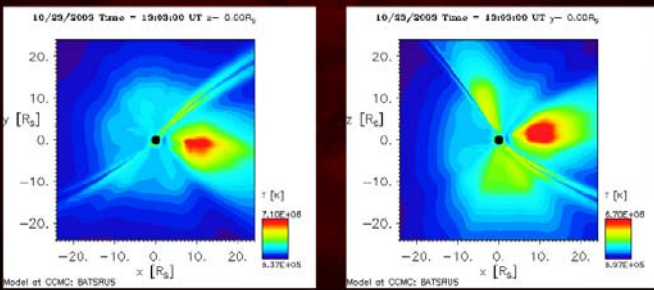
VALUES AT EARTH:
N = 6.80 cm⁻³
T = 64.7 eV
Vr = 539 km/s
Pdyn = 0.31 nPa

VALUES AT 0.10 AU:
IMF lat = 3.14 AU
IMF lon = -3.58°
IMF lat = 4.37 AU

OBJECTS:
● Earth ● Planets

SWMF: Solar Corona

✓ Temperature

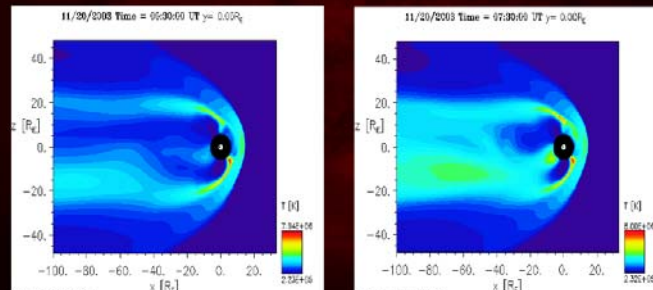


10/29/2003 Time = 19:03:00 UT z = 0.00R_s
10/23/2009 Time = 19:05:00 UT z = 0.00R_s

Model of CCMC: BATSURS

SWMF: Global magnetosphere

✓ Temperature



11/26/2003 Time = 05:30:00 UT y = 0.00R_s
11/20/2003 Time = 07:30:00 UT y = 0.00R_s

Model of CCMC: BATSURS

Tasks relative to effects of space weather

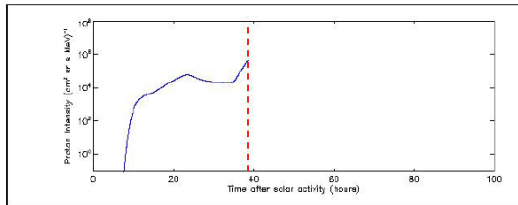


Figure 6: The intensity of 125 eV protons after the solar activity.

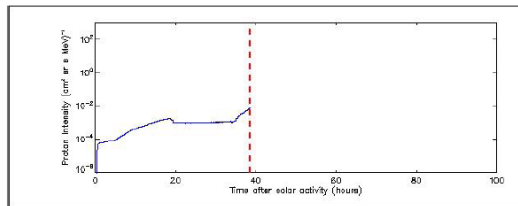


Figure 7: The intensity of 64 MeV protons after the solar activity.

Input Details Compound Details Options

Input

Projectile

Projectile Ion:

Energy (MeV):

Target

Water (liquid) Density (g/cm³):

Mono-element Solid

Predefined compound Gas

User defined compound

Results

alpha on Water (liquid)

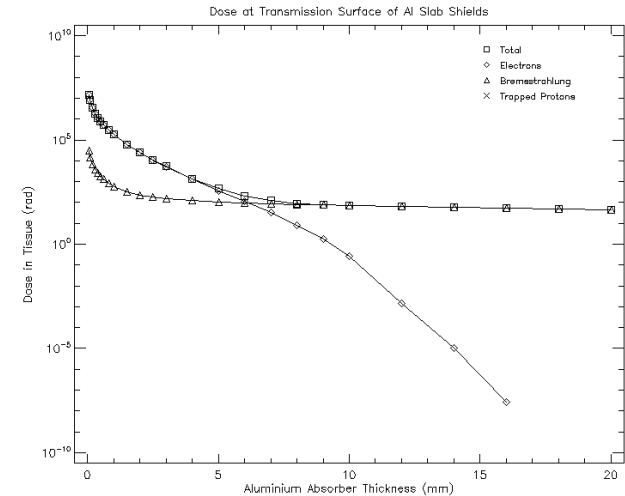
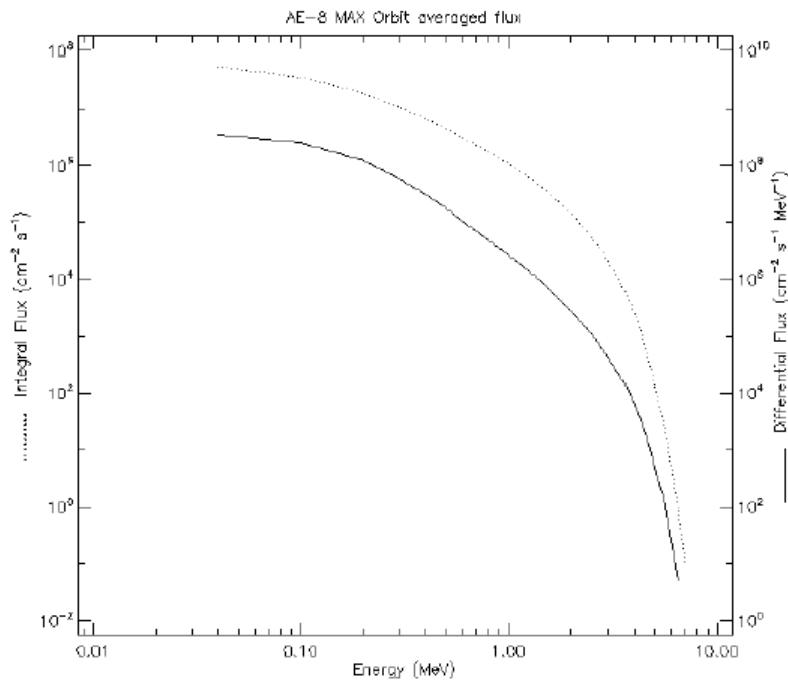
Projected range, R: 1.790E+0 mm

Mass thickness: 1.790E+1 g/cm²

Stopping Power (total): 1.554E+2 keV/(mg/cm²)

- Use SOLPENCO to study the propagation of high energy particles
- Determine fluences, time delays for different energies
- Use models to predict range of high energy particles in matter and compare then with the simulations off the NUCLEONICA web site.

Use of Spenvis by the students: radiation dose



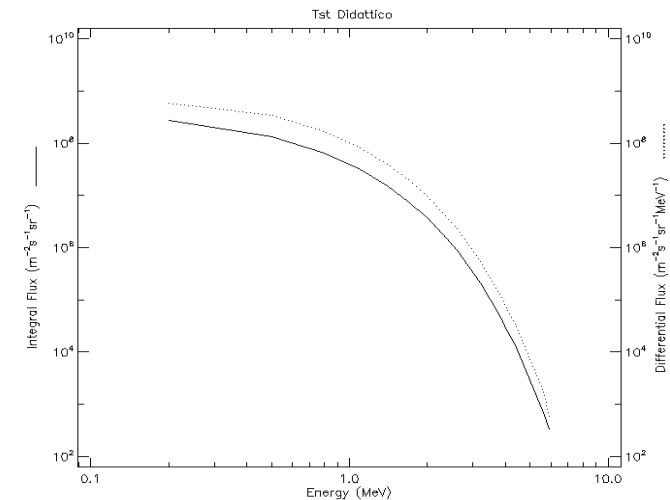
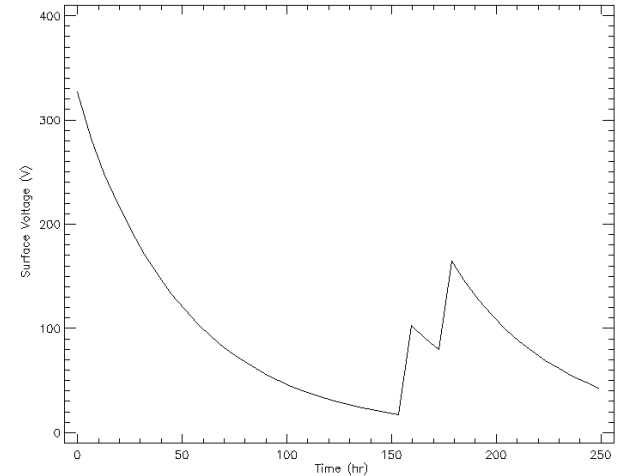
- Obtain the spectrum from the models in Spenvis
- Measure the penetration
- Evaluate dose and risk of cancer to personnel
- Determine thickness of Al to reduce the dose below a prescribed limit

Satellite charging with Spenvis

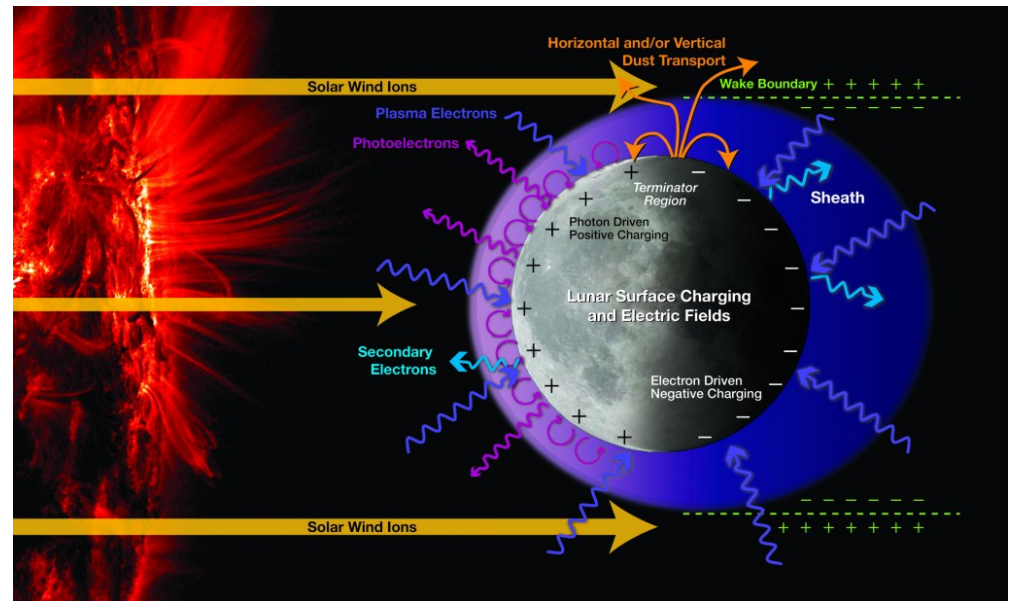
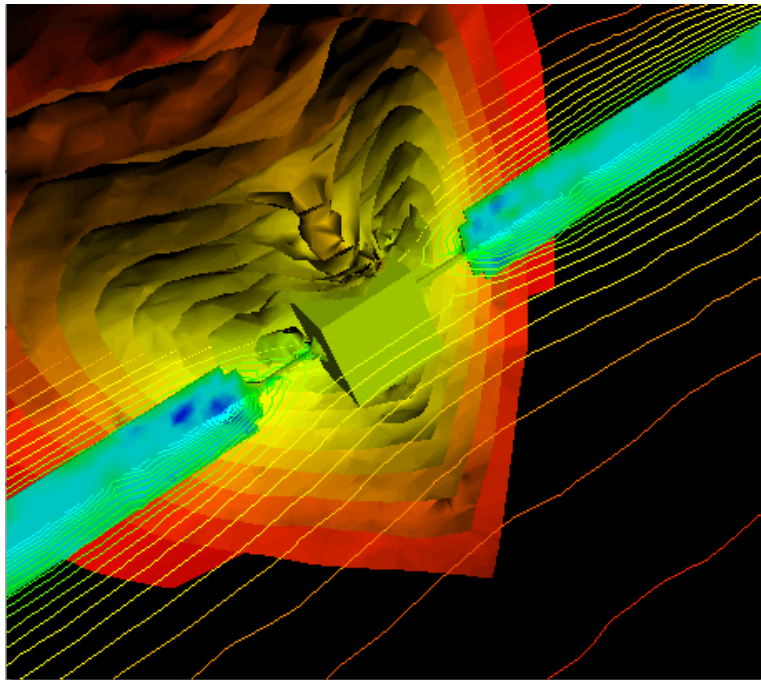
Electron environment:

Geometry and materials. Caution: the default values for the dielectric material parameters are given for reference only. The results of the simulation critically depend on the values of the input parameters.

Geometry: <input type="text" value="cylindrical"/>	
Field of view: <input type="text" value="90.0"/> deg	
Dielectric: <input type="text" value="teflon"/>	Conductors
Thickness [cm]: <input type="text" value="0.1"/>	Shield: <input type="text" value="gold"/>
Temperature [K]: <input type="text" value="298.0"/>	Thickness [cm]: <input type="text" value="0.1"/>
Density [g cm ⁻³]: <input type="text" value="2.17"/>	Core: <input type="text" value="aluminium"/>
Conductivity [Ohm ⁻¹ m ⁻¹]: <input type="text" value="1.0E-16"/>	Radius [cm]: <input type="text" value="0.1"/>
Dielectric constant: <input type="text" value="2.15"/>	
Breakdown el. field [V m ⁻¹]: <input type="text" value="1.0E7"/>	
RIC dose rate factor k_p : <input type="text" value="2.0E-14"/>	
Delta: <input type="text" value="0.7"/>	
Activation energy [eV]: <input type="text" value="0.0"/>	
Grounded at <input type="text" value="one surface"/>	
<input type="text" value="inner"/> <input type="text" value="surface"/>	



Plasma Simulation in Space



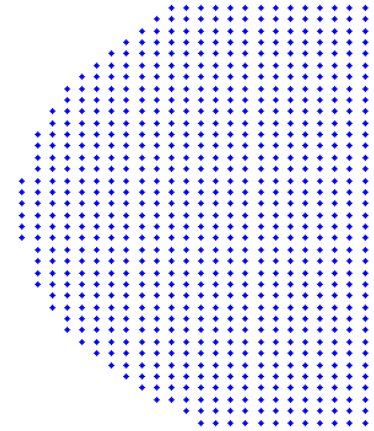
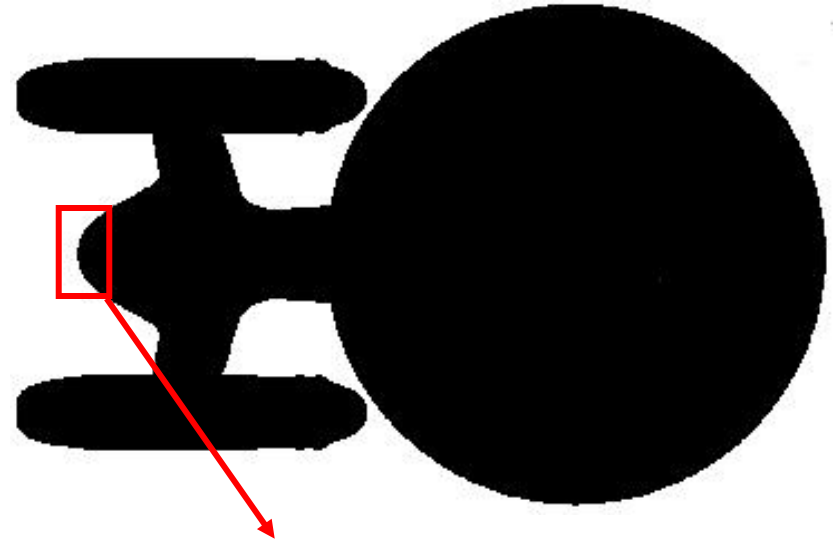
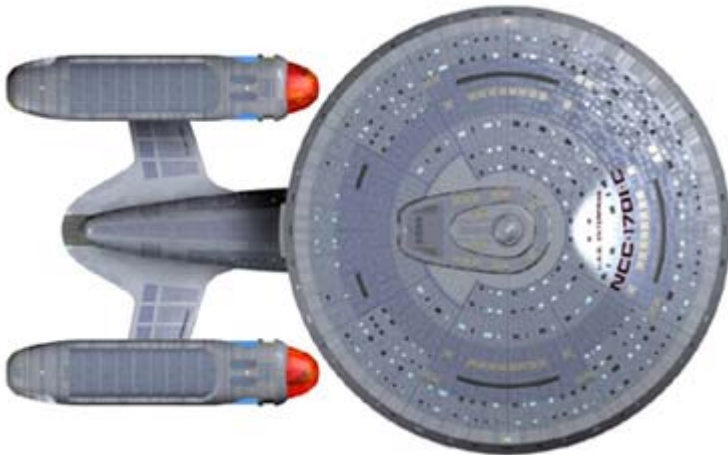
Lunar Science Institute in Boulder

ESA Spine Program
(SPACECRAFT PLASMA
INTERACTIONS NETWORK IN EUROPE)

Charging: The DEMOCRITUS Code

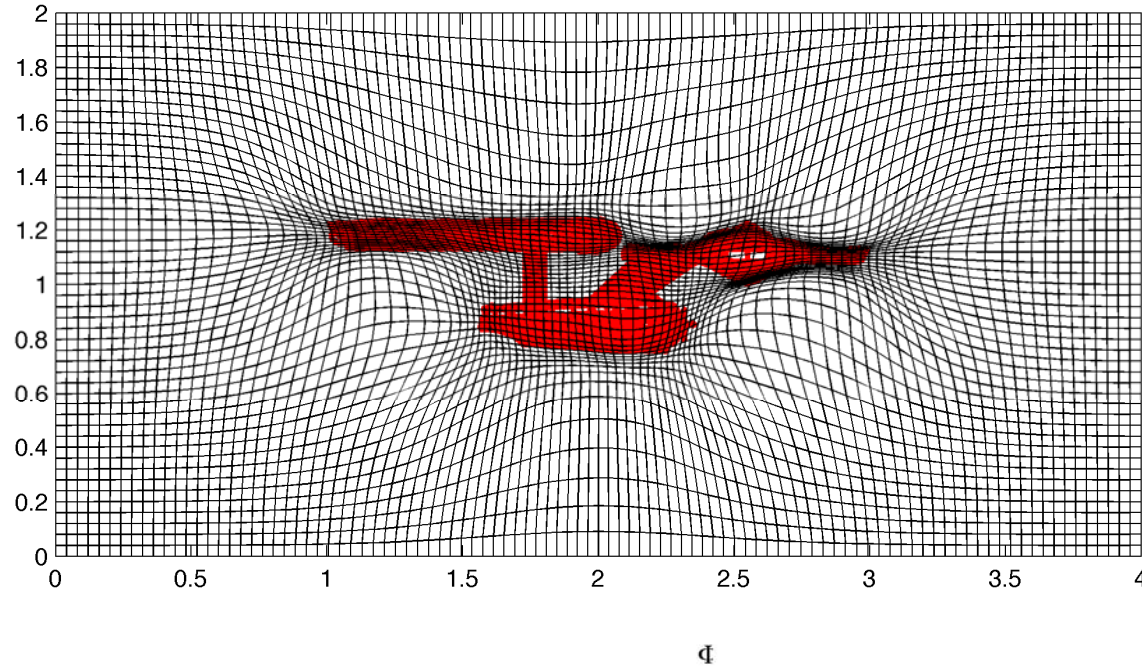
Model Features

- Model of the Enterprise
- Simulations with our code
Democritus
<http://code.google.com/p/democritus/>

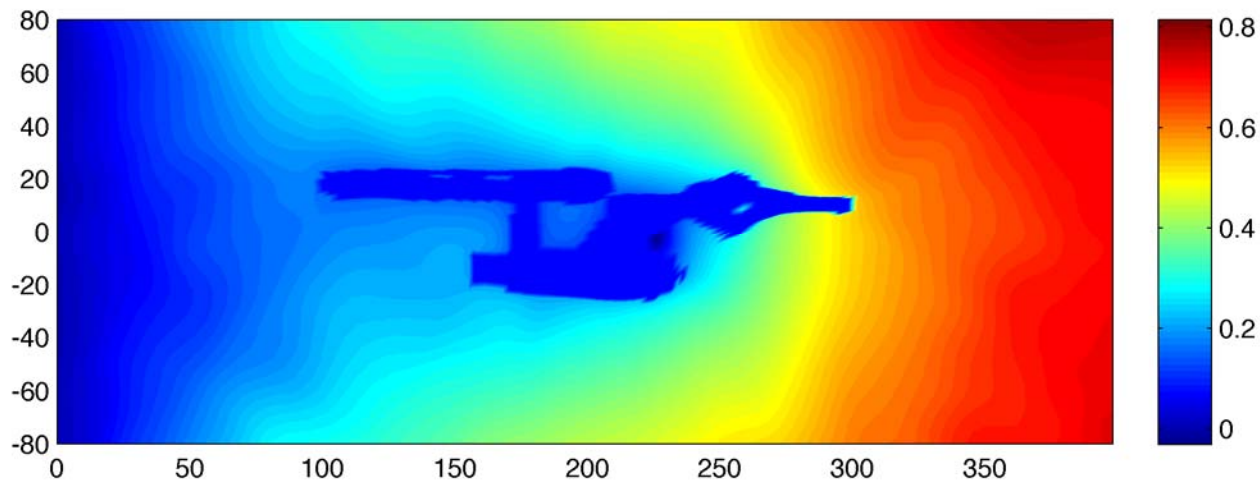


DEMOCRITUS (2D) and CELESTE (3D) available on **google codes**

Charging in a flowing plasma



Adaptive Grids



A shock hitting the Enterprise

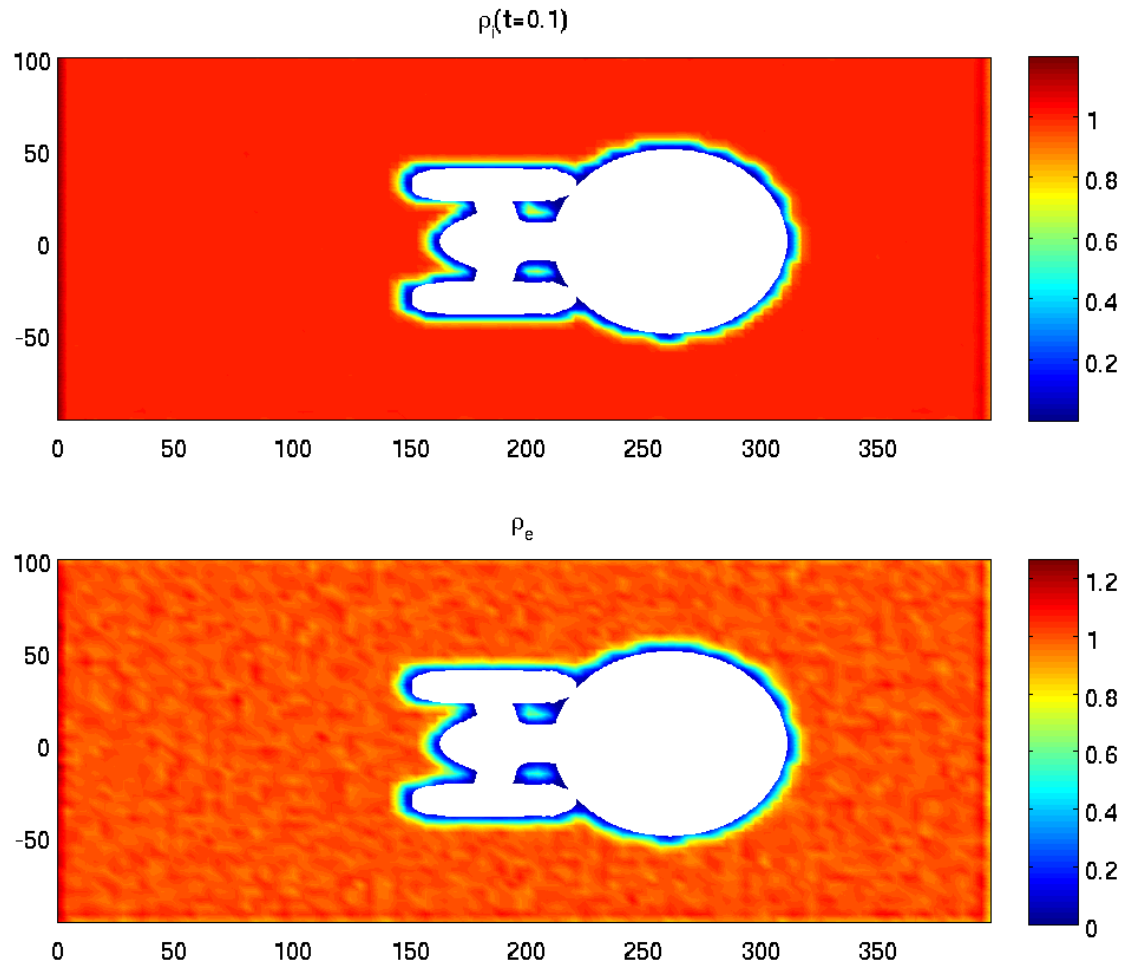
barrier

shock



Plasma arriving from the right, hits barrier on the left and causes a shock traveling forward.

Example: Enterprise hit by a shock



Ion (top) and Electron (bottom) density

Use of Space weather resources

Training on the use of the space-weather resources.

EUROPEAN SPACE WEATHER PORTAL
The European gateway to Space Weather resources

Home | Search | Log in

Navigation

- About
 - COST
 - GOTERIA
 - STCE
 - SWENET
 - SWWT
- Services
 - Model Access
 - Repository
 - Data Access
 - Now / forecasting
 - Software
- Outreach
 - Introduction
 - Activities
 - Bibliography
 - Images
 - Glossary
 - Books
 - Your Language
- Other resources
 - Events
 - Topical Links
 - Audio
 - Publications
- Feedback
- Groups

Welcome
Submitted by Sighi Cadden on Wed, 11/05/2010 - 18:33.

Welcome to the European Space Weather Portal (ESWeP), an integrated website providing a centralized access point to the space weather community to share their knowledge and results. Initiated under the COST 724 Action and hosted by the Belgian Institute for Space Aeronomy, the ESWeP will be further developed in the framework of various European space weather projects.

On the left-hand side of this website, you will find the ESWeP menu. It provides links to web services, contact pages and various outreach pages. You will also find a login section, where you can register if you want to. Registered users have more privileges than others. There is also a search engine which you can use to find text contained in this website.

A service for the general public

On the ESWeP, a large section is devoted to education and outreach. Children as young as five years old are invited to get involved in some of these activities. For example, artworks illustrating space weather made by primary school children from several countries are presented on the website. Most of the outreach pages are translated into different languages thanks to the contribution of several members of the COST Action. You will be able to see the translations by searching on the right-hand side of the website. Please note that if no translation is available English is used as the default language.

You can read more about Space Weather on our Introduction page. The Portal provides also a platform to run local and remote models and access their results both in graphical and various numerical forms.

Plasmapause location



2010-06-02 12:30

SEP event forecast



2010-06-03 09:35:00

[Add your forecast]

National Weather Service
Space Weather Prediction Center

Site Map | News | Organization

Top News of the Day: On 01 June 2010 Thule Neutron Monitor Data was discontinued in Space Weather Prediction Center products.

Space Weather Enterprise Forum 2010 -- Building an Informed and Resilient Society -- the Decade Ahead -- National Press Club Washington DC June 8, 2010

Current Space Weather Conditions

----- Satellite Displays ----- | ----- Popular Pages -----

Latest GOES Solar X-ray image | **NOAA Scales Activity**

NOAA Scale	Range 1 (minor) to 5 (extreme)	Past 24 hours	Current
Geomagnetic Storms		none	none
Solar Radiation Storms		none	none
Radio Blackouts		none	none

Support Services: About Us, Staff, Email Products, Space Wx Workshop, Education/Outreach, Customer Services, News & Media Info.

SWENET | **esa** | **h**

SWENET Contents

- Introduction
- SWENET Services
- Look for Services
- Latest Data
- Space Weather Data
- Data Browsing
- Data Analysis
- Index Quality
- FTP Mirror
- Latest SWPC Plots
- Latest Alerts
- Latest Indices
- Statistics
- Daily Reports
- Message of the Day
- Report Browsing
- Resources
- Documentation
- Tutorials
- Release Information
- Web Service
- User Area
- Login
- Register

Welcome to SWENET
Space Weather European Network

What is SWENET?	What is Spaceweather?	What can I do on this site?	Latest Upgrades
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The SWENET team is pleased to inform you about the latest features and functions upgrades as well as interface enhancements to the Space Weather European Network Portal, version 3.08.

Upgrades:

- Index Quality Statistics made easier by introducing compact vs. full view functionality, and by adding an explanatory section on space weather indices.
- The service DIAS (European Digital Upper Atmosphere Server) has been added with the following data:
 - foF2 maps over Europe
 - Daily sunspot numbers plots
- The service SWACI was introduced. Update 2009-03: Hourly TEC maps over Europe added to database.
- The service BINCASTS added smoothed monthly sunspot data, a long-term data set.
- The service Innoatera added more detailed amateur radio connection data

SWENET Search

Latest Alerts

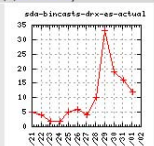
- No active alerts.

SWENET Services

- Ground Effects
- Ionospheric Effects
- Spacecraft Effects

Latest Indices (14 days)

Ap (BINCASTS)



Kp (IRF)



SOTERIA



SOLAR-TERRESTRIAL INVESTIGATIONS AND ARCHIVES

- **Funded by the EC in FP7 -Space Science**
- **Coordinator: G. Lapenta, CPA**
- **Fcous on data and its**

interpretation:

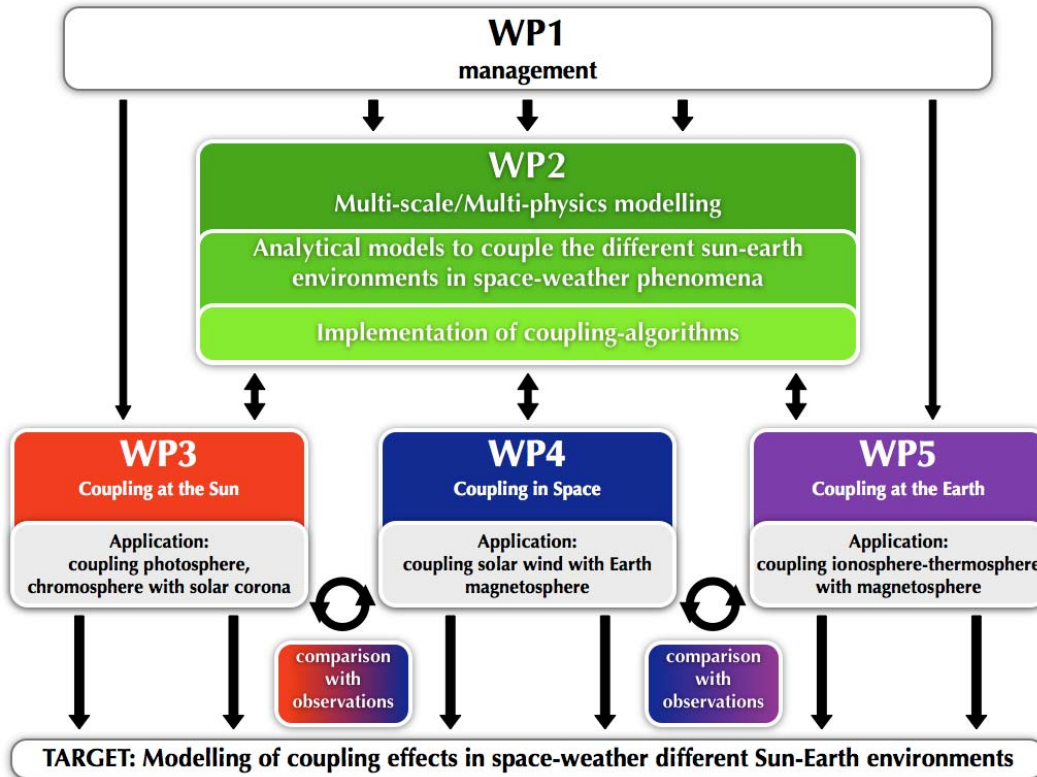
- 1. Photosphere**
- 2. Chromosphere/Corona**
- 3. Heliosphere/Terrestrial effects**
- 4. Irradiance**

Participant Number	Participant short name	Participant organisation name	Country
1 (coordinator)	KU Leuven	Katholieke Universiteit Leuven	Belgium
2	UNIGRAZ	Universitaet Graz	Austria
3	PMOD-WRC	Pyhsikalisch-Meteorologisches Observatorium Davos and World Radiation Center	Switzerland
4	KO	Konkoly Observatory	Hungary
5	CNRS LPCE & LP	Centre National de la Recherche Scientifique	France
6	ROB/SIDC	Koninklijke Sterrenwacht van Belgie	Belgium
7	OBSPARIS	Observatoire de Paris	France
8	SRC-PAS	Space Research Centre, Polish Academy of Sciences	Poland
9	MTA-KFKI-RMKI	MTA-KFKI-RMKI Research Institute for Particle and Nuclear Physics	Hungary
10	DTU	Technical University of Denmark	Denmark
11	UOulu	University of Oulu	Finland
12	UGOE	Georg-August-Universität Göttingen Stiftung Öffentlichen Rechts	Germany
13	HVAR	Hvar Observatory, Faculty of Geodesy, University of Zagreb	Croatia
14	NOVELTIS	Noveltis Sas	France
15	FIAN	P.N. Lebedev Physical Institute	Russia
16	IEEA	Informatique Electromagnetisme Electronique Analyse numérique	France

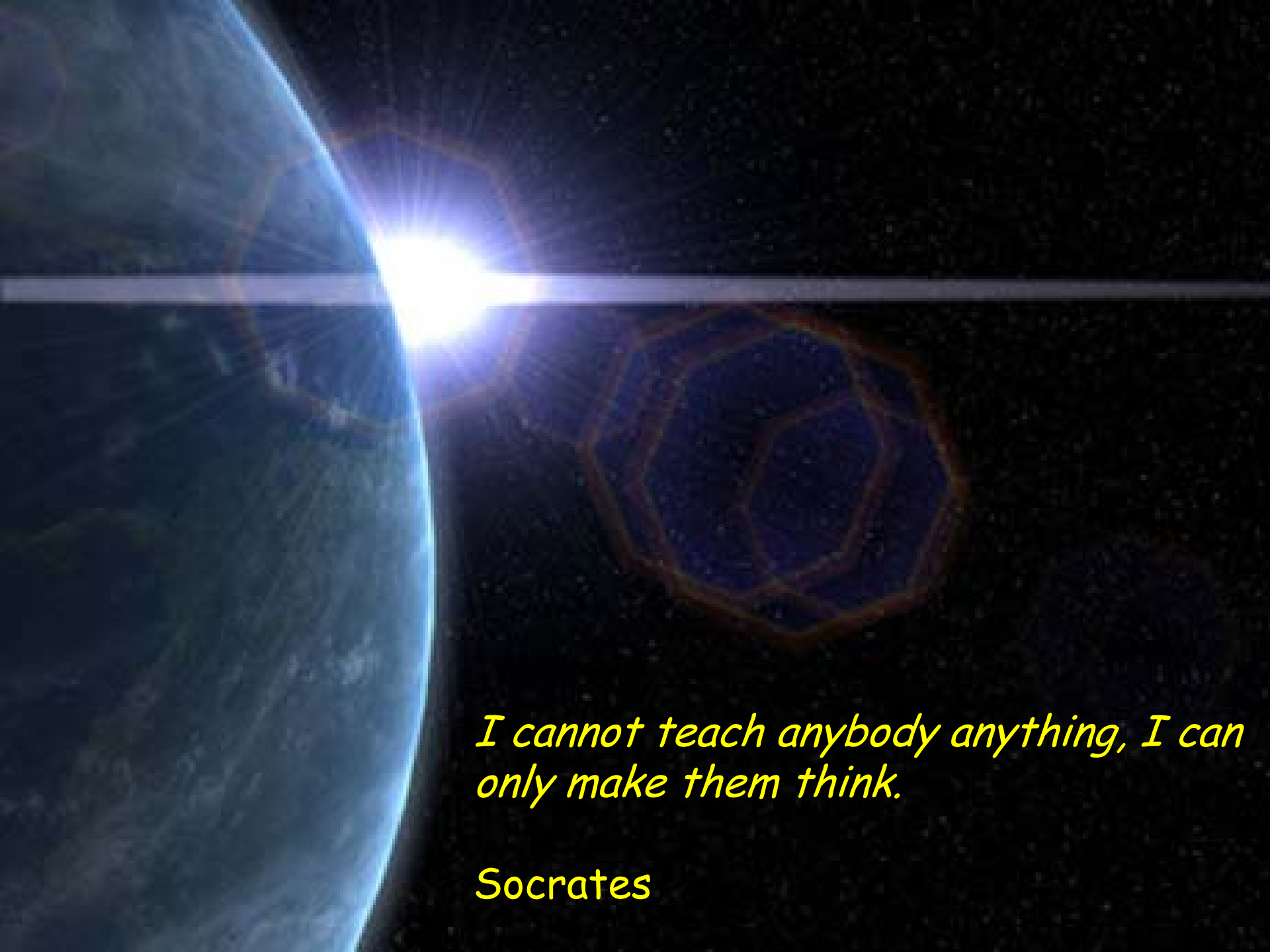
www.soteria-space.eu



SWIFF: New FP7 project on space weather modelling



Participant short name	Participant organisation name	Country
KU Leuven	Katholieke Universiteit Leuven	Belgium
BISA	Belgian Institute for Space Aeronomy	Belgium
UNIPI	Università di Pisa	Italy
UCPH	Københavns Universitet	Denmark
OATO	Astronomical Observatory Turin - Istituto Nazionale di Astrofisica	Italy
ASI	Astronomical Institute, Academy of Sciences of the Czech Republic	Czech Republic
USTAN	University of St Andrews	Scotland, UK



I cannot teach anybody anything, I can only make them think.

Socrates

EXTRA SLIDES

Summary of Student's projects - Modelling

- Seven students did a PIC study of streaming instabilities in 2010 (space weather class)
- Three students studied relativistic acceleration with the PIC code in 2009 (astronomy endprojects)
- One student of astronomy is using the PIC code for acceleration by wave-particle interaction (thesis)
- One student of mathematics is using the PIC code for the study of electron holes in the magnetosphere (thesis)
- One student of physics is using the PIC code for the study of solar system formation (thesis)