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# RESPONSE OF PLANETARY ATMOSPHERES OVER TIME TO EXTREME SOLAR CONDITIONS – A SCIENCE THEME FOR THE PLANNED EUROPLANET EU FP-7 PROJECT

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**Abstract.** The European Commission will announce the call for Research Infrastructure proposals for its 7th Framework Programme (FP7) in autumn 2007. In preparation for this, we participate in the EUROPLANET (European Planetology Network: http://europlanet.cesr.fr) project with a research theme called "Response of planetary atmospheres over time to extreme solar conditions." The scientific focus of this activity is a coordinated study of the behaviour of the upper atmosphere, ionosphere, magnetospheric environment and thermal and non-thermal atmospheric loss processes of Earth, Venus, and Mars during "extreme solar events". The idea behind is, that such events can serve as a proxy for the influence of the active young Sun with implications for the evolution of planetary atmospheres (solar system and even beyond - exoplanets), water inventories and habitability.

## 1. Indroduction

The present EUROPLANET project which is supported by the EU within their 6th framework program sated up a network, of co-ordinated activities in Planetary Sciences to achieve a long-term integration of this discipline in Europe. Their aims are to:

1) increase the productivity of planetary projects with European investment, with emphasis on major planetary exploration missions;

2) initiate a long-term improvement of the European planetary work infrastructure;

3) improve European scientific competitiveness, develop and spread expertise in this research area;

4) improve public understanding of planetary environments.

These goals are under achievement by:

1) maximizing synergies between different fields contributing to planetary sciences: space observations, earth-based observations, laboratory studies, numerical simulations, data base development;

2) designing and developing an Integrated and Distributed Information Service (IDIS) providing access to the full set of data sources produced by these complementary fields.

The EUROPLANET project integrated most of the European planetary exploration work, but initially focused on the Cassini/Huygens mission to Saturn

and Titan. In addition to overall co-ordination, 6 further activities were initiated over a 5-years period:

1) set up discipline working groups;
2) co-ordination of Earth-based observations to support space missions;
3) design an outreach strategy;
4) exchange personnel;
5) plan meetings;
6) design and implement IDIS.

At present about 60 planetary science research laboratories and institutes from 17 European countries take part in the project, together with partners in USA, Japan and former Soviet Union countries.

Besides the networking activities the next step will be to use the opportunity of FP7 to upgrade EUROPLANET by proposing to implement it as an Integrated Infrastructure Initiative (I3) within the frame of the Research Infrastructures part of the "Capacities" specific programme. In view of that EUROPLANET issued a call of ideas for categories of research infrastructure activities that are mandatory for I3 projects in February 2007:

1) Joint Research Activities (JRAs):

JRAs are focused on enhancing the capabilities of the current suite of facilities (space missions, observing instruments, laboratory setups, data bases, computing or data analysis centers, etc) available for the European planetary scientists, as well as on establishing technologies and techniques that will be of use for future development of such facilities.

2) Trans-National Access (TNAs):

The TNAs should be based on proposals for enhancing the scientific utilisation of facilities or groups of facilities that are offering or wish to offer their service to European planetary scientists from outside the institutions or countries to which these facilities belong. Under the TNA programme the involved facilities and related users (individual users, working groups, etc.) will get a support which can be used to help with the operating costs of the facility.

As a response to the call of ideas we proposed the space weather related "Response of planetary atmospheres over time to extreme solar conditions" project which raised a big interest within the EUROPLANET community. In the following sections we present the concept of the project and in section 6 we give an update on the stage of the general EUROPLANET FP7 activities.

## 2. Extreme solar events as proxy for the young Sun epoch and low mass stars

The extreme events studied by our team involve enhanced solar EUV and X-ray radiation, neutron fluxes, coronal mass ejections (CMEs) and related intense solar proton/electron fluxes (e.g., SPEs), auroral phenomena, magnetic storms, etc. and the related responses of planetary atmospheres include: thermospheric and ionospheric density variations, changes in atmospheric composition including $O_3$ depletion leading to changes in heating/cooling, temperature and wind perturbations, photo-chemistry, collisional excitation, deactivation and cooling due to IR-, optical and UV-emissions, magnetospheric compression, enhancement of secondary particles, etc. Studies of the evolution of the spectral irradiances (X-ray, EUV, UV) of solar-type stars of different ages will be used as a proxy for reconstructing the history of the Sun's radiation output.

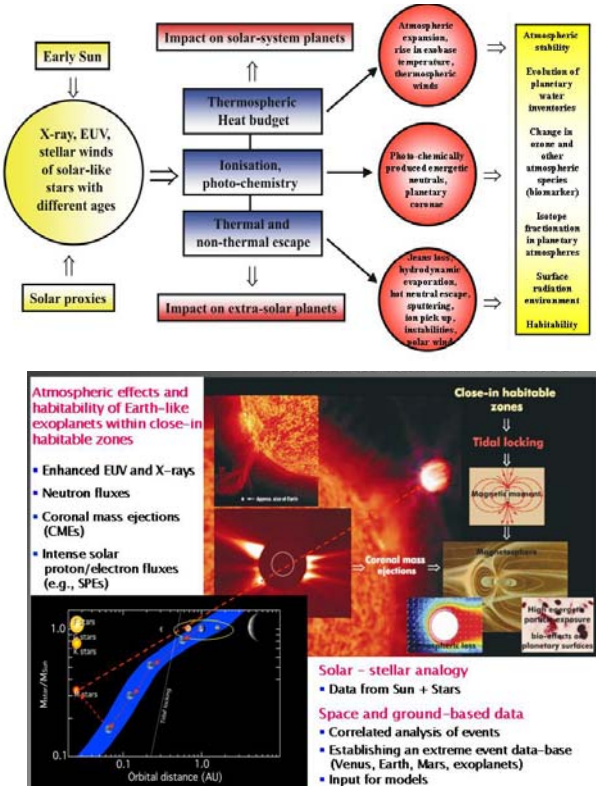


**Fig. 1:** Illustration how solar/stellar radiation affects planets. The observations and scientific data obtained at Earth during extreme solar events can be used as a proxy for studying the response of atmospheric environments on Earth-like planets within close-in habitable zones of lower mass stars which are more active compared to the Sun.

Complementary information concerning solar mass loss (solar wind) will be derived from studies of the energy distributions of flare related CMEs during low and high solar activity by extrapolating CME related solar mass loss to the early stage of the solar system using solar proxies. The available resources or our team contains both, space-based and ground based data sets as well as advanced numerical tools.

## 3. Available space-based and airborne data sets

Our group has access to energetic particle data (40 keV, several 10s MeV) recorded at L1 over eleven years by the LION instrument on SOHO, data which will be obtained by the WAVE instrument on board

of STERO, particle, near-Earth proton fluxes will be used from GOES satellites, magnetic field and electromagnetic data from the Phobos 2 mission to Mars and its Moons, plasma data from ASPERA-3 (Mars Express / MEX) and ASPERA-4/magnetic MAG data (Venus Express / VEX), CLUSTER and Double Star, ENA data from MEX, VEX, and NUADU (Double Star). Density and temperature changes in the Earth's thermosphere during extreme solar events will be analyzed using low perigee satellite data (e.g., CHAMP, GOCE). Short/medium duration ionospheric disturbances can be monitored using GPS and GLONASS transmissions revealing large variations in the northern hemisphere total electron content (TEC). Europe's GOMOS/Envisat instruments provide observations of both short-term (days) and long-term (months) atmospheric effects caused by extreme solar events such as SPEs. GOMOS which was developed at the FMI measures e.g. $O_3$, $NO_2$, and $NO_3$ in the stratosphere and mesosphere.


**Fig. 2:** Access of space-based data of the institutes which are involved in the proposed "Response of planetary atmospheres over time to extreme solar conditions" activities.

Data obtained by the Millimetre-wave Airborne Receivers for Spectroscopic CHaracterisation in Atmospheric Limb Sounding (MARSCHALS) project will be utilized to analyze the chemistry and composition in the Earth's thermosphere. Solar and stellar data needed for the reconstruction of the history of the Sun's radiation and particle emissions will be available from observations obtained aboard the SOHO, STEREO, ASCA, ROSAT, EUVE, FUSE, and IUE a satellites . New specific observations will be obtained by XMM/Newton, Chandra and Suzaku. Feasibility studies to observe the stellar hard non-thermal emission with Symbol-X will be performed.

## 4. Ground-based observations

The ground-based observations could include radio tomographic monitoring of the TEC allowing reconstruction of the 2-D structure of the terrestrial ionosphere/thermosphere during extreme solar events. Parameters of the ionosphere can be determined using the EISCAT radar network and magnetometer chain in northern Europe. Furthermore, continuous registration of cosmic rays by the Russian (PGI) neutron monitors located at high latitudes can be used to provide ongoing diagnostics of the near-Earth space environment. A technique is available to identify the characteristics of relativistic solar protons and their sources on the Sun from the data of ground based cosmic ray detectors.

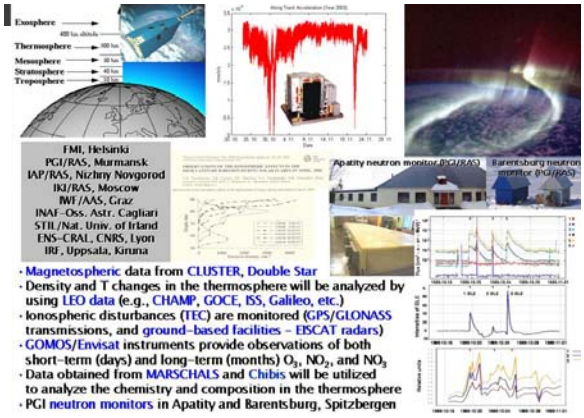


**Fig. 3:** Satellite and ground-based facilities which could be used in the project for studying extreme solar events and their response to the Earth atmosphere and ionosphere environment.

## 5. Advanced modelling tools

Our interdisciplinary team has access to highly advanced numerical tools like test-particle/Monte Carlo type models, MHD models, hybrid models, diffusive-photochemical, thermal balance, and global circulation models. These numerical models are available for: investigating ionized and neutral atmospheres, solar wind/planetary interactions, and particle energy deposition in the upper atmospheres. Codes like the 1-D Sodankylä ion and neutral chemistry model are planned to be used to study the ionospheric-atmosphere interaction processes, caused by e.g. proton/electron precipitation or X-ray flares, which lead to changes in atmospheric composition. The new results which will be obtained by a coordinated application of these different models will

connect existing and establish new databases concerning planetary responses to extreme solar events and can be made available to the general scientific community. Besides the relevant enhancement in science the results of our planned project will have interesting synergies to space weather effects on satellites (drag, anomalous behaviour / failure), navigation and tracking difficulties, spacecraft/mission design, as well as radiation hazard issues for future manned missions (e.g., Moon, Mars).

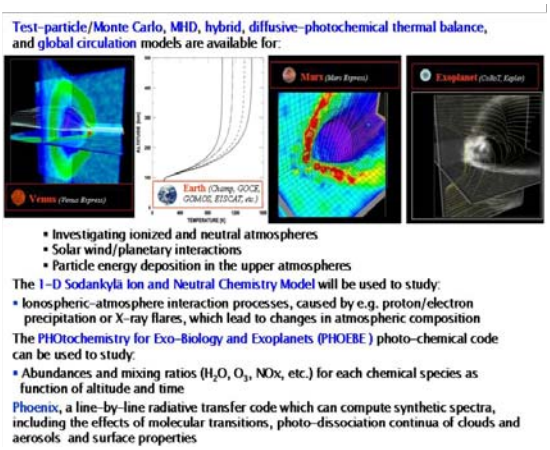


**Fig. 4:** Illustration and examples of highly advances modeling tools which are planned to be applied in a coordinated way for studying the response of planetary atmospheres to extreme solar events.

## 6. Present stage of the EUROPLANET FP7 EU project

After briefings at the EU in Brussels it is clear that the budget for the whole EUROPLANET FP7 project will be limited to up to about 6 M€ and can not be more than about 10 - 15 M€ for exceptional cases justified by the size of the community. The duration of the project will be 4 years at maximum. The number of main institutes will be about 20 with a large numbers of potential users. The complete proposal will focus on the following scientific themes:

1) giant planets systems as templates of planetary systems (Galileo, Cassini-Huygens, New Horizon, JUNO, Cosmic Vision missions);

2) small bodies and origin of the solar system (Asteroid and comets missions, Dawn, Rosetta, Phobos-Grunt, New-Horizon, Cosmic Vision);

3) terrestrial planets and comparative planetology (strong link to Earth sciences, MEX, VEX, Chandrayaan, Selene, Phoenix, B-C, Aurora programme);

4) magnetic worlds: the Sun-planets connection (Ulysses, all planetary missions, SOHO, Stereo and SOLO, Sentinel, synergies with CLUSTER et al.);

5) exoplanets and Other Planetary Systems (strong link to astrophysics community, COROT, KEPLER, GAIA, Cosmic Vision missions).

The main scientific aim of this EU project will focus on:

1) Planetary aurorae - indicators of magnetospheric activity and magnetosphere-atmosphere coupling.

2) Atmospheric winds and circulation - mechanisms for driving weather systems and energy distribution

3) Planetary surfaces - the results of geological processes and potential life-supporting habitats.

4) Meteoroid and comet studies - comparative study of meteoroid-planet interactions in the inner solar system.

5) Stellar occultations.

6) exoplanets - transferring our understanding of the solar system to predict and interpret future observations.

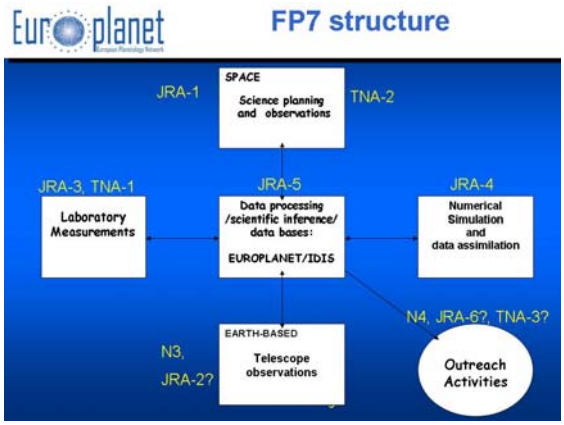


**Fig. 5:** Illustration of the planned Joint Research Activities and Transnational Access subprojects within the next EUROPLANET FP7 EU proposal.

## 7. Conclusions

As one can see form the science themes addressed in section 6, the space weather related topic as discussed in sections 3 - 5 fit well within the whole science structure. The next step will be the identification of all interested parties, including those from outside the EU like from the Russian Federation (e.g. PGI, IKI, etc.) the formation of a draft team which will prepare the first draft with main contents, budget, actions, contractors and user institutes.

The finalisation and integration of the proposal is scheduled for January 2008 and the proposal submission to the EU due February 15th 2008, shortly before the next Apatity Seminar.

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