Sun-Earth Problem: Modern Concepts and Physical Mechanisms

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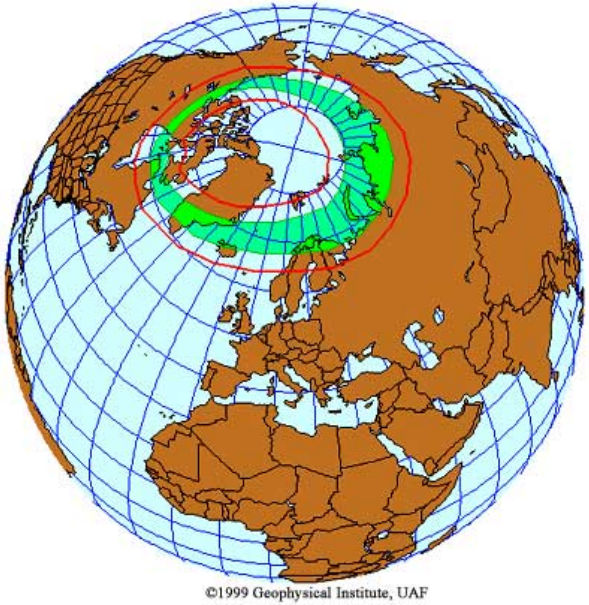
The Sun is a Mother of Our Life…



Space Weather,
Radiation Hazard
in Space, Climate,
Heliobilogy,
Human Health, etc.

Fundamental and Applied Aspects of Solar-Terrestrial Physics

Prerequisites and Background

- «A River of the Truth Flows through the Channels of Delusions».

  Rabindranath Tagore

Abstract

We present a brief review of modern concepts of the Sun-Earth problem and proposed physical mechanisms of solar-terrestrial relations (STR). In fact, this field covers a wide range of fundamental and actual applied problems of paramount importance (Space Weather, radiation hazard in space, functioning of space-borne and ground-based technological systems, heliobilogy etc.). It is also closely tied with some general gnosiological problems (Weltanschauung).

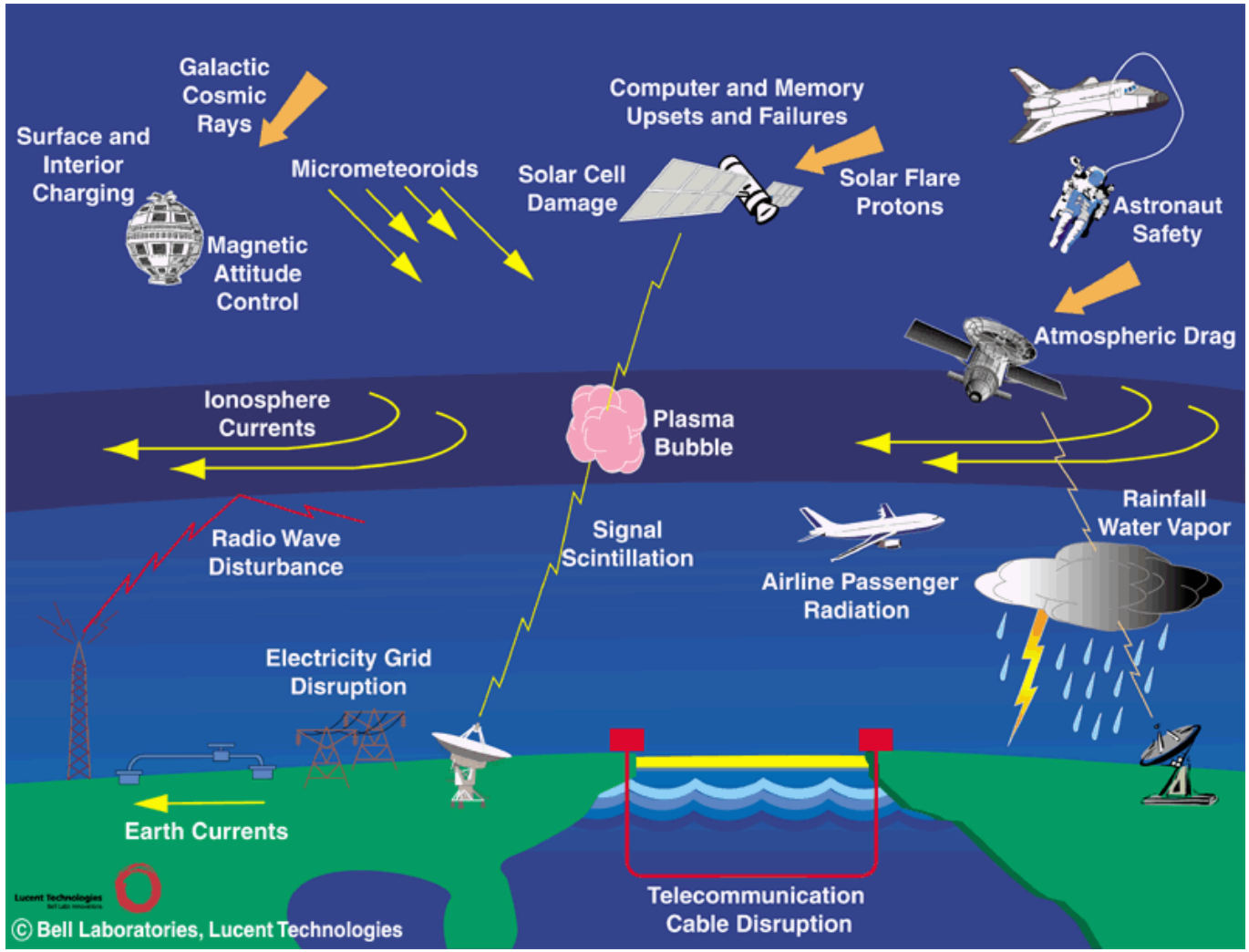
State-of-the-art information about existing problems is given and different channels for extraterrestrial influences are discussed at the up-to-date level: electromagnetic waves and fields, total solar irradiance, solar wind, energetic solar particles, galactic cosmic rays, cosmic dust, etc. Some of well-known and suggested STR effects and corresponding physical mechanisms are illustrated by several examples. In particular, a number of different external "signals" in observed changes of terrestrial climate and weather are considered.

Expected impact of STR

- **Especially, we analyze an expected impact of geophysical disturbances on the accuracy of some precise physical measurements and experiments. Due attention is paid to the heliobiological aspects of STR. In particular, it is emphasized the multifactor nature of magneto-biological effect (MBE), its non-stationary and non-linear behaviour.**
- **We discuss also main features of different physical mechanisms (electromagnetic fields, ionising radiation, triggers, rhythmic and resonances in solar-terrestrial systems) and their applicability to the Sun-Earth problem. The most of them are still needed in more sophisticated theoretical development and experimental confirmation.**

Scheme of STR

Hierarchy of Solar-Terrestrial Relations
(Internet, W-site by Bell Laboratories)



Interdisciplinary studies of STR

- **The main goals of interdisciplinary studies in this field are to determine partial impacts of solar-geomagnetic variability on the terrestrial environments and estimate (separate) relative contributions of different factors into various STR phenomena.**

Main effects in the chain of solar-terrestrial relations

1. Impact on magnetosphere and ionosphere
2. Solar-tropospheric relations
3. Heliobilogy (Sun and biosphere)
4. Solar activity and velocity of the Earth's rotation
5. Resonant structure of the Solar system
6. Total energetics of STR and energy release rate (Triggering of STR)

Crucial points and arising matters

- 1. Ambiguity and nonlinearity of STR (on the example of medical, geomagnetic and air pressure data).
- 2. Applied (prognostic) aspects (on the example of Akasofu parameter). Recent findings (discoveries) in SW-magnetosphere-ionosphere-atmosphere interactions. Role of SW number density in opposite to the role of SW velocity.
- 3. Accuracy of physical measurements and experiments, reliability of space astronomical observations (SOHO, BDE_2000; Mars-Odyssey, October 2003).
- 4. Physical mechanisms of STR (on the example of cosmic rays). Physical and chemical channels of impact.
- 5. Gnoseological aspects of STR.

Solar-tropospheric relations

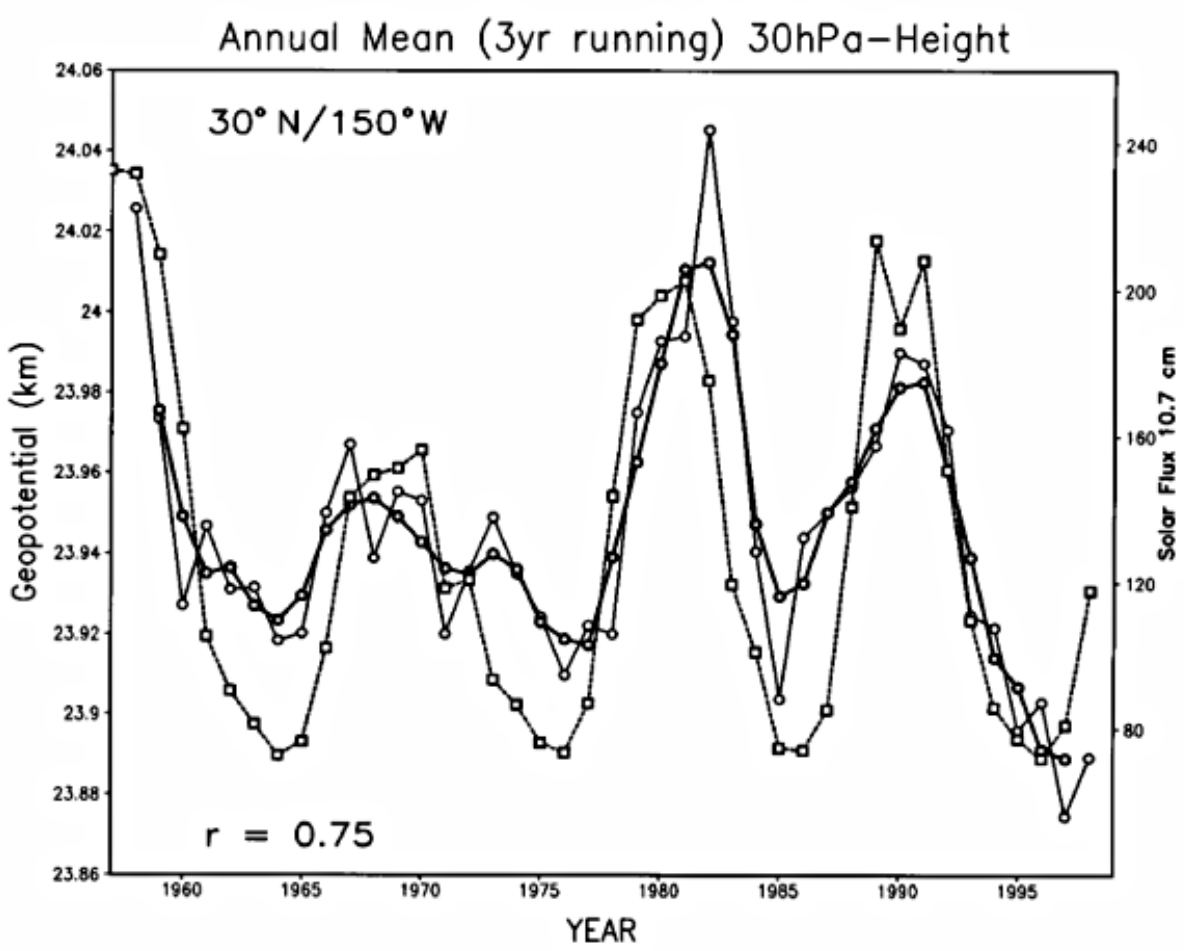
- 1. Heliosphere affects terrestrial climate through solar wind, IMF, cosmic dust etc.
- 2. Climate could be affected by irregular geomagnetic inversions.
- 3. There is an analogy with the processes observed in the Wilson chamber.
- 4. Nucleation (water vapour condensation) is important at the negative charges (ions) in the atmosphere.
- 5. It is possible an artificial (man-made) influence on the precipitations by ionizing radiation (experimental meteorology).
- Influence of ionization on the cloud formation: Experiment in Tomsk, Russia (Krymsky et al., 2007); Experiment CLOUD (CERN, Kirkby et al., 2009).

Geopotential and Solar Activity

Geopotential -

The gravitational potential energy per unit mass at the level h.

Работа, совершаемая при поднятии единицы массы воздуха в поле силы тяжести Земли от исходного уровня с давлением P(0) на высоту с давлением P(h).



- **Time series of annual mean 30 hPa geopotential height (km) at 30N, 150W (thin line with circles), its 3-year running mean (thick line with circles) and the solar 10.7 cm radio flux (dashed line with squares).**

Solar signals throughout the atmosphere

The pioneering work of Karin Labitzke demonstrated a solar cycle variation in stratospheric temperatures. An example of her work is presented above. Figure shows the annual mean, at a location near Hawaii in the sub-tropical Pacific Ocean, of the geopotential height of the 30 hPa pressure surface. This is a measure of the mean temperature of the atmosphere below about 24 km altitude. It varies in phase with the solar 10.7 cm radio wave flux over three and a half solar cycles with an amplitude suggesting that the lower atmosphere is 0.5 – 1.0 K warmer at solar maximum than at solar minimum. This is a large response, but from this figure alone it is not clear whether it applies locally or globally or how the temperature anomaly is distributed in the vertical.

Labitzke, K., van Loon, H. Connection between the troposphere and stratosphere on a decadal scale. *Tellus A*, 47, 275–286, 1995.

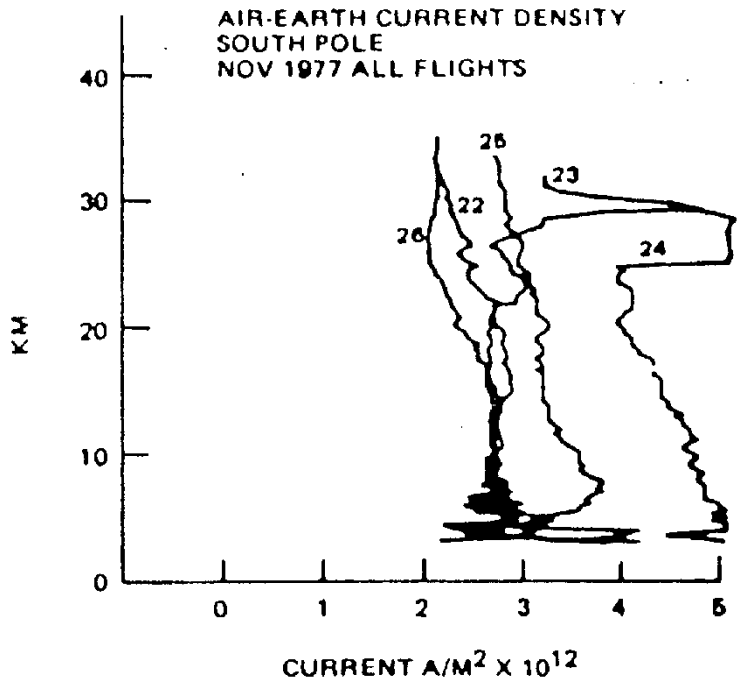
Main channels and basic mechanisms of STR

- 1. Electromagnetic radiation from the Sun
- 2. Ionizing radiation (GCR and SCR)
- 3. Shock wave in solar wind
- 4. Low frequency pulsations of magnetosphere
- 6. Infrasound
- 7. «Chemical channel» (cosmogenic isotopes and nitrates)
- 8. Trigger mechanism
- 9. Resonance relations in the Solar system

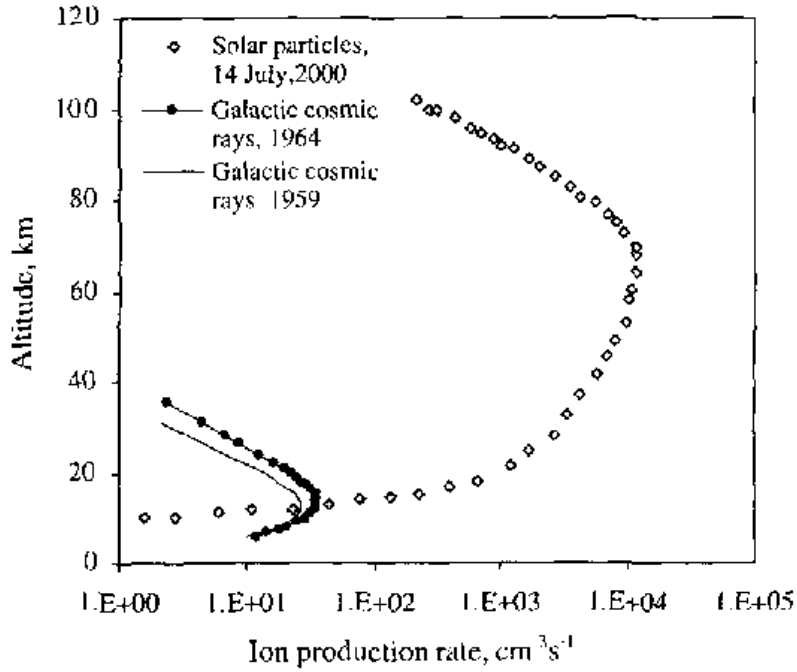
Cosmic rays, weather and climate

- 1. Maunder minimum of SA (1645-1715) was notable for cooling (small ice period).
- 2. Forbush-decreases in GCR intensity are notable for decreasing of precipitation.
- 3. Precipitation become more intensive after solar cosmic ray (SCR) events.
- There are also a number of other important effects of SCR in the Earth's atmosphere: devastation of ozone layer; change of conductivity in the global chain of atmospheric electricity (GEC); influence on the parameters of Schumann resonances in the waveguide «Earth-ionosphere»; influence on the indexes of atmospheric vorticity etc.
- 4. At long-term scale there is a direct relation between GCR, cloudiness, and thunderstorm activity. This correlation become higher when one takes into account a phase of quasi-biannual variations.

Atmospheric conductivity and ionization profiles from SCR and GCR

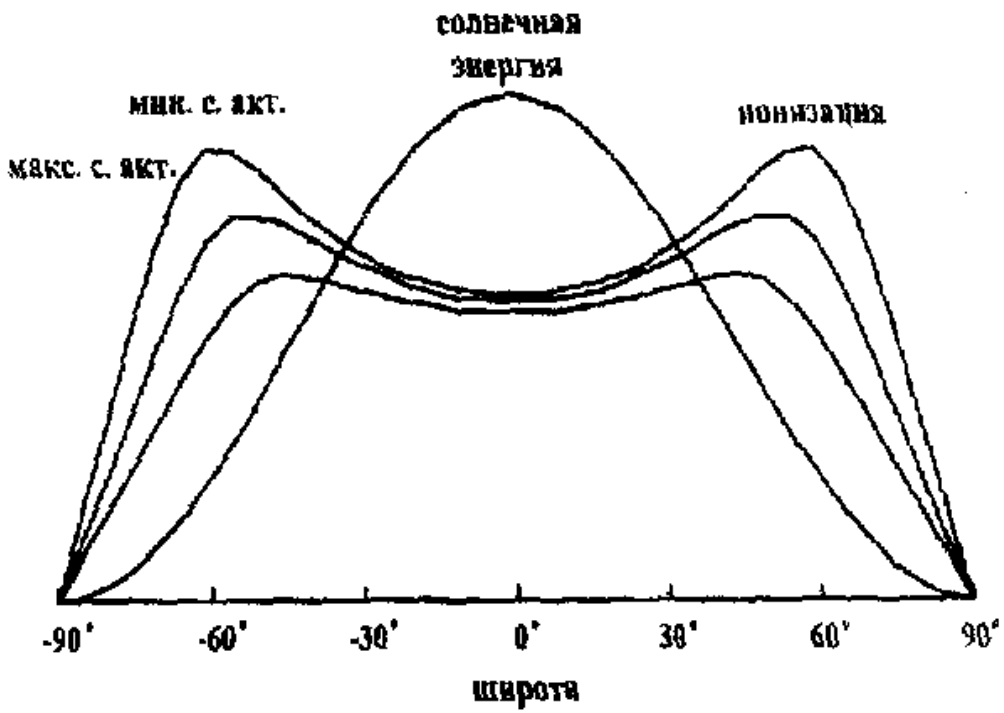


Left: **Density of electric current «air Earth» above South pole by measurements in the stratosphere during SCR event of 22 November 1977 (Cobb,1978).**



Right: Ion production rate in the polar atmosphere during the BDE event of 14 July 2000 due to SCR (Quack et al., 2001), in comparison with ionization from GCR in the minimum (1964) and maximum (1959) of solar activity (Neher, 1971).
Compiled by Bazilevskaya, 2005.

Solar energy input and ionization of terrestrial atmosphere

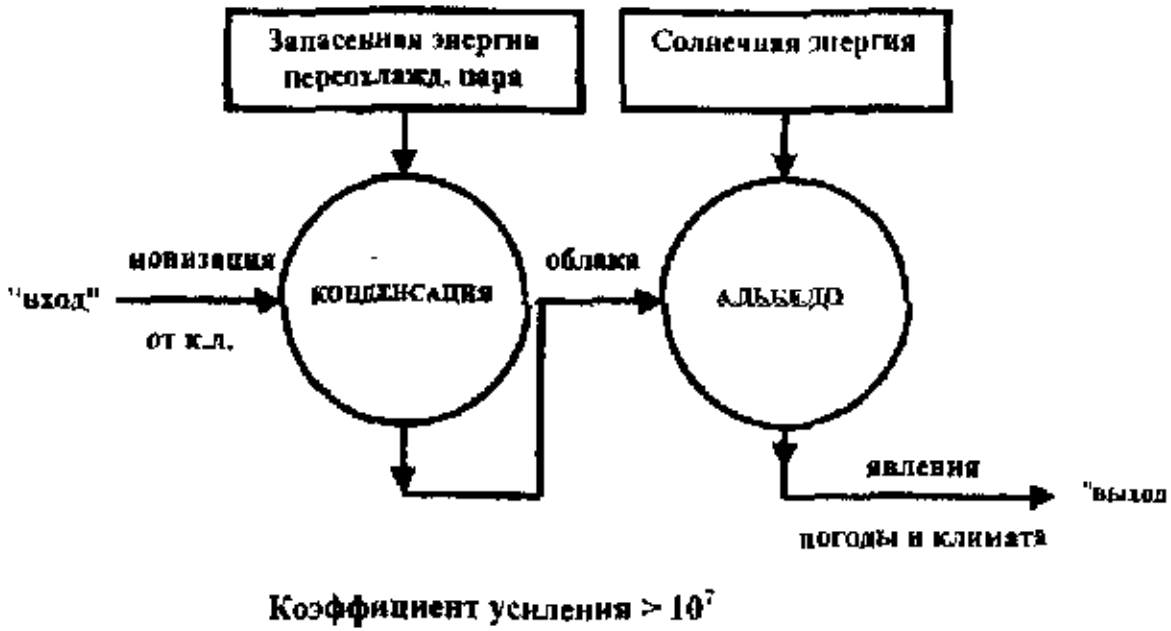


Latitude distribution of solar energy input, that determines the vapour formation, and ionization, responsible for vapour condensation (Krymsky, 2002).

Difference of two latitude curves should work in favour of rise and formation of meridional circulation in the atmosphere.

Cosmic rays and atmospheric albedo

Mechanism of influence of galactic cosmic rays (GCR) on tropospheric processes: «two-cascade amplifier» (Krymsky, 2002).
Energy flux of GCR: ~10^(-3) erg/(cm^2 s); energy flux of tropospheric disturbance: 10^(-3) Wt/cm^2 = 10^4 erg/(cm^2 s).
Amplification coefficient should be >10^7 in a time scale < 1 day (Tinsley & Deen,1991).



Condensation of water vapour in the upper layers of the atmosphere under the action of ionization from GCR. Cloud formation regulates the atmospheric albedo, i.e., solar energy input to the Earth's surface.

GCRs and Clouds: Two Hypotheses

- There are two different hypotheses to link GCRs with clouds.
- The first is that the ionisation from GCRs increase the number of cloud condensation nuclei (CCN), upon which cloud droplets form.
- The second hypothesis is that GCR ionisation modulates the entire ionosphere-Earth electric current system which, in turn, influences cloud properties through charge effects on droplet freezing (Kirkby, 2008).

CLOUD – Cosmics Leaving OUtdoor Droplets

- **Cosmic rays and cloud formation.**
- **CLOUD is an experiment that uses a cloud chamber to study the possible link between galactic cosmic rays and cloud formation.**
- **Based at the Proton Synchrotron at CERN, this is the first time a high-energy physics accelerator has been used to study atmospheric and climate science.**
- **The results could greatly modify our understanding of clouds and climate (Kirkby et al., 2009).**

Cosmic rays, EAS and thunderstorms

- **Lightning discharges are due to extensive air showers (EAS) of secondary particles that are produced by primary particles of GCR at the energies of E>10^14 eV as a result of GCR interactions with the nuclei of terrestrial atmosphere (V.I. Ermakov, 1992; Yu.I. Stozhkov, 2003).**

Thunderstorms and escaping electrons

- **Alternative hypothesis:**
- **Lightning discharges are due to showers of low-energy electrons that are produced in strong electric fields of thunderstorm clouds (A.V. Gurevich et al., 1999).**

Sun and Biosphere: Heliobiology

- History
- Concepts
- Observations
- Theory (physical basis)
- Experiments
- Prospects
- Gnosiology

Some relevant notes

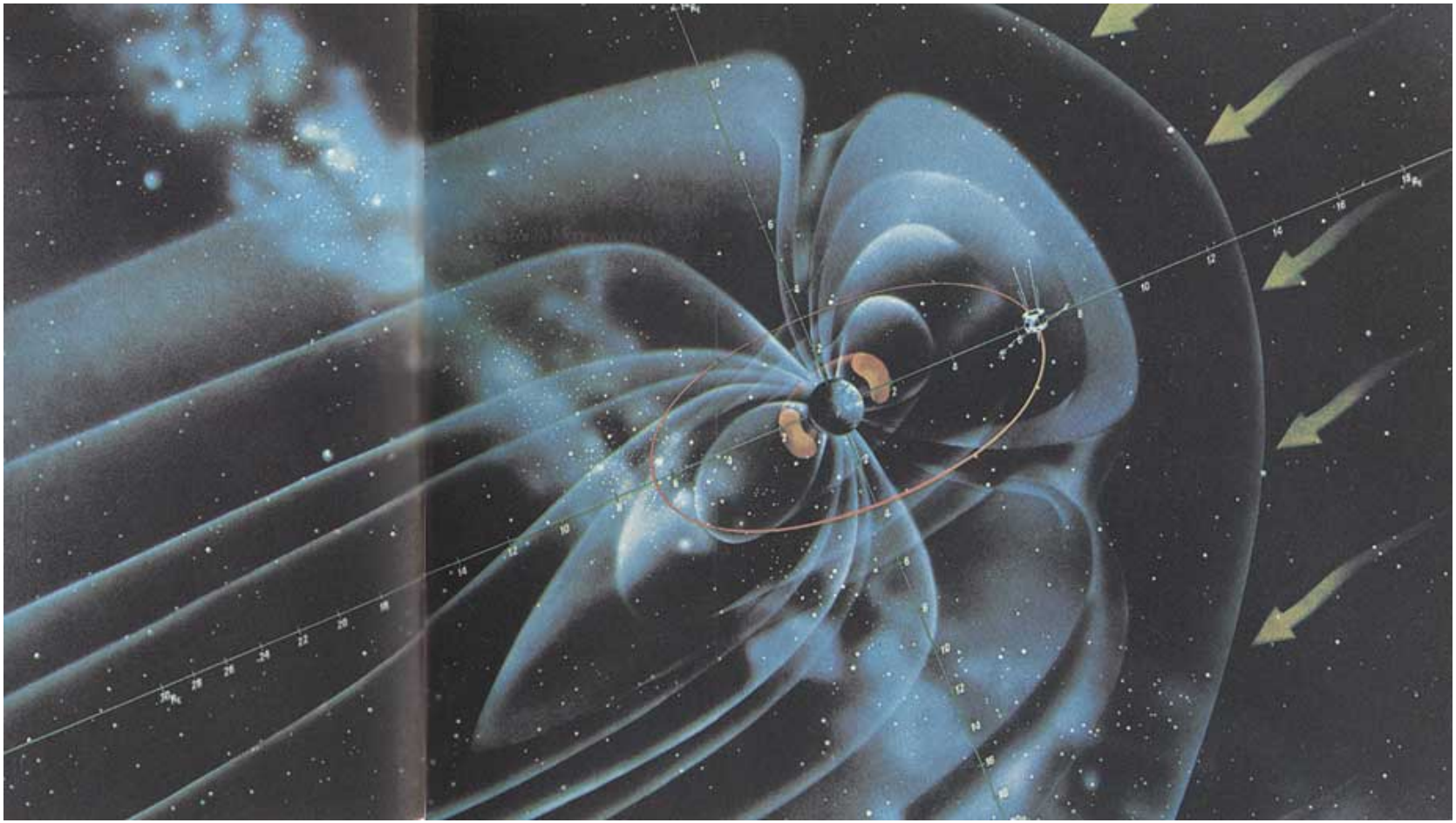
- 1. «We are living in the deepest minimum of solar activity, but people are dying though!..» (Crimea, Sudak, 2009, «Cosmos and Biosphere», remark in discussion).
- 2. «Magnetosphere in the minimum of SA has gained in breadth, «swelled up», but who seriously cares of it?» (Ukraine, Odessa, 27.08.2010).
- 3. Space rhythms of the biosphere and mankind place in the Universe? Gnosiology...

Theorem of Existence and Uniqueness

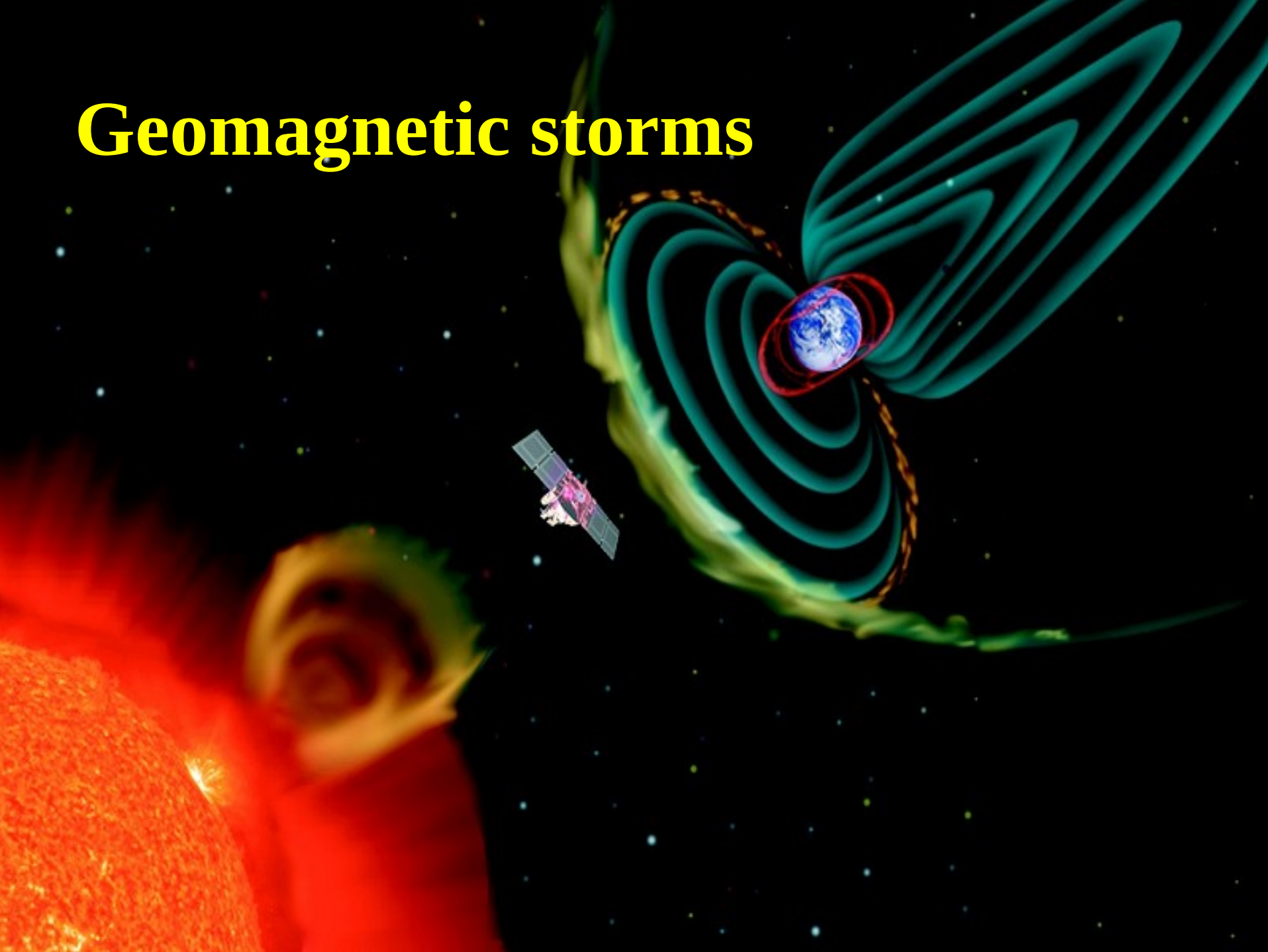
- **“Theorem of existence and uniqueness” of the solution (effect, interpretation, etc.) in Solar-Terrestrial Relations – main research difficulty in Solar-Terrestrial Physics.**

Terrestrial magnetosphere in solar wind

- **Red line – orbit of geostationary satellite**

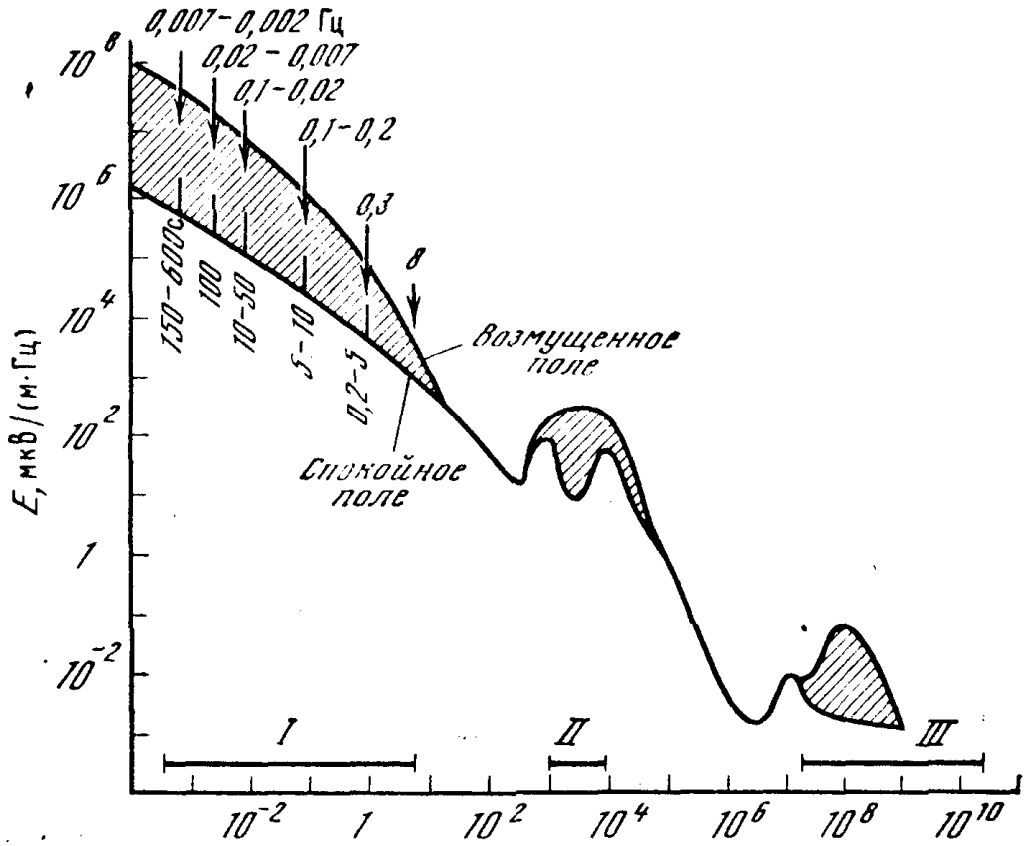


Geomagnetic storms



Геомагнитные пульсации: Основной канал гелиобиологических связей?

- **Спектр электромагнитного поля на поверхности Земли. Стрелками отмечены частоты, на которых наблюдаются короткопериодические пульсации геомагнитного поля, вызванные изменением солнечной активности.**
- **I-III – окна прозрачности**
- **(Б.М. Владимирский, 1976).**



Magnetobiological effect

- **Ozheredov Vadim Andreyevich. Investigation of solar-terrestrial relations by optimization algorythms** (PhD, 01.03.03. – Physics of the Sun, 2010, Space Research Institute, Moscow, Russia).
- **Inverse problem are considered from the point of view of pattern recognition. The values that are called traditionally as *predictor* and *adaptor* in the situation analysis, have the names *tag and reply* in the theory of pattern recognition. Experimentally measured pair «*tag-reply* » is called *precedent*. Theory (model) of *convex envelops of precedents.***
- ***Reply* is a variable value that allows us to judge about the presence or absence of the organism or society (socium) reaction under interest. Arterial blood pressure P > 153 мм Hg is a signature of coming hypertension crisis, HC. Excess of daily number of infarctions in comparison with its average value may be evidence of danger of rise of diseases in the cardiac-vascular systems.**
- ***Tag ensemble* (or *tag vector*) forms a *convex envelop* in the *tag space* and reflects current state of parameters of surrounding medium (environments), those parameters being provide a corresponding *reply*.**

Theory of pattern recognition

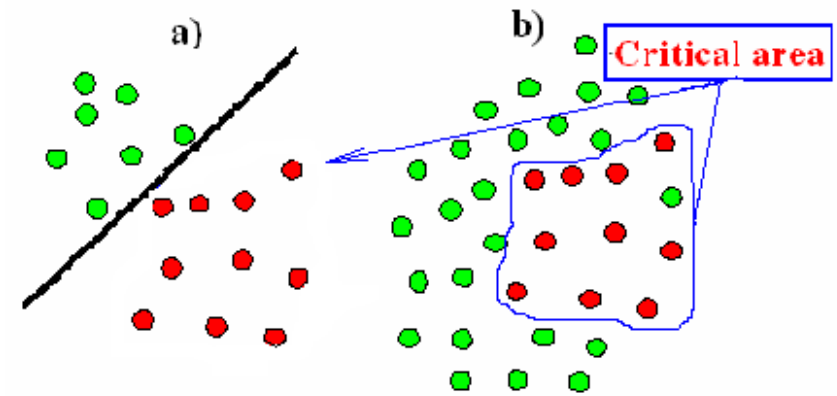
- **1) Dividing of tag space by linear separatrice if this method is adequate in particular case**
- **2) Dividing of tag space by nonlinear closed separatrice using a conjunctional method in case of overlapping of convex envelops of precedents (objects that are involved in algorithm teaching process)**

In both cases:

Separatrice permits to find a "critical area" in tag space that allows us to make decision to which from two classes given object belongs.

Decision is based on the position of the tag vector of a new object: if this vector is inside the critical area – we make decision that this object belongs to the I-st class; if it is outside, then the object belong to the 2-nd class.

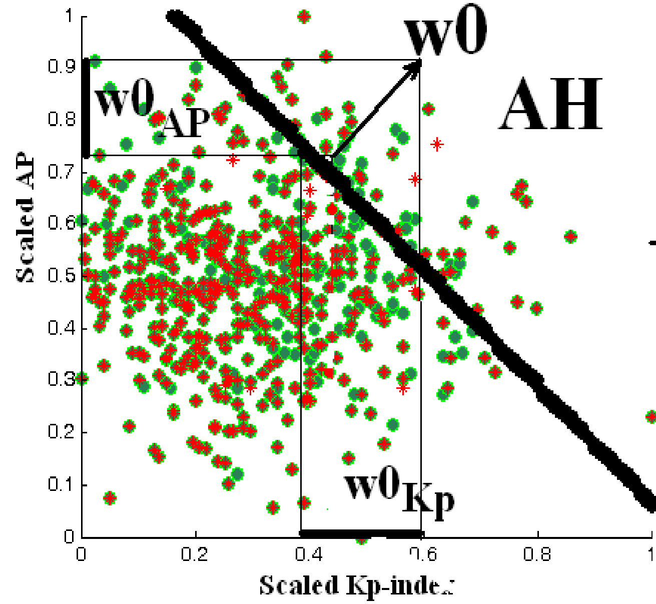
The final purpose of the theory is to learn how to classify objects according to classes using set of their tags.



Tag space division in the case of separation (a) and overlapping (b) of convex envelops of precedents. So, one of the main tasks of STR is a search for certain configuration of tag space for usual and space weather as well as for critical area inside it. This search should be done in the manner that provides satisfactory confidence of the following statement: if the tag vector comes to the critical area then selected biological effect (reply) takes place.

Geomagnetic storm and hypertonic disease

Results of linear division of 2-dimensional tag space (Kp-index and Atmospheric Pressure AP) for revealing of weather influence on arterial blood pressure (Hypertension - AH).



$$\frac{w0_{Kp}^{2}}{w0_{AP}^{2}} = \frac{6}{4.8}$$

Materials:

2503 ABP every day data (once in morning) of the people suffering from AH and monitored in the A.L.Miasnikov's Cardiology Center (Moscow) in 2001-2002. Corresponding Space (Kp-index) and Terrestrial (AP) Weather parameters were taken from Internet sites.

Both factors are acting simultaneously, with their relative input (contribution) to the effect: 6.0(Kp)/4.8(AP) = 5 : 4 (Breus, Ozheredov, 2009).

B
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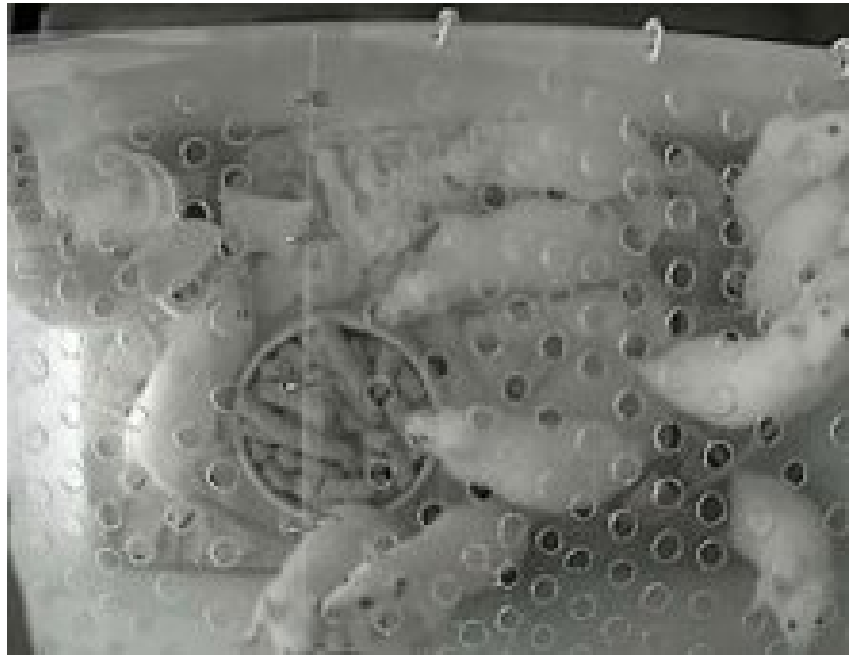
Hypomagnetic effect

- **N.A. Krivova (Institute of Biology and Biophysics of Tomsk State University, Tomsk, Russia), K.A. Trukhanov (Institute of Medical and Biological Problems, Russian Academy of Sciences, Moscow), 2008.**

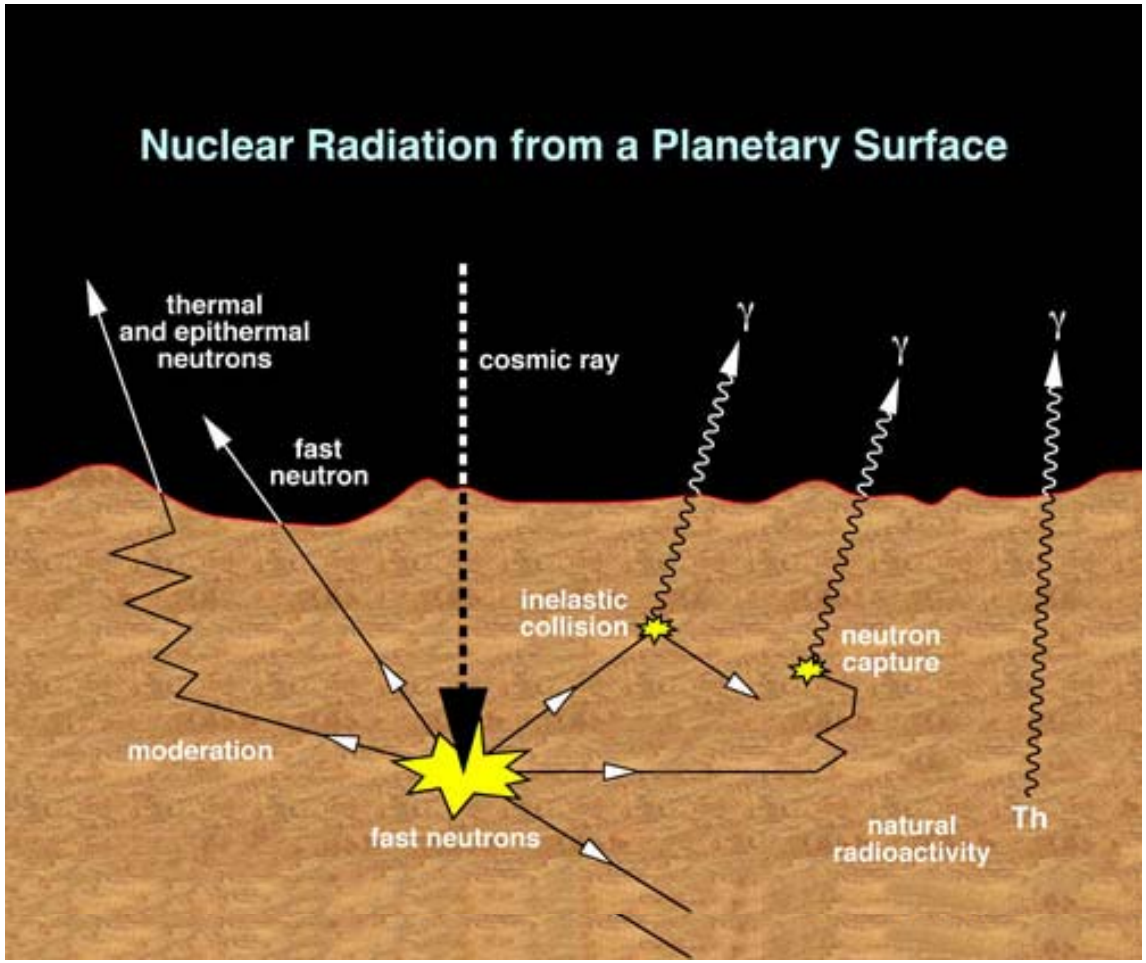
Rats under hypomagnetic conditions are always fighting, with extremely high aggression. After that they are sleeping in exhaustive state and do not awake even when the food has been brought them. Rat fight (scuffle) is a means to establish the hierarchy between them. Since the hierarchy is established the fight stops. Rodents (rats) without geomagnetic field seem to "forget" how to establish the hierarchy, i.e., they lost their social habits. In addition, the rats under experiment displayed some physiological changes.



Rats in experimental chamber under hypomagnetic conditions.

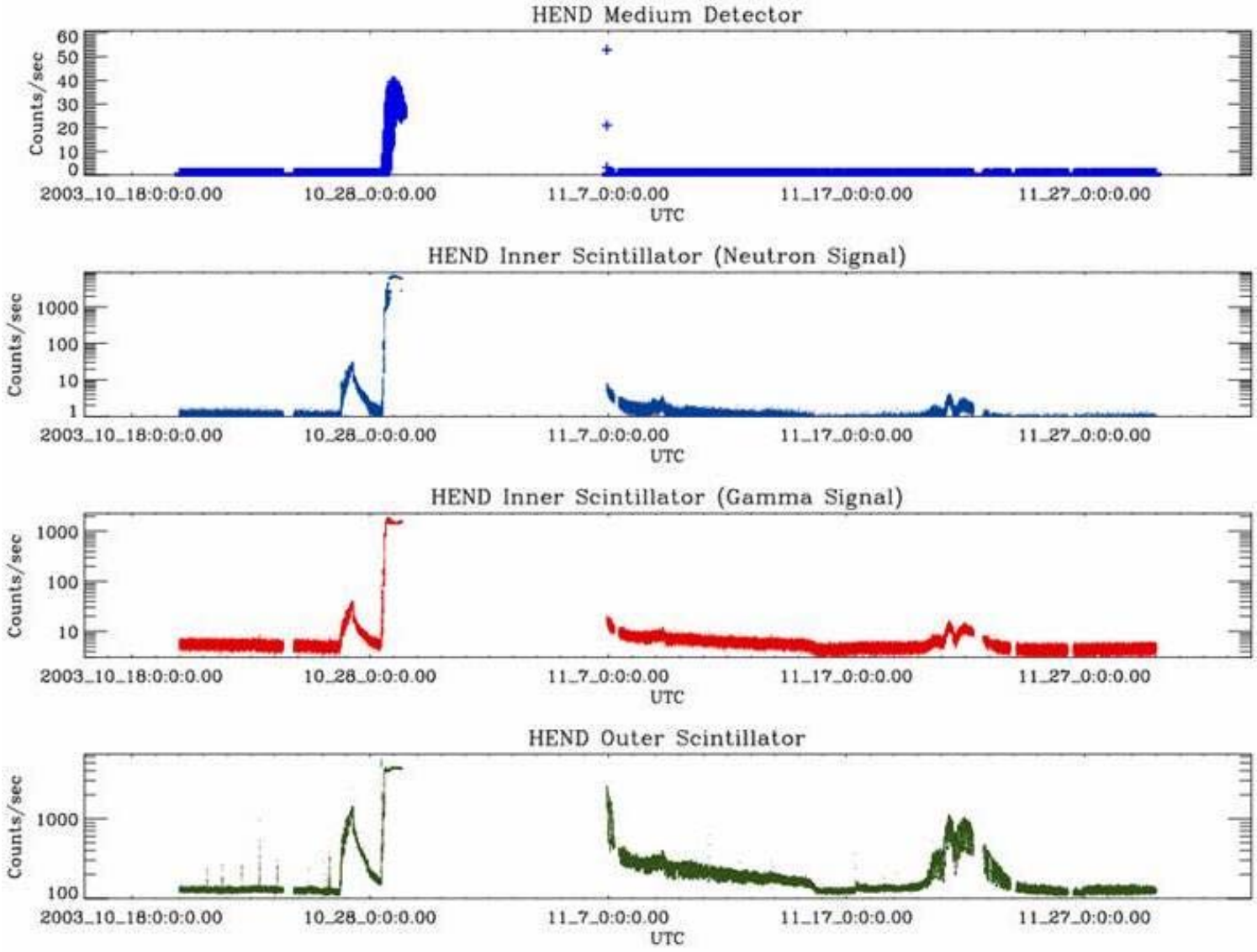
P.S. Space stations are orbiting now at the heights where the geomagnetic field is about 80% of its surface value…

Nuclear Radiation from a Planetary Surface (Mars Odyssey Mission)

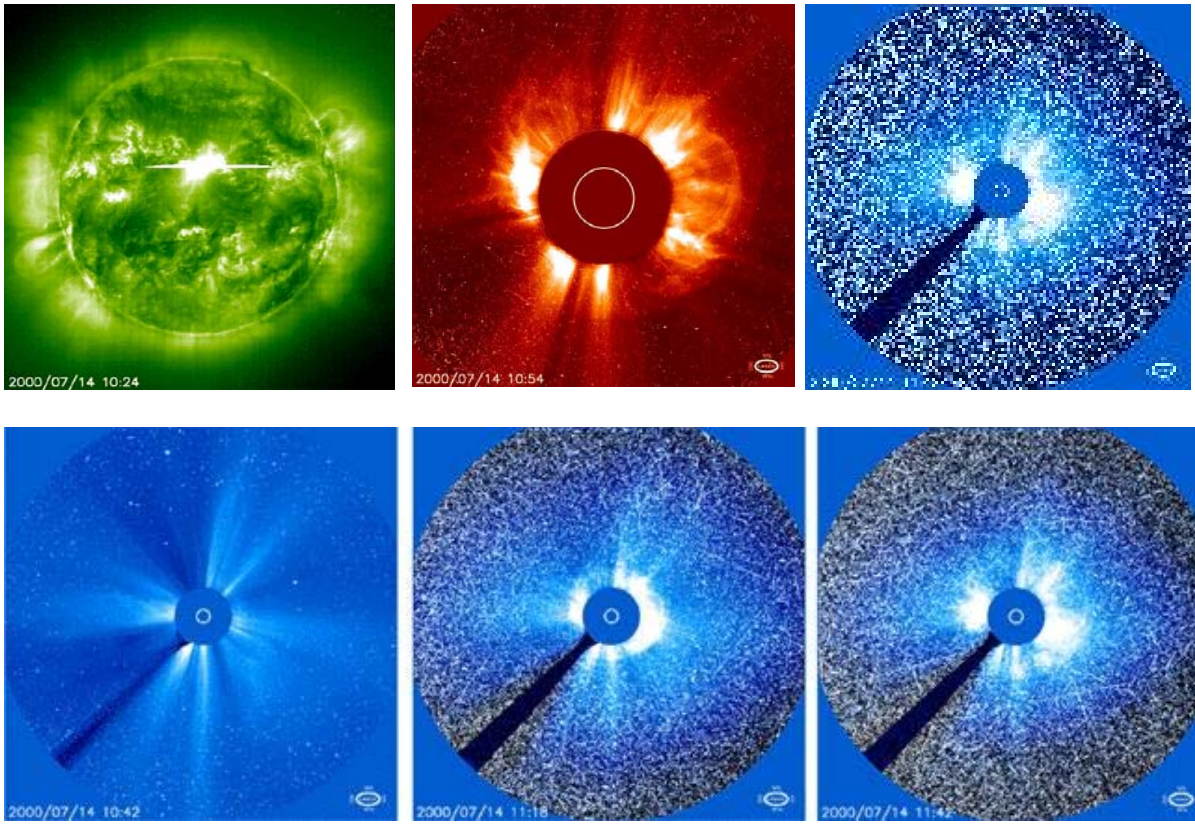


Martian satellite 2001 Mars Odyssey with three principal Scientific instruments: Thermal Emission Imaging System (THEMIS), Gamma Ray Spectrometer (GRS), which includes the High Energy Neutron Detector (HEND) from Russia, and Mars Radiation Environment Experiment (MARIE). Deep-space mission anomaly + detrimental effects from SEPs?

Hard electromagnetic emission and neutrons near the Mars (HEND, 2003)



Bastille Day Event (14 July 2000): Flare, CME, Radiation Storm



The images at the left are a good example of how severely detectors can be influenced by high-energy particles from such events. The CDS (Coronal and Diagnostic Spectrometer) instrument on board SOHO was observing a totally different part of the Sun than the flaring region.

However, the observations taken during the particle shower were almost useless, and the sequence was in fact aborted as a precaution to avoid any damage to the instrument. *Detrimental effects of the SEPs!*

¡MUCHAS GRACIAS!

- **“Aquellos que observan Cielo, regresan a las cosas mundanas muchas mas sublimes…”**
- ***Marcus Tulius Cicerón (106-43 BC)***

Contact information

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Aphorisms

- “ - Moon, what do you wait for?
- - For an opportunity to greet the Sun
- whom I should make way for."
- Rabindranath Tagore (1861-1941)

- "A LINK OF THE SPACE REALITY WITH US IS MUCH MORE PROFOUND AND ROUTINE THAN IT IS THOUGHT..."
- Academician V.I. Vernadsky (1863-1945)