Galactic Cosmic Ray Processes as Key Governing the Solar Influence on the Earth and Planets

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Introduction

In the beginning of the cosmic era it was established the important role of the different particle types in the extraterrestrial and interplanetary space: galactic cosmic rays (GCR), solar cosmic rays (SCR), radiation belt and aurora particles, solar wind (SW), etc. Because of that the energetics and the variations of these particles appear as essential aspect of solar-terrestrial physics. All energy fluxes in the interplanetary space with extrasolar origin are neglectable small in comparison with the energy fluxes from the Sun, at least near the Earth's orbit. But namely GCR possess maximal penetration capability [1 - 3], which, in our opinion, is the key of understanding of solar-terrestrial relationships.

Cosmic rays and processes in space and Earth

Cosmic rays (CRs) form the lower parts of the terrestrial and planetary ionospheres. They create in the Earth environment independent cosmic ray layer, so called C layer in the ionosphere D region, which is situated at heights 50 - 80 km ([4 - 6]). Therefore they influence on the propagation on radiowaves, particularly in the range of medium, long and very long waves. The cosmic rays maintain the ionization not only in the ionosphere but also in the atmosphere, the hydrosphere, the lithosphere and the cryosphere of the Earth.

CRs determine the ionization rate and conductivities in the atmosphere and the ionosphere and therefore the atmospheric electric fields. The last influence the thunderstorms, the Earth's global charge and global electric circuit between the ionosphere and the ground. It is already established [7, 8], that one of the main causes of thunderstorm discharges are external atmospheric showers (EAS) of high energy primary CR particles with energy more than 10^{14} eV.

CRs produce also nuclear reactions with ground, water and air atoms. On this way cosmogenic nuclides in space, in bodies, and in atmospheres are created. Such cosmogenic isotopes are ^{10}Be, ^{7}Be, ^{3}He and ^{3}H [9]. All this shows the great importance of cosmic rays for the processes of solar - terrestrial relationships, solar - terrestrial physics and solar - planetary physics in the whole heliosphere.

On the mechanism of solar-terrestrial influences

We suppose the following helio - geomagnetic mechanism (see the Fig.1): the Sun sends to the Earth different types of radiations - photons (visible optical OPT, infrared IR, X-rays, gamma rays, etc.) and particles (the permanent SW, the sporadic SCR, etc.). The Sun also generates magnetic field, i.e. the interplanetary magnetic field (IMF). The whole solar system is radiated by GCR, which are generated in the supernovae stars and in the nucleus of the Galaxy in the galactic centre (GC). The solar wind and interplanetary magnetic fields modulate GCR with their cycles (11- and 22-years, 27-days, etc.). Besides in the magnetosphere, ionosphere and atmosphere exist 12-hour and diurnal variations. Consequently SW and IMF modulate all primary and secondary GCR particles.

However GCR determine the chemistry and electrical parameters in the atmosphere. They create ozonosphere and influence actively on O_3 processes. GCR transmit to the ozonosphere their solar modulation. But the ozonosphere controls the meteorological solar constant and the thermal regime and dynamics (including the dynamics of the cloud system) of the lower atmosphere, i.e. the weather and climate [10, 11].

This mechanism may be expanded still taking into account that the GCR create not only the atmospheric but the hydrosphere and lithosphere part of the ozonosphere also. This mechanism of the solar-terrestrial relationships shows the way to a non-contradictory solution of the key problems of the solar - terrestrial physics.

CR spectrum and ionization

The observed CR spectrum can be distributed into the following five intervals:

I ($E = 3.10^{6} - 10^{11}$ GeV/n),

II ($E = 3.10^{2} - 3.10^{6}$ GeV/n),

III (E = 30 MeV/n - 3.10^{2} GeV/n),

IV (E = 1 - 30 MeV/n),

V (E = 10 KeV/n - 1 MeV/n),

where E is the kinetic energy of the particles [9, 12]. Some methods exist for calculating of ionization by relativistic particles in CR intervals I, II and III. For the high-latitude and polar ionosphere, however, intervals III, IV and V are also significant since they contain solar cosmic ray and anomalous cosmic ray components. Formulas for the electron production rate q(cm^{-3}s^{-1}) at height h in the planetary ionosphere as a result of penetration of energetic particles from intervals III, IV and V are deduced in this paper. For this purpose the law of particle energy transformation by penetration through the ionosphere - atmosphere system is obtained.

A model for the calculation of the cosmic ray spectrum on the basis of satellite measurements is created. This computed analytical model gives a practical possibility for investigation of experimental data from measurements of galactic cosmic rays and their anomalous component [13].

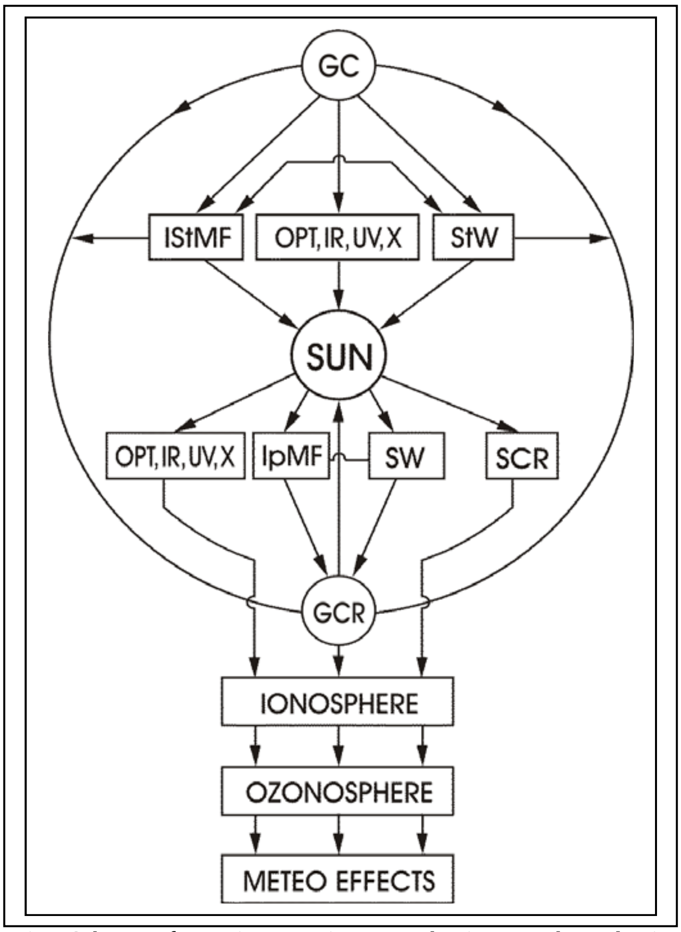

Fig.1.Scheme of cosmic ray trigger mechanism on the galactic-solar-terrestrial and galactic-solar-planetary relationships. In the upper part of the figure the discussed mechanism is generalized using the principle of the hierarchical analogy and symmetry. The notations here are: GC - galactic centre, StW - stellar wind, IstMF - interstellar magnetic field. On this way the actual ideas for solar-terrestrial physics are logically expanded in the system Galactic nucleus - Sun - Earth.

3D-modelling GCR ionization in terrestrial atmosphere

3D-model of the CR electron production rate $q(h)$ ($cm^{-3}s^{-1}$) has been developed for the strato-mesosphere and lower thermosphere (altitude range 30 - 100 km) with 10 km step [14]. The proposed 3D-model contains a theoretical part and numerical computation [15]. The galactic CR spectrum is modeled with analytical expression with input data from CREME '96 (2002). The longitudinal effect of CR ionization has been calculated. The longitudinal effect corresponds to the planetary distribution of the geomagnetic threshold rigidities R(GV).

The atmosphere density profiles are taken from COSPAR International Reference Atmospheres - CIRA'72 and CIRA'86. In the polar regions the contribution of the anomalous CR with energies less than 50 - 60 MeV significantly increases [15]. These results provide a basis for quantitative understanding of the processes of space weather.

CR ionization in the planetary ionospheres

As a continuation of our studies of cosmic ray (CR) ionization in the atmospheres of the planets in the solar system [13, 15] we present a new method for the calculation of the electron production rate *q(h)* profiles due to particles of all energy intervals: galactic CR, anomalous CR component and other types of high energy particles. In the above mentioned papers ionospheres of terrestrial planets are investigated, where the spherical model is used. For giant planets which have significant oblateness in spite of the isotropic penetration of the galactic CR in their atmospheres, the trivial integration on the azimuth angle is not applicable, because of the presentation of the planets as rotational ellipsoids and the azimuth dependence of the integrand function.

The difference between profiles for spherical *q_S* and ellipsoidal *q_E* models of the terrestrial planets (Earth, Venus and Mars) is small. These differences between *q_S* and *q_E* profiles increase significantly in the upper atmospheric layers of giant planets Jupiter, Saturn, Uranus and Neptune. This requires the introduction of a modified Chapman function for oblate planet in the Particle Depth Parameter (PDP), while considering the CR influence and ionization processes in the ionospheres of the giant planets. New calculations for relative profiles *q_E* / *q_S* in the atmosphere of Saturn are presented. For this purpose an improved primary CR spectrum with a new type of smoothing function *f* with *tangents hyperbolicus* is used [16].

Generalization for biophysical processes

Undoubtedly the proposed galactic – solar-terrestrial CR mechanism will influence the processes in the biosphere also. In this manner the discussed here relationships may be generalized in galactic-solar-terrestrial biophysics relations. The latter are especially sensitive to the variations of the electric and magnetic fields and the high energy particle ionization. As most penetrating radiation the galactic cosmic rays ionize the whole planetary environment and thus resulting electric conductivities (field-aligned conductivity, Pedersen conductivity and Hall conductivity), electrical currents and fields. They play a role as a link between the different spheres: magnetosphere - ionosphere - middle atmosphere - troposphere - biosphere - noosphere.

Synergetic processes in galactic – solar-terrestrial relationships

The processes in galactic – solar-terrestrial physics and biophysics may be modeled with help of the graph theory and the theory of flows in networks. As these processes develop in the Solar system and in the Galaxy, which are open and non-equilibrium, thus in them may occur synergetic processes of self-organization. In the concrete case in this work the galactic cosmic rays influence upon the solar system as continuous external impact. By this way a flow type equilibrium (according to *Bertalanfi*) is established.

Conclusion

On 4 October 2007 it will be celebrated 50 years of the first artificial satellite and the beginning of space exploration. Fifty years after the International Geophysical Year (1957-1958), the world scientific community will come again for an international collaboration: the International Heliophysical Year (IHY) 2007. The term "heliophysical" is an extension of the term "geophysical" in the region of the whole solar system. One of the objects of International Heliophysical

Year 2007 will be undoubtedly the advancing our understanding of the cosmic ray processes that govern the solar influence on the Earth and planets.

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