D.V. Skobeltsyn Institute of Nuclear Physics of M.V. Lomonosov Moscow State University (SINP)

4. Information about Scientific Projects of the Federal Space Program of the Russian Federation with are at the Development (Working out) Stage

The MSU project Lomonosov

There are three basic goals of the Lomonosov experiment:

- ultra-high energy cosmic rays (UHECR) studies;
- gamma-bursts registration and observations in multi-spectral mode;
- complex monitoring of the near-Earth space.

These problems are at the frontier of the current space research.

Calculated parameters of the spacecraft's orbit:

- altitude 490 ± 10 km;
- inclination 98^{o};
- local time ascending node (local time of the spacecraft) 11:15.

Expected active life of the spacecraft is 3 years.

The basic scientific purposes of the scientific equipment of Lomonosov spacecraft are the following:

1) Adjustment of the methods of UHECR registration from space by fluorescent method, measurements of UV background of the neigt atmosphere.
2) Registration of UHECR events near Greizen-Zatsepin-Kuzmin cut-off, measurements of UHECR particles energy and coming direction.

3) Measurements of UV bursts, associated with thunderstorms, in the Earth's atmosphere (so-called transient atmospheric phenomena – sprites, blue jets, elves, etc.).
4) Registration of gamma-bursts within wide wave range – from optical and UV to X-ray and gamma.
5) Real-time transmission of the coordinates of gamma-burst to the ground-based telescope network (GCN) in order to guide them to the event.
6) Registration of moving objects in the upper hemisphere of the spacecraft, including small asteroids and space debris.
7) Experimental determination of the total radiation danger (both from charged and neutral particles) during the flight along the polar orbit by means of dosimetry equipment, developed for this purpose.
8) Simultaneous measurements of spatial distribution of the charged particles and magnetic field variations in the same point.
9) Measurements of micro-gravitational conditions onboard small spacecraft.

A complex of scientific equipment consisted of several scientific instruments connected with a common system of power supply, control, scientific data and telemetry accumulation, storage, processing and transmission to the Earth (see Figure 1) was developed in order to realize the scientific purposes of the project. Scientific problems, solved by separate tools are partly covered with each other in order to obtain more full and objective data and to improve the safety of the instrument.

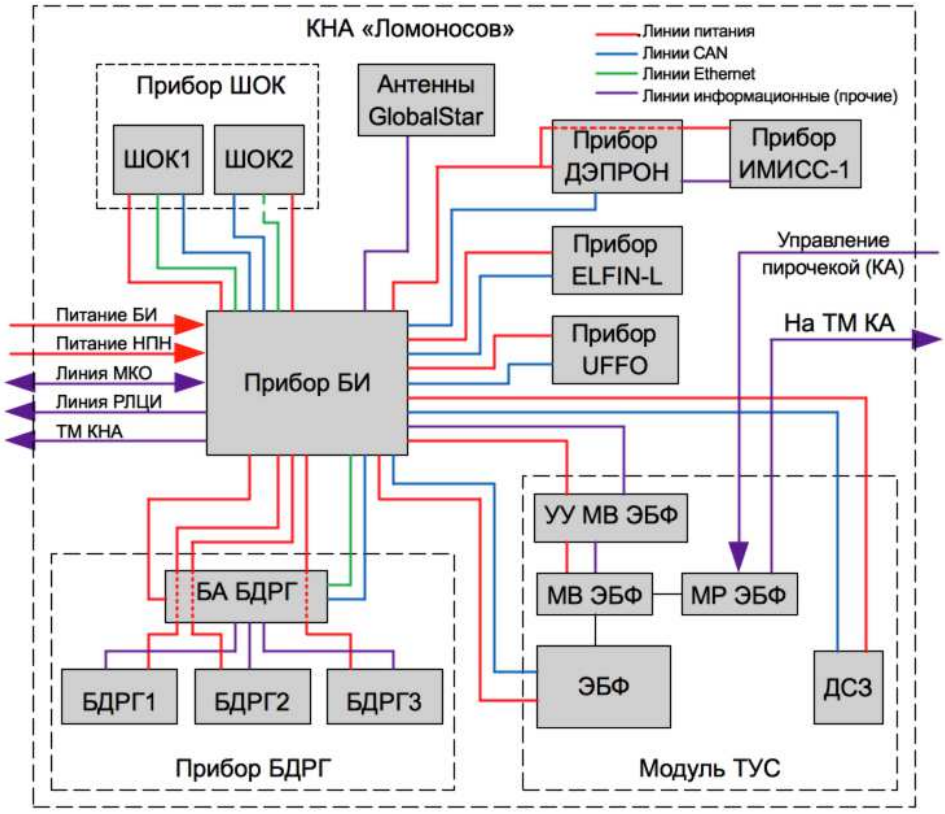

Figure 1. Structural diagram of the Lomonosov scientific equipment.

Complex of scientific equipment of the Lomonosov experiment consists of:

- module TUS (track device), intended first of all, for the UHECR studies;

- information module BI, distributing power supply, control, accumulation, storage and transmission of the scientific and telemetry information to the specific radio-line;

- BGRG devices (Russian abbreviation for the block of X-ray and gamma-emission detectors);

- ShOK (Russian abbreviation for wide-aperture optical camera);

- UFFO (ultra fast flash observatory), intended for the detection and observation of the events in the upper hemisphere of the spacecraft, including search for gamma-bursts in multi-spectral mode;

- DEPRON device (Dosimeter of Electrons, PROtons and Neutrons);

- ELFIN-L (electron and field investigator for Lomonosov), providing

monitoring of the near-Earth radiation;

- IMISS-1 device, measuring micro-accelerations and microvibrations of the spacecraft.

Structurally all devices are mounted on the separate base (manufctured by JSC NIIEM) with autonomous system of thermal regulation (see Figure 2). The total weight of the scientific equipment module (without the transmitter of the specific radio-line) is about 300 kg, the total daily volume of the transmitted data is up to 8 Gbytes (can be adjusted within wide range under the changes of the operational mode or real-time correction of the scientific tasks), general power consumption is about 230 W. Service platform of the spacecraft (manufactured by JSC “VNIIEM Corporation”), providing power supply, orientation and connection with onboard and specific radio-complexes, is fixed on the base (see Figure 3).

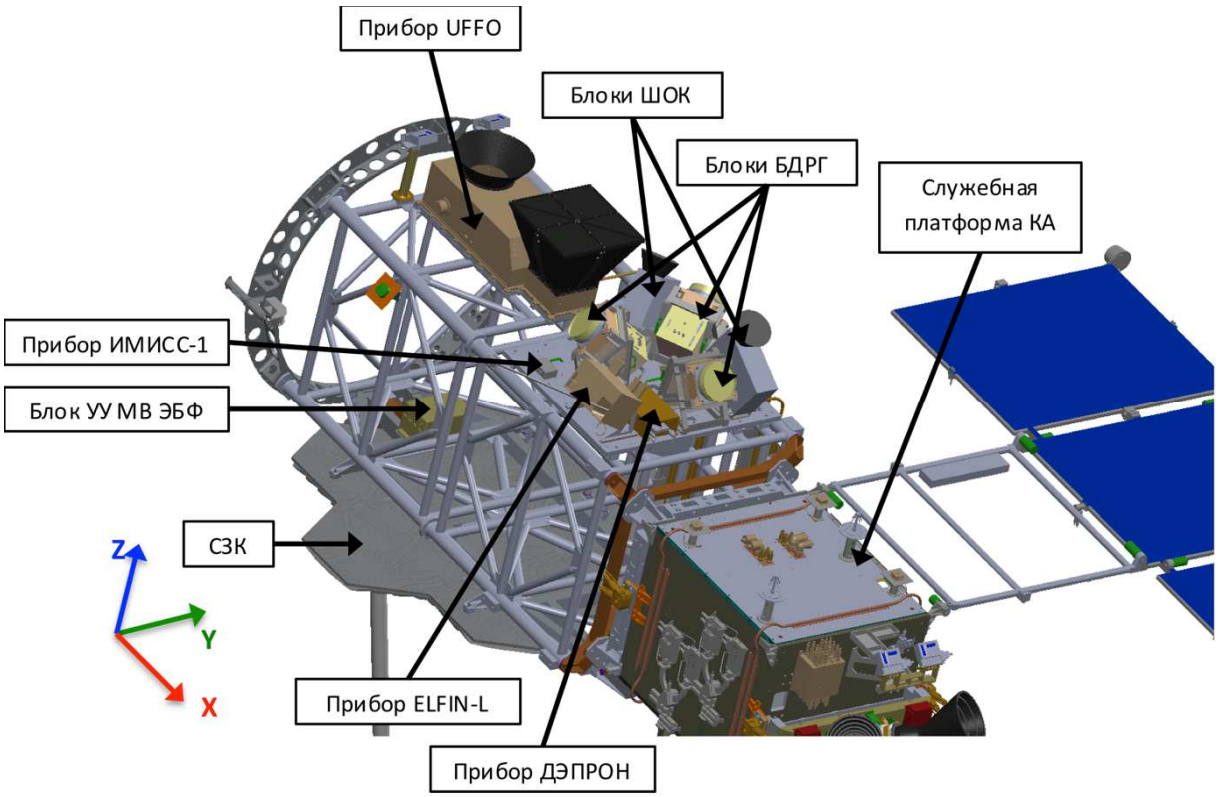

Figure 2. Location of the devices on the base of the scientific equipment module of the Lomonosov experiment.

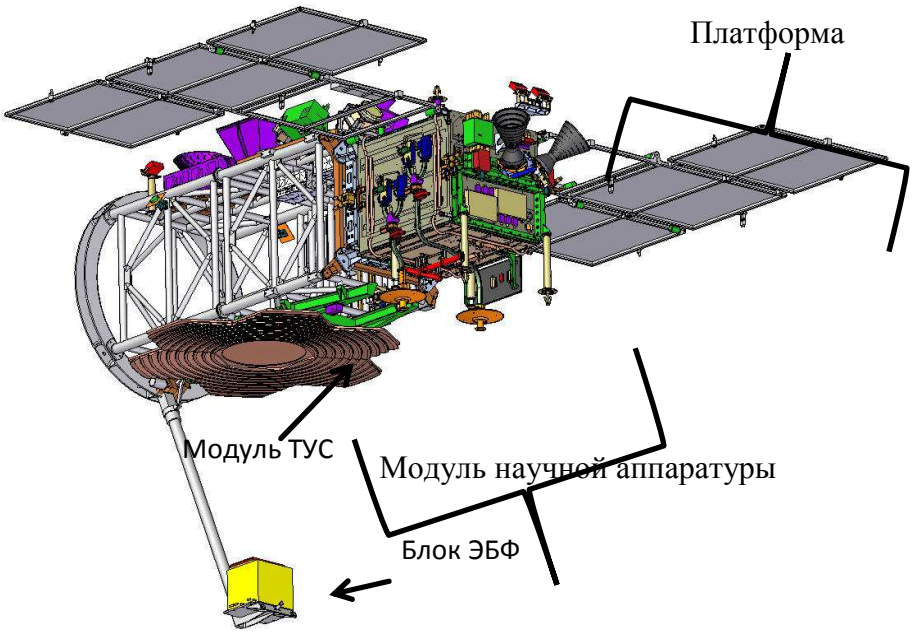

Figure 3. General view of the Lomonosov spacecraft.

Figure 4. The Lomonosov spacecraft at the test-bench.

The TUS detector is the first fluorescent detector of UHECR, which will record UHECR from the spacecraft. This detector has high temporal resolutions

(0.8 mks) and large luminosity (area of the mirror-concentrator is about 2 m^2). It provides a possibility for registration of weak tracks of UV illumination from the shower of particles, which moves with light speed through the Earth's atmosphere. Development of this method opens possibility for UHECR observations with very large and uniform exposure in the whole celestial sphere. It will increase statistics of the recorded events for an order of magnitude and more.

Quasi real-time (during the first seconds after the eginning of the event) alert of the GCN network about the gamma-burst beginning will allow the scientific complex to become one of the best gamma-burst alerters in the world and the best one in Russia.

ShOK cameras become the first experiment with super-wide field of view cameras on the Earth's orbit. Adjustment of the methods for registration of dangerous asteroids and space debris from space is of particular interest. It's necessary to note, that optical cameras onboard the Lomonosov spacecraft will be operated in the single control space with the network of the ground-based automatic telescopes “MASTER”. It will allow to announce deploying of a completed automatic system of optical observations of the near-Earth space.

DEPRON device is a prototype of a new system for radiation control, developed for the manned missions, including the ISS. Obtained data will allow to refine radiation conditions inside perspective manned spacecrafts (at middle and high latitudes, where currently there are no manned missions).

Simultaneous recording of the magnetic fiedl variations and quasi-trapped charged particles fluxes is a new, extremely actual tool for the observations of the radiation conditions in the near-Earth space, which allows to study short- and mean-temporal dynamics of the Earth's radiation belts.

Expected results of the experiment:

1) Confirmation and argumentation of the methods of UHECR registration from the satellite under conditions of variable UV background of the night Earth's atmosphere;
2) Obtaining of additional information on the UHECR flux near the Greizen-Ztsepin-Kuzmin cut-off. Analysis of large-scale anisotropy and search for possible sources of UHECR.
3) Measurements of UV background of night atmosphere and estimation of the transient atmospheric events effects on the efficiency of UHECR registration.
4) Registration of approximately 100 new gamma-bursts per year within the range of wavelengths from optical to gamma, inclusion into GCN as real-time gamma-bursts alerter.
5) Development of a space segment of a system for optical observations of the near-Earth space.
6) Obtaining of a large volume of regular monitoring data on the radiation, including dosimetry, conditions in the near-Earth space in order to adjust empirical and verify physical models of the near-Earth radiation.
7) Development of a system for reduction of cosmonauts' vestibular apparatus dysfunction under conditions of microgravity.
8) Adjustment of apparatus and software solutions for the control systems under space conditions.
9) Adjustment of GlobalStar system as inexpensive reserved two-sides radio-channel.

The results of the most experiments within the frames of the Lomonosov experiment are necessary for the planning and development of the larger projects (in particular, TUS – for UHECR registration experiments KLYPVE and JEM-EUSO onboard the ISS). The results of the gamma-bursts observation are, first of all, of

extremely high importance for the problems of fundamental astrophysics. The results of the radiation conditions monitoring will expand the database, accumulated by SINP MSU, for different orbits, altitudes and time periods. It will support the radiation models of the near-Earth space and allow to develop theoretical models of the near-Earth radiation dynamics. Development of the methods for the reduction of the cosmonauts' vestibular apparatus dysfunction under conditions of microgravity is carried within the frames of the scientific program of the ISS Russian segment. It is proposed to use both technological experience, obtained during the development of the IMISS-1 device, and the data on microvibrations and microaccelerations of a free-flying spacecraft.

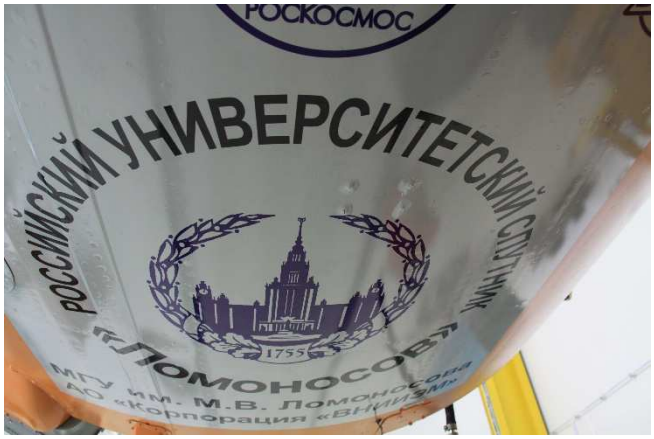

Figure 5. The third stage of the rocket-carrier “Soyuz 2.1a” with a logotype of the Lomonosov spacecraft.

The Lomonosov spacecraft was launched to the polar circular orbit with altitude of about 500 km on April 28, 2016 from the Vostochny launching site.

Sadovnichiy V.A., Amelyushkin A.M., Angelopoulos V., et.al., Space experiments aboard the Lomonosov MSU satellite. Cosmic Research (English translation of Kosimicheskie Issledovaniya) (51), 427-433, 2013

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Orbital detectors KLYPVE and JEM-EUSO

Scientific purposes of the KLYPVE and JEM-EUSO detectors

Primary purposes of the KLYPVE and JEM-EUSO projects are the following:

1. The studies of energy spectrum and composition of primary space radiation both GZK cut-off (energy from 30 up to 50 EeV), and after it (energy higher than 50 EeV) – ultra-high energy cosmic rays (UHECR).
2. Search for “point” sources of the particles and studies of the anisotropy of coming of the particles with energy > 20 EeV in the whole celestial sphere.
3. Comparison of the data from the space detector and from the ground-based detectors at energy 20-100 EeV.
4. Development of new “space” detectors in order to increase the observed area of the atmosphere up to 10^5-10^7 km^2 at threshold energy of 100 EeV and to decrease threshold energy to 3 EeV at the observed area of the atmosphere of 10^4 km^2.

Currently it is proposed to join two experiments, independently developed till 2014 and based on different optical systems (OS) in order to develop an International on-orbit observatory for the studies of the Universe in the rays of the ultra-high energy particles. The first experiment, KLYPVE, is based on a simple

OS, consisting of a mirror-concentrator with photodetector, located in its focus. Such system provides relatively narrow field of view. Its advantage is a possibility for diminishing of the energy threshold of the detector by means of production of huge mirrors-concentrators (space detector with mirror's area over 100 m^2 operated at the altitude of 400 km can detect particles with threshold energy of 1 EeV with exposure factor of ~10^4 km^2sr/year – unrealizable parameters for the ground-based instruments). Such space detector will provide a possibility for observations of the anisotropy of UHECR particles coming directions with high statistical accuracy, evaluation of mass composition of primary particles and, probably, solving of these problems for separate areas of the celestial sphere, for which anisotropy of the particles' coming direction will be observed. Currently detector TUS was already developed and launched onboard the Lomonosov spacecraft (mirror's area of 2 m^2) and the KLYPVE detector is being prepared to be mounted onboard the ISS (mirror's area of 10 m^2) within the frames of this study.

In the JEM-EUSO project a complicated OS with 2-3 Fresnel lenses with wide field of view of 60 degrees is considered. It allows to increase the observed area of the atmosphere at the given satellite's altitude. For the ISS orbit the area of the observed atmosphere is ~2x10^5 km^2. Disadvantage of such wide-angular detector is high cost of the OS production with large area of light accumulation. Developed OS of the JEM-EUSO detector has an area of light accumulation of 4,5 m^2 and efficiency of fluorescent light passing through the focusing optical system of 50%. The energy threshold of the detector are evaluated at the level of 50 EeV.

1. Current status of the projects

1.1. KLYPVE

In 2015 technical proposal on the scientific equipment KLYPVE was issued. The experiment is planned to be hold in 2021-2024.

According to the conceptual design the KLYPVE detector consisted of the following systems:

– mirror-concentrator;

– module of photodetectors;

– support structure;

– module of data processing and storage.

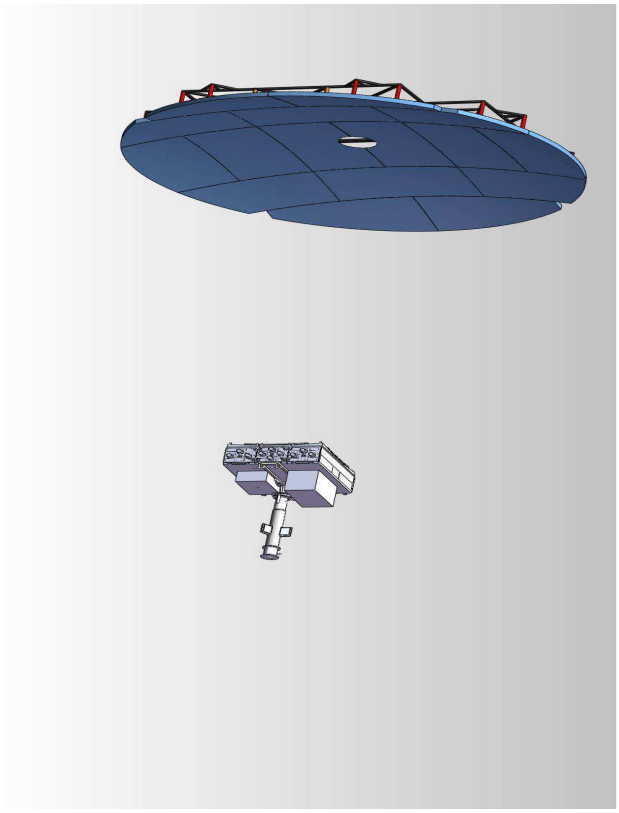

Figure 1. Scientific equipment on KLYPVE experiment (according to conceptual design).

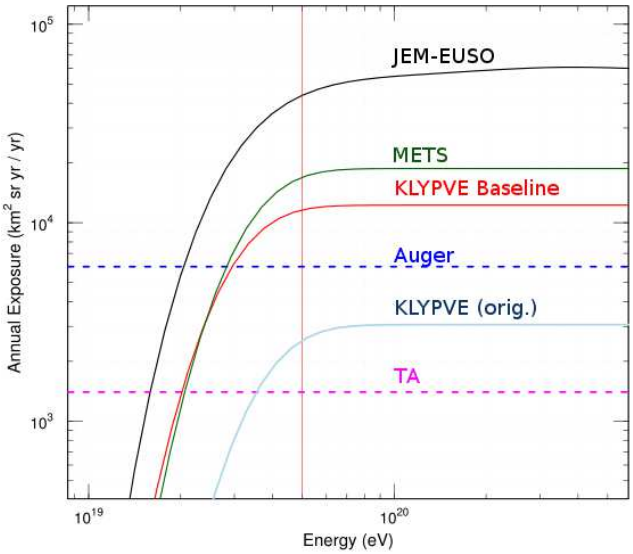

Figure 2. Exposition of ground-based and space experiments on the UHECR registration: TA – Telescope Array, Auger – Auger Observatory, KLYPVE (orig.) – KLYPVE according to the conceptual design, KLYPVE Baseline and METS – improved variants of the KLYPVE experiment.

According to the initial project the field of view of the detector was 7.5 degrees. It was found out to be insufficient even compared to the ground-based instruments (see Figure 2 – KLYPVE orig.) and annual exposition was less than one for the Pierre Auger Observatory. So it was decided to improve the OS by means of correcting optical elements.

1.2 JEM-EUSO

Developed by an international collaboration of scientists JEM-EUSO is a wide-angular camera (±30°), consisted of three large (2.65 m in diameter) Fresnel lenses and ptotodetector with several hundred of thousand pixels. Angular resolution of the camera is 1 mrad. Initially it was planned to place the telescope onboard the Japanese experimental module of the ISS, but later the Japanese space agency had abandoned the financing and the leading role in the project, so it was decided to realize the project of the basis of the Russian experiment KLYPVE, using the experience of the JEM-EUSO collaboration (in particular, experience in the production of large Fresnel lenses).

The main directions of the collaboration acitivity in 2014-2015 were the following:

- Participation in the improvement of the KLYPVE experiment (KLYPVE-EUSO).
- Development of new experiments for the tests of the elements of JEM-EUSO detectors and algorithms for events registration and data processing (EUSO Super Pressure Balloon, mini-EUSO)

2. Optical systems of the improved version of KLYPVE detector

Development of the detector's OS became one of the most actively developed directions within the frames of KLYPVE experiment. It consists of three basic sub-directions:

10) Simulation and development of a project of the variants of OS.
11) Production and tests of a press-form for the segment of mirror-concentration.
12) Production and tests of the samples of the mirror for the KLYPVE detector.

Within the frames of the first subdirection two optical schemes (baseline and three-eye variants) were developed.

In the baseline variant the size of reflector is kept the same as at the previous stage was planned – its diameter is 3.4 m. On order to correct strong off-axis aberrations it is proposed to place correcting lens relatively far from the photodetector: axial distance from the back surface of the lens to the focal surface is 70 cm (see Figure 3, left). Lens's diameter is 1.7 m. Total axial length of the system (distance from the mirror's pole to the center of the focal surface) is 4 m, diameter of the focal surface is 1.4 m. The both surfaces of the lens have the same radius (1.872 m). At the thickness of 10 mm lens's mass is 27.5 kg.

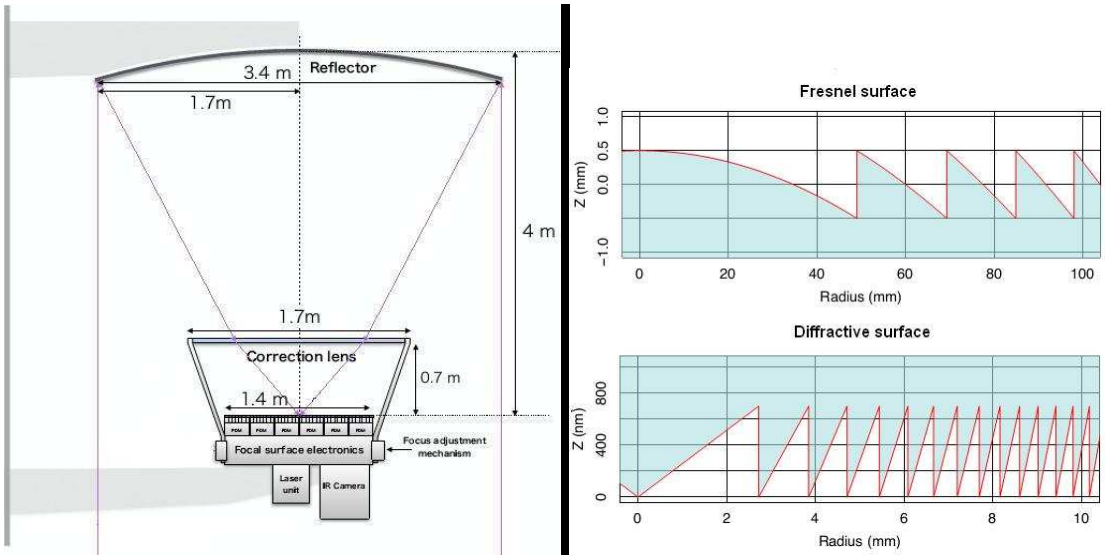

Figure 3. Left – baseline version of the K-EUSO optical system. Right – Baseline lens's surfaces.

A significant problem of this OS version is delivery of such a huge system to the orbit and additional problems with the system's deployment and its adjustment in open space, which appear under using of elements' segments (mirrors, lens, photodetector, support structure). It became one of the key reasons for the development of the second version of the deterctor – multi-eye system (Multi Eye telescope system –METS).

The basic idea of the METS concept is splitting of the wide field of view into several smaller fields, interlinked with each other. Separate parts of the system are telescopes with their own reflector, photodetector and correcting lens (see Figure 4). But due to the smaller field of view of the separate telescope the lens can be placed only in the direct vicinity of the focal surface. Different position of photodetector during the delivery and operation is possible.

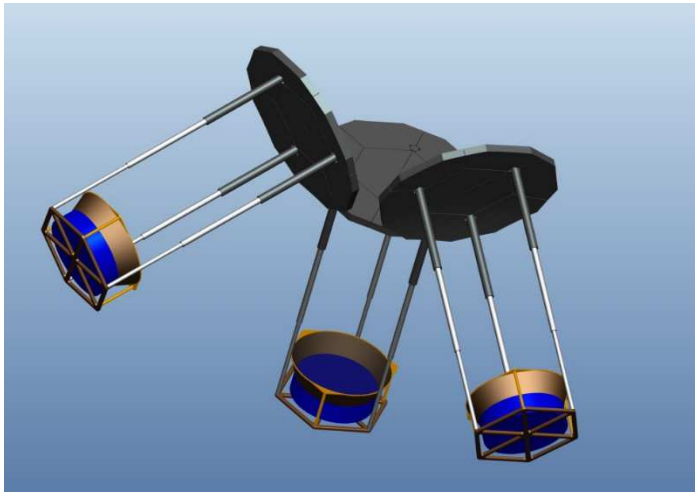

Figure 4. Multi-eye version of the KLYPVE detector.

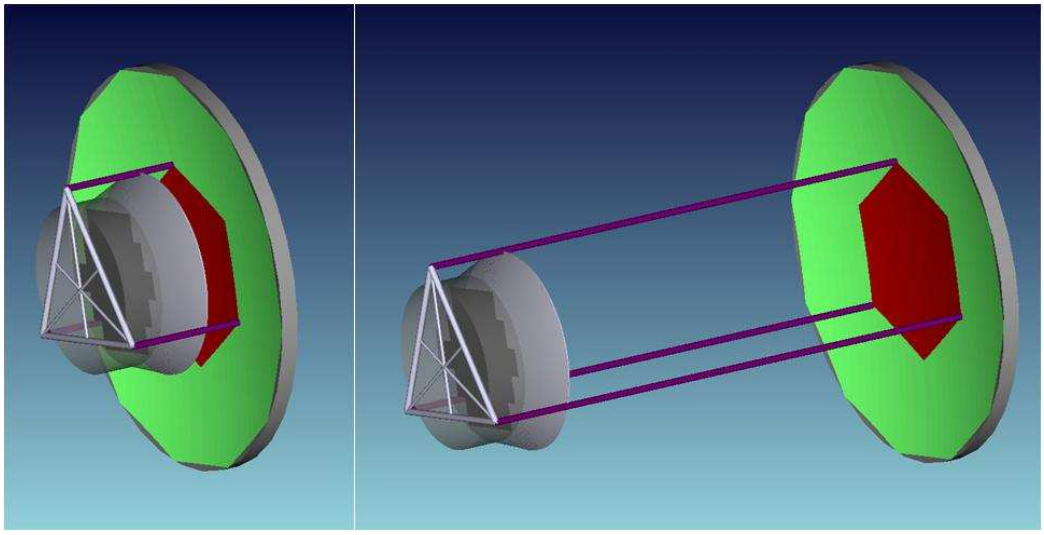

Figure 5. One of the METS telescopes during delivery (left) and operation (right). Photodetector and corrector form the unite module.

A system of three-eye telescope METS-3 with 2.4 diameter of each reflector and 3 m axial length is the best variant for the given size limits for the ISS project.

The rest characteristics of the system (parameters of the lens corrector, its location, reflector's and focal surface's shapes) are selected by means of optimization calculations.

Press-form production

In order to check the possibility for the production of a mirror with large area and improved requirements on the quality of the surface is was decided to manufacture a test sample of the central segment of the KLYPVE mirror as a METS-3 with parabolic shape of the surface (model of the mirror is presented in Figure 6). It will allow to test the technological chain of the mirror's manufacturing (from the press-form production up to applying of the reflecting and protective layers) and optical testing.

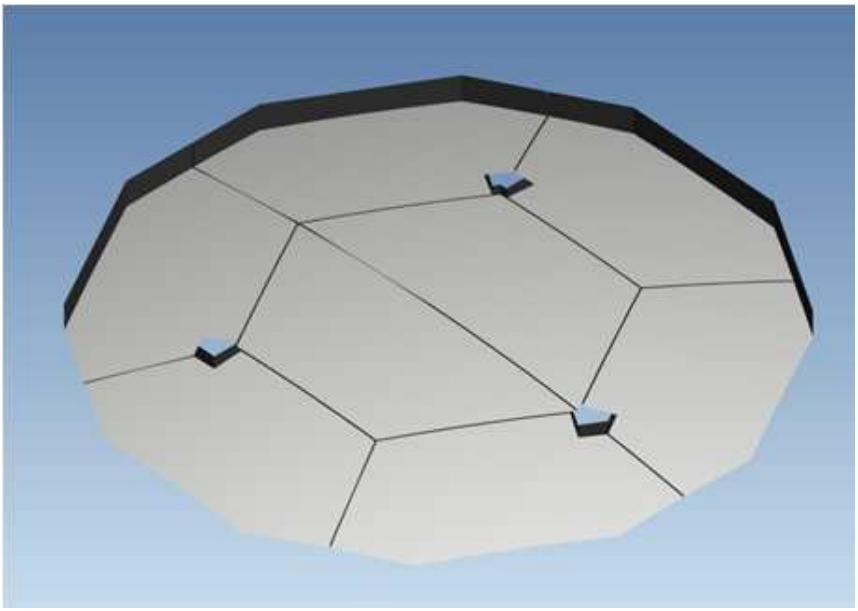

Figure 6. 3D-model of the mirror-concentrator METS-3.

Press-form of the central segment of the mirror was developed and produced in the Scientific-engineering center of instrumentation of SINP MSU. In future a mirror's segment will be manufactured according to this form.

At the same time carbon-plastic mirrors were developed and improved. The manufactured samples (one plane sample and two spherical ones) are tested in

order to evaluate their degree of roughness, profile and optical characteristics. Preliminary studies have shown that it is necessary to make the upper layer of carbon-plastic thicker and to use fabric with lower diameter of fiber in order to improve the quality of reflecting surface.

3. **KLYPVE photodector**

After the development of a two-component OS with added correcting lens it became possible to provide signal's focusing in one pixel of 64-channel MAPMT in a wider field of view. So it was decided to use two-component OS and photodetector based on MAPMT (photosensor, used within the frames of JEM-EUSO project).

The arrangement of the focal plane of the JEM-EUSO detector is presented in Figure 7. Four MAPMTs form an elementary cell of the photodetector, 9 cells (36 MAPMTs) form a module of photodetector, 137 modules are located at the focal surface and form a photodetector. Each module is operated independently from the rest (own power supply system, analog and digital electronics). The signal is processed independently in each module of the photodetector up to the trigger of the first level (trigger on the increasing of a threshold in a separate cell of protodetector).

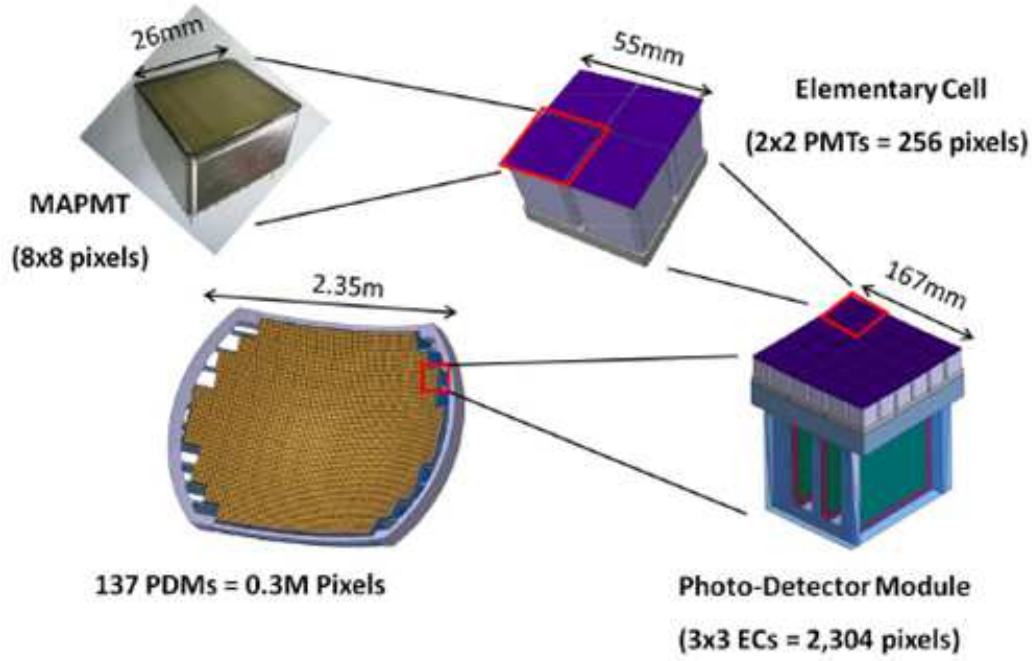

Figure 7. Arrangement of the focal surface of the JEM-EUSO detector.

In case of the improved detector KLYPVE (baseline) the focal surface has diameter of 1.4 m and can be filled with 1872 MAPMTs. MAPMTs are joined into elementary cells and modules of photodetector. The total number of pixels is 1.2×10^5.

It's important to note, that due to the limits on the size of the instrument's parts whhich can be delivered onboard the ISS by “Progress” spacecraft and then put through the air lock and located on the outer surface of the ISS, the photodetector should consist of four parts each approximately 70×70 cm^2 large.

In the improved version of the KLYPVE detector the hierarchical structure at the digital level of the signal processing is changed by network one. Each module of photodetector is complete and full-functional element of the photodetector system.

It was decided to realize digital part of signal processing in the photodetector module on the basis of integral circuits Zynq by XILINX. This chip combines FPLD, which allows very fast scanning of MAPMTs and processing part,

where more complicated algoriths of the detected events processing can be realized. Therefore it is possible to realize complete registration of an event and production of event's trigger on the base of one module (in JEM-EUSO at the module level only trigger of the first level is produced).

M.I. Panasyuk, M. Casolino, G.K. Garipov, T. Ebisuzaki, P. Gorodetzky, B.A. Khrenov, P.A. Klimov, V.S. Morozenko, N. Sakaki, O.A. Saprykin, S.A. Sharakin, Y. Takizawa, L.G. Tkachev, I.V. Yashin, and M.Yu Zotov. The current status of orbital experiments for UHECR studies. Journal of Physics, 632(1):012097, 2015.

G.K. Garipov, M.Yu. Zotov, P.A. klimov, M.I. Panasyuk, O.A. Saprykin, L.G. Tkachev, S.A. Sharakin, B.A. Khrenov, I.V. Yashin. The KLYPVE ultrahigh energy cosmic rays detector on board the ISS. Bulletin of the Russian Academy of Sciences. Physics, 79(3):326–328, 2015.

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UV-atmosphere (mini-EUSO)

There are two classes of the experiment's purposes: scientific and technological.

I. Scientific purposed:

5. Measurements of the **spatial-temporal structure of the atmospheric night glow in the "near" UV range (300-400 nm)** with high temporal (2.5 mks) and spatial (5 km) resolution in the wide field of view **(±18,3°)**.
6. Studies of the temporal and spatial distribution of the glow during fast (1-100 ms) and electric atmospheric discharges **(transient atmospheric phenomena)** and search for correlation of the map of different types of

TAP with geophysical phenomena in the upper atmosphere, ionosphere and magnetosphere.

The instrument provides possibility for detection of the glow of other nature: bioluminescene, meteors, space debris.

II. Technological purposes:

- Application of Fresnel lenses in space experiment
- Development and improvement of detecting systems of ultra-high energy cosmic rays (EUSO).
- Development and testing of new methods and apparatus for the future space experiments, in particular, application of silicon photomultipliers.

In 2015 the experiment was included into the Stage program of the scientific and applied research and experiments onboard the ISS Russian segment. Its implementation is planned for 2019-2020. Currently the experiment is fully included into the program, technical task for the instrument is prepared for approval.

In 2015 a scientific protocol between SINP MSU and JEM-EUSO collaboration, where the parties consider the experiment as joint one, was signed.

I

Scientific equipment "mini-EUSO"

The scientific equipment "mini-EUSO" includes wide-angular detector and adapter for its fixing to the luminaire from silica glass.

Physical characteristics of the equipment are presented in Table 1.

Table 1. Physical characteristics of the scientific equipment "mini-EUSO":

Size	Not more than 370×370×620 mm
Observed wavelengths range	UV: 300 – 450 nm
Field of view	36˚× 36˚ = 0.42 sr

Entrance eye: Diameter Area	 25 cm 490 cm^2
Focus distance	25 – 27 cm
Cell's size	3 mm
Number of cells; number of 64-channel MAPMT	2304 36
Resolution of an object in the atmosphere	4.5 – 5 km
Area of the view of the atmosphere	260 km × 260 km = $6.8 \cdot 10^4$ km^2
Maximum time resolution	2,5 mks

The detector's chart is presented in Figure 1.

The detector includes the following parts:

4. telescope, consisting of the case, providing structural integrity of the instrument and optical system, which is intended for the concentration of UV-radiation of the atmosphere on the surface of the photoelectric detector.
5. Telemetry control module, intended for the control of the detector's blocks control.
6. Photodetector's module, intended for UV registration and primary trigger production.
7. Module for data processing and storage, intended for the processing, recording and storage of experimental data.
8. Additional sensors' system, intended for the supportive measurements of atmospheric radiation in other wavelengths range (visual and IR).
9. Power supply system for the electric supply of the scientific equipment.

10. Onboard cabel network for the internal commutation of the modules.

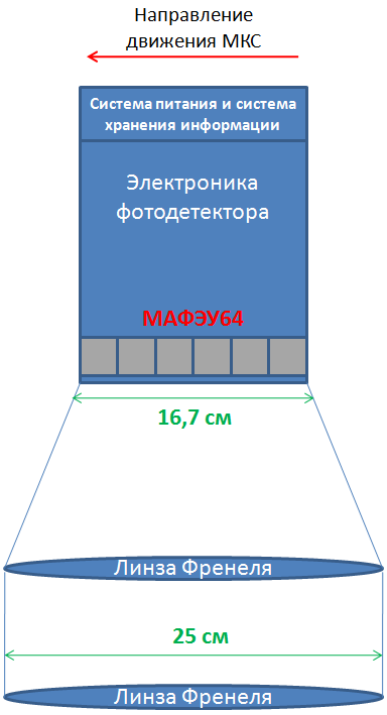

Figure 1. The chart of the “mini-EUSO” experiment.

Preliminary projecting of the separate detector's subsystems was started in 2015.

Mechanical system

A variant of design with location of the modules inside the instrument is presented in Figure 2 (left), and 3D-model of the adapter for the fixing to the ISS luminaire – in Figure 2 (right).

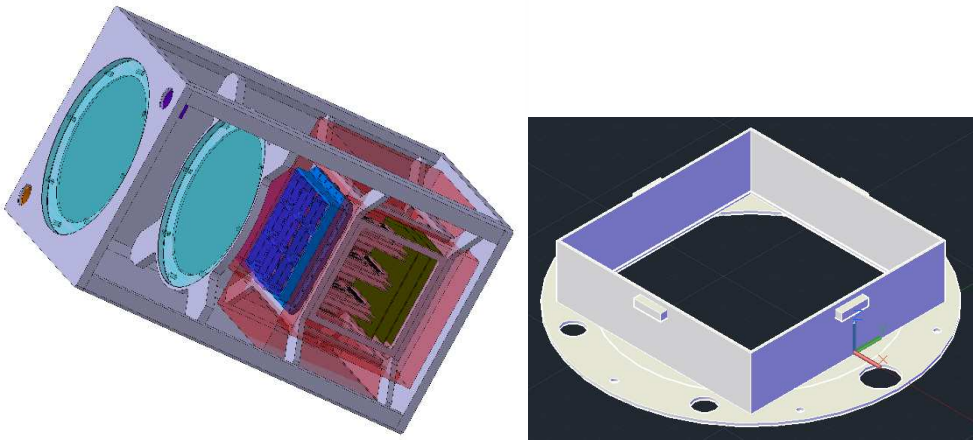

Figure 2. Design of “mini-EUSO” equipment (left), adapter for the luminaire (right).

Optical system

Optical system (OS) of the detector is intended for the imaging of the object in the field of view. The basic requirement to the OS is that the size of the spot from the parallel light beam should not exceed size of separate cell of photodetector in the total field of view (sufficiently wide – up to 40 degrees in diameter).

Detector's OS includes two-lense telescope, where each lense is two-side Fresnel one. Diameter of both lenses is 250 mm, thickness is 11 mm, material is specific UV-sensitive plastic PMMA-000 (reflection coefficient in the near UV is about 1.5). Four Fresnel surfaces allowed to satisfy the basic requirement on the signal's focusing.

The result of step-by-step tracing of the beams in the software ZEMAX is presented in Figure 3. OS and the way of UV beams for the field angles of 0˚, 5˚, 10˚, 15˚, 20˚ and 25˚ are presented there, and point diagram – image in the focal plate – for the same angles is shown in Figure 4. Spot's size expressed in RMS-diameter is not more than 2 mm, which is less than the size of photodetector's cell.

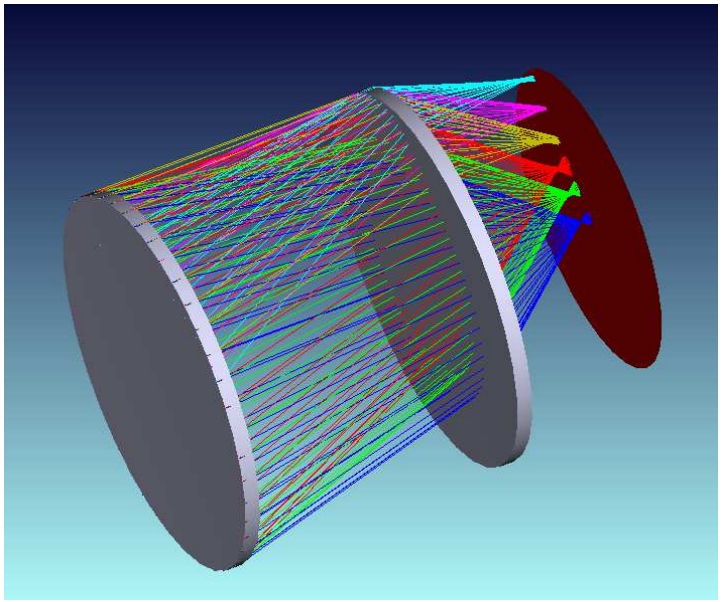

Figure 3. Step-by-step tracing of the beams in OS, field angle: 0˚, 5˚, 10˚, 15˚, 20˚ and 25˚.

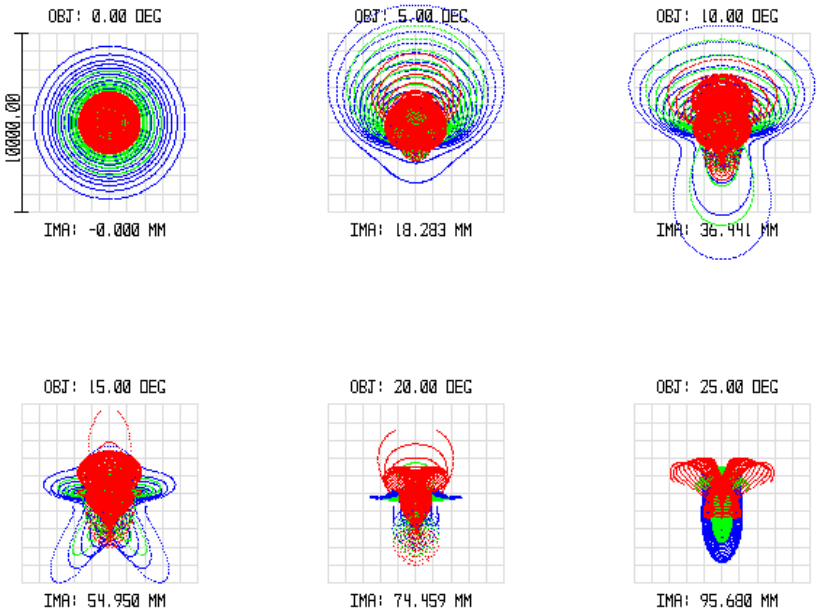

Figure 4. Point diagram for the field angles of 0˚, 5˚, 10˚, 15˚, 20˚ and 25˚.

Focal plate

Photo-sensitive element of photodetector is a multi-channel (multi-anode) photomultiplier tube (MAPMT), which provides high sensitivity and possibility for fast signals registration in UV-range.

R11265-M64 produced by Hamamatsu, developed for JEM-EUSO project, is considered as a basic variant of MAPMT. It has bi-alcaline photo-cathode with quantum efficiency about 35%. Size of separate pixel is 2.88 × 2.88 mm, maximum of sensitive area of the whole MAPMT is about 23.04 × 23.04 mm. This photomultiplier ran through flight tests, in particular, it was successfully used during balloon experiment on the studies of night atmospheric background (EUSO-Balloon). Focal plate is presented in Figure 5 (left), and 3D-model of photodetector in Figure 5 (right).

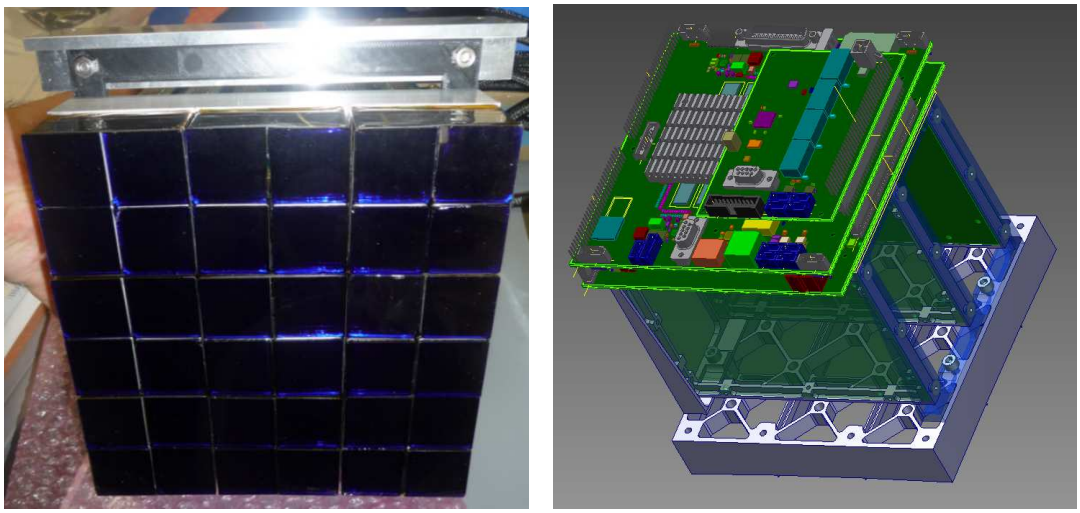

Figure 5. Focal plate of the detector (left), 3D-model of photodetector (right).

Currently SINP MSU and JEM-EUSO collaboration actively develop equipment for the probable execution of space experiment onboard the ISS in 2017 with participation of Italian astronaut P. Nespoli (53/54 expedition) and Russian cosmonaut, MSU graduate S.Ryazansky (54/55 expedition).

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InterhelioProbe Project

The goal of the project is to obtain original information in the field of solar physics during out-of-ecliptic observations of the Sun, including its subpolar regions, and measurements near the Sun (up to 60-70 solar radii).

It is supposed to place not less than two identical SPER “telescopes” directed at different angles to the line “SC – Sun” with single electonics block onboard the SC “Interheliozond” in order to detect anisotropy of the particles from different directions.

A neutron directed telescope InterSONG is developed by SINP scientists in order to study solar neutron flux during out-of-ecliptic observations of the Sun, including its subpolar regions and measurements near the Sun by means of instruments onboard the SC “Interheliozond”. Detection of fast neutrons is based on the sequence of interactions of the detected neutron with the matter of the hodoscope consisting of scintillation fibers and scintillation calorimeter. A long program of simulation of the events and selection criteria in the neutron telescope was developed in order to find out the characteristic properties of interactions of the neutrons, both primary and after the first interaction in hodoscope.

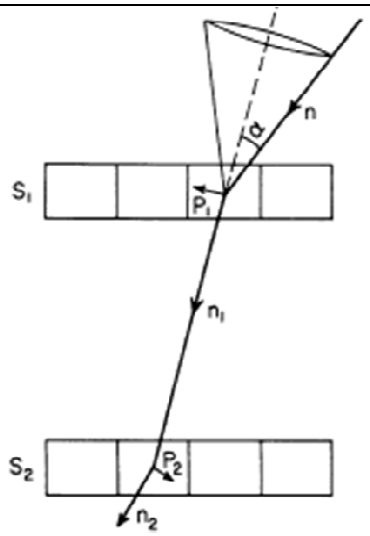

Fig. 1. Principle of detection of the neutrons based on the scattering of the neutron in two position-sensitive detectors. Direction of the neutron's coming is determined as the surface of a cone with cone angle α, found from the event's kinematics.

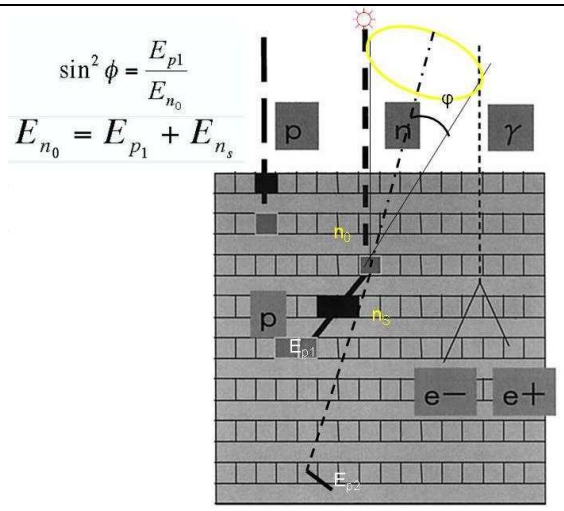

Fig. 2. Principle of fast neutrons detection is based on their scattering on the hydrogen nuclei or other element. Kinematics of the neutron scattering is presented in comparison with passing of protons and gammas through the godoscope volume.

During 2014-2015 some additions and correction to the detailed design of the project were made. In particular, an experimental sample of the InterSONG device was manufactured and was exposed to some metrological measurements.

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An Observatory of High-Energy Cosmic Rays (OHECR) – development of conception of a project, scientific-technical bases for the project's technical task development

The goal of the research concerns the field of extra-atmospheric studies of the high-energy cosmic rays. The basic concepts for the development of the OHECR experiment development were determined. Scientific-technical basis of the primary data for the development of the technical task of the OHECR space complex development were defined. Basic principles and technologies for high-

energy cosmic rays registration are presented. Project layout of the experimental equipment and main characteristics are found. Input data for the development of the technical task on the development of OHECR space complex were produced. For the realization of the experiment it is necessary to implement the following four principles:

1) high value of the exposure factor, which should be 1.5 orders of magnitude higher than for all past and present experiments during 50 years of studies;

2) high measurements accuracy, which means large mass of the exposed scientific instrument;

3) possibility frontier for the leadout of the Russian heavy spacecrafts should be used;

4) the OHECR scientific complex is manufactured by means of the leading technologies of the high-energy experimental physics, which were put to an evaluation test in a numberr of ground-based and space experiments. All used methods should be open to Russian manufacturers.

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NEUTRONIUM space complex for the studies of the primary cosmic rays – concept's development

The goals and the basic scientific purposes of the cosmic rays detection on the Moon surface are defined according the the latest world-wide data. Large scale and wide range of the scientific tasks prove the extreme importance of continuation of the studies in this field. Specific characteristics of the detection of cosmic rays nuclear component were studied. It is proposed to use three runback components: gammas, neutrons and radio-emission at the frequency of 1-10 GGz

for the operation in the high-energy area. Low-energy nuclei should be recorded by multi-layered silicon detector – a part of the NEUTRONIUM complex. It is proposed to use the NEUTRONIUM complex as gamma-observatory and for the geological studies on the Moon (by using of the radio-signal reflected from the basalt layer). As a result the following concept of the NEUTRONIUM space complex is defined: three components are proposed to be used for the measurements of the paramters of the primary cosmic rays particles falling to the Moon's surface. For the simultaneous registration of three components an error of the energy definition is about 50%. The complex should include silicon pad detectors of charge, scintillation runback detectors and plate antennas for radio-emission registration. At the first stage the total geometry factor will be not less than 300 m^2sr. For gamma-astronomical studies part of modules should include scintillator rods approximately 1 m long buried into regolyth.

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Development of the component of the technical proposal on the outer radiation conditions for the Laplas-P spacecraft

Radiation conditions for the Laplas-P mission to Ganimed, Jupiter's satellite, were calculated. The following parameters were obtained: integral and differential energy spectra of the electrons and protons of the Jovian magnetosphere and of the protons and ions of the solar and galactic cosmic rays, linear energy transfer (LET) spectra of the cosmic rays' ions along the flight's trajectory behind the protection of different thickness, radiation doses behind the protection of different thickness during the interplanetary flight, gravitational manoeuvres in

the Jovian system and during Laplas-P operation on orbit and at the surface of Ganimed.

Podzolko M. V., Getselev I. V., Gubar Yu. I. Radiation hazard for different scenarios of space missions to Jupiter's moons, 6th Moscow Solar System Symposium (6M-S3), 5–9 October 2015, IKI RAS, Moscow, Russia, p. 6MS3-GP-02.

Contact: Podzolko Mikhail Vladimirovich, spacerad@mail.ru

Calculations of the radiation conditions for the Arktika-M spacecraft's flight

Fluxes of the electrons and the protons of the Earth's radiation belts and of the cosmic rays and radiation doses behind the protection of different thickness on the orbit of the Arktika-M spacecraft are calculated. The results were compared to the radiation levels on the other near-Earth orbits. It is shown that the spacecraft on the determined orbit will be exposed to an essential radiation danger. Calculated value of the annual radiation dose for the solar cycle maximum behind the protection of 1 g/cm^2 is about 20 krad, behind 1.5 g/cm^2 is about 5 krad (active operation of the spacecraft is 5-7 years). Radiation belts particles will affect on the spacecraft on the inoperative parts of the orbit; on the basic part: 3 hours before and 3 hours after apogee passing, the spacecraft will be over the belts, where the cosmic rays will affect it. Selecting the higher perigee of an orbit will decrease the dose behind the protection ≥1.5–2 g/cm^2 for a factor of ≥1.5–2. The results can be used for the definition of the requirements for the scientific equipment's resistance to the influence of space radiation.

Podzolko M.V., Getselev I.V., Tasenko S.V., Shatov P.V. Radiation conditions of the Arktika-M spacecraft flight, Heliogeophysical research, v. 14, 2015 (in Russian)

Contact: Getselev Igor Vladimirovich, getselev@mail.ru

Space complex consisting of three specialized small spacecrafts with mass not over 100 kg

In order to provide monitoring of radiation conditions in the near-Earth space with possibility of prediction of radiation conditions for a spacecraft on the near-Earth orbit a specialized space complex is proposed. It consists of three small spacecrafts with mass less than 100 kg. The spacecrafts should be launched to several circular orbits with altitudes of 650, 1700 and 800 km and inclination of 80, 77 and 60 degrees, correspondingly. Each spacecraft will measure fluxes of high-energy protons and electrons by means of identical detector systems (spectrometers) differently directed. Original design of 4 spectrometers is proposed. Spacecrafts will have the same measuring complex onboard.

The proposed space complex will allow real-time observation of the particle fluxes distribution. It will provide real-time monitoring of radiation conditions on the mentioned orbits and possibility for evaluation of radiation doses at any location of the nearest space, i.e. for other spacecrafts.

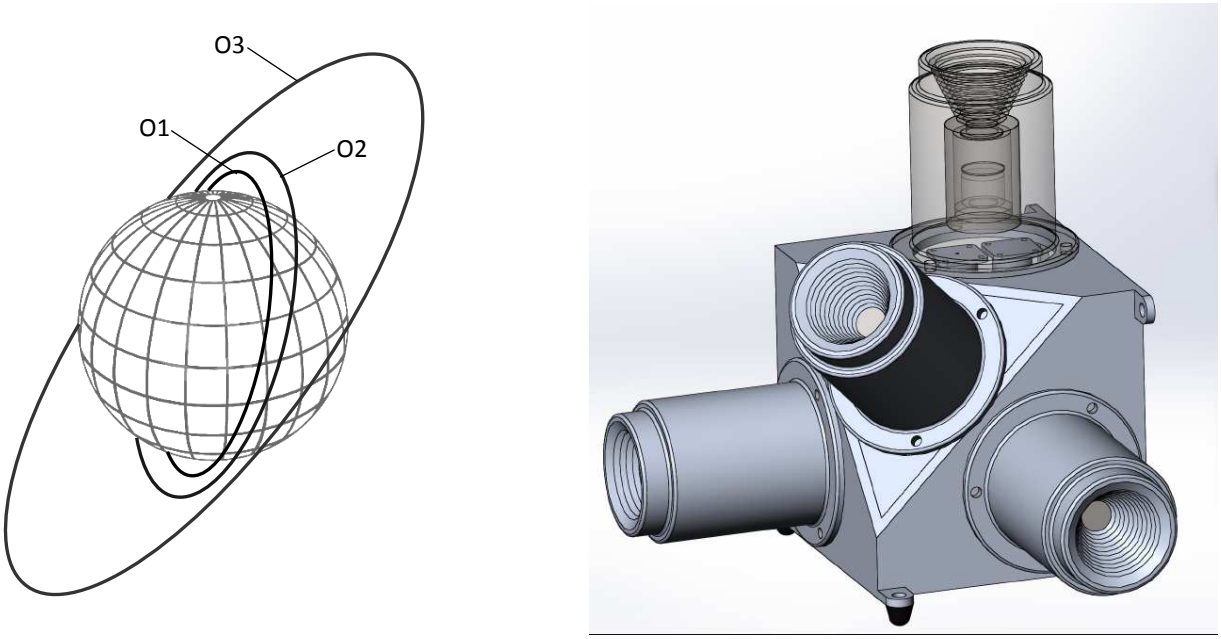


Figure. Group of three small spacecrafts on different circular orbits (left), original design of four spectrometers for separate detection of the protons and electrons – basic radiation components of the near-Earth space.

M.I. Panasyuk, M.V. Podzolko, A.S. Kovtyukh, I.A. Brilkov, N.A. Vlasova, V.V. Kalegaev, V.I. Osedlo, V.I. Tulupov, Operational radiation monitoring in near-Earth space based on the system of multiple small satellites. Cosmic Research, 2015, v.53, N6, pp. 423-429.

Contact: Tulupov Vladimir Ivanovich, ikt0840@mail.ru

Instruments for fast neutrons fluxes registration in the upper atmosphere

An instrument for registration of neutral radiation (gammas, neutrons) during the satellites and balloon monitoring studies is developed in several modifications. The instrument provides spatial sensitivity and allows determination of the direction of the detected particles and quanta coming. Spectral and temporal

characteristics of the instrument provide a possibility for registration of gamma-lines and thin temporal structure of the bursts.

Iyudin A.F., Bogomolov V.V., Galkin V.I. et al. Instruments to study fast neutrons fluxes in the upper atmosphere with the use of high-altitude balloons, Advances in Space Research, 2015, 56(10), 2073-2079, doi 10.1016/j.asr.2015.08.002

Contact: Iyudin Anatoly Fedorovich, aiyudin@srd.sinp.msu.ru

Development of experimental and theoretical methods for radiation fields registration in the near-Earth space

Single particles tracks in the charged coupled matrix were simulated and the calculated images were compared with experimental ones. It allowed to understand density spectra of energy separation in SOHO/STEREO matrices.

Anokhin M.V., Galkin V.I., Ditlov V.A., Dubov A.E., Kalegaev V.V., Korolev A.G., Kuznetsov N.V., Makarychev S.V., Panasyuk M.I., Popov V.D., Chabanov V.M., Shillo A.G. To the problem of the Bragg peak's role in the evaluation of the influence of the ionizing particles' field on the microelectronics of spacecrafts. Scientific-technical review “Resistance – 2015”, Abstracts of the 18th All-Russian scientific and technical conference on radiation resistance of electronic systems, Lytkarino, Russia, June 2-3, 2015, pp. 27-29, ISSN 1997-2830 (in Russian).

Contact: Galkin Vladimir Igorevich, v_i_galkin@mail.ru

Development of new methods for Auger showers registration and Cherenkov gamma-astronomy

A new method for the studies of mass composition of the primary cosmic rays by angular distributions of muons in the Auger showers is proposed. A possibility for separation of the total flux of primary nuclei into three groups due to primary mass was demonstrated. Analysis of the sensitivity of the basic (pilot) set of optical detectors of the Pamir-XXI instrument has shown that for the point sources it is approximately comparable to the sensitivity of the full-size LHAASO instrument.

Galkin V.I., Anokhina A.M., Bakhromzod R., Mukumov A. How to deal with PCR composition problem at $E_0 >= 10^{17}$ eV arXiv:1507.03150v1

Contact: Galkin Vladimir Igorevich, v_i_galkin@mail.ru

The studies of the chemical composition of the galactic cosmic rays by space and balloons experiments

Energy spectra of the nuclei from protons to iron in the sources according to the ATIC experiment

Measured energy spectra of the rich nuclei of cosmic rays: protons, He, C, O, Ne, Mg, Si, Fe in the terms of energy per particle within the energy range from 50 GeV

to several dozens of TeV became one of the main results of the stratospheric experiment ATIC. The problem of reverse propagation was solved for the measured energy spectra of rich nuclei from the ATIC experiment basing on the several models of cosmic rays propagation in the Galaxy, based on the GALPROP system in order to obtain spectra of magnetic rigidity in the sources. It is shown that the results for the differ of spectral indices of different nuclei in the source are stable relative to particular selection of the propagation model. With high statistical significancy it is shown that Helium spectrum in the source is flatter than protons spectrum. It was demonstrated that within the range of magnetic rigidity from 50 GV to 1500 GV the steepness of nuclei spectra in the source increases steady and statistically significantly with charge increase from Helium to Iron. It means that the nuclei with different charge are accelerated in different conditions, i.e. there is no universal accelerator of cosmic rays, which operates equally for different nuclei.

A.D. Panov, N.V. Sokolskaya and V.I. Zatsepin, Energy spectra of nuclei from protons to iron in sources, according to the ATIC experiment, Доклад на ICRC2015, 29 July - 06 August 2015, Hague, Netherlands, PoS(ICRC2015)321, http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=236#session-2514

Contact: Panov Aleksandr Dmitrievich, panov@dec1.sinp.msu.ru

High-energy gamma-astronomy and cosmic rays studies by means of ground-based instruments

Correlation of the primary cosmic rays energy, measured by radio-emission and Chernkov light of the Auger showers

Within the frames of the joint experiment on the experimental plants Tunka-133 and Tunka-Rex correlation of the primary cosmic rays energy, measured by the shower's radio-emission with energy, measured by the flux of the shower's Cherenkov light. This result opens perspectives for the studies of the spectrum and composition of the cosmic rays with energy 10^{17} – 10^{19} eV in the joint experiment with scintillator detectors Tunka-GRANDE with the rate of the statistics accumulation, 20 times faster than for the shower's Cherenkov light registration.

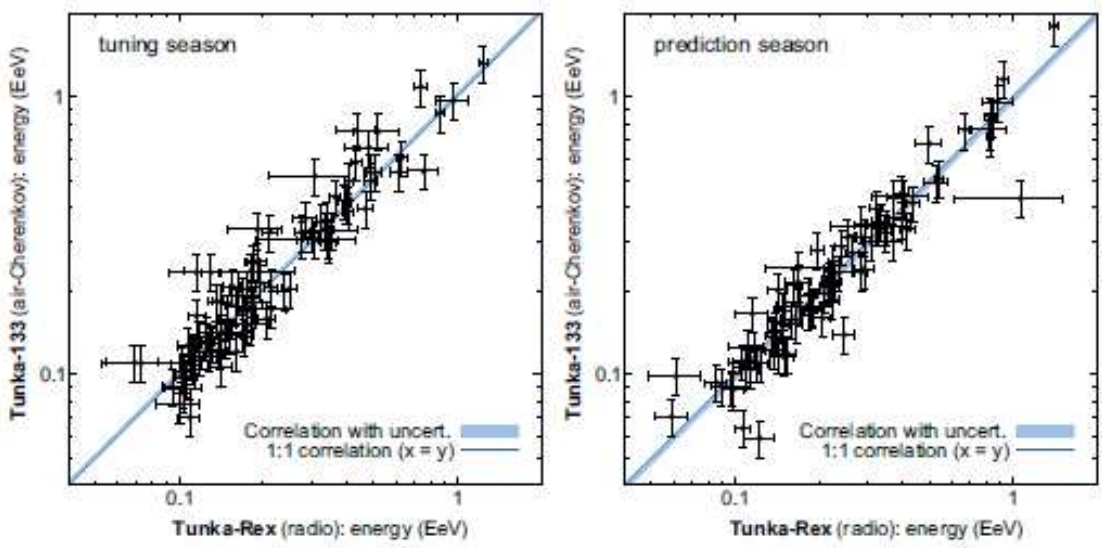


Figure. Correlation of the primary cosmic rays energy, measured by the shower's radio-emission with those, measured by the shower's Cherenkov light flux, for the first and the second years of the plant's operation.

Kostunin D., Korosteleva E.E., Kuzmichev L.A., Lubsandorzhiev N., Prosin V.V. The Tunka Radio Extension: reconstruction of energy and shower maximum of the first year data. Hague, Netherlands, July 30 – August 6, 2015.

Contact: Kuzmichev Leonid Aleksandrovich, kuz@dec1.sinp.msu.ru

Energy spectrum of the primary cosmic rays by the Tunka-HiSCORE data

Energy specrum of the primary cosmic rays is obtained within the energy range from 300 TeV up to 10 PeV by the data of 80 hours of operation of the first prototype of the HiSCORE array, which consists of 9 stations for the shower's Cherenkov light registration with low threshold. It opens perspectives for the studies of the spectrum and composition of the cosmic rays at energy 10 times lower than the energy of classic “knee” and the structure of the spectrum in the “knee”.

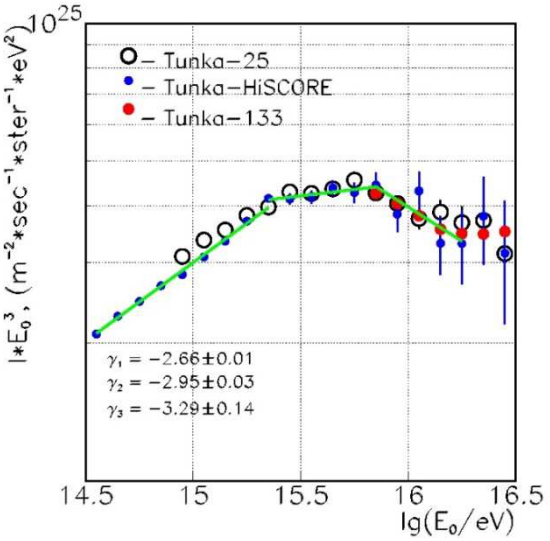


Figure. Energy spectrum of the primary cosmic rays according the data of 80 hours of operation of the first prototype of the Tunka-HiSCORE.

Berezhnev S.F., Budnev N.M., Buker M., et al., First results from the operation of the prototype Tunka-HiSCORE array, Bulletin of the Russian Academy of Sciences: Physics, 2015, v.79, N3, pp. 348-351.

Contact: Kuzmichev Leonid Aleksandrovich, kuz@dec1.sinp.msu.ru

Beginning of the data accumulation at a new experimental plant Tunka-HiSCORE-28

In 2015 a new low-threshold plant for registration of Auger showers by Cherenkov light Tunka-HiSCORE-28 was put into operation. During the first month of observation in October 2015 (~100 hours) it recorded ~ 4 millions showers with using of 4 or more stations. Such rate of data accumulation will allow finding of the abundance of the events from a point source (gammas from Crab nebula) on the background of the charged cosmic particles flux.

Prosin V. The Results and Perspectives of Cosmic Rays Mass Composition Study with EAS Arrays in the Tunka Valley, Доклад на конференции: TAUP-2015, Torino, September 2015

Contact: Prosin Vasily Vladimirovich, v-prosin@yandex.ru

Theoretical and experimental studies of the radiation transport in the Earth and astrophysical media

Direct observations of neutrino oscillations in the channel $\nu_\mu \rightarrow \nu_\tau$ with the OPERA experiment

In September 2015 OPERA collaboration announced discovery of neutrino oscillations in the channel $\nu_\mu \rightarrow \nu_\tau$. The research was done on the base of the hybrid detector OPERA, located in the underground laboratory Gran-Sasso (Italy), using muon neutrino beam from CERN and consisting of electronic sensors, muon spectrometers and nuclear emulsions layered with tungsten plates. Spatial resolution of emulsions (~ 1 mkm) allowed to identify part of ν_τ interactions in the charged weak current channel. Search for these events is based on the observations of the marks of short-living particle's decay. The background is basically formed by the events of ν_μ resulted with charmed hadrons' generation. They also contain track of short-living particle and similar to ν_τ interactions in the decay's topology. Exposure was made in 2008-2012. Earlier on the part of experimental data 4 candidates for ν_τ in the emulsion detector were observed. In total 5408 events were analyzed (it is for 15% more than statistics used for 4 candidates observation). Besides, background was evaluated. Statistical significance for the hypothesis of background only was 5.1σ. Characteristics of all 5 events–candidates are noncontroversial to the expected ones for ν_τ interactions. Consequently, neutrino oscillations in the channel $\nu_\mu \rightarrow \nu_\tau$ were discovered with the OPERA experiment.

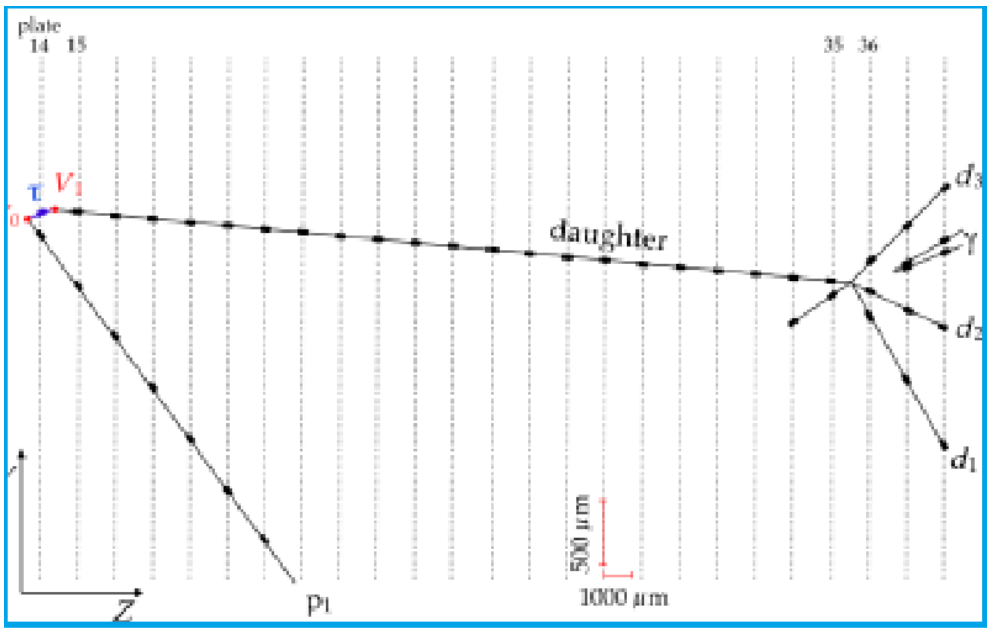


Figure. Direct observation of neutrino oscillations in νμ→ντ channel with the OPERA experiment.

Agafonova, N.; Aleksandrov, A.; Anokhina, A., Dzhatdoev, T., Podgrudkov D., Roganova T., et al., (The OPERA Collaboration) Discovery of tau neutrino appearance in the CNGS neutrino beam with the OPERA experiment. Phys.Rev.Lett. v.115, 121802 (1-7) 2015, (ArXiv e-prints. n. arXiv150701417O , pp. 1-7, 2015) DOI:http://dx.doi.org/10.1103/PhysRevLett.115.121802

Agafonova N., Anokhina A., Dzhatdoev T., Podgrudkov D., Roganova T., et al., (The OPERA Collaboration) Limits on muon-neutrino to tau-neutrino oscillations induced by a sterile neutrino state obtained by OPERA at the CNGS beam Journal of High Energy Physics. vol. 2015, n. 6, 2015. (ArXiv ePrint n.arXiv:: 1503.01876, pp. 1-8, 2015)

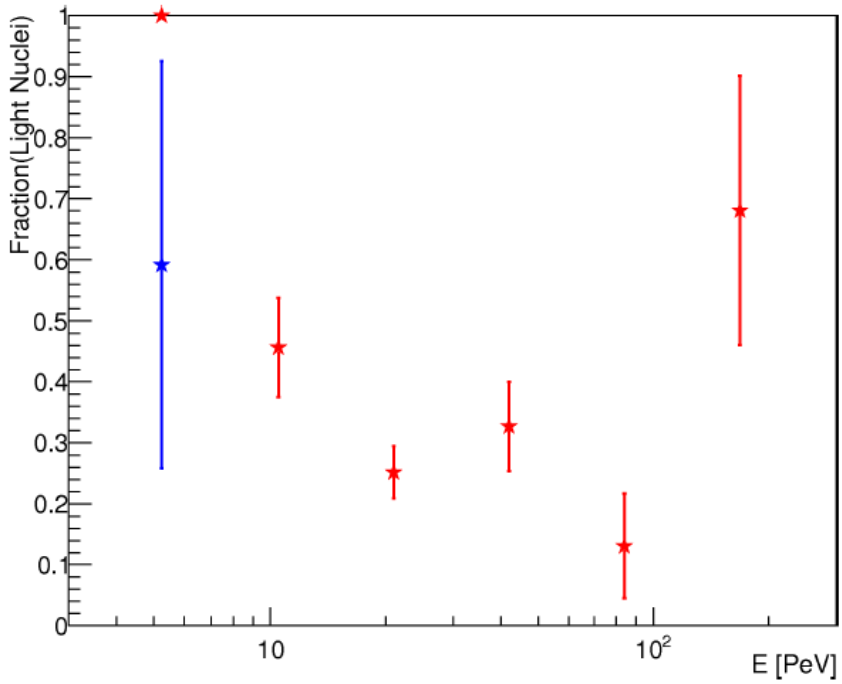
Anokhina, A.; Dzhatdoev, T.; Morgunova O., Roganova T., et al., (The NESSiE collaboration) Search for Sterile Neutrinos in the Muon Neutrino Disappearance Mode at FNAL, ArXiv e-prints., (ArXiv:1503.07471v2 [hep-ph] pp. 1- 18, 2015)

Contact: Roganova Tatiana Mikhailovna, rogatm@yandex.ru

Extraction of light nuclei of the primary cosmic rays in the event-by-event mode of the SPHERE experiment

In order to study the primary cosmic rays composition in the range of 5-200 PeV an analysis of individual events' characteristics was used for the experimental data of the SPHERE-2. A possibility for extraction of the light component of the Auger shower against the background of the hard component was found out. The

value of the primary energy can be determined with an accuracy of 10-20% depending on energy. As a result a plot of light component fraction depending on the primary energy was obtained. This result does not contradict to the results of



the KASKADE-Grande experiment. Besides, it was demonstrated that essentially multiscale criteria allow to increase separability of the groups of primary cosmic rays nuclei during evaluation of the chemical composition.

Figure. Fraction of light nuclei of the primary cosmic rays against the energy using the 2013 experimental data of the SPHERE-2 experiment in 2013.

Antonov R.A., Aulova T.V., Bonvech E.A., Chernov D.V., Dzhatdoev T.A. Finger M Фингер Mikh. Galkin V.I., Podgrudkov D.A.,Roganova T.M. Event-by-event study of CR composition with the SPHERE experiment using the 2013 data . Journal of Physics: Conference Series. vol.632, n. 012090, pp. 1-8, 2015. (ArXiv e-prints. n.arXiv:1503.04988, pp. 1-8, 2015)

Chernov D.V., Antonov R.A., Aulova T.V., Bonvech E.A., Dzhatdoev T.A., Galkin V.I., Podgrudkov D.A.,Roganova T.M. Detection of reflected Cherenkov light from extensive air showers in the SPHERE experiment as a method of studying

superhigh energy cosmic rays Physics of Particles and Nuclei. vol. 46, n. 1, pp. 60- 93, 2015

Contact: Chernov Dmitry Valentinovich, chr@dec1.sinp.msu.ru

A method for calculation of the atmospheric muons energy spectrum

A method for the calculation of the atmospheric muons energy spectrum is proposed. Muon energy distributions from the primary protons and Helium with different fixed values of energy, calculated by means of CORSIKA 7.4 software, are multiplied by the fluxes of primary particles and then an integral is taken over the particles' energy. At muon energy of $E_\mu = 10^4$ GeV predictions of SIBYLL 2.1, QGSJET II-03, QGSJET II-04 and QGSJET01 models differ from the Gajser spectrum for ~30-50%. The main input to the muon spectrum is made by the decays of $\pi^\pm$ and $K^\pm$ mesons of the 1^{st} generation. So, the models predict undervalued or overvalued generation of $\pi^\pm$ and $K^\pm$ mesons in high-energy range. It is confirmed by the data of accelerator experiments LHCf and TOTEM. Models' errors are taken into account by the TELESCOPE ARRAY collaboration by normalizing of the signal for the fluorescent light value (the signal becomes 1.27 times lower).

Dedenko L.G., Roganova T.M., Fedorova G.F. Testing model energy spectra of charged particles produced in hadron interactions on the basis of atmospheric muonsPhysics of Atomic Nuclei, 2015, vol. 78, N7, p. 840-848)

Lukyashin A.V., Dedenko L.G., Roganova T.M., Fedorova G.F. Constrains of hadronic interaction models from the cosmic muon observations Web of Conferences Proceedings, 2015, vol.99, p. 10003 (ArXiv Astrophysics e-prints, 2015, №1504.0585, p. 1-5)

Contact: Dedenko Leonid Grigorievich, ddn@dec1.sinp.msu.ru

Development of the muon radiography method with emulsion track detectors in Russia

By means of the test experiments on muon radiography with emulsion track detectors it was shown that according to the simulation, emulsion track methods allows to obtain information on the characteristics of the structure of the studied massive industrial and natural objects. Spatial distributions of muon fluxes, measured during test experiments, and calculated predictions of the inhomogeneities in the structure of the objects are in good agreement, generally. It demonstrates a possibility for the development of the muon radiography method with emulsion track detectors of the proposed design and for the emulsion data processing means, available for Russian institutes.

Pudlications:

Aleksandrov A.B., Bagulya A.V., Chernyavsky M.M., Galkin V.I., Dedenko L.G., Fomenko N.V., Konovalova N.S., De Lellis G., Managadze A.K., Orurk O.I., Polukhina N.G., Roganova T.M., Shchedrina T.V., Sirignano C., Starkov N.I., Tan Naing So, Tioukov V.E., Vladimirov M.S., Zemskova S.G. Test experiments on muon radiography with emulsion track detectors in Russia Physics of Particles and Nuclei Letters. 2015. Vol. 12, № 5, PP. 713-719

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Cascade model of “the pair-production anomaly” in blazar spectra at very high energies

Characteristics of the spectra, resulted from the absorption of primary gamma by the photons of Extragalactic Background Light (EBL), in some blazars' spectra are weaker, than it is predicted by the most EBL models. It demonstrates insufficiency of the simplest models of extragalactic propagation of gammas, which takes into account only absorption of primary photons. The simplest model of the mentioned anomaly, including secondary (cascade) component of gammas, was considered, and it was shown that the cascade component is able to diminish statistical significance of the anomaly essentially.

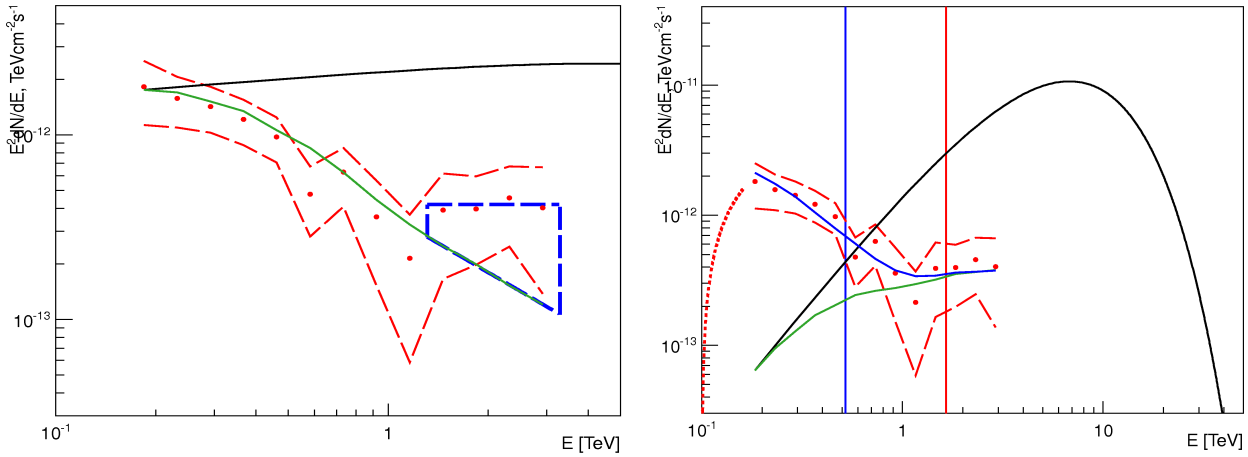

Figure. The (absorbed) model spectral energy distribution (SED) of blazar 1ES 1101-232 (left panel, green line) and including the cascade component (right panel, blue line).

Dzhatdoev T.A., Cascade model of the anomaly in blazar spectra at very high energies, Bulletin of the Russian Academy of Sciences: Physics, V. 79, P. 329-331 (2015)

Dzhatdoev T.A., On conservative models of “the pair-production anomaly” in blazar spectra at Very High Energies, Journal of Physics: Conference Series, V. 632, id. 012035 (2015)

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Studies of the Sun, monitoring and simulation of the radiation medium and plasma processes in the heliosphere and in the near-Earth space

Influence of non-thermal nuclear reactions on catalythic burning processes in the solar core plasma

Nonthermal nuclear effects triggered in the solar carbon-nitrogen-oxygen (CNO) cycle by fast α particles—products of the pp chain reactions—are examined. The main attention is paid to 8.674-MeV α particles generated in the ^{7}Li(p,α)α reaction. Nonthermal characteristics of these α particles and their influence on some nuclear processes are determined. It is found that the α-particle effective temperature is at a level of 1.1 MeV and exceeds the solar core temperature by 3 orders of magnitude. These fast particles are able to significantly enhance some endoergic (α,p) reactions neglected in standard solar model calculations. In particular, they can substantially affect the balance of the p + ^{17}O ↔ α + ^{14}N reactions due to an appreciable increase of the reverse reaction rate. It is shown that in the region R = 0.08–0.25R_{Sun} the reverse α + ^{14}N reaction can block the forward p + ^{17}O reaction, thus preventing closing of the CNO-II cycle, and increase the ^{17}O abundance by a factor of 2–155 depending on R. This indicates that the fast α particles produced in the pp cycle can distort running of the CNO cycle, making it essentially different in the inner and outer core regions.

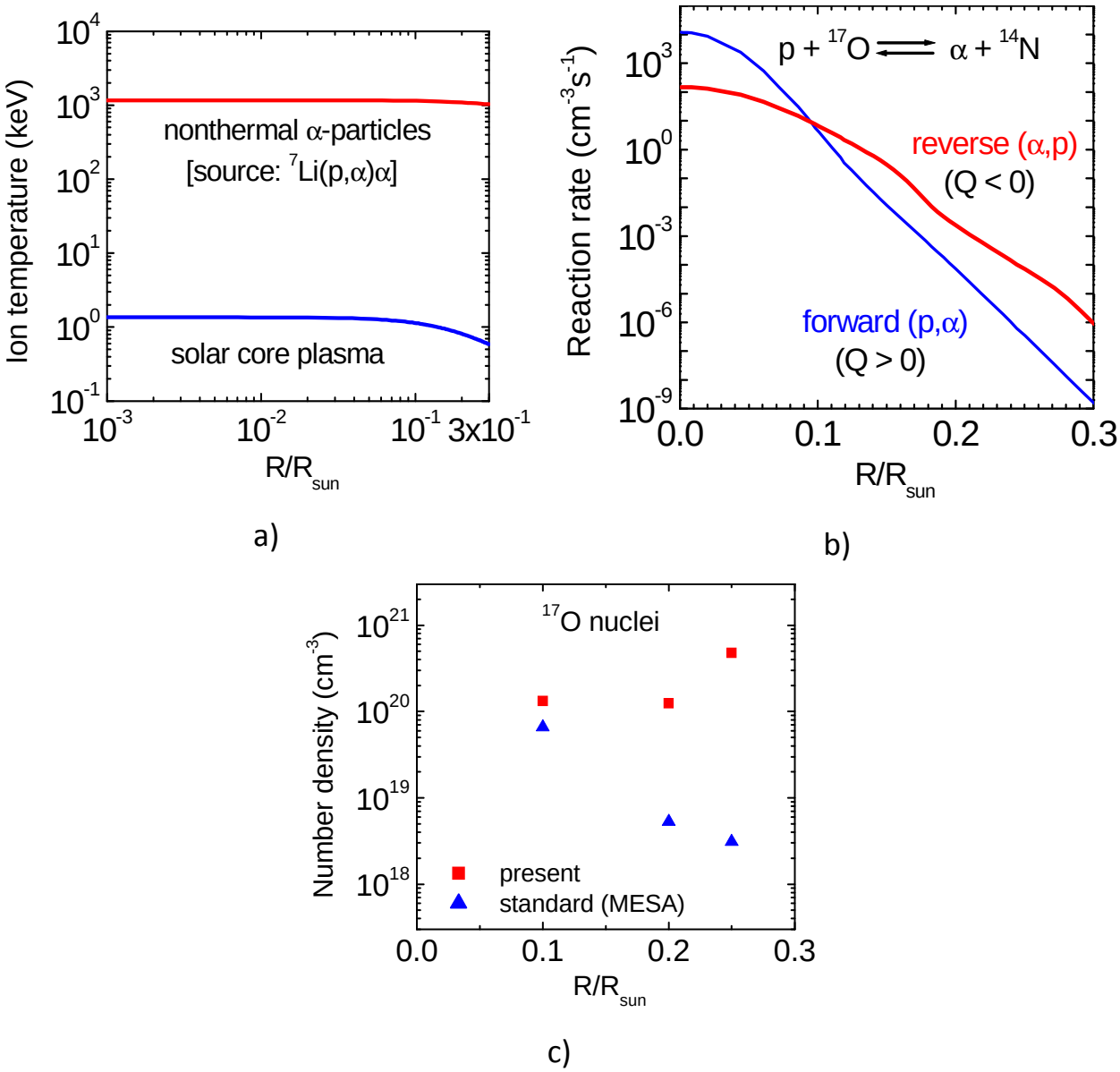

Figure. Effective temperature (a), the rates of the direct and reverse reactions 17O (p,⍰) 14N (b) and 17O contain (c) described by standard model (blue dots and lines) and taking into account non-thermal nuclear reactions (red dots and lines).

V.T. Voronchev, Nonthermal nuclear reactions induced by fast ⍰ particles in the solar core, Physical Review C vol.91, No.2, p.028801 (2015);

Contact: Voronchev Viktor Tikhonovich, voronchev@srd.sinp.msu.ru

Magnetic fields' effects in big bang nucleosynthesis

A standard nuclear reaction network for big bang nucleosynthesis (BBN) simulations operates with spin-averaged nuclear inputs—unpolarized reaction cross sections. At the same time, the major part of reactions controlling the abundances of light elements is spin dependent, i.e., their cross sections depend on the mutual orientation of reacting particle spins. Primordial magnetic fields in the BBN epoch may to a certain degree polarize particles and thereby affect some reactions between them, introducing uncertainties in standard BBN predictions. To clarify the points, we have examined the effects of induced polarization on key BBN reactions—p(n,γ)d, d(d,p)t, d(d,n)^{3}He, t(d,n)α, ^{3}He(n,p)t, ^{3}He(d,p)α, ^{7}Li(p,α)α, ^{7}Be(n,p)^{7}Li—and the abundances of elements with A ≤ 7. It has been obtained that the magnetic field with the strength $B_0 \leq 10^{12}$ G (at the temperature of 10^9 K) has almost no effect on the reaction cross sections, and the spin polarization mechanism plays a minor role in the element production, changing the abundances at most by 0.01%. However, if the magnetic field B_0 reaches 10^{15} G its effect on the key reactions appears and becomes appreciable at $B_0 \geq 10^{16}$ G. In particular, it has been found that such a field can increase the p(n,γ)d cross section (relevant to the starting point of BBN) by a factor of 2 (left figure) and at the same time almost block the ^{3}He(n,p)t reaction responsible for the interconversion of A=3 nuclei in the early Universe (right figure). This suggests that the spin polarization effects may become important in nonstandard scenarios of BBN considering the existence of local magnetic bubbles inside which the field can reach ~ 10^{15} G.

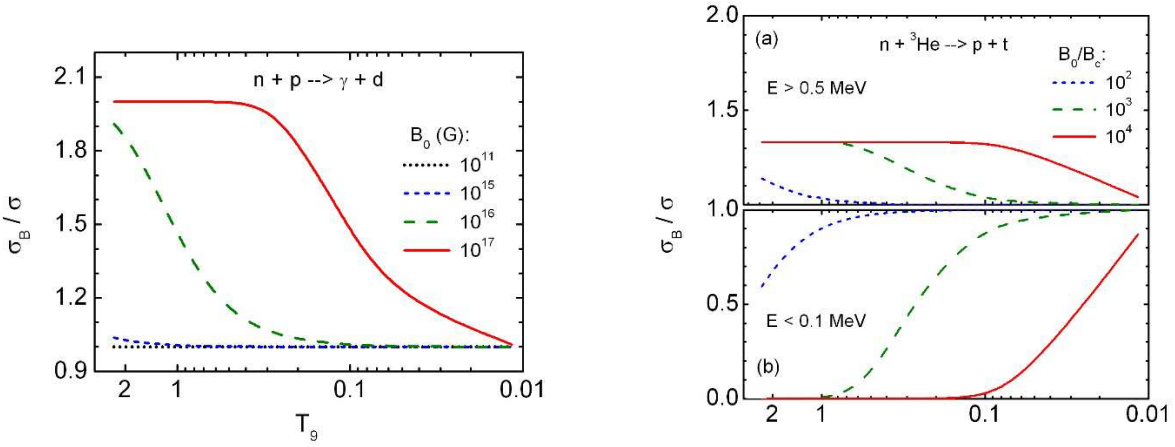

Figure. Effects of the magnetic fields on BBN reactions: cross section of the key reaction p(n,γ)d (a), and cross section of ^{3}He(n,p)^{3}H – reaction of interconversion of A=3 nuclei (b).

V.T. Voronchev, Y. Nakao Nuclear polarization effects in big bang nucleosynthesis, Physical Review D vol.92, No.8, p. 083008 (2015).

Contact: Voronchev Viktor Tikhonovich, voronchev@srd.sinp.msu.ru

Energetic electrons in the Earth's magnetotail

A comparative analysis of the parameters of energetic electrons in Earth's magnetotail, belonging to three sources - solar origin, generated in Jupiter's magnetosphere and in the Earth's magnetosphere is fulfilled. Differences are considered of flux time profiles and energy spectra of the three electron sources, as well as, relationship with the fluxes outside of the magnetosphere, and the periods of the appearance of electron fluxes of each type.

In interplanetary space, in addition to the constant flux of galactic cosmic ray electrons, increase of electrons fluxes of different nature are observed, in particular solar flares, accelerated by turbulent magnetic field in interplanetary

space and at the fronts of shock waves of the planets magnetospheres. In addition, the acceleration of electrons takes place and within planet's magnetospheres, in particular the Earth and Jupiter, which are the subject of this study. Consideration of spatial, temporal and energy characteristics of the various increases of the electron fluxes allowed almost uniquely identify their sources - solar, Jovian or magnetospheric.

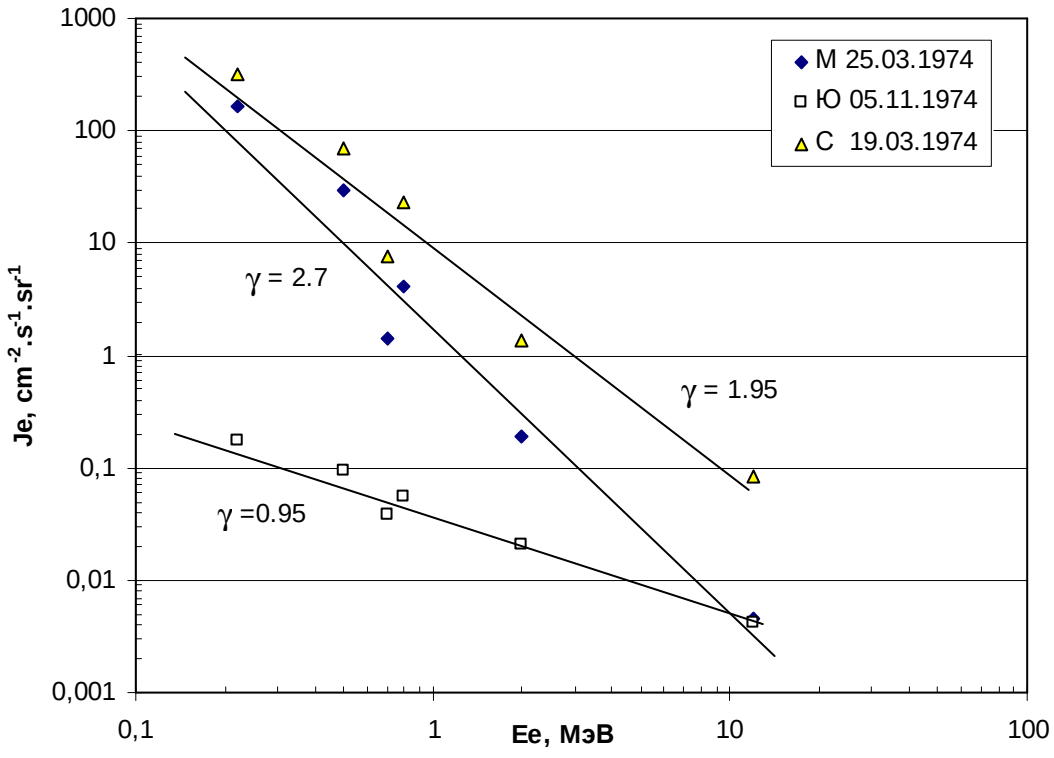

Figure. Electron spectra according to IMP-8 data. Solar CR (Nov. 5, 1974); magnetosphere (March 25, 1974); Jovian (March 19, 1974).

Lazutin L.L., Logachev Yu.I., Daibog E.I., Surova G.M. Energetic electrons in the magnetospheric tail and magnetopause. 10-th annual conference “Plasma Physics in Solar Sistem”. IKI RAN, Moscow, Russia, February 13-23, 2015

Contact: Daibog Elena Isaevna, daibog@srd.sinp.msu.ru

Jovian electrons and magnetic traps with inner acceleration regions

Simultaneously with 27-day variations of MeV Jovian electrons, observed during the deep solar minimum in 2007-2008 in 14 consequent solar rotations, also short duration (2-3 days) enhancements of the fluxes of 0.1-1 MeV electrons and protons were registered. These enhancements took place during each solar rotation simultaneously at SOHO (observed by COSTEP/EPHIN and LION) and ACE (EPAM) and appeared earlier and later at STEREO B and STEREO A (IMPACT/SEPT), respectively, usually before the flux of high-energy Jovian electrons started to rise, so the lower energy peaks did not coincide with those maxima. The Sun was extremely quiet throughout the whole period considered (no 10.7 cm radio or soft X-ray emission) and could not be the origin of these low energy particles. We consider the hypothesis that a magnetic trap with trapped Jovian electrons, corotating with the Sun, had some specific regions – «ridges» - with enhanced level of turbulence inside capable of accelerating electrons and protons up to 1 MeV. The formation of such «a ridge» is natural at the front part of the trap; differently located accelerating regions may appear due to the penetration of new field lines into the trap. These ridges appear to be rather stable, much of them are observed to survive a few solar rotations, disappear and appear again, initiating series of short-living enhancements of low energy electrons and protons, separated by 27-day intervals. According to this hypothesis, the electrons registered during the 2007-2008 solar activity minimum have two components: (a) periodic 27-day gradual Jovian-originated variations; (b) quasi-periodic short (2-3 days) increases of low-energy electrons and protons, accelerated directly inside the magnetic trap. Numerical simulations to model the propagation of energetic protons and electrons in the presence of such magnetic configuration are presented.

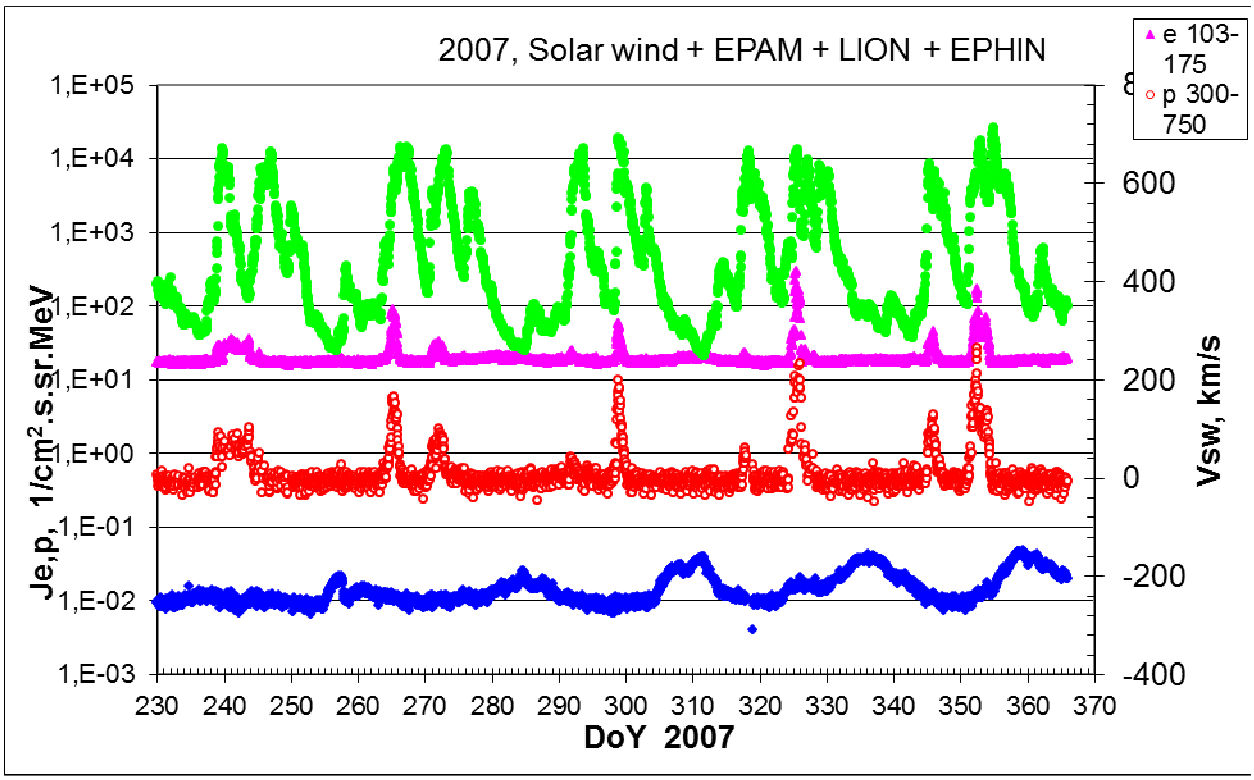

Fig. 1. Fluxes of energetic 0.7-3 MeV electrons (SOHO/EPHIN) and solar wind.

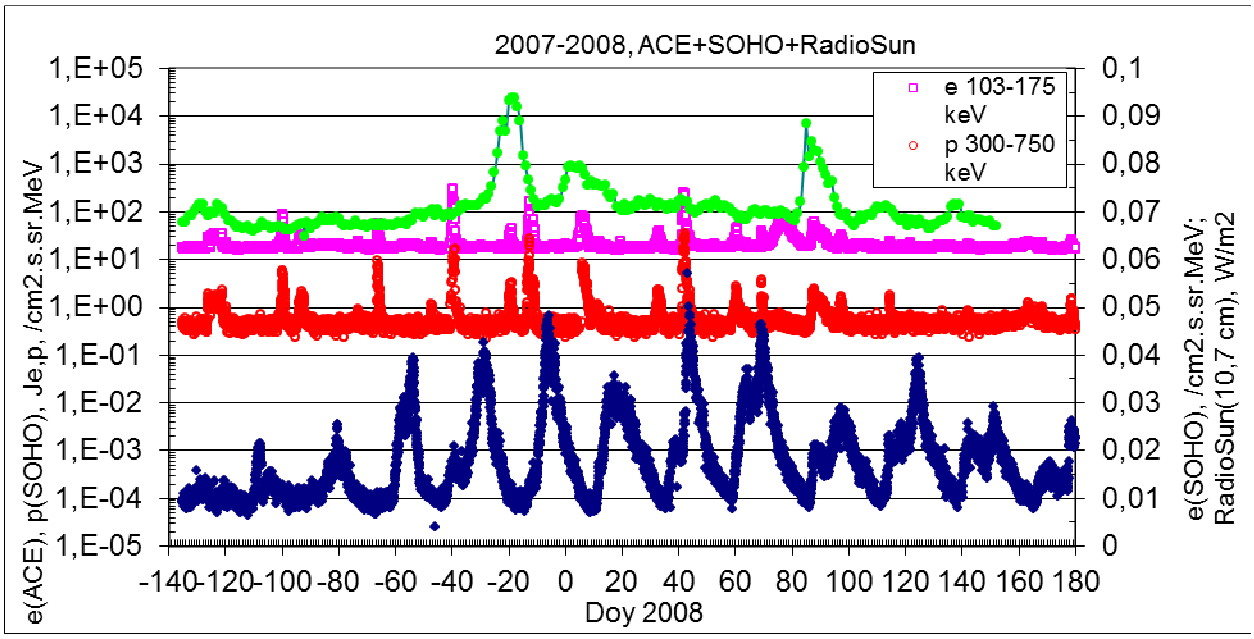

Fig. 2. Jovian electrons and accompanying bursts of low-energy electrons and protons of non- solar origin, which follow from the absence of radio bursts during most part of this time interval.

and magnetic traps with inner acceleration regions, 34th Int.Cosmic Rays Conf.

Contact: Daibog Elena Isaevna, daibog@srd.sinp.msu.ru

Large-scale jets in the magnetosheath and plasma penetration across the magnetopause

Time History of Events and Macroscale Interactions during Substorms multipoint observation of the plasma and magnetic fields, conducted simultaneously in the dayside magnetosheath and magnetosphere, were used to collect 646 large-scale magnetosheath plasma jets interacting with the magnetopause. The jets were identified as dense and fast streams of the magnetosheath plasma whose energy density is higher than that of the upstream solar wind. The jet interaction with the magnetopause was revealed from sudden inward motion of the magnetopause and an enhancement in the geomagnetic field. The penetration was determined as appearance of the magnetosheath plasma against the background of the hot magnetospheric particle population. We found that almost 60% of the jets penetrated through the magnetopause. Vast majority of the penetrating jets was characterized by high velocities $V > 220$ km/s and kinetic $\beta_k > 1$ that corresponded to a combination of finite Larmor radius effect with a mechanism of impulsive penetration. The average plasma flux in the penetrating jets was found to be 1.5 times larger than the average plasma flux of the solar wind. The average rate of jet-related penetration of the magnetosheath plasma into the dayside magnetosphere was estimated to be $\sim 10^{29}$ particles/d. The rate varies highly with time and can achieve values of 1.5×10^{29} particles/h that is comparable with estimates of the total amount of plasma entering the dayside magnetosphere.

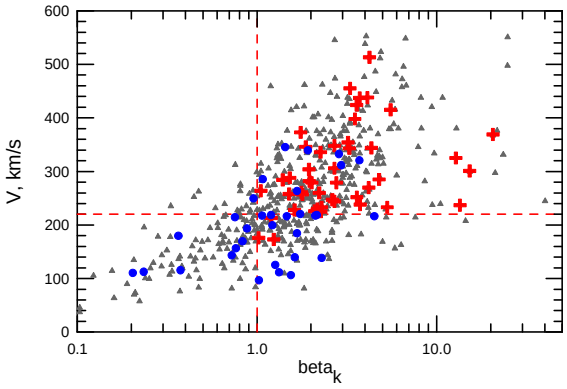

Fig. 1. Distribution of plasma jects in the magnetosheath (grey triangles) depending on the kinetic β_k and jets' speed V. Penetrating and non-penetrating jets are marked with red crosses and blue circles, correspondingly. The most part of penetrating jets is characterized with $\beta_k > 1$ and V > 210 km/s.

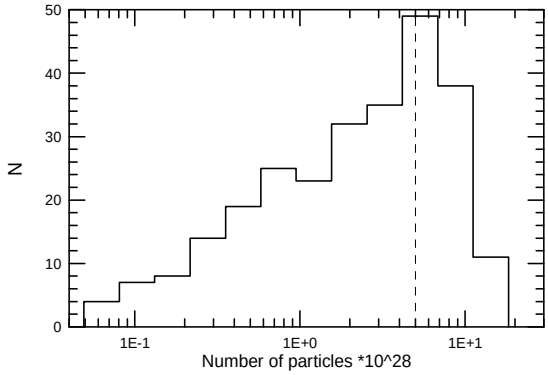

Fig. 2. Statistical distribution of the number of ions brought to the magnetosphere by jets penetrating from the magnetosheath. The most probable value is $5*10^{28}$ particles.

Dmitriev A.V., Suvorova A.V. Large-scale jets in the magnetosheath and plasma penetration across the magnetopause: THEMIS observations, J. Geophys. Res., 2015, 120(6), 4423 – 4437, DOI: 10.1002/2014JA020953

Contact: Dmitriev Aleksey Vladimirovich, dalexav@mail.ru

Ionizing effect of forbidden energetic electrons during the December 2006 geomagnetic storm

We studied a new mechanism of ionization enhancement or positive ionospheric

storm, which relates to ionizing effect of electrons with energy of tens keV on upper atmosphere at low latitudes. As was recently found from the NOAA/POES satellite observations, energetic electrons enhance near the equator under the inner radiation belt during geomagnetic storms. The electrons were called forbidden energetic electrons or FEE. We used measurements of >30 keV electron fluxes from NOAA/POES satellites, Global ionospheric Maps and radio-occultation measurements from COSMIC/FORMOSAT-3 satellites during the major geomagnetic storm on 14-16 December 2006. We analyzed simultaneous enhancements of FEE and total electron content (TEC) in the ionosphere at all storm phases, initial, main and recovery. We found that the ionizing FEE effect contributes up to 50% into the positive storms at the initial and main phases, and even significantly larger at the recovery phase in comparison with the standard electrodynamical and thermospherical mechanisms of the ionospheric storm. Additionally, the FEE-effect explains a large duration of the positive ionospheric storm.

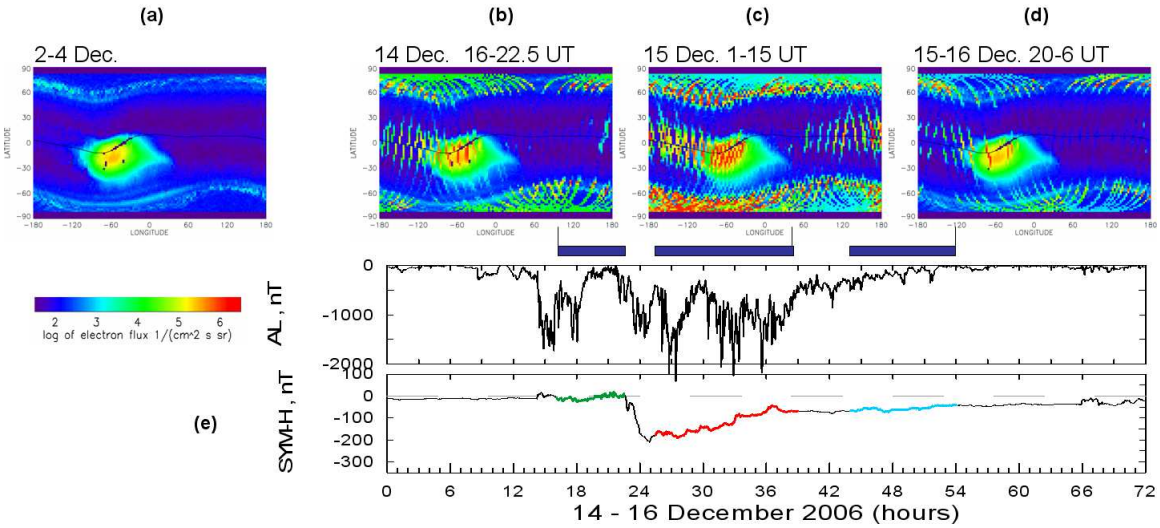

Рис. Динамика экваториальных возрастаний квази-захваченных электронов с энергией >30 кэВ (a) в спокойные дни 2-4 декабря 2006 и (b-d) на разных фазах геомагнитной бури 14-16 декабря 2006; (e) геомагнитные индексы AL и Dst.

Suvorova, A.V., C.-M. Huang, L.-C. Tsai, Dmitriev A.V., Ratovsky K.G. Long-duration ionospheric positive storm during the December 2006 geomagnetic storm: Ionizing effect of forbidden electrons, Advances in Space Research, 2015, 56(9), 2001-2011, doi: 10.1016/j.asr.2015.06.001

Contact: Suvorova Alla Vladimirovna, alla@jupiter.ss.ncu.edu.tw

Relative abundances of suprathermal ions ^{3}He, ^{4}He, C, O and Fe in fast solar wind streams from near equatorial coronal holes

Energy ion spectra in energy range 0.04 – 1 MeV/nucleon have been studied in ion fluxes from 34 near equatorial coronal holes during the 2006-09 solar cycle minimum. It was shown that suprathermal ions from coronal holes appear to be the high energy tail of thermal solar wind. The evidence of existence of addition external sources of He ions in observed suprathermal fluxes from coronal holes.

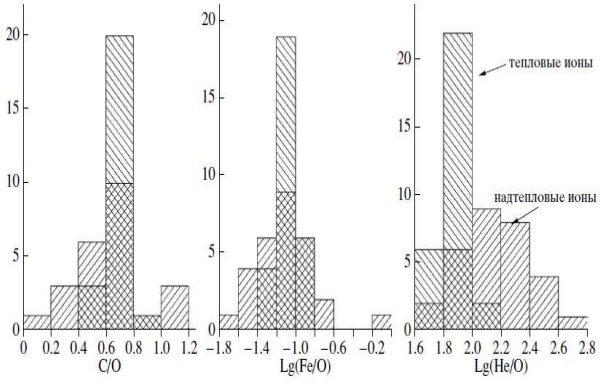

Fig. 1. Distributions of values of ion ratios He/O, C/O and Fe/O in thermal and suprathermal (marked by different slope of stroke lines) ion fluxes in solar wind streams from 34 near equatorial coronal holes in 2006–2011.

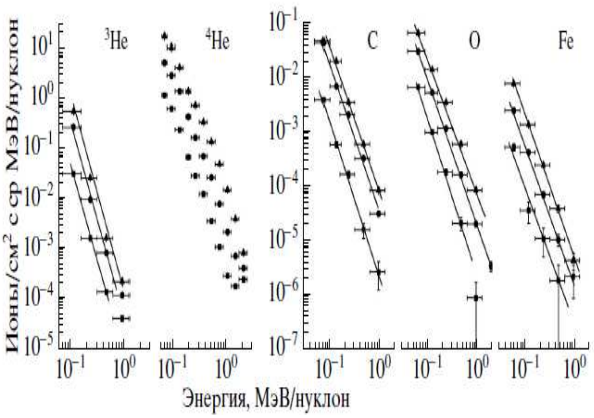

Fig.2. Averaged energy spectra of suprathermal ^{3}He, ^{4}He, C, O, and Fe ions in the solar wind in 3 ranges of maximum solar wind speed <400 km s–1 (squares), 400–500 km s–1 (dots) and >500 km s–1 (triangles) from near equatorial coronal holes by amount of 4, 6 and 15 respectively. Ion intensity is expressed in units (cm^{2} s ster MeV/nucleon) $^{-1}$

M.A. Zeldovich, Yu.I. Logachev. Suprathermal Ions in the Solar Wind during the Minimum Activities of the 23rd and 24th Cycles at 1 AU, Bulletin of the Russian Academy of Sciences. Physics, 2015, Vol. 79, No. 5, pp. 603–605.

Zeldovich M.A., Logachev Yu.I., Kecskemety K., Veselovsky I.S. Suprathermal ions at 1 AU in solar wind streams from near equatorial coronal holes in 2006-2010, Proc. 34th Int. Cosmic Ray Conf., The Hague, paper no. 091 (2015).

Contact: Zeldovich Mariya Aleksandrovna, mariya@srd.sinp.msu.ru

Simulation and prediction of solar magnetic activity

Solar magnetic activity is related with generation strong magnetic fields in the depths of the Sun and manifested in sunspot occurrence on the solar surface. The amplitude and the spatial configuration of the magnetic field of our star are changing over the years. The most widely known variations of solar magnetic field are 11-years cycles and grand minima. The generation and evolution of the solar

magnetic field and other stars is usually related to the dynamo mechanism. This mechanism is based on the consideration of the joint influence of the alpha-effect and differential rotation. Dynamo sources can be located at different depths (active layers) of the convection zone and can have different intensities. Based on such a system, the dynamical system with meridional fluxes in the case of the stellar dynamo with independent active layers has been constructed. Magnetic field waves from top and bottom layers of the convective zone are found generated with close frequencies whose interaction leads to beating effects responsible for the grand cycles (350–400 years) superimposed on a standard 22 year cycle. Using our model we made prediction of poloidal and toroidal fields on short (until 2040 year) and long-term timescale (until 3200 year) (V. V. Zharkova, S. J. Shepherd, E. Popova & S. I. Zharkov, Nature SR, 2015). According our model the new minimum of the solar magnetic activity will occur in the years 2020-2050.

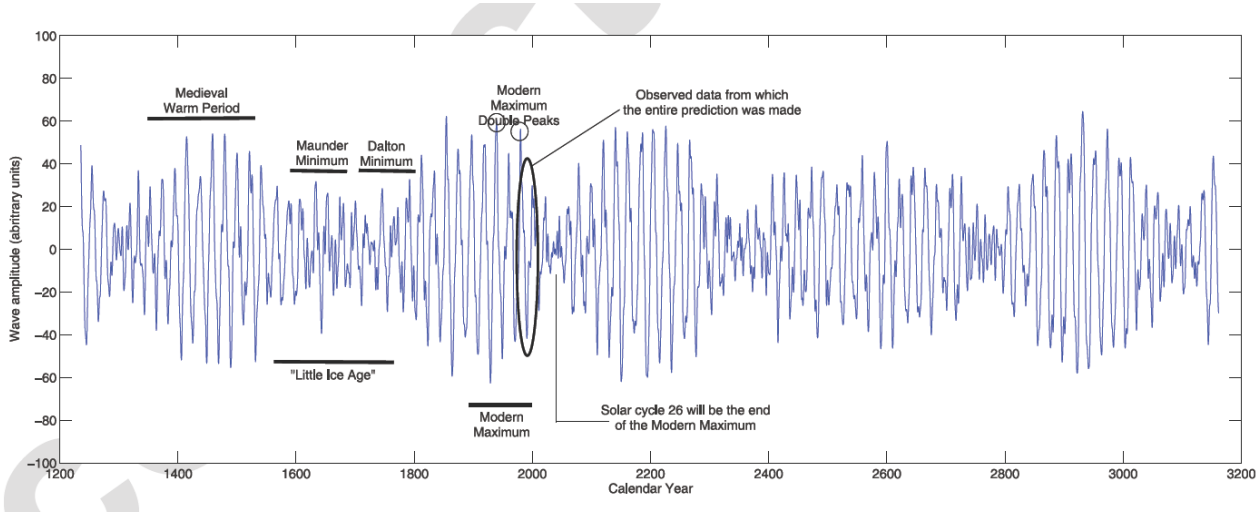

Figure. The predicted summary wave (the sum of two principal components) calculated from 1200 to 3200 years from the ‘historical’ period (cycles 21–23) marked with a black oval.

Zharkova V., Shepherd S., Popova E.P., Zharkov S. Heartbeat of the Sun from Principal Component Analysis and prediction of solar activity on millennium

scale, Scientific reports, издательство Nature Publishing Group (United Kingdom), том 5, с. 15689, 2015.

Zharkova V., Shepherd S., Popova E.P., Zharkov S. Heartbeat of the sun derived with principal component analyses and prediction of solar activity on millennium scale, National Astronomy Meeting 2015, Llandudno, North Wales, Great Britain, July 5-10, 2015

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Identification of the coronal sources basing on simulation of their ion composition

Methods of localization coronal sources based on vacuum–ultraviolet (EUV) images of the corona showed that the images at a wavelength of 19.3 nm can be used for more reliably describing the parameters of large coronal holes, that represent sources of fast quasi-stationary solar wind (SW) streams, and at a wavelength of 17.1 nm for better revealing the small areas of low brightness based on which the component of slow SW is calculated to a high accuracy (up to 65 km/s).To identify the source of coronal transient SW flows was developed diagnostic method of ionic composition in the flares and conducted analysis of SW parameters and traced the evolution of ion composition of the solar corona using several geoeffective coronal mass ejections.

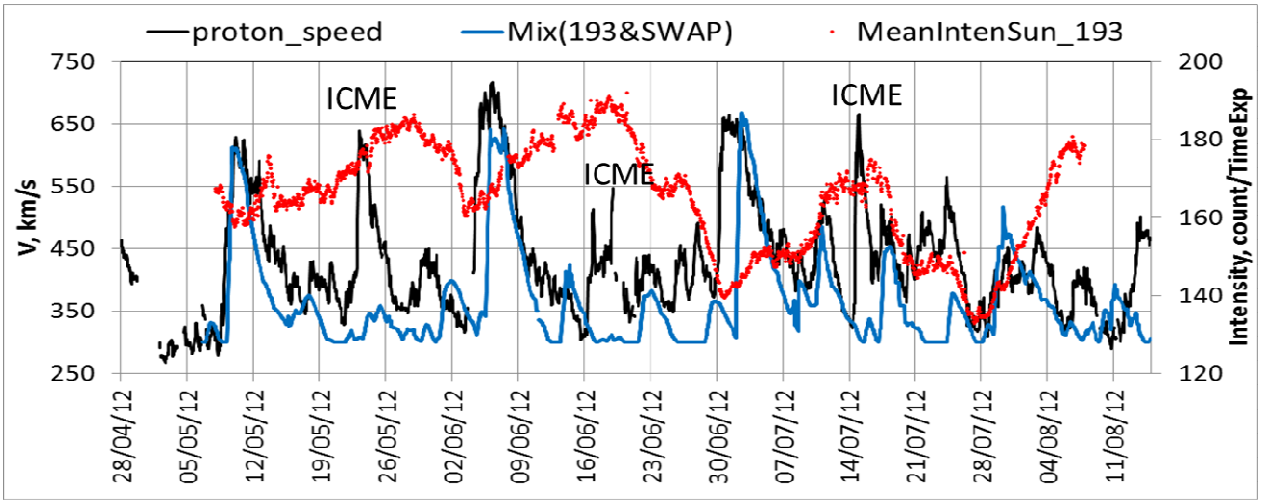


Figure. The black curve shows the hourly values of the observed SW velocities (ACE); the blue curve shows the SW velocities forecasted using CH areas obtained from AIA 193Å and SWAP 174Å images; the red curve shows the intensity of Sun images obtained from AIA 193 Å. An increased intensity of the Sun image, obtained from SDO/AIA at a wavelength of 193Å, correlates with solar sporadic activity.

V. A. Slemzin and Yu. S. Shugai Identification of Coronal Sources of the Solar Wind from Solar Images in the EUV Spectral Range, Cosmic Research, 2015, Vol. 53, No. 1, pp. 47–58.

V. Slemzin, Yu. Shugay, F. Goryaev, P. Pagano, D. Rodkin, I. Veselovsky Identification of solar origins of several geo-effective ICMEs by modeling of their ion composition, Доклад на ISEST 2015 Workshop Mexico, 25-30 October 2015

Contact: Shugai Yulia Sergeevna, jshugai@srd.sinp.msu.ru

Atypical Dynamics of the Magnetosphere during Geomagnetic Storms on January 21–22, 2005 and December 14–15, 2006

The dynamics of large-scale magnetospheric current systems during geomagnetic storms on January 21–22, 2005 and December 14–15, 2006 is investigated using the A2000 model of the magnetospheric magnetic field. Storm development is controlled by both the interplanetary magnetic field and solar wind pressure that create conditions for injection of plasma into the inner magnetosphere. It is demonstrated that the development of the January 21–22, 2005 magnetic storm was triggered by a strong solar wind pressure pulse, while the December 14–15, 2006 storm was initiated by a changed orientation of the interplanetary magnetic field. As a consequence, the Dst variation of the geomagnetic field during the January 21–22, 2005 storm is determined basically by the ring current development. On December 14–15, 2006 the contributions of the ring current and of the magnetotail currents were comparable. The results of modeling are confirmed by data on dynamic properties of the fluxes of three populations of ions with energies 30–80 keV (at low latitudes $L < 2$, and at latitudes below and above the isotropic precipitation boundary) measured by the solar-synchronous satellites of NOAA (POES 15, POES 16, and POES 17).

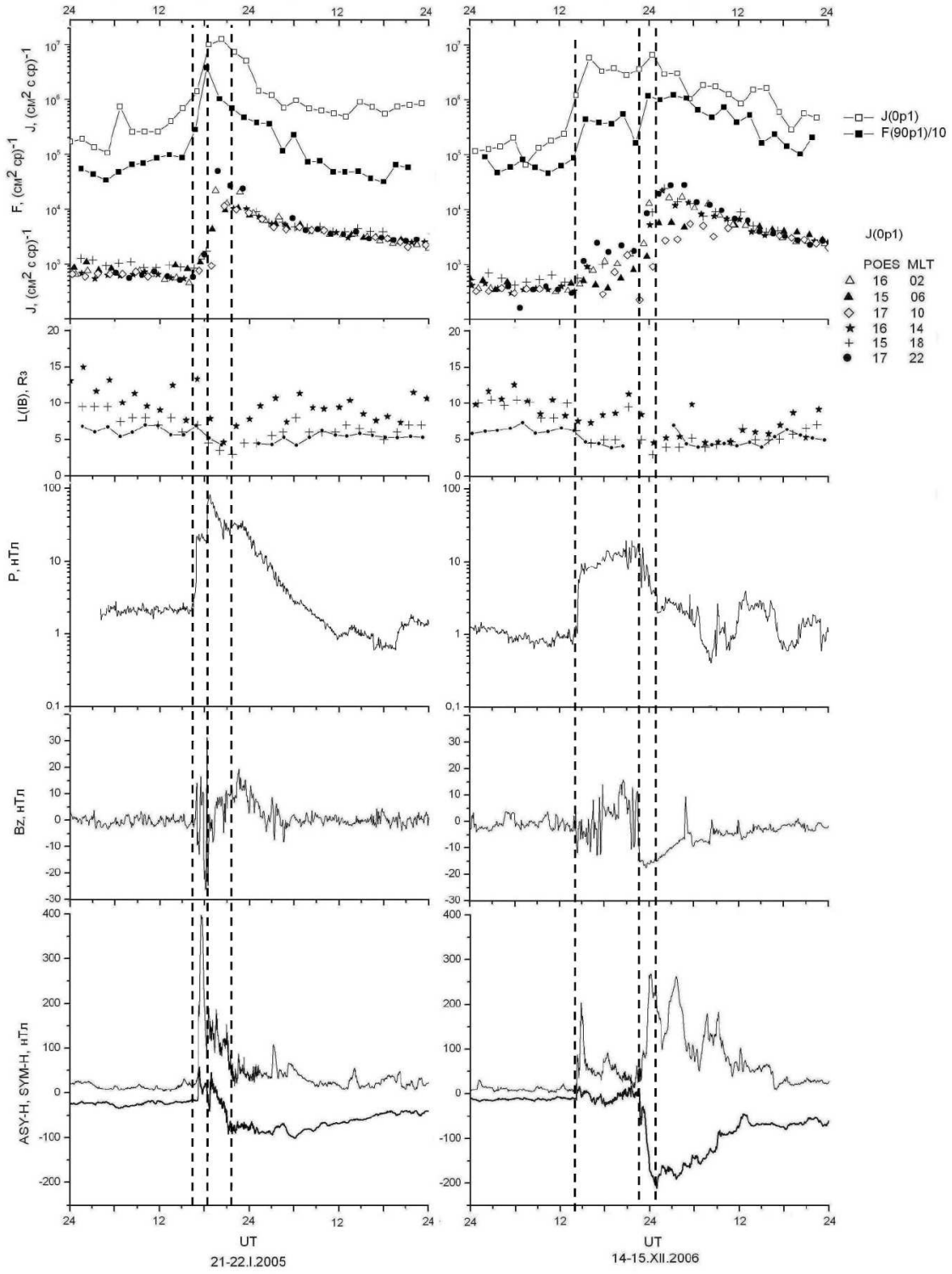


Fig. Time profiles of the following parameters:

MLT-averaged maximal fluxes of precipitation ions (multiplied by 10) – Jmax(0p1) and total fluxes of quasi-trapped – F(90p1);

not MLT-averaged maximal fluxes of trapped ions – J(0p1);

the isotropisation boundary position – L(IB);

the solar wind pressure (P);

the IMF B_z – component;

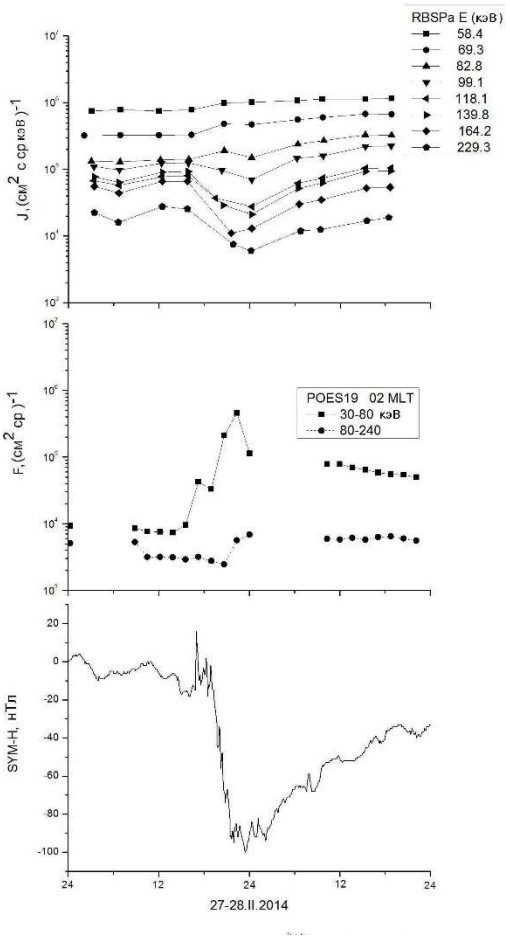
ASY-H and SYM-H indexes

V. V. Kalegaev, N. A. Vlasova, and Z. Peng Dynamics of the Magnetosphere during Geomagnetic Storms on January 21–22, 2005 and December 14–15, 2006 // Cosmic Research, 2015, Vol. 53, No. 2, pp. 98–110.

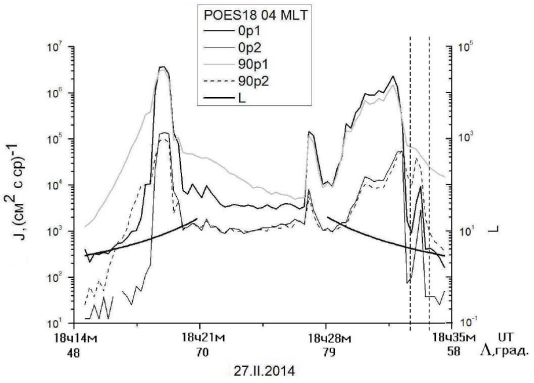
Contact: Kalegaev Vladimir Vladimirovich, klg@dec1.sinp.msu.ru

Softening Effect of Spectra of the Ring Current and Ion Fluxes at Low Altitudes during the February 27–28, 2014 Magnetic Storm

A comparative analysis of the ring current and ion fluxes at low altitudes has been performed for February 27, 2014 geomagnetic storm. We used concurrent experimental data on ion fluxes with the energies of 30-250 keV measured in the near-equatorial magnetospheric region by the Van Allen Probes satellite at altitudes up to 30000 km and by NOAA Polar Orbiting Environmental Satellite (POES) at the orbit up to 1000 km. The main phase of the storm was characterized by increased ion fluxes with E < 100 keV and decreased fluxes with E > 100 keV, registered in the ring current directly as well as in the near-equatorial region of the low-orbit satellite, reflecting the fact that the particle spectrum of the ring current in the main phase of the storm becomes more soften. The observed phenomenon corresponds by the precipitation of ring current particles at high latitudes registered by POES below the isotropization boundary. It was shown that the variations of the near-equatorial ion fluxes at low orbit during the geomagnetic storm generally reflect the ring current dynamics.



a



b

Fig. a Time profiles of ion fluxes according to RBSPa and POES satellite data and geomagnetic index SYM_H

Fig. b Time profiles of ion fluxes when the POES 18 satellite passes through high-latitude regions of the magnetosphere

V. V. Kalegaev, N. A. Vlasova, and I. S. Nazarkov Dynamics of the Ring Current and Ion Fluxes at Low Altitudes during the February 27–28, 2014 Magnetic Storm, Geomagnetism and Aeronomy, 2015, Vol. 55, No. 6, pp. 715–722.

Contact: Kalegaev Vladimir Vladimirovich, klg@dec1.sinp.msu.ru

Correlation of the density of transient events of the electric charge forming in the spacecrafts, located in neutral point L1 and on the Earth's orbit with the

density of the protons and alfa-particles fluxes of solar cosmic rays

In the full-scale study the following facts, already known for over a century, but still did not taken into account in the guideline documents, were confirmed:

- Changing of the properties of the condensed medium in the field of ionizing particles happens in the tracks of these particles;
- The strongest changes of the medium conditions take place in the area of the Bragg peak, i.e. it is expectable that the energy released near the Bragg peak is the main affecting factor of the ionizing particles field, because just in this part of track volume density of the power (oscillators' power at quantum-mechanical analysis) is maximum.

Spectrum of the electric charge, formed under the influence of cosmic rays in the neutral point L1 and on the Earth's orbit, is presented for the first time. Changes of the density of electric charge near the Bragg peak is observed for the first time during the solar flare. It exceeded the level of critical charge of the typical electronic elements, used onboard the Russian spacecrafts. Strongly marked angular anisotropy of the fast particles flux in spacecraft is detected during powerful solar flares.

Anokhin M.V., Galkin V.I., Ditlov V.A., Dubov A.E., Kalegaev V.V., Korolev A.G., Kuznetsov N.V., Makarychev S.V., Panasyuk M.I., Popov V.D., Chabanov V.M., Shillo A.G. On the role of the role of the Bragg peak during the evaluation of the influence of the ionizing particles field on the microelectronics of the spacecrafts, Abstracts of "Resistance-2015" All-Russian scientific and technical conference on the radiation stability of electronic systems, Lytkarino, June 2-3, 2015, pp.27-29. ISSN 1997-2830. ФГУП НИИП.

Contact: Kalegaev Vladimir Vladimirovich, klg@dec1.sinp.msu.ru

Gradual and impulsive energisation of chromospheric plasma (numerical MHD simulation of the coupled evolution of plasma and magnetic field in the top solar chromosphere)

The phenomena in the contact zone between two magneticfields of opposite polarities and β about unity generate motion and heating of the plasma assumed to be initially motionless and having a temperature of50,000K.The plasma temperature gradually increasesby a factor of two to three. Against this background, animpulsive (in 0.1~seconds or less) enhancement in plasma velocityoccurs due to the pinch sausage-type instability.The process results in an increasein the kinetic temperature of the protons to high values, even to those observedin flares. It canbe considered as analternative to the impulsive proton energisation due to magnetic-reconnection.

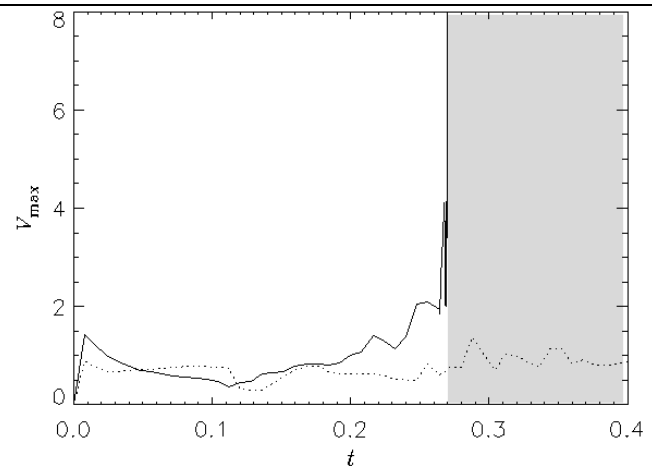


Fig. The maximum absolute velocity over the computation domain as a function of time in the cases of partial initial balance between the magnetic and gas pressures (solid curve) and its absence (dotted curve) at β=1.5. The unit of velocity (time) is 23.8 km/s (1.1 min).

L.M. Alekseeva, S.P. Kshevetskii Numerical MHD simulation of the coupled

evolution of plasma and magnetic field in the solar chromosphere. I. Gradual and impulsive energisation. Solar Physics (online first) , doi 10.1007/s11207-015-0788-7

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The gravitational influence of the planets Venus, Earth and Jupiter in the 11-year solar activity cycle

We used option introduced by the author - the average difference between the heliocentric longitude (ADL) of the planets Venus, Earth and Jupiter. For the minimum ADL (the planets are in conjunction), as well as at the minimum deviation of the planets from a line passing through them and the Sun at the location of the planets on opposite sides from the Sun, an index was composed (JEV) that uniquely describes the 11_year cycle of solar activity.

The calculations made of the resulting tidal force from Jupiter, Earth and Venus, acting on the sun. Considering the tidal forces as the difference between the forces of gravity acting on the extremes of the diameter of the Sun point and center of the sun, it is shown that there are large variations in the resulting tidal forces (RTF) in the times of linear configurations of the planets Venus, Earth and Jupiter, and that the maximum RTF variations very well they meet the minimum values of the planetary index JEV, ie linear configuration of Venus, Earth and Jupiter. Rapid changes in the tidal forces acting on the sun side of the planet Venus, Earth and Jupiter, can cause disturbances in the physical parameters of the field tachocline to be passed later in the convective zone and will have an impact on the manifestation of solar activity.The calculations were performed for the

time period from 1000 to the present time, but to illustrate the given interval from 1700 to the present time.

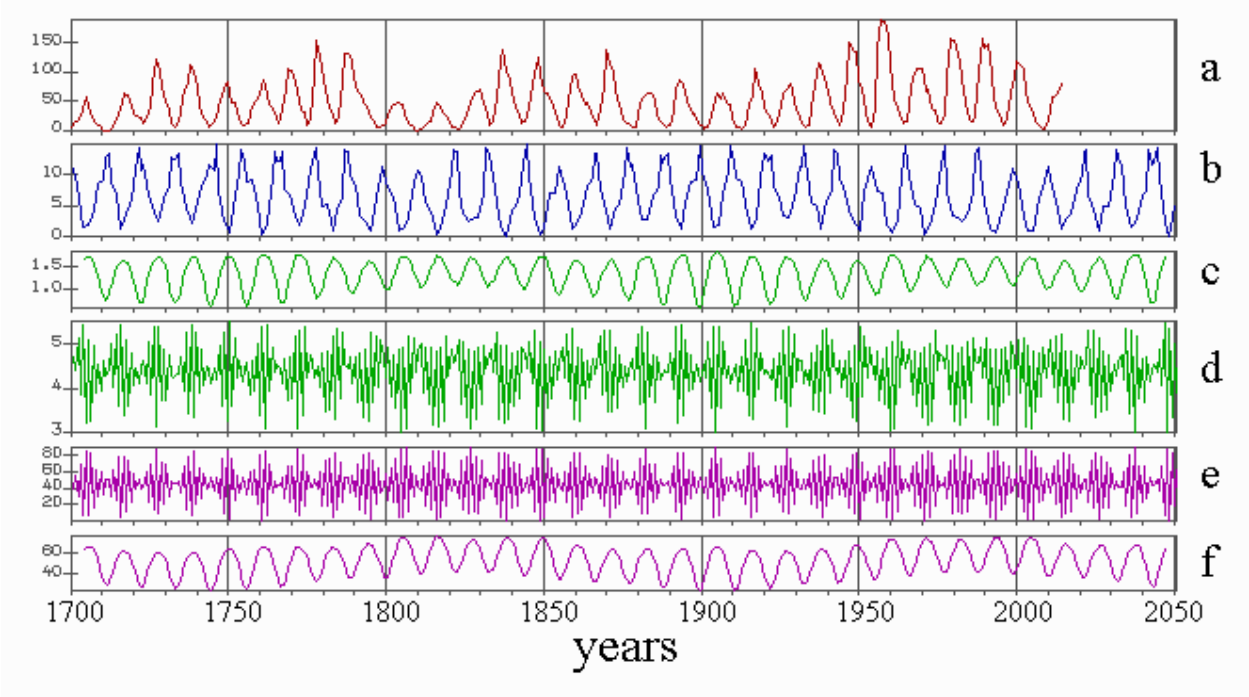

Fig. For the period from 1700 to 2050: a - number of solar activity on the Wolf numbers (1700 - 2015) (relative units..), b - the data JEV index (degrees), c - moving standard deviation according to the number of "d", d - the resulting tidal force three planets (Venus, Earth and Jupiter), acting on the sun (relative units), e - the angle between the radius vector of Jupiter and the line of Venus-Earth-Sun (deg), f - moving standard deviation of a number of "e" angle.

Okhlopkov V.P. The new 11-year planetary index of solar activity, Collection of scientific papers on the materials of the International scientific-practical conference "Theoretical and applied problems of science and education", 31 January 2015, series 3, p. 77-91.

Okhlopkov V.P. The gravitational influence of the planets on the 11-year cycle of solar activity, Collection of scientific works on materials of the international scientific-practical conference "Science and education: current status and prospects of development", Tambov, 31 August 2015, tom 3, p. 79-88.

Okhlopkov V.P. 11-year planetary index of solar activity, Actual problems of Arts and Sciences, Moscow, 2015, tom 7, № 4, p. 8-19.

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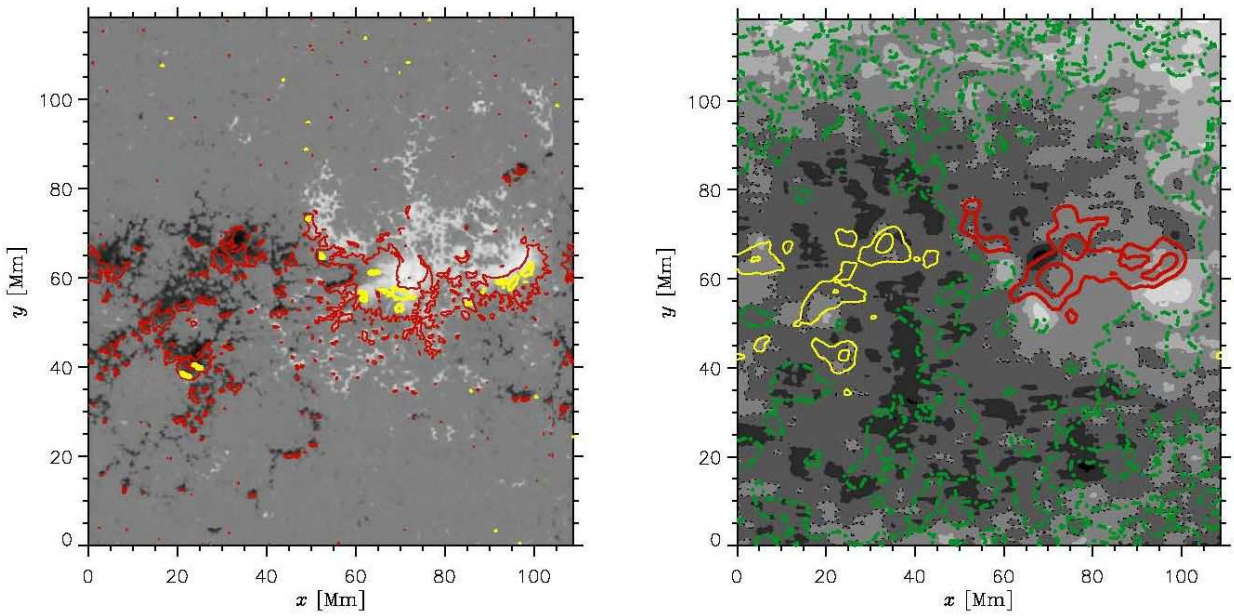
Correlation between the velocity and magnetic-field components in growing active regions. The bordering effect

Full-vector data for the magnetic and velocity fields in a growing sunspot group obtained from the Hinode spacecraft using our purposely developed observational plan reveal spatial correlation between the distributions of the vertical [B_v] and horizontal [B_h] magnetic-field components without any definite correlation of these with the velocity field. Найдена характерная особенность картины – эффект окаймления: локальные экстремумы B_v окаймлены областями локально усиленного B_h. Все это не поддается интерпретации с позиций популярной модели всплывающей трубки сильного магнитного поля и указывает на действие другого механизма формирования поля активной области.



Left: comparison between the vertical (grey-scale map) and horizontal (contours) components of the magnetic field; right: comparison between the patterns of the smoothed vertical-velocity field (grey-scale filled contour map with the dotted contours for zero velocity) and smoothed vertical magnetic field (colour contours) for the same session; red contours correspond to $B_v > 0$, green dot–dashed contours to $B_v = 0$ and yellow contours to $B_v < 0$. The dark areas in both grey-scale maps correspond to negative values (vectors directed upward) and light areas to positive values (vectors directed downward).

A.V. Getling, R. Ishikawa, A.A. Buchnev, Doubts about the crucial role of the rising-tube mechanism in the formation of sunspot groups, Advances in Space Research, v. 55, no. 3, pp. 862–870, 2015, doi:10.1016/j.asr.2014.07.024.

A.V. Getling, R. Ishikawa, A.A. Buchnev, Development of active regions: flows, magnetic-field patterns and bordering effect, Solar Physics (submitted); препринт: arXiv:1506.01848 [astro-ph.SR].

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A possible formation mechanism for multiscale solar convection due to variable thermal conductivity

Such factors as the variability of the ionisation state, transport coefficients, density stratification etc. can be responsible for the coexistence of variously scaled flows in the solar convection zone. Our three-dimensional numerical simulations of convection in a horizontal layer demonstrates that, if the temperature dependence of the thermal diffusivity ensures near the upper layer surface such a static temperature gradient that exceeds many times in its magnitude the gradient in the remaining portion of the layer, the coexistence of three different convection-flow scales becomes possible.

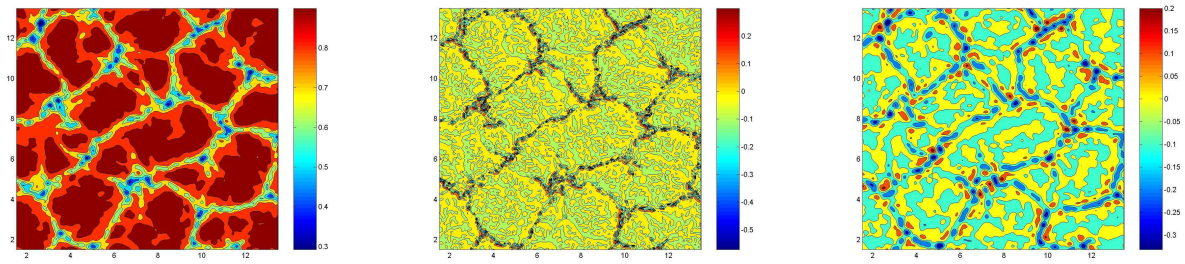

Figure. Simulated velocity field at a height of z = 0.97 processed using various techniques. Convection structures of three different scales can be distinguished.

O.V. Shcheritsa, A.V. Getling, O.S. Mazhorova, Stratification-induced scale splitting in convection, Advances in Space Research, v. 55, no. 3, pp. 927–936, 2015, doi: 10.1016/j.asr.2014.08.034.

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Forecast horizon for the fluxes of relativistic electrons on the geostationary orbit by means of artificial neural network

By means of the artificial neural network the fluxes of the relativistic electrons with energy over 2 MeV on the geostationary orbit were predicted for the period from 3 up to 12 hours.

Myagkova I., Dolenko S., Shiroky V., Sentemova N., Persiantsev I. Horizon of Neural Network Prediction of Relativistic Electrons Flux in the Outer Radiation Belt of the Earth, 16th EANN Workshops, September 25-28, 2015m Rhodes Island, Greece, ACM Proceedings, p. 9

Contact: Myagkova Irina Nikolaevna, irina@srd.sinp.msu.ru

Observation of high-energy gamma emission from solar flares onboard of the CORONAS-F mission (Complex Orbital Observations of the Active Sun) by the SONG instrument (Solar Neutrons and Gamma-rays)

Processing and analysis of data obtained in this experiment are continued. Improved routines of restoration of solar-flare emission spectra and models allowed us to increase reliability of results. In particular, HXR and gamma-ray emissions in the 0.04–150 MeV energy range associated with the solar flare on 29 October 2003 (X10/3B) were observed. We restored consecutive flare gamma-emission spectra from SONG and RHESSI data and made a cross-calibration between them in the common energy range 0.04-10 MeV. We elicited confidently

the pion-decay component of the flare gamma-emission. A power-law spectrum index of accelerated protons was estimated from the ratio between intensities of the pion-decay and gamma-line components. An apparent temporal association was found between efficiency of particle acceleration above the pion-production threshold and the process of restructuring of flare magnetic field. Pion-decay emission onset coincided in time with a change of HXR foot point (FPs) motion from converging one to motion away from each other. The hardest spectrum (the power-law index S=3.4-3.7) coincided in time with the latter type of motion.

This flare was accompanied by GLE 66. The time profile of the pion-decay gamma-emission was compared with GLE onset time. It was shown that both protons interacting at the Sun and the particles responsible for GLE onset could belong to the same population of accelerated particles.

The time of ion acceleration up to high energies during an energetic eruption process is one of the open questions in solar physics. It is not still very clear whether this acceleration is initiated by CME/fast shock-wave propagation in the lower corona or occurs during the process of a fundamental restructuring of the flare magnetic field. It was found that at list in the event of 29 October 2003 particle acceleration up to energies ≥300 MeV was simultaneously with process of restructuring of flare magnetic field.

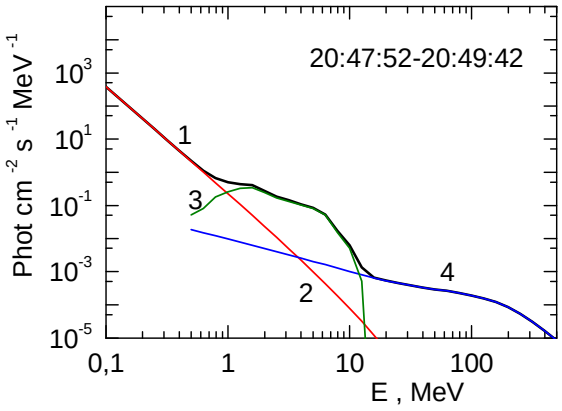

Fig. 1. Restored spectrum of the 29 October 2003 solar flare (1); 2 - electron bremsstrahlung; 3 - nuclear de-excitation component; 4 - the pion-decay component.

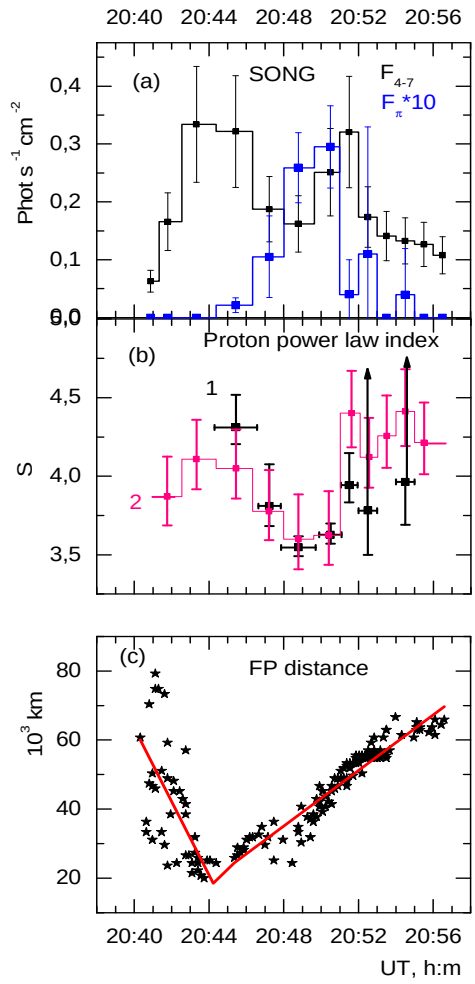

Fig. 2.

Panel (a) – gamma-line emission (black lines) and the pion-decay emission (blue lines, scaled by factor of 10).

Panel (b) –the proton power-law spectrum index; 1 – from the SONG data; 2 – from the RHESSI data.

Panel (c) – foot-point separation observed by RHESSI.

Kurt V.G., Yushkov B.Yu., Kudela K., Galkin V.I., Kashapova L.K. CORONAS-F observation of HXR and gamma-ray emissions from the solar flare X10 on 29 October 2003 as a probe of accelerated proton spectrum", Contributions of the Astronomical Observatory Skalnate Pleso, т.45, № 1, с. 42-59 (2015)

Kurt Viktoria Gdalievna, vgk@srd.sinp.msu.ru

Accumulation of the absorbed dose in the Earth orbit of spacecraft at influence of particle fluxes of solar cosmic rays

Calculated method is developed to predict the accumulation of the absorbed dose

in the near-Earth spacecraft during proton events of solar cosmic rays.

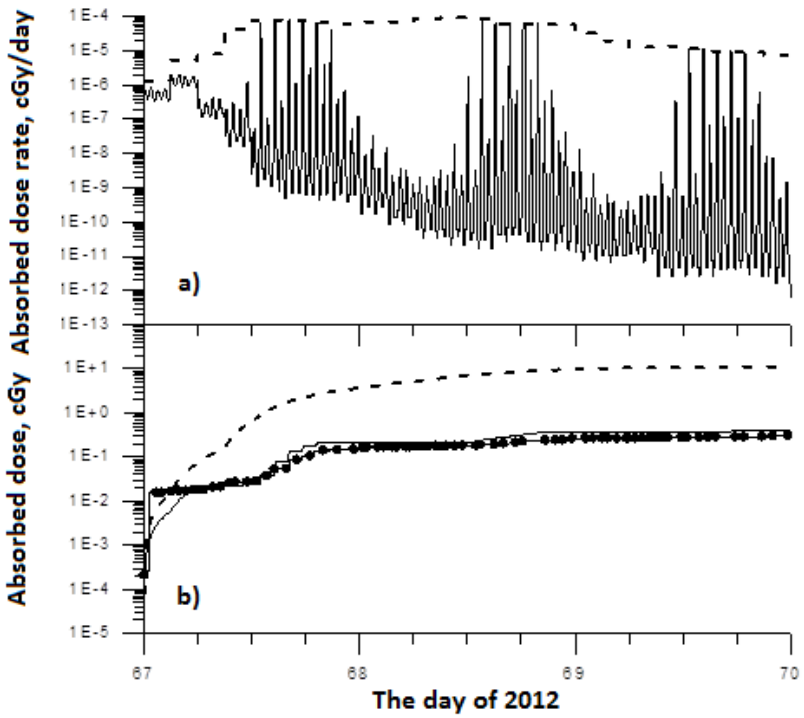

Figure. The dose rate (a) and the absorbed dose (b) inside the International Space Station (ISS) depending on the flight time during a solar proton event in March 2012. The abscissa origin corresponds to the time 00:00 UT on 7 March.

Solid curves are for ISS orbit. Dashed curves are for geostationary orbit (hypothetical case for ISS). Points are the data measured by the dosimeter in ISS orbit.

Kuznetsov N.V., Nymmik R.A., Panasyuk M.I., Yushkov B.Yu., Bengin V.V., Mitrikas V.G. Accumulation of the absorbed dose in Earth orbit of spacecraft at influence of particle fluxes of solar cosmic rays. Voprosy atomnoy nauki I techniki, seriya: Fizika radiatsionnogo vosdejstvija na radioeltctronnuyu apparaturu. No. 2, P.20-23, 2015 (Russian)

Contact: Kuznetsov Nikolay Viktorovich, nvk@srd.sinp.msu.ru

Comparison of the models of charged particle fluxes in space

The particle energy spectra predicted for space by Russian and European codes (COSRAD and SPENVIS consequently) are compared. The features of the models (Earth radiation belts, galactic and solar cosmic rays) used in these codes are discussed.

Kuznetsov N.V., Nikolaeva N.I., Nymmik R.A., Panasyuk M.I., Uzhegov V.M., Yakovlev M.V. Comparison of the models of the charged particle fluxes in space that are used for the calculation of the radiation environment in space missions, International Conference on Radiation Effects on Components and Systems - RADECS-2015 (Moscow, September 14-18)

Contact: Kuznetsov Nikolay Viktorovich, nvk@srd.sinp.msu.ru

Forecasting of the Space Weather Factors in the near-Earth's Space and on the Satellite Orbits

Space Monitoring Data Centre (SMDC) of Moscow State University provides mission support for Russian satellites and gives operational analysis of radiation conditions in space. SMDC Web-resources (http://smdc.sinp.msu.ru/ and http://swx.sinp.msu.ru/) and operational services describe the geomagnetic and radiation state of Earth's magnetosphere in near-real time. Operational services automatically generate alerts on particle fluxes enhancements above the threshold values, both for SEP and relativistic electrons using data from GEO and LEO orbits as input.

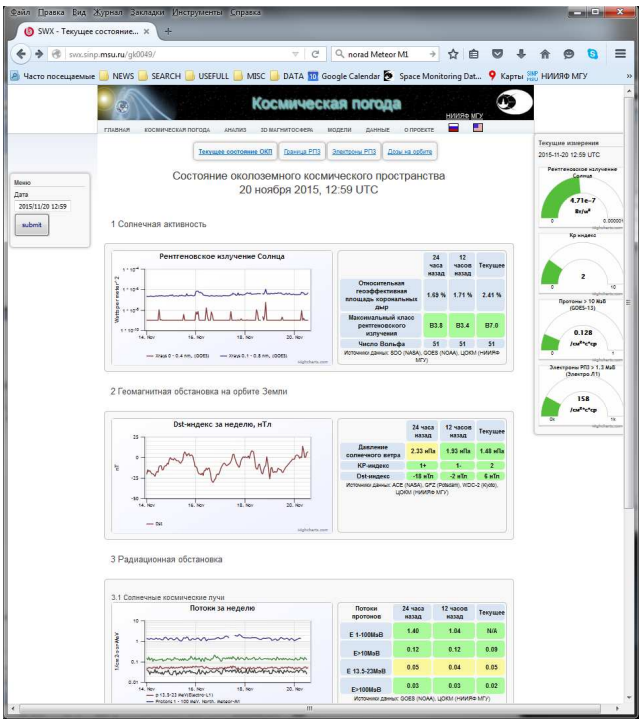

Figure. Physical conditions in the near-Earth's space at 12:59 UTC on 20.11.2015

Carolus J. Schrijver, Kauristie Kirsti, Alan D. Aylward, Clezio M. Denardini, Sarah E. Gibson, Glover Alexi, Gopalswamy Nat, Grande Manuel, Hapgood Mike, Heynderickx Daniel, Jakowski Norbert, Vladimir V. Kalegaev, Lapenta Giovanni, Jon A. Linker, Liu Siqing, Cristina H. Mandrini, Ian R. Mann, Nagatsuma Tsutomu, Nandy Dibyendu, Obara Takahiro, O'Brien T. Paul, Onsager Terrance, Hermann J. Opgenoorth, Terkildsen Michael, Cesar E. Valladares, and Vilmer Nicole. Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS. Advances in Space Research, 55(12): 2745–2807, 2015. http://dx.doi.org/10.1016/j.asr.2015.03.023

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Registration of the plasma pressure peak and the equatorial boundary of the westward auroral electrojet in the region of the formation of the outer electron radiation belt during magnetic storm

Results shedding light on the solution of the problem of the formation of the outer radiation belt of the Earth first observed on the second artificial satellite [Vernov, Grigorov, Logachev, Chudakov, DAN, v. 120, No 6, p. 1231-1233, 1958] are obtained. The key moment of the problem solution is the analysis of the dynamics of the phase space density of relativistic electrons. In spite of the long period of the study of the outer radiation belt including Van Allen project, the problem was not solved. It was possible to describe the dynamics of the phase space density of relativistic electrons and obtain the position the location of the maximum in such density only in one case for the magnetic storm 8-9 October 2012 [Reeves etal., 2013, doi:10.1126/science.1237743]. However, the auroral oval dynamics during this storm and the role of auroral processes in the acceleration of the outer radiation belt was not studied in a proper way.

The auroral oval and auroral electrojet motion to the equator during magnetic storm 8-9 October 2012 was analyzed using data of DMSP satellite observations and magnetic IMAGE chain. Sharp local increase of plasma pressure at geocentric distance L=4, on which the maximum of phase space density is observed during the storm recovery phase, for the first time is observed. It is shown, that the position of the equatorial boundary of the westward electrojet coincides with the position of the maximum of phase space density of relativistic electrons during recovery phase of the storm. Comparison of the position of the maximum of

formed belt with the value of minimal Dst for analyzed storm supported in the limit of experimental uncertainties the dependence obtained by Tverskaya [2011, doi: 10.1134/S0016793211010142] (Tverskaya prediction - Lmin=4.02, the result of Reevesetal. -Lmin=4.2).

The obtained results give the possibility to develop the method of the prediction the location of the maximum of formed new radiation belt using data of auroral satellites such as METEOR and ground base magnetic observations.

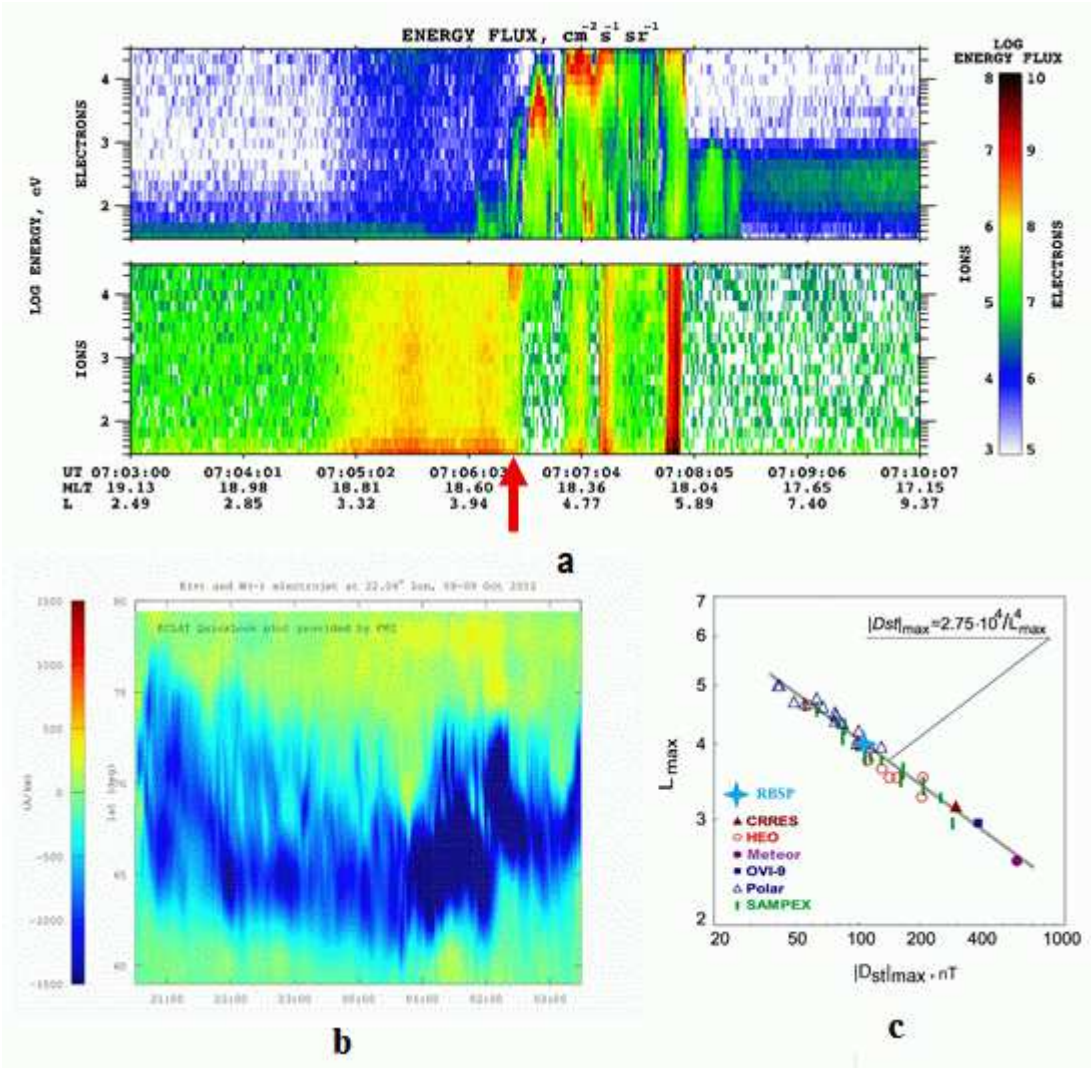

Fig. 1. Results of DMSP observations (a), position of the auroral electrojet in accordance with magnetic chain IMAGE (b) and the position of the new radiation belt maximum on the Tverskaya curve (c). The observed event is shown by blue

star on the figure (c). Arrow on figure (a) shows the position of the observed pressure maximum.

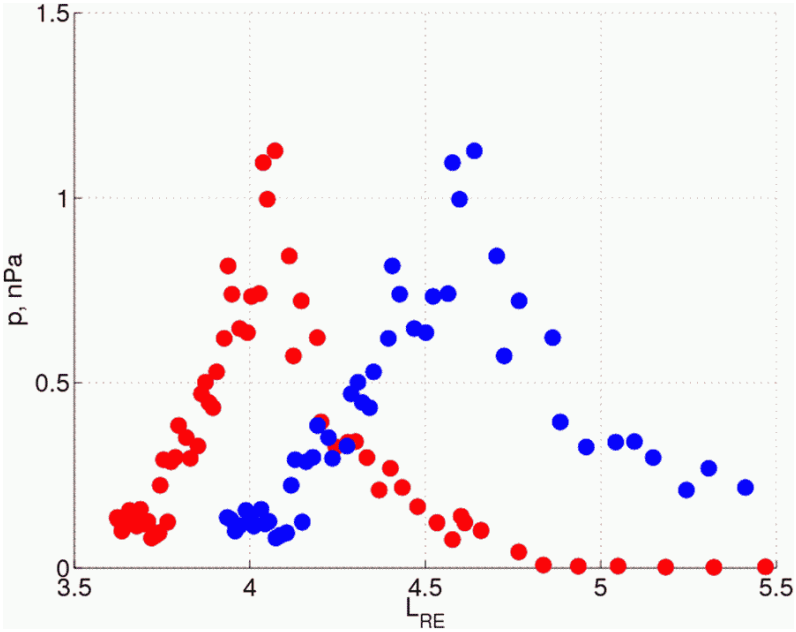

Fig. 2. Plasma pressure profiles obtained from the DMSP F17 satellite data during the auroral crossing on 8 October 2012 between 21:47:40and 21:52:50 UT mapped to the equatorial plane by IGRF (red)and Tsyganenko 2004 (blue) models. The maximum of the phase space density of relativistic electrons is obtained using data of Van Allen [Reevesetal., 2013, Science341:991, doi:10.1126/science.1237743] at L=4.2.

Antonova E. E., M. V. Stepanova, The problem of the acceleration of electrons of the outer radiation belt and magnetospheric substorms. Earth, Planets and Space, v. **67.**doi:10.1186/s40623-015-0319-7.

Antonova E. E., V. G. Vorobjev, M. O. Riazantseva, I. P. Kirpichev, O. I. Yagodkina, V. V. Vovchenko, M. S. Pulinets, S. S. Znatkova, I. L. Ovchinnikov, I. A. Kornilov, T. A. Kornilova, M. V. Stepanova,Auroral oval mapping and the

main problems of magnetospheric dynamics, Unsolved problems in magnetospheric physics, 6-12th September, 2015, Scarborough, UK, p. 2

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Determination of parameter changes of ion and electron kappa-distributions with the growth of geocentric distance in the tail of the magnetosphere of the Earth

The evolution of ion and electron distribution functions, approximated by kappa distributions, in the plasma sheet with the distance from the Earth using the data of THEMIS mission is analyzed. At least four spacecraft were aligned along the tail between approximately 7 and 30 RE (see Fig.) for analyzed events. It is shown, that observed distribution functions can be approximated by kappa distribution. For these events. It was found that for the majority of events the values of $\kappa$of kappa distribution is increased tailward. The role of regular and turbulent transport in the formation of observed dependence is analyzed. It is shown, that turbulent transport accompanied by the processes of electron and ion distribution function relaxation plays the important role in the formation of distribution functions in the tail of the magnetosphere of the Earth.

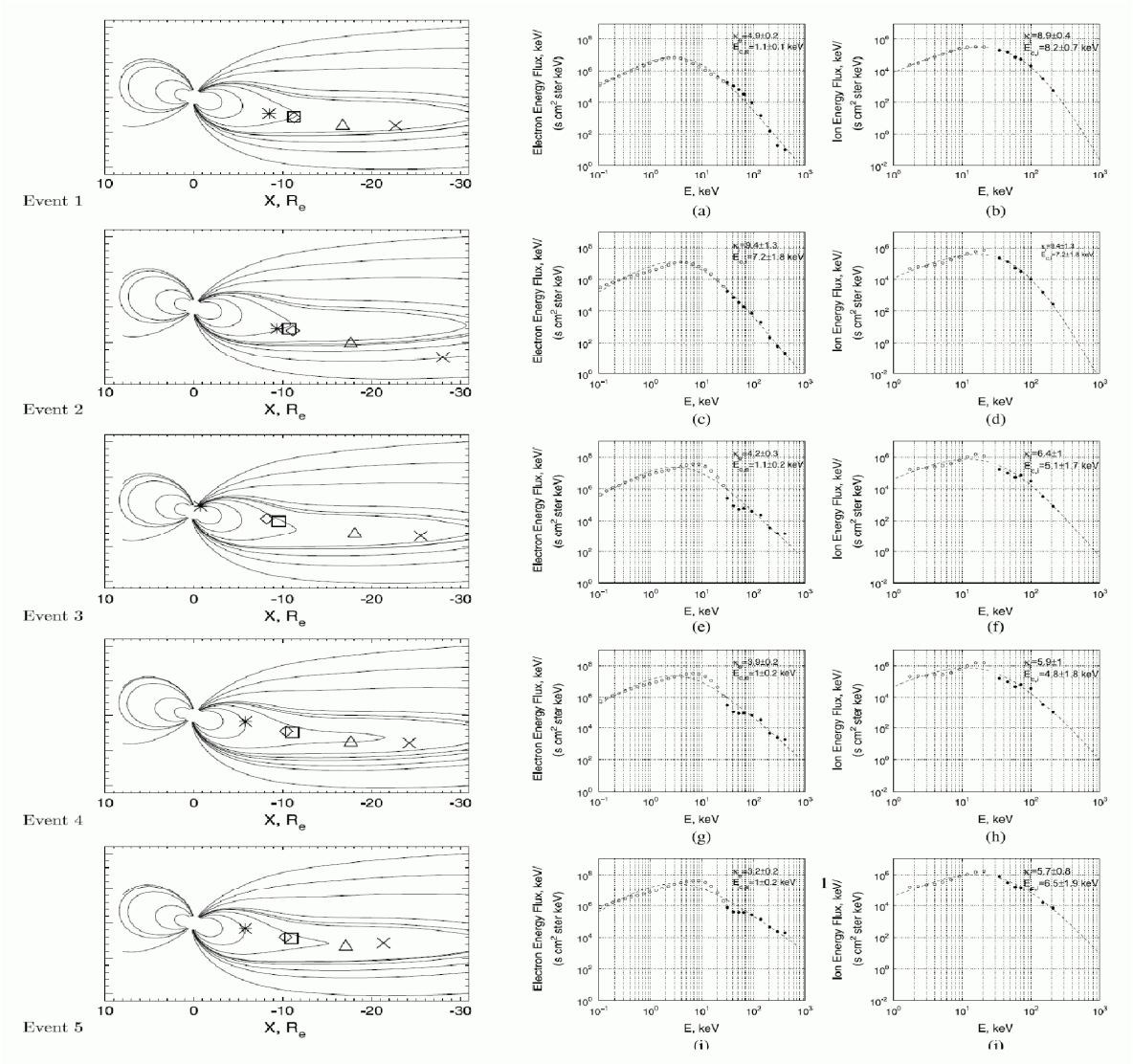

Fig. Positions of the five THEMIS satellites in GSM coordinates for five events analyzed showing satellite alignment in the tailward direction (left part of figure). Averaged electron and ion energy flux spectra, measured on 22 February 2008 between 7:26 and 7:38 UT and fitted by kappa distribution: (a, b) THB, X_{GSM}= −22.9R_E, (c, d) THC, X_{GSM}= −16.9R_E, (e, f) THD, X_{GSM}= −11.3R_E, (g, h) THE, X_{GSM}= −11.2R_E, and (i, j) THA, X_{GSM}= −8.3R_E (right part of figure).

Stepanova M., E. E. Antonova, Role of turbulent transport in the evolution of the distribution functions in the plasma sheet, J. Geophys. Res., v. 120, No 5, p. 3702-3714, 2015,doi:10.1002/2014JA020684.

Stepanova M., E.E. Antonova, Turbulent transport and evolution of kappa distribution in the plasma sheet, Unsolved problems in magnetospheric physics, 6-12th September, 2015,Scarborough, UK, p. 49.

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Mapping of the main part of the auroral oval to the surrounding the Earth plasmaring

It is shown, based on the developed earlier method of mapping of auroral regions to the equatorial plane without using of magnetic field models, that the main part of the auroral oval is mapped not to the plasma sheet of the magnetosphere of the Earth, as was considered earlier. It is mapped to the surrounding the Earth plasma ring. Used method is based on the comparison of plasma pressure at low altitudes and at the equatorial plane in the conditions of the magnetostatic equilibrium and pressure isotropy. Plasma pressure in such conditions has constant value at the field line. This give the possibility to mark the magnetic field line. Distributions of plasma pressure at the ionospheric altitudes and at the equatorial plane are obtained using data of DMSP satellites and five satellites of THEMIS mission during quite (see Fig.) and disturbed geomagnetic conditions. The existence of transverse current in the region of auroral oval mapping to the equatorial planeis shown. This current is the high latitude continuation of the ring current and not included in the models of the geomagnetic field with predetermined geometry of current systems. This leads to

the nonrealistic stretching of magnetic field lines in the nightside sector. Obtained result give the possibility to explain the ring like form of the auroral oval which has finite width near noon.

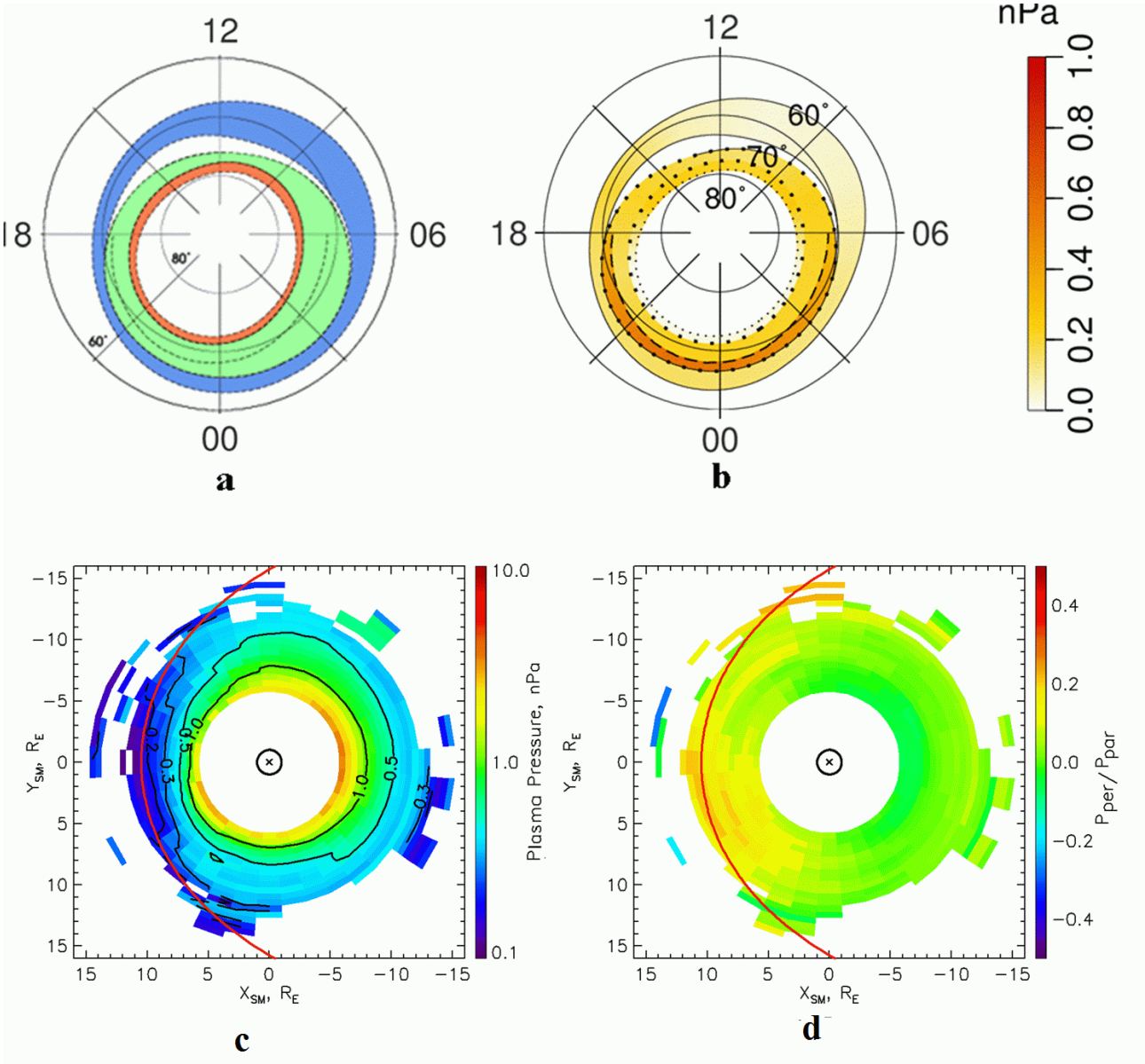

Fig. Results demonstrating the mapping of the auroral oval (shown by green on Fig. a) to the surrounding the Earth plasma ring in the magnetoquite conditions AL = −100 nT and Dst = −5 nT: distribution of auroral precipitations at low altitudes (a), distribution of plasma pressure at low altitudes (b) and at the

equatorial plane (c), pressure anisotropy at the equatorial plane (d).

Antonova E. E., V. G. Vorobjev, I. P. Kirpichev, O. I. Yagodkina, M. V., Stepanova, Problems with mapping the auroral oval and magnetospheric substorms, Earth, Planets and Space, 2015, 67:166, DOI: 10.1186/s40623-015-0336-6

VorobjevV. G., O. I. Yagodkina, and E. E. Antonova, Features of the Planetary Distribution of Ion Precipitation at Different Levels of Magnetic Activity, Geomagnetism and Aeronomy, 2015, Vol. 55, No. 5, pp. 585–595.DOI: 10.1134/S0016793215050187.

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Determination of the role of fluctuations in the magnetosheath of the magnetosphere of the Earth in the process of plasma penetration inside magnetosphere and formation of the low latitude boundary layer

The role of high level of fluctuations in the magnetoaheath of the magnetosphere of the Earth in the process of plasma penetration inside the magnetosphere and formations of the low latitude boundary layer (LLBL)has been considered basedon the events that occurred on November 1 and 5, 2007, using the THEMIS-A satellite observations (see Fig.). During the selected LLBL crossings, the satellite was measuring behind the quasi-parallel and quasi-perpendicular bow shocks.

The angle between the magnetic field direction in the solar wind and the normal to the bow shock(ΘBn) has been taken as a parameter reflecting the level of magnetic field and plasma parameter fluctuations in the magnetosheath. It has been indicated that a thick LLBL is observed when angle ΘBn is small and the turbulence level in the magnetosheath is high. When angle ΘBn is large, the layer thickness decreases. The possible mechanisms by which a thick LLBL is formed are discussed.

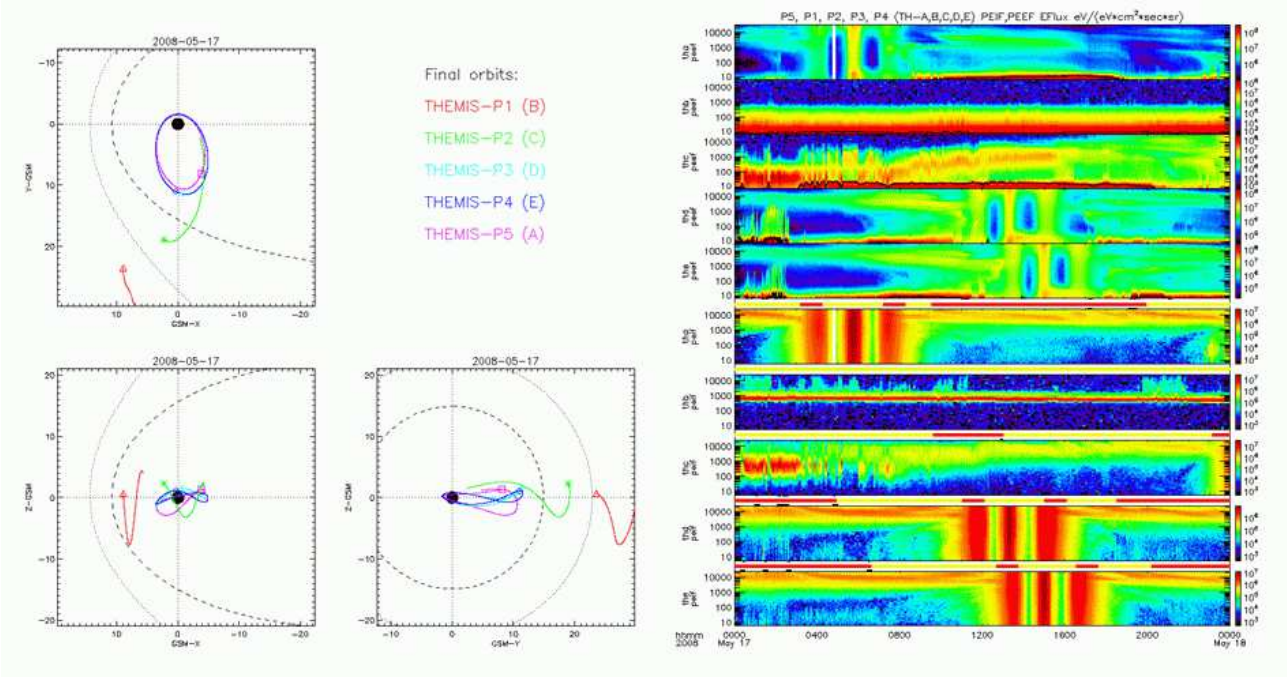

Fig.Exampleoflow latitude boundary layer crossing by satellites of THEMIS mission.

ZnatkovaS. S., E. E. Antonova, M. S. Pulinets, I. P. Kirpichev, and M. O. Riazantseva, Thickness of the low-latitude boundary layer at different levels of magnetic field fluctuations in the magnetosheath, Geomagnetism and Aeronomy, 2015, Vol. 55, No. 5, pp. 573–581.doi:10.1134/S0016793215050205.

PulinetsM., E. Antonova, M. Riazantseva, S. Znatkova, I. Kirpichev, Statistical comparison of the magnetopause crossings in a quiet geomagnetic conditions and during magnetic storms according to the THEMIS data. 26th General Assembly of the International Union of Geodesy and Geophysics (IUGG), Prague, Czech Republic, June 22 - July 2, 2015. Abstract: A33p-003

ZnatkovaS., E. Antonova, I. Kirpichev, M. Pulinets, Plasma velocities in the low-latitude boundary layer, 26th General Assembly of the International Union of Geodesy and Geophysics (IUGG), Prague, Czech Republic, June 22 - July 2, 2015. Abstract: A33p-002.

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The studies of the dynamical properties of small-scale structures of the solar wind plasma

The studies were based on the measurements of the plasma spectrometer BMSV with an extremely high temporal resolution (up to 0.03 s). It is located onboard an astrophysical spacecraft SPEKTR-R, which is leaving from the Earth to 350 000 km. The spectra of the fluctuations of the solar wind ions flux are studied systematically at the scales from 0.03 up to 100n s. The difference between the slopes of low-frequency and high-frequency parts of fluctuation spectrum and the frequency of the salient point between them are studied for different conditions of the solar wind. Statistical properties of the fluctuations of the solar wind ions flux are also analyzed in details at the scale less than 10 s. High level of intermittence of the studied flux is demonstrated. It was shown, that expanded self-similarity of the turbulent flux of the solar wind ions is observed permanently. Non-Gaussian distribution functions of ion flux fluctuations were approximated by

means of Callis statistics, a non-extensive character of the solar wind fluctuations was shown. Statistic characteristics of the ion flux fluctuations were compared to the predictions of the Log-Poisson model. Log-Poisson parametrization of the structural functions scaling has shown, that as a rule filament-like structures are observed in the turbulent solar wind flow.

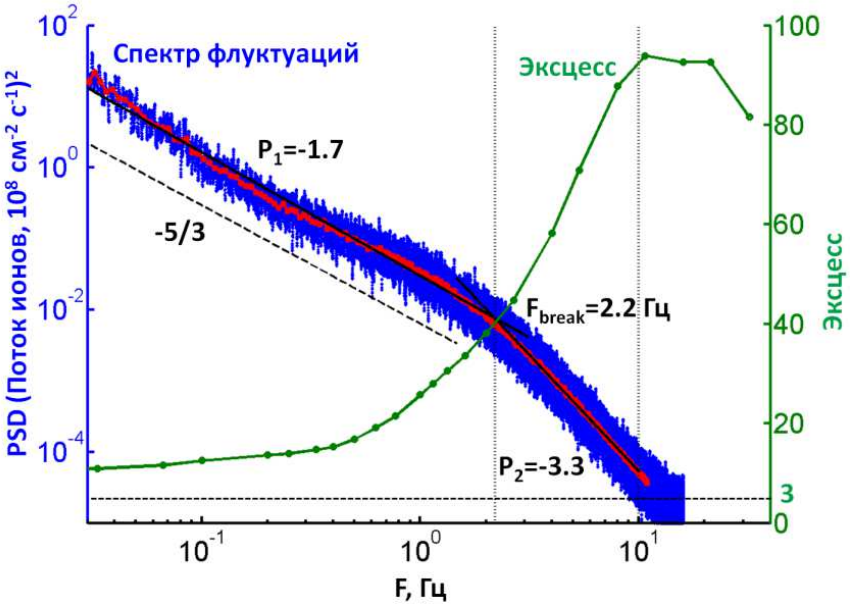

Figure. An example of the spectrum of fluctuations of the solar wind ions flux and the dependence of the excess value depending on the fluctuation frequency for time interval 27-28/09/2011 23:00-09:00 UT. Growth of excess with decreasing of scale demonstrates intermittence of the flux.

Riazantseva M.O., Budaev V.P., Zelenyi L.M., Zastenker G.N., Pavlos G.P., Safrankova J., Nemecek Z., Prech L. and Nemec F., Dynamic properties of small scale solar wind plasma fluctuations, Phil. Trans. R. Soc. A, 373 (2041), 20140146, 2015. http://dx.doi.org/ 10.1098/rsta.2014.0146. Impact factor (Web of Science) – 3.04

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Study of solar event enriched by ^{3}He isotope

A powerful solar flare of January 20, 2005 was analyzed by a previously proposed method, based on the properties of gamma radiation in the neutron line and nuclear de-excitation lines, mainly of ^{16}O and ^{12}C. The techniques of gamma neutron line of 2.223 MeV emissions temporal profile modeling and comparing with the data have been proposed. The study was based on gamma-emission data of AVS-F apparatus from SONG-D detector onboard CORONAS-F satellite. The calculations were performed under assumptions of Bessel type of accelerated particles energy spectrum, different ^{3}He/H abundance in the region of nuclear reactions to occur, and two density models of the solar atmosphere. Comparison the simulation results with observational 2.223 MeV data reveals the numerical values of all mentioned parameters.

The method gives the possibility to detect not only the time-averaged 2.223-MeV gamma-emission parameters over the whole flare, but also their evolution with the time of the flare. The increase of ^{3}He/H concentration ratio during the flare from 2×10^{-5} at the rise phase of gamma-ray flux up to 2×10^{-4} power at the decay one was found. The ^{3}He/H concentration ratio, averaged over whole time of 2.223-MeV-emission, is equal to $(1.40\pm0.15)\times10^{-4}$. The results of the numeric approximation are presented in Figure. It is also shown that accelerated He-3 ions are expanded and accumulated in the areas of photosphere and lower chromosphere.

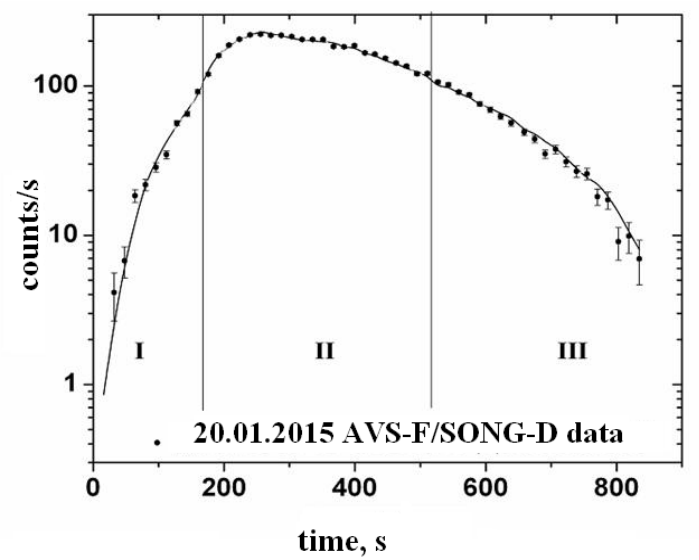

Figure. Combined approximation of temporal profile of 2.223-MeV γ-emissions during the January 20, 2005 solar flare. The revealed meanings of 3 parameters in three time intervals (I-III) are presented:

I – $n(^3He)/n(H)= 2\times10^{-5}$, $\alpha T=0.005$, model – non-disturbed density of the solar atmosphere (model HSRA), 1.5×10^{16} см$^{-3}$ at the top of the photosphere.

II – $n(^3He)/n(H)=1.4\times10^{-4}$, $\alpha T=0.03$;

III – $n(^3He)/n(H)=2.0\times10^{-4}$, $\alpha T=0.1$.

Density model in II and III is typical for flares - the density is enlarged up to 2×10^{17} cm^{-3} in lower chromosphere and corona.

E.V. Troitskaya, I.V. Arkhangelskaja, A.I. Arkhangelskiy, About ^{3}He Ions Predominant Acceleration During the January 20, 2005 Solar Flare, Physics Procedia, V. 74, 2015, P 274–280.

I.V. Arkhangelskaja, A.I. Arkhangelskiy, A.R. Lyapin, E.V. Troitskaya, Background Conditions for the October 29, 2003 Solar Flare by the AVS-F Apparatus Data Physics Procedia, V. 74, 2015, P. 281–286.

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Increased content of the elements with low first potential of ionization on the border of the photosphere and the corona. North-south annual asymmetry of the ionosphere

a) Analysis of the spectra obtained by French scientists with high spatial resolution (45 km) during full solar eclipse in 2008, 2009, 2010, 2012 and 2013 have shown presence of increased content of the elements with low first ionization potential (Fe II, Ti II, Ba II) in the area of the temperature minimum at the altitudes from 200 to 600 km over the photosphere.
b) Ionosphere's asymmetry in the North and South magnetic hemispheres was analyzed in retrospective during equinox in 1996-2012 according to the data of multiple satellite experiments and adjusted to a common measure of full electronic content by means of a new asymmetry index. It allowed to find out several significant characteristics, associated with solar activity and other factors.

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Topological structure of the magnetic fields near zero points. Energy and matter flows near the Sun

Common principles for the description of geometrical and topological properties of the magnetic field lines near the zero points of the second and higher order in space due to basic functions selection and solution of the eigenvalue problem by specific method were formulated. They were classified in the potential case and possible applications for the processes on the Sun were considered. It was shown (theoretically and basing on the experimental data) that energy and matter flows

are not parallel in the turbosphere of the Sun at distances of 1-6 solar raii and possibly have different directions. Sources of the matter and energy are located differently, and in general case they do not coincide. It makes the problem of the solar wind origin non-local and evolutionary. It is concluded that at the present stage of evolution of the Sun for the most part the solar wind exists due to acceleration by the electromagnetic fields, not by the gas pressure gradient.

Lukashenko A.T., Veselovsky I.S. General Principles of Describing Second- and Higher-Order Null Points of a Potential Magnetic Field in 3D // Geomagnetism and Aeronomy, Vol. 55, № 8, p. 1152–1158. 2015.

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Theoretical models of the Solar system planets

Necessary conditions for dynamo action beyond the heliopause

A possible mechanism is presented for explanation of the amplified magnetic field just beyond the heliopause with the same direction as in the outer heliosphere observed by Voyager 1. Simultaneously with the increase of magnetic-field magnitude at the heliopause, the number of energetic heliospheric particles and the temperature decreased substantially. At the same time, the Galactic cosmic-ray intensity enhanced together with the plasma density. We suggest a dynamo mechanism as a possible reason for the observed magnetic-field behavior. We enumerate the necessary conditions for the dynamo process and analyze the Voyager 1 observations to test whether these conditions hold or not. We show

that all preconditions are realized and estimate the energy of the dynamo action potential. We conclude that in principle, this process could work just beyond the heliopause, because differential rotation may exist in the nearest part of the outer heliosheath, in a layer where electric conductivity is high, but lower than the field-aligned conductivity in the surrounding regions and where the rotational kinetic-energy density is comparable with the observed magnetic-energy density. The latter circumstance corresponds to a requirement of dynamo action, for which kinetic energy of rotation provided by the Sun is an energy source for magnetic amplification.

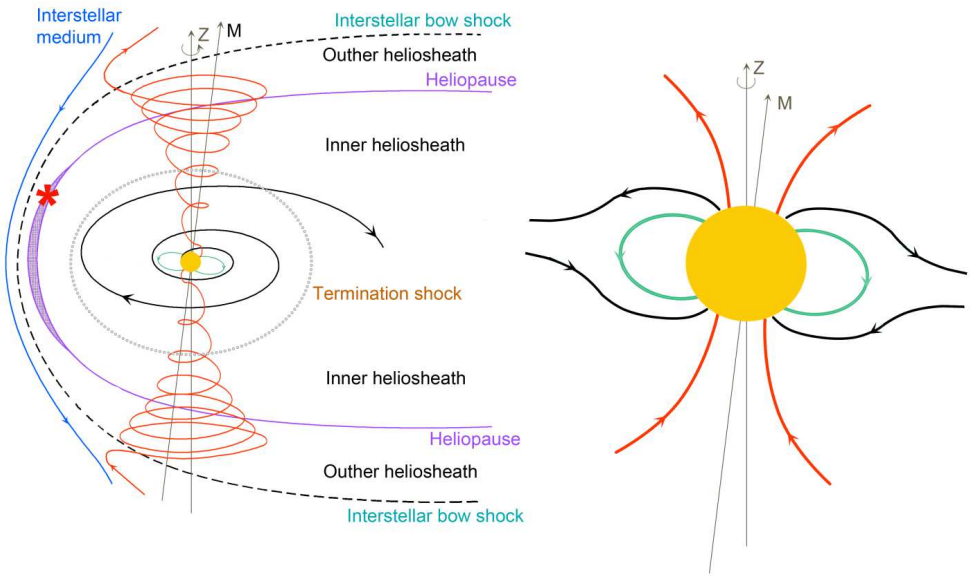

Figure. Z is the rotation axis and M is the magnetic axis of the Sun. Left: Schematic view of the heliosphere located in the flow of the interstellar medium. The heliopause is shown as a violet curve, the interstellar bow shock as a dashed curve, and the termination shock as a dotted curve. The dynamo layer in violet is shaded; the asterisk marks the Voyager 1 intersection with the heliosphere; open-field lines are red, closed field lines are green, between them there are black lines belonging to the heliospheric current sheet. The interstellar magnetic field is

marked by blue curve. Right: The inner heliosphere.

E.S. Belenkaya, Dynamo in the Outer Heliosheath: Necessary Conditions, Solar Physics, 290, Issue 7, pp. 2077-2092, 2015, DOI 10.1007/s11207-015-0741-9. Impact Factor: 4.039

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Development of thin current sheet model

Thin current sheets with thickness of several Larmor radii of thermal ions are fundamental physical objects, playing significant role in the forming of the basic magnetospheric current systems (current sheet of the magnetotail, equatorial magnetodisc of Jove, heliospheric current sheet, etc.). The distributions of the current density and magnetic fields are studied within the frames of the hybrid model of the current sheet in the Earth's magnetotail taking into account the shear magnetic component. Non-linear dynamics of the charged particles, which form the sheet and provide the observed statistic balance, is studied. Analytic solution for the current's density and profile is compared to the result of numerical calculations and to the experimental data from the Cluster satellites. Indicative spatial scale (the distance between the maxima) is obtained as a function of pitch-angular distribution of the bombarding particles taking into account the effect of the incoming beam thermal dispersion. It is shown that within the frames of the numerical model of the current sheet, based on the method of large particles, appearance of self-consistent component of the electric field near the current sheet can lead to the significant decrease of the sheet's thickness and, finally, to the forming of a large-scale configuration with a

thin current sheet sustained by transit particles in the center. Significant input of electrons to the forming of the balanced current structure is demonstrated. New type of balanced solutions with shear modes, appeared at certain initial conditions, is obtained.

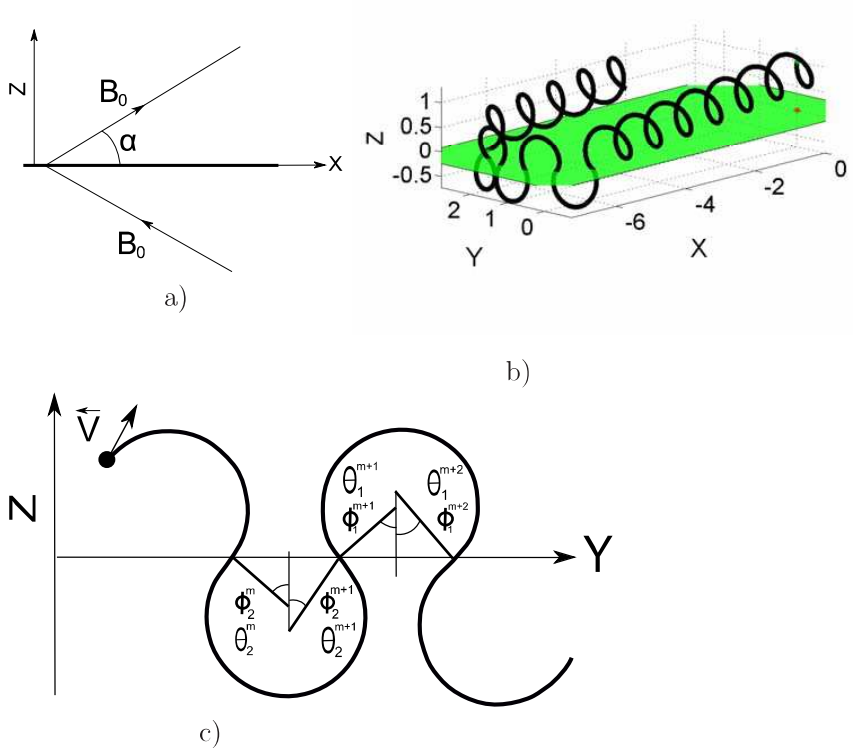

Fig. 1. Configuration of the magnetic field (a). Schematic diagram of the trajectory of the proton, oscillating near the current sheet (b, c).

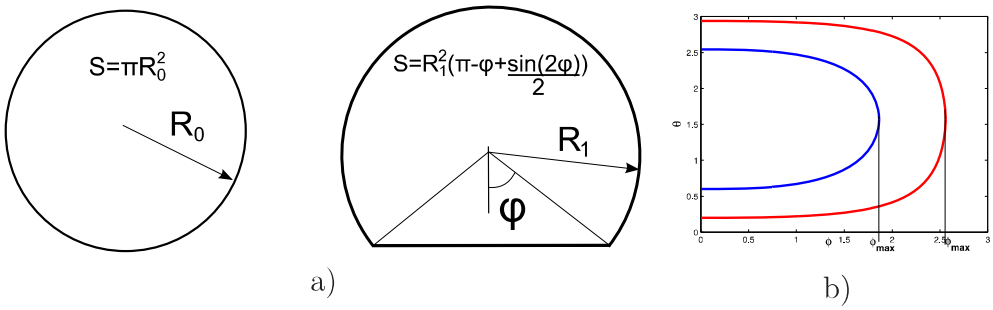

Fig. 2. Variation of pitch-angle and Larmor rotation phase depending on the initial pith angle θ_0 (a). Red and blue curves correspond to $\theta_0 = 0.2$ and $\theta_0 = 0.6$. (b)

shear structures in thin current sheets, Journal of Geophys.Res.-Space Physics. 120(6). pp. 4802-4824. 2015.

Sasunov Yu. L.; Khodachenko M. L.; Alexeev I. I.; Belenkaya E.S., et al., Investigation of scaling properties of a thin current sheet by means of particle trajectories study, Journal of Geophys.Res.-Space Physics. 120(3). pp. 1633-1645. 2015.

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Calculations of the longitudinal currents in the southern night magnetosphere of Saturn

Basing on the analysis of magnetic disturbances, associated with the longitudinal currents, obtained by 34 passes of the Cassini spacecraft in the pre-midnight sector of the northern auroral area in 2008 it was found out that they are modulated not only by northern system, responsible for the planetary period oscillations (PPO), but also by the southern PPO system. It indicates an existence of the migration currents between the hemispheres associated with the PPO systems. The basic longitudinal currents of two PPO systems are found out to be located at the same place as the northern ionospheric co-latitude of the northern PPO system, localized between the area of the border between the open and the close lines of field and lines of field, projected to ~9 radii of Saturn in the equatorial plate. The currents of all three current systems are of the similar value ~3 MA in each PPO half-cycle.

Hunt G.J., Cowley S.W.H., Provan G. et al. Field-aligned currents in Saturn's northern nightside magnetosphere: Evidence for inter-hemispheric current

flow associated with planetary period oscillations, Journal of Geophysical Research, 120, doi:10.1002/2015JA021454

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The models of axisymmetric current sheets in space plasma

The models of the axisymmetric current sheets of the Jovian magnetodisc and heliospheric current sheet are developed and analyzed. The effect of the Jupiter's satellite Io's volcanicity and finite conductivity of the planet's ionosphere were taken into consideration. It was shown, that unipolar generation, associated with the disturbance of the corotation in the upper layers of the ionosphere is the basic mechanism of longitudinal currents generation. It is demonstrated that in order to understand the physical mechanisms of the magnetodisc's formation it is necessary to take into account not only latitudinal, but also longitudinal currents closed on the planet's ionosphere. Within the frames of a new MHD modelof heliospheric current and plasma layers their imbedded multi-scale structure, which separates magnetic flows with different polarity, is taken into consideration. The full current in the heliospheric current layer at different heliocentric distances was evaluated. The possibility for the turnover of the radial current behind the Earth's orbit was predicted. It is a difference of this model from the well-known Parker's model. It was shown, that the current layers, constraining plasma layer, are located on the separatrices, which separate the areas of the open and the close magnetic lines. The thickness of the plasma layer is evaluated and it's agreements with the observations of the Ulysses spacecraft is shown.

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Kislov R.A., H.V. Malova, I.Yu. Vas'ko, Two-dimensional MHD model of the Jovian magnetodisc, Cosmic Research, 2015, v.53, N5, pp.341-353.

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Effects of the magnetic field in the evolution of the exoplanet's atmosphere and mass losses under the influence of stellar radiation and stellar wind

A self-consistent model describing mass loss for a magnetized giant exoplanet on the near orbit (so-called hot Jupiter) is developed. Hydrodynamical model of the expanding hydrogen atmosphere of hot Jupiter was generalized by taking into account of self-magnetic field of the giant exoplanet. The model takes into consideration the real radiation spectrum in X-ray and UV ranges of solar type and chemical composition of the atmosphere and cooling at radiation in H_3^+ и Lyα lines. Interaction of the expanding atmosphere and the planetary field result in formation of a magnetodisc. The process is found out to be cyclic with periodic disposal of the plasmoid of a ring form. If magnetic field plays an essential role in mass loss of an exoplanet of HD 209458b type, the field on the surface of the planet should be about 1 Gs.

Khodachenko, M.L., Shaykhislamov, I., Lammer, H., Prokopov, P.A., Atmosphere Expansion and Mass Loss of Close-Orbit Giant Exoplanets heated by Stellar XUV. II. Effects of Planetary Magnetic Field; Structuring of inner Magnetosphere, Astrophys. J., 2015, 813:50 (DOI: 10.1088/0004-

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