2.2. The Results of the Current Flight Scientific Programmes of Investigation and Observation

2.2.1. Space Research Institute of the RAS

Results of the current flight scientific programmes «Mars-Express», «Venus-Express», «Integral» are presented in chapter 2.1.1.

2.2.2. V.A. Kotelnikov Institute of Radio Engineering and Electronics of The RAS

2.2.2.1. Advanced Ocean Color Scanner

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A new satellite instrument (Advanced Ocean Color Scanner) is designed for studies of ocean environment and of main climatic factors. It is intended for biological and ecological monitoring of seas and oceans as well as for investigations of physical processes in their upper layer. A peculiarity of the new scanner is that provides data not only from measurements in different spectral ranges but also from along-track scanning in three spectral bands. That gives additional information for better atmospheric correction.

Key words: multi-spectral scanning system, space experiment, ocean color, biological and biochemical characteristics, ecological monitoring.

INTRODUCTION

Earth observation from Space is important from the scientific and practical standpoint. Study of natural phenomena and processes on the earth surface, including the energy hot-spot areas, and within the ocean biosphere, affecting climate and environment changeability, severity of natural catastrophes, are very significant for science and human activity. Satellite observation systems enable to collect data for solving fundamental scientific problems in physics of ocean-atmosphere interaction, for assessment of state and dynamics of the energy hot-spot areas as well as for development of prediction models of medium-and long- term climatic changes, for advancement of the reliability of weather forecast, of trends in changeability of the energy hot-spot areas state.

Development of satellite methods opens up new possibilities for continuous monitoring of spatial and temporal changes of characteristics of underlying surface, including the sea surface and the near-surface layer, as well as the oceanic atmosphere in regional and global scales.

An enormous volume of information about ocean and atmosphere is provided by satellite ocean color scanners allowing to derive such important characteristics as chlorophyll concentration and primary production, atmospheric aerosol content and cloud parameters (cloud cover), seawater optical characteristics, in particular the absorption and backscattering coefficients, which determine propagation of solar radiation into water body, describe content of suspended and dissolved matter in seawater and serve as convenient parameters of bio-geo-ecological monitoring. Satellite ocean color measurements allow to perform systematic observations of existent changeability, in particular in structure and functioning of coastal ecosystems, provide operational useful information for fishery, to control a water quality in coastal zone, to observe various hydrodynamic processes (spreading of river runoff, meso-scale eddies, variability of frontal zones). Satellite sensors enable to perform long-term quasi-continuous observations covering the whole globe.

SCIENTIFIC INSTRUMENT

For testing of methods of satellite optical observations, the Federal State Unitary Enterprise "Russian Institute of Space Device Engineering" (FGUP RISDE) makes a new multi-spectral scanning system (Advanced Ocean Color Scanner – scientific instrument "ROSS-1"). This scanner is a main instrument for a future satellite experiment aimed at biological and ecological monitoring of seas and oceans and studies of physical processes in the near-surface layer. Up to now the requirements specification and technical documentation have been issued, the development type has been produced and its off-line test has been executed. In this year development and coordination of the requirements specification for adaptation and revision of ROSS-1 to mount it on a spacecraft are planned.

A draft of the science program for satellite experiment with ROSS-1 has been prepared. The program is intended to further development of methods and technical means for satellite remote sensing of ocean environment and basic climatic factors in the atmosphere-ocean system. The satellite experiment ROSS-1 is planned from 2012. Keeping in mind the current lack of Russian specialized scientific satellite modules, it is worth to use for solving the above mentioned tasks the end-use spacecrafts such as the satellite system for operational Earth monitoring "Meteor-M". ROSS-1 is planned to install on the "Meteor-M" No.3 satellite (Fig.1) which launch is set for 2012.

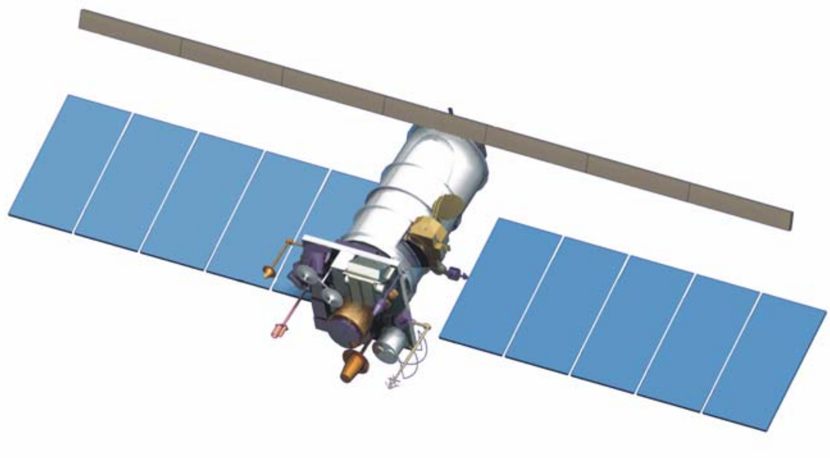

Fig.1 Meteorological satellite "Meteor-M" No.3.

A schematic diagram and the scanning geometry is shown on Fig. 2.

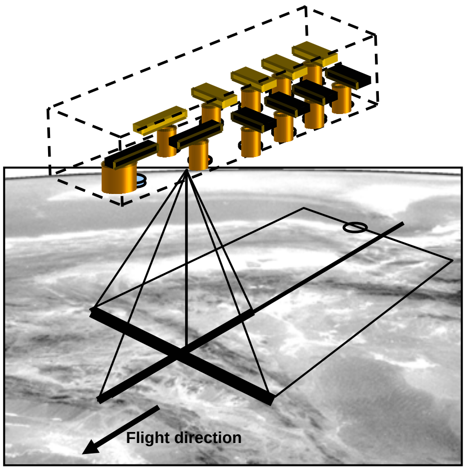

Fig.2. A schematic diagram and the scanning geometry.

The main performance characteristics of the advanced ocean color scanner ROSS-1 are given in the Table.

Table Main performance characteristics of the advanced ocean color scanner ROSS-1

Parameters	Values
Spectral bands*, μ (8 bands at across track scanning)	0.402-0.422 0.433-0.453 0.480-0.500 0.500-0.520 0.545-0.565 0.660-0.680 0.725-0.765 0.845-0.885
Uncertainty in the edge of spectral band, nm	±5
Viewing angle, degrees	66 (±33)
Swath, km	>900
Angular resolution, mrad	0.65±0.05
Spatial resolution at nadir (with the orbit altitude of 800 km), km	0.5±0.1
Operating mode	by sessions
Duration of continuous work, min	≤30
Interval between the sessions, min	≤20
Power consumption	<100 W
Weight, kg	<40

*At least three spectral bands are planned for the along-track scanning (their parameters will be defined during the engineering process)

Its design is based on the modular approach (each spectral channel is formed by a self-dependent optoelectronic system) [1].

A peculiarity of the new scanner is that the useful information is provided not only from measurements in different spectral ranges but also from measurements at different viewing angles by along-track scanning. This important additional information allows to improve an accuracy of the atmospheric correction, in particular to estimate contribution arising from sun glints.

Initial satellite ocean color data are the values of upwelling radiance at the top-of-the-atmosphere. To get information about the ocean parameters it is needed to derive from the measured data the values of water-leaving radiance, that is to solve the so-called atmospheric correction problem.

The new approach to the atmospheric correction problem has been developed by specialists from P.P. Shirshov Institute of Oceanology Russian Academy of Sciences (SIO RAS). This approach is based on a simultaneous retrieval of the contributions arising from aerosol scattering and the water-leaving radiance from measured data in both infrared and visible spectral bands [3]. The atmospheric correction for the new ocean color scanner will be performed with data both from the across-track measurements and from the along-track scanning at different viewing angles [2]. The approach developed will be validated with data from concurrent measurements of spectral radiance at the-top-of-the-atmosphere by satellite sensor and of water-leaving radiance and the aerosol parameters by ship instruments. Refinement of the algorithms will be executed on the basis of results of validation from the match-ups and from computer modeling.

GOALS OF THE STUDIES

The studies of ocean environment and basic climatic factors will be performed by the ocean color scanner ROSS-1 in combination with microwave scientific instruments (microwave radiometers, radio altimeter, microwave scatterometer). They will provide information needed for solving many scientific and practical problems such as:

- Analysis of optical and biological characteristics of upper ocean, assessment of bioproductivity and carbon stream in euphotic zone;
- Studies of elements of circulation and the admixture dynamics, in particular spreading of river runoffs and contaminants;
- Assessment of light penetration into water body, ocean albedo, and volume absorption in upper ocean for more precise estimation of the ocean heat budget;
- Development of integrated methods for processing and analysis of satellite ocean color data, including data from microwave radiometers;
- Development of algorithms for processing satellite data and of methods for validation of the algorithms.

The computer modeling, calculations, and processing of measured data will be performed with soft hardware of SIO RAS and in the Center of processing and archiving satellite information of the Institute Radioengineering and Electronics RAS equipped with high-performance servers. The efficiency of analysis of results from measurements will be secured by resources of the active archive of the Center with about 1 TB in size and catalog of the database ORACLE. The Center resources are operationally compatible with the NASA EOSDIS system and have the high-performance communication link with global network for interchange of satellite information through Internet.

CONCLUSIONS

The satellite experiment ROSS-1 with scientific instruments on spacecraft “Meteor-M” No.3 will result in new methods of processing of satellite ocean color data, in particular in combination with data from other sensors; the recommendations for practical use and further refinement of the methods will be given.

New data on optical, biological and biogeochemical characteristics of seas and oceans as well as on physical processes in near-surface layer will be obtained.

The experiment results will be used in the interests of satellite instrument-making, as well as for handling specific problems in ocean biology and physics, ocean-atmosphere interaction, ecological monitoring of the Russian seas.

With the help of the advanced ocean color scanner, new results will be obtained superior to a level of current investigations. The obtained results will allow to improve the atmospheric correction and bio-optical algorithms. They will be used for solving the problems of prediction of environment state and climatic changes.

The authors express their gratitude to colleagues from FGUP RISDE and SIO RAS for help with preparation of this paper.

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2.2.3. Institute of Cosmophysics of the Moscow Institute for Engineering and Physics

High-energy electrons and positrons in cosmic rays and dark matter

International Russian-Italian project “RIM-PAMELA”

National Research Nuclear University “MEPHI”, Russia
Lebedev Physical Institute, Russia
Ioffe Physical Institute, Russia
State Research and Production Space-Rocket Center "TsSKB-Progress", Russia
Research Center for Earth Operative Monitoring (NTs OMZ), Russia
INFN, Structure of Naples and Physics Department of University of Naples Federico II, Italy
INFN, Structure of Bari and Physics Department of University of Bari, Italy
INFN, Structure of Florence and Physics Department of University of Florence, Italy
INFN, Structure of Trieste, Italy
INFN, Structure of Rome Tor Vergata and Physics Department of University of Rome Tor Vergata, Italy
KTH, Department of Physics, Sweden
IFAC,I-50019 Sesto Fiorentino, Italy
Physics Department of Universitat Siegen, Germany
INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi Italy

I. Introduction

June 15, 2006 from the Baikonur Cosmodrome launched the satellite “Resurs-DK №1” on the Earth elliptical orbit with parameters of 600 km and 350 km, apogee and perigee, respectively, and the inclination of the orbit 70,4 ° (Figure 1). Installed on the main satellite equipment designed for photographing the Earth's surface. As an additional burden on the scientific satellite set precision magnetic spectrometer PAMELA. Experiment PAMELA is part of the Russian-Italian project “RIM-PAMELA” with the participation of Swedish and German scientists.

Fig.1: Launch of the “Resurs-DK №1”

From the beginning of project implementation "RIM-PAMELA" defines the main directions of research and specific research objectives:

1. The problem of the baryon asymmetry of the Universe - searching for antimatter (i.e., nuclei antideuterons and antihelium) in the primary cosmic radiation;

2. The problem of the nature of dark matter, the hypothetical part of which can annihilate, in particular, antiprotons and positrons - the study of energy spectra of antiprotons and positrons in the energy range of more than 10 GeV;

3. Consideration of the mechanisms of generation and propagation of primary particles in the Galaxy - high-precision measurements of galactic electrons, positrons, protons and light nuclei with energies up to several hundred GeV per nucleon;

4. Study of mechanisms of generation of energetic particles in solar flares - the study of fluxes of energetic particles from solar flares;

5. Applied aspect of basic research - the study of flows of high energy charged particles in near-Earth space, including in the Earth's radiation belts.

II. Scientific equipment

In order to solve the tasks was designed and developed high-precision magnetic spectrometer PAMELA. Physical diagram of the device PAMELA is shown in Figure 2.

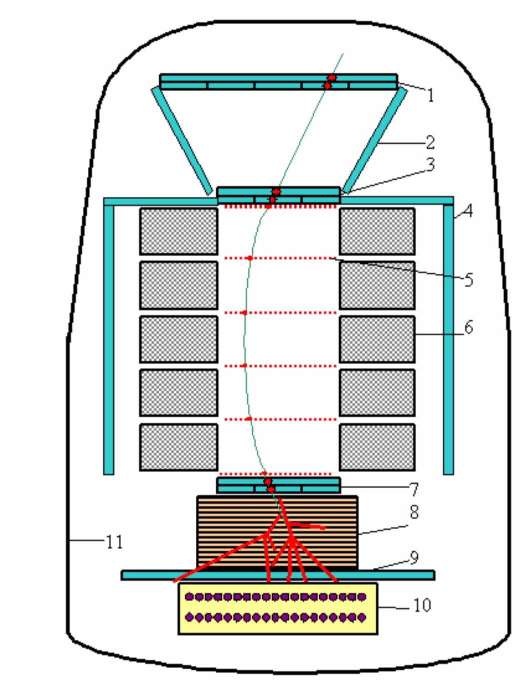


Fig.2: Physical scheme of magnetic spectrometer PAMELA
1,3,7 - time of flight system; 2,4 - anticoincidence system; 5 - silicon strip tracker (6 double plates); 6 - magnet (5 sections); 8 - silicon strip imaging calorimeter; 9 - bottom scintillator S4; 10 - neutron detector; 11 - container.

The main elements of the detecting device are: the trigger system of scintillation counters to measure the direction and velocity of particles, the magnetic system to measure the momentum (rigidity) of the particles, position sensitive calorimeter to measure the energy released by the interaction of particles in the calorimeter, as well as the spatial pattern of development shower; storm water scintillation detector that generates a trigger for the registration of showers produced by particles passing through the calorimeter is outside the apparatus and a neutron detector that registers the neutrons produced by particle interactions in the calorimeter, an anticoincidence system of scintillation detectors, which eliminates the particles passing the device outside the aperture, or cause interactions before reaching the calorimeter.

- **Magnetic spectrometer (MS)**

Structure: magnetic spectrometer consists of a magnet that produces a constant magnetic field of 1.3 T, and the tracker, which is 6 detector planes, separated by sections of the magnet; each plane consists of 6 microstrip silicon detectors of thickness 300 microns. Each of them consists of a few micrometers thick strips, located in the 2 - perpendicular directions. Dimensions MS 132 × 162 × 445, which creates a geometric factor of instrument ~ 20.5 sm^2sr.

Application: MS allows to measure the ionization losses of particles in each strip plane, to determine the coordinates of the intersection of the track with the planes and to restore the rigidity of the particles on them. The coordinate resolution is 3 micrometre.

- **Calorimeter**

Structure: Coordinate-sensitive Calorimeter consists of 44 one-sided silicon detectors, separated by layers of tungsten absorber. Each plane has a thickness of 380 micrometre and is divided into segments of 2.6 mm, each of which measured the total energy release. This allows to fully restore the spatial pattern of the electromagnetic or hadronic shower. The thickness of the calorimeter is 16.3 radiation lengths and 0.6 nuclear lengths.

Application: calorimeter is used to identify the type of particles on the development of the shower (for the Cascade curves), rejection of hadrons from leptons can reach 104.

- **Time-of-flight system**

Structure: consists of 6 planes of scintillation detectors, which pairs located over the anticoincidence system, over MS and under MS. Each pair of planes is divided into strips so that strips of the first and second plane are oriented perpendicularly. Application: a system of scintillation counters provides the trigger, allows to select aperture events, to determine the direction of arrival and measure the speed of the particles, to measure the ionization losses.

- **Anticoincidence system**

Structure: AC system consists of a 4-side detectors, which close magnetic spectrometer from each side and one top detector, all detectors are made of plastic scintillator; the efficiency is determined by cosmic muons, and is 99.9% for each detector. Application: system is intended to exclude from the analysis of events that came out of the aperture of the device.

- **Lower scintillation detector and neutron detector**

Structure, application: plastic scintillator located below the calorimeter and register particles emitted from it. Used to generate a trigger at high energies (> 100 GeV). Neutron detector filled with He^3, used for separation leptons and hadrons up to $10^{11} – 10^{13}$ eV.

Fig.3: PAMELA flight model

You can imagine how multilayered device PAMELA detector capable of detecting passing through a charged cosmic particles, measure their trajectories and energy losses. All of this information, the volume of the order of 5 kB at one event, allows to measure the sign of the charge and the charge, velocity, momentum, energy and mass of the particle.

The basic physical and technical characteristics obtained Monte Carlo calculations, calibration of instrumentation systems on electronic, positron and proton beam from CERN. All the characteristics of the instrument calibration constant tested in flight.

III. Measurements

Every day in the center receiving information from a spacecraft “Resurs DK №1” comes with the device PAMELA ~ 15 GB, and so far accumulated about 15 TB of raw data. After a preliminary screening identified $\sim 10^9$ events, mainly protons in the energy range 0.1÷1000 GeV.

The passage of the radiation belt, so much of the detected particles refers to the near-Earth space, including to the Earth's radiation belt. The magnetic spectrometer PAMELA continues to operate.

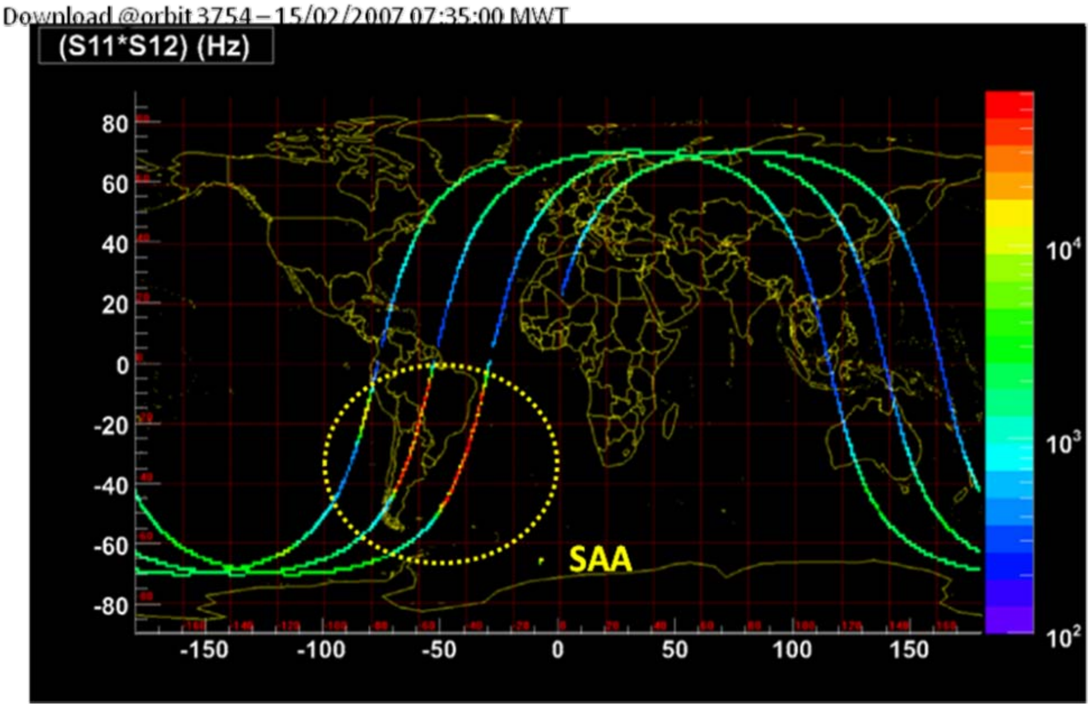


Fig. 4: The orbits of spacecraft "Resurs DK-1"

IV. Scientific results of the experiment PAMELA

The results concentrations of antiparticles - antihelium, antiprotons and positrons, i.e. paragraphs 1 and 2 of the main program of the Project "RIM-PAMELA", are as follows:

4.1 Search for antihelium

The maximum limit of the $\overline{He}/He$ ratio of galactic flows antihelium to helium balloon made in the Antarctic measurements on a magnetic spectrometer BESS is ~ $3\cdot10^{-7}$ in the energy range 1 ÷ 12 GeV. "PAMELA" spectrometer measurements at the end of 2009 amount to ~$1\cdot10^{-6}$, but in a more important energy range 1 ÷ 100 GeV. Note that the interaction of cosmic rays of ultrahigh energy with the interstellar gas may have so-called secondary antinucleus. The flux of secondary antiprotons to protons about $\overline{p}/p$ ~ 10^{-5} and for antihelium $\overline{He}/He$ ~ 10^{-12}. If the galactic radiation relations will be more - it would mean the existence of an additional mechanism for the generation of anti-particles, such as the annihilation or decay of dark matter particles, etc.;

4.2 Measuring the flux of antiprotons, positrons and electrons

The results of measurements in the experiment "PAMELA" relations antiprotons to protons in the energy dependence of the particles shown in Figure 4. The same figure presents the calculations of this ratio based on the model GALPROP. The figure shows that the experimental data and calculations on models of secondary origin of antiprotons are in good agreement.

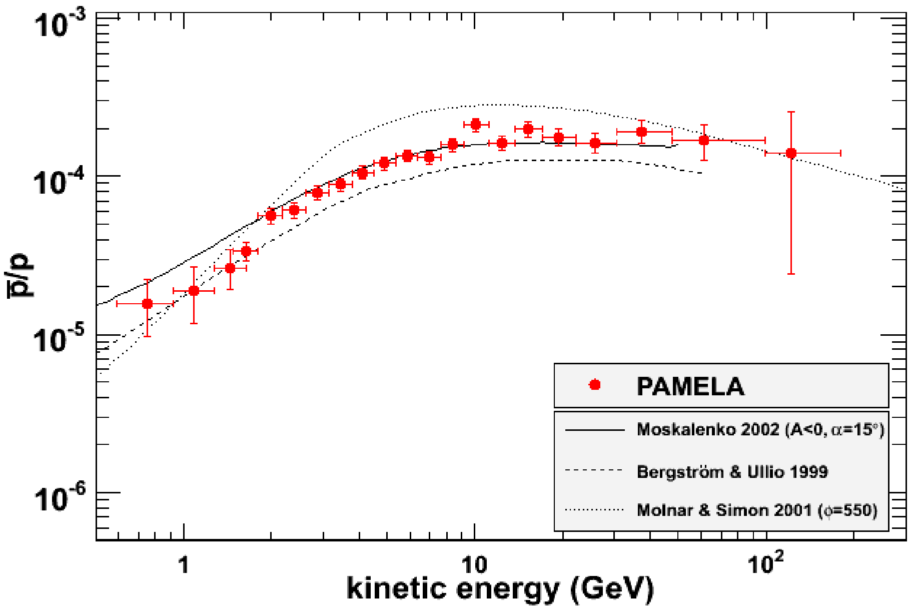


Fig.5: Antiproton/proton ratio measured by "PAMELA"

The experimental results of model calculations can be interpreted as confirmation that the main source of galactic antiprotons is the mechanism giving rise to them in conjunction with the interstellar gas and the absence of an additional source of antiprotons in the flow of galactic cosmic rays.

4.3 Measuring the flow of positrons

It should be noted that the positrons are recorded at the level of proton flux in three-four orders of magnitude greater than the flow of positrons. Therefore, the allocation of positrons is a special, complex program of these studies. The program includes the following stages of selection:

- Are the particles with β close to unity;
- The comparison of the pulse measured in a magnetic field of the spectrometer and the energy released in the calorimeter (the value of these quantities should be close to each other);
- Are the events in which electron-positron showers began to develop in the upper layers of the calorimeter;
- Use information in the development and cross electron-positron showers, in particular electron-positron showers has highlighted the central part, where the main division and focused energy ("Moliere" radius of the shower);
- Are evidence of the neutron detector to distinguish between hadronic and electromagnetic showers on the number of matching shower of neutrons;
- Are the results of calibration calorimeter in a monochromatic beam of electrons, positrons, protons, accelerator CERN.

All of these methods yield rejection of protons in the measurement of positrons at a level of 10^{-5} but even in this case increases with the energy fraction of contamination by protons, but not more than 10%.

In Figure 5 shows the ratio $\frac{e^+}{e^+ + e^-}$ measured in the experiment PAMELA and the same ratio calculated by the program GALPROP. There is a significant difference between the experimental values from the calculation in the energy range 10 ÷ 100 GeV. The differences in the energy interval less then some GeV connects with Solar modulation in the time of our measurements.

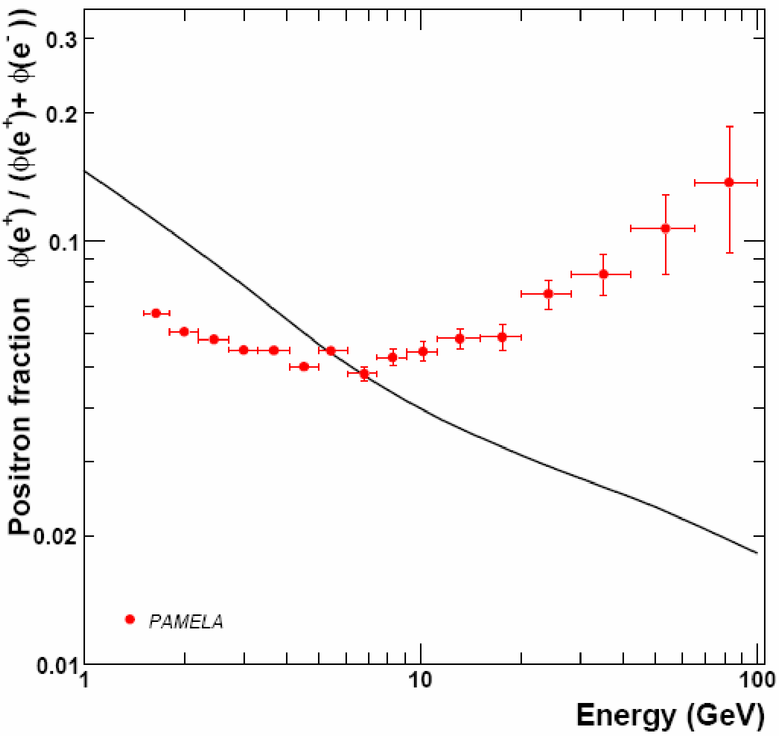


Fig.6: Electron to electron + positron ratio measured by «PAMELA»

4.4. Thus, the main results of the experiment PAMELA to measure the flow of antiparticles (antiprotons and positrons) are:

1. The measured ratio $\bar{p}/p$, as well as the energy spectrum of antiprotons, with the calculations on the program GALPROP.

2. The measured ratio $\frac{e^{+}}{e^{+}+e^{-}}$ is contrary to calculations by the program GALPROP, which requires an unknown early supplementary source of positrons.

3. Measuring the energy spectra of positrons and electrons does not contradict the assumption of additional sources created equally an additional stream of electrons and positrons. This source generates an electron-positron pairs.

V. Disscussion

5.1. Measurement of the total galactic flux of electrons and positrons to energies ~ TeV were maid in the experiment ATIC, Fermi / LAT, HESS.

The Joint analysis of the results of ATIC, Fermi / LAT and HESS are:

- There is flattening of the spectrum, ranging from hundreds of GeV

- There is a broad "bump from ~ 300 GeV to 600 ÷ 800 GeV

- An index of the energy spectrum of electron-positron component is ~ -3.05, which differs significantly from taking before ~ -3.2 (calculated by GALPROP code)

Finally, in the ~ 1 GeV, a sharp drop in the intensity of electron-positron component of the galactic cosmic radiation.

However, there remains one important point: Are not the appearance of bump and so hard energy spectrum of electron-positron component with failure rate notch, equal to $10^{-3} \div 10^{-4}$ to highlight the flow of electrons and positrons in the background is much superior to proton fluxes.

5.2. Interpreting the results of measurement devices PAMELA

ATIC and Fermi/LAT measured the energetic electron-positron component of galactic cosmic rays. This section - is a review of the interpretation of the results obtained in the experiments PAMELA, ATIC and Fermi/LAT broad range of research groups working in the field of cosmic ray physics, astrophysics, and the so-called new physics, including physics and dark matter. It is interesting to note that every scientific group is looking for explanations in their energies, which is reflected in the results of published studies. At the same time every time it is assumed that an additional source, if it exists, generates both electron-positron pair.

a) Consideration of the generation and propagation of cosmic rays.

It is also clear that we can and must continue to seek an additional source of electrons and positrons, considering the sources, which can occur simultaneously accelerated and electrons and positrons, or particular arrangements for the promotion of the particles. However, you always need to bear in mind the second the result of the experiment PAMELA - no additional flux of antiprotons, which leads to an additional restriction on the choice of mechanisms for accelerating electrons and positrons.

b) Generation of electron-positron pairs in the pulsar magnetosphere.

Neutron star, appearing in a number of cases at the final stage of the evolution of massive stars and not destroyed by explosion (supernova) may have a great speed up to tens of MHz and a huge magnetic field to the Gauss.

In the rotating magnetic field of the pulsar is accelerating particles, including electrons. In addition to the strong magnetic field pulsar, and high-energy gamma rays can directly give rise to electron-positron pairs. I.e. there is another process of simultaneous production of electron-positron pair. Over time, the speed of rotation of the pulsar and the intensity of its magnetic field are falling. You can find such conditions, when there will be both a relatively large magnetic field and particles is a high probability of electron-positron pair out into interstellar space, while keeping the energy of hundreds of billions of electron volts. Then they are distributed in space like particles from traditional sources. Then you can pick up the dissemination of pulsars in circumsolar space with a distance not exceeding kpc (from a distance of more than 1 kpc, high-energy electrons and positrons do not reach the solar system. The energy losses are very large), while that of the seven known gamma-ray pulsars, but only three are at distances less than kpc to finally explain the "anomalous effect of Pamela and the increase in electron-positron flux and energy spectrum in the measurements ATIC and Fermi/LAT.

It is also clear that more can and should continue this review. In particular, try to extract additional information from spatial measurements recorded positrons, electrons, or electrons, positrons, without separation of charge.

c) The annihilation and decay of dark matter particles with the formation of electron-positron pairs.

Today, the most exciting interest explanation of the "anomalous Pamela and increased flows of electrons and positrons in the experiments ATIC and Fermi/LAT, annihilation and decay of heavy weakly interacting particles of wimps until the hypothetical particle, the candidates for the role of dark matter.

At the turn of 20 and 21 centuries after the high-precision measurements of the anisotropy of the cosmic microwave background in the observatory WMAP, it became clear that the bulk of the universe ~ 25% is concentrated in the form of dark matter and the known matter - baryon, now makes up less than 5%, the remaining 70% is the dark energy. If we assume that dark matter is particles, they can either be heavy - by wimps or very light – axion. Wimps could occur at an early stage of evolution of the universe when the temperature of excitation of the medium was extremely high, and able to perform the conditions of grand unification, or even supergravity, and today make up the relic background.

So the galaxy average density of dark matter is ~ 0.3 $\frac{GeV}{cm^3}$. There is no one model or hypothesis, presupposing option particle - wimp. It seems to me two of them are most developed. This model is the existence of symmetry, and further supergravity, in which there are particles called neutralino (χ) and the model of multiple spaces in which there are nodes on the coordinate axes - so-called can annihilate the Kaluza-Klyayns bosons CNVs. Both particles can annihilate, forming an electron-positron pairs. However, for bosons, this path is preferred. On the other hand, recently began to examine the process of disintegration. And again for the boson WCC direct leptonic decay is more preferable because He has spin one. Neutralino decay is suppressed by a ban on R-parity. It would seem that there is every reason to assume that the annihilation of WIMPs may explain the "anomalous effect of Pamela, the measurement data ATIC and Fermi/LAT. However, there is one serious limitation associated with a small cross section of annihilation of wimps. Indeed, in order to ensure that the existing density of dark matter, it must be assumed that the annihilation cross section multiplied by the speed of the particles should be $<\sigma_{ann}\, \upsilon> = 10^{-26}$ cm^3/sec. And if we consider the decay, the average lifetime must be ~ 10^{-26} c. However, to explain the observed results must be $< \sigma_{ann}\, \upsilon >$, at least three orders of magnitude larger (10^{-23} cm^3/sec). Ie there must exist a mechanism that increases the work. Such a mechanism called "boost" factor (boost factor).

It is proposed and considered two mechanisms.

First. The density of dark matter (n) in the galaxy is not uniform. In particular, it can grow to the plane of the disk to the center of the galaxy, there may be compaction and in the halo. In this case, the number of annihilation proportional to n^2, will substantially increase.

Second. Sommerfeld effect, with a very weak speed of annihilating particles cross-section of the electroweak interaction can significantly increase. This effect resembles the cross section Breit-Wigner and also can give an increase in cross section in the hundreds or thousands of times.

Conclusions

Much of the work is devoted to the possibility of generating dark matter and search techniques (signature) and the allocation of these particles.

It is assumed that the standard model (SM) on the basis of the electroweak interaction and strong interaction with the neutron energy increases, the interacting particles (up to 7 TeV in the cms) allows to evaluate the cross section generation and the mass of dark matter particles, which should be between two hundred GeV and several TeV.

If indeed the decay and annihilation of dark matter particles provide appreciable flows of energetic electrons and positrons with energies up to several TeV, then one should observe a background of synchrotron radiation, the radiation from the density and the center of the galaxy, this may be due to observation of the line 0.5 MeV from the galactic center, where the annihilation, positrons stopping, possibly with a related excess of microwave emission from the center. Along with the electron-positron decay, may decay into neutrinos, gamma rays. In this case, you can see streams of high-energy neutrinos, high-energy gamma rays. The sun can also "collect" particles of dark matter and are a source of monochromatic high-energy neutrinos.

PAMELA opened a new opportunity to search and study of dark matter particles on the study of galactic flows of electrons and positrons.

In any case, find the dark matter in the LHC experiments or not, it is in the universe around us and the composition of cosmic rays continues. Continues flight spectrometer PAMELA and gamma-ray telescope Fermi/LAT, new experiments are prepared AMS-2, GAMMA-400, etc.

2.2.4. National research nuclear university MEPhI

Geophysical Resarch

2.2.4.1. ARINA and VSPLESK satellite experiments on study of geophysics effects in the high-energy particle fluxes in the magnetosphere of the Earth

1. Conditions of carrying out of ARINA and VSPLESK experiments.

Scintillation spectrometers ARINA and VSPLESK were developed in MEPhI for study energy spectra and temporal profiles of bursts of high-energy proton and electron fluxes.

The ARINA experiment is conducted on board the low-orbital Resurs-DK1 satellite which has been successfully launched in the orbit on June 15, 2006 with the orbital parameters: the altitude within 350--600 km and inclination of 70°. The position of ARINA instrument on board the satellite is shown in fig.1. The main orientation of the satellite is the orbital one. In this case the ARINA spectrometer axis is perpendicular to the plane of the spacecraft orbit, and optimal conditions for detection of precipitating particles below the radiation belt are realized.

The measurements of particle fluxes are conducted continuously. It is carried out from July 2006 till now, that is more than 3 years.

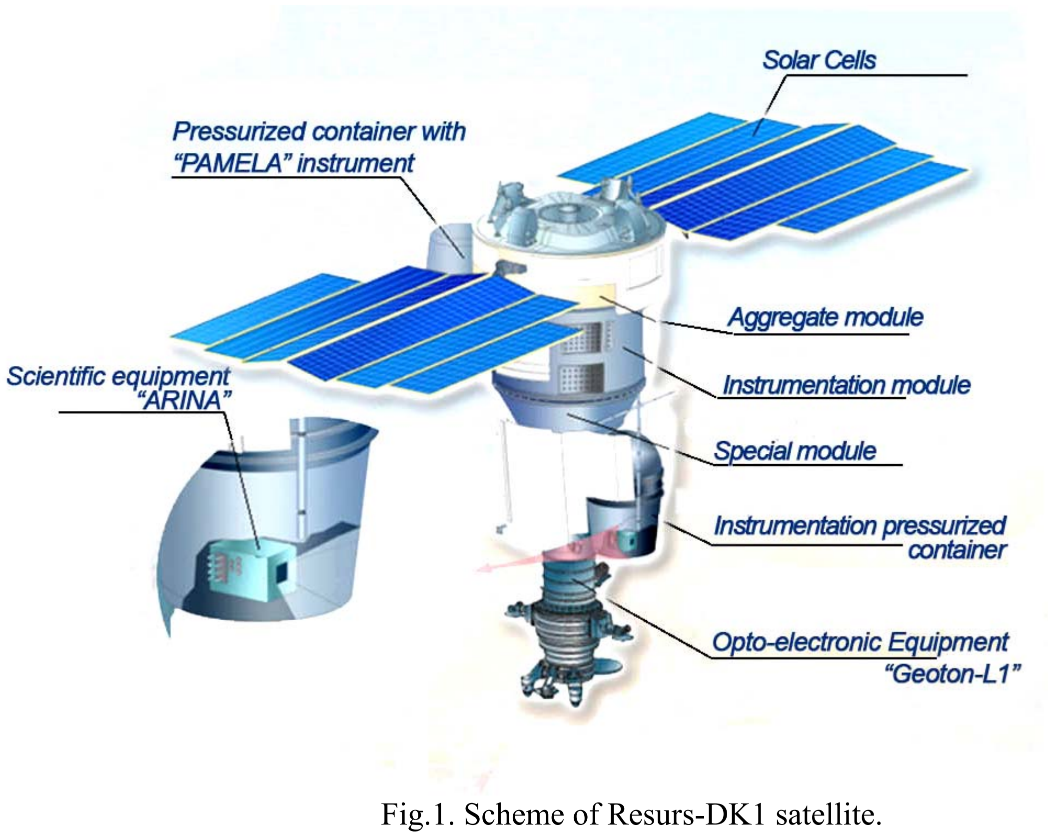


Fig.1. Scheme of Resurs-DK1 satellite.

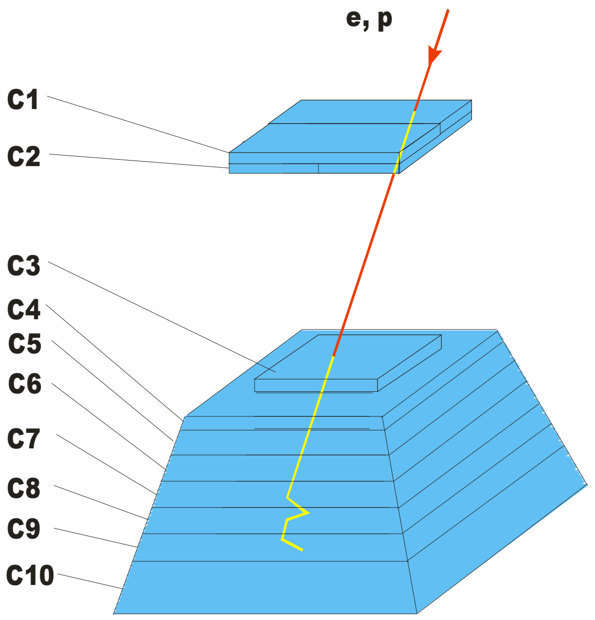
Experiment VSPLESK is carried out on board the International Space Station (ISS) from August 2008 (orbit parameters: altitude is about 350 km, inclination is 52°). Instrument was installed on the outside surface of ISS, is oriented perpendicular to the plane of the ISS orbit. VSPLESK spectrometer functionates under space vacuum conditions,

2. ARINA and VSPLESK instrument description.

The specialized instrumentation for detection of bursts of high-energy electrons and protons (spectrometers ARINA and VSPLESK) have been developed in MEPI [1]. Instruments are the same in physics scheme, have the same physics characteristics (geomfactor, energy resolutuion, energy range et. al.), register electron (3-30 MeV) and protons (30-100 MeV), measure their energies and give the possibility to study energy spectra and temoral profiles of particle fluxes.

A multi-layer scintillation detector (C1, C2, …, C10) which registers the particles stopped in it (electrons with energies of 3-30 MeV and protons with energies of 30--100 MeV) is the basic instrument (fig.2). The electron-proton separation is performed on the basis of the energy release in the detector system. The particle energy is determined using their path length. The energy and angular resolutions of the spectrometers are 10-15% and 10°, respectively.

The spectrometers make it possible to conduct measurements of the particle energy spectra and their evolution and to determine time profiles of particle bursts with high time resolution. They can operate in high-intensity particle fluxes.



Geometric factor	10 cm^2sr	
Acceptance angle	±40°	
Energy range	protons	(30-100) MeV
	electrons	(3-30) MeV
Energy resolution	protons	10 %
	electrons	15 %
Time resolution	100 ns	
Mass	8.6 kg	
Power consumption	13.5 W	

Fig. 2. Layout of ARINA and VSPLESK instruments.

The instrument acceptance is 10 cm^2sr, which is by a factor of a few tens higher than the acceptance of the instruments with the help of which the main results on observation of seismic effects in particle fluxes were obtained.

An example of observation of one of the bursts in the near-Earth space with ARINA is shown in fig.3.

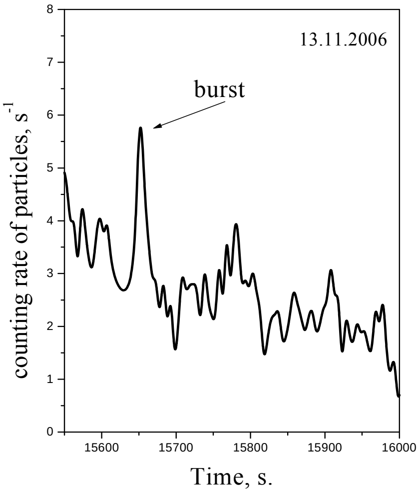


Fig.3. An example of observation of high-energy electron burst (L=2.2).

3. Study of the radiation belt disturbances.

It was shown in a number of works [2, 3 and references therein], carried out in last years as in Russia and abroad, that the bursts of high-energy charged particles are caused by local disturbances of the radiation belt and can have various origin: magnetospheric, seismic, lightning and others. Particle bursts have been observed (on the confidence level of 5 standard deviations) in each experiment. There were about 90 particle bursts in ARINA experiment and 23 bursts in VSPLESK. The duration of particle bursts was in the range from several seconds to several dozens of seconds. Geographical distributions of particle bursts, obtained in these experiments, have been studied in detail. It was carried out the comparison of these distributions with analogical ones obtained in experiments, fulfilled earlier (MARIA-2, PET/SAMPEX and others). New specialties were revealed in geographical distributions, pointing out that the large part of high-energy particle bursts interrelates with thunderstorm activity. Correlation analysis of spatial and temporal characteristics of observed particle bursts and the data on the seismic events was executed. The results of this analysis confirmed on the high level of statistics the conclusion that ~20% of particle bursts have a seismic origin. At that they appear several hours before the earthquakes with magnitude (M) more than 4 and can be considered as earthquake precursors. Analysis of distributions of particle bursts of seismic origin and earthquakes on magnitudes of earthquakes gave the possibility for low orbit satellite measurements to estimate the efficiency of registration of particle burst–earthquake precursor in dependence on magnitude. It was shown that the probability of the registration of particle burst of seismic origin closes to 100% for M>7 and sharply decreases about two order of value for M~4.

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2.2.5. Ioffe Physical-Technical Institute of the Russian Academy of Sciences

2.2.5.1. Studies of Cosmic Gamma-ray Bursts and Soft Gamma-ray Repeaters in Konus-Wind and Konus-RF Experiments

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Abstract

The nature of cosmic gamma-ray bursts and the mechanisms by which extremely intense fluxes of electromagnetic radiation from their sources are generated are among the most topical issues of the basic space research. The joint Russian-American experiment Konus-Wind has been successfully operating since November 1994 onboard the U.S. Wind spacecraft with the Konus Russian scientific instrument. Owing to its high sensitivity, exceedingly favorable location in the interplanetary space, and optimal observation programm, the Konus-Wind experiment is a unique source of information about the temporal and spectral characteristics of gamma-ray bursts through the 20 keV to 10 MeV energy range. These data constitute an essential element of the modern multi-wavelength studies of sources of gamma-ray bursts (GRBs) by spacecraft and a network of terrestrial optical and radio telescopes. The Konus-Wind observations are thus in wide demand. The Konus-RF experiment onboard the CORONAS-Foton orbiting solar observatory effectively supplemented with synchronous observational data the Konus-Wind experiment in 2009.

1. Experimental Approach

The joint Russian-American Konus-Wind experiment consisting in study of cosmic gamma-ray transients has been operating with high scientific efficiency onboard the U.S. Wind spacecraft since November 1994. The experiment employs the Konus scientific instrument created at the Ioffe Institute, Russian Academy of Sciences. The instrument operates in exceedingly favorable conditions for detection of gamma-ray bursts. The orbit of the spacecraft lies far outside the Earth's magnetosphere, which enables permanent all-sky observations and provides a stable radiation background, zero interference from the Earth's radiation belts, and no shadowing by the Earth. The two detectors of the instrument, high-sensitivity gamma-ray spectrometers, permanently view the celestial sphere and thereby provide detection of gamma-ray bursts from any directions.

The scientific instrument of the Konus-RF experiment is a gamma-ray spectrometer having two identical gamma-ray detectors and an electronic unit for recording and preliminarily processing of the detector signals. Each detector comprises a NaI(Tl) spectrometric scintillation crystal 130 mm in diameter and 75 mm high, placed in a thin-walled aluminum container with a beryllium input window and an output window made of a highly transparent lead glass to protect the detectors from the soft background radiation. Such a detector, similar in design and size to the detectors of the Konus-Wind instrument, provides a low (10 keV) threshold energy of radiation detection, up to 10 MeV detection range of gamma-ray photons with an energy resolution of 8.5 to 9.0% at the 660-keV Cs137 line, and event detection sensitivity on the order of 10^{-7} erg cm^{-2}.

The Konus-RF experiment was carried out onboard the CORONAS-FOTON orbiting solar observatory from January through December 2009 in a near-Earth orbit with an inclination of 82.5° and height of 547 to 592 km. The spacecraft was stabilized within several minutes of arc from the axis directed at the Sun. The Konus-RF detectors were mounted on the spacecraft so that the axis of the field of view of one of the detectors was aimed at the Sun. The second detector viewed the anti-Sun half of the full sky. The procedure used to measure the characteristics of gamma-ray bursts in the Konus-RF experiment is a result of the further development of the approaches and methods employed in the Konus-Wind experiment. It is substantially more informative because of the use in the instrument of a modern element base with digital signal processors, precision analog-to-digital converters with a short "dead" time, and high-capacity random-access memory integrated circuits. In the BACKGROUND mode, each detector measures the intensity of cosmic gamma-ray radiation in twelve energy intervals in the range from 10 keV to 1 MeV, with an accumulation time of 1 s, and in ten energy intervals in the range from 280 keV to 10 MeV, with an accumulation time of 4 s. Simultaneously, detailed measurements of the emission spectra are made in the BACKGROUND mode in two energy ranges, from 10 keV to 1 MeV and from 280 keV to 10 MeV, divided into 112 and 154 quasi-logarithmic channels, respectively. The accumulation time of the spectra in the BACKGROUND mode was 1 min. In the BURST mode, the radiation intensity was measured in the same energy intervals with a time resolution of 2 ms to 64 ms. Multichannel spectra were measured in the BURST mode in the same energy intervals as in the BACKGROUND mode, but with a time resolution of 100 ms to 2 s.

At present, the Konus-Wind experiment is a unique source of most complete data regarding temporal, spectral, and energetic characteristics of cosmic gamma-ray bursts in a wide energy range from 20 keV to 10 MeV.

2. Konus-Wind experiment as an essential part of multi-wavelength studies of cosmic gamma-ray bursts.

Owing to the wide energy range, the optimal recording program of the main parameters of gamma-ray bursts, and the possibility of viewing the entire celestial sphere in deep space, the Konus-Wind experiment has become an essential part of multi-wavelength studies of cosmic gamma-ray bursts by a broad network of terrestrial and space-born telescopes guided by the immediate and precise localization of burst sources by the BAT telescope onboard NASA's SWIFT mission.

GRB080721. A high-intensity multiple-pulse burst was studied in synchronous observations by the BAT-SWIFT telescope and by the Konus-Wind instrument. This observation provided data on the spectral characteristics of the emission in a wide energy range from 15 keV to 7 MeV. The light curves measured in synchronous observations are shown in Fig. 1. Figure 2 presents the results of a joint processing of the results of the spectral measurements. The data provided by the Konus-Wind gamma-ray spectrometer served as a basis for an analysis of the proper phase of a gamma-ray burst, in which its energetic and spectral characteristics were determined. A joint fitting to the Konus-Wind and BAT-SWIFT spectral data provided reliable estimations of the radiation flux in a wide energy range. Intensive observations of the afterglow of a gamma-ray burst emission by the network of terrestrial and space-born telescopes continued for 26 days after the burst source was detected at a red shift z = 2.6. These observations established the lower bound to the emission collimation angle, equal to 7.3 deg. Combined with the integral energy flux of a gamma-ray burst, found from the Konus-Wind and BAT-SWIFT measurements, these data made it possible to determine the lower bound to the full energy release of 9.9×10^{51} erg in a gamma-ray burst. This energy release is one of the highest ever measured for gamma-ray burst emissions.

GRB050717. The results obtained in joint observations of the spectral characteristics of this prolonged gamma-ray burst by the BAT telescope onboard NASA's SWIFT mission and by the Konus-Wind instrument are shown in Fig. 3. This event has aroused a considerable researchers' interest because of the record-breaking peak energy E_p = 2400 keV.

GRB080319B. The efforts of a large international team of observers have resulted in the most detailed portrait of a gamma-ray transient ever obtained since the discovery of this unusual astrophysical phenomenon. The source of the event on March 19, 2008 was examined in detail by a network of terrestrial and space-born telescopes. The observations covered a wavelength range of 11.5 orders of magnitude, from radio-frequency radiation to gamma-ray photons. The observations were commenced 30 min before the beginning of the burst and continued for several weeks. This circumstance made it possible to investigate all the stages of its afterglow and to compare these stages with a number of model concepts.

The gamma-ray transient was immediately and precisely localized by the BAT telescope onboard NASA's SWIFT mission and its coordinates were transmitted in the on-line mode to the Earth. The situation was particularly favorable for two flare-patrol broad-field optical telescopes in Chile. Thirty minutes before the new event, these telescopes commenced an analysis of the preceding gamma-ray transient GRB080319A. The new event was found to occur at a distance of only 10 degrees of arc, and the telescopes immediately commenced its analysis. The first to detect this event was the Polish telescope "Pi of the Sky." The data provided by this telescope demonstrated that the burst luminosity reached a magnitude of 5.5 in 15 sec. Such an event can be seen in the night sky by a naked human eye. A gamma-ray source with such a luminosity in the optical spectral range has been observed for the first time. The second telescope, "TORTORA" at the Special astrophysical observatory, Russian Academy of Sciences, recorded the light curve of this event with a previously unachievable time resolution of 100 ms. This enabled the first detailed comparison of the optical luminosity of the burst source with its gamma-ray emission.

The Konus-Wind Russian gamma-ray spectrometer made it possible to determine the energy release from the source and to obtain a detailed pattern of the gamma-ray emission of the burst in a wide energy range. The analysis revealed a complex energy-dependent structure of the spectral variability of the emission that continued for approximately a minute (Fig. 5). Comparison of the data provided by the Konus-Wind experiment and the results of observation by the TORTORA telescope shows that the main phases of the optical activity and the high-intensity gamma-ray emission begin and end at approximately the same time. This convincingly demonstrates that both the components originate from the same physical region. The results of these studies have been published in Nature.

3. Studies of Soft Gamma-ray Repeaters

A result important for the physics of gamma-ray repeaters has been obtained in a study of the burst activity of a new source of soft repeated bursts, SGR 0501+4516, discovered in August 2008 by the BAT-SWIFT telescope. Five intense bursts from the new gamma-ray repeater were detected by the Konus-Wind gamma-ray spectrometer (Fig. 6). A study of the temporal histories and results of a multichannel spectral analysis demonstrated that the source behaves as a typical gamma-ray repeater. The duration of bursts did not exceed 0.75 s and their spectra at energies exceeding 20 keV are well described in terms of the model of braking radiation from an optically thin plasma with kT ~20 - 40 keV. An important specific feature of the new repeater, detected in the Konus-Wind experiment, is the strong spectral variability of the burst emission (Fig. 7). A correlation of this kind between the emission hardness of repeated transients and their intensity was observed previously only for the SGR1627-41 gamma-ray repeater, also in a Konus-Wind experiment, in 1998. This may be indicative of similar specific features of these two sources. The maximum energy fluxes for all the five repeated transients observed in the Konus-Wind experiment (Fig. 8) substantially exceed those for most of repeated bursts from the rest of the known Milky Way gamma repeaters. This points to a comparatively small distance to the source, ~1.5 kpc.

As one more example of the efficiency of the approaches employed in the Konus experiments can served the discovery of a new soft gamma-ray repeater SGRJ0418+5729, initiated by the detailed temporal profiles obtained in the Konus-RF experiment. On June 5, 2009, the GBM detectors of the Fermi observatory, the Konus-RF detector of the CORONAS-FOTON observatory (Figs. 9 and 10), and the BAT telescope of the SWIFT observatory detected a weak and short soft burst similar to a burst of a soft gamma-ray repeater. The localization of the burst by the GBM instrument mistakenly attributed this transient emission to the known gamma-ray repeater SGR J0501+4516. Only a burst localization by triangulation method on the basis of the Konus-RF, Fermi-GBM, and SWIFT-BAT data demonstrated that the position of the burst source does not correspond to any of the six known gamma-ray repeaters. A ground analysis of the BAT telescope data revealed a new source in the triangulation error box and thereby determined its precise coordinates (Fig. 11). The source was named SGR J0418+5729. The later detection of X-ray pulsations with a period of 9.08 s by the RXTE telescope confirmed that the new source is a soft gamma-ray repeater. The discovery of a new, seventh, gamma-ray repeater by a near-threshold detection of such a weak burst gives reason to believe that there exist numerous gamma-ray repeaters of this kind (undetectable except in cases of a comparatively close proximity to the Earth) and their number possibly exceeds that of the population of bright gamma-ray repeaters.

5. Conclusions

In summary, it should be emphasized that a reliable Konus instrument, adequate to the problem of investigation of cosmic gamma-ray transients, has been developed at the Ioffe Institute. Thanks to the importance, quality, and completeness of the information obtained, the joint Russian-American Konus-Wind experiment has advanced to the forefront of the research into extremal explosive phenomena in the Universe.

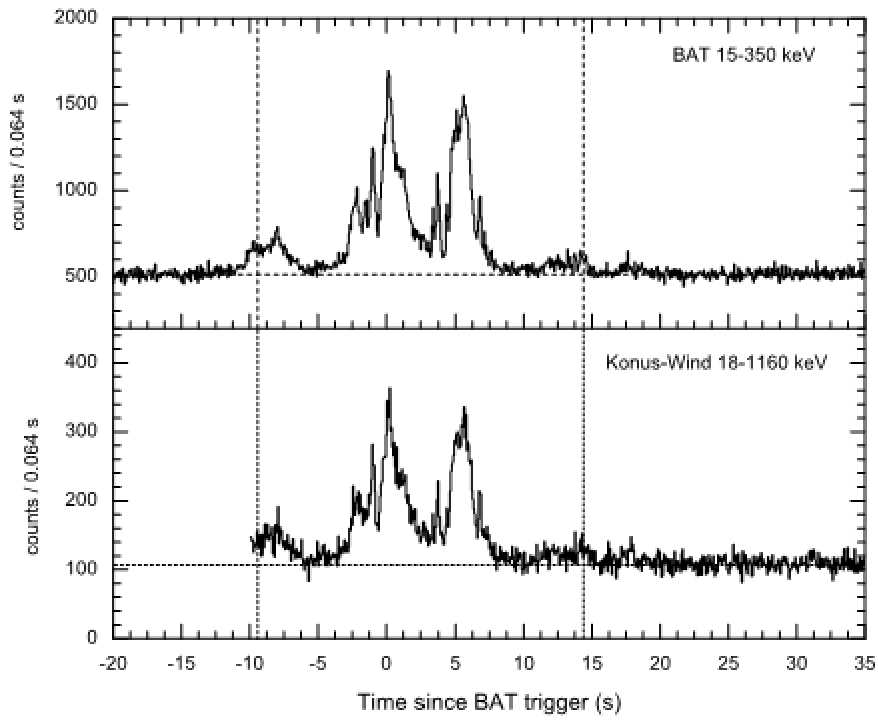

Fig. 1. The light curves of the GRB080721 gamma-ray burst, as determined by synchronous observations by the BAT telescope onboard NASA's SWIFT mission and by the Konus-Wind instrument.

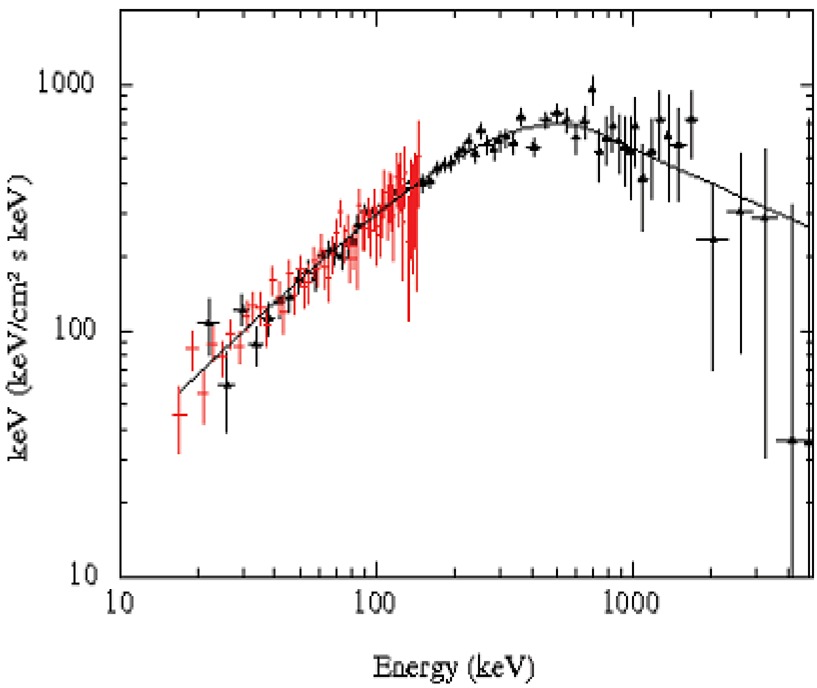

Fig. 2. The results of a joint fitting to the spectral data for the gamma-ray emission of the GRB080721 transient by BAT-SWIFT (15 to 350 keV) and Konus-Wind (21 keV to 7 MeV) instruments.

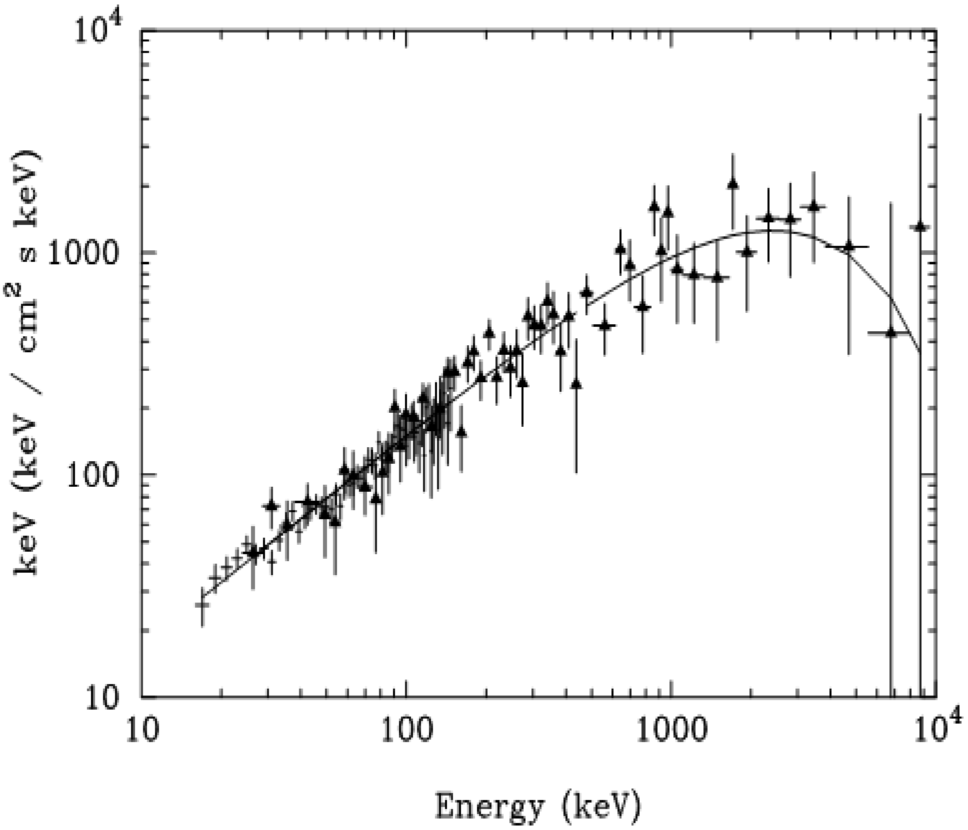

Fig. 3. A joint spectral analysis of GRB050717 on the basis of the experimental data provided by the BAT-SWIFT experiment in the range from 15 to 350 keV and by the Konus-Wind in the range from 21 to 1300 keV.

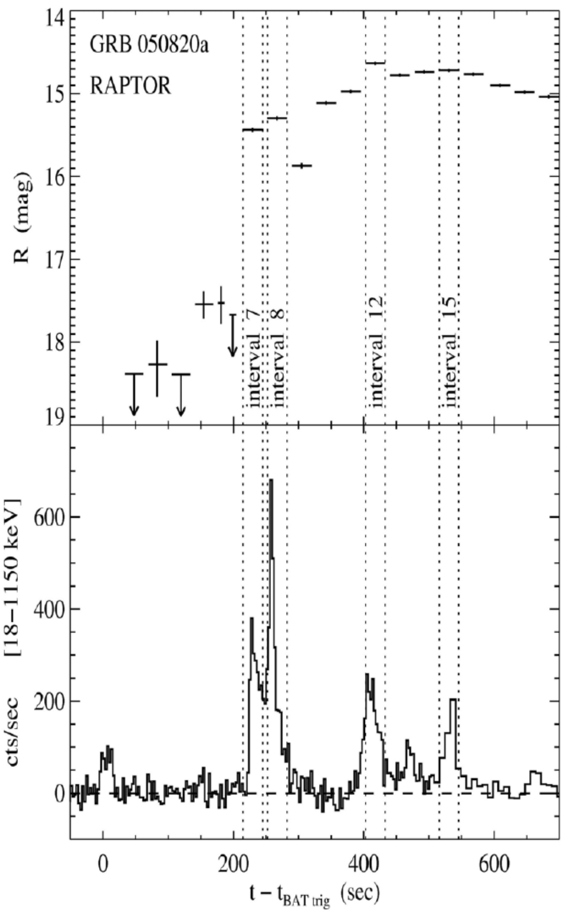

Fig. 4. A comparison of the optical light curve of the GRB050820A gamma-ray transient, as measured by the RAPTOR telescope at the Los Alamos laboratory (upper panel) and the gamma-ray light curve of the same burst, as determined by the Konus-Wind instrument.

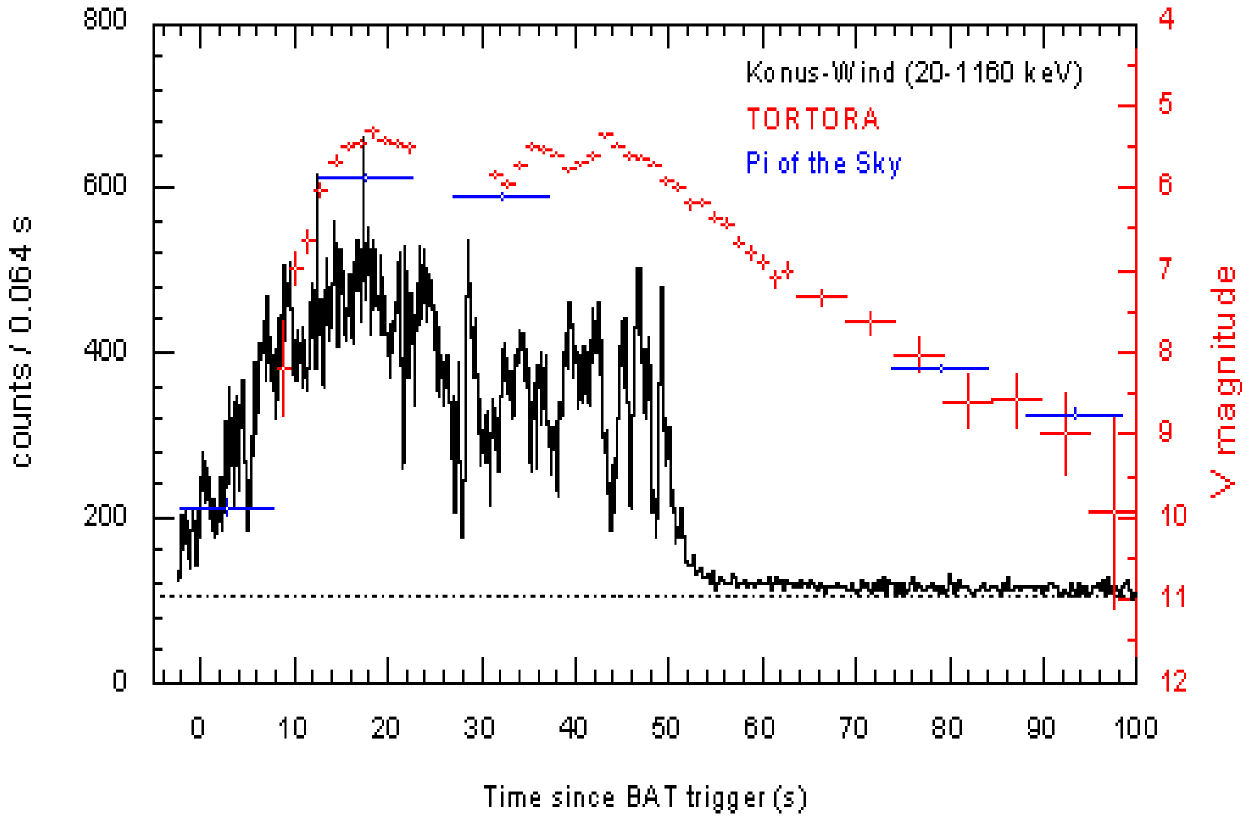

Fig. 5. The gamma-ray (Konus-Wind) and optical [TORTORA (Special astrophysical observatory, Russian Academy of Sciences) and "Pi of the Sky" telescopes] light curves for the GRB080319B gamma-ray transient.

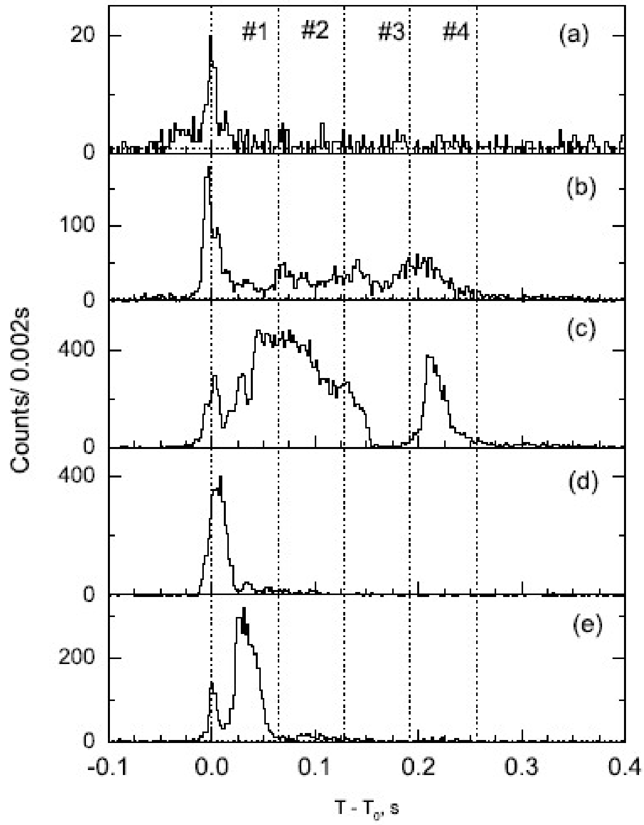

Fig. 6. The light curves of the repeated bursts from the new gamma-ray repeater SGR0501+4516, as determined by the Konus-Wind instrument on August 23 through 25, 2008.

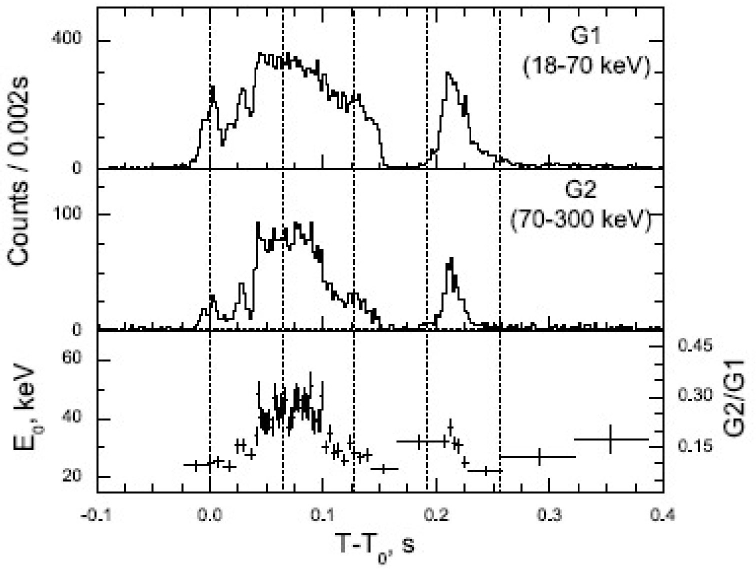

Fig. 7. The radiation hardness variation in the course of the most intense repeated burst from the new gamma-ray repeater SGR0501+4516, as observed by the Konus-Wind instrument.

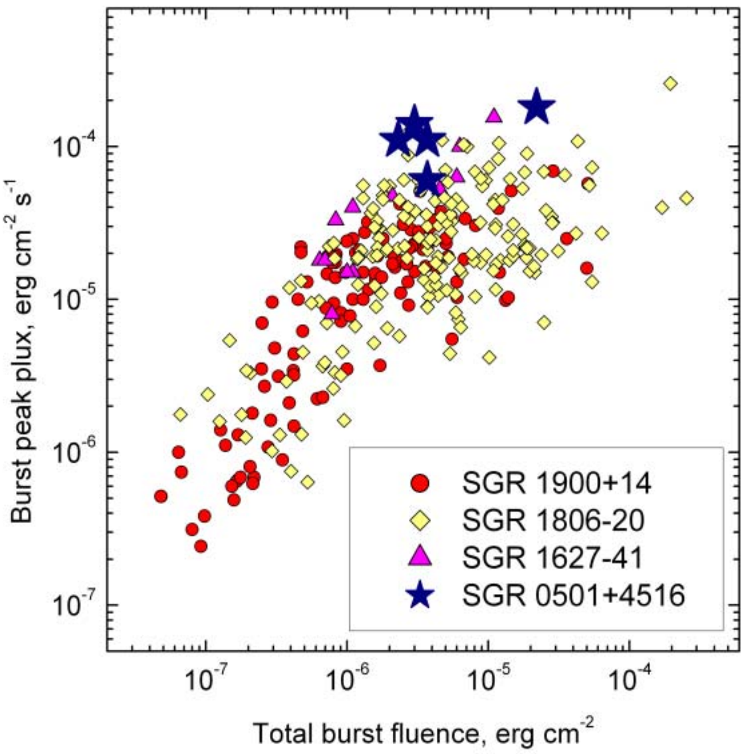

Fig. 8. The energy data for the new gamma-ray repeater in comparison with the observational results for other repeaters in the Konus-Wind experiment. All the values in the range from 20 to 200 keV and the peak fluxes are plotted on the 2-ms scale.

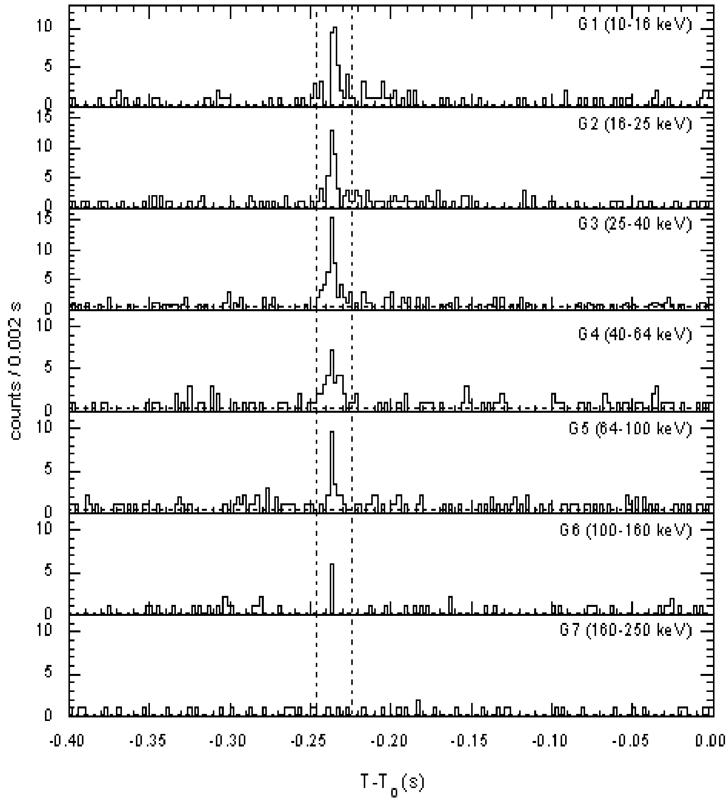

Fig. 9. The discovery of a new gamma-ray repeater SGR0418+5729 in the synchronous observations by the Konus-Wind instrument (CORONAS-FOTON) and the Fermi (GBM) and Swift (BAT) observatories.

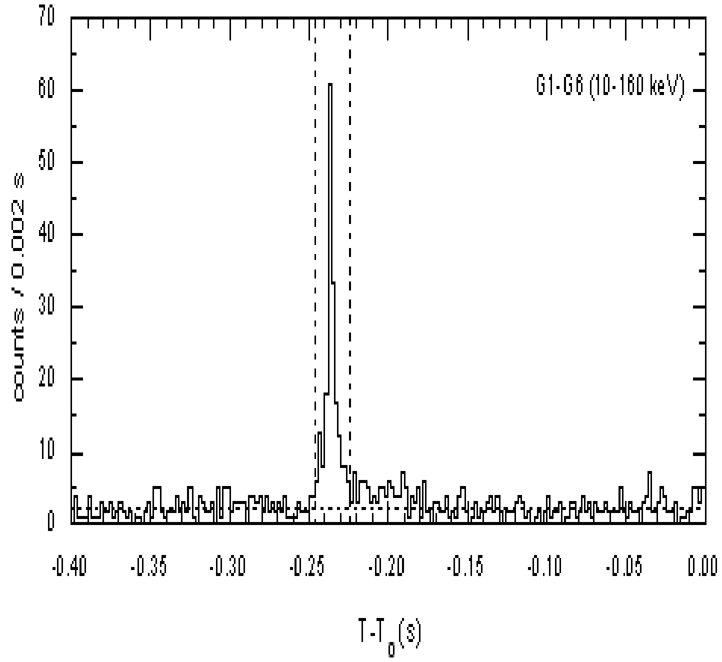

Fig. 10. A detailed temporal profile of a burst from the new gamma-ray repeater SGR0418+5729, as measured by the Konus-Wind instrument (CORONAS-FOTON).

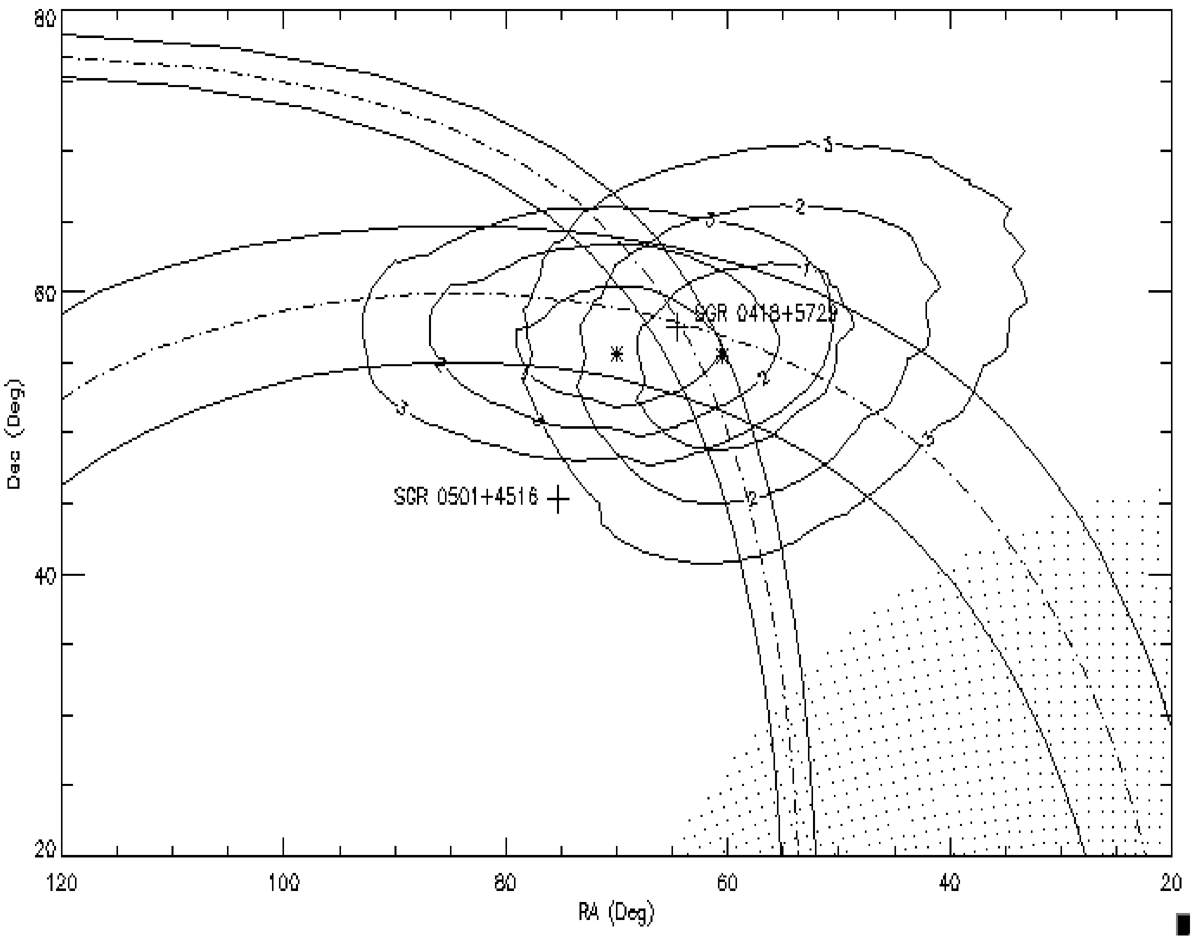

Fig. 11. The localization of the new gamma-ray repeater SGR0418+5729 by the Interplanetary Network.

2.2.6. V.N. Pushkov Institute of Terrestrial Magnetism, Ionosphera and Radiowaves Porpogation of the RAS

2.2.6.1. Experiments on the Russian Segment of the International Space Station

The “Hurricane” space experiment (Experimental Tryout of the Land-Space System for Monitoring and Forecast of Natural and Man-Made Catastrophes) is continued within the long-term program of scientific and applied studies on board the Russian Segment of the International Space Station (RS ISS). A new photo-spectral system (Fig.4) has been developed in cooperation with the Institute of Geography RAS and Institute of Applied Physical Problems of Belorussian State University. In the second quarter of 2010, it will substitute the acting one in the RS ISS Service Module for measuring the spectra of the reflected emissions from underlying surfaces in the wavelength range from 350 to 1050 nm and for the white-light imaging.

Fig.4.Monoblock of the photo-spectral system for the “Hurricane” experiment.

The preparation to four space experiments on board the RS ISS was continued.

Within the “Molniya-Gamma” space experiment (The Study of Atmospheric Gamma and Optical Bursts under the Thunderstorm Conditions), the ground-based tryout of the equipment was completed in cooperation with the Lebedev Physical Institute and the Institute of Applied Physical Problems of Belorussian State University. The flight tests on RS ISS are scheduled for the fourth quarter of 2010. Fig.5 illustrates the model monoblock of external sensors (3 optical and 3 gamma sensors) for the crew training in hydro laboratory.

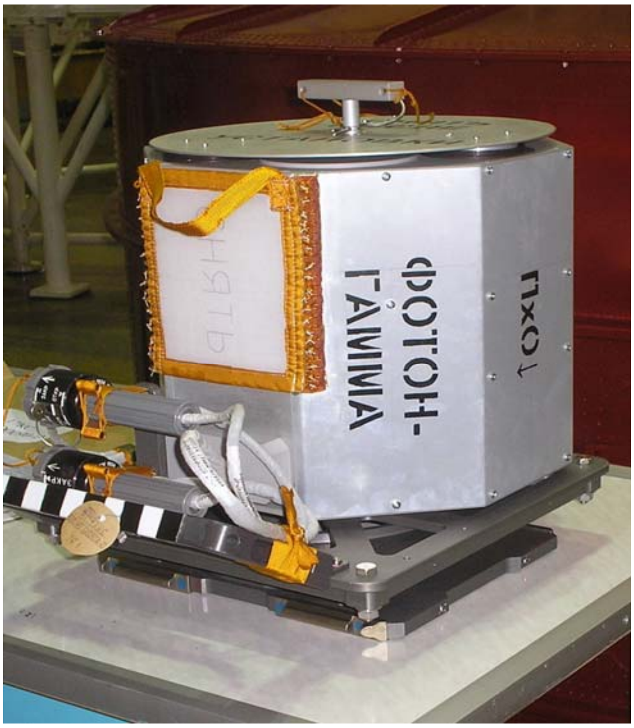

Fig.5.Model monoblock of external sensors (3 optical and 3 gamma sensors) for the crew training in hydro laboratory.

The ground-based tryout of the equipment was continued within the frames of the “Seismoprognoz” space experiment (Experimental Refinement of Monitoring of Electromagnetic and Plasma Precursors of Earthquakes, Emergency Situations, and Man-Made Catastrophes). The flight tests on board the RS ISS will start in 2011.

Within the “Hydroxyl” space experiment (Optical Observations of the Upper Atmosphere Aimed at Prediction of Geophysical Catastrophes), the ground-based tryout of the spectrophotometric complex was continued together with the Institute of Applied Physical Problems of the Belorussian State University. The experiment is included in the launch design of the multipurpose laboratory module of RS ISS (approximately 2012).

“Sura”-RS ISS complex experiments

The optical system on board the RS ISS- “Fialka” - was used to study the heating effects in the ionosphere in the complex experiments with the “Sura” mid-latitude heating facility. A series of experiments was carried out on 2 October 2007, 16 March 2009, 20 April 2009, and 9-10 November 2009.

The advantage of the “Sura” mid-latitude heating facility is the opportunity to carry out plasma investigations in the ionosphere out of the highly active and dynamic auroral zone. In all experiments, the working frequency was 4.3 MHz with the ordinary wave polarization always exceeding the critical frequency of the ionospheric F2-layer. In this case, the powerful radio emission from the heating facility covers the entire volume of the ionosphere within the aerial knife-edge pattern with the angle of 36º in the meridian plane. These experiment conditions suggest that modulation of the ionospheric plasma by radio emission must result in the appearance of high-energy electrons in a significantly larger cross-section of the magnetic flux tube resting on the heated spot compared to the classical heating experiments, where it is restricted to the first (narrow in altitude) Fresnel zone in the heating wave reflection region.

In the experiment of October 2, 2007, the facility was working in the mode of periodic heating. The modulation frequency was close to the frequency of natural Alfven oscillations of plasma in the magnetic flux tube resting on the heated spot in the ionosphere The RS ISS observations provided more than 1000 images of a bright local glow, which appeared within the field of view of the camera as the Space Station was passing over the location of the "Sura" facility. The glow region appeared Northeast of the heating facility (150-200 km) and was moving East in the image plane at a speed of 4-5 km/s. The analysis of helio-geophysical conditions did not reveal any significant anomalies during the experiment. According to the Intermagnet network data, the planetary index of magnetic activity did not exceed 3, the auroral oval was quiet, noticeable variations in the solar wind and interplanetary magnetic field were absent (data from GOES, SOHO, etc.). The DEMETER satellite, which was passing 400 km west of the "Sura" facility during the heating experiment, recorded at least two electromagnetic responses in VLF range (electric component, 0.1-18 kHz) to the second and fifth heating pulses. Their generation processes were different. For the second pulse, the range of the frequencies recorded was rather broad (of the order of 5 kHz) and was centered at 7 kHz (lower hybrid frequency of the ionospheric F2 layer). For the fifth pulse (the satellite was passing close to the "Sura" facility – between the latter and Moscow), these were the frequencies of about 12.5 kHz, and, separately, a disturbance was recorded in the lower spectral range (0-1.5 kHz). Besides, a bright glow was detected on board the Space Station. The electromagnetic emission in the range of 12.5 kHz might be the result excitation of lower hybrid oscillations in the zone of the Alfven wave limit currents (at more than 1000 km over the spot of active heating of the electron component of ionospheric plasma by the "Sura" facility), while the low-frequency emission might be accounted for by the impact of the beam, which caused the bright glow. The analysis of the bulk of data obtained suggests that we are dealing with the artificial aurora triggered by modulation heating with a period close to natural oscillations of the plasma Alfven mode in the magnetic force tube resting on the modified ionospheric region. However, this suggestion can not be considered absolutely reliable, and further experiments are required for a comprehensive study of the observed phenomena.

In the experiment of 16 March 2009, the pulse stimulation against the weakly disturbed background produced responses to each heating pulse in the magnetic field horizontal component. The strongest responses were recorded to the 3rd, 4th, and 5th pulses. The analysis of the global magnetic conditions showed that the burst amplitude recorded in the experiment region was a few times larger than in other regions. For example, the Baksan station (Elbrus) recorded a decrease of amplitude of the corresponding bursts by a factor of 7-8. The heating by radio emission was realized within 12^{o} of the aerial diagram by three transmitters, which ensured the effective emission power of 80 MW. Only the responses to the 3rd, 4th, and 5th pulses reached maximum amplitudes, obviously, due to synchronization of the heating periodicity with the natural plasma oscillations in the corresponding magnetic tube. The maximum amplitude manifests the resonance effect, i.e., the phase coincidence of the heating pulses and natural oscillations of the previously excited magnetoionospheric system in the heating area.

In the experiment of 20 April 2009, the heating effects were analyzed in the magnetically conjugate region when the Space Station was passing over the south hemisphere. The effects were recorded using the "Fialka" optical complex. In the north hemisphere, IZMIRAN carried out complex observations of the ionosphere and magnetic field at the location of the "Sura" facility. A weak glow was detected at the site corresponding to the "Sura" magnetically conjugate region as calculated by the IGRF 2010 model. Since this glow was absent both before and after the experiment, it was treated as artificial aurora generated by the heating facility.

During the experiments of 9 and 10 November 2009, the magnetosphere-ionosphere system was absolutely quiet. Local anomalies in the geomagnetic field variation that might be associated with the ionosphere modulation by the "Sura" heating facility were recorded by the IZMIRAN station at Karpogory on 9 November after the first heating session (at ~16 UT) and on 10 November, during the last session (at ~21 UT). In both cases, immediately after the switch-off of the heating facility, geomagnetic disturbances were recorded, which, to judge from their amplitude (compared to Intermagnet data), were localized in the region under discussion. The event of 10

November could be, from all evidence, classified as micro-substorm lasting for 1-1.5 hours. A similar event was observed in the first experiment on 2 October 2007.

Thus, the experimental data obtained show that the powerful emission from the mid-latitude heating facility is able to produce a strong effect on natural processes in the ionosphere and magnetosphere even if the minimum effective power of 10 MW and a broad aerial diagram are used. The experience gained will be used when planning the future studies in this area.