Earlier, we developed the diffraction and statistical RT methods [1, 2, 7]. The diffraction RT method allows reconstructing the structure of individual localized inhomogeneities with the diffraction effects taken into account. Statistical RT methods give an opportunity to obtain the spatial structure of the statistical characteristics of a stochastically nonuniform ionosphere [7, 35].

5. Conclusion

We have briefly reviewed the main results of tomographic ionospheric studies completed with our participation. A brief description of satellite radio tomography methods of the near-Earth plasma, including LORT and HORT, has been given. During the last two decades, numerous ionospheric RT studies of the near-equatorial, middle, sub-auroral, and auroral latitudes have been carried out in various regions of the world (Europe, USA, Southeast Asia). We have given examples of experimental RT reconstructions of the electron concentration distributions in the ionosphere.

The satellite RT system is a distributed sounding system: the moving artificial Earth satellites and a network of receivers give an opportunity to continuously sound the medium in various directions and to reconstruct the spatial structure of the ionosphere. The LORT systems allow obtaining 'instantaneous' (10 – 15 min) two-dimensional cross sections of the ionosphere at distances of a few thousand kilometers. The HORT systems, based on a network of independent receivers, together with traditional ionospheric sounding methods, allow realizing the regional and global monitoring of the near-Earth plasma.

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Space research at the Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russian Academy of Sciences

V D Kuznetsov

1. Introduction

The space research at the Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, RAS (IZMIRAN) covers all the main areas of the institute activities: the study of the ionosphere and wave propagation, terrestrial and planetary magnetism, and solar–terrestrial physics. During the 70 years of its history, 50 of which are related to space research, IZMIRAN has participated in more than 50 space projects and conducted space research from the first artificial Earth satellite (AES) to modern complex space observatories like Interkosmos-19, APEX, CORONAS-F, and Compass-2. Substantial progress in the investigations pursued by the institute in recent years has been inseparably linked with spacecraft-borne measurements. Space research is an important constituent in the complex approach to the study of diversified and complex phenomena and physical processes in the Sun–Earth system, objects like the Sun, the terrestrial magnetosphere, the ionosphere, etc., which require dedicated experiments and a comprehensive analysis of observational data and their comparison with theoretical models.

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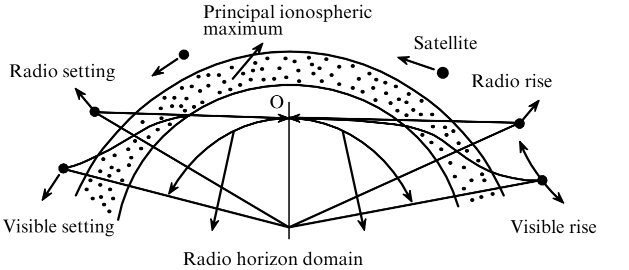

Figure 1. Observation of the radio rising and radio setting of the first AES, which respectively occurred before and after satellite's optical rising and setting behind the horizon owing to the effect of radio wave refraction in the ionosphere. (Adapted picture borrowed from Ref. [3].)

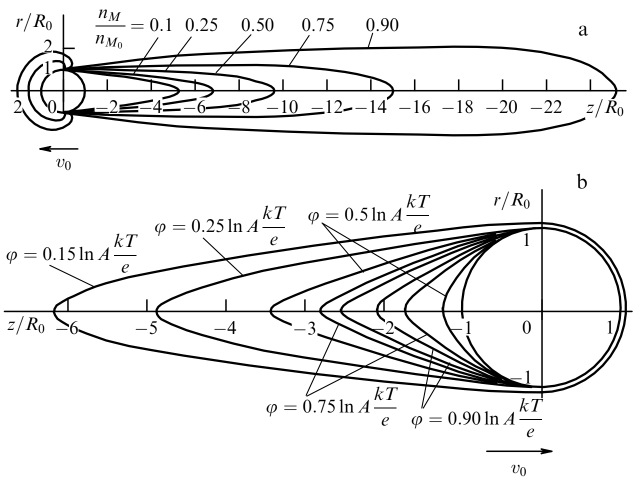

Figure 2. (a) Contours of equal particle density (the plasma rarefaction is indicated with mumbers). (b) Contours of equal potential in the vicinity of a metal satellite. (Borrowed from Refs [4, 5].)

It is noteworthy that in 1957, IZMIRAN carried out the world's first space experiment with the first AES, in which a radio beacon was used to observe the effects of radio rise and radio setting of the satellite, and outer ionospheric layers were studied [1, 2] (Fig. 1). Even prior to the launch of the first AES, A V Gurevich — at that time, a staff member at IZMIRAN — made the first theoretical calculations of the interaction of a metal satellite with rarefied ionospheric plasmas and obtained density and electric potential distributions in the vicinity of the satellite [4, 5] (Fig. 2). These distributions were important for the formulation and interpretation of different satellite-borne experiments and underlay the subsequent more sophisticated investigations of this problem [6, 7].

The main space projects carried out with IZMIRAN's participation are listed in Table 1. They are subdivided into two main groups: projects aimed at studying near-Earth space (NES) — the magnetosphere and the ionosphere — and spacecraft-borne projects to investigate space beyond NES, which involve investigations of the Sun and the planets of the Solar System. Given below is a brief discussion of the main findings that have emerged from the implementation of space projects, the current status of ongoing space research, and the prospects of future research in this area.

2. Space ionospheric research

The structural study of the outer ionosphere, whose smooth electron density distribution at a height above the principal maximum was first determined using the radio beacon of the first AES [1, 2], was continued with the use of the Interkosmos-19 satellite (1979 – 1982) by on-board outer ionosphere probing with an ionosonde developed at IZMIRAN [8]. The probing was effected over a vast terrestrial region and a detailed matching of the inner and outer profiles of the electron density was made (Fig. 3). Interkosmos-19, which was one of the most successful ionospheric research projects, yielded a wealth of data, which underlay the construction of the global parameter distribution for the outer ionosphere for different points in local time and different conditions; new elements of the global ionospheric structure were discovered: an annular ionospheric dip and a low-latitude ionization dip; longitude variations of ionosphere parameters were investigated, the characteristics of the principal ionospheric dip and its dynamics during magnetic storms were found, the effect of the B_z-component of the interplanetary magnetic field on the structural change of the equatorial anomaly was established, the phenomenon of F-scattering in the outer ionosphere and radio wave propagation in the region of structural iono-

Table 1. Space projects with IZMIRAN's participation

Projects	NES magnetosphere, ionosphere	The Sun and solar–terrestrial physics, planets
Realized	First AES, third AES, Cosmos-1 (-12, -26, -49, -321, -381, -1809), Electron-2 (-4), Intercosmos-3 (-5, -10, -13, -18, -19), Intercosmos-24 (Aktivnyi), Intercosmos-25 (APEX), Prognoz-1 (-6, -7, -9), Intasat, ATS-6, Tsikada, Oreol-3, Intercosmos-Bolgariya-1300, Interbol, Compass-2, balloons	Luna-1 (-2, -10), Lunokhod-2, Venera-1 (-2, -4, -9, -10), Mars-2 (-3, -5), Soyuz-Apollo, Vega-1 (-2), Fobos-2, CORONAS-I, CORONAS-F
At realization stage (ongoing)	CE* Impul's (RS ISS**), balloon experiments	CORONAS-Foton (SOKOL experiment)
At preparation stage (development work)	CE Molniya-Gamma (RS ISS), CE Seismoprognoz-SM (RS ISS), CE Gidroksil (RS ISS), Rezonans	Interhelioprobe, Luna-Glob, Luna-Resurs
At development stage (research work)	Ionosat, Geomag, GLONASS-Nauka	PEP, Sistema

* CE, cosmic experiment.

** RS ISS, Russian Segment of the International Space Station.

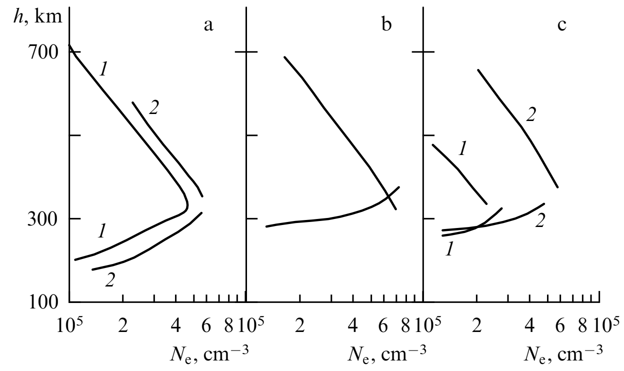

Figure 3. Different versions of the matching of the ionospheric electron density distribution profiles obtained from ground-based measurements (the lower profile, low altitudes) and from Intercosmos-19 satellite data (upper profile). The line pairs 1 and 2 correspond to different observations.

spheric features were studied; the outer $N_e(h)$-profile and the global model of electron temperature were constructed; the ionospheric effects of strong earthquakes were localized; the effects of a high-power internal gravity wave were found to possibly embrace the entire depth of the outer ionosphere up to the satellite altitude ($\approx$ 1000 km).

Satellite-borne investigations of the ionosphere, magnetosphere, and near-Earth plasma were continued in the projects Aktivnyi (Interkosmos-24 AES launched in 1989), APEX (Active Plasma EXperiments) (Interkosmos-25 AES launched in 1991), and Compass-2 (launched in 2006).

The very-low-frequency (VLF) effects of the underground nuclear explosion on Novaya Zemlya Island on October 24, 1990 (broadband data) were discovered with the Interkosmos-24 (Aktivnyi, 1989 – 1991) AES [9]. Observed in the extremely low frequency (ELF) range (narrowband data) were anomalously high absolute values of the electric field component during typhoons, primarily above the subequatorial region of the Pacific Ocean. An analysis of the spectra of whistling atmospherics performed in flight above seismoactive regions under different geophysical conditions enabled separating seismic and geomagnetic effects in the D-region of the ionosphere.

Active experiments involving the injection of plasma beams into ionospheric and magnetospheric plasmas were performed with the Interkosmos-25 (APEX, 1991 – 1999) AES [10]. A series of ground-based and satellite-borne experiments have allowed obtaining real-time tomographic reconstructions of ionospheric profiles, discovering inclined and 'oblique' ionospheric dips (electron density lowerings) in middle and high latitudes of the polar region, and performing the diagnostics of numerous natural ionospheric phenomena: the principal ionospheric dip, plasma bubbles, the equatorial anomaly, and plasma radiation at gyrofrequency harmonics. Ionospheric measurements were made above the site of operation of heating facilities, and the effect of nontunnel radiowave transmission through the wave ionospheric barrier was recorded. The APEX satellite data were used to develop methods of satellite radio tomography with a network of ground-based radiotomographic facilities. A group of authors including V N Oraevskii and Yu Ya Ruzhin were awarded a 1998 State Prize in Science and Technology for this work.

Measurements of the amplitude–frequency characteristics of VLF waves upon injection of plasma beams were also conducted in the framework of the APEX project. The VLF wave excitation was accompanied by the acceleration of high-energy electrons and ions up to 500 – 700 keV; these electron fluxes were detected by the Magion-3 subsatellite. Such generation of high-energy charged particles was discovered for the first time. Lower-energy electron fluxes were also recorded, testifying to resonance mechanisms of the interaction between the excited waves and background plasma particles in the injection of electrons. High-frequency (HF) wave excitation at the point of injection was recorded by the main satellite and by the Magion-3 subsatellite. In the regime of modulated beam injection, it was possible to obtain data related to the formation of special electromagnetic plasma structures that induce electromagnetic fields in the VLF range like a VLF antenna in plasma. Electron injection in an unmodulated regime results in HF pumping in the injection region and further relay-race wave energy transfer to the low-frequency spectral domain, thereby enhancing low-frequency turbulence. The analysis of the data obtained continues.

The procedures for measuring ionospheric parameters and investigating different ionospheric phenomena caused by natural perturbations and anthropogenic factors were elaborated and tested in experiments performed aboard the Compass-2 small satellite (2006 – 2007). In the framework of concerted ground-based and satellite measurements with the Compass-2 small spacecraft (SS) performed jointly with the Institute of Cosmophysical Research and Radio Wave Propagation, Far East Division of the RAS, electric and electromagnetic processes in the near-surface atmosphere of the seismoactive Kamchatka region were investigated experimentally, with the aim to study the lithospheric–atmospheric–ionospheric relation during the preliminary phases of earthquakes. The effects of different sources (of a meteorological, geomagnetic, and seismic nature) were investigated from the measurements of the variations of the quasistatic electric field strength, the intensity of natural VLF radiation ($f = 20 - 20000$ Hz), and the variations of the geomagnetic field. Oscillations in the power-density spectra of these parameters were discovered in a wide range of atmospheric waves: internal gravity waves (with periods $T = 0.5 - 3.3$ h), thermal tidal waves ($T = 4 - 24$ h), and planetary-scale waves ($T > 24$ h), which may be regarded as experimental confirmation of one of the possible lithospheric–ionospheric interaction mechanisms involving internal gravity waves. It was found that the oscillations with $T = 0.5 - 1.5$ h become stronger during the preliminary phase of earthquakes and that their source is localized in the near-surface atmosphere. Waves with such periods are capable of reaching the altitudes of the dynamo region of the ionosphere ($h \approx 120 - 130$ km). Oscillations with $T = 1.5 - 3.0$ h are enhanced for high geomagnetic activity. The source of these oscillations is localized in the dynamo region of the polar ionosphere or higher. In the study of whistler propagation at altitudes of 400 km, it was determined from the Compass-2 SS data that under certain conditions, the low-frequency whistler branch reaches zero frequency in a finite time, rather than tending to a nonzero asymptote.

The cooperation of several scientific institutions (Radiophysical Research Institute, Central Research Institute of Machine Building) under IZMIRAN's coordination resulted in the realization of a series of experiments aboard the Russian segment of the International Space Station (ISS RS) on recording the influence of the Sura radio heating facility on the terrestrial ionosphere. In one of these experiments

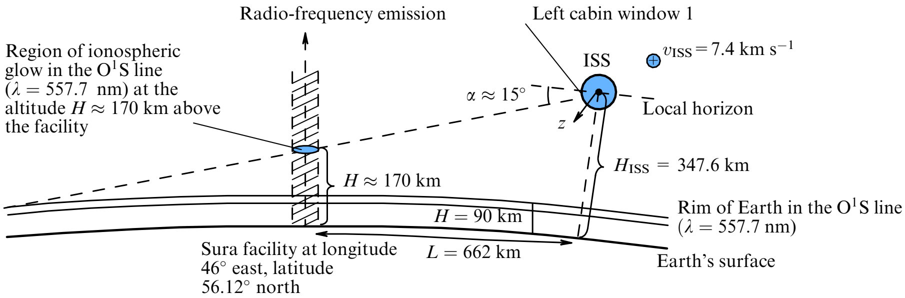

Figure 4. Layout of the experiment aboard the ISS RS for recording the effect of the Sura radio heating facility on the terrestrial ionosphere.

performed on October 2, 2007 using the Relaksatsiya equipment aboard the ISS RS (Fig. 4), a weak atmospheric glow was observed in the O^{1}S line ($\lambda = 557.7$ nm) in the direction of the heating region above the Sura facility. This glow coincided in time with the period of operation of the heating facility [11, 12]. The observed glow could not have been caused directly by the heating effects owing to the low power of the heating radiation, and might have been caused by particle precipitation from a magnetic tube stimulated by the effects of modulated heating, when the modulation period of the heating radiation was close to the period of Alfvén eigenmodes of the tube. The processing and analysis of the resultant data continues, as does the preparation for pursuing new experimental sessions.

In the Impul's experiment aboard the ISS RS, which is being carried out by IZMIRAN in cooperation with Moscow Aviation Institute (MAI) in 2009–2010, a pulsed plasma injector (with the ion velocity about 30–40 km s^{-1}, plasma ionization degree $\beta = 10\%$, injection periodicity 1.8 ± 0.2 Hz, and pulse duration of the order of 10 μs) is being used to study the effects of ionospheric modification. Test injection sessions have been conducted, the equipment is being calibrated, and optimal modes for its operation are being selected. It is planned to record the influence of injection by means of onboard instrumentation and ground-based IZMIRAN facilities in the low-frequency (LF), ultralow-frequency (ULF), ELF, and VLF ranges.

IZMIRAN is developing promising space projects in ionospheric research — a series of experiments on the RS ISS, the Ionosat satellite project, and a project involving the use of the Global Navigation Satellite System (GLONASS).

Three cosmic experiments (CEs) are in the stage of preparation for realization on the RS ISS: 'Molniya-gamma' to study atmospheric gamma-ray and optical radiation bursts in thunderstorm conditions (2010), 'Seismoprognoz-SM' to investigate physical effects in the NES arising from the lead-up to earthquakes and the anthropogenic impact (2011), and 'Gidroksil' to study the optical radiation of the upper atmosphere and its response to anomalous natural and anthropogenic effects (2012).

The Ionosat satellite project is aimed at studies of the ionosphere as an indicator of solar–terrestrial and litho-spheric–atmospheric interactions. This satellite will be a part of a cluster of three closely located satellites intended for studying the small-scale structure and nonuniformity of the ionosphere.

To monitor and diagnose the terrestrial plasmasphere and magnetosphere, IZMIRAN has formulated a proposal to use GLONASS. The heart of this proposal consists in every spacecraft (SC) of the GLONASS system accommodating a

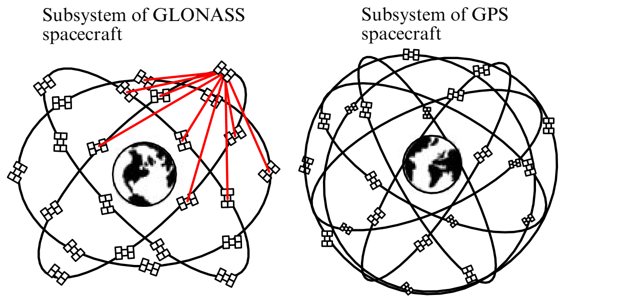

Figure 5. Schematic of using GLONASS for monitoring and diagnosing the terrestrial plasmasphere and magnetosphere.

transmitter–receiver facility to afford continuous measurement of the phase delay of coherent 150/400 MHz signals between any pair of SCs within the line-of-sight range (Fig. 5). The algorithm for processing the measurement data by radiotomographic techniques will enable reconstructing the three-dimensional structure of the inner magnetosphere and its dynamics caused by the influence of natural and anthropogenic sources. The measurement scheme may also incorporate the signals of GPS satellites and other satellite systems.

3. Magnetic measurements on spacecraft

Magnetic fields are one of the most important characteristics of Earth, the interplanetary medium, the planets, and small bodies of the Solar System.

Using the third AES (1958), IZMIRAN performed the first-ever cosmic experiment to measure the geomagnetic field with an SG-45 magnetometer (Fig. 6) [13, 14]. The resultant data for the first time permitted comparing the measured geomagnetic field with different versions of its analytic representation and choosing the most precise one. Also

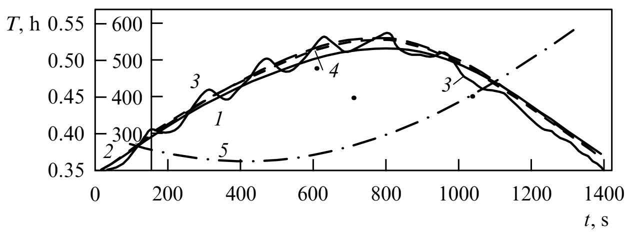

Figure 6. Magnetograms of the measured and calculated values of the magnetic field along the trajectory of the third AES: *1*, *2* — calculated, *3* — measured, *4* (dashed) — measured, allowing for deviation. Line *5* represents the satellite altitude.

shown was the feasibility of using the geomagnetic field for determining spacecraft orientation.

More recently, a world magnetic survey was made in a series of satellite measurements. Measurements made with a proton magnetometer PM-4 developed in IZMIRAN, which was installed on Kosmos-26 (1964) and Kosmos-49 (1964) satellites, covered 75% of the terrestrial surface; the magnetic anomalies related to the structure and tectonics of Earth's crust were determined to stretch to the altitudes of low-orbit satellites [15, 16]. These measurement data became a part of the analytic model for the International Geomagnetic Reference Field for 1965. With the Kosmos-321 satellite (1970), the geomagnetic field was measured over 94% of the terrestrial surface [17]. These data allowed studying the magnetic effects of longitudinal currents in high-latitude regions of the ionosphere and determining the magnetic effects caused by the equatorial current jet. These data became a part of the analytic model for the International Geomagnetic Reference Field for 1970.

The precision with which an analytic model approximates the geomagnetic field and especially the anomalous magnetic field is determined by the satellite magnetic survey density. In the Geomag project developed by IZMIRAN, it is planned to use a system of five small polar-orbit satellites for a global survey of the terrestrial magnetic field. Measurements along these orbits would furnish a substantial improvement of the representation of the anomalous magnetic field.

Magnetic measurements on the Electron-2 and Electron-4 satellites (1964, 1965) for the first time enabled investigating the field topology in the high-latitude outer terrestrial magnetosphere and in the trapped radiation zone, revealing indications of the penetration of solar wind plasmas through the cusp into the magnetosphere, constructing the first model of the terrestrial magnetosphere that includes tail formation, and studying the altitude–time electron density distribution and the nonuniform structures of the outer ionosphere [18]. With the Interkosmos-Bolgariya-1300 satellite (1981), the longitudinal currents in the polar terrestrial ionosphere and strong jumps in electric fields and particle fluxes in the polar ionosphere were investigated [19].

In the framework of the projects Prognoz (1971 – 1985) and Interbol (1995 – 2000) (lead organization: the Institute of Space Research (ISR), RAS), magnetic measurements were performed with the use of IZMIRAN's magnetometers in the outer terrestrial magnetosphere and the interplanetary space [20]. Based on the resultant magnetic data combined with plasma measurements in the Interbol project, the fine structure of the outer boundary and layers of the magnetosphere were investigated that comprise the outgoing shock wave, the magnetopause, the magnetosheath, and the boundary layer [21]. Also investigated were flux transfer events (FTEs) associated with the pulsed reconnection of magnetic field lines of the magnetosheath and magnetosphere, as well as the longitudinal currents flowing along the geomagnetic field lines in the auroral zone of the magnetosphere.

IZMIRAN's experiment in the Rezonans project (ISR, RAS), which is under preparation, is aimed at the pursuance of magnetic measurements in the study of resonance plasma processes in the magnetosphere and the effects of a magnetospheric cyclotron maser, the prerequisites for which may be realized in isolated geomagnetic field tubes [22].

Successful magnetic measurements in the near-Earth space have allowed conducting similar measurements on interplanetary stations in the study of the planets and small bodies of the Solar System. Proceeding from the analysis of the first magnetic measurements performed by IZMIRAN with Luna-2 (1959) and Luna-10 (1966) unmanned interplanetary probes, the Moon was found to have no dipole magnetic field of appreciable strength [23].

For the first magnetic measurements in space, a group of invstigators, including IZMIRAN's Director N V Pushkov and the leading magnetologist Sh Sh Dolginov, were awarded one of the first Lenin Prizes in the area of space research (1960).

Magnetic measurements on Lunokhod-2 (1973) permitted determining the correlation between local magnetic fields (6 – 300 nT) and tectonic relief features (craters, fractures, etc.) [24].

Discovered in the samples of lunar soil brought to Earth was a relatively strong magnetization the rock acquired in fields up to 100,000 nT. The study of the nature of this heretofore unknown magnetization is one of the fundamental issues in lunar investigations that remains to be solved. IZMIRAN's participation with magnetic measurements in the Luna-Glob (lunar orbital satellite) and Luna-Resurs (landing module) projects under preparation is aimed at solving this important question of lunar origin.

Magnetic measurements in the study of Venus and Mars in the series of projects Venera-4 (1967), Venera-9, and Venera-10 (1975) and Mars-2 (-3, -5) (1972 – 1974) have shown that Venus and Mars have no intrinsic dipole field and that their magnetospheres, like the cometary ones, are induced. Venus and Mars were discovered to have a bow shock wave and a magnetic plasma tail, which have been investigated [25, 26]. In the Phobos-2 (1989) and Vega-1 (-2) (1986) projects, the interaction of solar wind with Halley's Comet and the environment of the Mars satellite Phobos was studied [27, 28].

Magnetic measurements with balloons enable obtaining data about the low-altitude geomagnetic field, comprehensively studying magnetic anomalies on the terrestrial surface, and refining models of the geomagnetic field subject to continuous changes. In 2007 – 2009, IZMIRAN performed pioneering balloon-borne experiments in measuring and using vertical geomagnetic field gradients in the stratosphere with the aid of a balloon-borne magnetic gradiometer developed in [29]. This instrument is an exclusive IZMIRAN product and is unprecedented in the world's practice of geomagnetic research. Techniques have been devised for extracting the field of magnetic anomalies from the data of balloon-borne gradient magnetic surveys and the amplitude spectrum of magnetic anomalies was studied along the trajectory of a balloon flight from Kamchatka to Povolzh'e, which revealed regional and long-wavelength magnetic anomalies. The parameters of the sources of these anomalies were studied by different methods, including spectral ones. The findings of this research permitted improving the spatial accuracy of the data on the depth structure of Earth's crust and improving its magnetic model.

Combining modern satellite- and balloon-borne geomagnetic measurements allows achieving a satisfactory agreement of experimental data with the theoretical models of geomagnetic field generation and advancing the studies of the magnetic properties of Earth's crust, magnetic anomalies, and other features of geomagnetic field distribution.

4. Solar and solar–terrestrial physics

In recent years, beginning from the 1990s, IZMIRAN has broadened the scope of its space research: with IZMIRAN as the lead organization, two major space projects involving solar research, CORONAS-I and CORONAS-F have been carried out, which are constituents of the CORONAS (complex orbital near-Earth observations of Solar activity) program [30, 31].

With the use of data from the CORONAS-F satellite, coronal mass ejections (CMEs) and their related manifestations of solar activity, which have a high degree of geoefficiency, were investigated [32]. It was determined that the eruption of large CMEs involves global solar magnetospheric structures with a spatial scale far exceeding the size of active regions and ordinary activity systems. The large-scale regions of low brightness in extreme ultraviolet and soft X-ray regions (dimmings) observed in this case visualize the structures involved in the CMEs, which are supposedly produced due to the opening (extension) of magnetic field lines and the plasma outflow from transient coronal holes. The substantial rearrangement of the magnetic field, the partial opening of field lines, and the matter outflow that occur in a CME take place in the corona, but also affect the cold plasma of the transition layer.

On the CORONAS-I and CORONAS-F satellites, solar brightness variations at wavelengths ranging from ultraviolet to infrared were observed and global solar oscillations were studied with the use of the DIFOS (Differential Solar Oscillation Photometer) instrument. Power-density spectra were constructed for global low-l ($l = 0$, 1, 2) p-mode oscillations (Fig. 7) [33, 34]. It was experimentally determined that the p-modes exhibited frequency splitting due to solar rotation. Out-of-phase long-period p-mode amplitude variations of global solar oscillations were found to occur, which reflect internal solar dynamics, and an appreciable increase in the amplitude of global oscillations was observed in the ultraviolet spectral range. Observations of global solar oscillations were continued in the SOKOL experiment (Solar Oscillations) aboard the CORONAS-Foton satellite (launched on January 30, 2009). The work on the CORONAS-F project was awarded a 2008 Russian Federation Government Science and Technology Prize.

Over the last several years, IZMIRAN has been developing promising solar space projects: the Interhelioprobe project for investigating the Sun at close distances, and the Polar–Ecliptic Patrol (PEP) for observing global solar activity and studying the solar sources of cosmic weather [22, 35]. In the Interhelioprobe project, it is planned to approach the Sun using multiple gravitational maneuvers near Venus due to the commensurability of spacecraft's and Venus's periods of revolution around the Sun. The gravitational maneuvers also enable inclining the spacecraft orbital plane relative to the ecliptic plane. In the PEP project, it is planned to position two spacecraft in two oppositely inclined heliocentric orbits at the distance 0.5 a.u. from the Sun and shift them in orbit by a quarter period relative to each other, such that the Sun–Earth line and the plane of the ecliptic, in which most of mass ejection events and other active phenomena occur, will be uninterruptedly controlled from out-of-ecliptic positions (Fig. 8).

In connection with the projected flights to Mars, during which it will be necessary to ensure the radiation safety of the astronauts and accordingly observe the activity of the side of the Sun invisible from Earth, IZMIRAN is developing the Sistema project, in which three spacecraft spaced at 120° orbit the Sun in the plane of the ecliptic and one spacecraft is in an inclined orbit. This configuration of a system of spacecraft would allow realizing the global monitoring of solar activity, and the Interhelioprobe and PEP projects are regarded as the first steps on the path to the formation of this system.

5. Summary

This report is only a brief review of IZMIRAN's space research, beginning with the world's first space experiment involving the radio beacon of the first AES (1957) and ending with those space projects that are presently operating in space

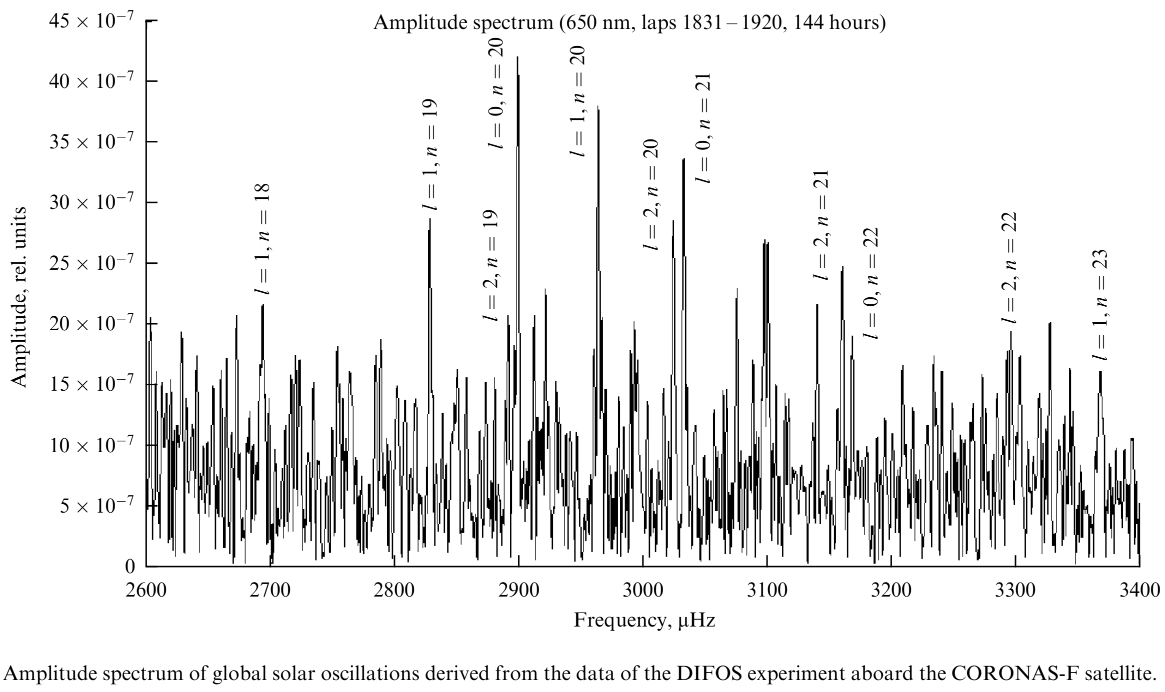

Figure 7. Amplitude spectrum of global solar oscillations derived from the data of the DIFOS experiment aboard the CORONAS-F satellite.

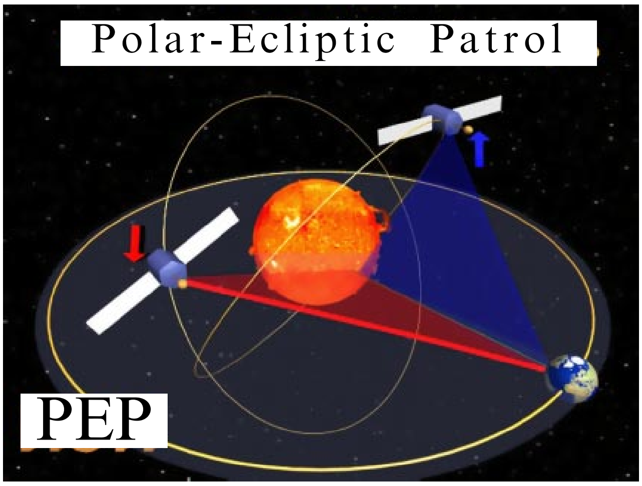

Figure 8. Ballistic scheme of the Polar–Ecliptic Patrol project intended for global solar activity observations and studies of the solar sources of cosmic weather.

or are being developed for the future. These projects are listed in Table 1. The space projects under development are aimed at solving a series of scientific questions posed by contemporary research into the terrestrial ionosphere and magnetosphere, the planets and small bodies of the Solar System, and the Sun and the influence of its activity on the near-Earth space. In the years to come, space investigations in IZMIRAN's research area will grow in importance due to the further broadening of human activity in space and a greater dependence of the space technologies being elaborated on space weather (the state of near-Earth space), the ionosphere, and the geomagnetic field.

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