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A SET OF SATELLITE EXPERIMENTS FOR STUDYING THE MAGNETOSPHERE-IONOSPHERE COMMUNICATIONS

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16. Abstract
Magnetospheric substorms are one of the basic problems in the physics of near Earth space. They appear as magnetic and ionospheric perturbations, disturbances in radio communication, polar auroras and electromagnetic radiation in different frequency ranges. These phenomena have been studied from single satellites. However, it is impossible to study theses phenomena adequately without simultaneous measurements from at least two different positions with two identical instruments. A suitable program can be developed based on the Interkosmos work using new achievements in electronics.

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A SET OF SATELLITE EXPERIMENTS FOR STUDYING THE MAGNETOSPHERE-IONOSPHERE COMMUNICATIONS

K.I. Gringauz

I. General Information /3*

One of the basic problems in the physics of near Earth space is the nature of magnetospheric substorms appearing in magnetic and ionospheric perturbations, disturbances in radio communication, the appearance of polar aurora and electromagnetic radiation in different frequency ranges, etc.

The phenomena listed have been studied separately in the last 10 years both in the USSR and in the USA using a number of satellites: in the USSR, the Kosmos series of satellites (261, 348, 378) and certain satellites according to a program of joint studies with socialist countries and France, in the USA, on satellites of the Injun, OGO, Isis and Explorer. However, using one satellite, it is mainly impossible to separate space and time variations of the phenomena studied and comparatively small allowable weights for scientific instruments on the satellites used precluded adequately studying simultaneously the complex of interconnected phenomena on one satellite. Moreover, up to the present time a study of flows of auroral particles and fields with a simultaneous study of images of the polar aurora obtained on the same satellite has not been adequately done on any one of the satellites (Soviet, American or Western European).

In order to carry out a complex study of the phenomena mentioned which would make it possible to obtain more complete information on occurrences in high latitude field processes, a whole complex of satellite experiments is necessary.

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*Numbers in the margin indicate pagination in the foreign text.

A feature of this complex must be the possibility of carrying out simultaneous measurements at two different positions but with identical scientific instruments, satellites (whose high latitude orbits simultaneously move along particularly important meridians, in the mid-day, midnight and morning and evening directions), see Figure 1, and a very complete set of experiments on each of the satellites (for which one needs, respectively, large weight scientific equipment) including recording of polar auroras not only at night but also in the daytime sectors (using photometers, including those operating in different ranges of wavelengths) and obtaining images of the polar aurora in the visible spectrum using scanning photometers. /4

No studies with an adequately complete program which make it possible to trace the cause and effect connection in detail during substorms have been made up to the present time and as far as is known are not yet planned either in the USA, or by the European Space Agency (ESA).

Such a program basically can be compiled on the basis of methods and equipment already used in practical studies of near earth space according to the Interkosmos line taking into account, naturally, the results obtained and new achievements in electronics.

II. Scientific Tasks

At the present time, it was established that most geophysical phenomena which develop in the ionosphere at high (> 60°) geomagnetic latitudes are closely connected to penetration into the upper atmosphere of charged particles of solar plasma from the transition field in front of the near earth shockwave on the diurnal side and charged particles from the rear of the magnetosphere on the nocturnal side. The magnetosphere and ionosphere are connected to each other by geomagnetic lines of force. Remote areas of the magnetosphere affect the phenomena in the ionosphere both as a result of energy charged particles pouring /5 out and due to constant and variable electrical and magnetic fields, the wave processes, etc. whereas, the lower layers of the ionosphere ($h < 400$ km) are a natural screen, which reflect (not only in the visible part of the spectrum of the electromagnetic waves but also in its ultraviolet section) the structure of the magnetosphere and the processes occurring in it. The accumulation of changes of plasma and the magnetic field in separate regions of the magnetosphere involving the effect of the interplanetary medium causes magnetospheric substorms. Large scale motion of the plasma in the magnetosphere results in separation of the charges and in the appearance of the electrical field and corresponding current along the lines of force with flux closure through the ionosphere (at altitudes of ≈ 100--150 km). In turn, these currents result in redistribution of electrical fields affecting motion of the plasma.

The main purpose of the complex of satellite experiments must be to show the cause and effect relationship of the phenomena in the process of the magnetosphere substorm. For this, a complex study is necessary of incoming charged particles with high time, spatial and energy resolution and simultaneous measurements of the characteristics of cold ionospheric plasma, which significantly perturb the incoming particles, observation of effects, which are apparent during interaction of incoming particles with the monosphere plasma and the neutral atmosphere and illumination in different frequency ranges, wave processes, and also measurements of quasi-stationary and electrical fields rapidly changing in time.

Such a set of experiments can give valuable scientific information at all latitudes. Program devices can advantageously be used on satellites, making it possible to separate the scientific program of the satellite into several subprograms (on command from Earth) each of which corresponds to the most complete solution of one or two scientific problems. /6

The most important scientific problem is the following:

A. <u>Studies of the phenomena in the subauroral zone (physics of the formation of stable red arcs, an ionospheric trough, a "hot" zone in the plasma sphere)</u>

In the subauroral zone of the upper atmosphere and the agnetosphere (at geomagnetic latitudes of 50--60°) phenomena re observed which do not yet have an unambiguous explanation. n this particular zone, often the so-called "stable red arcs" ccur, fields of high intensity of red illumination which create adiation in the 6300 Å lines of atmospheric oxygen (Figure 2). he most probable possible cause of these red arcs is the ncrease in electron temperature (which can be caused either by n increase in the electrical fields and currents created by them r transmission of heat from sources located higher or inflow f energy particles, or absorption of waves which occur in the lasma under certain conditions). Each of these explanations as a certain foundation.

Increases in electron temperature in this zone are recorded airly frequently, however, their cause is not adequately clear. ne of the reasons (and, possibly, one of the results) is a harp decrease in the concentration of ionospheric plasma in the rea indicated, the so-called "middle-latitude ionosphereic rough."

At high altitudes (h > 2000 km), apparently, along these eomagnetic lines of force, a "hot zone of the plasmosphere" is ocated, a zone where the temperature of the ions is very high etected on the Soviet Prognoz satellites.

In order to investigate the phenomena indicated in the ubauroral zone, instruments are obviously nesessary which can measure the following values:

a) intensity of red luminescence λ = 6300 Å,

b) temperature and concentrations of ionospheric electrons,

c) temperature, concentration, mass of ionospheric ions and composition of neutral particles,

d) flux and power spectra of energy particles (in particular, from a power of ≈ 10 eV to ≈ 100 keV),

e) quasistatic electrical fields,

f) characteristics of oscillation of the plasma,

g) low frequency characteristics--electromagnetic oscillations.

The combination of such simultaneously conducted measurements undoubtedly makes it possible to clarify the initial cause of the formation of stable red arcs and to understand the physical processes which control the phenomena in the subauroral zone.

B. Studies of the Physical Phenomena in the Zones of the Polar Auroras

These zones are located on the diurnal side of the upper atmosphere close to geomagnetic latitudes of ≈ 77°, and on the nocturnal side, ≈ 70° and are projected on the Earth in the form of a certain likeness to an oval. Then, the morphology of distribution of the polar aurora in the diurnal sector and their communication with the inflowing particles, in particular, the relative increase in intensity of luminescence in the *Ly-α* lines, as a result of perturbation of atmospheric hydrogen by rapid protons has been studied very little. As recent studies have shown, the polar aurora exists practically always, however, during magnetospheric substorms, the intensity of the polar auroras increases and the width of the zone essentially increases. The increase in intensity of visible polar auroras is only one of the manifestations of magnetospheric substorms which are accompanied by simultaneous significant increases in the flows of energy particles, X-ray radiation, very low frequency radiation and by changes in the characteristics of the ionospheric plasma. Neither the parts of the mechanism which form the flux of auroral particles causing the polar auroras nor the zones of their formation (particularly in the diurnal sector) have yet been adequately investigated and for studying them, one needs simultaneous identical measurements in a broad range of energy particles, distributed in space. These conditions will be fulfilled with the simultaneous use of two satellites launched into orbits whose planes are perpendicular to each other. /8

It is necessary to measure the following physical characteristics:

a) intensity and spectral distribution of flows of particles and angles formed by the velocities of these particles from the vector of the magnetic field, pitch angles;

b) the intensity of fluxes of particles of captured radiation (these measurements, in particular, make it possible to determine the boundary of the field of diurnal (polar) cusps which are, apparently, the sources of auroral particles which create the diurnal polar auroras;

c) concentrations of temperature of electrons of the ionospheric plasma;

d) concentration, temperature and mass composition of the ions;

e) oscillation of the plasma;

f) composition of the neutral atmosphere;

g) quasistationary electrical field;

h) very low frequency radiation;

i) intensity of optical emission, in particular, in the 1216 Å, 1302 Å--1305 Å--1306 Å, 1356 Å, 3914 Å, 4861 Å, 6300 Å, 5577 Å lines;

j) the dimensions and distribution of intensity of luminescence of polar auroras (by television recording of the visible section of the spectrum and in separate spectral ranges).

For measurement of the energy and pitch angle distribution /9
of auroral electrons and protons in a range of 0.1--20 keV, it is desirable that electrical pitch angle analyzers are mounted on the satellites with microchannel electron multipliers and electrical scanning of angle characteristics.

C. Study of the Motion and Instability of Ionospheric Plasma, Irregularities and Waves in the Ionosphere

Ionospheric plasma is not found in a state of thermodynamic equilibrium (temperatures of the electrons and ions, as a rule, differ significantly from each other); it is penetrated by flows of energy charged particles, locally heated by solar ultraviolet radiation, electrical currents, etc.; with large scale movement of the plasma, anisotropy of the electron temperature is created, and so forth. Different types of instabilities develop as a result of these processes in the plasma and oscillations and irregularities occur.

The most favorable zones for occurrence of these phenomena are located not only in the polar regions of the ionosphere but also in the equatorial (where equatorial electrical streams occur.).

Nonuniformity of concentrations involves wave processes and can be generated by different mechanisms, for example, gradient drift instability, two flow instability, for example, during motion of electrons through a background of neutral gas and ions (equatorial and auroral electrical streams, pouring particles into the polar regions), turbulence, etc. In the polar regions on auroral latitudes, between the ionosphere and the magnetosphere, intense longitudinal current flow which under certain conditions can be unstable; this results in a large drop in the potential along the magnetic force lines and strongly affects processes in the ionosphere and the magnetosphere.

The experimental data existing at the present time is inadequate for establishing the cause and mechanism for the occurrence of these phenomena. For example, rocket measurements of irregularities in the electron concentration which occurred in the equatorial region are not accompanied by simultaneous measurements of electrical fields, although for their manifestation of such irregularities as gradient drift, it is necessary to complete certain relationships between the gradient of concentration and the electrical fields. /10

The set of scientific instruments necessary for solving problems A and B in addition to the instruments listed below are the most complete of the set used formerly or planned at the present time which can provide measurement of most physical characteristics necessary for studying the problem considered including: concentration and temperature of electrons, mass composition of ions, rate of drift in two mutually perpendicular directions and, consequently, evaluation of electrical fields involving these motions (besides direct measurements of quasi-stationary electrical fields).

For determining the frequency of oscillations of the ionospheric plasma, one needs to establish a special instrument of the type for analyzing ions (ion trap) which contains a system of band frequency filters in the collector network and for measurement of shifts in the ionospheric plasma (drifts), a block of 5 oriented in a different way, flat ion traps with the appropriate block of electronics.

For realizing the complex of satellite experiments designed for solving the aforementioned problems, satellites are necessary with a prepolar orbit directed along the vector of velocity. The optimum orbit is approximately circular at at altitude of 500--600 km.

It was noted above that the proposed complex of instruments makes it possible to obtain valuable information not only for the problems A, B and C already noted.

In particular, it makes it possible to lengthen and deepen /11 the detailed study of the phenomenon in the equatorial ionosphere (including the interconnection of anomolies in latitudes of distributed concentrations and temperature of charged particles in this region) begun on the Interkosmos-2, 8, 12, 14 satellites.

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Figure 1. Mutual position of the orbits of satellites for resolution of time and large scale spatial changes in the physical parameters studied.

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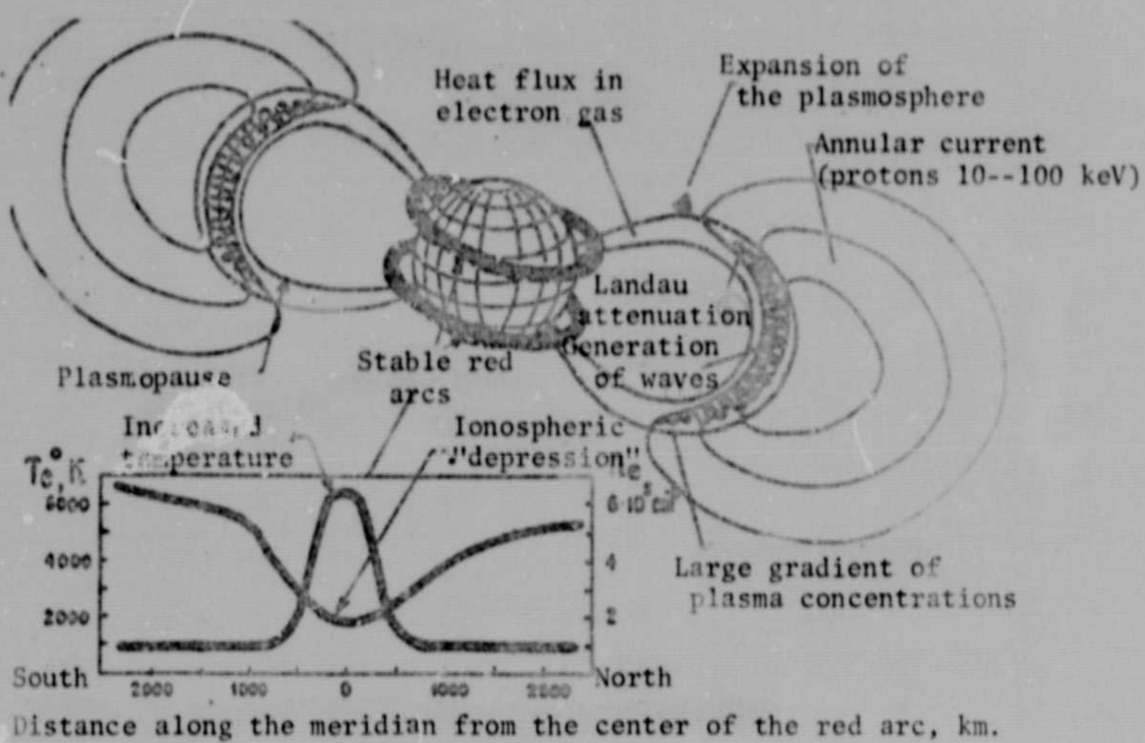

Figure 2. Diagram of the process of ionospheric and magnetospheric interaction in the subauroral region (based on drawings from the work of Rice and Robla in the Reviews of Geophysics and Space Physics, v. 13, 1, 201, 1975).