Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (25–26 November 1987)

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A scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR was held on 25 and 26 November 1987 at the S. I. Vavilov Institute of Physics Problems, Academy of Sciences of the USSR. The following papers were presented at the session:

November 25

1. A. A. Chernov. Surface melting and wetting.

2. A. P. Levanyuk. Incommensurable phases in real crystals.

November 26

3. R. A. Syunyaev. The supernova in the Large Magellanic Cloud and its x-ray emission (theory and first observational results).

4. G. S. Ivanov-Kholodnyĭ. Problems of the solar-terrestrial physics and research on the ionosphere.

One of these papers is summarized below.

G. S. Ivanov-Kholodnyĭ. *Problems of solar-terrestrial physics and research on the ionosphere.* The problem of studying and making use of space is being actively solved through the use of unmanned satellites and manned space stations. The need for a good understanding of the state of the space environment of the earth, where satellites fly and where most space experiments and projects are carried out, is obvious. There was the memorable event of the premature descent of the Skylab manned space station from orbit at the peak of rescue efforts aimed at lifting the station into a higher orbit and prolonging its life. Solving the problem of improving methods for forecasting the state of the upper atmosphere and the ionosphere is intimately related to the development of the basic solar-terrestrial physics.

1. One of the most important fundamental problems is that of finding the physical mechanism by which solar radiations influence the state of the plasma in near space, which under ordinary conditions is known to be determined primarily by the background fluxes of the solar ionizing and dissociating radiation and the solar wind. During disturbances associated with solar flares and other explosive processes on the sun, it is necessary to take account of the changes in these fluxes, the appearance of shock waves in interplanetary space, solar cosmic rays, etc. Similar problems were posed in a study of the atmospheres of Mars and Venus and also Halley's Comet.

Another important problem is determining those physical processes on the sun which cause geoactive radiation under ordinary conditions and during solar flares. Understandably, unless we solve this problem we will not be able to find a complete solution for the first problem. Here, however, we will discuss the problems of solar-terrestrial physics solely in the example of the ionosphere, which is one of the leading fields of solar-terrestrial physics, since the formation mechanism is clearest in this case.

2. Three decades ago, research on the effect of solar activity on the ionosphere was being carried out at a morphological level[1] (a search for general relationships and correlations). The scanty information available on the rate constants for various processes and the various physical parameters of the ionosphere were not sufficient for constructing a complete, noncontradictory theory of the ionosphere. Today, the situation has changed in three respects:

1) Careful studies of the recombination coefficients (particularly for dissociative recombination, which is dominant in the ionosphere) and the rate constants for physicochemical reactions have now been carried out, with an error of less than 10–20%, in several laboratories. The temperature dependence of these constants has been found.

2) After the International Geophysical Year (1958), information on the slowing down of satellites started to emerge, as did data from the network of ionospheric stations and incoherent-scattering stations. This information has made it possible to construct semiempirical planetary models of both the neutral upper atmosphere and the ionosphere at various heights and under various heliogeophysical conditions.

3) The direct data from measurements of the flux and spectrum of ionizing radiation from the sun (1–1000 Å) have made it possible to calculate accurately profiles of the ion production rate for the ionosphere.

All this information has been combined with our understanding of the physicochemical reactions to derive a theory for the formation of the ionosphere in the region of the ionization-recombination equilibrium at heights of 100–200 km. With ambipolar diffusion taken into account, it has also been possible to develop a mechanism for the formation of the F2 layer of the ionosphere and to describe all the anomalies in the behavior of this part of the ionosphere. The theory for the formation of the ionosphere has been derived for ordinary conditions. The problem now is to derive a corresponding theory for disturbed conditions.

3. A topic of particular interest is the distribution of ions in the ionosphere. We can cite some examples for various heights h. At heights above ~ 1000 km, H^+ ions are predominant. Figure 1 shows the distribution of the density of singly and doubly ionized atoms at heights of $(0.5–3) \cdot 10^3$ km (z is the reduced height, reckoned from the level 1250

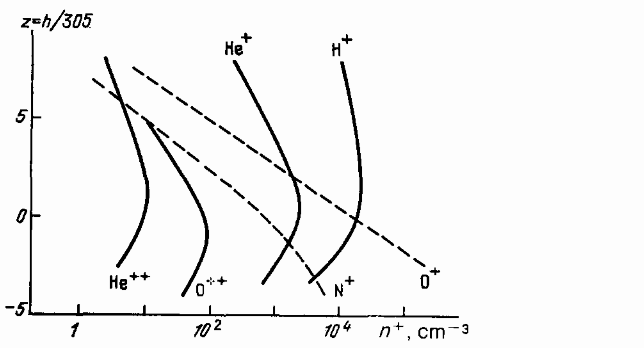

FIG. 1. Height distribution of the densities of ions in the region $(0.5–3) \cdot 10^3$ km.

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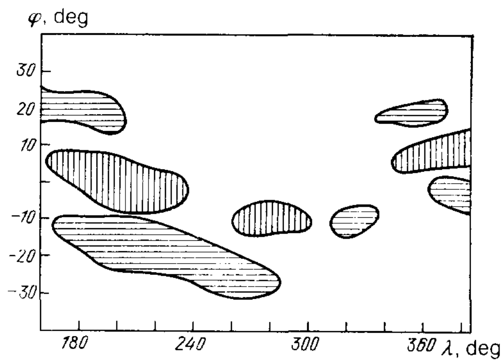

FIG. 2. Map of the distribution over latitude φ and longitude λ of zones of reduced values (vertical hatching) and elevated values (horizontal hatching) of the critical frequencies according to data from the satellite IK-19 on 22 May 1980 at 16 h LT.

km, where the relation $[O^+] = [H^+]$ is assumed to hold). Each ion of a small component has its own maximum. The height at which this maximum is reached depends on the temperature in the ionosphere and is determined by the mass-to-charge ratio of the ion.[2] The density of O^+ and N^+ ions, on the other hand, reaches a maximum at heights at which the electron density reaches a maximum, i.e., in the F2 layer, whose height, ~ 300 km, varies over a range of ± 100 km, depending on the solar-activity level, the season of the year, the time of day, and other conditions. These changes are described by the existing theory, which is based on a consideration of ambipolar diffusion and drifts and data on the temperature and composition changes of the neutral atmosphere.[3,4]

Below $h \approx 200$ km, an ionization-recombination equilibrium is established, and the molecular ions NO^+ and O_2^+ are predominant. The double maximum in the densities of these ions occurs at a height ~ 170 km (the F1 layer) and ~ 100 km (the E layer). These maxima stem from maxima in the rate at which ions are formed by the ionizing solar radiation.[3] In the F1 layer, the comparatively high recombination coefficient and other properties of the plasma are determined by the relatively high concentrations of molecular ions. At heights ~ 110 km, the lower recombination coefficient and many features of the E layer stem from the presence of a maximum in the density of excited NO^+ ions.[5] In summary, distinctive physicochemical processes occur at each height in the ionosphere and determine the ion composition and other physical properties.

4. Working from the data obtained on the satellite IK-19, which carried an ionospheric station for sounding the ionosphere from above, onc can construct a map of the distribution of the critical frequencies f_0 of the F2 layer over the greater part of the earth's surface for a given local time (LT). Figure 2 shows such a map for 22 May 1980 at 16 h LT. The hatching shows characteristic zones of anomalously low values of f_0 (at the geomagnetic equator) and high values of f_0 (parallel to the equator at a magnetic dip $\pm$ 15–25°). Similar zones in the ionosphere in the equatorial belt are observed at any time of day and in all seasons. They usually group near certain longitudes.[6] It has been suggested that the source of these zones may be Rossby-wave solitons in the neutral atmosphere.[7]

We would like to conclude by stressing the importance of this research. The effort to draw a coherent physical picture of the processes which occur in the plasma in near space is not aimed solely at satisfying the natural-science interest. It is also important from the practical standpoint: for mastering a new medium in which satellites and manned space stations move, especially at a time at which the use of near space is becoming vitally important to the development of the human race.

[1]É. R. Mustel', The Sun and the Earth's Atmosphere, Gostekhizdat, Moscow, 1957.
[2]G. S. Ivanov-Kholodnyi and Yu. K. Kalinin, Geomagn. Aeronom. **25**, 400 (1985) [Geomagn. Aeronom. (USSR) **25**, 331 (1985)].
[3]G. S. Ivanov-Kholodnyĭ, and G. M. Nikol'skiĭ, The Sun and the Ionosphere, Nauka, Moscow, 1969.
[4]G. S. Ivanov-Kholodnyĭ and A. V. Mikhaĭlov, *The Prediction of Ionospheric Conditions*, Reidel, Dordrecht; Boston, 1986 [Russ. original, Gidrometeoizdat, Leningrad, 1980].
[5]L. A. Antonova and G. S. Ivanov-Kholodnyĭ, Geomagn. Aeronom. **25**, 203, 900 (1985) [Geomagn. Aeronom. (USSR) **25**, 757, 841 (1985)].
[6]G. V. Givishvili, G. S. Ivanov-Kholodnyĭ, V. V. Migulin, *et al.*, Dokl. Akad. Nauk SSSR **295**, 1330 (1987) [Dokl. Acad. Sci. USSR, Earth Sci. Sec. (1987)].
[7]G. S. Ivanov-Kholodnyĭ, V. I. Petviashvili, A. Ya. Fel'dshteĭn, and L. A. Yudovich, Geomagn. Aeronom. **27**, 393 (1987) [Geomagn. Aeron. (USSR) **27**, 343 (1987)].

Translated by Dave Parsons