the stability and inhomogeneous structure of the ionosphere and the magnetosphere. Experimental measurements of the electric field have recently been the subject of a large number of studies (see the review[5]). The quasistationary electric field in the plane of the geomagnetic equator $\mathbf{E} = -\mathrm{grad}\,\Psi$ is determined by the equation[6]

$$\frac{\partial}{\partial L}\left\{\frac{L}{\sqrt{1-(1/L)}}\left[[4-(3/L)]\,\bar{\sigma}_{\perp}E_L+[4-(3/L)]^{1/2}\,\bar{\sigma}_{\Lambda}E_{\varphi}\right]\right\}+$$
$$+\frac{1}{\sqrt{1-(1/L)}}\frac{\partial}{\partial\varphi}\left(\bar{\sigma}_{\perp}E_{\varphi}-\sqrt{4-(3/L)}\,\bar{\sigma}_{\Lambda}E_L\right)=eR_0\left[\frac{\partial\bar{N}_{\mathrm{fe}}}{\partial t}+\omega_0\frac{\partial\bar{N}_{\mathrm{fe}}}{\partial\varphi}-\frac{\partial\bar{N}_{\mathrm{fi}}}{\partial t}\right.$$
$$\left.-\omega_0\frac{\partial\bar{N}_{\mathrm{fi}}}{\partial\varphi}\right]+Q_g. \tag{2}$$

We have taken into account here the fact that the high longitudinal conductivity of the magnetosphere causes the surfaces on which the force lines of the magnetic field are situated to be equipotential surfaces for the electric field, $\Psi = \Psi(L, \varphi)$(φ is the longitude); $\bar{\sigma}_{\perp}$ and $\bar{\sigma}_{\Lambda}$ are the transverse and Hall conductivities of the ionosphere, averaged over the altitude. The term in the square brackets determines the generation of the field by the fast electrons or ions of the magnetosphere. Here $\bar{N}_{\mathrm{fe}}$ and $\bar{N}_{\mathrm{fi}}$ are the fast-particle concentrations averaged over the force line, and ω_0 is the angular frequency of the earth's rotation. The term Q_g determines the generation of the field under the influence of the wind of neutral molecules in the ionosphere (the "dynamo field")[7].

Near the geomagnetic equator ($L \to 1$) a singularity appears in (2). An analysis of the solution in the vicinity of the singularity shows that the electric field in a narrow layer of the ionosphere near the geomagnetic equator increases by 20—30 times (the equatorial current jet)[8]. In the polar ionosphere ($L \gg 1$) the intensity of the electric field also increases by more than one order of magnitude. This is the consequence of the geometry of the force lines: the field E_i in the ionosphere is connected with the field in the plane of the geomagnetic equator E by the relations $E_{i\varphi} = E_{\varphi}L^{3/2}$ and $E_{iL} = E_L \cdot 2L^{3/2}[1 - (3/4L)]^{1/2}$. The action of the electric field on the fast electrons and ions is determined by the parameter[6]

$$\lambda \approx 2.7 \cdot 10^{-2}\,L^4\,[1-(1/L)]^{1/2}N_{\mathrm{fo}}\left(\frac{10^{12}}{\bar{\sigma}_{\perp}}\right)\ ; \tag{3}$$

here N_{f0} is the average concentration of the fast particles in cm^{-3}, and $\bar{\sigma}_{\perp}$ is expressed in cm/sec ($10^{12}/\bar{\sigma}_{\perp} \sim 1$). We see that in the polar zone ($L \sim 5$—10) we have $\lambda \gtrsim 1$ already at low values of N_{f0}. Instabilities of the flute type arise in this case, and the electric field acquires an oscillator structure[9,6].

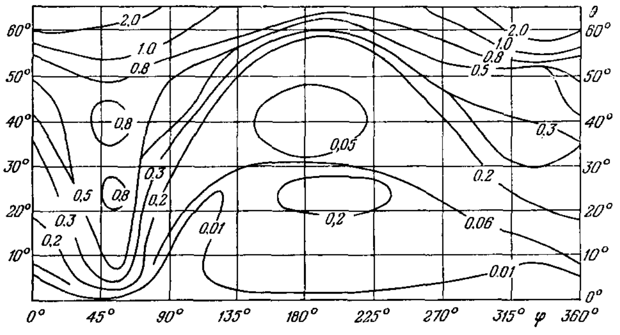

FIG. 2. Electric field intensity in the earth's ionosphere at t ≈ 6 min after the burst of the electrons on the force line $\varphi = 0$, $L = 1, 2$ (i.e., $\theta \approx 25°$). φ—longitude, θ—geomagnetic latitude. The curves are labeled with the values of E/E_1, where E_1 is a constant that depends on the total number of fast electrons n and on the integral conductivity $\bar{\sigma}_{\perp}$ of the ionosphere ($E_1 \approx 30$ mV/m at $n = 10^{26}$ and $\sigma_{\perp} = 10^{12}$ cm/sec).

Figure 2 shows the results of a numerical solution of Eq. (1) jointly with the kinetic equation for the fast electrons under conditions when an artificial radiation belt is produced[10,11]. We see that the field is maximal in the polar region. Ion-acoustic waves are excited here[12] and considerable heating of the ionosphere takes place.

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Yu. I. Gal'perin, Auroras and the "Resonance" Concept of a Magnetic Storm

The concept described below[1,2] constitutes, in fact, an attempt to construct a cohesive phenomenological picture of the processes occurring in the magnetosphere during the time of an "elementary magnetic storm"—the so called substorm, based on extensive results of measurements on satellites and on land-based geophysical observatories, and also attempts at their theoretical analysis.

The groundwork was laid by theoretical calculations[3] that revealed the possibility of existence, in the nighttime magnetosphere, of a special "resonant" component p_+^0 (Fig. 1) of protons (ions) with energy $E_0 \sim 10$ keV (more accurately, $E_0/Z \sim 10$ keV, where Z is the charge of the ion), having a longitudinal drift frequency ω_{dr} close to the frequency ω_{E} of the earth's rotation. According to[3] this captured component in a non-rotating coordinate system should have an asymmetrical component and becomes concentrated in the near-midnight region; the motion of these particles is

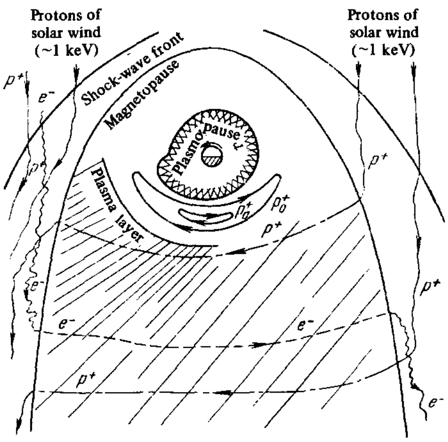

FIG. 1

determined only by the asymmetry of the geomagnetic field and the electric fields in the magnetosphere.

The main elements of the proposed concept reduce briefly to the following:

a) After a quiescent period in the solar wind (average proton energy ~1 keV) there appears in the interplanetary space, as a result of the processes on the sun, a "corpuscular flux" moving with velocity ~1000–1500 km/sec, representing a component of higher energy-protons with ~10 keV energy (see[4]).

b) These solar-wind particles p^+ (see Fig. 1) are capable of penetrating inside the magnetosphere in the so-called "plasma layer" on the morning side and can be displaced as a result of the gradient drift towards the evening side of the magnetosphere[5,6], since the magnetosphere is closed at least up to distances $30R_E$[7,8] and the magnetosphere represents an equipotential surface[5,9,10].

c) An analysis of the experimental data on the plasma motion in the midnight region near the plasmopause[11], in the zone of the annular current[12], on the internal edge of the plasma layer[13-15], and inside the plasma layer[16] leads to the concordant conclusion that 0.5–1 hours ahead of the start of the substorm there occur motions of the plasma towards the earth, corresponding to the appearance of a large-scale electric field directed towards the nighttime side from east to west, and particularly strong (~0.3–1 mV/m) in the near-midnight sector (more accurately, near 23^h). The boundary of the plasma layer then comes within a distance $(5-7)R_E$[12-14], so that now the solar-wind particles, moving through the plasma layer, are capable of reaching the region where the closed resonant trajectories of the protons (ions) p_0^+ were located during the quiescent time. The physical meaning for the occurrence of a field of this type is simply postulated on the basis of the experimental data.

d) As a result of the loss of energy of the quasicaptured particles (in particular, loss to Joule dissipation of the produced electric polarization fields in the lower ionosphere), the resonant particles are capable of accumulating in the potential wells produced on the night side of the magnetosphere, giving rise to clouds of quasiparticle hot protons and ions with approximate energy 10 keV.

e) The appearance of azimuthal asymmetry of the quasicaptured protons (this corresponds to asymmetry of the annular current) causes the appearance of an electric field at these L-shells[17]; the field subtends, in local time, the entire magnetosphere beyond the plasmopause, which changes in turn the character of the drift of all the cold and high-energy captured particles in these regions of the magnetosphere.

f) It is assumed that the accumulation of the resonant particles and of the annular current in general continues until a certain threshold density value is reached, followed by an as yet unidentified instability—magnetospheric explosion" or "magnetospheric substorm" (for example, some convective instability at $\beta > 1$). As shown by ground-based magnetometric measurements[18] and also the results of an analysis of the drift directions of a hot plasma during the flare[12,16], this is accompanied by a strong increase of the electric field produced prior to the start of the substorm, and by a further decrease of the distance between the plasma and the earth, by an eruptive flare of hot plasma in a radial direction away from the earth, and the particles having the same sign and energies up to 20–30 keV rapidly spread under the influence of the $\mathbf{E} \times \mathbf{H}$ drift on both sides of the midnight region. As a result of the appearance of large fluctuating induction electric fields, the particles are appreciably accelerated in the magnetosphere and the flux of particles in the loss cone, increases strongly, corresponding to an aurora flare (cf., e.g., the concept of[20], where there is no accumulation of particles).

g) In the case of continuing "pumping" of the magnetosphere by resonant particles from the solar wind, the process of substorm generation may repeat. The proposed scheme differs only in the picture of the large-scale background (or "mantle") aurora, caused by the auroral electrons, and comparatively uniform emission band due to the penetration of auroral protons, i.e., quasicaptured particles with characteristic energy on the order of 10 keV. It has become clear long ago that the auroral phenomena are determined by particles having characteristic energies of this order[19].

Resonant model of substorm

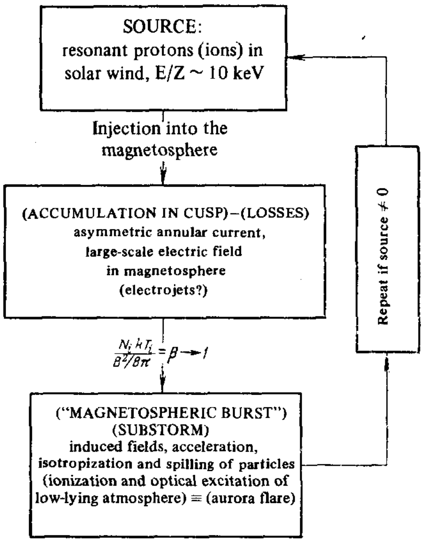

FIG. 2

The processes of eruption and spreading of a cloud of hot plasma in the magnetosphere is clearly reflected in the expansion towards the pole and in longitude of such forms of auroral glows during the substorm time[21,22]

The energies of the substorm is determined in this case by the depth of modulation of the energy flux carried by the solar-wind particles drifting across the tail of the magnetosphere, i.e., essentially by the energy of the plasma-layer particles. The role of the electric field produced in the substorm is analogous in this case to the role of the grid voltage that controls the plate current in a vacuum tube.

The appearance of intense local (so-called discrete) forms of auroras excited by the electrons and protons (ions) with average energies ~1–5 keV does not follow directly from the described picture, and their interpretation calls apparently for a detailed analysis of the vibrational and other collective processes in the magnetospheric plasma.

It is interesting that for Jupiter, which also has a magnetosphere and belts of captured particles, owing to the large magnetic moment M_Ψ and the rapid rotation ω_Ψ, the resonant energy may be the particle energy E_Ψ:

$$E_\Psi \approx E_0 \frac{\omega_\Psi}{\omega_E} \frac{R_E}{R_\Psi} \frac{M_\Psi}{M_E} \approx 0.22\, E_o \frac{M_\Psi}{M_E},$$

i.e., higher by at least one and a half or two orders of magnitude than the value $E_0 \sim 10$ keV which is typical for the earth. In this case, if the conclusion that Jupiter's magnetic moment has a direction opposite that of the earth is correct, then the resonant particles there are relativistic electrons, which appear relatively rarely in the solar wind, but are effectively generated in Jupiter's magnetosphere.

The purpose of this communication was to emphasize the presently unclear aspects in the planetary physical picture of the phenomenon of magnetospheric substorm and auroras, and to present a working hypothesis that is presently being verified and compared with the experimental data obtained in recent comprehensive earth-based and outer-space experiments with the satellites "Kosmos-264" and "Kosmos-348," and are also further analyzed theoretically.

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N. S. Kardashev, Yu. N. Pariiskiĭ, and A. G. Sokolov, Cosmic Radioastronomy

The present paper discusses the prospects of investigations in the ordinary radioastronomical band, without discussing the region where the earth's atmosphere and ionosphere are not fully transparent.

The recent major discoveries in the field of radioastronomy (observation and investigation of quasars, pulsars, residual background, discovery of numerous interstellar molecules) are due, on the one hand, to the expansion of the spectral band of the research, and on the other to the increased size of the radio telescopes and the sharp reduction of the receiver noise. Of tremendous significance is also the use of computer both during the course of radioastronomical observations and during the time of their reduction.

The most important parameters characterizing the capabilities of experimental radioastronomy is the minimum observable spectral flux density min F [W/m²Hz] and the minimum angular resolution min θ["].

The F_ν band covers in modern radioastronomy about 10 orders, and the weakest among the observed sources have approximate fluxes of 10^{-28} W/m²Hz. The angular resolution is attained with the aid of interferometers, and the highest attainable resolution is $\sim 3 \times 10^{-4}$ seconds of arc[1]. For comparison, in the optical band astronomical observations cover about 20 orders in F_ν and the attained angular resolution (also with the aid of interferometry) is $\sim 10^{-4}$ second of arc[2]. It is important to note that by methods of radio and optical observations we usually obtain information on different