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SOME PECULIARITIES OF IONOSPHERIC PLASMA IN THE SOUTHERN POLAR CUSP REGION

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The results of measurements of electrons with E =0.07 ÷ 10 keV and E >40 keV, temperature and energy distribution function of ionospheric electrons made on November 18, 1970 onboard the Cosmos-378 satellite are given. In the presence of low energy electron fluxes the ionospheric electron temperature rises and the energy distribution function considerably deviates from maxwellian one. The electrons with mean energy $\sim$1 eV and the temperature lower than ionospheric electron temperature were observed. The possible reasons of existence of such quasienergetic ionospheric electrons are considered.

This paper deals with the results of the simultaneous measurements in the southern day polar cusp of the fluxes of low-energy electrons ($E=0.07 \div 8.5$ kev), electrons with E 40 kev, temperature and the energy distribution function of ionospheric electrons carried out in November 18, 1970 from the "Cosmos-378" satellite. For the measurements of low-energy electron fluxes two cylindric electrostatic analyzers were installed on board the satellite that recorde the fluxes of electrons with the following energies: 0.07; I; 2.2; 4.2; 8.5 kev [I] and were oriented in the opposite directions. Geiger counter was used for the measurements of the fluxes of electrons with $E > 40$ kev [2] . Temperature of ionospheric electrons was taken by means of spherical high-frequency probe [3] and Langmuir spherical probe with modulation [4] . To find the velocity distribution function of thermal electrons Langmuir probe with modulation was also used.

The satellite apogee was about I750 km, perigee about 240 km, revolution period near I00 min. The orbital plane inclination to the equator plane was $\sim 74°$. The maximum invariant latitudes were $\sim 82°$. Such an orbital inclination of the satellite allowed to perform the long-time measurements (up to I5-20 min) in the day high-latitudinal region of low-energy electron precipitation (the day cusp region). The data from five flights of the Cosmos-378 satellite was registered in the cusp region.

Fig.I gives the typical example of the results obtained by means of the mentioned above instruments in the southern day polar cusp region. During I5 min of the flight (from 00.22 to 00.37 UT) the satellite orbit was within altitudes from II70 to I650 km; here invariant geomagnetic latitude of the satellite increased at first from 66° to 82° and then decreased up to 65°. The appropriate variations of local time LT were 8^h-$I5^h$.

The top of Fig.I presents the fluxes of electrons averaged over three-second intervals according to the readings of one of the analyzers corresponding to three accepted energies of electrons: 0.07; 1.0; 8.5 kev. The bottom of this Fig. shows the time variation for electron fluxes with E > 40 kev. The solid and dashed lines denoted by α conform with the orientation of analyzer and Geiger counter relative to the magnetic field vector.

Let us consider the variations of electron fluxes against the Λ invariant latitude changes. The sharp increase of electron fluxes with E $\leq$ 8.5 kev began at 00.22 UT for Λ =66° when the satellite was still at the trapped radiation region (electron fluxes with E > 40 kev exceed the background level by the order of two). Up to 00.25 UT the fluxes of these low-energy electrons were almost continuously registered, spectral density of the energy flux having a maximum in 2-4 kev range and fluxes being relatively stable within I5 sec. At 00.25 UT the fluxes became fast-changeable, often varying by the order of magnitude during 0.2-0.3 sec. At the same time moment the fluxes of electrons with E=0.07 kev and I.0 kev sharply increased whereas the fluxes of electrons with E=8.5 kev did not practically change on an average. The given moment coincides with the beginning of sharp fall (up to the background level) of the trapped electron flux (Λ ~76°). At 00.36 (Λ ~72°) the fluxes of electrons with E > 40 kev sharply increase and in about 30 sec the flux of electrons with E $\leq$ 8.5 kev falls up to the background level.

Such a character of fluxes registered allows to identify a zone of the precipitation of soft particles in the region of open force lines of the magnetic field (the boundary of which we determine from the sharp fall of fluxes of electrons with E > 40 kev) with the high-latitudinal region of penetration of the plasma of the magnetosheath into the magnetosphere, the day polar cusp.

At the bottom of Fig.I the solid-lines show the results of ionospheric electron temperatures measured by means of high frequency probe, triangles show that obtained by Langmuir probe with modulation. At the region outside the cusp ($\Lambda < 66°$) electron temperatures measured by these two techniques are in good agreement. When the satellite enter the region of intensive precipitation of low-energy electrons (00.25 UT, $\Lambda = 77°$) the found agreement is often broken and sharp fluctuations of temperature up to 3000°-4000°K are observed.

Fig.2 gives as example some volt-ampere characteristics for derivatives of electron current of Langmuir spherical probe dependent on decelerating voltage V. Vertical arrows at the Fig.I bottom part denote the time moments for which in Fig.2 volt-ampere characteristics are given marked by the same figures. It is known from the Langmuir probe theory that at the region of decelerating potential with the velocity Maxwell distribution the volt-ampere characteristic of spherical probe plotted on a semilogarithmic scale is a straight line. This line slope is defined by temperature of measured particles. In the ionosphere regions outside the precipitation zone the form of volt-ampere characteristics in most cases corresponds to the velocity Maxwell distribution of electrons. (Characteristics I and 6 in Fig.2). The so-called high-temperature tails are the most abundant type of irregularities in the Maxwell distribution that can appear with the presence of photoelectrons and precipitating particles in the ionosphere.

At the region of low-energy electron precipitation ($E \geqslant 0.I$ kev) including the cusp once more type of deformation of voltage-current characteristics is often seen (characteristics 2 and 3 in Fig.2). Two rectilinear parts appear on the characteristics with the different steepness, the steeper part corresponding to the greater values of V. The analysis of such characteristics allows to assume that there are two groups of electrons in the plasma electron component registered by Langmuir probe. Electrons of the first group have the higher density and temperature of about 4000°-5000°; electrons of the other group, "cool" electrons, have temperature of about 2000°-3000° but the mean kinetic energy of them is equal to about I÷I.5 ev, i.e. approximately 5 times exceeds the mean energy defined by temperature of these particles. It proves the fact that some mechanism of acceleration of these particles up to energy of about I ev exists. Electrons with such a mean kinetic energy are often registered in the satellite passing of the cusp region.

Triangles connected by vertical lines in Fig.I show temperatures for the two groups of electrons. Note that the temperature value measured by high-frequency probe is close to the temperature value of the "cool" electron group. It is evidently associated with the fact that floating potential of this probe is within - I ÷ I.5 v, i.e. within the linear part of volt-ampere characteristic of Langmuir probe for "cool" electrons.

So the given results of the plasma measurements at the day polar cusp region indicate the presence on this region at ~I500 km of electrons with temperature T_e=2000° ÷ 3000°K and with the mean energy of about I ÷ I.5 ev considerably exceeding the mean energy of ionospheric thermal electrons with T_e=4000°÷ 5000°. The "Cosmos-378" equipment and its performances do not allow to determine the distribution of "cool" electrons over pitch-angles that does not permit to define the direction of "cool" electron flux relative to the geomagnetic field.

The local formation of electrons with the mean energy of I ÷ I.5 ev at ~ I500 km is highly probable as all the mechanisms of acceleration and heating of electrons at this altitude associated with the formation of secondary electrons or photoelectrons and with the local electric fields should lead to acceleration or heating of the total mass of ionospheric electrons but not to appearance of the two groups of electrons with the different mean energy. The formation of such electrons at an altitude higher than I500 km is also impossible; at this region temperature of electron increases with altitude and when accelerating thermal electrons the thermal spreading must be kept. Since the energy corresponding to temperature of "cool" electrons is much less than their mean energy (I-I.5 ev) it is probable that their formation should occur in the region below the satellite orbit, i.e. at altitudes ~ I500 km. In this connection we can assume that the phenomenon observed is caused by the flux of electrons accelerated in the lower layers of the ionosphere by the longitudinal electric field. The flux of these electrons can also be a return current which occurs in the ionosphere under the predominant precipitation of fluxes of particles with the same sign or fluxes of particles with different signs but with the various pitch-angular distributions.

To accelerate electrons up to energies I ÷ I.5 ev at

300 km to 1500 km altitudes the electric field is necessary with $E_\parallel = 10^{-8}$ v/cm. The question on the presence and the value of the longitudinal electric fields along magnetic force tubes is contradictory since there are disagreements between the various experimental results. During the direct measurements by probe the values $E_\parallel \sim 2 \times 10^{-4}$ v/cm are recorded, i.e. by four orders greater than 10^{-8} v/cm. The question on longitudinal currents (Berkeland currents) in the ionosphere has been considered in detail in Arnoldy's paper [5] . This work deals with the review of the phenomena associated with the appearance of longitudinal currents with precipitation of particles. Arnoldy has made the following conclusions:

"There appears to be little doubt that Birkeland current exist... The data from polar orbiting satellites indicate that the current sheets are associated with auroral displays and that field aligned electron fluxes on the order I kev energy are significant charge carries for connectional currents directed out of the atmosphere... The return current is the illusive part of the overall ystem. It is uncertain whether it is carried by positive charges or very low energy electrons below the threshold of instruments which have attempted to measure it. There are a few measurements which indicate that low energy tail of the distribution responsible for the return current". The longitudinal electric fields of 10^{-4}- 10^{-5} v/cm were registered in the experiments of [6] , [7] .

All the considered above allows to assume that our plasma measurements can confirm the fact that in the ionosphere of the day polar cusp the longitudinal electric fields with $E_\parallel \sim 1 \times 10^{-8}$ v/cm can exist providing return current from the ionosphere during precipitation into the ionosphere of the fluxes of particles with the same sign or with the different signs and the different pitch-angular distribution.

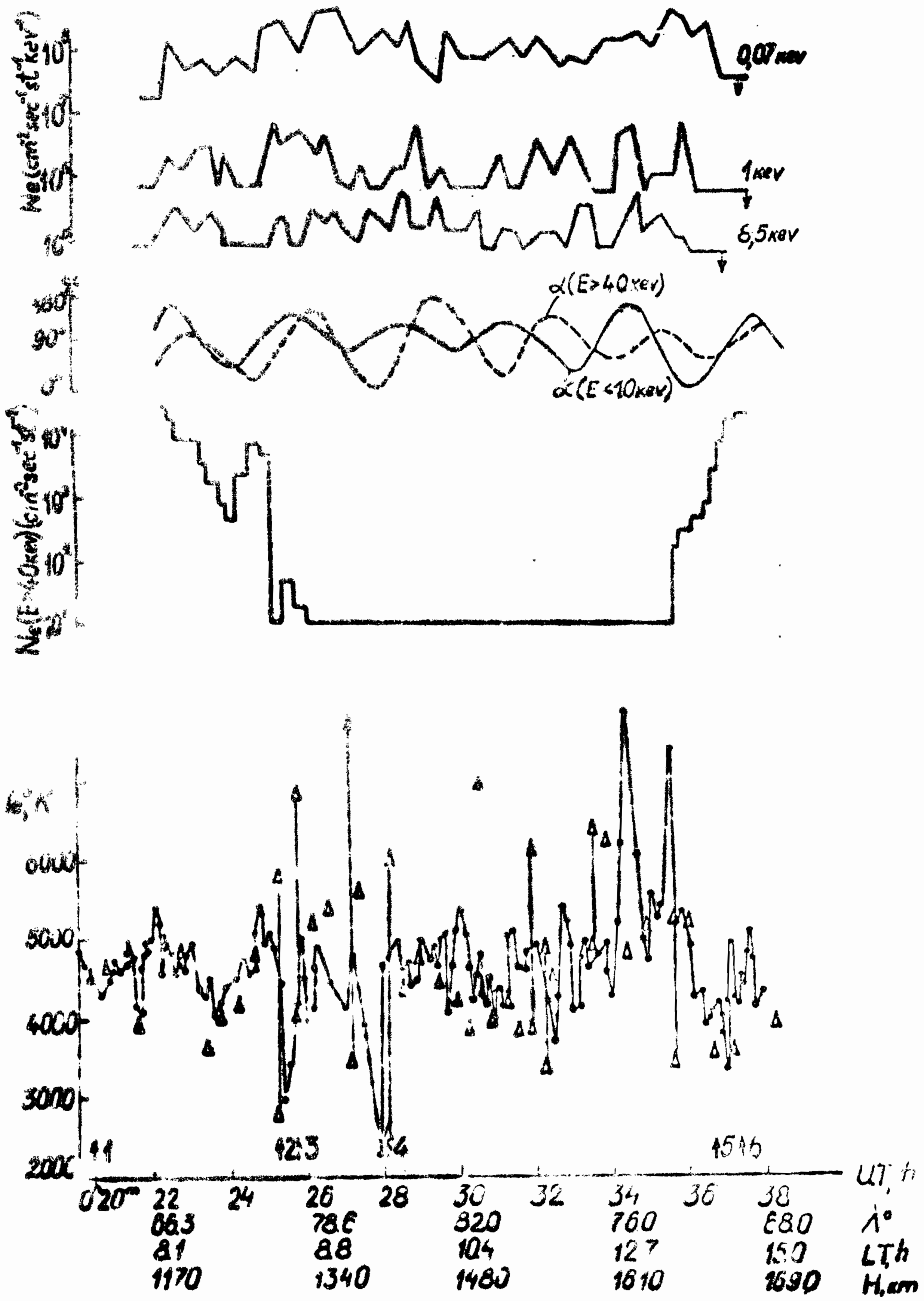

Fig. 1

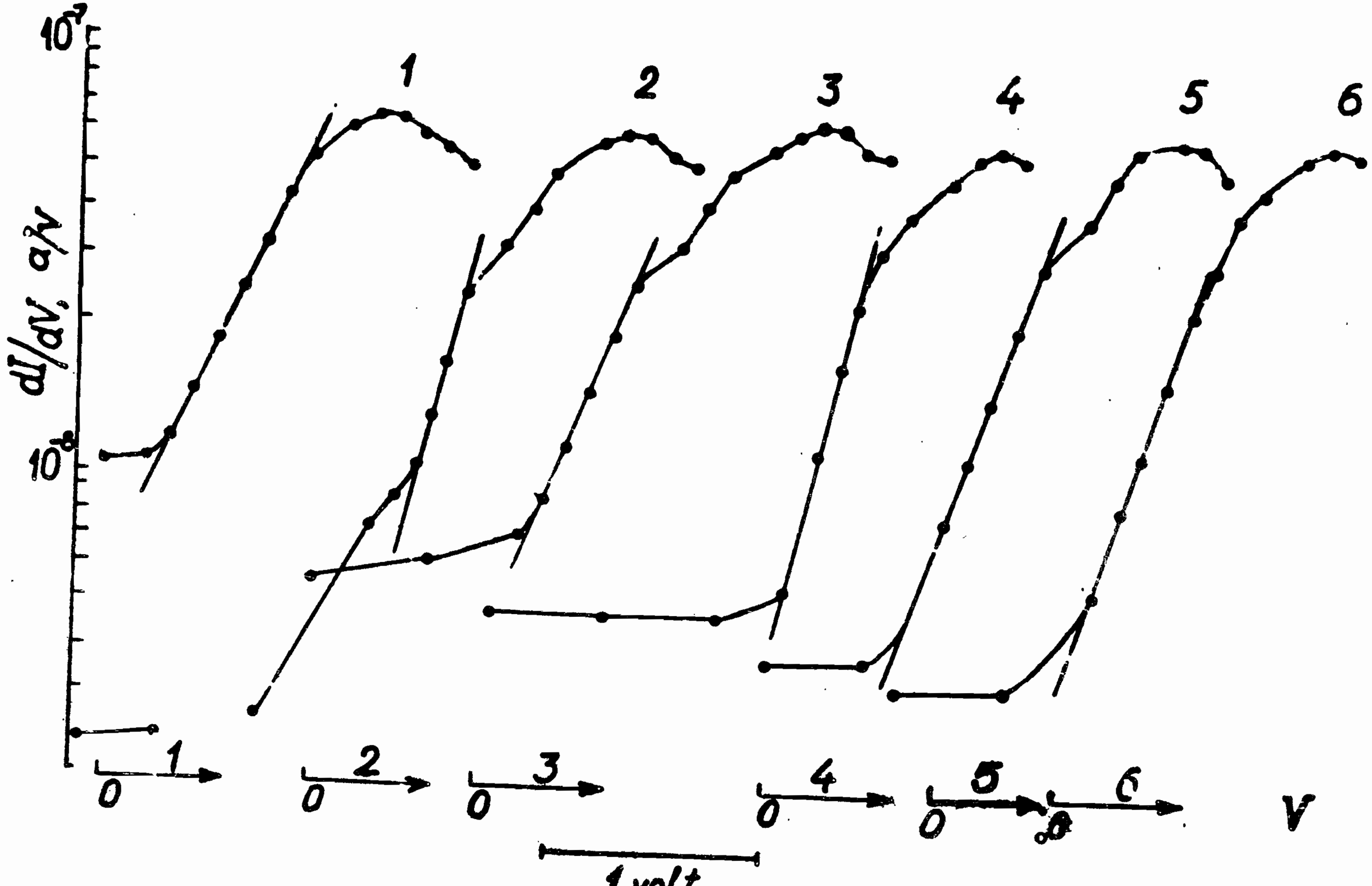

Fig.2

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