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SOME PECULIARITIES OF THE IONOSPHERIC PLASMA IN THE SOUTHERN POLAR CUSP REGION

V. V. AFONIN[a], YU. V. GOTZELUK[b], A. P. REMIZOV[a], E. K. SOLOMATINA[a], V. G. STOLPOVSKY[b] and S. M. SHERONOVA[a]

[a]Institute for Space Research, Academy of Sciences of the USSR, Moscow, USSR
[b]Institute of Nuclear Physics, Moscow State University, Moscow, USSR

The results of measurements of electron fluxes between 0.07 and 10 keV and > 40 keV, and of the temperature and energy distribution function of ionospheric electrons made on 18 November 1970 aboard the Cosmos 378 satellite are given. In the presence of low energy electron fluxes the ionospheric electron temperature rises and the energy distribution function departs considerably from Maxwellian. Electrons with mean energy ~ 1 eV and a temperature lower than that of ionospheric electrons were observed; possible reasons for the existence of such electrons are considered.

This paper deals with the results of simultaneous measurements in the southern day polar cusp of fluxes of low-energy electrons (0.07—8.5 keV), electrons > 40 keV, and the temperature and the energy distribution function of ionospheric electrons carried out in November 1970 from the Cosmos 378 satellite. For the measurements of low-energy electrons two cylindrical electrostatic analysers were installed on board the satellite to record the fluxes of electrons of 0.07; 1; 2.2; 4.2; 8.5 keV [1]. A Geiger counter was used for the measurement of the fluxes of > 40 keV electrons [2]. The temperature of the ionospheric electrons was taken by means of a spherical high-frequency probe [3] and a spherical Langmuir probe using modulation [4]. The velocity distribution function of the thermal electrons was investigated using the Langmuir probe characteristic.

The satellite apogee was about 1750 km, perigee about 240 km, revolution period near 100 min; the inclination of the orbital plane to the equatorial plane was ~ 74°. The maximum invariant latitudes were ~ 82°. Such an orbital inclination allowed us to perform measurements for up to 15—20 minutes on five passes in the region of low-energy electron precipitation known as the dayside cusp region.

Fig. 1 gives a typical example of the results obtained in the southern day polar cusp region. The top of Fig. 1 presents the fluxes of electrons averaged over three-second intervals according to the readings of one of the analysers corresponding to the three energies 0.07; 1.0; 8.5 keV. The bottom of this figure shows the time variation for electron fluxes with energy > 40 keV. The solid and dashed lines denoted by α show the orientation of the analyser and Geiger counter respectively relative to the magnetic field vector.

The sharp increase of electron fluxes ≤ 8.5 keV began at 0022 UT at $\Lambda = 66°$ when the satellite was still in the region of trapped radiation (the electron fluxes > 40 keV exceed the background level by at least two orders of magnitude)

Up to 0025 UT the fluxes of these low-energy electrons were almost continuously registered, the spectral density of the energy flux having a maximum in the 2—4 keV range and the fluxes being relatively constant over 15 sec. At 0025 UT the fluxes became changeable, often varying by an order of magnitude within 0.2—0.3 sec. At the same time the fluxes of 0.07 keV and 1.0 keV electrons sharply increased, whereas the fluxes of 8.5 keV electrons did not change. This time coincides with the beginning of a sharp fall (to the background level) of the trapped electron flux ($\Lambda \sim 76°$). At 0036 ($\Lambda \sim 72°$) the fluxes of 40 keV electrons sharply increased and in about 30 sec the flux of ≤ 8.5 keV electrons fell to the background level.

We identify a zone of precipitation of soft particles in the region of open magnetic field lines (the boundary of which we determine from the sharp fall of fluxes of > 40 keV electrons) with the high-latitudinal region of penetration of magnetosheath plasma into the magnetosphere, namely the daytime polar cusp.

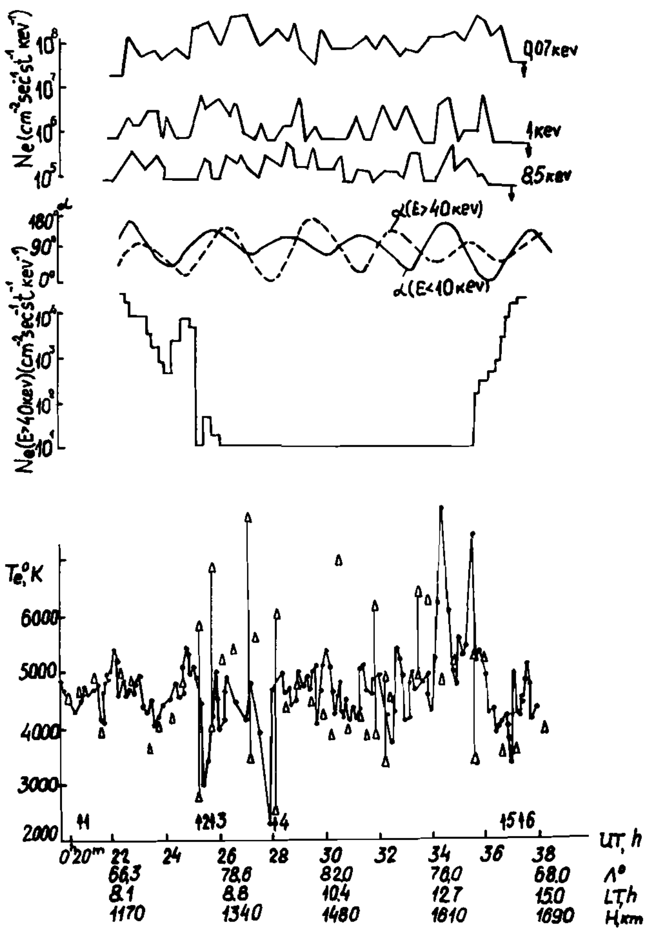

Fig. 1. Variations of auroral (0.07, 1 and 8 keV) and trapped (≥ 40 keV) electron fluxes of the electrostatic analyser attitude (α) relative to the geomagnetic field, and of the ionospheric electron temperature in the cusp region.

At the bottom of Fig. 1 the solid lines show the ionospheric electron temperatures the triangles showing those obtained by the modulated Langmuir probe. Outside the cusp ($\Lambda < 66°$) electron temperatures measured by these two techniques are in good agreement. When the satellite enters the region of intense low-energy precipitation this agreement often disappears and sharp fluctuations of temperature of up to 2000°—4000°K are observed.

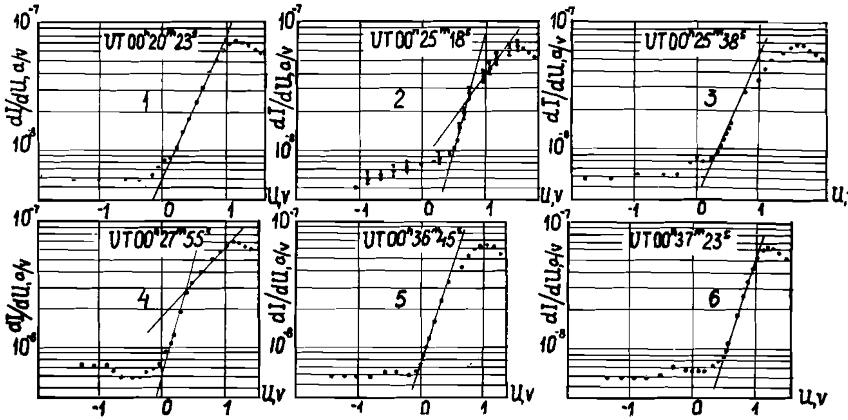

Fig. 2. First derivatives of the current-voltage characteristics of the spherical Langmuir probe. The abscissa gives the voltage of the saw-tooth generator of the probe bias relative to the satellite body. The vertical bars on the middle top frame give the total measurement errors. The kinks in characteristics 2, 3 and 4 between rectilinear portions correspond to the transition from electrons of one temperature to another.

Fig. 2 gives examples of some characteristics; i.e. the derivative of the electron current to the spherical Langmuir probe with respect to voltage, against the decelerating voltage V. Vertical arrows at the bottom part of Fig. 1 denote the times for which the characteristics given in Fig. 2 were taken. It is known from Langmuir probe theory that in the region of decelerating potential the volt-ampere characteristic of a spherical probe plotted on a semi-logarithmic scale is a straight line for a plasma with a Maxwellian distribution. The slope of this line defines the temperature of the electrons. In the ionosphere, in regions outside the precipitation zone, the form of the characteristics corresponds in most cases to a Maxwellian distribution of electrons (characteristics 1 and 6 in Fig. 2). The so-called high-temperature tail is the most abundant type of departure from the Maxwellian distribution that can appear with the presence of photoelectrons and precipitating particles in the ionosphere. In the region of low-energy electron precipitation including the cusp this type of characteristic is seen in about 30% of the passes (characteristics 2, 3 and 4 in Fig. 2). The analysis of such characteristics suggests that there are two groups of electrons in the plasma registered by this Langmuir probe. Electrons of the first group have the higher density and a temperature of about 4000°—5000°; electrons of the other group, "cool" electrons, have a temperature of about 2000°—3000°K but their mean kinetic energy is about 1—1.5 eV, i.e. approximately 5 times the mean energy defined by the temperature of these particles. This suggests that a mechanism for the acceleration of these particles up to an energy of about 1 eV exists. Electrons with such a mean kinetic energy are often registered in the satellite passage of the cusp region.

Triangles connected by vertical lines in Fig. 1 show temperatures for the two groups of electrons; note that the temperature measured by the high-frequency probe is close to the temperature of the "cool" electrons. It is evidently associated with the fact that the floating potential of this probe varies from 1 to 1.5 V, i.e. within the linear part of the current-voltage characteristic of the Langmuir probe for "cool" electrons. The Cosmos 378 equipment does not allow determination of the pitch angle distribution of the "cool" electrons nor of the direction of "cool" electron flux relative to the geomagnetic field.

The occurrence of electrons with a mean energy of 1—1.5 eV at ~ 1500 km altitude cannot be explained by the acceleration and heating of electrons associated with the formation of secondary electrons or photoelectrons and with local electric fields, since these processes cannot lead to the appearance of two groups of electrons with different mean energies. The formation of such electrons at an altitude above 1500 km is also impossible; in this region the temperature of electrons increases with increasing altitude. It is probable that the "cool" electrons occur in the region below the satellite, and are caused by the flux of electrons accelerated in the ionosphere by a longitudinal electric field. The flux of these electrons can constitute a return current under the precipitation of fluxes of particles with the same sign, or of fluxes of particles with different signs but with various pitch-angle distributions.

To accelerate electrons up to energies 1—1.5 eV between 300 km and 1500 km a parallel electric field of 10^{-8} V cm^{-1} is required. The presence of parallel electric fields is debatable.

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