

KFKI-1980-29

YU.V. MINEEV
E.S. SPIR'KOVA
K.I. GRINGAUZ
M.I. VERIGIN
G.A. KOTOVA
A.J. SOMOGYI

PROGNOZ 4 OBSERVATIONS OF ELECTRONS
ACCELERATED UP TO ENERGIES $\lesssim 2$ MeV
AND OF THE COLD PLASMA BETWEEN THE
MAGNETOPAUSE AND THE BOW SHOCK

Hungarian Academy of Sciences

CENTRAL
RESEARCH
INSTITUTE FOR
PHYSICS

BUDAPEST

PROGNOZ 4 OBSERVATIONS OF ELECTRONS ACCELERATED UP TO
ENERGIES ≤ 2 MeV AND OF THE COLD PLASMA BETWEEN THE
MAGNETOPAUSE AND THE BOW SHOCK

Yu.V. Mineev, E.S. Spir'kova,
Nuclear Physics Research Institute,
Moscow State University, Moscow, USSR

K.I. Gringauz, M.I. Verigin, G.A. Kotova
Space Research Institute,
Academy of Sciences, USSR

A.J. Somogyi
Central Research Institute for Physics,
Hungarian Academy of Sciences

ABSTRACT

The experimental data from Prognoz 4 satellite obtained on a layer of electrons with energies ≤ 2 MeV in the magnetosheath adjacent to magnetopause at different latitudes are given. At moderate latitudes the data are in favour of the leakage of electrons from the outer radiation belt as a source of the layer considered. At high latitudes these electrons apparently arrive along magnetosheath magnetic field lines trapping the magnetopause.

АННОТАЦИЯ

Проводятся экспериментальные данные со спутника Прогноз-4 относящиеся к слою электронов с $E \sim 2$ МэВ прилегающему к магнитопаузе внутри переходного слоя на различных широтах. На медленных широтах эти данные свидетельствуют в пользу того, что источником рассматриваемого слоя является утечка электронов из высшего радиационного пояса. На высокие широты эти электроны повидимому поступают вдоль магнитных силовых линий переходного слоя, отволакивающих магнитопаузу.

KIVONAT

A Prognoz 4 mesterséges holdnak a magnetopauza mellett elhelyezkedő magnetosheath-ban lévő, ~ 2 MeV alatti energiájú elektronokat tartalmazó rétegben mért kísérleti adatait tárgyaljuk. Közepes szélességnél az adatok azt mutatják, hogy az elektronok a külső sugárzási övből kifolynak és ezek szolgáltatják a vizsgált réteg forrását. Magas szélességnél ezek az elektronok a magnetosheath mágneses erővonalai mentén érkeznek és a magnetopauza mentén befogódnak.

INTRODUCTION

Since 1970, when Meng and Anderson [1970] had reported about the permanent existence of an energetic electron layer in the magnetosheath adjacent to the magnetopause based on the measurements of electron fluxes with $E_e > 40$ keV made by the IMP 1 and 3 earth satellites and the Explorer 35 lunar satellite more than 20 papers of various groups of experimenters who had observed this event were published. For example, it was reported about the increase of the energetic electron fluxes in the layer just outside the magnetopause from the HEOS 2 data [Page et al., 1973; Domingo et al., 1974, 1977], the PROGNOZ 3 data [Lutcenko et al., 1975; Nikolaeva and Pisarenko, 1979], the IMP 5 data [Meng and Anderson, 1975; Meng et al., 1979] the IMP-8 data [Baker and Stone, 1977 a,b; 1978, Bieber and Stone, 1979], the Vela 5,6 data [Palmer and Hones, 1978], the ISEE 1, 2 data [Daly et al., 1979; Williams et al., 1979] and from the Helios 1, 2 spacecraft [Richter et al., 1979].

Such a large amount of experimental papers dealt with the consideration of physical processes due to which the energetic electron layer is formed presents evidence for the significant interest to this problem. However, there is not now available the generally accepted mechanism for forming the energetic electron layer in the magnetosheath adjacent to the magnetopause. Taking into account the magnetopause dimensions and electron velocities the possible time of their presence on the interplanetary magnetic field lines in the magnetopause vicinity can be estimated: it is not large (≈ 10 sec) and, therefore, the fact of the layer registration practically at each magnetopause crossing requires a permanent source supplying energetic electrons to the layer [Baker and Stone, 1977 a].

The energetic electron sources proposed by various authors for the layer discussed can be conventionally divided into two groups: the local sources associated with the accelerating mechanisms possibly occurring in the magnetopause vicinity e.g. with reconnection on the dayside and tail magnetopause, with resonance heating of electrons by electromagnetic waves generated in the magnetosheath [Meng and Anderson, 1970; Baker and Stone, 1977, 1978; Daly et al. 1979; Richter et al., 1979] and the sources associated

with the energetic electrons originated from the different magnetosphere regions [Baker and Stone, 1978; Palmer and Hones, 1978; Nikolaeva and Pissarenko, 1979; Antonova and Nikolaeva, 1979; Williams et al., 1979].

In the magnetopause vicinity the spectra of energetic electrons up to energies 1-2 MeV were studied only by means of the IMP 8 [Baker and Stone, 1978] and ISEE 1, 2 [Williams et al., 1979] satellites. However the IMP 8 orbit made it possible to measure these electron only close to the tail magnetopause ($-10R_e > X_{SE} > -40R_e$) and the ISEE 1,2 orbit within the period described in that publication - only on the dayside at latitudes lower than those of Prognoz 4 (ISEE 1, 2 orbit inclination is 30°). The Prognoz 4 satellite measured spectra of energetic electrons within the 0.3 + 3 MeV range. Its orbit permitted measurements in the dayside magnetopause vicinity at moderate (on the inbound passes) and high (on the outbound passes) solar-magnetic latitudes. The spectral measurements of electrons with the energy of the order of 1 MeV in the magnetopause vicinity have not been ever carried out at such latitudes. Therefore, some Prognoz-4 results on the energetic electron and plasma fluxes given below will provide the additional information which could be useful for proper understanding the source of the layer adjacent to the magnetopause and for the manner of its supplying with energetic electrons.

INSTRUMENTATION

The Prognoz-4 measurements of the energetic electron fluxes were carried out by means of a spectrometer consisting of three semiconductor detectors surrounded by a plastic scintillator which was looked through by a photo-multiplier. The spectrometer is located in an aluminium collimator with acceptance angle of 60° . The anticoincidence screen allows the decrease of the background from the penetrating cosmic radiation and from proton with their paths out of the electron acceptance angle. The electron fluxes were measured within five energy ranges: 0.3 to 0.5; 0.5 to 0.8; 0.8 to 1.2; 1.2 to 2.0; 2.0 to 3.0 MeV. The geometrical factor of the instrument was $\approx 1.8 \text{ cm}^2 \text{ ster}^{-1}$, the calibration was performed with radioactive sources Cs^{137} , Bi^{207} , Ru^{106} . The electron spectrometer was oriented perpendicularly to the Prognoz 4 spin-axis directed towards the Sun with an accuracy of about 10° . The satellite spin period was ≈ 2 min. The energetic electron spectrometer has been described in more detail in Mineev et al. [1978].

The low energy ion fluxes within the range 0 to 4400 eV (16 energy intervals) were measured on board the Prognoz 4 satellite with a wide-angle differential modulation-type analyzer (Faraday cup) oriented parallel to the satellite spin-axis. The instrument sensitivity to the unidirectional flux was $\approx 4 \times 10^5 \text{ cm}^{-2} \text{ sec}^{-1}$; ions were recorded within the acceptance angle of 90° . To measure the total energy spectrum of ions and also the spectrum

of energetic electrons ≈ 2 min 44 sec were required. The more detailed description of the ion analyzer can be found in Gringauz et al. [1974].

EXPERIMENTAL RESULTS

The Prognoz 4 orbit (the apogee was ≈ 200000 km; the perigee was ≈ 600 km; the inclination was $\approx 65^\circ$, the rotation period was ≈ 4 days) made it possible to study the energetic electron and plasma fluxes in the solar wind, in the magnetosheath and in the magnetosphere. During its active operating period (from the end of December, 1975 up to the middle of March, 1976) the satellite passed through the magnetosphere more than 20 times. The magnetopause crossings during the satellite inbound passes were within $35^\circ \leq \varphi_{SM} \leq 50^\circ$ and $-30^\circ \leq \lambda_{SM} \leq 30^\circ$, and during its outbound passes within $60^\circ \leq \varphi_{SM} \leq 75^\circ$ and $-90^\circ \leq \lambda_{SM} \leq -10^\circ$, φ_{SM} and λ_{SM} are the latitude and longitude in the solar-magnetic coordinate system, respectively.

Fig. 1 shows three Prognoz 4 orbits on 1-2; 14-15 and 19-20 revolutions in the solar ecliptic coordinate system. In *Fig. 1* the dashed curve indicates the magnetopause location and the dot-and-dash curve does the position of the earth bow shock according to plasma measurements on 14-15 revolutions on February, 15-16, 1976. The thick solid line presents the portions of the orbits on which in the magnetosheath the spectrometer recorded electron fluxes more intense than those in the solar wind. The double line marks the satellite position when the enhanced electron fluxes were observed in the magnetosphere and double dashed line does the case when the energetic electron fluxes exceeded the maximum ones recorded by the instrument.

More detailed results on the energetic electron and plasma fluxes measurements during Prognoz 4 pass through the magnetosheath and the magnetosphere are presented in *Fig. 2*. This figure shows the electron fluxes J_e within the energy ranges: 0.5-0.8; 0.8-1.2 and 2-3 MeV and the total flux of ions J_i within the energy range 0-4, 400 eV ($J_i = 6.7 \times 10^{17} \sum_{K=1}^{16} I_K$, where I_K is the current in the K-energy interval) recorded during the outbound pass (*Fig. 2b*). In *Fig. 2* the arrows indicate the moments when the satellite traversed the bow shock and the magnetopause determined from the characteristic change of ion spectrum (thermalization and drop of plasma bulk velocity) and from the considerable drop of ion flux, respectively. *Fig. 2a* shows that when the satellite crosses the dayside magnetopause at medium latitudes ($\varphi_{SM} \approx 45^\circ$, $\lambda_{SM} \approx -10^\circ$) the flux of 0.5 to 0.8 and 0.8 to 1.2 MeV electron starts to increase in the magnetosheath. The electron fluxes with these energies do not change significantly on the magnetopause and continuing to increase as Prognoz 4 deepens into the magnetosphere they reach the values higher than those maximally recorded by the instrument apparently in the stable trapping region of the outer radiation belt.