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ENERGY DISTRIBUTION OF ELECTRONS WITH $E < 800$ eV IN THE AREOMAGNETOSPHERE

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Abstract—The electron distribution functions measured in the neighborhood of Mars by means of the Hyperbolic Retarding Potential Analyzer (HARP) carried aboard the *Phobos* 2 spacecraft are presented. The measurements were carried out over an energy/charge (E/q) from ~0.3 eV to ~800 eV in eight independent angular sectors ~20° × 10° covering the FOV ~ 180° in the X–Z plane in the antisolar directions.

The total intensity and energy distribution function of electrons downstream of the bow shock clearly differ from those in the undisturbed solar wind. The electron fluxes are significantly increased and the energy distribution of electrons in the magnetosheath was found to be characterized by the double-peaked structure. The high energy fluxes often exceed the flux values for the low energy peak.

INTRODUCTION

This presentation considers some features of energy distributions for the electron fluxes recorded in the Martian magnetosphere with the HARP instrument (a differential hyperbolic electrostatic analyzer) (Shyn *et al.*, 1976; Kiraly *et al.*, 1989; Szucs *et al.*, 1990) installed aboard the *Phobos* 2 spacecraft.

The previous studies made in the vicinity of Mars with the retarding potential analyzers on board the Mars-series spacecraft showed that downstream of the bow shock, in the magnetosheath, the energy spectra are significantly widened, and more energetic electrons and fluctuations of the flux intensity appear (Gringauz, 1975).

In contrast to the *Mars* 2, 3 and 5 orbits, those of *Phobos* 2 made it possible to penetrate deeply into the Martian magnetospheric tail; and on the circular orbits, i.e. at a distance of about 6000 km from the planet surface, the plasmasheet was regularly crossed by the spacecraft.

It is worthwhile comparing the most typical distributions of electrons measured in the solar wind with the *Helios* spacecraft data (Rosenbauer *et al.*, 1977). Figure 1 presents the results of solar wind measurements made from the *Helios* and *Phobos* 2 spacecraft. The resemblance of the presented distributions is quite obvious. This gives evidence that the instrument was reliably operated.

RESULTS OF MEASUREMENTS

The HARP instrument crossing the bow shock was determined via the increase in the intensity of the electron and ion fluxes, and was accompanied by the appearance of high-energy electron fluxes with $E > 500$ eV (Shutte *et al.*, 1989). Figure 2 shows the energy distributions of electron fluxes recorded in one of the angular sectors as the spacecraft approached the planet on 5 February 1989 (the second elliptical orbit). It is seen that in the magnetosheath the energy distributions were essentially non-Maxwellian in their character, they had two distinct maxima in all distributions of the measurements. Note that the second maximum, being initially of very low intensity, appeared several minutes before crossing the bow-shock front.

In the inner magnetosphere the electron fluxes are more isotropic than those in the magnetosheath; the

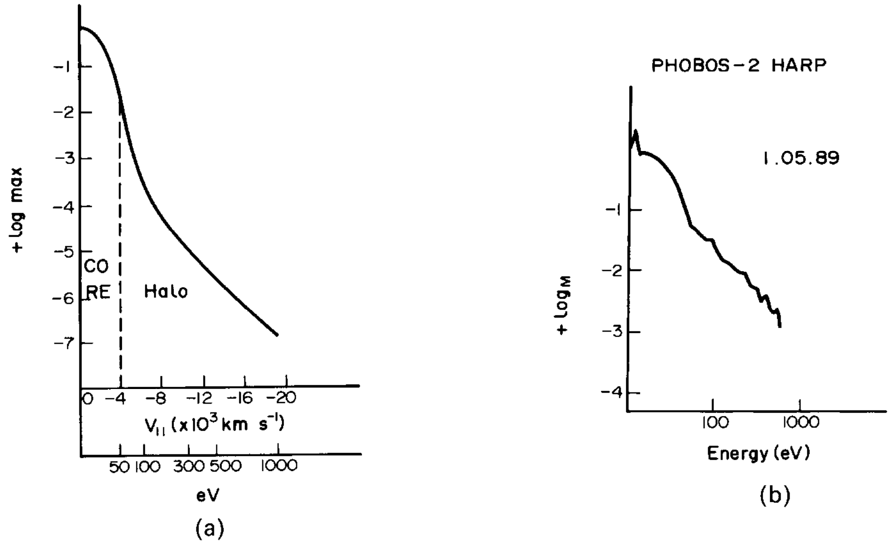

FIG. 1. THE EXAMPLES OF THE RESULTS OF SOLAR WIND ELECTRONS FROM THE *Helios* (FIG. 1a) AND THE *Phobos* 2 (FIG. 1b) SPACECRAFTS.

maximum energy does not exceed hundreds of electron-volts. The energy distributions have a comparatively broad maximum from 20 to 150 eV within which one can see the binary structure being not so explicit.

In the planet tail, energetic electron fluxes appear again in the optical shadow; their energy distribution shape is somewhat similar to those observed in the magnetosheath. This region of the tail, by analogy with the magnetospheres of other planets (Gringauz, 1981) can be considered as a plasmasheet.

The double-peaked electron distributions are a typical feature of energy distributions of the magnetosheath and are always observed during its crossing by *Phobos* 2 as well as on the elliptical orbits when the spacecraft was in the dayside region of the magnetosheath, and on the circular orbits in the tail. The energy distribution recorded in one angular sector of the HARP instrument in the tail part of the magnetosheath is demonstrated in Fig. 3. The comparison of energy distributions presented in Figs 2 and 3 shows that in the tailside of the magnetosheath the flux values corresponded to the second maximum in the distribution function and the mean energies of this maximum are somewhat lower than those of the magnetosheath subsolar part.

Figure 4 illustrates the characteristic features of electron distributions in the magnetosheath and the plasmasheet at various distances from the planetary surface. The intensity and energy of electrons increase in the plasmasheet with an increase in the distance from the planet. The position of a maximum in the energy distributions of electron fluxes of the plasmasheet varied from about 100 to 300 eV.

DISCUSSION

The results of measurements of the near-planetary Martian plasma allow us to suggest that such specific regions as the magnetosheath, inner magnetosphere and plasmasheet are characterized by various energy distributions of electrons. Their unique features permit reliable identification of these regions.

It was shown that immediately prior to the bow shock front and downstream of it in the magnetosheath the energy distributions always have two maxima. This fact indicates that there are two different mechanisms of heating and cooling in the turbulent plasma of the magnetosheath. It is known that an electron component of the solar wind plasma usually consists of the cold quasi-isotropic electron gas ("core") and hot electrons accelerated along the magnetic field ("halo"). It can be assumed that the electron gas, two components in the solar wind with the different energies, and the isotropization level, are subject to different types of interactions with the electrostatic turbulence waves. Namely, there exists the resonance acceleration of hot "halo" and heating of the more isotropic "core".

The difference between the electron flux energy values in the subsolar and antisolar parts of the mag-

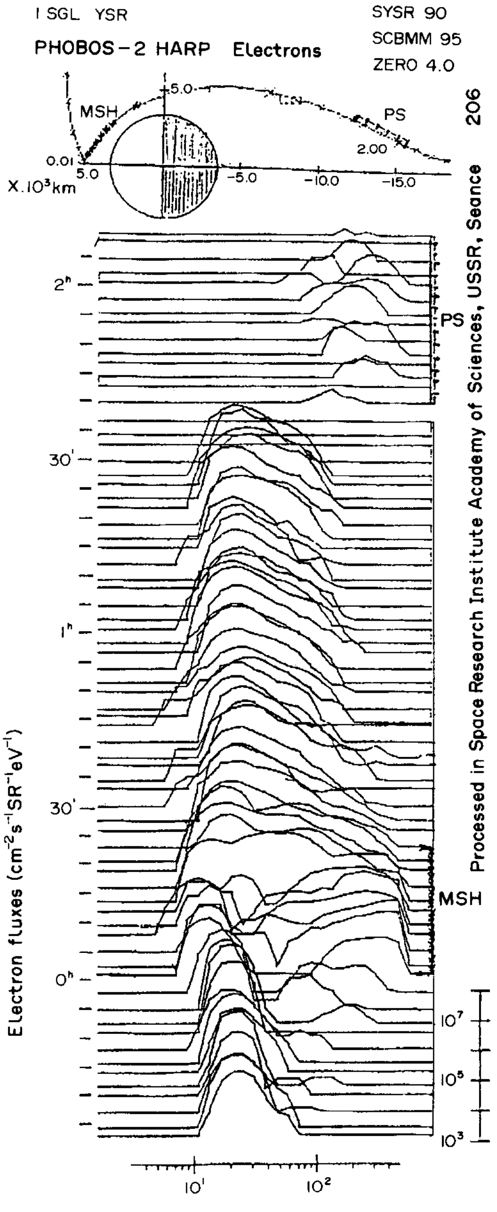

FIG. 2. THE ENERGY DISTRIBUTIONS OF THE ELECTRON FLUXES RECORDED ON THE SECOND ELLIPTICAL ORBIT ON 5 FEBRUARY 1989.

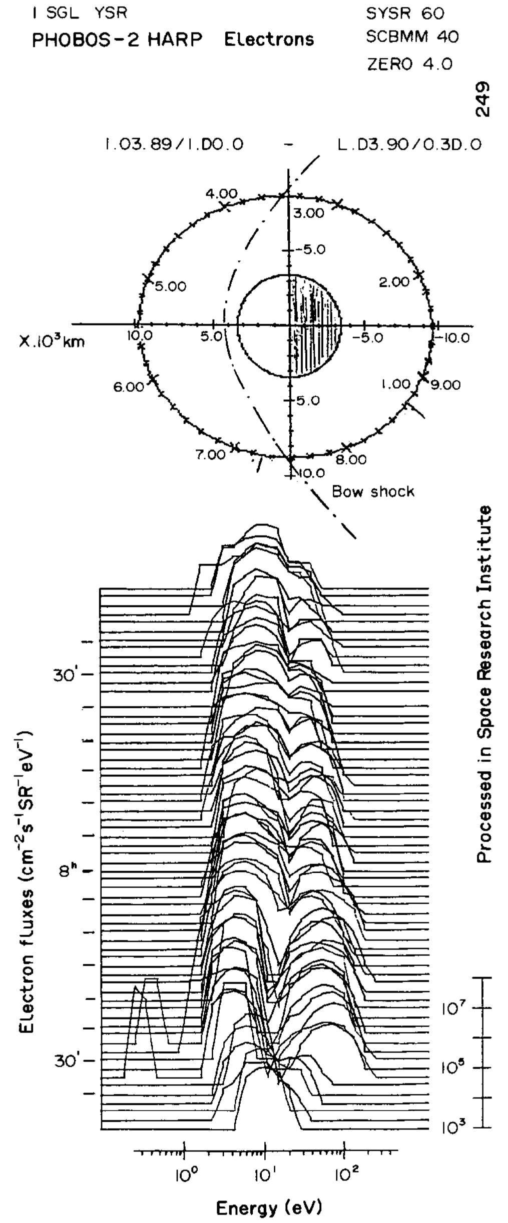

FIG. 3. THE ENERGY DISTRIBUTION OF THE ELECTRON FLUXES RECORDED ON 1 MARCH 1989.

netosheath possibly means that the particle acceleration effect in the Martian magnetosheath is more sufficient on its dayside, the more compressed part.

As mentioned above the energy distributions with two maxima possibly due to the different effects of local electromagnetic fields are always observed in the magnetosheath. The character of energy distributions of the electron fluxes is the same over the whole magnetosheath.

A comparison between the measured electron spectra and the TAUS ion spectrometer data, showed that the electron energy distributions in the magnetosheath with the double-peaks correlate with the widened spectra of protons recorded in this region (see Fig. 5).

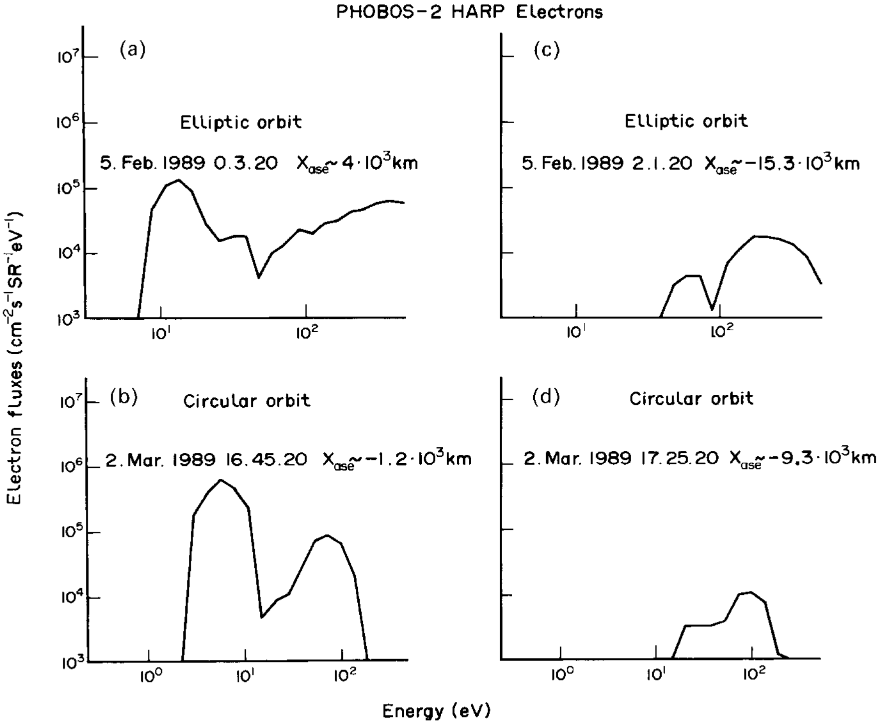

FIG. 4. THE CHARACTERISTIC FEATURE OF ELECTRON DISTRIBUTIONS IN THE DIFFERENT PARTS OF THE MARTIAN MAGNETOSPHERE: (a) AND (b)—THE MAGNETOSHEATH; (c) AND (d)—THE PLASMASHEATH.

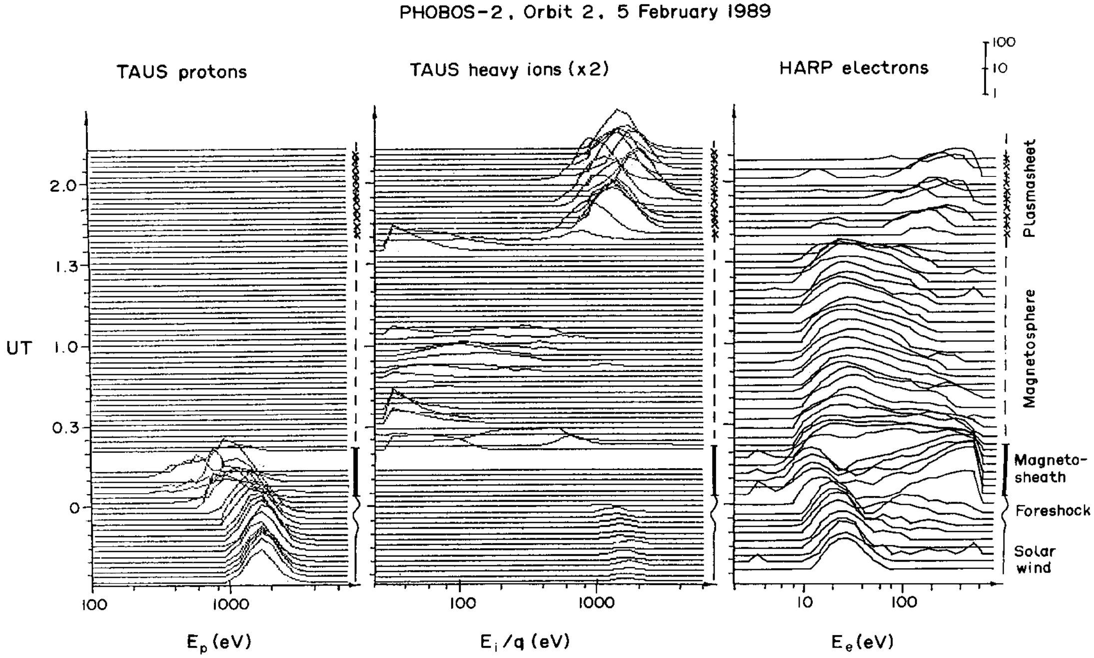

FIG. 5. THE ENERGY DISTRIBUTIONS OF PROTONS, HEAVY IONS (TAUS MEASUREMENTS) AND ELECTRONS RECORDED SIMULTANEOUSLY ON THE SECOND ELLIPTICAL ORBIT ON 5 FEBRUARY 1989.

In the inner magnetosphere where the proton flux intensity turned out to be lower than the TAUS sensitivity threshold, the heavy ion fluxes with energies $E < 1000$ eV were observed.

It is typical that in the magnetosphere tail, in the plasmasheet, where more energetic electrons were measured, the heavier ion fluxes were also observed. Their highest energies did not exceed ~4 keV. According to the *Phobos* 2 magnetic measurements (Riedler *et al.*, 1989; Verigin *et al.*, 1990), these supersonic plasma flows in the magnetotail, in the shadow, were commonly recorded close to the region where E_x-component of the magnetic field reverses sign and the total magnetic field is close to minimum. As is shown above, the significant orbit-to-orbit plasma variability in the plasmasheet manifested itself in the ion flux observations as well. This fact may indicate that the plasmasheet of Mars is more moveable than that of the Earth. This may be due to the great effect of the magnetic field "induced" component in the Martian magnetosphere and also may be connected with the interplanetary magnetic field orientation.

CONCLUSIONS

(1) The electron energy distributions essentially change after crossing the bow shock, magnetopause and plasmasheet boundaries. Each of these regions of the Martian magnetosphere is characterized by the specific electron energy distributions; their distinguishing features make it possible to reliably identify them.

(2) The electron energy distributions always have two maxima in the magnetosheath. It is conceivable that such energy distributions give some evidence of different interactions between two components of the solar wind electron gas and the electrostatic wave turbulences.

(3) Electrons with an energy peak of ~200 to ~300 eV are observed in the plasmasheet of the magnetotail. The plasmasheet positions determined from the magnetic field, ion and electron measurements practically coincide.

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